USB-TEMP-AI

Temperature and Voltage Measurement

User's Guide

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About this User's Guide

What you will learn from this user's guide

This user's guide describes the Measurement Computing USB-TEMP-AI data acquisition device and lists device specifications.

Conventions in this user's guide

For more information

Text presented in a box signifies additional information related to the subject matter.

Caution! Shaded caution statements present information to help you avoid injuring yourself and others, damaging your hardware, or losing your data.

bold text — **Bold** text is used for the names of objects on a screen, such as buttons, text boxes, and check boxes.

italic text — *Italic* text is used for the names of manuals and help topic titles, and to emphasize a word or phrase.

Where to find more information

Additional information about USB-TEMP hardware is available on our website at www.mccdaq.com. You can also contact Measurement Computing Corporation with specific questions.

- Knowledgebase: kb.mccdaq.com
- Phone: 508-946-5100 and follow the instructions for reaching Tech Support
- Fax: 508-946-9500 to the attention of Tech Support
- Email: techsupport@mccdaq.com

Introducing the USB-TEMP-AI

The USB-TEMP-AI is a USB 2.0 full-speed, temperature measurement module that is supported under popular Microsoft® Windows® operating systems. The USB-TEMP-AI is fully compatible with both USB 1.1 and USB 2.0 ports.

The USB-TEMP-AI provides eight analog input channels that are configured as four differential temperature inputs and four differential or single-ended voltage inputs. A 24-bit analog-to-digital (A/D) converter is provided for each pair of analog inputs. Eight independent, TTL-compatible digital I/O channels are provided to monitor TTL-level inputs, communicate with external devices, and to generate alarms. The digital I/O channels are software programmable for input or output.

The temperature input channels are configured as two channel pairs that accept temperature sensor type inputs. You can take measurements from four sensor categories. The sensor category is software programmable for each channel pair:

- Thermocouple – types J, K, R, S, T, N, E, and B
- Resistance temperature detectors (RTDs) – 2, 3, or 4-wire measurements of 100 Ω platinum RTDs
- Thermistors – 2, 3, or 4-wire measurements
- Semiconductor temperature sensors – LM35, TMP35 or equivalent

You can connect a different category of sensor to each temperature channel pair, but you cannot mix sensor categories between the channels that constitute a channel pair. You can, however, mix thermocouple types within channel pairs.

Each voltage input channel is software configurable for differential or single-ended mode. The voltage input range is software programmable for ±10 V, ±5 V, ±2.5 V, ±1.25 V.

The USB-TEMP-AI provides a integrated cold junction compensation (CJC) sensor for thermocouple measurements, and built-in current excitation sources for resistive sensor measurements.

An open thermocouple detection feature lets you detect a broken thermocouple. An on-board microprocessor automatically linearizes the measurement data according to the sensor category.

The USB-TEMP-AI features eight independent temperature alarms. Each alarm controls an associated digital I/O channel as an alarm output. The input to each alarm is one of the temperature input channels. The output of each alarm is software configurable as active high or low. You set up the temperature threshold conditions to activate each alarm. When an alarm is activated, the associated DIO channel is driven to the output state.

The USB-TEMP-AI is a standalone plug-and-play module which draws power from the USB cable. No external power supply is required. All configurable options are software programmable.

The USB-TEMP-AI is fully software calibrated.

Functional block diagram

USB-TEMP-AI functions are illustrated in the block diagram shown here.

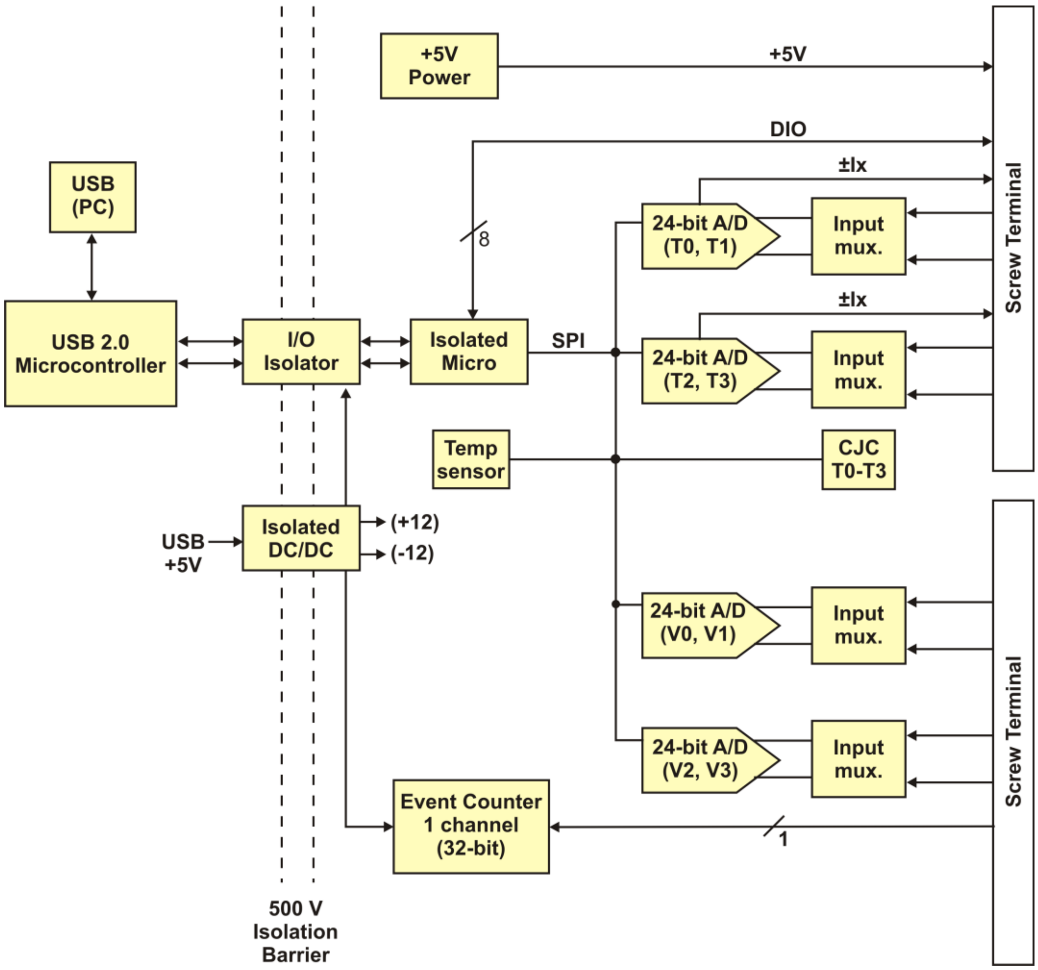


Figure 1. Functional block diagram

Connecting a USB-TEMP-AI to your computer is easy

Installing a data acquisition device has never been easier:

- The USB-TEMP-AI relies upon the Microsoft Human Interface Device (HID) class drivers. The HID class drivers ship with every copy of Windows that is designed to work with USB ports. We use the Microsoft HID because it is a standard, and its performance delivers full control and maximizes data transfer rates for your USB-TEMP-AI. No third-party device driver is required.
- The USB-TEMP-AI is plug-and-play. There are no jumpers to position, DIP switches to set, or interrupts to configure.
- You can connect the USB-TEMP-AI before or after you install the software, and without powering down your computer first. When you connect an HID to your system, your computer automatically detects it and configures the necessary software. You can connect and power multiple HID peripherals to your system using a USB hub.
- You can connect your system to various devices using a standard USB cable. The USB connector replaces the serial and parallel port connectors with one standardized plug and port combination.
- You do not need a separate power supply module. The USB automatically delivers the electrical power required by each peripheral connected to your system.
- Data can flow two ways between a computer and peripheral over USB connections.

Installing the USB-TEMP-AI

What comes with your shipment?

The following items are shipped with the USB-TEMP-AI.

Hardware

- USB-TEMP-AI
- USB cable

Documentation

In addition to this hardware user's guide, you should also receive the *Quick Start Guide*. This booklet provides an overview of the MCC DAQ software you received with the device, and includes information about installing the software. Please read this booklet completely before installing any software or hardware.

Unpacking

As with any electronic device, you should take care while handling to avoid damage from static electricity. Before removing the USB-TEMP-AI from its packaging, ground yourself using a wrist strap or by simply touching the computer chassis or other grounded object to eliminate any stored static charge.

If any components are missing or damaged, contact us immediately using one of the following methods:

- Knowledgebase: kb.mccdaq.com
- Phone: 508-946-5100 and follow the instructions for reaching Tech Support
- Fax: 508-946-9500 to the attention of Tech Support
- Email: techsupport@mccdaq.com

For international customers, contact your local distributor. Refer to the International Distributors section on our website at www.mccdaq.com/International.

Installing the software

Refer to the *Quick Start Guide* for instructions on installing the software on the MCC DAQ CD. This booklet is available in PDF at www.mccdaq.com/PDFmanuals/DAQ-Software-Quick-Start.pdf.

Installing the hardware

To connect the USB-TEMP-AI to your system, turn your computer on, and connect the USB cable to a USB port on your computer or to an external USB hub that is connected to your computer. The USB cable provides power and communication to the USB-TEMP-AI.

When you connect the USB-TEMP-AI for the first time, a notification message opens as the USB-TEMP-AI is detected. When the message closes, the installation is complete. The upper **LED** (Activity) blinks when initially connected and then stays on. The lower LED (USB) turns on to indicate that communication is established between the device and computer.

If the USB LED turns off

If the LED is lit but then turns off, the computer has lost communication with the USB-TEMP-AI. To restore communication, disconnect the USB cable from the computer, and then reconnect it. This should restore communication, and the LED should turn back *on*.

Configuring the hardware

All hardware configuration options on the USB-TEMP-AI are programmable with software. Use InstaCal to set the sensor type for each temperature channel, the range and input configuration of each voltage channel, and the alarm conditions. Any channel you don't intend to use should be left disabled.

The configurable options dynamically update according to the selected sensor category. Configuration options are stored on the USB-TEMP-AI 's isolated microcontroller in EEPROM, which is non-volatile memory on the USB-TEMP-AI module. Configuration options are loaded on power up.

Default configuration

The factory default configuration is *Disabled*. The Disabled mode disconnects the analog inputs from the terminal blocks and internally grounds all of the A/D inputs. This mode also disables each of the current excitation sources.

Warm up

Allow the USB-TEMP-AI to warm up for 30 minutes before taking measurements. This warm up time minimizes thermal drift and achieves the specified rated accuracy of measurements.

For analog, RTD or thermistor measurements, this warm-up time is also required to stabilize the internal current reference.

Calibrating the USB-TEMP-AI

The USB-TEMP-AI is fully calibrated via software. InstaCal prompts you to run its calibration utility when you change from one sensor category to another.

Allow the USB-TEMP-AI to operate for at least 30 minutes before calibrating. This warm up time minimizes thermal drift and achieves the specified rated accuracy of measurements.

Signal I/O Connections

Screw terminal pinout

The device screw terminals are identified in Figure 2. Between screw terminals 10 and 11 is the integrated CJC sensor used for thermocouple measurements.

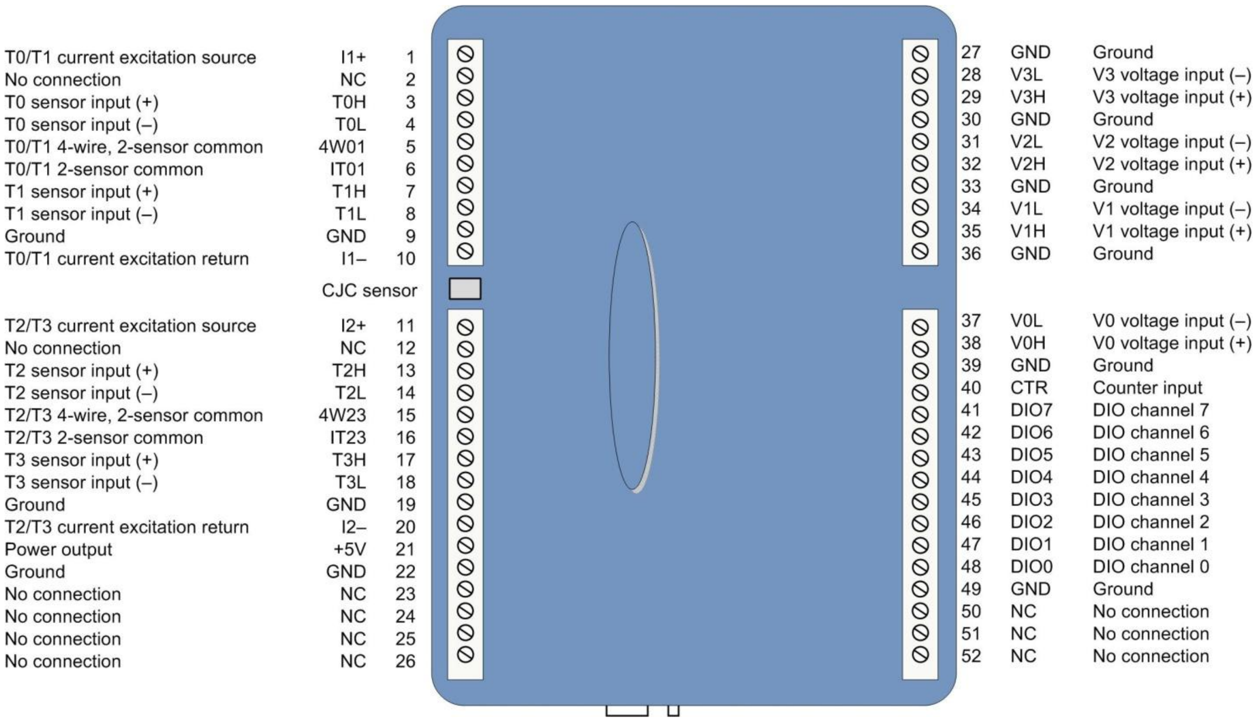


Figure 2. USB-TEMP-AI screw terminal pin numbers

Use 16 AWG to 30 AWG wire for your signal connections.

Tighten screw terminal connections

When making connections to the screw terminals, be sure to tighten the screw until tight. Simply touching the top of the screw terminal is not sufficient to make a proper connection.

Voltage input terminals (±V0H/V0L to ±V3H/V3L)

You can connect up to four voltage inputs to the voltage channels (V0H/V0L to V3H/V3L). The input range is software programmable for ±10 V, ±5 V, ±2.5 V, or ±1.25 V. Each voltage channel is software configurable for differential or single-ended mode.

When connecting differential inputs to floating input sources, you must provide a DC return path from each differential input to ground. One way to do this is to connect a resistor from one side of each of the differential inputs to GND. A value of approximately 100 kΩ can be used for most applications.

Caution! All ground pins are common and isolated from earth ground. If a connection is made to earth ground when using digital I/O and conductive thermocouples, the thermocouples are no longer isolated. In this case, thermocouples must not be connected to any conductive surfaces that may be referenced to earth ground.

Sensor input terminals (T0H/T0L to T3H/T3L)

The USB-TEMP-AI supports the following temperature sensor types:

- Thermocouple – types J, K, R, S, T, N, E, and B
- Resistance temperature detectors (RTDs) – 2, 3, or 4-wire measurement modes of 100 Ω platinum RTDs.
- Thermistors – 2, 3, or 4-wire measurement modes.
- Semiconductor temperature sensors – LM35, TMP35 or equivalent

Sensor selection

The type of sensor you select will depend on your application needs. Review the temperature ranges and accuracies of each sensor type to determine which is best suited for your application.

You can connect up to four temperature sensors to the differential sensor inputs (T0H/T0L to T3H/T3L). Supported sensor categories include thermocouples, RTDs, thermistors, or semiconductor sensors.

Do not mix sensor categories within channel pairs. You can mix thermocouple types (J, K, R, S, T, N, E, and B) within channel pairs, however.

Do not connect two different sensor categories to the same channel pair

The USB-TEMP-AI provides a 24 bit A/D converter for each channel pair. Each channel pair can monitor one sensor category. To monitor a sensor from a different category, connect the sensor to a different pair of sensor input terminals.

Current excitation output terminals (±I1 and ±I2)

The USB-TEMP-AI has two dedicated pairs of current excitation output terminals (±**I1** and ±**I2**). These terminals have a built-in precision current source to provide excitation for the resistive sensors used for RTD and thermistor measurements. Each current excitation terminal is dedicated to one pair of sensor input channels:

- I1+ is the current excitation source, and I1- is the current excitation return for channel 0 and channel 1
- I2+ is the current excitation source, and I2- is the current excitation return for channel 2 and channel 3

Four-wire, two sensor common terminals (4W01 and 4W23)

The 4W01 and 4W23 terminals are used as the common connection for four-wire configurations with two RTD or thermistor sensors.

Sensor common terminals (IT01 and IT23)

The IT01 and IT23 terminals are used as the common connection for two-wire configurations with two RTD or thermistor sensors.

Digital terminals (DIO0 to DIO7)

You can connect up to eight digital I/O lines to the screw terminals labeled **DIO0** to **DIO7**. Each terminal is software configurable for input or output.

Counter terminal (CTR)

The **CTR** terminal (pin 40) is the input to the 32-bit event counter. The internal counter increments when the TTL level transitions from low to high. The counter can count events at frequencies of up to 1 MHz.

Caution! All ground pins are common and isolated from earth ground. If a connection is made to earth ground when using digital I/O and conductive thermocouples, the thermocouples are no longer isolated. In this case, thermocouples must not be connected to any conductive surfaces that may be referenced to earth ground.

Ground terminals (GND)

The nine ground terminals (**GND**) provide a common ground for the input channels and DIO bits and are isolated (500 VDC) from the USB GND.

Power output (+5V)

The **+5V** output terminal is isolated (500 VDC) from the USB +5V.

Caution! The +5V terminal is an output terminal. Do not connect to an external power supply or you may damage the USB-TEMP-AI and possibly the computer.

CJC sensor

The USB-TEMP-AI has one built-in high-resolution temperature sensor. The CJC sensor measures the ambient temperature at the terminal block so that the cold junction voltage can be calculated.

Thermocouple connections

A thermocouple consists of two dissimilar metals that are joined together at one end. When the junction of the metals is heated or cooled, a voltage is produced that correlates to temperature.

The USB-TEMP-AI makes fully differential thermocouple measurements without requiring ground-referencing resistors. A 32-bit floating point value in either a voltage or temperature format is returned by software. An open thermocouple detection (OTD) feature is available for each thermocouple input. This feature automatically detects an open or broken thermocouple.

Use InstaCal to select the thermocouple type (J, K, R, S, T, N, E, and B) on one or more sensor input channels to connect the thermocouple.

Wiring configuration

Connect the thermocouple to the USB-TEMP-AI using a differential configuration, as shown in Figure 3.

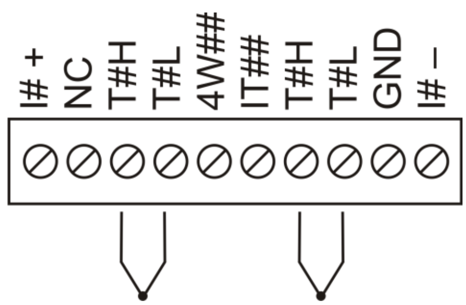


Figure 3. Typical thermocouple connection

The USB-TEMP-AI **GND** pins are isolated from earth ground. You can connect thermocouple sensors to voltages referenced to earth ground as long as the isolation between the GND pins and earth ground is maintained.

When thermocouples are attached to conductive surfaces, the voltage differential between multiple thermocouples must remain within ±1.4 V. For best results, we recommend the use of insulated or ungrounded thermocouples when possible.

Maximum input voltage between analog input and ground

The absolute maximum input voltage between an analog input and the isolated GND pins is ±25 VDC when the USB-TEMP-AI is powered on, and ±40 VDC when the USB-TEMP-AI is powered off.

If you need to increase the length of your thermocouple, use the same type of thermocouple wires to minimize the error introduced by thermal EMFs.

RTD and thermistor connections

A resistance temperature detector (RTD) measures temperature by correlating the resistance of the RTD element with temperature. A thermistor is a thermally-sensitive resistor that is similar to an RTD in that its resistance changes with temperature — thermistors show a large change in resistance that is proportional to a small change in temperature. The main difference between RTD and thermistor measurements is the method used to linearize the sensor data.

RTDs and thermistors are resistive devices that require an excitation current to produce a voltage drop that can be measured differentially across the sensor. The USB-TEMP-AI features two built-in current excitation sources (±I1 and ±I2) for measuring resistive type sensors. Each current excitation terminal is dedicated to one channel pair.

The USB-TEMP-AI makes two, three, and four-wire measurements of RTDs (100 Ω platinum type) and thermistors.

Use InstaCal to select the sensor type and the wiring configuration. Once the resistance value is calculated, the value is linearized in order to convert it to a temperature value. A 32-bit floating point value in either temperature or resistance is returned by software.

RTD maximum resistance

Resistance values greater than 660 Ω cannot be measured by the USB-TEMP-AI in the RTD mode. The 660 Ω resistance limit includes the total resistance across the current excitation (±Ix) pins, which is the sum of the RTD resistance and the lead resistances.

Thermistor maximum resistance

Resistance values greater than 180 kΩ cannot be measured by the USB-TEMP-AI in the thermistor mode. The 180 kΩ resistance limit includes the total resistance across the current excitation (±Ix) pins, which is the sum of the thermistor resistance and the lead resistance.

Two-wire configuration

The easiest way to connect an RTD sensor or thermistor to the USB-TEMP-AI is with a two-wire configuration, since it requires the fewest connections to the sensor. With this method, the two wires that provide the RTD sensor with its excitation current also measure the voltage across the sensor.

Since RTDs exhibit a low nominal resistance, measurement accuracy can be affected due to the lead wire resistance. For example, connecting lead wires that have a resistance of 1 Ω (0.5 Ω each lead) to a 100 Ω platinum RTD will result in a 1% measurement error.

With a two-wire configuration, you can connect either one sensor per channel pair, or two sensors per channel pair.

Two-wire, single-sensor

A two-wire single-sensor measurement configuration is shown in Figure 4.

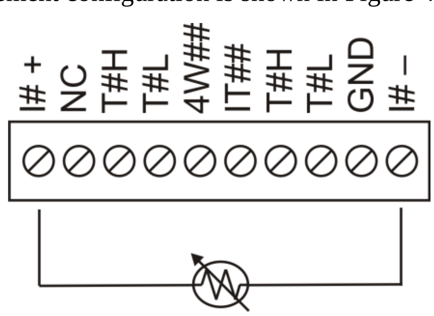


Figure 4. Two-wire, single RTD or thermistor sensor measurement configuration

When you select a two-wire single sensor configuration with InstaCal, connections to T#H and T#L are made internally.

Two-wire, two sensor

A two-wire, two-sensor measurement configuration is shown in Figure 5.

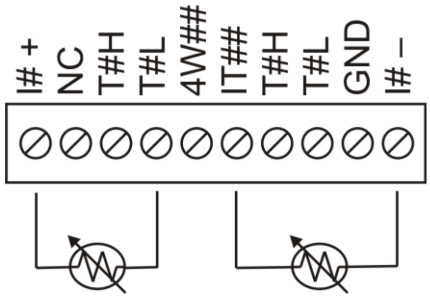


Figure 5. Two-wire, two RTD or thermistor sensors measurement configuration

When you select a two-wire, two sensor configuration with InstaCal, connections to T#H (first sensor) and T#H/T#L (second sensor) are made internally.

When configured for two-wire mode, both sensors must be connected to obtain proper measurements.

Three-wire configuration

A three-wire configuration compensates for lead-wire resistance by using a single voltage sense connection. With a three-wire configuration, you can connect only one sensor per channel pair. A three-wire measurement configuration is shown in Figure 6.

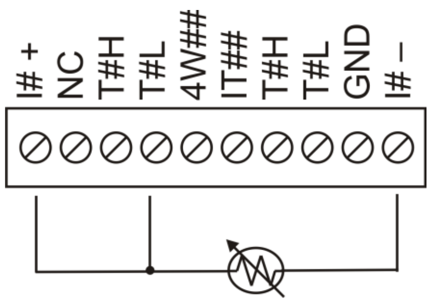


Figure 6. Three-wire RTD or thermistor sensor measurement configuration

When you select a three-wire sensor configuration with InstaCal, the USB-TEMP-AI measures the lead resistance on the first channel (T#H/T#L) and measures the sensor itself using the second channel (T#H/T#L). This configuration compensates for any lead-wire resistance and temperature change in lead-wire resistance. Connections to T#H for the first channel and T#H/T#L of the second channel are made internally.

Three-wire compensation

For accurate three wire compensation, the individual lead resistances connected to the ±I# pins must be of equal resistance value.

Four-wire configuration

With a four-wire configuration, connect two sets of sense/excitation wires at each end of the RTD or thermistor sensor. This configuration completely compensates for any lead-wire resistance and temperature change in lead-wire resistance.

Connect your sensor with a four-wire configuration when your application requires very high accuracy measurements. Examples of a four-wire single-sensor measurement configuration are shown in Figure 7 and Figure 8.

You can configure the USB-TEMP-AI with either a single sensor per channel or two sensors per channel pair.

Four-wire, single-sensor

A four-wire, single-sensor connected to the first channel of a channel pair is shown in Figure 7.

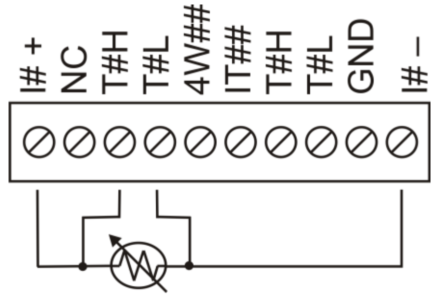


Figure 7. Four-wire, single RTD or thermistor sensor measurement configuration

A four-wire, single-sensor connected to the second channel of a channel pair is shown in Figure 8.

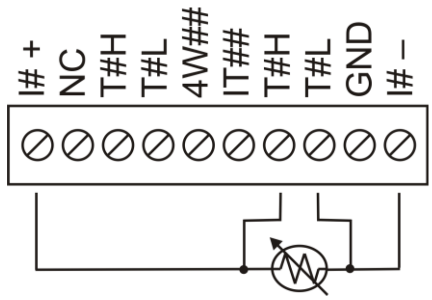


Figure 8. Four-wire, single RTD or thermistor sensor measurement configuration

A four-wire, two-sensor measurement configuration is shown in Figure 9.

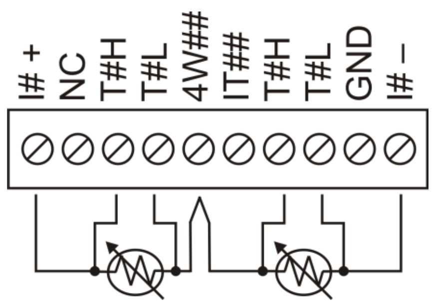


Figure 9. Four-wire, two RTD or thermistor sensors measurement configuration

When configured for four-wire, two sensor mode, both sensors must be connected to obtain proper measurements.

Semiconductor sensor measurements

Semiconductor sensors are suitable over a range of approximately –40 °C to 125 °C, where an accuracy of ±2 °C is adequate. The temperature measurement range of a semiconductor sensor is small when compared to thermocouples and RTDs. However, semiconductor sensors can be accurate, inexpensive and easy to interface with other electronics for display and control.

The USB-TEMP-AI makes high-resolution measurements of semiconductor sensors, and returns a 32-bit floating point value in either voltage or temperature.

Use InstaCal to select the sensor type (LM35, TMP35 or equivalent) and the sensor input channel to connect the sensor.

Wiring configuration

Connect the semiconductor sensor to the USB-TEMP-AI using a single-ended configuration, as shown in Figure 10. The device provides **+5V** and **GND** pins for powering the sensor.

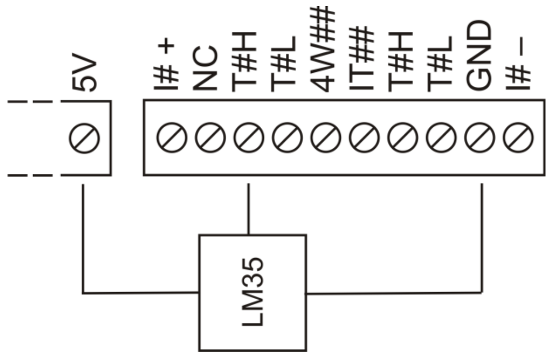


Figure 10. Semiconductor sensor measurement configuration

The software outputs the measurement data as a 32-bit floating point value in either voltage or temperature.

Digital I/O connections

You can connect up to eight digital I/O lines to the screw terminals labeled **DIO0** to **DIO7**. You can configure each digital bit for either input or output. All digital I/O lines are pulled up to +5V with a 47 kΩ resistor (default). You can request the factory to configure the resistor for pull-down to ground if desired.

When you configure the digital bits for input, you can use the USB-TEMP-AI digital I/O terminals to detect the state of a TTL-compatible device. Refer to the schematic shown in Figure 11. If you set the switch to the +5V input, DIO0 reads *TRUE* (1). If you move the switch to GND, DIO0 reads *FALSE* (0).

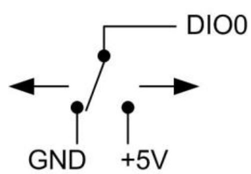


Figure 11. Schematic showing switch detection by digital channel DIO0

Caution! All ground pins on the USB-TEMP-AI (pins 9, 19, 22, 27, 30, 33, 36, 39, 49) are common and are isolated from earth ground. If a connection is made to earth ground when using digital I/O and conductive thermocouples, the thermocouples are no longer isolated. In this case, thermocouples must not be connected to any conductive surfaces that may be referenced to earth ground.

For general information regarding digital signal connections and digital I/O techniques, refer to the *Guide to DAQ Signal Connections* (available on our website at www.mccdaq.com/signals/signals.pdf).

Configuring the DIO channels to generate alarms

The USB-TEMP-AI features eight independent temperature alarms. All alarm options are software configurable.

When a digital bit is configured as an alarm, that bit will be configured as an output on the next power cycle and assume the state defined by the alarm configuration.

Each alarm controls an associated digital I/O channel as an alarm output. The input to each alarm is one of the temperature input channels. You set up the temperature conditions to activate an alarm, and the output state of the channel (active high or low) when activated. When an alarm is activated, its associated DIO channel is driven to the output state specified.

The alarm configurations are stored in non-volatile memory and are loaded on power up. The temperature alarms function both in data logging mode and while attached to the USB port on a computer.

Functional Details

Thermocouple measurements

A thermocouple consists of two dissimilar metals that are joined together at one end. When the junction of the metals is heated or cooled, a voltage is produced that correlates to temperature.

The USB-TEMP-AI hardware level-shifts the thermocouple's output voltage into the A/D's common mode input range by applying +2.5 V to the thermocouple's low side at the C#L input. Always connect thermocouple sensors to the USB-TEMP-AI in a floating fashion. Do not attempt to connect the thermocouple low side C#L to GND or to a ground referencing resistor.

Cold junction compensation (CJC)

When you connect the thermocouple sensor leads to the sensor input channel, the dissimilar metals at the USB-TEMP-AI terminal blocks produce two additional thermocouple junctions. This junction creates a small voltage error term which must be removed from the overall sensor measurement using a cold junction compensation technique. The measured voltage includes both the thermocouple voltage and the cold junction voltage. To compensate for the additional cold junction voltage, the USB-TEMP-AI subtracts the *cold junction* voltage from the thermocouple voltage.

The USB-TEMP-AI has one high-resolution temperature sensor integrated into the design. The CJC sensor measures the average temperature at the terminal block so that the cold junction voltage can be calculated. A software algorithm automatically corrects for the additional thermocouples created at the terminal blocks by subtracting the calculated cold junction voltage from the analog input's thermocouple voltage measurement.

Increasing the thermocouple length

If you need to increase the length of your thermocouple, use the same type of thermocouple wires to minimize the error introduced by thermal EMFs.

Data linearization

After the CJC correction is performed on the measurement data, an on-board microcontroller automatically linearizes the thermocouple measurement data using National Institute of Standards and Technology (NIST) linearization coefficients for the selected thermocouple type. The measurement data is then output as a 32-bit floating point value in the configured format (voltage or temperature).

Open-thermocouple detection (OTD)

The USB-TEMP-AI is equipped with open-thermocouple detection for each analog input channel. With OTD, any open-circuit or short-circuit condition at the thermocouple sensor is detected by the software. An open channel is detected by driving the input voltage to a negative value outside the range of any thermocouple output. The software recognizes this as an invalid reading and flags the appropriate channel. The software continues to sample all channels when OTD is detected.

RTD and thermistor measurements

RTDs and thermistors are resistive devices that require an excitation current to produce a voltage drop that can be measured differentially across the sensor. The USB-TEMP-AI measures the sensor resistance by forcing a known excitation current through the sensor and then measuring (differentially) the voltage across the sensor to determine its resistance.

After the voltage measurement is made, the resistance of the RTD is calculated using Ohms law – the sensor resistance is calculated by dividing the measured voltage by the current excitation level (±**Ix**) source. The value of the ±**Ix** source is stored in local memory.

Once the resistance value is calculated, the value is linearized in order to convert it to a temperature value. The measurement is returned by software as a 32-bit floating point value in either temperature or resistance.

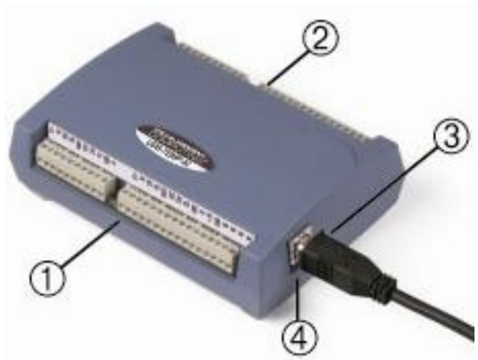
Data linearization

An on-board microcontroller automatically performs linearization on RTD and thermistor measurements.

- RTD measurements are linearized using a Callendar-Van Dusen coefficients algorithm (you select DIN, SAMA, or ITS-90).
- Thermistor measurements are linearized using a Steinhart-Hart linearization algorithm (you supply the coefficients from the sensor manufacturer's data sheet).

External components

The USB-5203 has the following external components, as shown in Figure 12.



1	Screw terminal pins 1 to 26	3	LEDs: Activity (top) and Power (bottom)
2	Screw terminal pins 27 to 52	4	USB connector

Figure 12.External component locations

Screw terminals

Use the screw terminals for connecting temperature sensors and digital I/O lines. These terminals also provide ground and power output connections. Refer to the "**Error! Reference source not found.**" chapter for screw erminal descriptions.

USB connector

The USB connector provides +5V power and communication. No external power supply is required.

LEDs

USB-TEMP-AI has two LEDs –**Activity** and **Power**.

- The **Activity** LED (top) blinks when data is transferred.
- The **Power** LED (bottom) turns on when the device is receiving power from the USB cable .

Specifications

All specifications are subject to change without notice.
Typical for 25 °C unless otherwise specified.
All specifications apply to all temperature and voltage input channels unless otherwise specified.
Specifications in *italic* text are guaranteed by design.

Analog input

Table 1. Generic analog input specifications

Parameter	Conditions	Specification
A/D converter type	T0x to T3x, V0x toV3x	AD42_321 Dual 24-bit Sigma-Delta
Number of channels	Voltage input; V0x toV3x	4 differential, 4 single-ended
	Temperature input; T0x toT3x	4 differential
Input isolation		*500 VDC minimum between field wiring and USB interface*
Channel configuration	T0x toT3x	Temperature input. Software programmable to match sensor type
	V0x toV3x	Voltage input
Analog input modes	Power up and reset state	Factory default configuration is Disabled mode. Once configured, each channel reverts to the mode previously set by the user.
	Single-ended	Vx_H inputs are connected directly to their screw terminal pins. Vx_L inputs are disconnected from their screw terminal pins and internally connected to GND.
	Differential	Vx_H and Vx_L inputs are connected directly to their screw terminal pins.
		Tx_H and Tx_L inputs are connected directly to their screw terminal pins.
Input ranges	Thermocouple; T0x toT3x	±0.080 V
	RTD; T0x toT3x	0 to 0.5 V
	Thermistor; T0x toT3x	0 to 2 V
	Semiconductor sensor; T0x toT3x	0 to 2.5 V
	Voltage; V0x toV3x	±10 V, ±5 V, ±2.5 V, ±1.25 V; software selectable
Absolute maximum input voltage	*T0x to T3x relative to GND (pins 9, 19, 22, 27, 30, 33, 36, 39, 49)*	*±25 V max (power on)* *±40 V max (power off)*
	V0x to V3x relative to GND (pins 9, 19, 22, 27, 30, 33, 36, 39, 49)	*±25 V max (power on)* *±15 V max (power off)*
Input impedance	*T0x* to *T3x*	*5 GΩ (power on)* *1 MΩ (power off)*
	V0x to *V3x*	*10 GΩ (power on)* *2.49 kΩ (power off)*
Input leakage current	*T0x* to *T3x, with open thermocouple detect disabled.*	*30 nA max*
	T0x to *T3x, with open thermocouple detect enabled.*	*105 nA max*
	V0x to *V3x*	*±1.5 nA typ, ±25 nA max*
Input bandwidth (–3 dB)	T0x to T3x	50 Hz
	V0x to V3x	3 kHz

Parameter	Conditions	Specification
Maximum working voltage (signal + common mode)	V0x to V3x	±10.25 V max
Common mode rejection ratio	*T0x* to *T3x*, f_{IN} *= 60 Hz*	*100 dB*
	V0x to *V3x*, f_{IN} *= 60 Hz, all input ranges*	*83 dB*
ADC resolution		24 bits
ADC No missing codes		*24 bits*
Input coupling		DC
Warm-up time		30 minutes min
Open thermocouple detect	T0x to T3x	Automatically enabled when the channel pair is configured for thermocouple sensor. The maximum open detection time is 3 seconds.
CJC sensor accuracy	T0x to T3x, *15 °C to 35 °C*	*±0.25 °C typ, ±0.5 °C max*
	T0x to T3x, *0 °C to 70 °C*	*–1.0 to +0.75 °C max*

Channel configurations

Table 2. Channel configuration specifications

Channel	Category	Conditions	Max number of sensors (all channels configured alike)
T0x-T3x	Disabled	All temperature input channels are disconnected from screw terminals and internally connected to GND.	See Note 4
T0x-T3x	Thermocouple (Note 1)		4 differential channels
T0x-T3x	Semiconductor sensor (Note 1)		4 differential channels
T0x-T3x	RTD and Thermistor (Note 1)	2-wire input configuration with a single sensor per channel pair	2 differential channels
		2-wire input configuration with two sensors per channel pair	4 differential channels
		3-wire configuration with a single sensor per channel pair	2 differential channels
		4-wire input configuration with a single sensor per channel pair	2 differential channels
		4-wire input configuration with two sensors per channel pair	4 differential channels
V0x-V3x	Disabled	All voltage input channels are disconnected from screw terminals and internally connected to GND.	See Note 4
V0x-V3x	Differential (Note 2)		4 differential channels
V0x-V3x	Single-ended		4 single-ended channels

Note 1: Internally, the device has four, dual-channel, fully differential A/Ds providing a total of eight input channels. The temperature input channels are configured as two channel pairs with T0x/T1x and T2x/T3x accepting temperature sensor type inputs. This "channel-pairing" requires T0x/T1x, and T2x/T3x to be configured to monitor the same category of temperature sensor. Mixing different sensor types of the same category (such as a type J thermocouple on temperature channel 0 and a type T thermocouple on temperature channel 1) is valid.

Note 2: The voltage input channels V0x, V1x, V2x, and V3x are *not* configured as channel pairs. Therefore each channel can be configured independently. When connecting differential inputs to floating input sources, you must provide a DC return path from each differential input to ground. To do this, simply connect a resistor from each of the differential inputs to GND. A value of approximately 1 MΩ can be used for most applications.

Note 3: Channel configuration information is stored in the EEPROM of the isolated microcontroller by the firmware whenever any item is modified. Modification is performed by commands issued over USB from an external application, and the configuration is made non-volatile through the use of the EEPROM.

Note 4: The factory default configuration is **Disabled**. The Disabled mode disconnects the temperature and voltage inputs from the terminal blocks, and internally connects ground (GND) to all of the A/D inputs. This mode also disables each of the current excitation sources.

Compatible sensors: T0x-T3x

Table 3. Compatible sensor type specifications

Parameter	Conditions
Thermocouple	J: -210 °C to 1200 °C
	K: -270 °C to 1372 °C
	R: -50 °C to 1768 °C
	S: -50 °C to 1768 °C
	T: -270 °C to 400 °C
	N: -270 °C to 1300 °C
	E: -270 °C to 1000 °C
	B: 0 °C to 1820 °C
RTD	100 Ω PT (DIN 43760: 0.00385 ohms/ohm/°C)
	100 Ω PT (SAMA: 0.003911 ohms/ohm/°C)
	100 Ω PT (ITS-90/IEC751:0.0038505 ohms/ohm/°C)
Thermistor	Standard 2,252 Ω through 30,000 Ω
Semiconductor / IC	LM35, TMP35 or equivalent

Accuracy

Thermocouple measurement accuracy: T0x-T3x

Table 4. Thermocouple accuracy specifications, including CJC measurement error. All specifications are (±).

Sensor Type	Sensor temperature range (°C)	Accuracy error maximum (°C)	Accuracy error Typical (°C)	Tempco (°C/°C)
J	–210	2.028	0.707	0.031
	0	0.835	0.278	
	1200	0.783	0.288	
K	–210	2.137	0.762	0.035
	0	0.842	0.280	
	1372	0.931	0.389	
S	–50	1.225	0.435	0.021
	250	0.554	0.195	
	1768	0.480	0.157	
R	–50	1.301	0.458	0.019
	250	0.549	0.190	
	1768	0.400	0.134	
B	250	2.193	2.185	0.001
	700	0.822	0.819	
	1820	0.469	0.468	
E	–200	1.976	0.684	0.030
	0	0.954	0.321	
	1000	0.653	0.240	
T	–200	2.082	0.744	0.035

Sensor Type	Sensor temperature range (°C)	Accuracy error maximum (°C)	Accuracy error Typical (°C)	Tempco (°C/°C)
	0	0.870	0.290	
	400	0.568	0.208	
N	–200	2.197	0.760	0.028
	0	0.848	0.283	
	1300	0.653	0.245	

Note 5: Thermocouple measurement accuracy specifications include polynomial linearization, cold-junction compensation and system noise. These specs are for one year, or 3000 operating hours, whichever comes first, and for operation of the device between 15 °C and 35 °C. There is a CJC sensor on each temperature sensor input side of the module. The accuracy listed above assumes the screw terminals are at the same temperature as the CJC sensor. Errors shown do not include inherent thermocouple error. Contact your thermocouple supplier for details on the actual thermocouple accuracy error.

Note 6: Thermocouples must be connected to the device such that they are floating with respect to GND (pins 9, 19, 22, 27, 30, 33, 36, 39, 49). The device GND pins are isolated from earth ground. You can connect thermocouple sensors to voltages referenced to earth ground as long as the isolation between the GND pins and earth ground is maintained.

Note 7: When thermocouples are attached to conductive surfaces, the voltage differential between multiple thermocouples must remain within ±1.4 V. For best results, we recommend using insulated or ungrounded thermocouples when possible.

Semiconductor sensor measurement accuracy: T0x-T3x

Table 5. Semiconductor sensor accuracy specifications

Sensor type	Temperature Range	Accuracy Error maximum
LM35, TMP35 or equivalent	–40 °C to 150 °C	±0.50 °C

Note 8: Error shown does not include errors of the sensor itself. These specifications are for one year while operation of the device is between 15 °C and 35 °C. Contact your sensor supplier for details on the actual sensor error limitations.

RTD measurement accuracy: T0x-T3x

Table 6. RTD measurement accuracy specifications, I_{x+} = 210 µA. All specifications are (±).

RTD	Sensor temperature range (°C)	Accuracy error (°C) maximum	Accuracy error (°C) typical	Tempco (°C/°C)
PT100, DIN, US or ITS-90	–200	2.913	2.784	0.001
	–150	1.201	1.070	0.001
	–100	0.482	0.349	0.001
	0	0.261	0.124	0.001
	100	0.269	0.127	0.001
	300	0.287	0.136	0.001
	600	0.318	0.150	0.001

Note 9: The error shown does not include errors of the sensor itself. The sensor linearization is performed using a Callendar-Van Dusen linearization algorithm. The accuracy and tempco specifications *include* the accuracy of the Callendar-Van Dusen linearization algorithm. These specifications are for one year while operation of the device is between 15 °C and 35 °C. The specification does not include lead resistance errors for 2-wire RTD connections. Please contact your sensor supplier for details on the actual sensor error limitations.

Note 10: Resistance values greater than 660 Ω cannot be measured by the device in the RTD mode. The 660 Ω resistance limit includes the total resistance across the current excitation (±Ix) pins, which is the sum of the RTD resistance and the lead resistances.

Note 11: For accurate three wire compensation, the individual lead resistances connected to the ±Ix pins must be of equal ohmic value. To ensure this, use connection leads of equal lengths.

Thermistor measurement accuracy: T0x-T3x

Table 7. Thermistor measurement accuracy specifications, I_{x+} = 10 µA. All specifications are (±)

Thermistor	Sensor temperature range	Accuracy error maximum (°C)	Accuracy error typical (°C)	Tempco (°C/°C)
2252 Ω	-40 °C	0.001	0.0007	0.001
	0 °C	0.021	0.008	0.001
	50 °C	0.263	0.130	0.001
	120 °C	3.473	1.750	0.001
5000 Ω	-35 °C	0.001	0.0006	0.001
	0 °C	0.009	0.004	0.001
	50 °C	0.115	0.049	0.001
	120 °C	1.535	0.658	0.001
10000 Ω	-25 °C	0.001	0.0005	0.001
	0 °C	0.005	0.002	0.001
	50 °C	0.060	0.028	0.001
	120 °C	0.771	0.328	0.001
30000 Ω	-10 °C	0.001	0.0005	0.001
	0 °C	0.002	0.001	0.001
	50 °C	0.019	0.009	0.001
	120 °C	0.267	0.128	0.001

Note 12: Error shown does not include errors of the sensor itself. The sensor linearization is performed using a Steinhart-Hart linearization algorithm. The accuracy and tempco specifications *include* the accuracy of the Callendar-Van Dusen linearization algorithm. These specifications are for one year while operation is between 15 °C and 35 °C. The specification does not include lead resistance errors for 2-wire thermistor connections. Contact your sensor supplier for details on the actual sensor error limitations. Total thermistor resistance on any given channel pair must not exceed 180 kΩ. Typical resistance values at various temperatures for supported thermistors are shown in Table 8.

Table 8. Typical thermistor resistance measurement range

Temp °C	2252 Ω thermistor	3000 Ω thermistor	5 kΩ thermistor	10 kΩ thermistor	30 kΩ thermistor
–40	76 kΩ	101 kΩ	168 kΩ	240 kΩ (Note 13)	885 kΩ (Note 13)
–35	55 kΩ	73 kΩ	121 kΩ	179 kΩ	649 kΩ (Note 13)
–30	40 kΩ	53 kΩ	88 kΩ	135 kΩ	481 kΩ (Note 13)
–25	29 kΩ	39 kΩ	65 kΩ	103 kΩ	360 kΩ (Note 13)
–20	22 kΩ	29 kΩ	49 kΩ	79 kΩ	271 kΩ (Note 13)
–15	16 kΩ	22 kΩ	36 kΩ	61 kΩ	206 kΩ (Note 13)
–10	12 kΩ	17 kΩ	28 kΩ	48 kΩ	158 kΩ
–5	9.5 kΩ	13 kΩ	21 kΩ	37 kΩ	122 kΩ
0	7.4 kΩ	9.8 kΩ	16 kΩ	29 kΩ	95 kΩ

Note 13: Resistance values greater than 180 kΩ cannot be measured by the device in the thermistor mode. The 180 k Ω resistance limit includes the total resistance across the current excitation (±Ix) pins, which is the sum of the thermistor resistance and the lead resistances.

Note 14: For accurate three wire compensation, the individual lead resistances connected to the ±Ix pins must be of equal ohmic value. To ensure this, use connection leads of equal lengths.

Absolute Accuracy: V0x-V3x

Table 9. Calibrated absolute accuracy specifications

Range	Absolute Accuracy (mV)
±10 V	±2.779
±5 V	±1.398
±2.5 V	±0.707
±1.25 V	±0.362

Note 15: When connecting differential inputs to floating input sources, the user must provide a ground return path from each differential input to ground. To do this, simply connect a resistor from each of the differential inputs to GND. A value of approximately 1 M Ω can be used for most applications.

Note 16: All ground pins are common and are isolated from earth ground. If a connection is made to earth ground when using both voltage inputs and conductive thermocouples, the thermocouples are no longer isolated. In this case, thermocouples must not be connected to any conductive surfaces that may be referenced to earth ground

Note 17: Unused voltage inputs should not be left floating. These inputs should be placed in the Disabled mode or connected to GND.

Table 10. Accuracy components. All values are (±)

Range	Gain error (% of reading)	Offset error (µV)	INL error (% of range)	Gain Temperature Coefficient (ppm/°C)	Offset Temperature Coefficient (µV/°C)
±10 V	0.0246	16.75	0.0015	3.68	0.42
±5 V	0.0246	16.75	0.0015	3.68	0.42
±2.5 V	0.0246	16.75	0.0015	3.68	0.42
±1.25 V	0.0246	16.75	0.0015	3.68	0.42

Table 11. Noise performance specifications

Range	Peak to peak noise (µV)	RMS noise (µVrms)	Noise-Free resolution (bits)
±10 V	41.13	6.23	*19.09*
±5 V	30.85	4.67	*18.51*
±2.5 V	17.14	2.60	*18.36*
±1.25 V	11.14	1.69	*17.98*

Table 11 summarizes the noise performance for the device. Noise distribution is determined by gathering 1000 samples with inputs tied to ground at the user connector. Samples are gathered at the maximum specified sample rate of 2 S/s.

Settling time: V0x-V3x

Table 12. Settling time specifications

Range	Accuracy
	±0.0004% (seconds)
±10 V	15.0
±5 V	0.40
±2.5 V	0.40
±1.25 V	0.40

Settling time is defined as the time required for a channel to settle within a specified accuracy in response to a full-scale (FS) step input.

Analog input calibration

Table 13. Analog input calibration specifications

Parameter	Specifications
Recommended warm-up time	30 minutes min
Calibration	Firmware calibration
Calibration interval	1 year
Calibration reference	+10.000 V, ±5 mV max. Actual measured values stored in EEPROM
	Tempco: 5 ppm/°C max
	Long term stability: 30 ppm/1000 h

Throughput rate

Table 14. Throughput rate specifications

Number of Input Channels	Maximum throughput
1	2 Samples/second
2	2 S/s on each channel, 4 S/s total
3	2 S/s on each channel, 6 S/s total
4	2 S/s on each channel, 8 S/s total
5	2 S/s on each channel, 10 S/s total
6	2 S/s on each channel, 12 S/s total
7	2 S/s on each channel, 14 S/s total
8	2 S/s on each channel, 16 S/s total

Note 18: The analog inputs are configured to run continuously. Each channel is sampled twice per second. The maximum latency between when a sample is acquired and the voltage/temperature data is provided by the USB unit is approximately 0.4 seconds.

Digital input/output

Table 15. Digital input/output specifications

Parameter	Specification
Digital type	5V CMOS
Number of I/O	8 (DIO0 through DIO7)
Configuration	Independently configured for input or output. Power on reset is input mode unless bit is configured for alarm.
Pull-up/pull-down configuration	All pins pulled up to +5 V via 47 K resistors (default). Contact MCC factory for pull-down to ground (GND) capability.
Digital I/O transfer rate (software paced)	▪ Digital input – 50 port reads or single bit reads per second typ ▪ Digital output – 100 port writes or single bit writes per second typ
Input high voltage	2.0 V min, 5.5 V absolute max
Input low voltage	0.8 V max, –0.5 V absolute min
Output low voltage (IOL = 2.5 mA max)	0.7 V max
Output high voltage (IOH = –2.5 mA max)	3.8 V min

Note 19: All ground pins are common and are isolated from earth ground. If a connection is made to earth ground when using both digital I/O and conductive thermocouples, the thermocouples are no longer isolated. In this case, thermocouples must not be connected to any conductive surfaces that may be referenced to earth ground.

Counter

Table 16. CTR I/O specifications

Parameter	Specification
Pin name	CTR
Number of channels	1
Resolution	32-bits
Counter type	Event counter
Input type	TTL, rising edge triggered
Input source	CTR screw terminal
Counter read/writes rates (software paced)	Counter read: System dependent, 33 to 1000 reads per second.
	Counter write: System dependent, 33 to 1000 reads per second.
Schmidt trigger hysteresis	20 mV to 100 mV
Input leakage current	*±1.0 µA typ*
Input frequency	1 MHz max
High pulse width	*500 nS min*
Low pulse width	*500 ns min*
Input high voltage	4.0 V min, 5.5 V absolute max
Input low voltage	1.0 V max, –0.5 V absolute min

Note 20: All ground pins are common and are isolated from earth ground. If a connection is made to earth ground with both the counter (CTR) and conductive thermocouples, the thermocouples are no longer isolated. In this case, thermocouples must not be connected to any conductive surfaces that may be referenced to earth ground.

Memory

Table 17. Memory specifications

Parameter	Specification
EEPROM	1,024 bytes isolated micro reserved for sensor configuration 256 bytes USB micro for external application use

Microcontroller

Table 18. Microcontroller specifications

Parameter	Specification
Type	Two high-performance 8-bit RISC microcontrollers

USB +5V voltage

Table 19. USB +5V voltage specifications

Parameter	Specification
USB +5V (VBUS) input voltage range	4.75 V min to 5.25 V max

Power

Table 20. Power specifications

Parameter	Conditions	Specification
Supply current	USB enumeration	<100 mA
Supply current (Note 21)	Quiescent mode with all inputs configured for Disabled mode	270 mA typ
User +5V output voltage range (terminal block pin 21)		4.9 V min to 5.1 V max
User +5V output current (terminal block pin 21)	Bus-powered and connected to a self-powered hub. (Note 21)	5 mA max
Isolation	Measurement system to PC	500 VDC min

Note 21: This is the total current requirement for the device which includes up to 10 mA for the status LED.

USB specifications

Table 21. USB specifications

USB device type	USB 2.0 (full-speed)
Device compatibility	USB 1.1, USB 2.0
Device power capability	Self-powered
USB cable type	*A-B cable, UL type AWM 2725 or equivalent (min 24 AWG VBUS/GND, min 28 AWG D+/D–)*
USB cable length	3 meters max

Current excitation outputs (±Ix, T0x-T3x)

Table 22. Current excitation output specifications

Parameter	Specification
Configuration	2 dedicated pairs: ▪ ±I1: T0x/T1x ▪ ±I2: T2x/T3x
Current excitation output ranges	Thermistor: 10 µA
	RTD: 210 µA
Tolerance	±5.0%
Drift	200 ppm/°C
Line regulation	*2.1 ppm/V max*
Load regulation	*0.3 ppm/V*
Output compliance voltage (relative to GND pins)	3.90 V max –0.03 V min

Note 22: The device has two current excitation outputs, with ±I1 dedicated to the T0x/T1x analog inputs, and ±I2 dedicated to T2x/T3x. The excitation output currents should always be used in this dedicated configuration.

Note 23: The current excitation outputs are automatically configured based on the sensor (thermistor or RTD) selected.

Environmental

Table 23. Environmental specifications

Operating temperature range	0 °C to 55 °C max
Storage temperature range	–40 °C to 85 °C max
Humidity	0% to 90% non-condensing max

Mechanical

Table 24. Mechanical specifications

Dimensions (L × W × H)	128.52 x 88.39 × 35.56 mm (5.06 × 3.48 × 1.43 ft)
User connection length	3 m (9.84 ft) max

Screw terminal connector

Table 25. Screw terminal connector specifications

Connector type	Screw terminal
Wire gauge range	16 AWG to 30 AWG

Table 26. Screw terminal pinout

Pin	Signal Name	Pin Description	Pin	Signal Name	Pin Description
1	I1+	T0/T1 current excitation source	27	GND	Ground
2	NC	No connection	28	V3L	V3 voltage input (–)
3	T0H	T0 sensor input (+)	29	V3H	V3 voltage input (+)
4	T0L	T0 sensor input (–)	30	GND	Ground
5	4W01	T0/T1 4-wire, 2 sensor common	31	V2L	V2 voltage input (–)
6	IT01	T0/T1 2-sensor common	32	V2H	V2 voltage input (+)
7	T1H	T1 sensor input (+)	33	GND	Ground
8	T1L	T1 sensor input (–)	34	V1L	V1 voltage input (–)
9	GND	Ground	35	V1H	V1 voltage input (+)
10	I1–	T0/T1 current excitation return	36	GND	Ground
	CJC sensor				
11	I2+	T2/T3 current excitation source	37	V0L	V0 voltage input (–)
12	NC		38	V0H	V0 voltage input (+)
13	T2H	T2 sensor input (+)	39	GND	Ground
14	T2L	T2 sensor input (–)	40	CTR	Counter Input
15	4W23	T2/T3 4-wire, 2 sensor common	41	DIO7	DIO channel 7
16	IT23	T2/T3 2 sensor common	42	DIO6	DIO channel 6
17	T3H	T3 sensor input (+)	43	DIO5	DIO channel 5
18	T3L	T3 sensor input (–)	44	DIO4	DIO channel 4
19	GND	Ground	45	DIO3	DIO channel 3
20	I2–	T2/T3 current excitation return	46	DIO2	DIO channel 2
21	+5V	+5V output	47	DIO1	DIO channel 1
22	GND	Ground	48	DIO0	DIO channel 0
23	NC	No connection	49	GND	Ground
24	NC	No connection	50	NC	No connection
25	NC	No connection	51	NC	No connection
26	NC	No connection	52	NC	No connection

Declaration of Conformity

Manufacturer: Measurement Computing Corporation
Address: 10 Commerce Way
Suite 1008
Norton, MA 02766
USA
Category: Electrical equipment for measurement, control and laboratory use.

Measurement Computing Corporation declares under sole responsibility that the product

USB-TEMP-AI

EU EMC Directive 89/336/EEC: Electromagnetic Compatibility, EN 61326 (1997) Amendment 1 (1998)

Emissions: Group 1, Class A

- EN 55011 (1990)/CISPR 11: Radiated and Conducted emissions.

Immunity: EN61326, Annex A

- IEC 61000-4-2 (1995): Electrostatic Discharge immunity, Criteria C.
- IEC 61000-4-3 (1995): Radiated Electromagnetic Field immunity Criteria A.
- IEC 61000-4-8 (1994): Power frequency magnetic field immunity Criteria A.

Declaration of Conformity based on tests conducted by Chomerics Test Services, Woburn, MA 01801, USA in July, 2007. Test records are outlined in Chomerics Test Report #EMI4833.07.

We hereby declare that the equipment specified conforms to the above Directives and Standards.

Carl Haapaoja, Director of Quality Assurance

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