Keysight DAQ970A Data Acquisition System

KEYSIGHT
TECHNOLOGIES

Notices

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Software Revision

The latest firmware is available at www.keysight.com/find/DAQ970Afirmware.

The latest product documentation is available at www.keysight.com/find/DAQ970Amanuals.

A portion of the software in this product is licensed under terms of the General Public License Version 2 (GPLv2). The text of the license and source code can be found at www.keysight.com/find/GPLV2.

This product uses Microsoft Windows CE. Keysight highly recommends that all Windows-based computers connected to Windows CE instruments use current anti-virus software. For more information, see www.keysight.com/find/DAQ970A.

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Waste Electrical and Electronic Equipment (WEEE)

This product complies with the European WEEE directive marketing 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 European WEEE directive Annex 1, this product is classified as "Monitoring and Control instrumentation" product. Do not dispose in domestic household waste.

To return unwanted products, contact your local Keysight office, or see http://about.keysight.com/en/companyinfo/environment/takeback.shtml for more information.

Notices

Declarations of Conformity

Declarations of Conformity for this product and for other Keysight products may be downloaded from the Web. Go to https://regulations.about.keysight.com/DoC/default.htm, you can then search by product model number to find the latest Declaration of Conformity.

Safety and Regulatory Information

Safety Considerations

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

WARNING BEFORE APPLYING POWER
Verify that all safety precautions are taken. Make all connections to the unit before applying power.

GROUND THE INSTRUMENT
This product is provided with protective earth terminals. To minimize shock hazard, the instrument must be connected to the ac power mains through a grounded power cable, with the ground wire family connected to an electrical ground (safety ground) at the protective (grounding) conductor. Disconnection of the protective earth terminal will cause a potential shock hazard that could result in personal injury.

BEFORE POWER ON AND OFF
Before powering on the instrument, make sure all signal sources connected to modules are turned off. Turn on signal sources after the instrument is powered on. Turn off signal sources before the instrument is powered off.

DO NOT REMOVE THE INSTRUMENT COVER
Only qualified, service-trained personnel who are aware of the hazards involved should remove the instrument covers. Always disconnect the power cable and any external circuits before removing the instrument cover.

MODULE COVERS
Always replace module covers after terminal wiring and before inserting into mainframe.

DO NOT OPERATE IN AN EXPLOSIVE ATMOSPHERE
Do not operate the instrument in the presence of flammable gases or fumes.

DO NOT MODIFY THE INSTRUMENT
Do not install substitute parts or perform any unauthorized modification to the product. Return the product to a Keysight Sales and Service Office for service and repair to ensure that safety features are maintained.

DO NOT MEASURE MORE THAN THE RATED VOLTAGE
Maximum voltage as marked on each module is as below:
a) DAQM900A: 120 Vrms
b) DAQM901A, DAQM902A, DAQM903A, DAQM904A, DAQM908A: 300 Vrms
c) DAQM905A, DAQM907A: 42 Vpk

DO NOT CONNECT ANY MODULE CHANNELS TO MAINS
Measurement category of the instrument is rated as CAT 'Others', terminals should not be directly connected to the mains.

AC POWER CORD
Removal of the AC power cord is the disconnect method to remove power from the instrument. Be sure to allow for adequate access to the power cord to permit disconnection from AC power. Use only the Keysight specified power cord for the country of use or one with equivalent ratings.

SELF-TEST

Before measuring any hazardous voltage or current, run the *TST? query from the remote interface, and read the result to verify that the instrument is performing properly. The *TST? query is a self-test that returns +0 if the instrument passes and +1 if the instrument fails. You can also perform this query from the front panel by pressing [Utility] > **Self Test** > **Quick Test**. If this self-test fails, make sure that the instrument is repaired and passes the self-test before continuing.

IN CASE OF DAMAGE

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

CAUTION	This is a sensitive measurement apparatus by design and may have some performance loss when exposed to ambient continuous electromagnetic phenomenon. Measurement Considerations – use shielded or twisted cable, use common mode choke, ferrite clamp and damping resistor before the input to DAQ970A.

CLEANING

To prevent electrical shock, disconnect the instrument from AC mains power before cleaning. Clean the outside of the instrument using a soft, lint-free, cloth slightly dampened with water. Do not use detergent or solvents. Do not attempt to clean internally. If needed, contact a Keysight Technologies Sales and Service Office to arrange for proper cleaning to ensure that safety features and performance are maintained.

NOTE	Connect USB cable with ferrite core to the rear panel USB port of the instrument.

Safety Symbols and Regulatory Markings

Symbol	Description
∿	Alternating current (AC).
⏚	Protective earth (ground) terminal.
⏚	Earth (ground) terminal.
⚠	Caution, risk of danger (refer to the manual for specific Warning or Caution information).
⏚	Frame or chassis (ground) terminal.
🔒	Instrument cable lock.

Safety and Regulatory Information

Symbol	Description
	This product is marked with the ACMA RCM mark for compliance in Australia/New Zealand. A copy of the Manufacturer's Australia Declaration of Conformity for this instrument can be obtained by contacting your local Keysight Technologies Sales Representative.
	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.
CE ICES/NMB-001 ISM GRP 1-A	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** - This ISM device complies with the Canadian ICES-001. *Cet appareil ISM est conforme a la norme NMB-001 du Canada.* **ISM GRP 1-A** - This is an Industrial Scientific and Medical (ISM) Group 1 Class A product.
CSA® C US	The CSA mark is a registered trademark of the Canadian Standards Association, with the 'C' and 'US' subscript indicates the instrument is certified to the applicable Canadian and United States of America standards respectively.
KC MSIP-REM-Kst-GM16412	This symbol is a South Korean Class A EMC Declaration, with the product identification code "MSIP-REM-Kst-GM16412". **MSIP** - Identification of Broadcasting and communications equipment. **REM** - Identification of basic certification information. **Kst** - Identification of applicant's information **GM16412** - Product identification. This is a Class A instrument suitable for professional use and in electromagnetic environment outside of the home.
WARNING	The WARNING sign denotes a hazard. It calls attention to a procedure, practice, or the like, which, if not correctly performed or adhered to, could result in personal injury. Do not proceed beyond a WARNING sign until the indicated conditions are fully understood and met.
CAUTION	The CAUTION sign denotes a hazard. It calls attention to an operating procedure, or the like, which, if not correctly performed or adhered to, could result in damage to or destruction of part or all of the product. Do not proceed beyond CAUTION sign until the indicated conditions are fully understood and met.
NOTE	The NOTE sign denotes important information. It calls attention to a procedure, practice, condition or the like, which is essential to highlight.

South Korean Class A EMC Declaration

Information to the user:

This instrument has been conformity assessed for used in business environments. In a residential environment this equipment may caused radio interference.

This EMC statement applies to the equipment only for use in business environment.

사 용 자 안 내 문
이 기 기 는 업 무 용 환 경 에 서 사 용 할 목 적 으 로 적 합 성 평 가 를 받 은 기 기 로 서 가 정 용 환 경 에 서 사 용 하 는 경 우 전 파 간 섭 의 우 려 가 있 습 니 다 .

사용자 안내문은"업무용 방송통신기자재"에만 적용한다.

Safety and EMC Requirements

This instrument is designed to comply with the following safety and EMC requirements:

Safety compliance

- IEC 61010-1:2010/EN 61010-1:2010; IEC 61010-2-030:2010/EN61010-2-030:2010

- Canada: CAN/CSA-C22.2 No.61010-1-12; CAN/CSA-C22.2 No. 61010-2-030-12

- USA: ANSI/UL Std. No. 61010-1:2012; ANSI/UL Std No.61010-2-030:2012

EMC compliance

- IEC 61326-1:2012 / EN 61326-1:2013

- Canada: ICES/NMB-001:2006

- Australia/New Zealand: AS/NZS CISPR 11:2011

- South Korea RRA Notice 2016-24

Environmental Conditions

Keysight DAQ970A is designed for indoor use and in an area with low condensation. Table below shows the general environmental requirements for this instrument.

Environmental condition	Requirement
Temperature	Operating condition: 0 ℃ to 55 ℃
	Storage condition: −40 ℃ to 70 ℃
Humidity	Operating condition: Up to 80% RH at 40 ℃ (non-condensing), decreasing linearly to 50% RH at 55 ℃ (non-condensing)
	Storage condition: Up to 50% RH at 55 ℃ (non-condensing)
Altitude	Up to 3000 m
Pollution degree	2

1   Introduction to the Instrument

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Instrument Annunciators

Rear Panel at a Glance

Plug-In Modules at a Glance

Dimension Diagram

Remote Interface Configuration

LAN Configuration Procedure

Firmware Update

Contacting Keysight Technologies

This chapter introduces the overview and basic functionality of the DAQ970A.

Instrument at a Glance

The DAQ970A combines precision measurement capability with flexible signal connections for your production and development test systems. Three module slots are built into the rear of the instrument to accept any combination of data acquisition or switching modules. The combination of USB data logging and data acquisition features make this instrument a versatile solution for your testing requirements now and in the future.

Easily display, save, and document your measurement results

- High usability with an intuitive, menu driven user interface.

- Histogram, trend chart, meter, and numeric views on a high-resolution color display.

- Supported on both LAN and USB interfaces.

- Drag and drop, driverless USB connectivity.

Convenient data logging features

- Direct measurement of temperature (thermocouples, RTDs, and thermistors), strain, DC voltage, AC voltage, 2-wire and 4-wire resistance, frequency, period, diode, capacitance, DC current, and AC current.

- Patented, metrology-level performance that serves as the foundation for all measurements.

- Interval scanning with storage of up to 100,000 time-stamped readings.

- Independent channel configuration with function, measurement scaling, and alarm limits available on a per-channel basis.

- Intuitive user interface with knob cursor navigation keypad, data entry from both softkeys (menu keys inside the screen view) and hardkeys (menu keys in front of the instrument).

- Portable, rugged case with non-skid feet.

- BenchVue Data Acquisition (DAQ) software for Microsoft $^®$ Windows $^®$ available for download from www.keysight.com/find/benchvue.

Flexible data acquisition/switching features

- Up to 60 channels per instrument (120 single-ended channels).

- Reading rates are more than 5,000 readings per second on a single channel and scan rates up to 450 channels per second.

- Choice of multiplexing, matrix, general-purpose Form C switching, RF switching, digital I/O, totalize, DAC output, and DAC readback functions.

- Built-in Web Interface for monitoring and controlling the instrument via a Web browser.

Programming language

- Compatible with SCPI (Standard Commands for Programmable Instruments) programming language.

Front Panel at a Glance

Label	Description
1	USB port
2	On/Standby switch with LED indicator
3	Display
4	Softkeys
5	Measurement operation menu (to control the initiation of the measurements)
6	Measurement configuration menu (to set parameters for measurements)
7	Knob
8	Cursor navigation keypad

Front panel key

NOTE Press the **Save Recall** (Local) key to return the instrument into local control when the instrument is in remote (indicated by the **RMT** annunciator).

Instrument Annunciators

The table below shows the various annunciators that are available on the DAQ970A. The annunciators will be shown on the top of the display when the corresponding conditions are met.

Annunciator	Description
● M	• Monitor mode is enabled.
ALARM H1234L	• **ALARM** - Alarms are present in the alarm queue. • **H1234L** - A High or Low alarm condition has occurred.
DMM OFF	• Internal DMM is disabled. Instrument is configured for an external scan interval when DMM is Off.
MEM	• Reading memory overflowed at 100,000 readings. New readings will overwrite the oldest readings.
USB	• A USB drive is inserted in the front panel USB host port.
RMT	• Instrument is in remote (remote interface).
ERR	• Errors are present in the error queue. Press **[View]** > **Errors** to view the list of errors.

Rear Panel at a Glance

Label	Description
1	Slot identifier (100, 200, 300)
2	External trigger input, alarm outputs, channel advance input, and channel close output
3	AC mains input
4	Instrument cable lock
5	LAN interface connector
6	Chassis ground screw
7	USB interface connector

Plug-In Modules at a Glance

The DAQ970A offers a complete selection of plug-in modules to provide a high quality measurement, switching, and control capabilities. For more details, see Module Overview.

Supported modules on the DAQ970A:

- DAQM900A 20-Channel FET Multiplexer Module

- DAQM901A 20-Channel Armature Multiplexer Module

- DAQM902A 16-Channel Reed Multiplexer Module

- DAQM903A 20-Channel Actuator/General-Purpose Switch Module

- DAQM904A 4x8 Two-Wire Matrix Switch Module

- DAQM905A Dual 1:4 RF Multiplexer (50 Ω) Module

- DAQM907A Multifunction Module

- DAQM908A 40-Channel Single-Ended Multiplexer Module

NOTE	Refer to the product data sheet at http://literature.cdn.keysight.com/litweb/pdf/5992-3168EN.pdf for a complete specifications on all the supported modules.

Dimension Diagram

Bench dimension:
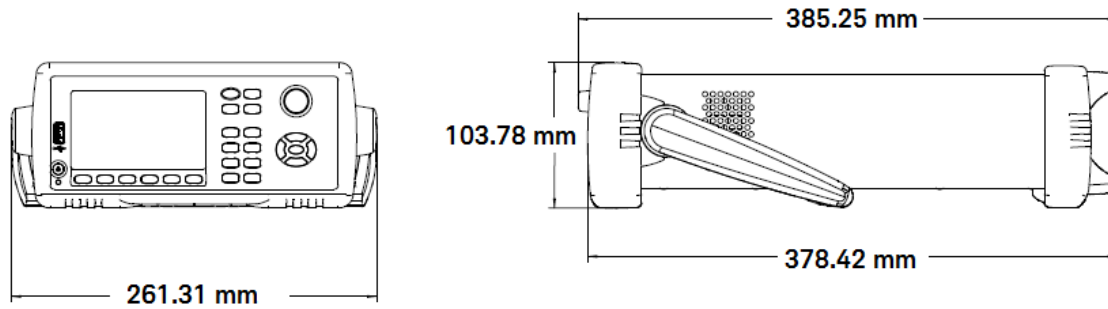
Rack dimension:
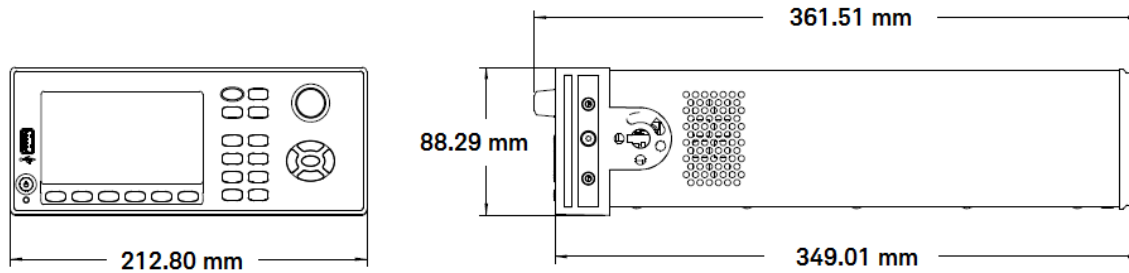
Module dimension:
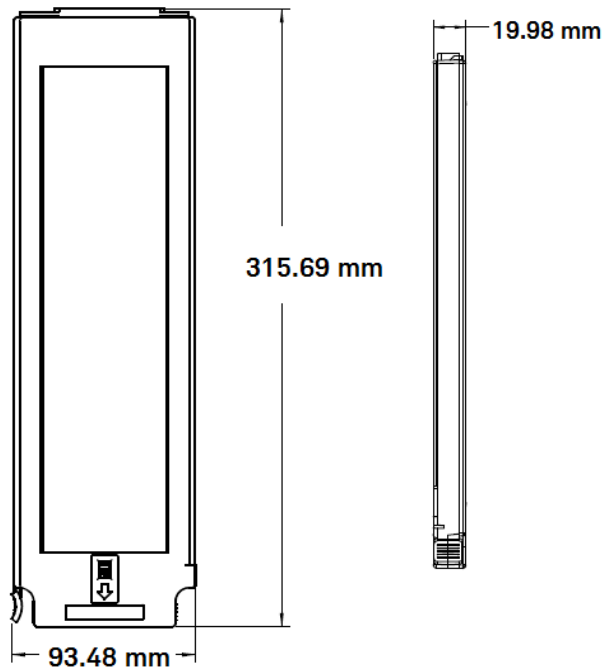
Remote Interface Configuration

WARNING	REMOTE OPERATION

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.

NOTE	If Secure mode is enabled, the instrument must be unlocked with the correct security code to perform many of these actions. See Security for more information.

The DAQ970A supports remote interface communication over two interfaces: LAN and USB. Both interfaces are "live" at power up when the instrument ships from the factory.

- **LAN Interface:** By default, the DHCP (Dynamic Host Configuration Protocol) is on, a protocol for assigning dynamic IP addresses to network devices, which may enable communication over LAN. With dynamic addressing, a device can have a different IP address every time it connects to the network. See LAN Settings for more information.

- **USB Interface:** Use the rear panel USB interface connector to communicate with the instrument using your PC. See USB Settings for more information.

Keysight IO Libraries Suite

NOTE	Ensure that the Keysight IO Libraries Suite is installed before you proceed for the remote interface configuration.

Keysight IO Libraries Suite is a collection of free instrument control software that automatically discovers instruments and allows you to control instruments over LAN and USB interfaces. For more information, or to download the IO Libraries, go to www.keysight.com/find/iosuite.

LAN Settings

The following sections describe the primary front panel LAN configuration functions, including SCPI commands where applicable. In the DAQ970A Programming Guide, see "SYSTem Subsystem - Remote Interface Configuration Commands" for all LAN configuration commands.

NOTE	Some LAN settings require you to cycle power to activate them. The instrument briefly displays a message when this is the case. Observe the display closely as you change the LAN settings.

Enable or disable LAN interface

Front panel	Remote interface
Press [Home] > User Settings > I/O > LAN Set the softkey to On or Off	SYSTem:COMMunicate:ENABle {OFF	ON}, LAN

View the LAN status, MAC address, and current LAN configuration settings

Once the LAN interface is enabled, you can view the LAN status, MAC address, and current LAN configuration settings from the front panel. The LAN status may be different from the front panel

configuration menu settings, which depends on the network configuration. If the settings are different, it is because the network has automatically assigned its own settings. If the instrument goes into remote, all LAN changes will be disabled and the display will go into a different screen. Re-selecting with LAN Settings page will display the new settings if a LAN restart took place.

Front panel	Remote interface
Press **[Home]** > **User Settings** > **I/O** > **LAN Settings**	(none)

Modify Settings

As shipped from the factory, the instrument pre-configured settings should work in most LAN environments. To configure the LAN settings manually:

Manual/DHCP

The DHCP can automatically assign a dynamic IP address to a LAN device. This is typically the easiest way to configure the instrument for LAN. This setting is non-volatile, it will not be changed by cycling power, factory reset (*RST command), or instrument present (SYSTem:PRESet command). Enabling the DHCP will disable the Manual setting, and vice versa.

Front panel	Remote interface
Press **[Home]** > **User Settings** > **I/O** > **LAN Settings** > **Modify Settings**.	SYSTem:COMMunicate:LAN:DHCP {OFF|ON}

To enable DHCP:
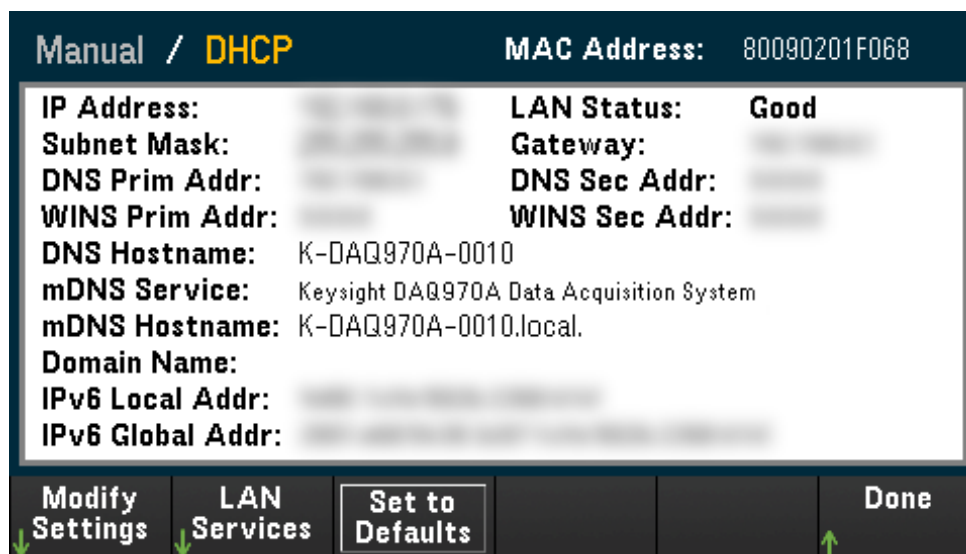
Step	Front panel	Remote interface
1	Press **[Home]** > **User Settings** > **I/O** > **LAN Settings** > **Modify Settings**. Set the first softkey to **DHCP**.	SYSTem:COMMunicate:LAN:DHCP ON
2	If you change this parameter, you must press **[Done]** > **[Apply Changes]** for the change to take effect.	SYSTem:COMMunicate:LAN:UPDate

To disable DHCP:

Step	Front panel	Remote interface
1	Press **[Home]** > **User Settings** > **I/O** > **LAN Settings** > **Modify Settings**. Set the first softkey to **Manual**.	SYSTem:COMMunicate:LAN:DHCP OFF
2	If you change this parameter, you must press **[Done]** > **[Apply Changes]** for the change to take effect.	SYSTem:COMMunicate:LAN:UPDate

Host Name

IP Address

Subnet Mask

Gateway

Primary and Secondary DNS

Primary and Secondary WINS

Service mDNS

Host Name

A hostname is the host portion of the domain name, which is translated into an IP address.

Step	Front panel	Remote interface
1	Press [Home] > User Settings > I/O > LAN Settings > Modify Settings. Set the first softkey to Manual and press Host Name to enter the hostname.	SYSTem:COMMunicate:LAN:HOSTname
2	If you change this parameter, you must press [Done] > [Done] > [Apply Changes] for the change to take effect.	SYSTem:COMMunicate:LAN:UPDate

Each instrument is shipped with a default host name with the format: *K-modelnumber-serialnumber*, where *modelnumber* is the instrument's 7-character model number (e.g. DAQ970A), and *serialnumber* is the last five characters of the 10-character instrument serial number located on the label on the top of the unit (e.g. 5678 if the serial number is MY12345678).
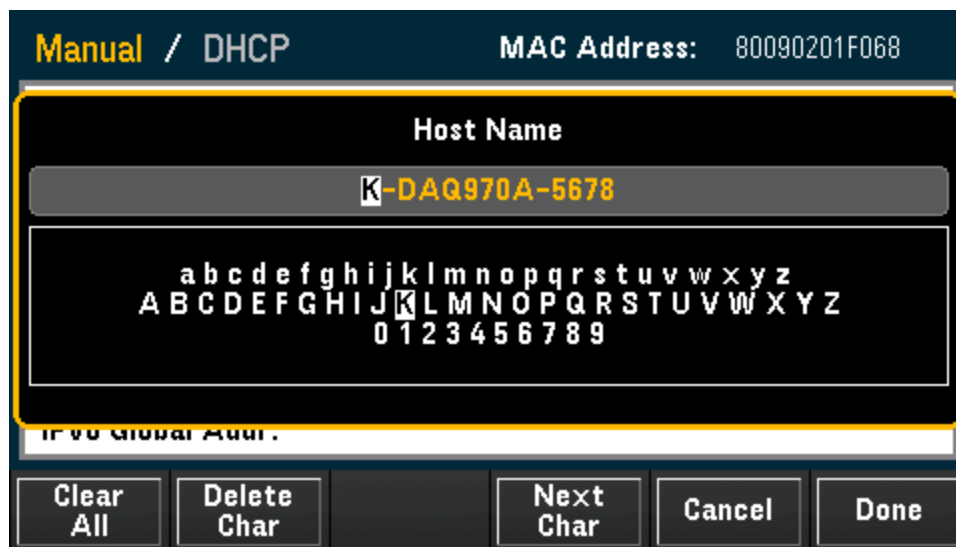
- The instrument receives a unique hostname at the factory, but you may change it. The hostname must be unique on the LAN.

- The name must start with letter, other characters can be an upper or lower case letters, numeric digits, or dashes "-".

- This setting is non-volatile, it will not be changed by cycling power, factory reset (*RST command), or instrument present (SYSTem:PRESet command).

IP Address

You can enter a static IP address for the instrument as a four-byte integer expressed in dot notation. Each byte is a decimal value, with no leading zeros (for example, 169.254.2.20). Refer to "More about IP Addresses and Dot Notation" for further details.

Step	Front panel	Remote interface
1	Press [Home] > User Settings > I/O > LAN Settings > Modify Settings. Set the first softkey to Manual and press IP Address to set the desired IP address.	SYSTem:COMMunicate:LAN:IPADdress

Step	Front panel	Remote interface
2	If you change this parameter, you must press [Done] > [Apply Changes] for the change to take effect.	SYSTem:COMMunicate:LAN:UPDate

- If DHCP is on, it attempts to assign an IP address to the instrument. If it fails, Auto-IP attempts to assign an IP address to the instrument.

- Contact your LAN administrator to obtain an IP address.

- This setting is non-volatile, it will not be changed by cycling power, factory reset (*RST command), or instrument present (SYSTem:PRESet command).

Subnet Mask

Subnetting allows the LAN administrator to subdivide a network to simplify administration and minimize network traffic. The subnet mask indicates the portion of the host address used to indicate the subnet.

Step	Front panel	Remote interface
1	Press [Home] > User Settings > I/O > LAN Settings > Modify Settings. Set the first softkey to Manual and press Subnet Mask to set the desired subnet mask address.	SYSTem:COMMunicate:LAN:SMASk
2	If you change this parameter, you must press [Done] > [Apply Changes] for the change to take effect.	SYSTem:COMMunicate:LAN:UPDate

- Contact your LAN administrator to obtain an IP address.

- This setting is non-volatile, it will not be changed by cycling power, factory reset (*RST command), or instrument present (SYSTem:PRESet command).

Gateway

A gateway is a network device that connects networks. The default gateway setting is the IP address of the instrument.

Step	Front panel	Remote interface
1	Press [Home] > User Settings > I/O > LAN Settings > Modify Settings. Set the first softkey to Manual and press Gateway in the second page of menu to set the desired gateway address.	SYSTem:COMMunicate:LAN:GATEway
2	If you change this parameter, you must press [Done] > [Apply Changes] for the change to take effect.	SYSTem:COMMunicate:LAN:UPDate

- **Do not set a gateway address when DHCP is enabled (factory default).**

- Contact your LAN administrator to obtain an IP address.

- This setting is non-volatile, it will not be changed by cycling power, factory reset (*RST command), or instrument present (SYSTem:PRESet command).

Primary and Secondary DNS

A DNS (Domain Name Service) is an Internet service that translates domain names into IP addresses. The DNS server address is the IP address of a server that performs this service.

Step	Front panel	Remote interface
1	Press [Home] > User Settings > I/O > LAN Settings > Modify Settings. Set the first softkey to Manual and press Primary DNS or Second DNS in the second page of menu to set the desired gateway address.	SYSTem:COMMunicate:LAN:DNS[{1|2}] Note: The [{1|2}] syntax indicates the type of primary (1) or secondary (2) DNS server address.
2	If you change this parameter, you must press [Done] > [Apply Changes] for the change to take effect.	SYSTem:COMMunicate:LAN:UPDate

- Normally, DHCP discovers the DNS address information; you only need to change this if DHCP is unused or nonfunctional.

- Contact your LAN administrator to obtain an IP address.

- This setting is non-volatile, it will not be changed by cycling power, factory reset (*RST command), or instrument present (SYSTem:PRESet command).

Primary and Secondary WINS

A WINS (Windows Internet Name System) is a system that enables Windows to identify NetBIOS systems on a TCP/IP network.

Step	Front panel	Remote interface
1	Press [Home] > User Settings > I/O > LAN Settings > Modify Settings. Set the first softkey to Manual and press Primary WINS or Second WINS in the third page of menu to set the desired gateway address.	SYSTem:COMMunicate:LAN:WINS[{1|2}] Note: The [{1|2}] syntax indicates the type of primary (1) and secondary (2) WINS server address.
2	If you change this parameter, you must press [Done] > [Apply Changes] for the change to take effect.	SYSTem:COMMunicate:LAN:UPDate

- Normally, DHCP discovers the WINS address information; you only need to change this if DHCP is unused or nonfunctional.

- Contact your LAN administrator to obtain an IP address.

- This setting is non-volatile, it will not be changed by cycling power, factory reset (*RST command), or instrument present (SYSTem:PRESet command).

Service mDNS

An mDNS (multicast Domain Name Service) is an Internet service that is registered with the selected naming service.

Step	Front panel	Remote interface
1	Press [Home] > User Settings > I/O > LAN Settings > Modify Settings. Set the first softkey to Manual and press Service mDNS in the third page of menu to set the desired gateway address.	LXI:MDNS:SNAMe:DESired
2	If you change this parameter, you must press [Done] > [Done] > [Apply Changes] for the change to take effect.	SYSTem:COMMunicate:LAN:UPDate

Each instrument is shipped with a default service name with the format:

Keysight Technologies_<modelNumber>_-serialNumber

where modelNumber is the instrument 7-character model number (DAQ970A) and product name (Data Acquisition System), and serialNumber is the last five characters of the 10-character instrument serial number located on the label on top of the unit (e.g. 45678 if the serial number is MY12345678).

- **The instrument receives a unique mDNS service name at the factory, but you may change it. The mDNS service name must be unique on the LAN.**

- The name must start with letter, other characters can be an upper or lower case letters, numeric digits, or dashes "-".

- This setting is non-volatile, it will not be changed by cycling power, factory reset (*RST command), or instrument present (SYSTem:PRESet command).

LAN Restart

Any modification on the LAN settings described above will restart the LAN after pressing **Apply Changes**. This feature restarts the networking using ALL current LAN settings. LAN restart does not clear the Web Interface password.

Remote interface: LXI:REStart

LAN Services

Enables (On) or disables (Off) LAN services on the instrument.
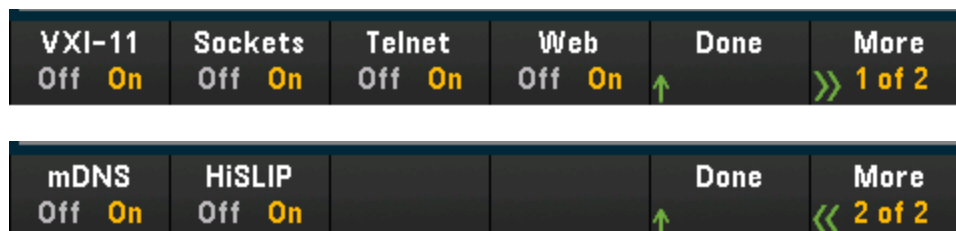
Step	Front panel	Remote interface
1	Press [Home] > User Settings > I/O > LAN Settings > LAN Services Press On to enable or Off to disable each settings.	(none)

Step	Front panel	Remote interface
2	If you change this parameter, you must press **[Done]** > **[Apply Changes]** for the change to take effect.	SYSTem:COMMunicate:LAN:UPDate

- Refer to the Keysight IO Libraries help for information on the VXI-11, Sockets, and HiSLIP protocols.

- Telnet – The instrument telnet port is 5024. Open SCPI sessions on the Telnet connection by entering: telnet *IP address* 5024

- Web – Enable or disable instrument programming from the instrument's Web Interface.

- mDNS – mDNS service is for use in networks where no conventional DNS server is installed. Cycling power or resetting the LAN always enables mDNS.

Set to Defaults

This feature resets the LAN settings to the respective factory default values.

Front panel	Remote interface
Press **[Home]** > **User Settings** > **I/O** > **LAN Settings** > **Set to Defaults**	(none)

LAN Reset

Resets the LAN using its current settings and enables DHCP mode and mDNS service. The LAN reset also clears any user-defined Web user interface (Web UI) password.

Front panel	Remote interface
Press **[Home]** > **User Settings** > **I/O** > **LAN Reset**	LXI:RESet

Web Interface

The DAQ970A includes a built-in Web Interface for remote instrument access and control over LAN via a Web browser. Further details, refer to Web Interface.

More about IP addresses and dot notation

Dot-notation addresses ("nnn.nnn.nnn.nnn" where "nnn" is a byte value from 0 to 255) must be expressed with care, as most PC web software interprets byte values with leading zeros as octal (base 8) numbers. For example, "192.168.020.011" is actually equivalent to decimal "192.168.16.9" due to ".020" is interpreted as "16" expressed in octal, and ".011" as "9". To avoid confusion, use only decimal values from 0 to 255, with no leading zeros.

USB Settings

USB Settings configures the front panel USB (storage) and rear panel USB (connectivity) connectors.

Front panel	Remote interface
Press [Home] > User Settings > I/O > USB Settings	SYSTem:COMMunicate:ENABle {OFF	ON}, USB

USB SCPI

USB SCPI enables (On) or disables (Off) the instrument's USB control port on the rear panel. Once the interface state is changed, you must cycle the instrument power for the change to take effect. When disabled, the interface cannot be configured in the Keysight IO Libraries Connection Expert utility.

Easy File Access (File Access Softkey)

Easy File Access allows you to easily transfer files between the instrument and your PC. Simply connect the rear panel USB control port on the instrument to a USB port on your PC and then use the window that appears on your PC to copy files from the instrument to your PC.
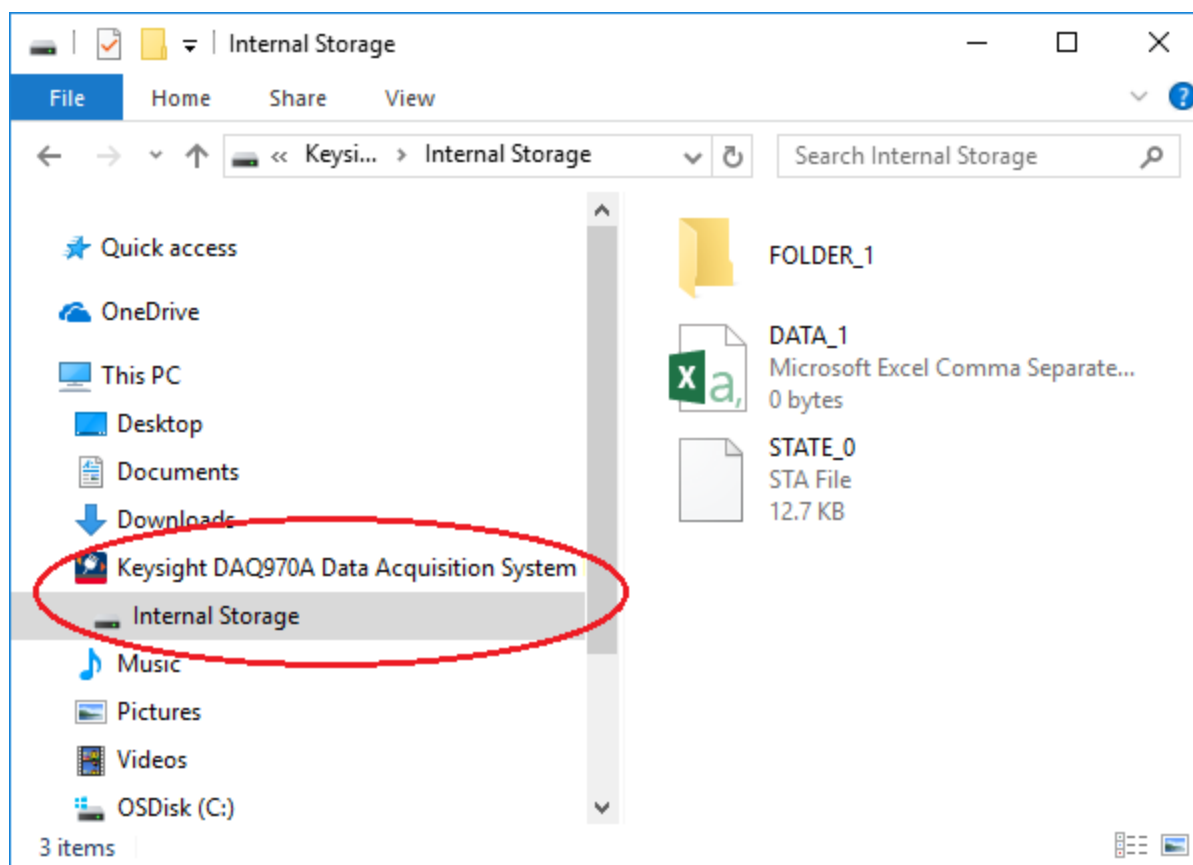
You can use your PC's standard file management features to copy files from the instrument to your PC.

> **NOTE** To use Easy File Access at the same time that you are remotely programming the instrument with SCPI over the USB interface (USB SCPI), you must have Keysight IO Libraries Suite 16.3 or later installed on your PC. You may download the latest version at www.keysight.com/find/iosuite.

To use Easy File Access on a PC running the Windows XP operating system, make sure you have Microsoft Windows Media Player 11 for Windows XP SP1, or are using a Microsoft Windows XP SP2, SP3, or a newer version of Windows. You may download this software at www.microsoft.com/en-us/- download/details.aspx?id=8163.

Show USB ID

Displays the USB address string as used in VISA programming applications.

Technical Connection Details

In most cases, you can easily connect to the instrument with the IO Libraries Suite or Web interface. In certain circumstances, it may be helpful to know the following information.

Interface	Details
LAN	VISA String: TCPIP0::*IP Address*::inst0::INSTR Example: TCPIP0::192.168.10.2::inst0::INSTR
Web Interface	Port number 80, URL http://*IP address*/
USB	USB ID is in the form of USB0::*Vendor ID*::*Prod ID*::*Serial Number*::0::INSTR Example: USB0::0x2A8D::0x0902::MY55160003::0::INSTR

LAN Configuration Procedure

There are several parameters that you might need to set to establish network communication using the LAN interface. Primarily, you will need to establish an IP address. You might need to contact your network administrator for help in establishing communication with the LAN interface.

NOTE	If Secure mode is enabled, the instrument must be unlocked with the correct security code to perform many of these actions. See Security for more information.

1. Press **[Home]** > **User Settings** > **I/O** > **LAN Settings**.

2. You can select **Modify Settings** to change the LAN settings, select **LAN Services** to enable (On) or disable (Off) LAN services on the instrument, or select **Set to Defaults** to restore the LAN settings to its factory default settings.
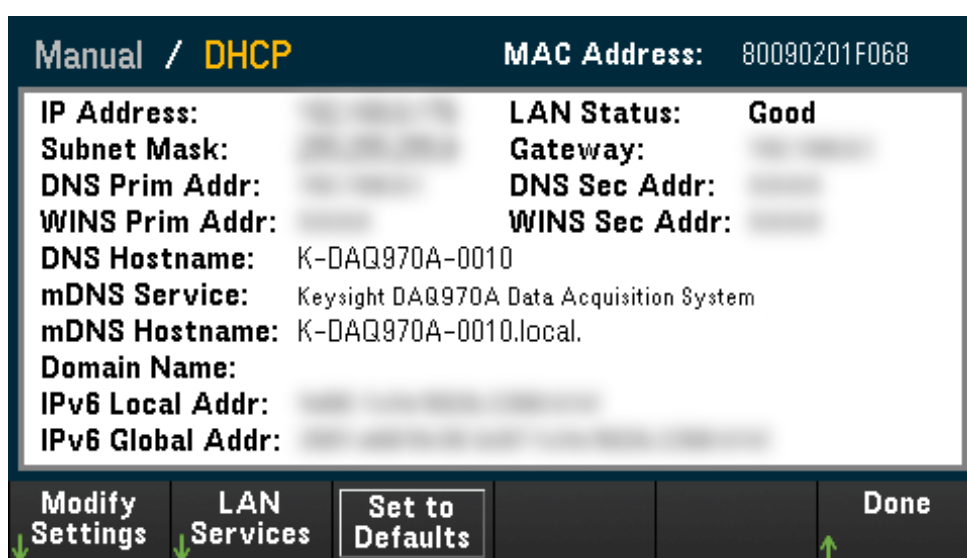
3. To change settings, press **Modify Settings**. To access most items on this screen, use the first softkey to switch from **DHCP** to **Manual**. With DHCP on, an IP address will automatically be set by the DHCP (Dynamic Host Configuration Protocol) when you connect the instrument to the network; provided that the DHCP server is found and is able to do so. The DHCP also automatically deals with the subnet mask, gateway address, DNS, WINS, and domain name, if required. This is typically the easiest way to establish LAN communication for your instrument; all you need to do is leave the DHCP on. Contact your LAN administrator for details.

4. **Establish an "IP Setup"**
   If you are not using DHCP (the first softkey is set to **Manual**), you must establish an IP setup, including an IP address, and possibly a subnet mask and gateway address. The **IP Address** and **Subnet Mask** softkeys are on the main screen. Press **More** to configure other settings.

   Contact your network administrator for the IP address, subnet mask, and gateway to use. All IP addresses take the dot-notation form "nnn.nnn.nnn.nnn" where "nnn" in each case is a byte value in the range 0 through 255. You can enter a new IP address using the knob or the front panel arrow keys. Do not enter leading zeros.

5. **Configure the "DNS Setup" (optional)**

The DNS (Domain Name Service) is an Internet service that translates domain names into IP addresses. Ask your network administrator whether the DNS is in use, and if it is, for the host name, domain name, and DNS server address to use.

a. Set the "hostname". Press **Host Name** and enter the hostname. A hostname is the host portion of the domain name, which is translated into an IP address. The hostname is entered as a string using the front panel arrow keys to select and change characters. The hostname may include letters, numbers, and dashes ("-").

b. Set the "DNS Server" addresses. From the LAN configuration screen, press **More** to go to the second of three sets of softkeys.

   Enter the **Primary DNS** and **Second DNS**. See your network administrator for details.

Firmware Update

CAUTION	Do not turn off the instrument during the update.

1. Press **[Home]** > **Help** > **About** to determine the firmware revision that is currently installed.

2. Go to www.keysight.com/find/DAQ970Afirmware to find the latest firmware revision. If this matches the revision installed on your instrument, there is no need to continue with this procedure. Otherwise, download the firmware update utility and a ZIP file of the firmware. Detailed firmware instructions are in the Firmware Update Utility Instructions located on the download page.

3. Unzip the ZIP file and use the firmware update utility to prepare a USB drive with the updated firmware.

4. Attach the USB drive to the instrument front panel and press **[Utility]** > **Admin** > **Firmware Update** to update the firmware. If Secure mode is enabled, unlock the instrument with the security code before installing firmware.

Important: In order to update the instrument firmware from remote, the model number in the *IDN? response must match the actual instrument model number. If you have changed the instrument's *IDN? response to another instrument, when attempting to update the firmware from remote, you will see this error: "The instrument is not supported by this firmware file". To update the firmware, either update using the front panel procedure or, from remote, use SYSTem:PERSona:MODel to set the *IDN? to match the actual model number, update the firmware, and then use SYSTem:PERSona:MODel again to set the *IDN? response to the other model number.

Contacting Keysight Technologies

You can contact Keysight Technologies for warranty, service, or technical support.

In the United States: (800) 829-4444

In Europe: 31 20 547 2111

In Japan: 0120-421-345

Use www.keysight.com/find/assist to contact Keysight worldwide, or contact your Keysight Technologies representative.

2   Quick Start

Prepare Instrument for Use

Module Wiring Connection and Installation

Connect Power and I/O Cables

Use the Built-in Help System

Adjust the Carrying Handle

Rack Mounting the Instrument

Keysight BenchVue Data Acquisition (DAQ) Software

Prepare Instrument for Use

Verify that you received the following items. If anything is missing, please contact your nearest Keysight sales office or Keysight authorized reseller.

- Power cord (for country of destination)

- Certificate of calibration (optional)

- Supplemental documentation packet

- USB 2.0 cable

- One J-type thermocouple and a flatblade screwdriver

- Keysight IO Libraries Suite Software CD

The Keysight BenchVue Data Acquisition (DAQ) Software can be downloaded from www.key-sight.com/find/benchvue.

Any plug-in modules that you ordered are delivered in a separate shipping container. An additional cable kit (50 Ω) is also included when you order the DAQM905A Dual 1:4 RF Multiplexer (50 Ω) Module.

The latest product documentation is available at www.keysight.com/find/DAQ970Amanuals.

Module Wiring Connection and Installation

WARNING	To prevent electrical shock, use only wires that are rated for the maximum voltage applied to any channel.
	Before removing a module cover, turn off all power to external devices that are connected to the module.
	When any channel is connected to a hazardous voltage source, all channels in the module should be treated as hazardous.
	When any channel is connected to a hazardous voltage source, all channel wiring in the module should be rated for the maximum voltage applied.
	When any channel is connected to a hazardous voltage source, thermocouples attached to any other channel on the module shall have insulation rated for the maximum voltage, or have additional insulation added rated for the maximum voltage, and will be isolated from conductive parts using a thermal compound or tape rated for the maximum voltage applied.
	Do not mount, move or remove any thermocouples when the device under test is connected to a signal source.
	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	During power on, any action to install or uninstall the modules from the rear panel will reboot the instrument.

To connect wiring to a module and install to the rear panel of the instrument, follow the five steps shown below:

1. Using a flat head screwdriver, push forward to detach the cover from the module.
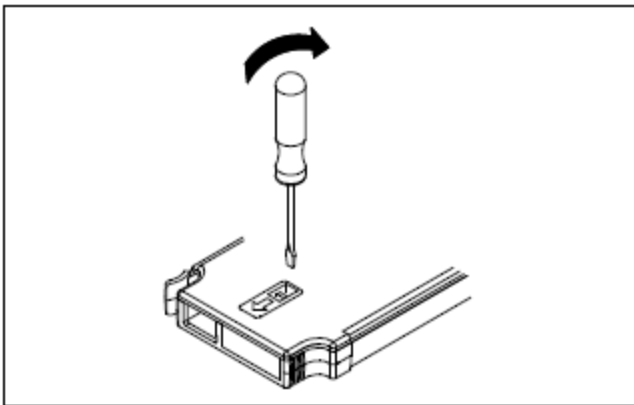
2. Connect the wiring to the screwdriver.
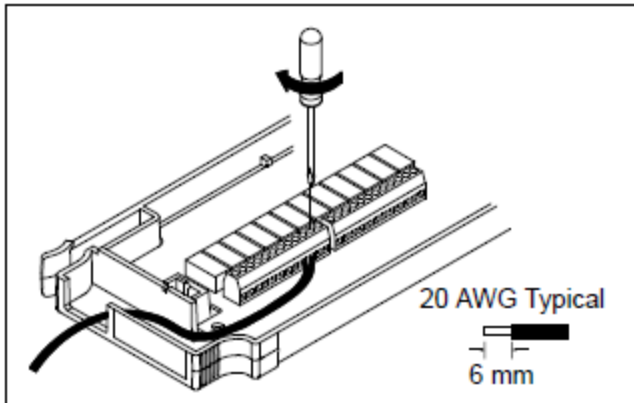
3. Route the wiring through the strain relief.
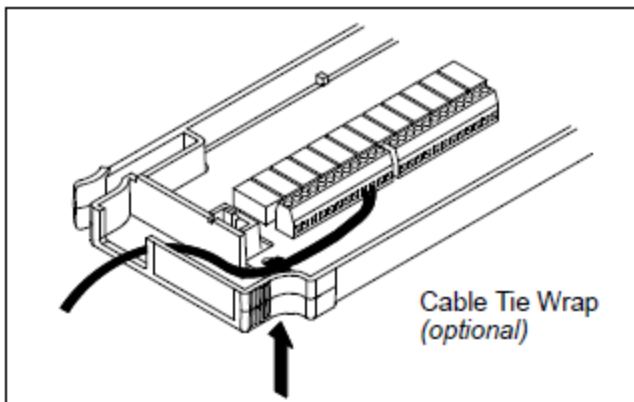
4. Replace the module cover.
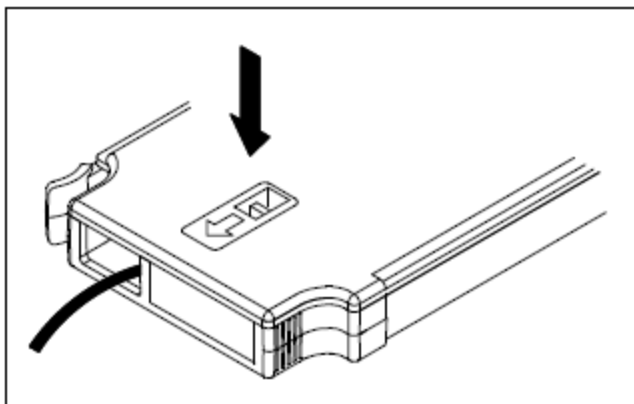
5. Install the module in to the instrument (at the rear panel).
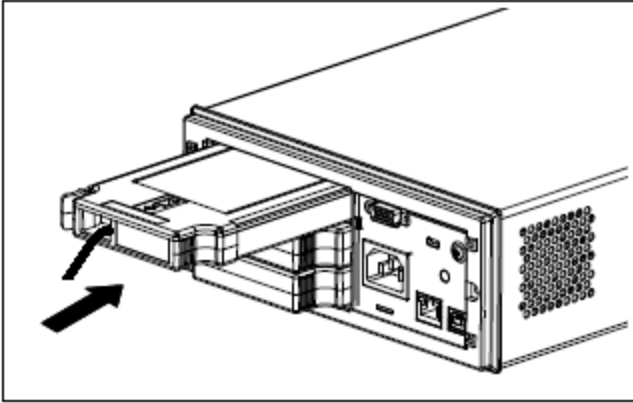
Uninstalling the Module

To unplug or replace any modules, push inward the clip located at rear left side of the module, and then pull it out from rear panel.
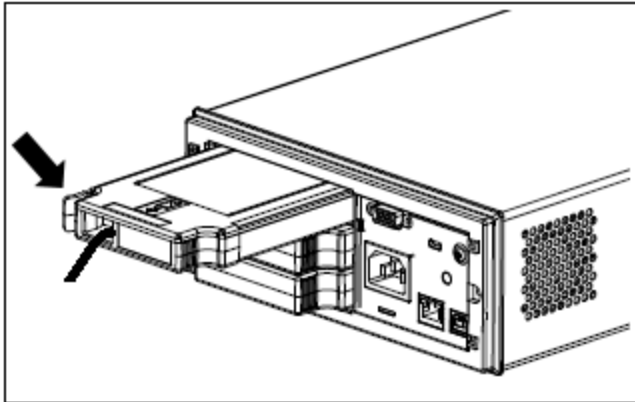
Connect Power and I/O Cables

To turn on the instrument

Before powering on the instrument, make sure all signal sources are turned off. Turn on signal sources after the instrument is powered on. Turn off signal sources before the instrument is powered off. Connect the power cord and LAN or USB cable as desired. Press the **On/Standby** switch on the front panel. Note that this switch is for standby purpose only. To disconnect the mains from the instrument, remove the power cord. If the instrument does not turn on, verify that the power cord is firmly connected.

The table below shows the statuses of the LED color displayed while the instrument is powered-on:

LED color	Instrument status
LED off	No AC mains power connected.
LED is amber	Instrument is in standby mode with AC mains power connected.
LED is green	Instrument is turned on.

Power-on self test

After turning on, the instrument runs a power-on self test and displays a message on how to obtain help, along with the current IP address.

The front-panel display will light up briefly while the instrument perform its power-on self test, with all measurement channels turned off. If the power-on self test fails, the error annunciator, **ERR** is displayed on the screen. See "SCPI Error Messages" in the *DAQ970A Programming Guide* for more information on SCPI error codes and error messages.

> **NOTE**   A complete self-test performs a more extensive set of tests than those performed at power-on. See the *DAQ970A Service Guide* for more informationon the instrument complete self-test procedure.

The instrument's default measurement function is DC voltage (DCV), with autoranging enabled.

To turn off the instrument

Press and hold the **On/Standby** switch for about half a second. This prevents you from accidentally turning off the instrument by brushing against the power switch.

> **NOTE**   If you turn off the instrument by disconnecting the power source (this is not recommended), the instrument turns on as soon as the power is reconnected. You do need to press the **On/Standby** switch again.

Use the Built-in Help System

The built-in help system provides context-sensitive help on any front panel key or menu softkey. A list of help topics is also available to help you learn about the instrument. All messages, context-sensitive help, and help topics appear in the selected language. The menu softkey labels are not translated.

View the list of help topics

Press [Home] > Help > Help Topics to view the list of help topics. Use the knob or the front panel arrow keys to highlight the desired topic, and press [Select] to view the help contents.
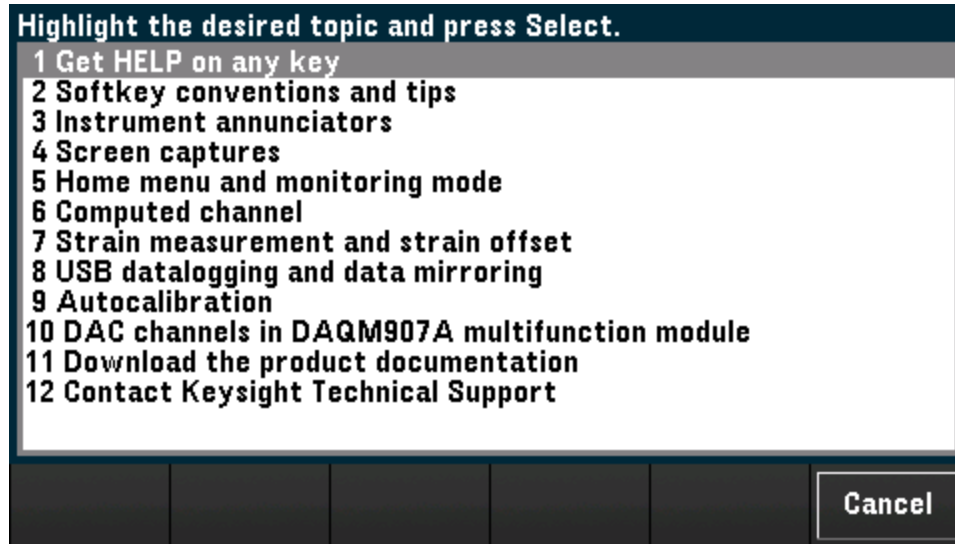
In this example, we selected 1 Get HELP on any key. The following help topic appears:
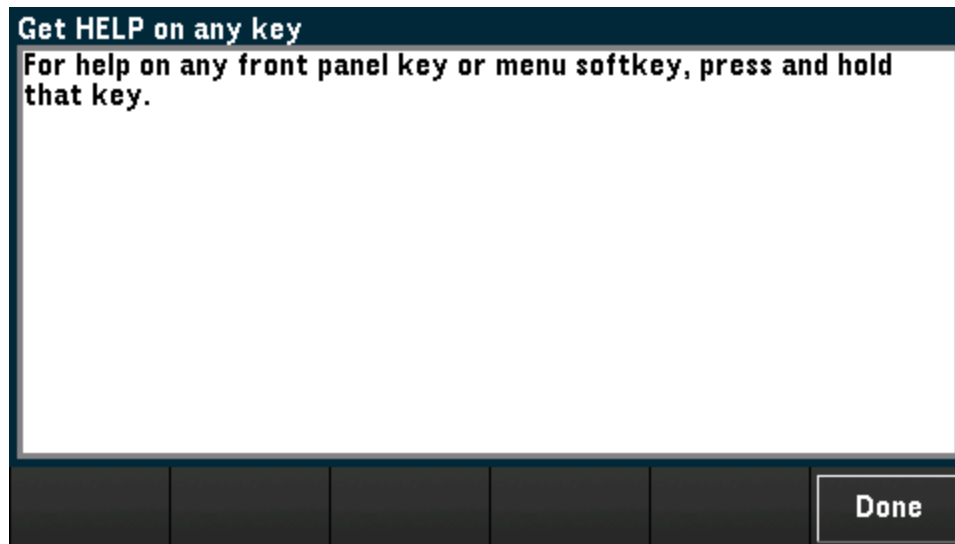
Press Done to exit the help.

View the help information for a front panel key

Press and hold any front panel key or softkey to get context-sensitive help, such as [Scan]. If the message contains more information than will fit on the display, use the knob or the front panel arrow keys to load in previous/next page.
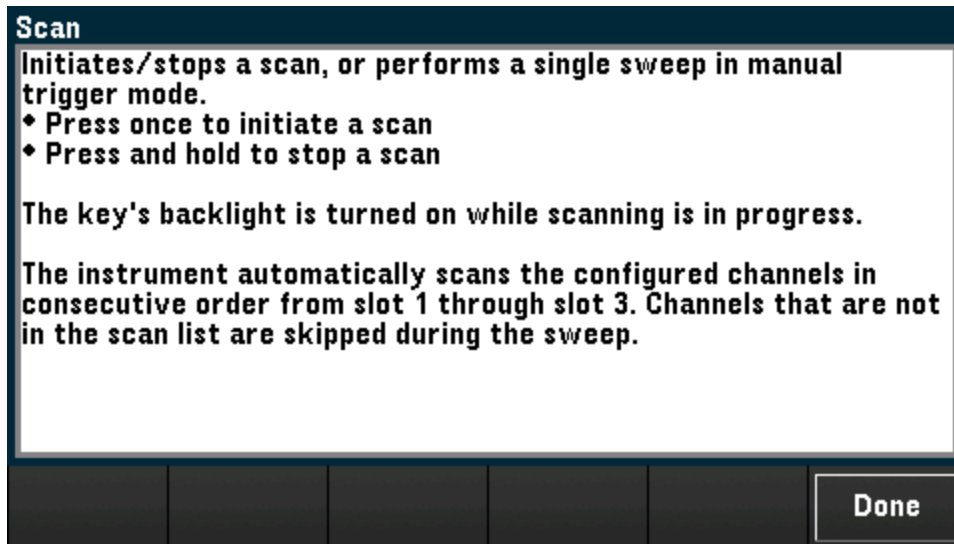
Press **Done** to exit the help.

View the instrument information

Press [Home] > Help > About to view the instrument information such as product serial number, IP address (when connected to LAN interface), and currently installed firmware revision. Press **Done** to exit.

Adjust the Carrying Handle

The carrying handle has three positions (as shown below). To adjust the handle position, grasp the sides of the handle, pull outward, and rotate the handle.
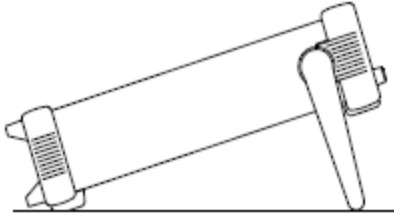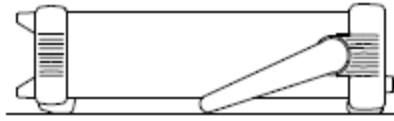
Bench-top viewing positions   Carrying position
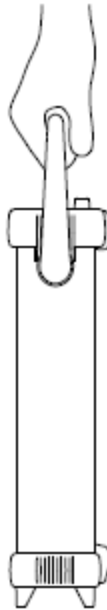
Rack Mounting the Instrument

You can mount the instrument in a standard 19-inch rack cabinet by ordering the rack mount kit with the part number provided as below. Instructions and mounting hardware are included with each rack-mounting kit. Any Keysight System II instrument of the same size can be rack-mounted beside the DAQ970A.

CAUTION	To prevent overheating, do not block air flow to or from the instrument. Allow enough clearance at the rear, sides, and bottom of the instrument to permit adequate internal air flow.

NOTE	Remove the carrying handle, and the front and rear rubber bumpers, before rack-mounting the instrument.

Removing the handle and bumpers

To remove the handle, rotate it to the vertical position and pull the ends outward.
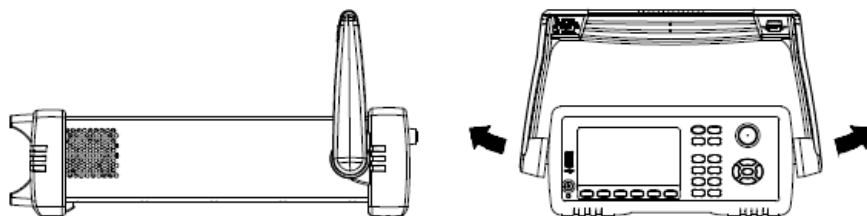
To remove the front and rear rubber bumpers, stretch a corner and then slide it off.

Front   Rear (bottom view)
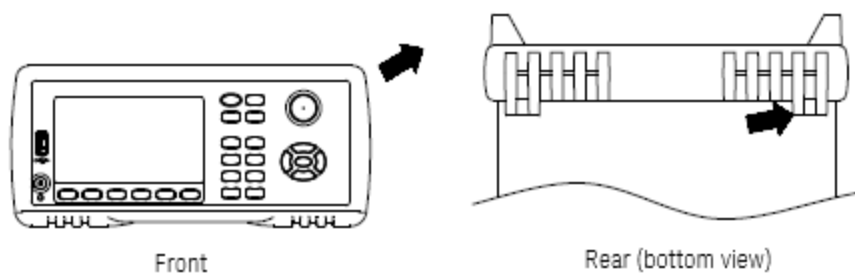
Rack mounting a single instrument

To rack mount a single instrument, order the adapter kit (part number: DAQA190A-FG).
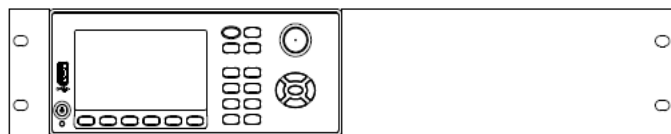
Rack mounting instruments side-by-side

To rack mount two instruments side-by-side, order the lock-link kit (part number: DAQA194A-FG) and flange kit (part number: DAQA191A-FG). Be sure to use the support rails inside the rack cabinet.
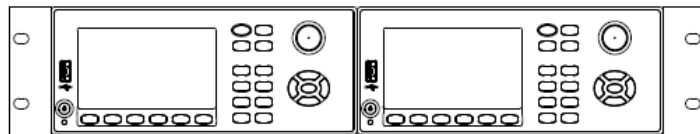
Keysight BenchVue Data Acquisition (DAQ) Software

The Keysight BenchVue Data Acquisition (DAQ) Software is a Windows-based application that makes it easy to use the instrument with your PC for gathering and analyzing measurements. Use this software to set up your test, acquire and archive measurement data, and perform real-time display and analysis results of your measurements. The Keysight BenchVue Data Acquisition (DAQ) Software can be downloaded from www.keysight.com/find/benchvue.

Application main screen:
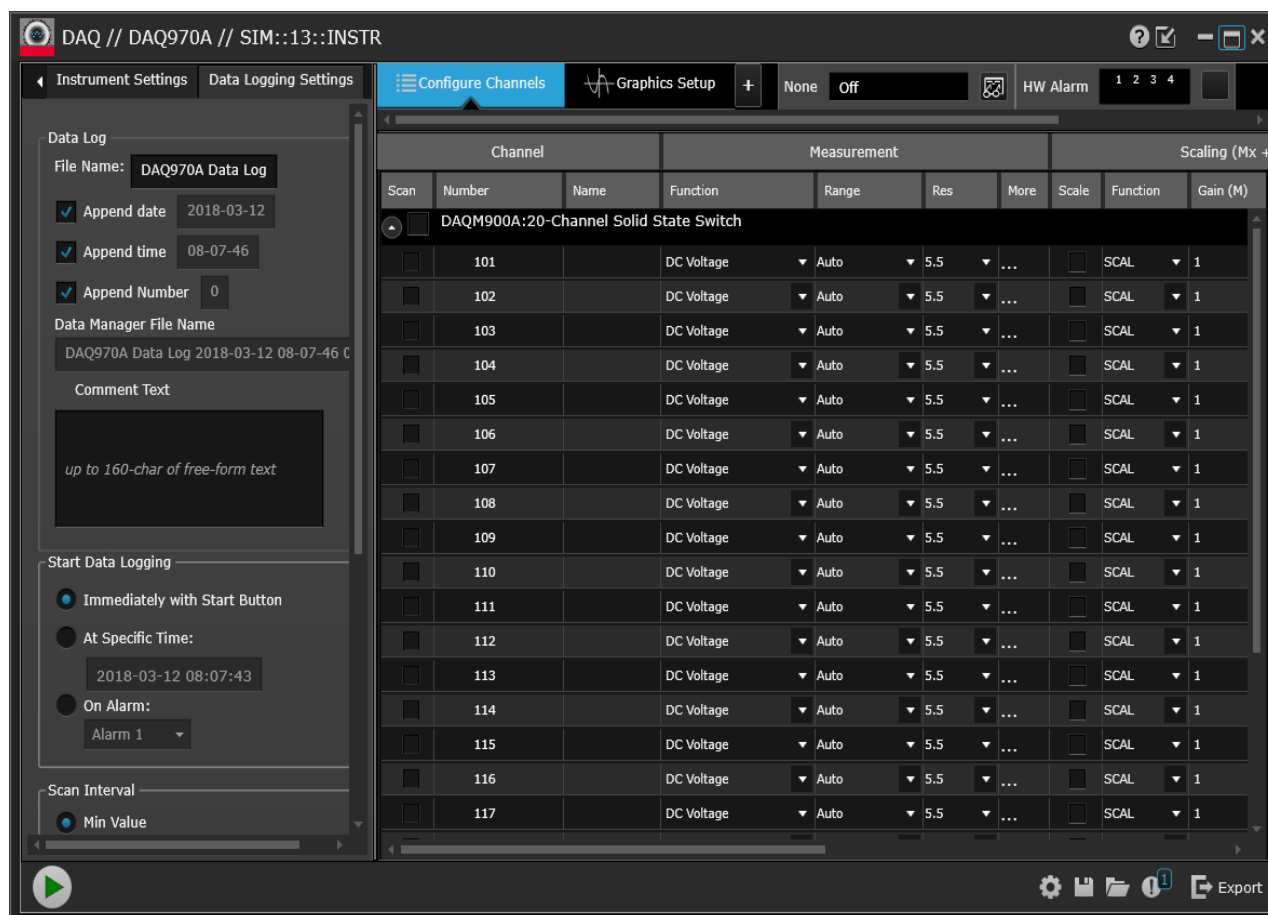
BenchVue Data Acquisition (DAQ) Software Licensing

To evaluate a BenchVue application for a free 30-day trial period, go to the BenchVue **Application** view, click once on the desired application, and then click on the "Start Trial" button – the trial period is based on the number of *calendar days* remaining. After the trial period expires, you will be required to purchase a software license for that application. Keysight's flexible licensing options allow you to select the license type and license terms that best fit your software needs. For more information on purchasing and installing a software license, see *BenchVue Software Licensing Options* in the Keysight BenchVue Data Acquisition (DAQ) Software Help .

3   Features and Functions

System Overview

This section provides an overview of a computer-based system and describes the parts of a data acquisition system.

Data Acquisition System Overview

Signal Routing and Switching

Measurement Input

Control Output

Data Acquisition System Overview

You can use the Keysight DAQ970A as a stand-alone instrument, but there are many applications where you will want to take advantage of the built-in PC connectivity features. A typical data acquisition system is shown below:
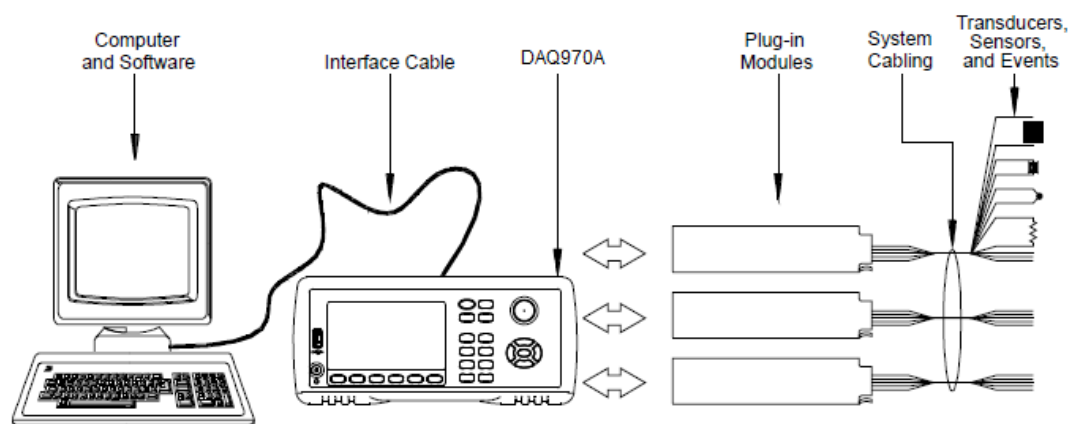
The configuration offers the following advantages:

- You can use the DAQ970A to perform data storage, data reduction, mathematical calculations, and conversion to engineering units. You can use the PC to provide easy configuration and data presentation.

- You can remove the analog signals and measurement sensors from the noisy PC environment and electrically isolate them from both the PC and earth ground.

- You can get a single PC to monitor multiple instruments and measurement points while performing other PC-based tasks.

DAQ970A logic circuitry

As shown below, the logic circuitry for the DAQ970A is divided into two sections: earth-referenced and floating. These two sections are isolated from each other in order to maintain measurement accuracy and repeatability. See Noise Caused by Ground Loops for further details on ground loops.
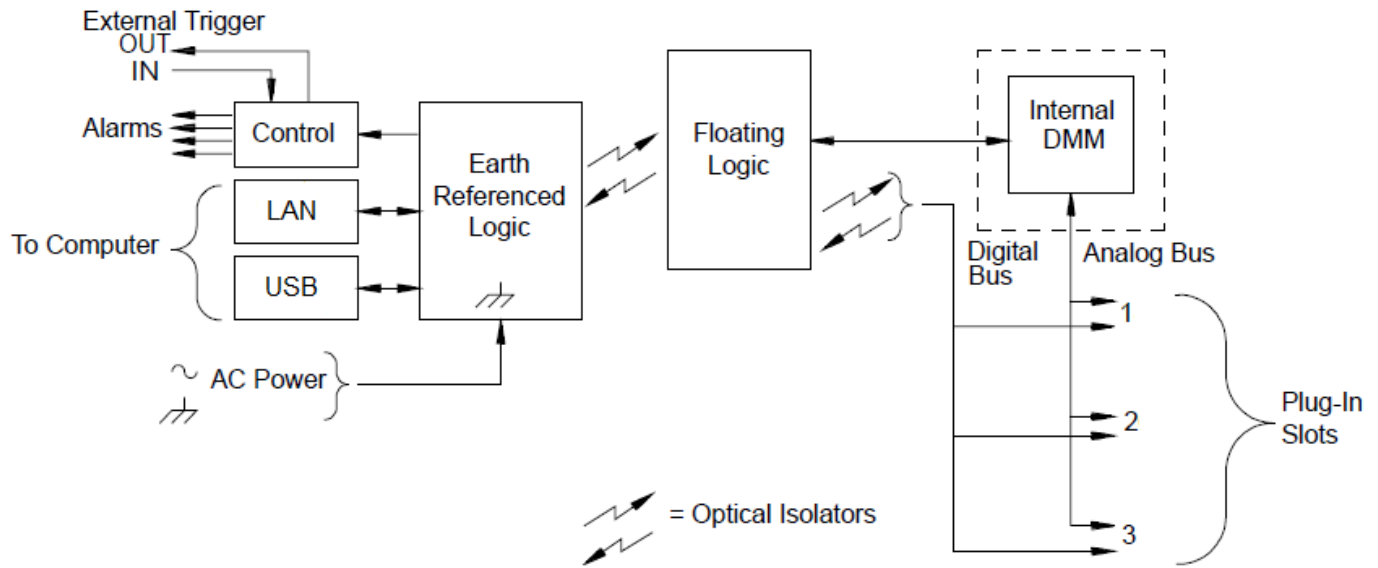
The earth-referenced and floating circuitry communicate with each other via an optically-isolated data link. The earth-referenced section communicates with the floating section to provide PC connectivity. The DAQ970A is shipped with LAN and USB interfaces connectivity.

The earth-referenced section also provides four hardware alarm outputs and external trigger lines. You can use the alarm output lines to trigger external alarm lights, sirens, or send a TTL-compatible pulse to your control system.

The floating section contains the main system processor and controls all of the basic functionality of the instrument. This is where the instrument communicates with the plug-in modules, scans the keyboard, controls the front-panel display, and controls the internal DMM. The floating sections also performs measurement scaling, monitors alarm conditions, converts transducer measurements to engineering units, time stamps scanned measurements, and saves data in non-volatile memory.

Plug-in modules

The DAQ970A offers a complete selection of plug-in modules to give you high-quality measurement, switching, and control capabilities. The plug-in modules communicate with the floating logic via the internal isolated digital bus. The multiplexer modules also connect to the internal DMM via the internal analog bus. Each modules has its own microprocessor to offload the mainframe processor and minimize backplane communications for faster throughput. See Module Overview for more information.

Module number	Common uses
Measurement input	
DAQM900A	Scanning and direct measurement of temperature, voltage, resistance, frequency, and current (DAQM901A only) by using the internal DMM.
DAQM901A	
DAQM902A	
DAQM907A	Digital Input, Event Counting.
DAQM908A	Scanning and direct measurement of temperature, voltage, and resistance by using the internal DMM.
Signal routing	

Module number	Common uses
DAQM900A	N/A
DAQM901A	Multiplexing of signals to or from external instruments.
DAQM902A	N/A
DAQM904A	32 Crosspoint Matrix Switching.
DAQM905A	50 Ω high-frequency applications (<2 GHz).
DAQM908A	N/A
Control output	
DAQM903A	General-purpose switching and control using Form C (SPDT) switches.
DAQM907A	Digital Output, Voltage (DAC) Outputs.

System cabling

The plug-in modules have screw-terminal connectors to make it easy to connect your system cabling. The type of cabling that you use to connect your signals, transducers, and sensors to the module is critical to measurement success. Some types of transducers, such as thermocouples, have very specific requirements for the type of cable that can be used to make connections. Be sure to consider the usage environment when choosing wire gauge and insulation qualities. Wire insulation typically consists of materials such as PVC or PTFE. Table below lists several common cable types and describes their typical uses.

> **NOTE**   Wiring insulation and usage is described in more detail in "System Cabling and Connections".

Cable type	Common uses	Comments
Thermocouple Extension Wire	Thermocouple measurements.	Available in specific thermocouple types. Also available in shielded cable for added noise immunity.
Twisted Pair, Shielded Twisted Pair	Measurement inputs, voltage outputs, switching, counting.	Most common cable for low-frequency measurement inputs. Twisted pair reduces common mode noise. Shielded-twisted pair provides additional noise immunity.
Shielded Coaxial, Double-Shielded Coaxial	VHF signal switching.	Most common cable for high-frequency signal routing. Available in specific impedance values (50 Ω or 75 Ω). Provides excellent noise immunity. Double-shielded cable improves isolation between channels. Requires special connectors.
Flat Ribbon, Twisted pair Ribbon	Digital Input/Output	Often used with mass termination connectors. These cables provide little noise immunity.

Transducers and sensors

Transducers and sensors convert a physical quantity into an electrical quantity. The electrical quantity is measured and the result is then converted to engineering units. For example, when measuring a thermocouple, the instrument measures a DC voltage and mathematically converts it to a corresponding temperature in °C, °F, or K.

Measurement	Typical transducer types	Typical transducer output
Temperature	Thermocouple	0 mV to 80 mV
	RTD	2-wire or 4-wire resistance from 5 Ω to 500 Ω
	Thermistor	2-wire resistance from 10 Ω to 1MΩ
Pressure	Solid State	±10 DVC
Flow	Rotary Type Thermal Type	4 mA to 20 mA
Strain	Resistive Elements	4-wire resistance from 10 Ω to 10 kΩ
Events	Limit Switches Optical Counters Rotary Encoder	0 V or 5 V Pulse Train
Digital	System Status	TTL-compatible Levels

Alarm limits

The DAQ970A has four alarm outputs which you can configure to alert you when a reading exceeds specified limits on a channel during a scan. You can assign a high limit, low limit, or both to any configured channel in the scan list. You can assign multiple channels to any of the four available alarms (numbered 1 through 4). For example, you can configure the instrument to generate an alarm on Alarm 1 when a limit is exceeded on any of the channels 103, 205, or 320.

You can also assign alarms to channels on the multifunction module. For example, generate an alarm when a specific bit pattern or bit pattern change is detected on a digital input channel or when a specific count is reached on a totalizer channel. With the multifunction module, the channels do not have to be part of the scan list to generate an alarm.

Signal Routing and Switching

The switching capabilities of the plug-in modules available with the DAQ970A provide test system flexibility and expandability. You can use the switching plug-in modules to route signals to and from your test system or multiplex signals to the internal DMM or external instruments.

Relays are electromechanical devices which are subject to wear-out failure modes. The life of a relay, or the number of actual operations before failure, is dependent upon how it is used - applied load, switching frequency, and environment. The DAQ970A relay maintenance system automatically counts the cycles of each relay in the instrument and stores the total count in non-volatile memory on each switch module. Use this feature to track relay failures and to predict system maintenance requirements.

Switching topologies

Several switching plug-in modules are available with different topologies for various applications:

Switching topologies	Plug-in modules
Multiplexer	DAQM900A, DAQM901A, DAQM902A, DAQM905A, DAQM908A
Matrix	DAQM904A
Form C (single pole, double throw)	DAQM903A

The following sections describe each of these switching topologies.

Multiplexer switching

Multiplexers allow you to connect one of multiple channels to a common channel, one at a time. A simple 4-to-1 multiplexer is shown below. When you combine a multiplexer with a measurement device, like the internal DMM, you create a scanner. For more information on scanning, see **"Scanning"**.
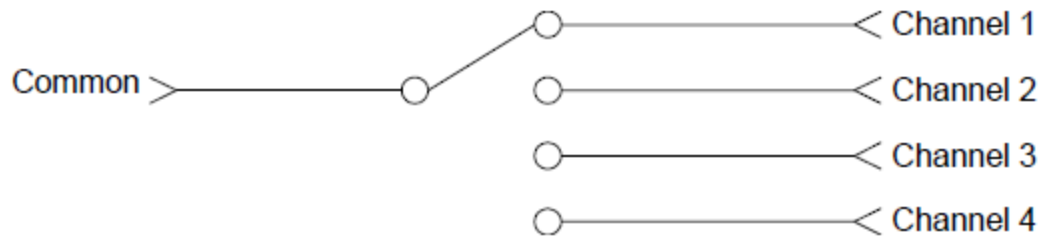
Multiplexers are available in several types:

Multiplexer type	Common use
One-wire (single-ended)	For common LO measurements. For more information, see **"One-Wire (Single-Ended) Multiplexers"**.
Two-wire	For floating measurements. For more information, see **"Two-Wire Multiplexers"**.
Four-wire	For resistance and RTD measurements. For more information, see **"Four-Wire Multiplexers"**.
RF Signal	Very High Frequency (VHF) for switching frequencies up to 2.8 GHz. For more information, see **"RF Signal Multiplexing"**.

Matrix switching

A matrix switch connects multiple inputs to multiple outputs and therefore offers more switching flexibility than a multiplexer. Use a matrix for switching low-frequency (less than 10 MHz) signals only. A matrix is arranged in rows and columns. For example, a simple 3×3 matrix could be used to connect three sources to three test points as shown below:
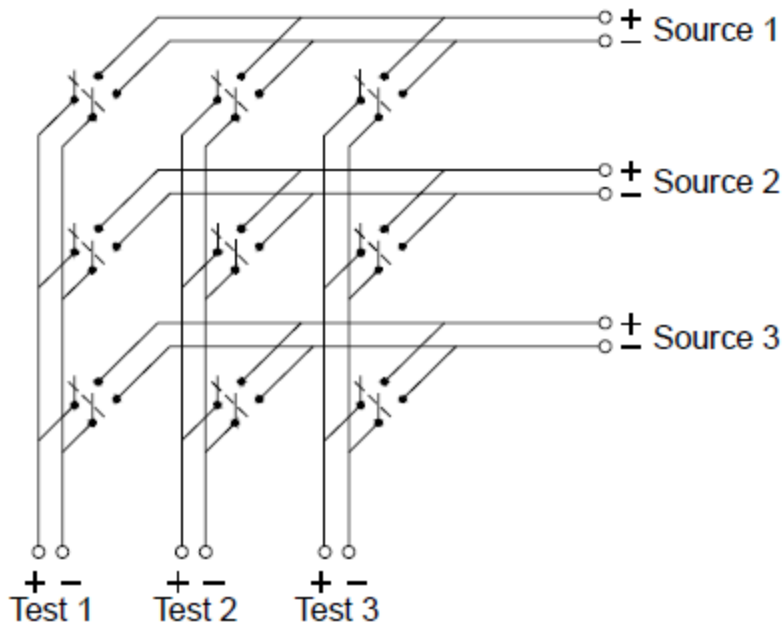
Any one of the signal sources can be connected to any one of the test inputs. Be aware that with a matrix, it is possible to make sure that dangerous or unwanted conditions are not created by these connections.

Form C (SPDT) switching

The DAQM903A contains 20 Form C switches (also called single-pole, double-throw). You can use Form C switches to route signals but they are typically used to control external devices.
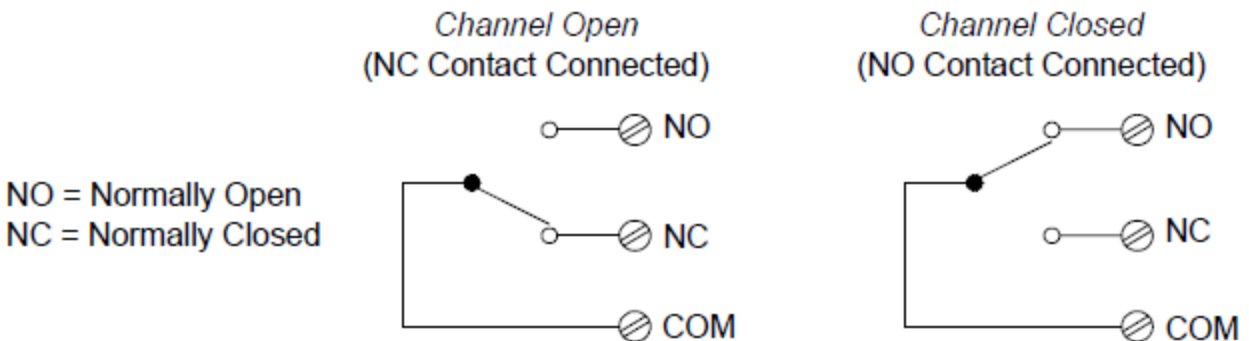
Measurement Input

The DAQ970A allows you to combine a DMM (either internal or external) with multiplexer channels to create a scan. During a scan, the instrument connects the DMM to the configured multiplexer channels one at a time and makes a measurement on each channel.

Any channel that can be "read" by the instrument can also be included in a scan. This includes any combination of temperature, voltage, resistance, current, frequency, or period measurements on multiplexer channels. A scan can also include a read of a digital port, a read via the sense channel, or a read of the totalizer count on the multifunction module.

The internal DMM

A transducer or sensor converts a physical quantity being measured into an electrical signal which can be measured by the internal DMM. To make these measurements, the internal DMM incorporates the following functions:

- Temperature (thermocouple, RTD, and thermistor)

- Voltage (DC and AC up to 300 V)

- Resistance (2-wire and 4-wire up to 1GΩ)

- Current (DC and AC up to 1 A)

- Frequency and Period (up to 300 kHz)

The internal DMM provides a universal input front-end for measuring a variety of transducer types without the need for additional external signal conditioning. The internal DMM includes signal conditioning, amplification (or attenuation), and a high resolution (up to 22 bits) analog-to-digital converter. A simplified diagram of the internal DMM is shown below:

Signal conditioning, ranging, and amplification

Analog input signals are multiplexed into the internal DMM's signal-conditioning section - typically comprising switching, ranging, and amplification circuitry. If the input signal is a DC voltage, the signal conditioner is composed of an attenuator for the higher input voltages and a DC amplifier for the lower input voltages. If the input signal is an AC voltage, a converte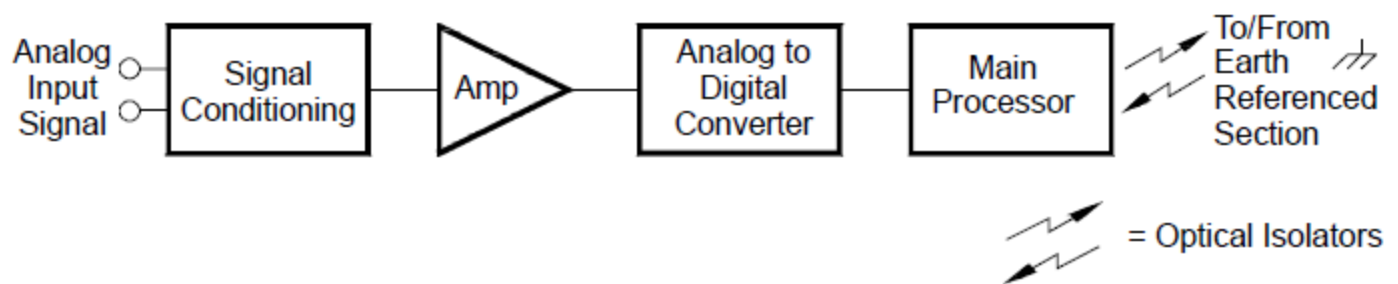r is used to convert the AC signal to its equivalent DC value (true RMS value). Resistance measurements are performed by supplying a known DC current to an unknown resistance and measuring the DC voltage drop across the resistor. The input signal switching and ranging circuitry, together with the amplifier circuitry, convert the input to a DC voltage which is within the measuring range of the internal DMM's analog-to-digital converter (ADC).

You can allow the instrument to automatically select the measurement range using autoranging or you can select a fixed measurement range using manual ranging. Autoranging is convenient because the instrument automatically selects the range to use for each measurement based on the input signal. For fastest scanning operation, use manual ranging for each measurement (some additional time is required for autoranging since the instrument has to make a range selection.

Analog-to-digital conversion (ADC)

The ADC takes a prescaled DC voltage from the signal-conditioning circuitry and converts it to digital data for output and display on the front panel. The ADC governs some of the most basic measurement

characteristics. These include measurement resolution, reading speed, and the ability to reject spurious noise. There are several analog-to-digital conversion techniques but they can be divided into two types: integrating and non-integrating. The integrating techniques measure the average input value over a defined time interval, thus rejecting many noise sources. The non-integrating techniques sample the instantaneous value of the input, plus noise, during a very short interval. The internal DMM uses an integrating ADC technique.

Main processor

The main processor, located in the floating logic section, controls the input signal conditioning, ranging, and the ADC. The main processor accepts commands from, and sends measurement results to, the earth-referenced logic section. The main processor synchronizes measurements during scanning and control operations. The main processor uses a multi-tasking operation system to manage the various system resources and demands.

The main processor also calibrates measurement results, performs Mx+B scaling, monitors alarm conditions, converts transducer measurements to engineering units, time stamps scanned measurements, and stores data in non-volatile memory.

Scanning

The instrument allows you to combine a DMM (either internal or external) with multiplexer channels to create a scan. During a scan, the instrument connects the DMM to the configured multiplexer channels one at a time and makes a measurement on each channel.

Before you can initiate a scan, you must set up a scan list to include all desired multiplexer or digital channels. Channels which are not in the scan list are skipped from the scan. The instrument automatically scans the list of channels in ascending order from slot 1 through slot 3. Measurements are taken only during a scan and only on those channels which are included in the scan list.

You can store up to 100,000 readings in non-volatile memory during a scan. Readings are stored only during a scan and all readings are automatically time stamped. Each time you start a new scan, the instrument clears all readings stored in memory from the previous scan. Therefore, all readings currently stored in memory are from the most recent scan.

You can configure the event or action that controls the onset of each sweep through the scan list (a sweep is one pass through the scan list):

You can set the instrument's internal timer to automatically scan at a specific interval as shown below. You can also program a time delay between channels in the scan list.

Scan Count
1 to 50,000 sweeps (one sweep per trigger), or continuous

Scan List (1 sweep)

Scan-to-Scan interval
(0 to 99:59:59 hours)
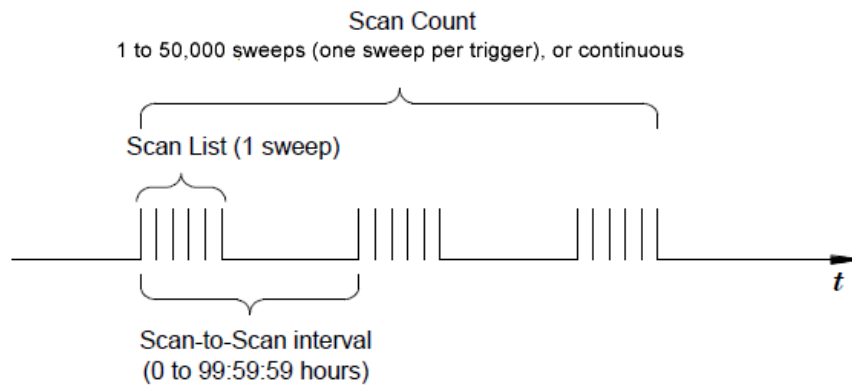
You can manually control a scan by repeatedly pressing [**Scan**] from the front panel.

You can start a scan by sending a software command from the remote interface.

You can start a scan when an external TTL-compatible trigger pulse is received.

You can start a scan when an alarm condition is logged on the channel being monitored.

Scanning with external instruments

You can use the DAQ970A for signal routing or control applications. If you install a multiplexer plug-in module, you can use the DAQ970A for scanning with an external instrument. You can connect an external instrument (such as a DMM) to the multiplexer COM terminal.

Input Channels

External DMM

Common Terminals
(COM)

H

L
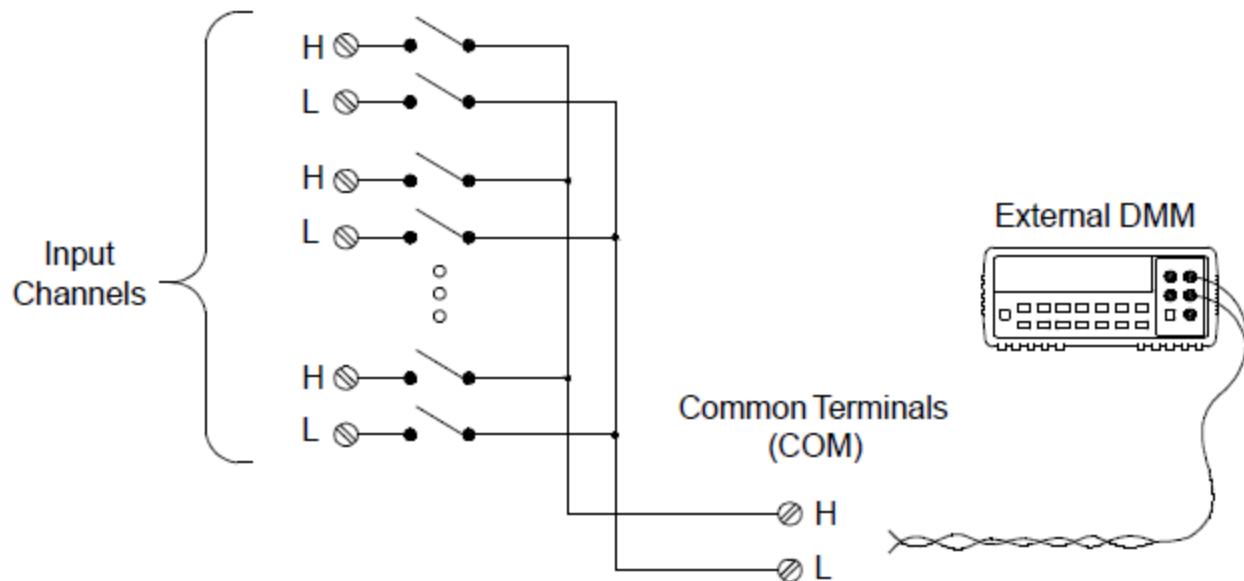
To control scanning with an external instrument, two control lines are provided. When the DAQ970A and the external instrument are properly configured, you can synchronize a scan sequence between the two.
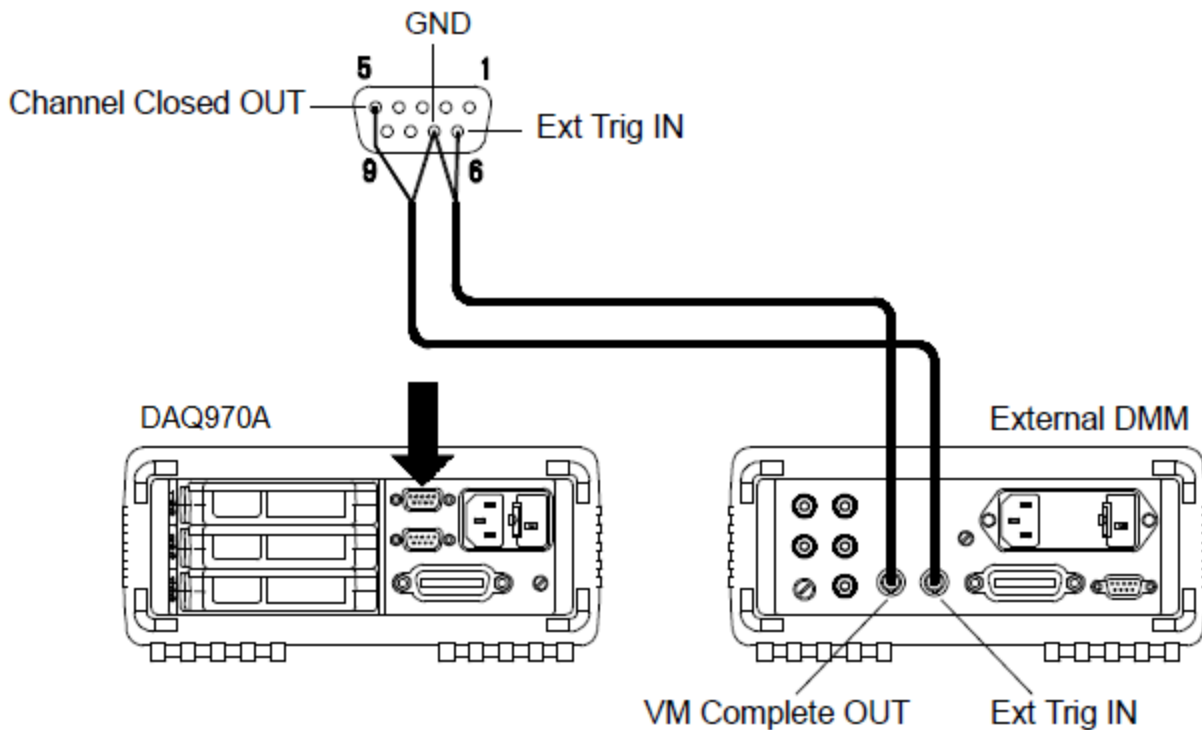
The multifunction module

The multifunction module (DAQM907A) adds two additional measurement input capabilities to the system: digital input and event totalize.

The multifunction module also contains a dual voltage output (DAC). For more details, see "Transducers and Sensors".

Digital input

The multifunction module has two non-isolated 8-bit input/output ports which you can use for reading digital patterns. You can read the live status of the bits on the port or you can configure a scan to include a digital read. Each port has a separate channel number on the module and contains 8-bits. You can combine the two ports to read a 16-bit word.
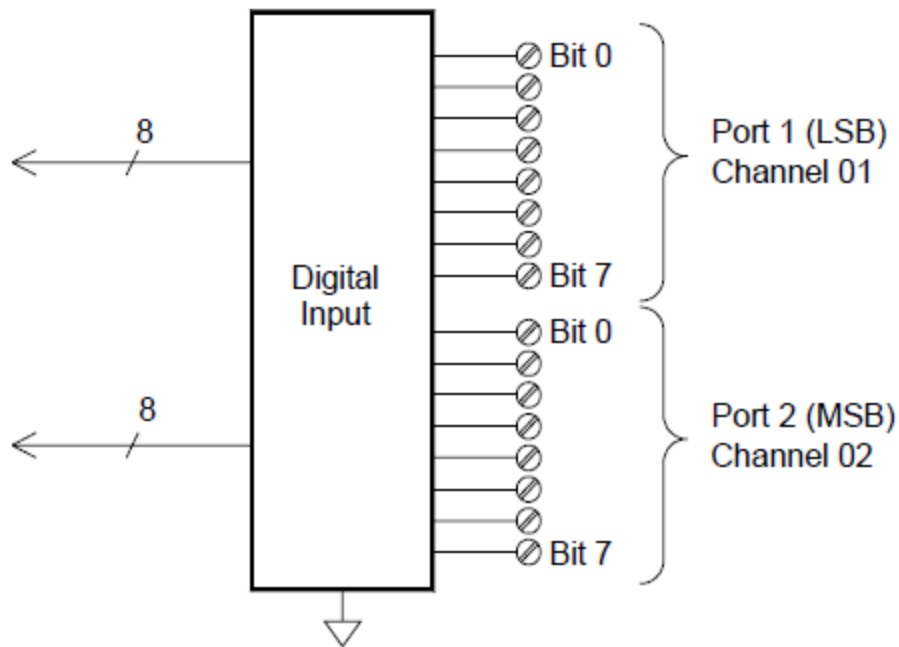
Totalizer

The multifunction module has a 26-bit totalizer which can count pulses at a 100 kHz rate. You can manually read the totalizer count or you can configure a scan to read the count.
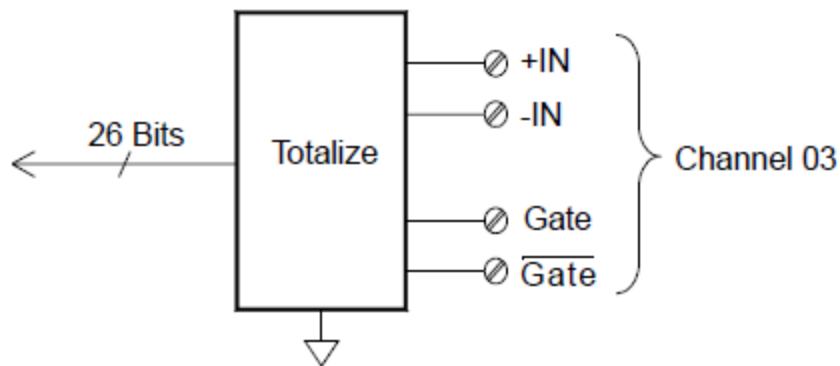
You can configure the totalizer to count on the rising edge or falling edge of the input signal.

The maximum count is 67,108,863 ($2^{26}-1$). The count rolls over to "0" after reaching the maximum allowed value.

You can configure the totalizer to read without affecting the count or reset the count to zero without losing any counts.

Control Output

In addition to signal routing and measurement, you can also use the DAQ970A to provide simple control outputs. For example, you can control external high-power relays using the actuator module or a digital output channel.

The multifunction module

The multifunction module (DAQM907A) adds two additional control output capabilities to the system: *digital output* and *voltage (DAC) output*.

The multifunction module also contains digital input and event totalizer capabilities. For more details, see "The Multifunction Module".

Digital output

The multifunction module has two non-isolated 8-bit input / output ports which you can use to output digital patterns. Each port has a separate channel number on the module and contains 8-bits. You can combine the two ports to output a 16-bit word.
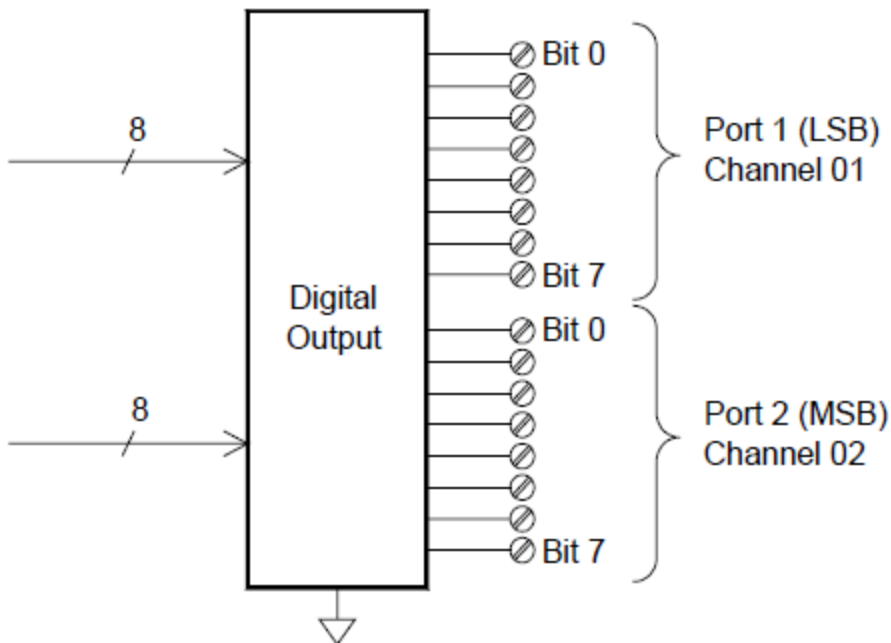
Voltage (DAC) output

The multifunction module has two analog outputs capable of outputting calibrated voltages between ±12 V with 18 bits of resolution. Each DAC (Digital-to-Analog Converter) channel can be used as a pro-grammable voltage source for analog input control of other devices. A simplified diagram is shown below:
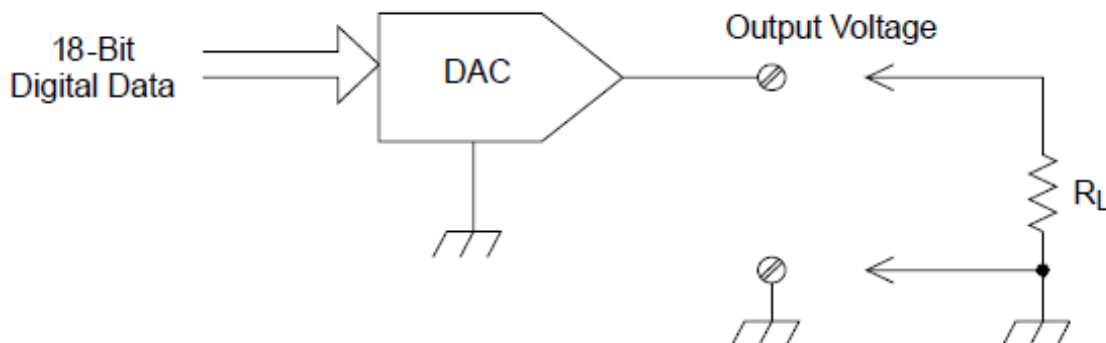
You can set the output voltage to any value between ±12 VDC, in 100 µV steps. Each DAC is earth referenced, it cannot float. Each DAC channel is capable of supplying 15 mA maximum current during output voltage mode. Or you can set the DAC to constant current mode, to output any current between ±24 mA, in 0.2 µA steps.

Each DAC channel is capable of supplying 24 mA maximum current.

NOTE	You must limit the output current to 40 mA for each slot (two DAC channels).

The actuator/general purpose switch

You can think of the DAQM903A Actuator as a control output because it is often used to control external power devices. The actuator provides 20 independent, isolated Form C (SPDT) switches.
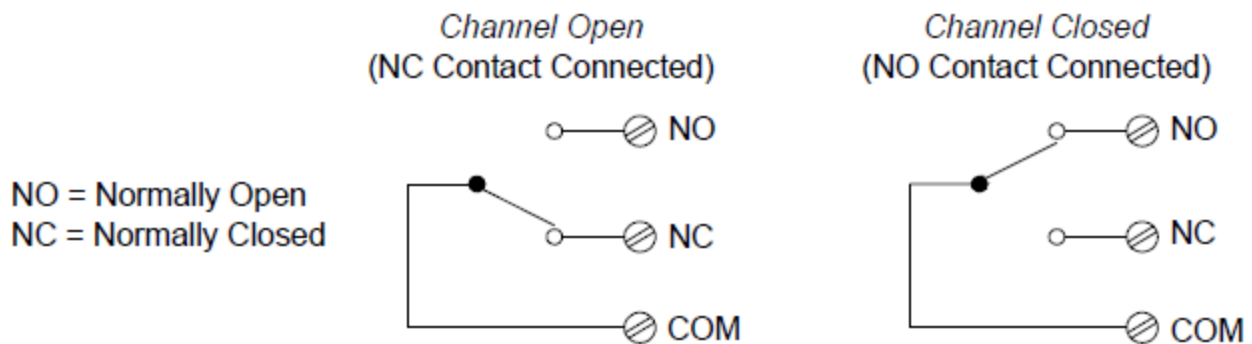
Each channel can switch up to 300 V DC or AC rms. Each switch can also switch up to 1 A DC or AC rms up to maximum 50 W. For example, the maximum current that you can switch at 120 V is 0.45 A as shown below:
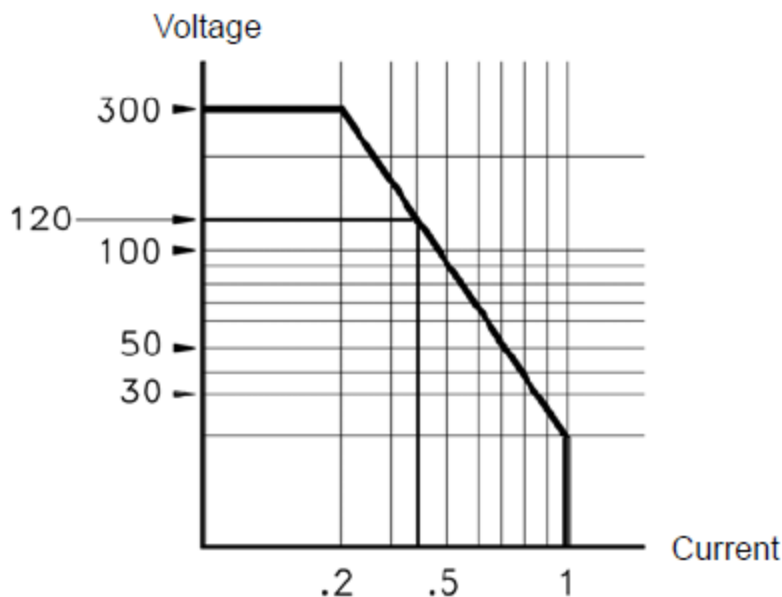
For control applications, the actuator has the following advantages:

Higher voltage and power rating than the digital output channels. The actuator switches can also be used to control power devices.

When used with high-power devices, however, it is critical that you provide protection to the switch from capacitive and inductive loads to ensure maximum relay life.

For more information on attenuators, see Using Attenuators.

Front Panel Menu Reference

Table below summarizes the front panel keys and the menu structure.

Key	Description
Scan	• Initiates/stops a scan, or performs a single sweep in manual trigger mode. • Press once to initiate a scan; press and hold to stop a scan. • The key's backlight is turned on while scanning is in progress. • The instrument automatically scans the configured channels in consecutive order from slot 1 through slot 3. Channels that are not in the scan list are skipped during the sweep.
Monitor	• Monitors a channel's measurement data that is useful for troubleshooting the instrument and observing an important signal. • You can select to view the monitor measurements in number, bar meter, trend chart, and histogram format. • The key's backlight is turned on while monitoring is enabled. The monitor annunciator will also be displayed, and the sample annunciator will flash when monitor measurements are made. • To stop the monitoring mode and return to Home menu page, press this key again on the Monitor menu page.
(home)	• Measures the offset on strain channels. • Configures the four alarm output hardware lines. • Displays the instrument information and a list of help topic in selected local language. • Configures various user preferences.
View	• Views scanned memory readings. • Views alarm queue. • Views error queue. • Views number of relay cycles.
Channel	• Channel labeling. • Closes or opens switches on switching channels. • Selects measurement function. • Selects measurement range or autorange. • Selects the integration time. • Configures advanced measurement features.
Interval	• Configures what starts each sweep, or the interval between sweeps, and the number of sweeps in the scan.
Math	• Configures the measurement scaling (mX+b, %, dBm, or dB) on the current channel.
Copy	• Copies the measurement configuration from the selected channel(s) to other channel(s).
Alarm	• Configures alarm on the selected channel. There are four configurable alarms in this instrument.
Utility	• Self-test. • Calibration. • Autocalibration. • Instrument security (NISPOM). • Firmware update.

Key	Description
Module	- Overview of the scan list for the module. - Performs a module reset. - Module labeling.
Save Recall Local	- Saves and recalls instrument state files (.sta extension) and preference files (.prf extension). - File management. - Saves the readings from trend chart or histogram. - Captures and saves the screen image. - Instrument factory reset and system preset. - Data logging to a USB drive on the front panel. - Returns the instrument into local control when the instrument is in remote.

[Scan] Key

Press the **[Scan]** key on the front panel to initiate or stop a scan, or to perform a single sweep when manual trigger mode is selected.

Press **[Scan]** once to initiate a scan.

The instrument automatically scans the configured channels in consecutive order from slot 1 through slot 3. Channels that are not in the scan list are skipped during the sweep. The **[Scan]** key's backlight is turned on while scanning is in progress.

Press and hold **[Scan]** for more than 2 seconds to stop the scan. "Scan stopped" is shown when the scanning is terminated.

Press **[Module]** > **Scan List** to view the available channels on the module that are included in the scan list. See [Module] Menu for more information on the **Scan List** softkey. See the [Channel] Menu for more information on how to include a channel in the scan list (using the **In Scan** softkey). Also, see the [Interval] Menu for more information on how the **[Scan]** key is used when the manual trigger mode is selected.

[Monitor] Menu

During scanning, you can monitor the measurement data on a selected channel by pressing the **[Monitor]** key. The key's backlight is turned on while monitoring is enabled. The monitor annunciator will also be displayed, and the sample annunciator will flash when monitor measurements are made.

You can view the monitor data for all channels in the scan list, except for computed channels (channels 401 through 420). Monitoring of computed channels is only available while scanning and will only display the reading from the most recent sweep. You can also view monitor data on the DAQM907A digital I/O and totalizer channels even if they are not in the scan list.

Monitor measurements are made repetitively when scanning is idle or between sweeps of a scan. To stop the monitoring mode and return to the Home menu page, press the **[Monitor]** key again on the Monitor menu page.

In the Monitor menu page, press **Display** to select the display mode as shown below:
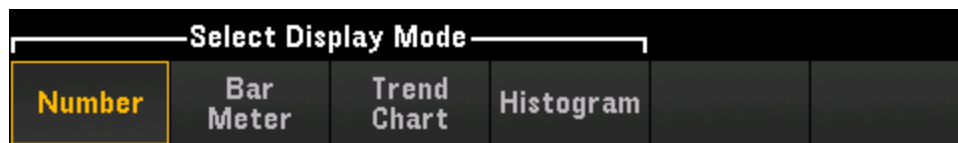
Number

Bar Meter

Trend Chart

Histogram

Number

Displays readings as a number.

Press **Peak** to enable (On) or disable (Off) the measurement of the Minimum, Maximum, and Peak to Peak values acquired within the measurement aperture. When enabled, **Clear Peaks** softkey will display. Press

this softkey to reset the reading of peak values by clearing the accumulated history of peak-to-peak function. This setting is also applicable to Bar Meter.

Press **Statistics** to select Hide or Show the measurement statistics for the monitor channel. Monitor channel statistics are cleared when monitor mode is turned on, when the monitor channel changes, or when the monitor channel's configuration is changed. Press **Clear Mon Data** softkey to clear the statistics, trend chart, and histogram on the monitor channel. This setting is also applicable to Bar Meter, Trend Chart, and Histogram.
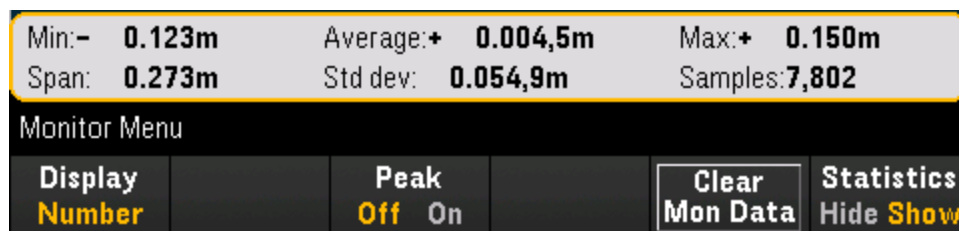
Bar Meter

The bar meter adds a moving bar below the standard Number display.

The **Peak** and **Statistics** softkeys behave as they do in Number display.

The **Scale** softkey specifies how the meter scale is determined.
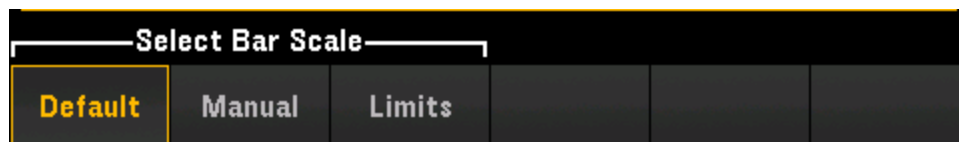
a. **Default** sets the scale to the measurement range.

b. **Manual** allows you to configures the scale either as **High** and **Low** values or as a **Span** around a **Center** value. For example, a scale that goes from a **Low** of –500 Ω to a **High** of 1000 Ω could also be specified as a **Center** of 250 Ω with a **Span** of 1500 Ω.

c. **Limits** set the scale to the alarm limits. Note that this softkey is only available when you configure alarm on the selected channel by pressing the **[Alarm]** key on the front panel.

Trend Chart

In the Continuous measurement mode, the trend chart shows data trends over time. Data is collected and displayed in pixel columns as described below:
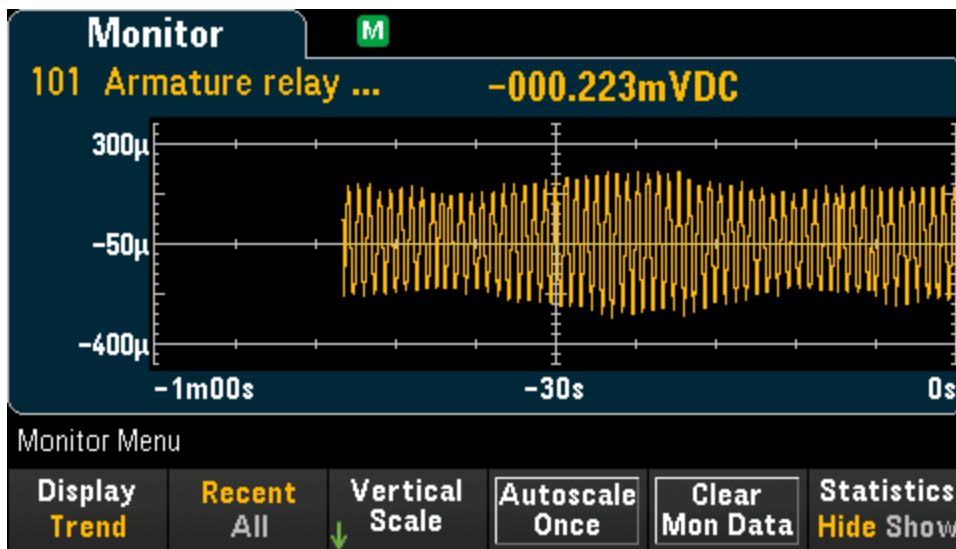
The **Statistics** softkey behave as in **Number** display.

The **Recent/All** softkey specifies whether all measurements (**All**) or only the most recent measurements (**Recent**) are shown on the trend chart. Neither selection clears reading memory. In All mode, the trend chart displays all readings being taken and builds from left to right. After the display is filled, the data becomes compressed on the left side of the display as new data is added on the right side of the display. In Recent mode, the trend chart displays data taken during a specified amount of time.

The **Vertical Scale** softkey specifies how the current vertical scale is determined.
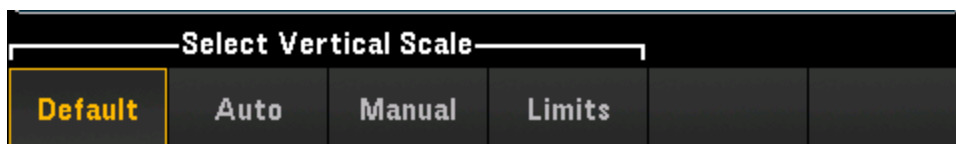
a. **Default** sets the scale to the measurement range.

b. **Auto** automatically adjusts the scale to appropriately fit the line currently shown on the screen.

c. **Manual** allows you to configure the scale either as **High** and **Low** values or as a **Span** around a **Center** value. For example, a scale from a **Low** of 0 V to a **High** of 5 V is equivalent to a **Center** of 2.5 V and a **Span** of 5 V.
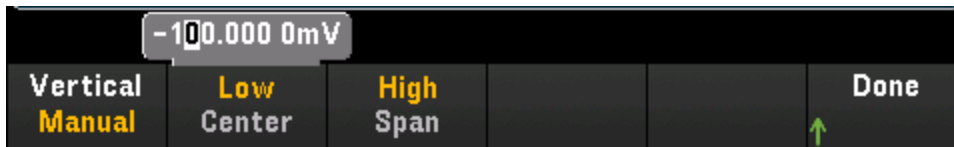
d. **Limits** set the scale to the alarm limits. Note that this softkey is only available when you configure alarm on the selected channel by pressing the **[Alarm]** key on the front panel.

Press **Autoscale Once** softkey to automatically scale the trend chart's vertical axis one time based on the scanned memory readings shown on the screen. This also sets the vertical scale mode to Manual.

Histogram

The histogram shows measurement data as a graphical representation of the distribution of measurement data. Data is grouped in bins represented by vertical bars in the histogram display.
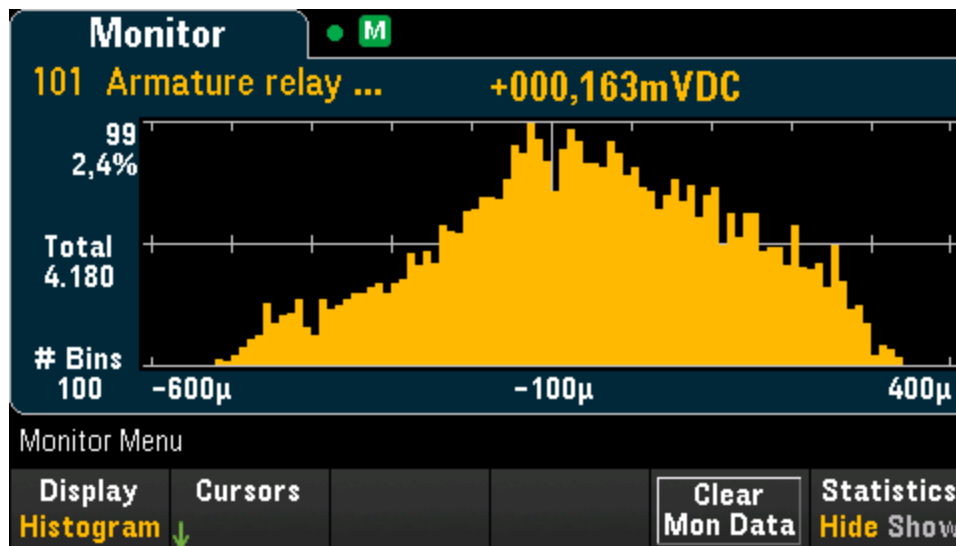
The **Statistics** softkey behave as in **Number** display.

Press the **Cursors** softkey to display the histogram cursors. Cursors in the histogram are specified as bin numbers and display the range of values covered by those bins, the count and the percentage of the total. The total count and percentage of total, as well as the measurement range covered, between the cursor bins, are also displayed.

In the graphic below, cursor B1 (violet vertical lines) is positioned on bin number 30 and cursor B2 (green vertical lines) is positioned on bin number 50 (bin number shown above the B2 softkey). The bin inform-

ation for cursor B1 is shown in the violet box, the bin information for B2 in the green box. For example, the information in the B1 box is in the graphic below is:
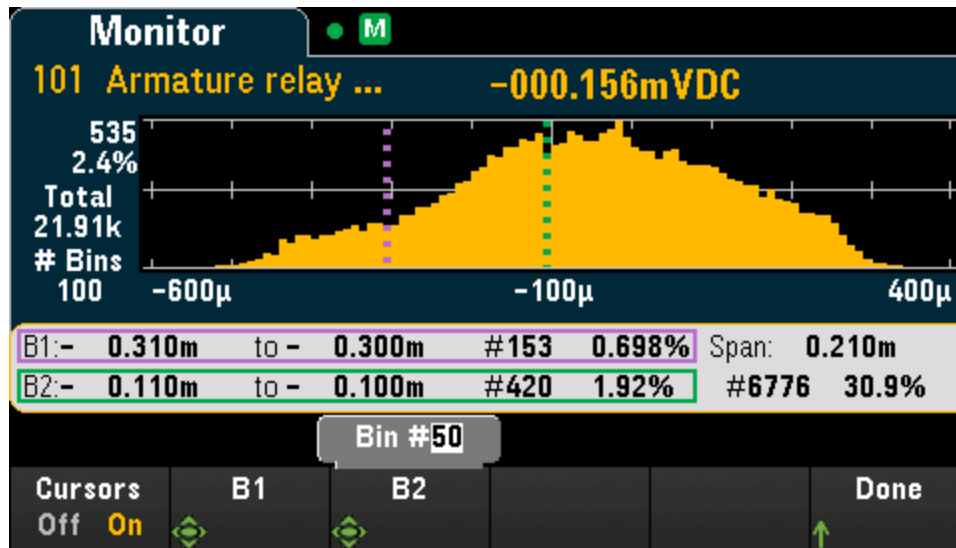
- **0.310m to 0.300m** – Range of DCV measurement values for this bin.
- **#153** – Number of samples in this bin.
- **0.698%** – Percentage of the total number of samples in this bin.

The data between the B1 and B2 cursors, including the data in the B1 and B2 bins, is shown to the right of the violet and green boxes. In the graphic above:

- **Span: 0.210m** – The measurement range covered from B1 to B2.
- **#6776** – The number of samples from B1 to B2.
- **30.9%** – The percentage of the total number of samples from B1 to B2.

[Home] Menu

In the Home menu page, you can see an overview of the current scan operation in a glance: sweep count, trigger source, next sweep time, scan start date and time, the measurement function of the selected channel, and whether data logging to USB drive is enabled. The instrument will return to this Home menu page when monitoring mode is stopped.
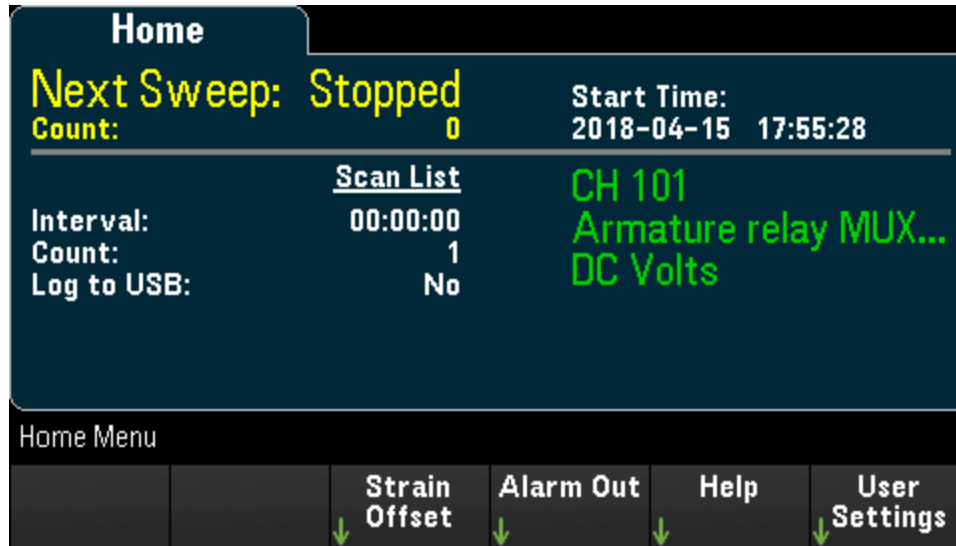
Measures the offset on strain channels

Configures the four alarm output hardware lines

Display instrument information and help topics

Configures various user preferences

Strain Offset

| NOTE | This softkey is only available after you configured the channel for strain measurements by pressing [Channel] > Measure, and select STRAIN with DAQM900A, DAQM901A, DAQM902A, and DAQM908A multiplexer modules. See Strain for details. |

Strain offset is also known as the unstrained value. You can select one or more channels on which you want to measure the offset value. The strain formula will automatically use this offset value when calculating the measurement result.

To configure the strain offset:

1. In **Select** softkey, use the knob or the front panel arrow keys to enable the strain offset measurement on the highlighted channel to perform. Currently selected channel is marked with an "X". Press this softkey again to disable the offset measurement on the highlighted channel. Pressing this softkey will enable the **Measure Now** and **Clear Offsets** softkeys.

2. Press **Select All** to enable the offset measurement on all listed channels. Press this softkey again to disable the offset measurement on all listed channels.

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3. Press **Measure Now** to immediately measures the offset value on the selected channel(s). Offset readings will display on the screen as shown below:

4. Press **Clear Offsets** softkey if you would like to immediately clear the strain offset value to 0 on the selected channel(s).

Alarm Output

Configures the four alarm output hardware lines. Four TTL-compatible alarm outputs are available on the rear panel Ext Trig/Alarms connector. You can use these hardware outputs to trigger external alarm lights, sirens, or send a TTL-compatible pulse to your control system. You can assign an alarm to any configured channel and multiple channels can be assigned to the same alarm number. Each alarm output line represents the logical "OR" of all channels assigned to that alarm number (an alarm on any of the associated channels will pulse the line).
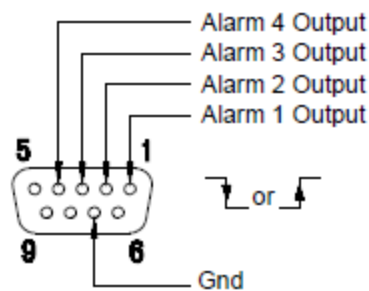
Alarms Connector

Clear - Clears the state of a specified alarm output line (alarms 1 through 4).

Clear All - Clears the state of all four alarm output lines.

Mode - Selects the output mode for all four alarm output lines.

a. **Latch** - The alarm output is asserted when a channel's reading crosses a limit, and remains asserted until you clear it manually, start a new scan, or cycle power.

b. **Track** - The alarm output is asserted when a channel's reading crosses a limit, and remains asserted only while subsequent readings remain outside the limit. When a reading returns within the limits, the output is automatically cleared.

Out Alarm - Configures the level for all four alarm output lines that indicates an alarm, either 0 V (TTL-compatible low) or 3.3 V (TTL-compatible high). Press this softkey to control the slope of the pulse from the alarm output

Help

Displays the instrument information and a list of help topics in the selected local language. See **Use the Built-in Help System** for details.

User Settings

Configures user preferences that control how the user interacts with the instrument. These settings are saved in non-volatile memory and can be saved in a preferences (.prf) file.
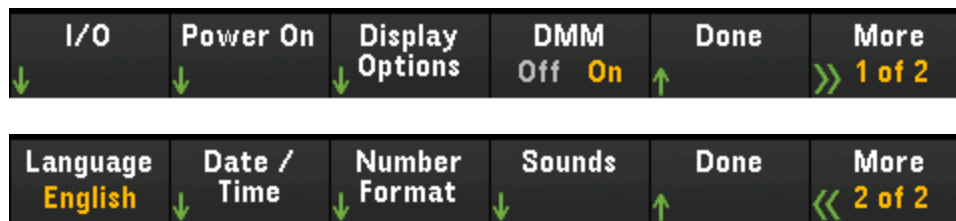
I/O

Power On

Display Options

DMM On/Off

Language

Date/Time

Number Format

Sounds

I/O

Configures the I/O parameters for remote operations over the LAN and USB interfaces.
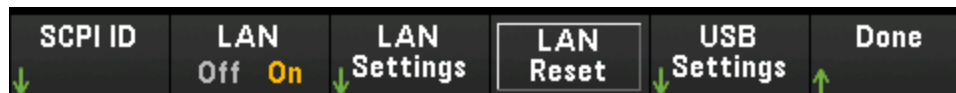
SCPI ID determines the manufacturer and model number returned by identification query (*IDN? command). The serial number and version information are unaffected. Use this setting to avoid changing existing test system code where the manufacturer or model number are verified and to maximize backwards compatibility with the Keysight 34970A and 34972A.

The default settings return "**Keysight Technologies**" followed by the model number "**DAQ970A**". For more information, see the *IDN? and SYSTem:PERSona Subsystem commands in the Keysight DAQ970A Programming Guide.

Important: In order to update the instrument firmware from remote, the model number in the *IDN? response must match the actual instrument model number. If you have changed the instrument's *IDN? response to another instrument, when attempting to update the firmware from remote, you will see this error: The instrument is not supported by this firmware file. To update the firmware, either update using the front panel procedure or, from remote, use SYSTem:PERSona:MODel to set the *IDN? to match the actual model number, update the firmware, and then use SYSTem:PERSona:MODel again to set the *IDN? response to the other model number.

Refer to the links below for the remaining of softkey settings.

- LAN On/Off

- LAN Settings

- LAN Reset

- USB Settings

Power On

Configures the instrument's power-on state and power-on message.

Power On selects the state that is loaded at power-up. This can be either the state when the instrument was powered down with the power switch (**Last**), a user-selected state file (**User Defined**), or the factory default state (**Factory Defaults**).

Power On Message sets a message that is displayed when the instrument powers up and when you press **[Home]** > **Help** >**About**. Use the knob or the front panel arrow keys and **[Select]** key to select the letters. Then press **Done** to exit and save the message. The message will appear as shown below when you turn the instrument on or press **[Home]** > **Help** > **About**.

Display Options

Display Options configures the display.
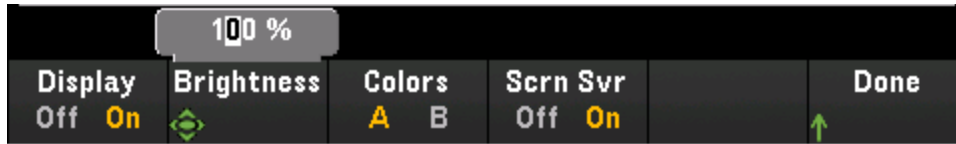
You can enable or disable the display, adjust the brightness (10 to 100%), pick a color scheme, and enable or disable the screen saver. If you turn off the display, press any front panel key to turn it on again. By default, the screen saver increases display life by dimming the display during long periods of inactivity. You may disable this screen saver from the front panel only. The display is enabled when power is cycled, after an instrument reset (*RST), or when you return to local (front panel) operation. Press the [Local] key ([Save Recall] key) to return to the local state.

DMM On/Off

Enables or disables the internal DMM. annunciator will display when internal DMM is disabled.

Language

Selects the local language for front panel use.

All messages, context-sensitive help, and help topics appear in the selected language. The menu softkey labels are not translated.

Date/Time

Sets the date and time of the real-time clock in 24-hour format. The real-time clock does not automatically adjust for time zone changes or daylight savings time. Be sure to set the date and time when you first receive your instrument. Use the knob or the front panel arrow keys to set the year, month, day, hour, and minute.
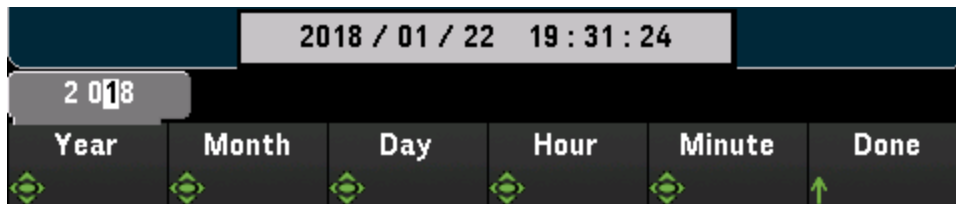
Number Format

Number Format specifies how numbers are displayed on the front panel: 12,345.6 or 12.345,6. Other possibilities also exist. For example, you can use the space as a separator.

Sounds

Enables or disables the tone heard associated when an error is generated from the front panel or remote interface (**Beeper**), or the click heard when keys are pressed (**Key Click**).

[View] Menu

Press **[View]** on the front panel to view the scanned memory readings, alarm queue, error queue, and number of relay cycles during scanning or monitoring mode on the selected channel.

Views scanned memory readings (List, Trend Chart, Histogram, Statistics)

In View menu page, press **Display** to select the display mode as shown below:
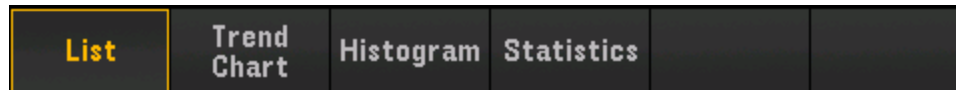
List
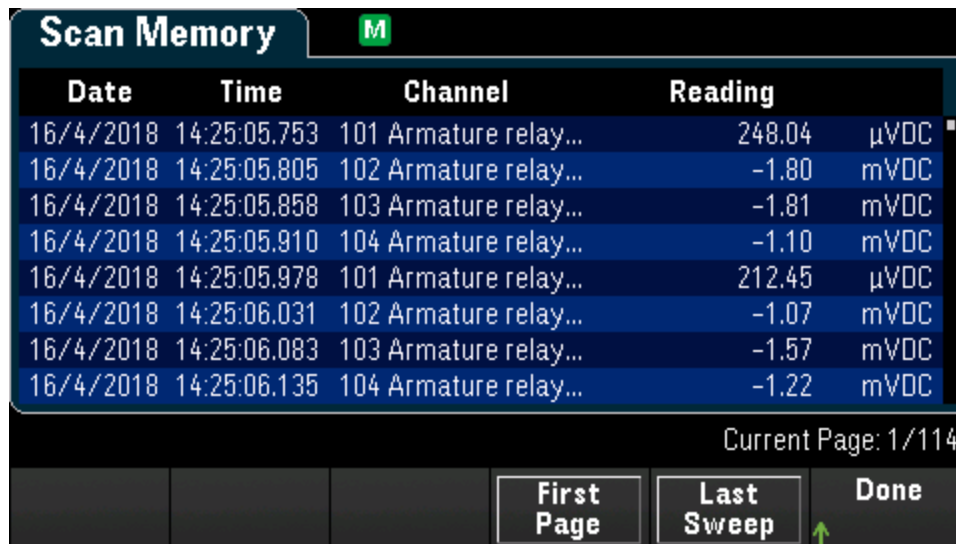
Trend Chart

Histogram

Statistics

List

Displays the scanned memory readings in list format. Press **Browse** to display the readings starting from the beginning of scan (**First Page**), or starting from the most recent sweep (**Last Sweep**). Use the knob or the front panel arrow keys to view the list on subsequent pages; use the right/left arrow keys to move or return the readings to the last/first page.

Trend Chart

Displays the scanned memory readings in trend chart format. Press **Settings** to configure the trend chart. Use the knob or the front panel arrow keys to view the settings on different configured channels. The **Vertical Scale** and **Autoscale Once** softkeys behave as they do in the [Monitor] > Display > Trend Chart display.

Press **Advanced** to display the advanced settings:

Pan - Selects which reading in memory is displayed at the center of the screen. Use the knob or the up/right arrow key to increase the reading number displayed which causes the graph data to move to the left. Use the knob or the down/left arrow key to decrease the reading number displayed which causes the graph data to move to the right.

Press and release an arrow key to move the cursor one display pixel. Hold down an arrow key to move the cursor in 20-pixel increments. The number of readings represented per pixel depends on the zoom percentage.
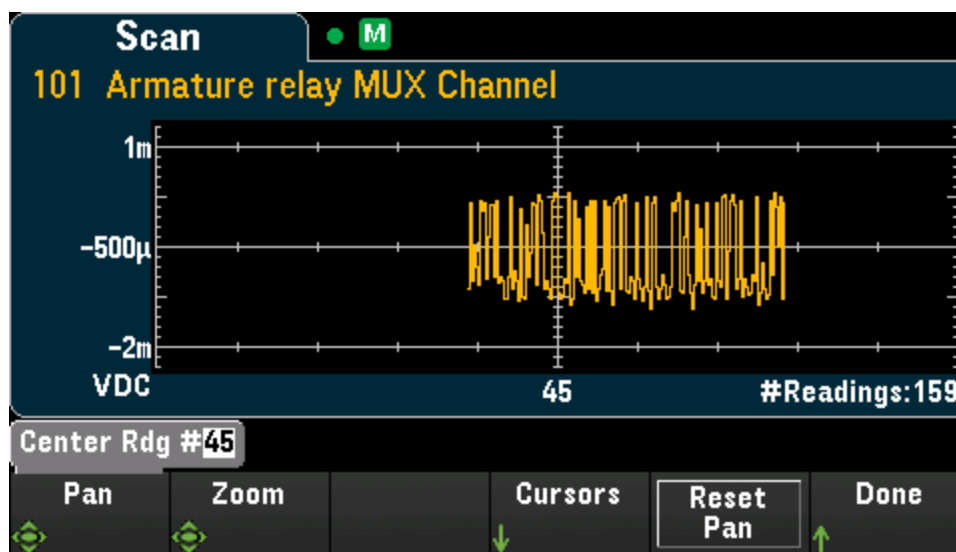
Zoom - Sets the horizontal axis zoom percentage. Press **Zoom** and use the knob or the up/down arrow keys to select the amount of zoom, in percent. 100% is the maximum amount of zoom with a maximum of one reading shown per display pixel column. The display is 400 pixels wide. You can select a zoom percentage of 0.02%, 0.05%, 0.1%, 0.2%, 0.5%, 1%, 2%, 5%, 10%, 20%, 50%, 100%, 200%, 500%, or 1000%.

Tip: Zoom to 1000% to pan one reading at a time. After selecting a reading, you can then decrease the zoom, if necessary, to view the surrounding signal.

Cursors - Display and control X1, X2, Y1, Y2, and tracking cursors (shown as lines) on the trend chart.

X cursors are vertical lines along the sample or time axis. Use the up or right arrow key to move the cursor to the right; the down or left arrow key to move the cursor to the left. Press and release an arrow key to move the cursor one display pixel. Hold down an arrow key to move the cursor in 10 pixel increments. Y cursors are horizontal lines along the measurement (magnitude) axis in units of the selected measurement (DCV or DCI). Use the left and or right arrow keys to select a digit of magnitude displayed above the Y1 or Y2 softkey. You can then use the up or down arrows keys to increment/decrement the digit and move the cursor up or down by that amount. Cursor X1 and Y1 are violet; cursor X2 and Y2 are green.

Press **Cursors** > **Cursors** to display the choices:
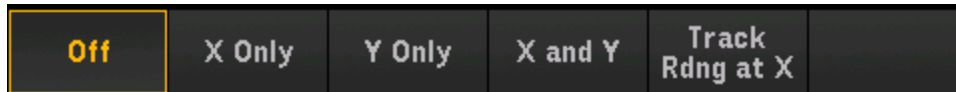
Off – Disables the cursors displayed.

X Only – Displays only the X1 and X2 cursors. In this mode, these softkeys are available:

- **X1** – Use the knob or the front panel arrow keys to control the X1 cursor.
- **X2** – Use the knob or the front panel arrow keys to control the X2 cursor.
- **ΔX Lock** – When **On**, keeps the X cursors a fixed distance apart as either cursor is moved.

Y Only – Displays only the Y1 and Y2 cursors. In this mode, these softkeys are available:

- **Y1** – Use the knob or the front panel arrow keys to control the Y1 cursor.
- **Y2** – Use the knob or the front panel arrow keys to control the Y2 cursor.
- **ΔY Lock** – When **On**, keeps the X cursors a fixed distance apart as either cursor is moved.
- **Place Y*n* on Screen** – Press **Y1** or **Y2** followed by this softkey to set the cursor to a value that puts it into view on the trend chart.

X and Y – Displays the X1, X2, Y1 and Y2 cursors. In this mode, these softkeys are available:

- **X1** – Use the knob or the front panel arrow keys to control the X1 cursor.
- **X2** – Use the knob or the front panel arrow keys to control the X2 cursor.
- **Y1** – Use the knob or the front panel arrow keys to control the Y1 cursor.
- **Y2** – Use the knob or the front panel arrow keys to control the Y2 cursor.

Track Rdng at X – Select two readings, by reading number, using **X1** and **X2** softkeys to display X (time) and Y (magnitude) values for each reading, and the delta X and delta Y values.

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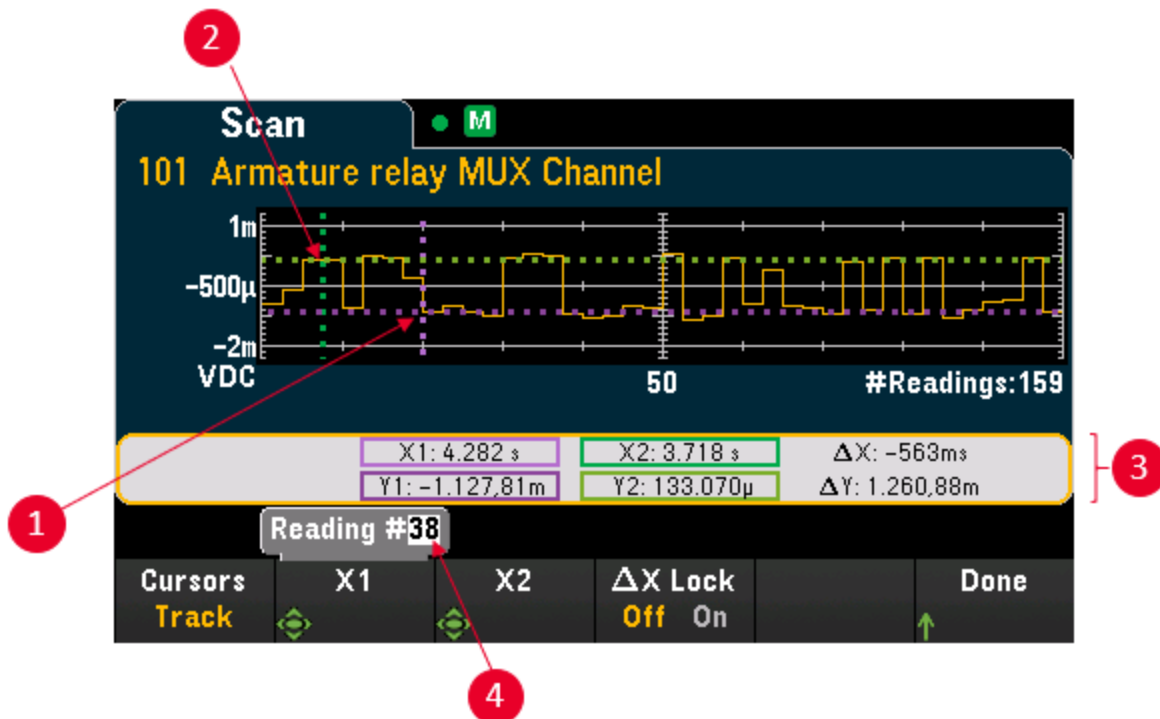
(1) Y1 cursor tracks X1 cursor position.

(2) Y2 cursor tracks X2 cursor position.

(3) Cursor time and amplitude information, ΔX, ΔY.

(4) Press X1 or X2 to display reading number.

These softkeys are available for **Track Rdng at X** mode:

- **X1** - Use the knob or the front panel arrow keys to control the X1 cursor.
- **X2** - Use the knob or the front panel arrow keys to control the X2 cursor.
- **ΔX Lock** - When **On**, keeps the X cursors a fixed distance apart as either cursor is moved.

Tip: To record the X and Y data and the delta X and Y data as a screen shot, take a screen shot of the Web UI, not the front panel screen shot utility.

Press **Reset Pan** to set the pan (center reading) to "0".

Histogram

Displays the scanned memory readings in histogram format. Press **Settings** to configure the histogram. The **Cursors** softkey behave as it does in the [Monitor] > Display > Histogram display. Press **Refresh** to recalculate the histogram, including any new readings.
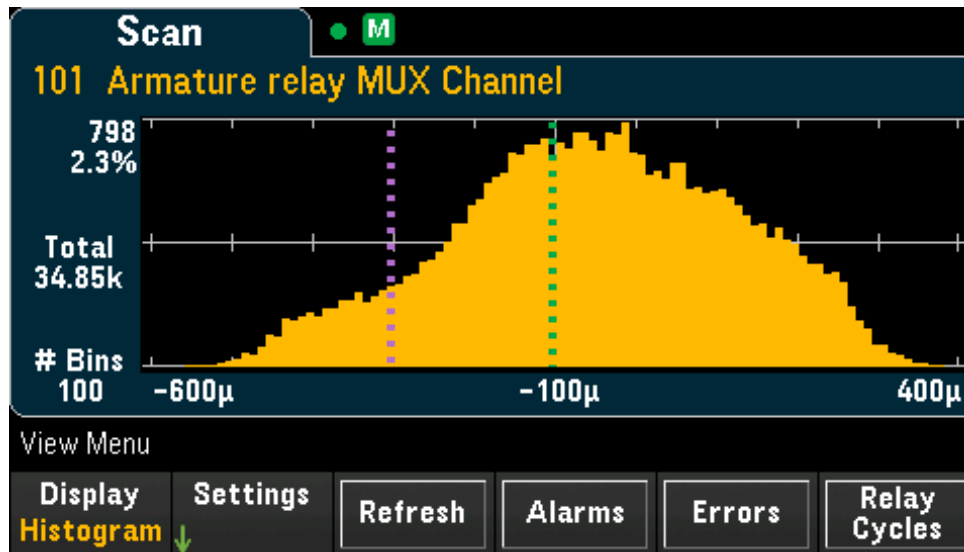
Statistics

Displays the scanned memory readings of a selected channel in statistics format (Maximum, Minimum, Peak to Peak, Average, and Standard Deviation). Toggle between **Statistics** to display the per-channel statistics and **Pk Times** to display the time of occurrence of the per-channel minimum and maximum peak readings.

View alarm queue

In View menu page, press **Alarms** to display the first 20 alarms, including the reading and time stamp, in the alarm queue. You are only able to view this alarm queue when the alarm limit is configured on the selected channel by pressing **[Alarm]** key on the front panel. Alarm annunciator, ALARM H1234L will display as below. In the following alarm queue, it shows that Alarm 1 with Low limit is configured on the channel 102. See Alarm Menu for details.

View error queue

In View menu page, press **Errors** to display up to the 20 errors in the error queue. Error annunciator, ERR is cleared as you read them.

When the front panel Error annunciator (ERR) turns on, one or more command syntax, execution, or hardware errors have been detected. A record of up to 20 errors is saved in the instrument's error queue.

Errors are retrieved in first-in-first-out (FIFO) order. The first error returned is the first error that was saved. Errors are cleared as you read them. When you have read all errors from the queue, the ERR annunciator turns off and the errors are cleared. The instrument beeps once each time an error is generated.

If more than 20 errors have occurred, the last error saved in the queue (the most recent error) is replaced with "Error queue overflow". No additional errors are stored until you remove errors from the queue. If no errors have occurred when you read the error queue, the instrument responds with "No error".

View number of relay cycles

In View menu page, press **Relay Cycles** to display the number of cycles for all relays on the selected module. Each module counts the number of closures on each relay and saves the counts in non-volatile memory on the module. Below image shows the number of cycles for all relays on the DAQM901A multiplexer module.

Relay Cycles	
Channel	**User Cycles**
101 Armature relay MUX Channel	3011
102 Armature relay MUX Channel	2413
103 Armature relay MUX Channel	1123
104 Armature relay MUX Channel	1101
105 Armature relay MUX Channel	1061
106 Armature relay MUX Channel	1047
107 Armature relay MUX Channel	793
108 Armature relay MUX Channel	225

[Channel] Menu Overview

Measurements on Multiplexer Modules

DAQM907A Multifunction Module

Computed Channel

Scanning with External Instruments

Channel Labelling

Measurements on Multiplexer Modules

The Keysight DAQ970A supports many common measurement functions with the multiplexer module. With any multiplexer module installed on the rear panel, press **[Module]** and use the knob or the front panel arrow keys to navigate into the desired multiplexer module.

You can configure the measurement function on the selected channel by pressing **[Channel]** > **Measure**. Selecting **Off** will disable the measurement function in current selected channel. No any measurement function will be displayed in the scan list on the selected channel. Default measurement function will set to DC voltage.

Table below shows the overview of each supported multiplexer module on the measurement function. Click on each link to see the details of each configuration step.

Measurement function	DAQ970A multiplexer module			
	DAQM900A	DAQM901A	DAQM902A	DAQM908A
Temperature - Thermocouple	√	√	√	
Temperature - RTD		√	√	√ [2]
Temperature - Thermistor		√	√	√ [2]
Strain - Bridge	√	√	√	√
Strain - Direct		√	√	√ [2]
DC voltage	√	√	√	√
AC voltage	√	√	√	√
DC current		√ [1]		
AC current		√ [1]		
Resistance	√	√	√	√ [2]
Frequency	√	√	√	√
Period	√	√	√	√
Diode		√	√	√
Capacitance		√	√	√

Notes:
[1] Channel 21 and 22 only.
[2] 2-wire measurements only. 4-wire measurements are not supported on DAQM908A multiplexer module.

Temperature

This section describes how to configure the selected channel for temperature measurements from the front panel. Temperature measurements require a temperature transducer probe. The supported probes are as below:

Thermocouple

2-wire or 4-wire thermistor

2-wire or 4-wire RTD

Thermocouple

1. Connect a thermocouple to the module's screw terminals.
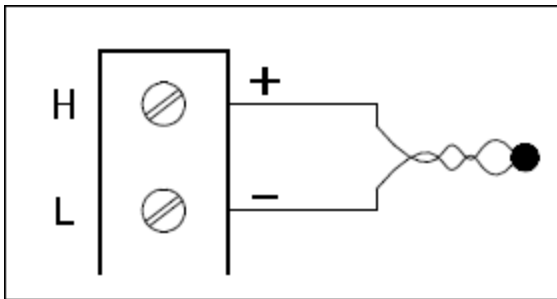
2. Press **[Channel]** > **Measure**, and select **TEMP** from the selection menu.

3. Press the **Units** softkey to specify the temperature measurement units as **°C** (Celsius), **°F** (Fahrenheit), or **K** (Kelvin). You can mix temperature units on different channels within the instrument and on the same module.

4. Press **Sensor Settings** > **Sensor**, specify the type of transducer probe used as **TCouple**, and press **Type** softkey to select the type of thermocouple. Supported types are J (default), K, E, T, N, R, B, and S.

5. Press **Integrate Settings** softkey to select whether the measurement integration time will be specified in terms of Number of Power Line Cycles (**NPLC**) or directly in seconds (**Time**). Only 1, 2, 10, 20, 100, and 200 PLC provide normal mode (line frequency noise) rejection. Selecting 100 PLC provides the best noise rejection and resolution, but the slowest measurements.

NPLC - Sets the integration time as 0.02, 0.06, 0.2, 1, 2, 10, 20, 100, and 200 Power Line Cycles (PLC). Only 1 PLC and longer times provide normal mode (line frequency noise) rejection. Selecting 100 or 200 PLC provides the best noise rejection and resolution.

Time - Directly sets the integration time in seconds.

Advanced settings

Press **Advanced** to configure the advanced settings for the measurement.

Auto Zero - Autozero provides the most accurate measurements, but requires additional measurement time to perform the zero measurement. With autozero enabled (**On**), the instrument internally measures the offset following each measurement. It then subtracts that measurement from the preceding reading. This prevents offset voltages present on the instrument's input circuitry from affecting measurement accuracy. With autozero disabled (**Off**), the instrument measures the offset once and subtracts the offset from all subsequent measurements. The instrument takes a new offset measurement each time you change the function, range, or integration time. (There is no autozero setting for 4-wire measurements).

Reference - Thermocouple measurements require a reference junction temperature. You can input a known fixed reference junction temperature (typically used for external reference junctions), use the internally measured temperature on the module as the reference junction temperature, or use the external thermistor or RTD measurement. Selects the reference junction source as **Internal**, **External**, or **Fixed**.

Open Check - Enables (On) or disables (Off) the thermocouple check feature to verify that the thermocouples are properly connected for measurements. When enabled, the instrument performs a resistance measurement with each temperature to check for an open circuit. If one is detected, the result will be shown as +Overload. If this check is not performed, measurement of an open circuit can produce a voltage reading near zero resulting in an invalid temperature reading.

Delay - Selects whether the delay between channels in the scan list will be automatically or manually selected. By selecting **Auto**, instrument will automatically determine the channel delay based on measurement function, range, integration time, and AC filter setting. By selecting **Time**, the specified delay (time in seconds) is inserted between the relay closure and the actual measurement on each channel, in addition to any delay that will implicitly occur due to relay settling time.

2-wire and 4-wire thermistor

[Channel] Menu Overview

1. Connect a thermistor to the module's screw terminals.

   2-wire thermistor:
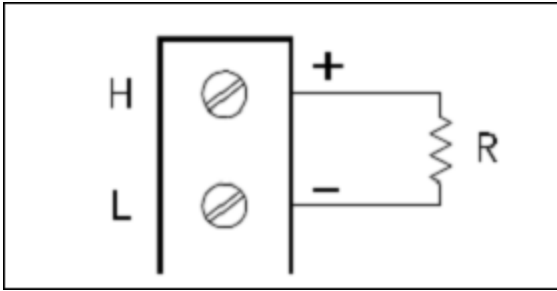
   4-wire thermistor:
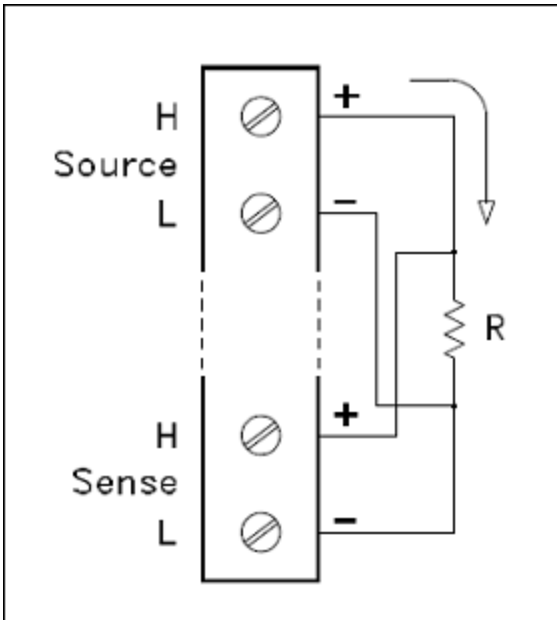
2. Press **[Channel]** > **Measure**, and select **TEMP** from the selection menu.

3. Press the **Units** softkey to specify the temperature measurement units as **°C** (Celsius), **°F** (Fahrenheit), or **K** (Kelvin). You can mix temperature units on different channels within the instrument and on the same module.

4. Press **Sensor Settings** > **Sensor**, specify the type of transducer probe used as **2-wire** or **4-wire Therm**, and press **Type** softkey to select the type of thermistor. Supported types are 2.2K, 5K (default), and 10K.

Keysight DAQ970A User's Guide

5. Press **Use as ref** to enable (**On**) or disable (**Off**) the currently selected channel to be used as the reference channel for subsequent thermocouple measurements that specify an external reference source.

6. Press **Integrate Settings** softkey to select whether the measurement integration time will be specified in terms of Number of Power Line Cycles (**NPLC**) or directly in seconds (**Time**). Only 1, 2, 10, 20, 100, and 200 PLC provide normal mode (line frequency noise) rejection. Selecting 100 PLC provides the best noise rejection and resolution, but the slowest measurements.

NPLC - Sets the integration time as 0.02, 0.06, 0.2, 1, 2, 10, 20, 100, and 200 Power Line Cycles (PLC). Only 1 PLC and longer times provide normal mode (line frequency noise) rejection. Selecting 100 or 200 PLC provides the best noise rejection and resolution.

Time - Directly sets the integration time in seconds.

Advanced settings

Press **Advanced** to configure the advanced settings for the measurement.

Auto Zero - Autozero provides the most accurate measurements, but requires additional measurement time to perform the zero measurement. With autozero enabled (**On**), the instrument internally measures the offset following each measurement. It then subtracts that measurement from the preceding reading. This prevents offset voltages present on the instrument's input circuitry from affecting measurement accuracy. With autozero disabled (**Off**), the instrument measures the offset once and subtracts the offset from all subsequent measurements. The instrument takes a new offset measurement each time you change the function, range, or integration time. (There is no autozero setting for 4-wire measurements).

Low Power - Selects the low-power resistance measurement. This sources less current resulting in lower power dissipation, and less self-heating, in the resistance under test. Typically, this is about 1/10th the current sourced for the standard resistance measurements. The approximate current sourced for each measurement range is shown at the bottom of the resistance range softkeys, for example: (~ 1 mA).

Delay - Selects whether the delay between channels in the scan list will be automatically or manually selected. By selecting **Auto**, instrument will automatically determine the channel delay based on measurement function, range, integration time, and AC filter setting. By selecting **Time**, the specified delay (time in seconds) is inserted between the relay closure and the actual measurement on each channel, in addition to any delay that will implicitly occur due to relay settling time.

2-wire and 4-wire RTD

1. Connect an RTD to the module's screw terminals.

   2-wire RTD:

[Channel] Menu Overview
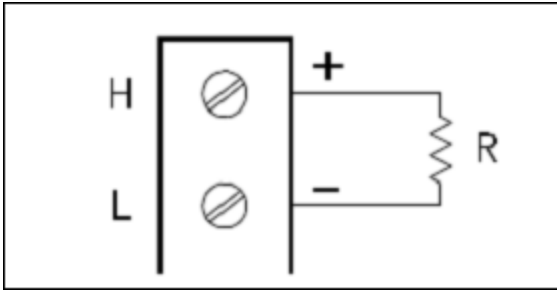
4-wire RTD:
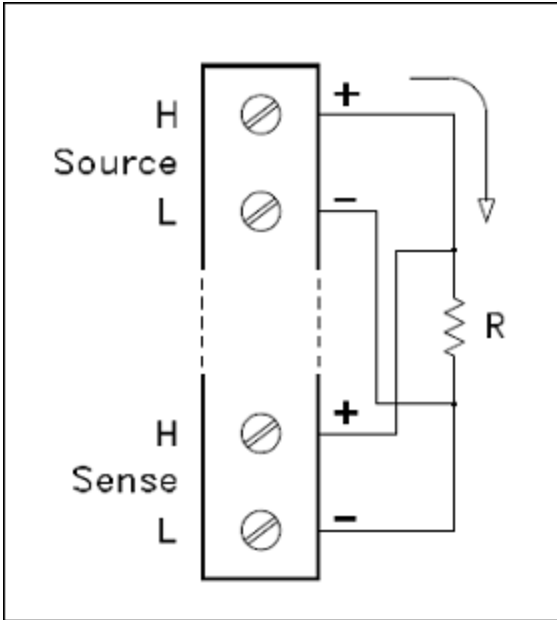
2. Press **[Channel]** > **Measure**, and select **TEMP** from the selection menu.

3. Press the **Units** softkey to specify the temperature measurement units as **°C** (Celsius), **°F** (Fahrenheit), or **K** (Kelvin). You can mix temperature units on different channels within the instrument and on the same module.

4. Press **Sensor Settings** > **Sensor**, specify the type of transducer probe used as **2-wire** or **4-wire RTD**. Then, selects the nominal resistance, R_0, as **PT100** (100 Ω) or **PT1000** (1000 Ω). R_0 is the nominal resistance of a RTD at 0 °C.

5. Press **Use as ref** to enable (**On**) or disable (**Off**) the currently selected channel to be used as the reference channel for subsequent thermocouple measurements that specify an external reference source.

6. Press **Integrate Settings** softkey to select whether the measurement integration time will be specified in terms of Number of Power Line Cycles (**NPLC**) or directly in seconds (**Time**). Only 1, 2, 10, 20, 100, and 200 PLC provide normal mode (line frequency noise) rejection. Selecting 100 PLC provides the best noise rejection and resolution, but the slowest measurements..

NPLC - Sets the integration time as 0.02, 0.06, 0.2, 1, 2, 10, 20, 100, and 200 Power Line Cycles (PLC). Only 1 PLC and longer times provide normal mode (line frequency noise) rejection. Selecting 100 or 200 PLC provides the best noise rejection and resolution.

Time - Directly sets the integration time in seconds.

Advanced settings

Press **Advanced** to configure the advanced settings for the measurement.

Auto Zero - Autozero provides the most accurate measurements, but requires additional measurement time to perform the zero measurement. With autozero enabled (**On**), the instrument internally measures the offset following each measurement. It then subtracts that measurement from the preceding reading. This prevents offset voltages present on the instrument's input circuitry from affecting measurement accuracy. With autozero disabled (**Off**), the instrument measures the offset once and subtracts the offset from all subsequent measurements. The instrument takes a new offset measurement each time you change the function, range, or integration time. (There is no autozero setting for 4-wire measurements).

Offset Compensation - Offset compensation removes the effects of small DC voltages in the circuit being measured. The technique involves taking the difference between two resistance measurements, one with the current source set to the normal value, and one with the current source set to a lower value.

Low Power - Selects the low-power resistance measurement. This sources less current resulting in lower power dissipation, and less self-heating, in the resistance under test. Typically, this is about 1/10th the current sourced for the standard resistance measurements. The approximate current sourced for each measurement range is shown at the bottom of the resistance range softkeys, for example: (~ 1 mA).

Delay - Selects whether the delay between channels in the scan list will be automatically or manually selected. By selecting **Auto**, instrument will automatically determine the channel delay based on measurement function, range, integration time, and AC filter setting. By selecting **Time**, the specified delay (time in seconds) is inserted between the relay closure and the actual measurement on each channel, in addition to any delay that will implicitly occur due to relay settling time.

[Channel] Menu Overview

# Strain

This section describes how to configure the selected channel for strain measurements from the front panel. When a force is applied to a body, the body deforms. The deformation per unit length is called strain (ε). Strain may be either tensile (+) or compressive (–).

The DAQ970A supports two types of strain measurements:

Bridge configuration

Direct resistive method

Once you have configured strain measurement function in all strain channels, press **[Home]** > **Strain Offset** to measure or specify the unstrained offset that will be subtracted from strain measurements before the strain conversion is performed.

Strain offset

Bridge Configuration

Full and half bridge in bending arrangement

Full and half bridge in Poisson arrangement

Full bridge in bending Poisson arrangement

Quarter bridge arrangement

Full and half bridge in bending arrangement

This section describes how to configure the selected channel for full and half bending bridge strain gage measurements from the front panel.

1. Connect bridge configuration source to the module's screw terminals.

Full bending bridge:

Half bending bridge:

2. Press **[Channel]** > **Measure**, and select **STRAIN** from the selection menu.

3. Press **Range** and use the knob or the front panel arrow keys to specify the measurement range. **Auto** (autorange) automatically selects the range for the measurement based on the input. Autoranging is convenient, but it results in slower measurements than using a manual range. Autoranging goes up a range at 120% of the present range, and down a range below 10% of the present range.

4. Press **Sense Settings** > **Sense**, specify the strain measurement method as full and half bridge in bend-ing arrangements.

5. Press **Gage Settings**, and use the knob or the front panel arrow keys to specify various strain gage settings.

Gage Factor - Gage factor is the ratio of the fractional change in resistance to the fractional change in length (strain) along the axis of the gage. The larger the value, the more sensitive strain gage. Gage factor is a dimensionless quantity. The typical value is approximately 2.

Strain bridge conversions require the voltage of the external bridge excitation. For this voltage, you can dedicate a multiplexer channel to measure the excitation voltage, or can specify a known fixed voltage value. Fixed (**Fix**) - The fixed value specified by the Excitation Voltage softkey will be used for the strain conversion. External (**Ext**) - DCV measurements on the enabled reference channel will be used for subsequent strain bridge measurements that specify an external excitation voltage source. Note that the external DCV reference channel must be a lower-numbered channel than the strain channel.

Excitation Voltage - Use the knob or the front panel arrow keys to specify the fixed excitation voltage applied to the bridge by an external voltage source. This value will be used to convert strain bridge measurements on the selected channel.

6. Press **Integrate Settings** softkey to select whether the measurement integration time will be specified in terms of Number of Power Line Cycles (**NPLC**) or directly in seconds (**Time**). Only 1, 2, 10, 20, 100, and 200 PLC provide normal mode (line frequency noise) rejection. Selecting 100 PLC provides the best noise rejection and resolution, but the slowest measurements..

NPLC - Sets the integration time as 0.02, 0.06, 0.2, 1, 2, 10, 20, 100, and 200 Power Line Cycles (PLC). Only 1 PLC and longer times provide normal mode (line frequency noise) rejection. Selecting 100 or 200 PLC provides the best noise rejection and resolution.

Time - Directly sets the integration time in seconds.

Advanced settings

Press **Advanced** to configure the advanced settings for the measurement.

Auto Zero - Autozero provides the most accurate measurements, but requires additional measurement time to perform the zero measurement. With autozero enabled (**On**), the instrument internally measures the offset following each measurement. It then subtracts that measurement from the preceding reading.

This prevents offset voltages present on the instrument's input circuitry from affecting measurement accuracy. With autozero disabled (**Off**), the instrument measures the offset once and subtracts the offset from all subsequent measurements. The instrument takes a new offset measurement each time you change the function, range, or integration time. (There is no autozero setting for 4-wire measurements).

Delay - Selects whether the delay between channels in the scan list will be automatically or manually selected. By selecting **Auto**, instrument will automatically determine the channel delay based on measurement function, range, integration time, and AC filter setting. By selecting **Time**, the specified delay (time in seconds) is inserted between the relay closure and the actual measurement on each channel, in addition to any delay that will implicitly occur due to relay settling time.
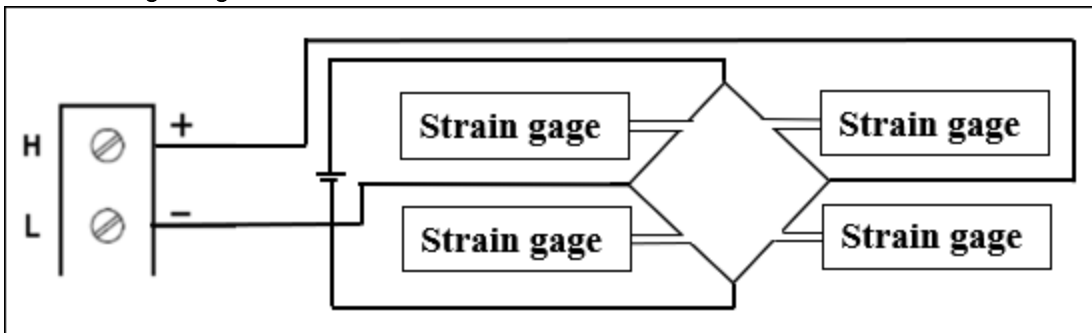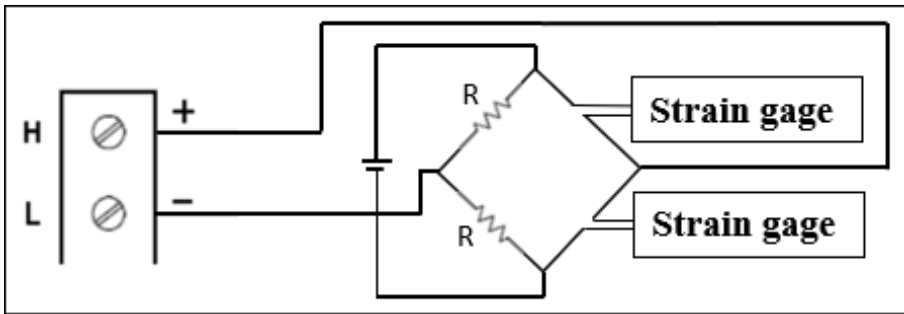
Full and half bridge in Poisson arrangement

This section describes how to configure the selected channel for full and half Poisson bridge strain gage measurements from the front panel.

1. Connect bridge configuration source to the module's screw terminals.

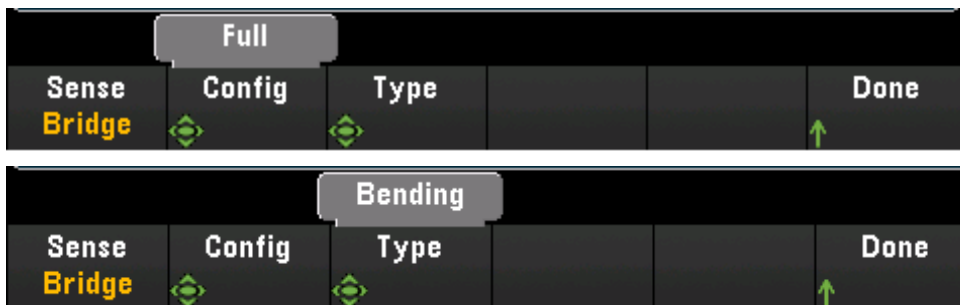Full bending bridge:

Half bending bridge:

2. Press **[Channel]** > **Measure**, and select **STRAIN** from the selection menu.

3. Press **Range** and use the knob or the front panel arrow keys to specify the measurement range. **Auto** (autorange) automatically selects the range for the measurement based on the input. Autoranging is convenient, but it results in slower measurements than using a manual range. Autoranging goes up a range at 120% of the present range, and down a range below 10% of the present range.
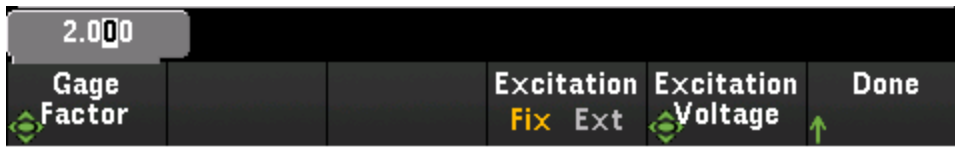

4. Press **Sense Settings** > **Sense**, specify the strain measurement method as full and half bridge in Poisson arrangements.

5. Press **Gage Settings**, and use the knob or the front panel arrow keys to specify various strain gage settings.

Gage Factor - Gage factor is the ratio of the fractional change in resistance to the fractional change in length (strain) along the axis of the gage. The larger the value, the more sensitive strain gage. Gage factor is a dimensionless quantity. The typical value is approximately 2.

Poisson Ratio - Specifies the Poisson ratio of the strain gage. Poisson ratio is defined as the negative ratio of the strain in the transverse direction to the strain in the longitudinal direction.

Strain bridge conversions require the voltage of the external bridge excitation. For this voltage, you can dedicate a multiplexer channel to measure the excitation voltage, or can specify a known fixed voltage value. Fixed (**Fix**) - The fixed value specified by the Excitation Voltage softkey will be used for the strain conversion. External (**Ext**) - DCV measurements on the enabled reference channel will be used for subsequent strain bridge measurements that specify an external excitation voltage source. Note that the external DCV reference channel must be a lower-numbered channel than the strain channel.

Excitation Voltage - Use the knob or the front panel arrow keys to specify the fixed excitation voltage applied to the bridge by an external voltage source. This value will be used to convert strain bridge measurements on the selected channel.

6. Press **Integrate Settings** softkey to select whether the measurement integration time will be specified in terms of Number of Power Line Cycles (**NPLC**) or directly in seconds (**Time**). Only 1, 2, 10, 20, 100, and 200 PLC provide normal mode (line frequency noise) rejection. Selecting 100 PLC provides the best noise rejection and resolution, but the slowest measurements..

NPLC - Sets the integration time as 0.02, 0.06, 0.2, 1, 2, 10, 20, 100, and 200 Power Line Cycles (PLC). Only 1 PLC and longer times provide normal mode (line frequency noise) rejection. Selecting 100 or 200 PLC provides the best noise rejection and resolution.

Time - Directly sets the integration time in seconds.

Advanced settings

Press **Advanced** to configure the advanced settings for the measurement.

Auto Zero - Autozero provides the most accurate measurements, but requires additional measurement time to perform the zero measurement. With autozero enabled (**On**), the instrument internally measures the offset following each measurement. It then subtracts that measurement from the preceding reading. This prevents offset voltages present on the instrument's input circuitry from affecting measurement accuracy. With autozero disabled (**Off**), the instrument measures the offset once and subtracts the offset from all subsequent measurements. The instrument takes a new offset measurement each time you change the function, range, or integration time. (There is no autozero setting for 4-wire measurements).
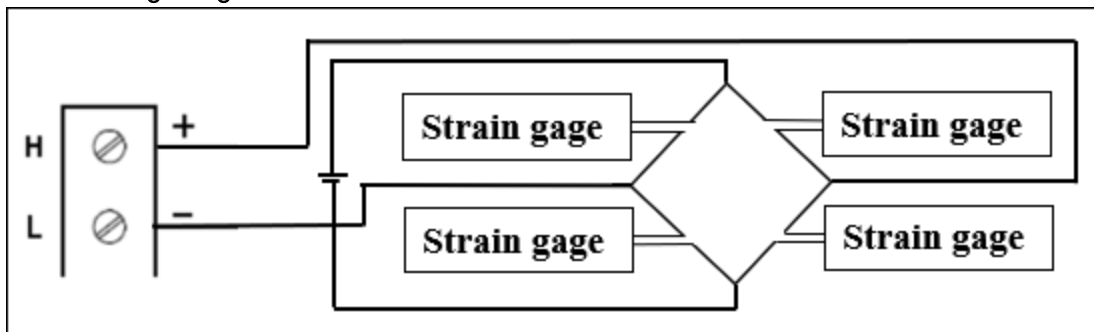
Delay - Selects whether the delay between channels in the scan list will be automatically or manually selected. By selecting **Auto**, instrument will automatically determine the channel delay based on measurement function, range, integration time, and AC filter setting. By selecting **Time**, the specified delay (time in seconds) is inserted between the relay closure and the actual measurement on each channel, in addition to any delay that will implicitly occur due to relay settling time.
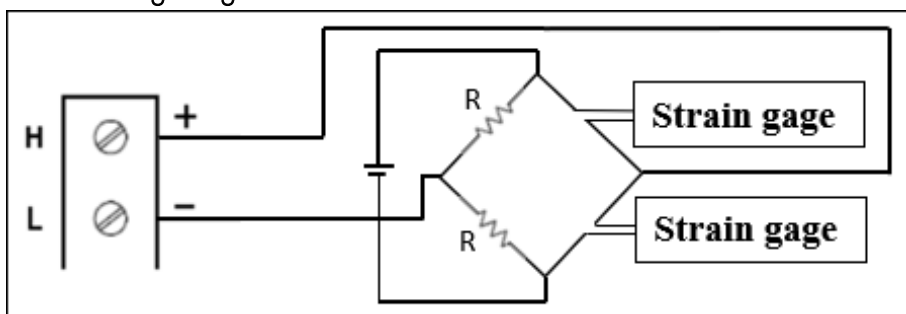
Full bridge in bending Poisson arrangement

This section describes how to configure the selected channel for full bending Poisson bridge strain gage measurements from the front panel.

1. Connect bridge configuration source to the module's screw terminals.

    Full bending bridge:

2. Press **[Channel]** > **Measure**, and select **STRAIN** from the selection menu.
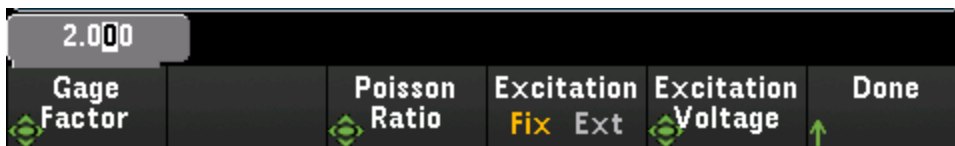

3. Press **Range** and use the knob or the front panel arrow keys to specify the measurement range. **Auto** (autorange) automatically selects the range for the measurement based on the input. Autoranging is convenient, but it results in slower measurements than using a manual range. Autoranging goes up a range at 120% of the present range, and down a range below 10% of the present range.

4. Press **Sense Settings** > **Sense**, specify the strain measurement method as full bridge in bending Poisson arrangement.

5. Press **Gage Settings**, and use the knob or the front panel arrow keys to specify various strain gage settings.

Gage Factor - Gage factor is the ratio of the fractional change in resistance to the fractional change in length (strain) along the axis of the gage. The larger the value, the more sensitive strain gage. Gage factor is a dimensionless quantity. The typical value is approximately 2.

Poisson Ratio - Specifies the Poisson ratio of the strain gage. Poisson ratio is defined as the negative ratio of the strain in the transverse direction to the strain in the longitudinal direction.

Strain bridge conversions require the voltage of the external bridge excitation. For this voltage, you can dedicate a multiplexer channel to measure the excitation voltage, or can specify a known fixed voltage value. Fixed (**Fix**) - The fixed value specified by the Excitation Voltage softkey will be used for the strain conversion. External (**Ext**) - DCV measurements on the enabled reference channel will be used for subsequent strain bridge measurements that specify an external excitation voltage source. Note that the external DCV reference channel must be a lower-numbered channel than the strain channel.

Excitation Voltage - Use the knob or the front panel arrow keys to specify the fixed excitation voltage applied to the bridge by an external voltage source. This value will be used to convert strain bridge measurements on the selected channel.

6. Press **Integrate Settings** softkey to select whether the measurement integration time will be specified in terms of Number of Power Line Cycles (**NPLC**) or directly in seconds (**Time**). Only 1, 2, 10, 20, 100, and 200 PLC provide normal mode (line frequency noise) rejection. Selecting 100 PLC provides the best noise rejection and resolution, but the slowest measurements..

NPLC - Sets the integration time as 0.02, 0.06, 0.2, 1, 2, 10, 20, 100, and 200 Power Line Cycles (PLC). Only 1 PLC and longer times provide normal mode (line frequency noise) rejection. Selecting 100 or 200 PLC provides the best noise rejection and resolution.

Time - Directly sets the integration time in seconds.

Advanced settings

Press **Advanced** to configure the advanced settings for the measurement.

[Channel] Menu Overview

Auto Zero - Autozero provides the most accurate measurements, but requires additional measurement time to perform the zero measurement. With autozero enabled (**On**), the instrument internally measures the offset following each measurement. It then subtracts that measurement from the preceding reading. This prevents offset voltages present on the instrument's input circuitry from affecting measurement accuracy. With autozero disabled (**Off**), the instrument measures the offset once and subtracts the offset from all subsequent measurements. The instrument takes a new offset measurement each time you change the function, range, or integration time. (There is no autozero setting for 4-wire measurements).
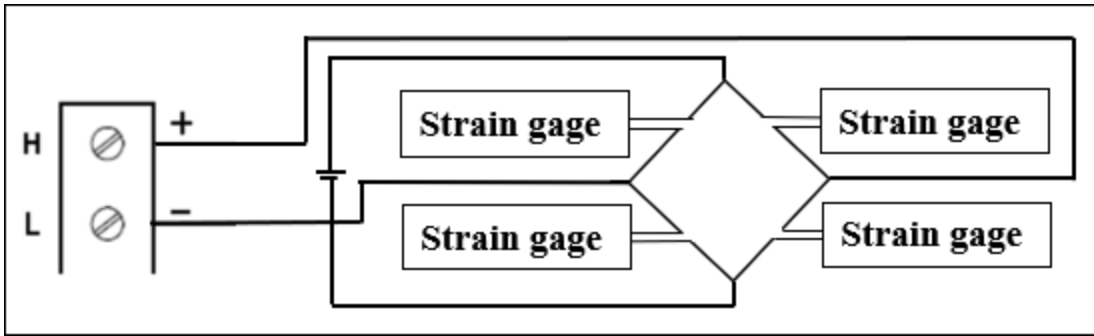
Delay - Selects whether the delay between channels in the scan list will be automatically or manually selected. By selecting **Auto**, instrument will automatically determine the channel delay based on measurement function, range, integration time, and AC filter setting. By selecting **Time**, the specified delay (time in seconds) is inserted between the relay closure and the actual measurement on each channel, in addition to any delay that will implicitly occur due to relay settling time.

Quarter bridge arrangement

This section describes how to configure the selected channel for quarter bridge strain gage measurements from the front panel.

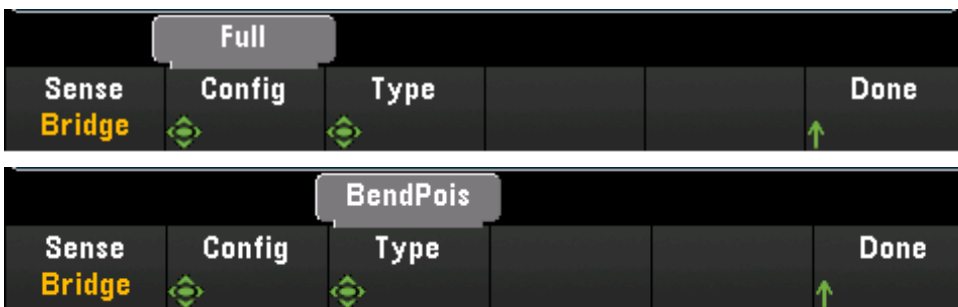1. Connect bridge configuration source to the module's screw terminals.

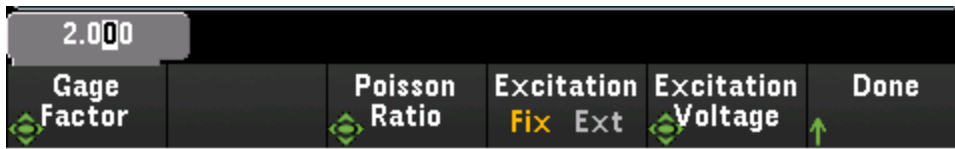2. Press **[Channel]** > **Measure**, and select **STRAIN** from the selection menu.

3. Press **Range** and use the knob or the front panel arrow keys to specify the measurement range. **Auto** (autorange) automatically selects the range for the measurement based on the input. Autoranging is convenient, but it results in slower measurements than using a manual range. Autoranging goes up a range at 120% of the present range, and down a range below 10% of the present range.

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4. Press **Sense Settings** > **Sense**, specify the strain measurement method as quarter bridge arrangement.

5. Press **Gage Settings**, and use the knob or the front panel arrow keys to specify various strain gage settings.

Gage Factor - Gage factor is the ratio of the fractional change in resistance to the fractional change in length (strain) along the axis of the gage. The larger the value, the more sensitive strain gage. Gage factor is a dimensionless quantity. The typical value is approximately 2.

Strain bridge conversions require the voltage of the external bridge excitation. For this voltage, you can dedicate a multiplexer channel to measure the excitation voltage, or can specify a known fixed voltage value. Fixed (**Fix**) – The fixed value specified by the Excitation Voltage softkey will be used for the strain conversion. External (**Ext**) – DCV measurements on the enabled reference channel will be used for subsequent strain bridge measurements that specify an external excitation voltage source. Note that the external DCV reference channel must be a lower-numbered channel than the strain channel.

Excitation Voltage - Use the knob or the front panel arrow keys to specify the fixed excitation voltage applied to the bridge by an external voltage source. This value will be used to convert strain bridge measurements on the selected channel.

6. Press **Integrate Settings** softkey to select whether the measurement integration time will be specified in terms of Number of Power Line Cycles (**NPLC**) or directly in seconds (**Time**). Only 1, 2, 10, 20, 100, and 200 PLC provide normal mode (line frequency noise) rejection. Selecting 100 PLC provides the best noise rejection and resolution, but the slowest measurements..

NPLC - Sets the integration time as 0.02, 0.06, 0.2, 1, 2, 10, 20, 100, and 200 Power Line Cycles (PLC). Only 1 PLC and longer times provide normal mode (line frequency noise) rejection. Selecting 100 or 200 PLC provides the best noise rejection and resolution.

Time - Directly sets the integration time in seconds.

Advanced settings

[Channel] Menu Overview

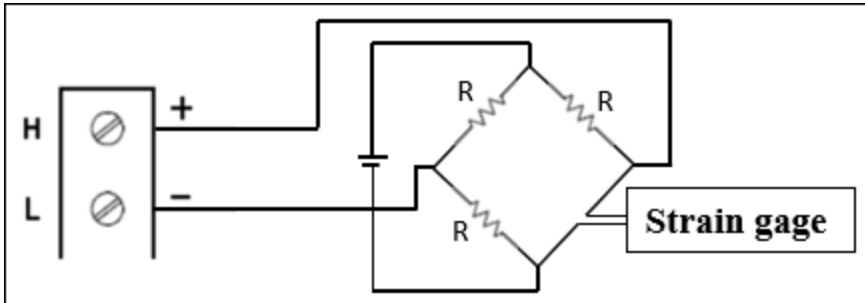Press **Advanced** to configure the advanced settings for the measurement.

Auto Zero - Autozero provides the most accurate measurements, but requires additional measurement time to perform the zero measurement. With autozero enabled (**On**), the instrument internally measures the offset following each measurement. It then subtracts that measurement from the preceding reading. This prevents offset voltages present on the instrument's input circuitry from affecting measurement accuracy. With autozero disabled (**Off**), the instrument measures the offset once and subtracts the offset from all subsequent measurements. The instrument takes a new offset measurement each time you change the function, range, or integration time. (There is no autozero setting for 4-wire measurements).

Delay - Selects whether the delay between channels in the scan list will be automatically or manually selected. By selecting **Auto**, instrument will automatically determine the channel delay based on measurement function, range, integration time, and AC filter setting. By selecting **Time**, the specified delay (time in seconds) is inserted between the relay closure and the actual measurement on each channel, in addition to any delay that will implicitly occur due to relay settling time.

Direct resistive method

This section describes how to configure the selected channel for direct 2-wire and 4-wire strain gage measurements from the front panel. The measurement configurations for 2-wire and 4-wire direct resistive are same, below descriptions explained by using 2-wire resistance measurements.

1. Connect direct resistive source to the module's screw terminals.

2-wire direct strain:
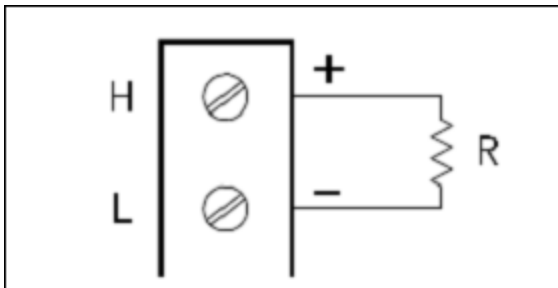
4-wire direct strain:
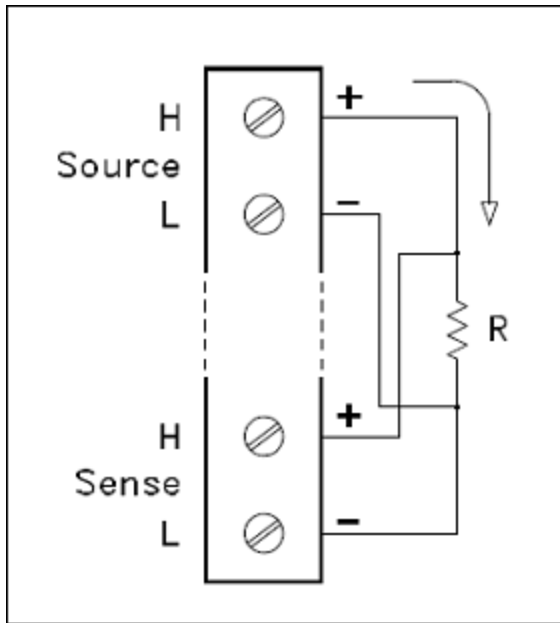
2. Press **[Channel]** > **Measure**, and select **STRAIN** from the selection menu.

3. Press **Sense Settings** > **Sense**, specify the strain measurement method as direct 2-wire or 4-wire.

4. Press **Gage Settings**, and use the knob or the front panel arrow keys to specify various strain gage settings.
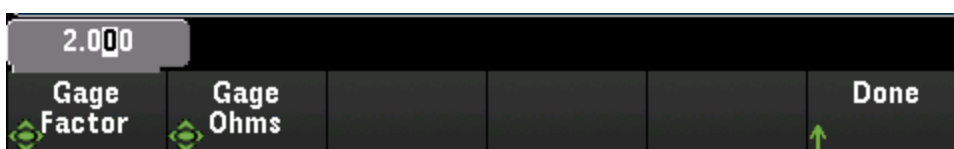
Gage Factor - Gage factor is the ratio of the fractional change in resistance to the fractional change in length (strain) along the axis of the gage. The larger the value, the more sensitive strain gage. Gage factor is a dimensionless quantity. The typical value is approximately 2.

Gage Ohms - Gage resistance to be used to convert direct strain measurements on the selected channel.

5. Press **Integrate Settings** softkey to select whether the measurement integration time will be specified in terms of Number of Power Line Cycles (**NPLC**) or directly in seconds (**Time**). Only 1, 2, 10, 20, 100, and 200 PLC provide normal mode (line frequency noise) rejection. Selecting 100 PLC provides the best noise rejection and resolution, but the slowest measurements..

NPLC - Sets the integration time as 0.02, 0.06, 0.2, 1, 2, 10, 20, 100, and 200 Power Line Cycles (PLC). Only 1 PLC and longer times provide normal mode (line frequency noise) rejection. Selecting 100 or 200 PLC provides the best noise rejection and resolution.

Time - Directly sets the integration time in seconds.

Advanced settings

Press **Advanced** to configure the advanced settings for the measurement.

Auto Zero - Autozero provides the most accurate measurements, but requires additional measurement time to perform the zero measurement. With autozero enabled (**On**), the instrument internally measures the offset following each measurement. It then subtracts that measurement from the preceding reading. This prevents offset voltages present on the instrument's input circuitry from affecting measurement accuracy. With autozero disabled (**Off**), the instrument measures the offset once and subtracts the offset from all subsequent measurements. The instrument takes a new offset measurement each time you change the function, range, or integration time. (There is no autozero setting for 4-wire measurements).

Offset Compensation - Offset compensation removes the effects of small DC voltages in the circuit being measured. The technique involves taking the difference between two resistance measurements, one with the current source set to the normal value, and one with the current source set to a lower value.

Delay - Selects whether the delay between channels in the scan list will be automatically or manually selected. By selecting **Auto**, instrument will automatically determine the channel delay based on measurement function, range, integration time, and AC filter setting. By selecting **Time**, the specified delay (time in seconds) is inserted between the relay closure and the actual measurement on each channel, in addition to any delay that will implicitly occur due to relay settling time.

DC Voltage

This section describes how to configure the selected channel for DC voltage measurements from the front panel.

1. Connect voltage source to the module's screw terminals.
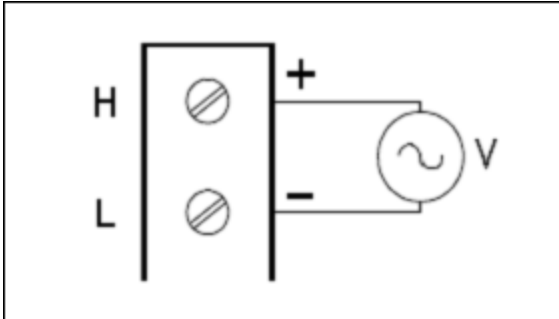
2. Press **[Channel]** > **Measure**, and select **DCV** from the selection menu.

3. Press **Range** and use the knob or the front panel arrow keys to specify the measurement range. **Auto** (autorange) automatically selects the range for the measurement based on the input. Autoranging is convenient, but it results in slower measurements than using a manual range. Autoranging goes up a range at 120% of the present range, and down a range below 10% of the present range.

4. Press **Integrate Settings** softkey to select whether the measurement integration time will be specified in terms of Number of Power Line Cycles (**NPLC**) or directly in seconds (**Time**). Only 1, 2, 10, 20, 100, and 200 PLC provide normal mode (line frequency noise) rejection. Selecting 100 PLC provides the best noise rejection and resolution, but the slowest measurements..

NPLC - Sets the integration time as 0.02, 0.06, 0.2, 1, 2, 10, 20, 100, and 200 Power Line Cycles (PLC). Only 1 PLC and longer times provide normal mode (line frequency noise) rejection. Selecting 100 or 200 PLC provides the best noise rejection and resolution.

Time - Directly sets the integration time in seconds.

Advanced settings

[Channel] Menu Overview

Press **Advanced** to configure the advanced settings for the measurement.

Auto Zero – Autozero provides the most accurate measurements, but requires additional measurement time to perform the zero measurement. With autozero enabled (**On**), the instrument internally measures the offset following each measurement. It then subtracts that measurement from the preceding reading. This prevents offset voltages present on the instrument's input circuitry from affecting measurement accuracy. With autozero disabled (**Off**), the instrument measures the offset once and subtracts the offset from all subsequent measurements. The instrument takes a new offset measurement each time you change the function, range, or integration time. (There is no autozero setting for 4-wire measurements).

Input Z – Specifies the measurement terminal input impedance, which is either 10 MΩ (**10 M**) or high impedance (**Auto**). The Auto mode selects high impedance (> 10 GΩ) for the 100 mV, 1 V, and 10 V ranges, and 10 MΩ for the 100 V and 300 V ranges. In most situations, 10 MΩ is high enough to not load most circuits, but low enough to make readings suitable for high impedance circuits. It also leads to readings with less noise than the high impedance option, which is included for situations where the 10 MΩ load is significant.

Delay – Selects whether the delay between channels in the scan list will be automatically or manually selected. By selecting **Auto**, instrument will automatically determine the channel delay based on measurement function, range, integration time, and AC filter setting. By selecting **Time**, the specified delay (time in seconds) is inserted between the relay closure and the actual measurement on each channel, in addition to any delay that will implicitly occur due to relay settling time.

AC Voltage

This section describes how to configure the selected channel for AC voltage measurements from the front panel.
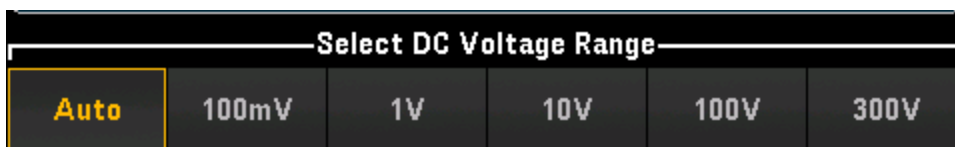
1. Connect AC voltage source to the module's screw terminals.
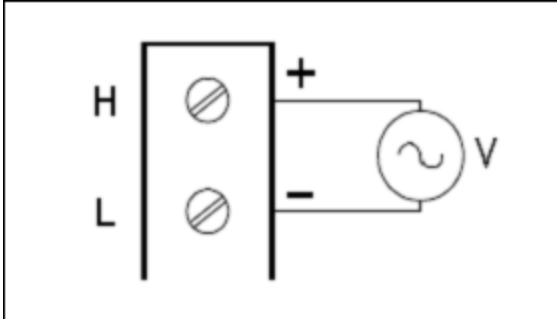
2. Press **[Channel]** > **Measure**, and select **ACV** from the selection menu.

3. Press **Range** and use the knob or the front panel arrow keys to specify the measurement range. **Auto** (autorange) automatically selects the range for the measurement based on the input. Autoranging is convenient, but it results in slower measurements than using a manual range. Autoranging goes up a range at 120% of the present range, and down a range below 10% of the present range.

Advanced settings

Press **Advanced** to configure the advanced settings for the measurement.

AC Filter - Specifies which AC filter to use. The instrument uses three different AC filters that enable you either to optimize low frequency accuracy or achieve faster AC settling following a change in input signal amplitude.

The three filters are **3 Hz**, **20 Hz**, and **200 Hz**, and you should generally select the highest frequency filter whose frequency is less than that of the signal you are measuring, because higher frequency filters result in faster measurements. For example, when you are measuring a signal between 20 and 200 Hz, you should use the 20 Hz filter.

If measurement speed is not an issue, choosing a lower frequency filter may result in quieter measurements, depending on the signal that you are measuring.

[Channel] Menu Overview

Delay - Selects whether the delay between channels in the scan list will be automatically or manually selected. By selecting **Auto**, instrument will automatically determine the channel delay based on measurement function, range, integration time, and AC filter setting. By selecting **Time**, the specified delay (time in seconds) is inserted between the relay closure and the actual measurement on each channel, in addition to any delay that will implicitly occur due to relay settling time.

DC Current

This section describes how to configure the selected channel for DC current measurements from the front panel.

1. Connect DC current source to the module's screw terminals.
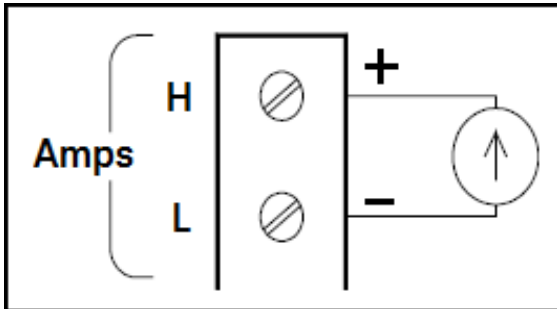
2. Press **[Channel]** > **Measure**, and select **DCI** from the selection menu.

3. Press **Range** and use the knob or the front panel arrow keys to specify the measurement range. **Auto** (autorange) automatically selects the range for the measurement based on the input. Autoranging is convenient, but it results in slower measurements than using a manual range. Autoranging goes up a range at 120% of the present range, and down a range below 10% of the present range.

4. Press **Integrate Settings** softkey to select whether the measurement integration time will be specified in terms of Number of Power Line Cycles (**NPLC**) or directly in seconds (**Time**). Only 1, 2, 10, 20, 100, and 200 PLC provide normal mode (line frequency noise) rejection. Selecting 100 PLC provides the best noise rejection and resolution, but the slowest measurements..

NPLC - Sets the integration time as 0.02, 0.06, 0.2, 1, 2, 10, 20, 100, and 200 Power Line Cycles (PLC). Only 1 PLC and longer times provide normal mode (line frequency noise) rejection. Selecting 100 or 200 PLC provides the best noise rejection and resolution.

Time - Directly sets the integration time in seconds.

Advanced settings

[Channel] Menu Overview

Press **Advanced** to configure the advanced settings for the measurement.

Auto Zero Off On				Delay Auto Time ↑	Done

Auto Zero – Autozero provides the most accurate measurements, but requires additional measurement time to perform the zero measurement. With autozero enabled (**On**), the instrument internally measures the offset following each measurement. It then subtracts that measurement from the preceding reading. This prevents offset voltages present on the instrument's input circuitry from affecting measurement accuracy. With autozero disabled (**Off**), the instrument measures the offset once and subtracts the offset from all subsequent measurements. The instrument takes a new offset measurement each time you change the function, range, or integration time. (There is no autozero setting for 4-wire measurements).

Delay – Selects whether the delay between channels in the scan list will be automatically or manually selected. By selecting **Auto**, instrument will automatically determine the channel delay based on measurement function, range, integration time, and AC filter setting. By selecting **Time**, the specified delay (time in seconds) is inserted between the relay closure and the actual measurement on each channel, in addition to any delay that will implicitly occur due to relay settling time.

Resistance

This section describes how to configure the selected channel for 2-wire and 4-wire measurements from the front panel. The measurement configurations for 2-wire and 4-wire resistance are same, below descriptions explained by using 2-wire resistance measurements.

1. Connect resistance source to the module's screw terminals.

    2-wire ohms:
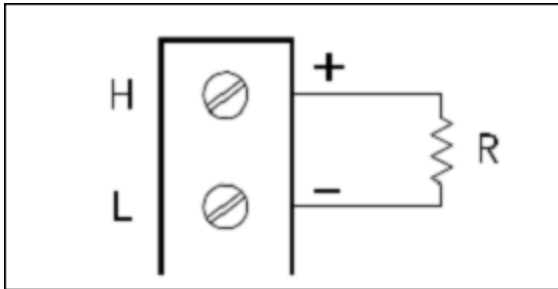
    4-wire ohms:
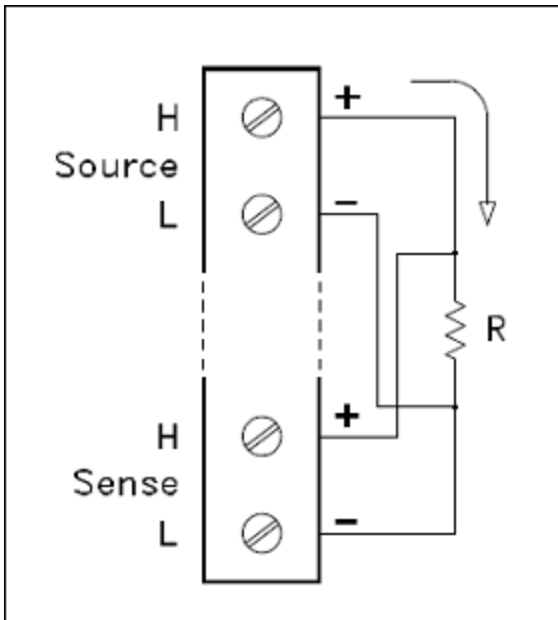
2. Press [Channel] > Measure, and select OHMS or OHMS 4W from the selection menu.

3. Press **Range** and use the knob or the front panel arrow keys to specify the measurement range. **Auto** (autorange) automatically selects the range for the measurement based on the input. Autoranging is convenient, but it results in slower measurements than using a manual range. Autoranging goes up a range at 120% of the present range, and down a range below 10% of the present range.

4. Press **Integrate Settings** softkey to select whether the measurement integration time will be specified in terms of Number of Power Line Cycles (**NPLC**) or directly in seconds (**Time**). Only 1, 2, 10, 20, 100, and 200 PLC provide normal mode (line frequency noise) rejection. Selecting 100 PLC provides the best noise rejection and resolution, but the slowest measurements..

NPLC - Sets the integration time as 0.02, 0.06, 0.2, 1, 2, 10, 20, 100, and 200 Power Line Cycles (PLC). Only 1 PLC and longer times provide normal mode (line frequency noise) rejection. Selecting 100 or 200 PLC provides the best noise rejection and resolution.

Time - Directly sets the integration time in seconds.

Advanced settings

Press **Advanced** to configure the advanced settings for the measurement.

Auto Zero - Autozero provides the most accurate measurements, but requires additional measurement time to perform the zero measurement. With autozero enabled (**On**), the instrument internally measures the offset following each measurement. It then subtracts that measurement from the preceding reading. This prevents offset voltages present on the instrument's input circuitry from affecting measurement accuracy. With autozero disabled (**Off**), the instrument measures the offset once and subtracts the offset from all subsequent measurements. The instrument takes a new offset measurement each time you change the function, range, or integration time. (There is no autozero setting for 4-wire measurements).

Offset Compensation - Offset compensation removes the effects of small DC voltages in the circuit being measured. The technique involves taking the difference between two resistance measurements, one with the current source set to the normal value, and one with the current source set to a lower value.

Low Power - Selects the low-power resistance measurement. This sources less current resulting in lower power dissipation, and less self-heating, in the resistance under test. Typically, this is about 1/10th the current sourced for the standard resistance measurements. The approximate current sourced for each measurement range is shown at the bottom of the resistance range softkeys, for example: (~ 1 mA).

Delay – Selects whether the delay between channels in the scan list will be automatically or manually selected. By selecting **Auto**, instrument will automatically determine the channel delay based on measurement function, range, integration time, and AC filter setting. By selecting **Time**, the specified delay (time in seconds) is inserted between the relay closure and the actual measurement on each channel, in addition to any delay that will implicitly occur due to relay settling time.

Frequency and Period

This section describes how to configure the selected channel for frequency and period measurements from the front panel.

1. Connect an AC source to the module's screw terminals.
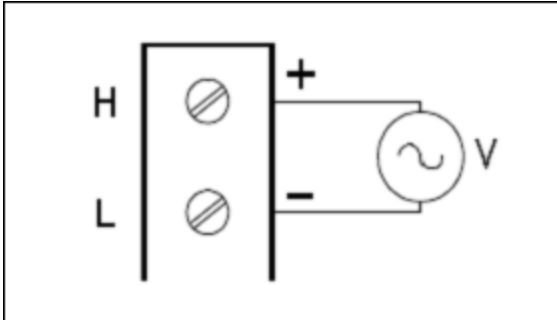
2. Press **[Channel] > Measure**, and select **FREQ** or **PERIOD** from the selection menu.

3. Press **Range** and use the knob or the front panel arrow keys to specify the measurement range. **Auto** (autorange) automatically selects the range for the measurement based on the input. Autoranging is convenient, but it results in slower measurements than using a manual range. Autoranging goes up a range at 120% of the present range, and down a range below 10% of the present range.

4. Press **Gate Time** to specify the measurement's aperture (integration time) as 1 ms, 10 ms, 100 ms, or 1 s.

Advanced settings

Press **Advanced** to configure the advanced settings for the measurement.

AC Filter – Specifies which AC filter to use. The instrument uses three different AC filters that enable you either to optimize low frequency accuracy or achieve faster AC settling following a change in input signal amplitude.

The three filters are **3 Hz**, **20 Hz**, and **200 Hz**, and you should generally select the highest frequency filter whose frequency is less than that of the signal you are measuring, because higher frequency filters result in faster measurements. For example, when you are measuring a signal between 20 and 200 Hz, you should use the 20 Hz filter.

If measurement speed is not an issue, choosing a lower frequency filter may result in quieter measurements, depending on the signal that you are measuring.

Delay – Selects whether the delay between channels in the scan list will be automatically or manually selected. By selecting **Auto**, instrument will automatically determine the channel delay based on measurement function, range, integration time, and AC filter setting. By selecting **Time**, the specified delay (time in seconds) is inserted between the relay closure and the actual measurement on each channel, in addition to any delay that will implicitly occur due to relay settling time.

Diode

This section describes how to configure the selected channel for diode test from the front panel.

1. Connect diode source to the module's screw terminals.
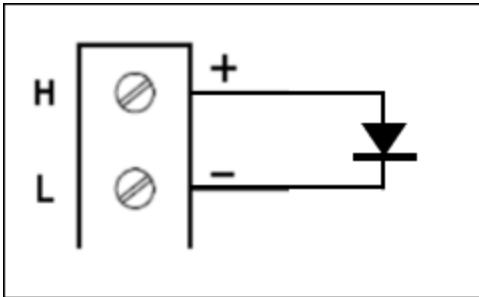
2. Press **[Channel]** > **Measure**, and select **DIODE** from the selection menu.

Advanced settings

Press **Advanced** to configure the advanced settings for the measurement.

Delay – Selects whether the delay between channels in the scan list will be automatically or manually selected. By selecting **Auto**, instrument will automatically determine the channel delay based on measurement function, range, integration time, and AC filter setting. By selecting **Time**, the specified delay (time in seconds) is inserted between the relay closure and the actual measurement on each channel, in addition to any delay that will implicitly occur due to relay settling time.

Capacitance

This section describes how to configure the selected channel for capacitance measurements from the front panel.

1. Connect capacitance source to the module's screw terminals.
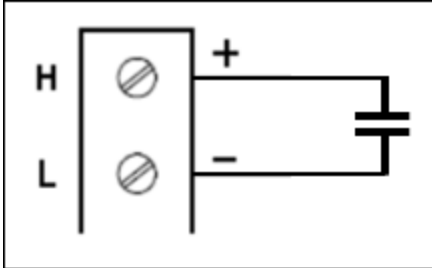
2. Press **[Channel]** > **Measure**, and select **CAP** from the selection menu.

3. Press **Range** and use the knob or the front panel arrow keys to specify the measurement range. **Auto** (autorange) automatically selects the range for the measurement based on the input. Autoranging is convenient, but it results in slower measurements than using a manual range. Autoranging goes up a range at 120% of the present range, and down a range below 10% of the present range.

Advanced settings

Press **Advanced** to configure the advanced settings for the measurement.

Delay – Selects whether the delay between channels in the scan list will be automatically or manually selected. By selecting **Auto**, instrument will automatically determine the channel delay based on measurement function, range, integration time, and AC filter setting. By selecting **Time**, the specified delay (time in seconds) is inserted between the relay closure and the actual measurement on each channel, in addition to any delay that will implicitly occur due to relay settling time.

DAQM907A Multifunction Module – Overview

There are total 7 channels available in the DAQM907A multifunction module.

Channel number	Channel label
01	8-bit Digital I/O Channel
02	8-bit Digital I/O Channel
03	Totalizer Channel
04	DAC Output Channel
05	DAC Output Channel
06	DAC Output Sense Channel
07	DAC Output Sense Channel

Digital I/O (DIO) Channels (Channel 01 and 02)

The DAQM907A multifunction module has two non-isolated 8-bit input/output ports which you can use for reading digital patterns. You can read the live status of the bits on the port or you can configure a scan to include a digital read.

To configure the DIO channel

1. Press **[Module]** and use the knob or the front panel arrow keys to select the slot containing the multifunction module.
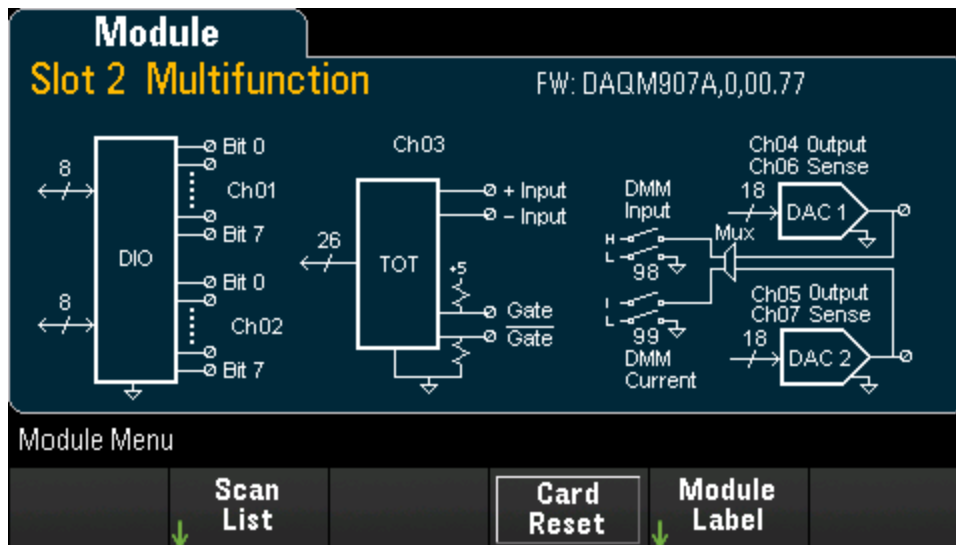
[Channel] Menu Overview

2. Press **[Channel]** and use the knob or the front panel arrow keys to select the DIO channels (channel 01 and 02).

3. Press **In Scan** to specify whether to include (**On**) or exclude (**Off**) the DIO channel from the scan list.

- **Read** - Select **Read** to read the bit patterns directly from a digital input port.

- **Write** - Select **Write** to specify and output the bit pattern to the specified port.

To read a digital input port

Press **Read** to define the DIO direction as Input.
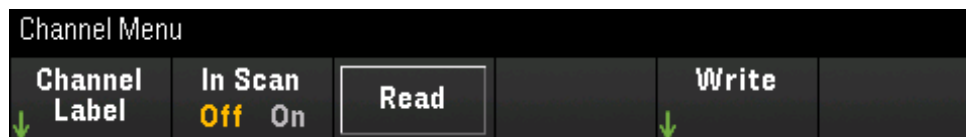
To write to a digital output port

1. Press **[Module]** and use the knob or the front panel arrow keys to select the slot containing the multifunction module.
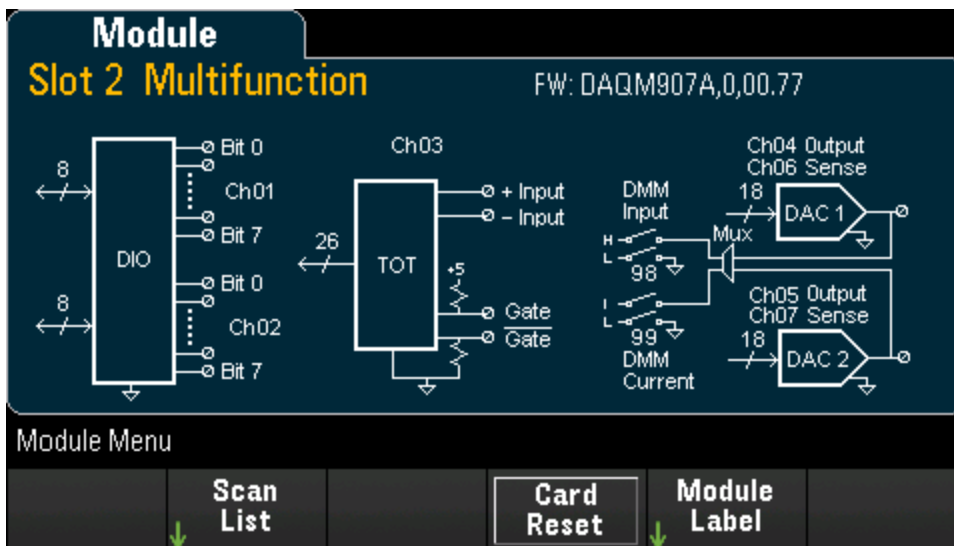
2. Press **[Channel]** and use the knob or the front panel arrow keys to select the DIO channels (channel 01 and 02).

3. Press **Write** > **Base** and use the knob or the front panel arrow keys to select the number base used (**Hex**, **Binary**, or **Decimal**), and then press **Pattern** to define each output pattern from the selected base.
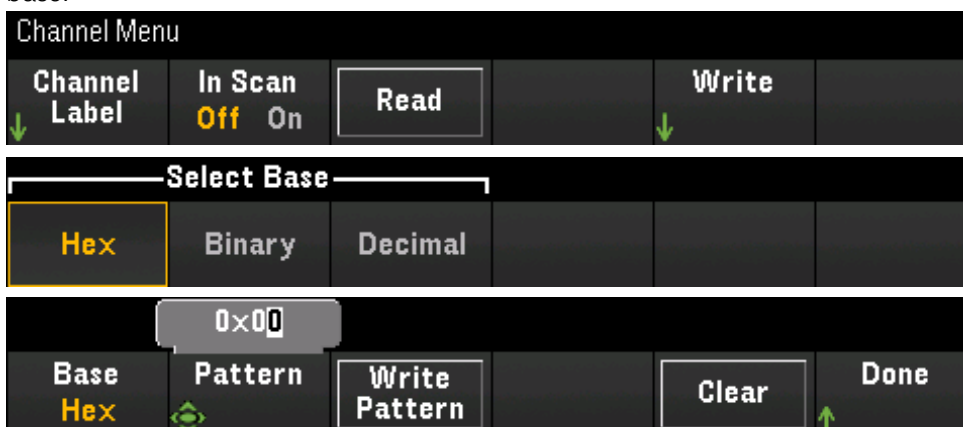
4. Press **Write Pattern** to output the bit pattern on the selected digital output port. The DIO direction will be set to Output.

5. Press **Clear** to set the output pattern to "0".
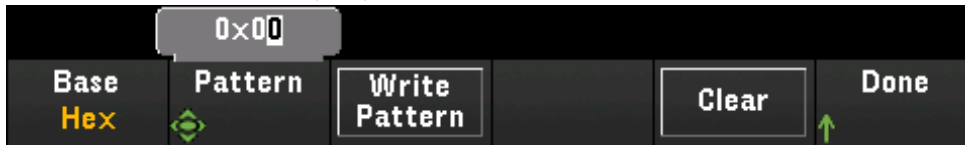
Totalizer Channel

The DAQM907A multifunction module has a 26-bit totalizer which can count TTL-compatible pulses at a 100 kHz rate. The totalizer channel is numbered "s03", where s represents the slot number. The totalizer channel is labeled as channel 03

You can manually read the totalizer count or you can configure a scan to read the count.

To configure the totalizer channel with the multifunction module:

1. Press **[Module]** and use the knob or the front panel arrow keys to select the slot which containing the DAQM907A multifunction module.
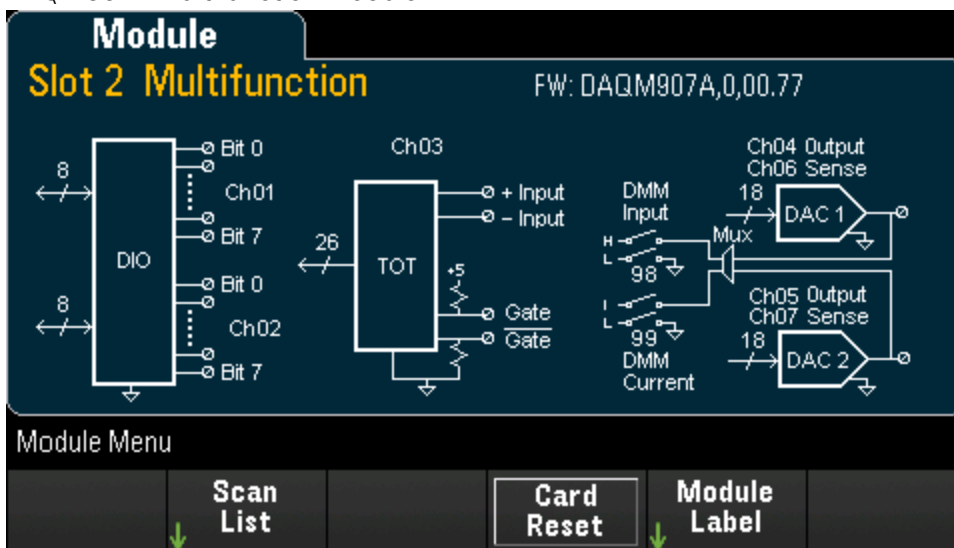
2. Press **[Channel]** and use the knob or the front panel arrow keys to select the totalizer channel (channel 03).

3. Press **In Scan** to specify whether to include (**On**) or exclude (**Off**) the totalizer channel from the scan list.

4. Press **Settings** > **Edge** to specify if the totalizer channel should count on the rising edge (**Pos**) or falling edge (**Neg**) if the input signal, and then press **ReadReset** to specify if the totalizer count should be automatically reset (**On**) or not (**Off**) when read.

5. Press **Read** to read the totalizer count.

The count is read once each time you press **Read**; the count does not update automatically on the display.

6. Press **Clear Count** to reset the totalizer count to "0".

7. Press **Start** to start the counting on the current totalizer channel or press **Stop** to stop the counting on the current totalizer channel.

DAC output and sense channels (Channels 04 through 07)

The DAQM907A multifunction module has two DAC output channels (channel 04 and 05), and two DAC output sense channels (channel 06 and 07). Any of these channels may be scanned.

For the DAC output channels, no actual output measurement is made; the scanned value will be the programmed output value (voltage or current).

[Channel] Menu Overview

The DAC output sense channels will make a complementary (voltage or current) measurement based on the output mode of the corresponding DAC output channel:

- Channel 06 will make the measurement based on the output mode set in channel 04.
- Channel 07 will make the measurement based on the output mode set in channel 05.

If DAC output channel 04 is set to voltage mode, then the corresponding DAC sense channel 06 will measure current. If the output channel is set to current mode, the sense channel will measure voltage.

1. Press [Module] and use the knob or the front panel arrow keys to select the slot containing the multifunction module.
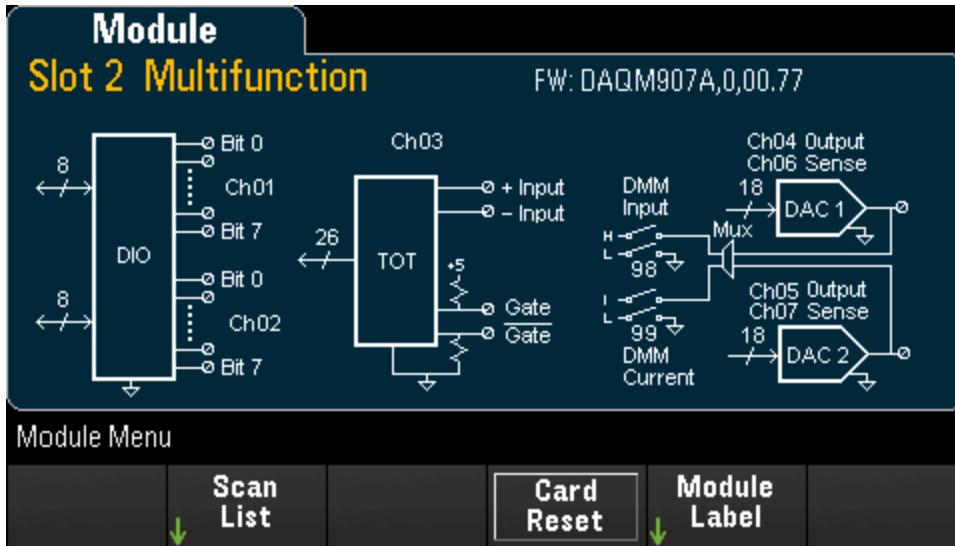
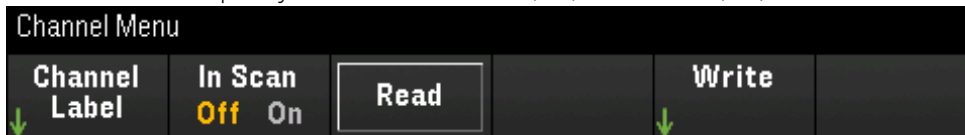2. Press **[Channel]** and use the knob or the front panel arrow keys to select the DAC output channels (channel 04 and 05) or the DAC sense channels (channel 06 and 07).
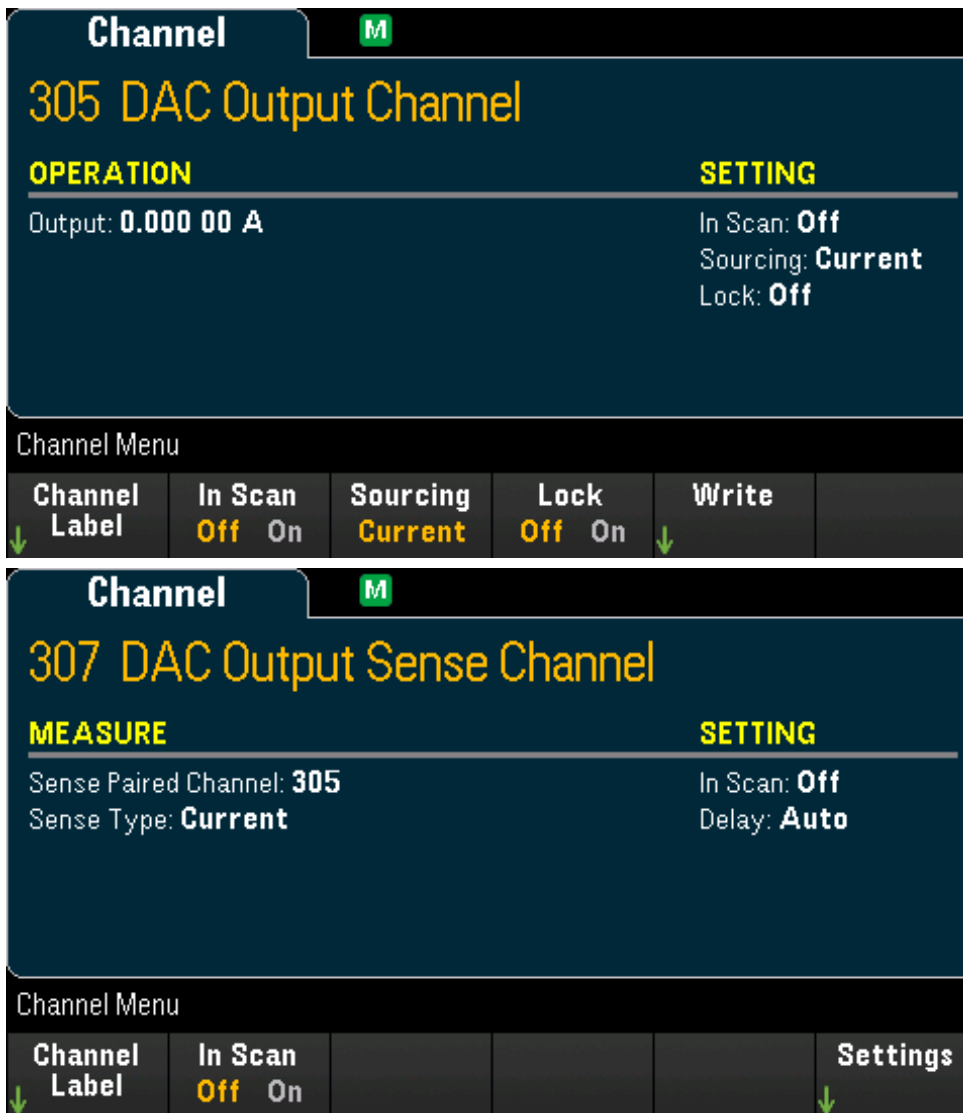
3. Press **In Scan** to specify whether to include (**On**) or exclude (**Off**) the DAC channel from the scan list.
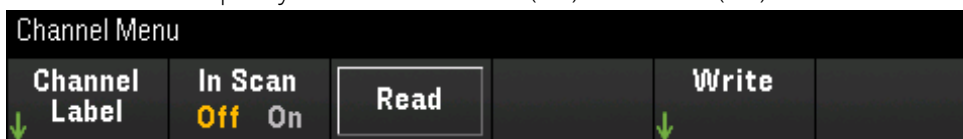
No actual measurement is made on this channel; the "measurement" will be the programmed DAC output value.

4. Press **Sourcing** to set the output mode in the DAC output channel to **Voltage** or **Current**.

5. Enable **Lock** (**On**) to lock the DAC output channel mode or disable **Lock** (**Off**) to disable the lock on the DAC output channel mode.

6. Press **Write** > **Output** to set the output voltage/current level, and then press **Write Output** to output the voltage/current from the selected DAC output channel.

Computed Channel

A computed channel performs mathematical operations on the readings from measurement channels, or other computed channels. To configure, press **Channel** and use the knob or right arrow key to select one of the computed channels (channels 401 through 420).

NOTE	You must configure the measurement channel(s) before performing the mathematical operations in the computed channel.
	Monitoring of computed channels is only available during scanning and will only display the reading from the most recent sweep.
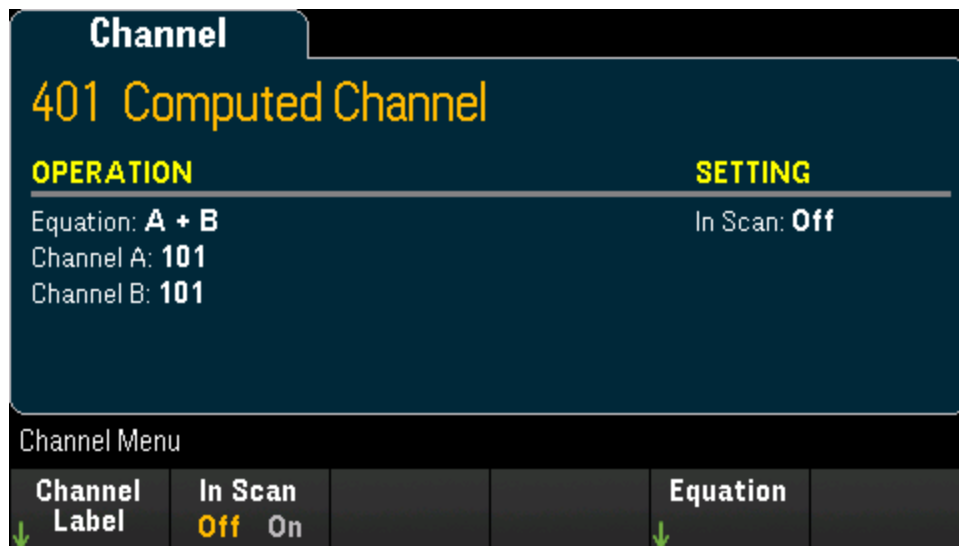
Press **In Scan** to specify whether the computed channel is included in (On) or excluded from (Off) the scan list. Press **Equation** to specify the equation to be used for the computed channel. The equations choices can be categorized in three main groups:

Basic math

Table below shows the supported basic math operations with the respective softkey label.

Operation	Softkey label
Add	A+B
Subtract	A–B
Multiply	A*B
Divide	A/B
Reciprocal	1/A
Power	A^2
Square root	Sqrt(A)

For example, to perform the Add operation from measurement channels (channel 101 and 102) to the computed channel (channel 401):

1. Press **Equation** > **A+B**, use the knob or the front panel arrow keys to specify the **Channel A** softkey to channel 101 and **Channel B** softkey to channel 102.
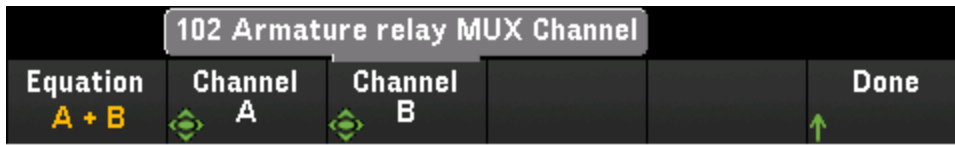
2. Press once on the **[Scan]** key to initiate a scan. You can view the scanned memory readings by pressing **[View]** key. Add operation from channel 101 and 102 to channel 401 will display as below, where the reading of:

   Channel 401 = Channel 101 + Channel 102

3. Repeat the above steps for the rest of basic math operations (subtract, multiply, etc). If you would like to compute from a single operand channel, set both Channel A and Channel B softkeys to the same channel. The computed readings will be the result of addition readings from the selected channel itself. For example:

   Channel 401 = Channel 101 + Channel 101

Polynomial fifth order

To perform this operation from operand channel (channel 101) to the computed channel (channel 401):
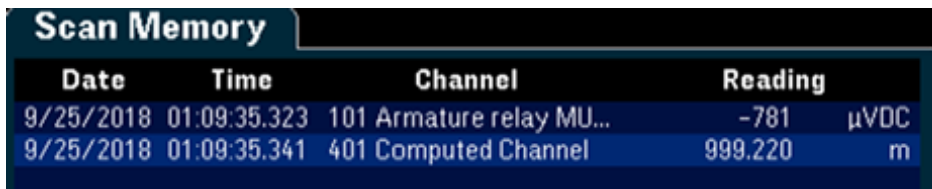
1. Press **Equation** > **5th Order**, use the knob or the front panel arrow keys to specify the **Channel A** softkey to channel 101.
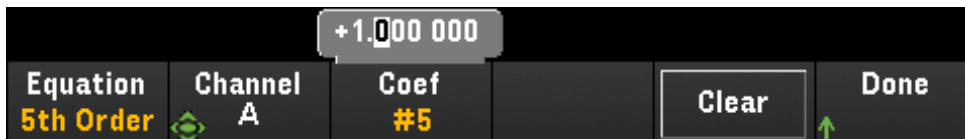
2. Press **Coef** to cycle through the coefficient order (**Coef #5**, **Coef #4**, **Coef #3**, **Coef #2**, **Coef #1**, and **Coef #0**). Specify the coefficient parameters for each coefficient order.

3. Press once on the **[Scan]** key to initiate a scan. You can view the scanned memory readings by pressing **[View]** key. The result of polynomial 5th order will display as below:

Statistics

Table below shows the supported statistics operations with the respective softkey label. For statistics, (list) means a set of operand channels that in the computation.

Operation	Softkey label	Description
Average	Avg(list)	Returns the average readings from a list of operand channels, where Average reading = Total sum of all the readings/number of operand channels selected
Maximum	Max(list)	Returns the maximum reading from a list of operand channels
Minimum	Min(list)	Returns the minimum reading from a list of operand channels
Standard deviation	SDev(list)	Returns the standard deviation readings from a list of operand channels

For example, to perform the Average operation from measurement channels (channels 101 through 103) to the computed channel (channel 401):

1. Press **Equation** > **Avg(list)**, use the knob or the front panel arrow keys to select the operand channels in the **Select** softkey, then press **Add to List** to add the selected operand channel to the operand channel list. Press this softkey repeatedly to add the subsequent operand channel to the operand channel list.

2. When the number of operand channel added is reached, **Remove from List** softkey will display. Press this key to remove the previous selected operand channel from the operand channel list.

3. Press **View List** to display a list of available measurement channels. Currently selected operand channels are marked with an "X". Press **Clear** to remove all selected operand channel from the operand channel list.

4. Press once on the **[Scan]** key to initiate a scan. You can view the scanned memory readings by pressing **[View]** key. The result of Average operation will display as below:

Channel 401 = (Channel 101+102+103)/3

Note: The format for numbers displayed here are Comma as decimal point separator, and thousand separator set to On where period is inserted between every three digits. See **Number Format** for details.

You can also include the computed channel as a operand channel in the computed channel list. For example, to include the computed channel 401 from above example to other computed channel (channel 402):

[Channel] Menu Overview

1. Repeat step 1–4 as mentioned above.

2. Press **[Channel]** and use the knob or the front panel arrow keys to set the channel into Channel 402. Press **In Scan** and enables the softkey to include channel 402 in the scan list. Then press **Equation** > **Avg(list)**, use the knob or the front panel arrow keys to specify the **Channel A** softkey to channel 101 and **Channel B** softkey to 401 computed channel.

3. Press once on the **[Scan]** key to initiate a scan. You can view the scanned memory readings by pressing **[View]** key. The result of Average operation will display as below:

Channel 402 = (Channel 101+102+103+401)/4

Date	Time	Channel	Reading	
17/4/2018	12:43:47.090	101 Armature relay...	−1,303.0	mVDC
17/4/2018	12:43:47.142	102 Armature relay...	−1,221.3	mVDC
17/4/2018	12:43:47.195	103 Armature relay...	−1,146.8	mVDC
17/4/2018	12:43:47.195	401 Computed Cha...	−1,223.7	m
17/4/2018	12:43:47.195	402 Computed Cha...	−1,223.7	m

Keysight DAQ970A User's Guide

Scanning with External Instruments

In this configuration, you can use the DAQ970A for signal routing or control applications. If you install a multiplexer plug-in module, you can use the DAQ970A for scanning with an external instrument. You can connect an external instrument (such as a DMM) to the multiplexer COM terminal.
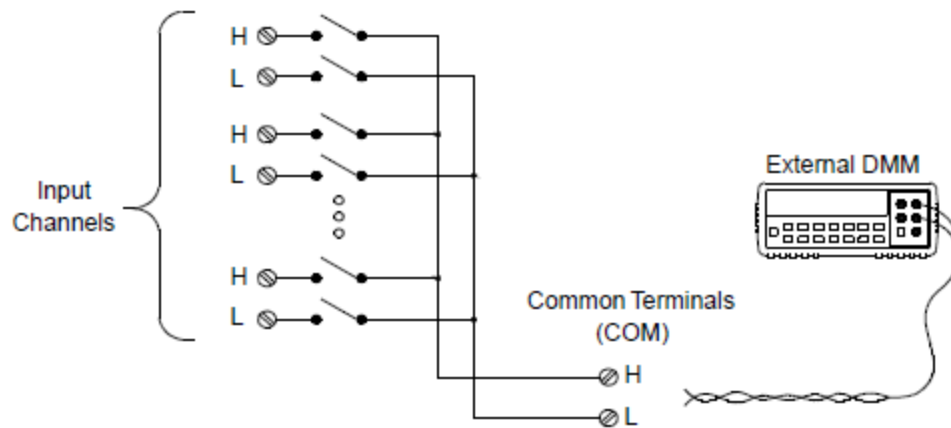
To control scanning with an external instrument, two control lines are provided. When the DAQ970A and the external instrument are properly configured, you can synchronize a scan sequence between the two.

In this configuration, you must set up a scan list to include all desired multiplexer or multifunction channels. Channels which are not in the scan list are skipped during the scan. The instrument automatically scans the list of channels in ascending order from slot 100 through slot 300.

For an externally-controlled scan, you must disable the internal DMM by pressing [Home] > User Settings > DMM Off. Since the internal DMM is disabled, readings from multiplexer channels are not stored in internal reading memory.

External connections are required to synchronize the scan sequence between the DAQ970A and the external instrument. The DAQ970A must notify the external instrument when a relay is closed and settled (including channel delay). The DAQ970A outputs a Channel Closed pulse from pin 5 on the rear-panel connector. In response, the external instrument must notify the DAQ970A when it has finished its measurement and ready to advance to the next channel in the scan list. The DAQ970A accepts a Channel Advance signal on the External Trigger input line (pin 6).

You can configure the event or action that controls the onset of each sweep through the scan list (a sweep is one pass through the scan list). When the DMM is disabled, the default scan interval source is "Auto" (Immediate). For more information, refer to Scan Interval. You can configure the event or action that notifies the DAQ970A to advance to the next channel in the scan list. Note that the Channel Advance source shares the same sources as the scan interval. However, an error is generated if you attempt to set the channel advance source to the same source used for the scan interval.

You can specify the number of times the instrument will sweep through the scan list. When the specified number of sweeps have occurred, the scan stops.

An externally-controlled scan can also include a read of a digital port or a read of the totalizer count on the multifunction module. When the channel advance reaches the first digit channel, the instrument scans through all the digital channels in that slot and stores the readings in reading memory (only one channel advance signal is required).

[Channel] Menu Overview

You can configure the list of channels for 4-wire external scanning. When enabled, the instrument auto-matically pairs channel n with channel n+10

Channel Labeling

Press **Channel Label** softkey to specify a label for current selected channel. Use the knob or the front panel arrow keys to enter the characters into the display. Note that you are only allowed to enter maximum of 10 characters for the module label, including letters, numbers, and special characters. To return into the default channel label, press **Channel Label** > **Clear All** > **Done**. This setting is applicable to all modules installed, as well as the computed channels.
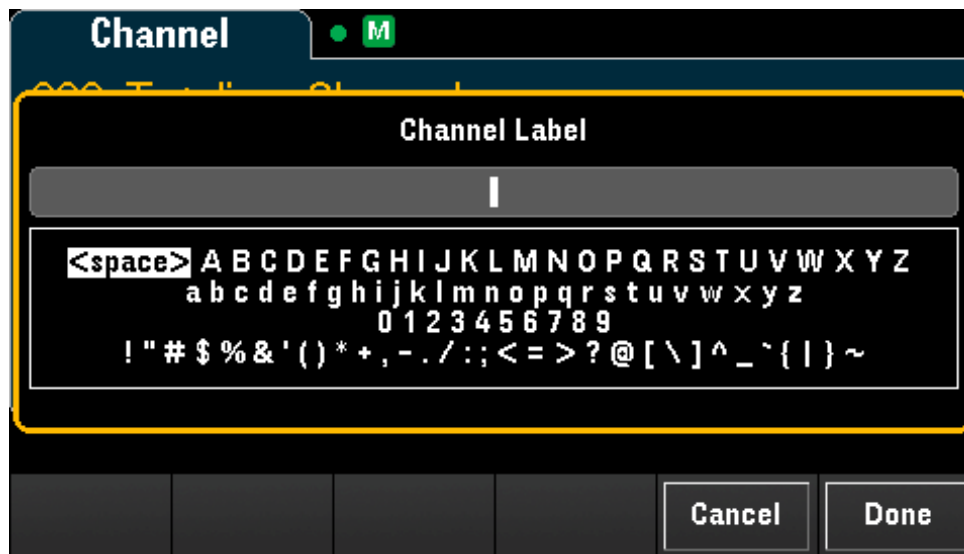
[Interval] Menu

Press **[Interval]** key on the front panel to configure what starts each a sweep and the number of sweeps in the scan.

Selecting the trigger source

Press **Source** softkey to select the trigger source to start a sweep. A sweep is one pass through the scan list.
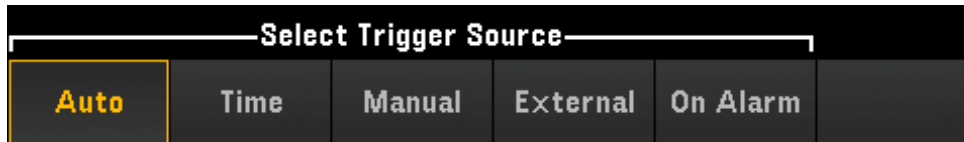
a. **Auto** - Selects an immediate trigger. When the scan is started, each sweep will start automatically.

b. **Time** - Sets the instrument's internal timer to automatically starts sweeps at a specific interval. Select this trigger source, and press **Time** softkey to configure the time interval between 0 and 100:00:00 hours.

c. **Manual** - Selects manual trigger. A sweep is started by pressing the **[Scan]** key once on the front panel.

d. **External** - Starts a sweep when an external TTL-compatible trigger pulse is received from the Ext Trig/Alarms connector on the rear panel. Select this trigger source, and press **Ext Trig** softkey to specify the polarity of the Ext Trig signal as rising edge (**Pos**) or falling edge (**Neg**).

e. **On Alarm** - Starts a sweep when an alarm condition is detected during a scan, on the monitor channel, or on a DIO or Totalizer channel. Select this trigger source, and press **On Alarm** softkey to specify which of the four alarms will be used to report alarm conditions on the selected channel.
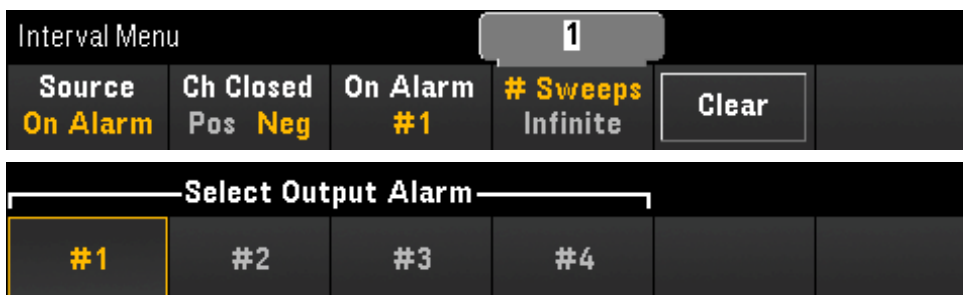
Selecting the output trigger polarity

Press **Ch Closed** softkey to select the rising edge (**Pos**) or falling edge (**Neg**) as the Chan Closed signal on the rear panel Ext Trig/Alarm connector.

[Channel] Menu Overview

The output trigger (channel closed signal) operates differently during internal or external scan:

- For internal scans (internal DMM enabled), it is generated at the END of a sweep, not the beginning of a sweep.

- For external scans (internal DMM disabled), it is generated when each channel is closed, and can be used to trigger the measurement on the external DMM.

Specifying number of sweeps in the scan

Specifies the number of times that the instrument will sweep through the scan list (**# Sweeps**) or con-tinuous sweeps (**Infinite**).

a. **# Sweeps** – Specifies the number of times (between 1 to 1,000,000 sweeps) that the instrument will sweep through the scan list after the scan is started. Press **Clear** to set the sweep count to 1.

b. **Infinite** – Sets a scan to continue indefinitely until manually stopped using the front panel **[Scan]** key, or the SCPI "ABORt" command is sent, or a "Device Clear" message is sent from the remote interface.

The instrument can hold up to 100,000 readings in reading memory, after which the MEM annunciator will be displayed indicating reading memory overflow. Any new readings will overwrite the first (oldest) readings saved; the most recent readings are always preserved.

[Math] Menu

> **NOTE**   You must configure the channel before applying any scaling values.

In the Math menu page, press the **Math** softkey to enable or disable measurement scaling.

```
Math Menu
  Math      Function   Settings
  Off  On    mX+b         ↓
```
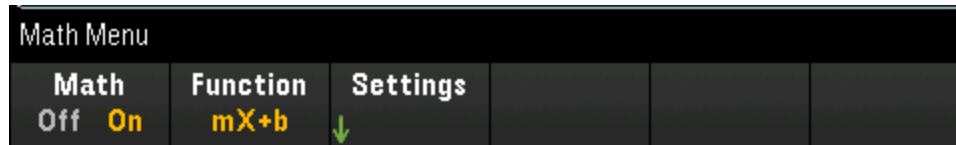
> **NOTE**   Math is set to Off when you change measurement functions (for example, changing from DCV to ACV). You must re-enable math after changing measurement functions.

Press the **Function** softkey to select a scaling function on the selected channel. The dBm and dB functions are only available on channels configured to measure DC or AC voltage.

```
───────── Select Function ─────────
  mX+b        %        dBm       dB
```
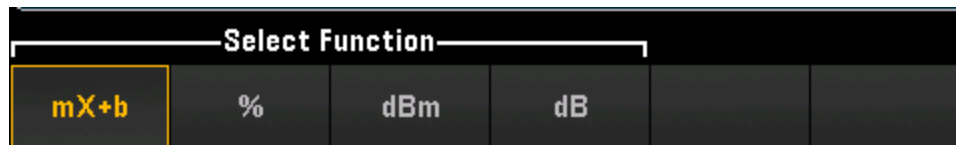
Selects a scaling function and press **Settings** softkey to perform various scaling settings. Scaling values are saved in non-volatile memory for the selected channel.

mX+b Scaling

mX+b scaling function allows you to perform a linear scaling with offset operation, by applying a gain (m) and offset (b) values to all readings on a selected channel during a scan. To configure, select scaling function as **mX+b** and press **Settings** to open the configuration menu.

```
+1.000 000
 Gain      Offset    Measure    Clear     User      Done
 (m)        (b)      Offset     Offset    Units
  ⬍          ⬍                             ↓         ↑
```

Press **User Units > User Units Off/On** to display (**On**) or turns off (**Off**) user-defined measurement units. Selecting **On** will display unit as defined by the Edit Units softkey; selecting **Off** will display default units (VDC).

Press **User Units > Edit Units** to specify a string containing up to three characters that will be shown in place of the standard measurement units. These units are subsequently used for the entry of various instrument settings such as limits and graph scaling.

Press **Default Units** to return the unit to the default units for the selected measurement type. For example, if you configure the selected channel as temperature measurement, pressing this softkey will return the default unit into °C.

Press **Measure Offset** to perform an immediate offset measurement and save the offset value for subsequent measurement.

[Channel] Menu Overview

Press **Clear Offset** to clear the offset values to 0.

% Scaling

% performs a percent change operation. The result is the difference between the reading and the reference value, expressed in percentage:

$$\mathbf{Result} = \frac{\mathbf{reading} - \mathbf{reference}}{\mathbf{reference}} \times \mathbf{100}$$

To configure, select scaling function as **%** and press **Settings** to open the configuration menu.
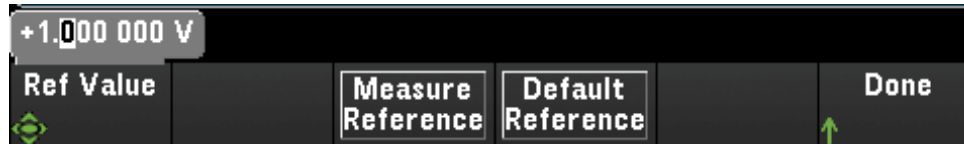
Press **Measure Reference** to perform an immediate reference measurement and saves the reference value for subsequent measurements, or press **Ref Value** to specify the reference value.

Press **Default Reference** to set the reference value to its factory default settings.

dBm Scaling

Selects dBm scaling for the present measurement function. The result is a calculation of power delivered to a reference resistance (specified using the **Ref R** softkey), relative to 1 milliwatt.

dBm = 10 x $\log_{10}$ (reading^2 / reference resistance / 1 mW)

To configure, select scaling function as **dBm** and press **Settings** to open the configuration menu.
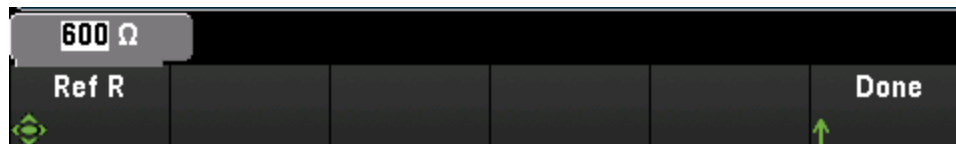
The reference resistance value (Ref R) may be 50, 75, 93, 110, 124, 125, 135, 150, 250, 300, 500, 600 (default), 800, 900, 1000, 1200, or 8000 Ω. Press **Ref R** to specify the reference resistance value for converting voltage measurements to dBm.

dB Scaling

Selects dB scaling for the present measurement function. The result is the difference between the input signal and a stored dB relative reference value, with both values converted to dBm:

dB = measurement in dBm - reference value in dBm

To configure, select scaling function as **dB** and press **Settings** to open the configuration menu.

The reference value can be a measurement converted to dBm (**Measure Ref Value** softkey), or you can specify a reference value (**dB Ref Value** softkey).

Press **Clear dB Ref** to clear the reference value for dB measurements.

[Copy] Menu

NOTE	Source channel (channel to copy the configuration from) must be included in the scan list before performing this feature.
	Copy/paste operation only available for channels with the similar measurement function (for example, from DCV to DCV); where the start channel and end channel are from the similar module slot.

Press [Copy] key on the front panel to copy the measurement configuration from the selected channel(s) to other channel(s). This feature makes it easy to configure several channels for the same measurement. When you copy the configuration from one channel to another, other configuration information such as measurement function, scaling function, alarm configuration, and advanced measurement configurations are automatically copied to other channel(s).

Three options available:

Copy/paste from a single channel to a single channel (one-to-one)

For example, to copy/paste the measurement configuration from channel 01 to channel 02:

1. Press [Channel] and use the knob or the front panel arrow keys to configure channel 01 as DCV (Autorange).

2. Press [Copy] > Source Chan(s). Both Start Channel and End Channel will be displayed with the selected channel 01 as there is no any other configured source channel except this channel. Press Done to exit this menu.
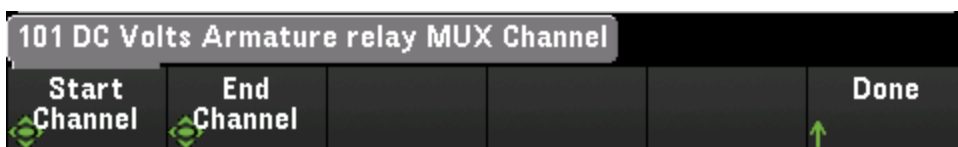
3. Press Dest. Chan(s) to select the destination channel for the paste operation. The instrument will automatically select the subsequent channel as default choice of destination channel. In this example, use the knob or the front panel arrow keys to determine both Start Channel and End Channel as channel 02. Press Done to proceed.

4. Press **Copy Now**. The measurement configuration from channel 01 will copy to channel 02. "COMPLETE" message will prompt out when the operation is completed. Press **Copy Now** to repeatedly copy the same configuration to the new selected channels (channel 03, channel 04, and so on).

Copy/paste from a single channel to multiple channels (one-to-many)

For example, to copy/paste the measurement configuration from channel 01 to channel 02 and 03:

1. Press **[Channel]** and use the knob or the front panel arrow keys to configure channel 01 as DCV (Autorange).

2. Press **[Copy]** > **Source Chan(s)**. Both **Start Channel** and **End Channel** will be displayed with the selected channel 01 as there is no any other configured source channel except this channel. Press **Done** to exit this menu.

3. Press **Dest. Chan(s)** to select the destination channel for the paste operation. The instrument will automatically select the subsequent channel as default choice of destination channels. In this example, use the knob or the front panel arrow keys to determine both **Start Channel** as channel 02 and **End Channel** as channel 03. Press **Done** to proceed.

4. Press **Copy Now**. The measurement configuration from channel 01 will copy to both channel 02 and 03. "COMPLETE" message will prompt out when the operation is completed. Press **Copy Now** to repeatedly copy the same configuration to the new selected channels (channel 04, channel 05, and so on).

Copy/paste from multiple channels to multiple channels (many-to-many)

For example, to copy/paste the measurement configuration from channels 01 through 04 to channels 05 through 08:

1. Press **[Channel]** and use the knob or the front panel arrow keys to configure the source channels as below:

    - Channel 01 (DCV with Autorange)

    - Channel 02 (ACV with the range of 100 mV)

    - Channel 03 (2-wire resistance with the range of 100 Ω)

    - Channel 04 (4-wire resistance with the range of 1 kΩ)

2. Press **[Copy]** > **Source Chan(s)**. Use the knob or the front panel arrow keys to determine the **Start Channel** as channel 01 while **End Channel** as channel 04. Press **Done** to exit this menu.

3. Press **Dest. Chan(s)** to select the destination channel for the paste operation. The instrument will auto-matically select the subsequent channel as default choice of destination channels. In this example, use the knob or the front panel arrow keys to determine both **Start Channel** as channel 05.

SOURCE CHAN(S)	DEST. CHAN(S)
CH **101** Armature relay MUX Channel	CH **105**
CH **104** Armature relay MUX Channel	CH 108
4 CH SELECTED	**4** CH SELECTED

End Channel softkey is unavailable in this option, instrument will automatically perform the copy/paste operation into the next *N* subsequent destination channels based on the *N* selected of source chan-nels. For example, if you set the Start Channel as channel 06, destination channels selected will be chan-nels 06 through 09. Press **Done** to proceed.

SOURCE CHAN(S)	DEST. CHAN(S)
CH **101** Armature relay MUX Channel	CH **106**
CH **104** Armature relay MUX Channel	CH 109
4 CH SELECTED	**4** CH SELECTED

4. Press **Copy Now**. The measurement configuration from channels 01 through 04 will copy to channels 05 through 08. "4 of 4 Channels Copied" message will prompt out when the operation is completed. Press **Copy Now** to repeatedly copy the same configuration to the new selected channels (channels 09 through 11, and so on).

[Alarm] Menu

Press **[Alarm]** key on the front panel to configure alarm on the selected channel. There are four configurable alarms in this instrument. You must configure the channel before setting any alarm limits. If you change the measurement configuration, alarms are turned off and the limit values are cleared. If you plan to use scaling function on a channel which will also use alarms, be sure to configure the scaling values first.

Configuring alarm limits on multiplexer module

1. In Alarm menu page, press **Output** to select which of the four alarms will be used to report alarm conditions on the selected channel. You can assign multiple channels to any of the four available alarms (numbered 1 through 4).
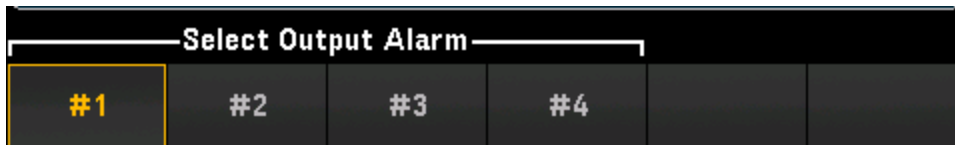
2. Press **Alarm** to disable (Off) or specify an alarm limit (high, low, or both), and then press **Set Limits** to determine the limit value. The instrument will generate an alarm when a scanned or monitor reading exceeds the specified limit.

a. High + Low

To configure, select limits type as **High + Low** and press **Set Limits** to specify the limits as high and low values, or as a center value with a span around the center value.

b. High

To configure, select limits type as **High** and press **Set Limits** to specify upper limit value. The upper limit value must always be greater than or equal to the lower limit.

c. Low

To configure, select limits type as **Low** and press **Set Limits** to specify lower limit value. The lower limit value must always be less than or equal to the upper limit.

3. Press **Clear** to return the limit value to the default value, 0.

4. Press **[Scan]** to initiate the scan and save the readings in reading memory. If an alarm occurs on a channel as it is being scanned, then that channel's alarm status is saved in reading memory as the readings are taken. Each time you start a new scan, the instrument clears all readings (including alarm data) stored in reading memory from the previous scan.

5. As alarms are generated, they are also logged in an alarm queue, which is separated from reading memory. Press [View] > Alarms to display the alarm queue.

Configuring Alarm Limits with the Multifunction Module

You can configure the DAQM907A multifunction module to generate an alarm when a specific bit pattern or bit pattern change is detected on a digital I/O channels (channel 01 and 02) or when a specific count is reached on a totalizer channel (channel 03).

To configure an alarm on a digital I/O channel

1. On a multifunction module slot, press [Alarm] and select the digital I/O channel.

2. Press **Set Pattern** > **Pattern**, and use the knob or the front panel arrow keys to set the digital mask data for 8-bit digital pattern comparison.

3. Sets each bit to "0", "1", or "X" by pressing the **Set to all 0's**, **Set to all 1's**, or **Set to all X's** softkeys. Bits set to "X" are excluded from the digital pattern comparison.

4. Press **Fail On** to configure the selected channel to generate an alarm when a specific 8-bit pattern read is equal or not equal to the digital data read.

To configure an alarm on a totalizer channel

1. On a multifunction module slot, press [Alarm] and select the totalizer channel.

2. Press **Set Limits** > **Limit Count** to specify the limit count. An alarm will be generated when a specific count is reached during scanning.

Alarm Limit Indications

The display uses colors to indicate limits and limit violations.

Number

The bright red color (shown below) indicates that the displayed measurement exceeds the limits.

Bar Meter

The bar meter (below) uses the same color scheme. The following example shows a limit violation. The word **FAIL** indicates that a limit has been exceeded.
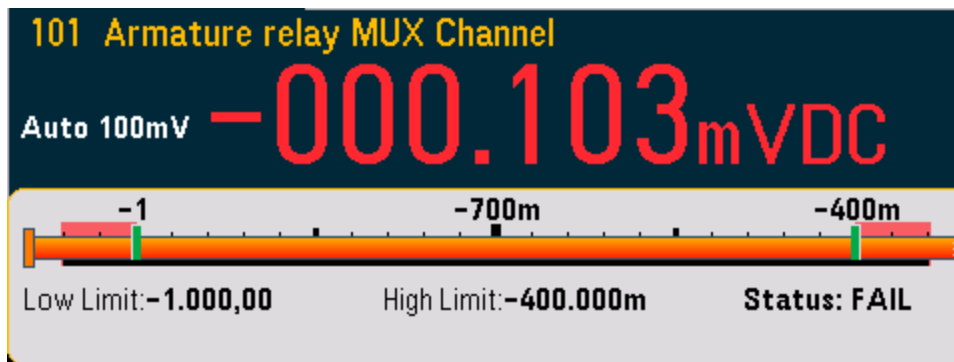
Trend Chart

The trend chart (below) uses the same color scheme. The following example shows a limit violation.
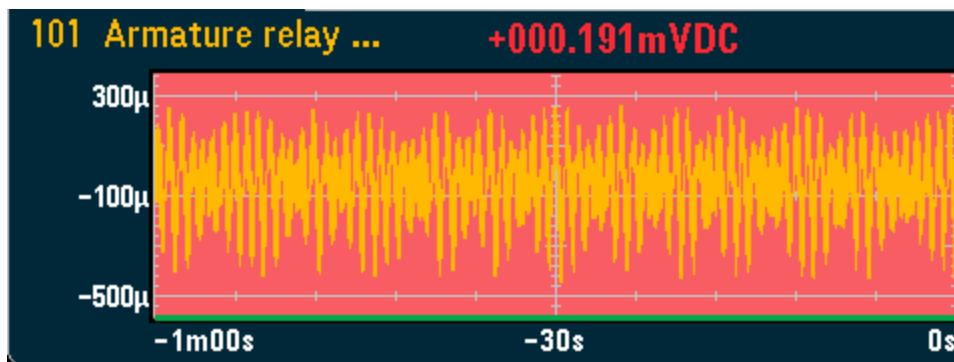
Histogram

The histogram (below) uses the same color scheme. The following example shows a limit violation.

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[Utility] Menu
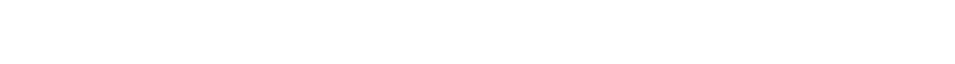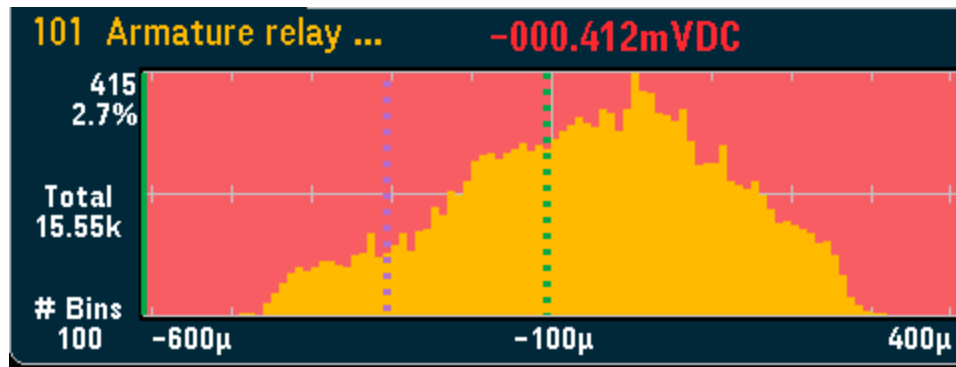
Self-test

Autocalibration (Internal DMM and DAQM907A Module Only)

Calibration

Instrument security (NISPOM)

Admin - Firmware update

Self-Test

Self-test verifies proper instrument operation. See Keysight DAQ970A Service Guide for details about the self-test procedures.
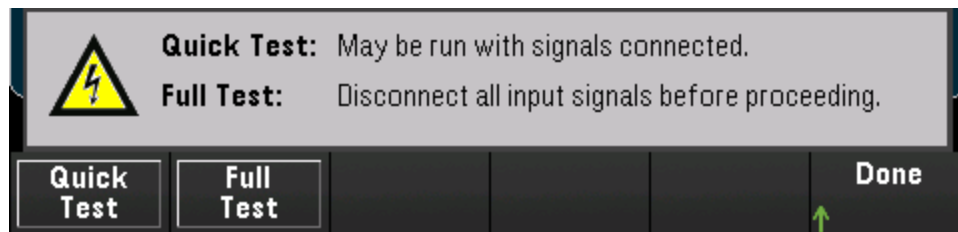
Autocalibration

Autocalibration compensates for internal drifts in the internal DMM or on DAQ970A modules caused by time and temperature change. This can help to eliminate the errors to achieve a better performance. In this DAQ970A, autocalibration is performed on the internal DMM and on the DAC output and sense channels (channels 04 through 07) on the DAQM907A multifunction module.

Autocalibration takes just a few seconds to complete. To start the autocalibration immediately, press **Perform Autocal** softkey and below screen will display:
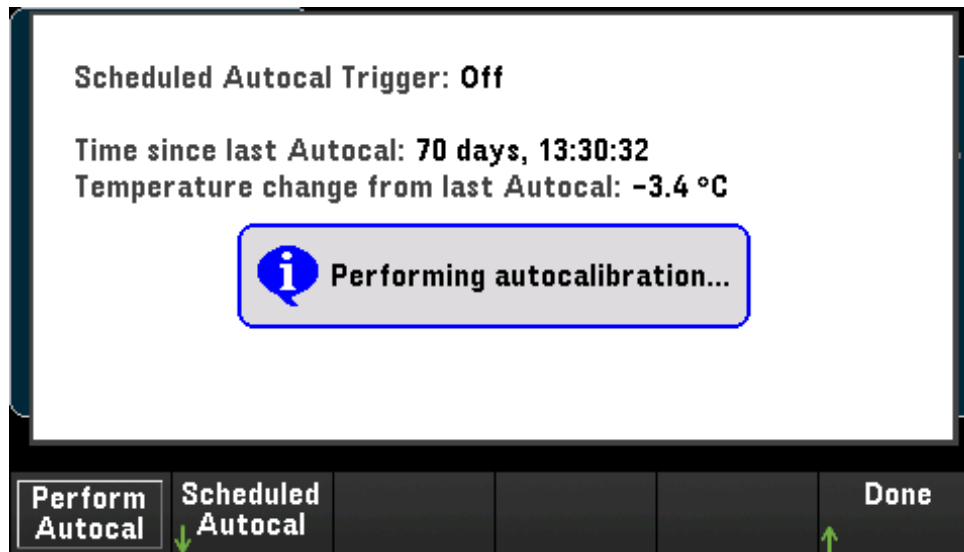
Schedule Autocalibration

You can also schedule the instrument to perform autocalibration automatically based on the selected interval. To use this feature, press **Scheduled Autocal > Schedule > On.** Specify the interval as daily, weekly, or monthly. Use the knob or the front panel arrow keys to select a start time.
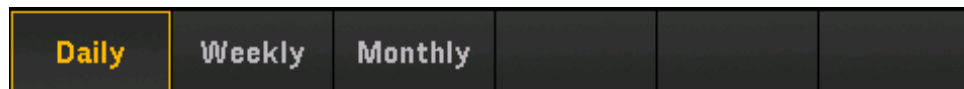
Daily - Schedules the daily autocalibration to start at a specific time (hour and minute) of day.

Weekly - Schedules the weekly autocalibration to start at a specific week day and time (hour and minute) of each week.

Monthly - Schedules the monthly autocalibration to start at a specific day and time (hour and minute) of each month.

Calibrate

Calibrate accesses the instrument calibration procedure. See Keysight DAQ970A Service Guide for further details.
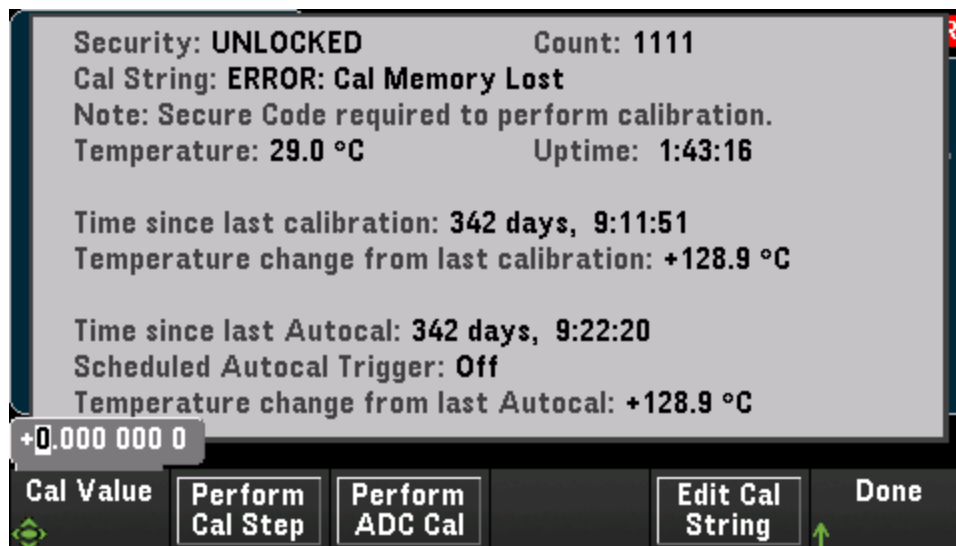
Security

Security shows current instrument security status and enables you to lock or unlock the instrument or enter a new secure code. The instrument must be unlocked to perform calibration, update firmware, or change the secure code.

If Secure Mode is enabled, this shows an overview of instrument I/O settings and provides access to the NISPOM Sanitize function and I/O configuration. The instrument must be unlocked to perform NISPOM Sanitize or to enable or disable I/Os. The Secure Count increments whenever any operation requiring the secure code is performed.

New Code – Press this softkey to enter a new secure code used to unlock instrument security. The code must start with a letter and may have up to 12 letters, digits, or the underscore character.

LOCK – Locks instrument security using the current secure code. Secure code was set to "DAQ970A" at the factory.

Secure - Enables (On) or disables (Off) the instrument security. When On, **NISPOM Sanitize** softkey will appear and security must be unlocked to make changes to I/O enables and configuration.

NISPOM Sanitize sanitizes all user-accessible instrument memory except for the calibration constants and reboots the instrument. This complies with requirements in chapter 8 of the National Industrial Security Program Operating Manual (NISPOM). When Off, I/O changes can be made without unlocking security.

CAUTION	The **NISPOM Sanitize** softkey and the SYSTem:SECurity:IMMEdiate command are equivalent. They are for customers, such as military contractors, who must comply with NISPOM.
	This feature destroys all user-defined state information, measurement data, and user-defined I/O settings such as the IP address. This feature is not recommended for use in routine applications because of the possibility of unintended data loss.

Admin

Press **Firmware Update** to update the instrument firmware to a new version. See Firmware Update details.

[Module] Menu
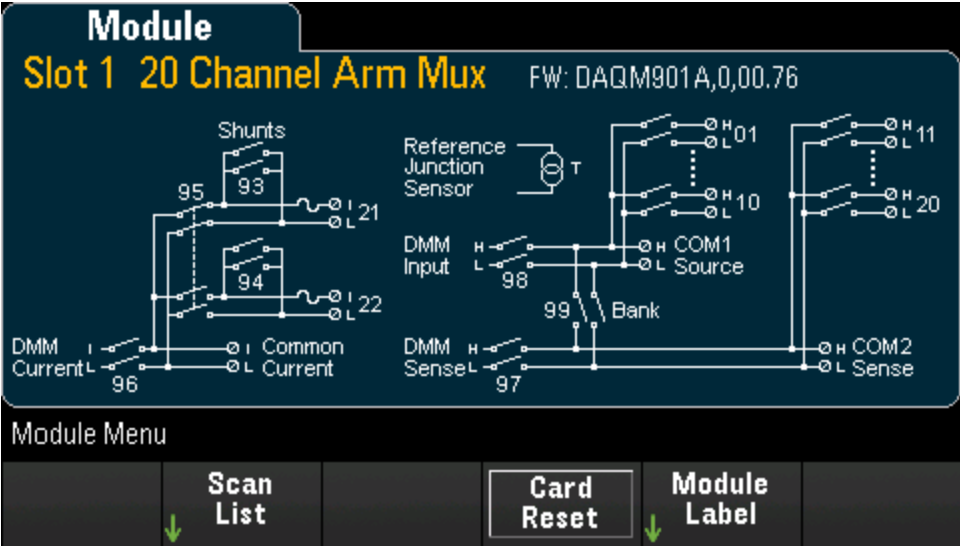
Overview of the scan list for the module

Press **Scan List** softkey to view the available channels on the module are included in the scan list (Scan Status = ON). If the channel list is longer than one page, press the up/down arrow keys to view the other pages. Press **Remove From Scan** softkey to turn off measurements on all channels on the module, and removes the channels from the scan list.

Perform a module reset

Sends a **Card Reset** to the module. This opens all channels on the module. On the multifunction module, this also configures the digital I/O ports as inputs and sets the DAC outputs to voltage mode (if not locked) and the output level to 0.

Module labeling

Press **Module Label** softkey to specify a label for current selected module. Use the knob or the front panel arrow keys to enter the characters into the display. Note that you are only allowed to enter maximum of 10 characters for the module label, including letters, numbers, and special characters. To return into the default module label, press **Module Label** > **Clear All** > **Done**.
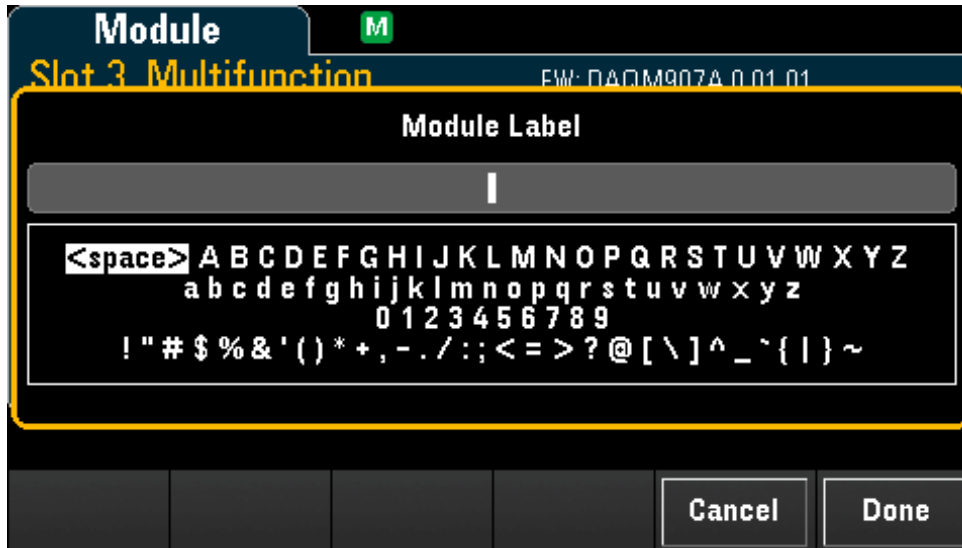
[Save Recall] Menu
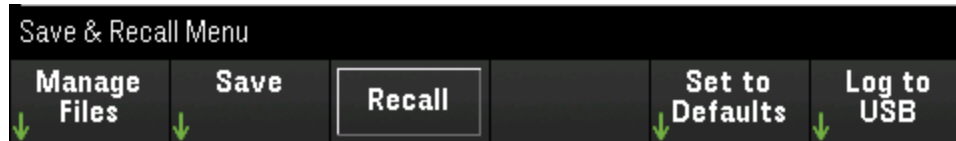
File management

Save state/preferences, readings, and screen captures

Recalls a previously saved state file or preferences file

Return selected settings to their Preset values

Data logging to USB drive on the front panel

Manage Files

The **Manage Files** softkey allows you to create, copy, delete, and rename files and folders in the instrument's internal flash memory or on a USB drive attached to the front panel. This is the default option, as shown below.

Action

Browse

Copy Path

Perform Copy

Action

Action specifies the file or folder action to perform.

Delete – To delete a file or folder, press **Delete** and **Browse** to the file or folder to be deleted. Press **Select** > **Perform Delete** > **Done**.

Folder – To create a folder, press **Folder** and **Browse** to the internal or external location for the folder, press **File Name**, enter a folder name and press **Done**. Press **Create Folder** > **Done**.

Copy – To copy a file or folder, press **Copy**. **Browse** to the file or folder to be copied and press **Select**. Press **Copy Path** and select an internal or external path for copying. Press **Perform Copy** > **Done**.

Rename – To rename a file or folder, press **Rename**. **Browse** to the file or folder to be renamed and press **Select**. Press **New Name**, enter a new name and press **Done**. Press **Perform Rename** > **Done**.

Browse

Browse selects the file or folder upon which the action will be performed.
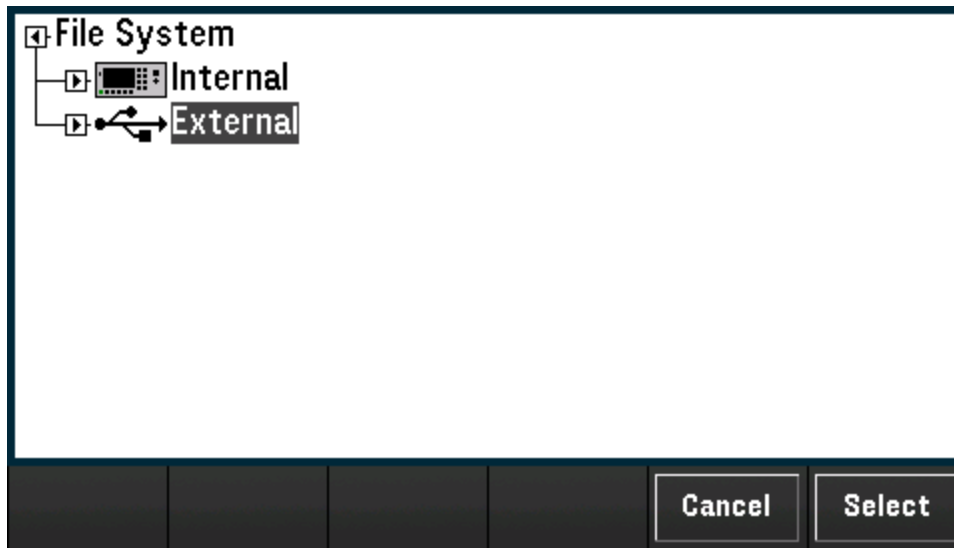
Use the knob, front panel arrow keys, and **[Select]** to navigate through the list, and press **Select** or **Cancel** to exit the browse window. The left and right arrow keys contract or expand a folder to hide or show its files.

Copy Path

Copy Path selects an internal or external folder path for copying.
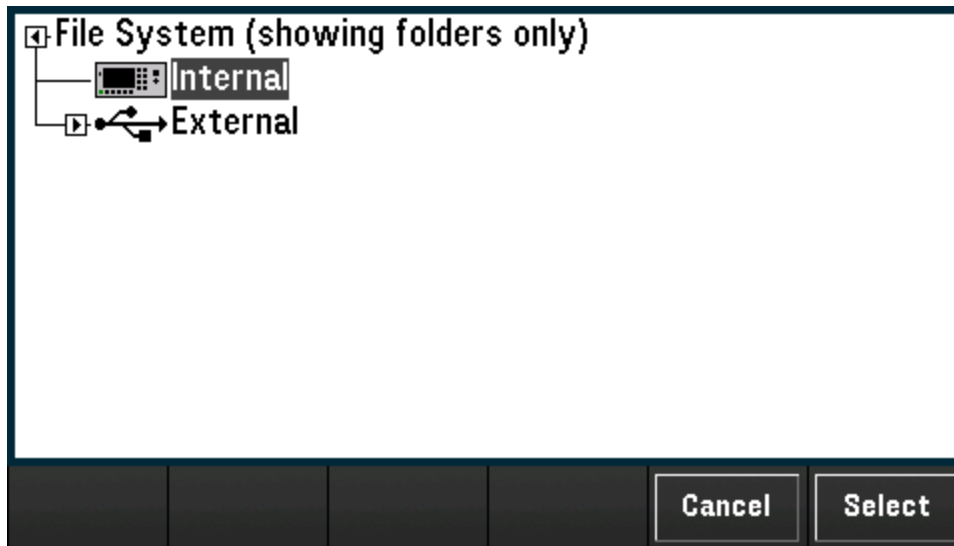
Use the knob, front panel arrow keys, and **[Select]** to navigate through the list, and press **Select** or **Cancel** to exit the browse window. The left and right arrow keys contract or expand a folder.

Perform Copy

Perform Copy copies the selected file or folder to its new location.

[Channel] Menu Overview

Save

The **Save** softkey allows you to creates folders and files for saving instrument state or user preferences. Also allows you capture and save a screen image.

Action

Selects the folder or file action to be performed.

State – Saves the current instrument state. State files may have any name, but always have the .sta extension. Instrument states saved by the SCPI (*SAV command) are saved in file names STATE_0.sta through STATE_4.sta.

To save, press **State** and **Browse** to the internal or external location for the folder and press **Select**, press **File Name**, enter a file name and press **Done**. Selects **State/Preference** to **Save State/Save Preference** on the specified file.

Readings – Saves the readings from the trend chart or histogram.

To save, press **Readings** and **Browse** to the internal or external location for the folder and press **Select**, press **File Name**, enter a file name and press **Done**. Press **Separator** softkey to specify the character (comma, tab, or semicolon) to use for separating the information on each row. When done, press **Save Readings** to save the readings used to create the trend chart or histogram to the specified path and file.

Capture Display – Captures the image on the display.

To save, press **Capture Display** and **Browse** to the internal or external location for the folder and press **Select**, press **File Name**, enter a file name and press **Done**. Selects the file format for captured screen as **.bmp** extension (bitmap file format) or **.png** extension (portable network graphics format), then press **Save Screen** to save the screen in the file and format specified. The content captured is the display state at the time the **[Save Recall]** key was pressed.

Browse

Opens a browser for the internal flash memory and external USB memory.
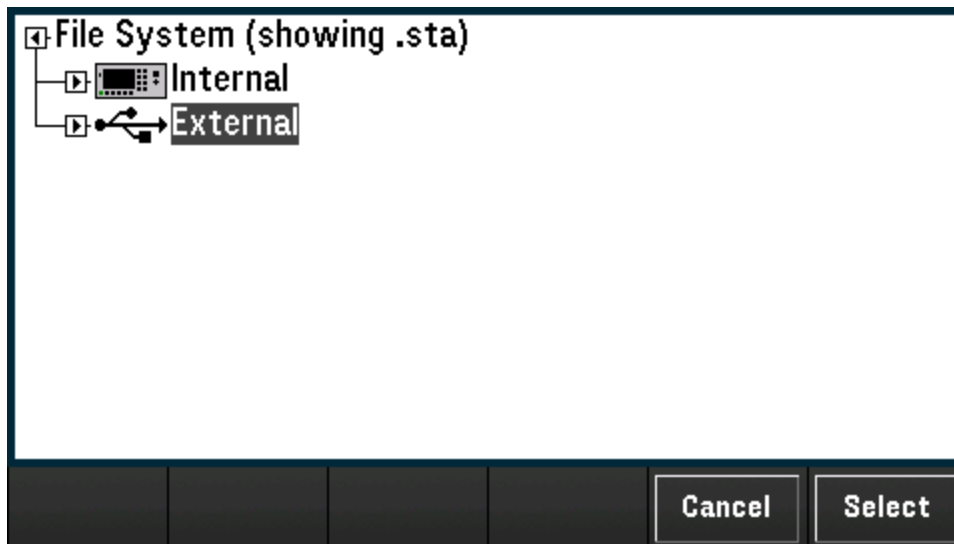
Use the knob or the front panel arrow keys to navigate through the list, and press **Select** or **Cancel** to exit the browse window. The left and right arrow keys contract or expand a folder to hide or show its files.

File Name

Sets the folder or file name for the selected action. To specify a folder or file name, use the knob or the front panel arrow keys to select the desired character. Then press **Select** to go to the next character. When you have finished entering characters, press **Done**.
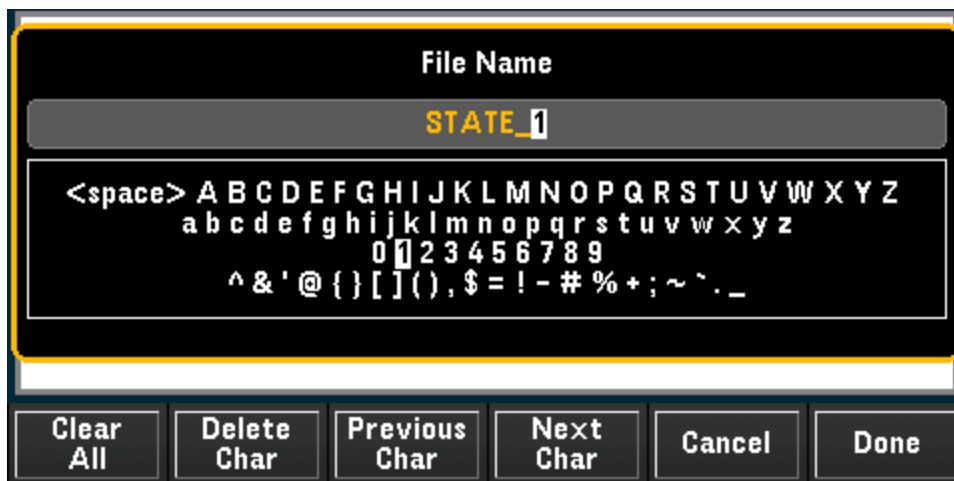
State/Preference

Press **State/Preference** to select whether the settings to be saved are instrument state settings or user preferences. Then press **Save State/Save Preference** on the next softkey to save the current state or user preferences to the selected path and file name, and adds the .sta or .prf extension to the file name.

State - Saves the measurement configuration including channel configurations and scan settings.

Preference - Saves non-volatile settings associated with instrument, including user preferences and I/O settings.
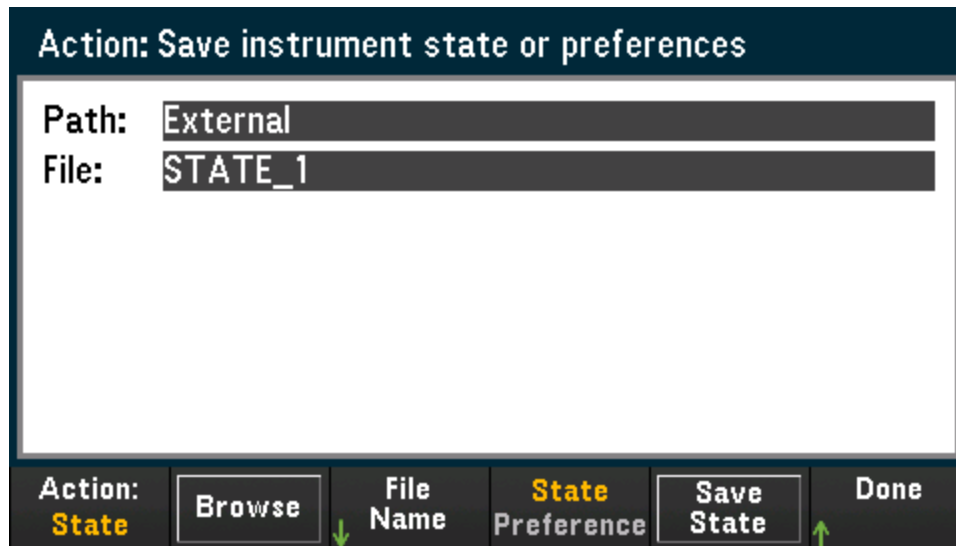
Recall

The **Recall** softkey allows you to recall a previously saved state file (.sta extension) or preference file (.prf extension). Use the knob or the front panel arrow keys to browse to a file on internal flash memory (Internal) or the USB drive (External). Use the right arrow key to expand a folder. Press **Select** to recall the selected file.
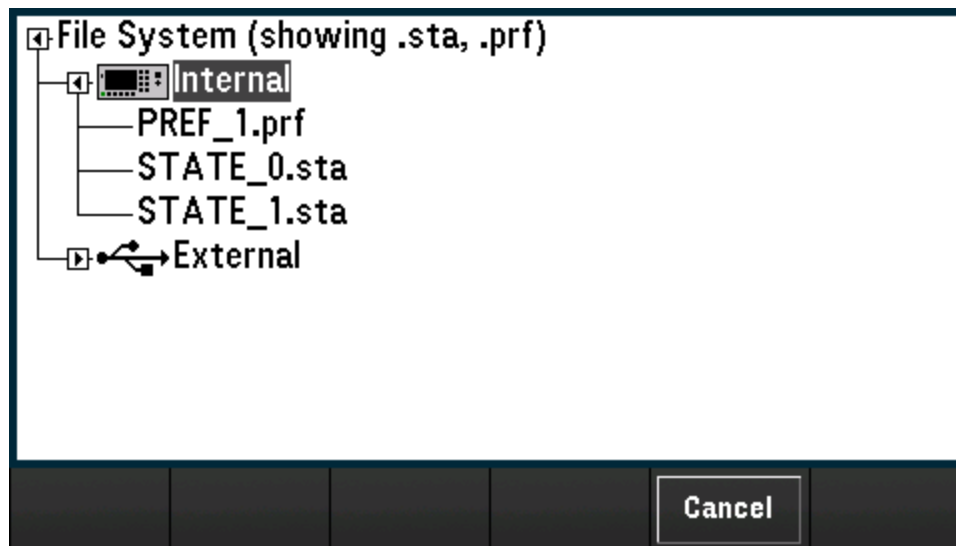
Set to Defaults

The **Set to Defaults** softkey allows you to return the selected settings to their Factory Reset and Preset values.
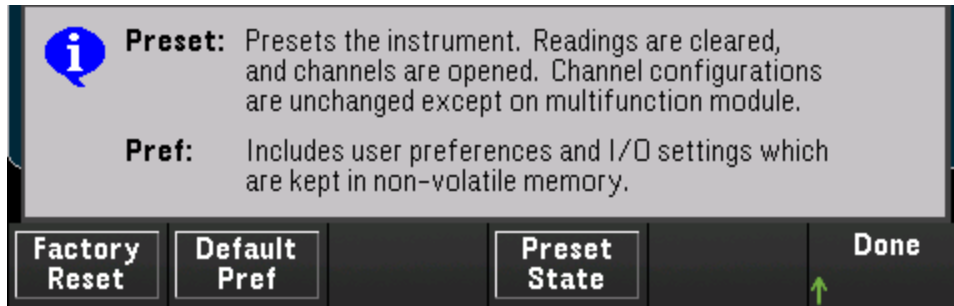
Factory Reset

Resets the instrument to the factory configuration. This softkey will not affect any previously-saved instrument states or I/O settings, such as IP address.

Log to USB

The **Log to USB** softkey allows you to log scanned memory readings to a USB drive connected to the front panel USB host port. The USB annunciator is displayed whenever a USB drive is connected.

Logging On/Off - Enables (**On**) or disables (**Off**) logging of the scanned memory readings to a USB drive connected to the front panel USB host port. When USB data logging is enabled, readings are saved to files in the USB drive. However, the readings will not be restored to reading memory after power is cycled.

 # Rows - Specifies the row limit (maximum number of rows for sweep data) that will be written to each data logging file. You may choose from three options: **65k** (the limit of each data logging file is 65,536 rows per file), **1M** (the limit of each data logging file is 1,048,576 rows per file), or **Infinite** (the limit is the number of bytes allowed by the file system - up to 4 GBytes or available storage space.)

Separator - Specifies the character (**Comma**, **Tab**, or **Semicolon**) to use for separating the information on each row.

Folder and File Structure

Folder Description

Each saved scan will be stored in a top-level folder named:

/DAQ970A/[instrument_SN]/[yyyymmdd_hhmmssmmm]

The square brackets ([ ]) are not actually part of the directory name, and the yyyymmdd_hhmmssmmm is a timestamp indicating the approximate start of the scan. The format is year (yyyy), month (mm), day (dd), underscore (_), hours (hh), minutes (mm), seconds (ss), and milliseconds (mmm).

For example, the folder named:

[Channel] Menu Overview

/DAQ970A/MY00012345/20181127_134523123

would indicate a scan on instrument number MY00012345 that started approximately 23.123 seconds after 1:45 pm (13:45) on November 27, 2018.

File Descriptions

The top level folder described above will contain two types of files. The first is a file named as follows:

config.csv

This is a text file that documents the instrument configuration for this scan. The timestamp is as described above. This file lists the configuration of the instrument in a human readable form.

In addition to the config.csv file, you will have one or more data files named as follows:

dat#####.csv

If you use the command MMEMory:FORMat:READing:RLIMit OFF, all of the data will be stored in one file, named dat00001.csv.

You can issue the command MMEMory:FORMat:READing:RLIMit ON to limit the data to 64K - 1 (65,535) sweeps per file, in which case the sweeps are stored in multiple files, named dat00001.csv, dat00002.csv, dat00003.csv, and so on. This is helpful for importing data into spreadsheet or other data analysis software. Note that some spreadsheet or data analysis software may import the data more easily if you change the extension from csv to txt. If your software does not import the file correctly, try changing the extension on the data file.

Contents of Data Files

Logging into data files is only supported for channels that are in the scan list. The possible channels are shown in the table below; note that s stands for the slot number, which is 1, 2, or 3.

For example, the DAQM901A module supports could have channels 101–120, 201–220, or 301–320.

Module	Description	Channels
DAQM900A	20-channel FET multiplexer	s01-s20
DAQM901A	20-channel, 2-wire armature multiplexer	s01-s20
DAQM902A	16-channel, 2-wire reed multiplexer	s01-s16
DAQM907A	2-channel DIO input	s01-s02
DAQM907A	1-channel totalizer, 4-channel DAC	s03, s04-s07
DAQM908A	40-channel, 1-wire armature multiplexer	s01-s40

The format for all USB data files is similar to what Keysight BenchLink Data Logger produces by default. The default field separator is a comma, but you can use the **Seperator** softkey to specify a different separator.

A sample file is shown below.

Sweep #	Time	Chan 201 (VDC)	Chan 202 (VDC)
1	11/27/2018 08:07:12:237	0.36823663	1.23895216

Sweep #	Time	Chan 201 (VDC)	Chan 202 (VDC)
2	11/27/2018 08:07:13:237	0.62819233	0.98372939
3	11/27/2018 08:07:14:237	0.38238212	0.39382906
4	11/27/2018 08:07:15:237	0.46773299	0.55543345
5	11/27/2018 08:07:16:237	1.32323567	0.21213335

- The channel numbers and the associated units are shown in the header row.
- If the row limit feature is ON and the data spills over into multiple files, scan numbering continues where it left off in the previous file. Thus, the first scan in the second data file would be number 65,536, the first scan in the third data file would be number 131,071, and so on.

Web Interface

The Keysight DAQ970A Data Acquisition System include a built-in Web Interface for monitoring and controlling the instrument via a Web browser.

Two available options to access the Web Interface:

- **LAN Interface:** Connect your instrument to the LAN interface and enter the instrument's IP address into the address bar at the top of your PC's Web browser.

- **Keysight IO Libraries Suite:** Select the instrument in Connection Expert and click the Web UI button. Ensure that the Keysight IO Libraries Suite is installed before you proceed for the remote interface configuration.

NOTE The following is a high-level overview of the Web Interface tabs shown on top of the Web Interface window. When using the Web Interface, open a particular tab, and then click the help button (?) to view help contents for that tab.

Home page

The Home Page displays basic instrument information. Click **More Information** or **Less Information** to toggle display of LAN details and LXI compliance information. To change any of the information displayed on this page, use the Control Instrument Page .

Check the "Enable front panel identification indicator" checkbox to enable a visual indicator that identifies the DAQ970A. This can help you physically locate the instrument in a rack, for example.

The indicator position and type can vary. Common indicators are LEDs, an onscreen message, or a message displayed in a dialog box.

Uncheck the checkbox to turn off the indicator.

Control Instrument page

Configure LAN page
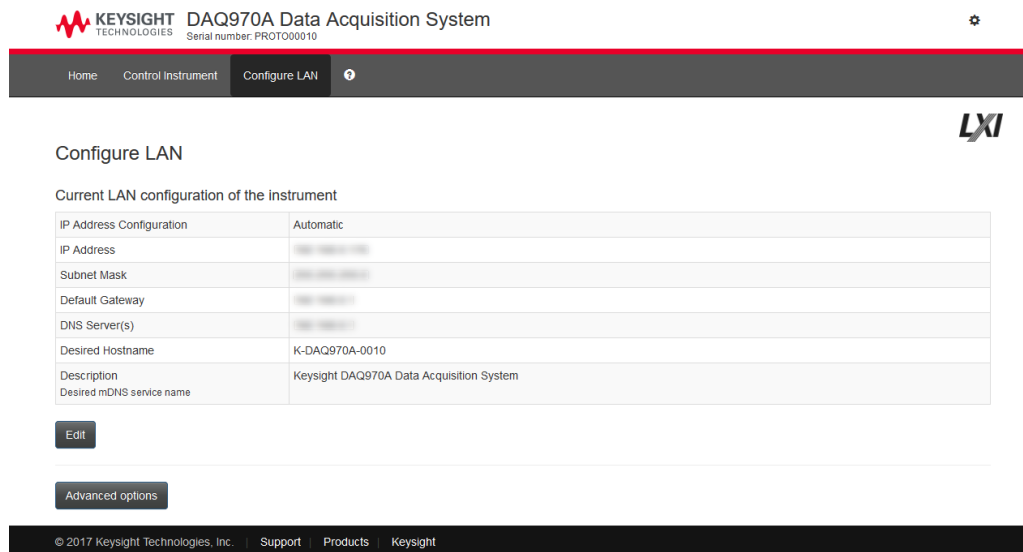
Click **Edit** button to edit network configuration page. When done, click **Apply Changes** to accept new settings or click **Cancel** to ignore changes.

Click **Advanced options** button to reset network configuration options.

Help page

Help is available for each of the tabs described above. For example:

[Channel] Menu Overview

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Module Overview

This section gives a description of each plug-in module, including simplified schematics and block diagrams. A wiring log is also included to make it easy to document your wiring configuration for each module.

DAQM900A 20-Channel FET Multiplexer Module

DAQM901A 20-Channel Armature Multiplexer Module

DAQM902A 16-Channel Reed Multiplexer Module

DAQM903A 20-Channel Actuator/General-Purpose Switch Module

DAQM904A 4x8 Two-Wire Matrix Switch Module

DAQM905A Dual 1:4 RF Multiplexer (50 Ω) Module

DAQM907A Multifunction Module

DAQM908A 40-Channel Single-ended Multiplexer Module

DAQM900A 20-Channel FET Multiplexer Module

This module is divided into two banks of 10 two-wire channels each. All 20 channels switch both HI and LO inputs, thus providing fully isolated inputs to the internal DMM or an external instrument. During 4-wire resistance measurements, channels from Bank A (channel n) are automatically paired with channels from Bank B (channel n+10) to provide the source and sense connections. The module has a built-in thermocouple reference junction to minimize errors due to thermal gradients when measuring thermocouples.

WARNING — TO PREVENT ELECTRICAL SHOCK

To prevent electrical shock, use only wire that is rated for the highest voltage to any channel. Before removing a module cover, turn off all power to external devices connected to the module.

CAUTION WITH MULTIPLE SIGNALS

To avoid the possibility of multiple signal sources becoming connected together, we recommend when multiplexing two or more sources they should be connected on separate modules or on separate banks of the same module.

CAUTION WITH HAZARDOUS VOLTAGES

When any channel is connected to a hazardous voltage source, all channels in the module should be treated as hazardous and all channel wiring in the module should be rated for the maximum voltage applied. Thermocouples attached to any other channel on the module should have insulation rated for the maximum voltage, or have additional insulation added rated for the maximum voltage and should be isolated from conductive parts using a thermal compound or tape rated for the maximum voltage applied. Do not mount, move, or remove any thermocouples when the device under test is connected to a supply source.

ENVIRONMENTAL HEALTH AND 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.

DAQM901A 20-Channel Armature Multiplexer Module

This module is divided into two banks of 10 two-wire channels each. Two additional fused channels are available on the module (total in 22 channels) for making direct, calibrated DC or AC current measurements with the internal DMM (external shunts resistors are not required). All 22 channels switch both HI and LO inputs, thus providing fully isolated inputs to the internal DMM or an external instrument. During 4-wire resistance measurements, channels from Bank A (channel n) are automatically paired with channels from Bank B (channel n+10) to provide the source and sense connections. The module has a built-in thermocouple reference junction to minimize errors due to thermal gradients when measuring thermocouples.
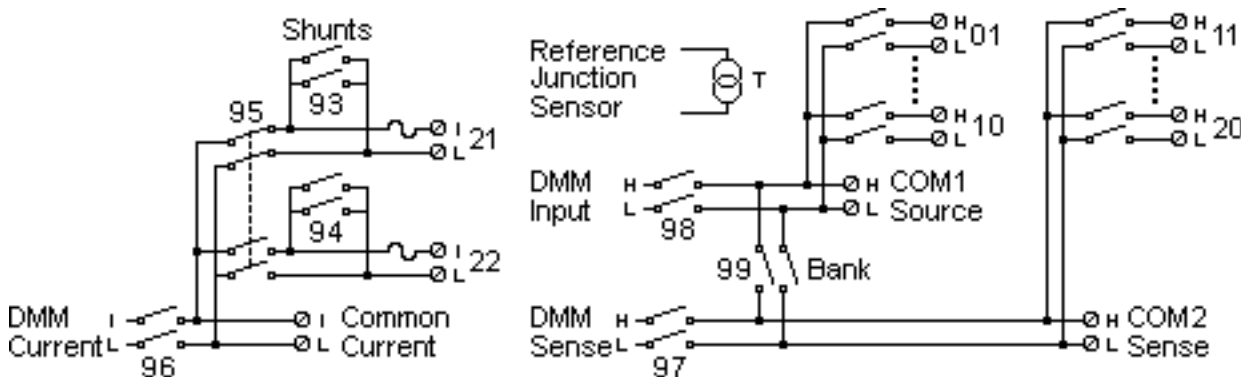
NOTE Only one of channels 21 and 22 can be connected to the internal DMM and/or COM at a time; connecting one channel will close the other (thus shorting the input "I" to "LO").

WARNING TO PREVENT ELECTRICAL SHOCK
To prevent electrical shock, use only wire that is rated for the highest voltage to any channel. Before removing a module cover, turn off all power to external devices connected to the module.

CAUTION WITH MULTIPLE SIGNALS
 To avoid the possibility of multiple signal sources becoming connected together, we recommend when multiplexing two or more sources they should be connected on separate modules or on separate banks of the same module.

CAUTION WITH HAZARDOUS VOLTAGES
When any channel is connected to a hazardous voltage source, all channels in the module should be treated as hazardous and all channel wiring in the module should be rated for the maximum voltage applied. Thermocouples attached to any other channel on the module should have insulation rated for the maximum voltage, or have additional insulation added rated for the maximum voltage and should be isolated from conductive parts using a thermal compound or tape rated for the maximum voltage applied. Do not mount, move, or remove any thermocouples when the device under test is connected to a supply source.

ENVIRONMENTAL HEALTH AND 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.

DAQM902A 16-Channel Reed Multiplexer Module

This module is divided into two banks of 8 two-wire channels each. Use this module for those applications that require high-speed scanning and high-throughput in automated test. All 16 channels switch both HI and LO inputs, thus providing fully isolated inputs to the internal DMM or an external instrument. During 4-wire resistance measurements, channels from Bank A (channel n) are automatically paired with channels from Bank B (channel n+8) to provide the source and sense connections The module has a built-in thermocouple reference junction to minimize errors due to thermal gradients when measuring thermocouples.

| **NOTE** | Current measurements on this module will require external shunt resistors. |

| **WARNING** | **TO PREVENT ELECTRICAL SHOCK**
To prevent electrical shock, use only wire that is rated for the highest voltage to any channel. Before removing a module cover, turn off all power to external devices connected to the module. |

CAUTION WITH MULTIPLE SIGNALS

To avoid the possibility of multiple signal sources becoming connected together, we recommend when multiplexing two or more sources they should be connected on separate modules or on separate banks of the same module.

CAUTION WITH HAZARDOUS VOLTAGES

When any channel is connected to a hazardous voltage source, all channels in the module should be treated as hazardous and all channel wiring in the module should be rated for the maximum voltage applied. Thermocouples attached to any other channel on the module should have insulation rated for the maximum voltage, or have additional insulation added rated for the maximum voltage and should be isolated from conductive parts using a thermal compound or tape rated for the maximum voltage applied. Do not mount, move, or remove any thermocouples when the device under test is connected to a supply source.

ENVIRONMENTAL HEALTH AND 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.

DAQM903A 20-Channel Actuator/General-Purpose Switch Module

This module contains 20 independent, and SPDT (Form C) latching relays. This module can switch 300 V, 1 A (50 W maximum switch power) to your device under test or to actuate external devices. Screw terminals on the module provide access to the Normally-Open, Normally-Closed, and Common contacts for each of the 20 switches. This module does not connect to the internal DMM. Use this module for those applications that require high-integrity contacts or quality connections of non-multiplexed signals.

A breadboard area is provided near the screw terminals to implement custom circuitry, such as simple filters, snubbers, and voltage dividers. The breadboard area provides the space necessary to insert your own components but there are no circuit board traces here. You must add your own circuitry and signal routing.
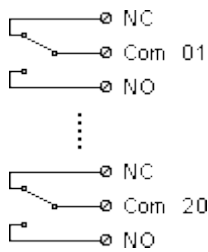
NOTE You can close multiple channels at the same time on this module.

The channel CLOSE and OPEN commands control the state of the Normally Open (NO) to COM connection on each channel. For example, CLOSE 201 connects the Normally Open contact to COM on channel 01.

WARNING TO PREVENT ELECTRICAL SHOCK
To prevent electrical shock, use only wire that is rated for the highest voltage to any channel. Before removing a module cover, turn off all power to external devices connected to the module.

CAUTION WITH MULTIPLE SIGNALS
 To avoid the possibility of multiple signal sources becoming connected together, we recommend when multiplexing two or more sources they should be connected on separate modules or on separate banks of the same module.
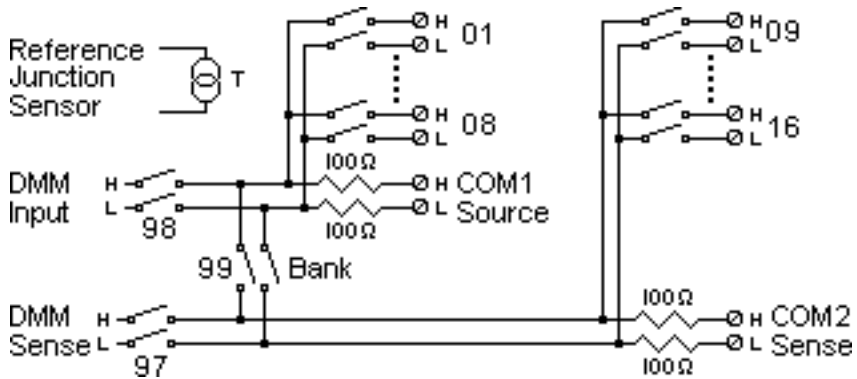
CAUTION WITH HAZARDOUS VOLTAGES
When any channel is connected to a hazardous voltage source, all channels in the module should be treated as hazardous and all channel wiring in the module should be rated for the maximum voltage applied. Thermocouples attached to any other channel on the module should have insulation rated for the maximum voltage, or have additional insulation added rated for the maximum voltage and should be isolated from conductive parts using a thermal compound or tape rated for the maximum voltage applied. Do not mount, move, or remove any thermocouples when the device under test is connected to a supply source.

ENVIRONMENTAL HEALTH AND 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.

DAQM904A 4x8 Two-Wire Matrix Switch

This module contains 32 two-wire crosspoints organized in a 4-row by 8-column configuration. You can connect rows and columns between multiple modules to build larger matrices such as 8×8 and 4×16, with up to 96 crosspoints in a single mainframe. Use this module to connect multiple instruments to multiple points, or any combination of inputs and outputs on your device under test at the same time.

This module does not connect to the internal DMM. Each crosspoint relay has its own unique channel label representing the row and column. For example, channel 32 represents the crosspoint connection between row 3 and column 2 as shown below:
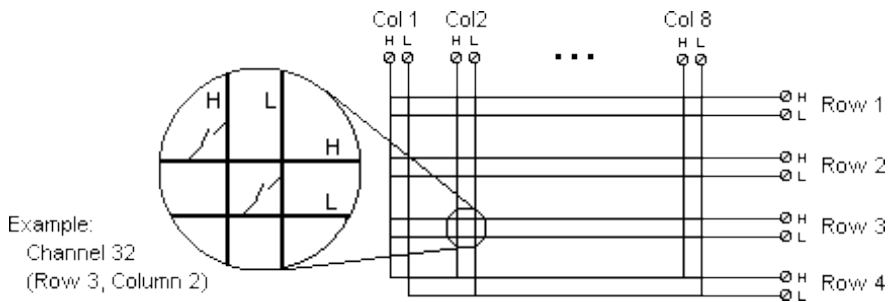
| NOTE | You can close multiple channels at the same time on this module. |

WARNING   TO PREVENT ELECTRICAL SHOCK
To prevent electrical shock, use only wire that is rated for the highest voltage to any channel. Before removing a module cover, turn off all power to external devices connected to the module.

CAUTION WITH MULTIPLE SIGNALS
 To avoid the possibility of multiple signal sources becoming connected together, we recommend when multiplexing two or more sources they should be connected on separate modules or on separate banks of the same module.

CAUTION WITH HAZARDOUS VOLTAGES
When any channel is connected to a hazardous voltage source, all channels in the module should be treated as hazardous and all channel wiring in the module should be rated for the maximum voltage applied. Thermocouples attached to any other channel on the module should have insulation rated for the maximum voltage, or have additional insulation added rated for the maximum voltage and should be isolated from conductive parts using a thermal compound or tape rated for the maximum voltage applied. Do not mount, move, or remove any thermocouples when the device under test is connected to a supply source.

ENVIRONMENTAL HEALTH AND 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.

DAQM905A Dual 1:4 RF Multiplexer (50 Ω) Module

These modules consist of two independent banks of 4-to-1 multiplexers, which offer wideband switching capabilities for high frequency and pulsed signals. The channels in each bank are organized in a "tree" structure to provide high isolation and low VSWR. Both modules have a common earth ground, offer low crosstalk and excellent insertion loss performance. To create larger RF multiplexers, you can cascade multiple banks together.

This module does not connect to the internal DMM. You can connect your signals directly to the on-board SMB connectors or to the SMB-to-BNC cables provided with the module.
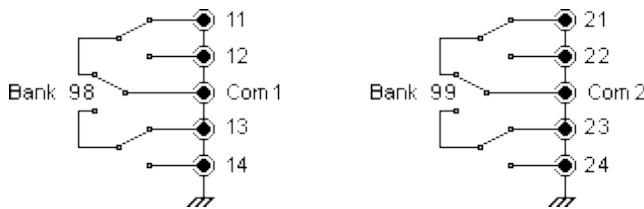
NOTE You can close only one channel per bank at a time on these modules; closing one channel in a bank will open the previously closed channel. One channel in each bank is always connected to COM.

This module responds only to the CLOSE command (OPEN does not apply). To OPEN a channel, send the CLOSE command to another channel in the same bank.

WARNING TO PREVENT ELECTRICAL SHOCK
To prevent electrical shock, use only wire that is rated for the highest voltage to any channel. Before removing a module cover, turn off all power to external devices connected to the module.

CAUTION WITH MULTIPLE SIGNALS
 To avoid the possibility of multiple signal sources becoming connected together, we recommend when multiplexing two or more sources they should be connected on separate modules or on separate banks of the same module.

CAUTION WITH HAZARDOUS VOLTAGES
When any channel is connected to a hazardous voltage source, all channels in the module should be treated as hazardous and all channel wiring in the module should be rated for the maximum voltage applied. Thermocouples attached to any other channel on the module should have insulation rated for the maximum voltage, or have additional insulation added rated for the maximum voltage and should be isolated from conductive parts using a thermal compound or tape rated for the maximum voltage applied. Do not mount, move, or remove any thermocouples when the device under test is connected to a supply source.

ENVIRONMENTAL HEALTH AND 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.

DAQM907A multifunction module

This module combines two 8-bit ports of digital input/output, a 100 kHz totalizer, and two ±12 V analog outputs (DAC). For greater flexibility, you can read digital inputs and the totalizer count during a scan. Use this module to sense status and control external devices such as solenoids, power relays, and microwave switches.

Digital Input/Output (DIO)
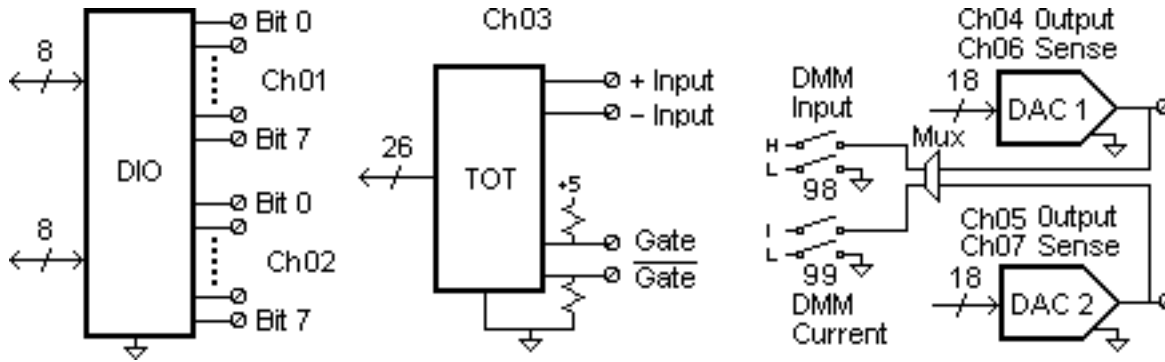
The DIO consists of two 8-bit ports with TTL-compatible inputs and output. The open-drain outputs can sink up to 400 mA. From the front panel, you can read data from only one 8-bit input port at a time. From the remote interface, you can read both ports simultaneously as a 16- bit word only if neither port is in the scan list.

Totalize Input
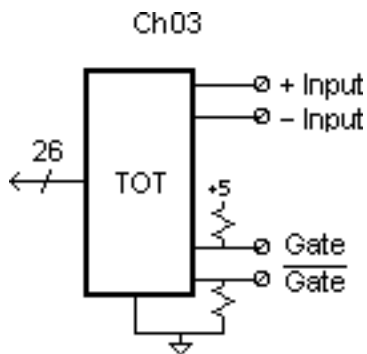
The 26-bit totalizer can count pulses at a 100 kHz rate. You can configure the totalizer to count on the rising edge or falling edge of the input signal. A TTL high signal applied to the "G" terminal enables counting and a low signal disables counting. A TTL-compatible low signal applied to the "$\overline{G}$" terminal enables counting and a high signal disables counting. The totalizer only counts when both terminals are enabled. Move the Totalize Threshold jumper to the "AC" position to detect changes through 0 V. Move the jumper to the "TTL" position (factory setting) to detect changes through TTL threshold levels.

Analog Output (DAC) Output and Sense
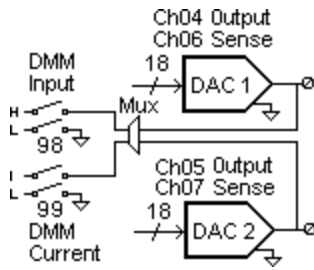
The two analog outputs (channel 04 and 05) and senses (channel 06 and 07) are capable of outputting cal-ibrated voltages or currents with 18 bits of resolution. You must limit the DAC output current to 40 mA total for each slot (two DAC channels). Table below shows the output values of DAC in current mode and voltage mode:

Mode	Current	Voltage
Current mode	± 24 mA	± 12 V
Voltage mode	± 15 mA	± 12 V

WARNING TO PREVENT ELECTRICAL SHOCK
To prevent electrical shock, use only wire that is rated for the highest voltage to any channel. Before removing a module cover, turn off all power to external devices connected to the module.

DAQM908A 40-channel single-ended multiplexer

The module is divided into two banks of 20 channels each. All of the 40 channels switch HI only, with a common LO for the module. Use this module for high-density switching applications which require single-wire inputs with a common LO.
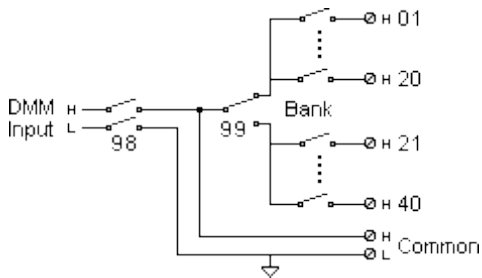
NOTE	Only one channel can be closed at a time, closing one channel will open the previously closed channel.

This module cannot be used to directly measure current or any 4-wire measurements.

WARNING	TO PREVENT ELECTRICAL SHOCK To prevent electrical shock, use only wire that is rated for the highest voltage to any channel. Before removing a module cover, turn off all power to external devices connected to the module.

CAUTION WITH MULTIPLE SIGNALS
 To avoid the possibility of multiple signal sources becoming connected together, we recommend when multiplexing two or more sources they should be connected on separate modules or on separate banks of the same module.

CAUTION WITH HAZARDOUS VOLTAGES
When any channel is connected to a hazardous voltage source, all channels in the module should be treated as hazardous and all channel wiring in the module should be rated for the maximum voltage applied. Thermistors attached to any other channel on the module should have insulation rated for the maximum voltage, or have additional insulation added rated for the maximum voltage and should be isolated from conductive parts using a thermal compound or tape rated for the maximum voltage applied. Do not mount, move, or remove any thermistors when the device under test is connected to a supply source.

ENVIRONMENTAL HEALTH AND 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.

4   Measurement Tutorials

System Cabling and Connections

Measurement Fundamentals

Low-Level Signal Multiplexing and Switching

Actuators and General-Purpose Switching

Matrix Switching

RF Signal Multiplexing

Multifunction Module

Relay Life and Preventive Maintenance

This chapter describes methods that you can use to reduce errors that can affect your measurements. You will also find information to help you better understand how the DAQ970A makes measurements and what you can do to get the best results.

System Cabling and Connections

This section describes methods to reduce measurement errors that can be introduced by your system cabling. Many system cabling errors can be reduced or eliminated by selecting the proper cable and grounding scheme for your system.

Cable specifications

Grounding techniques

Shielding techniques

Separation of high-level and low-level signals

Sources of system cabling errors

Cable specifications

A wide variety of general-purpose and custom cables are available. The following factors influence the type of cable that you choose.

- Signal requirement - such as voltage, frequency, accuracy, and measurement speed.

- Interconnection requirements - such as wire sizes, cable lengths, and cable routing.

- Maintenance requirements - such as intermediate connectors, cable terminations, strain reliefs, cable lengths, and cable routing.

Cables are specified in a variety of ways. Be sure to check the following specifications for the cable type you intend to use:

- Nominal impedance (insulation resistance) - Varies with the frequency of the input signal. Check for HI-to-LO, channel-to-channel, and HI-or LO-to-shield. High frequency RF applications have exact requirements for cable impedance.

- Dielectric withstand voltage - Must be high enough for your application.

WARNING To prevent electrical shock or equipment damage, insulate all channels to the highest potential in the system. It is recommended that you use a wire with at least 600 V rated insulation.

- Cable resistance - Varies with wire gauge size and cable length. Use the largest gauge wire possible and try to keep the cable lengths as short as possible to minimize the cable resistance. The following table lists typical cable resistance for copper wire of several gauge sizes (the temperature coefficient for copper wire is 0.35% per °C).

AWG	Ω / ft (2 conductors) at 25 °C
14	5 mΩ
16	10 mΩ
18	15 mΩ
20 [1]	20 mΩ
22	30 mΩ
24	50 mΩ

[1] Recommended wire size for the screw terminals on the DAQ970A plug-in modules.

- Cable capacitance - Varies with insulation type, cable length, and cable shielding. Cable should be kept as short as possible to minimize cable capacitance. In some cases, low-capacitance cable can be used.

The table below lists the typical cable specifications.

Cable type	Nominal impedance	Capacitance	Attenuation
Twisted pair	100 Ω at 1 MHz	10 to 20 pF/ft	Up to 1 dB/100 ft at 1 MHz
Shielded twisted pair	100 Ω at 1 MHz	10 to 20 pF/ft	Up to 1 dB/100 ft at 1 MHz
Coaxial	50 Ω or 75 Ω at 100 MHz	15 to 25 pF/ft	Up to 6 dB/100 ft at 100 MHz
Twisted pair ribbon	100 Ω at 1 MHz	15 to 20 pF/ft	Up to 1 dB/100 ft at 1 MHz

Grounding techniques

The purpose of grounding is to avoid ground loops and minimize noise. Most systems should have at least three separate ground returns.

1. One ground for signals. You may also want to provide separate signal grounds between high-level signals, low-level signals, and digital signals.
2. A second ground is used for noisy hardware such as relays, motors, and high-power equipment.
3. A ground is used for noisy hardware such as relays, motors, and high-power equipment.

In general, for frequencies below 1 MHz or for low-level signals, use single-point grounding (see image below). Parallel grounding is superior but it is also more expensive and more difficult to wire. If single-point grounding is adequate, the most critical points (those with the lowest levels and/or the most precise measurement requirements) should be positioned near the primary ground point. For frequencies above 10 MHz, use the separate grounding system. For signals between 1 MHz and 10 MHz, you can use a single-point system if the longest ground return path is kept to less than 1/20 of a wavelength. In all cases, return-path resistance and inductance should be minimized.
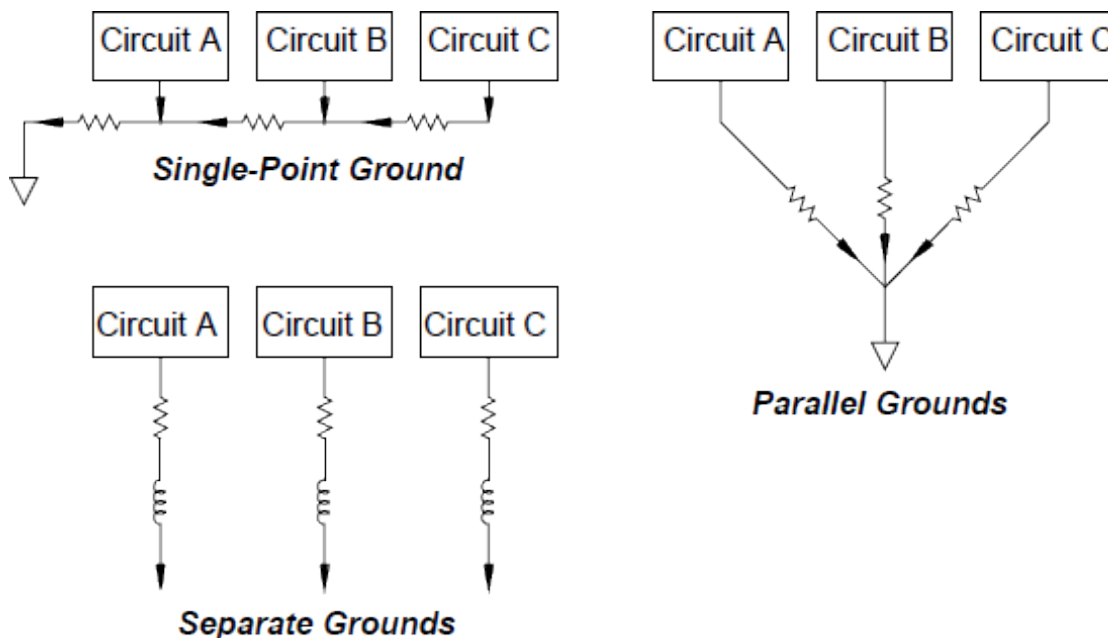
Shielding techniques

Shielding against noise must address both capacitive (electrical) and inductive (magnetic) coupling. The addition of a grounded shield around the conductor is highly effective against capacitive coupling. In switching networks, this shielding often takes the form of coaxial cables and connectors. For frequencies above 100 MHz, double-shielded coaxial cable is recommended to maximum shielding effectiveness.

Reducing loop area is the most effective method to shield against magnetic coupling. Below a few hundred kilohertz, twisted pairs may be used against magnetic coupling. Use shielded twisted pair for immunity from magnetic and capacitive pickup. For maximum protection below 1 MHz, make sure that the shield is not one of the signal conductors.
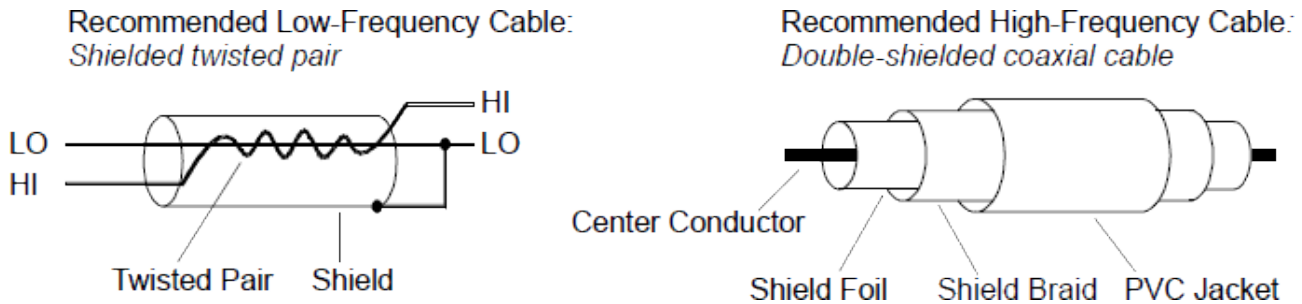
Separation of high-level and low-level signals

Signals whose levels exceed a 20-to-1 ratio should be physically separated as much as possible. The entire signal path should be examined including cabling and adjacent connections. All unused lines should be grounded (or tied to LO) and places between sensitive signal paths. When making your wiring connections to the screw terminals on the module, be sure to wire *like* functions on adjacent channels.

Source of system cabling errors

Radio frequency interference

Most voltage-measuring instruments can generate false readings in the presence of large, high-frequency signals. Possible sources of high-frequency signals include nearby radio and television transmitters, computer monitors, and cellular telephones. High-frequency energy can also be coupled to the internal DMM on the system cabling. To reduce the interference, try to minimize the exposure of the system cabling to high-frequency RF sources.

If your application is extremely sensitive to RF1 radiated from the instrument, use a common mode choke

in the system cabling as shown below to attenuate instrument emissions.
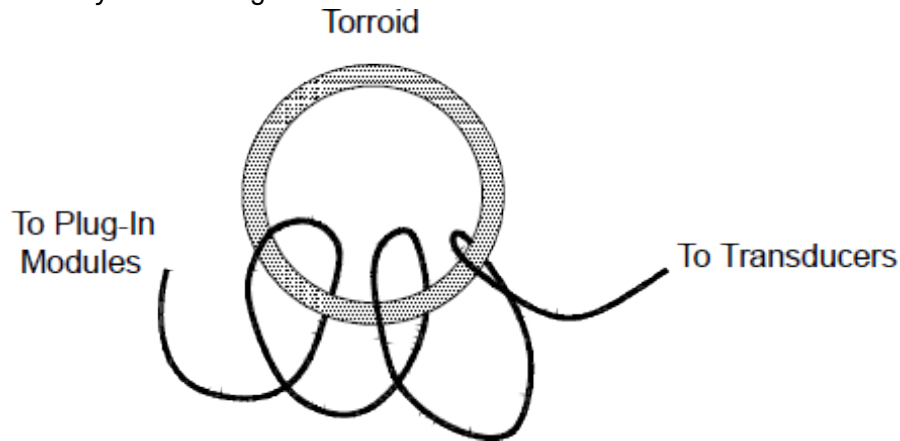
Thermal EMF errors

Thermoelectric voltages are the most common source of error in low-level DC voltage measurements. Thermoelectric voltages are generated when you make circuit connections using dissimilar metals at different temperatures. Each metal-to-metal junction forms a thermocouple, which generates a voltage proportional to the junction temperature difference. You should take the necessary precautions to minimize thermocouple voltages and temperature variations in low-level voltage measurements. The best connections are formed using copper-to-copper crimped connections. The table below shows common thermoelectric voltages for connections between dissimilar metals.

Copper-to-	Approx. μV/°C
Copper	<0.3
Gold	0.5
Silver	0.5
Brass	3
Beryllium Copper	5
Aluminium	5
Kovar or Alloy 42	40
Silicon	500
Copper-Oxide	1000
Cadmium-Tin Solder	0.2
Tim-Lead Solder	5

Noise caused by magnetic fields

If you are making measurements near magnetic fields, you should take precautions to avoid inducing voltages in the measurement connections. Voltage can be induced by either movement of the input connection wiring in a fixed magnetic field or by a varying magnetic field. An unshielded, poorly dressed input wire moving in the earth's magnetic field can generate several millivolts. The varying magnetic field around the AC power line can also induce voltages up to several hundred millivolts. You should be especially careful when working near conductors carrying large currents.

Where possible, you should route cabling away from magnetic fields. Magnetic fields are commonly present around electric motors, generators, televisions, and computer monitors. Also make sure that your input wiring has proper strain relief and is tied down securely when operating near magnetic fields. Use twisted-pair connections to the instrument to reduce the noise pickup loop area, or dress the wires as close together as possible.

Noise caused by ground loops

When measuring voltages in circuits where the internal DMM and the device-under-test are both referenced to a common earth ground, a ground loop is formed. As shown below, any voltage difference between the two ground reference points (V_{ground}) causes a current to flow through the LO measurement lead. This causes an error voltage (V_L) which is added to the measured voltage.
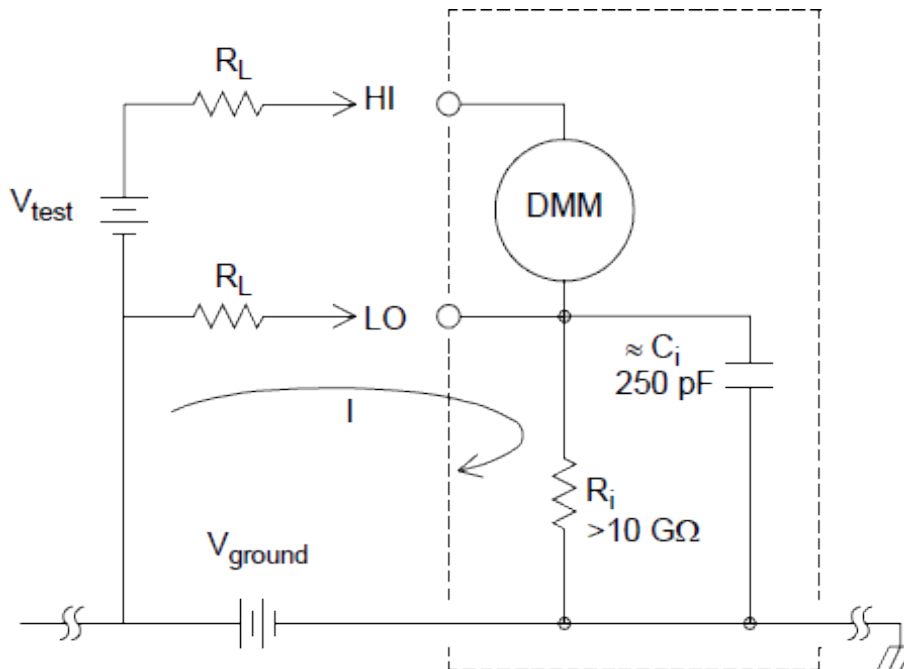
Where:

R_L = Lead resistance
R_i = DMM isolation resistance
C_i = DMM isolation capacitance
V_{ground} = Ground noise voltage

I = Current flow caused by $\mathbf{V_{ground}} = \frac{V_{ground}}{R_L + Z}$

$$\mathbf{Z \approx Z_{ci} = \frac{1}{2\pi f C} \approx 10\ M\Omega\ at\ 50\ or\ 60\ Hz}$$

$$\mathbf{V_L = I \times R_L}$$

To minimize ground loop errors:

If V_{ground} is a DC voltage, keep R_L small compared to R_i.

If V_{ground} is an AC voltage, keep R_L small compared to Z, and set the DMM's integration time to 1 PLC or greater.

Low-level AC measurement errors

When measuring AC voltages less than 100 mV, be aware that these measurements are especially susceptible to errors introduced by extraneous noise sources. An exposed test lead will act as an antenna and the internal DMM will measure the signals received. The entire measurement path, including the power line, act as a loop antenna. Circulating currents in the loop will create error voltages across any impedances in series with the instrument's input. For this reason, you should apply low-level AC voltages to the instrument through shielded cables. You should also connect the shield to the input LO terminal.

Be sure to minimize the area of any ground loops that cannot be avoided. A high-impedance source is more susceptible to noise pickup than a low-impedance source. You can reduce the high-frequency impedance of a source by placing a capacitor in parallel with the instrument's input terminals. You may have to experiment to determine the correct capacitance value for your application.

Most extraneous noise is not correlated with the input signal. You can determine the error as shown below:

$$\mathbf{Voltage\ Measured = \sqrt{V_{in}^2 + Noise^2}}$$

Correlated noise, while rare, is especially detrimental. Correlated noise will always add directly to the input signal. Measuring a low-level signal with the same frequency as the local power line is a common situation that is prone to this error.

You should use caution when switching high-level and low-level signals on the same module. It is possible that high-level charged voltages may be discharged onto a low-level channel. It is recommended that you either use two different modules or separate the high-level signals from the low-level signals with an unused channel connected to ground.

Measurement Fundamentals

This section explains how the DAQ970A makes measurements and discusses the most common sources of error related to these measurements.

The internal DMM

Temperature measurements

DC voltage measurements

AC voltage measurements

Current measurements

Resistance measurements

Strain gage measurements

Frequency and period measurements

Capacitance measurements

The Internal DMM

The internal DMM provides a universal input front-end for measuring a variety of transducer types without the need for additional external signal conditioning. The internal DMM includes signal conditioning, amplification (or attenuation), and a high resolution (up to 22 bits) analog-to-digital converter. A simplified diagram of the internal DMM is shown below.
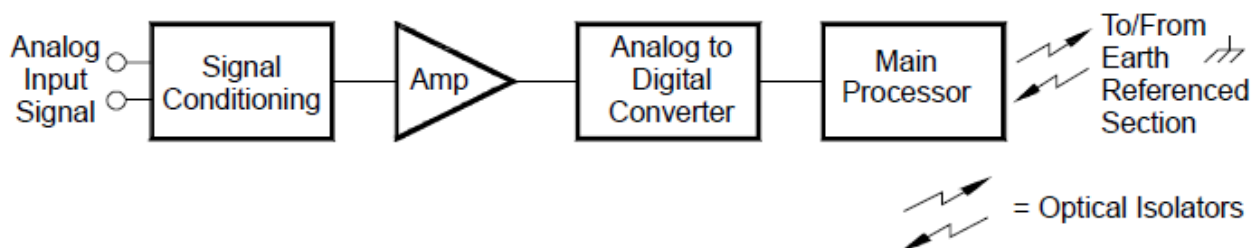
The internal DMM can directly make the following types of measurements. Each of these measurements is described in the following sections of this chapter:

- Temperature (thermocouple, 2-wire and 4-wire RTD, 2-wire and 4-wire thermistor)

- Voltage (DC and AC up to 300 V)

- Resistance (2-wire and 4-wire up to 1 GΩ)

- Current (DC and AC up to 1 A)

- Frequency and Period (up to 300 kHz)

- Strain (bridge and direct methods)

Rejecting Power-Line Noise Voltages

A desirable characteristic of an integrating analog-to-digital (A/D) converter is its ability to reject spurious signals. Integrating techniques reject power-line related noise present with DC signals on the input. This is called normal mode rejection or NMR. Normal mode noise rejection is achieved when the internal DMM measures the average of the input by "integrating" it over a fixed period. If you set the integration time to a whole number of power line cycles (PLCs) of the spurious input, these errors (and their harmonics) will average out to approximately zero.

When you apply power to the internal DMM, it measures the power-line frequency (50 Hz or 60 Hz), and uses this measurement to determine the integration time. The following graph shows the attenuation of AC signals measured in the DC voltage function for various A/D integration time settings. Note that signal frequencies at multiples of 1/T exhibit high attenuation.
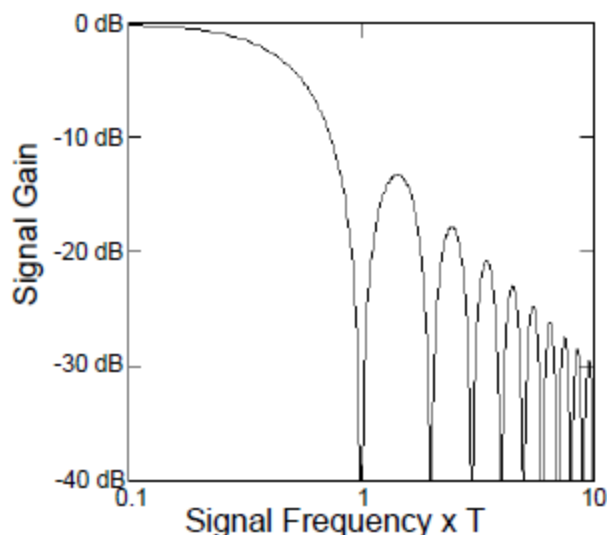
Temperature Measurements

A temperature transducer measurement is typically either a resistance or voltage measurement converted to an equivalent temperature by software conversion routines inside the instrument. The mathematical conversion is based on specific properties of the various transducers. The mathematical conversion accuracy (not including the transducer accuracy) for each transducer type is shown below:

Transducer	Conversion Accuracy
Thermocouple	0.05 ℃
RTD	0.02 ℃
Thermistor	0.05 ℃

Errors associated with temperature measurements include all of those listed for DC voltage and resistance measurements elsewhere in this chapter. The largest source of error in temperature measurements is generally the transducer itself.

Your measurement requirements will help you to determine which temperature transducer type to use. Each transducer type has a particular temperature range, accuracy, and cost. The table below summarizes some typical specifications for each transducer type. Use this information to help select the transducer for

your application. The transducer manufacturers can provide you with exact specifications for a particular transducer.

Parameter	Thermocouple	RTD	Thermistor
Temperature Range	-210 °C to 1820 °C	-200 °C to 850 °C	-80 °C to 150 °C
Measurement Type	Voltage	2- or 4- Wire Ohms	2- or 4- Wire Ohms
Transducer Sensitivity	6 μV/°C to 60 μV/°C	$\approx R_0 \times 0.004$ °C	≈ 400 Ω/°C
Probe Accuracy	0.5 °C to 5 °C	0.01 °C to 0.1 °C	0.1 °C to 1 °C
Cost (U.S. Dollars)	$1/foot	$20 to $100 each	$10 to $100 each
Durability	Rugged	Fragile	Fragile

RTD Measurements

An RTD is constructed of a metal (typically platinum) that changes resistance with a change in temperature in a precisely known way. The internal DMM measures the resistance of the RTD and then calculates the equivalent temperature.

An RTD has the highest stability of the temperature transducers. The output from an RTD is also very linear. This makes an RTD a good choice for high-accuracy and long-term measurements. The DAQ970A supports RTDs with α = 0.00385 (DIN / IEC 751) using ITS-90 software conversions. "PT100" is a special label that is sometimes used to refer to an RTD with α = 0.00385 and R_0 = 100 Ω.

The resistance of an RTD is nominal at 0 °C and is referred to as R_0. The DAQ970A can measure RTDs with R_0 values from 100 Ω ±1% or 1000 Ω ±1%.

You can measure RTDs using a 2-wire or 4-wire measurement method. The 4-wire method provides the most accurate way to measure small resistances. Connection lead resistance is automatically removed using the 4-wire method.

Thermistor Measurements

A thermistor is constructed of materials that non-linearly changes resistance with changes in temperature. The internal DMM measures the resistance of the thermistor and then calculates the equivalent temperature.

Thermistors have a higher sensitivity than thermocouples or RTDs. This makes a thermistor a good choice when measuring very small changes in temperature. Thermistors are, however, very non-linear, especially at high temperatures and function best below 100 °C.

Because of their high resistance, thermistors can be measured using a 2-wire measurement method. The internal DMM supports 2.2 kΩ (44004), 5 kΩ (44007), and 10 kΩ (44006) thermistors. The thermistor conversion routines used by the DAQ970A are compatible with the *International Temperature Scale of 1990* (ITS-90).

Thermocouple Measurements

A thermocouple converts temperature to voltage. When two wires composed of dissimilar metals are joined, a voltage is generated. The voltage is a function of the junction temperature and the types of metals in the thermocouple wire. Since the temperature characteristics of many dissimilar metals are well known, a

conversion from the voltage generated to the temperature of the junction can be made. For example, a voltage measurement of a T–type thermocouple (made of copper and constantan wire) might look like this
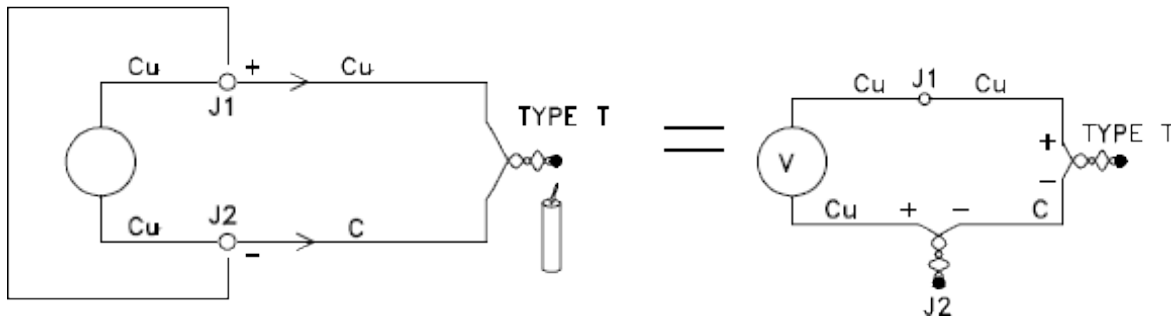
Notice, however, that the connections made between the thermocouple wire and the internal DMM make a second, unwanted thermocouple where the constantan (C) lead connects to the internal DMM's copper (Cu) input terminal. The voltage generated by this second thermocouple affects the voltage measurement of the T–type thermocouple.

If the temperature of the thermocouple created at J2 (the LO input terminal) is known, the temperature of the T–type thermocouple can be calculated. One way to do this is to connect two T–type thermocouples together to create only copper-to-copper connections at the internal DMM's input terminals, and to hold the second thermocouple at a known temperature.

An *ice bath* is used to create a known reference temperature (0 °C). Once the reference temperature and thermocouple type are known, the temperature of the measurement thermocouple can be calculated.
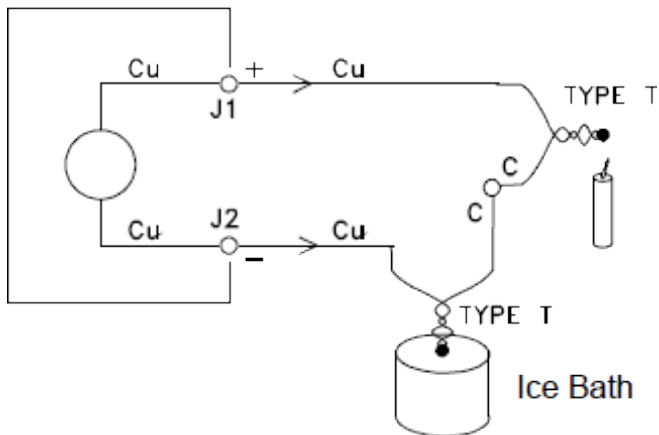
The T–type thermocouple is a unique case since one of the conductors (copper) is the same metal as the internal DMM's input terminals. If another type of thermocouple is used, two additional thermocouples are created. For example, take a look at the connections with a J–type thermocouple (iron and constantan):
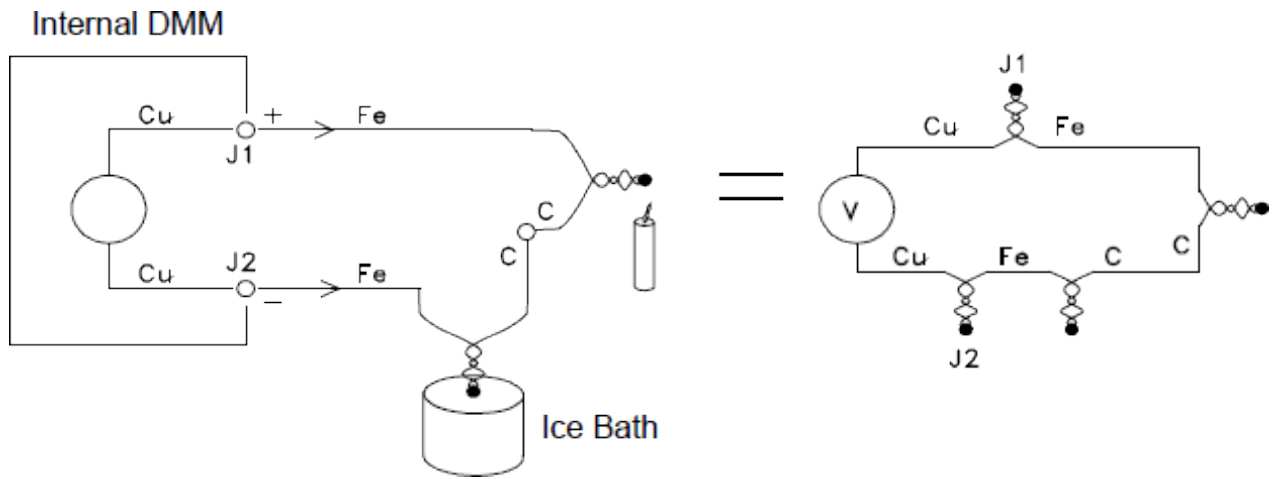
Two additional thermocouples have been created where the iron (Fe) lead connects to the internal DMM's copper (Cu) input terminals. Since these two junctions will generate opposing voltages, their effect will be to cancel each other. However, if the input terminals are not at the same temperature, an error will be created in the measurement.

To make a more accurate measurement, you should extend the copper test leads of the internal DMM closer to the measurement and hold the connections to the thermocouple at the same temperature.
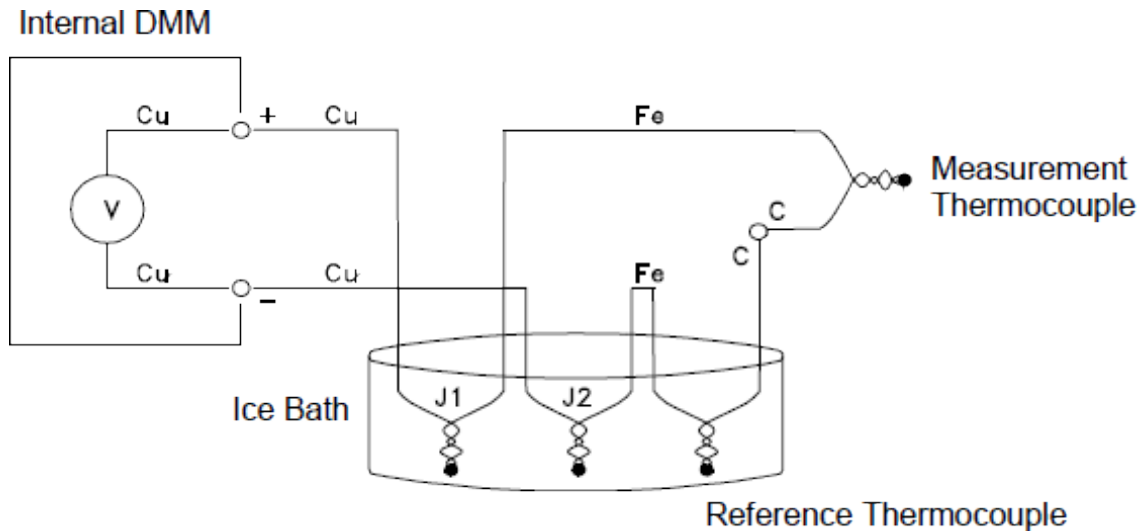
This circuit will give accurate temperature measurements. However, it is not very convenient to make two thermocouple connections and keep all connections at a known temperature. The Law of Intermediate Metals eliminates the need for the extra connection. This empirical law states that a third metal (iron (Fe) in this example) inserted between two dissimilar metals will have no effect upon the output voltage, provided the junctions formed are at the same temperature. Removing the reference thermocouple makes the connections much easier.
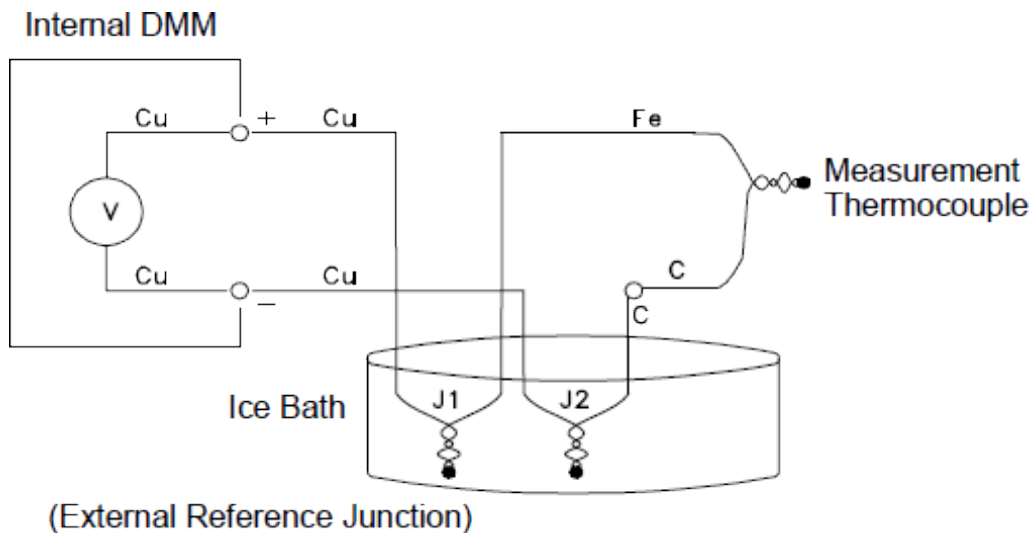
This circuit is the best solution for accurate thermocouple connections.
In some measurement situations, however, it would be nice to remove the need for an ice bath (or any other fixed external reference). To do this, an isothermal block is used to make the connections. An

isothermal block is an electrical insulator, but a good heat conductor. The additional thermocouples created at J1 and J2 are now held at the same temperature by the isothermal block.

Once the temperature of the isothermal block is known, accurate temperature measurements can be made. A temperature sensor is mounted to the isothermal block to measure its temperature.

Isothermal Block
(Internal or External Reference)
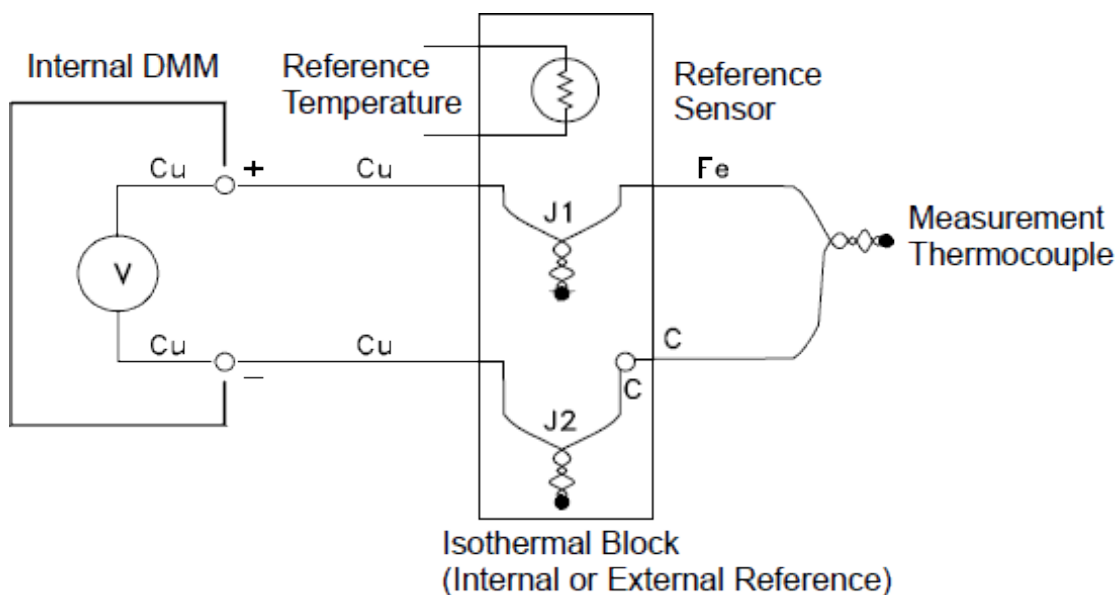
Thermocouples are available in a variety of types. The type is specified by a single letter. The table below shows the most commonly used thermocouple types and some key characteristics of each.

NOTE The thermocouple conversion routines used by the DAQ970A are compatible with the International Temperature Scale of 1990 (ITS-90).

Thermocouple Types:

T/C Type	Post (+) Lead	Neg (-) Lead	Temperature Range	Probe Accuracy	Comments
B	Platinum -30% Rhodium	Platinum -60% Rhodium	250 °C - 1820 °C	±0.5 °C	High temperature. Beware of contamination. Do not insert in metal tubes.
U.S.	Gray	Red			
British	N/A	N/A			
DIN	Red	Gray			
Japanese	Red	Gray			
French	N/A	N/A			
E	Nickel-Chromium	Constantan	-200 °C - 1000 °C	±1 °C - 1.7 °C	Highest output voltage. Highest resolution.
U.S.	Purple	Red			
British	Brown	Blue			
DIN	Red	Black			
Japanese	Red	White			
French	Yellow	Blue			
J	Iron	Constantan	-210 °C - 1200 °C	±1.1 °C - 2.2 °C	For vacuum, inert environments. Least expensive. Not recommended for low temperature.
U.S.	White	Red			
British	Yellow	Blue			
DIN	Red	Blue			
Japanese	Red	White			
French	Yellow	Black			
K	Nickel-Chromium	Nickel-Aluminium	-200 °C - 1370 °C	±1.1 °C - 2.2 °C	For oxidizing environments. Good linearity above 8 °C.
U.S.	Yellow	Red			
British	Brown	Blue			
DIN	Red	Green			
Japanese	Red	White			
French	Yellow	Purple			
N	Nicrosil	Nisil	-200 °C - 1300 °C	±1.1 °C - 2.2 °C	Superior stability to K type at higher temperatures.
U.S.	Orange	Red			
British	N/A	N/A			
DIN	N/A	N/A			
Japanese	N/A	N/A			
French	N/A	N/A			
R	Platinum -13% Rhodium	Rhodium	-50 °C - 1760 °C	±0.6 °C - 1.5 °C	Higher temperature. Beware of contamination. Do not insert in metal tubes.
U.S.	Black	Red			
British	White	Blue			
DIN	Red	White			
Japanese	Red	White			
French	Yellow	Green			

T/C Type	Post (+) Lead	Neg (-) Lead	Temperature Range	Probe Accuracy	Comments
S U.S. British DIN Japanese French	Platinum -10% Rho- dium Black White Red Red Yellow	Platinum Red Blue White White Green	-50 °C - 1760 °C	±0.6 °C - 1.5 °C	Low error, good sta- bility. High temperature. Beware of con- tamination. Do not insert
T U.S. British DIN Japanese French	Copper Blue White Red Red Yellow	Constantan Red Blue Brown White Blue	-200 °C - 400 °C	±0.5 °C - 1 °C	Withstands moisture. Has a copper lead. Low temperature applic- ations.

NOTE   Constantan = Copper-Nickel; Nicrosil = Nickel-Chromium-Silicon; Nisil = Nickel-Silicone-Mag-
nesium; N/A = Not Available

Sources of Error in Thermocouple Measurements

Reference Junction Error

A thermocouple is typically formed by welding or soldering two wires together to make the junction. Sol-
dering introduces a third metal into the junction. Provided that both sides of the thermocouple are at the
same temperature, the third metal has little effect.

Commercial thermocouples are welded using a capacitive-discharge technique. This technique is used to
prevent overheating of the thermocouple wire near the junction and to prevent the diffusion of the welding
gas and atmosphere into the thermocouple wire.

A poor weld or bad solder connection can also cause errors in a thermocouple measurement. Open ther-
mocouple junctions can be detected by checking the resistance of the thermocouple. A resistance meas-
urement of more than 5 kΩ. typically indicates a defective thermocouple. The DAQ970A contains a built-in,
automatic thermocouple check feature. If you enable this feature, the instrument measures the channel res-
istance after each thermocouple measurement to ensure a proper connection.

Diffusion Error

Diffusion in a thermocouple wire is the process of changing the alloy type along the wire itself. Atmospheric particles can actually diffuse into the metal. These changes in the wire alloy introduce small voltage changes in the measurement. Diffusion is caused by exposure to high temperatures along the wire or by physical stress to the wire such as stretching or vibration.

Temperature errors due to diffusion are hard to detect since the thermocouple will still respond to temperature changes and give nearly correct results. The diffusion effects are usually detected as a drift in the temperature measurements.

Replacing a thermocouple which exhibits a diffusion error may not correct the problem. The extension wire and connections are all subject to diffusion. Examine the entire measurement path for signs of temperature extremes or physical stress. If possible, keep the temperature gradient across the extension wire to a minimum.

Shunt Impedance

The insulation used for thermocouple wire and extension wire can be degraded by high temperatures or corrosive atmospheres. These breakdowns appear as a resistance in parallel with the thermocouple junction. This is especially apparent in systems using a small gauge wire where the series resistance of the wire is high.

Shielding

Shielding reduces the effect of common mode noise on a thermocouple measurement. Common mode noise is generated by sources such as power lines and electrical motors. The noise is coupled to the unshielded thermocouple wires through distributed capacitance. As the induced current flows to ground through the internal DMM, voltage errors are generated along the distributed resistance of the thermocouple wire. Adding a shield to the thermocouple wire will shunt the common mode noise to earth ground and preserve the measurement.
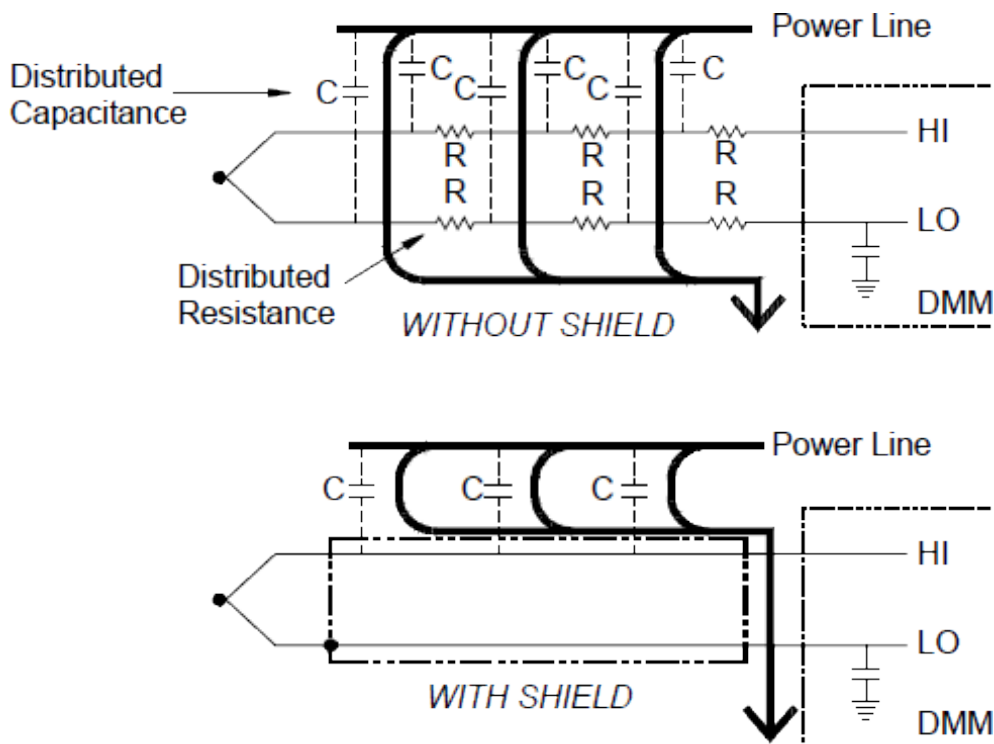
Common mode noise can dramatically affect the internal DMM. A typical thermocouple output is a few millivolts and a few millivolts of common mode noise can overload the input to the internal DMM.

Calculation Error

An error is inherent in the way a thermocouple voltage is converted to a temperature. These calculation errors are typically very small compared to the errors of the thermocouple, wiring connections, and reference junction.

DC Voltage Measurements

To make a useful DC meter, a "front-end" is required to condition the input before the analog-to-digital conversion. Signal conditioning increases the input resistance, amplifies small signals, and attenuates large signals to produce a selection of measuring ranges.

Signal Conditioning for DC Measurements

Input signal conditioning for DC voltage measurements includes both amplification and attenuation. A simplified input to the internal DMM is shown below:
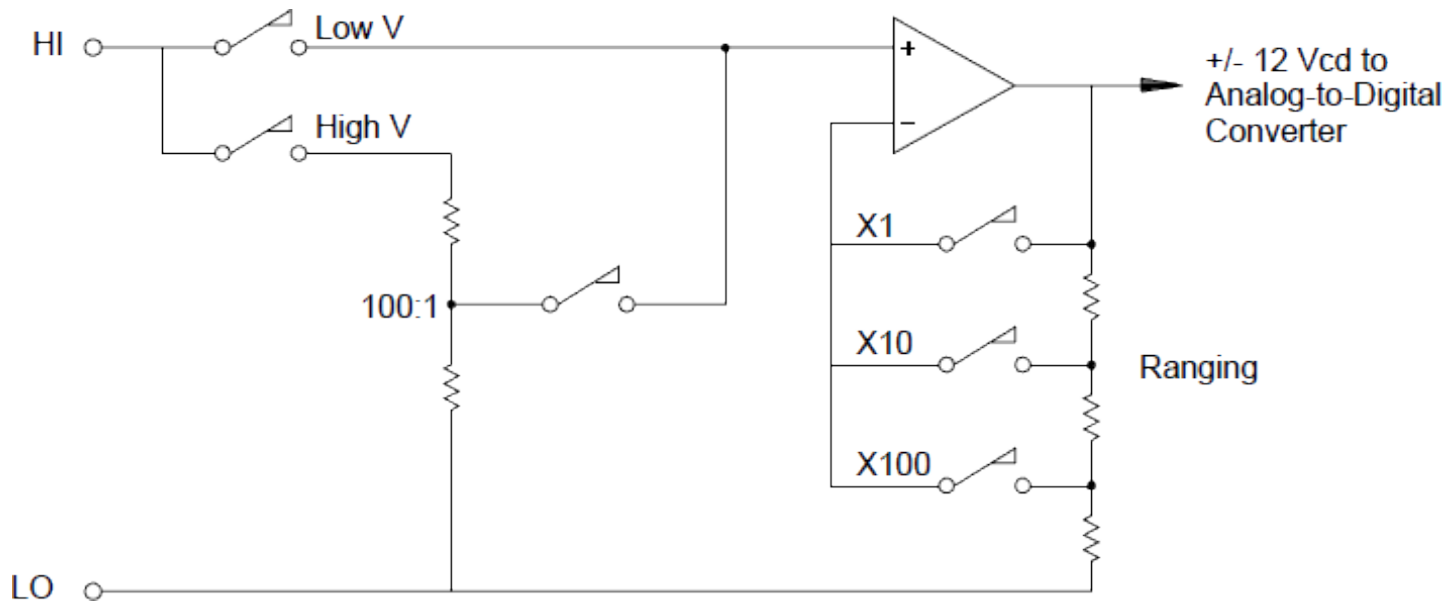
For input voltages less than 12 VDC, the Low V switch is closed and applies the input signal directly to the input amplifier. For higher voltages, the High V switch is closed and the signal is attenuated 100:1 before being applied to the input amplifier. The input amplifier gain is set to one of three values (x1, x10, or x100) to yield a signal in the range of ±12 VDC for the analog-to-digital converter.

For the lower voltage ranges, the internal DMM's input resistance is essentially that of the input amplifier. The input amplifier uses a lowbias current (less than 50 pA) FET input stage yielding an input resistance greater than 10 GΩ. On the 100V and 300V input ranges, the input resistance is determined by the total resistance of the 100:1 divider. You can also set the input resistance to 10 MΩ by continuously closing the High V switch.

Sources of Error in DC Voltage Measurements

Common Mode Rejection

Ideally, the internal DMM is completely isolated from earth-referenced circuits. However, there is finite resistance and capacitance between the input LO terminal and earth ground. If the input terminals are both driven by an earth-referenced signal (V_f) then a current will flow through R_S and create a voltage drop V_L as shown below:

Any resulting voltage (V_L) will appear as an input to the internal DMM. As the value of R_S approaches zero, so does the error. Additionally, if V_f is at the power line frequency (50 Hz or 60 Hz), the noise can be greatly reduced by setting the internal DMM's integration time to 1 PLC or greater.
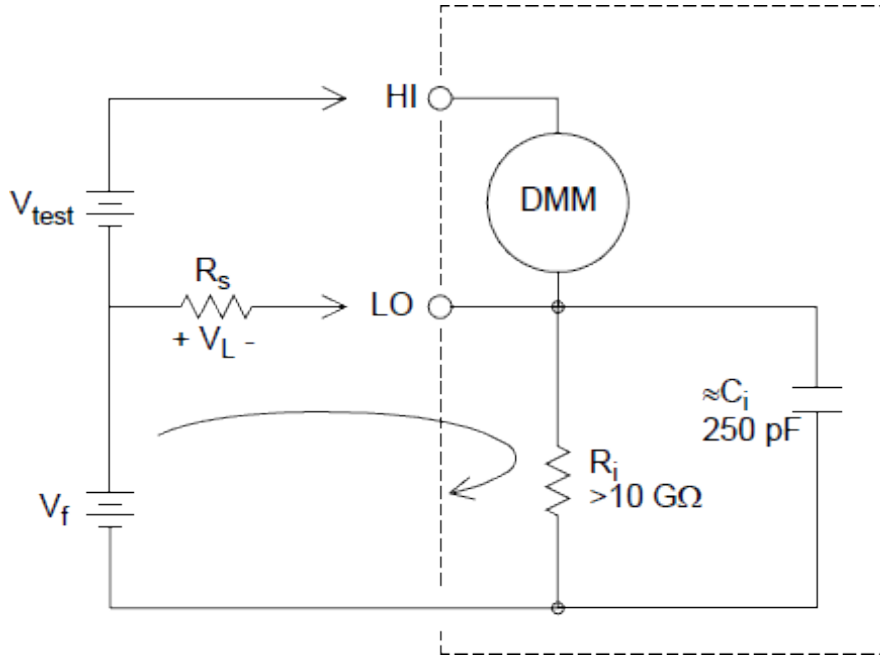
Where:
V_f = Common mode float voltage
R_s = LO lead resistance
R_i = Isolation resistance
C_i = Isolation capacitance
Z_i = Parallel impedance of $R_i + C_i$

$$\textbf{Error } (\textbf{V}_L) = \frac{V_f \times R_s}{R_s + Z}$$

Noise Caused by Injected Current

Residual capacitance in the instrument's power transformer cause small currents to flow from the LO terminal of the internal DMM to earth ground. The frequency of the "injected current" is the power line frequency or possibly harmonics of the power line frequency. The injected current is dependent upon the power line configuration and frequency. A simplified circuit is shown below:
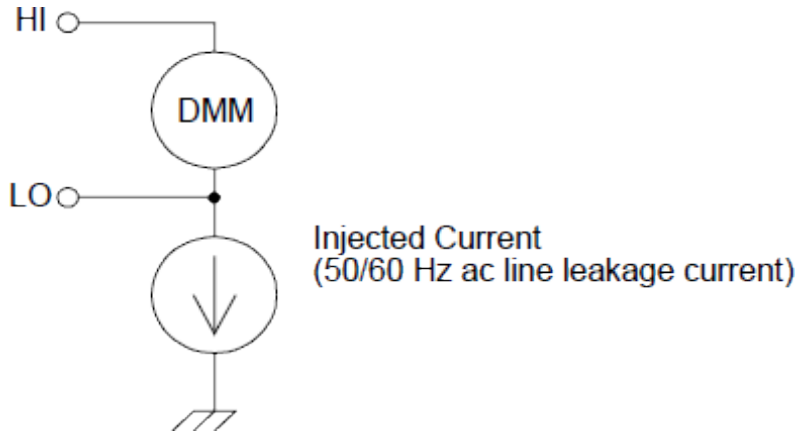
With Connection A (see below), the injected current flows from the earth connection provided by the circuit to the LO terminal of the internal DMM. This configuration adds no noise to the measurement. However, with Connection B, the injected current flows through the resistor R thus adding noise to the measurement. With Connection B, larger values of R will make the problem worse.
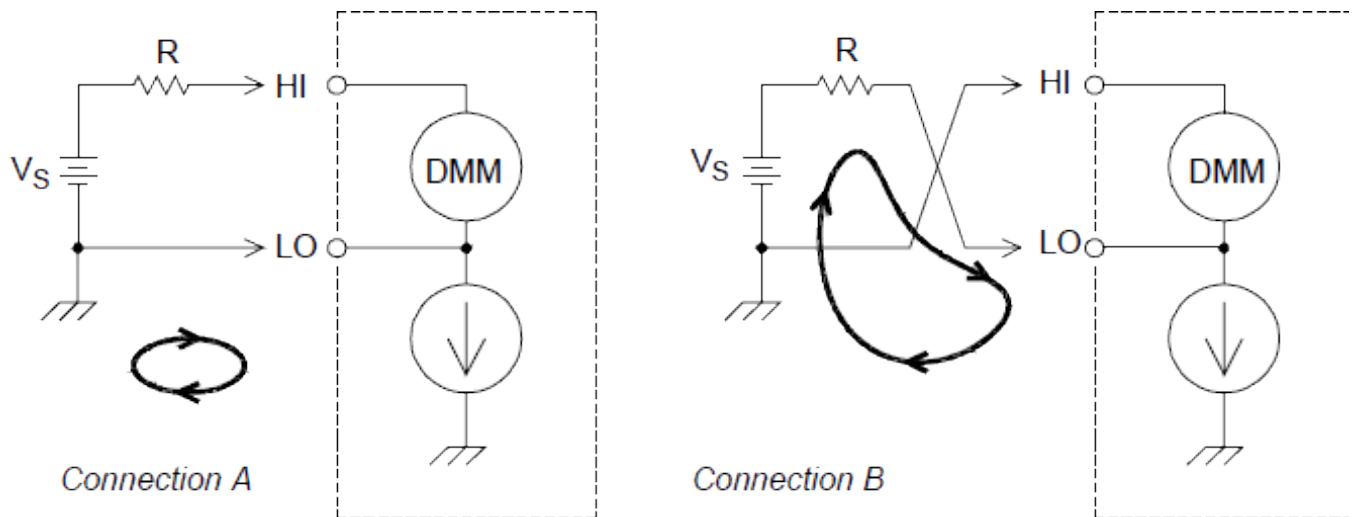
The measurement noise caused by injected current can be significantly reduced by setting the integration time of the internal DMM to 1 PLC or greater.

Loading Errors Due to Input Resistance

Measurement loading errors occur when the resistance of the device-under-test (DUT) is an appreciable percentage of the instrument's own input resistance. The diagram below shows this error source:
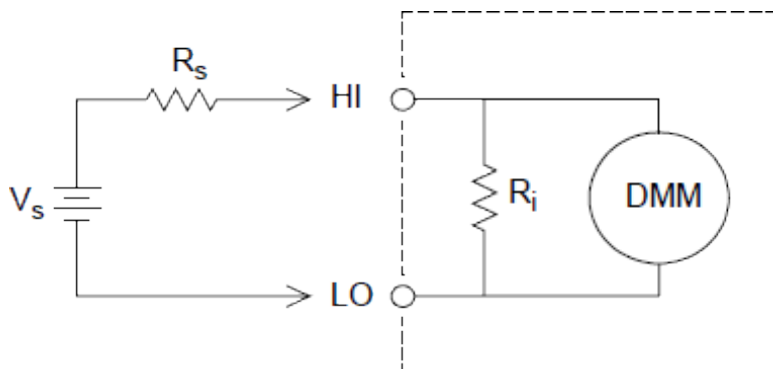
Where:

Vs = Ideal DUT voltage

Rs = DUT source resistance

Ri = Input resistance (10 MΩ or >10 GΩ)

$$\text{Error }(\%) = \frac{-100 \times R_s}{R_s + R_i}$$

To minimize loading errors, set the DMM's DC input resistance to greater than 10 GΩ when needed.

Loading Errors Due to Input Bias Current

The semiconductor devices used in the input circuits of the internal DMM have slight leakage currents called bias currents. The effect of the input bias current is a loading error at the internal DMM's input terminals. The leakage current will approximately double for every 10 °C temperature rise, thus making the problem much more apparent at higher temperatures.
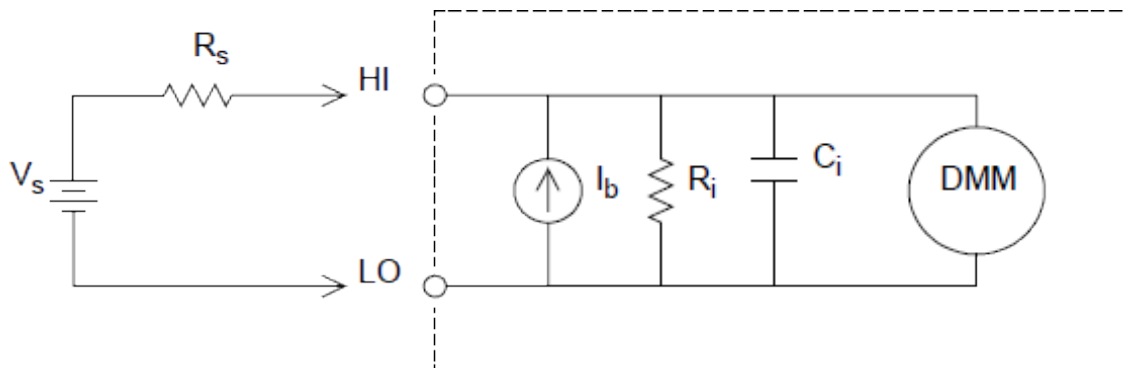
Where:

I_b = DMM bias current

R_s = DUT source resistance

R_i = Input resistance (10 MΩ or >10 GΩ)

C_i = DMM input capacitance

Error (V) = $I_b \times R_s$

AC Voltage Measurements

The main purpose of an AC "front end" is to change an AC voltage input into a DC voltage which can be measured by the ADC.

Signal Conditioning for AC Measurements

Input signal conditioning for AC voltage measurements includes both attenuation and amplification. An input coupling capacitor (C) blocks the DC portion of the input signal so that only the AC component is measured. Ranging is accomplished by combining signal attenuation from the first-stage amplifier and gain from the second-stage amplifier.

The first stage implements a high input impedance (1 MΩ) switchable compensated attenuator. The second stage provides variable-gain signal amplification to scale the input t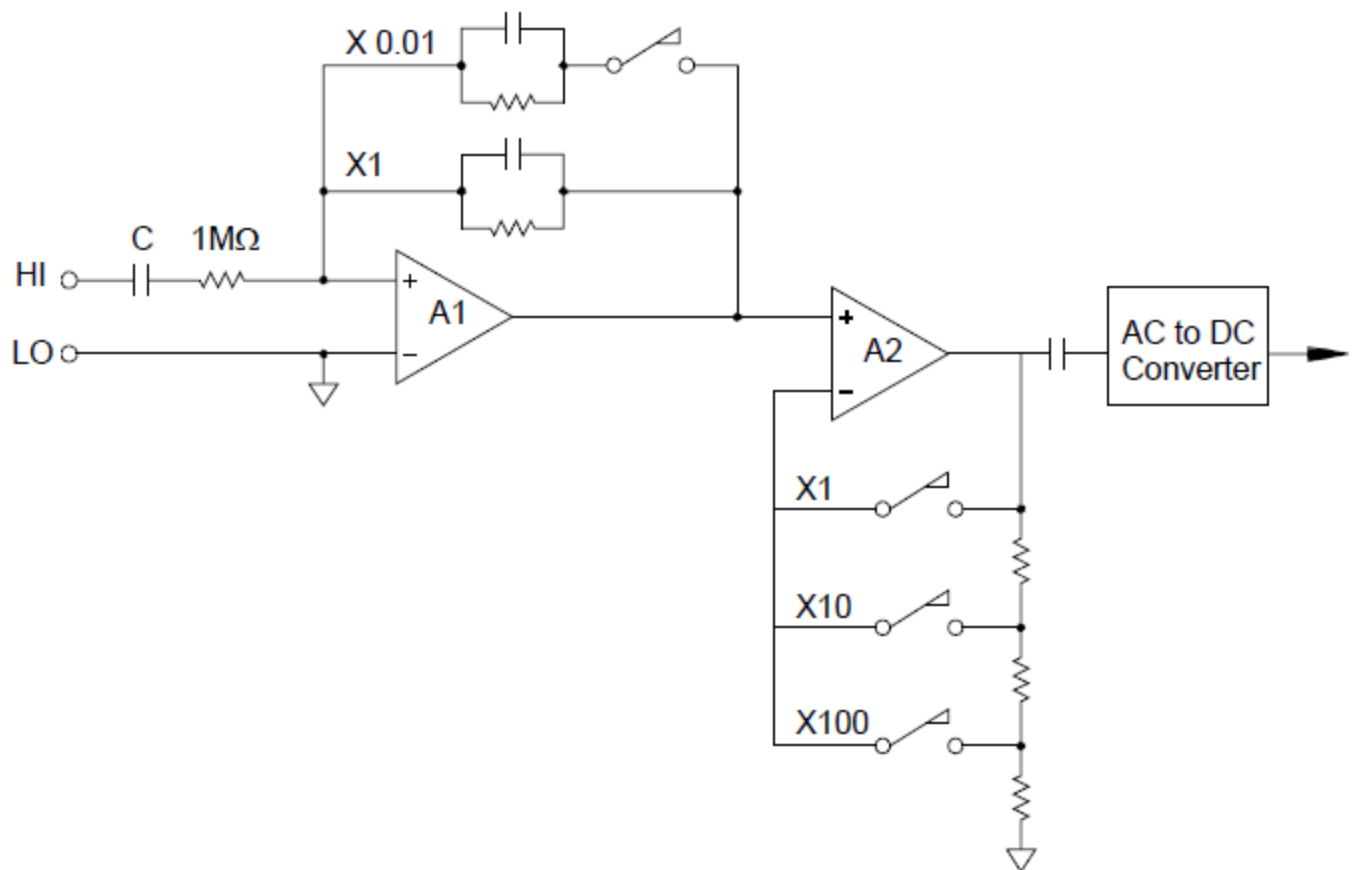o the AC converter to the full-scale level. Any residual DC offset from the attenuator and amplifier stages is blocked by a capacitor.

An AC voltage front end similar to the one discussed above is also used to measure AC current. Shunt resistors convert the AC current into an AC voltage which can then be measured. Current shunts are switched to provide selectable AC current ranges.

True RMS AC Meassurements

True RMS responding multimeters measure the "heating" potential of an applied voltage. Unlike an "average responding" measurement, a true RMS measurement is used to determine the power dissipated in a resistor. The power is proportional to the square of the measured true RMS voltage, independent of waveshape. An average responding AC multimeter is calibrated to read the same as a true RMS meter for sine-wave inputs only. For other waveform shapes, an average responding meter will exhibit substantial errors as shown below:

Waveform Shape	Crest Factor (C.F.)	AC RMS	AC+DC RMS	Average Responding Error
	1.414	$\dfrac{V}{1.414}$	$\dfrac{V}{1.414}$	Calibrated for 0 error
	1.732	$\dfrac{V}{1.732}$	$\dfrac{V}{1.732}$	-3.9%
	$\sqrt{\dfrac{T}{t}}$	$\dfrac{V}{C.F.} \times \sqrt{1-\left(\dfrac{1}{C.F.}\right)^2}$	$\dfrac{V}{C.F.}$	-46% for C.F. = 4

The internal DMM's AC voltage and AC current functions measure the ac-coupled true RMS value. This is in contrast to the ac+dc true RMS value shown above. Only the "heating value" of the AC component of the input waveform is measured (dc is rejected). For sinewaves, triangle waves, and square waves, the AC and AC+DC values are equal since these waveforms do not contain a DC offset. Non-symmetrical waveforms, such as pulse trains, contain DC voltages which are rejected by ac-coupled true RMS measurements.

An ac-coupled true RMS measurement is desirable in situations where you are measuring small AC signals in the presence of large DC offsets. For example, this situation is common when measuring AC ripple present on DC power supplies. There are situations, however, where you might want to know the ac+dc true RMS value. You can determine this value by combining results from DC and AC measurements as shown below. You should perform the DC measurement using at least 10 power line cycles of integration for best AC rejection.

$$\mathbf{AC + DC} = \sqrt{\mathbf{AC^2 + DC^2}}$$

Making High-Speed AC Measurements

The internal DMM's AC voltage and AC current functions implement three low-frequency filters. These filters allow you to trade-off low frequency accuracy for faster scanning speed. The fast filter settles in 0.12 seconds and is useful for measurements above 200 Hz. The medium filter settles in 1 second and is useful for measurements above 20 Hz. The slow filter settles in 7 seconds and is useful for measurements above 3 Hz.

With a few precautions, you can perform AC measurements at speeds up to 100 readings per second (use manual ranging to eliminate autoranging delays). By setting the preprogrammed channel settling delays to zero, each filter will allow up to 100 channels per second. However, the measurement might not be very accurate since the filter is not fully settled. In scanning applications where sample-to-sample levels vary widely, the medium filter (20 Hz) will settle at 1 reading per second, and the fast filter (200 Hz) will settle at 10 readings per second.

If the sample-to-sample levels are similar, little settling time is required for each new reading. Under this specialized condition, the medium filter (20 Hz) will provide reduced accuracy results at 5 readings per second, and the fast filter (200 Hz) will provide reduced accuracy results at 50 readings per second.

Additional settling time may be required when the DC level varies from sample to sample.

The internal DMM's DC blocking circuitry has a settling time constant of 0.2 seconds. This settling time only affects measurement accuracy when DC offset levels vary from sample to sample. If maximum measurement speed is desired in a scanning system, you may want to add an external DC blocking circuit to those channels with significant DC voltages present. This circuit can be as simple as a resistor and a capacitor.

AC filter	Channel delay	Settling time
200 Hz (Fast)	AUTO	0.12 seconds
20 Hz (Medium)	AUTO	1 second
3 Hz (Slow)	AUTO	7 seconds
200 Hz (Fast)	0	0.02 seconds
20 Hz (Medium)	0	0.2 seconds
3 Hz (Slow)	0	1.5 seconds

DC blocking settling time (1 time constant) = 0.2 seconds.

Sources of Error in AC Voltage Measurements

Many of the errors associated with DC voltage measurements also apply to AC voltage measurements. Additional errors unique to AC voltage measurements are described in this section.

Crest Factor Errors (non-sinusoidal inputs)

A common misconception is that "since the internal DMM is true RMS, its sinewave accuracy specifications apply to all waveforms." Actually, the shape of the input signal can dramatically affect measurement accuracy. A common way to describe signal waveshapes is crest factor. Crest factor is the ratio of the peak value to the RMS value of a waveform.

In general, the greater the crest factor the greater the energy contained in higher frequency harmonics. All multimeters exhibit measurement errors that are crest factor dependent. Note that the crest factor errors do not apply for input signals below 100 Hz when using the slow AC filter.

You can estimate the measurement error due to signal crest factor as shown below:
$$\text{Total Error} = \text{Error}_{sine} + \text{Error}_{crest\ factor} + \text{Error}_{bandwidth}$$

Where:
Error_{sine} = DMM's sinewave accuracy
$\text{Error}_{crest\ factor}$ = DMM's crest factor
$\text{Error}_{bandwidth}$ = Estimated bandwidth error as shown below:
$$\mathbf{Error_{bandwidth}} = \frac{\text{-C.F.}^2 \times \text{F}}{4\pi \times \text{BW}}$$

Where:
C.F. = Signal crest factor
F = Fundamental input signal frequency
BW = DMM's -3 dB bandwidth (1 MHz for the DAQ970A)

Example: Calculating Measurement Error

Calculate the approximate measurement error for a pulse train input with a crest factor of 3 and a fundamental frequency of 20 kHz. The internal DMM is set to the 1 V range. For this example, use the 90-day accuracy specifications of ± (0.05% of reading + 0.04% of range), as shown in chapter 8.

$Error_{sine} = \pm(0.05\% + 0.04\%) = \pm 0.09\%$

$Error_{crest\ factor} = 0.15\%$

$$\mathbf{Error_{bandwidth}} = \frac{-3^2 \times 20000}{4 \times 3.14159 \times 1000000} * 100 = 1.4\%$$

Total Error = 0.09% + 0.15 % + 1.4 % = 1.6 %

AC Loading Errors

In the AC voltage function, the input of the internal DMM appears as a 1 MΩ resistance in parallel with 150 pF of capacitance. The cabling that you use to connect signals to the instrument will also add additional capacitance and loading. The table below shows the approximate input resistance at various frequencies.

Input frequency	Input resistance
100 Hz	700 kΩ
1 kHz	600 kΩ
10 kHz	100 kΩ
100 kHz	10 kΩ

For low frequencies:

$$\mathbf{Error\ (\%)} = \frac{-100 \times R_s}{R_s + 1\ M\Omega}$$

Additional error for high frequencies:

$$\mathbf{Error\ (\%)} = 100 \times \left[\frac{1}{1 + \left(2\pi \times F \times R_s \times C_{in} \right)^2} - 1 \right]$$

Where:
F = Input Frequency
R_s = Source resistance
C_{in} = Input capacitance (150 pF) + Cable capacitance

Use low-capacitance cable when measuring high frequency AC signals.

Low-Level AC Measurement Errors

When measuring AC voltages less than 100 mV, be aware that these measurements are especially susceptible to errors introduced by extraneous noise sources. An exposed test lead will act as an antenna and the internal DMM will measure the signals received. The entire measurement path, including the power line, act as a loop antenna. Circulating currents in the loop will create error voltages across any impedances in series with the instrument's input. For this reason, you should apply low-level AC voltages to the instrument through shielded cables. You should also connect the shield to the input LO terminal.

Be sure to minimize the area of any ground loops that cannot be avoided. A high-impedance source is more susceptible to noise pickup than a low-impedance source. You can reduce the high-frequency

impedance of a source by placing a capacitor in parallel with the instrument's input terminals. You may have to experiment to determine the correct capacitance value for your application.

Most extraneous noise is not correlated with the input signal. You can determine the error as shown below:

$$\mathbf{Voltage\ Measured} = \sqrt{\mathbf{V_{in}}^2 + \mathbf{Noise}^2}$$

Correlated noise, while rare, is especially detrimental. Correlated noise will always add directly to the input signal. Measuring a low-level signal with the same frequency as the local power line is a common situation that is prone to this error.

You should use caution when switching high-level and low-level signals on the same module. It is possible that high-level charged voltages may be discharged onto a low-level channel. It is recommended that you either use two different modules or separate the high-level signals from the low-level signals with an unused channel connected to ground.

Measurements Below Full Scale

You can make the most accurate AC measurements when the internal DMM is at full scale of the selected range. Autoranging occurs at 10 % and 120 % of full scale. This enables you to measure some inputs at full scale on one range and 10% of full scale on the next higher range. Note that the measurement accuracy will be significantly different for the two cases. For highest accuracy, you should use manual ranging to select the lowest range possible for the measurement.

Temperature Coefficient and Overload Errors

The internal DMM uses an AC measurement technique that periodically measures and removes internal off-set voltages when you select a different function or range. When manual ranging to a new range in an over-load condition, the internal offset measurement may be degraded for the selected range. Typically, an additional 0.01% of range error may be introduced. This additional error will remain until the next periodic removal (typically 15 minutes).
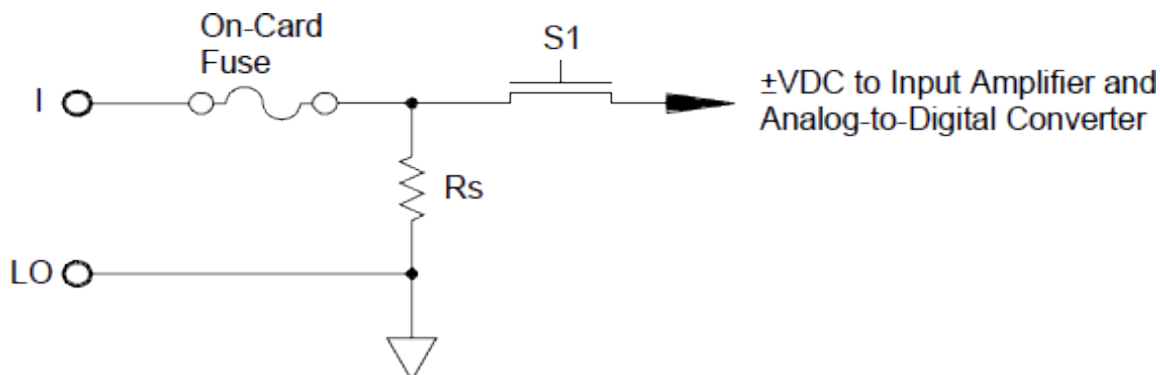
Current Measurements

> **NOTE**   Only supported on the DAQM901A multiplexer module.

An ammeter senses the current flowing through its input connections – approximating a short circuit between its input terminals. An ammeter must be connected in series with the circuit or device being measured such that current flows through both the meter and the test circuit.

A resistor, R_S in the diagram below, is connected across the input terminals such that a voltage drop proportional to the input current is generated. The value of R_S is selected as low as possible to minimize the instrument's burden voltage, or IR drop. This voltage drop is sensed by the internal DMM and scaled to the proper current value to complete the measurement (see the discussion on the following page).

AC current measurements are very similar to DC current measurements. The output of the current-to-voltage sensor is measured by an AC voltmeter. The input terminals are direct coupled (ac+dc coupled) to the shunt so that the internal DMM maintains DC continuity in the test circuit. Performing AC current measurements demands additional care. The burden voltage (loading) varies with frequency and input inductance, often causing unexpected behavior in the test circuit.

Sources of Error in DC Current Measurements

When you connect the internal DMM in series with a test circuit to measure current, a measurement error is introduced. The error is caused by the DMM's series burden voltage. A voltage is developed across the wiring resistance and current shunt resistance of the internal DMM as shown below:
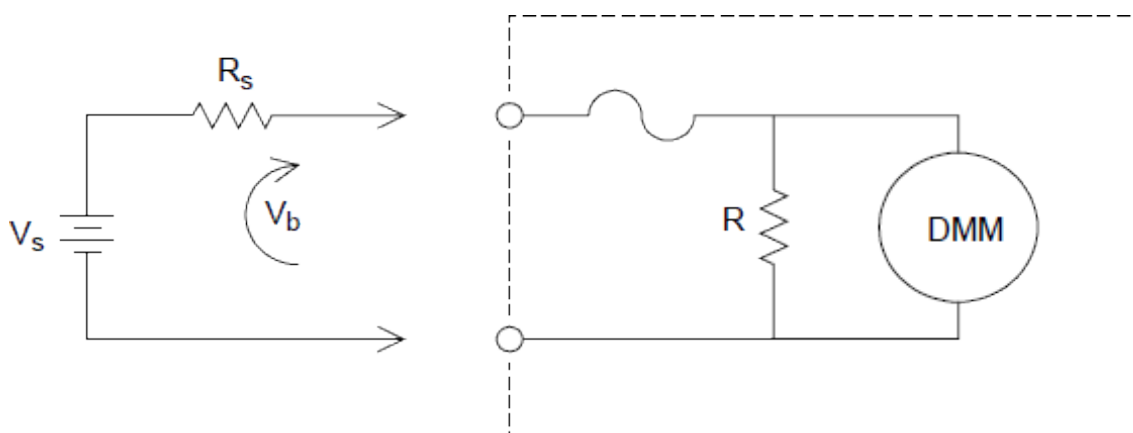
Where:
V_s = Source voltage
R_s = Source resistance
V_b = Current shunt resistance
$$\text{Error } (\%) = \frac{-100\% \times V_b}{V_s}$$

Sources of Error in AC Current Measurements

Burden voltage errors, which apply to DC current, also apply to AC current measurements. However, the burden voltage for AC current is larger due to the internal DMM's series inductance and the measurement connections. The burden voltage increases as the input frequency increases. Some circuits may oscillate when performing current measurements due to the internal DMM's series inductance and the measurement connections.

Resistance Measurements

NOTE	2-wire resistance measurements only supported on the DAQM900A, DAQM901A, DAQM902A, and DAQM908A multiplexer modules.
	4-wire resistance measurements only supported on the DAQM900A, DAQM901A, and DAQM902A multiplexer modules.

An ohmmeter measures the DC resistance of a device or circuit connected to its input. Resistance measurements are performed by supplying a known DC current to an unknown resistance and measuring the DC voltage drop.
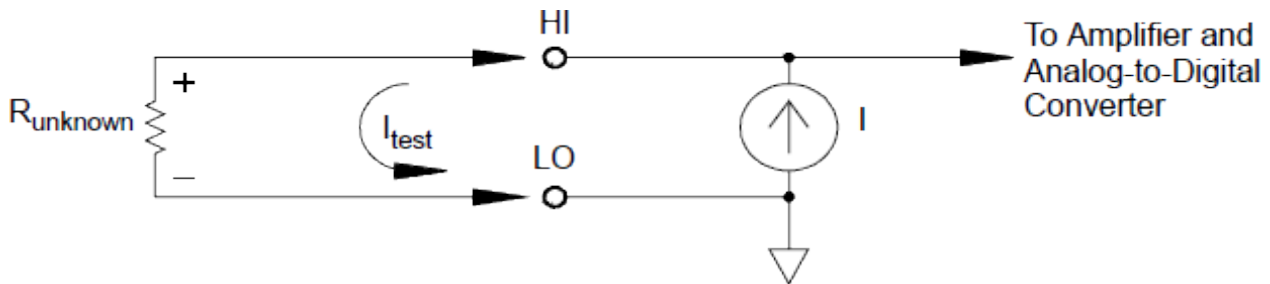

The internal DMM offers two methods for measuring resistance: 2-wire and 4-wire ohms. For both methods, the test current flows from the input HI terminal through the resistor being measured. For 2-wire ohms, the voltage drop across the resistor being measured is sensed internal to the DMM. Therefore, test lead resistance is also measured. For 4-wire ohms, separate "sense" connections are required. Since no current flows in the sense leads, the resistance in these leads does not give a measurement error.

4-Wire Ohms Measurements

The 4-wire ohms method provides the most accurate way to measure small resistances. Test lead, multiplexer, and contact resistances are automatically reduced using this method. The 4-wire ohms method is often used in automated test applications where long cable lengths, input connections, and a multiplexer exist between the internal DMM and the device-under-test.

The recommended connections for 4-wire ohms measurements are shown in the diagram on the following page. A constant current source, forcing current I through unknown resistance R, develops a voltage measured by a DC voltage front end. The unknown resistance is then calculated using Ohm's Law.

The 4-wire ohms method is used in systems where lead resistances can become quite large and variable and in automated test applications where cable lengths can be quite long. The 4-wire ohms method has the obvious disadvantage of requiring twice as many switches and twice as many wires as the 2-wire method. The 4-wire ohms method is used almost exclusively for measuring lower resistance values in any application, especially for values less than 10 Ω and for high-accuracy requirements such as RTD temperature transducers.

$$R = \frac{V_{meter}}{I_{test}}$$
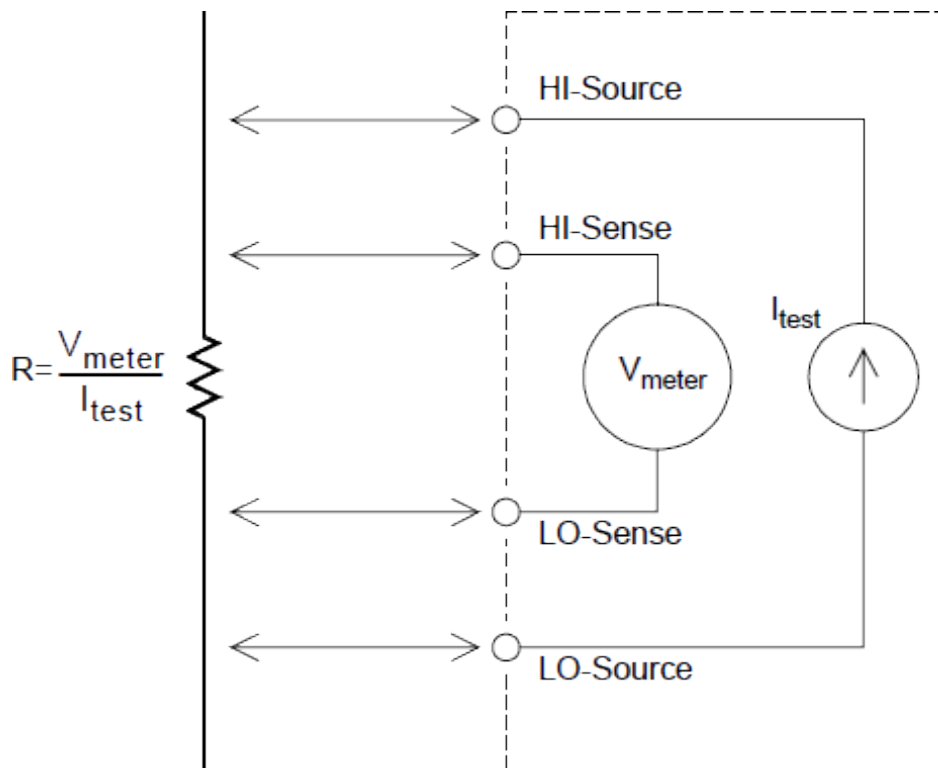
Offset Compensation

Most connections in a system use materials that produce small DC voltages due to dissimilar metal-to-metal contact (thermocouple effect) or electrochemical batteries. These DC voltages also add errors to resistance measurements. The offset-compensated measurement is designed to allow resistance measurements in the presence of small DC voltages.

Offset compensation makes two measurements on the circuit connected to the input channel. The first measurement is a conventional resistance measurement. The second is the same except the internal DMM's test current source is turned off (essentially a normal DC voltage measurement). The second measurement is subtracted from the first prior to scaling the result, thus giving a more accurate resistance measurement.

Offset compensation can be used for 2-wire or 4-wire ohms measurements (but not for RTD or thermistor measurements). The DAQ970A disables offset compensation when the measurement function is changed or after a Factory Reset (*RST command). An Instrument Preset (SYSTem:PRESet command) or Card Reset (SYSTem:CPON command) does not change the setting.

If the resistor being measured does not respond quickly to changes in current, offset compensation will not produce an accurate measurement. Resistors with very large inductances or resistors with large parallel capacitance would fall into this category. In these cases, the channel delay parameter can be increased to allow more settling time after the current source is switched on or off, or offset compensation can be turned off.

Sources of Error in Resistance Measurements

External Voltages

Any voltages present in the system cabling or connections will affect a resistance measurement. The effects of some of these voltages can be overcome by using offset compensation (as described on the above section).

Settling Time Effects

The internal DMM has the ability to insert automatic measurement settling delays. These delays are adequate for resistance measurements with less than 200 pF of combined cable and device capacitance. This is particularly important if you are measuring resistances above 100 kΩ. Settling due to RC time constant effects can be quite long. Some precision resistors and multifunction calibrators use large parallel capacitances (1000 pF to 0.1 μF) with high resistance values to filter out noise currents injected by their internal circuitry. Non-ideal capacitances due to dielectric absorption (soak) effects in cables and other devices may have much longer settling times than expected just by RC time constants. Errors will be measured when settling after the initial connection, after a range change, or when using offset compensation. You may need to increase the channel delay time before a measurement in these situations.

High-Resistance Measurement Errors

When you are measuring large resistances, significant errors can occur due to insulation resistance and surface cleanliness. You should take the necessary precautions to maintain a "clean" high-resistance system. Test leads and fixtures are susceptible to leakage due to moisture absorption in insulating materials and "dirty" surface films. Nylon and PVC are relatively poor insulators (10^9 ohms) when compared to PTFE insulators (10^{13} ohms). Leakage from nylon or PVC insulators can easily contribute a 0.1% error when measuring a 1 MΩ resistance in humid conditions. The table below shows several common insulating materials and their typical resistances.

| Insulating Material	Resistance Range	Moisture Absorbing
PTFE	1 TΩ to 1 PΩ	N
Nylon	1 GΩ to 10 TΩ	Y
PVC	10 GΩ to 10 TΩ	Y
Polystyrene	100 GΩ to 1 PΩ	N
Ceramic	1 GΩ to 1 PΩ	N
Glass Epoxy (FR-4, G-10)	1 GΩ to 10 TΩ	Y
Phenolic, Paper	10 MΩ to 10 GΩ	Y

N = No; Y = Yes

Strain Gage Measurements

You can measure a strain gage using a 4-wire resistance measurement with scaling.

When a force is applied to a body, the body deforms. The deformation per unit length is called strain (ε). Strain may be either tensile (+) or compressive (–). Practical strain values are usually quite small (typically less than 0.005 inch/inch for most metals) and are often expressed in micro-strains (με). There are three

common types of strain measurements as shown below:

Normal strain (ε) is a measure of the deformation along the axis of the applied force, where $\varepsilon = \Delta L / L$
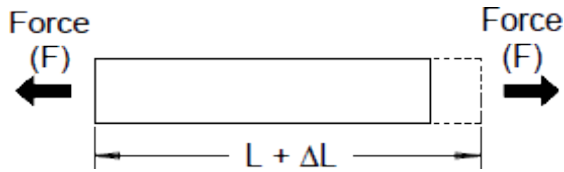
Shearing strain (γ) is a measure of the angular distortion of a body. It is approximated by the tangent of the angle formed by the angular change between two line segments that were parallel in the undeformed state.
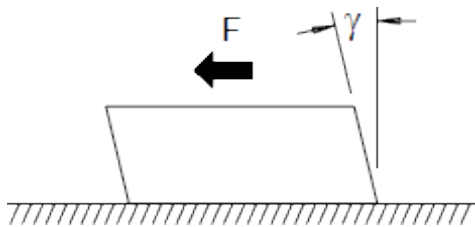
Poisson Strain (υ) measures a property of materials known as the Poisson Ratio. It is the negative ratio of transverse and longitudinal normal strain when a body has a longitudinal tensile force applied, where $\upsilon = -\varepsilon_t / \varepsilon$, where $\varepsilon_t = \Delta D / D$ and $\varepsilon = \Delta L / L$
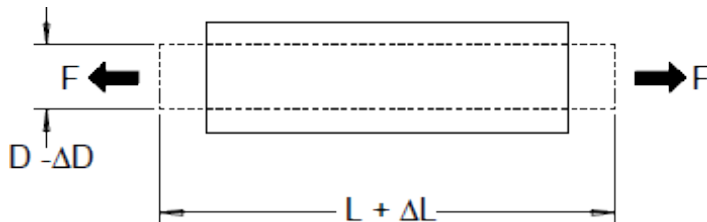

Stress Stress is a term used to compare the loading applied to a material with its ability to carry the load. Stress (σ) in a material can not be measured directly; it must be computed from material properties and measurable quantities such as strain and force.

Strain Sensors The metal foil resistance strain gage is by far the most widely used strain measurement sensor. It consists of a thin metallic foil grid bonded to a thin insulating, adhesive backing. The resistance of the foil varies linearly with strain. Strain in the test body is simply the ratio of the foil's strained to unstrained resistance: $\varepsilon = \Delta R / R$.

The **Gage Factor (GF)** indicates the sensitivity of a strain gage and is a measure of the fractional resistance change per strain: $GF = (\Delta R / R) / \varepsilon$. Devices with a higher gage factor will exhibit a greater resistance change per strain applied.

Strain gages are available in various numbers and configurations of elements. The most common element is the single gage form shown below. Multi-element strain gages, also called rosettes, are used to measure

components of strain in different directions. Two-element (90°) and three-element (45° or 60°) con-figurations are the most common.
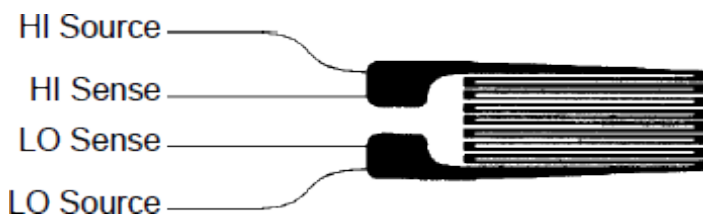
Common Uses for Strain Gages Strain gages are used to sense many types of physical parameters. Strain gages are primarily a force-sensing device. Force is measured indirectly by measuring the deform-ation of a test body to a known applied force thus producing a resistance change proportional to the applied force. Many other physical quantities can be measured through force measurements. Common applications of strain gages include weight, pressure, flow, and level measurements.

Making Strain Gage Measurements A Wheatstone bridge is commonly used to enable instruments with low-sensitivity measuring capabilities to measure small resistance changes common in strain meas-urements. Instruments with high-resolution resistance measuring capabilities, like the DAQ970A internal DMM, can directly measure small resistance changes with high precision and linearity. You should also use the 4-wire resistance method when measuring strain gages to eliminate system cabling errors.

An initial, unstrained, gage resistance measurement is used as the reference (R_0) measurement from which strain ($\Delta R / R0$) is measured. For best results, you should perform this reference measurement after the strain gage has been mounted to the test body. The table below shows the resistance changes cor-responding to 1 µε strain for common gage factor and unstrained gage resistance values.

| Strain	GF	R_0	ΔR	DMM Sensitivity
1 µε	2.0	120 Ω	0.24 mΩ	0.1 mΩ (0.4 µε)
1 µε	2.0	350 Ω	0.70 mΩ	1.0 mΩ (1.4 µε)
1 µε	2.0	1000 Ω	2.0 mΩ	1.0 mΩ (0.5 µε)

Using the measurement scaling function (mX+b) with the equations shown below will allow you to display results directly in strain on the DAQ970A front-panel display. You can use a custom measurement unit to display readings in "µε" (micro-strain) directly. The instrument will automatically add the micro ("µ") prefix based upon actual calculated values.

$$M = \frac{1}{GF \times R_0} \qquad B = -\frac{1}{GF}$$

Temperature Effects The resistive element of a strain gage will produce a resistance change ΔR due to measured strain as well as changes in gage temperature. This will create an "apparent" strain change which is undesirable. A second gage of similar type can be used to detect temperature changes and thus remove this error source. You should mount the second gage in close proximity and at 90° to the first gage, thus responding to local temperature changes but rejecting strain changes. Subtracting meas-urements from the second gage will remove any undesirable strain errors.
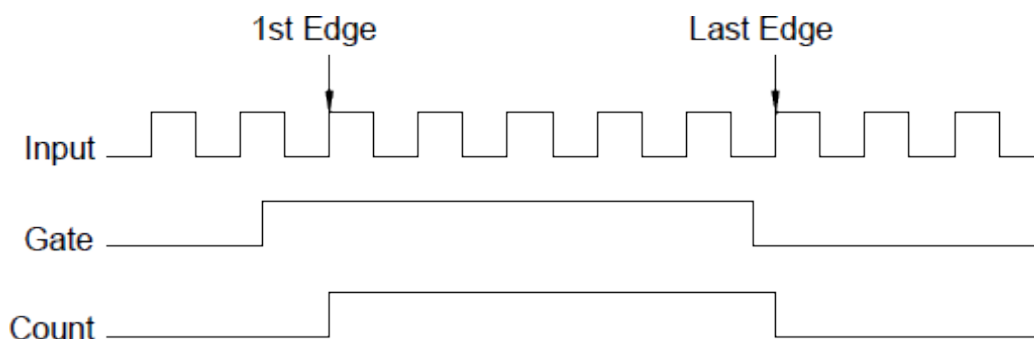
Frequency and Period Measurements

The internal DMM uses a reciprocal counting technique to measure frequency and period. This method generates constant measurement resolution for any input frequency. The internal DMM's AC voltage measurement section performs input signal conditioning for frequency and period measurements.
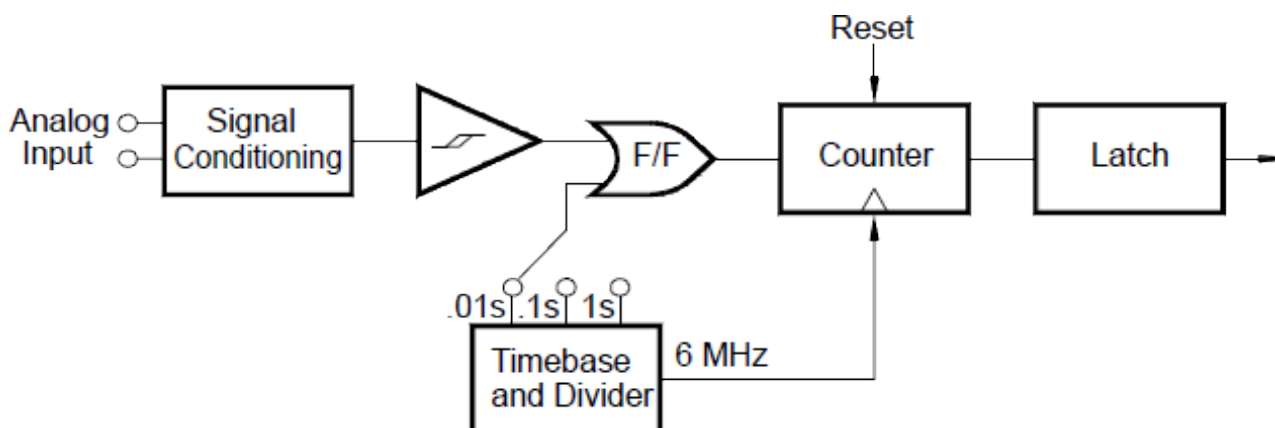

The timebase is divided to provide a gate signal. The gate signal and input signal are combined to enable the counter. During the "on" time, the counter counts the 6 MHz timebase signal. At the end of each gate period, the total count is latched and the result is divided by the known timebase frequency to determine the input frequency. The counter is then reset before the next gate period. The resolution of the measurement is tied to the timebase, and not the input frequency. This increases measurement speed especially at low frequencies.

The reciprocal counter has the advantage of a constant number of digits of display, no matter what the input frequency is. With a reciprocal counter, the number of digits of resolution scales with the gate time. If a 1-second gate gives six digits of resolution, a 0.1-second gate gives five digits, and so forth.

Sources of error in frequency and period measurements

The internal DMM's AC voltage measurement section performs input signal conditioning. All frequency counters are susceptible to errors when measuring low-voltage, low-frequency signals. The effects of both internal noise and external noise pickup are critical when measuring "slow" signals. The error is inversely proportional to frequency. Measurement errors will also occur if you attempt to measure the frequency (or period) of an input following a DC offset voltage change. You must allow the internal DMM's input DC blocking capacitor to fully settle before making frequency measurements.
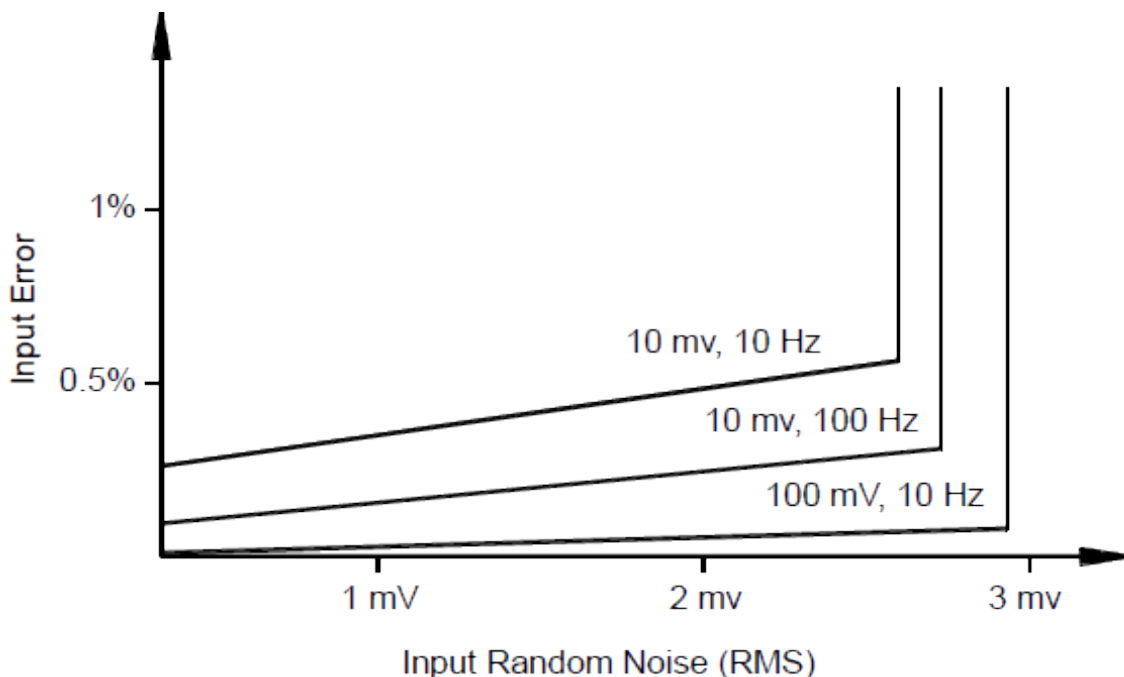
If the external noise pickup becomes large enough to exceed the hysteresis of the measuring circuitry, the frequency function may actually become unusable. External shielding and low-pass filtering may help.

Capacitance Measurements

The DAQ970A makes capacitance measurements by applying a known current to charge the capacitance and then a resistance to discharge as shown below:
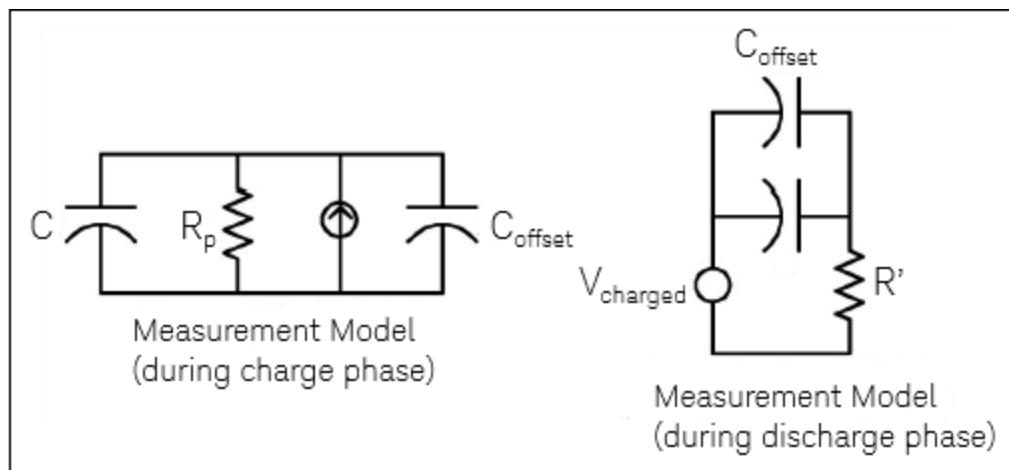
Capacitance is calculated by measuring the change in voltage (DV) that occurs over a "short aperture" time, (Dt). This measurement is repeated at two different times during the exponential rise that occurs. An algorithm takes the data from these four points, and by linearizing that exponential rise over these "short apertures", accurately calculates the capacitance value.

The measurement cycle consists of two parts: a charge phase (shown in the graph) and a discharge phase. The time–constant during the discharge phase is longer, due to a 100 kΩ protective resistor in the measurement path. This time–constant plays an important role in the resultant reading rate (measurement time). The incremental times (or "sample times") as well as the width of the "short apertures", vary by range, in order to minimize noise and increase reading accuracy. For the best accuracy, take a zero null measurement with open probes, to null out the test lead capacitance, before connecting the probes across the capacitor to be measured.

Capacitance Measurement Considerations

Capacitors that have a high dissipation factor or other non-ideal characteristics will affect capacitance measurements. Capacitors with high dissipation factors may exhibit a variance between the measured value using the multimeter versus the single frequency method of some other LCR meters. The single frequency method will also see more variation at different frequencies. For example, some inexpensive capacitance substitution boxes, when measured with the multimeter, are almost 5% different compared to the same capacitance measured with the single frequency method of an LCR meter. The LCR meter will also show different values at different frequencies.

Capacitors with long time constants (dielectric absorption) will result in slow measurement settling time, and will take a number of seconds to stabilize. You may see this when first connecting a capacitor or when the delay time to make a measurement is varied. A high quality film capacitor typically shows the least of this and an electrolytic capacitor the most, with ceramic capacitors typically in between.

Low-Level Signal Multiplexing and Switching

Low-level multiplexers are available in the following types: one-wire, 2-wire, and 4-wire. The following sections in this chapter describe each type of multiplexer. The following low-level multiplexer modules are available with the DAQ970A.

DAQM900A 20-Channel FET Multiplexer

DAQM901A 20-Channel Armature Multiplexer

DAQM902A 16-Channel Reed Multiplexer

DAQM908A 40-Channel Single-Ended Multiplexer

An important feature of a multiplexer used as a DMM input channel is that only one channel is connected at a time. For example, using a multiplexer module and the internal DMM, you could configure a voltage measurement on channel 1 and a temperature measurement on channel 2. The instrument first closes the channel 1 relay, makes the voltage measurement, and then opens the relay before moving on to channel 2 (called break-before-make switching).

Other low-level switching modules available with the DAQ970A include the following:

DAQM903A 20-Channel Actuator

DAQM904A 4×8 Two-Wire Matrix

## One-Wire (Single-Ended) Multiplexers

On the DAQM908A multiplexer, all of the 40 channels switch the HI input only, with a common LO for the module. The module also provides a thermocouple reference junction for making thermocouple measurements.
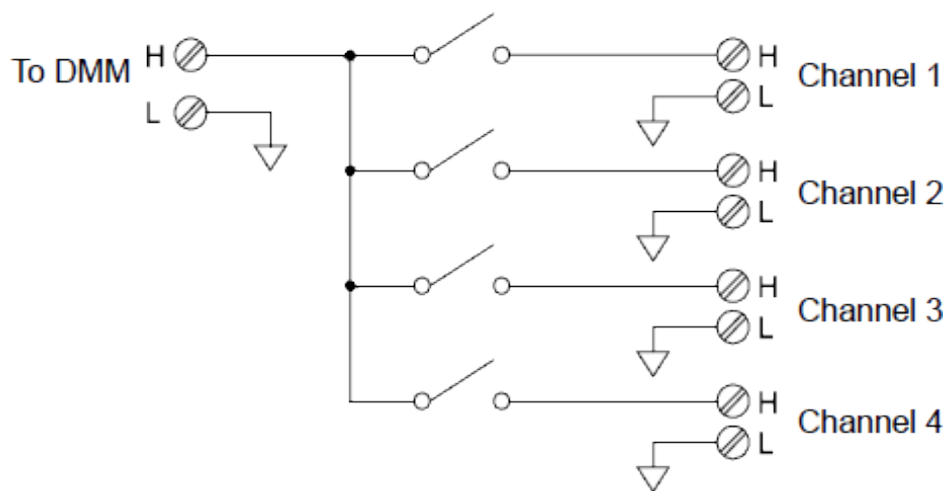
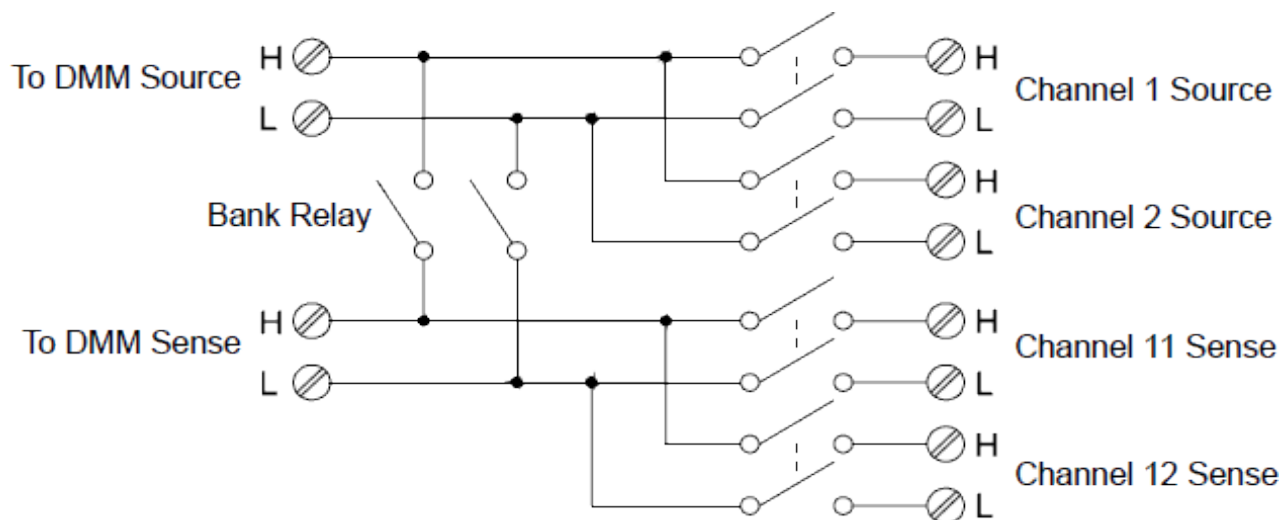| NOTE | Only one channel can be closed at a time; closing one channel will open the previously closed channel. |

Two-Wire Multiplexers

The DAQM900A, DAQM901A, and DAQM902A multiplexers switch both HI and LO inputs, thus providing fully isolated inputs to the internal DMM or an external instrument. These modules also provide a thermocouple reference junction for making thermocouple measurements.
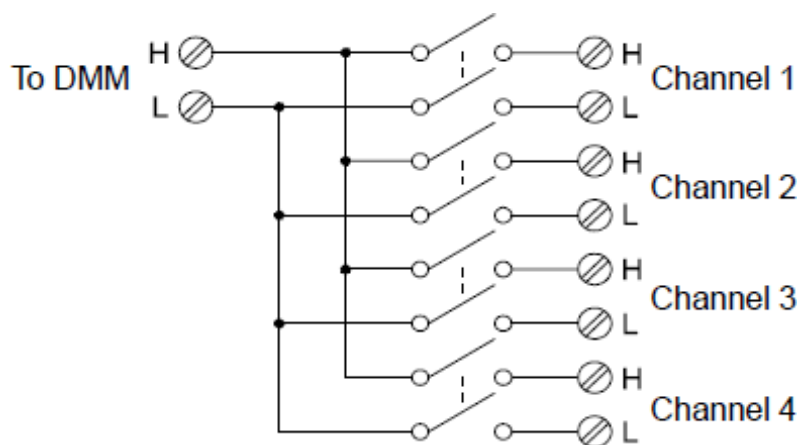
Four-Wire Multiplexers

You can make 4-wire ohms measurements using the DAQM900A, DAQM901A, and DAQM902A multiplexers. For a 4-wire ohms measurement, the channels are divided into two independent banks by opening the bank relay.

For 4-wire measurements, the instrument automatically pairs channel n with channel n+10 (DAQM901A) or n+8 (DAQM902A) to provide the source and sense connections. For example, make the source connections to the HI and LO terminals on channel 2 and the sense connections to the HI and LO terminals on channel 12.

| NOTE | If any channels are configured to be part of the scan list, you cannot close multiple channels; closing one channel will open the previously closed channel. |

When making a 4-wire measurement, the test current flows through the source connections from the HI terminal through the resistor being measured. To eliminate the test lead resistance, a separate set of sense connections are used as shown below:
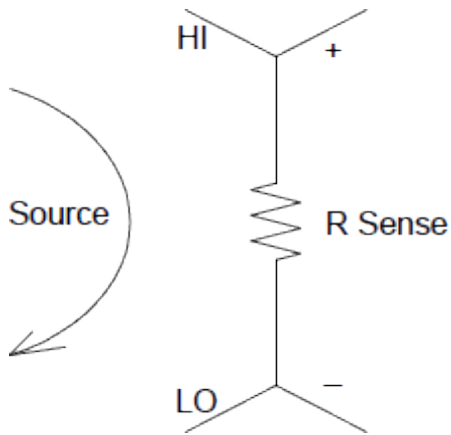
Signal Routing and Multiplexing

When used stand-alone for signal routing (not scanning or connected to the internal DMM), multiple chan-
nels on the DAQM901A and DAQM902A multiplexers can be closed at the same time. You must be careful
that this does not create a hazardous condition (for example, connecting two power sources together).

Note that a multiplexer is not directional. For example, you can use a multiplexer with a source (such as a
DAC) to connect a single source to multiple test points as shown below:
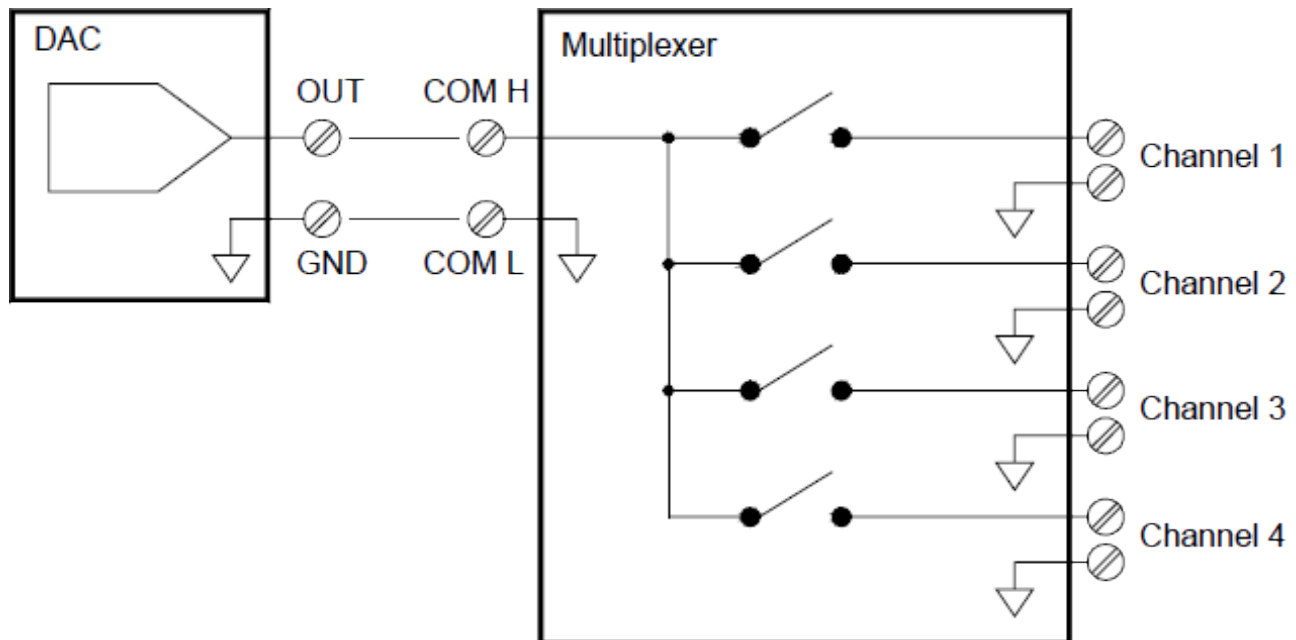
Sources of Error in Multiplexing and Switching

Noise can be coupled inside a switch by the drive circuitry, by switch thermal EMFs, or by coupling among
signal paths. Noise can also be generated outside the network and conducted or coupled into the switch.
Although noise problems apply to the entire system, they can become especially acute for switching.
Switch networks contain a high concentration of signals, which magnify the errors. Most problems with
electric noise can be traced to improper grounding and shielding.

Noise can be capacitively coupled between physically adjacent channels in a switching system. Noise can be coupled between the switch contacts themselves (C_{sw}) or between adjacent cabling (C_{adj}).
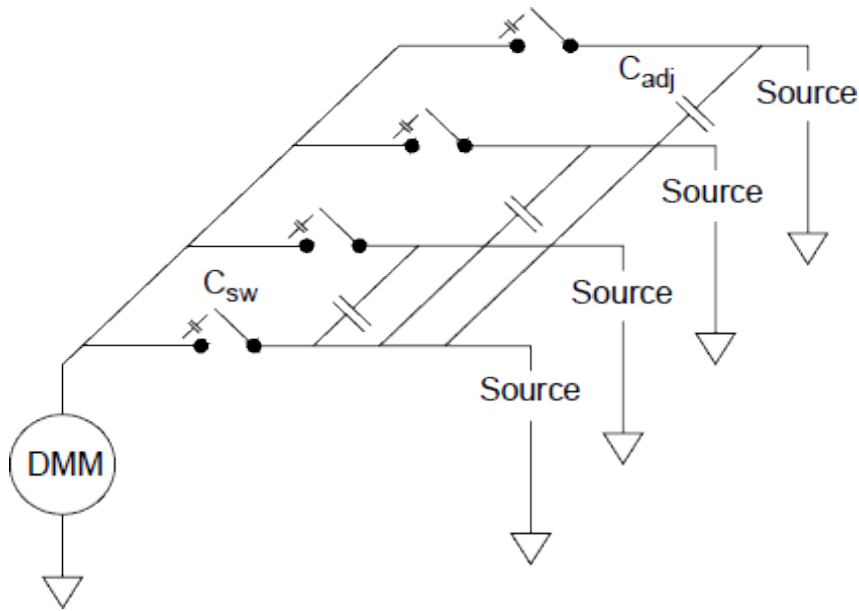
Capacitive noise coupling is a function of area and proximity. A simple method to reduce the noise coupling is to physically separate the switches and cables from each other. However, this may not be practical for all applications.

Another solution is to keep large amplitude signals and small amplitude signals away from each other. Group similar signals together (high voltages, low voltages, analog, and digital). If possible, use two separate switch modules; one for high-level signals and one for low-level signals. If you are using a single module for mixed-signal switching, leave one unused, grounded channel between the groups. Also, ground any unused channels on the module.

The DAQM901A and DAQM902A multiplexers have an additional relay, called a bank switch or tree switch, which helps reduce channel-to- channel noise (C_{adj}). The multiplexer channels are divided into two banks. The bank switch isolates one bank of channels from the other, effectively removing any parallel adjacent capacitance from the isolated bank. During a scan, the instrument automatically controls the bank switches.
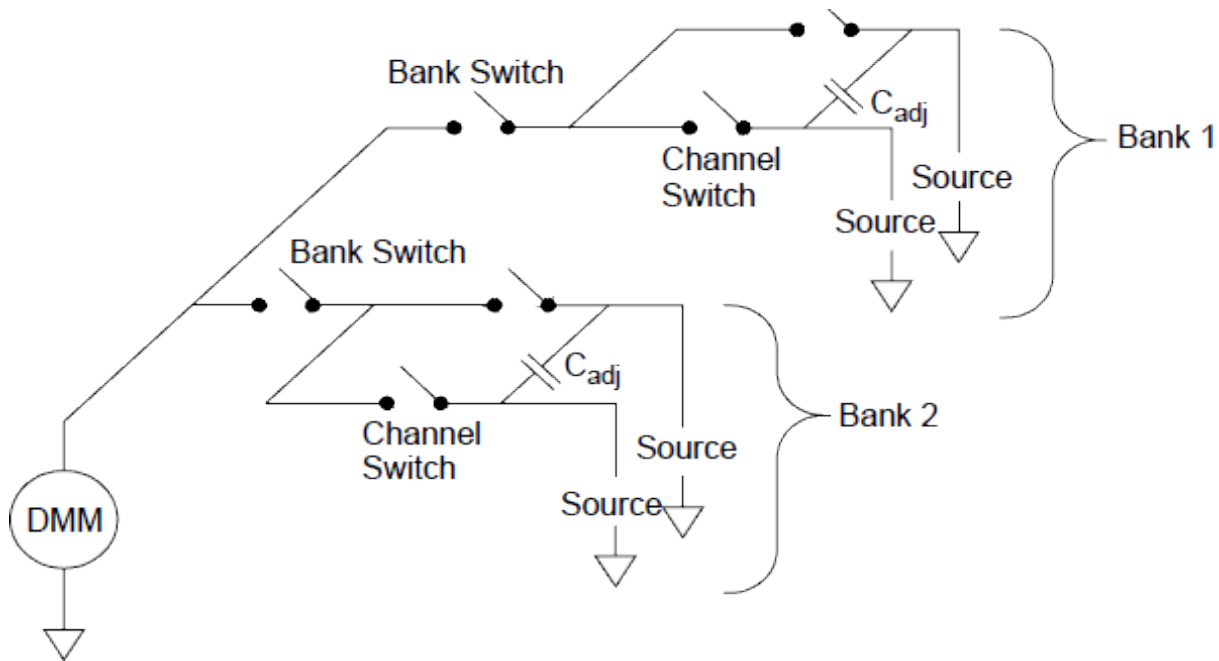
Module	Bank 1	Bank 2
DAQM900A	Channels 1 through 10	Channels 11 through 20
DAQM901A	Channels 1 through 10	Channels 11 through 20
DAQM902A	Channels 1 through 8	Channels 9 through 16
DAQM908A	Channels 1 through 20	Channels 21 through 40

Actuators and General-Purpose Switching

The DAQM903A Actuator provides 20 independent, isolated SPDT (single-pole, double-throw) or Form C switches. This module offers simple on-off switching which you can use to control power devices or for custom switching applications. For example, you can use an actuator to build a simple resistance ladder as shown below:
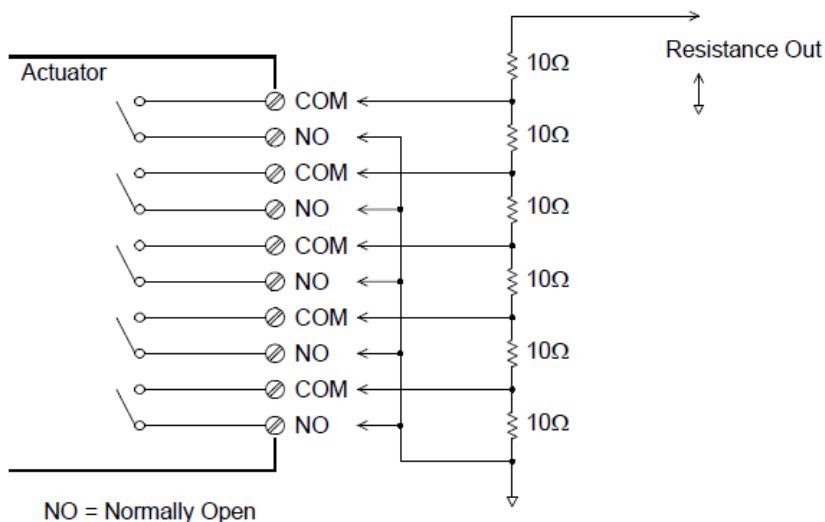
In the above diagram, the resistance is 60 Ω when all of the actuator channels are open (not connected to COM). Note that when the actuator channels are open, as shown above, the normally-closed contacts (not shown above) are connected to COM. Values from 10 Ω to 50 Ω are selected by closing the appropriate channel(s) on the module.

Snubber Circuits

Whenever a relay contact opens or closes, electrical breakdown or arching can occur between the contacts. This can cause high-frequency noise radiation, voltage and current surges, and physical damage to the relay contacts.

A breadboard area is provided on the DAQM903A to implement custom circuitry such as simple filters, snubbers, and voltage dividers. The breadboard area provides the space necessary to insert your own components but there are no circuit board traces here. You can build these networks to provide contact protection when actuating AC power line for reactive loads. Although many types of contact protection networks can be used, only RC networks and varistors are described in this section.
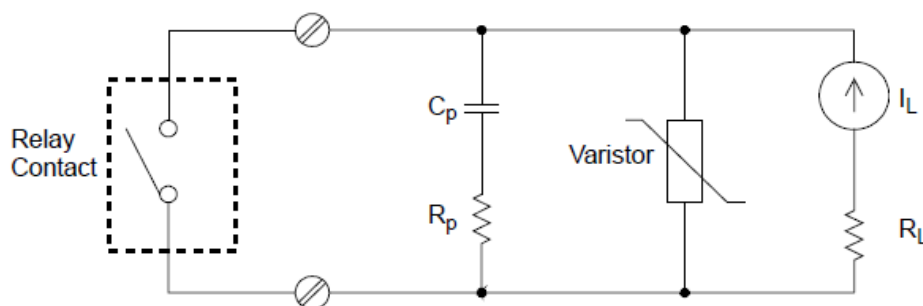
RC Protection Network

When designing RC protection networks, the protection resistor R_p is selected as a compromise between two resistance values. The minimum value of R_p is determined by the maximum acceptable relay contact current (I_{max}). For the DAQM903A, the maximum allowable relay current (I_{max}) is 1 A DC or AC rms. Thus, the minimum value for R_p is V/I_o, where V is the peak value of the supply voltage.

$$\mathbf{R_p} \ = \ \frac{\mathbf{V}}{\mathbf{I_{max}}} \ = \ \frac{\mathbf{V}}{\mathbf{2}}$$

The maximum value for R_p is usually made equal to the load resistance R_L. Therefore, the limits on R_p can be stated as:

$$\frac{\mathbf{V}}{\mathbf{I_{max}}} \ < \ \mathbf{R_p} \ < \ \mathbf{R_L}$$

Note that the actual value of the current (I_o) in a circuit is determined by the equation:

$$\mathbf{I_o} \ = \ \frac{\mathbf{V}}{\mathbf{R_L}}$$

where V is the peak value of the source voltage and R_L is the resistance of the load. The value for I_o will be used to determine the value of the protection capacitor (C_p).

In determining the value of the protection network capacitor (C_p), there are several things that you will need to consider. First, the total circuit capacitance (C_{tot}) must be such that the peak voltage across the open relay contacts does not exceed 300 V_{rms}. The equation for determining the minimum allowable circule capacitance is:

$$C_{tot} \geq (I_o/300)^2 \times L$$

where L is the inductance of the load and I_o is the current value calculated earlier.

The total circuit capacitance (C) is actually made up of the wiring capacitance plus the value of the protection network capacitor (C_p). Therefore, the minimum value for C_p should be the value obtained for the total circuit capacitance (C). Note that the actual value used for C_p should be substantially greater than the value calculated for C.

Using Varistors

Use a varistor to add an absolute voltage limit across the relay contacts. Varistors are available for a wide range of voltage and clamp energy ratings. Once the circuit reaches the voltage rating of the varistor, the varistor's resistance declines rapidly. A varistor can supplement an RC network and is especially useful when the required capacitance (C_p) is too large.

Using Attenuators

Provisions have been made on the DAQM903A circuit board for installing simple attenuators or filter networks. An attenuator is composed of two resistors that act as a voltage divider. A typical attenuator circuit is shown below:
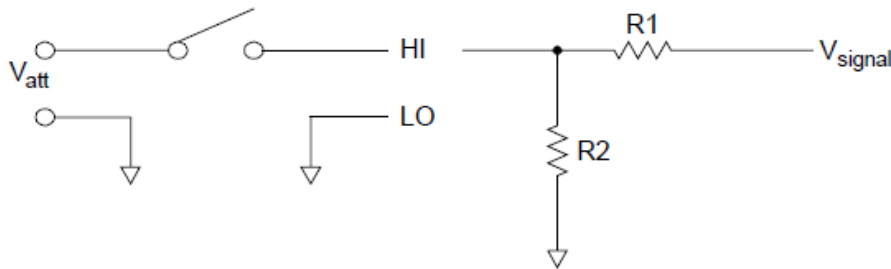

To select the attenuator components, use the following equation:

$$V_{att} = V_{signal} \times \frac{R_2}{R_1 + R_2}$$

One typical use for the shunt component is with 4 to 20 mA transducers. A 50 Ω, ±1%, 0.5 watt resistor can be installed in the R2 location. The resultant voltage drop (transducer current through the resistor) can be measured by the internal DMM. Thus, the 50 Ω resistor converts the 4 to 20 mA current to a 0.2 to 1 volt signal.

Matrix Switching

A matrix switch connects multiple inputs to multiple outputs and therefore offers more switching flexibility than a multiplexer. Use a matrix for switching low-frequency (less than 10 MHz) signals only. A matrix is arranged in rows and columns. For example, a simple 3x3 matrix could be used to connect three sources to three test points as shown below:
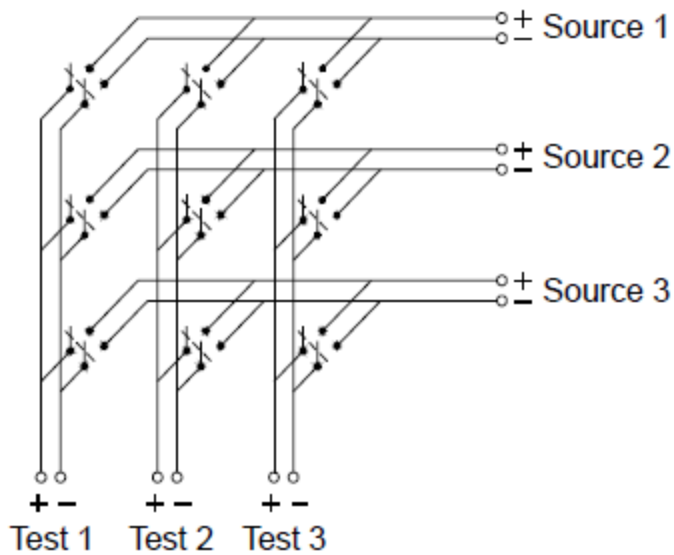
Any one of the signal sources can be connected to any one of the test inputs. Be aware that with a matrix, it is possible to connect more than one source at the same time. It is important to make sure that dangerous or unwanted conditions are not created by these connections.

Combining Matrices

You can combine two or more matrix switches to provide more complex switching. For example, the DAQM904A provides a 4-row by 8-column matrix. You can combine two of these modules as either a 4-row by 16-column matrix or an 8-row by 8-column matrix. An 8x8 matrix is shown below:

Matrix Module 1

Matrix Module 2
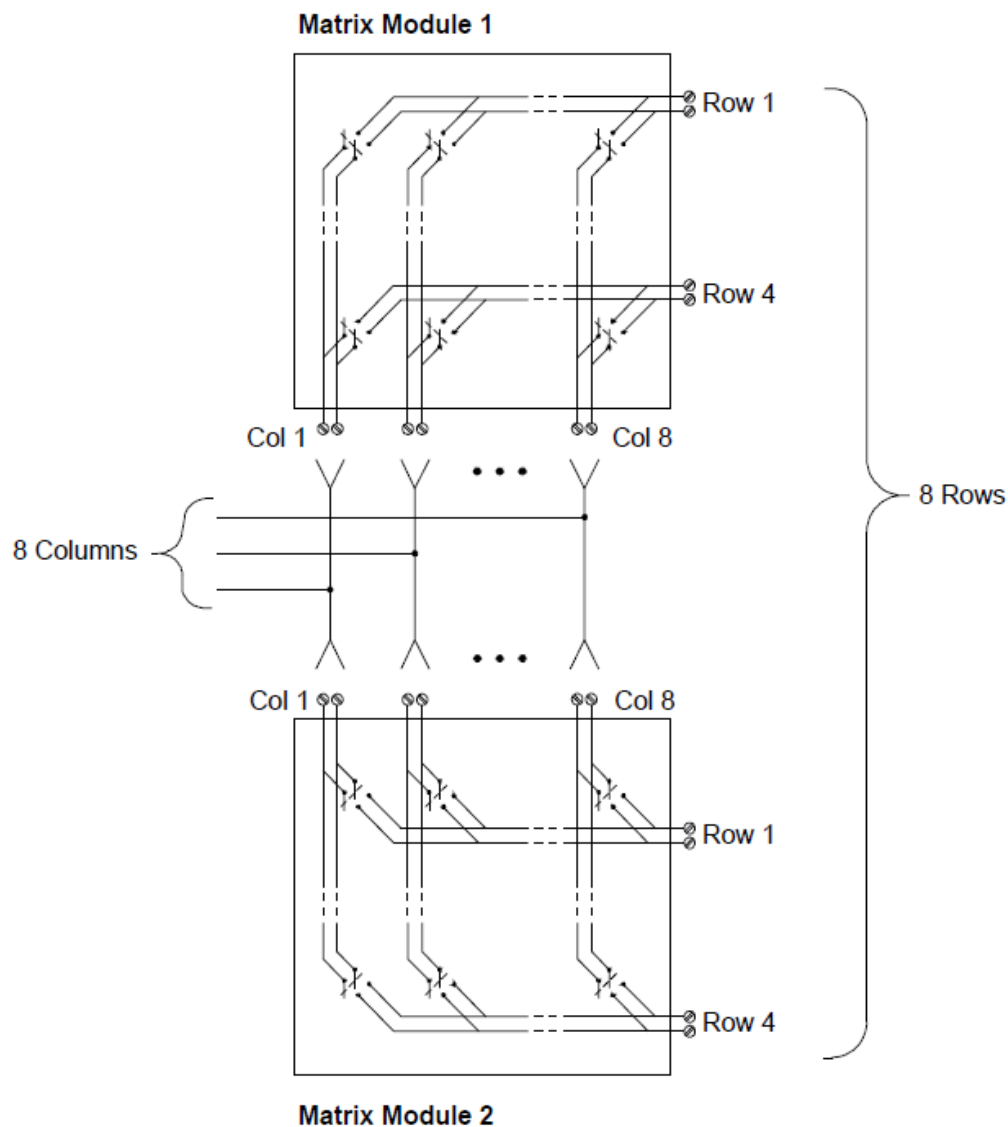
RF Signal Multiplexing

A special type of multiplexer is the RF multiplexer. This type of multiplexer uses special components to main-
tain a 50 Ω impedance in the signal line being switched. In a test system, these switches are often used to
route a test signal from a signal source to the device-under-test. The switches are bi-directional. The dia-
gram below shows two examples of a 4-to-1 channel RF multiplexer in a test system.
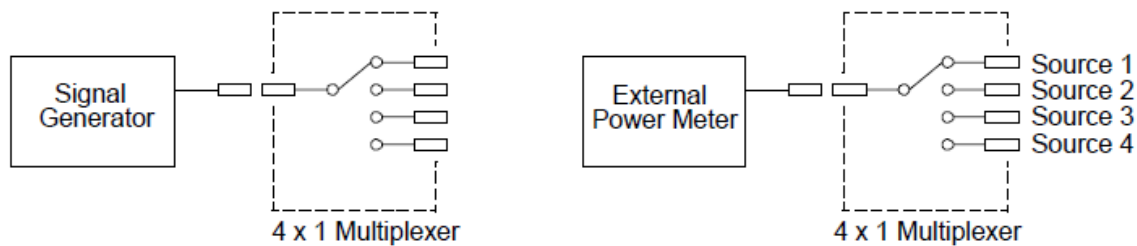
By using patch cables, you can expand RF multiplexers to provide additional test inputs or outputs. For example, you can combine two 4-to-1 multiplexers to create a 7-to-1 multiplexer as shown below:
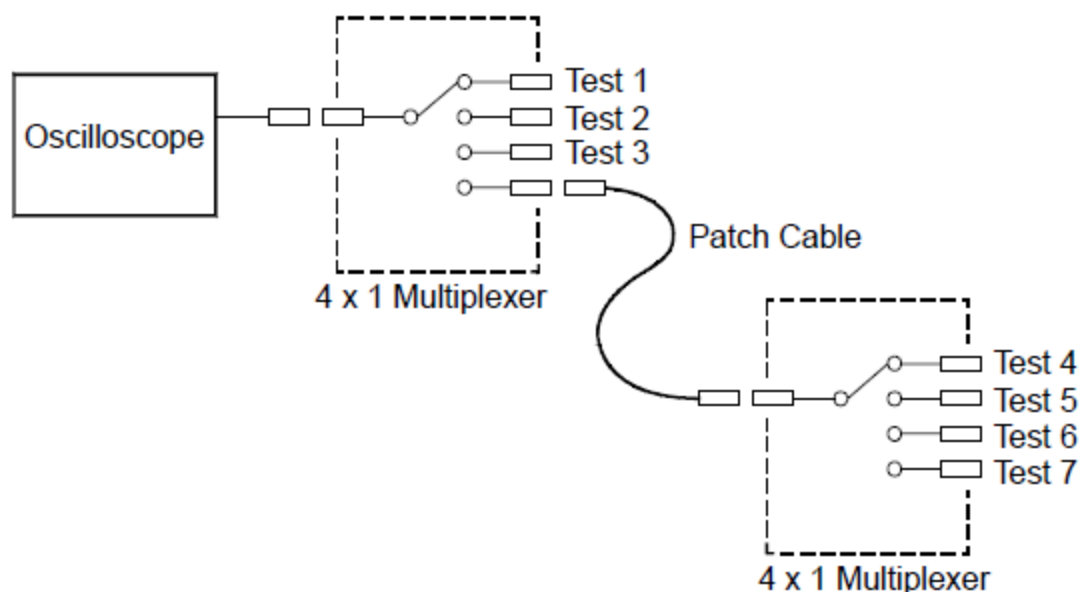

On the DAQM905A (50 Ω) RF multiplexers, you can close only one channel per bank at a time; closing one channel in a bank will open the previously closed channel. These modules respond only to the CLOSE command (OPEN does not apply). To open a channel, send the CLOSE command to another channel in the same bank. Note that DAQM905A module do not automatically terminate open channel.

Sources of Error in RF Switching

Impedance mismatching can cause a variety of errors in an RF multiplexing systenm. These errors can cause distorted waveforms, overvoltage, or undervoltage conditions.

To minimize RF impedance mismatching:

- Use the correct cable and connector for the circuit impedance (50 Ω). Be sure that all leads and signal paths are properly terminated. Unterminated sections of line can appear as near shorts at RF frequencies.
- Be sure that all leads and signal paths are properly terminated. Unterminated sections of line can appear as near shorts at RF frequencies.
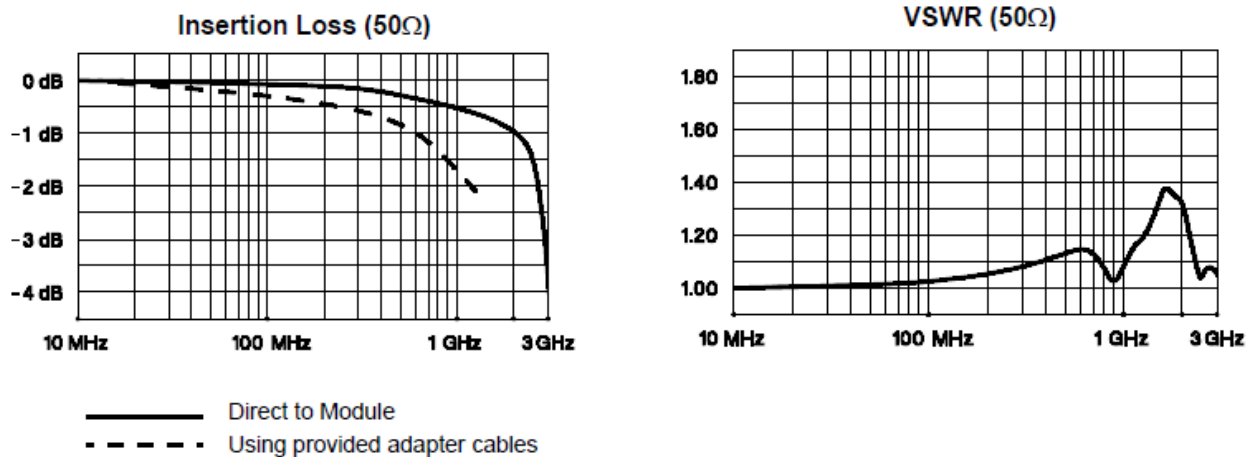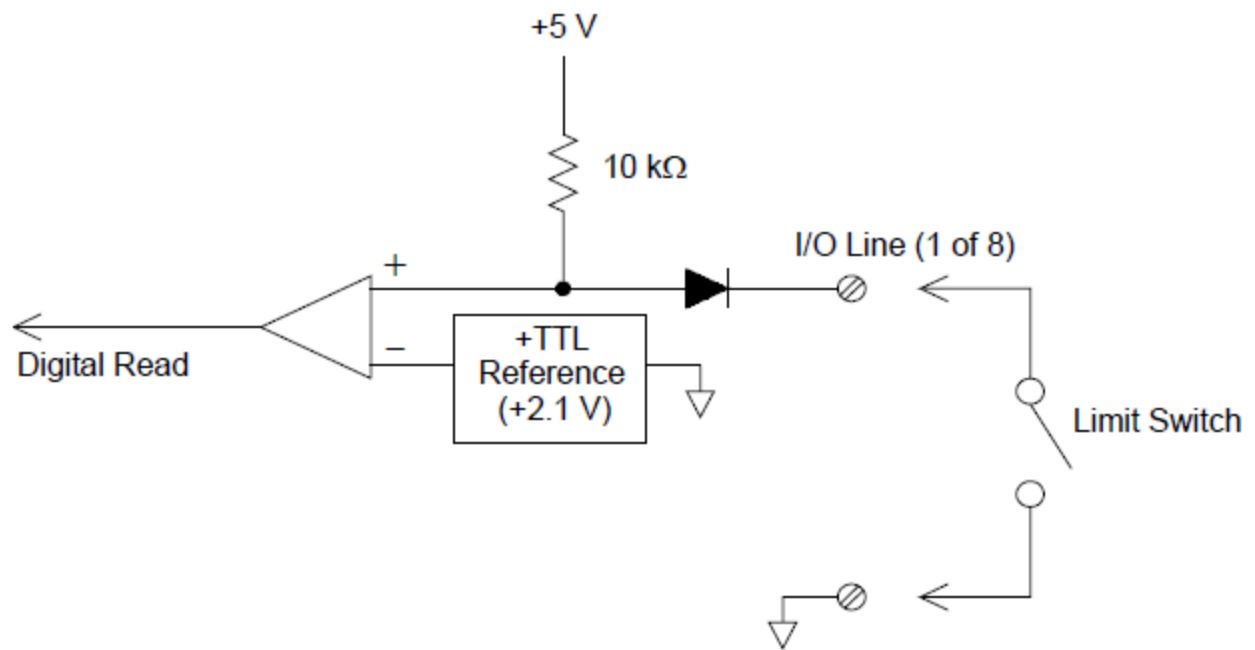

Multifunction Module

Digital Input

The DAQM907A module has two non-isolated 8-bit input/output ports which you can use for reading digital patterns.

- You can read the live status of the bits on the port or you can configure a scan to include a digital read.

- You can generate an alarm when a specific bit pattern or bit pattern change is detected on an input channel. The channels do not have to be part of the scan list to generate an alarm.

- The internal +5 V pull-up circuitry allows you to use the digital input to detect contacts closures like micro-switches or limit switches. An open input floats to +5 V and is read as a "1". An input shorted to ground is read as a "0". An example of a contact close detection channel is shown below:

Digital Output

The DAQM907A module has two non-isolated 8-bit input/output ports, which you can use for outputting digital patterns. You can combine the two ports to output a 16-bit word. A simplified diagram of a single output bit is shown below:
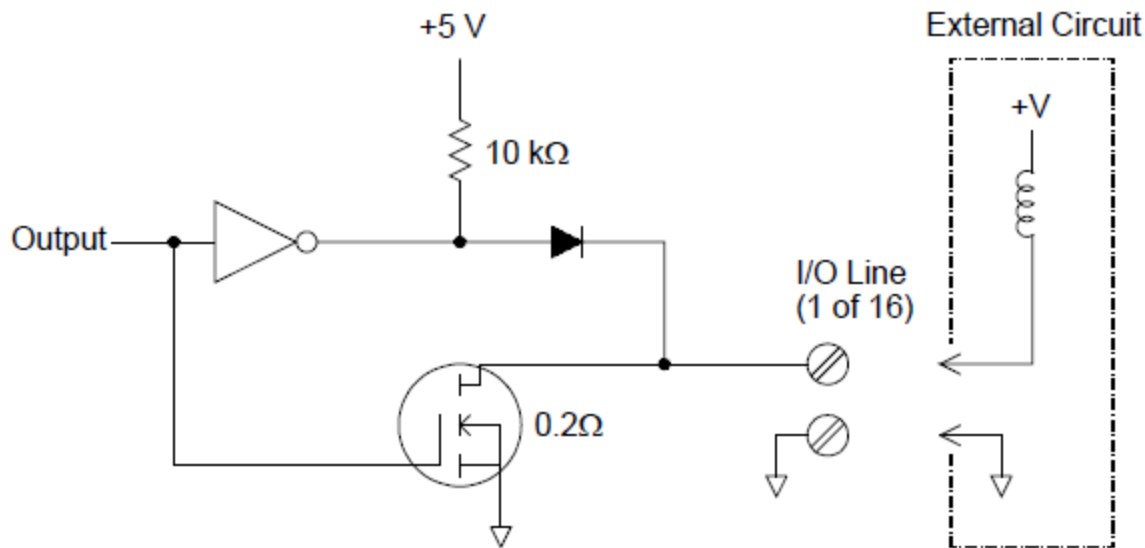
- Each output bit is capable of directly driving up to 10 TTL loads (less than 1 mA). The buffer for each port is used to drive a high output from the internal +5 V supply through the diode. The drive is rated at +2.4 V minimum at 1 mA.

- Each output bit is also can active sink, capable of sinking up to 400 mA from the external power supply. The FET is used to sink currents and has a nominal "on" resistance of 0.2 Ω.

- For non-TTL logic you must provide an external pull-up. A description of the pull-up cal-culation is given on the following section.

- If used with an external power supply and pull-up, the external supply must be greater than +5 VDC and less than +42 VDC.

Using an External Pull-Up

In general, an external pull-up is required only when you want to set the output "high" value greater than TTL levels. For example, to use a +12V external power supply, the value of the external pull-up resistor is calculated as follows:

V_{cc} = 12 VDC

I_{max} = $I_{out\ low}$ × safety factor = 1 mA × 0.5+0.5 mA

$$R = \frac{V_{cc}}{I_{max}} = \frac{12}{0.0005} = 24\ k\Omega$$

The value of the logic "high" level with the external 24 kΩ pull-up resistor is calculated as follows:

$$V_{high} = V_{cc} \times \frac{R_{external}}{R_{external}+R_{external}} = 12 \times \frac{24\ k\Omega}{24\ k\Omega + 10\ k\Omega} = 8.47\ VDC$$

Driving External Switches

You can use two digital output channels to control an external switch. For example, you can drive the Keysight 876X series of microwave switches using an external power supply and two digital output channels. The state of the 2-to-1 multiplexer is changed by setting the appropriate output bit low (0).
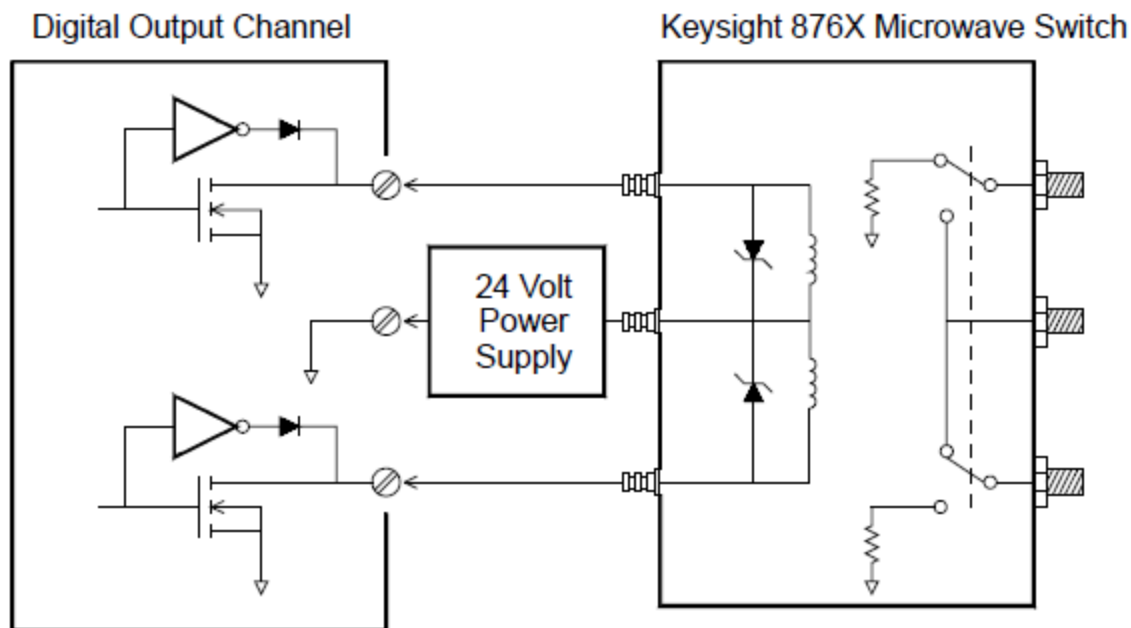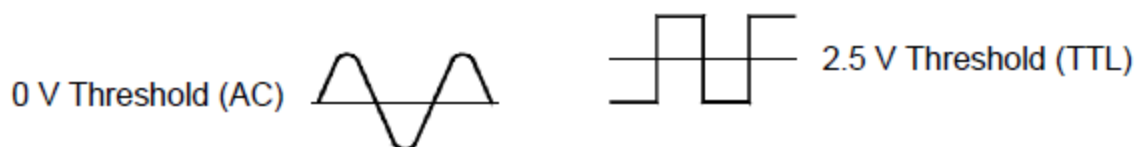
Totalizer

The DAQM907A module has a 26-bit totalizer which can count pulses at a 100 kHz rate. You can manually read the totalizer count or you can configure a scan to read the count.
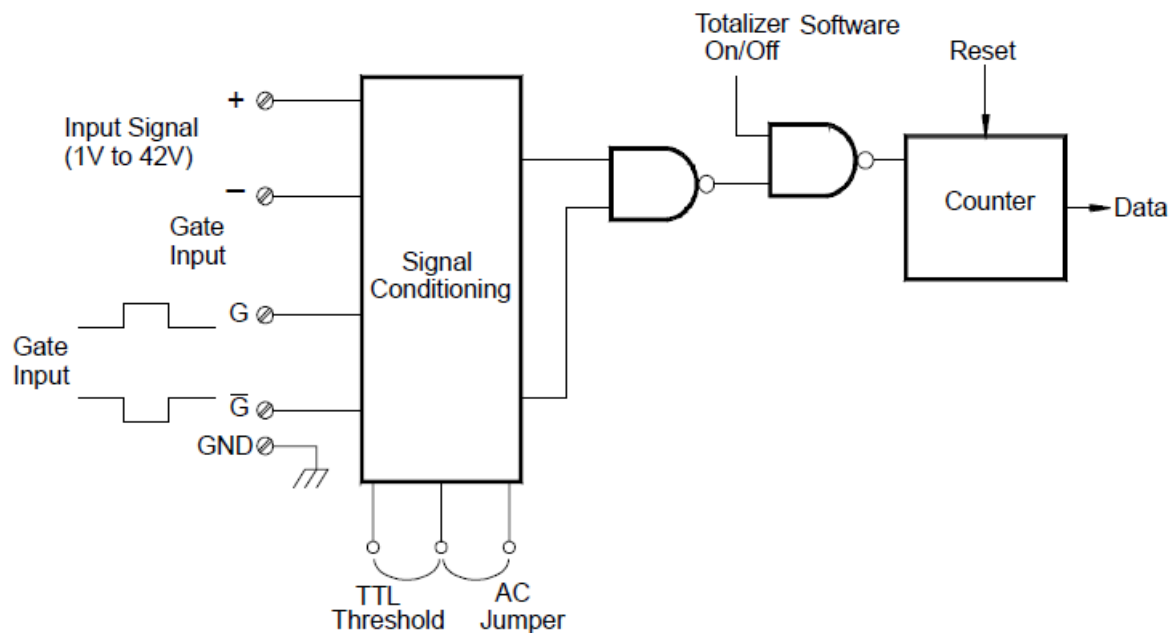

You can configure the totalizer to count on the rising edge or falling edge of the input signal.

Using the hardware jumper labeled "Totalize Threshold" on the module, you can control the threshold at which an edge is detected. Move the jumper to the "AC" position to detect changes through 0 volts. Move the jumper to the "TTL" position (factory setting) to detect changes through TTL threshold levels.

The maximum count is 67,108,863 (2^{26}-1). The count rolls over to "0" after reaching the maximum allowed value.

You can control when the totalizer actually records counts by providing a gate signal ($\mathbf{G}$ and $\overline{\mathbf{G}}$ terminals on the module). A TTL high signal applied to the "G" terminal enables counting and a low signal disables counting. A TTL low signal applied to the "$\overline{\mathbf{G}}$" terminal enables counting and a high signal disables counting. The totalizer only counts when both terminals are enabled. You can use the either G terminal, the $\overline{\mathbf{G}}$ terminal, or both. When a gate is not connected, the gate terminal floats to the enabled state, effectively creating a "gate always" condition.

Add to Total
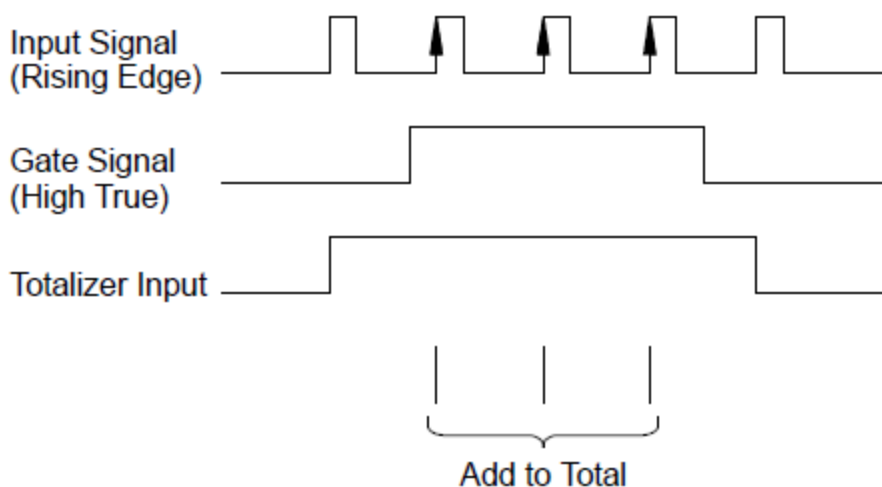
Totalizer Errors

Noise on the totalizer input can be a problem, especially on signals with a slow rise time. This noise can create a false indication of a threshold crossing. See System Cabling and Connections for more information.

Contact bounce on external switches can create false counts. All mechanical switches bounce when they open and close. Use an external capacitor to filter the contact bounce.
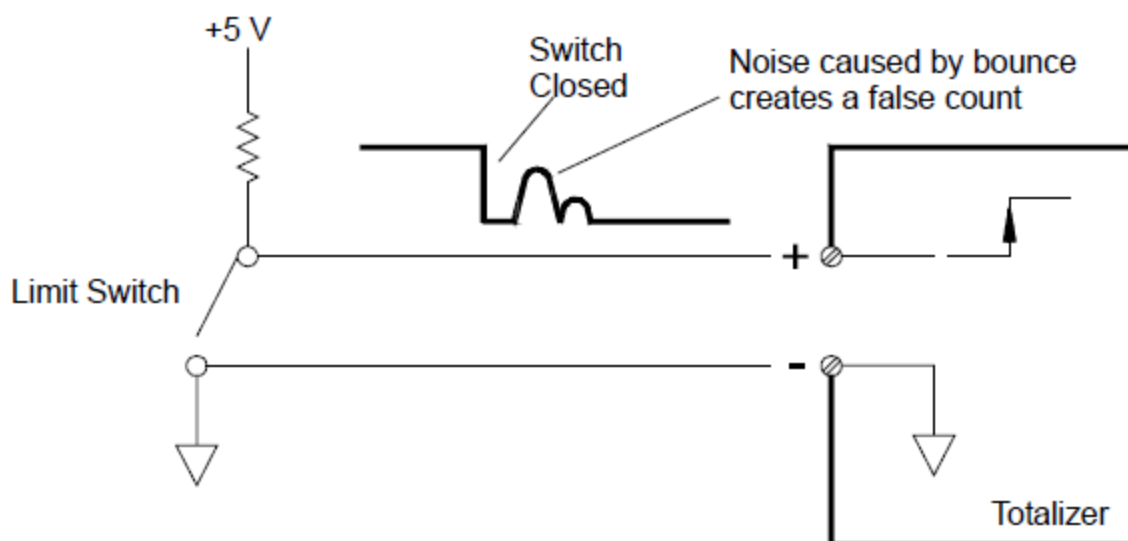
Analog Output (DAC)

The DAQM907A module has two analog outputs and senses capable of outputting calibrated voltages or currents with 18 bits of resolution.

Each DAC (Digital-to-Analog Converter) channel can be used as a programmable voltage or current source for analog input to other devices.
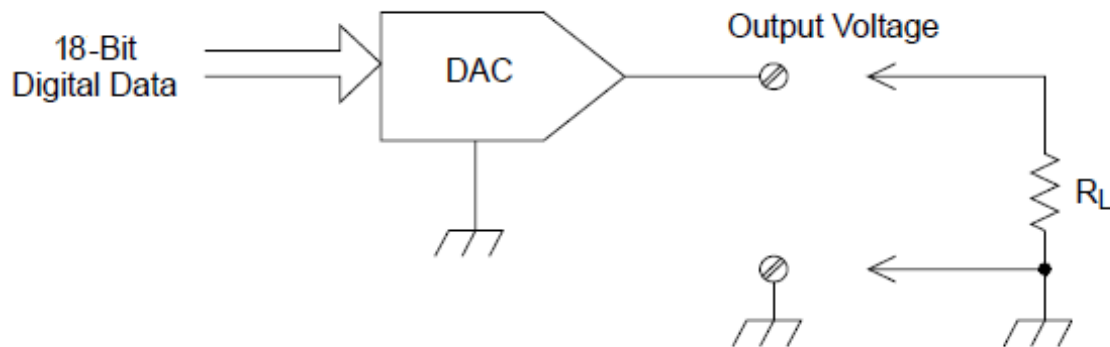
You can set the output voltage to any value between +12 VDC and –12 VDC, in 0.1 mV steps. Each DAC is earth referenced; it cannot float.

Each DAC channel is capable of supplying 15 mA maximum current.

| NOTE	You must limit the DAC output current to 40 mA total for each slot (two DAC channels).

To maintain the rated output accuracy, the load (R_L in the diagram shown above) must be greater than 1 kΩ.

DAC Errors

The output of a DAC varies with temperature. If possible, you should operate the instrument at a stable temperature and as close as possible to the calibration temperature of the DAC for greater accuracy, or perform autocalibration to recalibrate the DAC if the temperature has changed much from calibration temperature.

The output of a DAC also exhibits two other types of errors: differential error and integral error.

Type of errors	Descriptions
Differential error	Refers to the smallest possible change in voltage. The DAC output is not linear, but is stepped as progressively larger (or smaller) voltages are programmed. The step is in 100 μV.
Integral error	Refers to the difference between the programmed voltage and the actual output voltage from the DAC.

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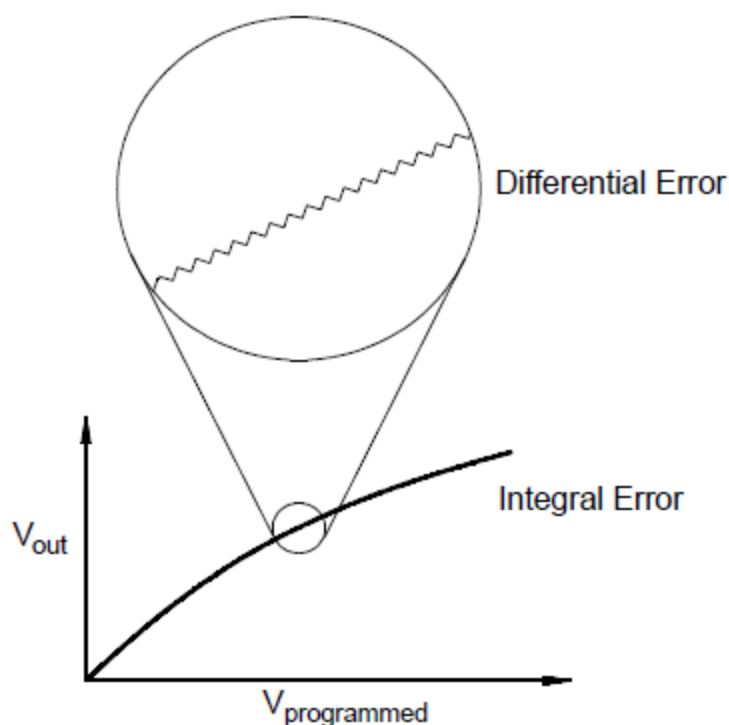
Relay Life and Preventive Maintenance

The DAQ970A Relay Maintenance System automatically counts the cycles on each relay in the instrument and stores the total count in nonvolatile memory on each switch module. Use this feature to track relay failures and predict system maintenance requirements.

Relays are electromechanical devices which are subject to wear-out failure modes. The life of a relay, or the number of actual operations before failure, is dependent upon how it is used – applied load, switching frequency, and environment.

You can use the graphs shown in this section to estimate relay lifetimes for your application. Additional background information is also provided to give you a better understanding of relay wear-out mechanisms. In general, relay lifetimes depend heavily upon the signals that are being switched and the types of measurements being performed.

- Switching typical signal levels will result in relay lifetimes from 1,000,000 to 10,000,000 operations.

- High-power switching (>25% rating) or high-voltage switching (>100 V) applications will yield relay lifetimes from 100,000 to 1,000,000 operations.

- Low-voltage switching (<25% rating) and low-current switching (<10 mA) applications will yield relay lifetimes to 10,000,000 operations.

- RF switching applications seldom exhibit relay lifetimes exceeding 1,000,000 operations due to more stringent constant resistance requirements (typically less than 0.2 Ω).

The following table shows the time required to reach the specified number of switch operations for several switching speeds.

| Continuous switching speed	Switching operations		
	100,000	1,000,000	10,000,000
1 / hour	12 years	N/A	N/A
1 / minute	10 weeks	2 years	N/A
1 / second	1 day	12 days	4 months
10 / second	3 hours	1 day	12 days

Relay Life

As a relay is used, the contacts begin to wear and the resistance of the closed contacts increases. The initial contact resistance of a relay is typically 50 mΩ (plus lead resistance). When the contact resistance exceeds 20 to 50 times its initial value, the contact resistance becomes very erratic and the relay should probably be replaced. For most applications, a relay with contact resistance greater than 1 Ω should be replaced. The graph below shows the typical contact resistance characteristics of the relays used on the DAQ970A switching modules.
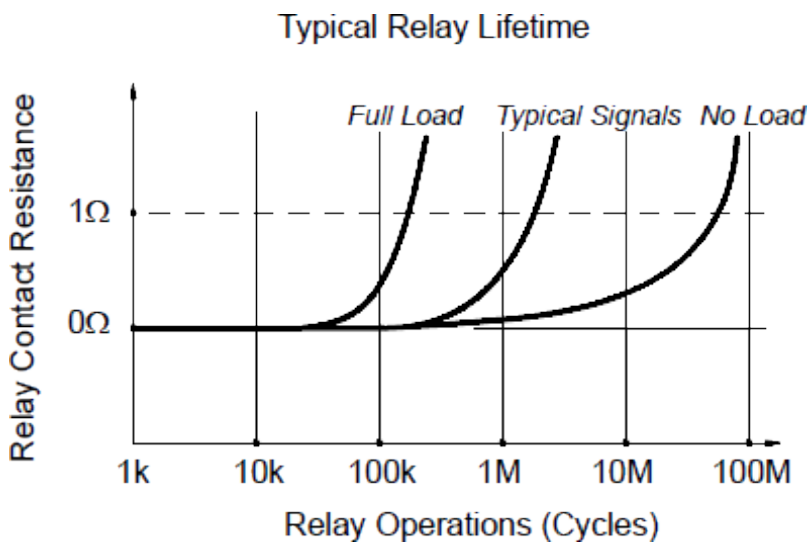
Relay Load

For most applications, the load switched by the relay is the most important factor affecting relay life. As shown in the graph below, relay life is maximized by switching low power. As the power switched increases, relay life deteriorates.
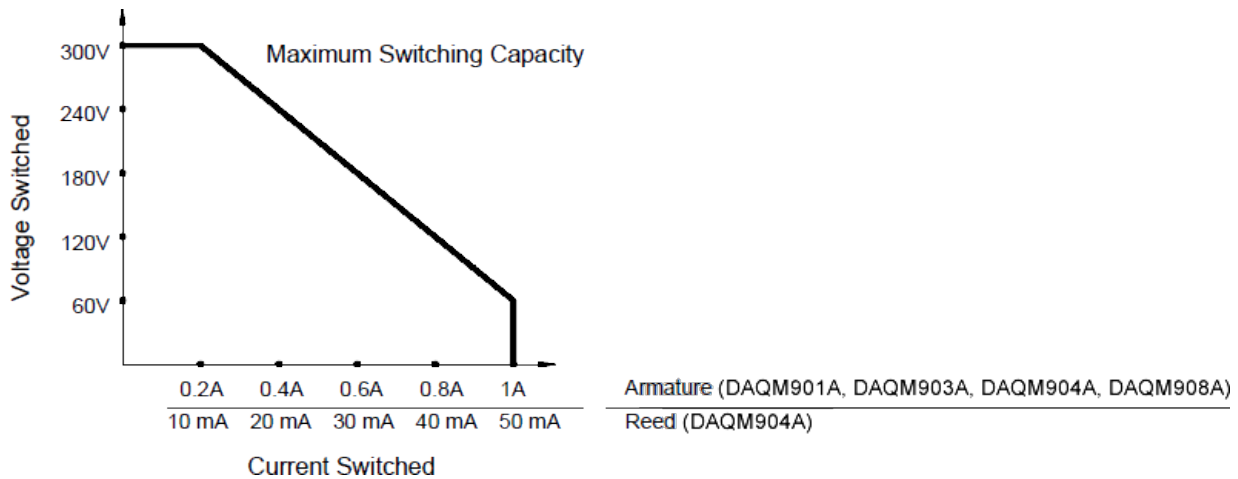
Switching Frequency

Relay contacts heat up as they switch significant power. The heat is dissipated through the leads and the body of the relay. As you increase the switching frequency to near its maximum, heat cannot dissipate before the next cycle. The contact temperature rises and the life of the relay is reduced.

Replacement Strategy

There are essentially two strategies that you can use for preventive maintenance of the relays on the switching modules. The strategy that you choose depends upon your application, the consequences of a relay failure in your system, and the number of relay cycles during a measurement session.

The first strategy is to replace each relay as needed after it fails or becomes erratic. This is suitable if you are switching higher loads on only a few relays on the module. The disadvantage of this strategy is the inconvenience of continually replacing relays as they near the end of their life at different times.

The second strategy is to replace all relays on the module or simply purchase a new module as the relays near the end of their life. This strategy is best suited for those applications where all relays on the module are switching similar loads. The failure of several relays over a relatively short period of time may indicate impending failures on other relays switching similar loads. This strategy decreases the risk of failure during actual use at the expense of replacing some relays that may have useful life remaining.

> **NOTE**   For switching frequency and replacement strategy as described above, you can use the DAQ970A Relay Maintenance System to track and even predict relay failures.

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