

Keysight 34959A Breadboard Module

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Safety Information

CAUTION

A CAUTION notice denotes a hazard. It calls attention to an operating procedure, practice, or the like 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.

WARNING

A WARNING notice denotes a hazard. It calls attention to an operating procedure, practice, or the like that, if not correctly performed or adhered to, could result in personal injury or death. Do not proceed beyond a WARNING notice until the indicated conditions are fully understood and met.

Safety Symbols

The following symbols or markings that may be on or with the instrument and in the documentation indicate precautions which must be taken to maintain safe operation of the instrument.

	Alternating current (AC)		Frame or chassis (ground) terminal
	Standby supply. Unit is not completely disconnected from ac mains when switch is off		Caution, risk of electric shock
	Caution, risk of danger (refer to this manual for specific Warning or Caution information)		Direct current (DC)
	Off (mains supply)		On (mains supply)
	Three phase alternating current		Presence of a laser device
	Protective earth (ground) terminal		Equipment protected throughout by double insulation or reinforced insulation
	Caution, hot surface		Product is sensitive to electrostatic discharge

Additional Safety Notices

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

WARNING

Refer to the 34980A User's Guide before using the equipment. The 34980A User's Guide contains additional important information about the modules.

WARNING

GENERAL

If this product is not used as specified in the operating instructions, the protection provided by the equipment could be impaired. This product must be used in a normal condition (in which all means for protection are intact) only. Any external connections must be made prior to applying power.

WARNING

The detachable power cord is the instrument disconnecting device. It disconnects the mains circuits from the mains supply before other parts of the instrument. The front panel switch is only a standby switch and is not a LINE switch (disconnecting device). The instrument power cord does not disconnect or de-energize external circuits connected to the analog bus, terminal blocks or modules.

WARNING**GROUND THE INSTRUMENT**

This is a Safety Protection Class I product (provided with a protective earthing ground incorporated in the power cord). The mains plug shall only be inserted in a socket outlet provided with a protective earth contact. Any interruption of the protective conductor inside or outside of the product is likely to make the product dangerous. Intentional interruption is prohibited. The mains wiring and connectors shall be compatible with the connector used in the premise electrical system. Inadequate earth grounding can damage the instrument or cause an electrical shock hazard. Always use the three prong AC power cord supplied with the instrument or one with equal or better ratings.

Connect to AC power cord as follows:

- Ensure the power cord is not damaged.
 - Install the signal generators so that one of the following items is readily identifiable and easily reached by the operator: AC power cord, alternative switch or circuit breaker.
 - Insert the mains plug into a socket outlet provided with a protective earth grounding.
-

WARNING**IN CASE OF DAMAGE**

Do not use the instrument if it is damaged. Before use, inspect the instrument and all connections. Pay particular attention to the insulation surrounding the connectors and / or cable assembly insulation. NEVER use a cable showing any signs of damage. Faulty cables can cause electrical shock and /or fire hazards and could lead to personal injury or death.

No operator serviceable parts inside. Do not perform any servicing or repair unless qualified to do so. Do not install substitute parts or perform any unauthorized modifications to the instrument. If needed, return the instrument to Keysight for service and repair to ensure the safety features are maintained in operational condition. Instruments that appear damaged or defective should be made inoperative and secured against unintended operation. Failure to recognize and observe normal safety precautions could result in personal injury or death.

WARNING

The detachable power cord is the instrument disconnecting device. It disconnects the mains circuits from the mains supply before other parts of the instrument. The front panel switch is only a standby switch and is not a LINE switch (disconnecting device). The instrument power cord does not disconnect or de-energize external circuits connected to the analog bus, terminal blocks or modules.

WARNING

Keysight Customers utilizing the Open Platform Test Systems are classified as follows and require the user to have the appropriate skillset:

Operator: Interacts with the test system in a production environment, selection of test sequences, defining variables, running tests (test results, test statistics, control of marking devices)

Supervisor: Includes access to maintenance functions and utility sequences (control of hardline system functions, access to test area)

Developer: Full access

WARNING

Removal of the instrument's cover is to be conducted by qualified personnel only. Only qualified, trained personnel who are aware of the hazards involved should remove instrument covers. Prevent operators from accessing any external circuits, test fixtures, cables or wherever hazardous voltages may be present. Failure to recognize and observe normal safety precautions could result in personal injury or death.

WARNING

ENVIRONMENTAL HEALTH & SAFETY: When any channel is connected to a hazardous voltage source, the instrument and the device under test should be supervised, following local EHS practices to restrict access.

CAUTION

Pollution Degree 1: No pollution or only dry, non-conductive pollution occurs. The pollution has no influence (on insulation).

Pollution Degree 2: Normally only non-conductive pollution occurs. Occasionally, a temporary conductivity (leakage current between isolated conductors) caused by condensation can be expected.

WARNING

The maximum common mode input to any one system component within the system installation is not to exceed the maximum stated ratings.

WARNING

Under certain conditions, hazardous voltage levels capable of causing injury or death may remain even after external circuits and the 34980A instrument have been disconnected. To avoid injuries, always disconnect the power and discharge all circuits before touching them. Ensure no hazardous voltages remain on any accessible parts before handling any part of the instrument and test setup.

Environmental Conditions

Keysight 34980A is designed for indoor use in an installation category II and low condensation environment. Table below shows the general environmental conditions for this instrument. Refer to the product data sheet at <https://literature.cdn.keysight.com/litweb/pdf/5989-1437EN.pdf> for more information on the instrument general specifications.

General specifications	Requirement
Temperature	Operating condition: 0°C to 55°C Storage condition: -40°C to 70°C
Humidity	Maximum Relative Humidity (non-condensing): 80% RH up to 40°C, decreases linearly to 37% RH at 55°C ^[a]
Altitude	Up to 2,000 m
Pollution degree	1 or 2

[a] From 40°C to 55°C, the maximum % Relative Humidity follows the line of constant dew point.

Regulatory Markings

	The CE mark is a registered trademark of the European Community. This CE mark shows that the product complies with all the relevant European Legal Directives.		The CSA component mark is a registered trademark of the Canadian Standards Association.
	The UK conformity mark is a UK government owned mark. Products showing this mark comply with all applicable UK regulations.		The Keysight email address is required by EU directives applicable to our product.
CAN ICES/NMB-001(A)	This indicates that this ISM device complies with the Canadian ICES-001. Interference-Causing Equipment Standard for industrial, scientific and medical (ISM) equipment. Matériel industriel, scientifique et médical (ISM)	ISM 1-A	This is a symbol of an Industrial Scientific and Medical Group 1 Class A product. (CISPR 11, Clause 5)
	The CE mark is a registered trademark of the European Community. This CE mark shows that the product complies with all the relevant European Legal Directives. ICES/NMB-001 indicates that this ISM device complies with the Canadian ICES-001. Cet appareil ISM est conforme à la norme NMB-001 du Canada. ISM GRP.1 Class A indicates that this is an Industrial Scientific and Medical Group 1 Class A product.		This is a combined marking to indicate product compliance with the Industry Canadian Interference-Causing Equipment Standard (ICES/NMB-001). This is also a symbol of an Industrial Scientific and Medical Group 1 Class A product (CISPR 11, Clause 5).
	This symbol is a South Korean Class A EMC Declaration. This is a Class A instrument suitable for professional use and in electromagnetic environment outside of the home.		The RCM mark is a registered trademark of the Australian Communications and Media Authority.

 This symbol indicates the time period during which no hazardous or toxic substance elements are expected to leak or deteriorate during normal use. Forty years is the expected useful life of the product.	 This instrument complies with the WEEE Directive (2002/96/EC) marking requirement. This affixed product label indicates that you must not discard this electrical or electronic product in domestic household waste.
 Universal recycling symbol.	IP x y This mark indicates product has been designed to meet the requirements of "IP x y", where "x" is the solid particle protection and "y" is the liquid ingress protection.

Waste Electrical and Electronic Equipment (WEEE) Directive 2002/96/EC

The crossed out wheeled bin symbol indicates that separate collection for waste electric and electronic equipment (WEEE) is required, as obligated by the EU DIRECTIVE and other National legislation.

Please refer to [keysight.com/go/takeback](https://www.keysight.com/go/takeback) to understand your Trade in options with Keysight in addition to product takeback instructions.



Sales and Technical Support

To contact Keysight for sales and technical support, refer to the support links on the following Keysight websites:

- www.keysight.com/find/34980a
(product-specific information and support, software and documentation updates)
- www.keysight.com/find/assist
(worldwide contact information for repair and service)

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34959A Breadboard Module Description

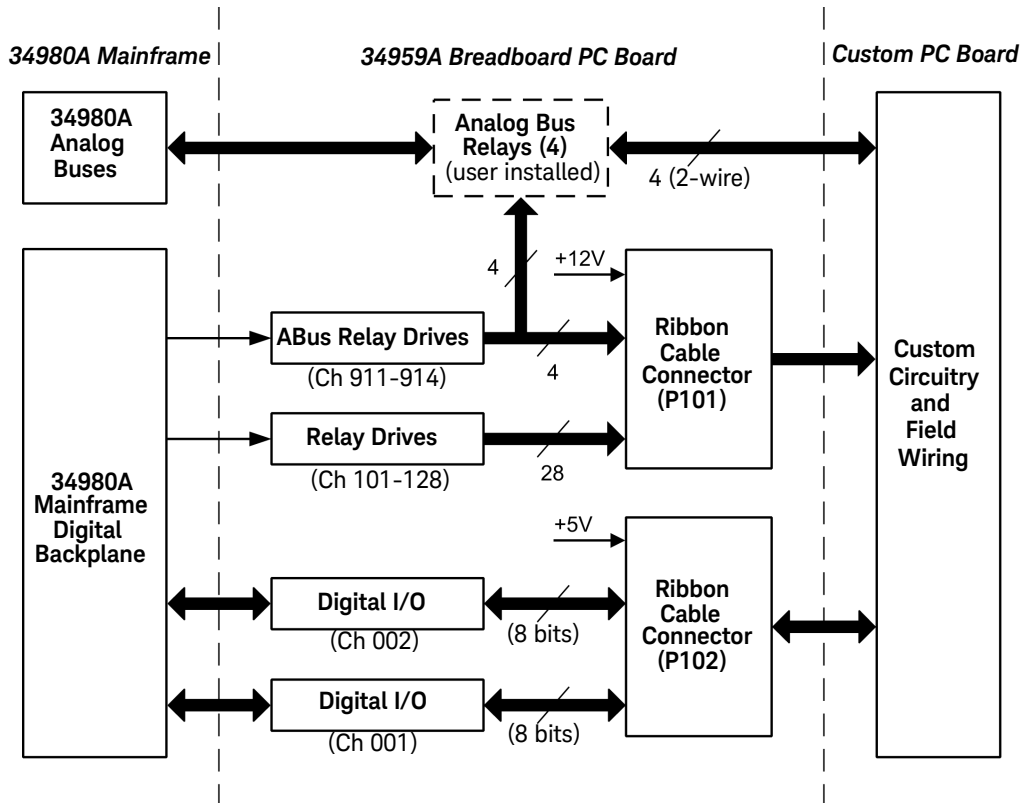
The 34959A Breadboard Module provides a 137mm x 190mm x 23mm (5.4" x 7.5" x 0.9") space inside the 34980A Multifunction Switch/Measure Unit, for you to install custom circuitry to support applications not available on the standard plug-in modules.

This module minimizes the need for customer-supplied circuitry by providing +5V and +12V power supplies for logic and relay drive use, 16 general purpose digital I/O bit lines with control lines, and 32 relay drive lines. Your custom circuitry can access the 34980A mainframe's internal DMM and four Analog Buses. Desired measurement and I/O functions can be programmed using standard read/write commands.

Internally, most of the customer-provided circuitry connects to the module through two ribbon cables; the Analog Bus connections are made by hard-soldering to a grid of holes provided on the Keysight-supplied PC board. Two external ports are provided for Dsub connectors (DB50 or DB78) between the module and your field wiring.

The sheet metal base of the module provides fifteen countersunk holes for flexible mounting of circuit boards, terminal blocks or other components. As with all other plug-in modules for the 34980A, cooling is provided within the mainframe chassis.

34959A Breadboard Simplified Block Diagram



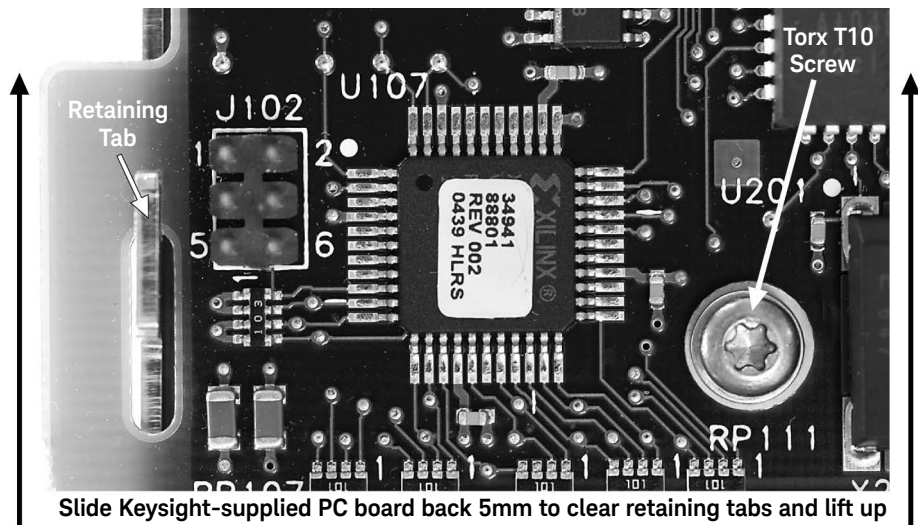
34959A Breadboard Module Disassembly

The module as shipped as shown below. The port covers must be removed if DB50/78 connectors will be installed for external connections; otherwise they can remain in place. The top cover provides mechanical integrity and shielding for the module, and should be attached except when the module is being configured. To unfasten the top cover, remove the screw with a Torx T10 driver, slide the cover back 5mm as shown, and lift the cover up. Reverse this procedure to replace the cover.

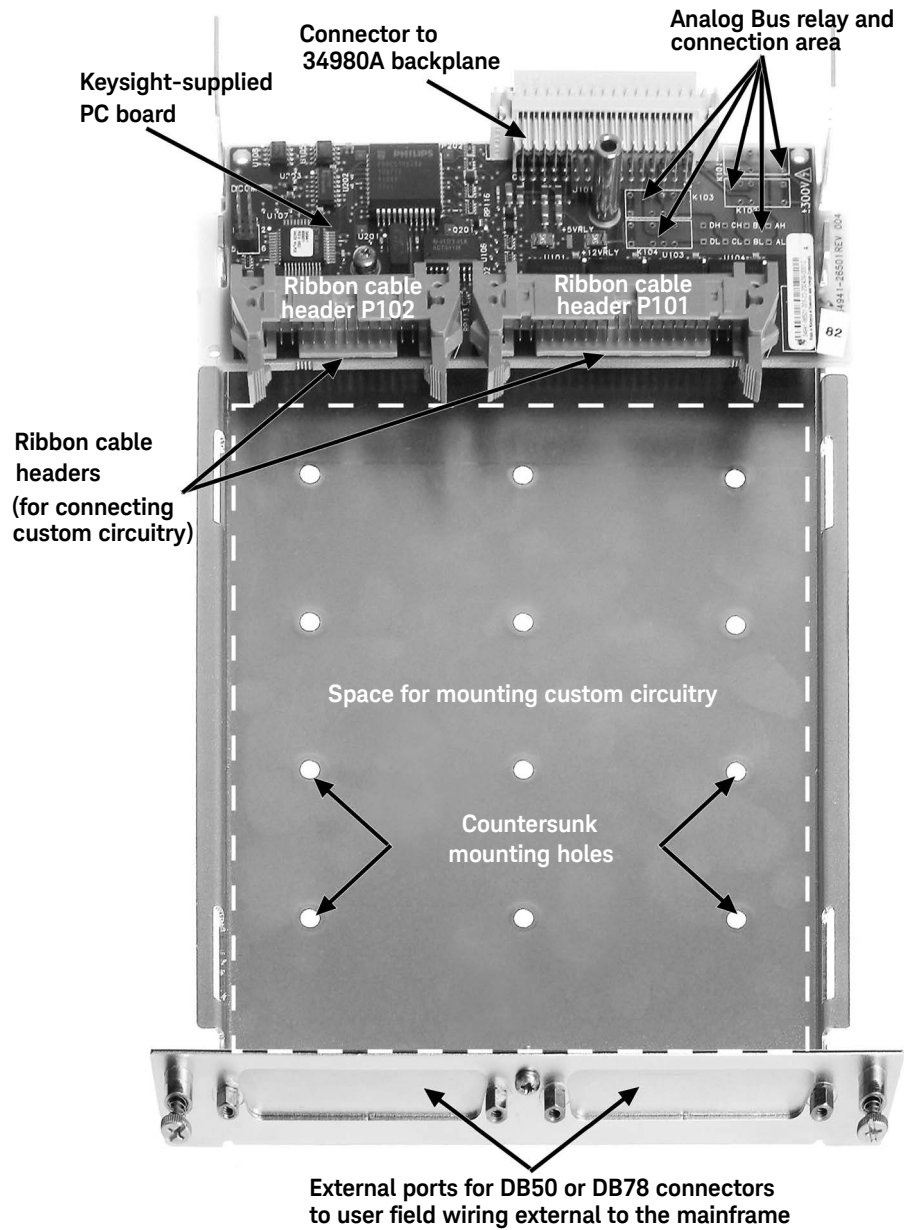


The Keysight-supplied PC board must be removed if you are making connections to the Analog Buses, in order to solder the necessary relays (not provided) and lead wires. To remove this PC board, remove the Torx T10 screw shown, slide the cover back 5mm to clear the two retaining tabs, and lift the board up. Reverse this procedure to reinstall the board.

Removal of the Keysight-Supplied PC Board



34959A Breadboard Module Layout (shown with cover removed)



Ribbon Cable Header Pin Assignment Information

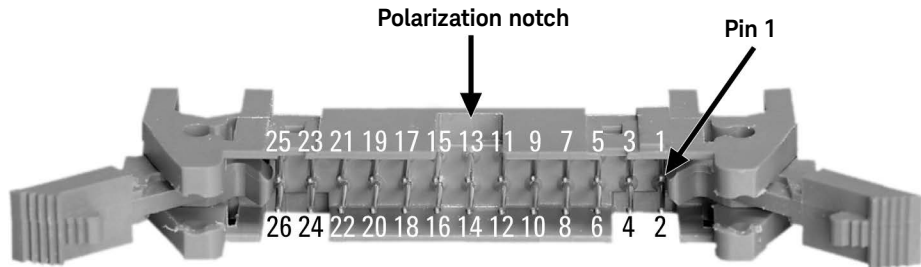
The 34959A breadboard is supplied with two ribbon cable headers, which may be used to access 5V and 12V power, open/close four Analog Bus channels, open/close up to 28 customer-supplied general-purpose relays (up to 100 mA sink to ground), and utilize two 8-bit banks of digital I/O. The supplied cable headers (3M Pak 100 series), recommended connectors and their respective pin assignments are shown below.

WARNING

Pay careful attention to the indexing keys on the connectors, to correctly identify terminal #1! Failure to follow the pin assignments could result in equipment damage and may result in hazardous conditions such as fire or shock and could lead to personal injury or death.

Connector P102

Supplied 26-Pin Ribbon Cable Header P102 (1252-2360)



26-pin 0.1" Ribbon Cable Connector (typical keyed connector)

Polarization key



-Pin numbers are shown from side facing header P102-

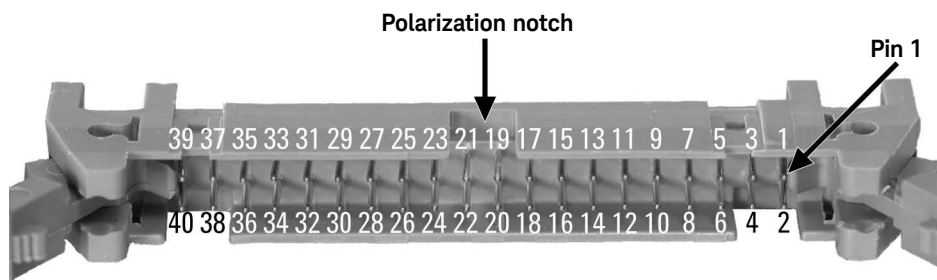
Pin Connection Information for 26-Pin Ribbon Cable Header P102

1	Relay Ground	14	Digital Channel 001; Bit 5
2	Digital Channel 002; Bit 7	15	Digital Channel 001; Bit 4

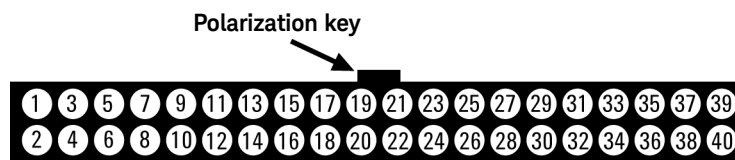
3	Digital Channel 002; Bit 6	16	+5V power supply
4	Digital Channel 002; Bit 5	17	Digital Channel 001; Bit 3
5	Digital Channel 002; Bit 4	18	Digital Channel 001; Bit 2
6	+5V power supply	19	Digital Channel 001; Bit 1
7	Digital Channel 002; Bit 3	20	Digital Channel 001; Bit 0
8	Digital Channel 002; Bit 2	21	Relay Ground
9	Digital Channel 002; Bit 1	22	Control Line 2: Channel 2 Strobe Line
10	Digital Channel 002; Bit 0	23	Control Line 1: Channel 1 Strobe Line
11	Relay Ground	24	Control Line 3: Read/Write Status Line
12	Digital Channel 001; Bit 7	25	+5V power supply
13	Digital Channel 001; Bit 6	26	Relay Ground

Connector P101

Supplied 40-Pin Ribbon Cable Header P101 (1251-8931)



40-pin 0.1" Ribbon Cable Connector (typical keyed connector)



-Pin numbers are shown from side facing header P101(1251-8931)-

Pin Connection Information for 40-Pin Ribbon Cable Header P101

1	Channel 914 (dual-purpose relay drive*)	21	+12V power supply
2	Channel 913 (dual-purpose relay drive*)	22	reserved - do not connect to this pin

3	Channel 912 (dual-purpose relay drive*)	23	reserved - do not connect to this pin
4	Channel 911 (dual-purpose relay drive*)	24	reserved - do not connect to this pin
5	Channel 128 (gen. purpose relay drive)	25	Channel 116 (gen. purpose relay drive)
6	Channel 127 (gen. purpose relay drive)	26	Channel 115 (gen. purpose relay drive)
7	Channel 126 (gen. purpose relay drive)	27	Channel 114 (gen. purpose relay drive)
8	Channel 125 (gen. purpose relay drive)	28	Channel 113 (gen. purpose relay drive)
9	Channel 124 (gen. purpose relay drive)	29	Channel 112 (gen. purpose relay drive)
10	Channel 123 (gen. purpose relay drive)	30	Channel 111 (gen. purpose relay drive)
11	Channel 122 (gen. purpose relay drive)	31	Channel 110 (gen. purpose relay drive)
12	Channel 121 (gen. purpose relay drive)	32	Channel 109 (gen. purpose relay drive)
13	Channel 120 (gen. purpose relay drive)	33	Channel 108 (gen. purpose relay drive)
14	Channel 119 (gen. purpose relay drive)	34	Channel 107 (gen. purpose relay drive)
15	Channel 118 (gen. purpose relay drive)	35	Channel 106 (gen. purpose relay drive)
16	Channel 117 (gen. purpose relay drive)	36	Channel 105 (gen. purpose relay drive)
17	reserved - do not connect to this pin	37	Channel 104 (gen. purpose relay drive)
18	reserved - do not connect to this pin	38	Channel 103 (gen. purpose relay drive)
19	reserved - do not connect to this pin	39	Channel 102 (gen. purpose relay drive)
20	+12V power supply	40	Channel 101 (gen. purpose relay drive)

CAUTION

*If Analog Bus relays K101-K104 are installed, channels 911-914 are dedicated to Analog Buses 1-4 and equipment damage may result from making connections to pins 1 through 4 of P101. Otherwise, channels 911-914 and pins 1-4 may be used as four additional general purpose relay drive lines.

Configuring the 34959A Breadboard Module

WARNING

Only qualified personnel who are aware of the hazards involved shall install, remove or configure the 34959A breadboard for the 34980A mainframe. Before touching any installed accessory, turn off all power to the mainframe and terminal blocks, and to all external devices connected to the mainframe or terminal blocks. Ensure all circuits are discharged before coming in contact with the system. Ensure no hazardous voltages remain on any accessible part before handling any part of the instrument and test setup, making connections to the system, removing covers or cleaning the instrument. Failure to recognize and observe normal safety precautions could result in personal injury or death.

WARNING

When interconnecting the 34959A component module to the system components during installation, the overall 34980A and all installed modules for the system and their maximum rated allowable inputs default to the lowest rating of any one system component or module. Failure to do so may result in hazardous conditions such as fire or shock and could lead to personal injury or death.

WARNING

Hazardous voltage levels capable of causing death, may be present on a channel. Use extreme caution when handling, testing and adjusting this instrument. Any voltages greater than 30 Vrms, 42.4 Vpeak and 60 Vdc are considered hazardous (IEC 61010-1).

When working with hazardous voltage levels, intentionally closing of multiple bus and channel relays could cause a potentially lethal hazard on external connections. Use extreme caution when handling and testing and adjusting this instrument. Do not perform these procedures unless qualified to do so. Failure to recognize and observe normal safety precautions could result in personal injury or death.

WARNING

It is possible to connect more than one power source at the same time with a matrix. Ensure that hazardous or unwanted conditions are not created by these connections. Failure to recognize or observe normal safety precautions could result in equipment damage and may result in hazardous conditions such as fire or shock and could lead to personal injury or death.

WARNING

Do not connect the Analog Buses directly to a mains power outlet. If it is necessary to measure a mains voltage or any circuit where a large inductive load may be switch, you must add signal conditioning elements to reduce the potential transients before they reach the Analog Buses.

WARNING**HIGH ENERGY SOURCES**

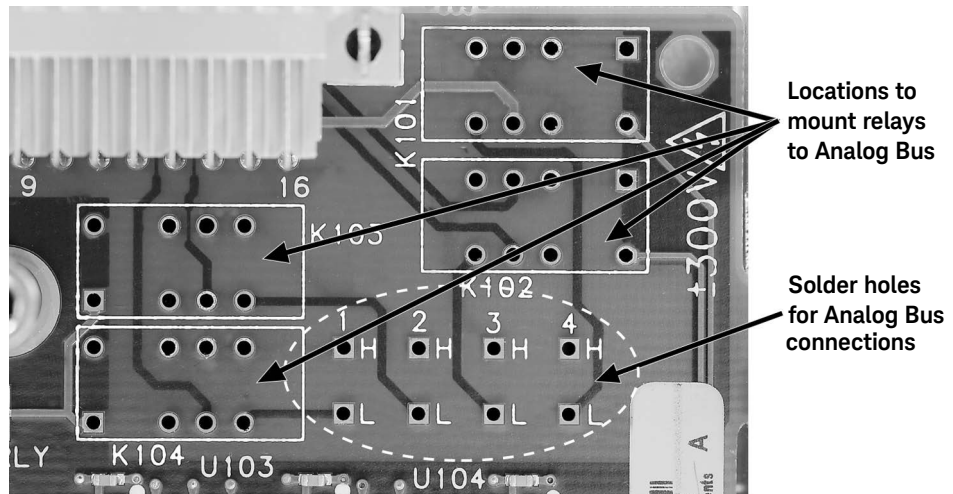
The Analog Buses are designed to handle inputs up to their rated currents or their rated powers, whichever is less. Under certain fault conditions, high energy sources could provide substantially more current or power than the instrument can handle. It is important to provide external current limiting, such as fuses if the inputs are connected to high-energy sources. The overcurrent protection is to be rated for the maximum available short circuit current of the hazardous sources. Ensure that the current limiting devices / snubber circuits are appropriate for the signal being tested. Failure to do so may result in hazardous conditions such as fire or shock and could lead to personal injury or death. Refer to **34980A Current Limiting Graphs** for the current limiting graphs of 34890A.

Accessing the 34980A Mainframe's Analog Bus

If your custom circuitry will need access to the four Analog Buses on the mainframe's backplane, you must install relays (Keysight 0490-1954) on and make connections directly to the Keysight-supplied PC board (see the explanation on [page 17](#) for PC board removal, and the table on [page 26](#) for connection

information). The following enlargement of the Analog Bus control area of the board shows where to install the relays and make wire connections:

Analog Bus Relay Installation and Solder Hole Locations



The locations for relays K101-104 (0490-1954) are marked on the board. You may install any or all of these relays, as needed.

WARNING

Failure to follow the instructions below could result in equipment damage and may result in hazardous conditions such as fire or shock and could lead to personal injury or death.

When soldering Keysight supplied relays 0490-1954 K101-K104 to the Keysight-supplied PC board, take special care to avoid reducing spacings and/or shorts between pins. Any reduction in spacings or shorting these connections may result in hazardous conditions and/or damage to the breadboard module, the 34980A mainframe, other installed modules, or your test circuitry.

The connections from the Analog Bus outputs (8 holes marked on the Keysight-supplied PC board as 1 through 4, H and L) to your custom circuitry to be made with wire insulated for two times the highest working voltage in the system. Refer to 34959A Safety Guidelines for details.

WARNING

Failure to follow the instructions below could result in equipment damage and may result in hazardous conditions such as fire or shock and could lead to personal injury or death.

When soldering wire to the Analog Bus connection holes, take special care to avoid any reduction in spacings or shorts between wires and/or holes. Shorting these connections may result in hazardous conditions and/or damage to the breadboard module, the 34980A mainframe, other installed modules, or your test circuitry.

The following table shows which relays must be installed to control the four Analog Bus channels, and which holes on the Keysight-supplied PC board (see the photo on [page 25](#) for the locations to solder each two-wire output connection):

34959A Breadboard: Connections to the 34980A Analog Buses

Relay #	Analog Bus Channel	Bus #	Connect to Hole on PC Board
K101	911	1	1H and 1L
K102	912	2	2H and 2L
K103	913	3	3H and 3L
K104	914	4	4H and 4L

WARNING

SHOCK HAZARD If any of the relays K101-K104 are installed on the 34959A module's Keysight-supplied PC board then an Analog Bus connection is possible to other installed plug-in modules. This connection can present hazardous voltages (up to 300V) to the user's custom PC board installed on the 34959A or any attached test circuitry.

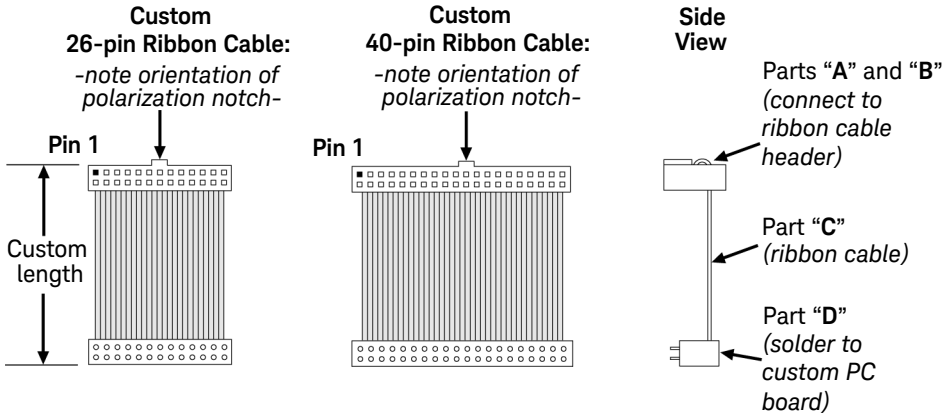
Installing Custom Circuitry on the 34959A Breadboard Module

Connection to the Ribbon Cable Headers

The two supplied headers P101 and P102 have ejecting latches and polarization notches. Although individual crimp terminals can be used to connect to the

header pins, the most secure connection will be achieved by using keyed ribbon cable connectors. The selection of ribbon connectors is left to the user. However, if you desire to hard-solder connections to your custom PC board, the following diagram is offered as a suggestion:

Connection from Headers P101 and P102 to a Custom PC Board



Suggested Part Numbers for Ribbon Cable Connections Shown above

Part	Description
for connection to 26-pin header	
A	26-pin wire-mount socket
B	26-pin strain relief
C	26-conductor ribbon cable
D	PC-board mount
for connection to 40-pin header	
A	40-pin wire-mount socket
B	40-pin strain relief
C	40-conductor ribbon cable
D	PC-board mount

Installing a Custom PC Board

The remaining space in the breadboard module is available for installing custom circuitry. Fifteen 3.18 mm (0.125") diameter holes, countersunk on the bottom of the sheet metal base, are provided for mounting the PC board to the base. The maximum allowable height of the board and attached components above the base, including spacers, is 23 mm. Assuming a PC board thickness of 1.6 mm, you should use 5.1 mm long spacers and M3x0.5mm thread flathead screws. The figure on [page 32](#) provides the dimensions of the largest PC board which will fit the breadboard module, the locations of the countersunk mounting holes, and their location relative to the ribbon cable headers and Dsub ports.

If you utilize a PC board with the maximum allowable dimensions, it may be necessary to first remove the Keysight-supplied PC board (34980A backplane interface with ribbon cable headers), install the custom board by inserting the Dsub connectors into the ports provided, secure the custom board, and then reinstall the Keysight-supplied PC board. When the module assembly is complete, replace the sheet metal cover and install the module in an available slot within the 34980A mainframe.

Extending the Breadboard Connections During Development

During development of your custom circuitry, you may need to work with your PC board on a test bench, outside the confines of the breadboard module. This should be done by using ribbon cable extenders and extra length of Analog Bus connection wire. Once your final PC board configuration is achieved, these leads should be shortened to allow fixed installation of the PC board inside the module.

WARNING

Use of the Y1132A Service Extender from the 34980A mainframe to the breadboard module is not recommended, because the Service Extender is not rated for the 300V potentials available on the breadboard's Analog Bus connectors.

Spacing and Insulation Requirements for High Voltage Applications

If your planned use of the 34959A breadboard module will involve the application of hazardous voltages ($>30V_{\text{rms}}$ AC or $>60V$ DC IEC 61010-1), refer to 34959A Safety Guidelines for Custom Built Circuitry with Hazardous Levels.

NOTE

The International Electrotechnical Commission (IEC) Standard 61010-1 (available at www.iec.ch) lists the insulation requirements for hazardous voltage applications in Pollution Degree Levels 1 and 2.

Operating Considerations

Electrical Specifications

The specifications below were derived from the individual components used to provide the relay drive and digital I/O functions:

Electrical Specifications for the 34959A Breadboard Module

Specification	Test Conditions	Minimum	Typical	Maximum
Total Power Consumption (by customer-installed circuits)	all connections total			6W
Maximum Power from 12V Supply				6W
Maximum Power from 5V Supply				1W
Connector P101 (Relay Drive)				
Current Limit (per relay drive pin)	all outputs driven simultaneously			150 mA
On Resistance (to chassis)	@ 100 mA output		4.2 Ω	5.7 Ω
	@ 400 mA output		6.5 Ω	8.0 Ω
Input Voltage				42Vdc
Leakage Current	@ max. input voltage			8 μ A
Connector P102 (Digital I/O)				
High Level Input Voltage		2V		5.5V
Low Level Input Voltage		0V		0.8V
High Level Output Voltage	@ 4 mA output	2.4V		
	@ 500 μ A output	3.0V		
Low Level Output Voltage	@ 8 mA output			0.4V

Environmental Voltage Limits

See the *Introduction to the Plug In Modules* chapter of the 34980A Mainframe User's Guide for detailed environmental operating conditions for the 34980A mainframe and its installed modules. That guidance sets a maximum voltage rating for the Analog Buses of 300V in pollution degree 1 (dry) conditions, and derates the maximum voltage to 100V for pollution degree 2 (possible condensation) conditions. That guidance applies to any circuitry installed in the 34959A module.

CAUTION

Exceeding the maximum power limits for the 12V and 5V power supplies (through improper wiring or cable damage) may cause the 34980A mainframe to reboot. Although over-current protection is provided on the power supply lines, operating in an overcurrent situation for extended periods could damage the mainframe.

Module Cooling

The maximum rated power consumption/dissipation for the breadboard module and its installed circuitry is 6 watts, resulting in a 5°C rise in temperature.

NOTE

To allow adequate cooling of the breadboard module, ensure that your circuit layout does not impede air flow.

Dimension Information for the Custom PC Board Area

Utilization of the empty space within the 34959A breadboard module is left entirely up to the user. However, assuming you want to most fully utilize the space provided, output signals through the Dsub ports, and connect your board securely to the supplied ribbon cable headers, four detailed dimension drawings are provided in this section to assist with your PC board fabrication.

The figure on [page 32](#) illustrates the external dimensions of the largest PC board that will fit into the space provided, and provides distances on the plane of that board from the datum to the following locations:

- The 15 PC board mounting holes in the sheet metal base.
- Pin 1 of the board mounting position for the 26-pin ribbon cable connector carrying digital I/O signals and control power to/from header P102.
- Pin 1 of the board mounting position for the 40-pin ribbon cable connector carrying relay drive signals and control power from header P101.
- The center of the two user-supplied Dsub output connectors.
- The mounting holes for the two Dsub connectors. Note that this dimension, labelled “Dimension A” on the drawing, varies with the selection of Dsub connector used (e.g., DB50, DB78M, DB78F).

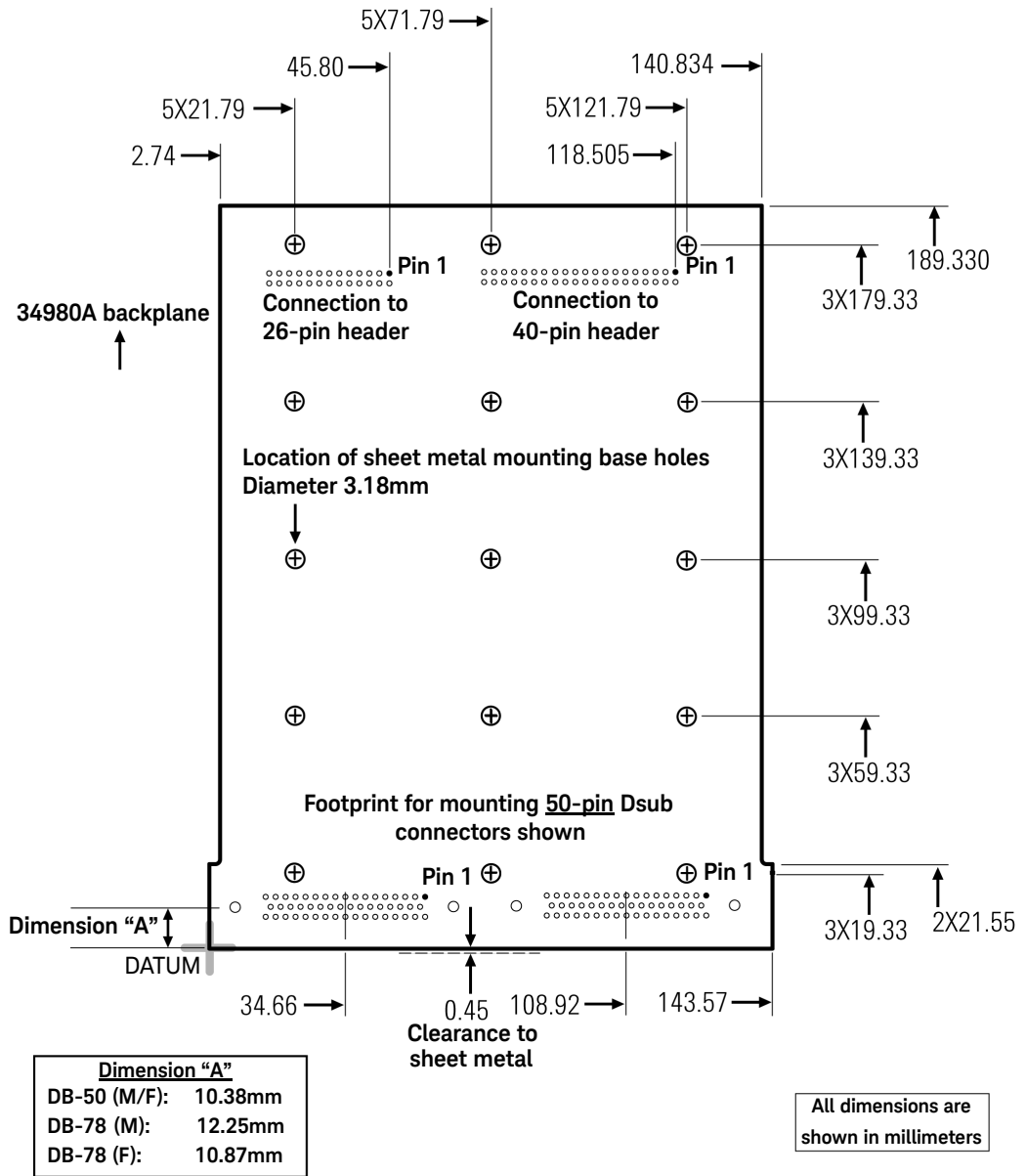
The figure on [page 34](#) shows the mounting footprints for the *recommended DB50(M/F) connectors. The two figures on [page 35](#) show the footprints for the DB78M and DB78F connectors, respectively. The part numbers for the connectors are listed in the following table:

Dsub Connectors as Shown in Dimension Drawings 2 through 4

Connector	Keysight Part Number
DB-50 (M)	1253-5853
DB-50 (F)	1253-5854
DB-78 (M)	1253-6006
DB-78 (F)	1253-6007

*Refer to 34959A Breadboard Component Module Conditions of Acceptability to determine the selection of Keysight D-Sub connectors to be used.

Dimensions of Suggested (maximum size) Custom PC Board



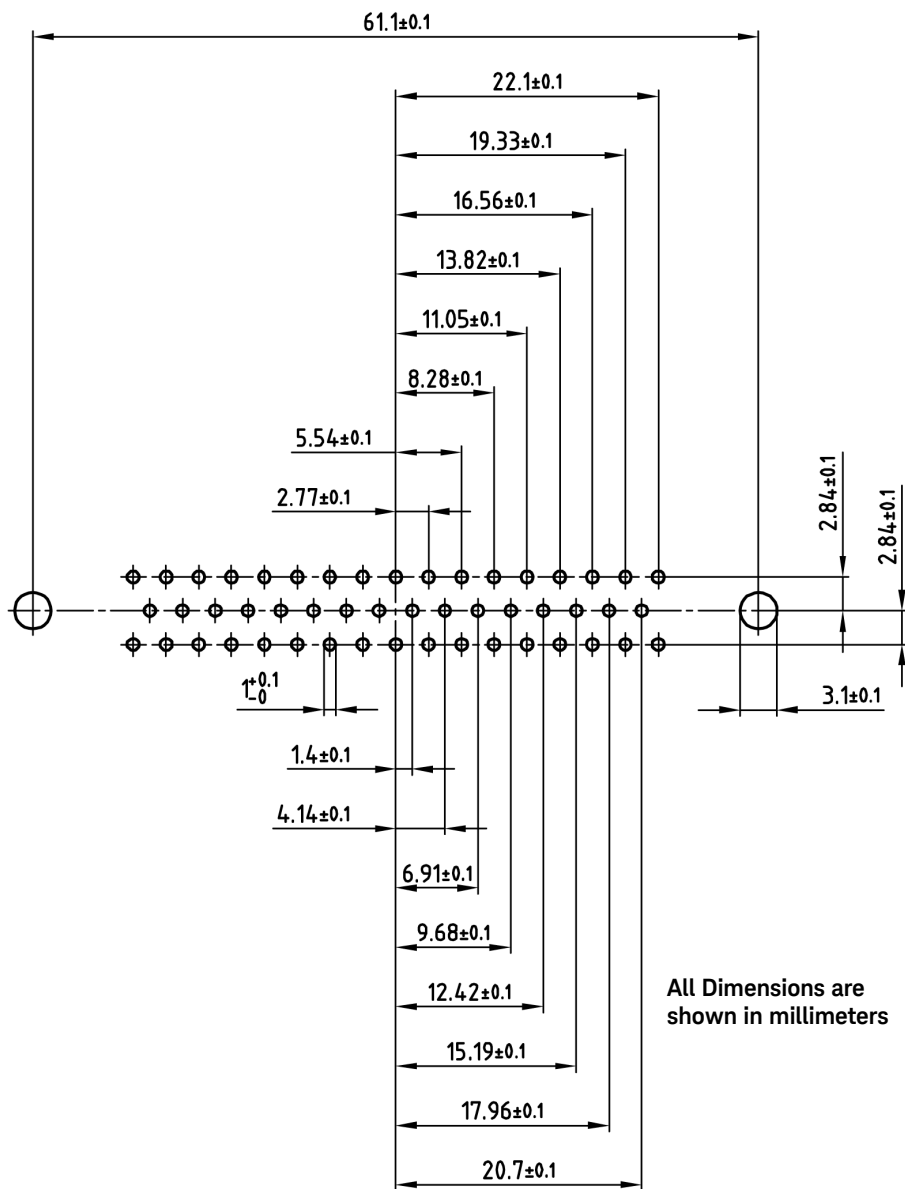
WARNING

Failure to follow the instructions below could result in equipment damage and may result in hazardous conditions such as fire or shock and could lead to personal injury or death.

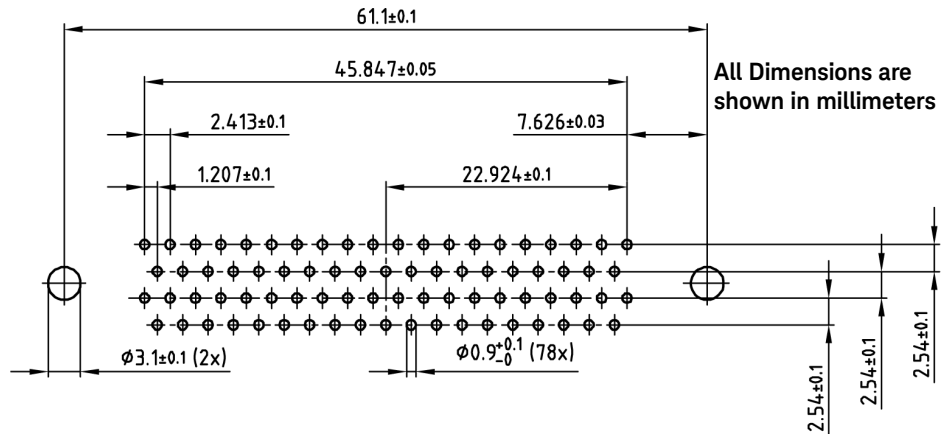
Keysight connectors to be used when the voltage of any one component or interconnecting system components / modules installed with the 34980A mainframe:

- Greater than 30 Vrms, 42.4 Vpeak or 60 Vdc: DB-50 (F) 1253-5854 or DB-78(F) 1253-6007
 - 30 Vrms, 42.4 Vpeak or 60 Vdc or less: DB-50(M) 1253-5853, DB-78(M) 1253-6006, DB-50 (F) 1253-5854 or DB-78(F) 1253-6007
-

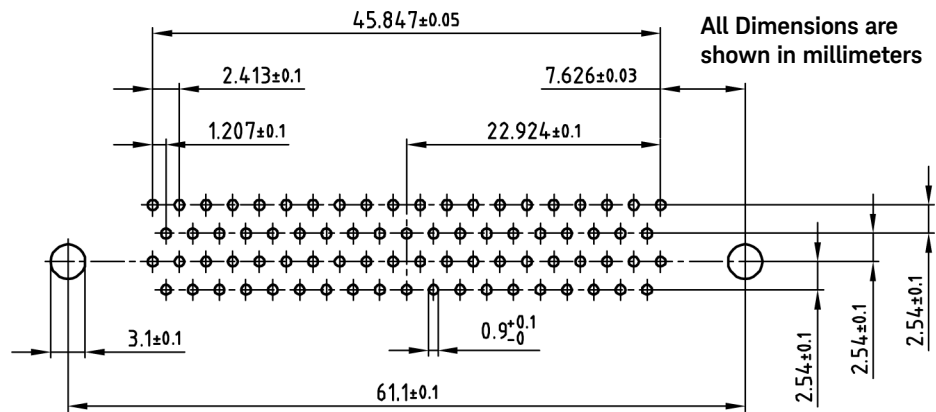
PC Board Footprint of Suggested DB50 Connectors (M/F)



PC Board Footprint of Suggested DB78M Connector



PC Board Footprint of Suggested DB78F Connector



Programming the 34959A Breadboard Module

The 34959A Breadboard Module has three methods of signal input/output between the 34980A mainframe and the user-designed circuitry. The first is to access the four Analog Buses. The second provides control for up to 32 general purpose relays you may install on your PC board (only 28 general purpose relays if the four Analog Bus relay control lines will be used). The third provides two bytes of simple digital I/O with handshake signals.

Analog Bus Relay Functions

The 34980A mainframe provides four two-wire internal Analog Buses for signal routing. The channels for the four Analog Buses are numbered 911 through 914. If any of the optional Analog Bus relays K101 through K104 are installed on the 34959A, you can route external signals to the Analog Buses or access signals introduced to those buses through other installed modules. Refer to the 34980A Mainframe User's Guide for configuring the internal DMM for making voltage, resistance, or frequency measurements.

NOTE

The internal DMM uses Analog Bus 1 for voltage, 2-wire resistance, and frequency measurements. For 4-wire resistance measurements, the internal DMM uses both Analog Bus 1 and Analog Bus 2.

The *Keysight 34980A Programmer's Reference* details the SCPI language and syntax for all commands available through the remote interface. Examples of some commands you will use to control relays to the analog bus, query relay status or assign custom labels to these channels are described below:

The **ROUTe:OPEN** command is used to open a relay. The syntax is:

ROUTe:OPEN (@<ch_list>)

Example: If the Breadboard Module is in slot 1, the following command opens relay K101 to Analog Bus 1 (channel 911):

ROUTe:OPEN (@1911)

The **ROUTe:OPEN?** command is used to query the status of a relay. The syntax is:

ROUTe:OPEN? (@<ch_list>)

Example: If the Breadboard Module is in slot 3, the following query returns the status of relay K104 to Analog Bus 4 (channel 914). A 1 is returned if the relay is open; a 0 is returned if the relay is closed:

ROUTe:OPEN? (@3914)

The **ROUTe:CLOSe** command is used to close a relay. The syntax is:

ROUTe:CLOSe (@<ch_list>)

Example: If the Breadboard Module is in slot 7, the following command closes relay K103 to Analog Bus 3 (channel 913):

ROUTe:CLOSe (@7913)

The **ROUTe:CLOSe?** command is used to query the status of a relay, with opposite results to the **ROUTe:OPEN?** command. The syntax is:

ROUTe:CLOSe? (@<ch_list>)

Example: If the Breadboard Module is in slot 6, the following query returns the status of relay K104 to Analog Bus 4 (channel 914). A 1 is returned if the relay is closed; a 0 is returned if the relay is open:

ROUTe:CLOSe? (@6914)

The **ROUTe:CHANnel:LABel** command is used to assign a user-defined label to any of the 32 channels accessible by the Breadboard Module, including the Analog Bus channels. These labels may be up to 18 ASCII characters in length, and are not required to be unique. The syntax is:

ROUTe:CHANnel:LABel <label>, (@<ch_list>)

Example: If the Breadboard Module is in slot 2, the following command assigns the label "Test Point A" to Analog Bus channel 913:

ROUTe:CHANnel:LABel "Test Point A", (@2913)

Most SCPI commands can address more than one channel at a time, including specifying a range of channels. Refer to the Keysight 34980A *Programmer's Reference* for more complete information.

General Purpose Relay Functions

In addition to the four dual-purpose relay channels 911-914, which may be used as general purpose relay drive channels if relays K101-K104 are not installed, the 34959A breadboard module provides 28 additional general purpose relay drive lines. The channels for these relay drives are numbered 101 through 128. All of the

SCPI commands described in the previous section, “[Analog Bus Relay Functions](#)” on page 36, also apply to these relay drives. Since relay selection is left to the user’s discretion, take particular note of the maximum current limits specified in the Electrical Specifications table on [page 29](#) when choosing and driving your relays.

Digital I/O Functions

The Digital input/output (DIO) interface provides two 8-bit bytes of DIO, which may be accessed individually or combined together to form one 16-bit word. Three control lines are provided. See the Pin Connection Information table (for P102) on [page 20](#) for connection information. The three control lines provide handshake of the read/write SCPI commands (**SENSe** and **SOURce**) sent to the mainframe, as follows:

Timing for Read Commands

When the 34980A receives a SCPI command to read from the breadboard, control line 3 is set high (its default setting, indicating a read request).

If the read target is byte 1, control line 1 is set strobe low, the byte 1 data is read, and then control line 1 is set strobe high. The strobe pulse width is 3.75 μs , and the time from strobe low to valid data is 1.25 μs .

Similarly, *if the read target is byte 2*, control line 2 is set strobe low, the byte 2 data is read, and then control line 2 is set strobe high. The strobe pulse width is 3.75 μs , and the time from strobe low to valid data is 1.25 μs .

*If both bytes are configured as a word, and targeted as a word in the read (**SENSe**) command*, both control lines 1 and 2 are set strobe low, all 16 bits are read, and then both control lines are set strobe high. The strobe pulse width is longer (5 μs) than for a single byte read, but the time from strobe low to valid data is still 1.25 μs .

In all three cases, once the data has been read by the mainframe, the data lines are left in tri-state (indeterminate).

The read timing diagram is shown on [page 40](#).

Timing for Write Commands

When the 34980A receives a SCPI command to write to the breadboard, control line 3 is set low (indicating a write request).

If the write target is byte 1, control line 1 is set strobe low, the byte 1 data is written to the 8 output bits, and then control line 1 is set strobe high. Valid data is present 1.25 μ s before the control line strobe is set high. Control line 3 is then set high.

Similarly, if the write target is byte 2, control line 2 is set strobe low, the byte 2 data is written to the 8 output bits, and then control line 2 is set strobe high. Valid data is present 1.25 μ s before the control line strobe is set high. Control line 3 is then set high.

*If both bytes are targeted in the write (**SOURCE**) command, both control lines 1 and 2 are set strobe low, both bytes' data are written to the 16 output bits, and then both control lines are set strobe high. Valid data is present 1.25 μ s before the control line strobe is set high. Control line 3 is then set high.*

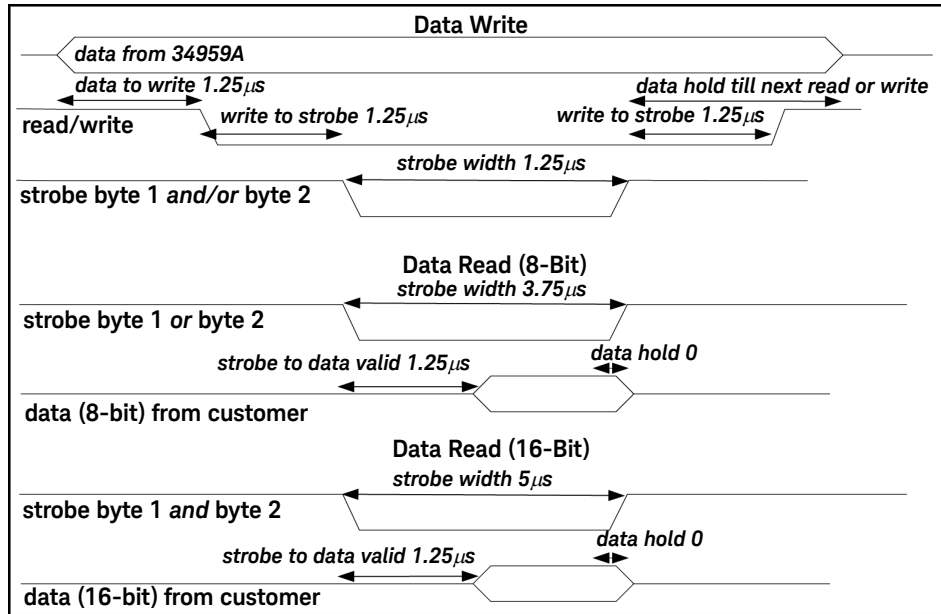
In all three cases, once the data has been written by the mainframe, the data is kept on the data lines until another (read or write) command changes them.

The write timing diagram is shown below.

Timing Diagrams for the Digital Read and Write Commands

The strobe timing, control line status and data timing for the read and write commands as explained above are illustrated in the diagrams that follow:

34959A Breadboard Module Digital I/O Timing Diagrams



Digital Channel Numbering

The two 8-bit DIO channels, numbered 001 and 002, are intended to be used as two separate channels (bytes). However, they can be grouped together as a single 16-bit channel (word). When these channels are grouped, all bits in Channel 002 will be reconfigured to operate in the same direction (input or output) as Channel 001; Channel 001 will become the control channel, and should be used for all DIO channel configuration commands.

Read Command Syntax

Before reading digital data from the breadboard, you must first configure the digital channel width as byte or word, using the **CONFIGure:DIGital:WIDTH** command. The syntax is:

CONFIGure:DIGital:WIDTH <width>, (@<ch_list>)

Example: If the Breadboard Module is in slot 1, the following command configures channel 002 as a byte:

CONFIGure:DIGital:WIDTH BYTE, (@1002)

Example: If the Breadboard Module is in slot 7, the following command configures channels 001 and 002 together as a word:

CONFigure:DIGital:WIDTh WORD, (@7001)

After either channel has been configured as a byte, or both have been configured as a word, you must then specify the target channel for *input* operations, using the **CONFigure:DIGital:DIRection** command. The syntax is:

CONFigure:DIGital:DIRection <direction>, (@<ch_list>)

Example: If the Breadboard Module is in slot 3, and channel 002 has been configured as a byte, the following command configures channel 002 as a byte-width input:

CONFigure:DIGital:DIRection INPut, (@3002)

Example: If the Breadboard Module is in slot 5, and both channels have been configured as a word, the following command configures the combined channel as a word-width input (note that it is only necessary to specify the first channel in SCPI, once the word width has been specified):

CONFigure:DIGital:DIRection INPut, (@5001)

Once the data width and direction have been configured, the data (either word, byte or bit) is read using the **SENSe** command. The syntax is:

SENSe:DIGital:DATA:<width>? (@<ch_list>)

Example: If the Breadboard Module is in slot 3, and channel 002 has been configured as a byte input, the following command returns the value of the channel 002 byte as an integer:

SENSe:DIGital:DATA:BYTE? (@3002)

Example: If the Breadboard Module is in slot 4, and channels 001 and 002 have been configured as a word input, the following command returns the value of the combined channel word as an integer:

SENSe:DIGital:DATA:WORD? (@4001)

Example: If the Breadboard Module is in slot 6, and channel 001 has been configured as a byte input, the following command returns the state of bit 4 on the channel 001 byte:

SENSe:DIGital:DATA:BIT? 4, (@6001)

Write Command Syntax

Before writing digital data to the breadboard outputs, you must first configure the digital channel width as byte or word, using the same commands listed under “[Read Command Syntax](#)” on page 40.

After either channel has been configured as a byte, or both have been configured as a word, you must then specify the target channel for *output* operations, using the **CONFigure:DIGital:DIRection** command. The syntax is the same as for input operations, except for the specified **<direction>**.

Example: If the Breadboard Module is in slot 3, and channel 002 has been configured as a byte, the following command configures channel 002 as a byte-width output:

```
CONFigure:DIGital:DIRection OUTPut, (@3002)
```

Example: If the Breadboard Module is in slot 5, and both channels have been configured as a word, the following command configures the combined channel as a word-width output (note that it is only necessary to specify the first channel in SCPI, once the two channels have been configured as a word):

```
CONFigure:DIGital:DIRection OUTPut, (@5001)
```

Once the data width and direction have been configured, the data (either word, byte or bit) is written to the output lines using the **SOURce** command. The syntax of that command is subtly different for writing a single bit versus writing an entire byte or word.

To output a digital bit, the specified bit number must be 0 (LSB) through 7 (MSB) of the targeted byte, and the syntax is:

```
SOURce:DIGital:DATA:BIT {0|1}, <bit>, (@<ch_list>)
```

Example: If the Breadboard Module is in slot 3, and channel 002 has been configured as a byte output, the following command writes a 1 to bit 6 of channel 002:

```
SOURce:DIGital:DATA:BIT 6,1 (@3002)
```

To output a digital byte, the specified value may be binary (valid values from #B00000000 through #B11111111), hexadecimal (valid values from #H0 through #HFF) or integer (valid values 0 through 255) and the syntax is:

```
SOURce:DIGital:DATA:BYTE <data>, (@<ch_list>)
```

Example: If the Breadboard Module is in slot 6, and channel 002 has been configured as a byte output, any of the following commands will write the value 10011101 to channel 002:

```
SOURce:DIgital:DATA:BYTE #B10011101, (@6002)
```

```
SOURce:DIgital:DATA:BYTE #H9D, (@6002)
```

```
SOURce:DIgital:DATA:BYTE 157, (@6002)
```

To output a digital word, the specified value may be binary (valid values from #B0000000000000000 through #B1111111111111111), hexadecimal (valid values from #H0 through #HFFFF) or integer (valid values 0 through 65535) and the syntax is:

```
SOURce:DIgital:DATA:WORD <data>, (@<ch_list>)
```

Example: If the Breadboard Module is in slot 8, and channels 001 and 002 have been configured as a word output, any of the following commands will write the value 1001100110011001 to the combined digital channel:

```
SOURce:DIgital:DATA:WORD #B1001100110011001, (@8001)
```

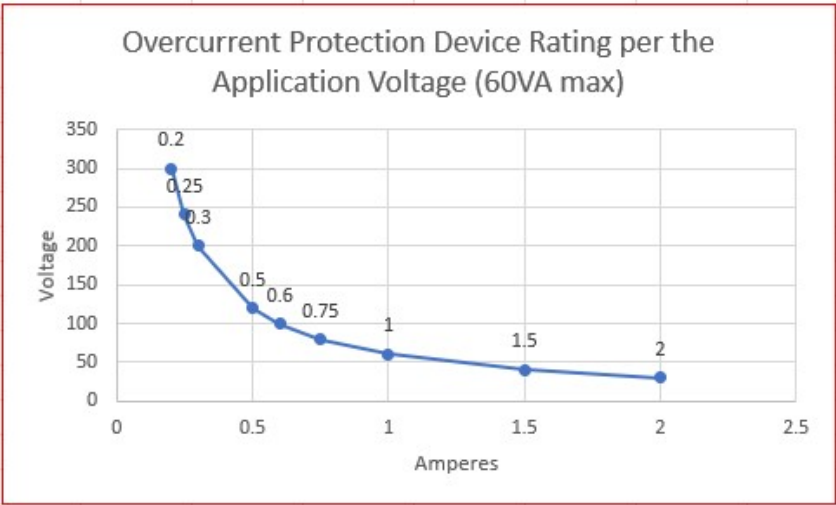
```
SOURce:DIgital:DATA:WORD #H9999, (@8001)
```

```
SOURce:DIgital:DATA:WORD 39321, (@8001)
```

34980A Current Limiting Graphs

Modules	Pollution Degree 1	Pollution Degree 2	Transients
Breadboard 34959A	40 channels, 45 MHz	40 channels, 45MHz	1000Vpk
	±300 Vrms or VDC ¹	±100 Vrms or VDC ¹	
	1A (switch) / 2A (carry)	1A (switch) / 2A (carry)	
	60VA per channel ²	60VA per channel ²	
	Volt-Hertz limit: 10 ⁸	Volt-Hertz limit: 10 ⁸	
	Initial closed channel resistance: <1.5 Ω ^{3,4}	Initial closed channel resistance: <1.5 Ω ^{3,4}	

The overcurrent protection devices will be rated, or the snubber circuits will limit the current, according to:



1. DC or AC RMS voltage, channel-to-channel or channel-to-earth.
2. Limited to 6 W of channel resistance power loss per module.
3. Into analog bus. System errors are included in the internal DMM measurement accuracy specifications.
4. Channel resistance is typically < 1.5 Ω but can go as high as 50 Ω when a channel is used in measurement applications with < 10 mA load current. Increased relay channel resistance for measurements with load currents below 10 mA can occur on cards that have been out of service or following relay inactivity for periods of greater than 1 week. Switching relays for 2K cycles prior to use may reduce the variation in channel resistance. Keysight recommends the use of 4-wire Ohms for resistance measurements. For high accuracy voltage measurements, select the DMM input resistance setting of >10 G ohms to minimize the impact of relay contact resistance.

Safety Guidelines (IEC 61010-1)

WARNING

Incorporating Safety Guidelines [IEC 61010-1] for Custom Built Circuitry with Hazardous Levels:

Allows integration of custom-build circuitry into the 34959A Module for interconnection to the 34980A Analog Bus and optional DMM while maintaining levels of protection. The following references IEC 61010-1 requirements when working with hazardous voltages.

- 1 **WARNING:** Hazardous voltage levels capable of causing death, may be present on a channel. Use extreme caution when handling, testing and adjusting this instrument. Any voltages greater than 30 Vrms, 42.4 Vpeak and 60 Vdc are considered hazardous (IEC 61010-1).
- 2 **WARNING:** Safety of any system incorporating the equipment is the responsibility of the assembler of the system.
- 3 **WARNING:** Only qualified personnel who are aware of the hazards involved shall install, remove or configure the 34959A breadboard for the 34980A mainframe. Before touching any installed accessory, turn off all power to the mainframe and terminal blocks, and to all external devices connected to the mainframe or terminal blocks. Under certain conditions, hazardous voltage levels capable of causing injury or death may remain even after external circuits and the 34980A instrument have been disconnected. To avoid injuries, always disconnect the power and discharge all circuits before touching them.

Ensure all circuits are fully discharged before coming in contact with the system. Ensure no hazardous voltages remain on any accessible before handling any part of the instrument and test setup, making connections to the system, removing covers or cleaning the instrument. Failure to recognize and observe normal safety precautions could result in personal injury or death.

- 4 **WARNING:** The maximum common mode input to any one system component within the system installation is not to exceed the maximum stated ratings.

WARNING**Printed Circuit Board Design Rules for Hazardous Voltages [IEC 61010-1]:**

Follow industry quality and workmanship that meets IPC standards or equivalent to ensure safety levels of protection are maintained.

If your planned use of the 34959A breadboard module will involve the application of hazardous voltages ($>30V_{rms}$ AC, $>42.4V_{peak}$ or $>60V$ DC per IEC 61010-1), use extreme caution when handling, testing and adjusting this instrument. Refer to the following:

- 1 **WARNING:** When interconnecting the 34959A component module to the system components during installation, the overall 34980A and all installed modules for the system and their maximum rated allowable inputs default to the lowest rating of any one system component or module.
- 2 **WARNING:** It is possible to connect more than one power source at the same time with a matrix. Ensure that hazardous or unwanted conditions are not created by these connections. Failure to recognize or observe normal safety precautions could result in equipment damage and may result in hazardous conditions such as fire or shock and could lead to personal injury or death.
- 3 **WARNING:** Working with ABUS3 and ABUS4 and closing multiple channels simultaneously are for qualified personnel use only. When working with hazardous voltage levels, intentionally closing of multiple bus and channel relays could cause a potentially lethal hazard on external connections. Use extreme caution when handling and testing and adjusting this instrument. Do not perform these procedures unless qualified to do so.
- 4 **WARNING:** To ensure minimum safety protection only the following connectors are permitted to be installed: Keysight connectors to be used when the voltage of any one component or interconnecting system components or modules installed with the 34980A mainframe:
 - Greater than 30 Vrms, 42.4 Vpeak or 60 Vdc: DB-50 (F) 1253-5854 or DB-78(F) 1253-6007.
 - 30 Vrms, 42.4 Vpeak or 60 Vdc or less: DB-50(M) 1253-5853, DB-78(M) 1253-6006, DB-50 (F) 1253-5854 or DB-78(F) 1253-6007.
- 5 **WARNING:** When soldering wire to the Analog Bus connection holes, take special care to avoid any reduction in PCB artwork spacing layouts or shorts between wires and/or via holes. Shortening these connections may result in hazardous conditions and/or damage to the breadboard module, the 34980A mainframe, other installed modules, or your test circuitry.

- 6 **WARNING:** When soldering Keysight supplied relays 0490-1954 K101-K104 to the Keysight-supplied PC board, take special care to avoid reducing spacings and/or avoid shorts between pins. Any reduction in spacings or shorting these connections may result in hazardous conditions to personnel and/or damage to the breadboard module, the 34980A mainframe, other installed modules, or your test circuitry.

WARNING

External Wiring for Hazardous Voltages:

To ensure minimum safety insulation when wiring with hazardous voltages, ensure all wiring (both internal and external to the instruments):

- 1 follow (USA) NFPA 79 Table 12.5.1 Conductor Ampacity and 12.5.5(a) Ambient Temperature Correction Factors (or equivalent National Code requirements) when selecting the AWG required.
- 2 are rated for at least 2 x the maximum applied voltage of the external source or any interconnecting system modules or external connections.
- 3 flame rated minimum:
 - Wires and cables with overall cross-sectional area of the conductors exceeding 0.5mm^2 meet test of IEC 60332-1-2 (IEC); or
 - Wires and cables with overall cross-sectional area of the conductors of 0.5mm^2 or less, the test of IEC 60332-2-2 (IEC); or
 - FT-1 of CSA C22.2 No. 0.3 (Canada); or
 - VW-1 of UL 1581 (US).
- 4 temperature rated for the application.
- 5 classified and suitable to be used external to the enclosure:
 - AWM Class II B or A/B - external/interconnecting wires (single- or multiple-conductor constructions with a jacket) and potentially subject to mechanical abuse (Canada)
 - AWM Style Use - external interconnection of electronic equipment or appliances (US)

WARNING**Critical Spacings (PCB Creepage) for Customer Supplied Circuitry - IEC 61010-1**

WARNING: Hazardous voltage circuits require a minimum trace layout spacings to ensure the minimum level of safety is not compromised:

- 1 Circuits of opposite polarity.
- 2 Channel to Channel.
- 3 Channel to Earthed Chassis.
- 4 Channel to Non-hazardous control circuitry.

Critical Spacings (PCB Creepage) for Customer Supplied Circuitry (In millimeters) @ 2000m Altitude				
Working Voltage	Pollution Degrees	Outer PCB Layers	*Inner PCB Spacings (thickness between layers)	Inner PCB Spacings (same layer)
80 Vpeak	1 and 2	0.2	0.05	0.05
100 Vac/dc	1 and 2	0.2	0.05	0.05
100 Vpeak	1 and 2	0.2	0.05	0.05
150 Vpeak	1	0.2	0.05	0.05
250 Vac/dc	1	0.6	0.1	0.1
300 Vac/dc	1	0.8	0.1	0.1

WARNING

Use only:

- PCB with minimum flammability classification of V-1 or V-0 [IEC 60695-11-10].
- 130 °C
- CTI PLC 3 (CTI Material Group IIIa).
- *Alternative to Inner PCB Spacings and thickness between layers noted above - For multi-layered board each PCB material and stack-up construction to have each prepreg or core be assembled from at least two separate glass layers having a combined dielectric thickness of 0.127 mm (5 mil) or greater and having a dielectric strength specification of 30 kV/mm or better.

NOTE

The International Electrotechnical Commission (IEC) Standard 61010-1 (available at www.iec.ch) lists the construction and insulation requirements for hazardous voltage applications in Pollution Degree Levels 1 and 2.

WARNING**Critical Components for Customer Supplied Circuitry used with Hazardous Voltages [IEC 61010-1]:**

These instruments are evaluated and conform to safety standards:

IEC 61010-1

EN 61010-1

CAN/CSA-C22.2 No 61010-1

ANSI/UL 61010-1

If your planned use of the 34959A breadboard module will involve the application of hazardous voltages ($>30V_{rms}$ AC, $>42.4V_{peak}$ or $>60V$ DC), use extreme caution when handling, testing and adjusting this instrument. To ensure minimum safety protection is maintained, ensure all customer supplied safety components, subassemblies and assemblies:

- 1 follow IEC 61010-1 requirements for components and subassemblies selection.
- 2 are rated for at least the maximum applied voltage and current of the external source or any interconnecting system modules or external connections.
- 3 are suitable for the voltage and current limiting protection of the external sources (see Limiting Current Graphs section of User Guides).
- 4 have appropriate spacing (creepage along PCB).
- 5 are temperature rated for the application.
- 6 tested by a recognized authority to safety requirements meeting or exceeding relevant IEC or other national standards (CSA / UL / EN or other as applicable).

34959A Breadboard Component Module Conditions of Acceptability:

- 1** Follow local laws and regulations provided by the Authority Having Jurisdictions (AHJ). This equipment is Certified as a component for use in other CSA Certified equipment where the suitability of the combination is to be determined in the end use application.
- 2** When interconnecting the 34959A component module to the system components during installation, the overall 34980A and all installed modules for the system and their maximum rated allowable inputs default to the lowest rating of any one system component or module.
- 3** With *hazardous voltages anywhere in the overall 34980A and all installed modules use only female D-Sub output connectors Keysight Part Number DB-50(F) 1253-5854 or DB-78(F) 1253-6007.
- 4** With only *non-hazardous voltages in the overall 34980A and all installed modules use either female D-Sub output connectors Keysight Part Number DB-50(F) 1253-5854 or DB-78(F) 1253-6007, or male D-Sub output connectors Keysight Part Number DB-50(M) 1253-5853 or DB-78(M) 1253-6006.
- 5** Install overcurrent protection with devices rated or the snubber circuits to limit the current according to the 34959A Current Limiting Graph located in the User's Guide.
- 6** Install only Keysight supplied relays 0490-1954 when connecting to the Analog Bus.

*Any voltages greater than 30Vrms, 42.4 Vpeak and 60Vdc are considered hazardous (IEC 61010-1).

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