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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.

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Edition 2 . . . . . September 1993
Edition 3 . . . . . August 1994
Edition 4 . . . . . July 1995

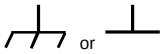
Safety Symbols



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 equipment—protects against electrical shock in case of fault.



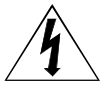
Frame or chassis ground terminal—typically connects to the equipment's metal frame.



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.

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Manufacturer's Address: 815 14th Street S.W.
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declares, that the product:

Product Name: 16-Channel FET Multiplexer Modules

Model Number: E1351A, E1353A

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): Group1 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

.

Supplementary Information: The product herewith complies with the requirements of the Low Voltage Directive 73/23/EEC and the EMC Directive 89/336/EEC and carries the CE-marking accordingly.

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



July 20, 1995 **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).

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Chapter 1
Getting Started with the HP E1351A/53A

Using This Chapter

This chapter describes the HP E1351A 16-Channel FET and the HP E1353A 16-Channel Thermocouple FET Multiplexer Modules, and shows how to program the modules using SCPI (Standard Commands for Programmable Instruments) commands. This chapter contains the following sections:

- FET Multiplexer Module Description . . . . . Page 11
- Multimeter Connection Points . . . . . Page 12
- Switchbox & Scanning Voltmeter Configurations . . . . . Page 14
- Digital Bus and Triggering . . . . . Page 15
- Programming Language . . . . . Page 16
- Initial Operation . . . . . Page 16

FET Multiplexer Module Description

The FET multiplexer module provides high-speed switching (multiplexing) for up to 16 channels. The module can be used as a scanning multiplexer for a scanning voltmeter configuration, or as a stand-alone multiplexer in a switchbox configuration. The channels are numbered 00 to 15. Each channel provides connections for High (H), Low (L) and Guard (G), although only High and Low are switched. The FET multiplexer module can switch up to 100,000 connections per second (100 K switches/sec).

The FET multiplexer module consists of a component assembly and a terminal module. There are three different terminal modules, one for each of the following applications: HP E1351A 16-Channel FET Multiplexer Module, HP E1353A 16-Channel Thermocouple FET Multiplexer Module, and HP E1352A 32-Channel Single-Ended FET Multiplexer Module. The component assembly is the same for all three applications. For information on the 32-Channel Single-Ended FET Multiplexer Module, see the *HP E1352A User's Manual*.

The component assembly contains the VXIbus interface, the FET switches, the analog bus connector and the digital bus. The terminal modules provide connection points for the individual channels, as well as monitoring points for the tree terminals and the direct terminals. The FET multiplexer module can be externally triggered from the VXIbus backplane or through the digital bus handshake lines on the front of the component assembly.

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For high-speed operation (100 K switches/sec.) the scanning list is automatically downloaded into RAM on the multiplexer module. Triggering for channel advance is from the two handshake lines on the digital bus. The scanning operation does not require any intervention from the mainframe CPU. This only applies for switchboxes or scanning voltmeter configurations that have all FET multiplexer modules. For a downloaded scan list in switchboxes, the trigger source must be TRIG:SOUR DBUS or TRIG:SOUR IMM.

Multimeter Connection Points

There are three places where signals on a closed channel can be measured: analog bus connector, tree terminals and direct terminals. Each of these provides a different capability for configuring the module.

Analog Bus Connector

The analog bus connector provides a direct connection between multiple multiplexer modules and also between a multiplexer module and HP E1326/E1411 Multimeters. A ribbon cable is used to daisy-chain multiple multiplexer modules together, and to connect a multimeter to the multiplexer modules for a scanning voltmeter. The SCAN:PORT ABUS command automatically closes the appropriate tree isolation switches to route closed channels to the analog bus. This command must be executed in a switchbox configuration. A scanning voltmeter automatically configures the multiplexer for the analog bus connector.

Tree Terminals

Tree terminals provide an external connection point through the terminal modules for the signals which are on the analog bus lines. Tree terminals are the recommended connection points for connecting stand-alone multimeters and external current sources for 4-wire resistance measurements.

Direct Terminals

The 16 channels are separated into two banks, Bank 0 and Bank 1. When a channel is closed, that channel is connected to a Bank Common. Channels 00 to 07 are on Bank 0 Common and channels 08 to 15 are on Bank 1 Common. The terminal module has connection points for the direct terminals, where you can measure signals on the respective Bank Commons. The banks can be isolated from each other, from the analog bus connector, and from the tree terminals with the A and B tree isolation switches.

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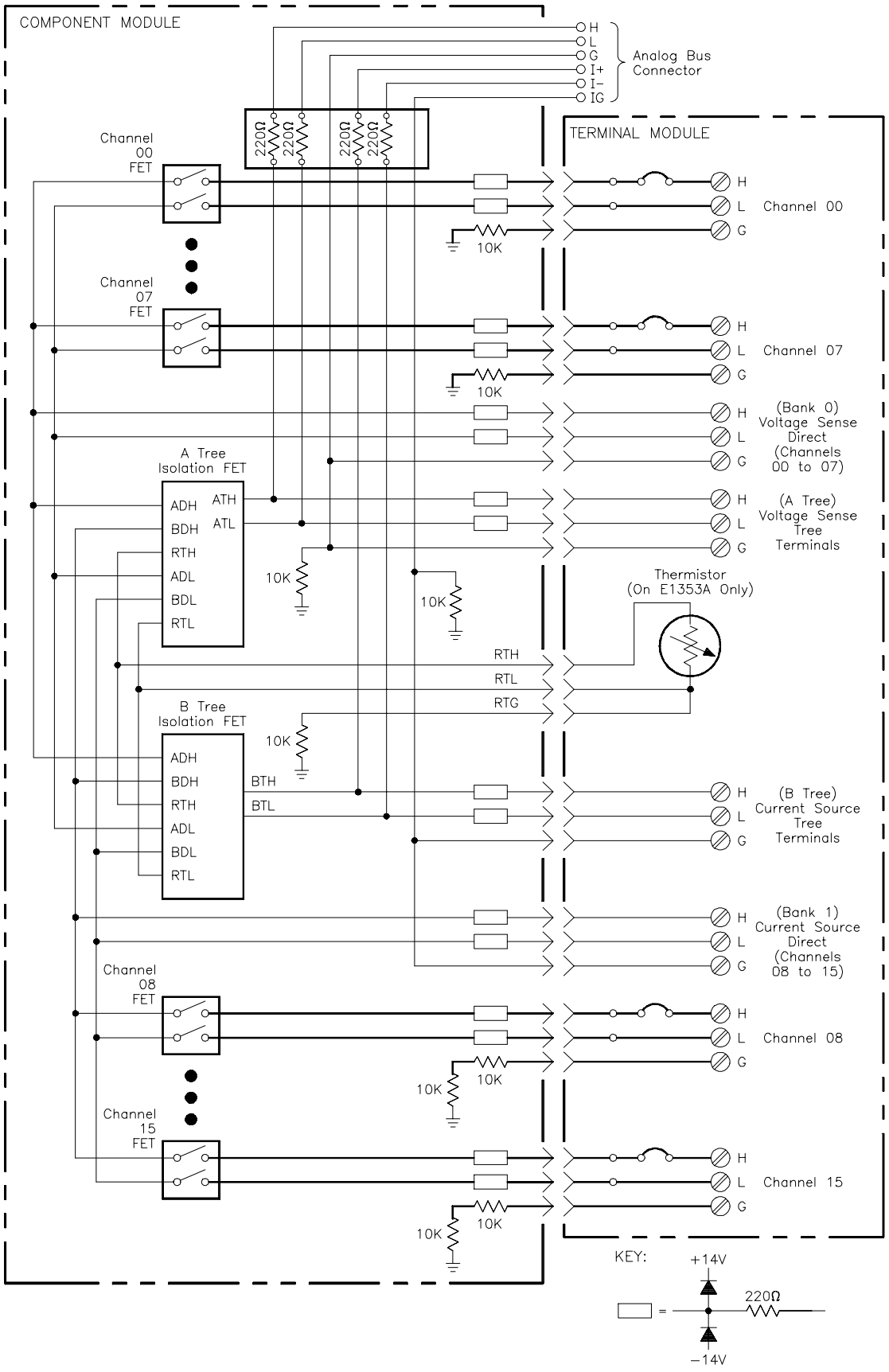


Figure 1-1. FET Multiplexer Module Block Diagram

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Switchbox and Scanning Voltmeter Configurations

A VXIbus instrument is a module or group of modules which perform a specified function. For the HP E1300/01 mainframe, the first module in an instrument must have a logical address which is evenly divisible by 8 (16, 24, 112), and the rest of the modules in the instrument are numbered consecutively. The instrument's secondary address is the whole number equal to the logical address divided by 8 (for a logical address of 16, 17, 18,…23, the secondary address is 02). For instrument definition in other mainframes, see the mainframe manual. If an instrument consists of only multiplexer modules, it is a switchbox configuration. If a multiplexer module(s) is combined with a multimeter to form an instrument, that is a scanning voltmeter configuration.

Switchbox

A switchbox is a multiplexer module or group of multiplexer modules which form a single instrument. A switchbox can be connected to a multimeter which is a different VXIbus instrument, to an HP-IB[1] controlled multimeter, or to a stand-alone multimeter. The switchbox and the multimeter have different secondary addresses. Separate configuration commands must be sent to the switchbox and to the multimeter. The following program illustrates the different addresses and the configuration commands required. The HP-IB interface select code is 7, and the mainframe address is 09. The multiplexer has an instrument address of 24, so its secondary address is 03. The multimeter is HP-IB controlled, and has a primary address of 22.

```
10  OUTPUT  722;"TRIG EXT;DC 10"          !Sets multimeter to external trigger
                                          and to measure DC volts
20  OUTPUT  70903;"OUTP ON"               !Enables "Trig Out" port
30  OUTPUT  70903;"TRIG:SOUR BUS"         !Sets switchbox to receive Bus
                                          triggers
40  OUTPUT  70903;"SCAN:MODE VOLT"        !Set up switchbox for voltage
                                          measurements
50  OUTPUT  70903;"SCAN:PORT ABUS"        !Closes the appropriate tree
                                          isolation switches while scanning,
                                          automatically makes connection to
                                          the analog bus and tree terminals.
60  OUTPUT  70903;"ARM:COUN 2"            !Set for two cycles through the
                                          scan list
70  OUTPUT  70903;"SCAN  (@100;115)"      !Selects the channel list. 100
                                          selects first channel on card 1;
                                          115 selects last channel on card 1
80  OUTPUT  70903;"INIT"                  !Close first channel to start
                                          scanning cycle
90  FOR I = 0 TO 15                       !Start count loop
100 ENTER 722;A                           !Enter reading into variable A
110 PRINT A                               !Print reading in variable A
```

1 HP-IB is Hewlett-Packard's implementation of IEEE Std 488.1-1978

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```
120 TRIGGER 70903          !Trigger the switchbox to advance the channel list
130 NEXT I                 !Increment count
140 END
```

Scanning Voltmeter

When the multiplexer(s) is combined with a multimeter to form a single instrument, they become a virtual instrument, a scanning voltmeter. The multiplexer(s) and the multimeter have the same secondary address. The multimeter automatically configures the multiplexer, so the SCAN:MODE, SCAN:PORT and TRIG:SOUR commands are not required. Channel advance is from the digital bus handshake lines, so the count loop is not required. The ARM:COUN command does not apply to downloaded scan lists, so you cannot specify the number of cycles through the scan list. You can, however, specify INIT:CONT ON for continuous scanning through the scan list.

```
10  DIM Rdgs(1:16)                          !Dimension an array for 16 readings
20  OUTPUT 70903;"*RST"                     !Reset instrument
30  OUTPUT 70903;"MEAS:VOLT:DC? (@100:115)"
                                            !Configure instrument
40  ENTER 70903;Rdgs(*)                     !Enter readings into array
50  PRINT Rdgs(*)                           !Print results
60  END
```

Digital Bus and Triggering

The HP E1351A/E1353A can be triggered for channel advance from the VXIbus backplane or through the digital bus handshake cable on the front of the component assembly. Backplane triggering can come from HP-IB computer commands over the HP-IB Bus or from the HP E1300/1301 Mainframe "Event In" port. Digital bus triggering uses two handshake lines; channel advance and channel closed. Channel advance (input to multiplexer) triggers an advance, and channel closed (output from multiplexer) signifies advance completed.

The HP E1326B Multimeter has a digital bus port on the face plate, and connects to the multiplexer with the digital bus cable (see Figures 2-10 and 2-11). To connect other multimeters for digital bus triggering, you must prepare a custom cable. Use a connector like the one on the digital bus cable (HP part number E1300-61611). Connect the measurement complete port from the multimeter to the channel advance pin, and the external trigger to the channel closed pin. Connect the grounds for both signals to the digital bus ground (second pin from right). You can use this cable to connect an external multimeter to a switchbox, and then use TRIG:SOUR DBUS (digital bus triggering). You can also order a custom cable with BNC to digital bus connectors, HP part number E1411-80001. See Figure 2-11 for more information on multiplexer-to-multiplexer and multiplexer-to-multimeter connections.

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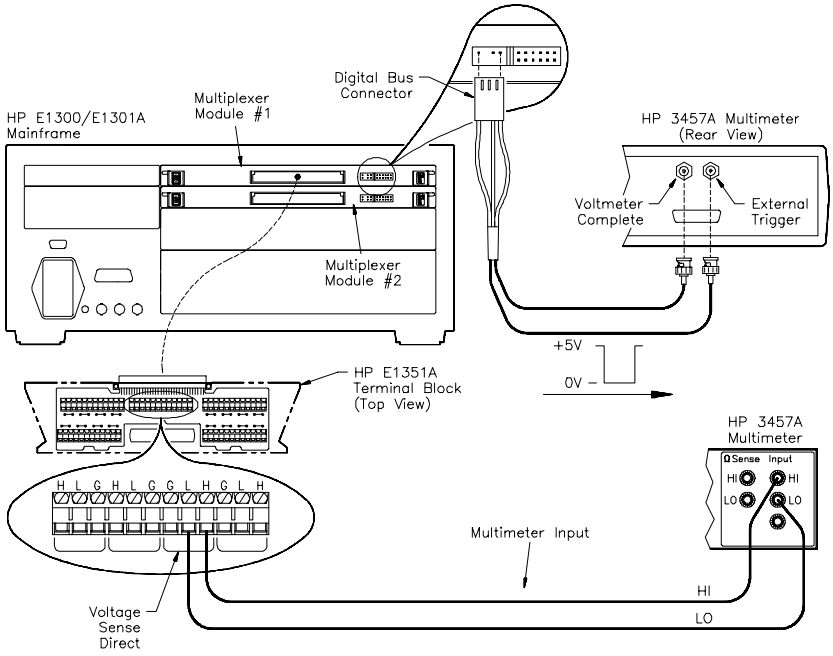


Figure 1-2. Custom Cable for Digital Bus Triggering

Programming Language

The examples in this manual use the Standard Commands for Programmable Instruments (SCPI) commands, Hewlett-Packard BASIC and an HP 9000 Series 200/300 computer over the HP-IB. Chapter 5 contains information on SCPI command format. Appendix B contains details on the registers for register-based programming.

Initial Operation

Use the following program to verify initial multiplexer operation by closing a channel and querying channel closure. The computer interfaces to the mainframe with the Hewlett-Packard Interface Bus (HP-IB). The HP-IB interface select code is 7, and the mainframe address is 09. The multiplexer has an instrument address of 24, so its secondary address is 03.

This example first resets the switchbox and then closes channel 02 of a single multiplexer module (card number 1) in the switchbox. The program next queries the channel closure state. A returned "1" shows that the channel is closed, a returned "0" designates an open channel.

```
10  OUTPUT  70903;"*RST"              !Opens all channels
20  OUTPUT  70903;"CLOS  (@102)"      !Close channel 02 on card 1
30  OUTPUT  70903;"CLOS?  (@102)"     !Query channel 02 state
40  ENTER  70903;Value                !Enter results into variable called
                                      Value
50  PRINT Value                       !Display result
60  END
```


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Chapter 2
Configuring the HP E1351A/53A FET Multiplexer Modules

Using This Chapter

This chapter shows how to configure the 16-Channel FET Multiplexer Modules, how to connect external wiring and how to connect multimeters. This chapter contains the following sections:

- Warnings and Cautions . . . . . Page 17
- Multiplexer Card Numbers . . . . . Page 18
- Selecting the Interrupt Line Number . . . . . Page 20
- Setting the Card ID Switch . . . . . Page 21
- Connecting User Inputs . . . . . Page 22
- Adding Signal Conditioning Components/Current Shunts . . . . . Page 23
- Connecting Field Wiring . . . . . Page 24
- Wiring a Terminal Module . . . . . Page 25
- Connecting Multimeters and Signal Generators . . . . . Page 26
- Analog Bus and Digital Bus Cables . . . . . Page 27

Warnings and Cautions

Warning **SHOCK HAZARD. Only service-trained personnel who are aware of the hazards involved should install, remove, or configure the multiplexer modules. Before you install any module, disconnect AC power from the mainframe and from user wiring.**

Caution **MAXIMUM VOLTAGE/CURRENT. The maximum voltage that may be applied between High (H), Low (L), and Guard (G) terminals is 15 V dc or 10.6 V rms (15 V peak). The maximum current is 1 mA per channel.**

STATIC ELECTRICITY. Static electricity is a major cause of component failure. To prevent damage to the electrical components in the multiplexer module, observe anti-static techniques whenever removing a module from the mainframe or whenever working on a module.

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Multiplexer Card Numbers

HP plug-in modules installed in an HP VXIbus mainframe are treated as independent instruments each having a unique secondary HP-IB address. An instrument may be composed of a single plug-in module or multiple plug-in modules. The card number identifies the module within a switchbox or scanning voltmeter configuration. The multiplexer module with the lowest logical address is always card number 01. The multiplexer module with the next successive address is 02, and so on. Figure 2-1 illustrates the card numbers and logical addresses of typical single-module switchboxes. Figure 2-2 illustrates the card numbers and logical addresses of a typical multiple-module switchbox. Figure 2-3 illustrates the card numbers and logical addresses of a typical multiple-module scanning voltmeter.

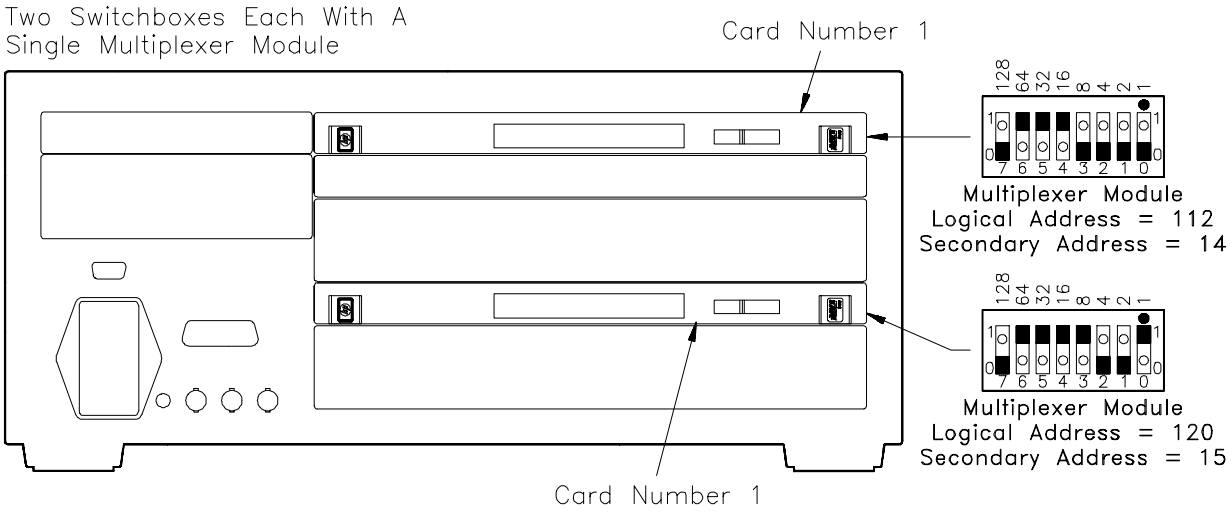


Figure 2-1. Card Numbers for Single-Module Switchboxes

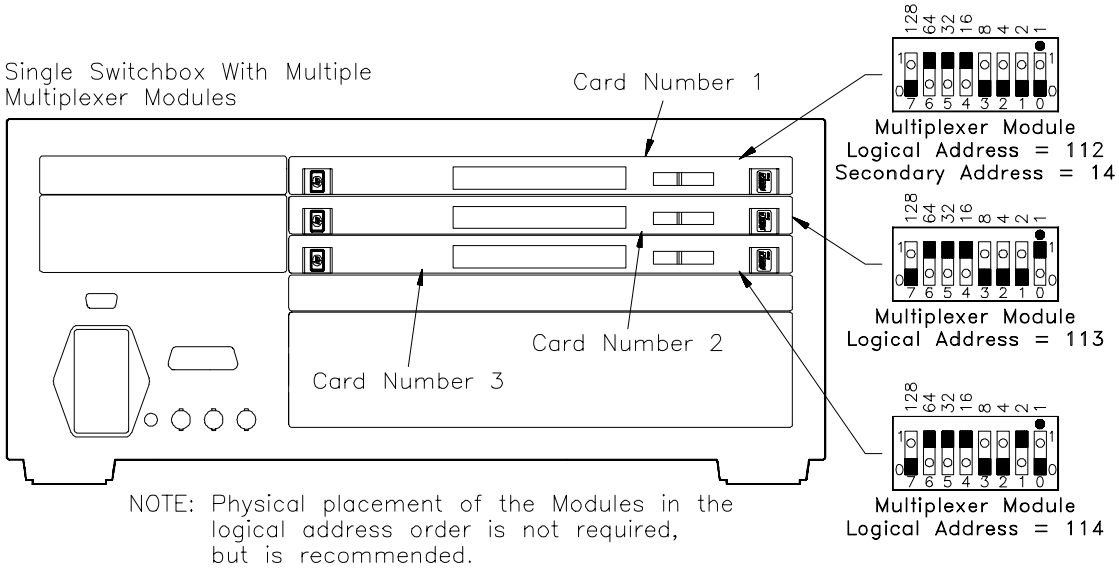


Figure 2-2. Card Numbers for Multiple-Module Switchbox

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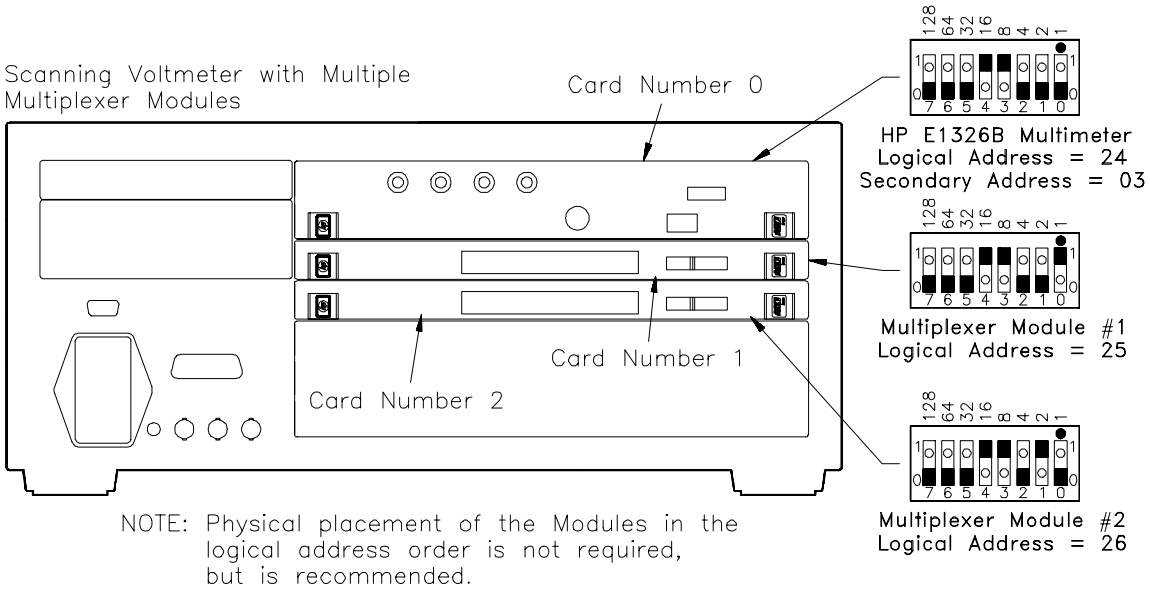


Figure 2-3. Card Numbers for Scanning Voltmeter

The logical addresses noted in Figures 2-1, 2-2, and 2-3 apply to modules installed in an HP 75000 Series B Mainframe (HP Model Number E1300A/E1301A) or in a mainframe with an HP E1405/1406 Command Module. See the *HP 75000 Series B Installation and Getting Started Guide* or the appropriate *HP Command Module Manual* for more information on switchboxes and scanning voltmeter configurations, and logical addressing. For uses in other systems or mainframes, see the appropriate manuals.

Setting the Address Switch

The logical address switch (LADDR) factory setting is 112. You may have changed the switch setting during module installation. Valid address values are from 1 to 255. Refer to the *HP 75000 Series B System Installation and Getting Started Guide* or the appropriate *HP Command Module Manual* for addressing information. Otherwise, refer to Figure 2-4 to reset the factory setting.

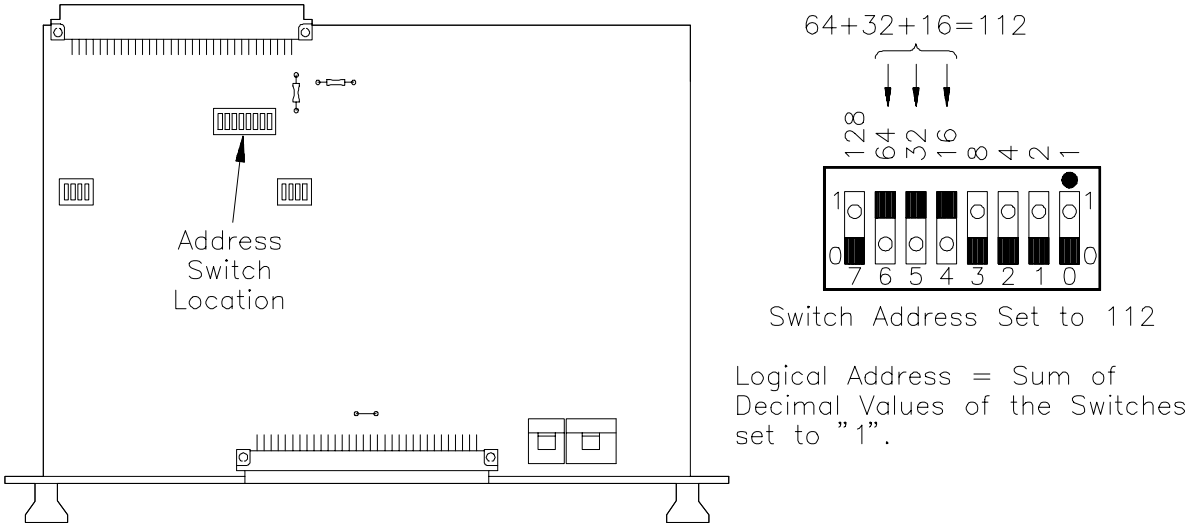


Figure 2-4. Setting the Logical Address Switch

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Selecting the Interrupt Line Number

The multiplexer module generates interrupts at the end of a downloaded scan list. The interrupt line number switch determines which backplane IRQ line will be used. Different mainframes and resource managers recognize different backplane IRQ lines. The interrupt line number must be set to the line number your system is programmed to recognize. Refer to your mainframe manual.

Refer to Figure 2-5 to change the interrupt lines. Valid line numbers are from 1 to 7. Set the interrupt line number to the mainframe interrupt handler number.

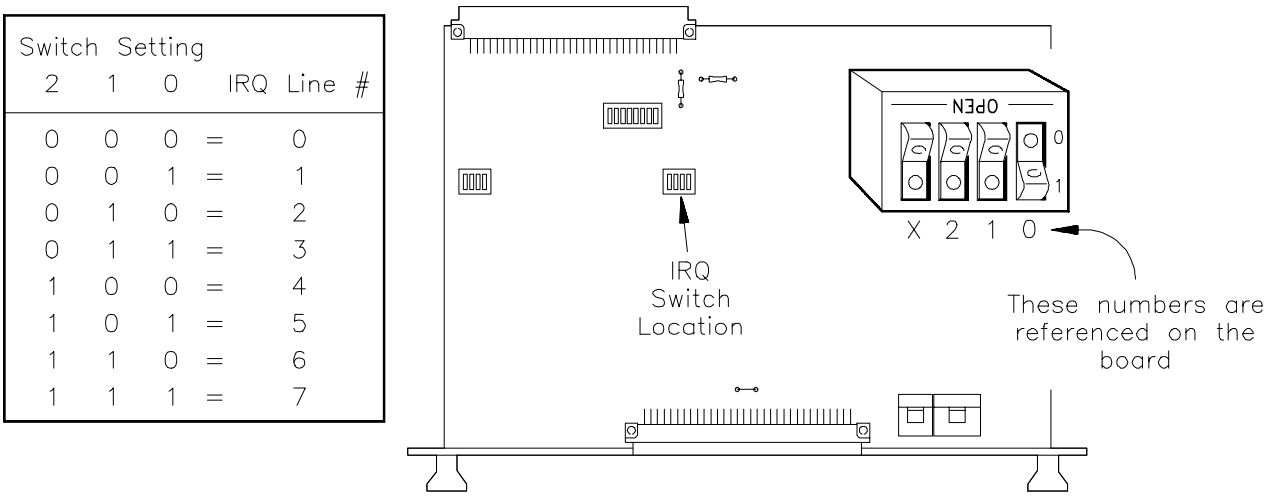


Figure 2-5. Setting the Interrupt Line Number

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Setting the Card ID Switch

The multiplexer module can be an HP E1351A, HP E1352A or HP E1353A depending on which terminal module is installed. With a normal connection, the terminal module will automatically configure the module for the appropriate model. To identify a module without a terminal module, set the Card ID switch as shown in Figure 2-6. The ID numbers are:

Model	Value	Configuration
HP E1351A	0	all pins open
HP E1352A	8	pin 3 closed
HP E1353A	2	pin 1 closed

For normal connections, leave the switch at the factory setting which is all pins open.

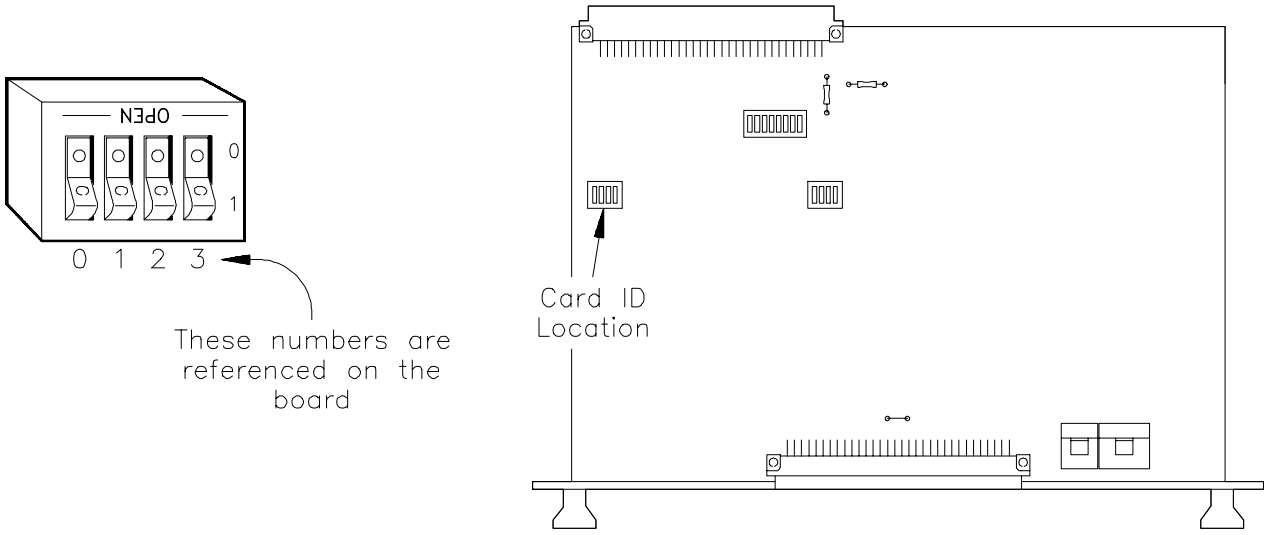


Figure 2-6. Card ID Switch

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Connecting User Inputs

The 16-Channel FET consists of a component module and a terminal module. If the terminal module is not desired, Figure 2-7 shows the front panel and the module's connector pin-out which mates to the terminal module.

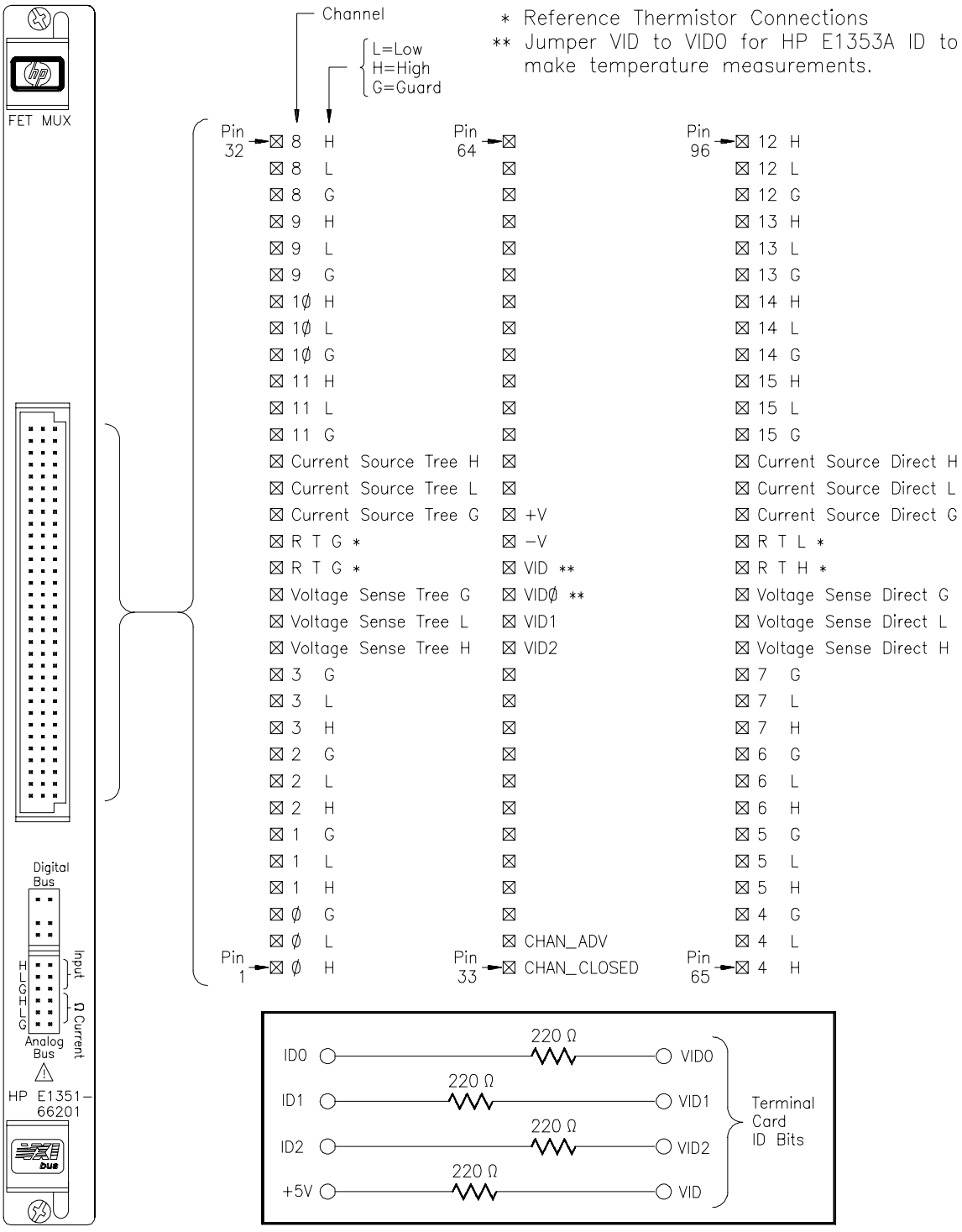


Figure 2-7. 16-Channel FET Multiplexer Connector Pin-out

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Adding Signal Conditioning Components/Current Shunts

The multiplexer module's terminal module allows you to add components on each channel for the following:

- Low-Pass Filters
- Attenuators
- Current Shunts (for current measurements using a voltmeter)

Figure 2-8 shows how to install the appropriate components for the above configurations. In the figure, channel 12 shows a low pass filter configuration, channel 07 an attenuator configuration, and channel 04 a current shunt configuration.

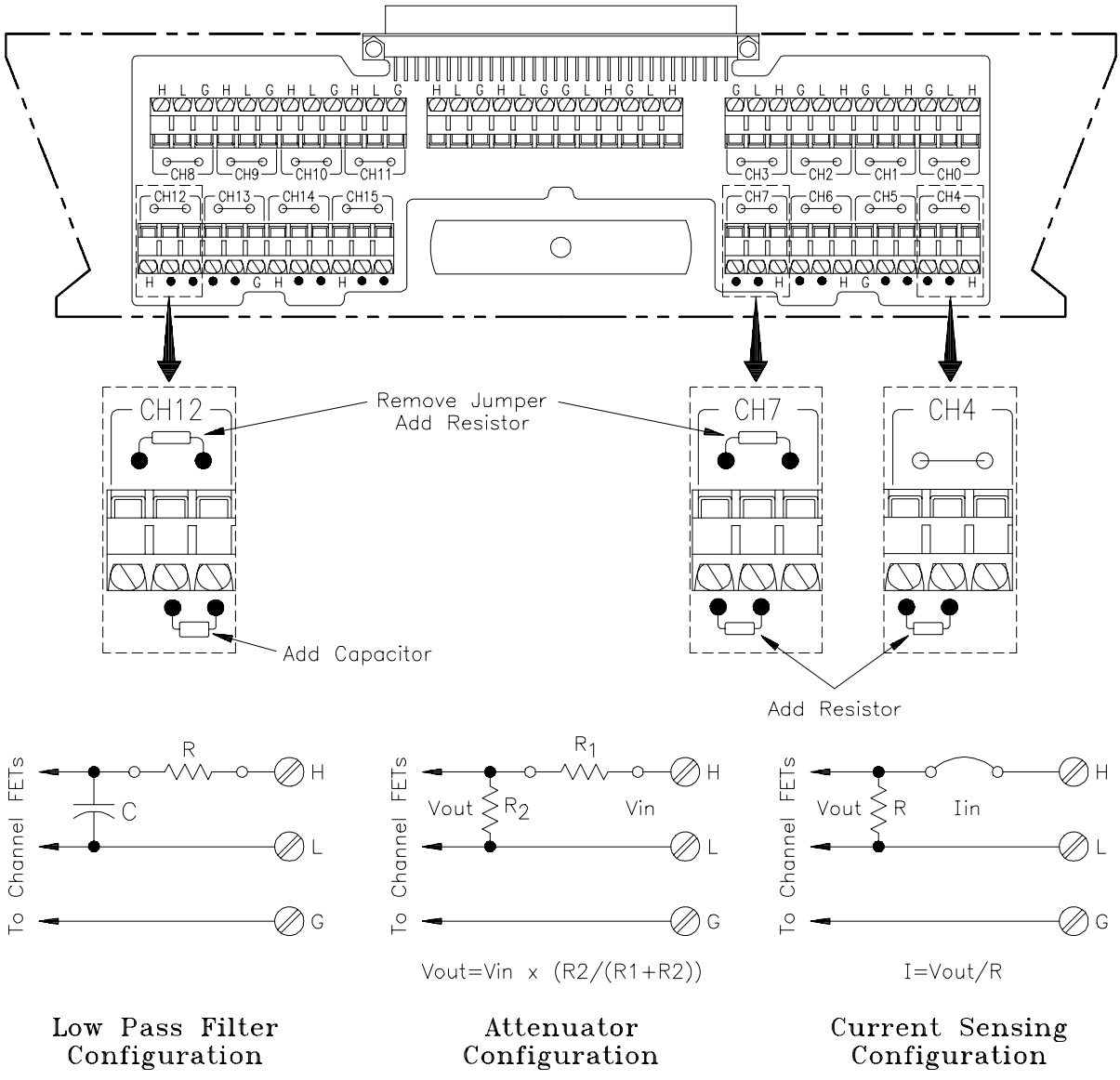


Figure 2-8. Signal Conditioning Components/Current Shunts

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Connecting Field Wiring

Leads for the individual channels are connected through the channel terminals on the terminal modules. Multimeters and signal generators can be connected to the direct terminals or tree terminals on the terminal modules. Figure 2-9 shows the terminal module channel terminals for the 16-Channel FET Multiplexer Module (HP E1351A) and the 16-Channel Thermocouple FET Multiplexer Module (HP E1353A).

Wiring Guidelines

- If possible, use shielded cables with the shields connected to the Guard (G) terminals and to the low connection near the measurement point.
- Be sure the wires make good connections on the screw terminals.
- For thermocouples, connect the Guard terminal to the thermocouple's shield lead and the low connection near the measurement point.

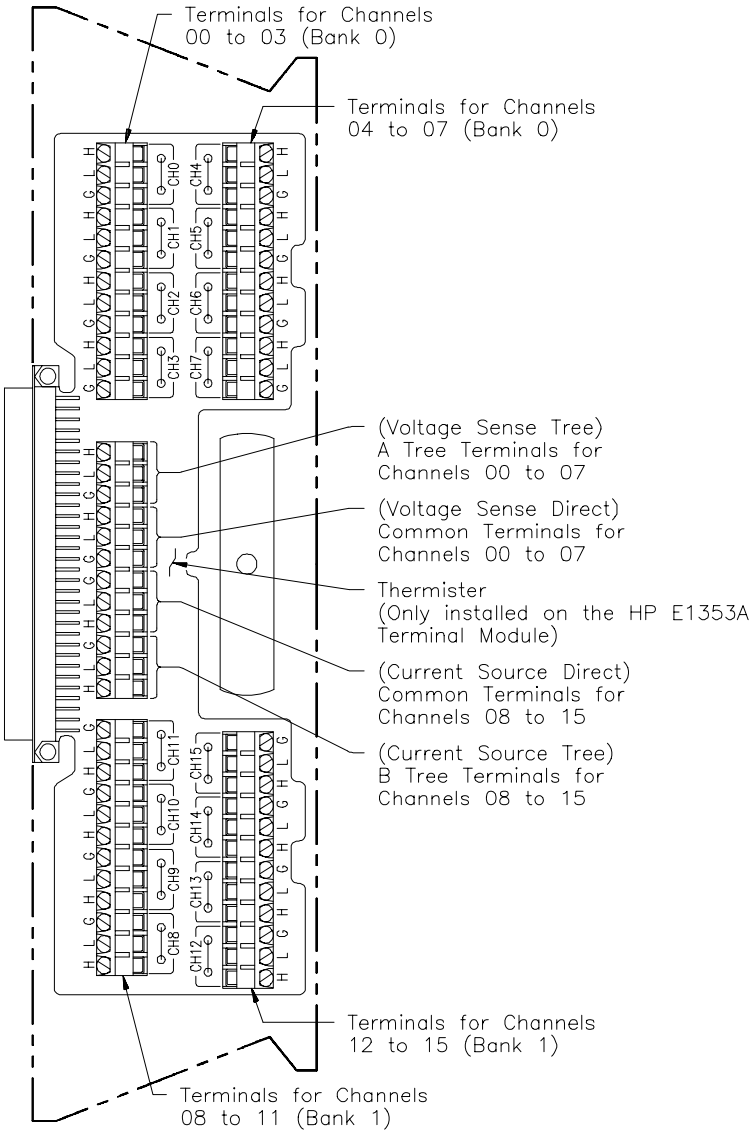
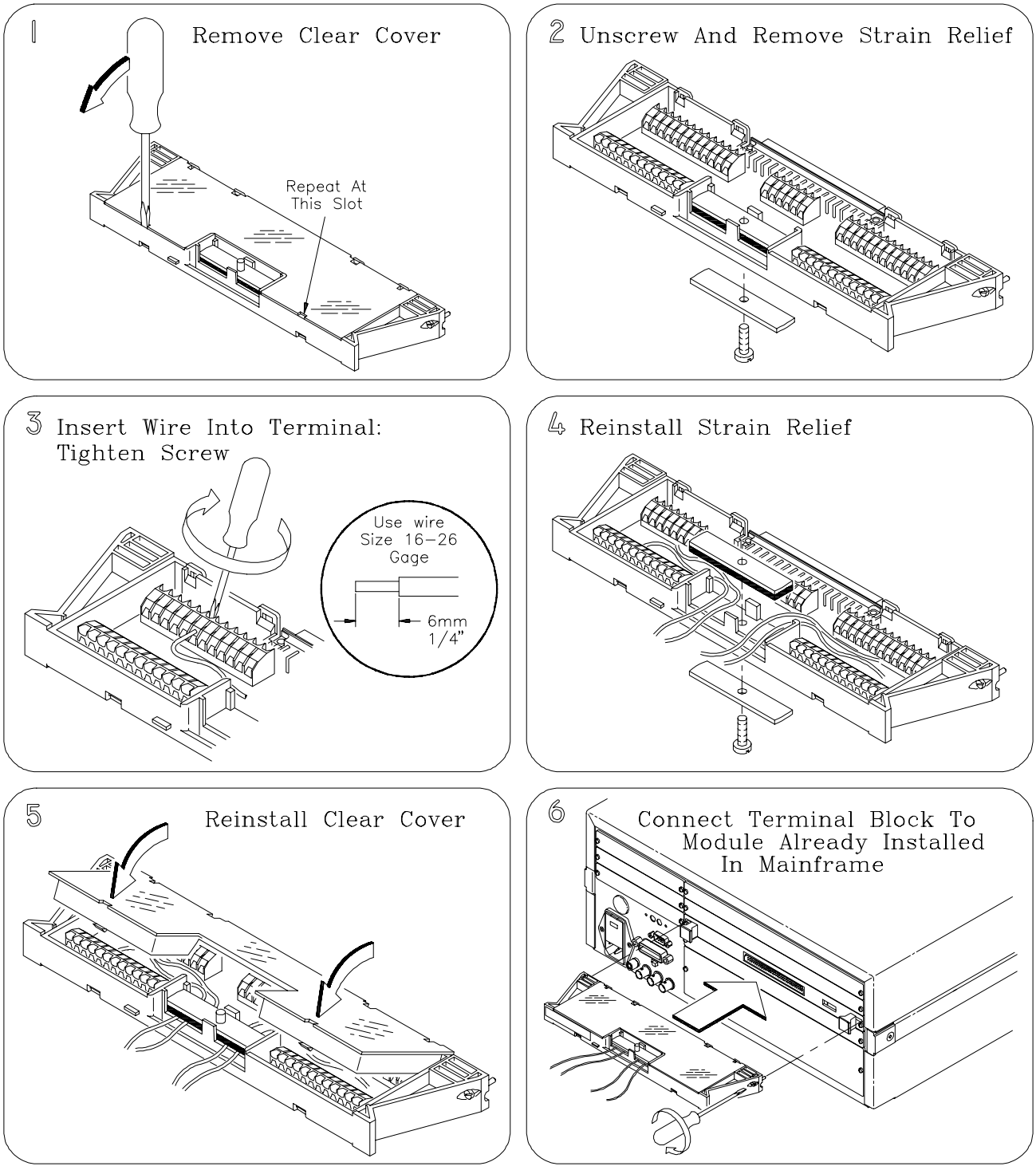


Figure 2-9. FET Multiplexer Modules Terminal Module

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Wiring a Terminal Module

The following illustrations show how to connect field wiring to the terminal module.



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Connecting Multimeters and Signal Generators

Figure 2-10 shows how to connect the analog bus connector and the digital bus handshake cable between multiple multiplexer modules and the HP E1326B Multimeter. Use the cables shipped with the multiplexer modules to make the connections.

Stand-alone multimeters and signal generators can also be connected to the tree terminals or the direct terminals. Connections to the tree terminals and the direct terminals are made on the terminal modules. If the multimeter has "Voltmeter Complete" and "External Trigger" ports that use an open collector TTL pulse, you can use a custom cable to connect it to the digital bus for triggering (see "Digital Bus and Triggering" in Chapter 1).

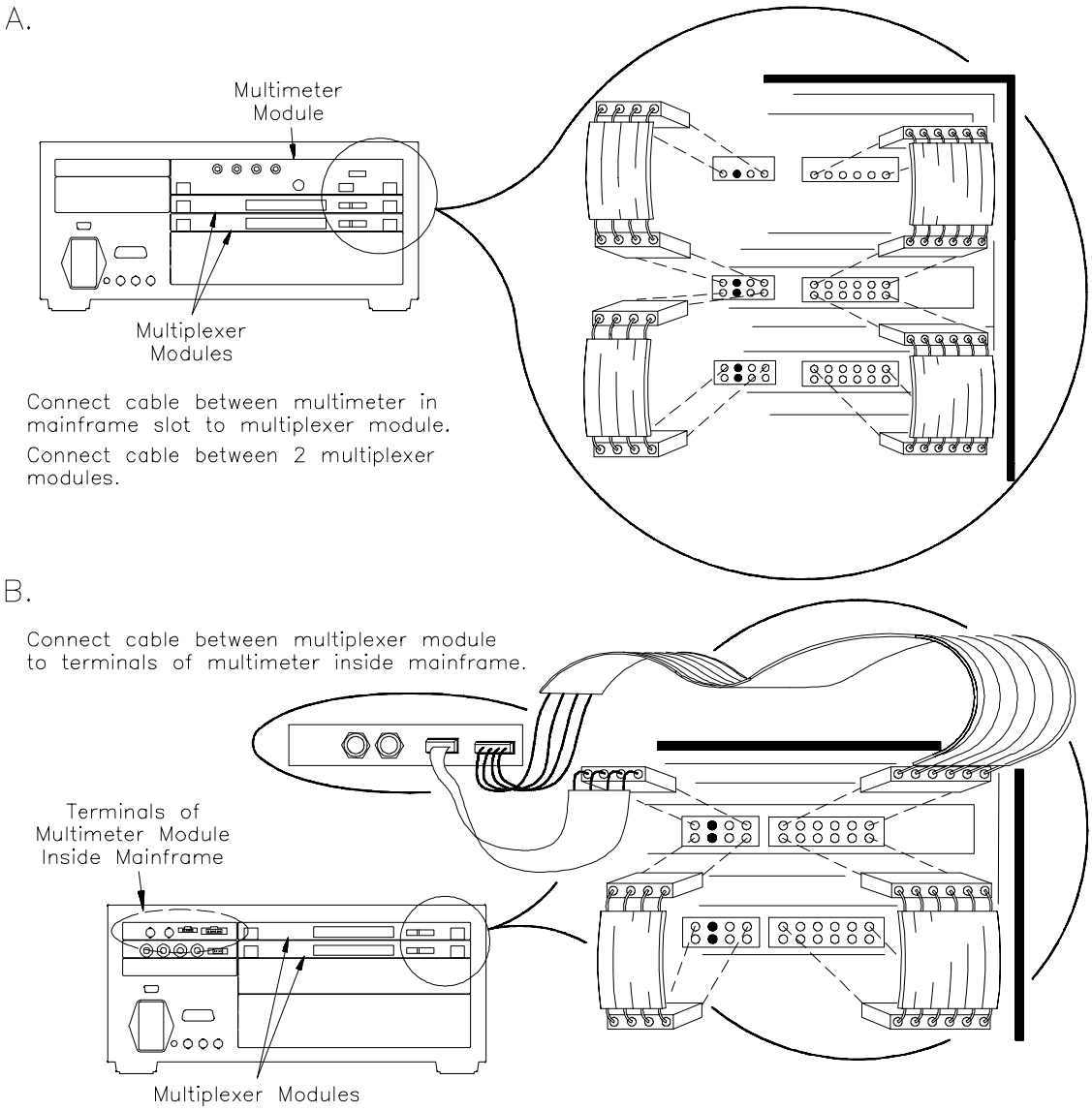
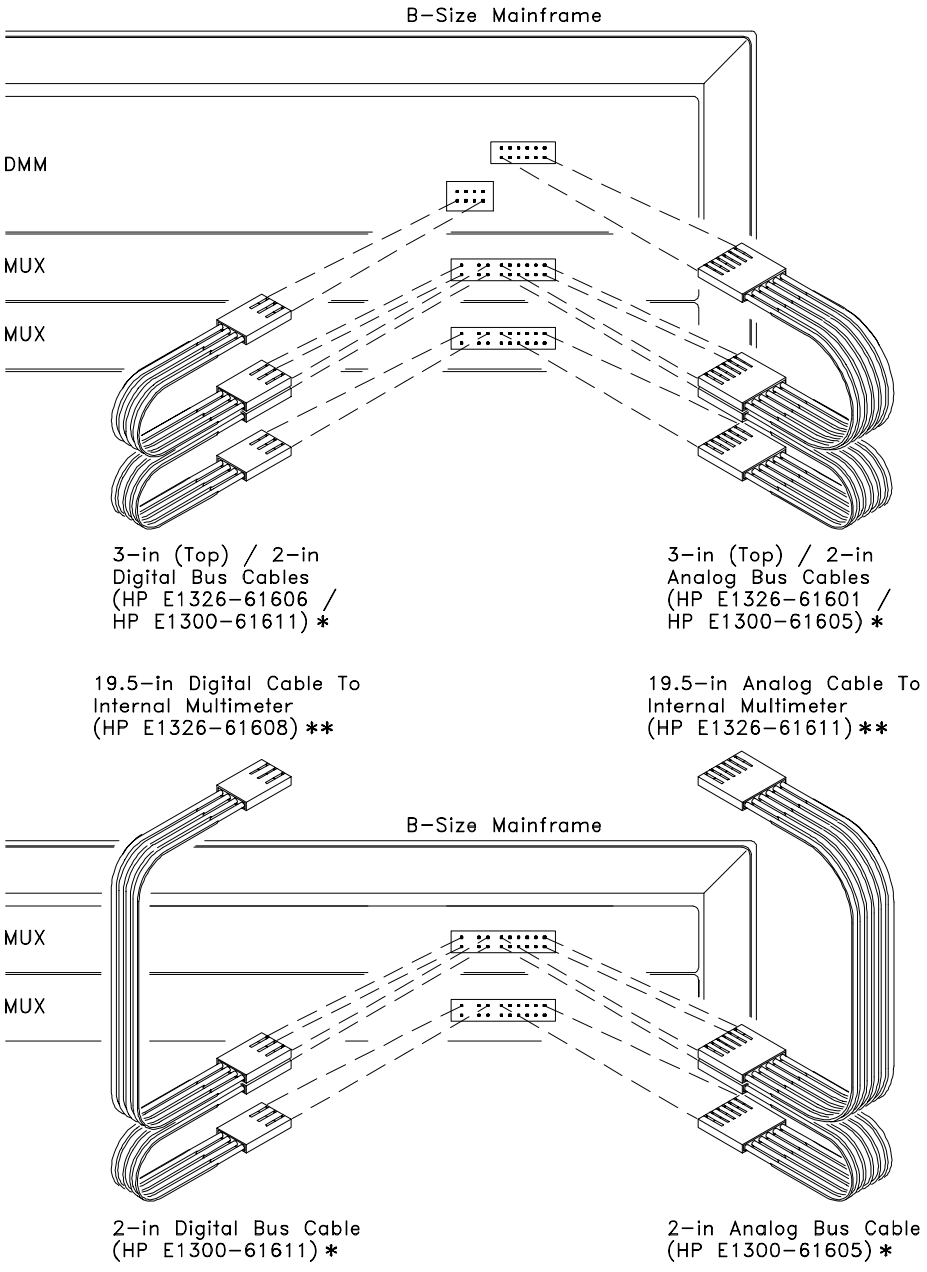


Figure 2-10. Analog Bus and Digital Bus Connections

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Analog Bus and Digital Bus Cables

Figure 2-11 shows analog bus and digital bus cables for multiplexer-to-multiplexer and multiplexer-to-multimeter connections.



* DMM–to–MUX and MUX–to–MUX Analog and Digital Bus Cables are provided with the purchase of the DMM and Mux Modules, respectively.

** 19.5–in Analog and Digital Bus Cable is provided with the purchase of HP E1300/01A Series B Mainframe with internal DMM option.

Figure 2-11. Analog Bus and Digital Bus Cables

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Notes

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Chapter 3
Using the HP E1351A/53A FET Multiplexer Modules

Using This Chapter

This chapter uses some typical examples to show how to use the 16-Channel FET and 16-Channel Thermocouple FET Multiplexer Modules. Refer to Chapter 4, "Understanding the HP E1351A/53A FET Multiplexers" for further information. This chapter contains the following sections:

- Selecting Channels . . . . . Page 29
- Multiplexer Commands . . . . . Page 31
- Connecting Switchbox Channels to Direct Terminals . . . . . Page 32
- Connecting Switchbox Channels to Tree Terminals for Making Measurements . . . . . Page 34
- Scanning a Range of Switchbox Channels . . . . . Page 36
- Downloading a Scan List . . . . . Page 39
- Scanning a Switchbox without a Downloaded Scan List . . . . . Page 40
- Scanning a Switchbox with a Downloaded Scan List . . . . . Page 41
- Scanning Voltmeter Configuration with HP E1326B . . . . . Page 42
- Measuring Temperature Using Thermocouples (HP E1353A Module only) . . . . . Page 43

Selecting Channels

Individual channels within a module or multiple-module instrument are selected with the SCAN <*channel_list*> or OPEN and CLOSe <*channel_list*> commands. OPEN and CLOSe <*channel_list*> immediately opens/closes the specified channel. The SCAN <*channel_list*> command creates a scanning list which can be downloaded into RAM on each module. The INITiate command closes the first channel on the scan list, and the selected trigger mode advances the rest of the channels.

The FET Multiplexer Module uses break-before-make logic so that a closed channel is opened before the next channel is closed. Only one channel can be closed at any given time on the FET multiplexer. The only exception is in SCAN:MODE FRES (4-wire resistance measurements). You can, however, have a channel closed on two different modules in the same instrument.

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To address specific channels within a multiplexer module in a switchbox or scanning voltmeter configuration, you must send the appropriate SCPI command string with a specified card number (cc) and channel number (nn). The card number refers to the multiplexer module within a switchbox or scanning voltmeter configuration. The multiplexer module with the lowest logical address in a VXIbus instrument is card number 01, and the next consecutively numbered multiplexer module is card number 02. If you have more than one switchbox or scanning voltmeter configuration, the card numbering sequence starts at 01 for each configuration. A channel address is, therefore, a four digit number (ccnn). For channel 07 on card 02 the address is 0207. You can delete leading zeros, so 207 is also a valid channel address. The channel address <*channel_list*> is in the form:

- (@ccnn) for a single channel;
- (@ccnn,ccnn) for multiple channels;
- (@ccnn:ccnn) for sequential channels;
- (@ccnn:ccnn,ccnn:ccnn) for groups of sequential channels.

The OPEN and CLOSe commands should only be used with the single-channel format and for one unique application of the multiple-channel format. You can close a channel on two different cards in the same instrument (e.g., 102 and 208) at the same time. You cannot close two channels on the same card at the same time (102 and 108). Closing a channel automatically opens all other channels on that card.

CLOSe (@102,208,309)	*Closes 02 on card 1, 08 on card 2 and 09 on card 3.*
CLOSe (@103,204)	*Opens 102 and 208, closes 103 and 204; 309 left closed.*

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Multiplexer Commands

The following commands are covered in Chapter 3. For a complete list and description of commands see Chapter 5, "Command Reference".

Table 3-1. Matrix Commands Used in Chapter 3

Command	Description
ARM:COUNt <*number*>	Selects number of scanning cycles for a switchbox only. Does not apply to downloaded scan lists.
INITiate[:IMMediate]	Channel advance for TRIGger:SOURce BUS | HOLD.
INITiate:CONTinuous <*mode*> <*mode*> = 1 | 0 | ON | OFF	Enables/disables continuous scanning cycles.
[ROUTe:]CLOSe <*channel_list*>	Closes specified channels.
[ROUTe:]CLOSe? <*channel_list*>	Queries mainframe for channel closure.
[ROUTe:]OPEN <*channel_list*>	Opens specified channels.
[ROUTe:]SCAN <*channel_list*>	Closes all channels in channel list one at a time. Previous channel opens before next channel closes.
[ROUTe:]SCAN:MODE FRES	Closes paired channel relays (for example, channels 01 and 09) during 4-wire ohms measurements.
[ROUTe:]SCAN:PORT ABUS	Automatically closes the tree isolation switches.
TRIGger[:IMMediate]	Channel advance for TRIGger:SOURce BUS | HOLD.
TRIGger:SOURce <*source*> <*source*> = EXT | BUS | DBUS | IMM	Selects the trigger source as EXTernal, HP-IB BUS, Digital BUS, or IMMediate.
NOTE: The commands with brackets ([ ]) are implied and are not shown in this chapter.	

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Connecting Switchbox Channels to Direct Terminals

The direct terminals provide direct access to closed channels. There is a direct terminal for each bank, Bank 0 and Bank 1. Closing any channel in Bank 0 (channels 00 to 07) connects the channel to the Bank 0 direct terminal. Closing any channel in Bank 1 (channels 08 to 15) connects the channel to the Bank 1 direct terminal. You can isolate the two banks from each other, and from the analog bus connector and tree terminals, with the SCAN:PORT NONE command. This command opens the A and B tree isolation switches. Figure 3-1 shows how to connect channels 02 and 09 of a single module to their respective direct terminals. Only one channel can be closed at a time.

```
SCAN:PORT NONE          Opens Tree Isolation Switches.
CLOSe (@102)            Closes channel 02 on card 01.
CLOSe (@109)            Opens 02 then closes 09.
```

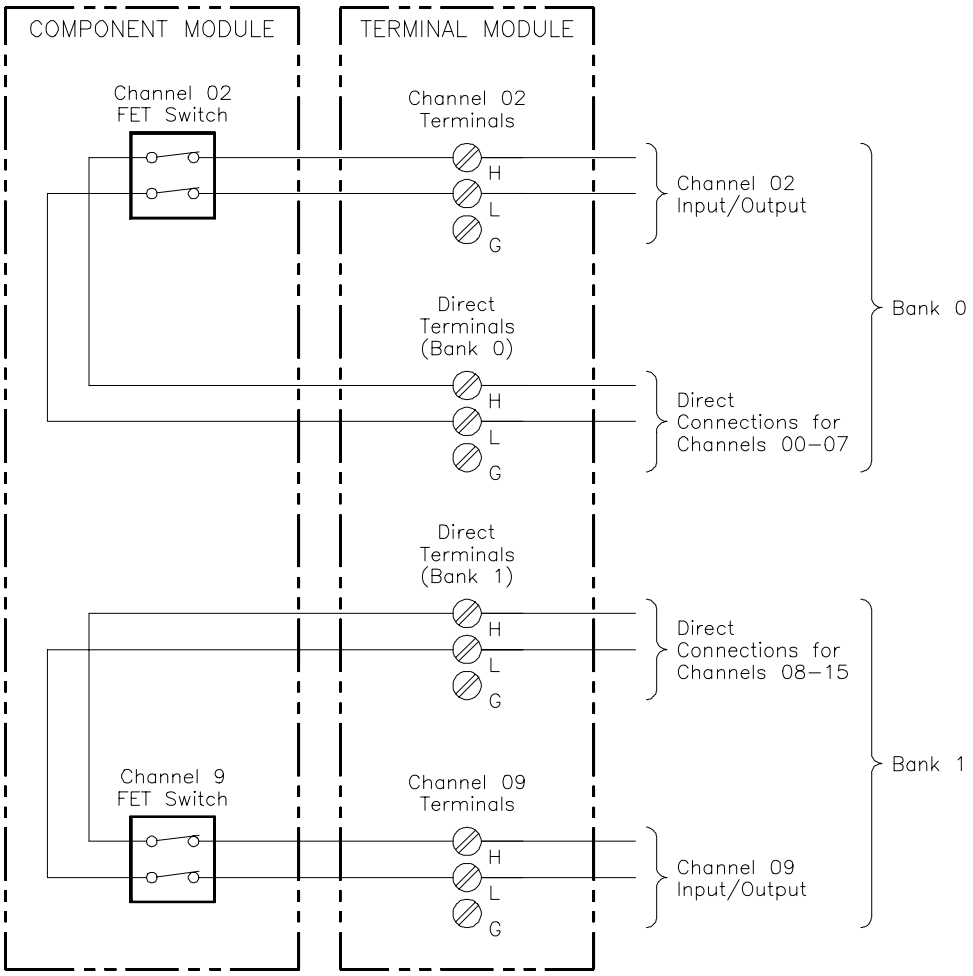


Figure 3-1. Connecting Channels 02 and 09 to their Respective Direct Terminals

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Comments

Isolation. The direct terminals provide a more accurate measurement than the tree terminals or the analog bus connector as the signal does not have to travel through the extra FET switches. The SCAN:PORT NONE command opens the tree isolation switches and isolates the direct terminals from the tree terminals and the analog bus connector.

The default value of SCAN:PORT is NONE for reset and power-on. If you have not specified a different SCAN:PORT since reset or power-on, you do not need to execute this command. You can also use the direct terminals with SCAN:PORT ABUS. The signal for a given closed channel will then be available at the direct terminal for that bank, the A tree terminal and the analog bus connector.

Closing Channels. The FET multiplexer module only allows one channel per card to be closed at a time, except for SCAN:MODE FRES (4-wire resistance measurements) where two channels are closed. You can close a channel on two different cards in the same instrument at the same time.

The SCAN <*channel_list*> command allows you to specify a list of channels to be closed sequentially. The FET multiplexer module uses a break-before-make procedure, so closed channels are opened before the next one on the list is closed. The channels are advanced according to the TRIGger mode selected.

Query Open/Closed Channels. The CLOSe? <*channel_list*> and OPEN? <*channel_list*> commands determine if the channel(s) in the *channel list* are open or closed, respectively. (The query command does not determine if, in the event of a hardware failure, the channel remains open/closed.) For example, to determine if channel 109 is closed, execute:

```
CLOS?  (@109)
```

A response of "1" indicates the channel is closed, and a "0" indicates the channel is open. The reverse is true for the OPEN? <*channel_list*> command. The response for the OPEN? and CLOSe? commands are:

```
CLOS?    1 = Closed
         0 = Open
OPEN?    1 = Open
         0 = Closed
```

To find out which channel on a card is closed, use a *channel list* for the card.

```
CLOS? (@100:115)
```

and enter the response into a string variable. If channel 09 is closed, the response will be:

```
0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0
```

NOTE: You must read the response after sending a query command or the switchbox will generate an error.

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Connecting Switchbox Channels to Tree Terminals for Making Measurements

Connect external multimeters to the A tree terminal. The SCAN:PORT ABUS command closes the appropriate FETs on the A and B tree isolation switches, so that the channels that are closed are connected to both the analog bus connector and the tree terminals. The A tree terminal is connected to the H, L, and G lines, and the B tree terminal is connected to the I +, I- and G lines. Figure 3-2 shows how to connect multimeters to measure channel 02 and channel 09.

SCAN:PORT ABUS	*Enables tree isolation switches.*
CLOS (@102)	*Close channel 02 on card 01.*
CLOS (@109)	*Open 02, close 09.*

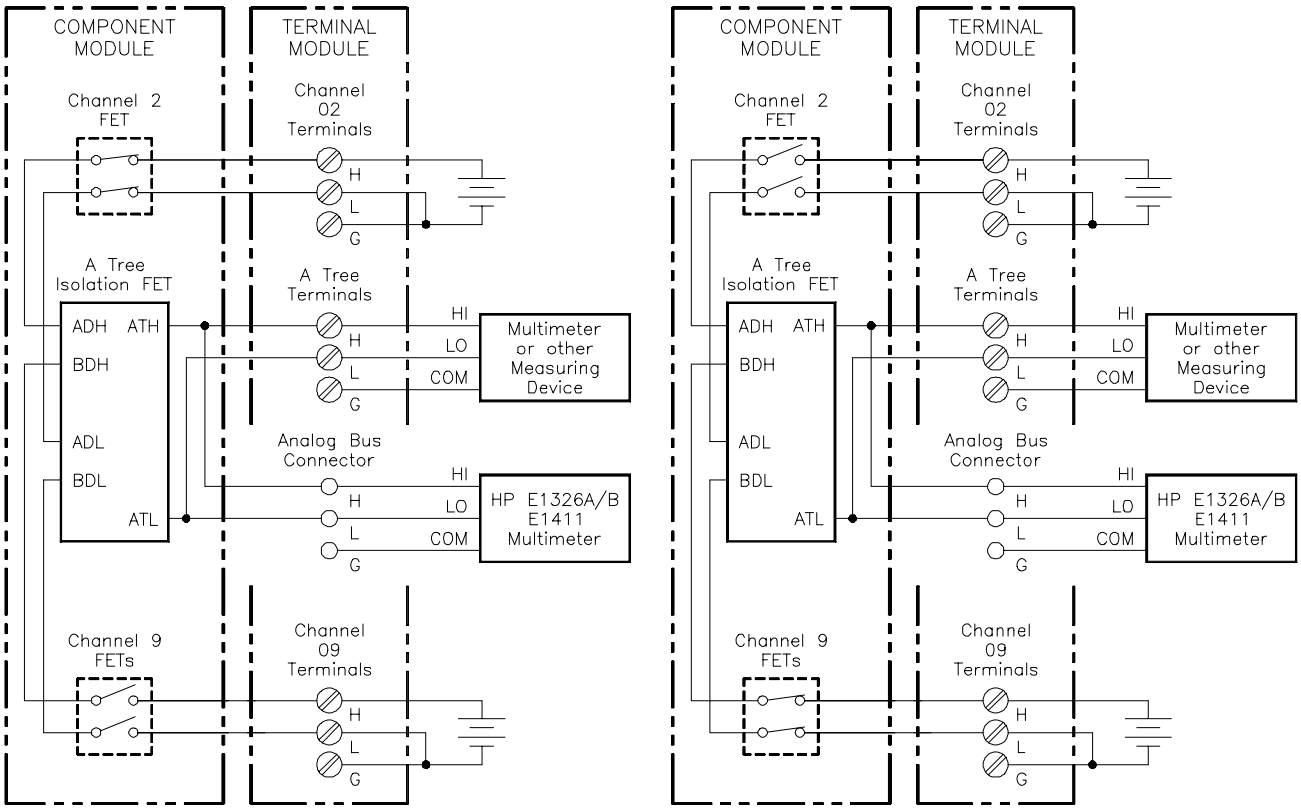


Figure 3-2. Closing Channels 02 and 09 for a Voltage Measurement

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Example: Connect Channels 02 and 10 to Tree Terminals for 4-Wire Ohms Measurement

The SCAN:MODE FRES command separates Bank 0 and Bank 1 for 4-wire resistance measurements or other stimulus/response testing. Current or signals are connected to the B tree terminal and go out through a channel on one bank. The voltage signal response comes in through a channel on the other bank and goes to the A tree terminal and the analog bus connector. The current source and voltage response must be on channels that are eight numbers apart (for example, 02 and 10, 15 and 07). You only need to specify the channel that the voltage reading is on as the FET multiplexer automatically closes the corresponding channel eight numbers away. Figure 3-3 shows a current source on channel 10 and the voltage reading on channel 02.

```
SCAN:MODE FRES
CLOSe  (@102)
```

Isolates Bank 0 from Bank 1.

Closes channels 02 and 10. 02 is routed to A tree terminal and 10 is routed to B tree terminal.

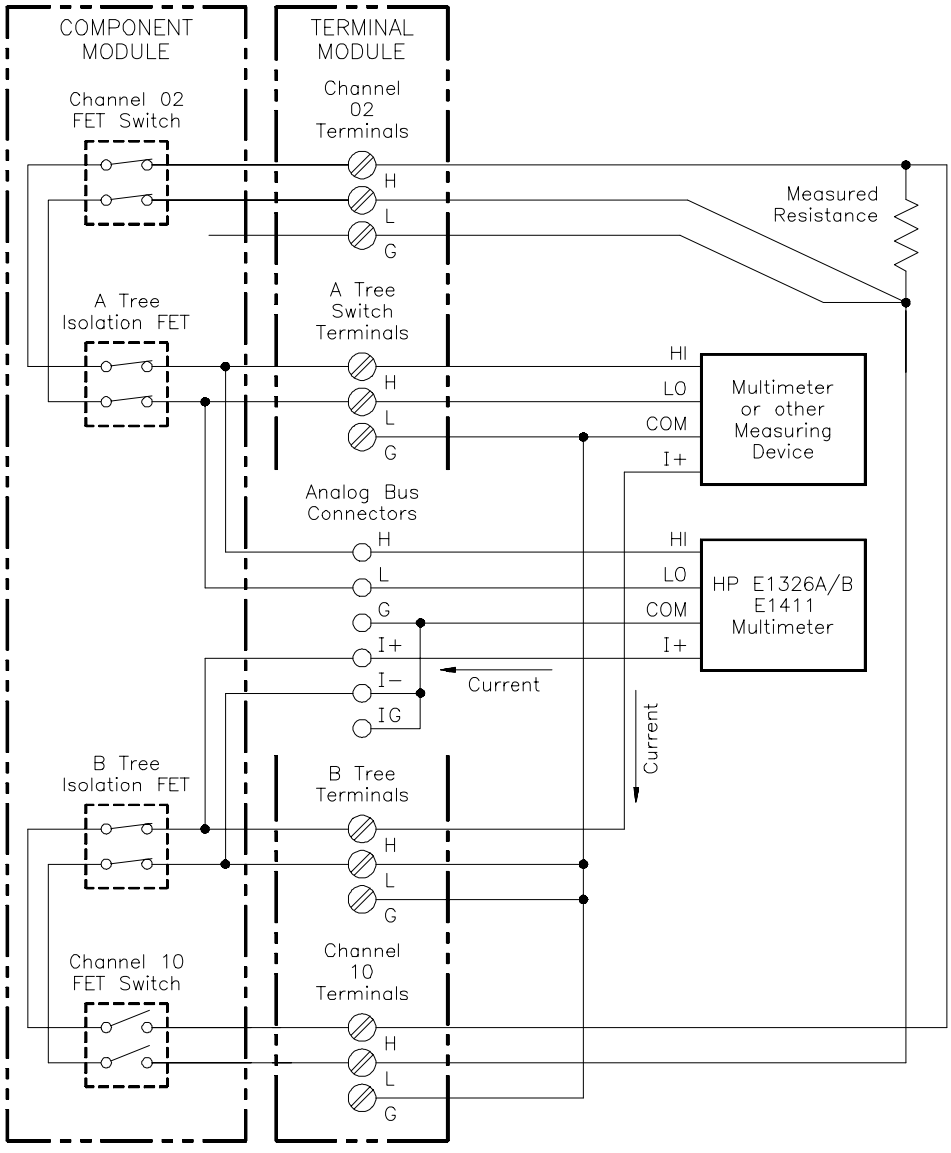


Figure 3-3. Connecting Channels 02 and 10 for 4-Wire Ohms Measurement

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Scanning a Range of Switchbox Channels

You can scan a range of channels of a switchbox consisting of single or multiple multiplexer modules. Scanning involves sequentially closing each channel on a range of specified channels. The selected TRIGger mode determines when the channel closure will advance. During scanning, the FET which was previously closed opens before the next FET closes.

You can use any of the TRIGger modes to advance the *channel list*. TRIGger:SOURce EXTernal requires an external trigger source to be connected to the HP E1300/1301 Mainframe "Event In" port. For computer controlled or HP-IB triggering (TRIGger or *TRG) use TRIGger:SOURce BUS. The OUTput ON command enables the mainframe's "Trig Out" port to synchronize multimeters when not in the TRIGger:SOURce DBUS | IMM modes.

For the fastest scan rate (up to 100 K switches/sec.) use TRIGger:SOURce DBUS. Use a custom cable (see "Digital Bus and Triggering" on page 15) to connect the multimeter handshake lines (Voltmeter Complete and External Trigger) to the multiplexer digital bus.

Example: Making Voltage Measurements by Scanning

Figures 3-4 and 3-5, and the following commands, show how to make voltage measurements by performing a single scanning cycle of all channels on two multiplexer modules in a single switchbox. In the example, the:

- A Tree Terminals of each terminal module connect to each other and to the multimeter in Figure 3-5. To connect the A tree terminals to each other, use either the analog bus cables (shown in Figures 2-10 and 2-11) or wire the terminals together between the terminal modules.
- HP-IB Bus trigger command advances the switchbox channel list.
- HP E1300A/E1301A Mainframe's "Trig Out" pulse synchronizes the switchbox with the multimeter.
- Multimeter HP-IB select code is 7 and primary address is 22.
- Switchbox HP-IB select code is 7, the HP-IB primary address is 09, and the HP-IB secondary address is 14.
- Computer is an HP Series 200/300 Computer with HP BASIC using HP-IB.

Enter and Execute:

```
10  OUTPUT  722;"TRIG EXT;DC 10"          !Sets multimeter to external
                                          triggers and to measure dc volts
20  OUTPUT  70914;"OUTP ON"               !Enables "Trig Out" port
30  OUTPUT  70914;"TRIG:SOUR BUS"         !Sets switchbox to receive bus
                                          triggers
40  OUTPUT  70914;"SCAN:MODE VOLT"        !Setup switchbox to measure
                                          voltage
50  OUTPUT  70914;"SCAN:PORT ABUS"        !Closes the appropriate tree
                                          isolation switches while scanning;
                                          automatically makes connection to
                                          the analog bus and tree terminals.
```


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```
60  OUTPUT 70914;"SCAN (@100:215)"  !Selects the channel list; 100 selects the first channel of module #1 and 215 selects the last channel of module #2.
70  OUTPUT 70914;"INIT"             !Close first channel to start the scanning cycle
80  FOR I = 1 TO 32                 !Start count loop
90  ENTER 722;A                     !Enter reading into variable A
100 PRINT A                         !Print reading in variable A
110 TRIGGER 70914                   !Trigger the switchbox to advance the scan list
120 NEXT I                          !Increment count
130 END
```

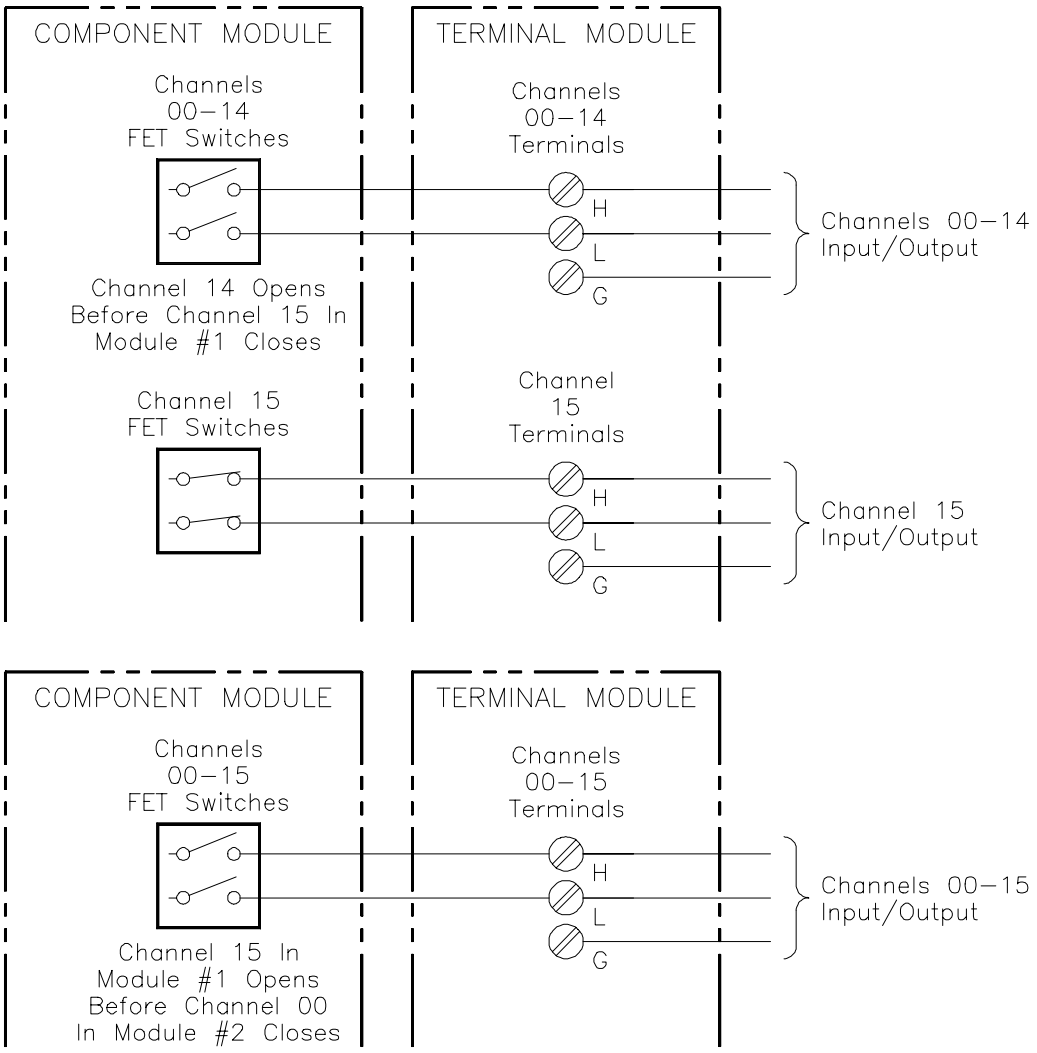


Figure 3-4. Scanning Channels 100 to 215 of a Two-Module Switchbox

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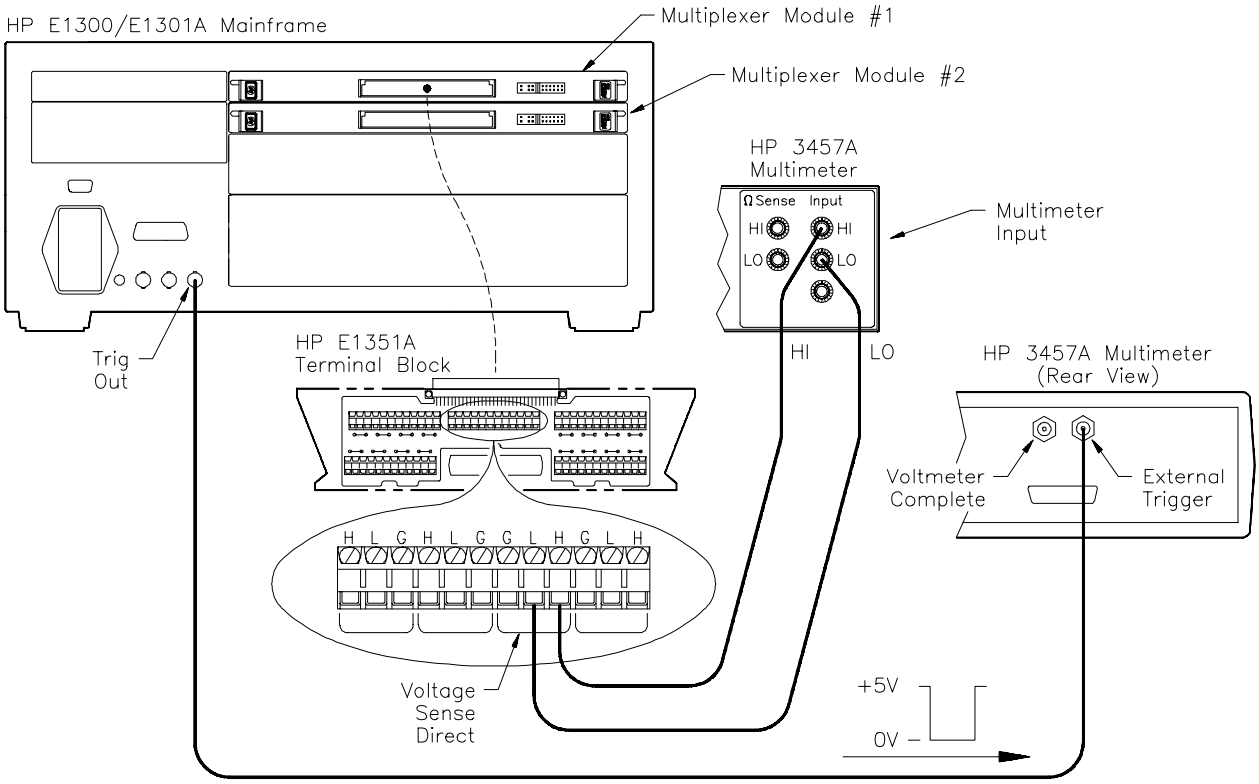


Figure 3-5. Mainframe to Multimeter Connection for Synchronization

Example: Making 2-Wire Ohms Measurements by Scanning

Use the same setup shown in the first program example in this section, except the current source from the multimeter must be connected to the B tree terminal. Change the commands in lines 10 and 40 to the following:

```
10   OUTPUT 722;"TRIG EXT;OHM"        !Set multimeter to 2-wire ohms
40   OUTPUT 70914;"SCAN:MODE RES"     !Closes the appropriate tree
                                      isolation switches
```

This command, when used with SCAN:PORT ABUS and SCAN <*channel_list*> commands, automatically closes the channels defined in the *channel list*, along with the appropriate tree isolation switches. The current source is superimposed on the channel being measured.

Example: Making 4-Wire Ohms Measurements by Scanning

This type of measurement requires a paired channel closure (for example, channels 02 and 10). Use the SCAN:MODE FRES command to automatically close the paired channels to the selected channels defined in the SCAN <*channel_list*> command. Connect High and Low to a Bank 0 channel and High and Low to the paired channel eight numbers away. Use only one of the channels of the channel pairs in the *channel_list*. Change the commands in lines 10, 40 and 60 to the following:

```
10   OUTPUT  722;"TRIG EXT;OHM"       !Set multimeter to 4-wire ohms
40   OUTPUT  70914;"SCAN:MODE FRES"   !Closes the appropriate tree
                                      isolation switches
60   OUTPUT  70914;"SCAN  (@100:107,200:207)"
```


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Example: Making Multiple Scans

The ARM:COUNt <*number*> command selects multiple scanning cycles for switchboxes with non-downloaded scans. It does not apply when the TRIGger:SOURce is DBUS or IMMediate.

Add the command before the SCAN <*channel_list*> in the first program example in this section. When the last channel in a *channel list* is closed, the pointer is reset back to the beginning of the *channel list*. The next trigger opens the last channel and closes the first one. This continues for the specified number of cycles.

```
59  OUTPUT  70914;"ARM:COUN 10"     !Enables 10 scanning cycles
60  OUTPUT 70914;"SCAN  (@100:215)"!Sets scan list
80  FOR I = 1 TO 320
```

Example: Making Continuous Scans

The INITiate:CONTinuous ON command selects continuous scanning cycles (INIT:CONT OFF disables continuous scanning cycles). Add the command to the first program example in this section, as follows:

```
59  OUTPUT  70914;"INIT:CONT ON"    !Enables continuous scanning
                                    cycles
60  OUTPUT  70914;"SCAN  (@100:215)"!Sets scan list
80  FOR I = 1 TO X                  !Set the number of measurements
                                    desired
```

Comments

Scanning consists of six steps:

- Connecting the multimeter to the switchbox
- Selecting the SCAN:MODE
- Selecting the SCAN:PORT
- Selecting the TRIGger:SOURce
- Specifying the SCAN <*channel_list*>
- Starting the scan (INIT or TRIG[:IMMediate])

Downloading a Scan List

The FET Multiplexer Module is primarily designed to be used as a high-speed scanning switchbox or scanning voltmeter. To enable it to make 100,000 connections per second, the SCAN <*channel_list*> scanning list is downloaded into RAM on the module. This download takes place automatically when you use TRIGger:SOURce DBUS or TRIGger:SOURce IMM. For a multiple-module switchbox, the entire scanning list is downloaded to each module. The channels are advanced to the next channel in the channel list without any direct intervention by the mainframe CPU during the scan.

The scan list is not downloaded for a switchbox or scanning voltmeter that combines both FET and relay multiplexer modules, or for TRIGger:SOURce BUS | EXT | HOLD. The channel closings are controlled by the mainframe CPU. Also, the ARM:COUNt <*number*> command does not apply to downloaded scan lists. You can use INITiate:CONTinuous ON for continuous scanning with downloaded scan lists.

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Scanning a Switchbox without a Downloaded Scan List

This example shows a FET switchbox connected to a multimeter with the analog bus cable. The switchbox and multimeter are separate VXIbus instruments. The multimeter has a secondary address of 03, and the switchbox has a secondary address of 04. The multiplexer is triggered by the *TRG command. OUTPut ON is enabled, and the multimeter is triggered by the OUTPut ON trigger to its "External Trigger" port. The following program illustrates the procedures:

```
10  DIM Rdgs(1:16)                          !Dimension array to store readings
20  OUTPUT 70903;"*RST;*OPC?"               !Clear the multimeter; *OPC?
                                            ensures reset is completed before
                                            program continues
30  ENTER 70903;A
40  OUTPUT 70903;"*CLS"
50  OUTPUT 70904;"*RST"                     !Reset multiplexer
60  OUTPUT 70904;"*CLS"
70  OUTPUT 70903;"CONF:VOLT:DC 58.1"!Configure the multimeter
80  OUTPUT 70903;"TRIG:SOUR EXT"  !External trigger source
90  OUTPUT 70903;"TRIG:COUN 16"   !Set for 16 triggers
100 OUTPUT 70903;"INIT"           !Initialize multimeter wait for
                                  trigger
110 OUTPUT 70904;"TRIG:SOUR BUS"  !Trigger on *TRG command
120 OUTPUT 70904;"SCAN:MODE VOLT"!Configure for voltage
130 OUTPUT 70904;"SCAN:PORT ABUS"!Enables analog bus
140 OUTPUT 70904;"SCAN  (@100:115)"!Enter scan list
150 OUTPUT 70904;"OUTP ON"        !Enable mainframe trig out port
160 OUTPUT 70904;"INIT"           !Close first channel
170 FOR I = 1 TO 16               !16 channels
180 OUTPUT 70904;"*TRG"           !Trigger for channel advance
190 WAIT .25                      !Allow time for measurement
                                  before next advance
200 NEXT I                        !Increment counter
210 OUTPUT 70903;"FETC?"          !Multimeter retrieves readings
                                  from mainframe memory when
                                  scan completes
220 ENTER 70903;Rdgs(*)           !Put readings in array
230 PRINT Rdgs(*)                 !Print
240 END
```


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Scanning a Switchbox with a Downloaded Scan List

This example shows a FET switchbox connected to multimeter with the analog bus cable and the digital bus cable. The switchbox and multimeter are separate VXIbus instruments. The multimeter has a secondary address of 03, and the switchbox has a secondary address of 04. The triggering is through the digital bus handshake lines, so the scan list is downloaded. The following program illustrates the procedures:

```
10  DIM Rdgs(1:16)                          !Dimension array to store readings
20  OUTPUT 70903,"*RST,*OPC?"               !Clear the multimeter; *OPC?
                                            ensures reset is completed before
                                            program continues
30  ENTER 70903;A
40  OUTPUT 70903;"*CLS"
50  OUTPUT 70904;"*RST"                     !Reset multiplexer
60  OUTPUT 70904;"*CLS"
70  OUTPUT 70903;"CONF:VOLT:DC 58.1"!Configure the multimeter
80  OUTPUT 70903;"TRIG:SOUR EXT"  !External trigger source
90  OUTPUT 70903;"TRIG:COUN 16"   !Set for 16 triggers
100 OUTPUT 70903;"INIT"           !Initialize multimeter, wait for
                                  trigger
110 OUTPUT 70904;"STAT:OPER:ENAB 256"
                                  !Enable operation complete bit
120 OUTPUT 70904;"TRIG:SOUR DBUS"!Digital bus triggers
130 OUTPUT 70904;"SCAN:MODE VOLT"!Configure for voltage
140 OUTPUT 70904;"SCAN:PORT ABUS"!Enables analog bus
150 OUTPUT 70904;"SETT:TIME MAX,(@100)"
                                  !Delay for signal to settle before
                                  multiplexer enables channel closed
                                  pulse
160 OUTPUT 70904;"SCAN  (@100:131)"!Enter scan list
170 OUTPUT 70904;"INIT"           !Close first channel
180 OUTPUT 70903;"FETC?"          !Multimeter retrieves readings
                                  from mainframe memory when
                                  scan completes
190 ENTER 70903;Rdgs(*)           !Put readings in array
200 PRINT Rdgs(*)                 !Print
210 END
```


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Scanning Voltmeter Configuration with HP E1326B

This example shows an HP E1326B Multimeter and an HP E1351A/ E1353A Multiplexer combined into a single VXIbus instrument, a scanning voltmeter. The secondary address for the scanning voltmeter is 03. Both the analog bus connector and the digital bus connector are used. Once the scanning starts, there is no intervention from the mainframe CPU. The scan list is in RAM on the multiplexer, and the two handshake lines on the digital bus control the triggering.

The following program illustrates the procedures:

```
10  DIM Rdgs(1:16)                          !Dimension array to store readings
20  OUTPUT 70903;"*RST;*OPC?"               !Clear the multimeter; OPC? ensures reset is completed before program continues
30  OUTPUT 70903;"*CLS"
40  OUTPUT 70903;"CONF:VOLT:DC (@100:115)"
                                            !Configures multimeter; also automatically configures multiplexer for SCAN:MODE, SCAN:PORT and TRIG:SOUR
50  OUTPUT 70903:"INIT"                     !Close first channel, start scan
60  OUTPUT 70903;"FETC?"                    !Retrieve readings from mainframe
70  ENTER 70903;Rdgs(*)
80  PRINT Rdgs(*)
90  END
```

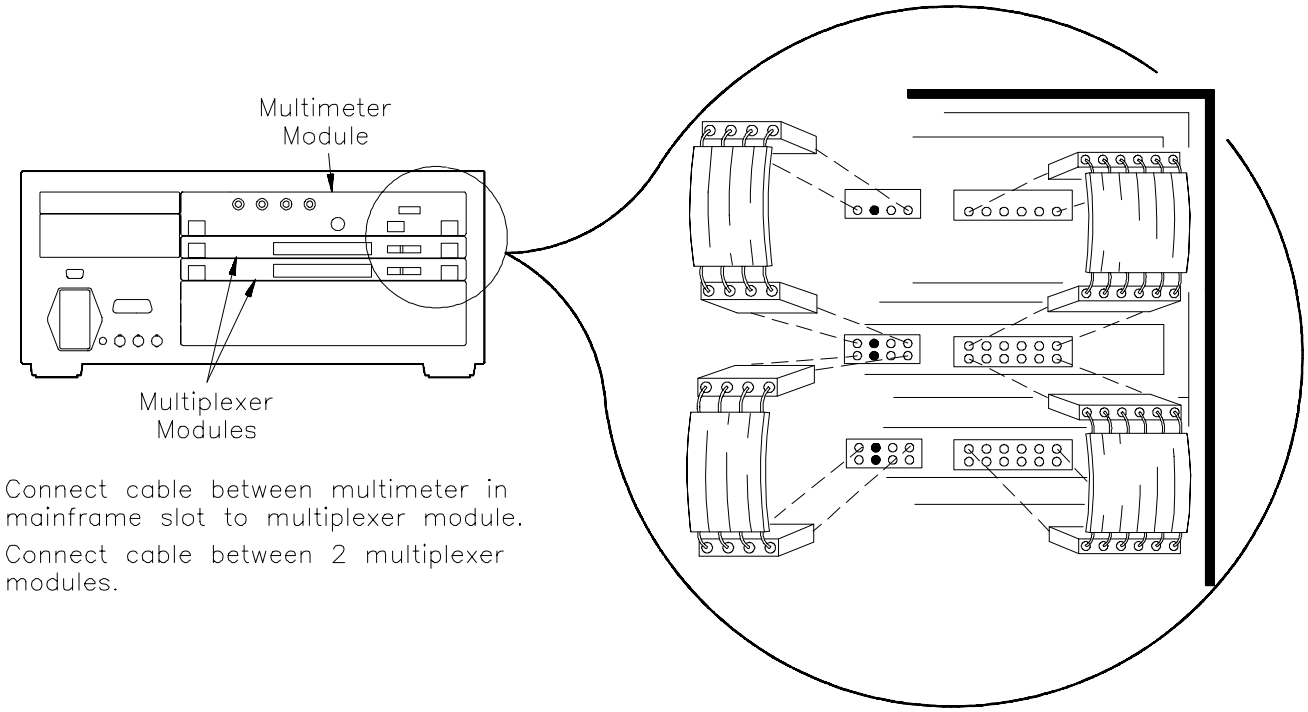


Figure 3-6. Connecting the Analog Bus and Digital Bus Cables

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Measuring Temperature Using Thermocouples (HP E1353A Module only)

The thermocouple terminal module automatically configures the HP E1353A FET Multiplexer Module for thermocouple readings. The multimeter measures the resistance of a thermistor on the terminal module to provide a reference temperature. This reference temperature is used to compensate for the change in temperature between the thermocouple (desired measurement) and the terminal temperature (see "Comments" later in this section).

Setup for Measuring Thermocouple Temperature using an External Multimeter

Figure 3-7 shows how to set up channel 01 of a single module switchbox to measure temperature using a thermocouple and an external multimeter.

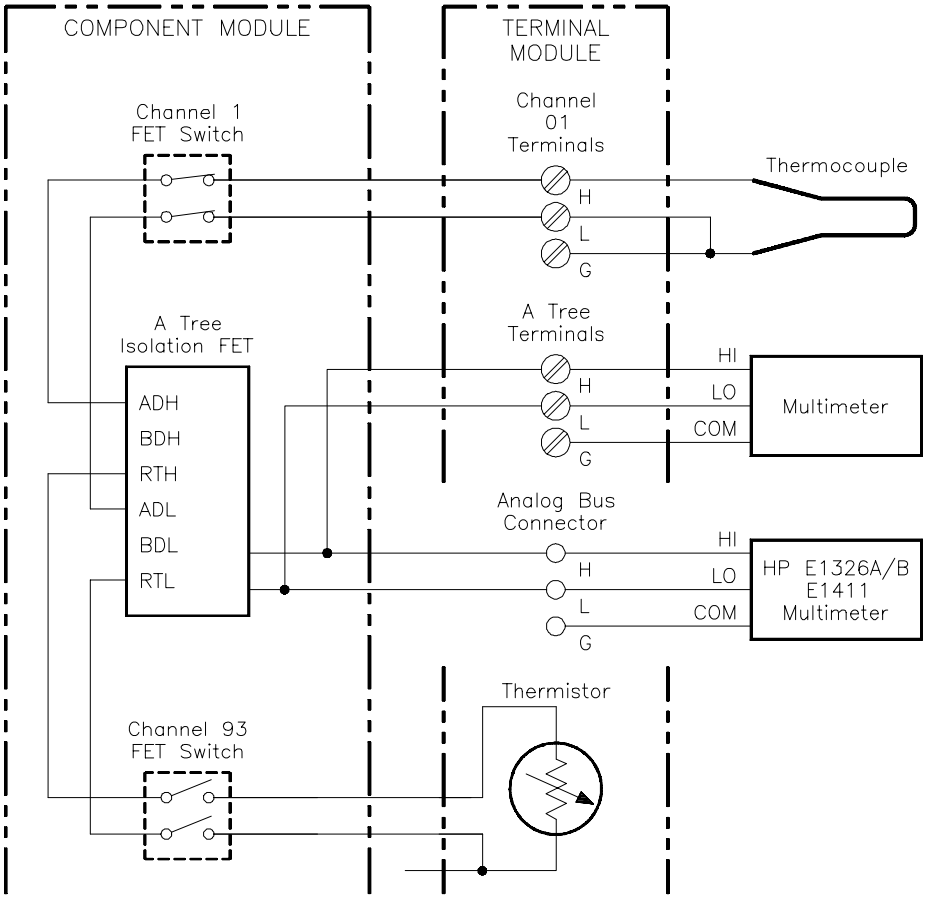


Figure 3-7. Temperature Measurement Using a Thermocouple

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Comments

Measuring Temperature with the HP El326B/El411B Multimeters. The HP E1326B/E1411B Multimeters can directly measure channels of single or multiple multiplexer modules. The multimeter automatically calculates the correct temperature for the specific thermistor or thermocouple type used. For more information, see the *HP E1326B/E1411B Multimeter User's Manual*.

Thermocouple Compensated Measurements. The HP E1353A FET Multiplexer makes thermocouple compensated measurements. Thermocouple compensation accounts for the temperature inside the multiplexer terminal module, which can affect the thermocouple reading. Thermocouple compensated measurements are made with the HP E1326B/E1411B. More information on these types of measurements can be found in Hewlett-Packard Application Note 290, *Practical Temperature Measurements*.

High-Speed Temperature Measurements. High-speed temperature measurements can be made by measuring the thermocouple voltage, compensating the reading, and then converting the voltage to a temperature. The instrument configuration used for these types of measurements may include an E1326B/E1411B Multimeter and a FET multiplexer switchbox, or an external voltmeter used with the FET switchbox. The procedure for these types of measurements is:

1. Measure the resistance of the thermistor (channel 93) on the multiplexer terminal module (CLOSe(@cc93)).
2. Measure the thermocouple voltage on the multiplexer channel.
3. Convert the thermistor resistance to a temperature using the following equation:

   $t = 1.0 / (A + B * lnr + C * (lnr)^3)$ calculate temperature
   $t = t - 273.15$ convert Kelvin to Centigrade

   where:

   A = 0.00128463
   B = 0.00023625
   C = 9.2697E-8
   lnr = natural log of the measured thermistor resistance

   A, B, and C are the curve-fitting constants for the multiplexer's 5K thermistor.
4. Convert the thermistor temperature (step 3) to a voltage using the reference table for the type of thermocouple used.
5. Subtract the voltage (step 4) from the thermocouple voltage measured in step 2. Convert the difference between the voltages to a temperature, again using the reference table for the type of thermocouple used.
6. Add the temperature (step 5) to the thermistor temperature computed in step 3 to obtain the result of the thermocouple measurement.

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Chapter 4
Understanding the HP E1351A/53A FET Multiplexer Modules

Using This Chapter

This chapter explains techniques to scan the channels of 16-Channel FET and 16-Channel Thermocouple FET Multiplexer Modules. This chapter contains the following sections:

- Commands for Scanning Switchbox Channels . . . . . Page 45
- Using Scanning Trigger Sources . . . . . Page 45
- Using the Scan Complete Bit. . . . . Page 52

Commands for Scanning Switchbox Channels

Scanning multiplexer channels consists of closing a set of channels, one at a time. The multiplexer has single, multiple, or continuous scanning modes. See Figure 4-1 for the different commands used in scanning.

Using Scanning Trigger Sources

The TRIGger:SOURce command specifies the source to advance the channel list. Figure 4-2 shows the different trigger sources. TRIG:SOUR DBUS uses the digital bus handshake lines. You can use the TRIG[:IMM] command to immediately advance the channel list while in the TRIG:SOUR BUS or TRIG:SOUR HOLD mode. (Note that TRIG:SOUR IMM is not the same as TRIG[:IMM].) To enable the HP E1300/E1301 Mainframe "Trig Out" port, use the OUTP ON command. The "Event In" mainframe trigger source is reserved with the TRIG:SOUR EXT command. "Trig Out" and "Event In" are mainframe resources, and can only be allocated to one instrument at a time.

Scanning with External Instruments

The examples in this chapter show different ways to scan channels of a switchbox in an HP E1300/E1301 Mainframe. The operation is similar to other HP VXIbus mainframes with HP command modules that have "Trig Out" and "Event In" ports. The computer used in the examples is an HP Series 200/300 used 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
- HP-IB primary address of 09 for the HP E1300/E1301 Mainframe
- HP-IB primary address of 22 for the HP 3457A Multimeter
- HP-IB secondary address of 14 for the multiplexer module

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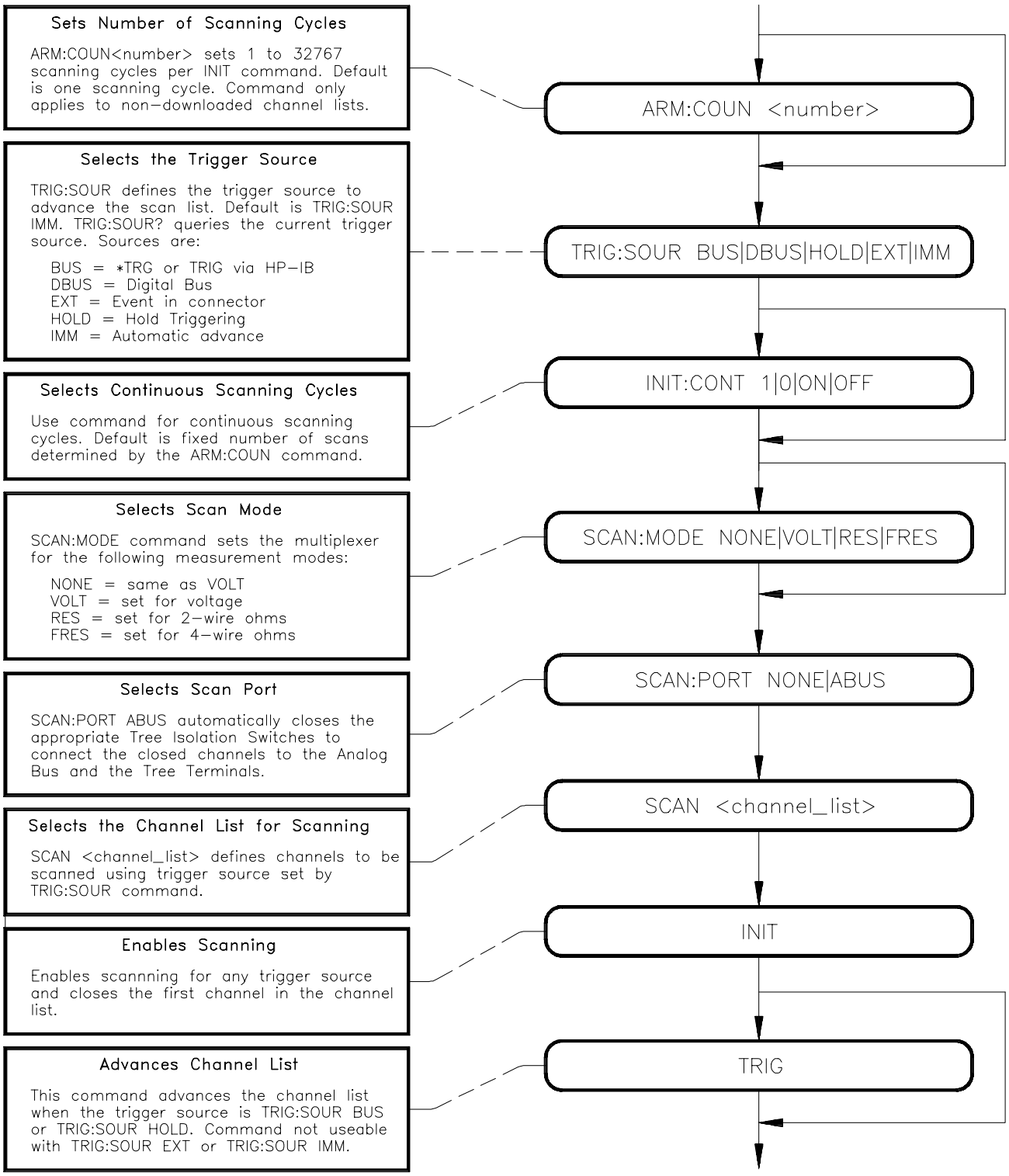


Figure 4-1. Scanning Commands

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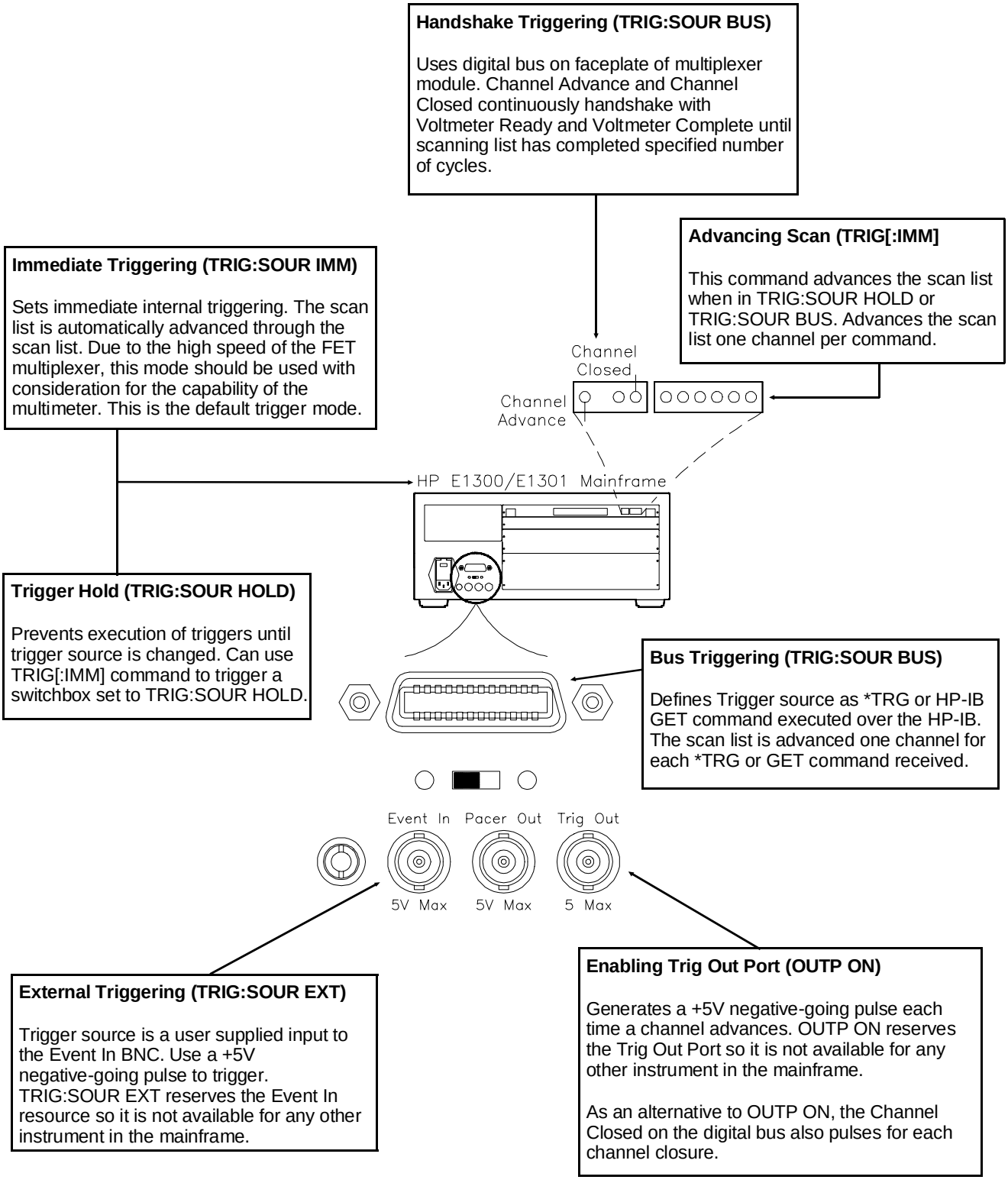


Figure 4-2. Trigger Sources

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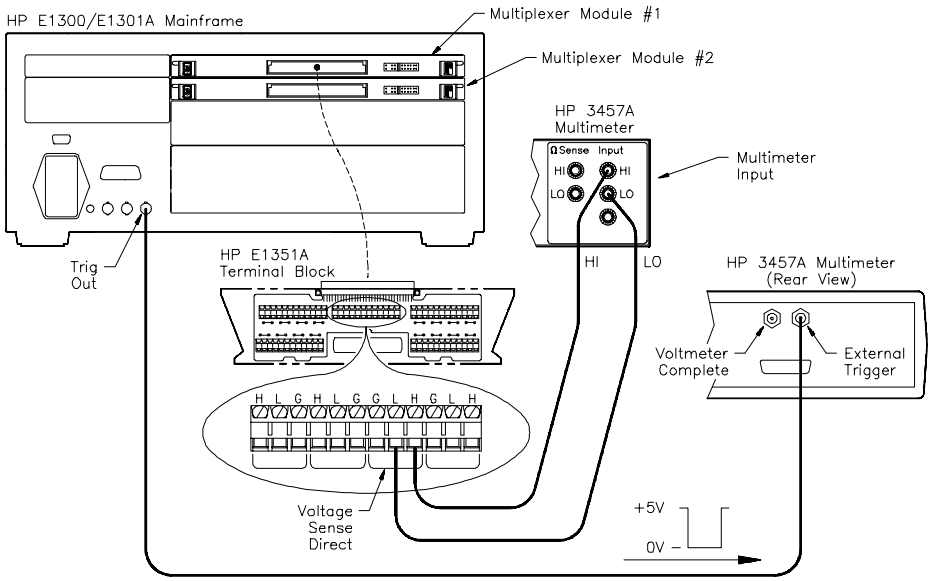
Example: Scanning with External Instruments

This example uses the mainframe "Trig Out" port to synchronize the multiplexers to an HP 3457A Digital Multimeter. See the following figure for typical connections. For this example, use the trigger output pulse of the mainframe "Trig Out" port to trigger the multimeter from its "External Trigger" port.

The sequence of operation is:

1. INIT (line 70) closes channel number 100.
2. The channel closure causes a trigger output from the "Trig Out" port.
3. The trigger causes the multimeter to make a measurement.
4. Measurement result is sent to the computer (lines 80 to 100).
5. TRIGGER command (line 110) advances the channel list to the next channel.
6. Steps 2-5 are repeated for channels 101 through 115.

```
10  OUTPUT 722;"TRIG EXT;DCV"          !Sets multimeter to external trigger
                                       and to measure dc volts
20  OUTPUT 70914;"OUTP ON"             !Enables "Trig Out" port
30  OUTPUT 70914;"TRIG:SOUR BUS"       !Sets switchbox to receive bus
                                       triggers
40  OUTPUT 70914;"SCAN:MODE VOLT"      !Sets switchbox to measure
                                       voltage
50  OUTPUT 70914;"SCAN:PORT ABUS"      !Closes the tree isolation switches
60  OUTPUT 70914;"SCAN (@100:115)"     !Selects the channel list for
                                       scanning
70  OUTPUT 70914;"INIT"                !Starts scanning cycle
80  FOR I = 1 TO 16                    !Start count loop
90  ENTER 722;A                        !Enter 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
```



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Example: Scanning Using "Trig Out" and "Event In" Ports

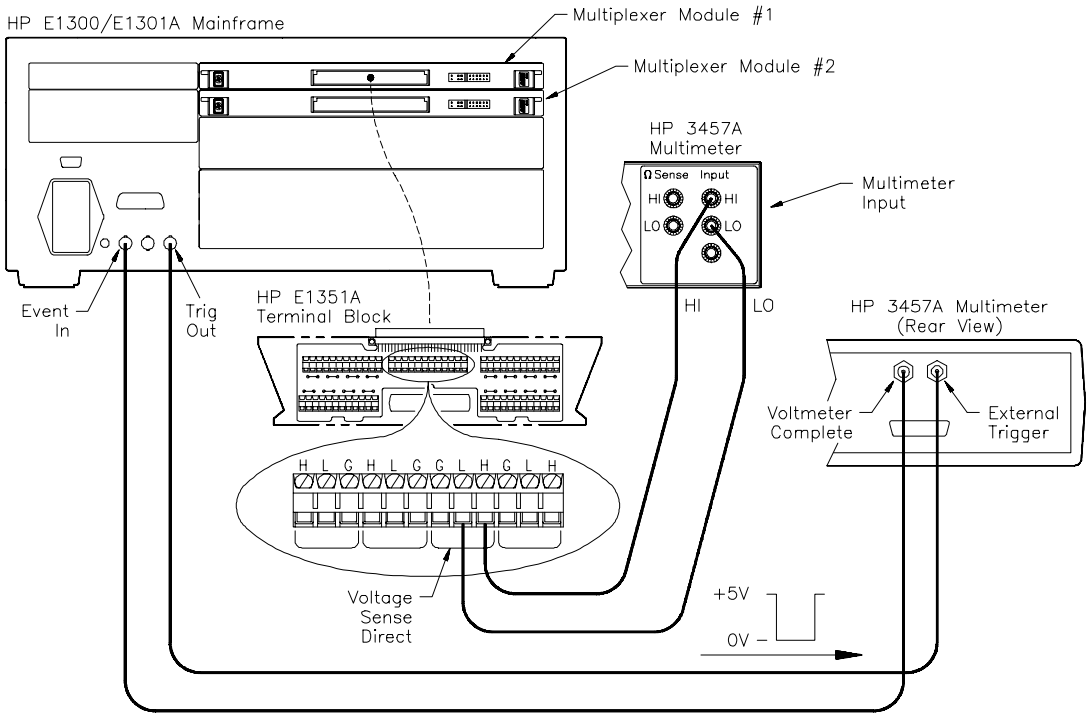
This example uses the mainframe "Trig Out" and "Event In" ports to synchronize the multiplexers to an HP 3457A Digital Multimeter. See the following figure for typical connections.

For this example, use the trigger output pulse of the mainframe's "Trig Out" port to trigger the multimeter from its "External Trigger" port. Note that the pulse output from the multimeter's "Voltmeter Complete" port triggers the switchbox to advance the channel list. Use the multimeter's reading storage capability to store readings.

The sequence of operation is:

1. INIT (line 50) closes channel number 100.
2. The channel closure causes a trigger output from the "Trig Out" port.
3. The trigger causes the multimeter to make a measurement.
4. Measurement result is stored into multimeter memory.
5. Trigger is output from multimeter's "Voltmeter Complete" port.
6. Trigger to "Event In" port advances the channel list to the next channel.
7. Steps 2-6 are repeated for channels 101 through 115.

```
10  OUTPUT 722;"TRIG EXT:DCV:MEM FIFO"
                                    !Sets multimeter to external trigger
                                    to measure dc volts and store
                                    readings
20  OUTPUT 70914;"OUTP ON"          !Enables "Trig Out" port
30  OUTPUT 70914;"TRIG:SOUR EXT"    !Sets switchbox to receive external
                                    triggers
40  OUTPUT 70914;"SCAN (@100:115)"  !Selects the channel list (channels
                                    100 to 115)
50  OUTPUT 70914;"INIT"             !Starts scanning cycle
60  END
```



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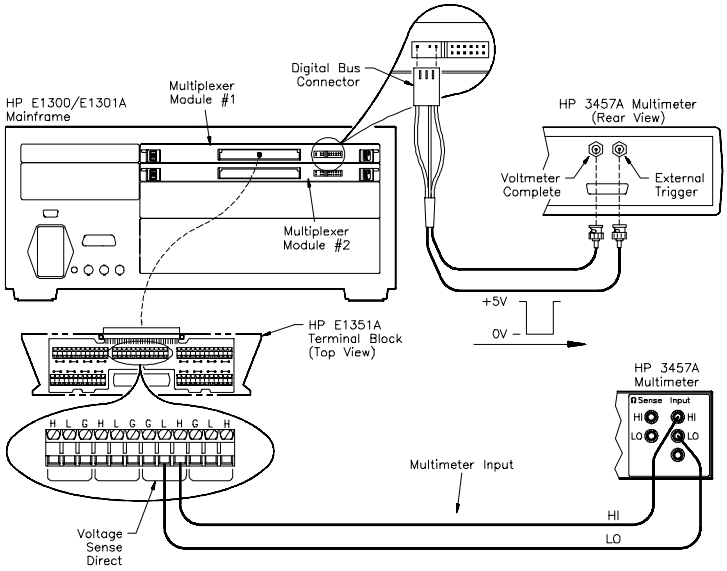
Example: Scanning Using Stand-Alone Multimeter and Digital Bus Triggering

This example is similar to the previous one except that the multimeter's "External Trigger" and "Voltmeter Complete" ports are connected to the "Channel Closed" and "Channel Advance" on the FET Multiplexer digital bus. See Chapter 1 for information on making custom digital bus cables. Once the scanning procedure has been initiated (INIT), the channel closure is advanced by the handshake lines. The INIT command closes the first channel, and when the channel is closed, the "Channel Closed" pulses. This is connected to the "External Trigger" on the multimeter, which triggers a reading. When the reading is complete, the "Voltmeter Complete" triggers, which pulses the "Channel Advance". This procedure continues until the end of the scan list.

The sequence of operation is:

1. TRIG:SOUR DBUS selects digital bus triggering.
2. INIT (line 50) closes channel number 100.
3. The channel closure causes a trigger output from the "Channel Closed" port.
4. The trigger causes the multimeter to make a measurement.
5. Measurement result is stored into multimeter memory.
6. Trigger is output from multimeter's "Voltmeter Complete" port.
7. Trigger to "Advance Channel" port advances the channel list to the next channel.
8. Steps 3-7 are repeated for channels 101 through 115.

```
10  OUTPUT 722;"TRIG EXT;DCV;MEM FIFO"
                                    !Sets multimeter to external trigger
                                    to measure dc volts and store
                                    readings
20  OUTPUT 70914;"SCAN:PORT ABUS"!Routes channels to analog bus
                                    connector and A tree terminal
30  OUTPUT 70914;"TRIG:SOUR DBUS"!Sets switchbox to receive external
                                    triggers
40  OUTPUT 70914;"SCAN (@100:115)" !Selects the channel list (channels
                                    100 to 115)
50  OUTPUT 70914;"INIT"             !Starts scanning cycle
60  END
```



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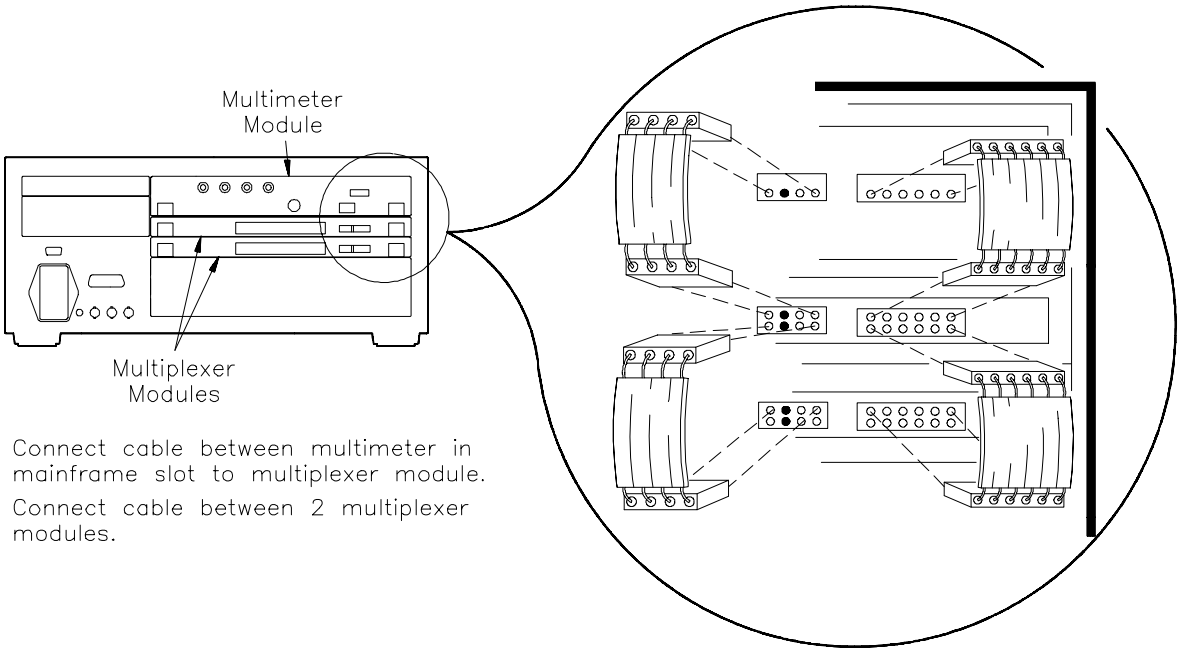
Example: Scanning Using Scanning Voltmeter Configuration and Digital Bus Triggering

In this example the HP E1326B Multimeter is combined with a FET multiplexer to form a scanning voltmeter VXIbus instrument. The multimeter is address 24, and the multiplexer is address 25, so the instrument secondary address is 03. The analog bus connector and the digital bus connector are connected between the modules. The TRIG:SOURce is set for DBUS. This configuration provides the fastest speed. Consult the *HP E1326B/E1411B Multimeter User's Manual* for further information on multimeter settings. Note that the ARM:COUNt command does not apply to downloaded scan lists.

The sequence of operation is:

1. The multimeter automatically configures the multiplexer for SCAN:MODE, SCAN:PORT and TRIGger:SOURce DBUS.
2. INIT closes first channel.
3. The channel closure causes a trigger output from the "Channel Closed" port.
4. The trigger causes the multimeter to make a measurement.
5. Measurement result is stored into multimeter memory.
6. Trigger is output from multimeter's "Voltmeter Complete" port.
7. Trigger to "Advance Channel" port advances the channel list to the next channel.
8. Steps 3-7 are repeated for channels 101 through 115.

```
10  DIM Rdgs(1:16)                    !Dimension array for readings
20  OUTPUT 70903;"*RST"               !Reset scanning voltmeter
30  OUTPUT 70903;"CONF:VOLT DC (@100:115)"
                                      !Sets multimeter to measure dc volts
40  OUTPUT 70903;"INIT"               !Starts scanning cycle
50  OUTPUT 70903;"FETC?"              !Get the readings
60  ENTER 70903;Rdgs(*)               !Place values in array
70  PRINT Rdgs(*)                     !Print values
80  END
```



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Using the Scan Complete Bit

You can use the Scan Complete Bit (bit 8) in the SCPI Operation Status Register to determine when a scanning cycle completes (no other bits in the register apply to the switchbox). 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 in Chapter 5 for an example). Note that this is not the same register as the multiplexer Status/Control Register.

When enabled by the STAT:OPER:ENAB 256 command, the Scan Complete Bit will be reported as bit 7 of the Status Register. Use the HP-IB Serial Poll or the IEEE 488.2 Common Command *STB? to read the Status Register. When bit 7 of the status Register is enabled by the *SRE 128 Common Command to assert an HP-IB Service Request (SRQ), you can interrupt the controller when the Scan Complete Bit is set, after a scanning cycle completes. This allows the controller to do other operations while the scanning cycle is in progress.

The following example monitors bit 7 in the Status Register to determine when the scanning cycle completes. The computer used in the example is an HP Series 200/300 used with HP BASIC as the program language. The computer interfaces with the mainframe over HP-IB. The HP-IB select code is 7, the HP-IB primary address is 09, and the HP-IB secondary address is 14.

Example: Scan Complete Monitor

```
10  OUTPUT 70914;"*CLS"                    !Clear all switchbox status
                                           structure
20  OUTPUT 70914;"STAT:OPER:ENAB 256"
                                           !Enable Scan Complete Bit to set
                                           bit 7 in Status Register
30  OUTPUT 70914;"*SRE 128"                !Enable bit 7 of Status Register to
                                           assert SRQ
40  OUTPUT 70914;"TRIG:SOUR EXT"           !Set to external trigger mode
50  OUTPUT 70914;"SCAN (@100:115)"         !Select channels to be scanned
60  OUTPUT 70914;"INIT"                    !Start scanning cycle
70  WHILE NOT BIT (SPOLL(70914),7)         !Waiting for scan complete
80  PRINT "DO OTHER OPERATION HERE"
                                           !Enter program lines for computer
                                           to do other operations
90  END WHILE
100 PRINT "INTERRUPT GENERATED"            !Program goes to this line after
                                           interrupt is generated by a
                                           completed scanning cycle
110 END
```


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Chapter 5
HP E1351A/53A 16-Channel FET Multiplexer Command Reference

Using This Chapter

This chapter describes Standard Commands for Programmable Instruments (SCPI) commands and summarizes IEEE 488.2 Common (*) Commands applicable to the 16-Channel FET and 16-Channel Thermocouple FET Multiplexer Modules. This chapter contains the following sections:

- Command Types . . . . . Page 53
- SCPI Command Reference . . . . . Page 55
- IEEE 488.2 Common Commands . . . . . Page 76
- Command Quick Reference . . . . . Page 77

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 like reset, self-test, status byte query, etc. Common Commands are three or four 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 perf`om functions like closing switches, making measurements, 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 VOLT
```

[ROUTe:] is the root command, CLOSe and SCAN are second-level commands with <*channel_list*> as a parameter, and MODE is a third-level command with the parameter VOLT.

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Command Separator

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

```
ROUTe:SCAN:MODE VOLT
```

Colons separate the root command from the second-level command (ROUTe:SCAN) and the second-level from the third-level (SCAN:MODE VOLT). The parameters of a command are separated from the command by a blank space.

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.

Command keywords can be entered in their full form, as shown above, or can be entered in their short form. In this manual, the entry required in short form commands is always capitalized. The short form is generally used for examples in this manual.

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 this excerpt from the [ROUTe:] subsystem shown below:

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

Both the root command [ROUTe:] is an implied command. To set the instrument's scanning list, you can send either of the following command statements:

```
ROUTe:SCAN  (@100:115)      or      SCAN  (@100:115)
```

Note You must include a space between the keywords and any parameters.

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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 numbers including optional signs, decimal points, and scientific notation. 123, 123E2, -123, -1.23E2, .123, 1.23E-2, 1.23000E-01. Special cases include MIN, MAX, and DEF. MIN selects minimum value available, MAX selects maximum value available, and DEF selects default or reset value.
Boolean	Represents a single binary condition that is either true or false. 1 or ON; 0 or OFF.
Discrete	Selects from a finite number of values. These parameters use mnemonics to represent each valid setting. An example is the TRIGger:SOURce <*source*> command where *source* can be BUS, DBUS, 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 value 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 BUS;*TRG
```

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

```
ARM:COUN 1;:TRIG:SOUR EXT
```

SCPI Command Reference

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

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ABORt

The ABORt subsystem stops a scan in progress when the scan is enabled via the interface, and the trigger modes are TRIGger:SOURce BUS or TRIGger:SOURce HOLD.

Subsystem Syntax

ABORt

Comments

- **ABORt Operation.** Resets the trigger system and places triggers in idle. The scan is stopped without resetting the scan conditions. The scan conditions stay in the current configuration.
- **Stopping Scans Enabled from Interface.** When a scan is enabled from the interface, use an interface CLEAR command or the HP E1301 front panel "Reset Instr" or "Clear Instr" key to stop the scan.

  When the scan is enabled from the interface and the trigger source is TRIGger:SOURce BUS or TRIGger:SOURce HOLD, use ABORt or the HP E1301 front panel "Reset Instr "or "Clear Instr "keys to stop the scan.
- **Stopping Scans Enabled from Front Panel.** When a scan is enabled from the HP E1301 front panel execute *RST over the interface or use the front panel "Reset Instr "or "Clear Instr" keys to stop the scan.
- **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)        Sets channel list.
INIT                   Starts scanning cycle.
 .
 .
 .
ABOR                   Aborts scan in progress.
```


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ARM

The ARM subsystem selects the number of scanning cycles (1 - 32767) for each INIT command. This command does not apply to downloaded scan lists. For downloaded scan lists, use INIT:CONT ON for multiple scans.

Subsystem Syntax

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

:COUNt

ARM:COUNt <*number*> MIN | MAX allows scanning cycles to occur a multiple of times (1 to 32767) with one INITiate command and when INITiate:CONTinuous OFF | 0 is set. MIN sets 1 scanning cycle and MAX sets 32,767 scanning cycles.

Parameters

Parameter Name	Parameter Type	Range of Values
number	Numeric	1 - 32767 | MIN | MAX

Comments

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

Example

Setting Ten Scanning Cycles

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

:COUNt?

ARM:COUNt? [MIN | MAX] returns the current number of scanning cycles set by ARM:COUNt. ARM:COUN? MIN returns 1 and ARM:COUN? MAX returns 32767.

Parameters

Parameter Name	Parameter Type	Range of Values
MIN | MAX	Numeric	MIN = 1, MAX = 32767

Comments

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

Example

Query Number of Scanning Cycles

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


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DISPlay

The DISPlay subsystem monitors the channel state of a selected module (or card). This command can only be used when the FET multiplexer module is used in a switchbox configuration. It operates with mainframes that have a display, such as the HP 75000 Series B Mainframe (HP Model Number E1301). It also operates with terminals connected to the serial interface port.

Subsystem Syntax

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

:MONitor:CARD

DISPlay:MONitor:CARD <*number* | AUTO> selects the module in a switchbox to be monitored.

Parameters

Parameter Name	Parameter Type	Range of Values
number | AUTO	Numeric	1 - 99

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:CARD AUTO command to select the last module addressed by a switching command (e.g., [ROUTe:]CLOSe).
- ***RST Condition:** DISPlay:MONitor:CARD AUTO

Example

Select Module #2 in a Switchbox for Monitoring

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


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:MONitor[:STATe]

DISPlay:MONitor[:STATe] <*mode*> turns the monitor mode on or off.

Parameters

Parameter Name	Parameter Type	Range of Values
mode	Boolean	0 | 1 | ON | OFF

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 monitor mode off.
- **Selecting the Module to be Monitored:** Use the DISPlay MONitor:CARD <*number*> | AUTO command to select the module.
- **Monitor Mode on an HP 1301 Mainframe Display:** The following three examples show the types of display you will get:

Chan: _	*No channels closed on this card.*
Chan: 12	*Channel 12 closed.*
Chan: 9,1	*4-wire ohms set-up with voltage on channel 9.*

- ***RST Condition:** DISPlay:MONitor[:STATe] OFF | 0

Example

Enabling the Monitor Mode

DISP:MON:CARD 2	*Selects module #2 in a switchbox.*
DISP:MON 1	*Turns the monitor mode on.*

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INITiate

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

Subsystem Syntax

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

:CONTinuous

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

Parameters

Parameter Name	Parameter Type	Range of Values
mode	Boolean	0 | 1 | ON | OFF

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 a 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. Continuous scanning can be stopped by the ABORt command for non-downloaded scans, and by a system reset or a power off for downloaded scan lists.

- **Scanning a Set Number of Cycles:** The INITiate:CONTinuous OFF or INITiate:CONTinuous 0 command goes through the scan list the number of times specified by the ARM:COUNt command. Sending the INITiate[:IMMediate] command closes the first channel in the *channel list*. Each trigger from a trigger source selected 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 *channel list*, and if the number of cycles has not reached the ARM:COUNt parameter, returns to the beginning of the scan list and closes the first channel. When the number of cycles equals the ARM:COUNt parameter, the scanning cycle stops. Note that ARM:COUNt does not apply to downloaded scan lists.

- **Stopping Continuous Scans:** Continuous scanning can be stopped by the ABORt command for non-downloaded scans, and by a system reset or a power off for downloaded scan lists.

- **Related Commands:** ABORt, ARM:COUNt, *RST, TRIGger, TRIGger:SOURce

- ***RST Condition:** INITiate:CONTinuous OFF

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Example Enabling Continuous Scans

```
INIT:CONT ON          Enables continuous scanning.
SCAN  (@100:115)      Sets channel list.
INIT                  Starts scanning cycle.
```

: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          Enables continuous scanning.
INIT:CONT?            Query continuous scanning state.
```

[:IMMediate]

INITiate[:IMMediate] starts the scanning cycle 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 the [ROUTe:]SCAN command).
- **Stopping Scanning Cycles:** See the ABORt command.

Example Enabling a Single Scan

```
SCAN  (@100:115)      Sets channel list.
INIT                  Starts scanning cycle.
```


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OUTPut

The OUTPut subsystem enables or disables the "Trig Out" port of the HP E1300/E1301 Mainframe.

Subsystem Syntax

```
OUTPut
    [:STATe] <state>
    [:STATe]?
```

[:STATe]

OUTPut[:STATe] <*state*> enables/disables the "Trig Out" port on the rear panel of the HP E1300/E1301 Mainframe. OUTPut[:STATe] ON | 1 enables the port and OUTPut[:STATe] OFF | 0 disables the port.

Parameters

Parameter Name	Parameter Type	Range of Values
state	Boolean	0 | 1 | ON | OFF

Comments

- **Downloaded Scans:** The OUTPut subsystem does not work with downloaded scan lists. The scan list is downloaded automatically if you use TRIG:SOUR DBUS or TRIG:SOUR IMM (FET multiplexers only). OUTPut works with all other scanning methods.
- **Enabling "Trig Out" Port:** When enabled, the "Trig Out" port is pulsed each time a channel is closed during scanning. When disabled, the "Trig Out" port is not pulsed.
- **Output Pulse:** The pulse is a +5 V negative-going pulse.
- **"Trig Out" Port Reserved by Switchboxes:** The "Trig Out" resource is a system resource, and can only be reserved by one instrument at a time.
- **Related Commands:** [ROUTe:]SCAN, TRIGger:SOURce
- ***RST Condition:** OUTPut[:STATe] OFF (port disabled)

Example

Enabling "Trig Out" Port

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

[:STATe]?

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

Example

Query "Trig Out" Port State

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


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[ROUTe:]

The [ROUTe:] 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>
        :PORT?
    SETTling
        [:TIME]  <time>, <channel_list>
        [:TIME]? [MIN | MAX] <channel_list>
```

CLOSe

[ROUTe:]CLOSe <*channel_list*> closes multiplexer channels specified in the *channel list*. The *channel_list* for CLOSe is in the form (@ccnn), or in special circumstances, (@ccnn,ccnn), where cc = card number (00-99) and nn = channel number (00-15). Before using the CLOSe command, you must specify the SCAN:MODE and SCAN:PORT, as these commands determine what switches will be closed for a given channel. You can only have one closed channel on a card at a time. If you want to close a channel on two different cards in the same VXIbus instrument (for example, 102,208) you can use (@ccnn,ccnn).

Parameters

Parameter Name	Parameter Type	Range of Values
channel_list	Numeric	cc00 - cc15

Comments

- **Specify SCAN:MODE and SCAN:PORT:** Before using the CLOSe command, specify the SCAN:MODE and SCAN:PORT.
- **Closing Channels:** To close:
  - use [ROUTe:]CLOSe (@ccnn) for a single channel;
  - use [ROUTe:]CLOSe (@ccnn,ccnn) for single channels on different cards;
  - use [ROUTe:]CLOSe (@ccnn,ccnn) for multiple channels;
  - use [ROUTe:]CLOSe (@ccnn:ccnn) for sequential channels;
  - use [ROUTe:]CLOSe (@ccnn:ccnn,ccnn:ccnn) for a group of sequential channels;
  - or any combination.

  Closure order for multiple channels with a single command is not guaranteed.
- **Related Commands:** [ROUTe:]OPEN, [ROUTe:]CLOSe?, [ROUTe:]SCAN:MODE, [ROUTe:]SCAN:PORT
- ***RST Condition:** All multiplexer channels are open.

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Example Closing Multiplexer Channels

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

```
SCAN:MODE VOLT
SCAN:PORT ABUS
CLOS  (@100,215)        100 closes channel 00 of card #1;
                        215 closes channel 15 of card #2.
```

CLOSe?

[ROUTe:]CLOSe? <*channel_list*> returns the current state of the channel(s) queried. The *channel list* is in the form (@ccnn). The command returns 1 if channels are closed and returns 0 if the channels are open.

Comments

- **Query is Software Readback:** The [ROUTe:]CLOSe? command returns the current software state of the channel specified. It does not account for relay hardware failures.

Example Query Multiplexer Channel Closure

```
CLOS  (@100,215)        100 closes channel 00 of card #1;
                        215 closes channel 15 of card #2.
CLOS?  (@215)           Query channel 215.
```

OPEN

[ROUTe:]OPEN <*channel_list*> opens the multiplexer channels specified in the *channel_list*. The *channel_list* is in the form (@ccnn), (@ccnn,ccnn), (@ccnn:ccnn) or (@ccnn:ccnn,ccnn:ccnn) where cc = card number (00-99) and nn = channel number (00-15).

Parameters

Parameter Name	Parameter Type	Range of Values
channel_list	Numeric	cc00 - cc15

Comments

- **Opening Channels:** To open:
  - use [ROUTe:]OPEN (@ccnn) for a single channel;
  - use [ROUTe:]OPEN (@ccnn,ccnn) for multiple channels;
  - use [ROUTe:]OPEN (@ccnn:ccnn) for sequential channels;
  - use [ROUTe:]OPEN (@ccnn:ccnn,ccnn:ccnn) for a group of sequential channels;
  - or any combination.

  Opening order for multiple channels with a single command is not guaranteed.

- **Open Channels:** Opening an already open channel has no effect.
- **Related Commands:** [ROUTe:]CLOSe, [ROUTe:]OPEN?
- ***RST Condition:** All multiplexer channels are open.

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Example Opening Multiplexer Channels

This example opens channel 00 of a multiplexer module card number 1 and channel 15 of multiplexer module card number 2 in a single switchbox.

```
OPEN  (@100,215)          100 opens channel 00 of card #1;
                          215 opens channel 15 of card #2.
```

OPEN?

[ROUTe:]OPEN? <*channel_list*> returns the current state of the channel(s) queried. The *channel list* is in the form (@ccnn). The command returns 1 if the channel is open or returns 0 if the channel is closed.

Comments

- **Query is Software Readback:** The [ROUTe:]OPEN? command returns the current software state of the channel(s) specified. It does not account for relay hardware failures.

Example Query Multiplexer Channel Open State

```
OPEN  (@100,215)          100 opens channel 00 of card #1;
                          215 opens channel 15 of card #2.
OPEN? (@215)              Query state of channel 215.
```

SCAN

[ROUTe:]SCAN <*channel_list*> defines the channels to be scanned. The *channel_list* has the form (@ccnn), (@ccnn,ccnn), (@ccnn:ccnn) or (@ccnn:ccnn,ccnn:ccnn) where cc = card number (00-99) and nn = channel number (00-15).

Parameters

Parameter Name	Parameter Type	Range of Values
channel_list	Numeric	cc00 - cc15

Comments

- **Channel List:** Valid *channel lists* are:
  - a single channel, use (@ccnn);
  - for multiple channels, use (@ccnn,ccnn);
  - sequential channels, use (@ccnn:ccnn);
  - a group of sequential channels, use (@ccnn:ccnn,ccnn:ccnn);
  - or any combination.

- **Defining the Channel List.** When executing [ROUTe:]SCAN, the *channel list* is checked for valid card and channel numbers. An error is generated for an invalid *channel list*.

- **Downloading a Scanning List:** The *channel_list* is automatically downloaded into RAM on the FET multiplexer modules for TRIG:SOUR DBUS and TRIG:SOUR IMM trigger modes. The complete list is downloaded onto each module in an instrument. The channels are advanced with no direct intervention by the mainframe CPU during the scan. If an instrument contains mixed modules (FET and Relay Multiplexers), the scan list will not be downloaded.

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- **Scanning Operation:** With a valid *channel list*, INITiate[:IMMediate] starts the scanning cycle and closes the first channel in the *channel list*. Successive triggers from the source specified by TRIGger:SOURce advances the scan through the *channel list*.
- **Stopping Scan:** See the ABORt command.
- **Related Commands:** TRIGger, TRIGger:SOURce
- ***RST Condition:** All multiplexers channels are open.

Example Scanning Using External Instruments

The following example shows how to scan channels using the HP E1300A/ E1301A Mainframe via HP-IB and an HP 3457A Digital Multimeter. This example uses the mainframe's "Trig Out" port to synchronize the multiplexer module in a switchbox to the multimeter. The trigger pulse from the port triggers the multimeter for a measurement. See Chapters 2 and 3 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 E1300A/E1301A Mainframe and HP 3457A Multimeter, respectively, and an HP-IB secondary address of 14 for the switchbox.

```
10  OUTPUT 722;"TRIG EXT;DCV"          !Sets multimeter to external trigger
                                       and to measure dc volts
20  OUTPUT 70914;"OUTP ON"             !Enables "Trig Out" port
30  OUTPUT 70914;"TRIG:SOUR BUS"       !Sets switchbox to receive bus
                                       triggers
40  OUTPUT 70914;"SCAN:MODE VOLT"      !Sets switchbox to measure
                                       voltage during scanning
50  OUTPUT 70914; "SCAN:PORT ABUS"     !Sets switchbox to close the
                                       appropriate tree switches during
                                       scanning
60  OUTPUT 70914;"SCAN  (@100:115)"    !Selects the channel list
70  OUTPUT 70914;"INIT"                !Starts scanning cycle
80  FOR I = 1 TO 16                    !Start count loop
90  ENTER 722;A                        !Enter 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
```


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SCAN:MODE

[ROUTe:]SCAN:MODE <*mode*> sets the multiplexer channels defined by the [ROUTe:]SCAN <*channel_list*> command for None, Volts, 2-Wire Ohms, or 4-Wire Ohms measurements.

Parameters

Parameter Name	Parameter Type	Range of Values
mode	Discrete	NONE | VOLT | RES | FRES

Comments

- **Order of Command Execution:** The [ROUTe:]SCAN:MODE command must be executed before the [ROUTe:]SCAN <*channel_list*> and [ROUTe:]CLOSe <*channel_list*> commands.
- **NONE and VOLT Mode Description:** When selected, *channel list* is set up for volts measurements.
- **RES Mode Description:** When selected, *channel list* is set up for 2-wire ohms measurements. The current source on I+ and I- is superimposed on the channel being measured. Appropriate tree isolation switches are automatically closed.
- **FRES Mode Description:** When selected, *channel list* is set up for 4-wire ohms measurements. Specify only the channel on which the voltage is to be measured. The paired channel (plus or minus eight channels away) on the other bank will automatically close. If you specify both channels (@102, 110), the module will first setup for FRES reading on 02, then setup for FRES reading on 10.
- ***RST Condition:** [ROUTe:]SCAN:MODE NONE

Example

Selecting the 4-Wire Ohms Mode. This example scans 8 channels for 4-wire ohms resistance measurements.

```
TRIG:SOUR EXT                 Selects external trigger source.
SCAN:MODE FRES                Selects the 4-wire ohms scanning mode.
SCAN  (@100:115)              Sets channel list.
INIT                          Starts scanning cycle.
```

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, VOLT, RES, or FRES mode, respectively.

Example

Query Scan Mode

This example selects the 4-wire ohms measurement mode (FRES), then queries the measurement state. Because 4-wire ohms mode is selected, the query command returns FRES.

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


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SCAN:PORT

[ROUTe:]SCAN:PORT <*port*> enables/disables the tree isolation switches. SCAN:PORT ABUS closes the appropriate tree switches (for analog bus connections). The [ROUTe:]SCAN:PORT NONE command disables the tree switches and leaves them open. With SCAN:PORT NONE the closed channels can only be measured through the respective bank direct terminals.

Parameters

Parameter Name	Parameter Type	Range of Values
port	Discrete	ABUS | NONE

Comments

- **Order of Command Execution:** The [ROUTe:]SCAN:PORT command must be executed before the [ROUTe:]SCAN <*channel_list*> and [ROUTe:]CLOSe <*channel_list*> commands.
- ***RST Condition:** [ROUTe:]SCAN:PORT NONE

Example

Selecting the ABUS Port

```
TRIG:SOUR EXT          Selects external trigger source.
SCAN:MODE FRES         Selects the 4-wire ohms scanning mode.
SCAN:PORT ABUS         Selects the analog bus port.
SCAN  (@100:107)       Sets channel list.
INIT                   Starts scanning cycle.
```

SCAN:PORT?

[ROUTe:]SCAN:PORT? returns the current state of the analog bus port. The command returns NONE if the analog bus connection control relays are disabled or ABUS if the control relays are enabled.

Example

Query Scan Port

This example selects the analog bus port, then queries the state. Because the analog bus port is selected, the query command returns ABUS.

```
SCAN:PORT  ABUS         Selects the analog bus port.
SCAN:PORT?              Query the port selection.
```


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SETTling[:TIME]

[ROUTe:]SETTling[:TIME] <*channel_list*> sets the delay between receipt of a channel closing trigger, and the pulse when the FET channel is closed. You must specify one and only one channel for each card in the instrument which has a channel in the *channel list*, and the <*time*> will then apply to all channels on the card. The range is 1 to 32768 µsec.

Parameters

Parameter Name	Parameter Type	Range of Values
time	Numeric	1E-6 | 32768E-6 | MIN | MAX
channel_list	Numeric	only one channel

Comments

- **Digital Bus Handshaking:** This command allows a user-defined settling time to allow a measurement to be made before the next channel is closed.
- **Related Commands:** TRIGger:SOURce DBUS, TRIGger:SOURce IMMediate

Example

Setting 16 µsec SETTling TIME

```
TRIGger:SOUR DBUS          Triggering on the digital bus handshake lines
SETTling:TIME 16E-6        Delay = l6µsec
```

SETTling[:TIME]?

[ROUTe:]SETTling[:TIME]? [MIN | MAX] <*channel_list*> returns the current setting for a specified channel. MIN or MAX returns the minimum and maximum allowable settings.

Parameters

Parameter Name	Parameter Type	Range of Values
MIN | MAX	Numeric	MIN = 1 µsec, MAX = 32768 µsec
channel_list	Numeric	only one channel

Comments

- Returned value is given in exponential notation.

Example

Set and Query the SETTling TIME

```
SETT:TIME 16E-6            Sets delay = 16µsec.
SETT:TIME?                 Returns + 1.600000E-005.
```


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STATus

The STATus subsystem reports the bit values of the Operation Status Register. This enables the Status Register to set a bit after a bit is set to 1 by the Operation Status Register.

Subsystem Syntax

```
STATus
    :OPERation
        :ENABle <number>
        [:EVENt]?
```

:OPERation:ENABle

STATus:OPERation:ENABle <*number*> enables the Operation Status Register to set a bit in the Status Register. For multiplexer modules, when bit 8 in the Operation Status Register is set to 1, bit 7 in the Status Register is set to 1.

Parameters

Parameter Name	Parameter Type	Range of Values
number	Numeric	1 - 32768

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.
- **Disabling STATus:OPERation:** The STATus:PRESet command disables the STATus:OPERation:ENABle command.
- **Related Commands:** [ROUTe:]SCAN, *SRE, *STB?, *SPOLL, STATus:PRESet

Example

Enable the Status Register Bit 7

```
STAT:OPER:ENAB 256          Enables bit 7 of the Status Register.
```

:OPERation[:EVENt]?

STATus:OPERation[:EVENt]? returns the bit value of the Operation Status Register (only bit 8 is used by the multiplexer modules).

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 after sending the STATus:OPERation[:EVENt]? command. For correct operation set to 0 by *CLS before scanning.
- **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.
- **Related Commands:** [ROUTe:]SCAN, *SRE, *STB?, *SPOLL

Example

Reading the Operation Status Register after a Scanning Cycle

```
STAT:OPER?                  Reads the register value
read and print the register value   +256 shows bit 8 is set to 1; +0
                                    shows bit 8 is set to 0.
```


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SYSTem

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

Subsystem Syntax

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

:CDEScription?

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

Parameters

Parameter Name	Parameter Type	Range of Values
number	Numeric	1 - 99

Comments

- **16-Channel FET Multiplexer Module Description:** The SYSTem:CDEScription? <*number*> command returns:

```
16 Channel FET Mux
```

- **16-Channel Thermocouple FET Multiplexer Module Description:** The SYSTem:CDEScription? <*number*> command returns:

```
16 Channel FET Mux with T/C
```

Example

Reading the Description of Card #1 Module

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

:CPON

SYSTem:CPON <*number* | ALL> opens all channels of a selected module, or all modules (cards) in a switchbox.

Parameters

Parameter Name	Parameter Type	Range of Values
number	Numeric	1 - 99 | ALL

Comments

- **Differences between *RST and CPON:** SYSTem:CPON only opens all channels of a selected module or all modules in a switchbox. *RST opens all channels of all modules in a switchbox and also sets the trigger modes to the power-on states.

Example

Opening All Channels on Card #1

```
SYST:CPON 1                     Opens all channels on card #1.
```


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:CTYPe?

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

Parameters

Parameter Name	Parameter Type	Range of Values
number	Numeric	1 - 99

Comments

- **16-Channel FET Multiplexer Module Model Number:** The **SYSTem:CTYPe? <***number*> command returns:

  ```
  HEWLETT-PACKARD,E1351A,0,A.03.00
  ```

- **16-Channel Thermocouple FET Multiplexer Module Model Number:** The **SYSTem:CTYPe? <***number*> command returns:

  ```
  HEWLETT-PACKARD,E1353A,0,A.03.00
  ```

  Note: The first number after the model number is the serial number of the module (always 0); the module revision code follows the serial number (for example, A.03.00).

Example

Reading the Model Number of a Card #1 Module

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

: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 the switchbox error numbers and messages.

Comments

- **Error Numbers/Messages in the Error Queue:** Errors generated by a switchbox stores an error number and corresponding error message in the error queue. Each error message can be up to 255 characters long.

- **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? command 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.
```


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TRIGger

The TRIGger subsystem commands control the scan triggering operation of the multiplexer modules.

Subsystem Syntax

```
TRIGger
    [:IMMediate]
    :SOURce BUS | DBUS | EXTernal | HOLD | IMMediate
    :SOURce?
```

[:IMMediate]

TRIGger[:IMMediate] causes a trigger to occur when the defined trigger source is TRIGger:SOURce HOLD or TRIGger:SOURce BUS. Note that TRIGger[:IMM] is not the same as TRIGger:SOURce IMM.

Comments

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

Example

Advancing Scan using the TRIGger Command

```
TRIG:SOUR HOLD          Sets trigger source to hold.
SCAN  (@100:115)        Sets channel list.
INIT                    Starts scanning cycle.
loop statement          Start count loop.
TRIG                    Advances scan to next channel.
increment loop          Increment count loop.
```


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:SOURce

TRIGger:SOURce BUS | DBUS | EXTernal | HOLD | IMMediate specifies the trigger source to advance the *channel list* during scanning.

Parameters

Parameter Name	Parameter Type	Range of Values
BUS	Discrete	*TRG command
DBUS	Discrete	Digital Bus
EXTernal	Discrete	Event In port
HOLD	Discrete	Hold Triggering
IMMediate	Discrete	Continuous Triggering

Comments

- **Enabling the Trigger Source:** The TRIGger:SOURce command only selects the trigger source. The INITiate[:IMMediate] command enables the trigger source.
- **Using the TRIG Command:** You can use TRIGger[:IMMediate] to advance the scan when TRIGger:SOURce BUS or TRIGger:SOURce HOLD is selected.
- **Using Digital Bus Trigger:** TRIGger:SOURce DBUS selects the digital bus on the multiplexer as the trigger. Any open collector TTL trigger source can be wired to the "Channel Advance" lead. A negative-going pulse triggers the multiplexer and advances it to the next channel on the scanning list. After the SETTling:TIME delay, the multiplexer asserts "Channel Closed" on the digital bus.
- **Using External Trigger Inputs:** With TRIGger:SOURce EXTernal selected, only one switchbox at a time can use the external trigger input at the HP E1300A/E1301A Mainframe's "Event In" port. The trigger input is assigned to the first switchbox requesting the external trigger source.
- **Assigning External Trigger:** A switchbox assigned with TRIG:SOUR EXT remains assigned to that source until the switchbox receives a command to change the source. When the source is changed, the external trigger source is available to another switchbox (with a TRIGger:SOURce EXTernal command). Another switchbox cannot receive an external trigger source if the source is already assigned, or an error is generated.
- **Using Bus Triggers:** To trigger the switchbox with TRIGger:SOURce BUS selected, use TRIGger[:IMMediate], the IEEE 488.2 common command *TRG or the HP-IB Group Execute Trigger (GET).
- **"Trig Out" Port Shared by Switchboxes:** See the OUTPut command.
- **Related Commands:** ABORt, [ROUTe:]SCAN, SETTling[:TIME], TRIGger
- ***RST Condition:** TRIGger:SOURce IMMediate

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Example Scanning Using External Triggers

In the following example, the trigger input is applied to the HP E1300A/E1301A Mainframe's "Event In" port.

```
TRIG:SOUR EXT          Sets trigger source to external.
SCAN  (@100:115)       Sets channel list.
INIT                   Starts scanning cycle.
trigger externally     Advances scan to next channel.
```

Scanning Using Bus Triggers

```
TRIG:SOUR BUS          Sets interface (bus) triggering.
SCAN  (@100:115)       Sets channel list.
INIT                   Starts scanning cycle.
*TRG                   Advances channel list.
```

:SOURce?

TRIGger:SOURce? returns the current trigger source for the switchbox. Command returns either BUS, DBUS, EXT, HOLD, or IMM for trigger sources BUS, DBUS, EXTernal, HOLD, or IMMediate, respectively.

Example Query Trigger Source

```
TRIG:SOUR EXT          Sets trigger source to external.
TRIG:SOUR?             Query trigger source; returns
                       "EXT".
```


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IEEE 488.2 Common Commands

The following table lists the IEEE 488.2 Common (*) Commands that the 16-Channel FET Multiplexer Modules accept. The operation of some of these commands is described in Chapter 4 of this manual. For more information on Common Commands, refer to the *HP 75000 Series B Mainframe User's Manual* (HP Model Number E1300/E1301) or the *ANSI/IEEE Standard 488.2-1987*.

Command	Title	Description
*IDN?	Identification	Returns identification string of the switchbox.
*RST	Reset	Opens all channels, and invalidates current *channel list* for scanning. Sets ARM:COUN 1, TRIG:SOUR IMM, and INIT:CONT OFF.
*TST?	Self-Test	Power-on interrupt returns +110 Incorrect MFR ID or model code returns +103 Test pass returns 0.
*OPC *OPC?	Operation Complete Operation Complete Query	See note below. See note below.
*WAI	Wait to Complete	See note below.
*CLS	Clear status	Clears all status registers (see STATus:OPERation[:EVENt]?).
*ESE *ESE?	Event status enable Event status enable query	See note below. See note below.
*ESR?	Event status register query	See note below.
*SRE *SRE?	Service request enable Service request enable query	Enables status register bits (see Chapter 4 for operation). See note below.
*STB?	Read status byte query	See note below.
*TRG	Trigger	Triggers the switchbox to advance the scan when scan is enabled and trigger source is TRIGger:SOURce BUS | HOLD.
*RCL	Recall instrument state	See note below.
*SAV	Store instrument state	See note below.
Note: These commands apply to many instruments and are not documented in detail here. See the *HP 75000 Series B E1300/E1301 Mainframe User's Manual* or the ANSI/IEEE Standard 488.2-1987 for more information.		

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Command Quick Reference

The following tables summarize SCPI and IEEE 488.2 Common (*) Commands for the 16-Channel FET Multiplexer Modules.

SCPI Commands Quick Reference

Command		Description
ABORt		Abort a scan in progress.
ARM	:COUNt <*number*> MIN | MAX :COUNt? [MIN | MAX]	Multiple scans per INIT command. Query number of scans.
DISPlay	:MONitor:CARD <*number*> | AUTO :MONitor[:STATe] <*mode*>	Selects module to be monitored. Selects monitor mode.
INITiate	:CONTinuous <*mode*> :CONTinuous? [:IMMediate]	Enables/disables continuous scanning. Query mode. Starts a scanning cycle.
OUTPut	[:STATe] <*state*> [:STATe]?	Enables/disables "Trig Out" pulse. Query state of trig out pulse.
[ROUTe:]	CLOSe <*channel _list*> CLOSe? <*channel _list*> OPEN <*channel _list*> OPEN? <*channel _list*> SCAN <*channel _list*> SCAN:MODE NONE | VOLT | RES | FRES SCAN:MODE? SCAN:PORT NONE | ABUS SCAN:PORT? SETTling[:TIME] <*channel_list*> SETTling[:TIME]? [MIN | MAX] <*channel_list*>	Close channel(s). Query channel(s) closed. Open channel(s). Query channel(s) opened. Define channels for scanning. Selects appropriate tree Isolation switches for measurements. Query state of scan mode. Enables tree isolation switches closure as part of a measurement. Query analog bus state. Sets delay between trigger pulse and channel closed pulse. Returns current parameter in SETTling[:TIME].
STATus	:OPERation:ENABle :OPERation[:EVENt]?	Enables the Operation Status Register to set a bit in the Status Register. Returns status of Operation Status Register.
SYSTem	:CDEScription? <*number*> :CPON <*number*> | ALL :CTYPe? <*number*> :ERRor?	Returns description of module in a switchbox. Sets specified module to its power-on state. Returns the module type. Returns error number/message in a switchbox error queue.
TRIGger	[:IMMediate] :SOURce BUS :SOURce DBUS :SOURce EXTernal :SOURce HOLD :SOURce IMMediate :SOURce?	Causes a trigger to occur. Trigger source is *TRG. Trigger source is Digital Bus. Trigger source is "Event In" port. Hold off triggering. Continuous (internal) triggers. Query scan trigger source.

IEEE 488.2 Common Commands Quick Reference

Command	Title	Description
*RST	Reset	Opens all channels and invalidates current channel list for scanning. Sets ARM:COUN 1, TRIG:SOUR IMM, and INIT:CONT OFF.
*TRG	Bus Trigger	When scan is enabled and trigger source is TRIG:SOUR BUS, use the *TRG command to trigger the switchbox to advance the scan.
*TST?	Self-Test	Power on interrupt returns +110. Incorrect MFR ID or model code returns +103. Test pass returns 0.

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Appendix A
HP E1351A/53A FET Multiplexer Specifications

Maximum Voltage:
Terminal to Chassis: ±16V peak*
(input impedance less above 14V peak)

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

Maximum Offset Voltage:
25 µV (0° to 28°C)
250 µV (28° to 55°C)

Input Impedance:
Power On (Vin <±10V)
High to Low: $>10^8\Omega$
High or Low to Chassis: $>10^8\Omega$
Guard to Chassis: 10 kΩ ±10%
Capacitance:
High or Low to Chassis: <200pf
High to Low: <200pf

Power Off (High to Low):
for Vin ≤14V: 1000Ω
for Vin >14V: 220Ω

Closed Channel Resistance:
<3.1 kΩ for high or low input
(Guard not switched)

Bandwidth (-3dB):
50Ω source, 1 MΩ | |10pF termination: >200 kHz

Screw Terminal Wire Size:
16 AWG Max, 26 AWG Min

Module Size/Device Type:
B, register-based

Connectors Used: P1

Number of Slots: 1

Interrupt Level: selectable

Power Requirements:

Voltage:	+5V	+12V
Peak module current, IPM (A):	0.20	0.13
Dynamic module current, IDM (A):	0.01	0.01

Strain Gage Excitation:
+ 4.63V ±10%
Max Current: 400mA
(short circuit protected)

Reference Junction Measurement Accuracy (HP E1353A only): 0.3°C
(over 18° to 28°C operating temperature)

Watts/Slot: 1

Cooling/Slot:
0.02 mm H_2O @ 0.10 liter/sec

Humidity: 65% 0° to 40°C

Operating Temperature:
0° to 55°C

Storage Temperature:
-40° to 75°C

EMC, RFI, Safety:
meets FTZ 1046/1984, CSA 556B, IEC 348, UL 1244

Net Weight (kg): 0.9

* Each FET is diode clamped to ±14V and a 220Ω series resistor. This limits the current to the clamp diodes.

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Appendix B
HP E1351A/53A Register-Based Programming

About This Appendix

The HP E1351A and HP E1353A FET and Thermocouple FET Multiplexers are register-based modules which do not support the VXIbus word serial protocol. When a SCPI command is sent to the multiplexer, the HP E1406A Command Module (Series C) or HP E1300A/E1301A Mainframe (Series B) 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, if slot 0, the resource manager, and the computer (HP-IB) interface are provided by other devices, a C-size system can be downsized by removing the command module.

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

- Register Addressing . . . . . Page 81
- Register Descriptions . . . . . Page 84
- Register Bit Descriptions . . . . . Page 86
- Executing Commands . . . . . Page 90
- Register-Based Programming for Maximum Speed . . . . . Page 93

Register Addressing

Register addresses for register-based devices are located in the upper 25% of VXIbus A16 address space. Every VXIbus device (up to 256 devices) is allocated a 32 word (64 byte) block of addresses. The HP E1351A/E1353A multiplexers use eight two-byte registers of the 64 addresses (32 word registers) 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 E1300A/E1301A Mainframe and HP E1405/06A Command Module.

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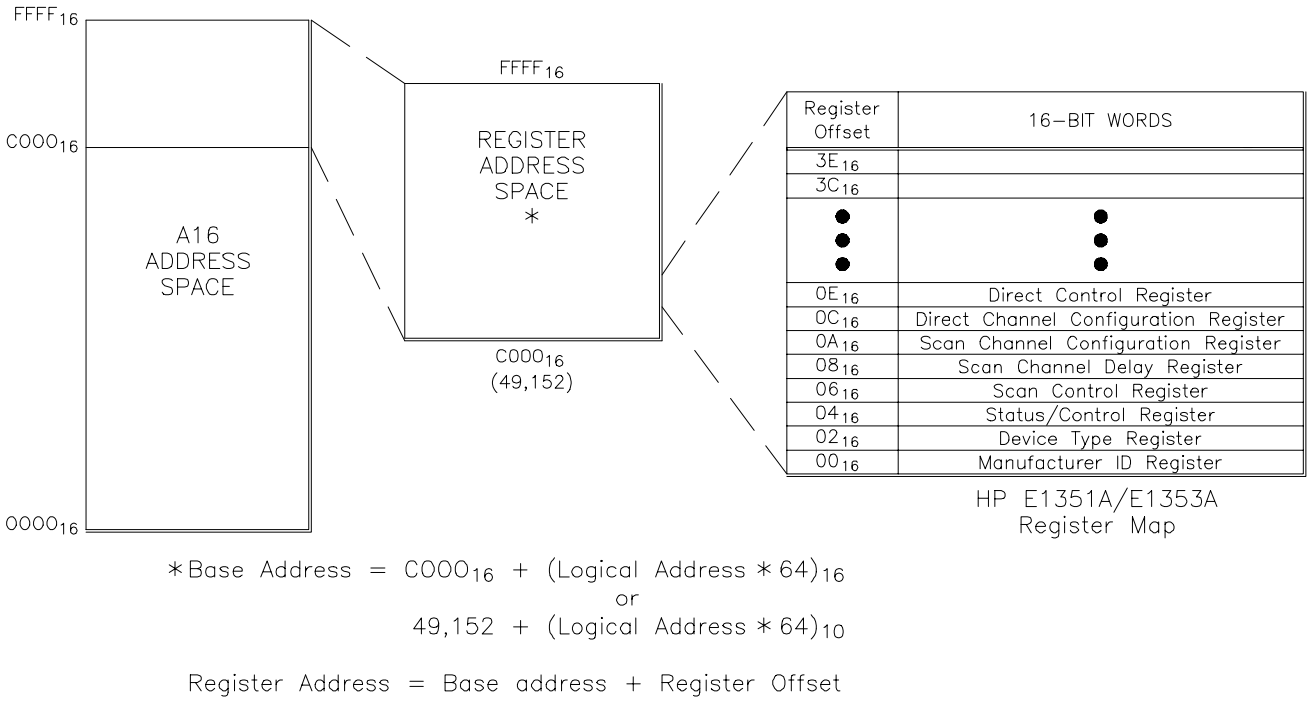


Figure B-1. Multiplexer Registers within A16 Address Space

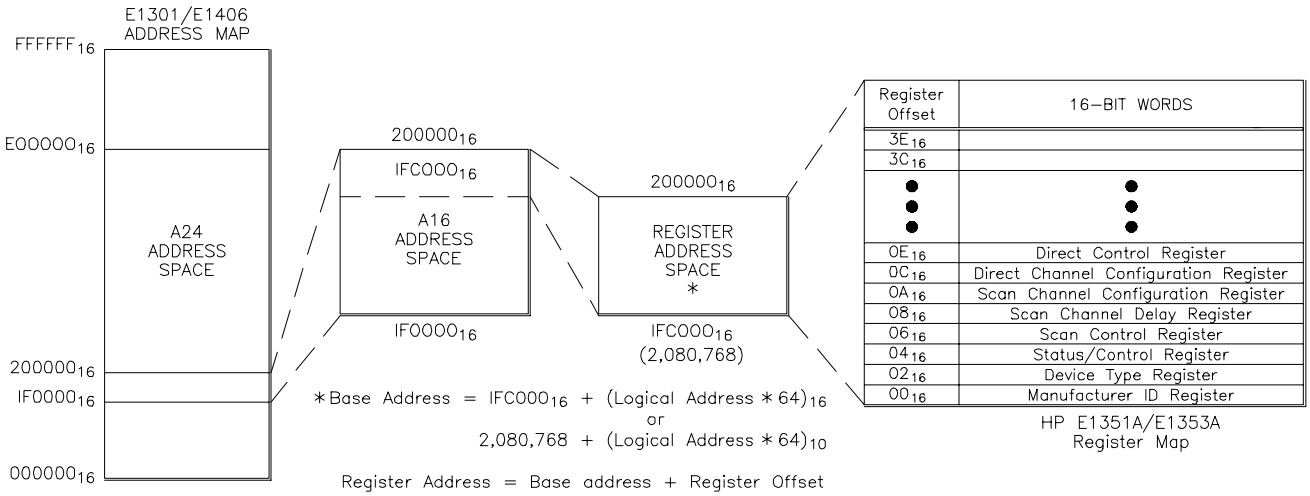


Figure B-2. Registers within HP E1301/E1406 A16 Address Space

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The Base Address

When reading or writing to a multiplexer register, specify a hexadecimal or decimal register address. This address consists of a base address plus a register offset. The base address used programming depends on whether the A16 address space is outside or inside the HP E1405A/E1406A Command Module or HP E1300A/E1301A Mainframe.

A16 Address Space Outside the Command Module or Mainframe

When the command module or mainframe is not part of your VXIbus system (Figure B-1), the multiplexer's base address is computed as:*

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

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 is the number of address bytes per VXIbus device. For example, the multiplexer's factory set logical address is 112. With this address, the multiplexer has a base address:

$C000_{16} + (112 * 64)_{16}$

$C000_{16} + 1C00_{16} = DC00_{16}$

or (decimal)

49,152 + (112 * 64)

49,152 + 7,168 = 56,320

A16 Address Space Inside the Command Module or Mainframe

When the A16 address space is inside the command module or mainframe (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 + 7,168 = 2,087,936

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

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Register Offset

The register offset is the register's location in the block of 64 address bytes. For example, with a LADDR of 112 the multiplexer's Scan Channel Delay Register has an offset of 08_{16}. When you write a command to this register, the offset is added to the base address to form the register address:

$DC00_{16} + 08_{16} = DC08_{16}$ (A16 outside the command module)

$1FDC00_{16} + 08_{16} = 1FDC08_{16}$ (A16 inside the command module)

or

56,320 + 8 = 56,328 (A16 outside the command module)

2,087,936 + 8 = 2,087,944 (A16 inside the command module)

Register Descriptions

There are six WRITE and two READ-only registers on the multiplexer. You can READ-back three of the WRITE registers. This section contains a description and a bit map of each register. Note that the bit names with an * after them are True (asserted) when low (zero). An X represents a "do not care" situation and a 1 always represents 1.

WRITE Registers

The following WRITE registers are located on the multiplexer:

- Status/Control Register (base + 04_{16})
- Scan Control Register (base + 06_{16})
- Scan Channel Delay Register (base + 08_{16})
- Scan Channel Configuration Register (base + $0A_{16}$)
- Direct Channel Configuration Register (base + $0C_{16}$)
- Direct Control Register (base + $0E_{16}$)

READ Registers

There are two READ-only registers and three READ-back registers.

- Manufacturer ID Register (base + 00_{16}) READ-only
- Device Type Register (base + 02_{16}) READ-only
- Status/Control Register (base + 04_{16})
- Scan Control Register (base + 06_{16})
- Scan Channel Delay Register (base + 08_{16})

Manufacturer ID Register

base + 00_{16}	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write	Undefined															
Read	Device Class		Address Space		Manufacturer ID											

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Device Type Register

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

Status/Control Register

base + 04_{16}	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write	Undefined								X	X	X	TRG INT	DIR	IRQ EN	X	CRD RST
Read	Undefined								1	1	1	BSY*	1	1	IRQ*	IRQ EN*

Scan Control Register

base + 06_{16}	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write	Undefined								X	X	X	RST PTR	CNT EN	IMM EN	DBS EN	CLR SCN
Read	Undefined								1	1	1	1	CNT EN	IMM EN	DBS EN	CLR SCN

Scan Channel Delay Register

base + 08_{16}	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write	Undefined								X	X	X	X	D3	D2	D1	D0
Read	Undefined								1	1	1	1	D3	D2	D1	D0

Scan Channel Configuration Register

base + $0A_{16}$	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write	VLD*	A_D*	B_D*	C1	C0	X	X	X	X	X	X	X	D3	D2	D1	D0
Read	Undefined															

Direct Channel Configuration Register

base + $0C_{16}$	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write	Undefined								X	X	X	X	D3	D2	D1	D0
Read	Undefined															

Direct Control Register

base + $0E_{16}$	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write	Undefined								X	X	X	VLD*	A_D*	B_D*	C1	C0
Read	Undefined															

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Register Bit Descriptions

This section contains a description of the function of each bit which is addressable in each register. The bits are listed according to the title of the WRITE bit name, with the READ definition at the end of the description. For registers 00_{16} and 02_{16}, the bits are listed according to the title of the READ definition.

Manufacturer ID Register

The 16-Channel FET Multiplexer Module always returns $FFFF_{16}$ on a Manufacturer ID Register READ.

base + 00_{16}	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write	Undefined															
Read	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Device Class

There are four classifications. The FET Multiplexer Module is a register-based device (11).

Address Space

The FET Multiplexer Module uses A16 address mode.

Manufacturer ID

Hewlett-Packard's identification number is 4095, which corresponds to bits 11 - 0 all set to 1.

Device Type Register

The Device Type Register contains a model code which identifies the module.

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

Model Code

Model Code. The following model codes identify the HP E1351A FET Multiplexer and HP E1353A Thermocouple FET Multiplexer:

$FF10_{16}$ HP E1351A 16-Channel FET Multiplexer
$FF12_{16}$ HP E1353A 16-Channel Thermocouple FET Multiplexer

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Status/Control Register

The Status/Control WRITE register is used to reset the module, enable interrupts, choose direct or scan list control of the channels and to internally trigger channel closing. The READ register indicates if interrupts are enabled, if there is an interrupt and if the module is busy.

base + 04_{16}	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write	Undefined								X	X	X	TRIG INT	DIR	IRQ EN	X	CRD RST
Read	Undefined								1	1	1	BSY*	1	1	IRQ*	IRQ EN*

Card Reset (CRD RST)

Writing a one (1) to bit 0 resets the multiplexer. Writing a zero turns the reset function off. You must write a zero after a reset or the module will not operate. The Reset conditions are: all Enables are set false, clear scan list, scan mode enabled (direct bit set 0), DELAY is l µsec and all channels opened.

Interrupt Request Enable (IRQ EN)

Writing a one (1) enables the card to generate interrupts, a zero (0) disables it. Enabling this bit puts a zero (0) in IRQ EN*.

Direct (DIR)

Selects between direct control and scan list control. A zero (0) indicates scan list control and a one (1) indicates direct control. For scan list control the Direct Registers (base + 0C, base + 0E) are invalidated. For direct control the Scan Channel Configuration Register is invalidated.

Trigger Internal (TRG INT)

Writing a one (1) immediately advances a channel on the scan list, a zero (0) is the idle state. Bit is automatically set back to zero (0) upon channel advance.

Interrupt Request Enable (IRQ EN*)

Reading a zero (0) indicates enabled, reading a one (1) indicates disabled.

Interrupt Request (IRQ*)

Reading a zero (0) indicates an interrupt, a one (1) indicates no interrupt. This bit remains one (1) if IRQ EN is disabled. Interrupt remains set until Card Reset or interrupt has been acknowledged.

Busy (BSY*)

This bit is set zero (0) during channel closing and the delay period. Triggers will not be accepted. BSY* is unasserted at the beginning of the Channel Closed pulse. If a trigger occurs during the Channel Closed pulse, the pulse is terminated and the channel is advanced. Operates only with downloaded scan list (DIR is zero).

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Scan Control Register

The Scan Control Register allows you to clear the scan list, set the trigger mode and reset the pointer to the beginning of the scan list. This register is a READ-back register, allowing you to verify the state of the WRITE register.

base + 06_{16}	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write	Undefined								X	X	X	RST PTR	CNT EN	IMM EN	DBS EN	CLR SCN
Read	Undefined								1	1	1	1	CNT EN	IMM EN	DBS EN	CLR SCN

Clear Scan List (CLR SCN)

Writing a one (1) in this bit clears the scan list. The bit must be set back to zero (0) after flushing. CLR SCN (Read) returns the state of the bit.

Digital Bus Enable (DBS EN)

Writing a one (1) enables the digital bus trigger mode. A zero (0) disables it. DBS EN (Read) returns the state of the bit.

Immediate Enable (IMM EN)

Writing a one (1) in this bit sets trigger to immediate, which means that as soon as the first channel is closed by the TRG INT, the entire scan list is run without any further triggering. Channel advance speed is determined by the delay time specified. This has extremely limited applications.

Continuous Enable (CNT EN)

Writing a one (1) in this bit enables the card to continually cycle through the scan list. When this bit is enabled, the last channel in a scan list resets the pointer back to the beginning of the scan list.

Reset Pointer (RST PTR)

Writing a one (1) resets the pointer back to the beginning of the scan list. CNT EN true automatically resets pointer at end of scan list. If CNT EN is set true, an interrupt also resets the pointer. If CNT EN is set false, the last channel in the scan list generates an interrupt if the channel is valid (VLD* set true).

Scan Channel Delay Register

The Scan Channel Delay Register sets the SETTling:TIME, the time between receipt of a channel closing trigger and the Channel Closed pulse. The delay is 2^n µS and ^{n} has a range of 0 to 15. D3 to D0 set ^{n}, and D0 is the least significant bit. This register is a read-back register, allowing you to verify the state of the WRITE register.

base + 08_{16}	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write	Undefined								X	X	X	X	D3	D2	D1	D0
Read	Undefined								1	1	1	1	D3	D2	D1	D0

D3 - D0

D0 is the least significant bit, D3 is the most significant. These bits designate a number between 0 and 15 for ^{n}.

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Scan Channel Configuration Register

These bits set the <*channel_list*> for a scan list, set the type of measurement and enable/disable the tree isolation switches. Note that the DIR in the Status/Control Register must be set false to enable this register.

base + $0A_{16}$	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write	VLD*	A_D*	B_D*	C1	C0	X	X	X	X	X	X	X	D3	D2	D1	D0
Read	Undefined															

D3 - D0

These bits set the channel number, with a range of 0 - 15. Bit D0 is the least significant bit, and bit D3 is the most significant.

Configuration Bit (C1 - C0)

These bits determine the measurement mode as listed below:

C1	C0	
0	0	Volts
0	1	2-wire ohms
1	1	4-wire ohms
1	0	Thermistor

Note that to obtain the Thermistor reference temperature for Thermocouple measurements, you must set the configuration bits for Thermistor. After you have obtained the reference temperature, set the bits for Volts.

B and A Tree Isolation Switch Disable (B-D*, A-D*)

A zero in either one disables the respective Tree Isolation Switch. Generally, both disabled together equal the [ROUTe:]SCAN:PORT NONE command.

Valid Channel (VLD*)

A zero indicates that the specified channel is valid. When entering a scan list the entire list must be loaded into each module. For the channels that are not on that module, the VLD* must be set false. See [ROUTe:]SCAN in the "Executing Commands" section in this Appendix.

Direct Channel Configuration Register

The Direct Channel Register allows you to specify channels to be closed individually. Note that the DIR bit in the Status/Control Register must be set true for this register to be enabled.

base + $0C_{16}$	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write	Undefined								X	X	X	X	D3	D2	D1	D0
Read	Undefined															

D3 - D0

These data bits set the channel number with a range of 0 - 15. Bit D0 is the least significant bit, and bit D3 is the most significant.

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Direct Control Register

The Direct Control Register allows you to set the controls for individual channels. Note that the DIR bit in the Status/Control Register must be set true for this register to be enabled.

base + $0E_{16}$	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write	Undefined								X	X	X	VLD*	A_D*	B_D*	C1	C0
Read	Undefined															

C1 - C0 These configuration bits determine the measurement mode as listed below:

C1	C0	
0	0	Volts
0	1	2-wire ohms
1	1	4-wire ohms
1	0	Thermistor

Note that to obtain the Thermistor reference temperature for Thermocouple measurements, you must set the configuration bits for Thermistor. After you have obtained the reference temperature, set the bits for Volts.

B and A Tree Isolation Switch Disable (B-D*, A-D*) A zero in either one disables the respective tree isolation switch. Generally, both disabled together equal the [ROUTe:]SCAN:PORT NONE command.

Valid Channel (VLD*) A zero indicates that the specified channel is valid. If DIR is valid and INT EN is true, a WRITE to this register will generate an interrupt.

Executing Commands

This command lists the SCPI commands and shows how to execute them with register-based programming. For further information on register-based programming see the *HP E1326B Multimeter User's Manual*.

ABORt **ABORt** does not have an equivalent in register-based programming. This command is executed from the front panel or over HP-IB.

ARM:COUNt The **ARM:COUNt** command does not have an equivalent in register-based programming. To scan for a specified number of cycles, use the interrupt generated at the end of the scan list to advance through a program loop for the set number of cycles. For each pass through the loop, reset the pointer to the beginning of the scan list. The IRQ EN in the Status/Control Register must be enabled.

DISPlay:MONitor The **DISPlay:MONitor[:STATe]** command does not have an equivalent in register-based programming. For high-speed operation it should be set to **DISPlay:MONitor OFF**.

INITiate **INITiate:CONTinuous** is equivalent to the CNT EN bit in the Scan Control Register.

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INITiate[:IMMediate] is equivalent to writing a one to the TRG INT in the Status/Control Register. The TRG INT sets itself back to zero after pulsing the FET. If you have a multiple-module configuration and a downloaded scan list, the module with the first channel on the scan list must be the last one to receive the TRG INT. The scan cycle will start as soon as the card with a valid channel receives TRG INT.

OUTPut The **OUTPut[:STATe]** command does not have an equivalent in register-based programming.

[ROUTe:] **[ROUTe:]CLOSe <*channel_list*>** is equivalent to the following:

- DIR in the Status/Control Register is enabled.
- D0 to D3 is set to a channel number in the Direct Channel Configuration Register.

[ROUTe:]OPEN <*channel_list*> can be implemented by setting VLD* false in either the Scan Channel Configuration Register or the Direct Control Register (whichever one closed the channel). It can also be implemented by toggling the DIR bit in the Status/Control Register.

For **[ROUTe:]SCAN <*channel_list*>**, the complete scan list must be loaded in each module in a multiple-module configuration. The channel is set valid if it is in that module, and invalid in the other modules. The *channel list* is downloaded in the following way:

- Set CLR SCN in Scan Control Register to one, then back to zero, to clear the previous scan list.
- DIR in the Status/Control Register is set to false.
- Channel number is set in D0 to D3 in the Scan Channel Configuration Register.

The example below shows how to set a scan list for channels (@100,101,200,201):

- Write to the Scan Channel Configuration Register on card 1:

VLD* true (0), 0000 to D3-D0	*Sets channel 100.*
VLD* true (0), 0001 to D3-D0	*Sets channel 101.*
VLD* false (1), XXXX to D3-D0	*Reserves position in scan list for channel 200.*
VLD* false (1), XXXX to D3-D0	*Reserves position in scan list for channel 201.*

- Write to the Scan Channel Configuration Register on card 2:

VLD* false (1), XXXX to D3-D0	*Reserves position in scan list for channel 100.*
VLD* false (1), XXXX to D3-D0	*Reserves position in scan list for channel 101.*
VLD* true (0), 0000 to D3-D0	*Sets channel 200.*
VLD* true (0), 0001 to D3-D0	*Sets channel 201.*

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The **[ROUTe:]SCAN:MODE VOLT | RES | FRES** is set with C1 and C0 in the Scan Channel or Direct Control Register. Note that to obtain the Thermistor reference temperature for Thermocouple measurements, you must set the configuration bits for Thermistor. After you have obtained the reference temperature, set the bits for Volts.

C1	C0	
0	0	Volts
0	1	2-wire ohms
1	1	4-wire ohms
1	0	Thermistor

[ROUTe:]SCAN:PORT NONE | ABUS is set with A_D* and B_D* on the Scan Channel Configuration or Direct Control Registers. Set both bits to one for ABUS and to zero for NONE.

[ROUTe:]SETTling[:TIME] is set with the D3 to D0 bits in the Scan Channel Delay Register. The bits form a number ^{n} (^{n} is between 0 and 16), and the delay is 2^{n} µsec.

SYSTem

SYSTem:CDEScription? is a READ on the Manufacturer ID Register.

SYSTem:CTYPe? is a READ on the Device Type Register.

SYSTem:CPON can be achieved by setting the DIR bit true in the Status/Control Register and setting VLD* false. This opens all channels without a card reset.

TRIGger

TRIGger[:IMMediate] is equivalent to writing a one to TRG INT in the Status Control Register. The register returns to zero after pulsing the channel.

TRIGger:SOURce IMMediate and **TRIGger:SOURce DBUS** are executed with the IMM EN and DBS EN bits in the Scan Control Register.

TRIGger:SOURce BUS and **TRIGger:SOURce EXTernal** are not implemented at the register level. These commands both write to the TRG INT bit when they are active and a trigger occurs.

TRIGger:SOURce HOLD is not implemented at the register level. It is in the normal state when all trigger sources are disabled.

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Register-Based Programming for Maximum Speed

This is an outline of the algorithm that needs to be followed to have the HP E1326B 5½ Digit Multimeter do high-speed scanning using the HP E1351A 16-Channel FET Multiplexer. This procedure programs the multimeter and downloads a scan list to the FET multiplexer so the hardware controls the entire scanning process. The HP E1326B has several things that should be understood when doing register programming.

1. Table B-1 on page 96 lists the multimeter's commands. When doing any of these commands, you are writing to registers which are read by the multimeter's voltmeter microprocessor. It is important to follow the procedure in Figure B-3 on page 97 on how to send commands. This will enable you to handshake with the E1326B microprocessor as you can easily write commands faster than the processor can execute them.

2. In order to program the HP E1326B Multimeter to take readings with the HP E1351A FET Multiplexer at its highest speed, do the commands from Table B-1 on page 96. Note that all values in Table B-1 are specified in decimal.

set the function	dcv
set the range	1V
Note: You must have a fixed range to do 13k. Auto range will do 2.5k.	
set the aperture	10 µsec
Note: This will cause readings to be returned as 16 bits.	
set the auto zero	off or once
set offset Compensation	off
set trigger source	Immediate
set trigger count	1
set trigger delay	0
set Sample Count	16
This should be the total number of A/D readings that you will take (for example, once through a 16 channel list = 16, 10 times through a 16 channel list = 160).	
set sample Source	Timer
This is the time between A/D readings.	
set sample Period	76µs
76 µsec is the minimum or fastest A/D time.	
set trigger arm	armed
This arms the DVM to take all of the reading specified above.	

Do not execute the next command yet. You still need to set the scan list in the HP E1351A. Trigger immediate will start everything.

3. Now download the channel list to the HP E1351A

- Set CLR SCN in Scan Control Register to one, then back to zero in order to clear the previous scan list.
- DIR in the Status/Control Register set to false.

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Now write once for each channel in your scan list to the Channel Configuration Register. This register loads up a FIFO that will later rotate each time the HP E1326B issues a VM complete on the digital bus. If you have more than one FET multiplexer, you must load up the FIFOs on each one. The VLD bit specifies if a channel is on this card. Note that you must load the entire scan list to each HP E1351A FET Multiplexer, with only the VLD bit being different. The FIFO, and hence the scan list, can be a maximum of 512 channels.

i.e. **VLD**	**A_D**	**B_D**	**C0-C1**	**D0-D3**
0	1	1	volts	0
0	1	1	volts	1
0	1	1	volts	2
0	1	1	volts	3
0	1	1	volts	4
0	1	1	volts	5
0	1	1	volts	6
0	1	1	volts	7
0	1	1	volts	8
0	1	1	volts	9
0	1	1	volts	10
0	1	1	volts	11
0	1	1	volts	12
0	1	1	volts	13
0	1	1	volts	14
0	1	1	volts	15

Now, do the following to the HP E1351A:

write to register:	**decimal code:**	
4	8	Select direct control.
6	26	Enable digital bus triggering continuous scanning, pointer to beginning of scan.
4	0	Control back to DVM.
4	16	Close first channel.

The HP E1351A FET Multiplexer is now ready. It will advance to the next channel every time a VM complete is received.

VM complete is a output from the multimeter that always occurs after an A/D reading is complete. The digital bus cable wires the VM Complete from the voltmeter to the Channel Advance on the FET multiplexer card. The above command (to reg 6 value 26) enables digital bus triggering, which enables the FET Multiplexer to use this signal. Make sure that you have both a analog bus cable and a digital bus cable connected.

4. To start everything, issue the Trigger Immediate command from Table B-1 on page 96, to the HP E1326B.

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The number of readings specified in sample count will now be taken. If the sample count is more than one scan, the scan list will start over again.

5. The voltmeter is now taking data which is being stored in the HP E1326B hardware FIFO. With the 10 µsec aperture set, 512 16-bit readings will collect here. In any other aperture only 256 32-bit readings will collect. If you specified more than 512 readings, the computer needs to be removing them from the FIFO while readings are being taken. The DVM FIFO is connected to the HP E1326B VXI DATA BUFFER register.

To read the FIFO check the Data Ready bit in the Status Register to determine if valid data is in the Data Buffer. Or, read the Data Buffer and throw away any -1 readings, as a -1 decimal reading or all bits set to "1" indicates invalid data. Keep reading the Data Buffer until you receive the number of readings specified in Sample Count. Convert the readings from voltmeter format to 32-bit real format.

6. To do debugging with the HP E1326B voltmeter, use the Query Opcodes in Table B-1. This will verify that you have set the correct parameters. Use the Send Error command (15) to get error codes back. Refer to Table B-2 on page 98.

With the HP E1351A you cannot read back the contents in the FIFO, therefore, debugging is difficult. Do verify that you get correct data back from the Manufacturer ID Register and Device Type Register.

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Multimeter Command and Parameter Opcodes

Table B-1 contains the multimeter command and parameter opcodes. The opcodes used to query the parameter settings are also included.

Table B-1. Multimeter Command and Parameter Opcodes

Multimeter Parameter	Command Opcode	Parameter Opcode	Value	Query Opcode	Query Response
Measurement Function	04	00 01 02	DCV ACV (4-wire) OHMS	05	parameter opcode
Range	02	00 01 02 03 04 05	125 mV / 256 Ω 1V / 2.048 kΩ 8V / 16.384 kΩ 64V / 131 kΩ 300V / 1.048 MΩ Autorange	03	parameter opcode
Aperture Time	00	00 01 02 03 04 05 06	267 ms 16.7 ms 320 ms 20 ms 2.5 ms 100 µs 10 µs	01	parameter opcode
Autozero	08	00 01 02	On Off Once	09	parameter opcode
Offset Compensation	36	00 01	Off On	37	parameter opcode
Trigger Source	06	00 01 02 03 - 0A	Immediate External Hold TTL trigger lines 0 - 7	29	parameter opcode
Trigger Count	39	<upper byte> <middle byte> <lower byte>	1 - 16,777,215 (1),(3)	33	24-bit unsigned number (2)
Trigger Delay	23	<upper byte> <middle byte> <lower byte>	0 - 16.777215s (1)	31	24-bit unsigned number (2)
Voltmeter Complete Signal Destination	40	8-bit binary number (7)	0 - 7 (TTL trigger lines)	41	8-bit binary number
Sample Count	38	<upper byte> <middle byte> <lower byte>	1 - 16,777,215 (1),(4)	32	24-bit unsigned number (2)
Sample Source	07	00 01 02 03	Immediate Timer Software Control Register	30	parameter opcode
Sample Period (5)	10	<upper byte> <lower byte>	76µs - 65.534ms (1)	11	16-bit unsigned number (2)
Software Sample (6)	35	—-	—-	—-	...
Trigger Arm	12	00 01	Un-armed Armed	—-	—-
Trigger Immediate	13	—-	—-	—-	...
Send Error	15	—-	—-	—-	—-

Table B-1 Continued on Next Page

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Table B-1. Multimeter Command and Parameter Opcodes (*continued*)

(1) Specified as a 2's complement binary number. For three byte parameters <upper byte> = value shifted 16 bits to the right (>>16), <middle byte> = value shifted 8 bits to the right (>>8), <lower byte> = value. For two byte parameters <upper byte> = value shifted 8 bits to the right (>>8), <lower byte> = value & 0xFF.

(2) Reading the Query Response register two times (16-bit number) or three times (24-bit number) returns in order; the high byte, middle byte, and low byte.

(3) A parameter value of 0 sets infinite triggers per trigger arm.

(4) A parameter value of 0 sets infinite samples per trigger.

(5) Set when Sample Source is Timer.

(6) Used when Sample Source is Software. The first measurement of each burst occurs when the trigger signal is received (e.g. Trigger Immediate). Subsequent measurements in the burst occur when Software Sample is written to the Command register.

(7) Up to seven VXIbus TTLTrg trigger lines can be selected. 01 selects line 0, FF selects all lines.

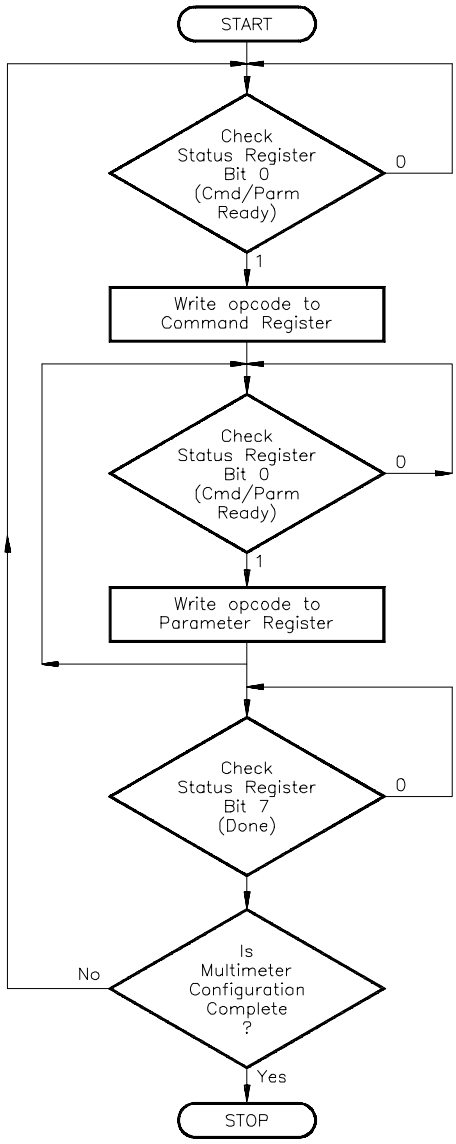


Figure B-3. Configuring the Multimeter

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Multimeter Register-Based Programming Error Codes

Multimeter error codes related to register-based programming are listed in Table B-2.

Table B-2. Multimeter Register-Based Programming Error Codes

Error Code	Cause
00_{16}	No error has occurred since the last error code was read.
01_{16}	Unrecognized command opcode.
02_{16}	A parameter was required but a command was received.
03_{16}	A parameter is invalid or out of range for the specified command.
04_{16}	Reading overrun. The data buffer is full and another measurement is taken. This error also occurs when a new command (opcode) is received while the multimeter is placing a reading in the data buffer. Trigger Arm is disabled.
05_{16}	The command or parameter received is not allowed in the two byte reading mode (10 µs aperture time).
$0C_{16}$	Command is terminated by another command.
$0E_{16}$	The aperture time is longer than the sample rate.
$0F_{16}$	Input overload. A potentially damaging voltage has been applied to the multimeter: > +- 40V between HI and LO or HI and COMMON with the range <= 8V > +- 40V between LO and COMMON on any range Under this condition, the multimeter disconnects itself from the input. A new range must be specified to restore operation.

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Appendix C
HP E1351A/53A FET Multiplexer Error Messages

Table C-1 lists the error messages associated with the multiplexer modules programmed with SCPI commands. See the *HP E1406A Command Module User's Manual* for complete information on error messages.

Table C-1. 16-Channel FET Multiplexer Error Messages

No.	Title	Potential Causes
–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.
–224	Illegal Parameter Value	Attempting to execute a command with a parameter not applicable to the command.
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.
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 (for example, ch. 99 of 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 Thi Card.	Attempting to execute a SCAN:MODE which is not supported.
2011	Empty Channel List	No valid channels in <*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	Incorrect ARM:COUNt	Attempting to run a downloaded scan list with ARM:COUNt set to value other than 1.
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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