Analog Signal Conditioning Accessories

NI AMUX-64T
- 64-channel multiplexer
- mV, V, current, and thermocouple inputs

NI SC-2040
- 8-channel simultaneous sample-and-hold
- mV, V inputs

NI SC-2042-RTD
- 8-channel RTD/thermistor
- RTD, thermistor, mV, V inputs

NI SC-2043-SG
- 8-channel bridge
- Strain, pressure, load torque, mV, V inputs

Operating Systems
- Windows 2000/NT/XP/Me/9x

Driver Software
- NI-DAQ

Accessory	Description	Sensor/Signal Type
AMUX-64T	64-channel multiplexer	mV, V, thermocouple
SC-2040	8-channel simultaneous sample-and-hold	mV, V
SC-2042-RTD	8-channel RTD/thermistor accessory	RTD, thermistor
SC-2043-SG	8-channel strain gauge accessory	Strain, bridge-based sensors

Table 1. Accessory Compatibility Guide

Overview
National Instruments offers several different front-end signal conditioning devices for use with E Series and basic multifunction DAQ devices. These devices offer a low-cost solution for applications requiring only one type of signal conditioning.

Connection to the E Series DAQ Device
You can connect each of these accessories directly to all E Series and basic multifunction DAQ devices. See Table 2 for more information on cabling required for each accessory. Cables are sold separately.

Each accessory also offers some special cabling features. The NI AMUX-64T and the SC-2040 include an additional 50-pin breakout cable connector for access to the unused I/O signals of the DAQ device. You can also use this second connector on the AMUX-64T to cascade up to four AMUX-64T devices to a single DAQ device, which thereby expands the analog input capacity of the DAQ device to 256 channels. In addition, you can connect up to four SC-2042-RTD or SC-2043-SG device to a single 603IE, 6033E, 6071E, or AT-MIO-64E-3 with the SC-2056 cable adapter device. See page 488 for details on this configuration.

Power
You can power each of these accessory devices with the 5 VDC supply on the DAQ device. This power is routed automatically through the I/O connector, unless specifically disabled on the accessory. Each device also offers screw terminals for connecting an external 5 VDC power supply. You need an external power supply only when using the SC-2043-SG with a DAQCard, or when using two or more SC-2043-SG devices with a single DAQ device. Each device includes a green LED to indicate that the device is powered.

Field Wiring
Signals from the transducers and signal sources connect to screw terminals located on each accessory.

Mounting
You can mount all of these accessories with the rack mount kit. The kit is available in either single or double height, with either an acrylic plastic cover or a metal wrap-around cover. All SC-204x accessories occupy half the width of this rack mount kit, while the AMUX-64T occupies two-thirds of the width. For custom connectivity applications, you can mount the SC-2040, SC-2042-RTD, and SC-2043-SG into the CA-1000 shielded enclosure, described on page 263.

Analog Signal Conditioning Accessories

AMUX-64T

Analog Input

The AMUX-64T contains 16 CMOS 4 x 1 analog input multiplexers. The analog inputs can operate as 64 single-ended or 32 differential inputs.

Channel Expandability

You can use one AMUX-64T for 64 input channels. You can also connect up to four devices together to provide up to 256 channels. With a single AMUX-64T, four analog input channels are multiplexed to each multifunction DAQ device analog input. With 4-device operation, 16 analog input channels (four from each AMUX-64T) are multiplexed to a single DAQ analog input.

Thermocouple Measurements and Cold-Junction Compensation

A movable jumper connects the temperature sensor of the AMUX-64T to analog input channel 0. An AMUX-64T configured with the temperature sensor connected has channels available for reading the temperature from 60 thermocouples in single-ended mode or 30 thermocouples in differential mode. You can cascade up to four AMUX-64T devices to increase the number of inputs to 240 in single-ended mode or 120 in differential mode. **Note:** National Instruments recommends 16-bit DAQ devices for measuring thermocouples with the AMUX-64T.

SC-2040

Analog Input

Each analog input channel of the SC-2040 has its own instrumentation amplifier with differential inputs. Using DIP switches, you can configure each channel independently for a gain of 1, 10, 100, 200, or 500. Each channel has input overvoltage protection of ±30 V powered on and ±15 V powered off.

Output

The output of each instrumentation amplifier is routed to a track-and-hold (T/H) amplifier. In track mode, the outputs of the T/H amplifiers follow their inputs. When put into hold mode, the T/H amplifier outputs simultaneously freeze, holding the signal levels constant. You can then digitize these held signals with an E Series device. Therefore, the digitized data includes negligible time skew (less than 50 ns) between channels.

Scan Rates

The maximum scan rate of the SC-2040 depends on the type of E Series device used and the number of channels scanned. Specifically, the minimum scan interval for a particular application is computed as $T_{SR} = T_{acq} + n * [\max(T_{HLD}, T_{MIO})]$ where T_{acq} is the SC-2040 acquisition time (7 µs), n is the number of channels scanned on the SC-2040, T_{MIO} is the sampling rate or settling time of the DAQ device, and T_{HLD} is the hold setting time of the SC-2040. For example, a scan of eight channels with a PCI-MIO-16E-1 device that has a 1 µs settling time requires a scan interval of T_{SR} = 7 µs+8 * [max (1 µs,1 µs)] = 7 µs+8 µs=15 µs, or 66,666 scans/s maximum.

Accessory	DAQ Device	Cabling
1st AMUX-64T	68-pin E Series (except DAQCards)	SH6868-EP or R6868
	100-pin E Series	SH1006868 or R1005050
	Latching E Series DAQCards: 6062E, 6024E	SHC6868-EP
	Nonlatching E Series DAQCards: AI-16E-4, AI-16XE-50	PSHR68-68 Shielded Cable Kit or PR68-68F
Additional AMUX-64T (up to 3)	–	NB1 (1 per AMUX-64T)
SC-2040	68-pin E Series (except DAQCards)	SH6868-EP or R6868
	100-pin E Series	SH1006868
	Latching E Series DAQCards: 6062E, 6024E	SHC6868-EP
	Nonlatching E Series DAQCards: AI-16E-4, AI-16XE-50	PSHR68-68 Shielded Cable Kit or PR68-68F
SC-2042-RTD or SC-2043-SG	68-pin E Series	SH6850 or R6850
	Latching E Series DAQCards: 6062E, 6024E	SHC6868-EP and 68M-50F
	Nonlatching E Series DAQCards: AI-16E-4, AI-16XE-50	PSHR68-50
	AT-MIO-16DE-10, 6025E	R1005050 [1]
	AT-MIO-64E-3, 6031E, 6033E, 6071E	R1005050 [1] or NB1 to SC-2056 [2]
Additional SC-2042-RTD or SC-2043-SG (up to 3)	AT-MIO-64E-3, 6031E, 6033E, 6071E	NB1 to SC-2056 [2]

[1] With the R1005050 cable, the SC-2042-RTD connects to pins 1-50 (ACH0-ACH15) only of the 100 pin MIO boards.

[2] You can connect up to four SC-2042-RTD boards or up to four SC-2043-SG boards to an SC 2056 for the AT-MIO-64E-3, 6031E, 6033E, or 6071E. You cannot use SC-2042-RTD and SC-2043-SG boards together. See page 488 for configuration details.

Table 2. Cabling Guide for the AMUX-64T and SC-204x Devices

SC-2042-RTD

The SC-2042-RTD is an 8-channel signal conditioning accessory for RTDs or thermistors. Each input channel has an independent 1 mA current excitation source and screw terminals for 4-wire RTD measurements. The RTD signals are routed to the eight differential inputs of the multifuction DAQ device. With the SC-2056 cable adapter accessory, you can use up to four SC-2042-RTDs to interface 32 RTDs to a single 6031E, 6033E, 6071E, or AT-MIO-64E-3 board. See page 256 for details of this configuration. Because each input is connected directly to an input of the DAQ device, you can mix in other types of voltage input signals.

Current Excitation

Each channel of the SC-2042-RTD includes a current excitation source with outputs connected to screw terminals. Each current excitation channel produces 1 mA and can drive loads up to 8.5 kΩ. You can calibrate all eight current outputs with a single onboard potentiometer. **Note:** Current excitation of 1 mA can cause overheating errors with some thermistors.

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SC-2043-SG

Input Channels

Each input channel of the SC-2043-SG includes an instrumentation amplifier with differential inputs and a fixed gain of 10. The inputs include overvoltage protection of ±45 VDC powered on and ±30 VDC powered off. Each channel also includes a lowpass noise filter with a bandwidth of 1.6 kHz. The output of each filter is buffered to prevent settling-time delays when used with a multiplexing DAQ device. With the SC-2056 cable adapter accessory, you can use up to four boards to interface 32 strain gauges to a single 6031E, 6033E, or 6071E.

Voltage Excitation

You can use the onboard regulated +2.5 VDC excitation source to power your strain gauge bridges. You can also adjust this supply from 1.5 to 2.5 VDC using an onboard potentiometer. This excitation supply can produce up to 167 mA – enough to drive eight 120 Ω (or higher) strain gauge bridges. Optionally, you can connect an external excitation source of up to 10 VDC.

Bridge Completion

You can enable full-bridge and half-bridge completion on each channel by setting a jumper that connects the negative input of the channel to the half-bridge network, which consists of two 2.5 kΩ precision resistors. Each channel also includes an open component location for installing quarter-bridge completion resistors. The optional quarter-bridge completion resistor pack includes eight 120 or 350 Ω precision resistors.

Offset Nulling

With the postgain offset nulling circuits, you can manually adjust trim pots to null out any bridge offsets (±5 mV, referred to input) on each input channel.

Ordering Information

AMUX-64T 776366-90
SC-2040 776937-01
SC-2042-RTD 777095-01
SC-2043-SG 777096-01

Rack-Mount Kit with Acrylic Plastic Cover

Single height 777212-01
Double height 777212-02

Rack-Mount Kit with Metal Wraparound Cover

Single height 777212-11
Double height 777212-12

Quarter-Bridge Completion Resistors (0.1%, 10 ppm/°C)

8 resistors, 120 Ω 777180-01
8 resistors, 350 Ω 777180-02

Cables

SH6868-EP (1 m) 184749-01
R6868 (1 m) 182482-01
SH1006868 (1 m) 182849-01
R1005050 (1 m) 182762-01
PSHR68-68 (Shielded Cable Kit) 777293-01
PR68-68F (1 m) 183646-01
68M-50F (1 m) 777660-0R3
NBI (0.5 cm) 180524-05

Number of channels

AMUX-64T	64 single-ended, 32 differential
SC-2040 SC-2042-RTD SC-2043-SG	8 differential

Input coupling .... DC

Input Signal Range

Module	Powered On	Gain	% of Reading	Offset
AMUX-64T	N/A	N/A	N/A	N/A
SC-2040	±1 V	1	±0.05%	±3.1 mV
	±100 mV	10	±0.1%	±400 µV
	±50 mV	100	±0.2%	±140 µV
	±20 mV	200	±0.4%	±120 µV
	±10 V	500	±1.0%	±112 µV
SC-2042-RTD[1]	–	–	–	–
SC-2043-SG	±1 V	10	±0.15%	–

Maximum working voltage (signal + common mode)

AMUX-64T	±10 V
SC-2040	Average of two inputs should remain within ±7 V of ground
SC-2042-RTD1	–
SC-2043-SG	Each input should remain within ±11 V of ground

Overvoltage protection

Device	Powered On	Powered Off
AMUX-64T	±35 V	±20 V
SC-2040	±30 V	±15 V
SC-2042-RTD1	–	–
SC-2043-SG	±42.4 V	±30 V

Inputs protected

AMUX-64T	CH <0..63>
SC-2040	CH <0..7>
SC-2042-RTD1	–
SC-2043-SG	CH <0..7>

Amplifier Characteristics

Input impedance

Device	Powered On	Powered Off
AMUX-64T	500 Ω in series with DAQ device	500 Ω
SC-2040	100 GΩ in parallel with 20 pF	–
SC-2042 RTD1	–	–
SC-2043-SG	10 GΩ	5.2 kΩ

Analog Signal Conditioning Accessories

Specifications

Input Bias Current

AMUX-64T	±100 pA
SC-2040	±100 pA
SC-2043-SG	±2.5 nA

Input offset current

AMUX-64T	±100 pA
SC-2040	±10 pA
SC-2043-SG	±1.5 nA

CMRR (DC to 60 Hz)

Device	Input Range	CMRR 50 or 60 Hz)
SC-2040	±10 V	90 dB
	±1 V	104 dB
	±100 mV to ± 20 mV	110 dB
SC-2042-RTD1	–	–
SC-2043-SG	±1 V	93 dB (minimum)

Output range

SC-2040	±10 V
SC-2043-SG	±11 V

Dynamic Characteristics

Settling time to 10 V

Device	± 0.012% (± 0.5 LSB) Accuracy	
Gain	PCI-6040E with one AMUX-64T	PCI-6040E with four AMUX-64Ts
0.5 to 5	5 µs	9 µs
10	6 µs	9 µs
20	6 µs	11 µs
50	7 µs	11 µs
100	9 µs	14 µs

Bandwidth and System Noise

Module	Input Range	Bandwidth	System Noise
SC-2040	±10 V	2 MHz*	175 μV_{rms}
	±1 V	800 kHz*	50 μV_{rms}
	±100 mV	500 kHz*	45 μV_{rms}
	±50 mV	300 kHz*	40 μV_{rms}
	±20 V	120 kHz*	33 μV_{rms}
SC-2043-SG	±1 V	1.6 kHz	5 μV_{rms}

* Small signal bandwidth

S/H Characteristics (SC-2040 Only)

	Accuracy		
Module	±0.012%	±0.006%	±0.0015%
SC-2040	7 µs	10 µs	50 µs

Hold mode settling time .... 1 µs
Droop rate .... ±10 mV/s
Interchannel skew .... ±50 ns
Aperature delay time
(from external clock) .... ±50 ns
Hold step .... ±5 mV

Stability

Recommended warm-up time .... 15 minutes
Gain and offset temperature coefficients
Cold-Junction Reference (AMUX-64T) only
Output .... 10 mV/°C
Accuracy .... ±1.0 °C from 0 to 110 °C

Module	Input Range	Gain Temperature Coefficient	Offset Temperature Coefficient
SC-2040	±10 V	25 ppm/°C	(± 10 ± 150/gain) µV/°C
	±1 V	25 ppm/°C	(± 10 ± 150/gain) µV/°C
	±100 mV	45 ppm/°C	(± 10 ± 150/gain) µV/°C
	±50 mV	60 ppm/°C	(± 10 ± 150/gain) µV/°C
	±20 mV	100 ppm/°C	(± 10 ± 150/gain) µV/°C
SC-2043-SG	±1 V	10 ppm/°C	± 3 µV/°C

Voltage Excitation (SC-2043-SG Only)
Channels .... 1, connected to 8 screw terminal pairs
Level .... 2.5 V ± 0.5% (adjustale from 1.5 - 2.5 V)
Current Drive .... 167 mA2 (at 2.5 V)
Drift .... ± 480 ppm/°C
Bridge type .... Half or full (jumper selectable); with sockets for quarter-bridge completion
Bridge completion .... Two 2.5 kΩ ± 0.02% ratio tolerance (2 ppm/°C drift) resistors
Offset nulling range .... ± 5 mV (referred to input)

Power Requirements

Device	Voltage	Current
AMUX-64T	± 5 VDC	78 mA
SC-2040	± 5 VDC	800 mA
SC-2042-RTD	± 5 VDC	60 mA
SC-2043-SG [3]	± 5 VDC	570 mA
		600 to 770 mA[4] (if using internal 2.5 V excitation)

Physical

Dimensions
AMUX-64T .... 26.9 by 12.4 cm (10.6 by 4.9 in.)
SC-204x .... 4.6 by 20.1 by 12.4 cm (1.8 by 7.9 by 4.9 in.)

I/O Connectors

AMUX-64T
Sensor Signals .... 64 screw terminals
DAQ Device .... Two 50-pin male ribbon connectors
One 68-pin male SCSI connector

SC-2040
Sensor Signals .... 20 screw terminals
DAQ Device .... 50-pin male ribbon connector
68-pin male SCSI connector

SC-2042-RTD
Sensor Signals .... 68 screw terminals (labeled)
DAQ Device .... Two 50-pin male ribbon connectors

SC-2043-SG
Sensor Signals .... 72 screw terminals (labeled)
DAQ Device .... Two 50-pin male ribbon connectors

Environment

Operating temperature .... 0 to 70 ˚C
Storage temperature .... -20 to 70 ˚C
Relative humidity .... 5% to 90% noncondensing

Certifications and Compliances

European Compliance

EMC .... EN 61326 Group I Class A, 10m, Table 1 Immunity
Safety .... EN 61010-1

North American Compliance

EMC .... FCC Part 15 Class A using CISPR

Australia and New Zealand Compliance

EMC .... AS/NZS 2064.1/2 (CISPR-11)

[1] The SC-2042-RTD passes analog input signals directly to the DAQ device. Therefore, see your DAQ device for these specifications
[2] Excitation current drive assumes eight full-bridge 120 Ω strain gauges.
[3] Power requirements assume all 8 inputs are used or shorted to ground. Open circuited inputs will increase power requirement.
[4] When using internal excitation, the power requirement will depend on number and type of strain gauges. The maximum power requirement listed (770 mA) assumes eight 120 Ω full-bridge inputs. The minimum power requirement listed (660 mA) assumes one 350 Ω half-bridge input.

Accuracy Specifications for Signal Conditioning

Every Measurement Counts

There is little room for error in your measurements. From sensor to software, your system must deliver accurate results. NI provides detailed specifications for our products so that you do not have to guess how they perform. Along with traditional specifications, our signal conditioning products include accuracy tables to assist you in selecting the appropriate hardware for your application. These tables are found on the specification pages for each product.

Absolute Accuracy

Absolute accuracy is the specification you must use to determine the overall maximum possible error of your measurement. Absolute accuracy does assume your signal conditioning equipment has been calibrated within the last year. There are four main components of an absolute accuracy specification:

- % of Reading is an uncertainty factor that is multiplied by the actual imput voltage for the measurement
- Offset is a constant value applied to all measurements
- System Noise is based on noise and depends on the number of points averaged for each measurement
- Temperature Drift is based on variations in your ambient temperature.

Absolute Acuracy RTI stands for relative to the input

Based on these components, the formula for calculating absolute accuracy for a given module is:

Absolute Accuracy = (Actual Input Voltage x % of Reading)
+ Offset + System Noise + Temperature Drift

Absolute Accuracy RTI = ±(Absolute Accuracy/Actual Input Voltage)

Temperature effects are already taken into account unless your ambient temperature is outside of the 15 to 35 °C range. For instance, if your ambient temperature is at 45 °C, you must account for 10 °C of drift. This is calculated by:

Temperature Drift = ± (Actual Input Voltage x % of Reading/°C + Offset/°C)
x Temperature Difference

Below is an example for calculating the absolute accuracy for the SCXI-1102 using the ±100 mV input range while averaging 100 samples of a 14 mV input signal. In this calculation, we assume the ambient temperature is between 15 and 35 °C, so Temperature Drift = 0. Using the accuracy table on pge 262, you find the following numbers for the calculation:

Actual Input Voltage = 0.014
Percent of Reading Max = 0.02% = 0.0002
Offset = 0.000025 V
System Noise = 0.000005 V

Absolute Accuracy = ±[(0.014 x 0.0002) + 0.000025 + 0.000005] V = ±32.8 μV

Absolute Accuracy RTI = ±(0.0000328 / 0.014) = ±0.234 %

The following example assumes the same conditions, except the ambient temperature is 40 °C. You can begin with the Absolute Accuracy calculation above and add in the Temperature Drift.

Absolute Accuracy = 32.8 μV + (0.014 x 0.000005 + 0.000001) x 5 = ±38.15 μV

Accuracy Specifications for Signal Conditioning

In many cases, it is helpful to calculate this value relative to the input (RTI). Therefore, you do not have to account for different input ranges at different stages of your system.

Absolute Accuracy RTI = ±(0.00003815 / 0.014) = ±0.273 %

If you are making single-point measurements, use the Single-Point System Noise specification from the accuracy table. If you are averaging multiple points for each measurement, the value for System Noise changes. The Average System Noise provided in the accuracy table assumes that you average 100 points per measurement. If you are averaging a different number of points, use the following equation to determine your system noise:

System Noise = Average System Noise from table x SQRT(100/number of points)

For example, if you are averaging 1,000 points per measurement with the SCXI-1102 in the ±100 mV range, the system noise is determined by:

System Noise = 5 μV x SQRT (100/1000) = 1.58 μV

Absolute System Accuracy

Absolute System Accuracy represents the end-to-end accuracy including the signal conditioning and DAQ device. Because absolute system accuracy includes components set for different input ranges, it is important to use Absolute Accuracy RTI numbers for each component. See page 194 for information on how to calculate the Absolute Accuracy RTI for your particular DAQ device.

Total System Accuracy RTI = ±SQRT [(Module Absolute Accuracy RTI)^2 + (DAQ Device Absolute Accuracy RTI)^2]

The following example calculates the Absolute System Accuracy for the SCXI-1102 described in the first example, and a PCI-MIO-16XE-50 with an Absolute Accuracy RTI of 0.00368%.

Total System Accuracy RTI = ±SQRT [(0.00273)2 + (0.00003682)] = ±0.273%

Units of Measure

In many applications, you are measuring some physical phenomenon, such as temperature. To determine the absolute accuracy in terms of your unit of measure, you must perform three steps:

(1) Convert a typical expected value from the unit of measure to voltage
(2) Calculate absolute accuracy for that voltage
(3) Convert absolute accuracy from voltage to the unit of measure

Note, it is important to use a typical measurement value in this process, because many conversion algorithms are not linearized. You may want to perform conversions for several different values in your probable range of inputs.

For an example calculation, we want to determine the absolute system accuracy of an SCXI-1102 system with a PCI-MIO-16XE-50, measuring a J-type thermocouple at 100 °C.

(1) A J-type thermocouple at 100 °C generates 5.268 mV (from a standard conversion table or formula)
(2) The absolute accuracy for the system at 5.268 mV is ±0.59%. This means the possible voltage reading is anywhere from 5.237 to 5.299 mV.
(3) Using the same thermocouple conversion table, these values represent a temperature spread of 99.4 to 100.6 °C.

Therefore, the absolute system accuracy is ±0.6 °C at 100 °C.

Benchmarks

The calculations described above represent the maximum error you should receive from any given component in your system, and a method for determining the overall system error. However, you typically have much better accuracy values than what you obtain from these tables.

If you need an extremely accurate system, you can perform an end-to-end calibration of your system to reduce all system errors. However, you must calibrate this system with your particular input type over the full range of expected use. Accuracy depends on the quality and precision of your source.

We have performed some end-to-end calibrations for some typical configurations and achieved the results below:

Module	Empirical Accuracy
SCXI-1102	±0.25 °C at 250 °C ±24 mV at 9.5 V
SCXI-1112	±0.21 °C at 300 °C
SCXI-1125	±2.2 mV at 2 V

Table 1. Possible Empirical Accuracy with System Calibration

To maintain your measurement accuracy, you must calibrate your measurement device at set intervals. Calibration improves your accuracy and ensures that your end product meets its required specifications. We are continually updating the calibration services available for our products. For a current list of SCXI signal conditioning products with calibration services, please visit **ni.com/calibration**