

The Agilent Technologies 34970A 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 data logging and data acquisition features makes this instrument a versatile solution for your testing requirements now and in the future.

Convenient Data Logging Features

- Direct measurement of thermocouples, RTDs, thermistors, dc voltage, ac voltage, resistance, dc current, ac current, frequency, and period
- Interval scanning with storage of up to 50,000 time-stamped readings
- Independent channel configuration with function, Mx+B scaling, and alarm limits available on a per-channel basis
- Intuitive user interface with knob for quick channel selection, menu navigation, and data entry from the front panel
- Portable, ruggedized case with non-skid feet
- *BenchLink Data Logger Software* for Microsoft® Windows® included

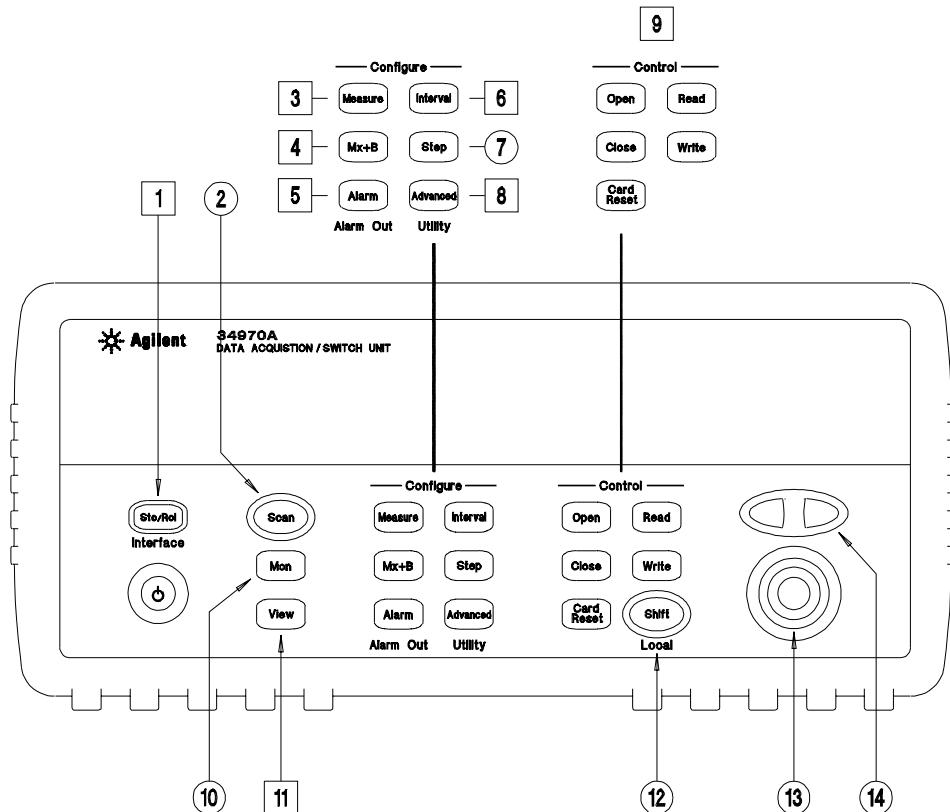
Flexible Data Acquisition/Switching Features

- 6½-digit multimeter accuracy, stability, and noise rejection
 - Up to 60 channels per instrument (120 single-ended channels)
 - Reading rates up to 600 readings per second on a single channel and scan rates up to 250 channels per second
 - Choice of multiplexing, matrix, general-purpose Form C switching, RF switching, digital I/O, totalize, and 16-bit analog output functions
 - GPIB (IEEE-488) interface and RS-232 interface are standard
 - SCPI (*Standard Commands for Programmable Instruments*) compatibility
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Agilent 34970A

Data Acquisition/Switch Unit

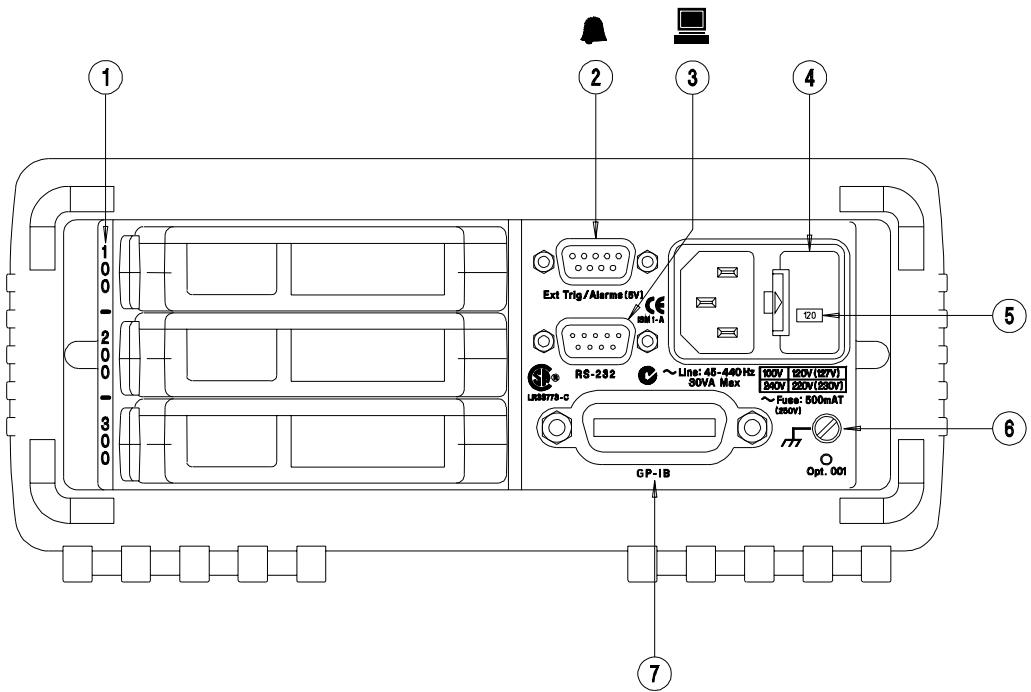
The Front Panel at a Glance



Denotes a menu key. See the next page for details on menu operation.

-
- 1 State Storage / Remote Interface Menus
 - 2 Scan Start / Stop Key
 - 3 Measurement Configuration Menu
 - 4 Scaling Configuration Menu
 - 5 Alarm / Alarm Output Configuration Menu
 - 6 Scan-to-Scan Interval Menu
 - 7 Scan List Single Step / Read Key
 - 8 Advanced Measurement / Utility Menus
 - 9 Low-Level Module Control Keys
 - 10 Single-Channel Monitor On / Off Key
 - 11 View Scanned Data, Alarms, Errors Menu
 - 12 Shift / Local Key
 - 13 Knob
 - 14 Navigation Arrow Keys
-

The Rear Panel at a Glance



-
- | | |
|---|--|
| 1 Slot Identifier (100, 200, 300) | 4 Power-Line Fuse-Holder Assembly |
| 2 Ext Trig Input / Alarm Outputs / Channel Advance Input / Channel Closed Output
(for pinouts, see pages 83 and 128) | 5 Power-Line Voltage Setting |
| 3 RS-232 Interface Connector | 6 Chassis Ground Screw |
| | 7 GP-IB (IEEE-488) Interface Connector |

Use the Interface Menu to:

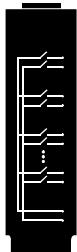
- Select the GP-IB or RS-232 interface (see chapter 2).
- Set the GP-IB address (see chapter 2).
- Set the RS-232 baud rate, parity, and flow control mode (see chapter 2).

WARNING

For protection from electrical shock, the power cord ground must not be defeated. If only a two-contact electrical outlet is available, connect the instrument's chassis ground screw (see above) to a good earth ground.

The Plug-In Modules at a Glance

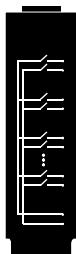
For complete specifications on each plug-in module, refer to the module sections in chapter 9.



34901A 20-Channel Armature Multiplexer

- 20 channels of 300 V switching
- Two channels for DC or AC current measurements (100 nA to 1A)
- Built-in thermocouple reference junction
- Switching speed of up to 60 channels per second
- Connects to the internal multimeter
- *For detailed information and a module diagram, see page 164.*

Each of the 20 channels switches both HI and LO inputs, thus providing fully isolated inputs to the internal multimeter. The module is divided into two banks of 10 two-wire channels each. When making four-wire resistance measurements, channels from *Bank A* are automatically paired with channels from *Bank B*. Two additional fused channels are included on the module (22 channels total) for making calibrated DC or AC current measurements with the internal multimeter (external shunt resistors are not required). You can close multiple channels on this module *only* if you have not configured any channels to be part of the scan list. Otherwise, all channels on the module are break-before-make.



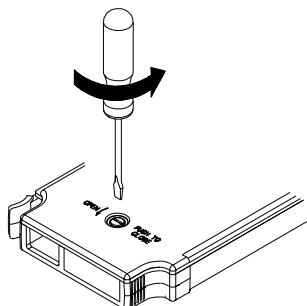
34902A 16-Channel Reed Multiplexer

- 16 channels of 300 V switching
- Built-in thermocouple reference junction
- Switching speed of up to 250 channels per second
- Connects to the internal multimeter
- *For detailed information and a module diagram, see page 166.*

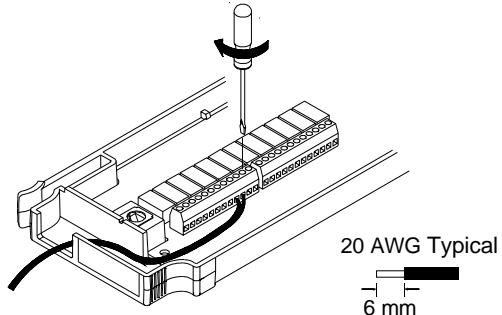
Use this module for high-speed scanning and high-throughput automated test applications. Each of the 16 channels switches both HI and LO inputs, thus providing fully isolated inputs to the internal multimeter. The module is divided into two banks of eight two-wire channels each. When making four-wire resistance measurements, channels from *Bank A* are automatically paired with channels from *Bank B*. You can close multiple channels on this module *only* if you have not configured any channels to be part of the scan list. Otherwise, all channels on the module are break-before-make.

To Connect Wiring to a Module

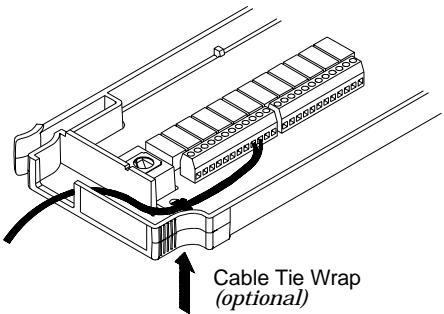
1 Remove the module cover.



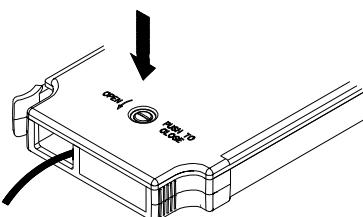
2 Connect wiring to the screw terminals.



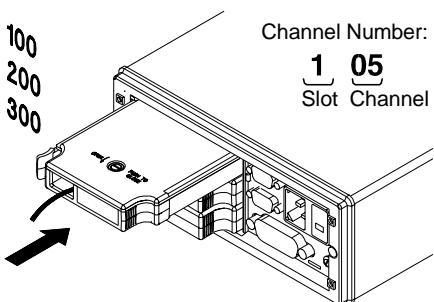
3 Route wiring through strain relief.



4 Replace the module cover.



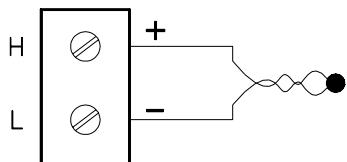
5 Install the module into mainframe.



Wiring Hints...

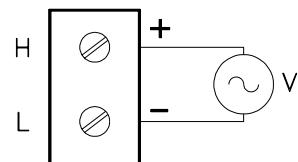
- For detailed information on each module, refer to the section starting on page 163.
- To reduce wear on the internal DMM relays, wire *like* functions on adjacent channels.
- For information on grounding and shielding, see page 335.
- The diagrams on the next page show how to connect wiring to a multiplexer module for each measurement function. ➔

Thermocouple



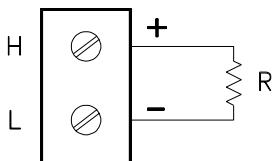
Thermocouple Types: B, E, J, K, N, R, S, T
See page 351 for thermocouple color codes.

DC Voltage / AC Voltage / Frequency



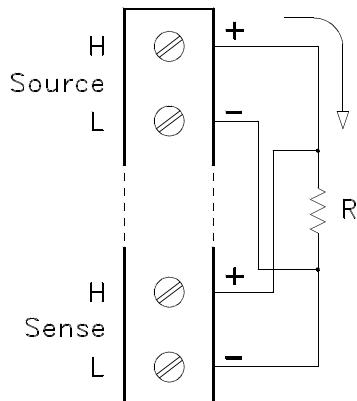
Ranges: 100 mV, 1 V, 10 V, 100 V, 300 V

2-Wire Ohms / RTD / Thermistor

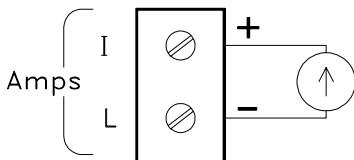


Ranges: 100, 1 k, 10 k, 100 k, 1 M, 10 M, 100 M Ω
RTD Types: 0.00385, 0.00391
Thermistor Types: 2.2 k, 5 k, 10 k

4-Wire Ohms / RTD



DC Current / AC Current



Valid only on channels 21 and 22 on the 34901A.
Ranges: 10 mA, 100 mA, 1A

Channel n (source) is automatically paired with
Channel $n+10$ (sense) on the 34901A or
Channel $n+8$ (sense) on the 34902A.

Ranges: 100, 1 k, 10 k, 100 k, 1 M, 10 M, 100 M Ω
RTD Types: 0.00385, 0.00391

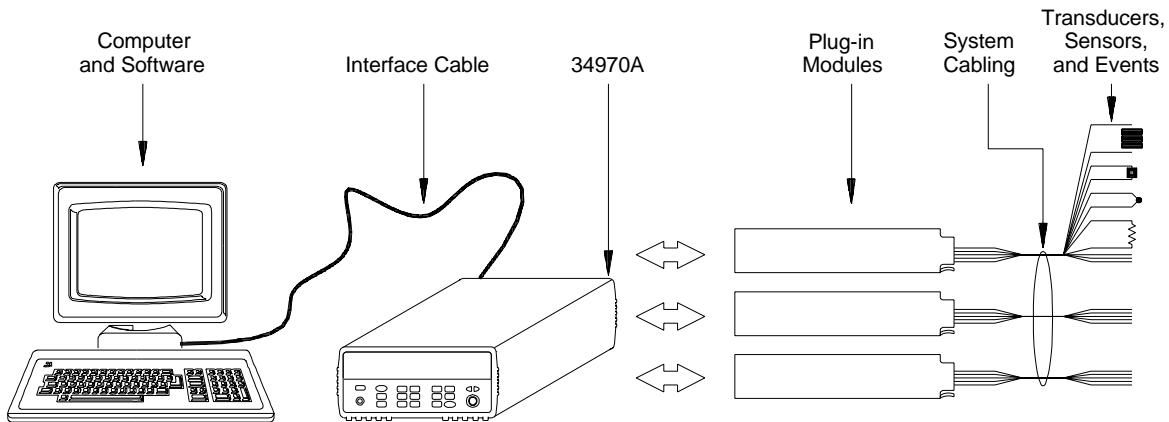
System Overview

This chapter provides an overview of a computer-based system and describes the parts of a data acquisition system. This chapter is divided into the following sections:

- Data Acquisition System Overview, *see below*
- Signal Routing and Switching, *starting on page 57*
- Measurement Input, *starting on page 60*
- Control Output, *starting on page 67*

Data Acquisition System Overview

You can use the Agilent 34970A 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 system configuration shown on the previous page offers the following advantages:

- You can use the 34970A 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 use a single PC to monitor multiple instruments and measurement points while performing other PC-based tasks.

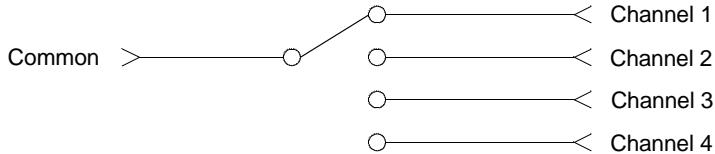
The Computer and Interface Cable

Since computers and operating systems are the subject of many books and periodicals, they are not discussed in this chapter. In addition to the computer and operating system, you will need a serial port (RS-232) or GPIB port (IEEE-488) and an interface cable.

Serial (RS-232)		GPIB (IEEE-488)	
Advantages	Disadvantages	Advantages	Disadvantages
Often built into the computer; no additional hardware is required.	Cable length is limited to 45 ft (15 m). *	Speed; faster data and command transfers.	Cable length is limited to 60 ft (20 m). *
Drivers usually included in the operating system.	Only one instrument or device can be connected per serial port.	Additional system flexibility, multiple instruments can be connected to the same GPIB port.	Requires an expansion slot plug-in card in PC and associated drivers.
Cables readily available and inexpensive. The 34970A is shipped with a serial cable (if internal DMM is ordered).	Cabling is susceptible to noise, causing slow or lost communications. Varying connector pinouts and styles.	Direct Memory Transfers are possible.	Requires special cable.
	Data transfers up to 85,000 characters/sec.	Data transfers up to 750,000 characters/sec.	

* You can overcome these cable length limitations using special communications hardware. For example, you can use the Agilent E5810A LAN-to-GPIB Gateway interface or a serial modem.

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 page 62.



Multiplexers are available in several types:

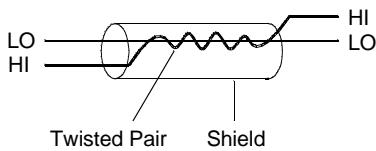
- *One-Wire (Single-Ended) Multiplexers* for common LO measurements.
For more information, see page 379.
- *Two-Wire Multiplexers* for floating measurements. For more information, see page 379.
- *Four-Wire Multiplexers* for resistance and RTD measurements.
For more information, see page 380.
- *Very High Frequency (VHF) Multiplexers* for switching frequencies up to 2.8 GHz. For more information, see page 390.

Shielding Techniques

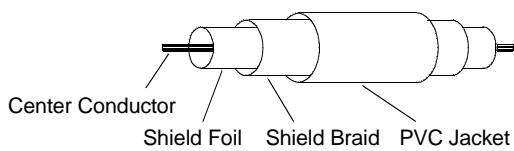
Shielding against noise must address both capacitive (electrical) and inductive (magnetic) coupling. The addition of a grounded shield around the conductor is highly effective against capacitive coupling. In switching networks, this shielding often takes the form of coaxial cables and connectors. For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

Recommended Low-Frequency Cable:
Shielded twisted pair



Recommended High-Frequency Cable:
Double-shielded coaxial cable



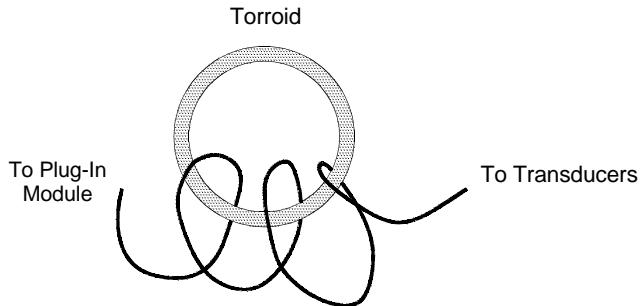
Separation of High-Level and Low-Level Signals

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 placed 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.

Sources 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 RFI 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. $\mu\text{V}/^\circ\text{C}$
Copper	<0.3
Gold	0.5
Silver	0.5
Brass	3
Beryllium Copper	5
Aluminum	5
Kovar or Alloy 42	40
Silicon	500
Copper-Oxide	1000
Cadmium-Tin Solder	0.2
Tin-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.

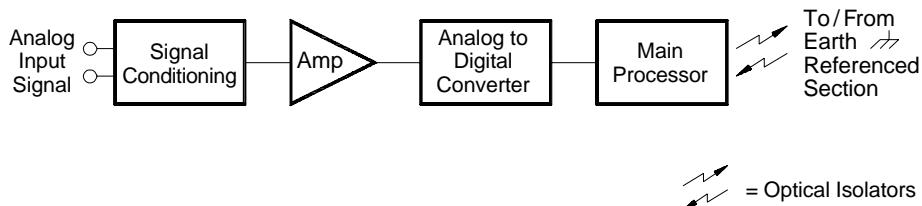
Where possible, you should route cabling away from magnetic fields. Magnetic fields are commonly present around electric motors, generators, televisions, and computer monitors. Also make sure that your input wiring has proper strain relief and is tied down securely when operating near magnetic fields.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

Measurement Fundamentals

This section explains how the 34970A makes measurements and discusses the most common sources of error related to these 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. *For complete details on the operation of the internal DMM, refer to "Measurement Input" on page 60.*



The internal DMM can directly make the following types of measurements. Each of these measurements is described in the following sections of this chapter.

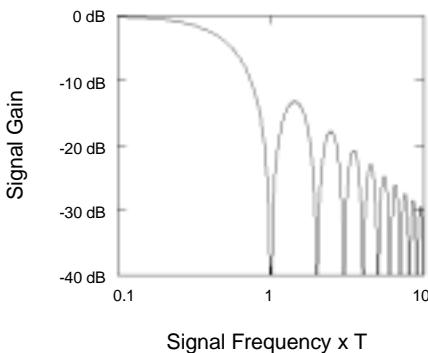
- Temperature (thermocouple, RTD, and thermistor)
- Voltage (dc and ac up to 300V)
- Resistance (2-wire and 4-wire up to 100 MΩ)
- Current (dc and ac up to 1A)
- Frequency and Period (up to 300 kHz)

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 table below shows the noise rejection achieved with various configurations. For better resolution and increased noise rejection, select a longer integration time.

PLCs	Digits	Bits	Integration Time 60 Hz (50 Hz)	NMR
0.02	4½	15	400 µs (400 µs)	0 dB
0.2	5½	18	3 ms (3 ms)	0 dB
1	5½	20	16.7 ms (20 ms)	60 dB
2	6½	21	33.3 ms (40 ms)	90 dB
10	6½	24	167 ms (200 ms)	95 dB
20	6½	25	333 ms (400 ms)	100 dB
100	6½	26	1.67 s (2 s)	105 dB
200	6½	26	3.33 s (4 s)	110 dB

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.



Chapter 8 Tutorial

Measurement Fundamentals

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 °C
RTD	0.02 °C
Thermistor	0.05 °C

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	$\approx R_0 \times 0.004 \text{ } ^\circ\text{C}$	$\approx 400 \text{ } \Omega / ^\circ\text{C}$
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, long-term measurements. The 34970A supports RTDs with $\alpha = 0.00385$ (DIN / IEC 751) using ITS-90 software conversions and $\alpha = 0.00391$ using IPTS-68 software conversions. “PT100” is a special label that is sometimes used to refer to an RTD with $\alpha = 0.00385$ and $R_0 = 100\Omega$.

The resistance of an RTD is nominal at 0 °C and is referred to as R_0 . The 34970A can measure RTDs with R_0 values from 49Ω to $2.1\text{ k}\Omega$.

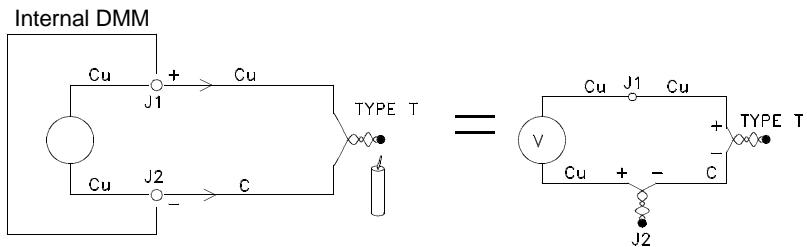
You can measure RTDs using a 2-wire or 4-wire measurement method. The 4-wire method (with offset compensation) provides the most accurate way to measure small resistances. Connection lead resistance is automatically removed using the 4-wire method.

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 $2.2\text{ k}\Omega$ (44004), $5\text{ k}\Omega$ (44007), and $10\text{ k}\Omega$ (44006) thermistors. The thermistor conversion routines used by the 34970A 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:

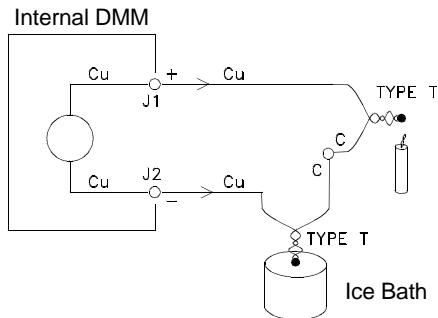


Notice, however, that the connections made between the thermocouple wire and the internal DMM make a second, unwanted thermocouple where the constantan (C) lead connects to the internal DMM's copper (Cu) input terminal. The voltage generated by this second thermocouple affects the voltage measurement of the T-type thermocouple.

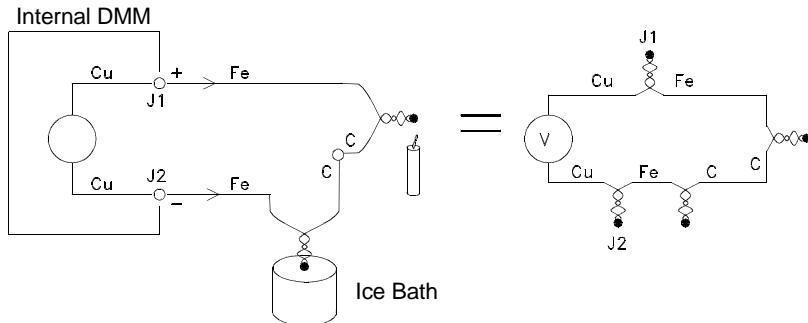
If the temperature of the thermocouple created at J2 (the LO input terminal) is known, the temperature of the T-type thermocouple can be calculated. One way to do this is to connect two T-type thermocouples together to create only copper-to-copper connections at the internal DMM's input terminals, and to hold the second thermocouple at a known temperature.

Chapter 8 Tutorial Measurement Fundamentals

An *ice bath* is used to create a known reference temperature ($0\text{ }^{\circ}\text{C}$). Once the reference temperature and thermocouple type are known, the temperature of the measurement thermocouple can be calculated.



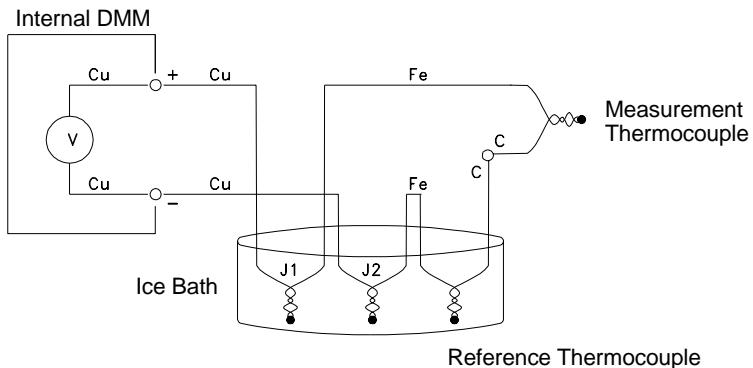
The T-type thermocouple is a unique case since one of the conductors (copper) is the same metal as the internal DMM's input terminals. If another type of thermocouple is used, two additional thermocouples are created. For example, take a look at the connections with a J-type thermocouple (iron and constantan):



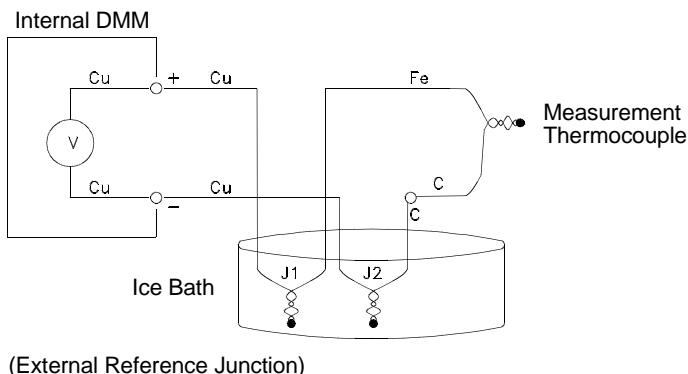
Two additional thermocouples have been created where the iron (Fe) lead connects to the internal DMM's copper (Cu) input terminals. Since these two junctions will generate opposing voltages, their effect will be to cancel each other. However, if the input terminals are not at the same temperature, an error will be created in the measurement.

Chapter 8 Tutorial Measurement Fundamentals

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.

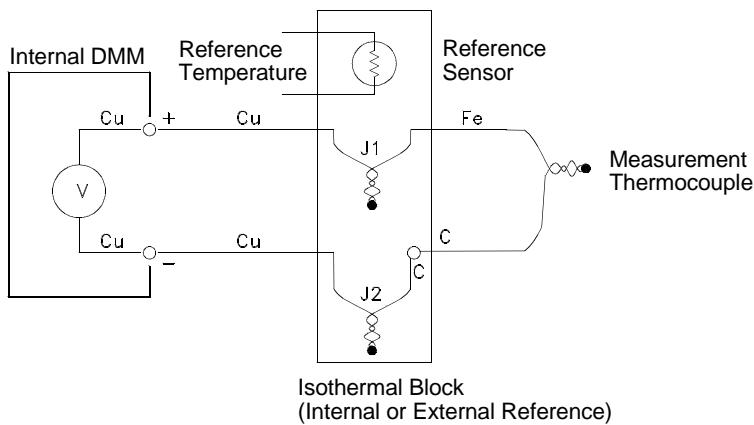


This circuit is the best solution for accurate thermocouple connections.

Chapter 8 Tutorial Measurement Fundamentals

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.

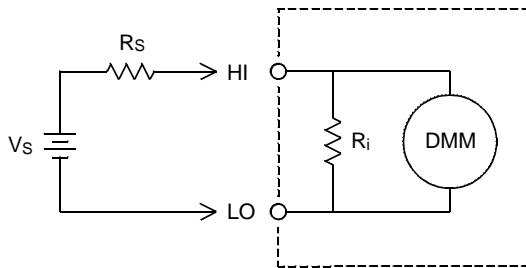
Once the temperature of the isothermal block is known, accurate temperature measurements can be made. A temperature sensor is mounted to the isothermal block to measure its temperature.



Thermocouples are available in a variety of types. The type is specified by a single letter. The table on the following page shows the most commonly used thermocouple types and some key characteristics of each.

Note: *The thermocouple conversion routines used by the 34970A are compatible with the International Temperature Scale of 1990 (ITS-90).*

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:

V_s = Ideal DUT voltage

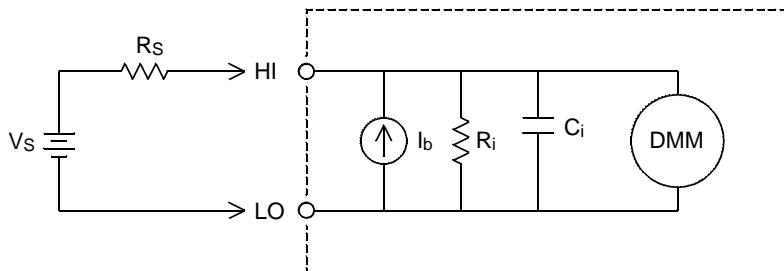
R_s = DUT source resistance

R_i = Input resistance ($10\text{ M}\Omega$ or $>10\text{ G}\Omega$)

$$\text{Error (\%)} = \frac{-100 \times R_s}{R_s + R_i}$$

To minimize loading errors, set the DMM's dc input resistance to greater than $10\text{ G}\Omega$ when needed (for more information on dc input resistance, see page 113).

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.



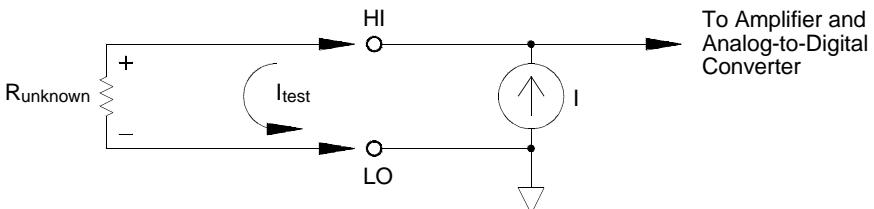
Where:

- I_b = DMM bias current
- R_s = DUT source resistance
- R_i = Input resistance ($10 \text{ M}\Omega$ or $>10 \text{ G}\Omega$)
- C_i = DMM input capacitance

$$\text{Error (V)} = I_b \times R_s$$

Resistance Measurements

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.



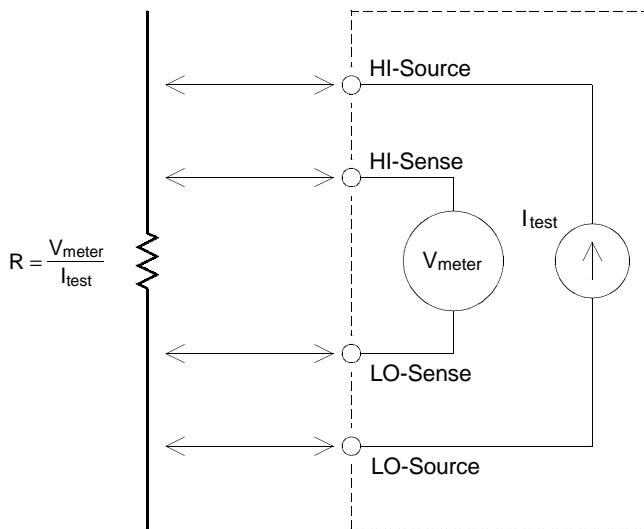
The internal DMM offers two methods for measuring resistance: **2-wire** and **4-wire** ohms. For both methods, the test current flows from the input HI terminal through the resistor being measured. For 2-wire ohms, the voltage drop across the resistor being measured is sensed internal to the DMM. Therefore, 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*.

Chapter 8 Tutorial Measurement Fundamentals

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 10Ω and for high-accuracy requirements such as RTD temperature transducers.



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 34970A.

- 34901A 20-Channel Armature Multiplexer
- 34902A 16-Channel Reed Multiplexer
- 34908A 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 34970A include the following:

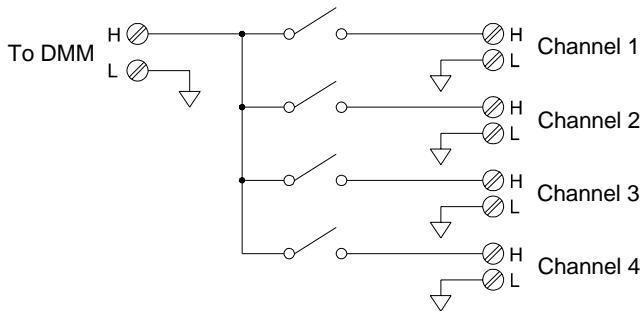
- 34903A 20-Channel Actuator
- 34904A 4x8 Two-Wire Matrix

Chapter 8 Tutorial

Low-Level Signal Multiplexing and Switching

One-Wire (Single-Ended) Multiplexers

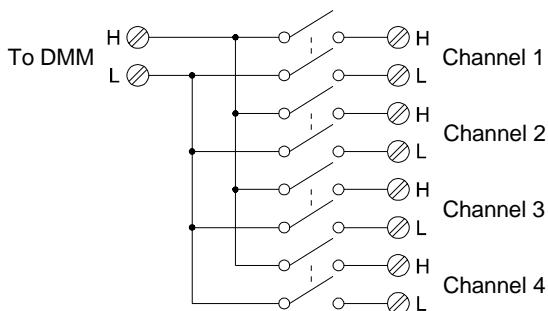
On the 34908A multiplexer, all of the 40 channels switch the HI input only, with a common LO for the module. The module also provides a thermocouple reference junction for making thermocouple measurements (*for more information on the purpose of an isothermal block, see page 350*).



Note: Only one channel can be closed at a time; closing one channel will open the previously closed channel.

Two-Wire Multiplexers

The 34901A and 34902A 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 (*for more information on the purpose of an isothermal block, see page 350*).

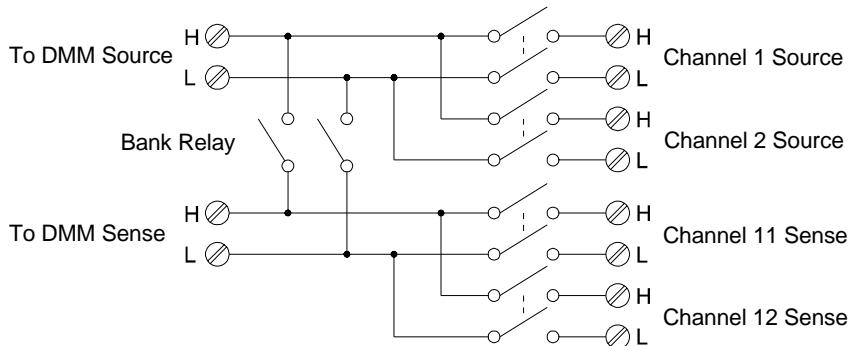


Note: If any channels are configured to be part of the scan list, you cannot close multiple channels; closing one channel will open the previously closed channel.

Four-Wire Multiplexers

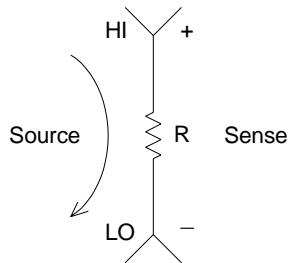
You can make 4-wire ohms measurements using the 34901A and 34902A multiplexers. For a 4-wire ohms measurement, the channels are divided into two independent banks by opening the bank relay.

For 4-wire measurements, the instrument automatically pairs channel n with channel $n+10$ (34901A) or $n+8$ (34902A) 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.

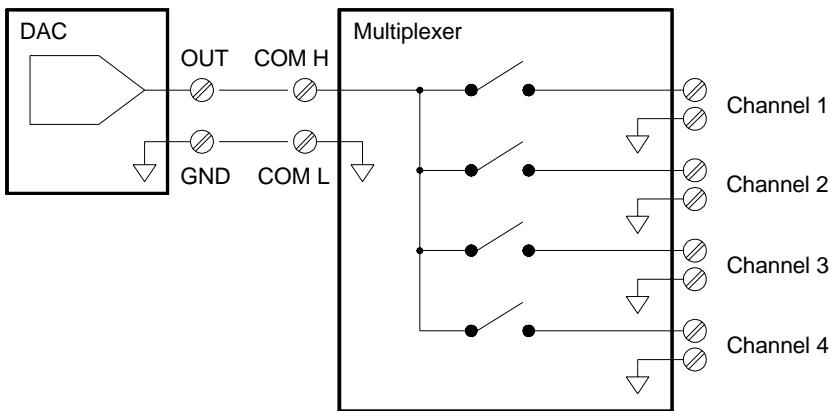
When making a 4-wire measurement, the test current flows through the *source* connections from the HI terminal through the resistor being measured. To eliminate the test lead resistance, a separate set of *sense* connections are used as shown below.



Signal Routing and Multiplexing

When used stand-alone for signal routing (not scanning or connected to the internal DMM), multiple channels on the 34901A and 34902A 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.



Chapter 9 Specifications

DC, Resistance, and Temperature Accuracy Specifications

■ DC, Resistance, and Temperature Accuracy Specifications

$\pm (\% \text{ of reading} + \% \text{ of range})^{[1]}$

Includes measurement error, switching error, and transducer conversion error

Function	Range ^[3]	Test Current or Burden Voltage	24 Hour ^[2] 23 °C ± 1 °C	90 Day 23 °C ± 5 °C	1 Year 23 °C ± 5 °C	Temperature Coefficient /°C 0 °C – 18 °C 28 °C – 55 °C
DC Voltage	100.0000 mV		0.0030 + 0.0035	0.0040 + 0.0040	0.0050 + 0.0040	0.0005 + 0.0005
	1.000000 V		0.0020 + 0.0006	0.0030 + 0.0007	0.0040 + 0.0007	0.0005 + 0.0001
	10.00000 V		0.0015 + 0.0004	0.0020 + 0.0005	0.0035 + 0.0005	0.0005 + 0.0001
	100.0000 V		0.0020 + 0.0006	0.0035 + 0.0006	0.0045 + 0.0006	0.0005 + 0.0001
	300.000 V		0.0020 + 0.0020	0.0035 + 0.0030	0.0045 + 0.0030	0.0005 + 0.0003
Resistance ^[4]	100.0000 Ω	1 mA current source 1 mA	0.0030 + 0.0035	0.008 + 0.004	0.010 + 0.004	0.0006 + 0.0005
	1.000000 kΩ		0.0020 + 0.0006	0.008 + 0.001	0.010 + 0.001	0.0006 + 0.0001
	10.00000 kΩ		0.0020 + 0.0005	0.008 + 0.001	0.010 + 0.001	0.0006 + 0.0001
	100.0000 kΩ		0.0020 + 0.0005	0.008 + 0.001	0.010 + 0.001	0.0006 + 0.0001
	1.000000 MΩ		0.002 + 0.001	0.008 + 0.001	0.010 + 0.001	0.0010 + 0.0002
	10.00000 MΩ		0.015 + 0.001	0.020 + 0.001	0.040 + 0.001	0.0030 + 0.0004
	100.0000 MΩ		0.300 + 0.010	0.800 + 0.010	0.800 + 0.010	0.1500 + 0.0002
DC Current <i>34901A Only</i>	10.00000 mA	< 0.1 V burden < 0.6 V < 2 V	0.005 + 0.010	0.030 + 0.020	0.050 + 0.020	0.002 + 0.0020
	100.0000 mA		0.010 + 0.004	0.030 + 0.005	0.050 + 0.005	0.002 + 0.0005
	1.000000 A		0.050 + 0.006	0.080 + 0.010	0.100 + 0.010	0.005 + 0.0010
Temperature	Type	Best Range Accuracy ^[5]		Extended Range Accuracy ^[5]		
Thermocouple ^[6]	B	1100°C to 1820°C	1.2°C	400°C to 1100°C	1.8°C	0.03°C
	E	-150°C to 1000°C	1.0°C	-200°C to -150°C	1.5°C	0.03°C
	J	-150°C to 1200°C	1.0°C	-210°C to -150°C	1.2°C	0.03°C
	K	-100°C to 1200°C	1.0°C	-200°C to -100°C	1.5°C	0.03°C
	N	-100°C to 1300°C	1.0°C	-200°C to -100°C	1.5°C	0.03°C
	R	300°C to 1760°C	1.2°C	-50°C to 300°C	1.8°C	0.03°C
	S	400°C to 1760°C	1.2°C	-50°C to 400°C	1.8°C	0.03°C
	T	-100°C to 400°C	1.0°C	-200°C to -100°C	1.5°C	0.03°C
RTD	R_0 from 49Ω to 2.1 kΩ	-200°C to 600°C	0.06°C			0.003°C
Thermistor	2.2 k, 5 k, 10 k	-80°C to 150°C	0.08°C			0.002°C

[1] Specifications are for 1 hour warm up and 6½ digits

[2] Relative to calibration standards

[3] 20% over range on all ranges except 300 Vdc and 1 Adc ranges

[4] Specifications are for 4-wire ohms function or 2-wire ohms using Scaling to remove the offset.
Without Scaling, add 4Ω additional error in 2-wire ohms function.

[5] 1 year accuracy. For total measurement accuracy, add temperature probe error.

[6] Thermocouple specifications not guaranteed when 34907A module is present

To Calculate Total Measurement Error

Each specification includes correction factors which account for errors present due to operational limitations of the internal DMM. This section explains these errors and shows how to apply them to your measurements. Refer to “Interpreting Internal DMM Specifications,” starting on page 416, to get a better understanding of the terminology used and to help you interpret the internal DMM’s specifications.

The internal DMM’s accuracy specifications are expressed in the form: (*% of reading + % of range*). In addition to the reading error and range error, you may need to add additional errors for certain operating conditions. Check the list below to make sure you include all measurement errors for a given function. Also, make sure you apply the conditions as described in the footnotes on the specification pages.

- If you are operating the internal DMM outside the $23\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$ temperature range specified, apply an additional *temperature coefficient error*.
- For dc voltage, dc current, and resistance measurements, you may need to apply an additional *reading speed error*.
- For ac voltage and ac current measurements, you may need to apply an additional *low frequency error* or *crest factor error*.

Understanding the “% of reading” Error The *reading error* compensates for inaccuracies that result from the function and range you select, as well as the input signal level. The reading error varies according to the input level on the selected range. This error is expressed in percent of reading. The following table shows the reading error applied to the internal DMM’s 24-hour dc voltage specification.

Range	Input Level	Reading Error (% of reading)	Reading Error Voltage
10 Vdc	10 Vdc	0.0015	$\leq 150\text{ }\mu\text{V}$
10 Vdc	1 Vdc	0.0015	$\leq 15\text{ }\mu\text{V}$
10 Vdc	0.1 Vdc	0.0015	$\leq 1.5\text{ }\mu\text{V}$

Chapter 9 Specifications To Calculate Total Measurement Error

Understanding the “% of range” Error The *range error* compensates for inaccuracies that result from the function and range you select. The range error contributes a constant error, expressed as a percent of range, *independent* of the input signal level. The following table shows the range error applied to the DMM’s 24-hour dc voltage specification.

Range	Input Level	Range Error (% of range)	Range Error Voltage
10 Vdc	10 Vdc	0.0004	$\leq 40 \mu\text{V}$
10 Vdc	1 Vdc	0.0004	$\leq 40 \mu\text{V}$
10 Vdc	0.1 Vdc	0.0004	$\leq 40 \mu\text{V}$

Total Measurement Error To compute the total measurement error, add the reading error and range error. You can then convert the total measurement error to a “percent of input” error or a “ppm (part-per-million) of input” error as shown below.

$$\% \text{ of input error} = \frac{\text{Total Measurement Error}}{\text{Input Signal Level}} \times 100$$

$$\text{ppm of input error} = \frac{\text{Total Measurement Error}}{\text{Input Signal Level}} \times 1,000,000$$

Example: Computing Total Measurement Error

Assume that a 5 Vdc signal is input to the DMM on the 10 Vdc range. Compute the total measurement error using the 90-day accuracy specification of $\pm(0.0020\% \text{ of reading} + 0.0005\% \text{ of range})$.

$$\text{Reading Error} = 0.0020\% \times 5 \text{ Vdc} = 100 \mu\text{V}$$

$$\text{Range Error} = 0.0005\% \times 10 \text{ Vdc} = 50 \mu\text{V}$$

$$\begin{aligned}\text{Total Error} &= 100 \mu\text{V} + 50 \mu\text{V} &= \pm 150 \mu\text{V} \\ &&= \pm 0.0030\% \text{ of } 5 \text{ Vdc} \\ &&= \pm 30 \text{ ppm of } 5 \text{ Vdc}\end{aligned}$$

Interpreting Internal DMM Specifications

This section is provided to give you a better understanding of the terminology used and will help you interpret the internal DMM's specifications.

Number of Digits and OVERRANGE

The "number of digits" specification is the most fundamental, and sometimes, the most confusing characteristic of a multimeter.

The number of digits is equal to the maximum number of "9's" the multimeter can measure or display. This indicates the number of *full digits*. Most multimeters have the ability to overrange and add a partial or "½" digit.

For example, the internal DMM can measure 9.99999 Vdc on the 10 V range. This represents six full digits of resolution. The internal DMM can also overrange on the 10 V range and measure up to a maximum of 12.00000 Vdc. This corresponds to a 6½-digit measurement with 20% overrange capability.

Sensitivity

Sensitivity is the minimum level that the internal DMM can detect for a given measurement. Sensitivity defines the ability of the internal DMM to respond to small changes in the input level. For example, suppose you are monitoring a 1 mVdc signal and you want to adjust the level to within $\pm 1 \mu\text{V}$. To be able to respond to an adjustment this small, this measurement would require a multimeter with a sensitivity of at least 1 μV . You could use a 6½-digit multimeter *if* it has a 1 Vdc or smaller range. You could also use a 4½-digit multimeter with a 10 mVdc range.

For ac voltage and ac current measurements, note that the smallest value that can be measured is different from the sensitivity. For the internal DMM, these functions are specified to measure down to 1% of the selected range. For example, the internal DMM can measure down to 1 mV on the 100 mV range.

Resolution

Resolution is the numeric ratio of the maximum displayed value divided by the minimum displayed value on a selected range. Resolution is often expressed in percent, parts-per-million (ppm), counts, or bits. For example, a 6½-digit multimeter with 20% overrange capability can display a measurement with up to 1,200,000 counts of resolution. This corresponds to about 0.0001% (1 ppm) of full scale, or 21 bits including the sign bit. All four specifications are equivalent.

Accuracy

Accuracy is a measure of the “exactness” to which the internal DMM’s measurement uncertainty can be determined *relative* to the calibration reference used. Absolute accuracy includes the internal DMM’s relative accuracy specification plus the known error of the calibration reference relative to national standards (such as the U.S. National Institute of Standards and Technology). To be meaningful, the accuracy specifications must be accompanied with the conditions under which they are valid. These conditions should include temperature, humidity, and time.

There is no standard convention among instrument manufacturers for the confidence limits at which specifications are set. The table below shows the probability of non-conformance for *each specification* with the given assumptions.

Specification Criteria	Probability of Failure
Mean \pm 2 sigma	4.5%
Mean \pm 3 sigma	0.3%

Variations in performance from reading to reading, and instrument to instrument, decrease for increasing number of sigma for a given specification. This means that you can achieve greater actual measurement precision for a specific accuracy specification number. The 34970A is designed and tested to meet performance better than mean \pm 3 sigma of the published accuracy specifications.

24-Hour Accuracy

The 24-hour accuracy specification indicates the internal DMM's relative accuracy over its full measurement range for short time intervals and within a stable environment. Short-term accuracy is usually specified for a 24-hour period and for a ± 1 °C temperature range.

90-Day and 1-Year Accuracy

These long-term accuracy specifications are valid for a 23 °C ± 5 °C temperature range. These specifications include the initial calibration errors plus the internal DMM's long-term drift errors.

Temperature Coefficients

Accuracy is usually specified for a 23 °C ± 5 °C temperature range. This is a common temperature range for many operating environments. You must add additional temperature coefficient errors to the accuracy specification if you are operating the internal DMM outside a 23 °C ± 5 °C temperature range (the specification is per °C).