Agilent
PXI RF Switch Modules

M9128A, M9146A, M9147A, M9148A, M9149A, M9150A, M9151A, M9152A, M9153A

Maintenance Guide

Agilent Technologies

Notices

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Do not use this product in any manner not specified by the manufacturer. The protective features of this product must not be impaired if it is used in a manner specified in the operation instructions.

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Verify that all safety precautions are taken. Make all connections to the module before applying power. Note the instrument's external markings described under “Safety Symbols”.

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Agilent chassis are provided with a grounding-type power plug. The instrument chassis and cover must be connected to an electrical ground to minimize shock hazard. The ground pin must be firmly connected to an electrical ground (safety ground) terminal at the power outlet. Any interruption of the protective (grounding) conductor or disconnection of the protective earth terminal will cause a potential shock hazard that could result in personal injury.

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Do not operate the Agilent module/chassis in the presence of flammable gases or fumes.

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Do not operate the Agilent module/chassis in the presence of flammable liquids or near containers of such liquids.

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Clean the outside of the Agilent module, chassis, or accessory with a soft, lint-free, slightly dampened cloth. Do not use detergent or chemical solvents.

Keep away from live circuits

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

DO NOT operate damaged equipment

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

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Instruments that appear damaged or defective should be made inoperative and secured against unintended operation until they can be repaired by qualified service personnel.

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A CAUTION notice denotes a hazard. It calls attention to an operating procedure or practice that, if not correctly performed or adhered to, could result in damage to the product or loss of important data. Do not proceed beyond a CAUTION notice until the indicated conditions are fully understood and met.

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Safety Symbols

Products display the following symbols:

Refer to manual for additional safety information.

Earth Ground.

Chassis Ground.

Alternating Current (AC).

Direct Current (DC).

Indicates that antistatic precautions should be taken.

Notice for European Community: This product complies with the relevant European legal Directives: EMC Directive (2004/108/EC) and Low Voltage Directive (2006/95/EC).

ISM

This is the symbol for an Industrial, Scientific, and Medical Group 1 Class A product.

ICES/NMB-001

ICES/NMB-001 indicates that this ISM device complies with the Canadian ICES-001.

N10149

The C-tick mark is a registered trademark of the Spectrum Management Agency of Australia. This signifies compliance with the Australia EMC Framework regulations under the terms of the Radio Communication Act of 1992.

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This product complies with the WEEE Directive (2002/96/EC) marking requirement. The affixed product label (see below) indicates that you must not discard this electrical/electronic product in domestic household waste.

Product Category: With reference to the equipment types in the WEEE directive Annex 1, this product is classified as a "Monitoring and Control instrumentation" product.

Do not dispose in domestic household waste.

To return unwanted products, contact your local Agilent office, or see www.agilent.com/environment/<product> for more information.

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1
General Information

The Agilent PXI RF switch modules deliver high-performance switching with fast, easy installation and configuration. The following modules are covered in this Maintenance Guide:

RF 50Ω matrix and multiplexer modules

- M9128A PXI RF Matrix Switch, 300 MHz, 8x12, 50Ω
- M9146A PXI RF Multiplexer, 3 GHz, Dual 1x4, 50Ω Terminated
- M9147A PXI RF Multiplexer, 3 GHz, Quad 1x4, 50Ω Terminated Common
- M9148A PXI RF Multiplexer, 3 GHz, 1x8, 50Ω
- M9149A PXI High Density RF Multiplexer, 3 GHz, 1x16, 50Ω

RF 75Ω multiplexer modules

- M9150A PXI RF Multiplexer, 3 GHz, Dual 1X4, 75Ω
- M9151A PXI RF Multiplexer, 3 GHz, Quad 1X4, 75Ω
- M9152A PXI RF Multiplexer, 3 GHz, 1X8, 75Ω
- M9153A PXI RF Multiplexer, 3 GHz, 1X16, 75Ω

Agilent also supplies software drivers that allow you to support the modules in all popular PXI chassis' and programming environments. Soft Front Panel software allows you to exercise the channels for test purposes.

NOTE

Agilent AgMSwitch driver version 1.1.x or later or the Agilent LabVIEW G driver version 1.1.x or later is required for programmatic control of these switch modules.

Related documentation

This Maintenance Guide, and the documentation listed below, are on the **Switch Module Software and Product Information CD**.

- Help file for the PXI RF Switch Modules Soft Front Panel
- Help file for the PXI RF Switch Modules IVI-C/IVI-COM device drivers
- Help file for the PXI RF Switch Modules LabVIEW G device drivers

Module characteristics

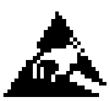
For detailed module characteristics, refer to the module data sheets on the *Switch Module Software and Product Information CD* or check the Agilent web site at: `www.agilent.com/find/pxiswitch`. Note that the characteristics are typical and not guaranteed specifications.

Safety Considerations

WARNING **SHOCK HAZARD. Only service-trained personnel who are aware of the hazards involved should attempt to remove these modules from the chassis and repair them. Remove all user wiring and connections from the plug- in modules before troubleshooting or testing.**

Electrostatic discharge precautions

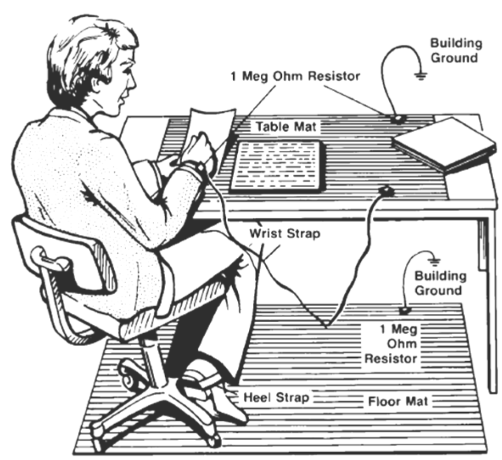
CAUTION



Agilent's PXI Switch Modules are shipped in materials that prevent static electricity damage. The modules should only be removed from the packaging in an anti-static area ensuring that correct anti-static precautions are taken. Store all modules in anti-static envelopes when not in use.

Electrostatic discharge (ESD) can damage or destroy electronic components. All work on electronic assemblies should be performed at a static-safe work station. The following figure shows an example of a static-safe work station using two types of ESD protection. Purchase acceptable ESD accessories from your local supplier.

- Conductive table-mat and wrist-strap combination.
- Conductive floor-mat and heel-strap combination.



Both types, when used together, provide a significant level of ESD protection. Of the two, only the table-mat and wrist-strap combination provides adequate ESD protection when used alone. To ensure user safety, the static-safe accessories must provide at least 1 MΩ of isolation from ground.

Inspect for Damage

Carefully inspect the modules for any damage. Report any shipping damage to the shipping agent immediately, as such damage is not covered by the warranty.

CAUTION To avoid damage when handling a module; do not touch exposed connector pins.

NOTE Information on preventing damage to your Agilent equipment can be found at www.agilent.com/find/tips.

Returning a Module for Service

Should it become necessary to return an Agilent PXI switch module for repair or service, follow the steps below:

1. Review the warranty information shipped with your product.
2. Contact Agilent to obtain a return authorization and return address. If you need assistance finding Agilent contact information go to www.agilent.com/find/assist (worldwide contact information for repair and service) or refer to the **Technical Support** information on the product web page at: *www.agilent.com/find/pxiswitch*.
3. Write the following information on a tag and attach it to the module.
   - Name and address of owner. A Post Office box is not acceptable as a return address.
   - Product model number (for example, M9128A)
   - Product serial number (for example, MYXXXXXXXX). The serial number label is located on the side of the module.
   - A description of failure or service required.
4. Carefully pack the module in its original ESD bag and carton. If the original carton is not available, use bubble wrap or packing peanuts, place the instrument in a sealed container and mark the container “FRAGILE”.
5. On the shipping label, write ATTENTION REPAIR DEPARTMENT and the service order number (if known).

NOTE If any correspondence is required, refer to the product by serial number and model number.

Operational Check of the Modules

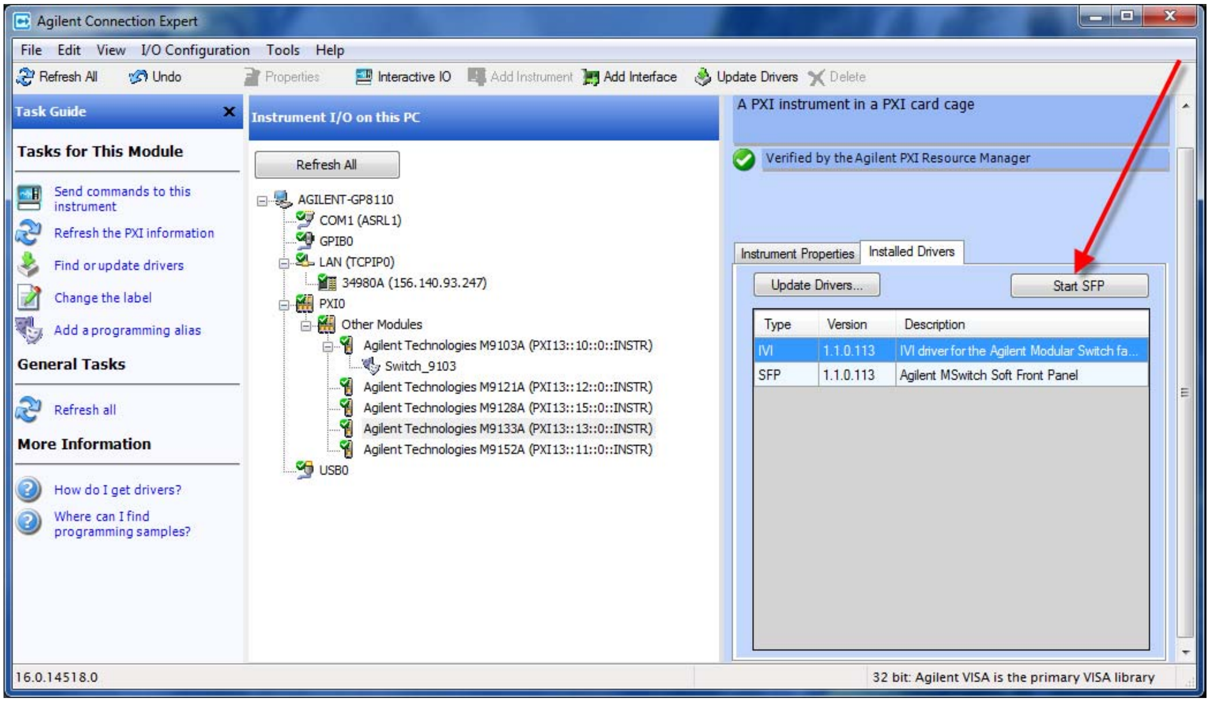
There are no specific programmable operational or self test procedures for these modules. However, you can use the Soft Front Panel software to open/close individual channels. This will verify that the module is installed correctly and that the host controller can communicate with the module. If the controller can communicate with one module but not another, the PXIe interface circuitry on the module may be bad.

To control the modules -- that is open and close channel relays -- you must have Agilent IO Libraries Suite installed (version 16.0 or later). IO Libraries Suite is required for the IVI instrument drivers. Use the Agilent Soft Front Panel interface to control the modules. Module drivers and the Soft Front Panel software were provided on the Product and Information CD supplied with the modules. Agilent IO Libraries version 16.0 (or later) must be installed prior to installing and running any other software and prior to powering the chassis. The latest version can be downloaded from: **www.agilent.com/find/iosuite**.

Run Agilent IO Libraries Connection Expert

- If Agilent Connection Expert is already running on the host controller, click the **Refresh All** button to identify any hardware you have just installed or re-connected.
- If Connection Expert is not already running, run it now to verify your I/O configuration. In the Windows Notification Area, click the **IO** icon then click **Agilent Connection Expert.**

Locate your interfaces and instruments in the Agilent Connection Expert Explorer Pane. The following graphic shows the Connection Expert screen.



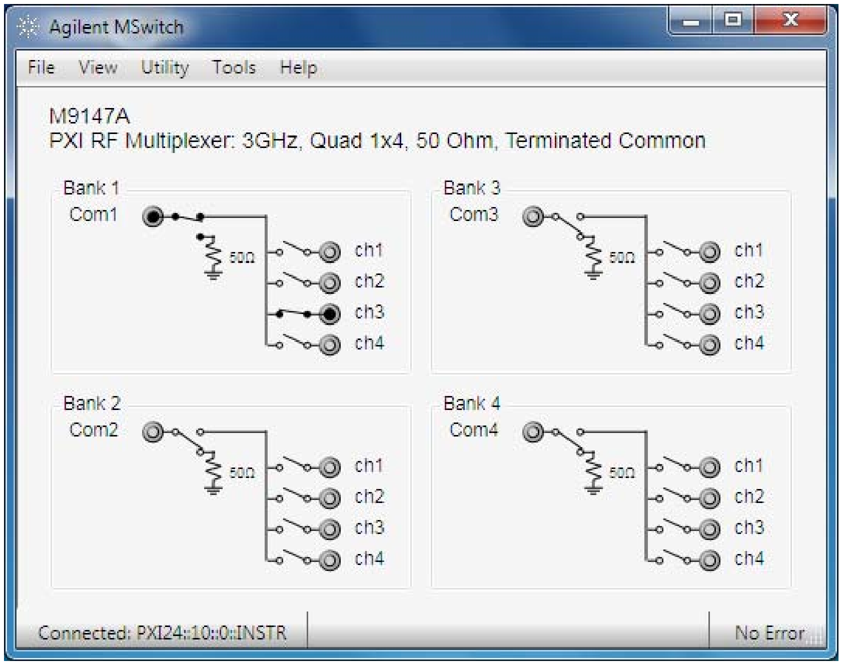
Select a module in the center pane (**Instrument I/O on this PC**). The right-hand Pane shows the instrument properties. Select the **`Installed Drivers`** tab then click the **`Start SFP`** button.

You can use the Soft Front Panel (SFP) software to open and close the relays and verify operation of the switch modules. The Soft Front Panel Software was installed as part of the Software installation process.

Refer to the SFP help file on the *Switch Module Software and Product Information CD* for specific detailed information on the SFP. The following graphic shows an example of the SFP for the M9147A PXI RF Switch module.

NOTE

You can use the Soft Front Panel software to close/open relays (channels) on any of the Agilent PXI switch modules for functional testing.

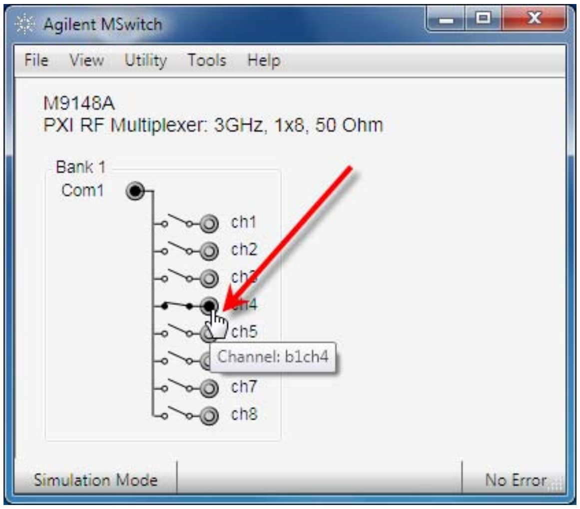


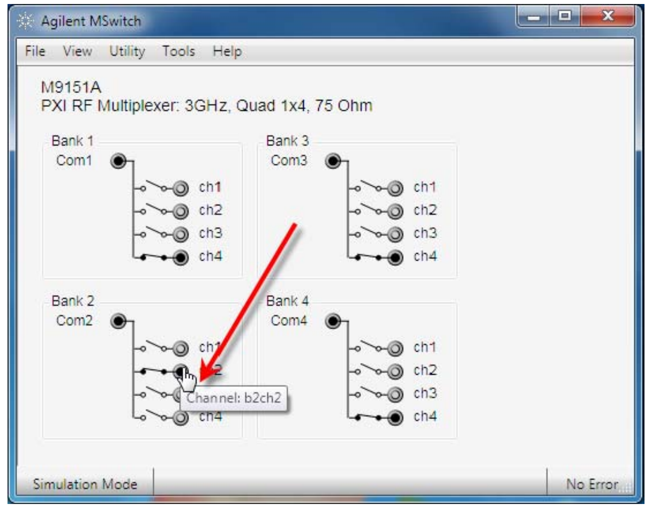
Beginning with SFP Version 1.1.x, if you have another application, either your own program or another instance of the SFP interface, that has initialized the switch module, then the SFP enters it's "monitor" mode. In this mode, you cannot change relay state and the menu buttons are grayed-out. However, as the other application controls the channels, the SFP interface monitors and displays the state of the individual relays. Refer to the SFP help file for additional information.

Identifying channel numbers

In the Soft Front Panel interface, when you mouse over a specific channel or cross point (such as the M9128A Matrix module) the cursor changes to a hand cursor, and a popup tool tip shows the Instrument Specific Syntax for the channel number as shown in the following graphics. The Instrument Specific Syntax for channel numbers is used by the IVI and LabVIEW driver open/close commands.

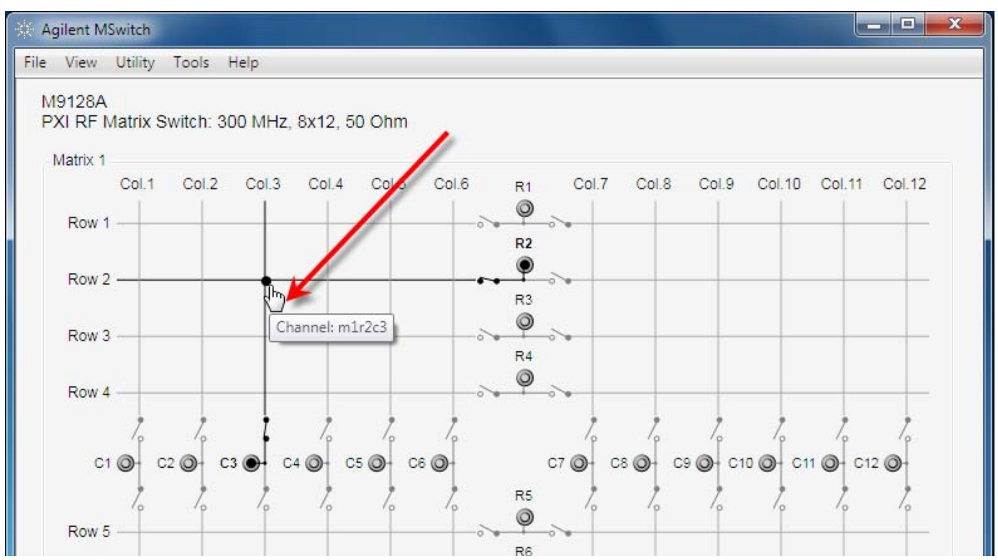
For multiplexer modules, the Instrument Specific Syntax for channel numbers is in the form: **b*n*ch*n*** where **b*n*** is the bank number and **ch*n*** is the actual channel number. For example, **RouteCloseChannel("b2ch2")** will close the relay that connects channel 2 of bank 2 to the common. For 1-of-n modules, the previously closed channel is opened as a result of this closure. The following graphics show the Soft Front Panel interface and illustrate the channel numbering scheme:





Note that modules without separate, distinct banks still use the same format where the bank number is always 1.

For the M9128A Matrix module, the Instrument Specific Syntax for channel numbers uses the form: **m***n***r***n***c***n* where **m** indicates a matrix module, **r***n* is the row and **c***n* is the column. For example, **RouteCloseChannel("m1r2c3")** will close the relays to connect row 2 to column 3 of matrix 1. See the SFP screen below:



Functional Test Procedures

The functional tests are used to test the module's electrical functionality. For the RF multiplexer and matrix modules, the functional tests consist of completing the VSWR, insertion loss, isolation, open and adjacent channel crosstalk tests as described in the module's chapter.

Recommended test equipment

The following test equipment is required for testing and servicing the PXI switch modules. Essential requirements for each piece of test equipment are described in the Requirements column. Other equipment may be substituted as long as it meets the requirements listed in the Requirements column.

Table 1 Recommended Test Equipment

Instrument	Requirements	Recommended Model	Used for PXI Switch Modules
Digital Multimeter	4-wire Ohms	Agilent 34401A, 34410A, 34411A, 3458A, etc.	All modules
Network Analyzer	VSWR from 10 MHZ to 3 GHz	Agilent E5071C ENA Network Analyzer	All RF modules
Calibration Kits	50Ω calibration load 50Ω calibration open 50Ω calibration short	85033E Standard Mechanical Calibration Kit, Type N 50 Ω / 3.5 mm or 85092C Ecal Module Type N 50 Ω	M9128A, M9146A, M9147A, M9148A, M9149A,
	75Ω calibration load 75Ω calibration open 75Ω calibration short	85036B Standard Mechanical Calibration Kit, Type N 75 Ω	M9150A, M9151A, M9152A, M9153A
Adapters and Cables	50Ω/75Ω Minimum Loss Pad	11852B, N type connectors, 50 ohm (m) to 75 ohm, (f)	M9150A, M9151A, M9152A, M9153A
	Various 50Ω and 75Ω interconnection cables with Type N, SMB, SMA connectors SMB Thru coupler 75 Ω Type N to SMB Adapter	Johnson 134-1069-011	

In addition, a PXI Chassis and controller are also necessary to control the modules (close/open relays, etc.). A recommended chassis is the M9018A 18-slot PXIe chassis and the M9036A Embedded Controller.

Test conditions

The following setup and environmental conditions are required when testing the modules to ensure the quality of measurements

- Secure all connections to modules, especially RF test connections.
- Maintain an ambient temperature of 23 °C (± 5 °C).
- Keep relative humidity (RH) below 80%.
- Allow adequate warm up time for the test equipment.
- Plug the PXI chassis all test equipment, and computer (if used) into the same ac power strip to avoid ground loops in the test environment.

You should complete the functional tests at least once per year. For heavy use or severe operating environments, perform the tests more often.

The person performing the tests must understand how to operate the chassis, the modules using the Agilent Soft Front Panel software, and the specified test equipment. The test procedures do not specify equipment settings for the test equipment except in general terms. It is assumed that a qualified, service-trained technician will select and connect the cables, adapters, and probes required for the tests.

Relay path resistance measurements

Relay module path resistance (relay contact) measurements are appropriate for all relay modules. Measurements are made from the module's front panel terminals, and do not include terminal block or connector resistance. Use 4-wire Ohms measurement techniques and measure directly at the module's front panel terminals where possible. Use shielded twisted pair PTFE insulated cables to reduce settling and noise errors. Keep the input cables as short as possible. Refer to Figure 1.

Note that the characteristics provided on the data sheet are typical and not guaranteed specifications.

WARNING **Do not attempt to measure relay contact resistance directly on the solder terminals on a switch module installed in the PXIe chassis.**

When all relays are "open," a resistance measured on any channel indicates a welded contacts condition and the relay or module must be replaced. There is no specific path resistance or test for this failure.

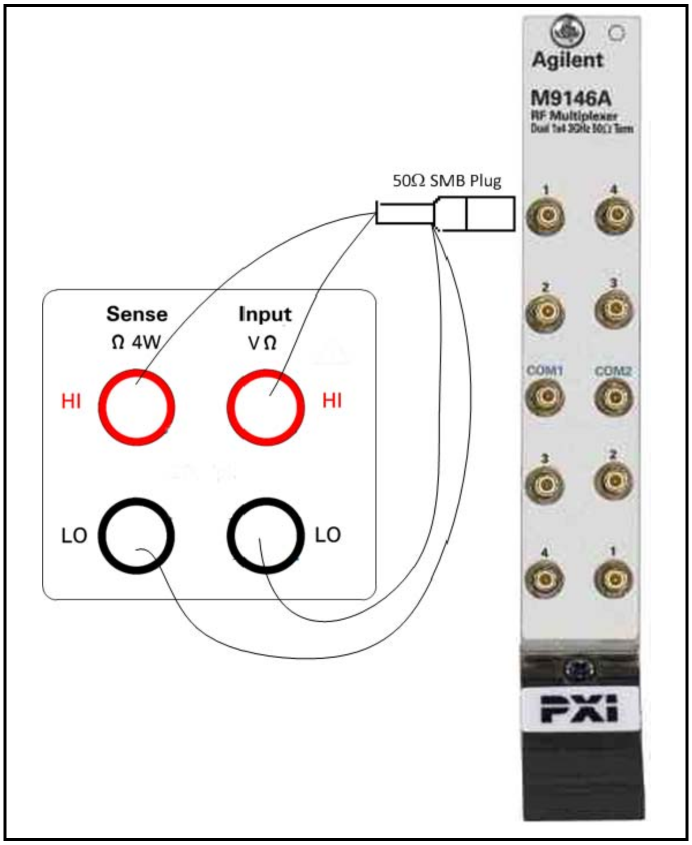


Figure 1 4-Wire Ohms Resistance Measurements

Note that the DC path resistance is not specified for the RF switch modules. Measuring dc path resistance provides a simple functional testing of the relays.

Functional Test Record

Each module chapter in this manual has a Functional Test Record. This is a form that you can copy and use to record functional test results of the module. Functional testing is used to determine proper functional operation of the modules.

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., when turning on a lamp or motor) reduce relay life. Exceeding the 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 reduces relay life.

NOTE Switch modules are considered "wear out" items and it is normal for relay performance to degrade over time. Life expectancy and performance depend on the specific application and use model.

End-of-Life Detection

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

Contact resistance. As the relay begins to wear out, its contact resistance will increase. When the resistance exceeds a pre-determined value, the relay should be replaced. Note that the characteristics provided on the data sheet are typical and not guaranteed.

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 relay operations. Alternatively, 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. The Agilent PXI switch modules do not provide a relay closure counter.

Agilent Application Note 1399, Maximizing the Life Span of Your Relays, offers suggestions for selecting the right relays for your application, predicting their longevity and preventing early failures.

Relay replacement strategy

For the RF modules, individual surface mount relays on the RF multiplexer modules may be replaced though not recommended. When replacing individual relays, improper relay placement, too much solder, etc., may alter the signal path RF characteristics (VSWR, insertion loss, crosstalk, etc.).

These RF modules have a PXI interface circuit board (with relay drivers) and either one or two daughter boards with the actual RF relays. In the event of a relay/channel failure, you should consider replacing one or both relay daughter boards rather than attempting to replace individual relays. Refer to the chapter for a specific module and also Appendix 11, “Disassembling the RF Matrix and Multiplexer Modules,” starting on page 93.

Surface mount relays on the RF Multiplexer modules should *only* be removed/replaced using soldering equipment *expressly* designed for surface mount components. *Use of conventional solder removal equipment may result in permanent damage to the printed circuit board and will void your Agilent warranty. Do not overheat the relays.*

Any repair work should be done by qualified service-trained technicians aware of the issues involved.

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.

Post-repair safety checks

After making repairs to the modules, inspect them for any signs of abnormal internally generated heat such as discolored printed circuit boards or components, damaged insulation, or evidence of arcing. Determine and correct the cause of the condition. Then perform the test as described for each module to verify that the modules is functional.

Replacement Relays and Daughter Boards

Table 2 Replacement Relays for RF PXI switch modules

Agilent PXI Switch Module	Agilent Part Number for Replacement Relays and Boards	
M9128A 8x12 RF Matrix, 50 Ω	0490-2768	Relay-reed 1 Form A 5VDC-coil 0.5AMP 100VAC/VDC 200 Ω through-hole
M9146A RF Mux, Dual 1x4 50 Ω Terminated	0490-2946	Relay 1C 5VDC-COIL 2A 250V 178 Ω SMT
	M9146-66502	RF module relay daughter board for M9146A
M9147A RF Mux Quad 1x4 50 Ω Terminated	0490-2946	Relay 1C 5VDC-coil 2A 250V 178- Ω SMT
	M9147-66502	RF module relay daughter board for M9147A
M9148A RF Mux 1x8 50 Ω	0490-2946	Relay 1C 5VDC-coil 2A 250V 178 Ω SMT
	M9148-66502	RF module relay daughter board for M9148A
M9149A RF Mux 1x16 50 Ω*	0490-2946	Relay 1C 5VDC-coil 2A 250V 178 Ω SMT
M9150A RF Mux Dual 1x4 75 Ω	0490-2945	Relay 1C 5VDC-coil 2A 250V 178 Ω SMT
	M9150-66502	RF module relay daughter board for M9150A
M9151A RF Mux Quad 1x4 75 Ω	0490-2945	Relay 1C 5VDC-coil 2A 250V 178 Ω SMT
	M9151-66502	RF module relay daughter board for M9151A
M9152A RF Mux 1x8 75 Ω	0490-2945	Relay 1C 5VDC-coil 2A 250V 178 Ω SMT
	M9152-66502	RF module relay daughter board for M9152A
M9153A RF Mux 1x16 75 Ω*	0490-2945	Relay 1C 5VDC-coil 2A 250V 178 Ω SMT

* The daughter boards for the M9149A and M9153A are not available. Replace either individual relays or the entire module.

2
M9128A RF Matrix Switch, 8x12, 50 Ohm

Introduction

The M9128A Matrix module provides isolation switches, located on all coaxial connectors, to disconnect the matrix cross point switches. Only the signal is switched, all grounds are common. While the module is an 8X12 matrix, it is formed by joining four separate 4X6 matrices using isolation relays (see the schematic). The module is a true 8X12 matrix where any combination of cross points may be selected. Multiple cross points may be closed on any row or column but this will significantly degrade RF performance. All relays are open when power is removed.

Default path settings

All cross point relays are open when power is removed.

Replacement Relays

No spare channel relays are provided on the M9128A PC board. The relays are through hole and can be individually replaced. When replacing individual relays, improper relay placement, too much solder, etc., may alter the signal path RF characteristics (VSWR, insertion loss, crosstalk, etc.). Agilent's replacement relay part number is 0490-2768.

CAUTION To maintain typical switching characteristics (refer to the module data sheet) and user safety, use only Agilent-specified relays. Do not substitute relays unless directed by Agilent support.

See Appendix 11, “Disassembling the RF Matrix and Multiplexer Modules,” starting on page 93 for disassembly instructions.

RF performance of the module

RF performance depends on the specific combination of crosspoints closed. For optimum RF performance, close only one crosspoint relay in any one row or column. Performance also depends on the area of the matrix where the crosspoint relay is closed. The following graphic shows the relative performance of different crosspoints. To achieve the best performance of the module -- minimum Voltage Standing Wave Ratio (VSWR), crosstalk, insertion loss, etc. -- route signals through the perimeter of the matrix (for example, Row1/Column1 or Row 8, column 11). Performance diminishes near the center of the matrix (e.g. Row4/Column6).

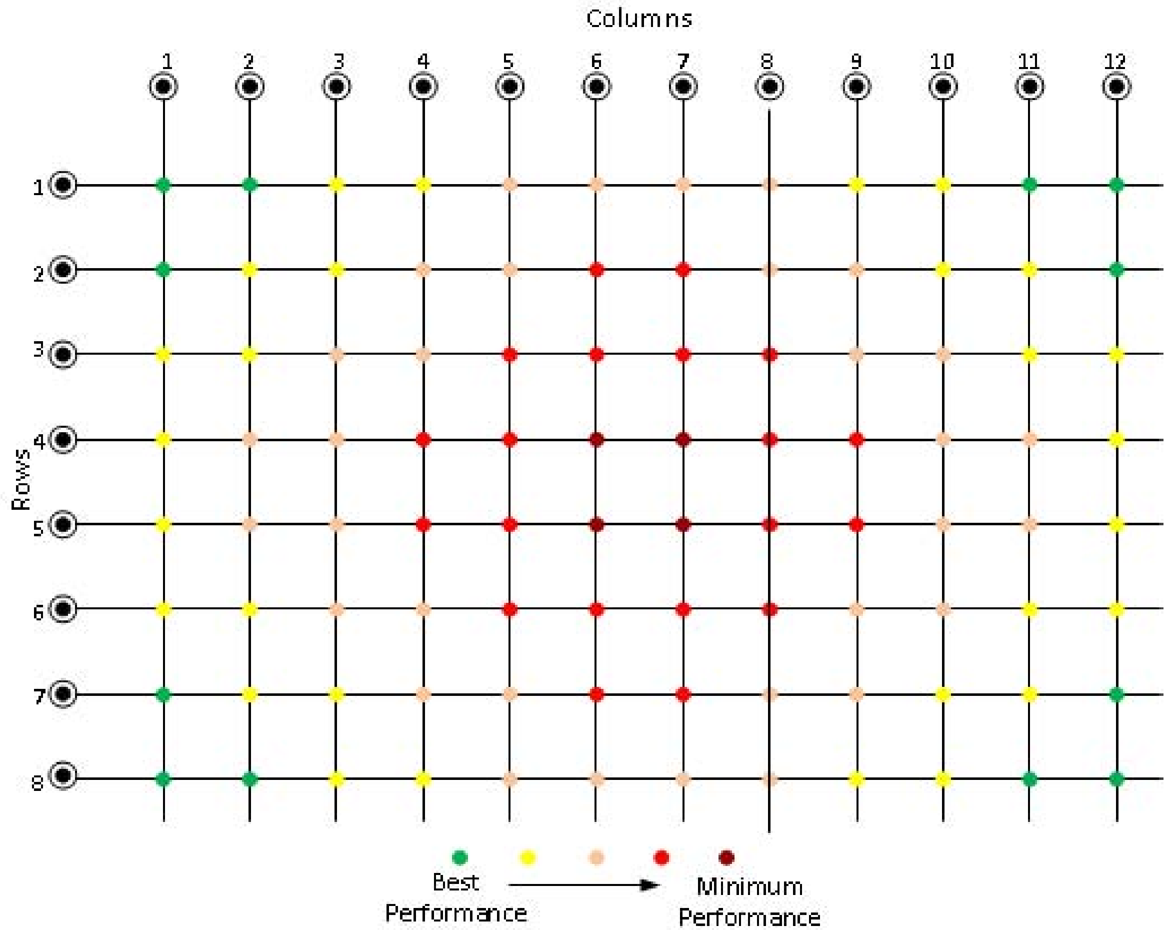


Figure 2 Relative RF performance of the crosspoint matrix switches

For optimum performance, only one crosspoint should be closed per row or column. Note that while multiple crosspoints may be closed in any row or column, significant RF performance degradation will occur.

Troubleshooting and Functional Testing

Testing Path Contact Resistance

Contact resistance checks can help isolate problems. When checking contact resistance through SMB connectors, each resistance measurement includes three relay contacts (a column isolation relay, a cross point relay, and a row isolation relay). Check all of the row/column paths to help isolate a problem to a specific relay. As an example, if all of the columns for a specific row are defective, it might indicate a defective row isolation relay. See Figure 4.

When all relays are “open,” a resistance measured on any channel path indicates a welded contacts condition and the relay or module must be replaced. There is no specific path resistance or test for this failure.

To check path resistance:

1 Set the DMM to measure 2-wire or 4-wire resistance.

2 Connect the DMM High to an SMB plug center conductor and the DMM Low to a different SMB plug center conductor (two SMB connectors are required).

3 Connect one SMB plug to a COLumn SMB jack on the module.

4 Connect the second SMB plug to a ROW SMB jack on the module.

5 Using the Soft Front Panel software, close the cross point channel to be tested.

6 Measure the contact resistance then open the channel.

7 Repeat steps 3 through 6 for all cross point channels on the module.

CAUTION Remove all user wiring and connections from the plug-in modules before troubleshooting or testing.

NOTE Contact or path resistance is not specified for the RF modules. Measuring dc path resistance provides a simple functional testing of the relays.

RF Measurements Tests

RF test measurements (VSWR, Insertion Loss, and Isolation tests) are described in Appendix A, “Making RF Test Measurements,” starting on page 103.

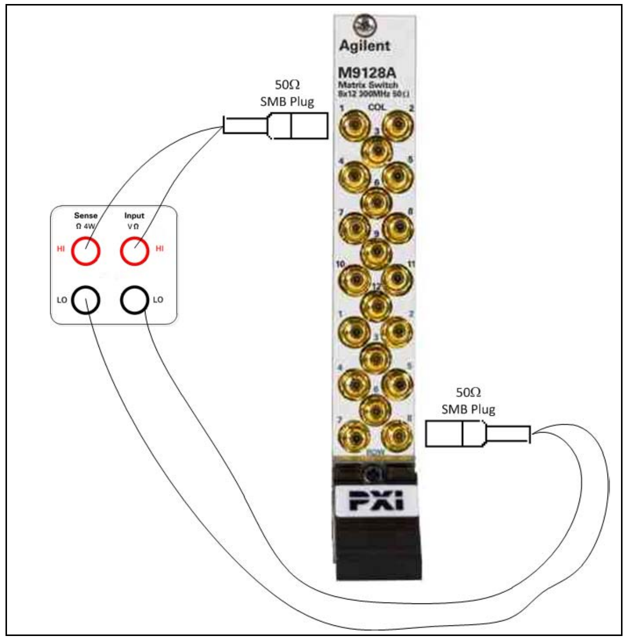


Figure 3 M9128A DC Path Resistance (DMM connected to COLumn 1 and ROW 8)

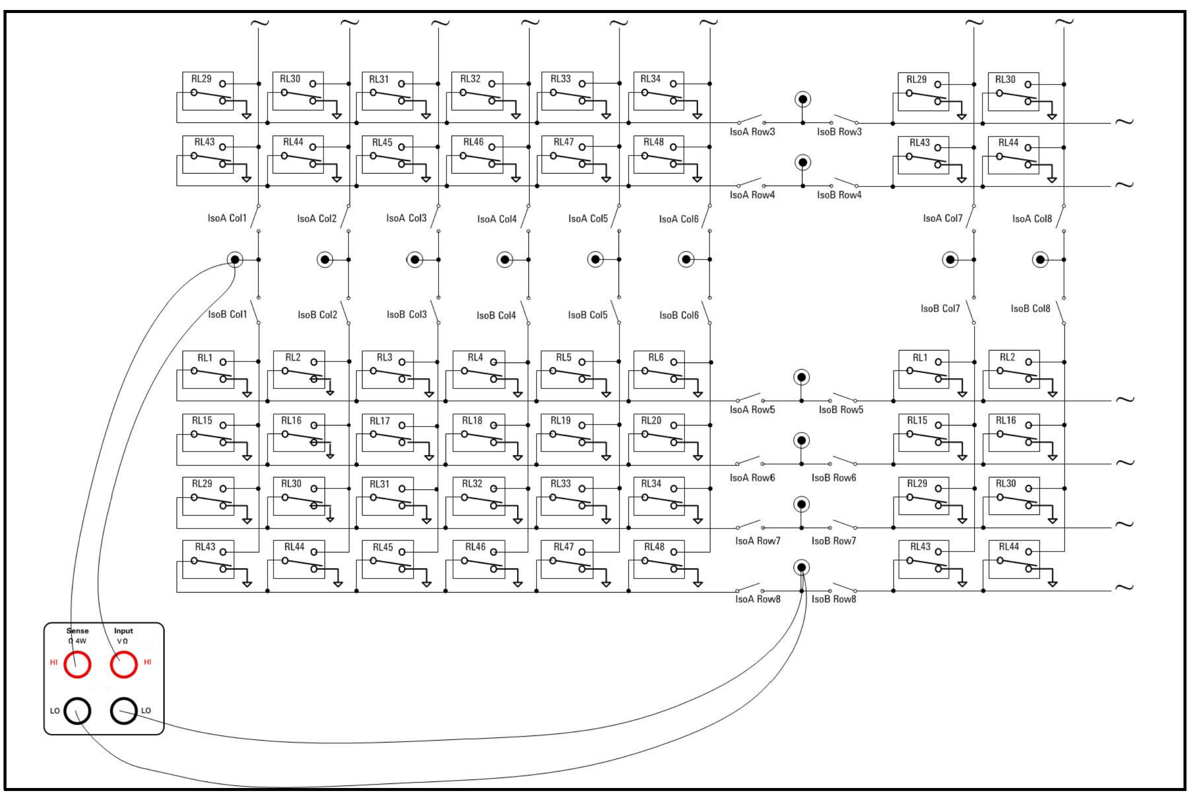


Figure 4 M9128A DC Path Resistance (DMM connected to COLumn 1 and ROW 8)

M9128A Functional Test Record

Path Contact Resistance Tests

DC path resistance is not specified for the RF switch modules. Measuring dc path resistance provides a simple test to determine if relays are closed or open. In general, maximum dc path resistance should not exceed 5Ω.

Row/Column	Measured Value	Row/Column	Measured Value
Row 1		Row 5	
Row1/Col1		Row5/Col1	
Row1/Col2		Row5/Col2	
Row1/Col3		Row5/Col3	
Row1/Col4		Row5/Col4	
Row1/Col5		Row5/Col5	
Row1/Col6		Row5/Col6	
Row1/Col7		Row5/Col7	
Row1/Col8		Row5/Col8	
Row1/Col9		Row5/Col9	
Row1/Col10		Row5/Col10	
Row1/Col11		Row5/Col11	
Row1/Col12		Row5/Col12	
Row 2		Row 6	
Row2/Col1		Row1/Col1	
Row2/Col2		Row 6/Col2	
Row2/Col3		Row 6/Col3	
Row2/Col4		Row6/Col4	
Row2/Col5		Row6/Col5	
Row2/Col6		Row6/Col6	
Row2/Col7		Row6/Col7	
Row2/Col8		Row6/Col8	
Row2/Col9		Row6/Col9	
Row2/Col10		Row6/Col10	
Row2/Col11		Row6/Col11	
Row2/Col12		Row6/Col12	

Row/Column	Measured Value
Row 3	
Row3/Col1	
Row3/Col2	
Row3/Col3	
Row3/Col4	
Row3/Col5	
Row3/Col6	
Row3/Col7	
Row3/Col8	
Row3/Col9	
Row3/Col10	
Row3/Col11	
Row3/Col12	
Row 4	
Row4/Col1	
Row4/Col2	
Row4/Col3	
Row4/Col4	
Row4/Col5	
Row4/Col6	
Row4/Col7	
Row4/Col8	
Row4/Col9	
Row4/Col10	
Row4/Col11	
Row4/Col12	

Row/Column	Measured Value
Row 7	
Row7/Col1	
Row7/Col2	
Row7/Col3	
Row7/Col4	
Row7/Col5	
Row7/Col6	
Row7/Col7	
Row7/Col8	
Row7/Col9	
Row7/Col10	
Row7/Col11	
Row7/Col12	
Row 8	
Row8/Col1	
Row8/Col2	
Row8/Col3	
Row8/Col4	
Row8/Col5	
Row8/Col6	
Row8/Col7	
Row8/Col8	
Row8/Col9	
Row8/Col10	
Row8/Col11	
Row8/Col12	

VSWR Tests

For VSWR, Insertion Loss and Crosstalk test procedures, refer to “Making RF Test Measurements” on page 103.

Row/Column	Functional Test Limit	Measured Value
Row 1		
Row1/Col1	< 2.6:1 to 300 MHz	
Row1/Col2	< 2.6:1 to 300 MHz	
Row1/Col3	< 2.6:1 to 300 MHz	
Row1/Col4	< 2.6:1 to 300 MHz	
Row1/Col5	< 2.6:1 to 300 MHz	
Row1/Col6	< 2.6:1 to 300 MHz	
Row1/Col7	< 2.6:1 to 300 MHz	
Row1/Col8	< 2.6:1 to 300 MHz	
Row1/Col9	< 2.6:1 to 300 MHz	
Row1/Col10	< 2.6:1 to 300 MHz	
Row1/Col11	< 2.6:1 to 300 MHz	
Row1/Col12	< 2.6:1 to 300 MHz	
Row 2		
Row2/Col1	< 2.6:1 to 300 MHz	
Row2/Col2	< 2.6:1 to 300 MHz	
Row2/Col3	< 2.6:1 to 300 MHz	
Row2/Col4	< 2.6:1 to 300 MHz	
Row2/Col5	< 2.6:1 to 300 MHz	
Row2/Col6	< 2.6:1 to 300 MHz	
Row2/Col7	< 2.6:1 to 300 MHz	
Row2/Col8	< 2.6:1 to 300 MHz	
Row2/Col9	< 2.6:1 to 300 MHz	
Row2/Col10	< 2.6:1 to 300 MHz	
Row2/Col11	< 2.6:1 to 300 MHz	
Row2/Col12	< 2.6:1 to 300 MHz	

Row/Column	Functional Test Limit	Measured Value
Row 5		
Row5/Col1	< 2.6:1 to 300 MHz	
Row5/Col2	< 2.6:1 to 300 MHz	
Row5/Col3	< 2.6:1 to 300 MHz	
Row5/Col4	< 2.6:1 to 300 MHz	
Row5/Col5	< 2.6:1 to 300 MHz	
Row5/Col6	< 2.6:1 to 300 MHz	
Row5/Col7	< 2.6:1 to 300 MHz	
Row5/Col8	< 2.6:1 to 300 MHz	
Row5/Col9	< 2.6:1 to 300 MHz	
Row5/Col10	< 2.6:1 to 300 MHz	
Row5/Col11	< 2.6:1 to 300 MHz	
Row5/Col12	< 2.6:1 to 300 MHz	
Row 6		
Row1/Col1	< 2.6:1 to 300 MHz	
Row 6/Col2	< 2.6:1 to 300 MHz	
Row 6/Col3	< 2.6:1 to 300 MHz	
Row6/Col4	< 2.6:1 to 300 MHz	
Row6/Col5	< 2.6:1 to 300 MHz	
Row6/Col6	< 2.6:1 to 300 MHz	
Row6/Col7	< 2.6:1 to 300 MHz	
Row6/Col8	< 2.6:1 to 300 MHz	
Row6/Col9	< 2.6:1 to 300 MHz	
Row6/Col10	< 2.6:1 to 300 MHz	
Row6/Col11	< 2.6:1 to 300 MHz	
Row6/Col12	< 2.6:1 to 300 MHz	

Row/Column	Functional Test Limit	Measured Value
Row 3		
Row3/Col1	< 2.6:1 to 300 MHz	
Row3/Col2	< 2.6:1 to 300 MHz	
Row3/Col3	< 2.6:1 to 300 MHz	
Row3/Col4	< 2.6:1 to 300 MHz	
Row3/Col5	< 2.6:1 to 300 MHz	
Row3/Col6	< 2.6:1 to 300 MHz	
Row3/Col7	< 2.6:1 to 300 MHz	
Row3/Col8	< 2.6:1 to 300 MHz	
Row3/Col9	< 2.6:1 to 300 MHz	
Row3/Col10	< 2.6:1 to 300 MHz	
Row3/Col11	< 2.6:1 to 300 MHz	
Row3/Col12	< 2.6:1 to 300 MHz	
Row 4		
Row4/Col1	< 2.6:1 to 300 MHz	
Row4/Col2	< 2.6:1 to 300 MHz	
Row4/Col3	< 2.6:1 to 300 MHz	
Row4/Col4	< 2.6:1 to 300 MHz	
Row4/Col5	< 2.6:1 to 300 MHz	
Row4/Col6	< 2.6:1 to 300 MHz	
Row4/Col7	< 2.6:1 to 300 MHz	
Row4/Col8	< 2.6:1 to 300 MHz	
Row4/Col9	< 2.6:1 to 300 MHz	
Row4/Col10	< 2.6:1 to 300 MHz	
Row4/Col11	< 2.6:1 to 300 MHz	
Row4/Col12	< 2.6:1 to 300 MHz	

Row/Column	Functional Test Limit	Measured Value
Row 7		
Row7/Col1	< 2.6:1 to 300 MHz	
Row7/Col2	< 2.6:1 to 300 MHz	
Row7/Col3	< 2.6:1 to 300 MHz	
Row7/Col4	< 2.6:1 to 300 MHz	
Row7/Col5	< 2.6:1 to 300 MHz	
Row7/Col6	< 2.6:1 to 300 MHz	
Row7/Col7	< 2.6:1 to 300 MHz	
Row7/Col8	< 2.6:1 to 300 MHz	
Row7/Col9	< 2.6:1 to 300 MHz	
Row7/Col10	< 2.6:1 to 300 MHz	
Row7/Col11	< 2.6:1 to 300 MHz	
Row7/Col12	< 2.6:1 to 300 MHz	
Row 8		
Row8/Col1	< 2.6:1 to 300 MHz	
Row8/Col2	< 2.6:1 to 300 MHz	
Row8/Col3	< 2.6:1 to 300 MHz	
Row8/Col4	< 2.6:1 to 300 MHz	
Row8/Col5	< 2.6:1 to 300 MHz	
Row8/Col6	< 2.6:1 to 300 MHz	
Row8/Col7	< 2.6:1 to 300 MHz	
Row8/Col8	< 2.6:1 to 300 MHz	
Row8/Col9	< 2.6:1 to 300 MHz	
Row8/Col10	< 2.6:1 to 300 MHz	
Row8/Col11	< 2.6:1 to 300 MHz	
Row8/Col12	< 2.6:1 to 300 MHz	

Insertion Loss Tests

Row/Column	Functional Test Limit	Measured Value
Row 1		
Row1/Col1	< 2.3 dB @ 300 MHz	
Row1/Col2	< 2.3 dB @ 300 MHz	
Row1/Col3	< 2.3 dB @ 300 MHz	
Row1/Col4	< 2.3 dB @ 300 MHz	
Row1/Col5	< 2.3 dB @ 300 MHz	
Row1/Col6	< 2.3 dB @ 300 MHz	
Row1/Col7	< 2.3 dB @ 300 MHz	
Row1/Col8	< 2.3 dB @ 300 MHz	
Row1/Col9	< 2.3 dB @ 300 MHz	
Row1/Col10	< 2.3 dB @ 300 MHz	
Row1/Col11	< 2.3 dB @ 300 MHz	
Row1/Col12	< 2.3 dB @ 300 MHz	
Row 2		
Row2/Col1	< 2.3 dB @ 300 MHz	
Row2/Col2	< 2.3 dB @ 300 MHz	
Row2/Col3	< 2.3 dB @ 300 MHz	
Row2/Col4	< 2.3 dB @ 300 MHz	
Row2/Col5	< 2.3 dB @ 300 MHz	
Row2/Col6	< 2.3 dB @ 300 MHz	
Row2/Col7	< 2.3 dB @ 300 MHz	
Row2/Col8	< 2.3 dB @ 300 MHz	
Row2/Col9	< 2.3 dB @ 300 MHz	
Row2/Col10	< 2.3 dB @ 300 MHz	
Row2/Col11	< 2.3 dB @ 300 MHz	
Row2/Col12	< 2.3 dB @ 300 MHz	

Row/Column	Functional Test Limit	Measured Value
Row 5		
Row5/Col1	< 2.3 dB @ 300 MHz	
Row5/Col2	< 2.3 dB @ 300 MHz	
Row5/Col3	< 2.3 dB @ 300 MHz	
Row5/Col4	< 2.3 dB @ 300 MHz	
Row5/Col5	< 2.3 dB @ 300 MHz	
Row5/Col6	< 2.3 dB @ 300 MHz	
Row5/Col7	< 2.3 dB @ 300 MHz	
Row5/Col8	< 2.3 dB @ 300 MHz	
Row5/Col9	< 2.3 dB @ 300 MHz	
Row5/Col10	< 2.3 dB @ 300 MHz	
Row5/Col11	< 2.3 dB @ 300 MHz	
Row5/Col12	< 2.3 dB @ 300 MHz	
Row 6		
Row1/Col1	< 2.3 dB @ 300 MHz	
Row 6/Col2	< 2.3 dB @ 300 MHz	
Row 6/Col3	< 2.3 dB @ 300 MHz	
Row6/Col4	< 2.3 dB @ 300 MHz	
Row6/Col5	< 2.3 dB @ 300 MHz	
Row6/Col6	< 2.3 dB @ 300 MHz	
Row6/Col7	< 2.3 dB @ 300 MHz	
Row6/Col8	< 2.3 dB @ 300 MHz	
Row6/Col9	< 2.3 dB @ 300 MHz	
Row6/Col10	< 2.3 dB @ 300 MHz	
Row6/Col11	< 2.3 dB @ 300 MHz	
Row6/Col12	< 2.3 dB @ 300 MHz	

Row/Column	Functional Test Limit	Measured Value
Row 3		
Row3/Col1	< 2.3 dB @ 300 MHz	
Row3/Col2	< 2.3 dB @ 300 MHz	
Row3/Col3	< 2.3 dB @ 300 MHz	
Row3/Col4	< 2.3 dB @ 300 MHz	
Row3/Col5	< 2.3 dB @ 300 MHz	
Row3/Col6	< 2.3 dB @ 300 MHz	
Row3/Col7	< 2.3 dB @ 300 MHz	
Row3/Col8	< 2.3 dB @ 300 MHz	
Row3/Col9	< 2.3 dB @ 300 MHz	
Row3/Col10	< 2.3 dB @ 300 MHz	
Row3/Col11	< 2.3 dB @ 300 MHz	
Row3/Col12	< 2.3 dB @ 300 MHz	
Row 4		
Row4/Col1	< 2.3 dB @ 300 MHz	
Row4/Col2	< 2.3 dB @ 300 MHz	
Row4/Col3	< 2.3 dB @ 300 MHz	
Row4/Col4	< 2.3 dB @ 300 MHz	
Row4/Col5	< 2.3 dB @ 300 MHz	
Row4/Col6	< 2.3 dB @ 300 MHz	
Row4/Col7	< 2.3 dB @ 300 MHz	
Row4/Col8	< 2.3 dB @ 300 MHz	
Row4/Col9	< 2.3 dB @ 300 MHz	
Row4/Col10	< 2.3 dB @ 300 MHz	
Row4/Col11	< 2.3 dB @ 300 MHz	
Row4/Col12	< 2.3 dB @ 300 MHz	

Row/Column	Functional Test Limit	Measured Value
Row 7		
Row7/Col1	< 2.3 dB @ 300 MHz	
Row7/Col2	< 2.3 dB @ 300 MHz	
Row7/Col3	< 2.3 dB @ 300 MHz	
Row7/Col4	< 2.3 dB @ 300 MHz	
Row7/Col5	< 2.3 dB @ 300 MHz	
Row7/Col6	< 2.3 dB @ 300 MHz	
Row7/Col7	< 2.3 dB @ 300 MHz	
Row7/Col8	< 2.3 dB @ 300 MHz	
Row7/Col9	< 2.3 dB @ 300 MHz	
Row7/Col10	< 2.3 dB @ 300 MHz	
Row7/Col11	< 2.3 dB @ 300 MHz	
Row7/Col12	< 2.3 dB @ 300 MHz	
Row 8		
Row8/Col1	< 2.3 dB @ 300 MHz	
Row8/Col2	< 2.3 dB @ 300 MHz	
Row8/Col3	< 2.3 dB @ 300 MHz	
Row8/Col4	< 2.3 dB @ 300 MHz	
Row8/Col5	< 2.3 dB @ 300 MHz	
Row8/Col6	< 2.3 dB @ 300 MHz	
Row8/Col7	< 2.3 dB @ 300 MHz	
Row8/Col8	< 2.3 dB @ 300 MHz	
Row8/Col9	< 2.3 dB @ 300 MHz	
Row8/Col10	< 2.3 dB @ 300 MHz	
Row8/Col11	< 2.3 dB @ 300 MHz	
Row8/Col12	< 2.3 dB @ 300 MHz	

Isolation (Open Channel Crosstalk) Adjacent Rows Tests

Row to Row	Functional Test Limit	Measured Value
Row 1 - Row 2	> 35 dB @ 300 MHz	
Row 2 - Row 3	> 35 dB @ 300 MHz	
Row 3 - Row 4	> 35 dB @ 300 MHz	
Row 4 - Row 5	> 35 dB @ 300 MHz	
Row 5 - Row 6	> 35 dB @ 300 MHz	
Row 6 - Row 7	> 35 dB @ 300 MHz	
Row 7 - Row 8	> 35 dB @ 300 MHz	

M9128A Schematic

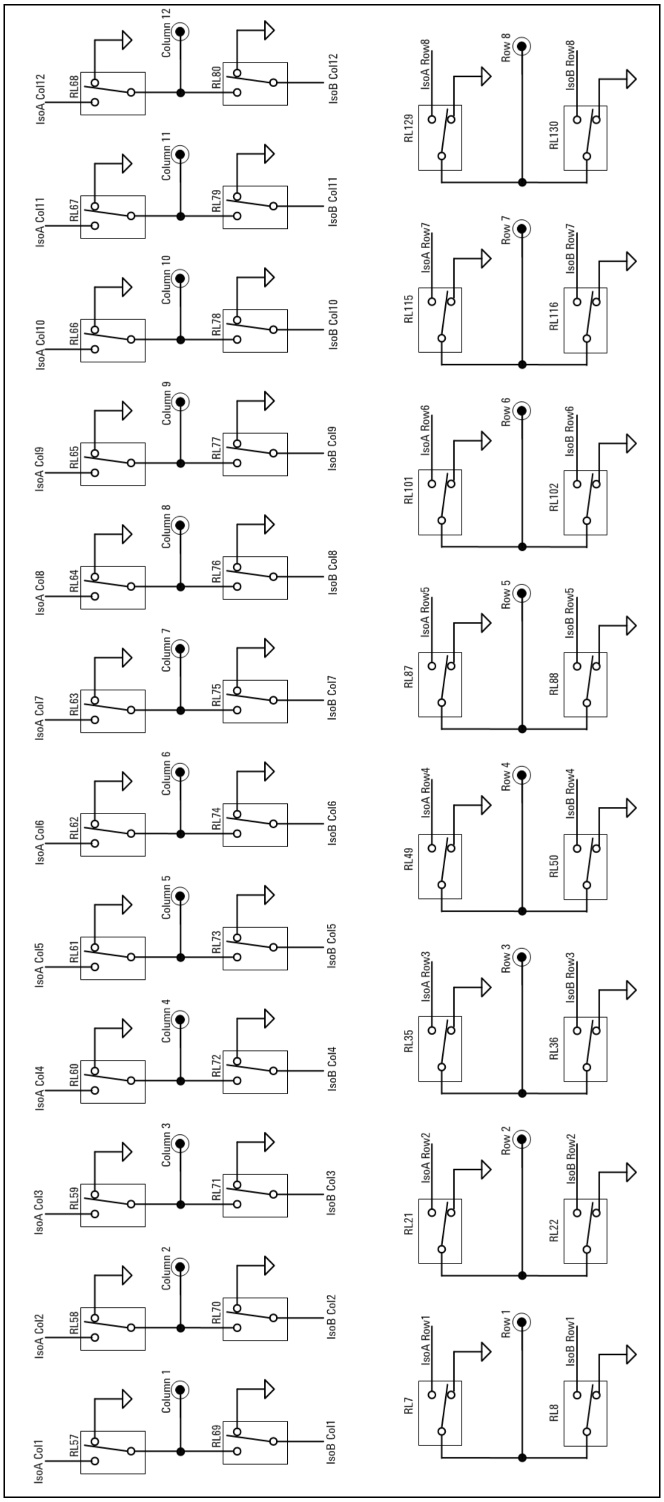


Figure 5 M9128A Isolation Relays Schematic

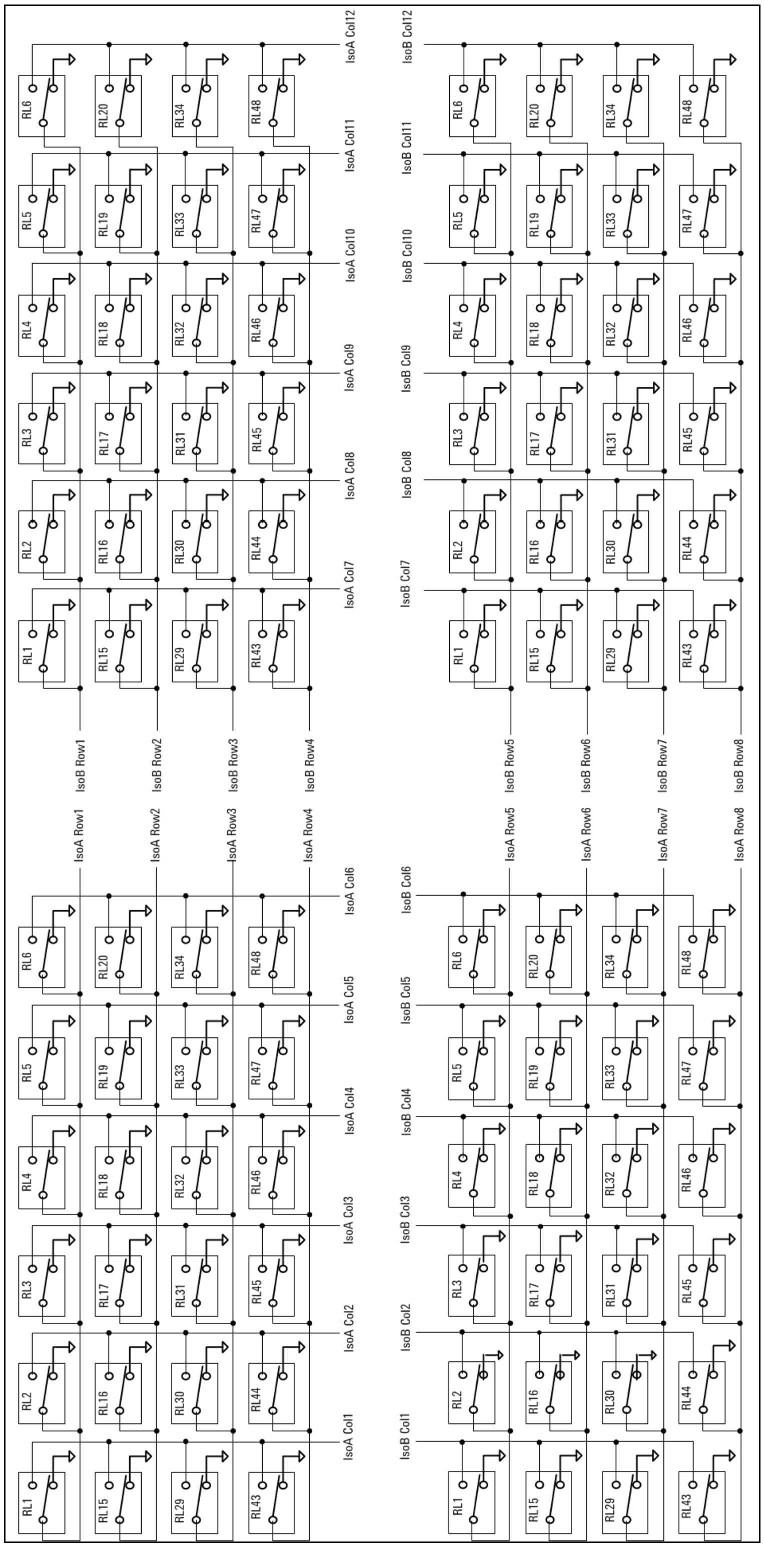


Figure 6 M9128A Cross Point Relays Schematic

M9128A PC Board Layout

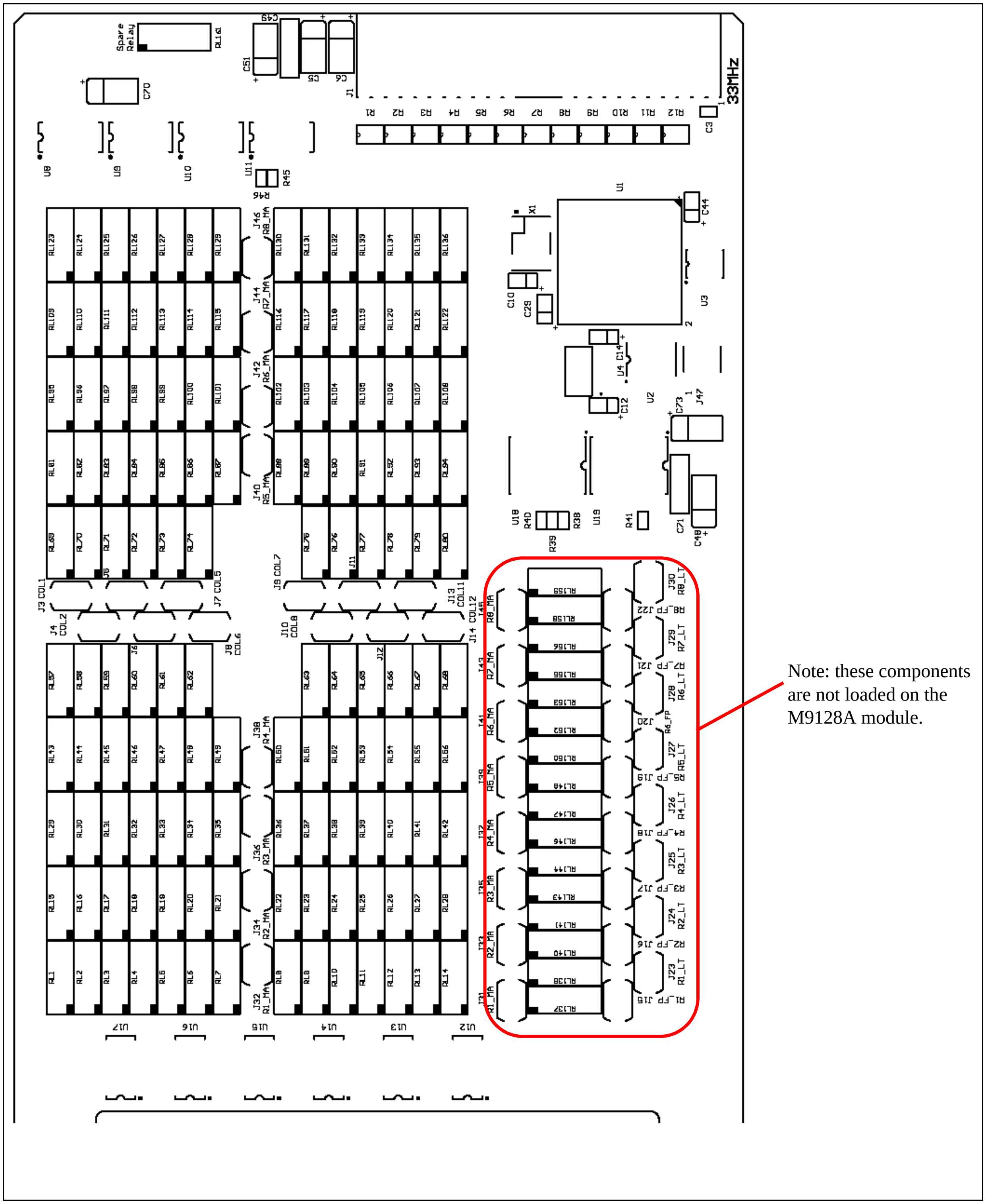


Figure 7 M9128A PC Board Layout

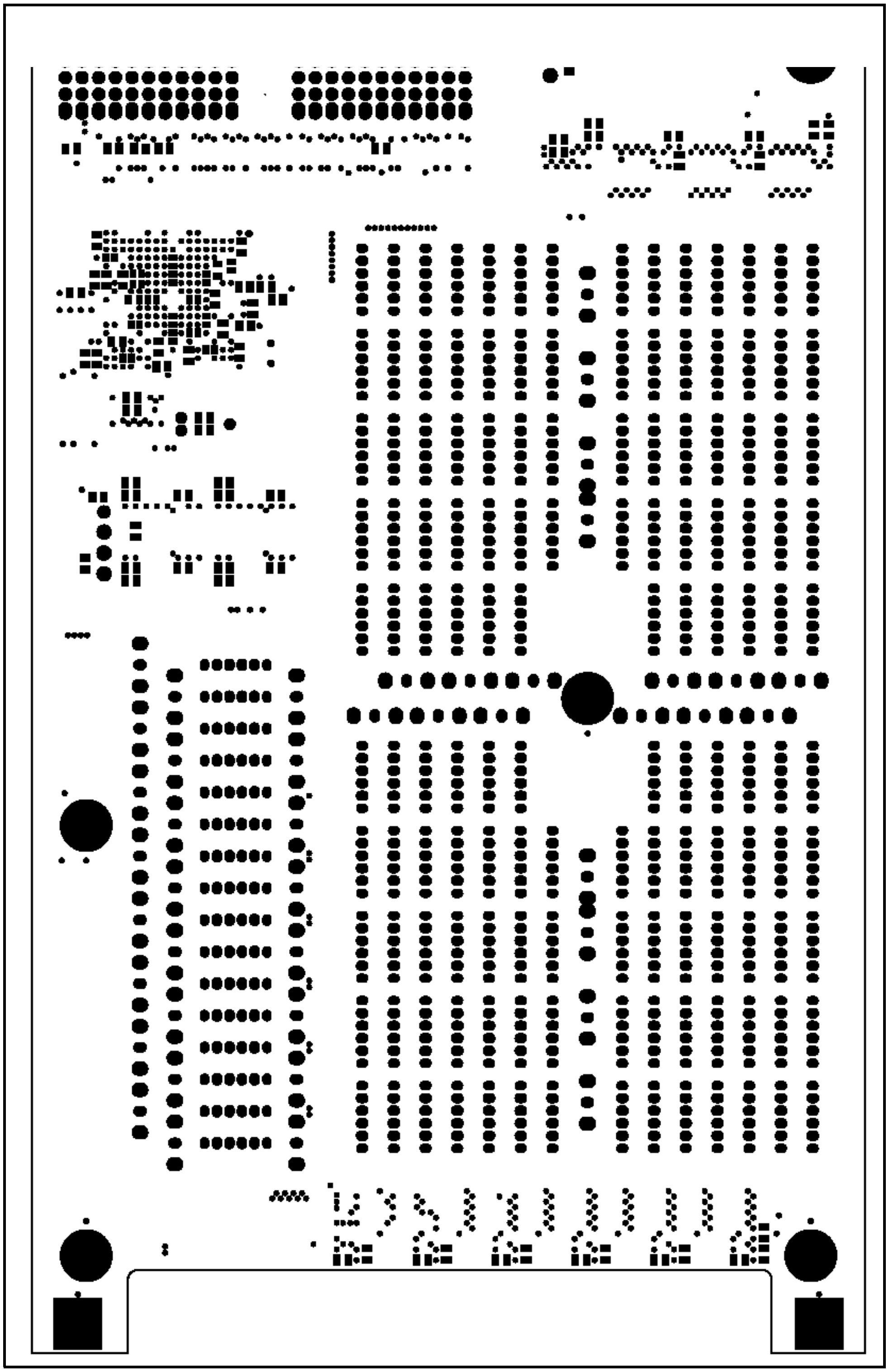


Figure 8 M9128A PC Board Back side (solder side)

3
M9146A RF Multiplexer, 3 GHz, Dual 1x4 50 Ohm Terminated

Introduction

Agilent's M9146A Dual 1x4 50 Ω Multiplexer Module exhibits low insertion loss and VSWR. The module is constructed as two separate 1X4 RF switch multiplexers. It offers 50 Ω inputs with bi-directional switching up to 3 GHz. This module features excellent insertion loss and VSWR for better RF signal integrity as well as outstanding dynamic range for routing RF signals into your measurement equipment. In addition, each path is carefully designed to ensure repeatable RF performance. Connections are made through easy, snap-on SMB front panel connectors. The default channel relay is terminated in a 50 Ω resistor as shown in the schematic diagram.

Default switch path

Switch Model	Bank	Default Path
M9146A, Dual 1x4, 50Ω Terminated	1	All channel input terminals terminated to the 50Ω resistor. Com1 is open circuit.
	2	All channel input terminals terminated to the 50Ω resistor. Com2 is open circuit.

Replacement Relays and Boards

The M9146A module has one PXI interface board with relay drivers and two daughter boards with the actual relays. The two daughter boards are identical. If a channel is defective, you may replace the individual relay(s) or replace the appropriate relay daughter board. When replacing individual relays, improper relay placement, too much solder, etc., may alter the signal path RF characteristics (VSWR, insertion loss, crosstalk, etc.).

Relay 5VDC coil, 2A 250V 178-Ohm SMT	Agilent P.N.: 0490-2946
M9146A Daughter Board	Agilent P.N.: M9146-66502

See Appendix 11, “Disassembling the RF Matrix and Multiplexer Modules,” starting on page 93 for disassembly instructions.

Troubleshooting and Functional Testing

Testing Path Contact Resistance

Contact resistance checks can help isolate problems. When checking contact resistance through the front panel SMB connectors, each resistance measurement includes three sets of relay contacts (a channel relay, a tree relay, and a COM relay). Check all of the paths in both banks to help isolate a problem to a specific relay. For example, if both channels 1 and 2 in Bank 1 have high contact resistance but channels 3 and 4 are normal, then the tree relay may be suspect. See Figure 11.

When all relays are “open,” a resistance measured on any channel path indicates a welded contacts condition and the relay or module must be replaced. There is no specific path resistance or test for this failure.

CAUTION Remove all user wiring and connections from the plug-in modules before troubleshooting or testing.

To check contact resistance:

1 Set the DMM to measure 2-wire or 4-wire resistance.
2 Connect the DMM High to an SMB plug center conductor and the Low to the SMB plug shield.
3 Connect the SMB plug to the module’s COM1 or COM2 jack.
4 Connect an SMB short to the channel jack to be tested.
5 Using the Soft Front Panel software, close the channel to be tested.
6 Measure the contact resistance and then open the channel.
7 Repeat steps 3 through 6 for all channels on the module.

NOTE Contact or path resistance is not specified for the RF modules. Measuring dc path resistance provides a simple functional testing of the relays.

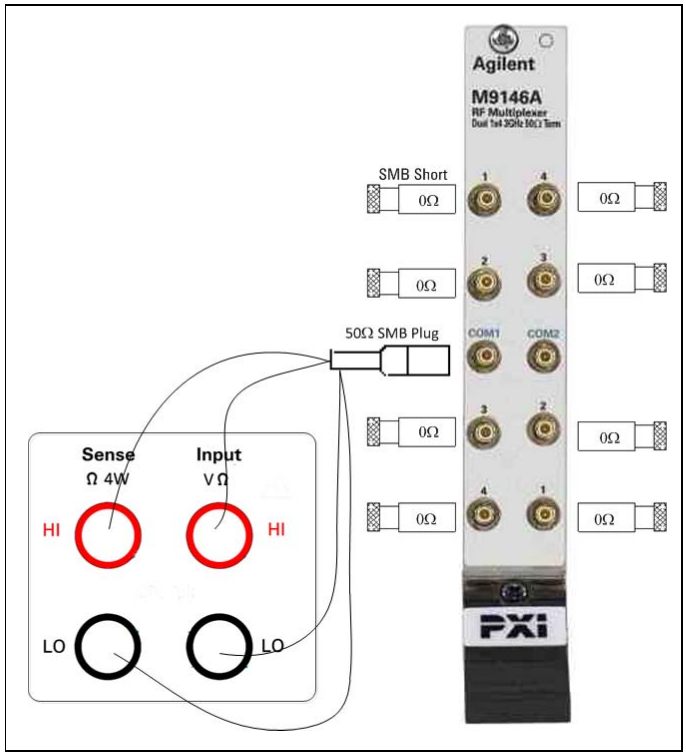


Figure 9 DC Path Resistance Measurements

Testing the Termination Resistors

Each channel is terminated through a resistor whenever the channel is open, following a reset command or when power is removed the module. Termination resistors can be checked from the module's front panel. The measured resistance includes the Normally Open channel relay contact resistance. Refer to Figure 10

To check the termination resistors:

1 Reset the module or remove power from the module.

2 Set the DMM to measure 4-wire Ω.

3 Connect the DMM High to an SMB plug center conductor and the Low to the SMB plug shield.

4 Connect the SMB plug to the channel being tested.

5 Measure the termination resistance.

6 Repeat for all channels.

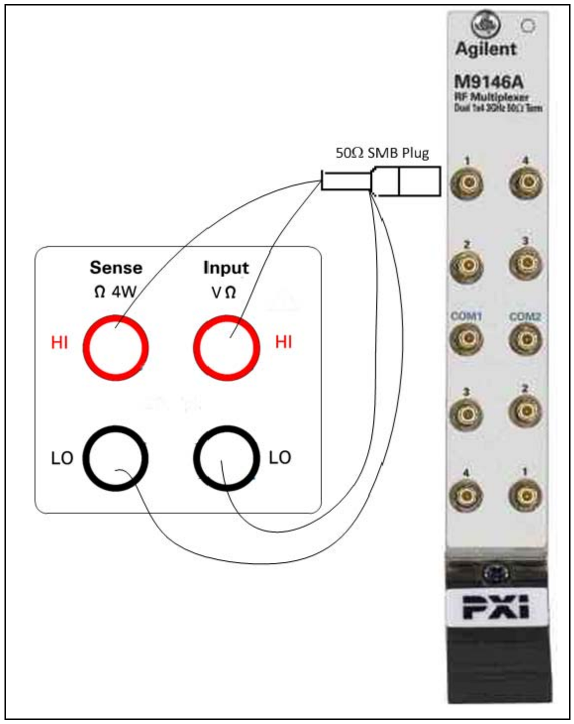


Figure 10 Measuring the Termination Resistors

A more accurate test of the termination resistors, and one that removes the effects of the relay contact resistance from the measurement, is performed by removing the module from the PXI chassis and performing a 4-wire resistance measurement directly on each termination resistor. The termination resistor locations are shown in Figure 12.

RF Measurements Tests

RF test measurements (VSWR, Insertion, and Isolation tests) are described in Appendix A, "Making RF Test Measurements," starting on page 103.

M9146A Functional Test Record

Path Contact Resistance Tests

DC path resistance is not specified for the RF switch modules. Measuring dc path resistance provides a simple test to determine if relays are closed or open. In general, maximum dc path resistance should not exceed 5Ω.

Test Description	Measured Value
Bank 1, Channel 1	
Bank 1, Channel 2	
Bank 1, Channel 3	
Bank 1, Channel 4	
Bank 2, Channel 1	
Bank 2, Channel 2	
Bank 2, Channel 3	
Bank 2, Channel 4	

Termination Resistor Tests

Bank/Channel	Nominal Value	Measured Value
Bank 1, Channel 1	50 Ω	
Bank 1, Channel 2	50 Ω	
Bank 1, Channel 3	50 Ω	
Bank 1, Channel 4	50 Ω	
Bank 2, Channel 1	50 Ω	
Bank 2, Channel 2	50 Ω	
Bank 2, Channel 3	50 Ω	
Bank 2, Channel 4	50 Ω	

VSWR Tests

Test Description	Functional Test Limit	Measured Value
Bank 1, Channel 1	<1.4:1 to 3 GHz	
Bank 1, Channel 2	<1.4:1 to 3 GHz	
Bank 1, Channel 3	<1.4:1 to 3 GHz	
Bank 1, Channel 4	<1.4:1 to 3 GHz	
Bank 2, Channel 1	<1.4:1 to 3 GHz	
Bank 2, Channel 2	<1.4:1 to 3 GHz	
Bank 2, Channel 3	<1.4:1 to 3 GHz	
Bank 2, Channel 4	<1.4:1 to 3 GHz	

Insertion Loss Tests

Test Description	Functional Test Limit	Measured Value
Bank 1, Channel 1	< 1.1 dB to 3 GHz	
Bank 1, Channel 2	< 1.1 dB to 3 GHz	
Bank 1, Channel 3	< 1.1 dB to 3 GHz	
Bank 1, Channel 4	< 1.1 dB to 3 GHz	
Bank 2, Channel 1	< 1.1 dB to 3 GHz	
Bank 2, Channel 2	< 1.1 dB to 3 GHz	
Bank 2, Channel 3	< 1.1 dB to 3 GHz	
Bank 2, Channel 4	< 1.1 dB to 3 GHz	

Open Channel Isolation Tests

Test Description	Functional Test Limit	Measured Value
Bank 1, Channel 1	> 43 dB @ 3 GHz	
Bank 1, Channel 2	> 43 dB @ 3 GHz	
Bank 1, Channel 3	> 43 dB @ 3 GHz	
Bank 1, Channel 4	> 43 dB @ 3 GHz	
Bank 2, Channel 1	> 43 dB @ 3 GHz	
Bank 2, Channel 2	> 43 dB @ 3 GHz	
Bank 2, Channel 3	> 43 dB @ 3 GHz	
Bank 2, Channel 4	> 43 dB @ 3 GHz	

Adjacent Channel Isolation (crosstalk) Tests

Test Description	Functional Test Limit	Measured Value
Bank 1, Channel 1 - Channel 2	> 35 dB @ 3 GHz	
Bank 1, Channel 2 - Channel 3	> 35 dB @ 3 GHz	
Bank 1, Channel 3 - Channel 4	> 35 dB @ 3 GHz	
Bank 2, Channel 1 - Channel 2	> 35 dB @ 3 GHz	
Bank 2, Channel 2 - Channel 3	> 35 dB @ 3 GHz	
Bank 2, Channel 3 - Channel 4	> 35 dB @ 3 GHz	

Bank to Bank Isolation (crosstalk) Tests

Test Description	Functional Test Limit	Measured Value
Bank 1- Bank2	> 35 dB @ 3 GHz	

M9146A Schematic

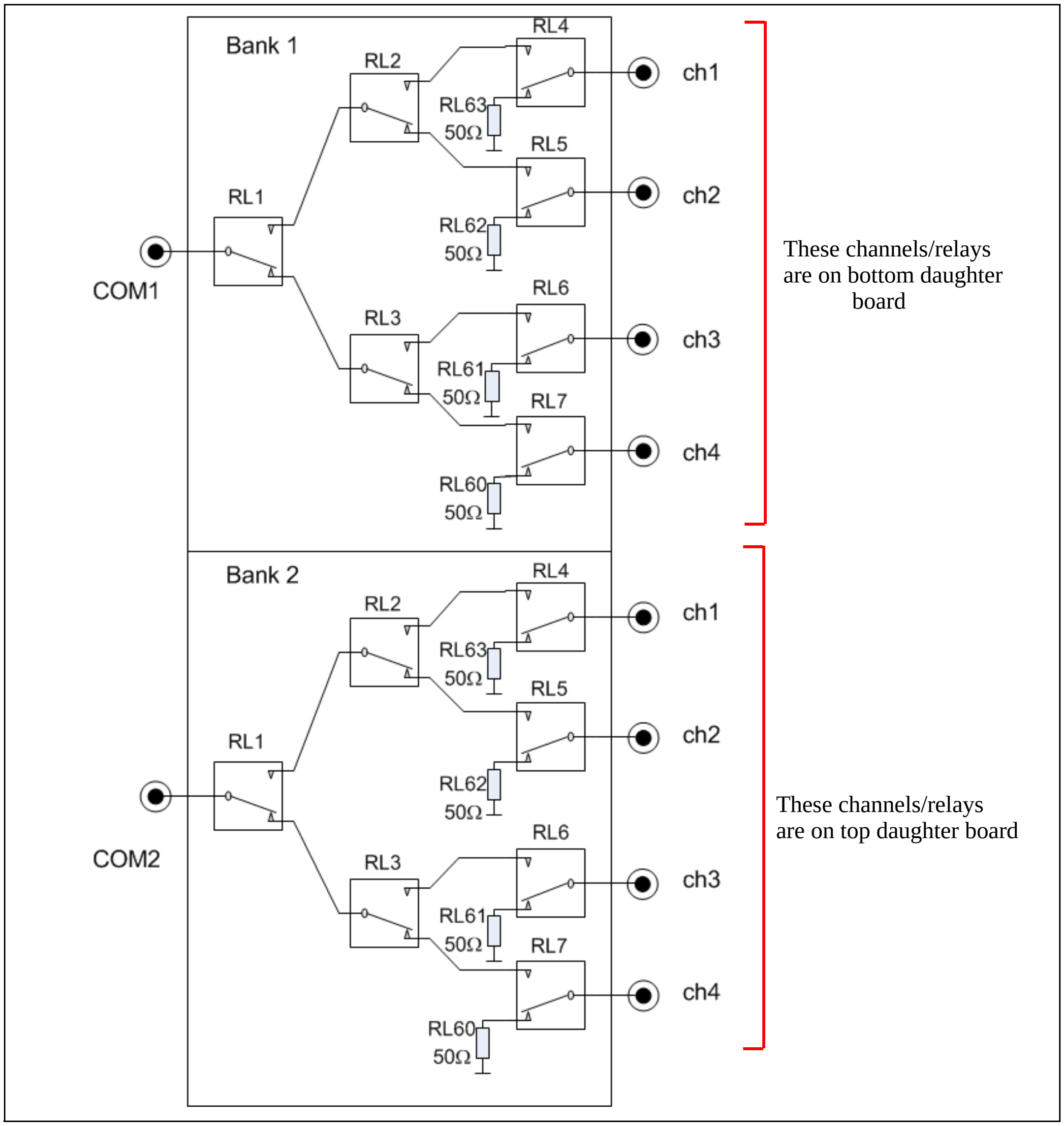


Figure 11 M9146A Schematic

M9146A PC Board Layout

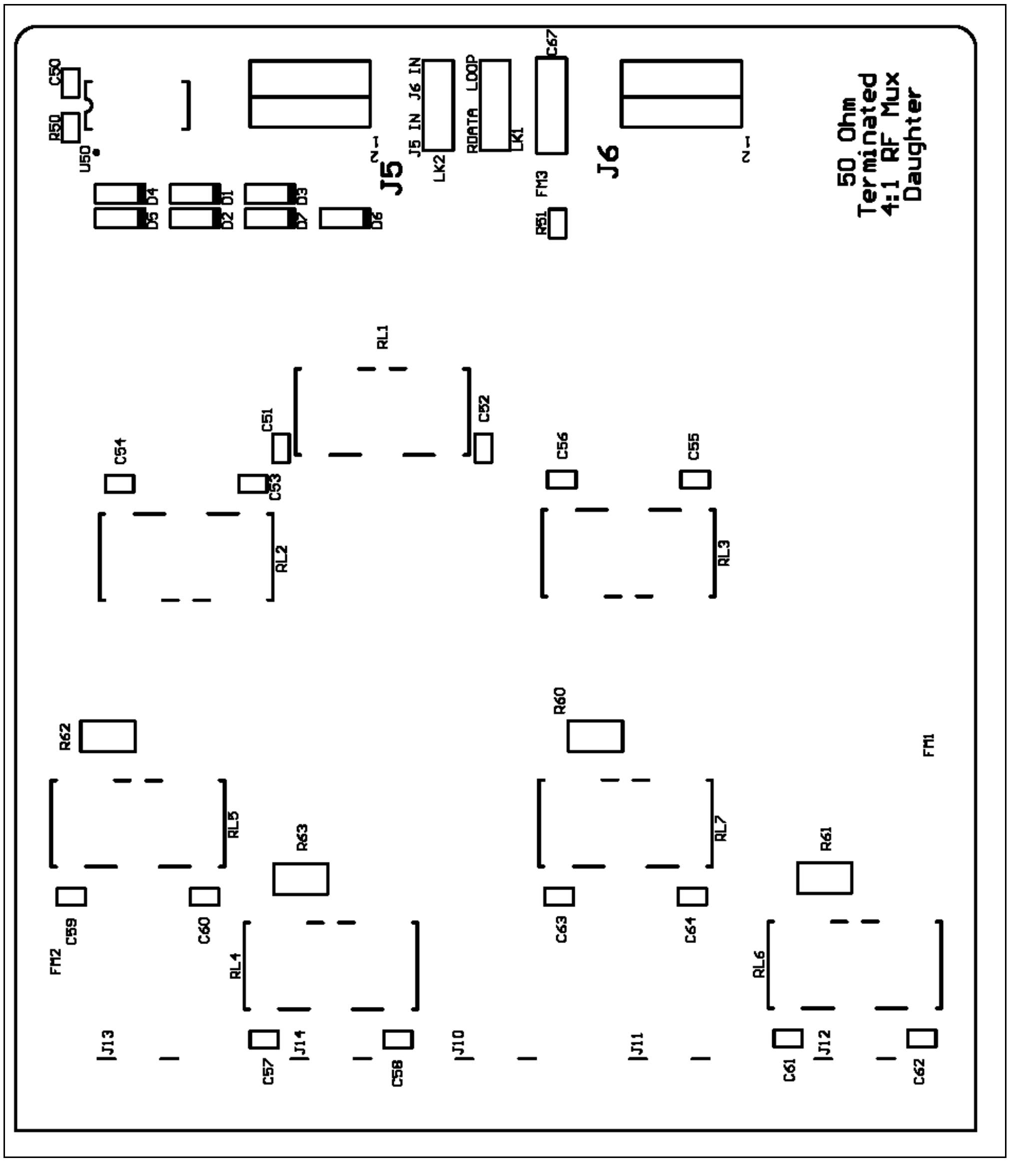


Figure 12 M9146A Daughter Board PC Board Layout
both daughter boards are identical

4
M9147A RF Multiplexer, 3 GHz, Quad 1x4 50 Ohm Terminated

Introduction

Agilent's M9147A Dual 1x4 50 Ω Multiplexer Module exhibit low insertion loss and VSWR. The module is constructed as four separate 1X4 multiplexers. The default state of the common relay is terminated in a 50Ω resistor as shown in the diagram below. It offers 50 Ω inputs with bi-directional switching up to 3 GHz. This module features excellent insertion loss and VSWR for better RF signal integrity as well as outstanding dynamic range for routing RF signals into your measurement equipment. In addition, each path is carefully designed to ensure repeatable RF performance. Connections are made through easy, snap-on SMB front panel connectors.

Default switch path

Switch Model	Bank	Default Path
M9147A, Quad 1x4, 50Ω Terminated Common	1	Com1 terminated to 50Ω, channels open circuit
	2	Com2 terminated to 50Ω, channels open circuit
	3	Com3 terminated to 50Ω, channels open circuit
	4	Com4 terminated to 50Ω, channels open circuit

Replacement Relays and Boards

The M9147A module has one PXI interface board with relay drivers and two daughter boards with the actual relays. The two daughter boards are identical. If a channel is defective, you may replace the individual relay(s) or replace the appropriate relay daughter board. When replacing individual relays, improper relay placement, too much solder, etc., may alter the signal path RF characteristics (VSWR, insertion loss, crosstalk, etc.).

Relay 5VDC coil, 2A 250V 178-Ohm SMT	Agilent P.N.: 0490-2946
M9147A Daughter Board	Agilent P.N.: M9147-66502

See Appendix 11, “Disassembling the RF Matrix and Multiplexer Modules,” starting on page 93 for disassembly instructions.

Troubleshooting and Functional Testing

Testing Path Contact Resistance

Contact resistance checks can help isolate problems. When checking contact resistance through SMB connectors, each resistance measurement includes three sets of relay contacts (a channel relay, a tree relay, and a COM relay). Check all of the paths in each bank to help isolate a problem to a specific relay. For example, if both channels 1 and 2 in Bank 1 have high contact resistance but channels 3 and 4 are normal, then the tree relay may be suspect. See Figure 15.

When all relays are “open,” a resistance measured on any channel path indicates a welded contacts condition and the relay or module must be replaced. There is no specific path resistance or test for this failure.

CAUTION Remove all user wiring and connections from the plug-in modules before troubleshooting or testing.

To check contact resistance:

1 Set the DMM to measure 4-wire Ω.
2 Connect the DMM High to an SMB plug center conductor and the Low to the SMB plug shield.
3 Connect the SMB plug to the module’s COM1, COM2, COM3 or COM4 SMB jack.
4 Connect an SMB short to the channel jack to be tested.
5 Using the Soft Front Panel software, close the channel to be tested.
6 Measure the contact resistance and then open the channel.
7 Repeat steps 3 through 6 for all channels on the module.

NOTE Contact or path resistance is not specified for the RF modules. Measuring dc path resistance provides a simple functional testing of the relays.

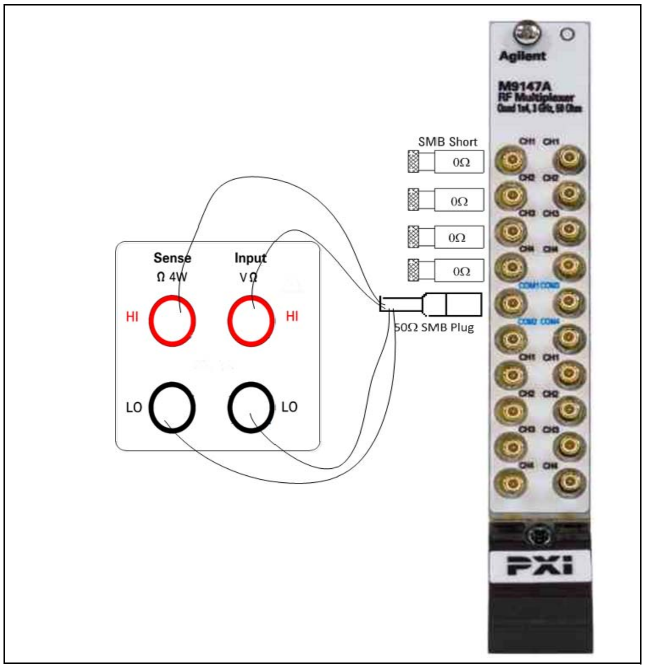


Figure 13 DC Path Resistance Measurements

Testing the Termination Resistors

Each COMmon is terminated through a resistor whenever the module is reset or when power is removed the module. Termination resistors can be checked from the module's front panel. The measured resistance includes the Normally Open channel relay contact resistance.

To check the termination resistors:

1. Reset the module or remove power from the module.
2. Set the DMM to measure 4-wire Ω.
3. Connect the DMM High to an SMB plug center conductor and the Low to the SMB plug shield.
4. Connect the SMB plug to the module's COM1, COM2, COM3 or COM4 SMB jack.
5. Measure the termination resistance.
6. Repeat steps 4 and 5 for the remaining COM connectors on the module.

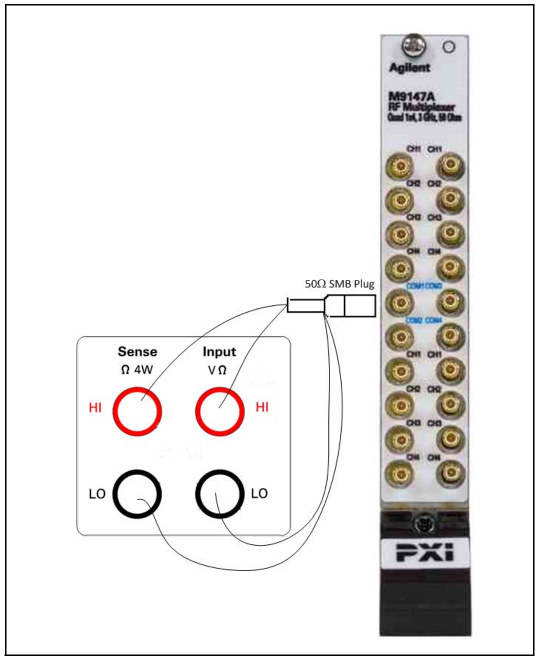


Figure 14 Measuring the Termination Resistors

A more accurate test of the termination resistors, and one that removes the effects of the relay contact resistance from the measurement, is performed by removing the module form the PXI chassis and performing a 4-wire resistance measurement directly on each termination resistor. The termination resistor locations are shown in Figure 16.

RF Measurements Tests

RF test measurements (VSWR, Insertion, and Isolation tests) are described in Appendix A, “Making RF Test Measurements,” starting on page 103.

M9147A Functional Test Record

Path Contact Resistance Tests

DC path resistance is not specified for the RF switch modules. Measuring dc path resistance provides a simple test to determine if relays are closed or open. In general, maximum dc path resistance should not exceed 5Ω.

Test Description	Measured Value
Bank 1, Channel 1	
Bank 1, Channel 2	
Bank 1, Channel 3	
Bank 1, Channel 4	
Bank 2, Channel 1	
Bank 2, Channel 2	
Bank 2, Channel 3	
Bank 2, Channel 4	
Bank 3, Channel 1	
Bank 3, Channel 2	
Bank 3, Channel 3	
Bank 3, Channel 4	
Bank 4, Channel 1	
Bank 4, Channel 2	
Bank 4, Channel 3	
Bank 4, Channel 4	
Bank 4, Channel 1	
Bank 4, Channel 2	
Bank 4, Channel 3	
Bank 4, Channel 4	

Termination Resistor Tests

Bank	Functional Test Limit	Measured Value
Bank 1	50 Ω	
Bank 2	50 Ω	
Bank 3	50 Ω	
Bank 4	50 Ω	

VSWR Tests

Test Description	Functional Test Limit	Measured Value
Bank 1, Channel 1	< 1.55:1 to 3 GHz	
Bank 1, Channel 2	< 1.55:1 to 3 GHz	
Bank 1, Channel 3	< 1.55:1 to 3 GHz	
Bank 1, Channel 4	< 1.55:1 to 3 GHz	
Bank 2, Channel 1	< 1.55:1 to 3 GHz	
Bank 2, Channel 2	< 1.55:1 to 3 GHz	
Bank 2, Channel 3	< 1.55:1 to 3 GHz	
Bank 2, Channel 4	< 1.55:1 to 3 GHz	
Bank 3, Channel 1	< 1.55:1 to 3 GHz	
Bank 3, Channel 2	< 1.55:1 to 3 GHz	
Bank 3, Channel 3	< 1.55:1 to 3 GHz	
Bank 3, Channel 4	< 1.55:1 to 3 GHz	
Bank 4, Channel 1	< 1.55:1 to 3 GHz	
Bank 4, Channel 2	< 1.55:1 to 3 GHz	
Bank 4, Channel 3	< 1.55:1 to 3 GHz	
Bank 4, Channel 4	< 1.55:1 to 3 GHz	
Bank 4, Channel 1	< 1.55:1 to 3 GHz	
Bank 4, Channel 2	< 1.55:1 to 3 GHz	
Bank 4, Channel 3	< 1.55:1 to 3 GHz	
Bank 4, Channel 4	< 1.55:1 to 3 GHz	

Insertion Loss Tests

Test Description	Functional Test Limit	Measured Value
Bank 1, Channel 1	< 1.3 dB @ 3 GHz	
Bank 1, Channel 2	< 1.3 dB @ 3 GHz	
Bank 1, Channel 3	< 1.3 dB @ 3 GHz	
Bank 1, Channel 4	< 1.3 dB @ 3 GHz	
Bank 2, Channel 1	< 1.3 dB @ 3 GHz	
Bank 2, Channel 2	< 1.3 dB @ 3 GHz	
Bank 2, Channel 3	< 1.3 dB @ 3 GHz	
Bank 2, Channel 4	< 1.3 dB @ 3 GHz	

Test Description	Functional Test Limit	Measured Value
Bank 3, Channel 1	< 1.3 dB @ 3 GHz	
Bank 3, Channel 2	< 1.3 dB @ 3 GHz	
Bank 3, Channel 3	< 1.3 dB @ 3 GHz	
Bank 3, Channel 4	< 1.3 dB @ 3 GHz	
Bank 4, Channel 1	< 1.3 dB @ 3 GHz	
Bank 4, Channel 2	< 1.3 dB @ 3 GHz	
Bank 4, Channel 3	< 1.3 dB @ 3 GHz	
Bank 4, Channel 4	< 1.3 dB @ 3 GHz	

Open Channel Isolation Tests

Test Description	Functional Test Limit	Measured Value
Bank 1, Channel 1	> 35 dB @ 3 GHz	
Bank 1, Channel 2	> 35 dB @ 3 GHz	
Bank 1, Channel 3	> 35 dB @ 3 GHz	
Bank 1, Channel 4	> 35 dB @ 3 GHz	
Bank 2, Channel 1	> 35 dB @ 3 GHz	
Bank 2, Channel 2	> 35 dB @ 3 GHz	
Bank 2, Channel 3	> 35 dB @ 3 GHz	
Bank 2, Channel 4	> 35 dB @ 3 GHz	
Bank 3, Channel 1	> 35 dB @ 3 GHz	
Bank 3, Channel 2	> 35 dB @ 3 GHz	
Bank 3, Channel 3	> 35 dB @ 3 GHz	
Bank 3, Channel 4	> 35 dB @ 3 GHz	
Bank 4, Channel 1	> 35 dB @ 3 GHz	
Bank 4, Channel 2	> 35 dB @ 3 GHz	
Bank 4, Channel 3	> 35 dB @ 3 GHz	
Bank 4, Channel 4	> 35 dB @ 3 GHz	

Adjacent Channel Isolation (crosstalk) Tests

Test Description	Functional Test Limit	Measured Value
Bank 1, Channel 1 - Channel 2	> 38 dB @ 3 GHz	
Bank 1, Channel 2 - Channel 3	> 38 dB @ 3 GHz	
Bank 1, Channel 3 - Channel 4	> 38 dB @ 3 GHz	
Bank 2, Channel 1 - Channel 2	> 38 dB @ 3 GHz	
Bank 2, Channel 2 - Channel 3	> 38 dB @ 3 GHz	
Bank 2, Channel 3 - Channel 4	> 38 dB @ 3 GHz	
Bank 3, Channel 1 - Channel 2	> 38 dB @ 3 GHz	
Bank 3, Channel 2 - Channel 3	> 38 dB @ 3 GHz	
Bank 3, Channel 3 - Channel 4	> 38 dB @ 3 GHz	
Bank 4, Channel 1 - Channel 2	> 38 dB @ 3 GHz	
Bank 4, Channel 2 - Channel 3	> 38 dB @ 3 GHz	
Bank 4, Channel 3 - Channel 4	> 38 dB @ 3 GHz	

Bank to Bank Isolation (crosstalk) Tests

Test Description	Functional Test Limit	Measured Value
Bank 1- Bank 2	> 38 dB @ 3 GHz	
Bank 2- Bank 3	> 38 dB @ 3 GHz	
Bank 3- Bank 4	> 38 dB @ 3 GHz	

M9147A Schematic

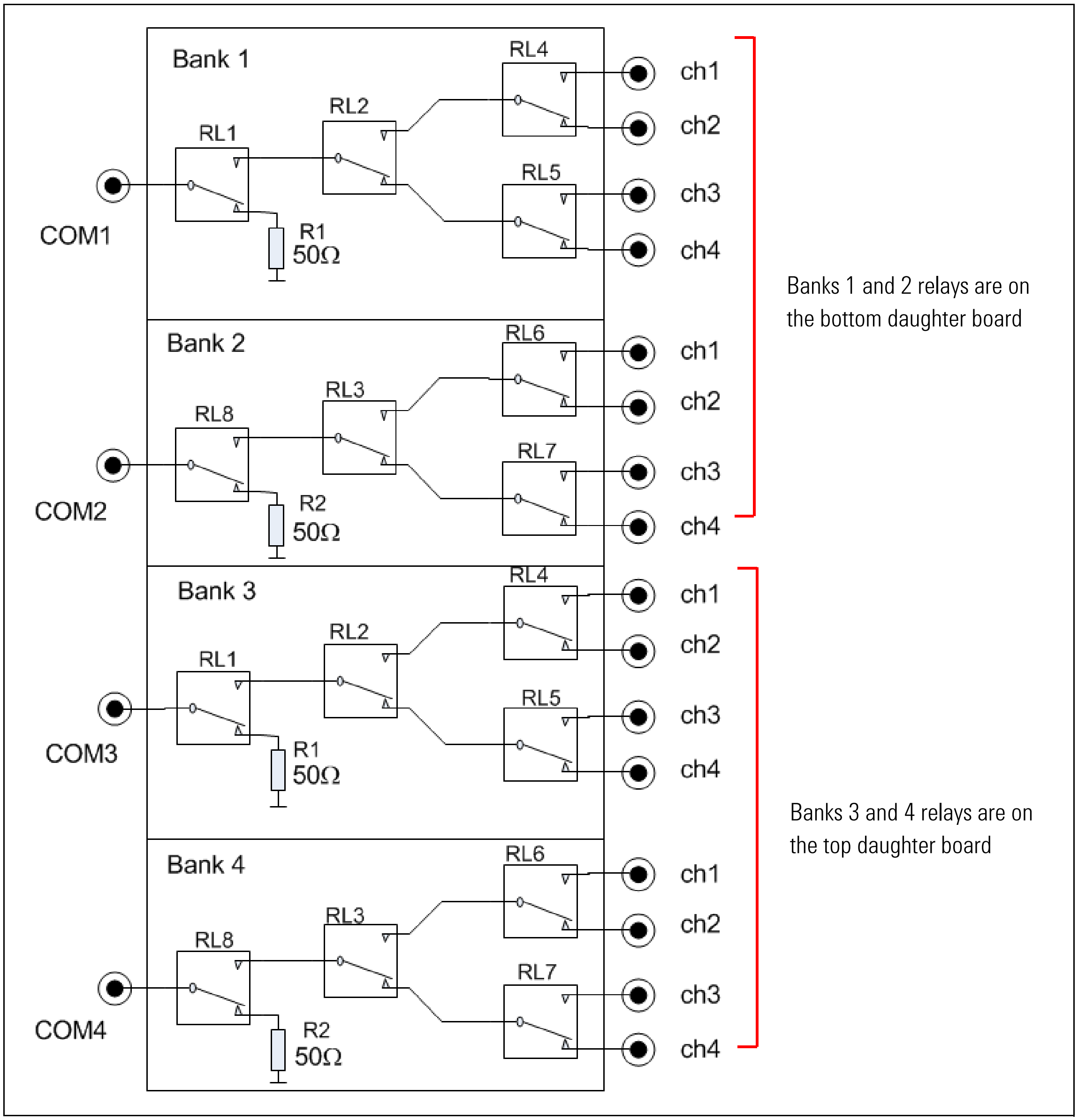


Figure 15 M9147A Schematic

M9147A PC Board Layout

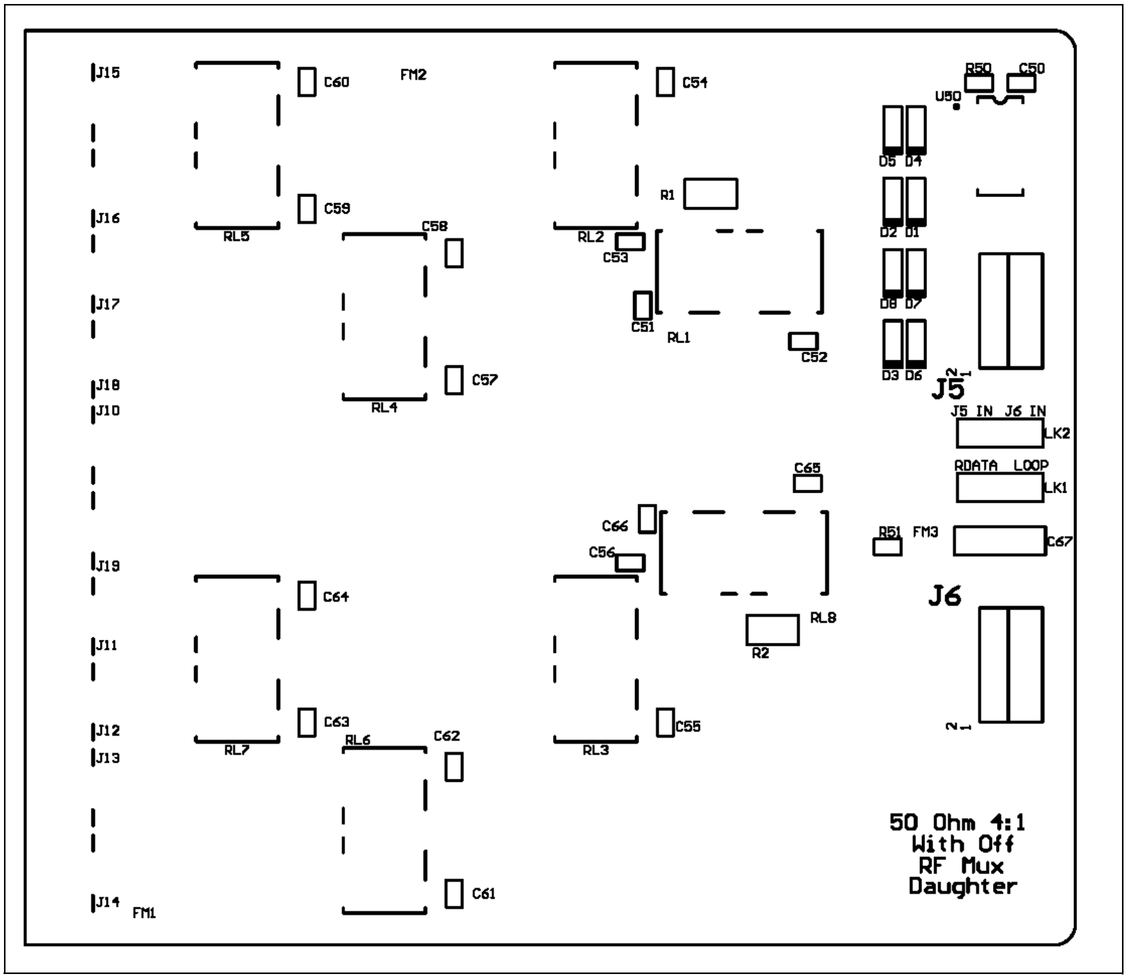


Figure 16 M9147A PC Board Relay Layout
both daughter boards are identical

5
M9148A RF Multiplexer, 3 GHz 1x8, 50 Ohm

Introduction

Agilent's M9148A 1x8 50 Ω Multiplexer Module exhibits low insertion loss and VSWR. This module features excellent insertion loss and VSWR for better RF signal integrity as well as outstanding dynamic range for routing RF signals into your measurement equipment. In addition, each path is carefully designed to ensure repeatable RF performance. Connections are made through easy, snap-on SMB front panel connectors.

Default switch path

Com to channel 4 remains closed when power is removed. Other channels are open.

Replacement Relays and Boards

The M9148A module has one PXI interface board with relay drivers and one daughter board with the actual relays. If a channel is defective, you may replace the individual relay(s) or replace the relay daughter board. When replacing individual relays, improper relay placement, too much solder, etc., may alter the signal path RF characteristics (VSWR, insertion loss, crosstalk, etc.).

Relay 5VDC coil, 2A 250V 178-Ohm SMT	Agilent P.N.: 0490-2946
M9148A Daughter Board	Agilent P.N.: M9148-66502

See Appendix 11, “Disassembling the RF Matrix and Multiplexer Modules,” starting on page 93 for disassembly instructions.

Troubleshooting and Functional Testing

Testing Path Contact Resistance

Contact resistance checks can help isolate problems. When checking contact resistance through SMB connectors, each resistance measurement includes three sets of relay contacts (a channel relay, a tree relay, and a COM relay). Check all of the paths in each bank to help isolate a problem to a specific relay. For example, if both channels 1 and 2 in Bank 1 have high contact resistance but channels 3 and 4 are normal, then the tree relay may be suspect.

When all relays are “open,” a resistance measured on any channel path indicates a welded contacts condition and the relay or module must be replaced. There is no specific path resistance or test for this failure.

CAUTION Remove all user wiring and connections from the plug-in modules before troubleshooting or testing.

To check contact resistance:

1 Set the DMM to measure 4-wire Ω.

2 Connect the DMM High to an SMB plug center conductor and the Low to the SMB plug shield.

3 Connect the SMB plug to the module’s COM connector.

4 Connect an SMB short to the channel jack to be tested.

5 Using the Soft Front Panel software, close the channel to be tested.

6 Measure the contact resistance then open the channel.

7 Repeat steps 4 through 6 for all channels on the module.

NOTE Contact or path resistance is not specified for the RF modules. Measuring dc path resistance provides a simple functional testing of the relays.

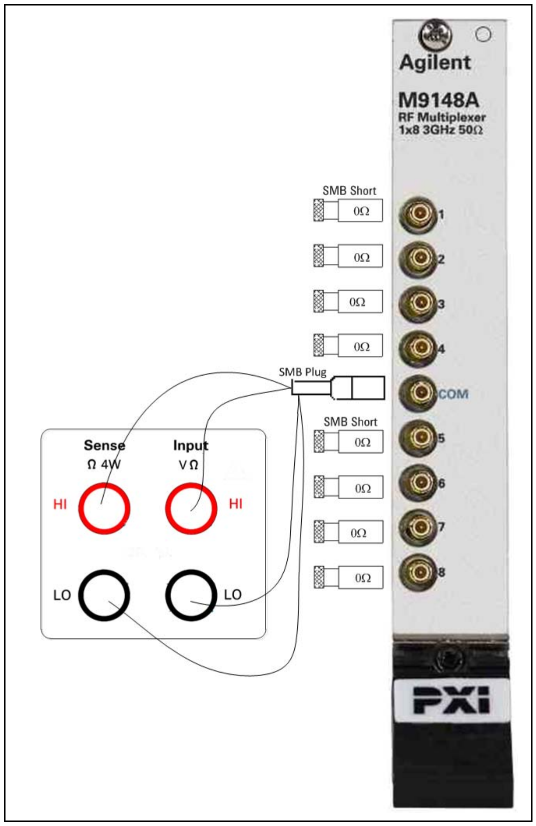


Figure 17 DC Path Resistance Measurements

RF Measurements Tests

RF test measurements (VSWR, Insertion, and Isolation tests) are described in Appendix A, “Making RF Test Measurements,” starting on page 103.

M9148A Functional Test Record

Path Contact Resistance Tests

DC path resistance is not specified for the RF switch modules. Measuring dc path resistance provides a simple test to determine if relays are closed or open. In general, maximum dc path resistance should not exceed 5Ω.

Channel	Measured Value
Channel 1	
Channel 2	
Channel 3	
Channel 4	
Channel 5	
Channel 6	
Channel 7	
Channel 8	

VSWR Tests

Channel	Functional Test Limit	Measured Value
Channel 1	< 1.35:1 to 3 GHz	
Channel 2	< 1.35:1 to 3 GHz	
Channel 3	< 1.35:1 to 3 GHz	
Channel 4	< 1.35:1 to 3 GHz	
Channel 5	< 1.35:1 to 3 GHz	
Channel 6	< 1.35:1 to 3 GHz	
Channel 7	< 1.35:1 to 3 GHz	
Channel 8	< 1.35:1 to 3 GHz	

Insertion Loss Tests

Channel	Functional Test Limit	Measured Value
Channel 1	> 1.2 dB @ 3 GHz	
Channel 2	> 1.2 dB @ 3 GHz	
Channel 3	> 1.2 dB @ 3 GHz	
Channel 4	> 1.2 dB @ 3 GHz	
Channel 5	> 1.2 dB @ 3 GHz	
Channel 6	> 1.2 dB @ 3 GHz	
Channel 7	> 1.2 dB @ 3 GHz	
Channel 8	> 1.2 dB @ 3 GHz	

Open Channel Isolation Tests

Channel	Functional Test Limit	Measured Value
Channel 1	> 38 dB @ 3 GHz	
Channel 2	> 38 dB @ 3 GHz	
Channel 3	> 38 dB @ 3 GHz	
Channel 4	> 38 dB @ 3 GHz	
Channel 5	> 38 dB @ 3 GHz	
Channel 6	> 38 dB @ 3 GHz	
Channel 7	> 38 dB @ 3 GHz	
Channel 8	> 38 dB @ 3 GHz	

Adjacent Channel Isolation (crosstalk) Tests

Channel	Functional Test Limit	Measured Value
Ch 1 - Ch 2	> 37 dB @ 3 GHz	
Ch 2- Ch 3	> 37 dB @ 3 GHz	
Ch 3- Ch 4	> 37 dB @ 3 GHz	
Ch 4- Ch 5	> 37 dB @ 3 GHz	
Ch 5- Ch 6	> 37 dB @ 3 GHz	
Ch 6- Ch 7	> 37 dB @ 3 GHz	
Ch 7- Ch 8	> 37 dB @ 3 GHz	

M9148A Schematic

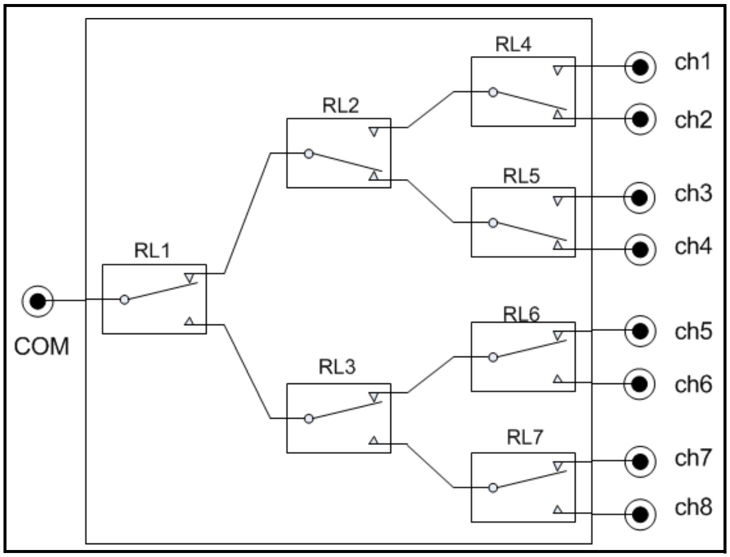


Figure 18 M9148A Schematic

M9148A PC Board Layout

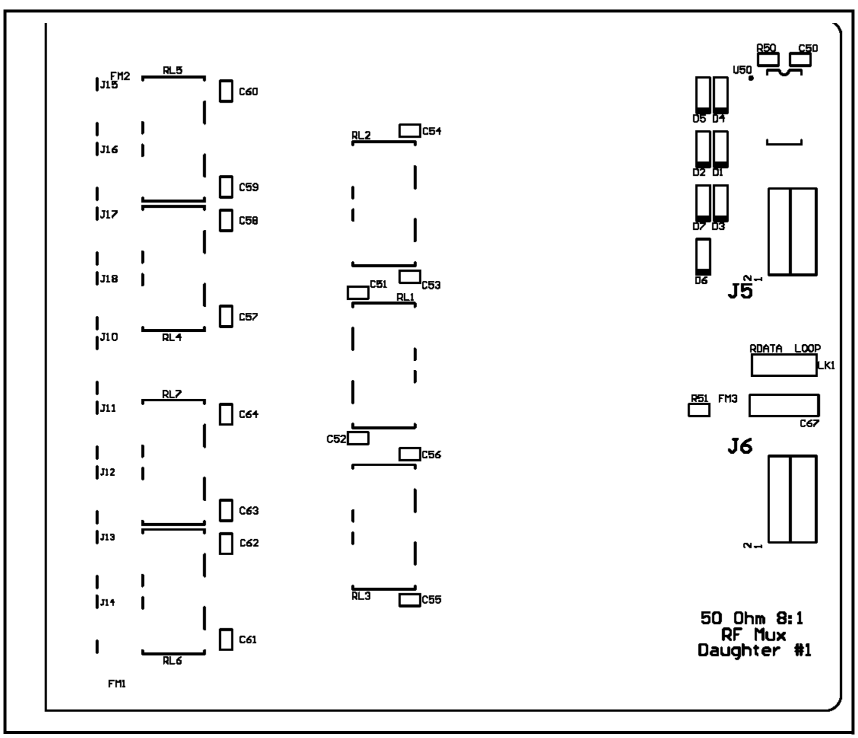


Figure 19 M9148A PC Board Relay Layout

6
M9149A High Density RF Multiplexer, 3 GHz, 1x16 50 Ohm

Introduction

Agilent's M9149A 1x16 50 Ω Multiplexer Module exhibits low insertion loss and VSWR. This module features excellent insertion loss and VSWR for better RF signal integrity as well as outstanding dynamic range for routing RF signals into your measurement equipment. In addition, each path is carefully designed to ensure repeatable RF performance. Connections are made through easy, snap-on SMB front panel connectors.

Default switch path

Switch Model	Bank	Default Path
M9149A, 1x16, 50Ω	1	Com to channel 13

Replacement Relays and Boards

The M9149A module has one PXI interface board with relay drivers and two daughter boards with the actual relays. If a channel is defective, you may replace the individual relay(s). The two daughter boards are not identical but they are a matched set and cannot be replaced individually. The two daughter boards mate together with an SMB jack/plug. When replacing individual relays, improper relay placement, too much solder, etc., may alter the signal path RF characteristics (VSWR, insertion loss, crosstalk, etc.).

Relay 5VDC coil, 2A 250V 178-Ohm SMT	Agilent P.N.: 0490-2946

See Appendix 11, “Disassembling the RF Matrix and Multiplexer Modules,” starting on page 93 for disassembly instructions.

Troubleshooting and Functional Testing

Testing Path Contact Resistance

Contact resistance checks can help isolate problems. When checking contact resistance through SMB connectors, each resistance measurement includes four sets of relay contacts (a channel relay, two tree relays, and a COM relay). Check all of the paths in each bank to help isolate a problem to a specific relay. For example, if both channels 1 and 2 in Bank 1 have high contact resistance but channels 3 and 4 are normal, then a tree relays may be suspect.

When all relays are "open," a resistance measured on any channel path indicates a welded contacts condition and the relay or module must be replaced. There is no specific path resistance or test for this failure.

CAUTION Remove all user wiring and connections from the plug-in modules before troubleshooting or testing.

To check contact resistance:

1 Set the DMM to measure 4-wire Ω.
2 Connect the DMM High to an SMB plug center conductor and the Low to the SMB plug shield.
3 Connect the SMB plug to the module's COM connector.
4 Connect an SMB short to the channel jack to be tested.
5 Using the Soft Front Panel software, close the channel to be tested.
6 Measure the contact resistance then open the channel.
7 Repeat steps 4 through 6 for all channels on the module.

NOTE Contact or path resistance is not specified for the RF modules. Measuring dc path resistance provides a simple functional testing of the relays.

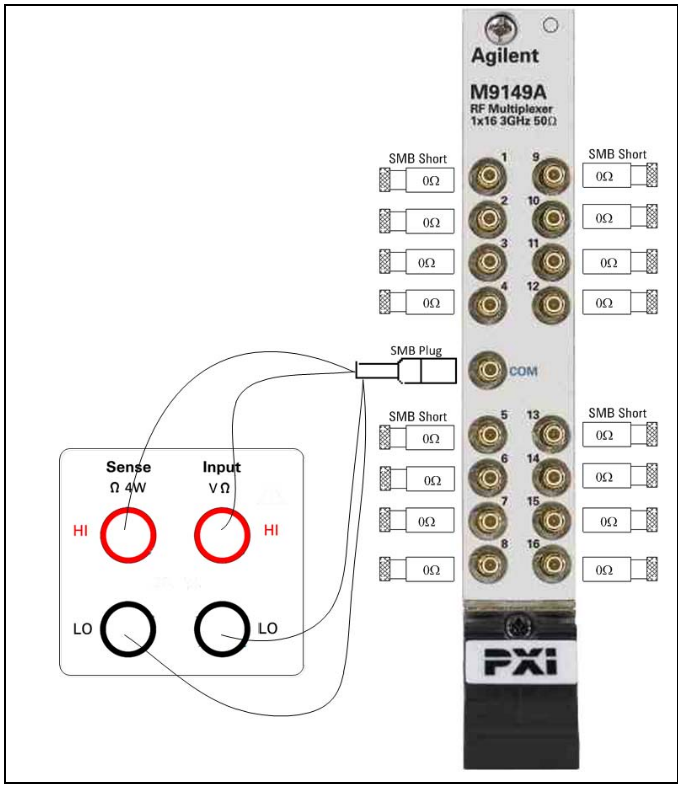


Figure 20 DC Path Resistance Measurements

RF Measurements Tests

RF test measurements (VSWR, Insertion, and Isolation tests) are described in Appendix A, “Making RF Test Measurements,” starting on page 103.

M9149A Functional Test Record

Path Contact Resistance Tests

DC path resistance is not specified for the RF switch modules. Measuring dc path resistance provides a simple test to determine if relays are closed or open. In general, maximum dc path resistance should not exceed 5Ω.

.

Channel	Measured Value
Channel 1	
Channel 2	
Channel 3	
Channel 4	
Channel 5	
Channel 6	
Channel 7	
Channel 8	

Channel	Measured Value
Channel 9	
Channel 10	
Channel 11	
Channel 12	
Channel 13	
Channel 14	
Channel 15	
Channel 16	

VSWR Tests

Channel	Functional Test Limit	Measured Value
Channel 1	< 1.55:1 to 3 GHz	
Channel 2	< 1.55:1 to 3 GHz	
Channel 3	< 1.55:1 to 3 GHz	
Channel 4	< 1.55:1 to 3 GHz	
Channel 5	< 1.55:1 to 3 GHz	
Channel 6	< 1.55:1 to 3 GHz	
Channel 7	< 1.55:1 to 3 GHz	
Channel 8	< 1.55:1 to 3 GHz	

Channel	Functional Test Limit	Measured Value
Channel 9	< 1.55:1 to 3 GHz	
Channel 10	< 1.55:1 to 3 GHz	
Channel 11	< 1.55:1 to 3 GHz	
Channel 12	< 1.55:1 to 3 GHz	
Channel 13	< 1.55:1 to 3 GHz	
Channel 14	< 1.55:1 to 3 GHz	
Channel 15	< 1.55:1 to 3 GHz	
Channel 16	< 1.55:1 to 3 GHz	

Insertion Loss Tests

Channel	Functional Test Limit	Measured Value
Channel 1	< 1.4 dB @ 3 GHz	
Channel 2	< 1.4 dB @ 3 GHz	
Channel 3	< 1.4 dB @ 3 GHz	
Channel 4	< 1.4 dB @ 3 GHz	
Channel 5	< 1.4 dB @ 3 GHz	
Channel 6	< 1.4 dB @ 3 GHz	
Channel 7	< 1.4 dB @ 3 GHz	
Channel 8	< 1.4 dB @ 3 GHz	

Channel	Functional Test Limit	Measured Value
Channel 9	< 1.4 dB @ 3 GHz	
Channel 10	< 1.4 dB @ 3 GHz	
Channel 11	< 1.4 dB @ 3 GHz	
Channel 12	< 1.4 dB @ 3 GHz	
Channel 13	< 1.4 dB @ 3 GHz	
Channel 14	< 1.4 dB @ 3 GHz	
Channel 15	< 1.4 dB @ 3 GHz	
Channel 16	< 1.4 dB @ 3 GHz	

Open Channel Isolation Tests

Channel	Functional Test Limit	Measured Value
Channel 1	> 38 dB @ 3 GHz	
Channel 2	> 38 dB @ 3 GHz	
Channel 3	> 38 dB @ 3 GHz	
Channel 4	> 38 dB @ 3 GHz	
Channel 5	> 38 dB @ 3 GHz	
Channel 6	> 38 dB @ 3 GHz	
Channel 7	> 38 dB @ 3 GHz	
Channel 8	> 38 dB @ 3 GHz	

Channel	Functional Test Limit	Measured Value
Channel 9	> 38 dB @ 3 GHz	
Channel 10	> 38 dB @ 3 GHz	
Channel 11	> 38 dB @ 3 GHz	
Channel 12	> 38 dB @ 3 GHz	
Channel 13	> 38 dB @ 3 GHz	
Channel 14	> 38 dB @ 3 GHz	
Channel 15	> 38 dB @ 3 GHz	
Channel 16	> 38 dB @ 3 GHz	

Adjacent Channel Isolation (crosstalk) Tests

Channel	Functional Test Limit	Measured Value
Ch 1 - Ch 2	> 37 dB @ 3 GHz	
Ch 2 - Ch 3	> 37 dB @ 3 GHz	
Ch 3 - Ch 4	> 37 dB @ 3 GHz	
Ch 4 - Ch 5	> 37 dB @ 3 GHz	
Ch 5 - Ch 6	> 37 dB @ 3 GHz	
Ch 6 - Ch 7	> 37 dB @ 3 GHz	
Ch 7 - Ch 8	> 37 dB @ 3 GHz	
Ch 8 - Ch 9	> 37 dB @ 3 GHz	

Channel	Functional Test Limit	Measured Value
Ch 9 - Ch 10	> 37 dB @ 3 GHz	
Ch 10 - Ch 11	> 37 dB @ 3 GHz	
Ch 11 - Ch 12	> 37 dB @ 3 GHz	
Ch 12 - Ch 13	> 37 dB @ 3 GHz	
Ch 13 - Ch 14	> 37 dB @ 3 GHz	
Ch 14 - Ch 15	> 37 dB @ 3 GHz	
Ch 15 - Ch 16	> 37 dB @ 3 GHz	

M9149A Schematic

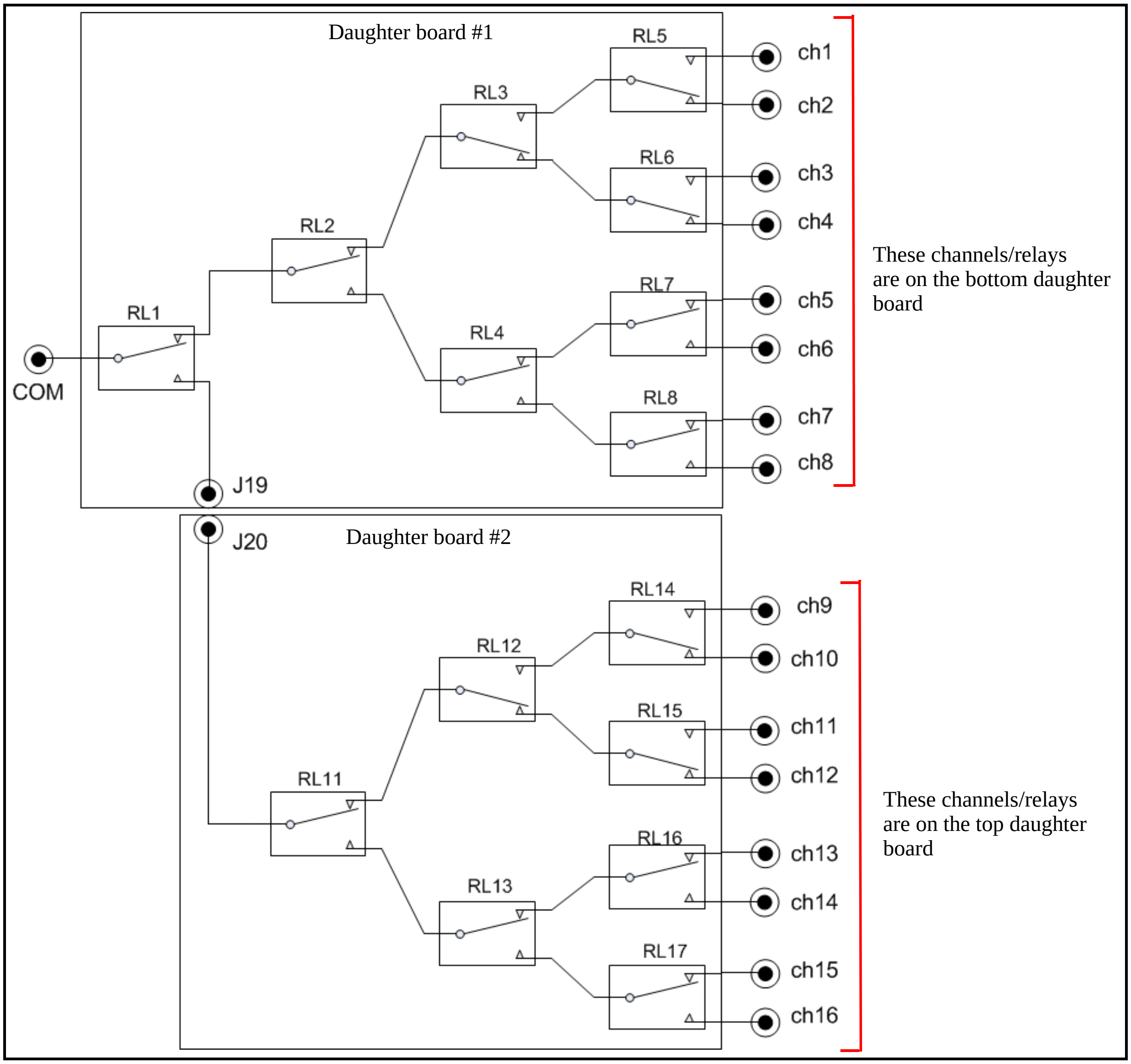


Figure 21 M9149A Schematic

M9149A PC Board Layout

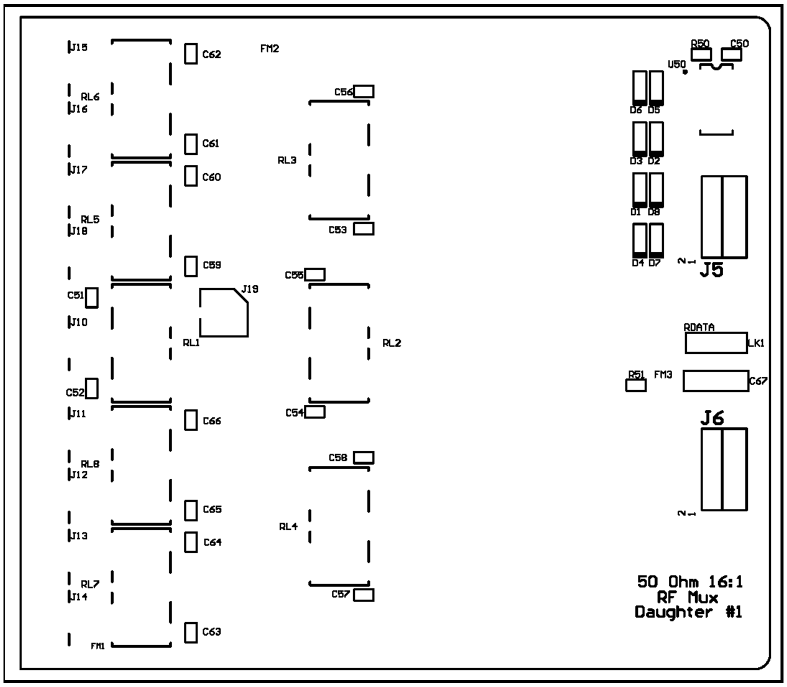


Figure 22 M9149A Daughter Board 1 PC Board Relay Layout

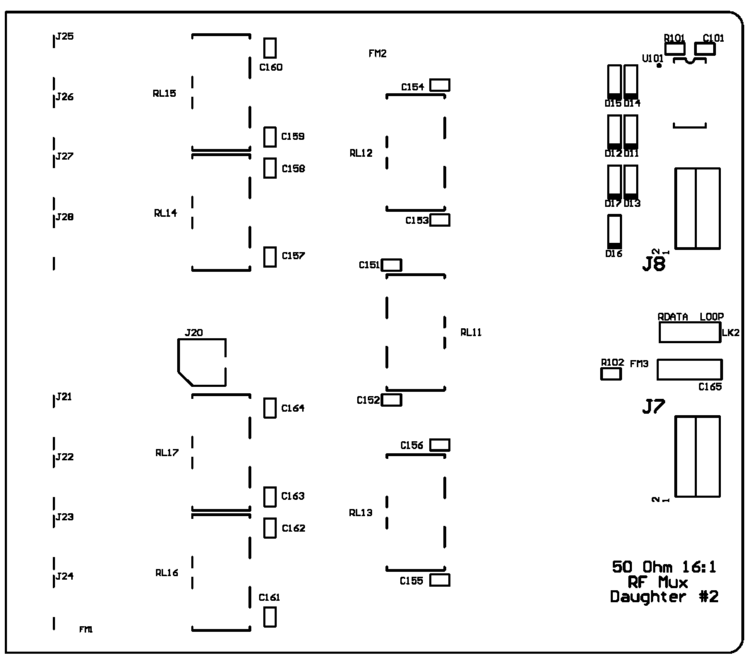


Figure 23 M9149A Daughter Board 2 PC Board Relay Layout

7
M9150A RF Multiplexer, 3 GHz, Dual 1x4, 75 Ohm

Introduction

Agilent's M9150A Dual 1x4 75 Ω Multiplexer Module exhibit low insertion loss and VSWR. The module is constructed as four separate 1X4 multiplexers. The 75 Ω inputs make it ideal for routing video RF signals. Each path is carefully designed to ensure repeatable RF performance. It also features easy, snap-on SMB front panel connectors.

NOTE A mini-SMB 75 Ω connector has the same physical dimensions as a standard 50 Ω SMB connector. For simplicity, this chapter refers to SMB connectors.

Default switch path

Switch Model	Bank	Default Path
M9150A, Dual 1X4, 75 Ω	1	Com1 to Bank 1, Channel 4
	2	Com 2 to Bank 2, Channel 4

Replacement Relays and Boards

The M9150A module has one PXI interface board with relay drivers and one daughter board with the actual channel relays. If a channel is defective, you may replace the individual relay(s) or replace the appropriate relay daughter board. When replacing individual relays, improper relay placement, too much solder, etc., may alter the signal path RF characteristics (VSWR, insertion loss, crosstalk, etc.).

Relay 5VDC coil, 2A 250V 178-Ohm SMT	Agilent P.N.: 0490-2945
M9150A Daughter Board	Agilent P.N.: M9150-66502

See Appendix 11, “Disassembling the RF Matrix and Multiplexer Modules,” starting on page 93 for disassembly instructions.

Troubleshooting and Functional Testing

Testing Path Contact Resistance

Contact resistance checks can help isolate problems. When checking contact resistance through SMB connectors, each resistance measurement includes two sets of relay contacts (a channel relay and a COM relay). Check all of the contacts in each bank to help isolate a problem to a specific relay. For example, if both channels 1 and 2 in Bank 1 have high contact resistance but channels 3 and 4 are normal, then the COM relay may be suspect.

When all relays are “open,” a resistance measured on any channel path indicates a welded contacts condition and the relay or module must be replaced. There is no specific path resistance or test for this failure.

CAUTION Remove all user wiring and connections from the plug-in modules before troubleshooting or testing.

To check contact resistance:

1 Set the DMM to measure 4-wire Ω.
2 Connect the DMM High to an SMB plug center conductor and the Low to the SMB plug shield.
3 Connect the SMB plug to the module’s COM1 connector.
4 Connect an SMB short to the channel jack to be tested.
5 Using the Soft Front Panel software, close the channel to be tested.
6 Measure the contact resistance then open the channel.
7 Repeat steps 4 through 6 for all channels on the module.

NOTE Contact or path resistance is not specified for the RF modules. Measuring dc path resistance provides a simple functional testing of the relays.

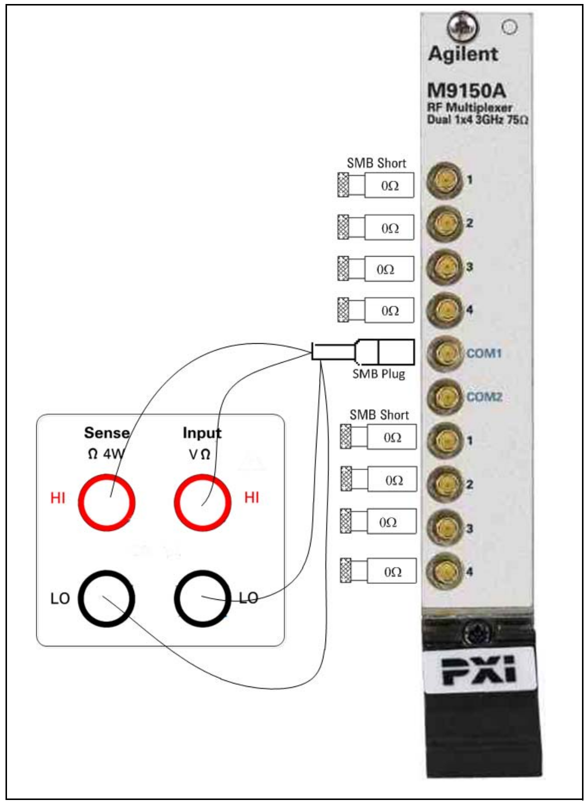


Figure 24 DC Path Resistance Measurements

RF Measurements Tests

RF test measurements (VSWR, Insertion, and Isolation tests) are described in Appendix A, “Making RF Test Measurements,” starting on page 103.

M9150A Functional Test Record

Path Contact Resistance Tests

DC path resistance is not specified for the RF switch modules. Measuring dc path resistance provides a simple test to determine if relays are closed or open. In general, maximum dc path resistance should not exceed 5Ω.

Channel	Measured Value
Bank 1	
Channel 1	
Channel 2	
Channel 3	
Channel 4	

Channel	Measured Value
Bank 2	
Channel 1	
Channel 2	
Channel 3	
Channel 3	

VSWR Tests

Channel	Functional Test Limit	Measured Value
Bank 1		
Channel 1	< 1.60:1 to 3 GHz	
Channel 2	< 1.60:1 to 3 GHz	
Channel 3	< 1.60:1 to 3 GHz	
Channel 4	< 1.60:1 to 3 GHz	

Channel	Functional Test Limit	Measured Value
Bank 2		
Channel 1	< 1.60:1 to 3 GHz	
Channel 2	< 1.60:1 to 3 GHz	
Channel 3	< 1.60:1 to 3 GHz	
Channel 3	< 1.60:1 to 3 GHz	

Insertion Loss Tests

Channel	Functional Test Limit	Measured Value
Bank 1		
Channel 1	< 1.6 dB to 3 GHz	
Channel 2	< 1.6 dB to 3 GHz	
Channel 3	< 1.6 dB to 3 GHz	
Channel 4	< 1.6 dB to 3 GHz	

Channel	Functional Test Limit	Measured Value
Bank 2		
Channel 1	< 1.6 dB to 3 GHz	
Channel 2	< 1.6 dB to 3 GHz	
Channel 3	< 1.6 dB to 3 GHz	
Channel 3	< 1.6 dB to 3 GHz	

Open Channel Isolation Tests

Channel	Functional Test Limit	Measured Value
Bank 1		
Channel 1	> 40 dB @ 3 GHz	
Channel 2	> 40 dB @ 3 GHz	
Channel 3	> 40 dB @ 3 GHz	
Channel 4	> 40 dB @ 3 GHz	

Channel	Functional Test Limit	Measured Value
Bank 2		
Channel 1	> 40 dB @ 3 GHz	
Channel 2	> 40 dB @ 3 GHz	
Channel 3	> 40 dB @ 3 GHz	
Channel 3	> 40 dB @ 3 GHz	

Adjacent Channel Isolation (crosstalk) Tests

Channel	Functional Test Limit	Measured Value
Bank 1		
Ch 1 - Ch 2	> 40 dB @ 3 GHz	
Ch 2 - Ch 3	> 40 dB @ 3 GHz	
Ch 3 - Ch 4	> 40 dB @ 3 GHz	

Channel	Functional Test Limit	Measured Value
Bank 2		
Ch 1 - Ch 2	> 40 dB @ 3 GHz	
Ch 2 - Ch 3	> 40 dB @ 3 GHz	
Ch 3 - Ch 4	> 40 dB @ 3 GHz	

Bank to Bank Isolation (crosstalk) Tests

Test Description	Functional Test Limit	Measured Value
Bank 1- Bank2	> 40 dB @ 3 GHz	

M9150A Schematic

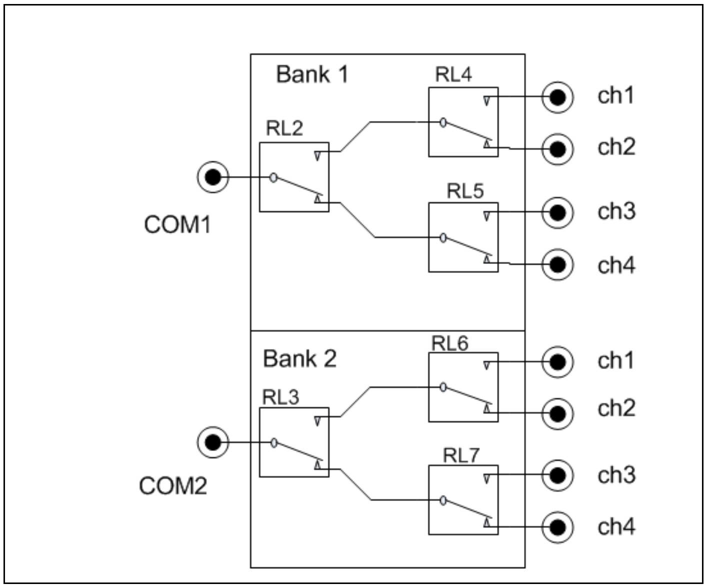


Figure 25 M9150A Schematic

M9150A PC Board Layout

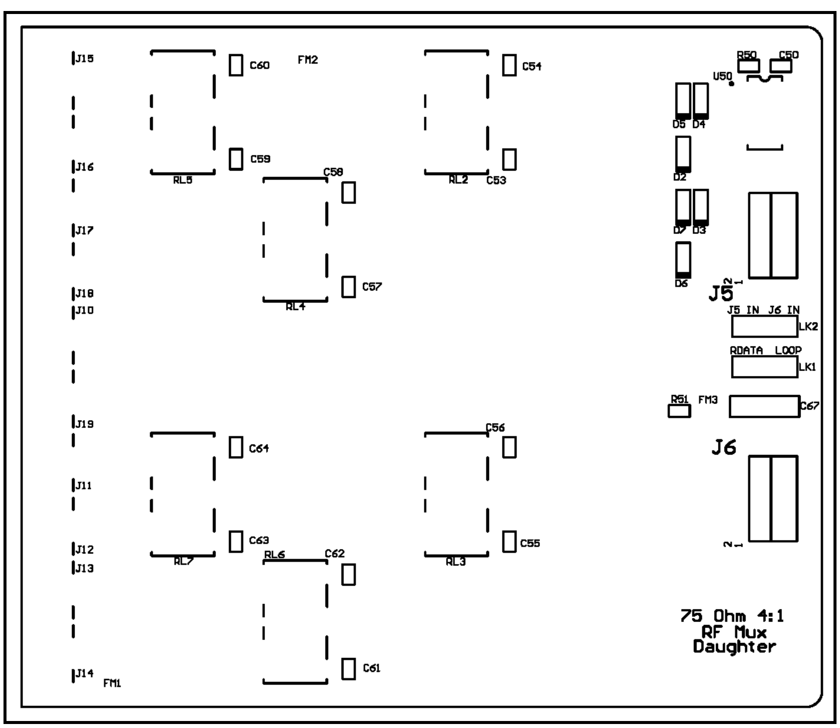


Figure 26 M9150A PC Board Relay Layout
both daughter boards are identical

8
M9151A RF Multiplexer, 3 GHz, Quad 1x4, 75 Ohm

Introduction

Agilent's M9151A quad 1x4 75 Ω Multiplexer Module exhibit low insertion loss and VSWR. The module is constructed as four separate 1X4 multiplexers. The 75 Ω inputs make it ideal for routing video RF signals. Each path is carefully designed to ensure repeatable RF performance. It also features easy, snap-on SMB front panel connectors.

NOTE A mini-SMB 75 Ω connector has the same physical dimensions as a standard 50 Ω SMB connector. For simplicity, this chapter refers to SMB connectors.

Default switch path

Switch Model	Bank	Default Path
M9151A, Quad 1X4, 75 Ω	1	Com1 to Bank 1, Channel 4
	2	Com2 to Bank 2, Channel 4
	3	Com3 to Bank 3, Channel 4
	4	Com4 to Bank 4, Channel 4

Replacement Relays and Boards

The M9151A module has one PXI interface board with relay drivers and two daughter boards with the actual relays. If a channel is defective, you may replace he individual relay(s) or replace the appropriate relay daughter board. The two daughter boards are identical. When replacing individual relays, improper relay placement, too much solder, etc., may alter the signal path RF characteristics (VSWR, insertion loss, crosstalk, etc.).

Relay 5VDC coil, 2A 250V 178-Ohm SMT	Agilent P.N.: 0490-2945
M9151A Daughter Board	Agilent P.N.: M9151-66502

See Appendix 11, “Disassembling the RF Matrix and Multiplexer Modules,” starting on page 93 for disassembly instructions.

Troubleshooting and Functional Testing

Testing Path Contact Resistance

Contact resistance checks can help isolate problems. When checking contact resistance through SMB connectors, each resistance measurement includes two sets of relay contacts (a channel relay and a COM relay). Check all of the paths in each bank to help isolate a problem to a specific relay. For example, if both channels 1 and 2 in Bank 1 have high contact resistance but channels 3 and 4 are normal, then the COM relay may be suspect.

When all relays are “open,” a resistance measured on any channel path indicates a welded contacts condition and the relay or module must be replaced. There is no specific path resistance or test for this failure.

CAUTION Remove all user wiring and connections from the plug-in modules before troubleshooting or testing.

To check contact resistance:

1 Set the DMM to measure 4-wire Ω.
2 Connect the DMM High to an SMB plug center conductor and the Low to the SMB plug shield.
3 Connect the SMB plug to the module’s COM1, COM2, COM3 or COM 4 connector.
4 Connect an SMB short to the channel jack to be tested.
5 Using the Soft Front Panel software, close the channel to be tested.
6 Measure the contact resistance then open the channel.
7 Repeat steps 3 through 6 for all channels on the module.

NOTE Contact or path resistance is not specified for the RF modules. Measuring dc path resistance provides a simple functional testing of the relays.

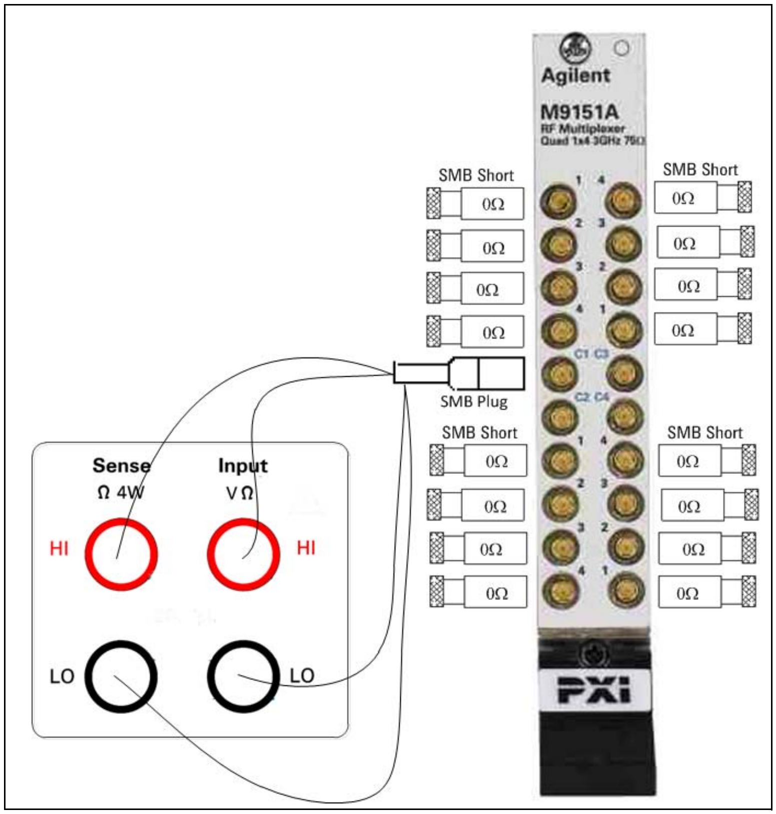


Figure 27 DC Path Resistance Measurements

RF Measurements Tests

RF test measurements (VSWR, Insertion, and Isolation tests) are described in Appendix A, “Making RF Test Measurements,” starting on page 103.

M9151A Functional Test Record

Path Contact Resistance Tests

DC path resistance is not specified for the RF switch modules. Measuring dc path resistance provides a simple test to determine if relays are closed or open. In general, maximum dc path resistance should not exceed 5Ω.

Channels	Measured Value
Bank 1	
Channel 1	
Channel 2	
Channel 3	
Channel 4	
Bank 3	
Channel 1	
Channel 2	
Channel 3	
Channel 4	

Channels	Measured Value
Bank 2	
Channel 1	
Channel 2	
Channel 3	
Channel 3	
Bank 4	
Channel 1	
Channel 2	
Channel 3	
Channel 4	

VSWR Tests

Channels	Functional Test Limit	Measured Value
Bank 1		
Channel 1	< 1.6:1 to 3 GHz	
Channel 2	< 1.6:1 to 3 GHz	
Channel 3	< 1.6:1 to 3 GHz	
Channel 4	< 1.6:1 to 3 GHz	
Bank 3		
Channel 1	< 1.6:1 to 3 GHz	
Channel 2	< 1.6:1 to 3 GHz	
Channel 3	< 1.6:1 to 3 GHz	
Channel 4	< 1.6:1 to 3 GHz	

Channels	Functional Test Limit	Measured Value
Bank 2		
Channel 1	< 1.6:1 to 3 GHz	
Channel 2	< 1.6:1 to 3 GHz	
Channel 3	< 1.6:1 to 3 GHz	
Channel 3	< 1.6:1 to 3 GHz	
Bank 4		
Channel 1	< 1.6:1 to 3 GHz	
Channel 2	< 1.6:1 to 3 GHz	
Channel 3	< 1.6:1 to 3 GHz	
Channel 4	< 1.6:1 to 3 GHz	

Insertion Loss Tests

Channels	Functional Test Limit	Measured Value
Bank 1		
Channel 1	< 1.6 dB @ 3 GHz	
Channel 2	< 1.6 dB @ 3 GHz	
Channel 3	< 1.6 dB @ 3 GHz	
Channel 4	< 1.6 dB @ 3 GHz	
Bank 3		
Channel 1	< 1.6 dB @ 3 GHz	
Channel 2	< 1.6 dB @ 3 GHz	
Channel 3	< 1.6 dB @ 3 GHz	
Channel 4	< 1.6 dB @ 3 GHz	

Channels	Functional Test Limit	Measured Value
Bank 2		
Channel 1	< 1.6 dB @ 3 GHz	
Channel 2	< 1.6 dB @ 3 GHz	
Channel 3	< 1.6 dB @ 3 GHz	
Channel 3	< 1.6 dB @ 3 GHz	
Bank 4		
Channel 1	< 1.6 dB @ 3 GHz	
Channel 2	< 1.6 dB @ 3 GHz	
Channel 3	< 1.6 dB @ 3 GHz	
Channel 4	< 1.6 dB @ 3 GHz	

Open Channel Isolation Tests

Channels	Functional Test Limit	Measured Value
Bank 1		
Channel 1	> 40 dB @ 3 GHz	
Channel 2	> 40 dB @ 3 GHz	
Channel 3	> 40 dB @ 3 GHz	
Channel 4	> 40 dB @ 3 GHz	
Bank 3		
Channel 1	> 40 dB @ 3 GHz	
Channel 2	> 40 dB @ 3 GHz	
Channel 3	> 40 dB @ 3 GHz	
Channel 4	> 40 dB @ 3 GHz	

Channels	Functional Test Limit	Measured Value
Bank 2		
Channel 1	> 40 dB @ 3 GHz	
Channel 2	> 40 dB @ 3 GHz	
Channel 3	> 40 dB @ 3 GHz	
Channel 3	> 40 dB @ 3 GHz	
Bank 4		
Channel 1	> 40 dB @ 3 GHz	
Channel 2	> 40 dB @ 3 GHz	
Channel 3	> 40 dB @ 3 GHz	
Channel 4	> 40 dB @ 3 GHz	

Adjacent Channel Isolation (crosstalk) Tests

Channels	Functional Test Limit	Measured Value
Bank 1		
Ch 1 - Ch 2	> 40 dB @ 3 GHz	
Ch 2 - Ch 3	> 40 dB @ 3 GHz	
Ch 3 - Ch 4	> 40 dB @ 3 GHz	
Bank 3		
Ch 1 - Ch 2	> 40 dB @ 3 GHz	
Ch 2 - Ch 3	> 40 dB @ 3 GHz	
Ch 3 - Ch 4	> 40 dB @ 3 GHz	

Channels	Functional Test Limit	Measured Value
Bank 2		
Ch 1 - Ch 2	> 40 dB @ 3 GHz	
Ch 2 - Ch 3	> 40 dB @ 3 GHz	
Ch 3 - Ch 4	> 40 dB @ 3 GHz	
Bank 4		
Ch 1 - Ch 2	> 40 dB @ 3 GHz	
Ch 2 - Ch 3	> 40 dB @ 3 GHz	
Ch 3 - Ch 4	> 40 dB @ 3 GHz	

Bank to Bank Isolation (crosstalk) Tests

Test Description	Functional Test Limit	Measured Value
Bank 1- Bank3	> 36dB @ 3 GHz	
Bank 2- Bank4	> 36 dB @ 3 GHz	

M9151A Schematic

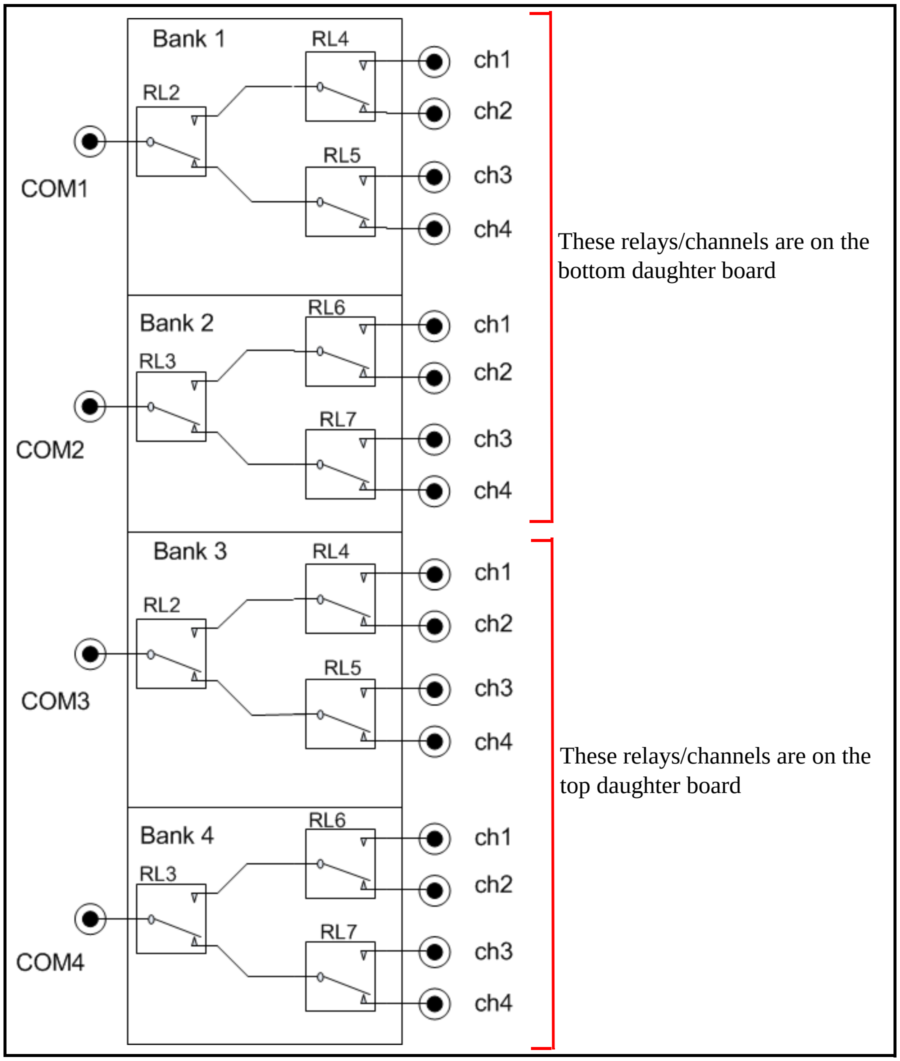


Figure 28 M9151A Schematic

M9151A PC Board Layout

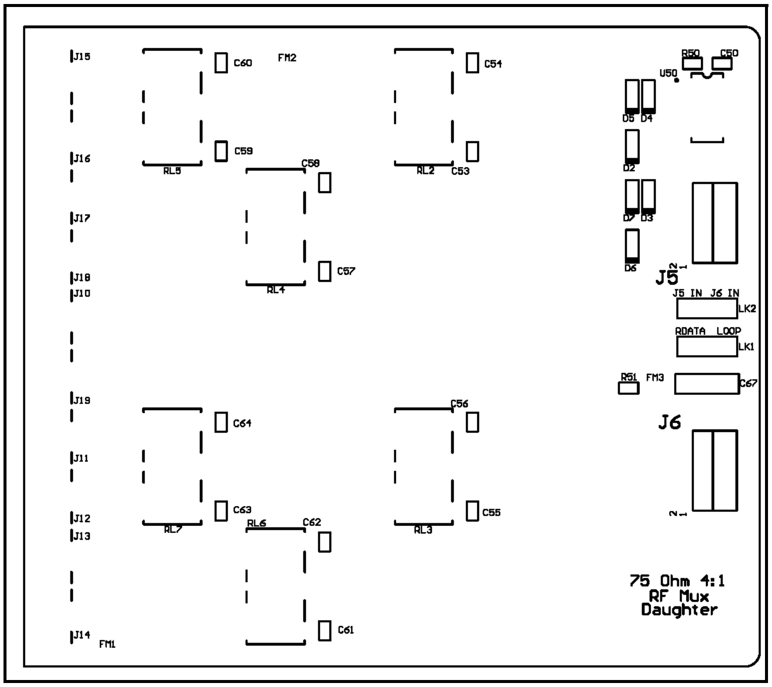


Figure 29 M9151A Daughter PC Board Relay Layout
both daughter boards are identical

9
M9152A RF Multiplexer, 3 GHz, 1x8, 75 Ohm

Introduction

Agilent's M9152A 1x8 75 Ω Multiplexer Module exhibits low insertion loss and VSWR. The 75 Ω inputs make it ideal for routing video RF signals. Each path is carefully designed to ensure repeatable RF performance. It also features easy, snap-on SMB front panel connectors.

NOTE A mini-SMB 75 Ω connector has the same physical dimensions as a standard 50 Ω SMB connector. For simplicity, this chapter refers to SMB connectors.

Default switch path

Switch Model	Bank	Default Path
M9152A, 1X8, 75 Ω	1	Com to Channel 4

Replacement Relays and Boards

The M9152A module has one PXI interface board with relay drivers and one daughter board with the actual channel relays. If a channel is defective, you may replace the individual relay(s) or replace the relay daughter board. When replacing individual relays, improper relay placement, too much solder, etc., may alter the signal path RF characteristics (VSWR, insertion loss, crosstalk, etc.).

Relay 5VDC coil, 2A 250V 178-Ohm SMT	Agilent P.N.: 0490-2945
M9152A Daughter Board	Agilent P.N.: M9152-66502

See Appendix 11, “Disassembling the RF Matrix and Multiplexer Modules,” starting on page 93 for disassembly instructions.

Troubleshooting and Functional Testing

Testing Path Contact Resistance

Contact resistance checks can help isolate problems. When checking contact resistance through SMB connectors, each resistance measurement includes three sets of relay contacts (a channel relay, a tree relay, and a COM relay). Check all of the paths in each bank to help isolate a problem to a specific relay. For example, if both channels 1 and 2 in Bank 1 have high contact resistance but channels 3 and 4 are normal, then the tree relay may be suspect.

When all relays are “open,” a resistance measured on any channel path indicates a welded contacts condition and the relay or module must be replaced. There is no specific path resistance or test for this failure.

CAUTION Remove all user wiring and connections from the plug-in modules before troubleshooting or testing.

To check contact resistance:

1. Set the DMM to measure 4-wire Ω.
2. Connect the DMM High to an SMB plug center conductor and the Low to the SMB plug shield.
3. Connect the SMB plug to the module’s COM connector.
4. Connect an SMB short to the channel jack to be tested.
5. Using the Soft Front Panel software, close the channel to be tested.
6. Measure the contact resistance then open the channel.
7. Repeat steps 4 through 6 for all channels on the module.

NOTE Contact or path resistance is not specified for the RF modules. Measuring dc path resistance provides a simple functional testing of the relays.

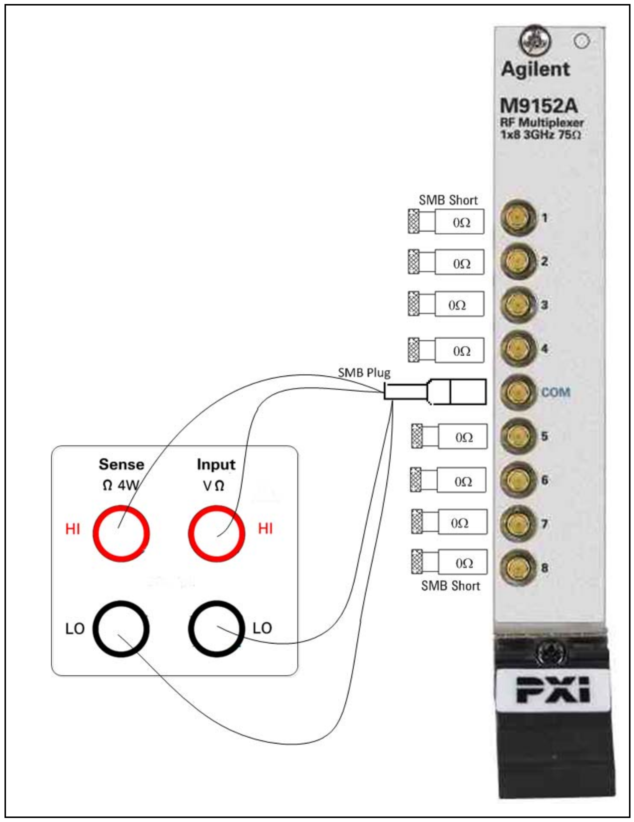


Figure 30 DC Path Resistance Measurements

RF Measurements Tests

RF test measurements (VSWR, Insertion, and Isolation tests) are described in Appendix A, “Making RF Test Measurements,” starting on page 103.

M9152A Functional Test Record

Path Contact Resistance Tests

DC path resistance is not specified for the RF switch modules. Measuring dc path resistance provides a simple test to determine if relays are closed or open. In general, maximum dc path resistance should not exceed 5Ω.

Channel	Measured Value
Channel 1	
Channel 2	
Channel 3	
Channel 4	
Channel 5	
Channel 6	
Channel 7	
Channel 8	

VSWR Tests

Channel	Functional Test Limit	Measured Value
Channel 1	< 1.55:1 to 3 GHz	
Channel 2	< 1.55:1 to 3 GHz	
Channel 3	< 1.55:1 to 3 GHz	
Channel 4	< 1.55:1 to 3 GHz	
Channel 5	< 1.55:1 to 3 GHz	
Channel 6	< 1.55:1 to 3 GHz	
Channel 7	< 1.55:1 to 3 GHz	
Channel 8	< 1.55:1 to 3 GHz	

Insertion Loss Tests

Channel	Functional Test Limit	Measured Value
Channel 1	< 2.1 dB @ 3 GHz	
Channel 2	< 2.1 dB @ 3 GHz	
Channel 3	< 2.1 dB @ 3 GHz	
Channel 4	< 2.1 dB @ 3 GHz	
Channel 5	< 2.1 dB @ 3 GHz	
Channel 6	< 2.1 dB @ 3 GHz	
Channel 7	< 2.1 dB @ 3 GHz	
Channel 8	< 2.1 dB @ 3 GHz	

Open Channel Isolation Tests

Channel	Functional Test Limit	Measured Value
Channel 1	> 39 dB @ 3 GHz	
Channel 2	> 39 dB @ 3 GHz	
Channel 3	> 39 dB @ 3 GHz	
Channel 4	> 39 dB @ 3 GHz	
Channel 5	> 39 dB @ 3 GHz	
Channel 6	> 39 dB @ 3 GHz	
Channel 7	> 39 dB @ 3 GHz	
Channel 8	> 39 dB @ 3 GHz	

Adjacent Channel Isolation (crosstalk) Tests

Channel	Functional Test Limit	Measured Value
Ch 1 - Ch 2	> 42 dB @ 3 GHz	
Ch 2 - Ch 3	> 42 dB @ 3 GHz	
Ch 3- Ch 4	> 42 dB @ 3 GHz	
Ch 4- Ch 5	> 42 dB @ 3 GHz	
Ch 5 - Ch 6	> 42 dB @ 3 GHz	
Ch 6- Ch 7	> 42 dB @ 3 GHz	
Ch 7- Ch 8	> 42 dB @ 3 GHz	

M9152A Schematic

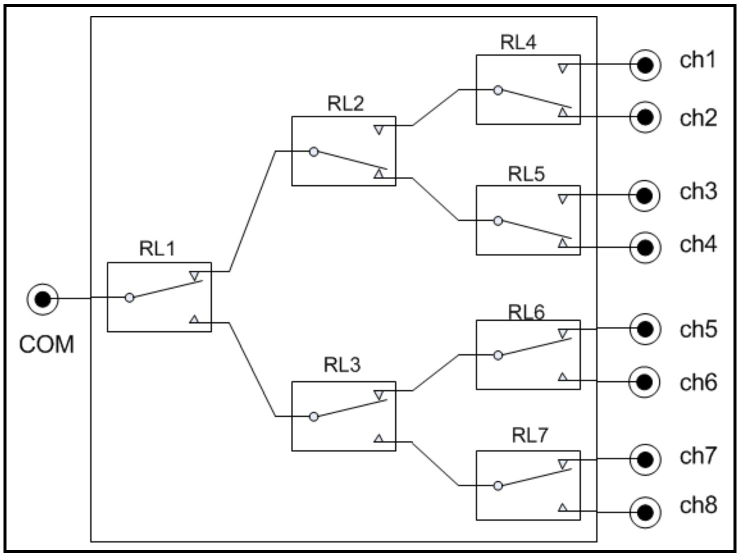


Figure 31 M9152A Schematic

M9152A PC Board Layout

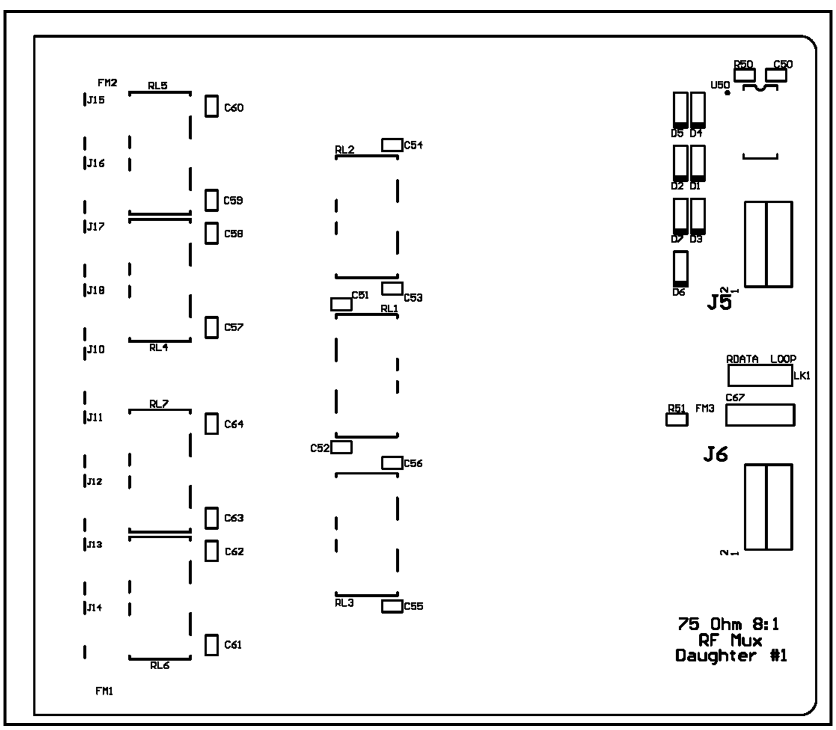


Figure 32 M9152A PC Board Relay Layout

10
M9153A RF Multiplexer, 3 GHz, 1x16, 75 Ohm

Introduction

Agilent's M9153A 1x16 75 Ω Multiplexer Module exhibits low insertion loss and VSWR. The 75 Ω inputs make it ideal for routing video RF signals. Each path is carefully designed to ensure repeatable RF performance. It also features easy, snap-on SMB front panel connectors.

NOTE A mini-SMB 75Ω connector has the same physical dimensions as a standard 50Ω SMB connector. For simplicity, this chapter refers to SMB connectors.

Default switch path

Switch Model	Bank	Default Path
M9153A, 1X16, 75 Ω	1	Com to Channel 13

Replacement Relays and Boards

The M9153A module has one PXI interface board with relay drivers and two daughter board with the actual channel relays. If a channel is defective, you may replace the individual relay(s). The two daughter boards are not identical but they are a matched set and cannot be replaced individually. They mate together with an SMB jack/plug. When replacing individual relays, improper relay placement, too much solder, etc., may alter the signal path RF characteristics (VSWR, insertion loss, crosstalk, etc.).

Relay 5VDC coil, 2A 250V 178-Ohm SMT	Agilent P.N.: 0490-2945

See Appendix 11, “Disassembling the RF Matrix and Multiplexer Modules,” starting on page 93 for disassembly instructions.

Troubleshooting and Functional Testing

Testing Path Contact Resistance

Contact resistance checks can help isolate problems. When checking contact resistance through SMB connectors, each resistance measurement includes four sets of relay contacts (a channel relay, two tree relays, and a COM relay). Check all of the paths in each bank to help isolate a problem to a specific relay. For example, if both channels 1 and 2 in Bank 1 have high contact resistance but channels 3 and 4 are normal, then a tree relay may be suspect.

When all relays are “open,” a resistance measured on any channel path indicates a welded contacts condition and the relay or module must be replaced. There is no specific path resistance or test for this failure.

CAUTION Remove all user wiring and connections from the plug-in modules before troubleshooting or testing.

To check contact resistance:

1 Set the DMM to measure 4-wire Ω.
2 Connect the DMM High to an SMB plug center conductor and the Low to the SMB plug shield.
3 Connect the SMB plug to the module’s COM connector.
4 Connect an SMB short to the channel jack to be tested.
5 Using the Soft Front Panel software, close the channel to be tested.
6 Measure the contact resistance then open the channel.
7 Repeat steps 4 through 6 for all channels on the module.

NOTE Contact or path resistance is not specified for the RF modules. Measuring dc path resistance provides a simple functional testing of the relays.

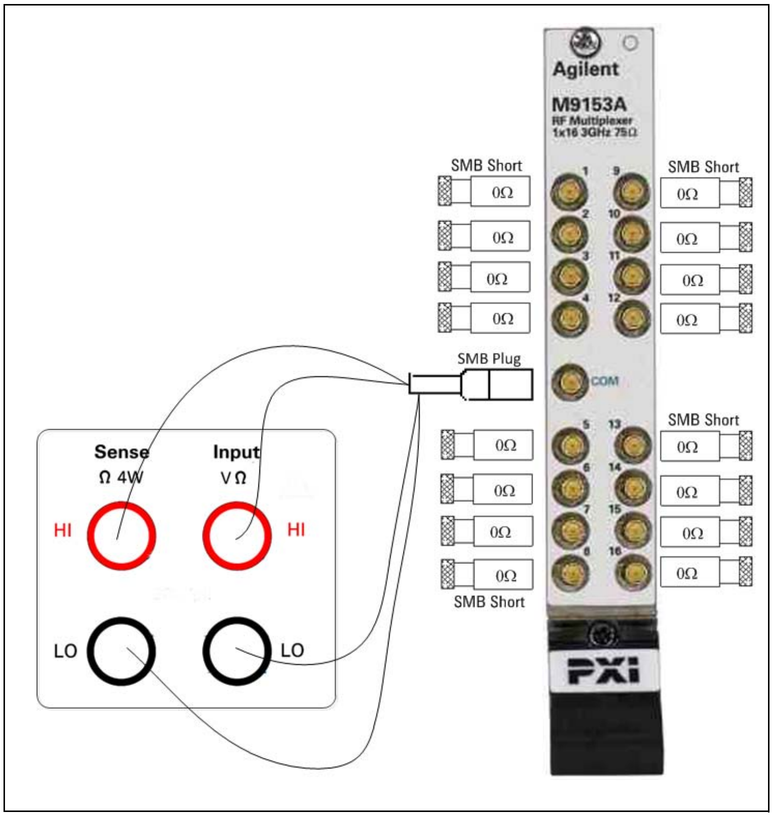


Figure 33 DC Path Resistance Measurements

RF Measurements Tests

RF test measurements (VSWR, Insertion, and Isolation tests) are described in Appendix A, “Making RF Test Measurements,” starting on page 103.

M9153A Functional Test Record

Path Contact Resistance Tests

DC path resistance is not specified for the RF switch modules. Measuring dc path resistance provides a simple test to determine if relays are closed or open. In general, maximum dc path resistance should not exceed 5Ω.

Channel	Measured Value
Channel 1	
Channel 2	
Channel 3	
Channel 4	
Channel 5	
Channel 6	
Channel 7	
Channel 8	

Channel	Measured Value
Channel 9	
Channel 10	
Channel 11	
Channel 12	
Channel 13	
Channel 14	
Channel 15	
Channel 16	

VSWR Tests

Channel	Functional Test Limit	Measured Value
Channel 1	< 1.6:1 to 3 GHz	
Channel 2	< 1.6:1 to 3 GHz	
Channel 3	< 1.6:1 to 3 GHz	
Channel 4	< 1.6:1 to 3 GHz	
Channel 5	< 1.6:1 to 3 GHz	
Channel 6	< 1.6:1 to 3 GHz	
Channel 7	< 1.6:1 to 3 GHz	
Channel 8	< 1.6:1 to 3 GHz	

Channel	Functional Test Limit	Measured Value
Channel 9	< 1.6:1 to 3 GHz	
Channel 10	< 1.6:1 to 3 GHz	
Channel 11	< 1.6:1 to 3 GHz	
Channel 12	< 1.6:1 to 3 GHz	
Channel 13	< 1.6:1 to 3 GHz	
Channel 14	< 1.6:1 to 3 GHz	
Channel 15	< 1.6:1 to 3 GHz	
Channel 16	< 1.6:1 to 3 GHz	

Insertion Loss Tests

Channel	Functional Test Limit	Measured Value
Channel 1	< 1.9 dB @ 3 GHz	
Channel 2	< 1.9 dB @ 3 GHz	
Channel 3	< 1.9 dB @ 3 GHz	
Channel 4	< 1.9 dB @ 3 GHz	
Channel 5	< 1.9 dB @ 3 GHz	
Channel 6	< 1.9 dB @ 3 GHz	
Channel 7	< 1.9 dB @ 3 GHz	
Channel 8	< 1.9 dB @ 3 GHz	

Channel	Functional Test Limit	Measured Value
Channel 9	< 1.9 dB @ 3 GHz	
Channel 10	< 1.9 dB @ 3 GHz	
Channel 11	< 1.9 dB @ 3 GHz	
Channel 12	< 1.9 dB @ 3 GHz	
Channel 13	< 1.9 dB @ 3 GHz	
Channel 14	< 1.9 dB @ 3 GHz	
Channel 15	< 1.9 dB @ 3 GHz	
Channel 16	< 1.9 dB @ 3 GHz	

Open Channel Isolation Tests

Channel	Functional Test Limit	Measured Value
Channel 1	> 38 dB @ 3 GHz	
Channel 2	> 38 dB @ 3 GHz	
Channel 3	> 38 dB @ 3 GHz	
Channel 4	> 38 dB @ 3 GHz	
Channel 5	> 38 dB @ 3 GHz	
Channel 6	> 38 dB @ 3 GHz	
Channel 7	> 38 dB @ 3 GHz	
Channel 8	> 38 dB @ 3 GHz	

Channel	Functional Test Limit	Measured Value
Channel 9	> 38 dB @ 3 GHz	
Channel 10	> 38 dB @ 3 GHz	
Channel 11	> 38 dB @ 3 GHz	
Channel 12	> 38 dB @ 3 GHz	
Channel 13	> 38 dB @ 3 GHz	
Channel 14	> 38 dB @ 3 GHz	
Channel 15	> 38 dB @ 3 GHz	
Channel 16	> 38 dB @ 3 GHz	

Adjacent Channel Isolation (crosstalk) Tests

Channel	Functional Test Limit	Measured Value
Ch 1 - Ch 2	> 42 dB @ 3 GHz	
Ch 2 - Ch 3	> 42 dB @ 3 GHz	
Ch 3 - Ch 4	> 42 dB @ 3 GHz	
Ch 4 - Ch 5	> 42 dB @ 3 GHz	
Ch 5 - Ch 6	> 42 dB @ 3 GHz	

Channel	Functional Test Limit	Measured Value
Ch 9- Ch 10	> 42 dB @ 3 GHz	
Ch 10 - Ch 11	> 42 dB @ 3 GHz	
Ch 11 - Ch 12	> 42 dB @ 3 GHz	
Ch 12 - Ch 13	> 42 dB @ 3 GHz	
Ch 13 - Ch 14	> 42 dB @ 3 GHz	

Channel	Functional Test Limit	Measured Value	Channel	Functional Test Limit	Measured Value
Ch 6 - Ch 7	> 42 dB @ 3 GHz		Ch 14 - Ch 15	> 42 dB @ 3 GHz	
Ch 7 - Ch 8	> 42 dB @ 3 GHz		Ch 15 - Ch 16	> 42 dB @ 3 GHz	
Ch 8 - Ch 9	> 42 dB @ 3 GHz				

M9153A Schematic

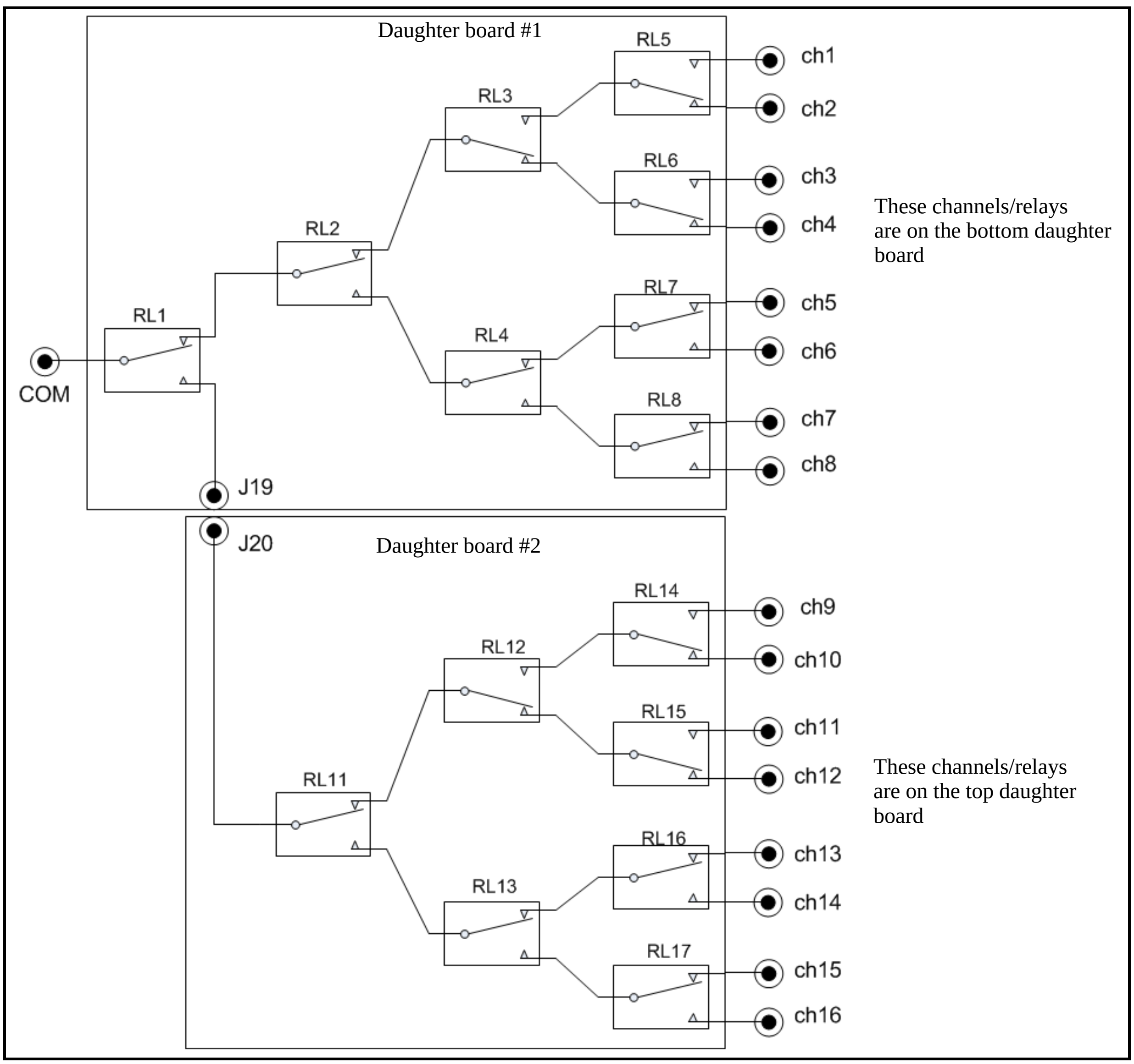


Figure 34 M9153A Schematic

M9153A PC Board Layout

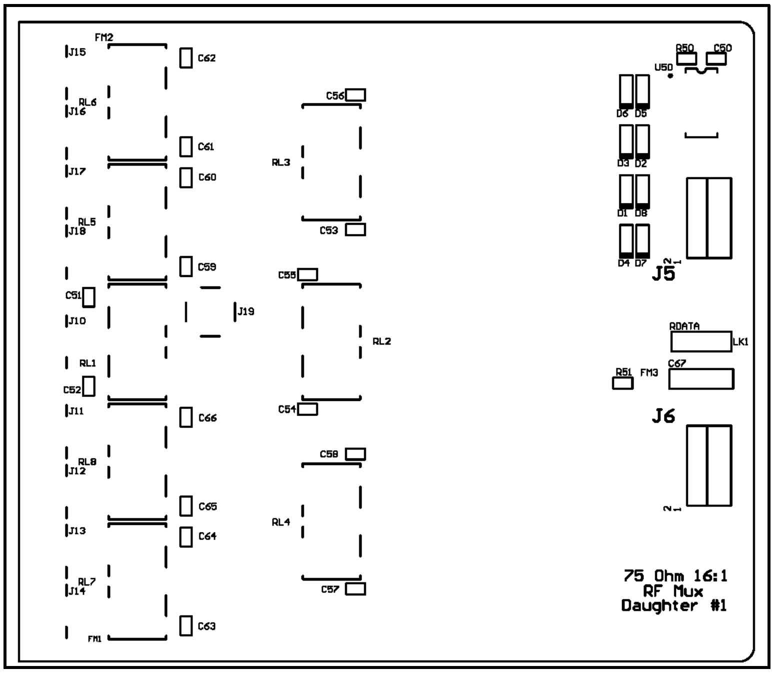


Figure 35 M9153A Daughter Board 1 PC Board Relay Layout

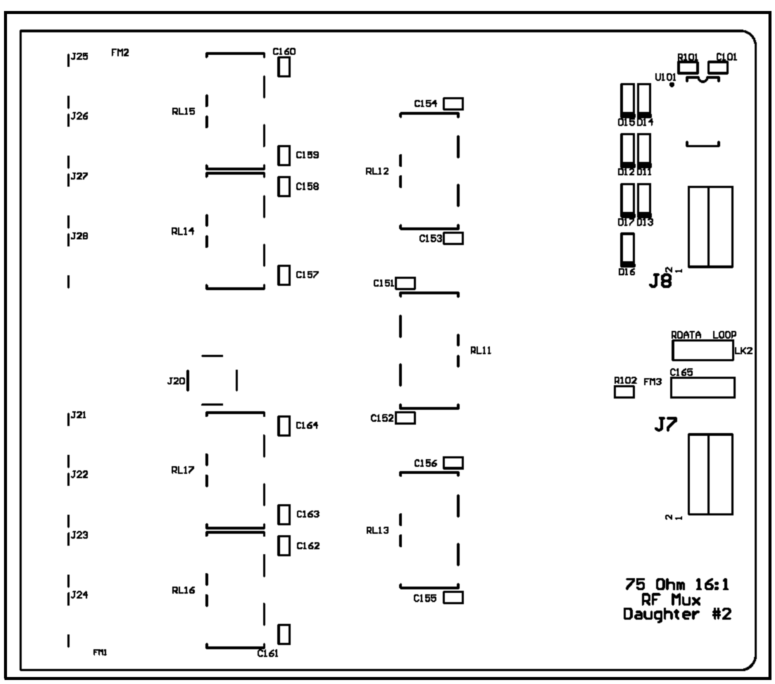


Figure 36 M9153A Daughter Board 2 PC Board Relay Layout

11
Disassembling the RF Matrix and Multiplexer Modules

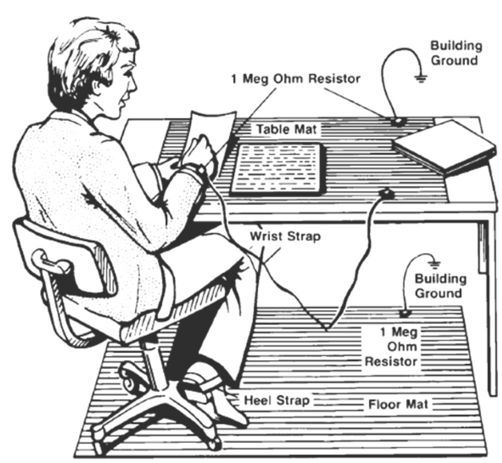
This chapter provides information about disassembling the Agilent PXI RF matrix and multiplexer modules. Please read all disassembly steps prior to starting the disassembly.

Electrostatic discharge precautions

CAUTION Agilent's PXI Switch Modules are shipped in materials that prevent static electricity damage. The modules should only be removed from the packaging in an anti-static area ensuring that correct anti-static precautions are taken. Store all modules in anti-static envelopes when not in use.

Electrostatic discharge (ESD) can damage or destroy electronic components. All work on electronic assemblies should be performed at a static-safe work station. The following figure shows an example of a static-safe work station using two types of ESD protection. Purchase acceptable ESD accessories from your local supplier.

- Conductive table-mat and wrist-strap combination.
- Conductive floor-mat and heel-strap combination.



Both types, when used together, provide a significant level of ESD protection. Of the two, only the table-mat and wrist-strap combination provides adequate ESD protection when used alone. To ensure user safety, the static-safe accessories must provide at least 1 MΩ of isolation from ground.

M9128A RF Matrix Module Disassembly

Refer to Figure 37.

1 The M9128A has one shield secured to the module with five screws. To gain access to the relays, remove the five screws and carefully lift the shield from the module.

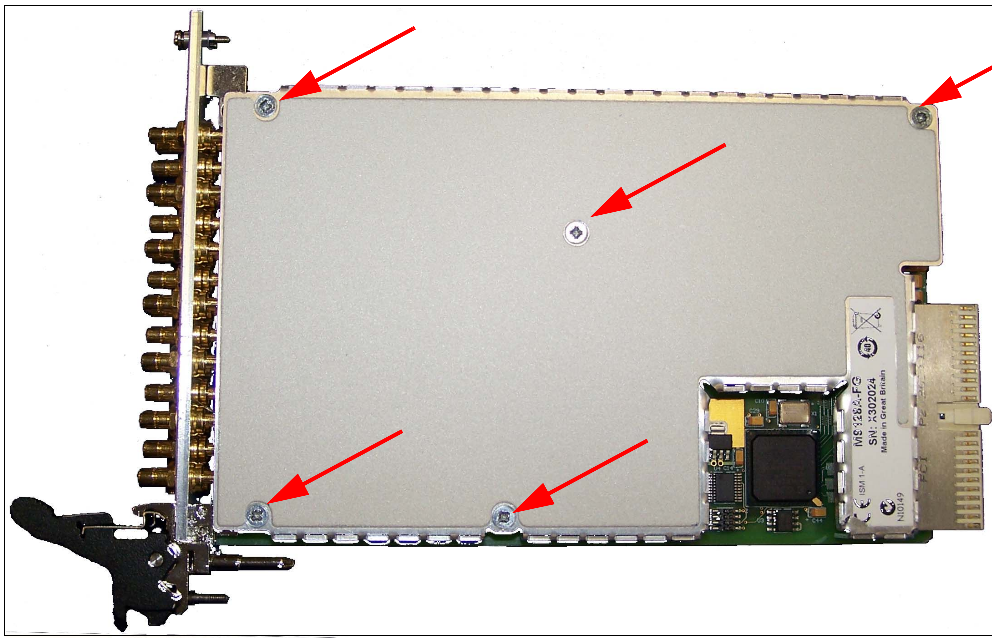


Figure 37 Top Shield of M9128A RF Matrix module

2 Locate and desolder the relay to replace on the bottom side; refer to Figure 7 on page 28 and Figure 8 on page 29.

3 On the top side of the module, carefully move the cabling to remove and replace the relays. See Figure 38.

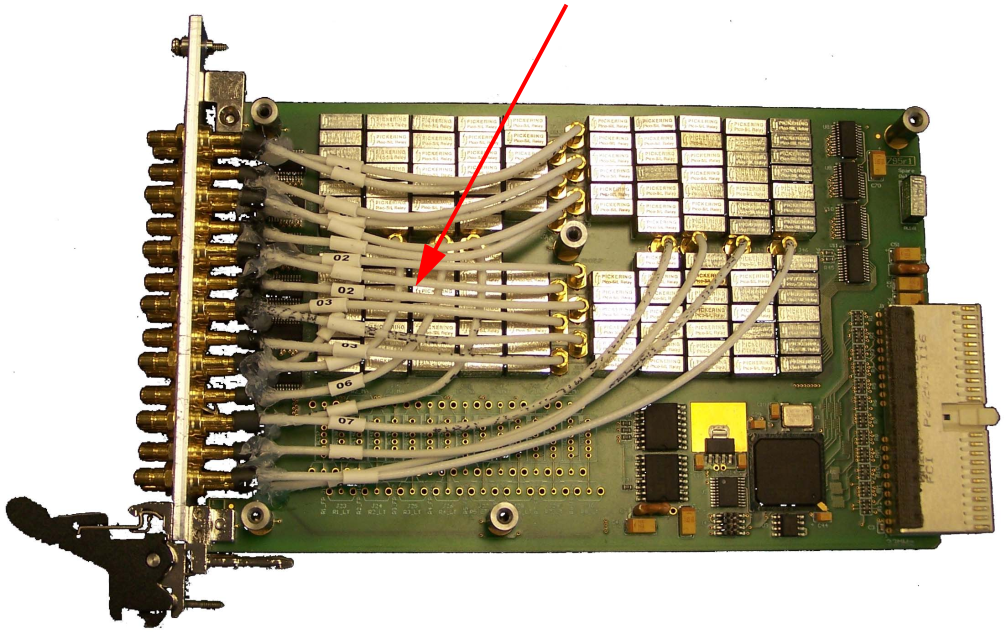


Figure 38 Cabling in the M9128A RF Matrix module

CAUTION On the M9128A RF Matrix module, the internal cables are soldered to the circuit board and to the front panel connectors--, they do not unplug. Be very careful as you move the cables. Do not bend cables.

4 After replacing the relay(s), replace the top shield and the five screws. Do not over tighten the screws.

RF Multiplexer Modules Disassembly

Figure 39 and Figure 40 show the basic assembly of the RF multiplexer modules (M9147A through M9153A). The M9147A module is shown, others are similar. Some modules have only one (the bottom) relay daughter board. The following instructions show how to disassemble, remove and replace the daughter boards.

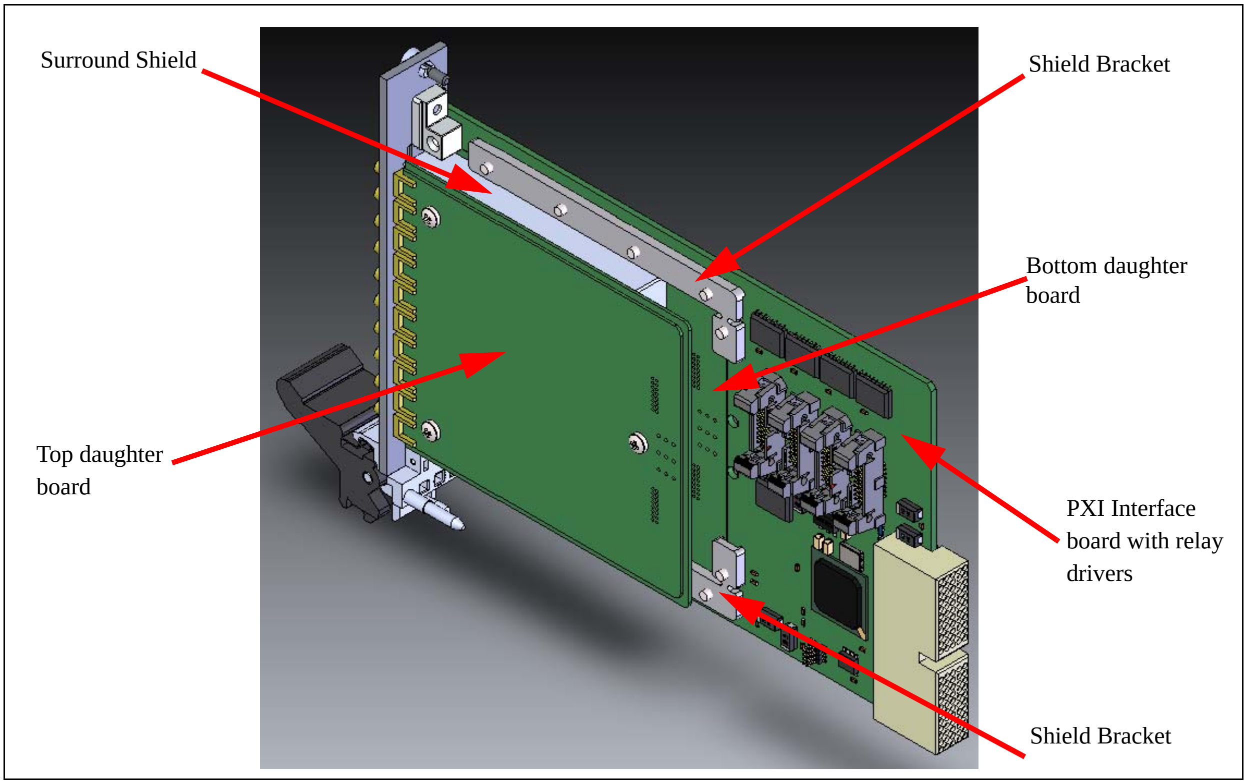


Figure 39 M9147A Top (ribbon cables from motherboard to daughter boards not shown)

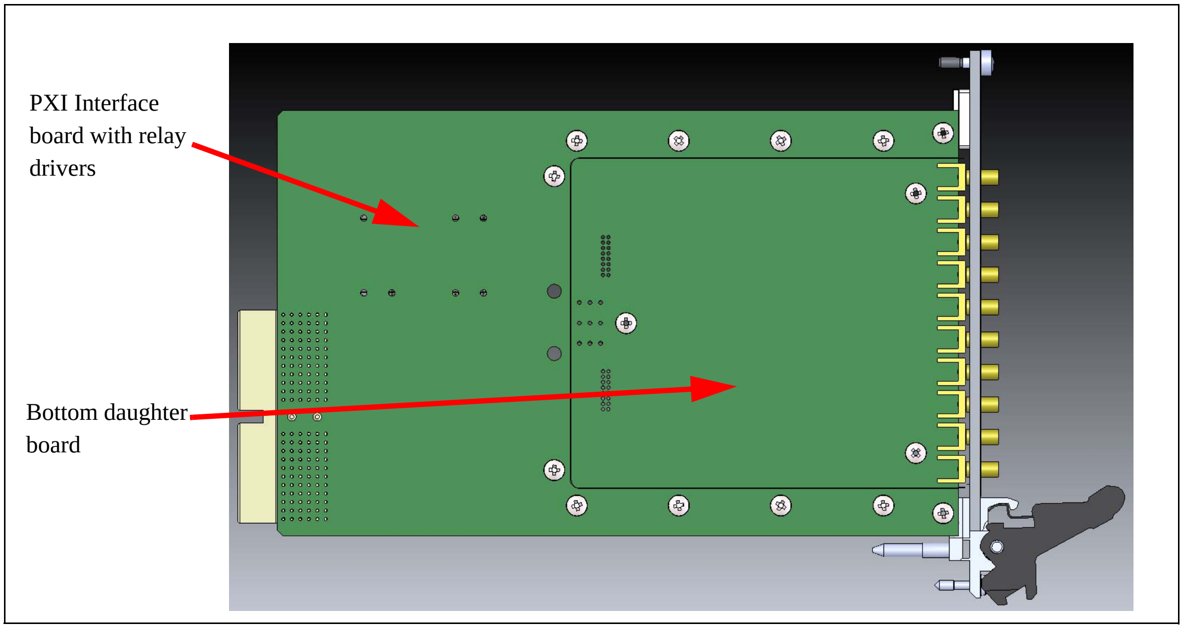


Figure 40 M9147A Module showing bottom daughter board

Removing/replacing the top daughter board

Please read all disassembly steps prior to starting the disassembly. Refer to Figure 41 and Figure 42 with the following disassembly steps.

1 Although it is not necessary, it is generally advisable to remove the front panel first. Remove the two screws indicated in Figure 41. Carefully slide the front panel away from the PC boards and SMB connectors. This is especially important on the M9149A and M9153A modules.

2 To remove/replace the top daughter board, disconnect the ribbon connector from the PXI interface board.

3 Remove the three screws indicated in Figure 42.

4 Carefully lift the top daughter board up and toward the rear of the module. On the M9149A and M9153A modules, lift the top daughter board straight up from the bottom daughter board to disengage the board-to-board SMB connectors.

5 If you are replacing the daughter board, remove the ribbon cable from the old daughter board and attach it to the replacement board.

6 To reinstall the top daughter board on the module, reverse the previous steps. On the M9149A and M9153A modules, make certain the board-to-board SMB connectors are properly aligned and connected.

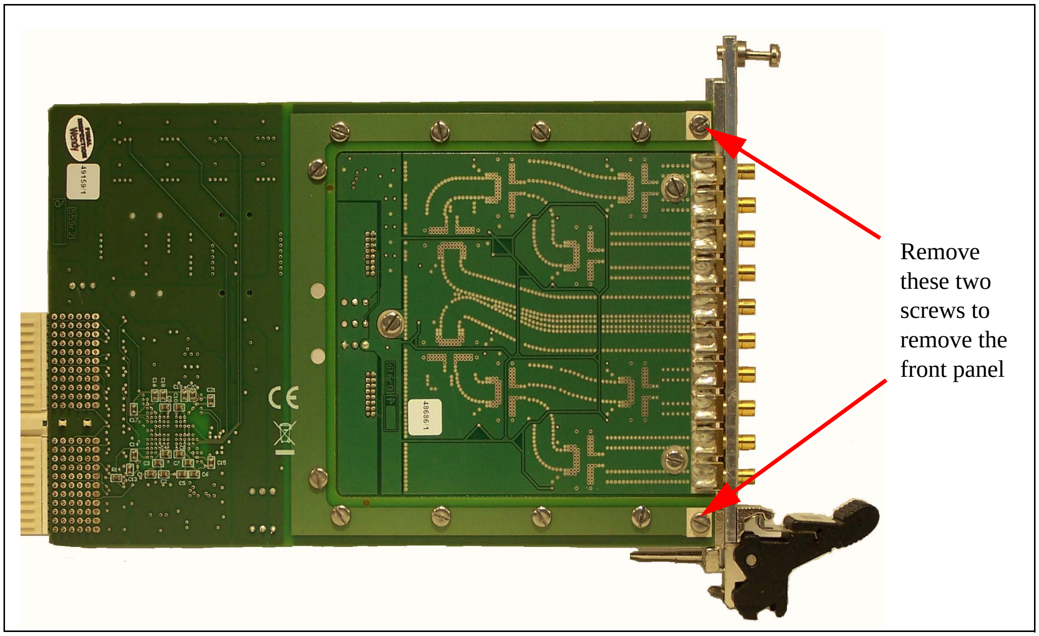


Figure 41 Remove module front panel

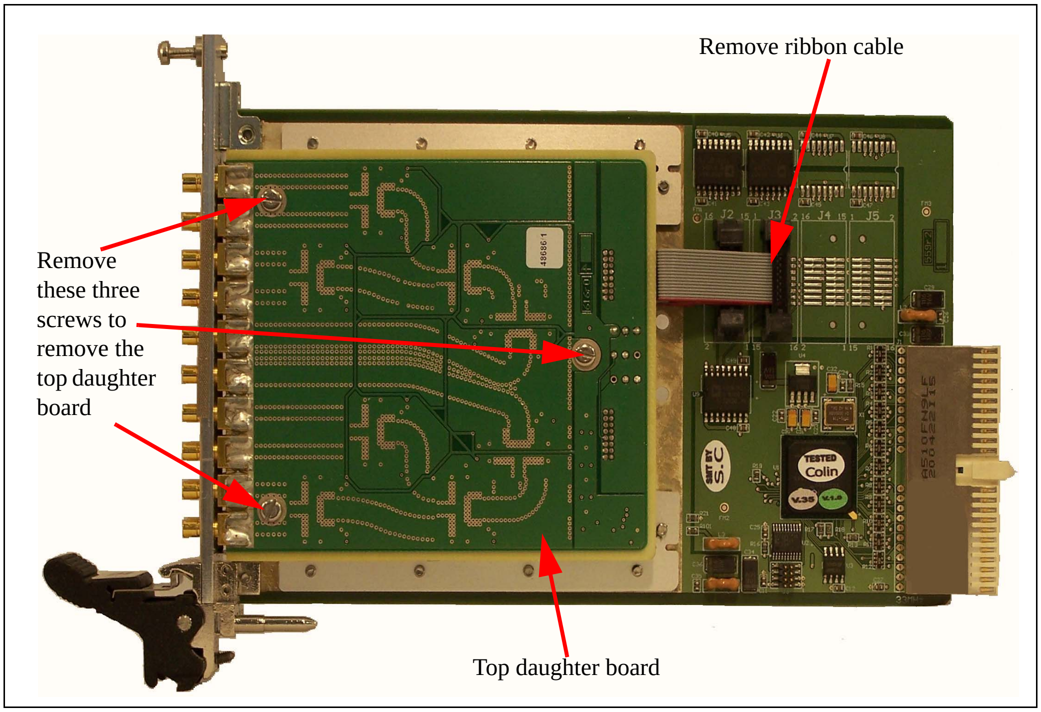


Figure 42 Top side of RF Multiplexer module

Removing/replacing the bottom daughter board

Please read all disassembly steps prior to starting the disassembly. Refer to Figure 43 and Figure 44 with the following disassembly steps.

1 Although it is not necessary, it is generally advisable to remove the front panel first. Remove the two screws indicated in Figure 41. Carefully slide the front panel away from the PC boards.

2 Remove the top daughter board per the instructions on page 97. For modules with only the bottom daughter board, remove the top shield.

3 Disconnect the bottom daughter board ribbon connector from the PXI interface board.

4 On the back side of the module, remove the eight screws indicated in Figure 43. These eight screws release the two Shield Brackets. Note, do not remove two back screws (you may need to slightly loosen them). Rotate the two Shield Brackets away from the module as shown in Figure 44.

   The Surround Shield is held in place by tabs under the Shield Brackets. As you remove the eight screws, the Surround Shield will come free from the bottom daughter board.

5 Carefully slide the bottom daughter board toward the module front.

6 If you are replacing the bottom daughter board, remove the ribbon cable and three standoffs from the old daughter board and install them on the new daughter board.

7 To install the bottom daughter board, reverse the previous steps.

   The RF module daughter boards are designed with a shoulder around edge of the PC board allowing the bottom daughter board to be installed flush with the PXI interface board. When installing the bottom daughter board, ensure the it is flush with the interface board and all the way toward the rear of the PXI interface module.

   Before tightening the eight screws securing the Shield Brackets, ensure the tabs of the Surround Shield are under the brackets and the Surround Shield does not extend beyond the front of the module. The Surround Shield must rest on the ground foil of the daughter PC board.

   Ensure the ribbon cables are reconnected to the correct connectors on the PXI interface board.

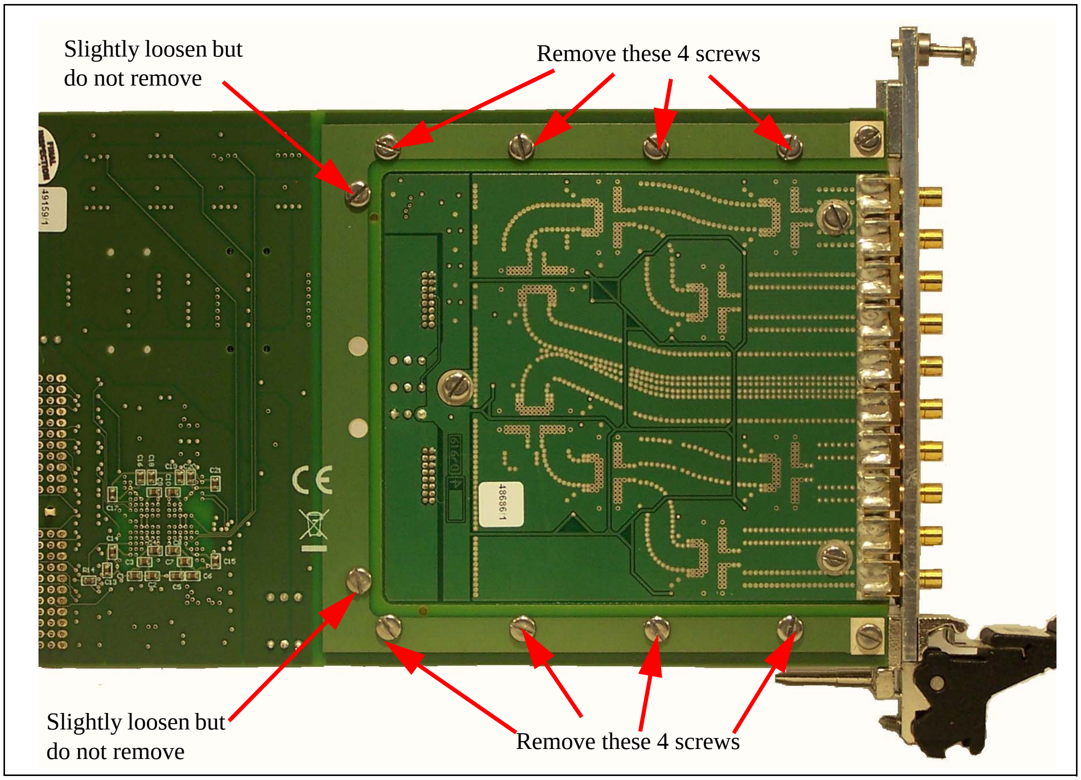


Figure 43 Remove screws for bottom daughter board

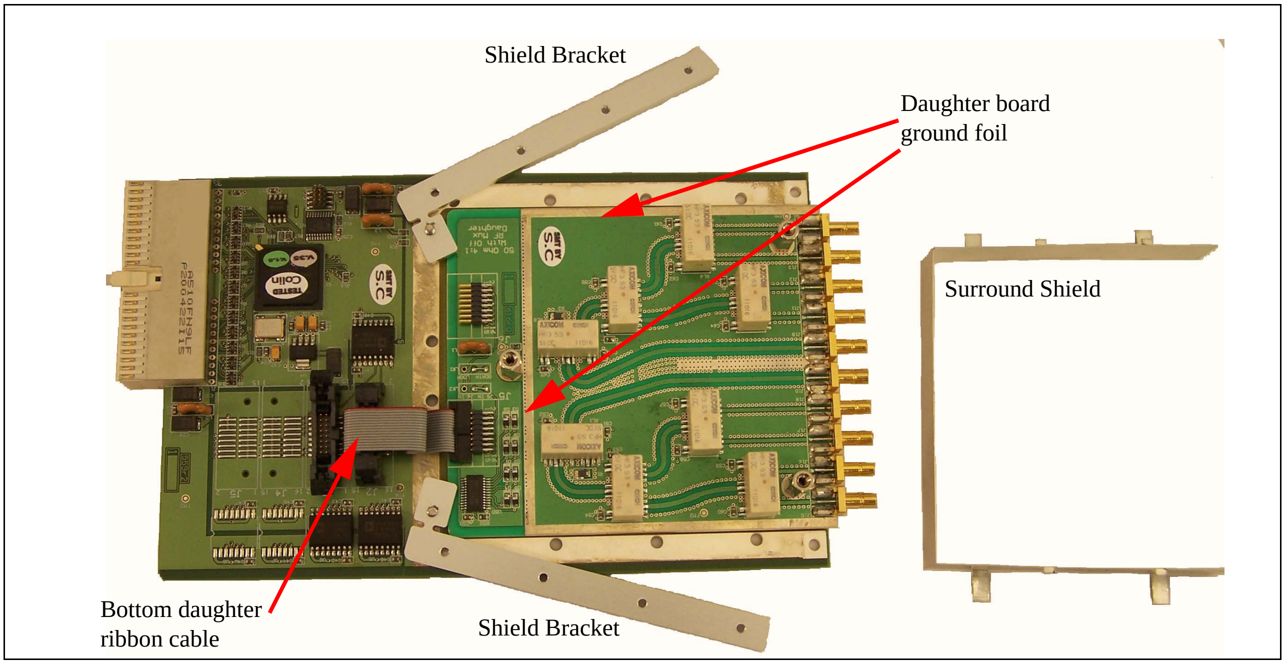


Figure 44 Remove RF Shields

Replacing the PXI Controller Board

Individual PXI controllers boards are not replaceable. You must replace the entire module.

A
Making RF Test Measurements

Introduction

This appendix provides information on making RF tests on the Agilent 50 Ω and 75 Ω PXI RF switch modules. These test may be necessary after replacing one or more RF relays on the switch modules. Note that if you replace an RF module daughter board, these tests are not necessary as the daughter boards are pre-tested at the factory. This information in this appendix assumes you are using a 50 Ω network analyzer. Refer to “Recommended test equipment” on page 8 of this manual for a list of recommended test equipment.

It is essential that the correct impedance connectors and cables are used when calibrating the equipment and testing these PXI switch modules. Mixing connectors and cables with different impedances will result in unreliable test results and possible equipment damage.

The test operator must be trained to safely operate and perform the required measurements using the test equipment.

The procedures described in this appendix use the Agilent E5071C ENA as the measurement instrument. However, the procedure descriptions are generic and suitable for most network analyzers.

RF System Calibration

In order to properly measure the RF characteristics of the PXI switch modules, the test system must be calibrated prior to performing the tests. During the calibration, the PXI switch module(s) must not be connected to the test system.

Make sure that you use the cables and connectors that will be used for the actual switch module tests. Each test type (VSWR, insertion loss, crosstalk, etc.) has its own calibration procedure that compensates for the test system components such as cables and connectors. Once a calibration is complete, the network analyzer should indicate minimal error.

Minimum Loss Pads

In order to perform 75 Ω tests with a 50 Ω network analyzer, it is necessary to use minimum loss pads. Insertion loss and isolation tests require a set of two pads; VSWR tests require only one minimum loss pad.

The Agilent 11852B minimum loss pads have 50 Ω N-type (jack) connectors and 75 Ω, N-type (plug) connectors. The 50 Ω N-type connector requires an N-type plug-to-plug coupler to connect to the network analyzer. The 75 Ω N-type requires an adapter to connect to the test cables (mini-SMB, MCX, etc.).

50 Ohm and 75 Ohm Voltage Standing Wave Ratio (VSWR) Tests

Any impedance mismatch along a transmission line causes a partial reflection of the signal. The difference in impedance determines the magnitude of the reflected signal. VSWR is a measurement of that reflected signal; the higher the VSWR, the greater the impedance mismatch.

For testing purposes, a signal is transmitted from the network analyzer, passes through the RF switch and is absorbed by a calibrated load. Any impedance mismatch causes a reflection of the signal back to the network analyzer.

VSWR is calculated as:

$$VSWR = \frac{10^{(ReturnLoss(dB))/20} + 1}{10^{(ReturnLoss(dB))/20} - 1}$$

50 Ohm VSWR Calibration

Connect the network analyzer, cable, and termination as shown in Figure 45 below.

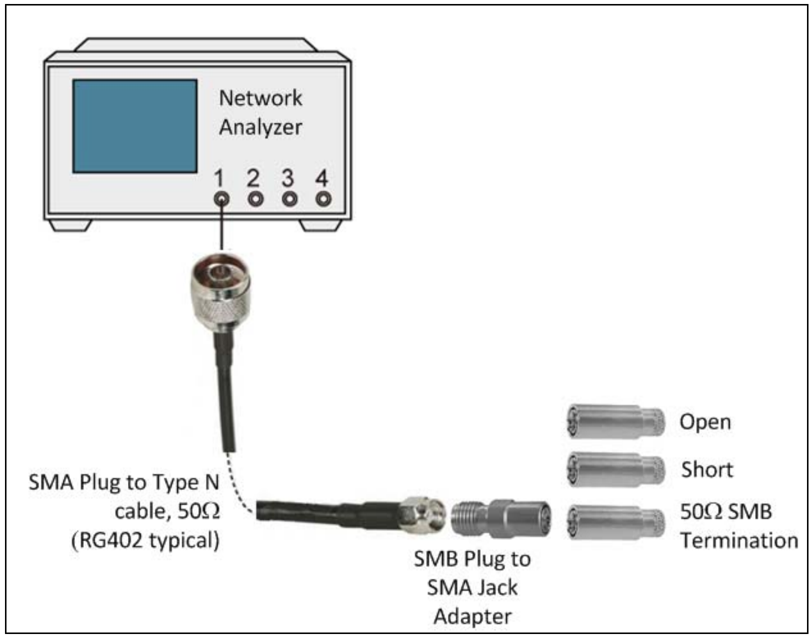


Figure 45 50 Ohm VSWR calibration test setup

Perform a one port calibration procedure using either an Ecal module or the mechanical calibration components as follows:

1 Connect the 50 Ω test cable to Port 1 of the VNA.

2 Press `Channel Next/Channel Prev` keys on the VNA to select the channel for which you want to perform the calibration.

3 Press the `Cal` key.

4 Select `Calibrate > 1-Port Cal >` *<select port to be cal'd>*.

5 Select a test port (and corresponding S parameter) on which the 1-port calibration will be performed.

6 Connect an **OPEN** calibration standard to the selected port's test cable.

7 Click `Open` to start the calibration measurement.

8 If you select the calibration kit which has different calibration definitions for each gender, (m) and (f) in the name (label) of the standard displayed in the softkey, then indicate male (m) and female (f) for the analyzer's connector, respectively.

9 Connect a **SHORT** calibration standard to the selected test port (connector to which the DUT is to be connected).

10 Click `Short` to start the calibration measurement.

11 Connect a **LOAD** calibration standard to the selected port's test cable.

12 Click `Load` to start the calibration measurement.

13 Click `Done` to terminate the 1-port calibration process. Upon pressing this key, calibration coefficients are calculated and saved. The error correction function is automatically enabled.

14 The 50 Ω VSWR calibration is now complete. Begin testing a 50Ω switch module. See "50 Ohm VSWR Test Procedure" on page 107.

50 Ohm VSWR Test Procedure

Figure 46 shows the basic measurement setup for making 50 Ω VSWR test measurements on a switch module.

NOTE For the M9128A matrix module, connect the 50 Ω load to a COLumn connector and the network analyzer to a ROW connector.

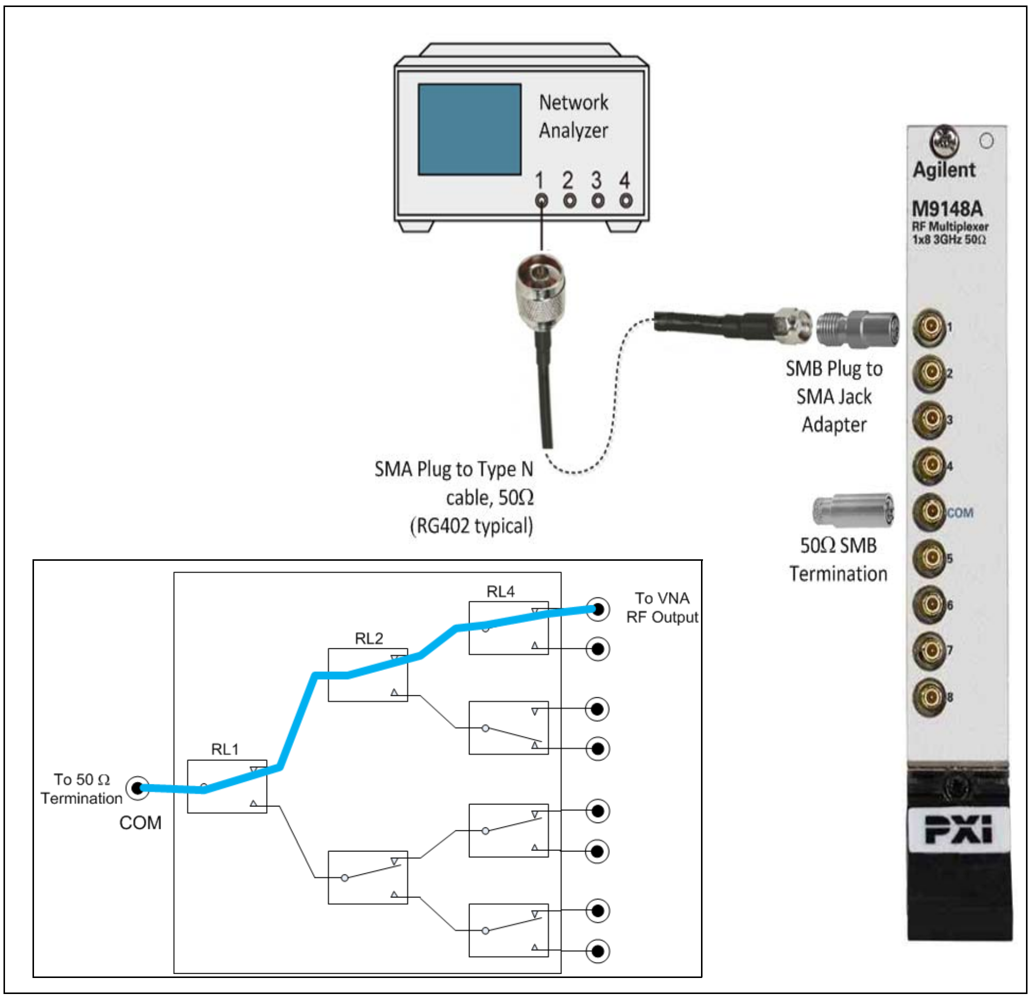


Figure 46 Basic VSWR measurement test setup for 50 Ohm RF modules

The test procedure is as follows:

1 Set up the network analyzer and cables as described in the calibration procedure. Perform the 50 Ω VSWR Calibration.

2 Attach one end of the test cable to the network analyzer’s Port 1.

3 Connect the other end of the test cable to the individual channel connector on the module under test.

4 Connect a 50 Ω load to the COM connector.

5 Use the Agilent PXI Switch Soft Front Panel utility to close the channel being tested.

6 Set the start and stop frequencies on the network analyzer as necessary for testing the switch module.

7 The network analyzer should show the VSWR for that channel. Search for MAX VSWR and record that value in the Functional Test Record for the module/channel being tested.

8 The 50 Ω VSWR test is complete for that channel.

9 Move the 50 Ω load to another channel and repeat the test.

75 Ohm VSWR Calibration

Connect the network analyzer, cable, and termination as shown in Figure 47 below.

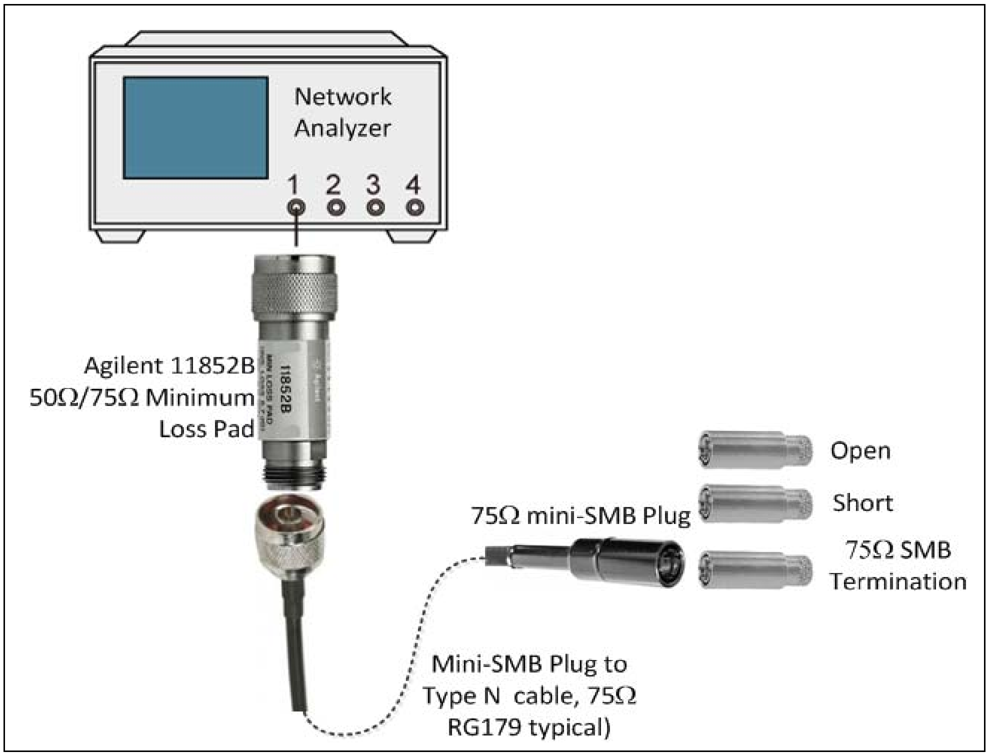


Figure 47 75 Ohm VSWR calibration test setup

NOTE If you do not have a Type N to Mini SMB 75 Ω cable, you can also use a Type N Jack to Type N Plug cable along with a Type N Plug to mini-SMB plug adapter.

Perform a one port calibration procedure using either an Ecal module or the mechanical calibration components as follows:

1 Attach an Agilent 11852B minimum loss pad to the network analyzer's Port 1.

2 Attach one end of the 75 Ω test cable to the 11852B.

3 Press `Channel Next/Channel Prev` keys on the VNA to select the channel for which you want to perform the calibration.

4 Press `Cal` key.

5 Click `Calibrate > 1-Port Cal >` <*select port to be cal'd*>.

6 Select the test port (and corresponding S parameter) on which the 1-port calibration will be performed.

7 Connect an **OPEN** calibration standard to the selected test cable (connector to which the DUT is to be connected).

8 Click `Open` to start the calibration measurement.

9 If you select the calibration kit which has different calibration definitions for each gender, (m) and (f) in the name (label) of the standard displayed in the softkey, then indicate male (m) and female (f) for the analyzer's connector, respectively.

10 Connect a **SHORT** calibration standard to the selected test cable (connector to which the DUT is to be connected).

11 Click `Short` to start the calibration measurement.

12 Connect a **LOAD** calibration standard to the selected test port (connector to which the DUT is to be connected).

13 Click `Load` to start the calibration measurement.

14 Click `Done` to terminate the 1-port calibration process. Upon pressing this key, calibration coefficients will be calculated and saved. The error correction function will also be automatically enabled.

15 The 75 Ω VSWR calibration is now complete. Begin testing a 75 Ω switch module.

75 Ohm VSWR Test Procedure

Figure 48 shows the basic measurement setup for making 75 Ω VSWR test measurements on a switch module. Note that this requires a 75 Ω load, 75 Ω test cable, and the 50 Ω / 75 Ω Minimum Loss Pad.

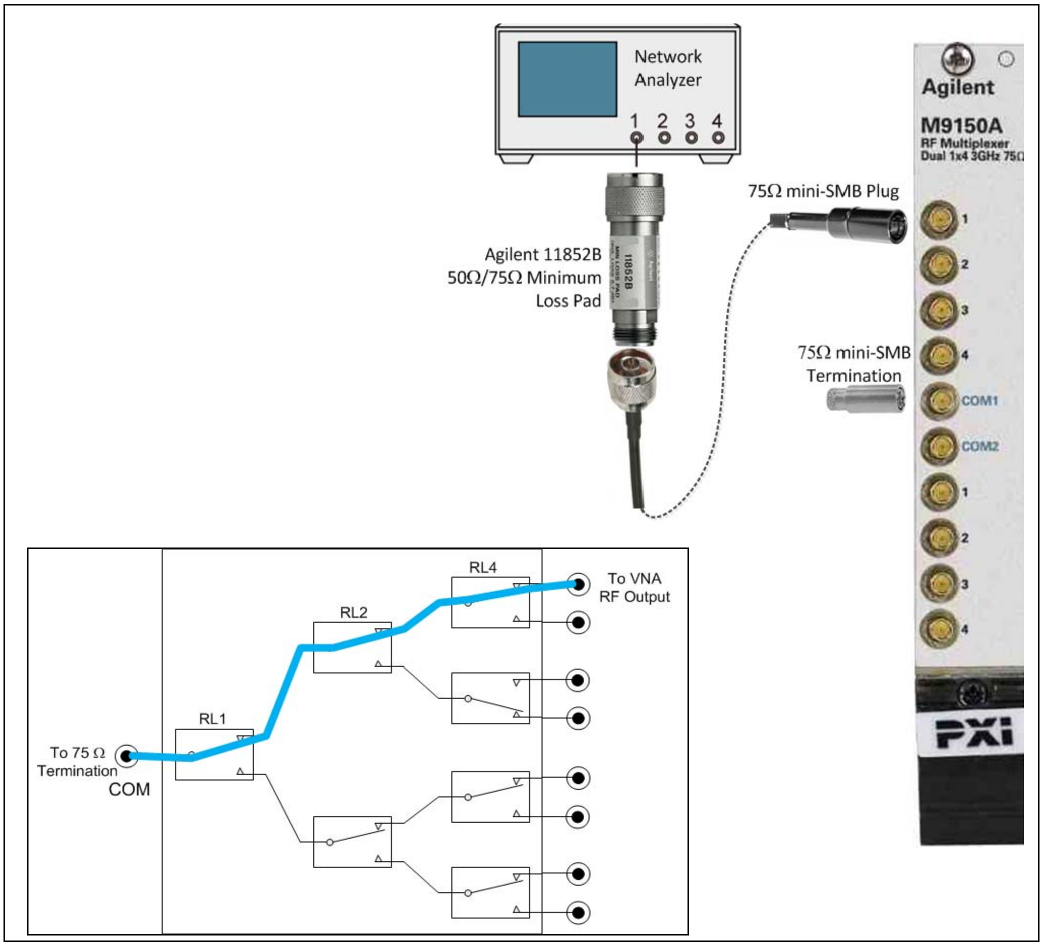


Figure 48 Basic VSWR measurement test setup for 75 Ohm RF modules

NOTE If you do not have a Type N to Mini SMB 75 Ω cable, you can also use a Type N Jack to Type N Plug cable along with a Type N Plug to mini-SMB plug adapter.

The test procedure is as follows:

1 Set up the network analyzer as described in the 75 Ω VSWR Calibration procedure. Perform the 75 Ω VSWR Calibration.

2 Attach one end of the test cable to the network analyzer's port 1 Minimum Loss Pad.

3. Connect the other end of the test cable to the individual channel connector on the module under test.
4. Connect a 75 Ω load to the COM connector.
5. Use the Soft Front Panel utility to close the channel being tested.
6. Set the start and stop frequencies on the network analyzer as necessary for testing the switch module.
7. The network analyzer should show the VSWR for that channel. Search for MAX VSWR and record that value in the Functional Test Record for the module/channel being tested.
8. The 75 Ω VSWR test is complete for that channel.
9. Move the 75 Ω load to another channel and repeat the test.

50 Ohm and 75 Ohm Insertion Loss Tests

As high frequency signals pass through a transmission line (or in this case a switch module), the signal is attenuated by series resistance, dielectric absorption, impedance mismatches, etc. This attenuation is called Insertion Loss. The amount of signal remaining at the output of the switch multiplexer is represented as a ration of the input signal in dB. The output magnitude is less than the input magnitude so insertion loss is always >0 dB.

This ratio is expressed in terms of either power or signal voltage:

Insertion Loss (dB) = $10 \log(P_{in}/P_{out}) = -10 \log(P_{out}/P_{in})$

Insertion Loss (dB) = $20 \log(V_{in}/V_{out}) = -20 \log(V_{out}/V_{in})$

Figure 50 illustrates the basic insertion loss measurement setup.

NOTE For the M9128A matrix module, connect port 1 of the network analyzer to a COLumn connector and port 2 of the network analyzer to a ROW connector.

50 Ohm Insertion Loss Calibration

Connect the network analyzer and cables as shown in Figure 49 below.

Figure 49 50 Ohm insertion loss calibration test setup

Perform a two port calibration procedure using either an Ecal module or the mechanical calibration components as follows:

1 Attach one end of each test cable to the network analyzer's test ports.

2 Press `Channel Next/Channel Prev` keys on the VNA to select the channel for which you want to perform the calibration.

3 Press `Cal` key.

4 Click `Calibrate > 2-Port Cal`.

5 Click `Select Ports`, then select the test ports on which you will perform full 2-port calibration. (In the procedure below, the selected test ports are denoted as x and y.)

6 Click `Reflection`.

7 Connect an **OPEN** calibration standard to test cable connected to port x.

8 Click `Port x Open` to start the calibration measurement (x denotes the test port to which the standard is connected).

9 If you select the calibration kit which has different calibration definitions for each gender, (m) and (f) in the name (label) of the standard displayed in the softkey, then indicate male (m) and female (f) for the analyzer's connector, respectively.

10 Disconnect the **OPEN** calibration standard and replace it with a **SHORT** calibration standard.

11 Click `Port x Short` to start the calibration measurement (x denotes the test port to which the standard is connected).

12 Disconnect the **SHORT** calibration standard and replace it with a **LOAD** standard.

13 Click `Port x Load` to start the calibration measurement (x denotes the test port to which the standard is connected).

14 Repeat steps 2 through 13 above for port y.

15 Click `Return`.

16 Click `Transmission`.

17 Make a **THRU** connection between ports x and y.

18 Click `Port x-y Thru` to start the calibration measurement (x and y denote the test ports between which the **THRU** connection is being made).

19 Click `Return`.

20 If an isolation calibration must be performed using a **LOAD** standard, follow the procedure below.

21 Click `Isolation` (Optional).

22 Connect a **LOAD** standard to each of the two test ports (connectors to which the DUT is to be connected).

23 Click `Port x-y Isol` to start the calibration measurement (x and y denote the port numbers to which the LOAD standard is connected).

24 Click `Return`.

25 Click `Done` to terminate the full 2-port calibration process. Upon pressing this key, calibration coefficients will be calculated and saved. The error correction function will also be automatically enabled.

26 The 50 Ω Insertion Loss calibration is now complete. Begin testing a 50 Ω switch module.

50 Ohm Insertion Loss Test Procedure

Figure 50 shows the basic measurement setup for making 50 Ω Insertion Loss test measurements on a switch module. Note that the switch module has the channel closed for the test. Use the Agilent Soft Front Panel software to open/close channels.

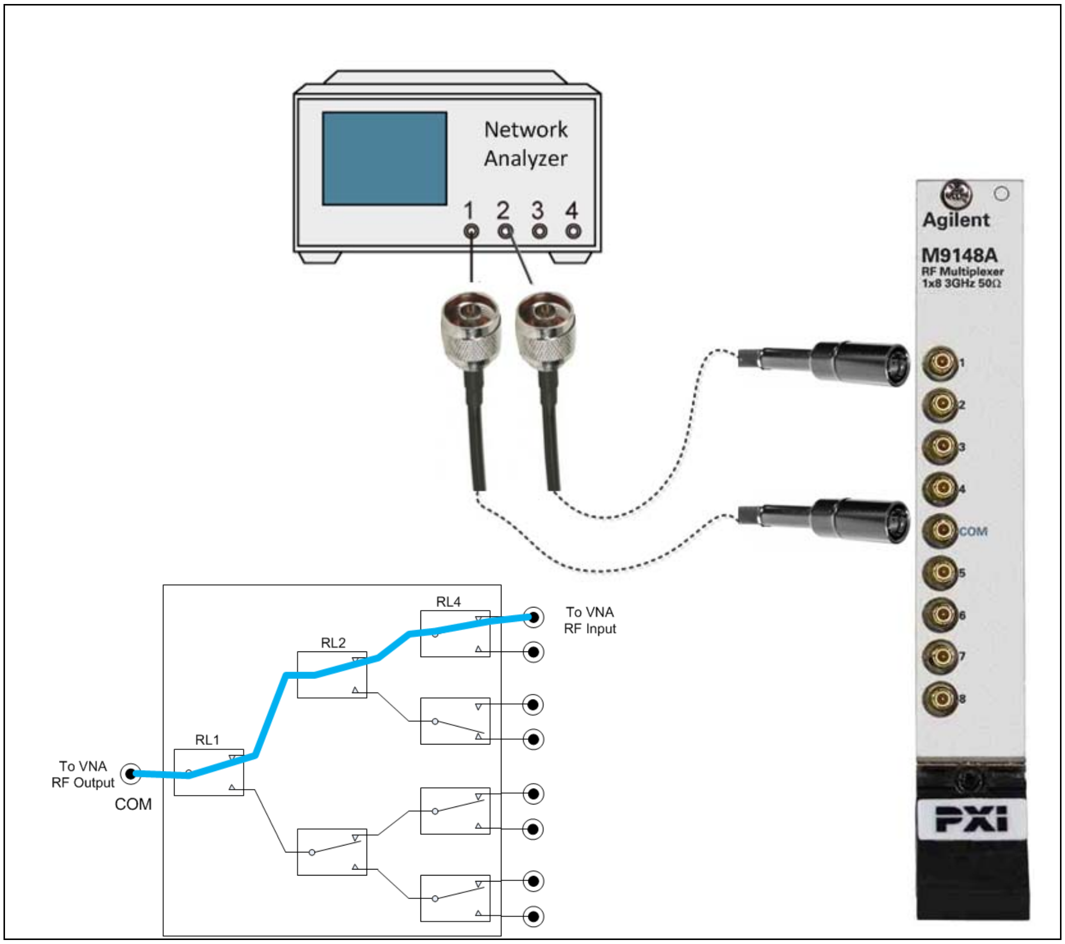


Figure 50 Basic insertion loss measurement test setup for 50 Ohm modules

The test procedure is as follows:

1 Set up the network analyzer and cables as described in the 50 Ω Insertion Loss Calibration procedure. Perform the 50 Ω Calibration.

2 Connect the other ends of the cables to the module being tested as shown in Figure 50.

3 Set the network analyzer to measure **S21 Transmission** in the **log mag** format.

4 Set the start and stop frequencies on the network analyzer as necessary for testing the switch module.

5 The 50 Ω VSWR test is complete for that channel.

6 Move the Port 2 cable to another channel and repeat the test. Make certain to close the appropriate channel under test.

75 Ohm Insertion Loss Calibration

Connect the network analyzer, cables, and minimum loss pads as shown in Figure 49 below.

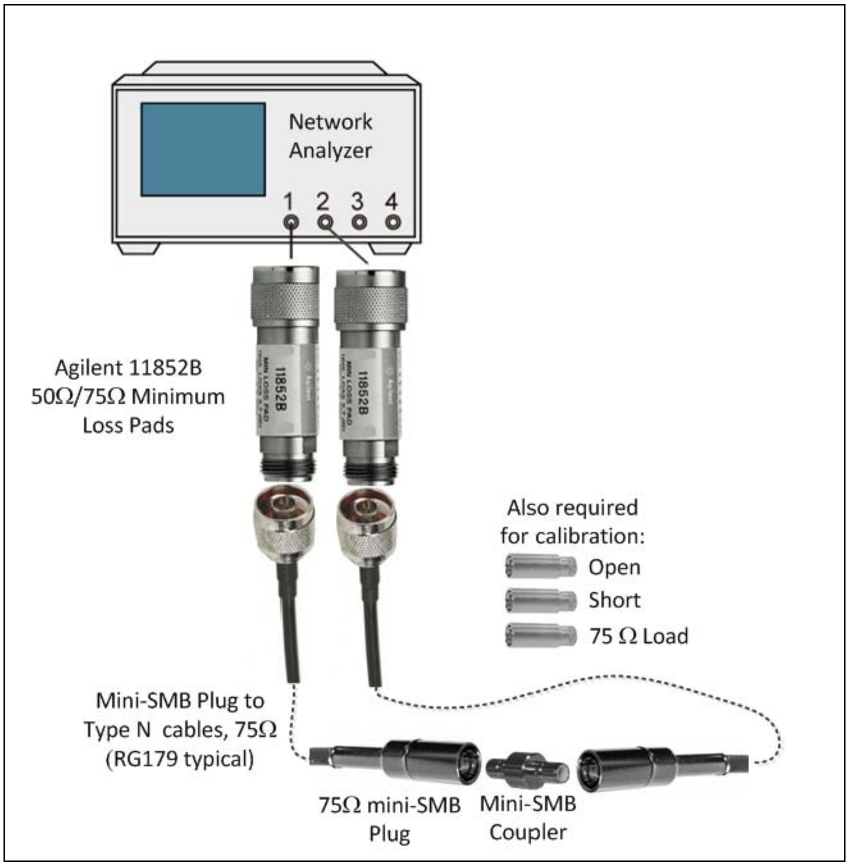


Figure 51 75 Ohm insertion loss calibration test setup

NOTE If you do not have Type N to Mini SMB 75 Ω cables, you can also use Type N Jack to Type N Plug cables along with Type N Plug to mini-SMB plug adapters.

Perform a two port calibration procedure using either an Ecal module or the mechanical calibration components as follows:

1 Attach two Agilent 11852B minimum loss pads to the network analyzer port 1 and port 2.

2 Attach one end of each test cable to the minimum loss pads.

3 Press `Channel Next/Channel Prev` keys on the VNA to select the channel for which you want to perform the calibration.

4 Press `Cal` key.

5 Click `Calibrate > 2-Port Cal`.

6 Click `Select Ports`, then select the test ports on which you will perform full 2-port calibration. (In the procedure below, the selected test ports are denoted as x and y.)

7 Click `Reflection`.

8 Connect an **OPEN** calibration standard to test port x (the connector to which the DUT is to be connected).

9 Click `Port x Open` to start the calibration measurement (x denotes the test port to which the standard is connected).

10 If you select the calibration kit which has different calibration definitions for each gender, (m) and (f) in the name (label) of the standard displayed in the softkey, then indicate male (m) and female (f) for the analyzer's connector, respectively.

11 Disconnect the **OPEN** standard and replace it with a **SHORT** standard.

12 Click `Port x Short` to start the calibration measurement (x denotes the test port to which the standard is connected).

13 Disconnect the **SHORT** standard and replace it with a **LOAD** standard.

14 Click `Port x Load` to start the calibration measurement (x denotes the test port to which the standard is connected).

15 Repeat steps 8 through 14 for Port y.

16 Click `Return`.

17 Click `Transmission`.

18 Make a **THRU** connection between ports x and y (between the connectors to which the DUT is to be connected).

19 Click `Port x-y Thru` to start the calibration measurement (x and y denote the test ports between which the THRU connection is being made).

20 Click `Return`.

21 If an isolation calibration must be performed using a **LOAD** standard, follow the procedure below.

22 Click `Isolation` (Optional).

23 Connect a **LOAD** standard to each of the two test ports (connectors to which the DUT is to be connected).

24 Click `Port x-y Isol` to start the calibration measurement (x and y denote the port numbers to which the **LOAD** standard is connected).

25 Click `Return`.

26 Click `Done` to terminate the full 2-port calibration process. Upon pressing this key, calibration coefficients will be calculated and saved. The error correction function will also be automatically enabled.

27 The 75 Ω Insertion Loss calibration is now complete.

75 Ohm Insertion Loss Test Procedure

Figure 52 shows the basic measurement setup for making 75 Ω Insertion Loss test measurements on a switch module. Note that the switch module has the channel closed for the test. Use the Agilent Soft Front Panel software to open/close channels.

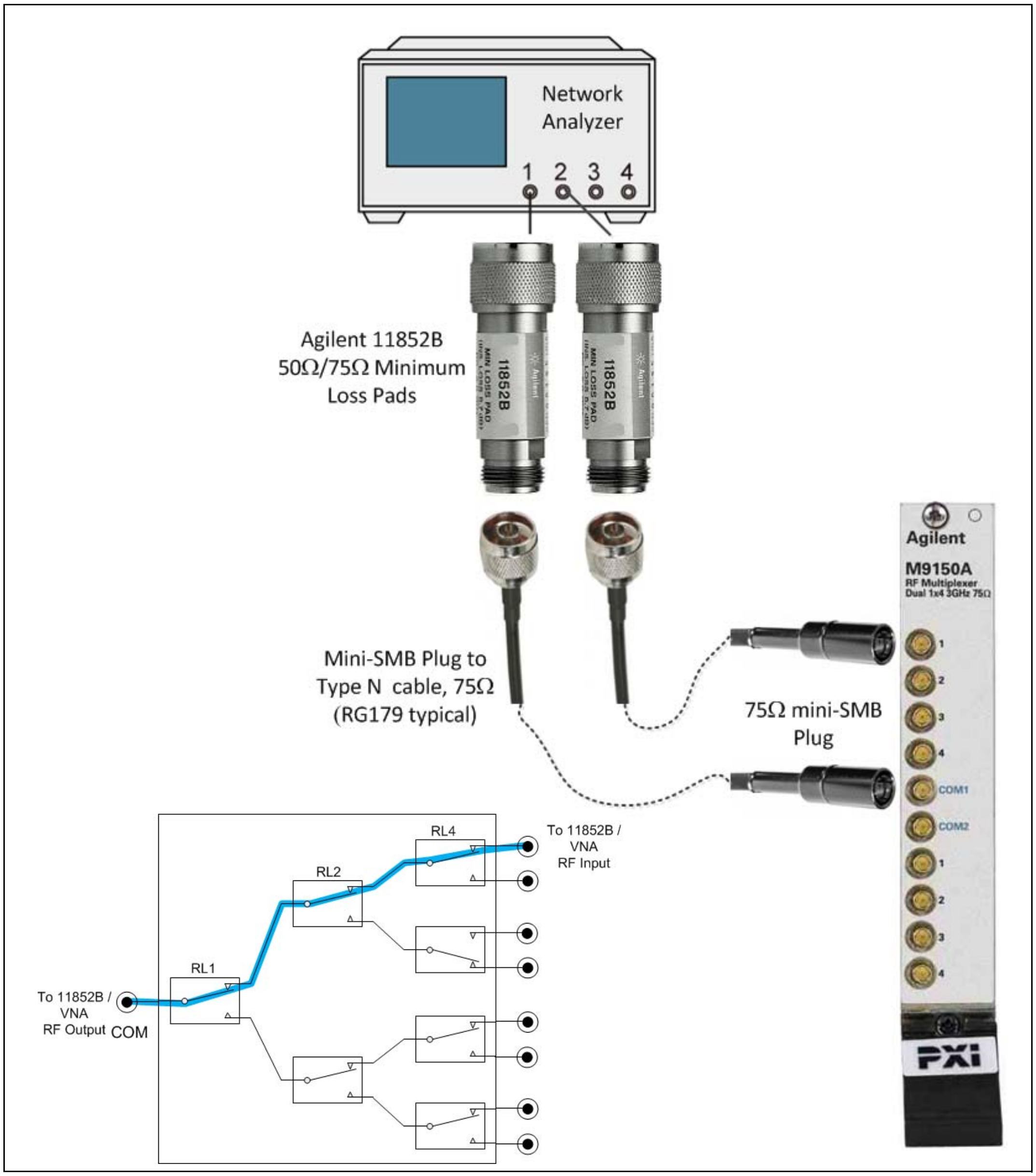


Figure 52 75 Ohm insertion loss tests

The test procedure is as follows:

1 Set up the network analyzer and cables as described in the 75 Ω Insertion Loss Calibration procedure. Perform the 75 Ω Calibration.
2 Connect the other ends of the cables to the module being tested as shown in Figure 50.
3 Set the network analyzer to measure **S21 Transmission** in the **log mag** format.
4 Set the start and stop frequencies on the network analyzer as necessary for testing the switch module.
5 The 75 Ω VSWR test is complete for that channel.
6 Move the Port 2 cable to another channel and repeat the test. Make certain to close the appropriate channel under test.

50 Ohm and 75 Ohm Isolation Tests

Isolation refers to the level of isolation between adjacent switch paths, connectors, etc. and is measurement in dB. There are actually two possible isolation paths on the PXI RF modules: Open Relay Isolation on a single channel and Channel to Channel Isolation. Isolation testing isolation involves applying as signal from the network analyzer and then measuring the signal level on an adjacent path connector.

Isolation is specified in dB of rejection and is expressed in terms or either power or voltage:

Isolation (dB) = $10 \log(P_{source}/P_{out})$

Isolation (dB) = $20 \log(V_{source}/V_{out})$

50 Ohm Isolation Calibration

The 50 Ω Isolation calibration is identical to the 50 Ω Insertion Loss Calibration except that the network analyzer should be set 10dB per division (See “50 Ohm Insertion Loss Calibration” on page 113.).

75 Ohm Isolation Calibration

The 75 Ω Isolation calibration is identical to the 75 Ω Insertion Loss Calibration except that the network analyzer should be set 10dB per division (See “75 Ohm Insertion Loss Calibration” on page 118.).

Open Relay, Single Channel Isolation Tests

Open Relay, Single Channel isolation testing measures the level of isolation on a single channel when all relays are open. It is measured in decibels. Testing consists of applying a signal from the network analyzer RF Output to the bank COM connector and then measuring the resulting signal the resulting signal at the end of the channel to determine the isolation.

50 Ohm Open Relay, Single Channel Isolation Tests

Figure 53 illustrates the basic open relay, single channel isolation measurement setup. Note that the channel path is open.

NOTE For the M9128A matrix module, connect port 1 of the network analyzer to a COLumn connector and port 2 of the network analyzer to a ROW connector.

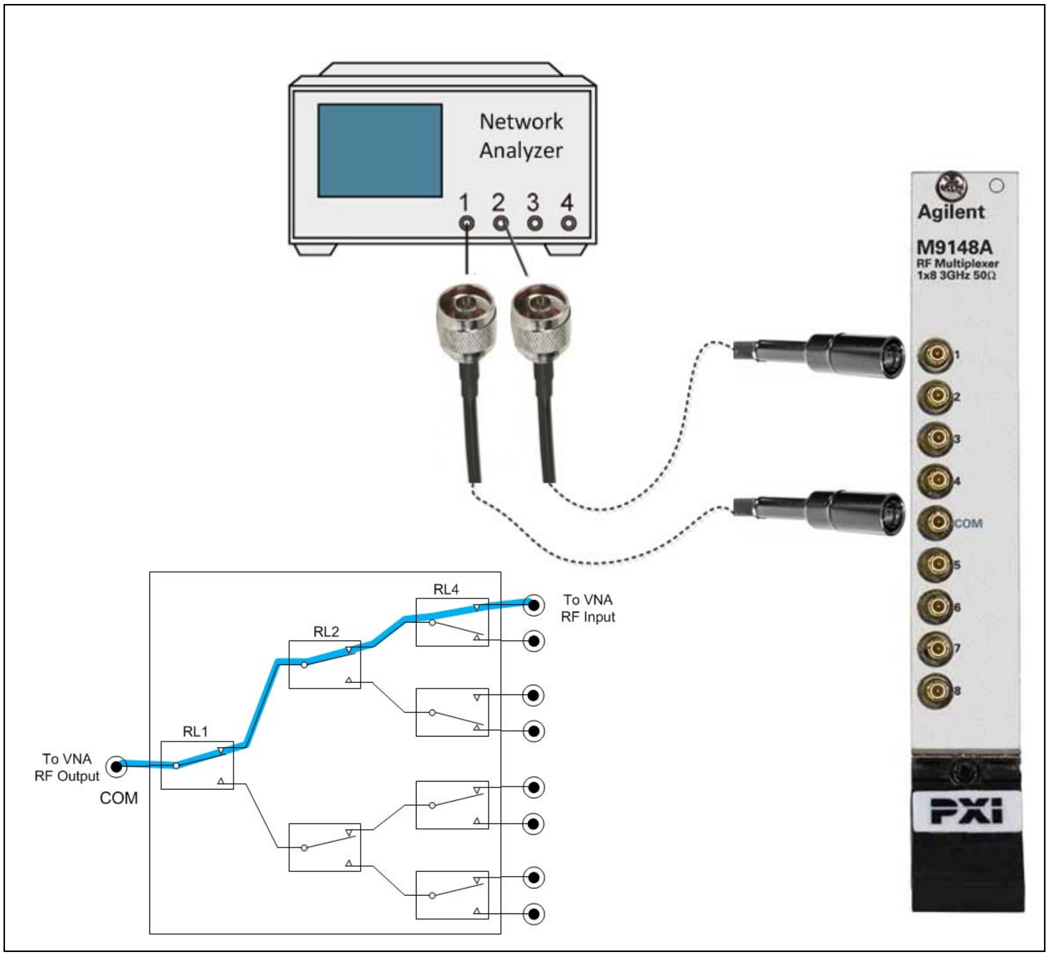


Figure 53 Basic 50 Ohm single channel, open relay isolation test setup

75 Ohm Open Relay, Single Channel Isolation Tests

Figure 54 illustrates the basic isolation measurement setup. Note that the channel path is open for the test.

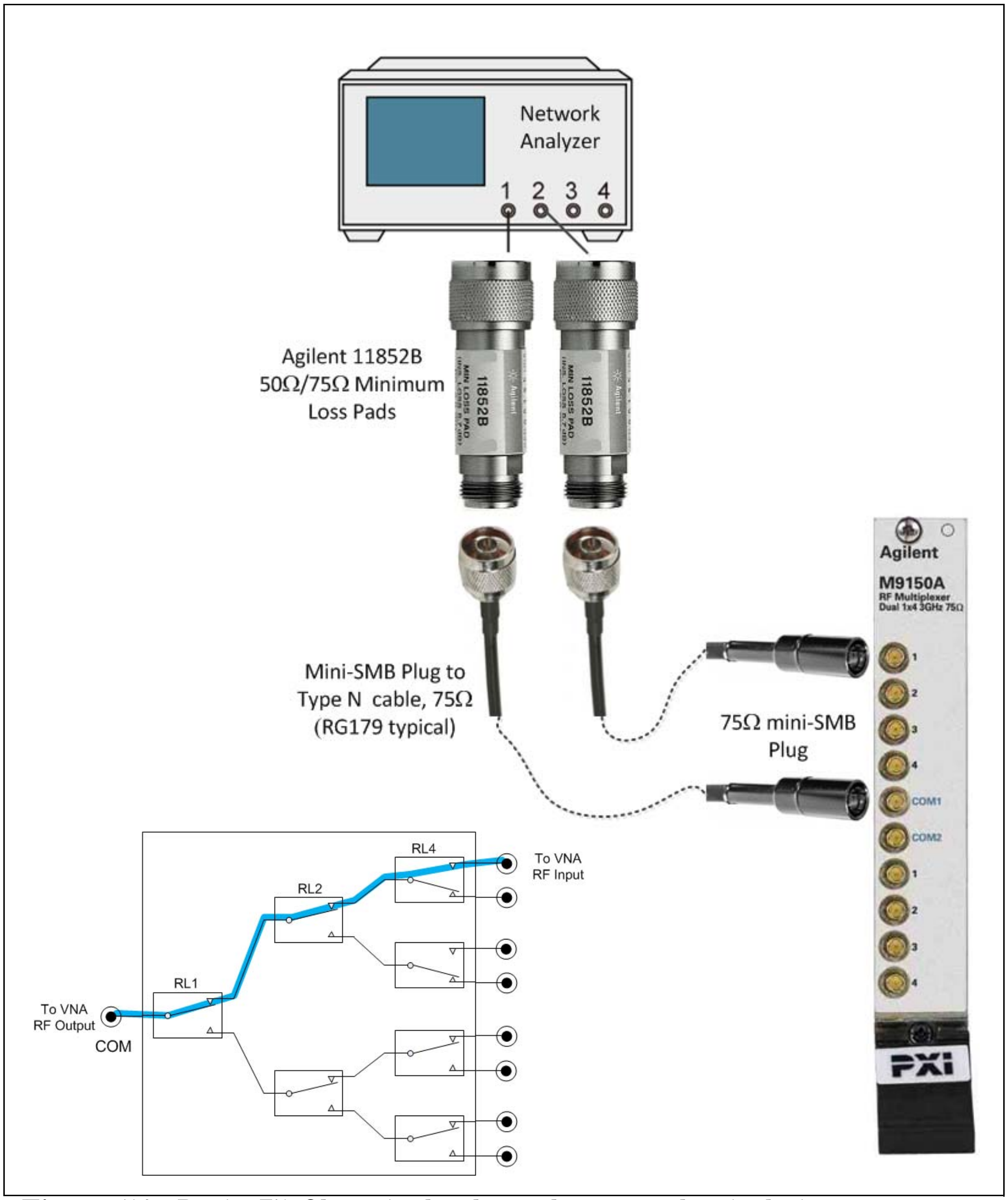


Figure 54 Basic 75 Ohm single channel, open relay isolation test setup

Channel-to-Channel (Crosstalk) Isolation Tests

Channel-to-Channel (Crosstalk) isolation testing determines the level of signal present on an adjacent path from the applied signal. Isolation is measured in decibels.

Testing is done by closing a complete signal channel (network analyzer port 1 to the COM connector, the network analyzer port 2 to the channel under test and a dummy load connected to an adjacent channel to terminate the transmission line). A signal is applied to COM from the network analyzer and the resulting signal is measured at the second channel.

NOTE The Calibration and test procedures are the same as for the single channel isolation tests.

When testing an M9128A 8x12 matrix module, you can perform crosstalk measurements from either axis. For example you can connect the network analyzer port 1 to a Row and the load and network analyzer port 2 connected to a Column. Alternatively you can connect the network analyzer port 1 to a Column and the load and network analyzer port 2 connected to a Row.

50 Ohm Channel-to-Channel (Crosstalk) Isolation Tests

Figure 55 illustrates the basic channel-to-channel (crosstalk) isolation test setup for a 50 Ω RF switch module. Note the channel is closed from the VNA Output to the load. The adjacent channel is open for the test.

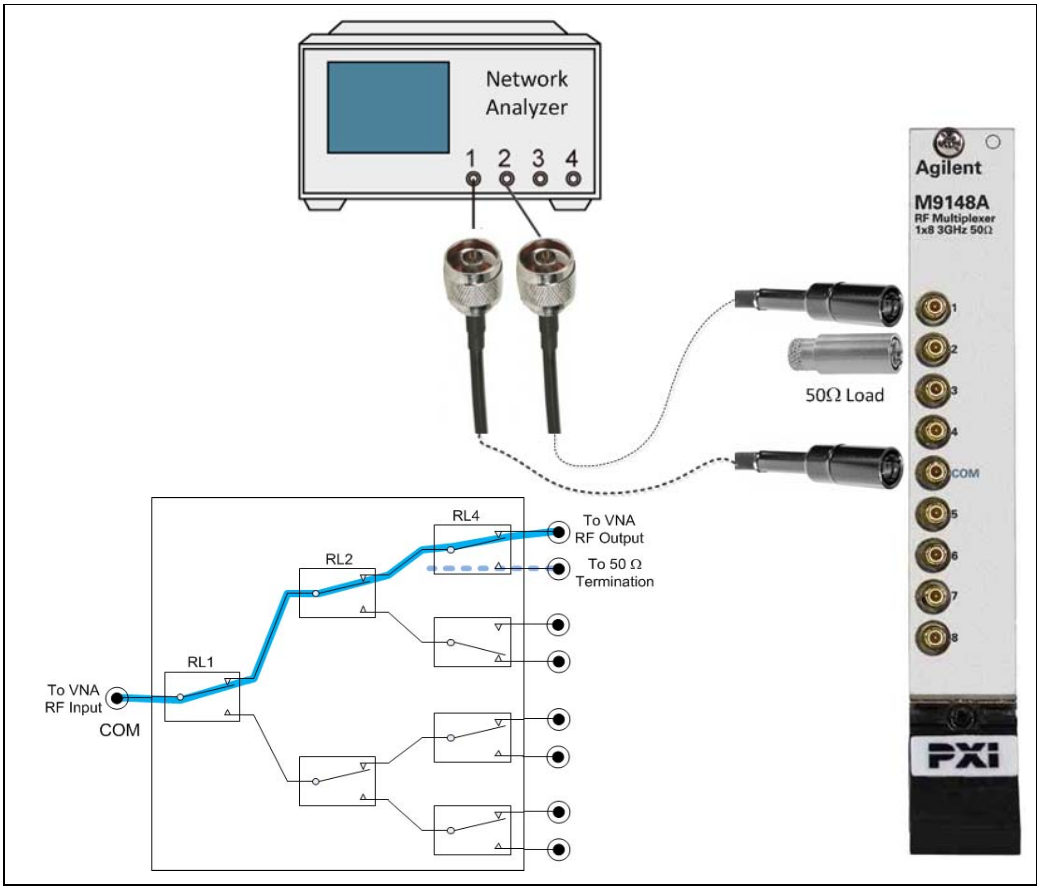


Figure 55 Basic 50 Ohm channel-to-channel isolation test setup

75 Ohm Channel-to-Channel (Crosstalk) Isolation Tests

Figure 56 illustrates the basic channel-to-channel isolation test setup.

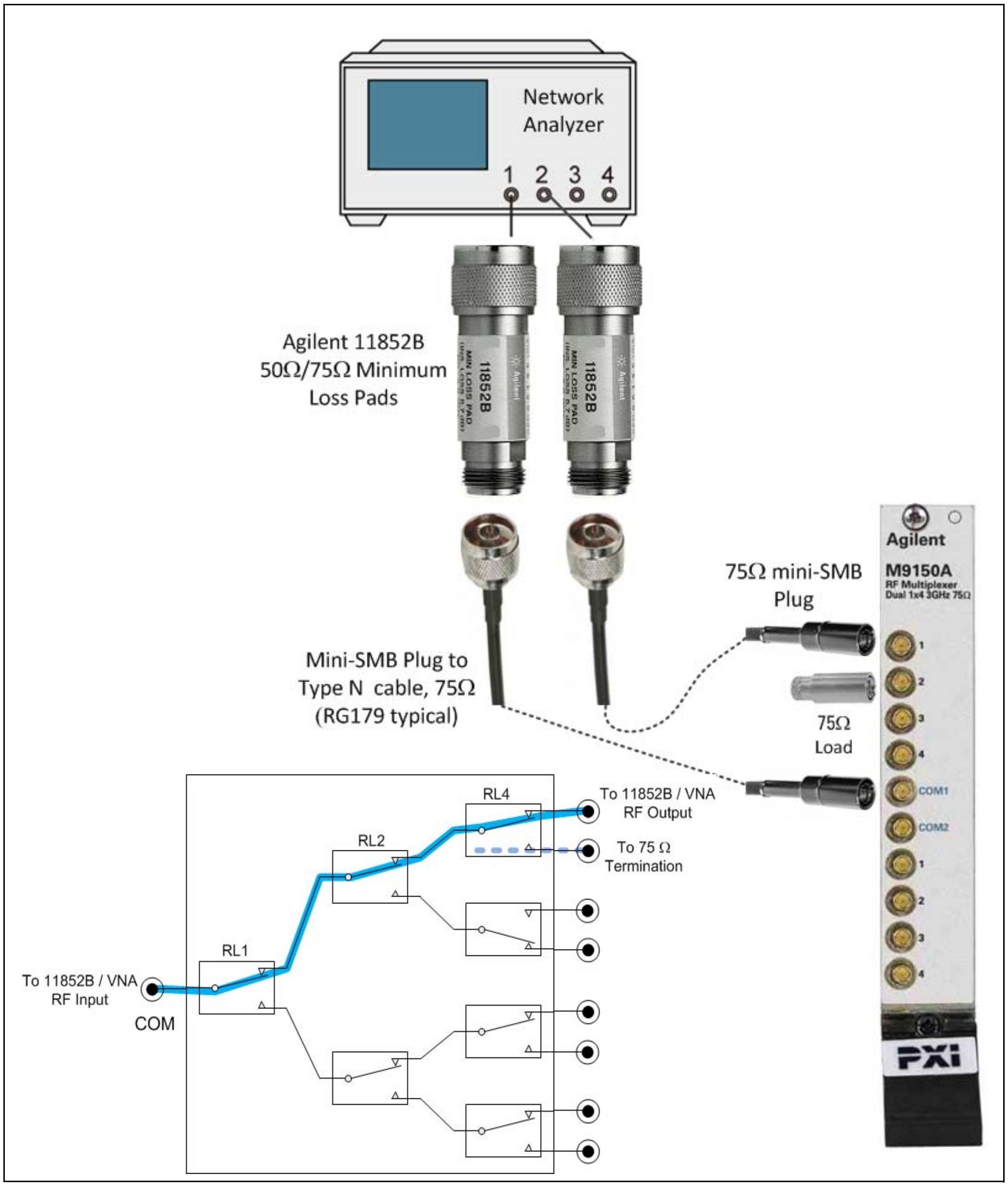


Figure 56 Basic 75 Ohm channel-to-channel isolation test setup

The Modular Tangram

The four-sided geometric symbol that appears in Agilent modular product literature is called a tangram. The goal of this seven-piece puzzle is to create shapes — from simple to complex. As with a tangram, the possibilities may seem infinite as you begin to create a new test system. With a set of clearly defined elements — architecture, hardware, software — Agilent can help you create the system you need, from simple to complex.

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