VXI
bus

Agilent 75000 SERIES B

50 Ohm RF Multiplexer Module
75 Ohm RF Multiplexer Module
Agilent E1366A/E1367A

User's Manual

Agilent Technologies

E1366-90003
E0406

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Contents

Agilent E1366A, E1367A RF Multiplexers

Notes

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Printing History

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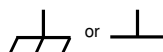
Indicates the field wiring terminal that must be connected to earth ground before operating the equipment—protects against electrical shock in case of fault.

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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	DECLARATION OF CONFORMITY According to ISO/IEC Guide 22 and CEN/CENELEC EN 45014	

Manufacturer's Name: Agilent Technologies, Incorporated
Manufacturer's Address: Measurement Product Generation Unit
815 14th ST. S.W.
Loveland, CO 80537 USA

Declares, that the product

Product Name: B-Size VXI RF Multiplexer
Model Number: E1366A/E1367A
Product Options: This declaration covers all options of the above product(s).

Conforms with the following European Directives:

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

Conforms with the following product standards:

EMC	Standard	Limit
	IEC 61326-1:1997+A1:1998 / EN 61326-1:1997+A1:1998	
	CISPR 11:1997 +A1:1997 / EN 55011:1998	Group 1 Class A [1]
	IEC 61000-4-2:1995+A1:1998 / EN 61000-4-2:1995	4kV CD, 8kV AD
	IEC 61000-4-3:1995 / EN 61000-4-3:1995	3 V/m, 80-1000 MHz
	IEC 61000-4-4:1995 / EN 61000-4-4:1995	0.5kV signal lines, 1kV power lines
	IEC 61000-4-5:1995 / EN 61000-4-5:1995	0.5 kV line-line, 1 kV line-ground
	IEC 61000-4-6:1996 / EN 61000-4-6:1996	3V, 0.15-80 MHz
	IEC 61000-4-11:1994 / EN 61000-4-11:1994	I cycle, 100%
	Canada: ICES-001:1998	
	Australia/New Zealand: AS/NZS 2064.1	

Safety IEC 61010-1:1990+A1:1992+A2:1995 / EN 61010-1:1993+A2:1995
Canada: CSA C22.2 No. 1010.1:1992
UL 3111-1:1994

Supplemental Information:

[1] The product was tested in a typical configuration with Agilent Technologies test systems.

September 5, 2000
Date

Name

Quality Manager
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Notes

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Using This Chapter

This chapter includes an RF multiplexer's description, addressing guidelines, and an example to check initial operation. Chapter contents are:

Multiplexer Module Description

The Agilent E1366A 50Ω RF Multiplexer (2 x 4:1) and the Agilent E1367A 75Ω RF Multiplexer (2 x 4:1) are VXIbus and VMEbus B-size register-based products which provide bidirectional switching and scanning for user inputs and outputs. The multiplexers can operate in a B-size VXIbus or VMEbus mainframe or (with an adapter) in a C-size VXIbus mainframe.

For the RF multiplexers, switching consists of connecting a channel to its common terminal. Scanning consists of connecting a series of channels (one at a time) to the appropriate common terminal.

Basic Operation
The multiplexers consist of two banks of channels (bank 0 and bank 1) to form two 4:1 multiplexers. Bank 0 includes channels 00 through 03 and com 00. Bank 1 includes channels 10 through 13 and com 10. See Figure 1-1 for a simplified switching diagram.

Each channel is switched (connected to its common) by closing the appropriate (nonlatching) relays. Channels 00 through 03 can be switched to com 00, and channels 10 through 13 can be switched to com 10. Only one channel in each bank can be connected to its common at a time.

User inputs and outputs to each channel are made through BNC connectors. When open (disconnected from common), each channel is terminated in its characteristic impedance (50Ω for the E1366A, 75Ω for the E1367A).

A termination resistor (50Ω for the Agilent E1366A or 75Ω for the Agilent E1367A) is mounted on each channel, but can be removed as desired. At power-on or reset, all channels are open and terminated in their characteristic impedance, and both commons are open.
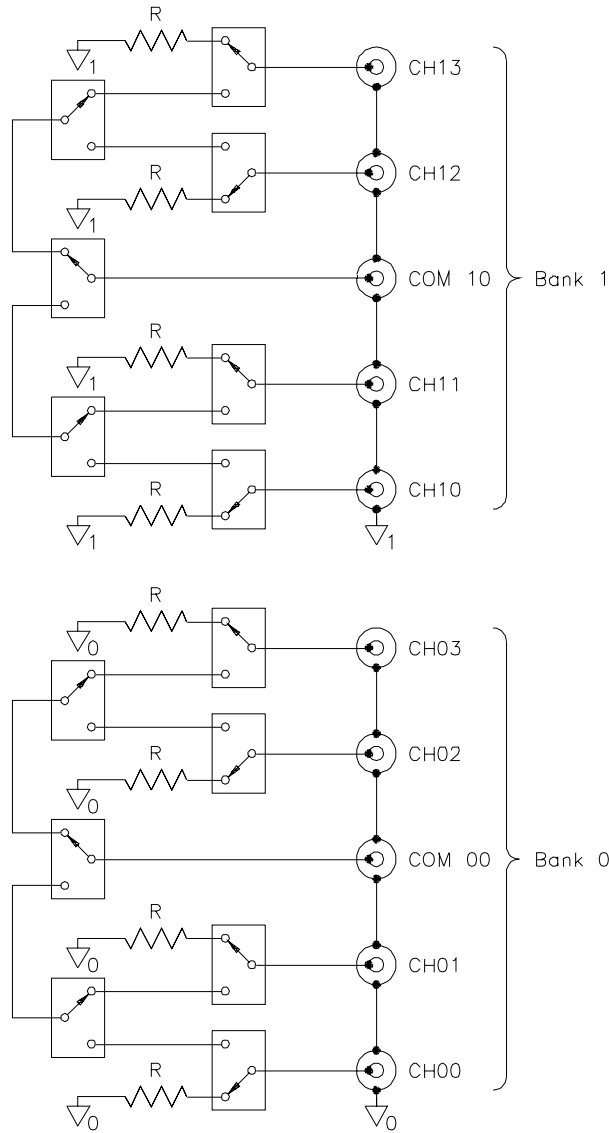
Figure 1-1. Multiplexers Switching Diagram

Typical Configuration

The multiplexer relays are configured in a "tree" structure which provides high isolation and low VSWR (voltage standing wave ratio). Each channel can switch user inputs up to 42 Vdc or 42 Vac peak. User input frequencies to the multiplexers can be from dc to 1.3 GHz.

The multiplexers can be configured for several arrangements, such as standard, tree, or matrix. You can use single scanning, multiple scanning, or continuous scanning for any configuration.

For a SCPI (Standard Commands for Programmable Instruments) environment, one or more multiplexers can be defined as a *switchbox* instrument. For a switchbox instrument, all multiplexer channels within the instrument can be addressed using a single interface address.

Programming the Multiplexer Module

To program the RF multiplexers using SCPI, you must select the controller language, interface address, and SCPI commands to be used. Guidelines to select SCPI commands for the RF multiplexers follow. See the appropriate Agilent B-size or C-size configuration guide for interface addressing and controller language information.

Note   This discussion applies to SCPI programming. See Appendix B, RF Multiplexers Registers, for information on multiplexer registers.

Specifying SCPI Commands

To address specific channels within an RF multiplexer, you must specify the SCPI command and multiplexer channel address. For the RF multiplexers, use CLOSe <*channel_list*> to switch (close) channels and use OPEN<*channel_list*> to disconnect channels. Use SCAN <*channel_list*> to scan (sequentially close) multiplexer channels.

Multiplexer Channel Address

For the RF multiplexers, 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
- or any combination of the above

where "cc" is the multiplexer card number (01-99) and "nn" is the channel numbers (00-03 and 10-13).

Multiplexer Card Numbers

The multiplexer card number depends on the switchbox configuration (single-module or multiple-module) set for the multiplexers. (Leading zeroes can be ignored for the card number.) For a single-module switchbox, the card number is always 01.

For a multiple-module switchbox, the card numbers are 01, 02,...,n. The switch module with the lowest logical address is always card number 01. The card number with the next successive logical address is card number 02, and so on. See the Agilent B-size configuration guide for a definition of logical addresses.

Example: Multiple-Module Switchbox Card Numbers

Assume the three multiplexers in the following figure form a multiple-multiplexer switchbox instrument with multiplexer logical addresses of 120, 121, and 122. Since card number 01 is assigned to the module with the lowest logical address, etc., the card numbers are as shown.

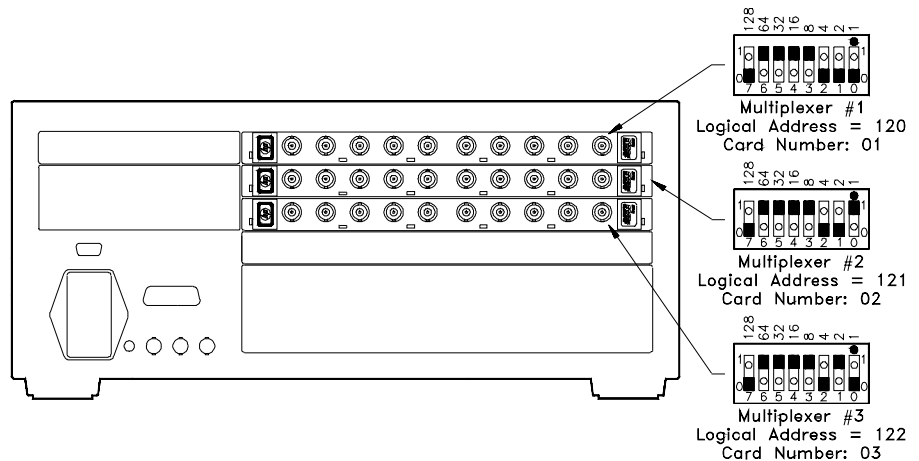**Figure 1-2. Multiple-Multiplexer Switchbox Instrument**

Multiplexer Channel Numbers

RF multiplexer channel numbers are 00 through 03 and 10 through 13. The channels can be addressed using channel numbers or channel ranges. For a single-module switchbox, channel ranges can span across the two channel banks. For multiple-module switchboxes, channel ranges can span across the channels of all modules.

Use commas (**,**) to form a channel list or use a colon (**:**) to form a channel range. Only valid channels can be accessed in a channel list or channel range. Also, the channel list or channel range must be from a lower channel number to a higher channel number. For example, SCAN (@100:213) is acceptable, but SCAN (@213:100) generates an error.

Example: RF Multiplexer Channel Lists/Ranges

Channel Lists:

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

Channel Ranges:

OPEN (@100:113)	*!Open all channels on card 01*
SCAN (@100:213)	*!Scan all channels on cards 01 and 02*

Initial Operation

An example program follows which uses BASIC and SCPI language to get you started using the RF multiplexers. The computer used in the example is an HP 9000 Series 200/300 (or equivalent) controller with BASIC as the program language. The computer interfaces to the mainframe using the General Purpose Interface Bus (GPIB)[*].

This program closes channel 02 of an RF multiplexer at logical address 120 (secondary address = 120/8 = 15) and queries the channel closure state. The result is returned to the controller and displayed (1 = channel closed, 0 = channel open). See the Agilent B-size configuration guide for information on addressing.

Example: Close Multiplexer Channel

OUTPUT 70915;"CLOS (@102)"	*! Close channel 02*
OUTPUT 70915;"CLOS? (@102)"	*! Query channel 02 state*
ENTER 70915;Value	*! Enter result into Value*
PRINT Value	*! Display result*
END	

---

[*] GPIB is the implementation of IEEE Std 488.1-1984

Configuring the Agilent E1366A/E1367A RF Multiplexers

Using This Chapter

This chapter shows how to make user connections to the RF multiplexers and how to configure the multiplexer modules. Chapter contents are:

Warnings and Cautions

Warning   SHOCK HAZARD. Only qualified, service-trained personnel who are aware of the hazards involved should install, configure, or remove the RF multiplexers. Remove all power sources from the mainframe and installed modules before installing or removing a module.

Warning   CHANNEL WIRING INSULATION. All channels that have a common connection must be insulated so that the user is protected from electrical shock in the event that two or more channels are connected together. This means wiring for all channels must be insulated as though each channel carries the voltage of the highest voltage channel.

Caution   MAXIMUM VOLTAGE/CURRENT. Maximum voltage between any RF multiplexer center conductor or shield to any other center conductor, shield, or chassis ground is 42 Vdc or 42 Vac peak. Maximum current per channel or common is 1 A dc or 1 A ac RMS. Maximum switching power is 24 W or 24 VA per channel or common. Maximum power per resistive termination is 1 W or 1 VA. Exceeding any limit may damage the module.

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Caution	CENTER CONDUCTOR MAY SHORT TO SHIELD. Each channel's center conductor may momentarily short to the shield when the channel is opened or closed. Use only resistive (50Ω or 75Ω) or current-limited (<1 A) inputs with less than 0.1 μF total capacitance.

Caution	STATIC-SENSITIVE DEVICE. Use anti-static procedures when removing, configuring, and installing a module. The multiplexer modules are susceptible to static discharges. Do not install a multiplexer without its metal shield attached.

Connecting User Inputs

User inputs to the RF multiplexers are made through user-supplied male BNC connectors to the female BNC connectors on the modules. Figure 2-1 shows the multiplexer female BNC connectors and associated channel numbers.
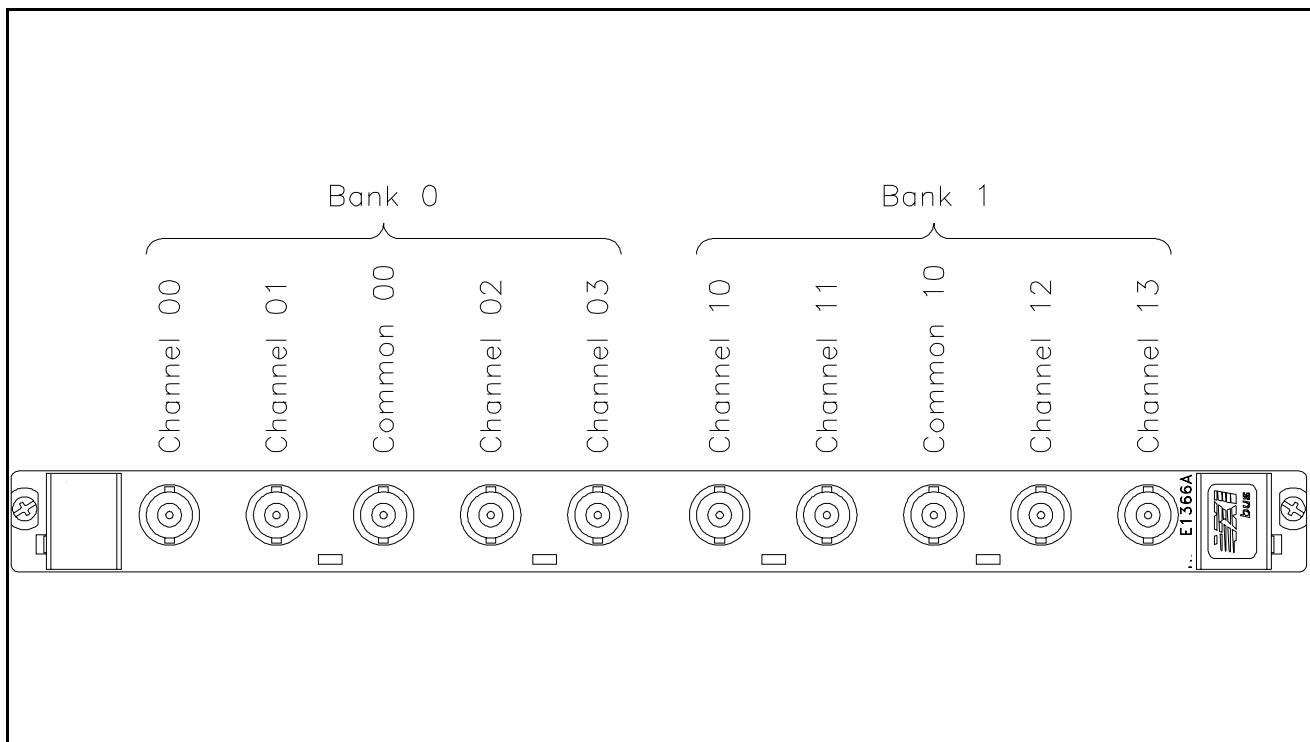
Figure 2-1. BNC Connector Locations

Some guidelines for user input cabling are:

- For best high-frequency performance, user cabling should have at least two braided shields or one braid and a foil wrap.

- Always use shielded coaxial cables with the characteristic impedance of the multiplexer used (50Ω or 75Ω). Keep cables as short as possible, especially in high-frequency circuits or pulse circuits where a rise/fall time of <50 nsec is critical.

- Long cables can add delay time which can cause timing problems. All test equipment, such as counters, spectrum analyzers, and oscilloscopes, must be terminated in the characteristic impedance to minimize reflection loss.

- To maintain low dc offset voltages, cables should have copper center conductors, not copper-clad steel. RG-233/U cable is recommended. Table 2-1 lists Agilent Technologies BNC cables which meet these guidelines.

Table 2-1. Agilent Technologies BNC Cables

Type	Length	Part Number
50 Ω coaxial	30 cm (12 in) 61 cm (24 in) 122 cm (48 in)	8120-1838 8120-1839 8120-1840
75 Ω coaxial	30 cm (12 in) 61 cm (24 in)	5062-6452 5063-0061

Typical Multiplexer Configurations

Typical RF multiplexer configurations are:

- Standard configuration (2 x 4:1 multiplexer)
- Tree configuration (1 x 12:1 multiplexer)
- Matrix-type configuration (4:1 to 4:1 multiplexer)

Standard Configuration

Figure 2-2 shows the standard configuration (2 x 4:1) for the RF multiplexers. With this configuration, you can switch channels 00-03 to com 00 and switch channels 10-13 to com 10. One channel per bank can be connected to its common at a time.
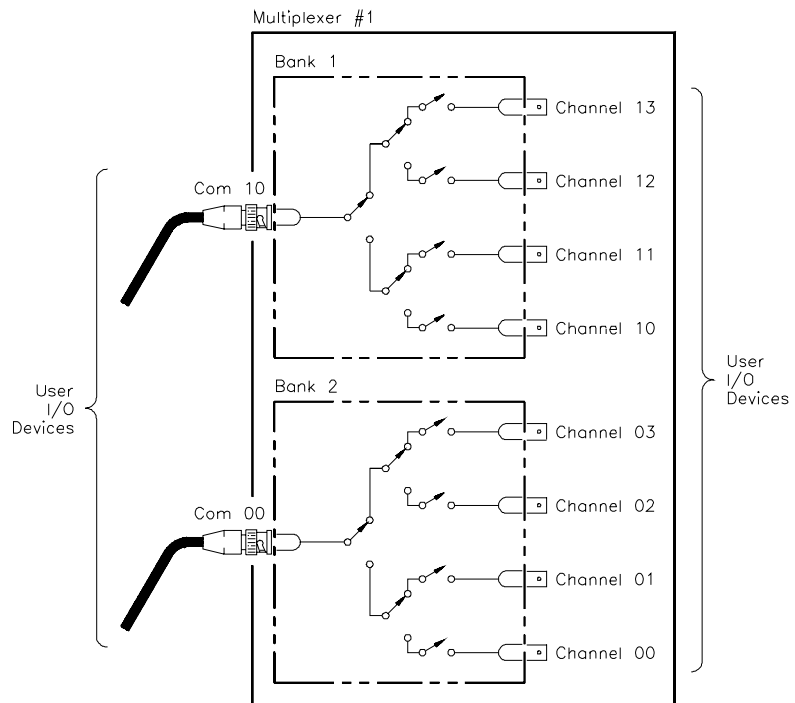
Figure 2-2. Typical Standard Configuration

Tree Configuration   Figure 2-3 shows a typical tree configuration which uses two RF multiplexers to provide a 1 x 12:1 multiplexer. This configuration provides isolation of test points while maintaining characteristic impedance. With tree configuration, signal delay time is more than doubled since the signal must pass through two channel banks plus extra cabling. Keep cables as short as possible, especially between channel banks, to minimize delay.
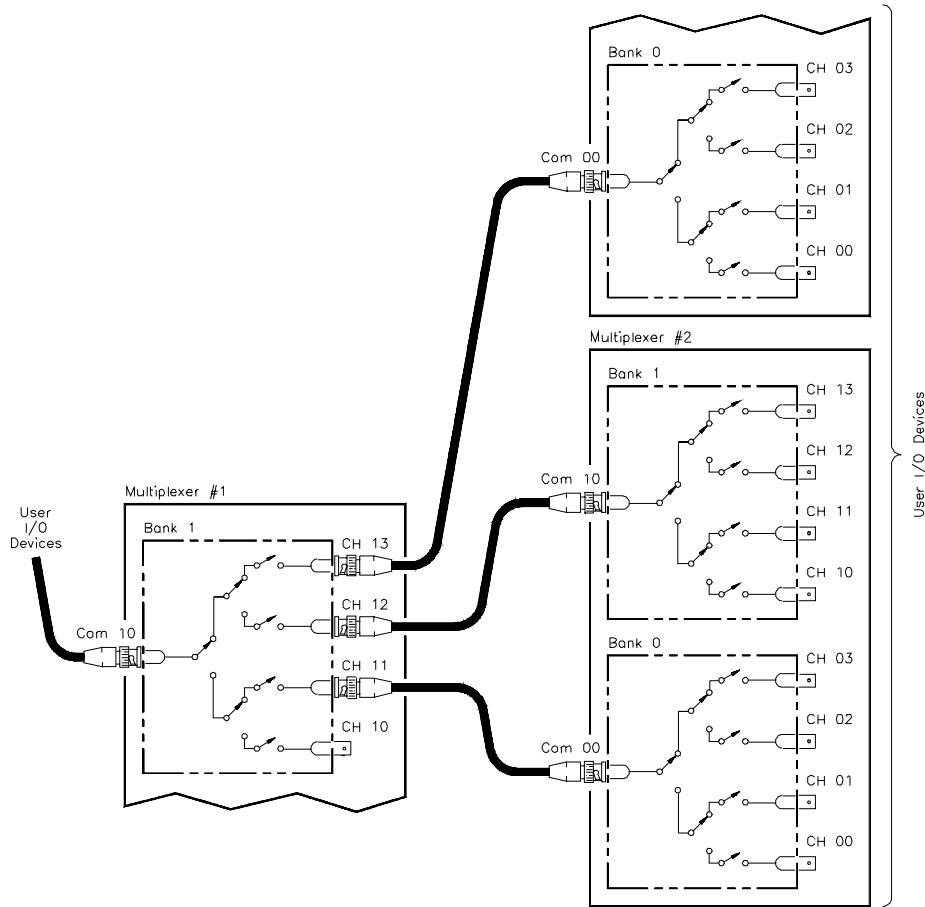
Figure 2-3. Typical Tree Configuration

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Matrix-Type Configuration

Figure 2-4 shows the two banks of an RF multiplexer connected to form a matrix-type arrangement. This configuration provides a way to connect multiple devices under test (DUTs) to multiple test instruments. With this configuration, only one channel in bank 0 (one "row") can be connected to one channel in bank 1 (one "column") at a time.
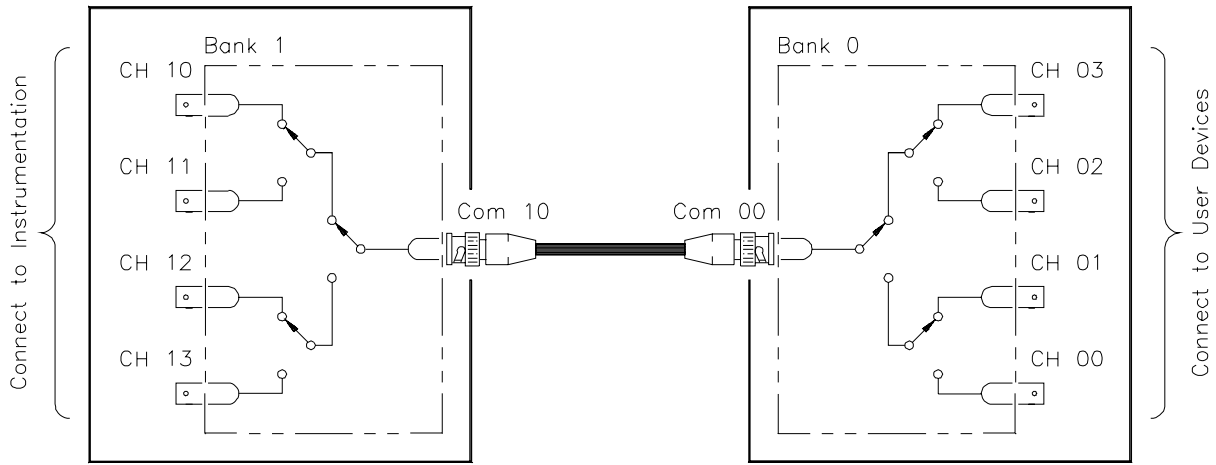
Figure 2-4. Typical Matrix-Type Configuration

Changing Multiplexer Components

As required, you can change the logical address switch setting, replace the protection fuses, change the interrupt priority jumper setting, or remove channel termination resistors. See Figure 2-5 for locations.
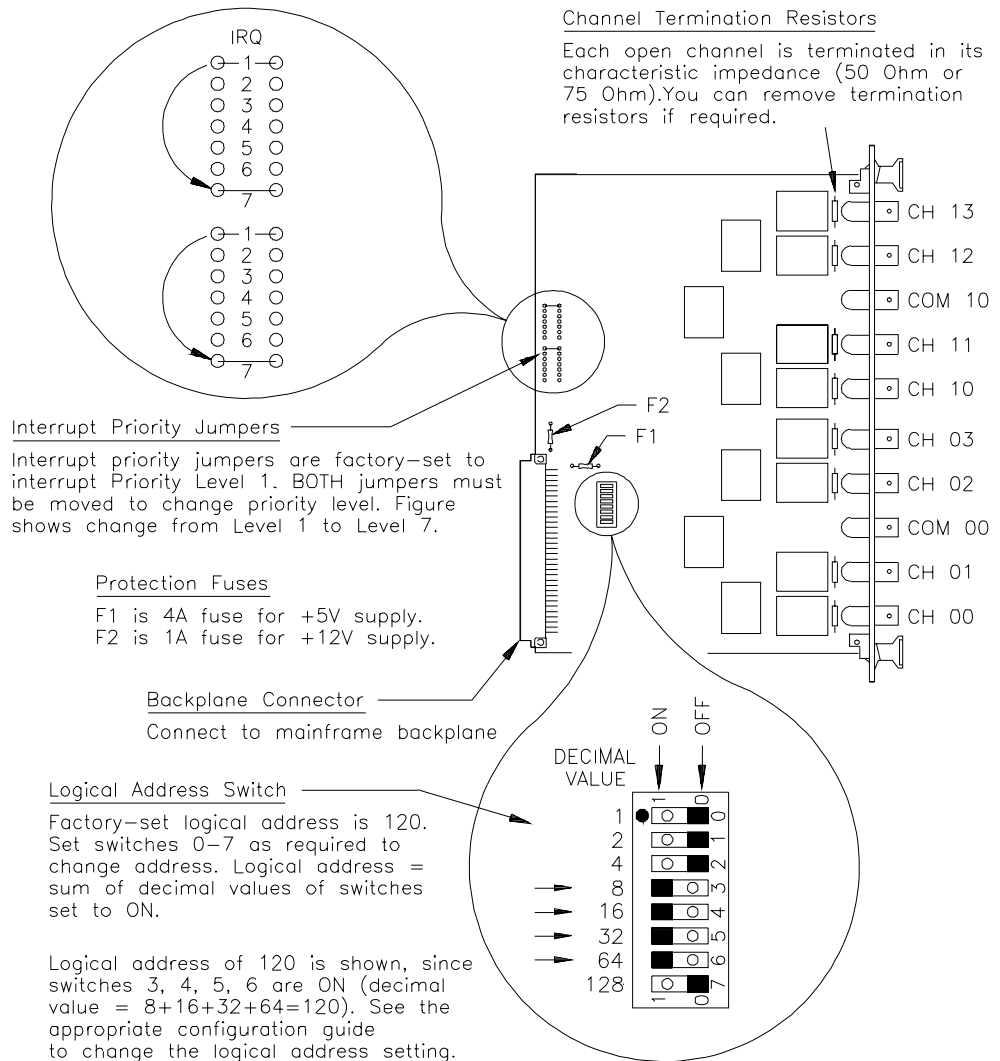
Figure 2-5. RF Multiplexer Component Locations

Using the Agilent E1366A/E1367A
RF Multiplexer Module

Using This Chapter

This chapter provides examples to switch multiplexer channels and to scan multiplexer channels. As required see Chapter 4, Understanding the RF Multiplexers, to modify the examples for your application. Also, see Chapter 5, RF Multiplexers Command Reference, for command information. Chapter contents are:

Multiplexer Commands

Table 3-1. RF Multiplexer Commands Used in Chapter 3

Command	Description
CLOS *<channel_list>* OPEN *<channel_list>*	Close channels Open channels
TRIG:SOUR BUS |EXT |HOLD |IMM SCAN *<channel_list>* INIT	Set scanning trigger source Define channels to be scanned Start scan, close first channel

Switching Channels

- Switching channels consists of closing or opening a channel. Close channels 00-03 by connecting a channel to com 00 or close channels 10-13 by connecting a channel to com 10. Only one channel per bank can be closed at a time.

- Use CLOSe *<channel_list>* to close channels or use OPEN *<channel_list>* to open channels. *channel_list* has the form (@ccnn) for a single channel, (@ccnn,ccnn,...) for two or more channels, or (@ccnn:ccnn) for a set of channels where cc = card number,   nn = channel number.

- Switching configurations include standard, matrix, and tree. See Chapter 2 for configuration details.

Example: Standard Switching

This example connects channel 02 to com 00 of an RF multiplexer in standard configuration. The multiplexer is defined as a single-multiplexer switchbox instrument. See the following figure for typical user connections. To connect channel 02 to com 00, execute:

CLOS (@102)   ! *Connect channel 02 to com 00.*
                               1 is the card number and 02 is the
                               channel number.

To open the channel, use OPEN (@102).
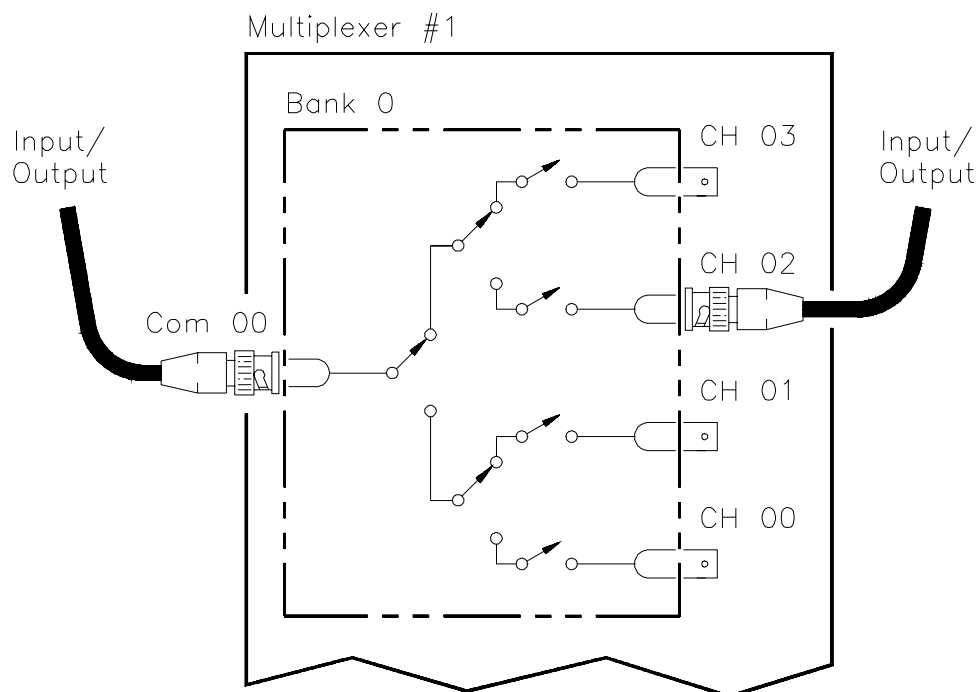
Figure 3-1. Standard Switching

Example: Tree Switching

This example uses two RF multiplexers in a tree configuration to connect com 10 of multiplexer #1 with channel 12 of multiplexer #2. The two multiplexers form a multiple-multiplexer switchbox instrument with multiplexer #1 as card 01 and multiplexer #2 as card 02. See the following figure for typical user connections. To make this connection, execute:

CLOS (@112,212)   ! *Connect com 10 of multiplexer #1*
                                    to channel 12 of multiplexer #2.

To open the channels, use OPEN (@112,212).
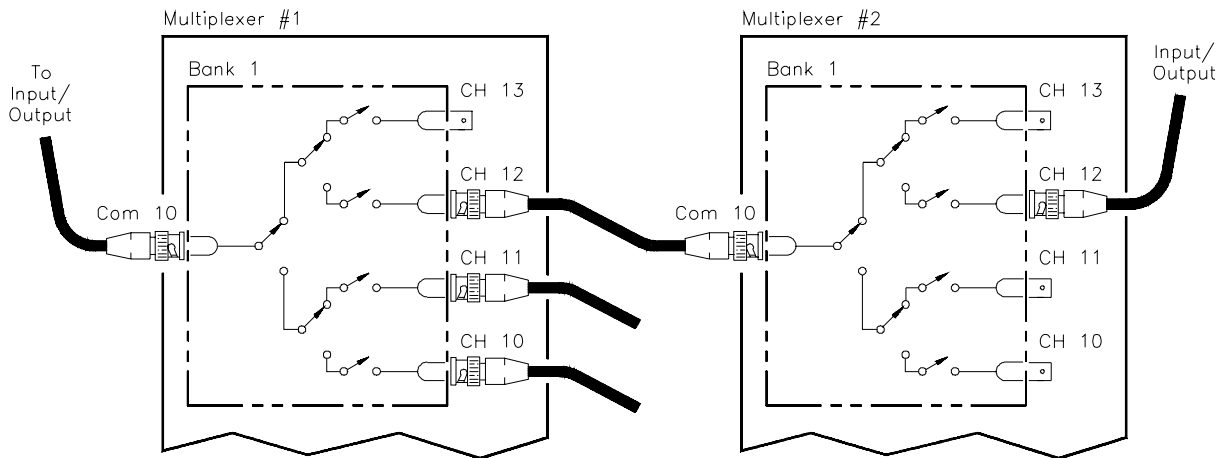
Figure 3-2. Tree Switching

Example: Matrix-Type Switching

This example connects channel 13 to channel 01 of an RF multiplexer in matrix-type configuration. The multiplexer is defined as a single-module switchbox instrument. See the following figure for typical user connections. To connect channel 13 to channel 01, execute:

CLOS (@101,113)   ! *Connect channel 01 to channel 13.*
1 is the card number and 01, 13
are channel numbers.

To open the channels, use OPEN (@101,113).
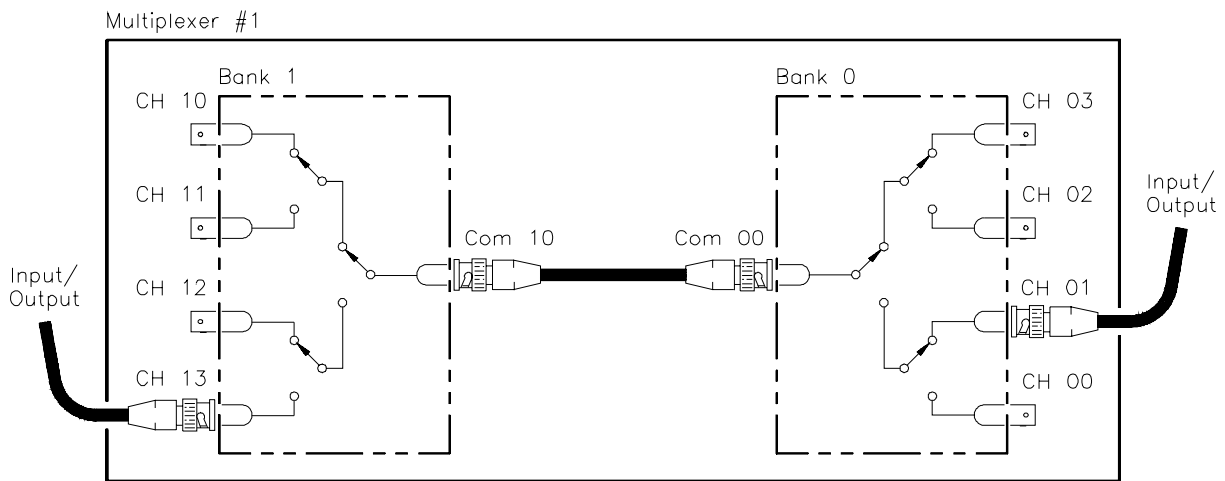
Figure 3-3. Matrix-Type Switching

Switching Channels Comments

Query Channel States. Use CLOSe? *<channel_list>* or OPEN? *<channel_list>* to query the channel states (open/closed). CLOSe? returns a 1 for channels closed, 0 for channels open. OPEN? returns a 0 for channels closed, 1 for channels open. (Commands do not account for relay hardware failures.)

Channel Closure Order. CLOSe *<channel_list>* can be used to close multiple channels (one at a time). However, the sequence in which multiple channels are closed with a single command is not guaranteed.

Scanning Channels

- Scanning channels consists of closing a set of channels, one channel at a time. You can scan any combination of channels for a single-multiplexer or multiple-multiplexer switchbox.
- Single, multiple, or continuous scanning modes are available. Any switching configuration can be used for scanning. See Chapter 4.

Example: Scanning Using Trig Out Port

This example shows one way to synchronize instrument measurements of DUTs with RF multiplexer channel closures. For measurement synchronization, the Agilent E1300B/E1301B Trig Out BNC port is connected to the instrument External Trigger In port. See the following figure for typical user connections.

For this example, the mainframe and instrument are connected via GPIB with mainframe address of 709 and instrument address of 722. The RF multiplexer is at logical address 120 (secondary address 15). (You must add required instrument commands to line 10.)

```
10  OUTPUT 722;"TRIG EXT;...."           ! Ext triggering
20  OUTPUT 70915;"OUTP ON"               ! Enable Trig Out
30  OUTPUT 70915;"TRIG:SOUR BUS"         ! Bus triggering
40  OUTPUT 70915;"SCAN (@100:103)"       ! Scan channels
50  OUTPUT 70915;"INIT"                  ! Enable scan
60  FOR I=1 TO 4                         ! Start loop
70  ENTER 722;A                          ! Enter result
80  PRINT A                              ! Display result
90  TRIGGER 70915                        ! Advance scan
100 NEXT I                               ! Increment count
110 END
```
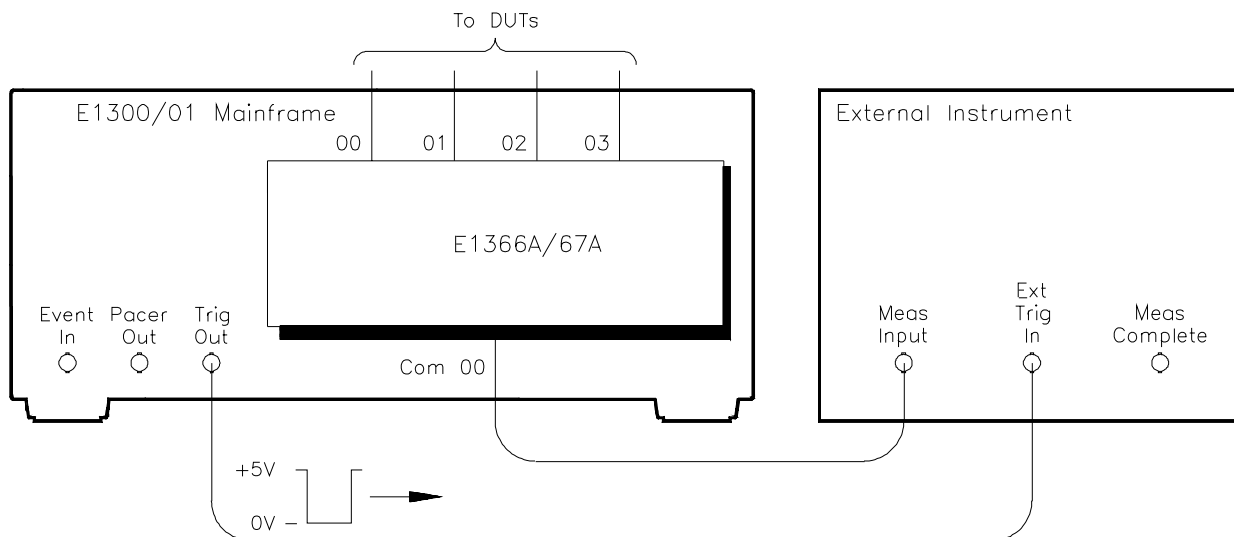

Figure 3-4. Scanning Using Trig Out Port

Scanning Channels Comments

Scan List Can Extend Across Boundaries. For multiple-multiplexer switchbox instruments, the scan list can extend across multiplexer boundaries. For example, for a two-multiplexer switchbox instrument, SCAN (@100:213) will scan all channels in both multiplexers.

Setting Multiple/Continuous Scans. Use ARM:COUN *<number>* to set from 1 to 32767 scans through the scan list. Use INIT:CONT ON to set continuous scanning. See Chapter 4.

Understanding the Agilent E1366A/E1367A RF Multiplexers

Using This Chapter

This chapter explains techniques to scan RF multiplexer channels and shows how to use the Scan Complete bit. The chapter contents are:

Scanning Channels Commands

Scanning RF multiplexer channels consists of closing a set of channels, one at a time. Single scan, multiple (2 to 32767) scans, or continuous scanning modes are available. See Figure 4-1 for scanning commands.

Using Scanning Trigger Sources

The TRIG:SOUR command specifies the source to advance the scan. You can use the TRIG command to advance the scan when TRIG:SOUR BUS or TRIG:SOUR HOLD is set. The OUTP command can be used to enable the Agilent E1300B/E1301B Trig Out or the Agilent E1405A/E1406A port. Figure 4-2 shows scanning trigger sources.

Scanning with External Instruments

Scanning RF multiplexer channels has the same effect as executing multiple CLOSe commands. Thus, scanning is useful when the outputs from a number of DUTs are to be measured with an instrument. Two examples using BASIC programming language follow.

Sets Number of Scanning Cycles

ARM:COUN<*number*> sets 1 to 32767 scans through the channel list per INIT command. Default is one scanning cycle.

```
ARM:COUN <number>
```

Selects the Trigger Source

TRIG:SOUR defines the trigger source to advance the scan. Default is TRIG:SOUR IMM. TRIG:SOUR? queries the current trigger source. Sources are:
- BUS = *TRG via GPIB interface
- EXT = Event In connector
- HOLD = Hold triggering
- IMM = Automatic advance

```
TRIG:SOUR  BUS|EXT|HOLD|IMM
```

Selects Continuous Scanning Cycles

Use INIT:CONT ON or INIT:CONT 1 to enable continuous scanning cycles. Default made is fixed number of scans, with number set by ARM:COUN<*number*>.

```
INIT:CONT  ON
```

Selects Scan Mode

SCAN:MODE sets the RF multiplexers for NONE, VOLT, RES, or FRES. NONE, VOLT, and RES have no effect on RF multiplexer operation. FRES sets "paired-channel" scanning.

```
SCAN:MODE  NONE|VOLT|RES|FRES
```

Selects the Scan List

SCAN<*channel_list*> defines channels to be scanned using the trigger source set by the TRIG:SOUR command.

```
SCAN<channel_list>
```

Enables Scanning

INIT starts scanning for any trigger source and closes the first channel in the channel list.

```
INIT
```

Advances the Scan

TRIG can be used to advance the scan for TRIG:SOUR BUS or TRIG:SOUR HOLD. The command is not functional when TRIG:SOUR IMM or TRIG:SOUR EXT is set.

```
TRIG
```

Figure 4-1. Scanning Channels Commands

Trigger Hold (TRIG:SOUR HOLD)

TRIG:SOUR HOLD prevents execution
of triggers until trigger source is changed.
Can use TRIG command to trigger a
switchbox set to TRIG:SOUR HOLD.

Advance Scan (TRIG)

Can use TRIG command to ad-
vance the scan list when switch-
box is in TRIG:SOUR HOLD or
TRIG:SOUR BUS. For either
trigger source, the scan list
advances one channel per
TRIG command.

Immediate Triggering (TRIG:SOUR IMM)

TRIG:SOUR IMM sets immediate
(internal) triggering. The scan list is
automatically advanced. This is the
default trigger mode.

Bus Triggering (TRIG:SOUR BUS)

TRIG:SOUR BUS defines trigger
source as a *TRG or GET
command executed over the GPIB.
With TRIG:SOUR BUS, the scan list
is advanced for each *TRG or GET
command received.

External Trigger (TRIG)

TRIG:SOUR EXT sets external
triggering. The trigger source is a
(user supplied) input to the Event In
port. Use a +5V negative-going pulse
to trigger.

With two or more switchboxes in a
mainframe, the first switchbox set for
EXT trigger keeps the trigger resource
until the switchbox source is changed
to BUS, HOLD, or IMM.

Enabling Trig Out Port (OUTP ON)

The Trig Out port is shared by all
instruments in the mainframe. With
the port enabled (with OUTP ON), it
generates an output trigger after
each channel closure for ANY
switchbox in the mainframe. The
Trig Out port outputs a +5V
negative-going pulse.

E1300/E1301 Mainframe

Event In   Pacer Out   Trig Out

5V Max   5V Max   5 Max
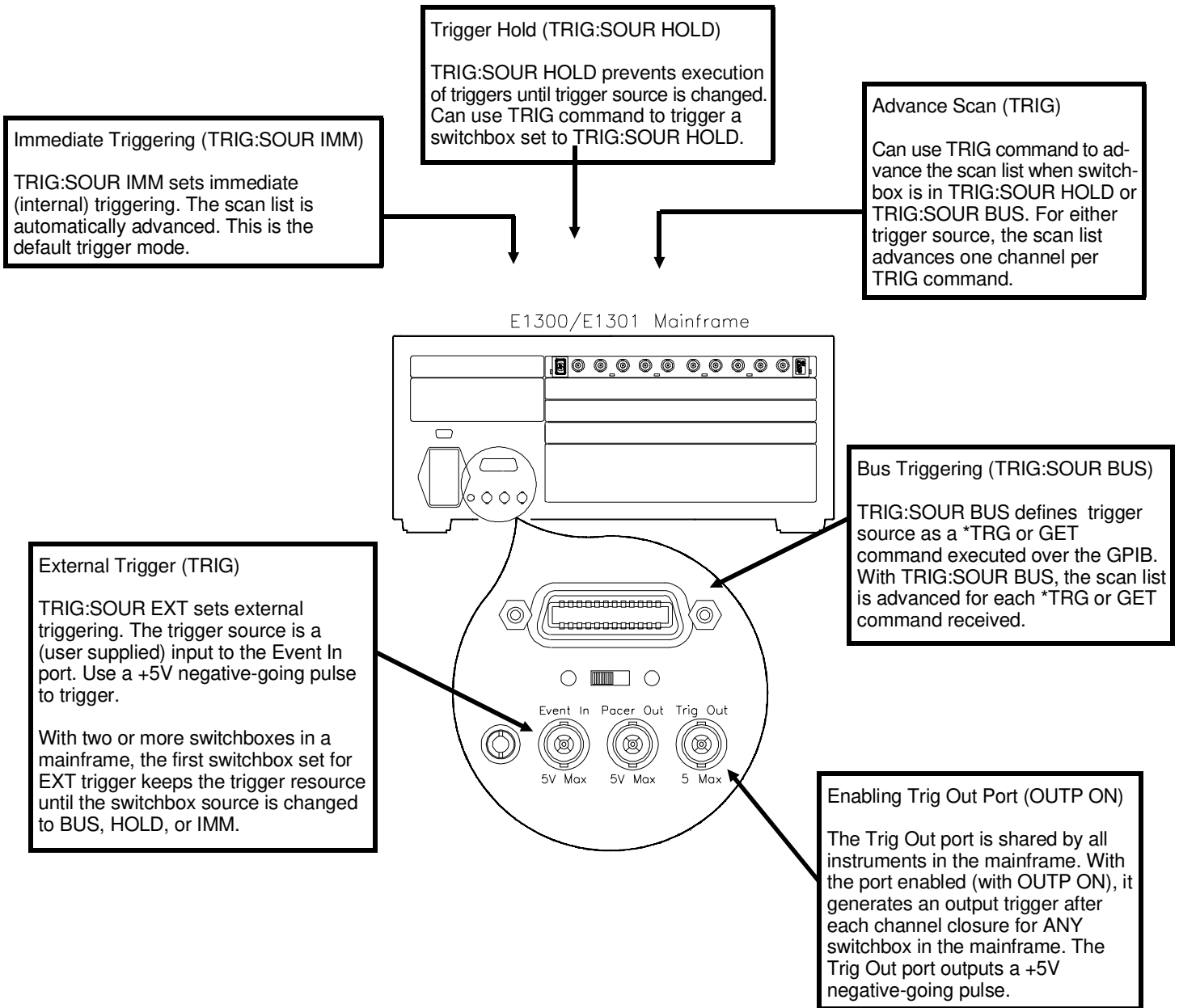
Figure 4-2. Scanning Trigger Sources

Example: Scanning with External Device

This example uses the Agilent E1300B/E1301B mainframe "Trig Out" port to synchronize the RF multiplexer channel closures to an external measurement device. See the figure below for typical user connections. For measurement synchronization, the Agilent E1300B/E1301B Trig Out BNC port is connected to the instrument External Trigger In port.

For this example, the Agilent E1300B/E1301B and the instrument are connected via GPIB with Agilent E1300B/E1301B address of 709 and instrument address of 722. The RF multiplexer logical address is 120 (secondary address =120/8 =15). The measurements are transferred directly to the computer. (Appropriate instrument commands must be added to line 10.) The sequence of operation is:

1. INIT (line 50) closes channel 100.
2. The channel closure causes a trigger output from the "Trig Out" port.
3. Trigger to Ext Trig In initiates channel 100 measurement.
4. Result is sent to the computer (lines 60 to 80).
5. TRIGGER command (line 90) advances the scan to channel 101.
6. Steps 2-5 are repeated for channels 101 through 102.

```
10  OUTPUT 722;"TRIG EXT;..."        ! Configure instrument
20  OUTPUT 70915;"OUTP ON"           ! Enables "Trig Out" port
30  OUTPUT 70915;"TRIG:SOUR BUS"     ! GPIB bus triggering
40  OUTPUT 70915;"SCAN  (@100;102)"  ! Scan channels 00-02
50  OUTPUT 70915;"INIT"              ! Enable scan
60  FOR I = 1 TO 3                   ! Start count loop
70  ENTER 722;A                      ! Enter reading
80  PRINT A                          ! Display reading
90  TRIGGER 70915                    ! Advance scan
100  NEXT I                          ! Increment count
110  END
```
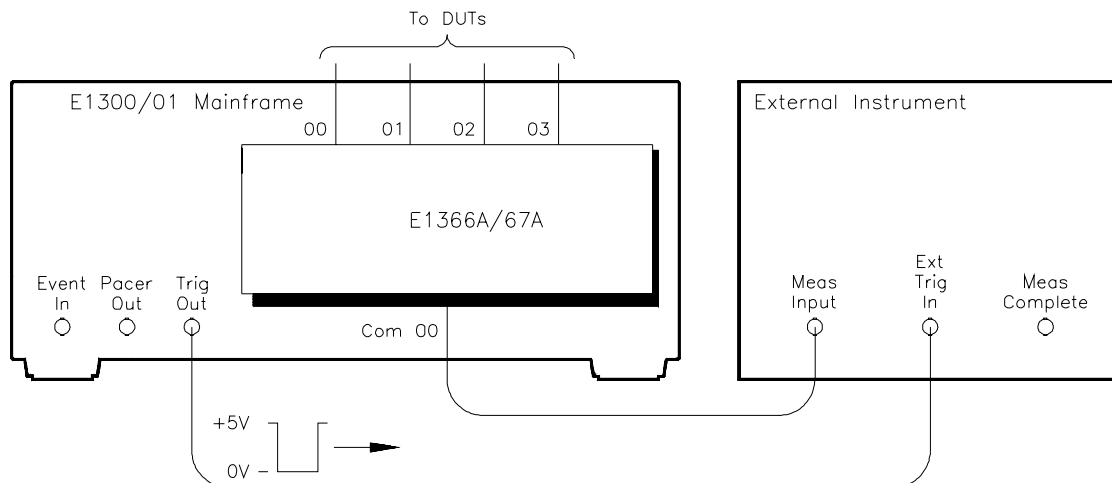

Figure 4-3. Scanning with External Device

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

This example uses the Agilent E1300B/E1301B mainframe "Trig Out" and "Event In" ports to synchronize RF multiplexer channel closures with an external measurement device. See the figure below for typical user connections. For this example, the mainframe and instrument are connected via GPIB with mainframe address of 709 and instrument address of 722. The RF multiplexer's logical address is 120 (secondary address =120/8 =15).

With this example, since synchronization with the computer cannot be ensured, the external instrument must have internal memory capacity to store the readings. Also, you must add the appropriate instrument commands to line 10. The sequence of operation is:

1. INIT (line 50) closes channel 100.
2. The channel closure causes a trigger output from the "Trig Out" port.
3. Trigger to Ext Trig In starts channel 100 measurement.
4. Channel 100 measurement result is stored in instrument.
5. Trigger is then output from multimeter's "MEASUREMENT COMPLETE" port.
6. Trigger to "Event In" port advances scan to channel 101.
7. Steps 2-6 are repeated for channels 101 through 102.

```
10  OUTPUT 722;"TRIG EXT;..."          ! Configure instrument
20  OUTPUT 70915;"OUTP ON"             ! Enables "Trig Out" port
30  OUTPUT 70915;"TRIG:SOUR EXT"       ! Event In triggering
40  OUTPUT 70915;"SCAN  (@100:102)"    ! Scan channels 00-02
50  OUTPUT 70915;"INIT"                ! Enable scan
60  END
```
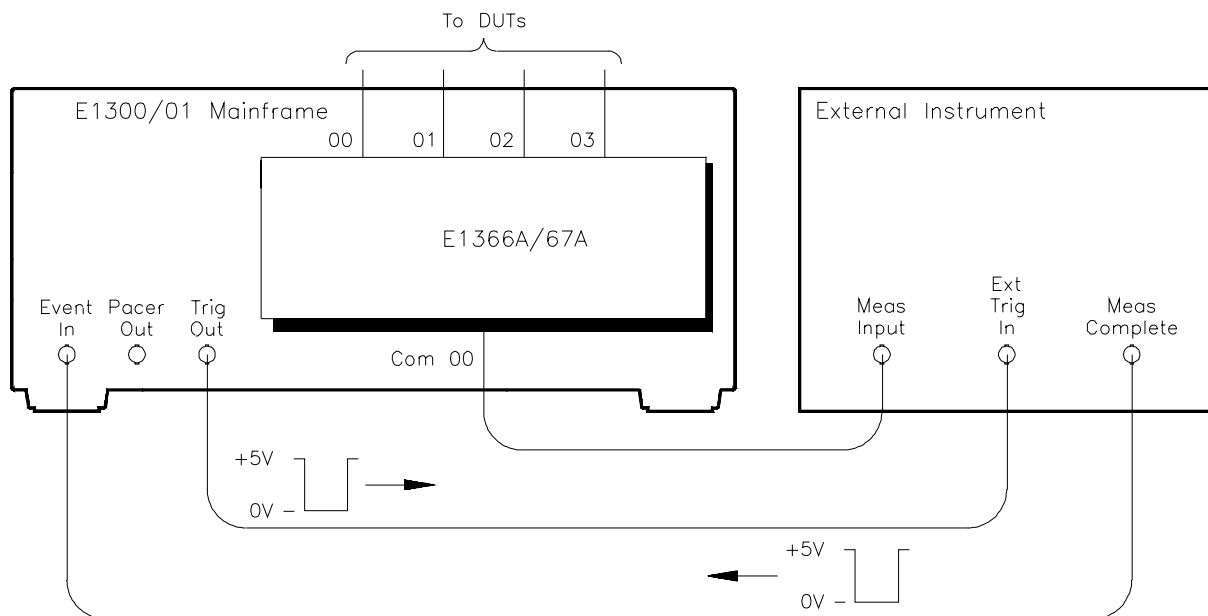

Figure 4-4. Scan Using "Trig Out" and "Event In" Ports

Using the Scan Complete Bit

You can use the Scan Complete Bit (bit 8) in the Operation Status register of a switchbox 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 STATus:OPERation[:EVENt]? command in Chapter 5 for an example.

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 GPIB 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 GPIB Service Request (SRQ), you can interrupt the computer 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 this example is an HP 9000 Series 200/300 used with BASIC as the programming language. The computer interfaces with an Agilent E1300B/E1301B mainframe over GPIB. The GPIB select code is 7, the GPIB primary address is 09, and the GPIB secondary address is 15.

Example: Scan Complete Interrupt

```
10   OUTPUT 70915;"*CLS"                    ! Clear all switchbox status structure
20   OUTPUT 70915;"STAT:OPER:ENAB 256" ! Enable Scan Complete Bit to
                                              set bit 7 in Status register
30   OUTPUT 70915;"*SRE 128"               ! Enable bit 7 of Status register to
                                              assert SRQ
40   OUTPUT 70915;"TRIG:SOUR EXT"        ! External trigger mode
50   OUTPUT 70915;"SCAN  (@100:105)"     ! Select channels to be scanned
60   OUTPUT 70915;"INIT"                    ! Start scanning cycle
70   WHILE NOT BIT(SPOLL(70915),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  generated by a completed
                                              scanning cycle
110  END
```

Agilent E1366A/E1367A RF Multiplexers Command Reference

Using This Chapter

This chapter describes Standard Commands for Programmable Instruments (SCPI) and summarizes IEEE 488.2 Common (*) commands applicable to both RF Multiplexer modules. See the appropriate Agilent B-size or C-size configuration guide for additional information on SCPI and Common commands. This chapter contains the following sections.

Command Types

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

Common Command Format

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

   *RST   *ESR 32   *STB?

SCPI Command Format

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

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

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

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

ROUTe:SCAN:MODE?

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

Abbreviated Commands	The command syntax shows most commands as a mixture of upper- and lowercase letters. The uppercase 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 lowercase letters. Therefore, MEASURE, measure, and MeAsUrE are all acceptable.

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

[SOURce:]
   PULSe
      :COUNt *<count>*
      :COUNt? [<MIN | MAX>]
      :PERiod *<period>*
      :PERiod? [<MIN | MAX>]

The root command SOURce: is an implied command. To set the instrument's pulse count to 25, you can send either of the following command statements:

SOUR:PULS:COUN 25   *or*   PULS:COUN 25

Parameters

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

Table 5-1. SCPI Parameter Types

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 INF.
Boolean	Represents a single binary condition that is either true or false. ON, OFF, 1, 0.
Discrete	Selects from a finite number of values. These parameters use mnemonics to represent each valid setting. An example is the TRIGger:SOURce <*source*> command where <*source*> can be BUS, EXT, HOLD, or IMM.

Optional Parameters. Parameters shown within square brackets ([ ]) are optional parameters. (Note that the brackets are not part of the command and are not sent to the instrument.) If you do not specify a value for an optional parameter, the instrument chooses a default value. For example, consider the ARM:COUNt? [<MIN | MAX>] command. If you send the command without specifying a parameter, the present ARM:COUNt 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 HOLD;*RST

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 RF multiplexers. Commands are listed alphabetically by subsystem and within each subsystem.

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 invalidates the current channel list and sets ARM:COUNt 1 (one scanning cycle per INITiate command), sets INITiate CONTinuous OFF (no continuous scanning cycles), and sets TRIGger:SOURce IMMediate (continuous internal triggering).

- **Stopping Scans Enabled from Interface:** When a scan is enabled from the interface, use an interface CLEAR command or the Agilent E1301B 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 Agilent E1301B front panel "Reset Instr" or "Clear Instr" key to stop the scan.

- **Stopping Scans Enabled from Front Panel:** When a scan is enabled from the Agilent E1301B front panel, execute *RST entered via the interface or the front panel "Reset Instr" or "Clear Instr" key to stop the scan.

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

Example   **Stopping a Scan with ABORt**

TRIG:SOUR BUS	! *TRG command is trigger source
INIT:CONT ON	! Set continuous scanning
SCAN (@100:103)	! Scan channels 00-03
INIT	! Start scan, close channel 00
.	
.	
ABOR	! Abort scan in progress

ARM

The ARM subsystem selects the number of scanning cycles (1 through 32767) for each INITiate command.

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 when INITiate:CONTinuous OFF |0 is set. MIN sets 1 cycle and MAX sets 32767 cycles.

Parameters

Parameter Name	Parameter Type	Range of Values
<number>	numeric	1 |32767 |MIN |MAX

Comments   • **Number of Scans:** Use only values between 1 to 32767 for the number of scanning cycles.

• **Related Commands:** ABORt, INITiate:IMMediate

• ***RST Condition:** ARM:COUNt 1

Example   Setting Ten Scanning Cycles

This example sets an RF multiplexer for 10 scans of channels 00 through 03. When the scan sequence completes, channel 03 is closed.

ARM:COUN 10	! *Set 10 scans per INIT command*
SCAN (@100:103)	! *Scan channels 00-03*
INIT	! *Start scan, close channel 00*

:COUNt?   **ARM:COUNt? [MIN | MAX]** returns current number of scanning cycles set by ARM:COUNt. The current number of scan cycles is returned when MIN or MAX is not supplied. With MIN or MAX passed as parameters, MIN returns 1 and 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

This example sets a switchbox for 10 scanning cycles of channels 00 through 03 and queries the number of scan cycles set. The ARM:COUN? command returns 10.

ARM:COUN 10	! *Set 10 scans per INIT command*
ARM COUN?	! *Query number of scans*

DISPlay

The DISPlay subsystem monitors the channel state of a selected module (or card) in a switchbox. This subsystem operates only with mainframes which have a display, such as the Agilent 75000 Series B Mainframe (Agilent E1301B).

Subsystem Syntax　DISPlay
　　　　　　　:MONitor
　　　　　　　　　[:STATe] *<boolean>*
　　　　　　　　　:CARD *<number>* | AUTO

:MONitor[:STATe]

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

Parameters

Parameter Name	Parameter Type	Range of Values
ON	OFF	1	0	boolean	ON	OFF	1	0

Comments

- **Monitoring Switchbox Channels:** DISPlay[:STATe] ON or DISPlay[:STATe] 1 turns the monitor mode on to show the channel state of the selected module. DISPlay[:STATe] OFF or DISPlay[: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 Agilent E1301B Mainframe Display:** A typical display for the Agilent E1366A or Agilent E1367A RF Multiplexer module follows, where channel 00 (in bank 0) and channel 13 (in bank 1) are closed.

  ```
  B0:0  B1:3
  ```

- ***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*

: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:** Use the
  DISPlay:MONitor:CARD command to send the module number for
  the switchbox to be monitored.

- **Selecting the Present Module to be Monitored:** Use the
  DISPlay:MONitor: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*

INITiate

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

Subsystem Syntax   INITiate
       :CONTinuous ON | OFF | 1 | 0
       :CONTinuous?
       [:IMMediate]

:CONTinuous   **INITiate:CONTinuous ON | OFF | 1 | 0** enables or disables continuous scanning cycles for the switchbox.

Parameters

Parameter Name	Parameter Type	Range of Values
ON	OFF	1	0	boolean	ON	OFF	1	0

Comments
- **Continuous Scanning Operation:** Continuous scanning is enabled with the INITiate:CONTinuous ON or INITiate:CONTinuous 1 command. Sending the INITiate[:IMMediate] command closes the first channel in the channel list.

- Each trigger from 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 closes the first channel in the channel list and the scan cycle repeats.

- **Non-Continuous Scanning Operation:** This is enabled with the INITiate:CONTinuous OFF or INIT:CONT 0 command. Sending the INIT:IMM 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. At the end of the scanning cycle, all channels in the channel list are closed.

- **Stopping Continuous Scans:** See the ABORt command.

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

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

Example   **Enabling Continuous Scans**

This example enables continuous scanning of channels 00 through 03 of a single-module switchbox. Since TRIGger:SOURce IMMediate (default) is set, use an interface clear command (such as CLEAR) to stop the scan.

```
INIT:CONT ON                          ! Enable continuous scanning
SCAN   (@100:103)                     ! Define channel list
INIT                                  ! Start scan cycle, close channel 00
```

:CONTinuous?   **INITiate:CONTinuous?** queries the scanning state. With continuous scanning enabled, the command returns 1. With continuous scanning disabled, the command returns 0.

Example   **Query Continuous Scanning State**

This example enables continuous scanning of a switchbox and queries the state. Since continuous scanning is enabled, INIT:CONT? returns 1.

    INIT:CONT ON   ! *Enable 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 selected 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 definition generates an error (see [ROUTe:]SCAN command).

    • **Stopping Scanning Cycles:** See the ABORt command.

Example   **Enabling a Single Scan**

This example enables a single scan of channels 00 through 03 of a single-module switchbox. The trigger source to advance the scan is immediate (internal) triggering set with (default) TRIGger:SOURce IMMediate.

    SCAN   (@100:103)   ! *Scan channels 00-03*
    INIT   ! *Begin scan, close channel 00 (use immediate triggering)*

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OUTPut

The OUTPut subsystem enables or disables the "Trig Out" port of the Agilent E1300B/E1301B mainframe or the Agilent E1405A/E1406A module.

Subsystem Syntax OUTPut
    [:STATe] ON | OFF | 1 | 0
    [:STATe]?

[:STATe] **OUTPut[:STATe] ON | OFF | 1 | 0** enables/disables the "Trig Out" port on the rear panel of the Agilent E1300B/E1301B mainframe or the Agilent E1405A/E1406A module. OUTPut[:STATe] ON | 1 enables the port and OUTPut[:STATe] OFF | 0 disables the port.

Parameters

Parameter Name	Parameter Type	Range of Values
ON	OFF	1	0	boolean	ON	OFF	1	0

Comments
- **Enabling "Trig Out" Port:** When enabled, a pulse is output from the "Trig Out" port after each scanned switchbox channel is closed. If disabled, a pulse is not output from the port after channel closures. The output pulse is a +5 V negative-going pulse.

- **"Trig Out" Port Shared by Switchboxes:** When enabled, the "Trig Out" port is pulsed by any switchbox each time a scanned channel is closed. To disable the output for a specific switchbox, send the OUTPut[:STATe] OFF or OUTPut[:STATe] 0 command for that switchbox.

- **Related Commands:** [ROUTE:]SCAN, TRIGger:SOURce

- ***RST Condition:** OUTPut[:STATe] OFF (port disabled)

Example **Enable "Trig Out" Port**

  OUTP:STAT ON   *! Enable "Trig Out" port to output pulse after each scanned channel is closed*

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

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

This example enables the "Trig Out" Port and queries the enable state. The OUTPut[:STATe]? command returns 1 since the port is enabled.

  OUTP:STAT ON   *! Enable "Trig Out" port*
  OUTP:STAT?   *! Query port enable state*

[ROUTe:]

The ROUTe subsystem controls switching and scanning operations for RF multiplexer modules in a switchbox.

Subsystem Syntax   [ROUTe:]
    CLOSe *<channel_list>*
    CLOSe? *<channel_list>*
    OPEN *<channel_list>*
    OPEN? *<channel_list>*
    SCAN *<channel_list>*
        :MODE NONE | VOLT | RES | FRES
        :MODE?

CLOSe   **[ROUTe:]CLOSe *<channel_list>*** closes the RF multiplexer channels specified by *channel_list*. The *channel_list* has the form (@ccnn) where cc = card number (01-99) and nn = channel number (00-03 and 10-13).

Parameters

Parameter Name	Parameter Type	Range of Values
<channel_list>	numeric	cc00-cc03, cc10-cc13

Comments   • **Closing Channels:** To close:

- a single channel, use [ROUTe:]CLOSe (@ccnn)
- multiple channels, use [ROUTe:]CLOSe (@ccnn,ccnn)
- sequential channels, use [ROUTe:]CLOSe (@ccnn:ccnn)
- groups of sequential channels, use [ROUTe:]CLOSe (@ccnn:ccnn,ccnn:ccnn)
- or any combination.

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

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

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

Example   **Closing Multiplexer Channels**

This example closes channels 100 and 213 of a two-module switchbox (card numbers 01 and 02).

CLOS   (@100,213)   ! *Close channels 100 and 213.*
                                     100 closes channel 00 of card #1;
                                     213 closes channel 13 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) (see [ROUTe:]CLOSe for definition). The command returns 1 for channel(s) closed or returns 0 for channel(s) opened.

Comments
- **Query is Software Readback:** The [ROUTe:]CLOSe? command returns the current software state of the channel(s) specified. It does not account for relay hardware failures. A maximum of 127 channels at a time can be queried for a multi-module switchbox.

Example   **Query Channel Closure**

This example closes channels 100 and 213 of a two-module switchbox and queries channel closure. Since the channels are programmed to be closed, 1,1 is returned as a string.

CLOS (@100,213)	! *Close channels 100 and 213*
CLOS? (@100,213)	! *Query channels 100 and 213 state*

OPEN   **[ROUTe:]OPEN** *<channel_list>* opens the RF multiplexer channels specified by *channel_list*. The *channel_list* has the form (@ccnn) where cc = card number (00-99) and nn = channel number (00-03 and 10-13).

Parameters

Parameter Name	Parameter Type	Range of Values
<channel_list>	numeric	cc00-cc03, cc10-cc13

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

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

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

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

Example   **Opening Channels**

This example opens channels 100 and 213 of a two-module switchbox (card numbers 01 and 02).

OPEN (@100,213)	! *Open channels 100 and 213.* *100 opens channel 00 of card #1;* *213 opens channel 13 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) (see [ROUTe:]OPEN for definition). The command returns 1 for channel(s) open or returns 0 for channel(s) closed.

Comments   • **Query is Software Readback:** The [ROUTe:]OPEN? command returns the current software state of the channels specified. It does not account for relay hardware failures. A maximum of 127 channels at a time can be queried for a multi-module switchbox.

Example   **Query Channel Open State**

This example opens channels 100 and 213 of a two-module switchbox and queries channel 213 state. Since channel 213 is programmed to be open, 1 is returned.

    OPEN (@100,213)   ! *Open channels 100 and 213*
    OPEN? (@213)   ! *Query channel 213 state*

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SCAN **[ROUTe:]SCAN** *<channel_list>* defines the channels to be scanned. The *channel_list* has the form (@ccnn) where cc = card number (01-99) and nn = channel number (00-03 and 10-13).

Parameters

Parameter Name	Parameter Type	Range of Values
<channel_list>	numeric	cc00-cc03, cc10-cc13

Comments

- **Defining Scan 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.

- **Scanning Channels:** You can scan single channels (@ccnn); multiple channels (@ccnn,ccnn,...); sequential channels (@ccnn:ccnn); groups of sequential channels (@ccnn:ccnn,ccnn:ccnn); or any combination.

- **Scanning Operation:** When a valid channel list is defined, INITiate[:IMMediate] begins the scan and closes the first channel in the channel list. Successive triggers from the source specified by TRIGger:SOURce advances the scan through the channel list.

- **Stopping Scan:** See the ABORt command.

- **Related Commands:** TRIGger, TRIGger:SOURce

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

Example   **Scanning Using External Devices**

See Chapter 4, "Example: Scanning With External Device" or "Example: Scanning Using "Trig Out" and "Event In" Ports" for example scanning programs using external instruments.

SCAN:MODE

[ROUTe:]SCAN:MODE NONE | VOLT | RES | FRES sets the scan mode for the RF multiplexers. NONE, VOLT, and RES have no effect on multiplexer operation. With FRES, the switch is set for "paired-channel" scanning. That is, when a channel in bank 0 is closed, the associated channel in bank 1 is simultaneously closed.

Parameters

Parameter Name	Parameter Type	Range of Values
NONE	VOLT	RES	FRES	discrete	NONE	VOLT	RES	FRES

Comments

- **Order of Command Execution:** The [ROUTe:]SCAN:MODE command must be executed before the [ROUTe:]SCAN *<channel_list>* command.

- **FRES Mode Description:** With FRES, and channel closed in bank 0 automatically closes the paired channel in bank 1. For example, with FRES, closing channel 00 also simultaneously closes channel 10, closing channel 01 closes channel 11, etc. Use only channels 00-03 for the *channel_list*. Specifying channels 10-13 causes an error.

- ***RST Condition:** ROUT:SCAN:MODE NONE

Example

Selecting Paired-Channel Scanning

TRIG:SOUR EXT	! *External trigger source*
SCAN:MODE FRES	! *Paired-channel scanning mode*
SCAN (@100:103)	! *Select channels for scanning*
INIT	! *Start scanning, close channels 100 and 110*

SCAN:MODE?

[ROUTe:]SCAN:MODE? returns the current state of the scan mode. The command returns `"NONE"`, `"VOLT"`, `"RES"`, or `"FRES"` depending on the [ROUTE:]SCAN:MODE parameter setting.

Example

Query Scan Mode

Since this example selects the FRES (paired-channel scanning), the query command returns `"FRES"`.

SCAN:MODE FRES	! *Selects paired-channel scanning*
SCAN:MODE?	! *Query scanning mode*

STATus

The STATus subsystem reports the bit values of a Standard Operation Status register. It enables the Status register to set a bit after a bit is set to 1 by the Standard Operation register.

Subsystem Syntax

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

: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 0 after sending the STATus:OPERation[:EVENt]? command.
- **Returned Data after sending the STATus:OPERation[:EVENt]? Command:** The command returns +256 if bit 8 of the Operation Status register is set to 1. The command returns +0 if bit 8 of the Operation Status register is set to 0.
- **Related Commands:** [ROUTe:]SCAN

Example

Reading the Operation Status Register After a Scanning Cycle

STAT:OPER?	*! Returns the bit values of the Standard Operation Status register. Returns +256 if bit 8 is set to 1 or returns +0 if bit 8 is set to 0.*

:OPERation:ENABle

STATus:OPERation:ENABle *<number>* enables the Operation Status register to set a bit in the Status register. For RF multiplexer modules, setting bit 8 in the Operation Status register to 1 sets bit 7 in the Status register to 1.

Parameters

Parameter Name	Parameter Type	Range of Values
<number>	numeric	1-32767

Comments

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

Example

Enabling Status Register Bit 7

STAT:OPER:ENAB 256	*! Enables bit 7 of Status register*

SYSTem

The SYSTem subsystem returns error numbers/messages in the error queue of a switchbox, and returns module types and descriptions in a switchbox.

Subsystem Syntax   SYSTem
    :ERRor?
    :CDEScription? *<number>*
    :CTYPe? *<number>*
    :CPON *<number>* | ALL

:ERRor?   **SYSTem:ERRor?** returns the error numbers/messages in the error queue of a switchbox. See Appendix C for error message information.

Comments
- **Error Numbers/Messages in the Error Queue:** Each error generated by a switchbox stores an error number and corresponding error message in the error queue. The error number is always negative and the 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 *CLS.
- **Maximum Error Numbers/Messages in the Error Queue:** The queue holds a maximum of 30 error numbers/messages for each switchbox. If it overflows, the last error 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*

: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
- **RF Multiplexers Module Description:**
  The SYST:CDESciption? *<number>* command returns: "50 Ohm RF Mux" for the Agilent E1366A or "75 Ohm RF Mux" for the Agilent E1367A.

Example   **Reading the Description of a Card #1 Module**

    SYST:CDES? 1   ! *Return the description*

: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   • **RF Multiplexers Model Number:**
The SYSTem:CTYPe? *<number>* command returns
`"HEWLETT-PACKARD,E1366A,0,A.01.00"` (E1366A), or
returns `"HEWLETT-PACKARD,E1367A,0,A.01.00"`
(E1367A), where the `"0"` after `"E1366A"` or `"E1367A"` is the
module serial number (always 0) and `"A.01.00"` is an example
of the module revision code number.

Example   **Reading the Model Number of a Card #1 Module**

SYST:CTYP? 1   ! *Return the model number*

:CPON   SYSTem:CPON <number> | **ALL** sets the selected module (card) in a switchbox to its power-on state.

Parameters

Parameter Name	Parameter Type	Range of Values
<number>	numeric	1-99

Comments   • **RF Multiplexers Power-On State:** The power-on state is all
channels (relays) open. Note that *RST opens all channels of all
modules in a switchbox, while SYSTem:CPON opens the channels in
only the module (card) specified in the command.

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

SYST:CPON 1   ! *Sets module #1 to power-on state*

TRIGger

The TRIGger subsystem controls the triggering operation of RF multiplexer modules in a switchbox.

Subsystem Syntax TRIGger
    [:IMMediate]
    :SOURce BUS | 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.

Comments
- **Executing the TRIGger[:IMMediate] Command:** A channel list must be defined with [ROUTe:]SCAN *<channel_list>* and an INITiate[:IMMediate] command must be executed before TRIGger[:IMMediate] will be executed.

- **HOLD or BUS Source Remains:** The TRIGger:SOURce HOLD or TRIGger:SOURce BUS commands remain in effect, if selected, after triggering a switchbox with the TRIGger[:IMMediate] command.

- **Related Commands:** INITiate, [ROUTe:]SCAN

Example **Advancing Scan Using the TRIGger Command**

This example uses the TRIGger command to advance the scan of a single-module switchbox from channel 00 through 03. Since TRIGger:SOURce HOLD is set, the scan is advanced one channel each time TRIGger is executed.

TRIG:SOUR HOLD	! *Sets trigger source to HOLD*
SCAN (@100:103)	! *Defines channel list*
INIT	! *Begin scan, close channel 00*
loop statement	! *Start count loop*
TRIG	! *Advance scan to next channel*
increment loop	! *Increment loop count*

:SOURce   **TRIGger:SOURce BUS | 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 or GET command
EXTernal	discrete	"Event In" BNC port
HOLD	discrete	Hold triggering
IMMediate	discrete	Immediate 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 HOLD or TRIGger:SOURce BUS is selected.

- **Using External Trigger Inputs:** With TRIGger:SOURce EXTernal selected, only one switchbox at a time can use the external trigger input at the Agilent E1300B/E1301B mainframe "Event In" BNC port. The trigger input is assigned to the first switchbox that requested the external trigger source (with a TRIGger:SOURce EXTernal command).

- **Assigning External Trigger:** A switchbox assigned with TRIGger:SOURce EXTernal remains assigned to that source until the switchbox trigger source is changed to BUS, HOLD, or IMMediate. When the source is changed, the external trigger source is available to the next switchbox which requests it (with a TRIGger:SOURce EXTernal command). If a switchbox requests an external trigger input already assigned to another switchbox an error is generated.

- **Using Bus Triggers:** To trigger the switchbox with TRIGger:SOURce BUS selected, use the IEEE 488.2 common command *TRG or the GPIB Group Execute Trigger (GET) command.

- **Trig Out Port Shared by Switchboxes:** See the OUTPut command.

- **Related Commands:** ABORt, [ROUTe:]SCAN, TRIGger

- ***RST Condition:** TRIGger:SOURce IMMediate

Example   **Scanning Using External Triggers**

This example uses external triggering (TRIG:SOUR EXT) to scan channels 00 through 03 of a single-module switchbox. The trigger source to advance the scan is the input to the "Event In" BNC on an Agilent E1300B/E1301B mainframe. When INIT is executed, the scan is started and channel 00 is closed. Then each trigger received at the "Event In" BNC advances the scan to the next channel.

```
TRIG:SOUR EXT                        ! Select external triggering
SCAN   (@100:103)                    ! Scan channels 00 through 03
INIT                                 ! Begin scan, close channel 00
trigger externally                   ! Advance scan to next channel
```

Example   **Scanning Using Bus Triggers**

This example uses bus triggering (TRIG:SOUR BUS) to scan channels 00 through 03 of a single-module switchbox. The trigger source to advance the scan is the *TRG command (as set with TRIGger:SOURce BUS). When INIT is executed, the scan is started and channel 00 is closed. Then each *TRG command advances the scan to the next channel.

```
TRIG:SOUR BUS                        ! Select interface (bus) triggering
SCAN   (@100:103)                    ! Scan channels 00 through 03
INIT                                 ! Start scan, close channel 00
loop statement                       ! Loop to scan all channels
*TRG                                 ! Advance scan using bus triggering
increment loop                       ! Increment loop count
```

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

Example   **Query Trigger Source**

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

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

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IEEE 488.2 Common Commands

The following table lists the IEEE 488.2 Common (*) Commands that apply to the RF Multiplexer module. The operation of some of these commands is described in Chapter 4 of this manual. For information on Common Commands, refer to the Agilent B-size configuration guide or the *ANSI/IEEE Standard 488.2-1987*.

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

Command Quick Reference

The following tables summarize SCPI and IEEE 488.2 Common (*) commands for the RF Multiplexer modules used in a switchbox.

SCPI Commands Quick Reference

Command		Description
ABORt		Abort a scan in progress.
ARM	:COUNt *<number>* :COUNt? [MIN |MAX]	Multiple scans per INIT command. Query number of scans.
DISPlay	:MONitor[:STATe] *<boolean>* :MONitor:CARD *<number>*|AUTO	Selects monitor mode. Selects module to be monitored.
INITiate	:CONTinuous ON |OFF :CONTinuous? [:IMMediate]	Enables/disables continuous scanning. Query continuous scan state. Starts a scanning cycle.
OUTPut	[:STATe] ON |OFF [:STATe]?	Enables/disables "Trig Out" pulse. Query port enable state.
[ROUTe:]	CLOSe *<channel_list>* CLOSe? *<channel_list>* OPEN *<channel_list>* OPEN? *<channel_list>* SCAN *<channel_list>* SCAN:MODE NONE |VOLT | RES |FRES	Close channel(s). Query channel(s) closed. Open channel(s). Query channel(s) opened. Define channels for scanning. Sets scan mode.
STATus	:OPERation[:EVENt]? :OPERation:ENABle	Returns status of Operation Status register. Enables the Operation Status register to set a bit in the Status register.
SYSTem	:ERRor? :CDEScription? *<number>*. :CTYPe? *<number>* :CPON *<number>*|ALL	Returns error number/message in a switchbox Error Queue. Returns description of module in a switchbox Returns the module type. Sets specified module to its power-on state.
TRIGger	[:IMMediate] :SOURce BUS :SOURce EXTernal :SOURce HOLD :SOURce IMMediate :SOURce?	Causes a trigger to occur. Trigger source is *TRG. Trigger source is "Event In". 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	Always returns 0.

Agilent E1366A/E1367A RF Multiplexer Specifications

Input Characteristics

Maximum Voltage - any center or shield to any other center, shield, or chassis: 42 V Peak

Maximum Current per Channel or Common: 1 Adc or ac$_{rms}$

Maximum Power per Channel or Common: 24 W or 24 VA

General

Channels consist of non-latching armature relays**.**

Typical Relay Life:
With no load: 5 x 10^6 operations
With max. rated load: 10^5 operations
Νοτε: Ρελαψσ αρε συβφεχτ το νορ∝αλ ωεαρουτ βασεδ ον τηε νυ∝βερ οφ οπερατιονσ.

DC Performance

Thermal Offset: <6∝V

Typical Closed Channel Resistance: <1Ω

End of Relay Life Closed Channel Resistance: <3Ω

Insulation Resistance (any terminal to any terminal):
≤(40° C, 65% RH): >10^8Ω

AC Performance

For Z$_\Lambda$= Z$_\Sigma$ = 50Ω (E1366A)
For Z$_\Lambda$= Z$_\Sigma$ = 75Ω (E1367A)

	<10MHz	<100MHz	<500MHz	<1.3GHz
Insertion Loss (dB)				
≤(40°C, 65% RH)	<0.3	<0.7	<1.5	<3.0
Crosstalk(dB) (Channel-Channel*, or Channel-Common)[1]				
	<-90	<-80	<-60	<-40
VSWR	<1.2	<1.25	<1.35	<1.55

* With one channel closed.

1 Specification assumes 50Ω or 75Ω termination. If all channels
 unterminated, derate specification by 6dB.

Risetime: <300psec
Signal Delay: <3nsec ± 50psec

Capacitance:
Center-shield <60pF
Chassis-shield <0.15∝F

Module Size/Device Type: B, register-based

Connectors Used: P1

Number of Slots: 1

VXIbus Interface Capability:
Slave, Interrupter, A16, D16

Interrupt Level: 1-7, selectable

Power Requirements:

Voltage	+5	+12
Peak module current, IPM (A):	0.10	0.18
Dynamic module current, IDM (A):	0.01	0.01

Watts/Slot: 3.0

Typical Crosstalk (channel-channel)

Cooling/Slot:
0.05 mm H_2O @ 0.25 liter/sec

Humidity: 65% 0° to 40° C

Operating Temperature: 0° to 55° C

Storage Temperature: - 40° to 75° C

EMC, RFI, Safety:
meets FTZ1046/1984, CSA556B, IEC348, UL1244

Net Weight (kg): 0.7
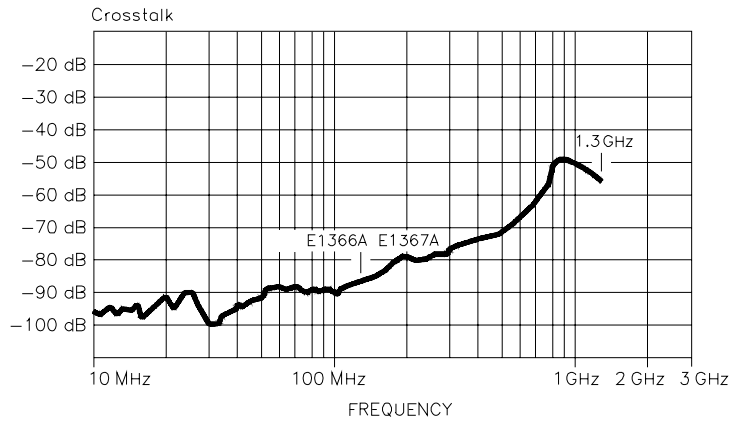
Typical Return/Loss VSVR
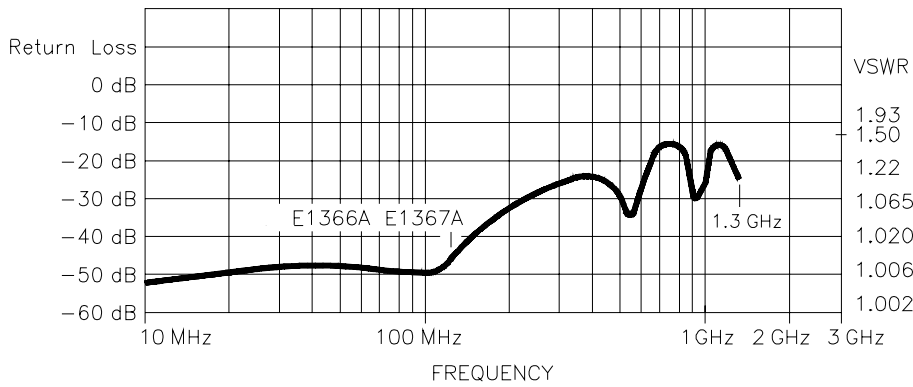
Typical Insertion Loss
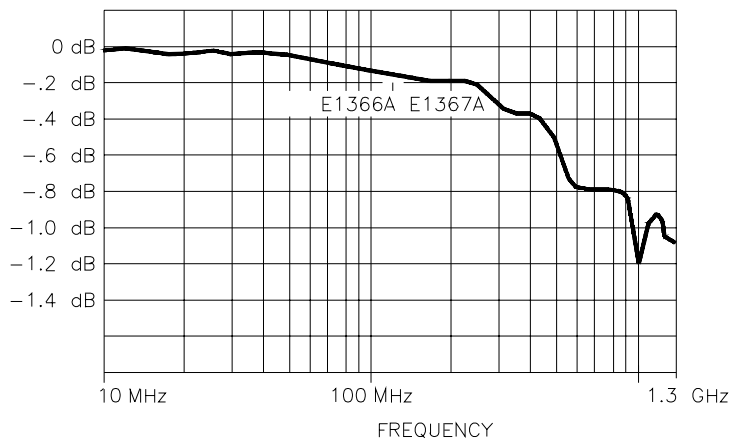
Relay Life

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

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

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

End of Life Detection

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

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

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

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

Replacement Strategy

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

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

Register Definitions

The Agilent E1366A and Agilent E1367A RF multiplexers are register-based slave devices. Register definitions are:

ID Register

b +00$_h$	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write	Undefined								Undefined							
Read*	Reg-Bas		A16		Manufacturer ID											

* Returns FFFF$_h$ = Agilent Technologies A16 only register-based

Device Type Register

b +02$_h$	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write	Undefined															
Read*	1 (A16 only)				Module ID Code											

* Returns: FF80$_h$ (E1366A) or FF84$_h$ (E1367A)

Status/Control Register

b +04$_h$	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write*	Undefined															R
Read**	FF$_h$								B	7F$_h$						

* R = Multiplexer reset to power-on state (all switches open)   ** Status "busy" is low-true in bit #7 (FF7F$_h$)

Bank 0 Channel Enable Register

b +08$_h$	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write*	Undefined												03	02	01	00
Read	Always returns FFFF$_h$															

* Write "1" closes channel, write "0" opens channel

Bank 1 Channel Enable Registers

b +0A$_h$	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write*	Undefined												13	12	11	10

Addressing the Registers

To read or write to specific registers, you must use the register address. Since the addresses for Agilent 75000 Series B or Series C plug-in modules are A00 through A15, use the VME A16 mnemonic for the address space. The address space within the mainframe/command module memory map depends on the mainframe/command module used. For example, the address of the Agilent E1300B/E1301B Mainframe starts at $1F0000_h$.

For the Agilent E1300/E1301, the A16 space is divided so modules are addressed only at locations beginning with $C000_h$ within A16. Each module is allocated 64 register addresses (40_h). The module base address is related to the logical address set by the logical address switch (LADDR) on the module:

base address ($_h$) = (logical address$_h$)*40_h + C000$_h$

For the RF multiplexers, the factory-set logical address is 120 (78_h), so the base address = (78_h)*(40_h) + $C000_h$ = $DE00_h$. Then, for example, to address the Status/Control register of an RF multiplexer in an Agilent E1300B/E1301B, the register address = [A16 location]$_h$ + [base address]$_h$ + [register offset]$_h$ = $1F0000_h$ + $DE00_h$ + 04_h = $1FDE04_h$.

Reading the Registers

You can read the following RF multiplexer registers:

- ID register (base + 00_h)
- Device Type register (base + 02_h)
- Status/Control register (base + 04_h)
- Bank 0 Channel Enable register (base + 08_h)
- Bank 1 Channel Enable register (base + A_h)

ID/Device Type Registers

For either RF multiplexer, a read of the ID register (address base + 00_h) returns $FFFF_h$ since the multiplexers are manufactured by Agilent Technologies and are A16 only, register-based devices. The Device Type register (base + 02_h) returns $FF80_h$ for the Agilent E1366A (50Ω) multiplexer and returns $FF84_h$ for the Agilent E1367A (75Ω) multiplexer.

Status/Control Register

Each relay requires about 15 msec execution time (close to open or open to close) during which time the RF multiplexers are "busy". A read of the Status/Control register (base + 04_h) returns $FFFF_h$ when the module is not busy or returns $FF7F_h$ (bit 7 is low-true) when the module is busy.

Channel Enable Registers

A read of either of the two Channel Enable registers (base + 08_h for bank 0 or base + A_h for bank 1) always returns $FFFF_h$, regardless of the channel states.

Writing to the Registers

You can write to the following RF multiplexer registers:

- Status/Control register (base + 04$_h$)
- Bank 0 Channel Enable register (base + 08$_h$)
- Bank 1 Channel Enable register (base + A$_h$)

Status/Control Register

The only write allowed to the Status/Control register (base + 04$_h$) is to bit 0. Writing a "1" to bit 0 resets the multiplexer to its power-on state with all channels open and terminated and both commons open.

Channel Enable Registers

Writes to the Channel Enable registers (base + 08$_h$ and base + A$_h$) enabling you to open or close the desired channel (see Register Defintions at the beginning of this chapter). For example, write a "1" to bit 2 of the bank 0 Channel Enable register to close channel 02. Or, write a "1" to bit 3 of the Bank 1 Channel Enable register to close channel 13. Writing a "0" to bits 0 - 3 results in all channels open and terminated and the common open. Only one channel per bank can be closed at a time. Any bit pattern not shown in Register Defintions at the beginning of this chapter, results in the lowest-numbered channel being closed.

The table below lists the error messages associated with the multiplexer modules programmed by SCPI. See the appropriate mainframe manual for a complete list of error messages.

No.	Title	Potential Cause(s)
-211	Trigger ignored	Trigger received when scan not enabled. Trigger received after scan complete. Trigger too fast.
-213	Init Ignored	Attempting to execute an INIT command when a scan is already in progress.
-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 (e.g., channel 99 of a multiplexer module).
2006	Command not supported on this card	Sending a command to a module (card) in a switchbox that is unsupported by the module.
2008	Scan list not initialized	Executing a scan without the INIT command.
2009	Too many channels in channel list	Attempting to address more channels than available in the switchbox.
2012	Invalid Channel Range	Invalid channel(s) specified in SCAN *channel_list* command. Attempting to begin scanning when no valid channel list is defined.
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.

C (cont'd)

D

E

F

G