# USB-TC

Thermocouple Measurement

# User's Guide

October 2016. Rev 10A


MEASUREMENT COMPUTING™

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# Table of Contents

# About this User's Guide

## What you will learn from this user's guide

This user's guide describes the Measurement Computing USB-TC 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-TC hardware is available on our website at www.mccdaq.com. You can also contact Measurement Computing Corporation with specific questions.

- Knowledgebase: kb.mccdaq.com
- Tech support form: www.mccdaq.com/support/support_form.aspx
- Email: techsupport@mccdaq.com
- Phone: 508-946-5100 and follow the instructions for reaching Tech Support

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

# Introducing the USB-TC

## Overview: USB-TC features

The USB-TC is a USB 2.0 full-speed, thermocouple input module that is supported under popular Microsoft® Windows® operating systems. The USB-TC is fully compatible with both USB 1.1 and USB 2.0 ports.

The USB-TC provides eight differential thermocouple input channels. 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.

With the USB-TC, you can take measurements from type J, K, R, S, T, N, E, and B thermocouples.

The USB-TC provides two integrated cold junction compensation (CJC) sensors for thermocouple measurements.

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

The USB-TC 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-TC is fully software calibrated.

## Functional block diagram

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

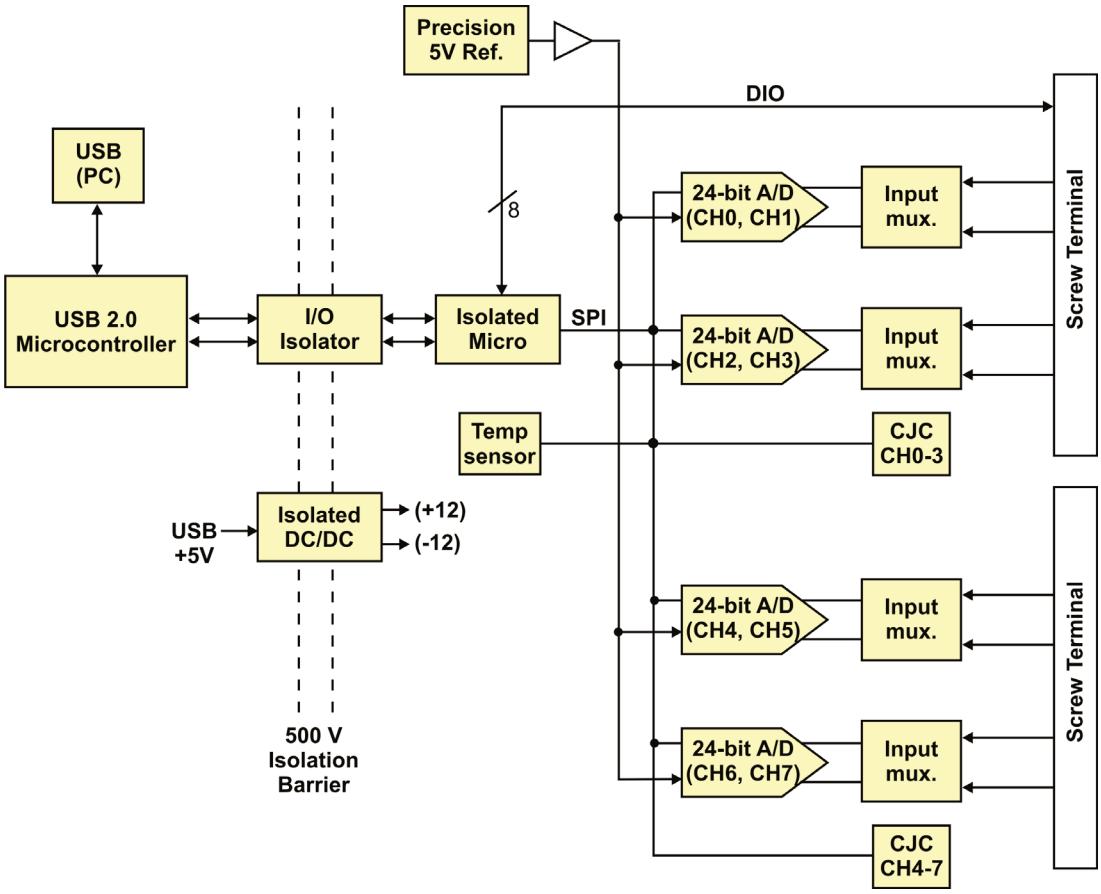



Figure 1. Functional block diagram

# Installing the USB-TC

## Unpacking

As with any electronic device, you should take care while handling to avoid damage from static electricity. Before removing the board 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.

## Installing the software

Refer to the MCC DAQ Quick Start and the USB-TC product page on our website for information about the available software.

**Install the software before you install your device**

The driver needed to run the USB-TC is installed with the software. Therefore, you need to install the software package you plan to use before you install the hardware.

## Installing the hardware

To connect the USB-TC 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-TC.

When you connect the USB-TC to a computer for the first time, a **Found New Hardware** dialog opens when the operating system detects the device. When the dialog closes, the installation is complete. The upper **Activity LED** blinks when initially connected and then stays on; the lower **Power LED** turns on when power is applied.

**Caution!** Do not disconnect the device from the USB bus while the Activity LED is on and the computer is communicating with the USB-TC, or you may lose data and/or your ability to communicate with the USB-TC.

## Configuring the hardware

All hardware configuration options on the USB-TC are programmable with software. Use InstaCal to set the thermocouple type for each channel pair. Configuration options are stored on the USB-TC 's isolated microcontroller in EEPROM, which is non-volatile memory on the USB-TC module. Configuration options are loaded on power up. The factory default configuration is *Type J* thermocouple.

**Warm up**

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

## Calibrating the hardware

The USB-TC is fully calibrated via InstaCal. Allow a 30 minute warm up before calibrating. This warm up time minimizes thermal drift and achieves the specified rated accuracy of measurements.

# Sensor Connections

The USB-TC supports type J, K, R, S, T, N, E, and B thermocouples.

**Thermocouple selection**

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

## Screw terminal pinout

The USB-TC has four rows of screw terminals — two rows on the top edge of the housing, and two rows on the bottom edge. Each row has 26 connections. Between each bank of screw terminals are two integrated CJC sensors used for thermocouple measurements. Signals are identified in Figure 2.

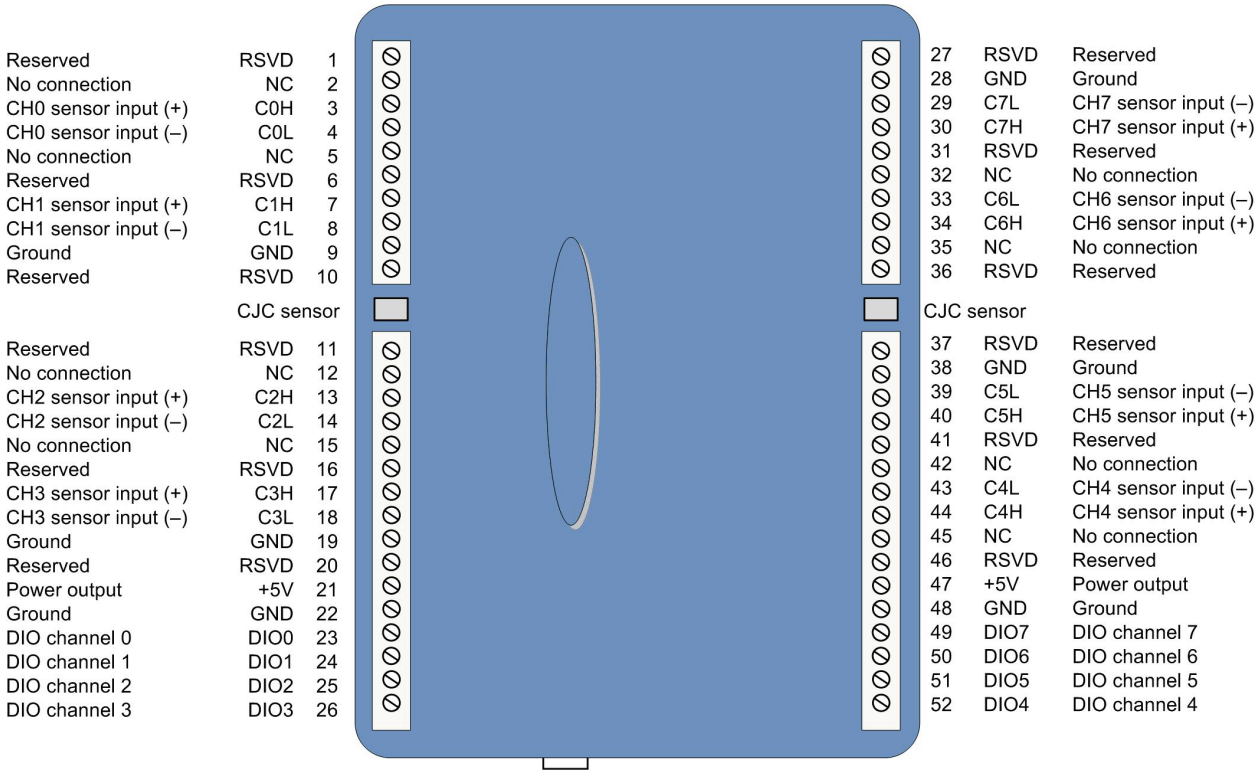



Figure 2. Screw terminal pinout

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.

### Thermocouple input

You can connect up to eight thermocouples to the differential sensor inputs (**C0H**/**C0L** to **C7H**/**C7L**). The device supports type J, K, R, S, T, N, E, and B thermocouples.

### CJC sensors

The USB-TC has two built in high-resolution temperature sensors. One sensor is located on the right side of the package, and one sensor is located at the left side.

### Digital I/O

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.

### Power output

The two **+5V** terminals are isolated (500 VDC) from the USB +5V.

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

### Ground

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

## 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-TC makes fully differential thermocouple measurements without the need of ground-referencing resistors. A 32-bit floating point value in either a voltage or temperature format is returned by software. An open thermocouple detection feature is available for each analog input which automatically detects an open or broken thermocouple.

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

### Wiring configuration

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

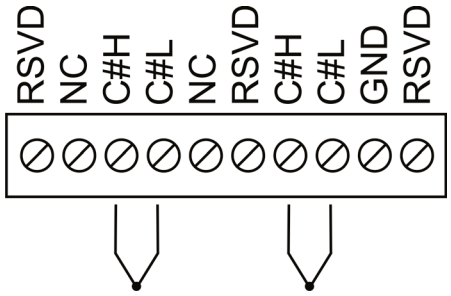



Figure 3. Typical thermocouple connection

Connect thermocouples to the USB-TC such that they are floating with respect to GND (pins 9, 19, 28, 38). The USB-TC **GND** pins are isolated from earth ground, so connecting thermocouple sensors to voltages referenced to earth ground is permissible as long as the isolation between the GND pins (9, 19, 28, 38) 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 device is powered on, and ±40 VDC when the device 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.

# 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-TC digital I/O terminals to detect the state of any TTL-level input. Refer to the schematic shown in Figure 4. If you set the switch to the +5V input, DIO0 reads *TRUE* (1). If you move the switch to GND, DIO0 reads *FALSE* (0).

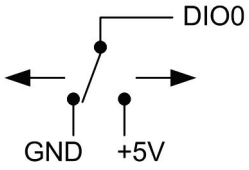



Figure 4. Schematic showing switch detection by digital channel DIO0

All ground pins 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 more information about digital signal connections**

For general information about digital signal connections and digital I/O techniques, refer to the *Guide to DAQ Signal Connections* (available on our web site at www.mccdaq.com/support/DAQ-Signal-Connections.aspx).

# 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-TC 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-TC 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-TC terminal blocks produce an additional thermocouple junction. 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-TC subtracts the *cold junction* voltage from the thermocouple voltage.

The USB-TC has two high-resolution temperature sensors that are integrated into the design of the USB-TC. One sensor is located on the right side of the package, and one sensor is located at the left side. The CJC sensors measure the average temperature at the terminal blocks 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-TC is equipped with an 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.

#### Input leakage current

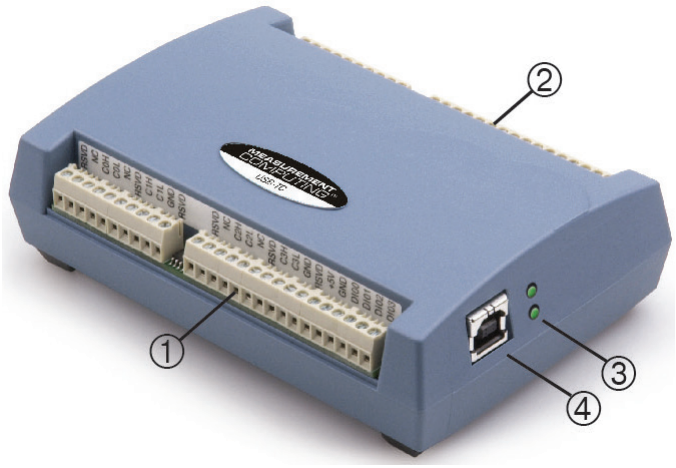
With open-thermocouple detection enabled, 105 nA (max.) of input leakage current is injected into the thermocouple. This current can cause an error voltage to develop across the lead resistance of the thermocouple that is indistinguishable from the thermocouple voltage you are measuring. You can estimate this error voltage with the following formula:

error voltage = resistance of the thermocouple × 105 nA

To reduce the error, reduce the length of the thermocouple to lower its resistance, or lower the AWG of the wire by using a wire with a larger diameter. With open-thermocouple detection disabled, 30 nA (max.) of input leakage current is injected into the thermocouple.

# External components

The USB-TC has the following external components, as shown in Figure 5.




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

Figure 5.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 "Sensor Connections" chapter on page 8 for information about the device screw terminals.

## USB connector

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

## Status LEDs

USB-TC has two LEDs that indicate the status of power and data. The LEDs are stacked one above the other.

- The **Activity** LED (top) blinks when data is transferred over the USB bus.
- The **Power** LED (bottom) turns on when power is applied.

# Specifications

**All specifications are subject to change without notice.**
**Typical for 25 °C unless otherwise specified.**
**Specifications in *italic* text are guaranteed by design.**

## Analog input

Table 1. Generic analog input specifications

| Parameter | Condition | Specification |
|---|---|---|
| A/D converters | | Four dual 24-bit, Sigma-Delta type |
| Number of channels | | 8 differential |
| *Input isolation* | | *500 VDC minimum between field wiring and USB interface* |
| Channel configuration | | Thermocouple sensor type |
| Differential input voltage range | Thermocouple | ±0.080 V |
| *Absolute maximum input voltage* | *±C0x through ±C7x relative to GND (pins 9, 19, 28, 38)* | ±24 V power on,<br>±24 V power off |
| Input impedance | | 5 GΩ, min |
| Input leakage current | Open thermocouple detect enabled | 105 nA max |
| *Normal mode rejection ratio* | *$f_{IN}$ = 60 Hz* | *90 dB min* |
| *Common mode rejection ratio* | *$f_{IN}$ = 50 Hz/60 Hz* | *100 dB min* |
| Resolution | | 24 bits |
| *No missing codes* | | *24 bits* |
| Input coupling | | DC |
| Warm-up time | | 30 minutes min |
| Open thermocouple detect | | Automatically enabled when the channel pair is configured for thermocouple sensors.<br>The maximum open detection time is 3 seconds. |
| *CJC sensor accuracy* | *15 °C to 35 °C* | *±0.25 °C typ,*<br>*±0.5 °C max* |
| | *0 °C to 70 °C* | *–1.0 °C to +0.5 °C max* |

## Channel configurations

Table 2. Channel configuration specifications

| Sensor Category | Condition | Specification |
|---|---|---|
| Thermocouple | J, K, S, R, B, E, T, or N | 8 differential channels |

**Note 1:** 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 2:** The factory default configuration is *Type J*.

# Accuracy

## Thermocouple measurement accuracy

Table 3. Thermocouple accuracy specifications, including CJC measurement error

| Sensor Type | Maximum error (°C) | Typical error (°C) | Temperature range (°C) |
|---|---|---|---|
| J | ±1.499 | ±0.507 | –210 to 0 |
| | ±0.643 | ±0.312 | 0 to 1200 |
| K | ±1.761 | ±0.538 | –210 to 0 |
| | ±0.691 | ±0.345 | 0 to 1372 |
| S | ±2.491 | ±0.648 | –50 to 250 |
| | ±1.841 | ±0.399 | 250 to 1768.1 |
| R | ±2.653 | ±0.650 | –50 to 250 |
| | ±1.070 | ±0.358 | 250 to 1768.1 |
| B | ±1.779 | ±0.581 | 250 to 700 |
| | ±0.912 | ±0.369 | 700 to 1820 |
| E | ±1.471 | ±0.462 | –200 to 0 |
| | ±0.639 | ±0.245 | 0 to 1000 |
| T | ±1.717 | ±0.514 | –200 to 0 |
| | ±0.713 | ±0.256 | 0 to 600 |
| N | ±1.969 | ±0.502 | –200 to 0 |
| | ±0.769 | ±0.272 | 0 to 1300 |

**Note 3:** Thermocouple specifications include 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. For measurements outside this range, add ±0.5 degree to the maximum error shown. There are CJC sensors on each 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. Please contact your thermocouple supplier for details on the actual thermocouple error.

**Note 4:** Thermocouples must be connected to the device such that they are floating with respect to GND. The GND pins are isolated from earth ground, so connecting thermocouple sensors to voltages referenced to earth ground is permissible as long as the isolation between the GND pins and earth ground is maintained.

**Note 5:** When thermocouples are attached to conductive surfaces, the voltage differential between multiple thermocouples must remain within ±1.4V. For best results we recommend the use of ungrounded or insulated thermocouples when possible.

# Throughput rate

Table 4. Throughput rate specifications

| Number of input channels | Maximum throughput |
|---|---|
| 1 | 2 S/s |
| 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 6:** 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 temperature data is provided by the USB unit is approximately 0.5 seconds.

# Digital input/output

Table 5. Digital input/output specifications

| Parameter | Specification |
|---|---|
| Digital type | CMOS |
| Number of I/O | 8 (DIO0 through DIO7) |
| Configuration | Independently configured for input or output.<br>Power on reset is input mode. |
| Pull-up/pull-down configuration | All pins pulled up to +5 V via 47 K resistors (default). Pull-down to ground (GND) also available. |
| Digital I/O transfer rate (software paced) | ■ Digital input: 50 port reads or single bit reads per second, typ<br>■ 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) | 0.7 V max |
| Output high voltage (IOH = –2.5 mA) | 3.8 V min |

**Note 7:** All ground pins 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.

# Memory

Table 6. Memory specifications

| Parameter | Specification |
|---|---|
| EEPROM | 1,024 bytes isolated micro reserved for sensor configuration<br>256 bytes USB micro for external application use |

# Microcontroller

Table 7. Microcontroller specifications

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

# USB +5V voltage

Table 8. USB +5V voltage specifications

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

# Power

Table 9. Power specifications

| Parameter | Condition | Specification |
|---|---|---|
| Supply current | USB enumeration | <100 mA |
| Supply current (Note 8) | Continuous mode | 140 mA typ |
| User +5V output voltage range (pins 21 and 47) | Connected to self-powered hub. (Note 9) | 4.75 V min to 5.25 V max |
| User +5V output current (pins 21 and 47) | Bus-powered and connected to a self-powered hub. (Note 9) | 10 mA max |
| Isolation | Measurement system to PC | 500 VDC min |

**Note 8:** This is the total current requirement for the device which includes up to 10 mA for the status LED.

**Note 9:** Self-Powered Hub refers to a USB hub with an external power supply. Self-powered hubs allow a connected USB device to draw up to 500 mA.

Root Port Hubs reside in the PC USB Host Controller. The USB port(s) on your PC are root port hubs. All externally powered root port hubs (desktop PC's) provide up to 500 mA of current for a USB device. Battery-powered root port hubs provide 100 mA or 500 mA, depending upon the manufacturer. A laptop PC that is not connected to an external power adapter is an example of a battery-powered root port hub.

# USB specifications

Table 10. USB specifications

| Parameter | Specification |
|---|---|
| USB device type | USB 2.0 (full-speed) |
| Device compatibility | USB 1.1, USB 2.0 |
| Device power capability | Self-powered, 100 mA consumption max |
| *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 m (9.84 ft) max |

# Environmental

Table 11. Environmental specifications

| Parameter | Specification |
|---|---|
| Operating temperature range | 0 °C to 70 °C |
| Storage temperature range | –40 °C to 85 °C |
| Humidity | 0% to 90% non-condensing |

# Mechanical

Table 12. Mechanical specifications

| Parameter | Specification |
|---|---|
| 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 |

# Signal connector

Table 13. Signal connector specifications

| Parameter | Specification |
|---|---|
| Connector type | Screw terminal |
| Wire gauge range | 16 AWG to 30 AWG |

Table 14. Screw terminal pinout

| Pin | Signal Name | Pin Description | Pin | Signal Name | Pin Description |
|---|---|---|---|---|---|
| 1 | RSVD | Reserved, Do Not Use | 27 | RSVD | Reserved, Do Not Use |
| 2 | NC | No connection | 28 | GND | Ground |
| 3 | C0H | CH0 sensor input (+) | 29 | C7L | CH7 sensor input (–) |
| 4 | C0L | CH0 sensor input (–) | 30 | C7H | CH7 sensor input (+) |
| 5 | NC | No connection | 31 | RSVD | Reserved, Do Not Use |
| 6 | RSVD | Reserved, Do Not Use | 32 | NC | No connection |
| 7 | C1H | CH1 sensor input (+) | 33 | C6L | CH6 sensor input (–) |
| 8 | C1L | CH1 sensor input (–) | 34 | C6H | CH6 sensor input (+) |
| 9 | GND | Ground | 35 | NC | No connection |
| 10 | RSVD | Reserved, Do Not Use | 36 | RSVD | Reserved, Do Not Use |
| | CJC sensor | | | CJC sensor | |
| 11 | RSVD | Reserved, Do Not Use | 37 | RSVD | Reserved, Do Not Use |
| 12 | NC | No connection | 38 | GND | Ground |
| 13 | C2H | CH2 sensor input (+) | 39 | C5L | CH5 sensor input (–) |
| 14 | C2L | CH2 sensor input (–) | 40 | C5H | CH5 sensor input (+) |
| 15 | NC | No connection | 41 | RSVD | Reserved, Do Not Use |
| 16 | RSVD | Reserved, Do Not Use | 42 | NC | No connection |
| 17 | C3H | CH3 sensor input (+) | 43 | C4L | CH4 sensor input (–) |
| 18 | C3L | CH3 sensor input (–) | 44 | C4H | CH4 sensor input (+) |
| 19 | GND | Ground | 45 | NC | No connection |
| 20 | RSVD | Reserved, Do Not Use | 46 | RSVD | Reserved, Do Not Use |
| 21 | +5V | +5V output | 47 | +5V | +5V output |
| 22 | GND | Ground | 48 | GND | Ground |
| 23 | DIO0 | DIO channel 0 | 49 | DIO7 | DIO channel 7 |
| 24 | DIO1 | DIO channel 1 | 50 | DIO6 | DIO channel 6 |
| 25 | DIO2 | DIO channel 2 | 51 | DIO5 | DIO channel 5 |
| 26 | DIO3 | DIO channel 3 | 52 | DIO4 | DIO channel 4 |

# CE EU Declaration of Conformity

**According to ISO/IEC 17050-1:2010**

| | |
|---|---|
| Manufacturer: | Measurement Computing Corporation |
| Address: | 10 Commerce Way |
| | Norton, MA 02766 |
| | USA |
| Product Category: | Electrical equipment for measurement, control and laboratory use. |
| Date and Place of Issue: | June 2, 2016, Norton, Massachusetts USA |
| Test Report Number: | EMI4193.05 / EMI5215B.08 |

Measurement Computing Corporation declares under sole responsibility that the product

**USB-TC**

is in conformity with the relevant Union Harmonization Legislation and complies with the essential requirements of the following applicable European Directives:

Electromagnetic Compatibility (EMC) Directive 2014/35/EU

Low Voltage Directive 2014/35/EU

RoHS Directive 2011/65/EU

Conformity is assessed in accordance to the following standards:

EMC:

Emissions:

- EN 61326-1:2013 (IEC 61326-1:2012), Class A
- EN 55011: 2009 + A1:2010 (IEC CISPR 11:2009 + A1:2010), Group 1, Class A

Immunity:

- EN 61326-1:2013 (IEC 61326-1:2012), Controlled EM Environments
- EN 61000-4-2:2008 (IEC 61000-4-2:2008)
- EN 61000-4-3 :2010 (IEC61000-4-3:2010)

Safety:

- EN 61010-1 (IEC 61010-1)

Environmental Affairs:

Articles manufactured on or after the Date of Issue of this Declaration of Conformity do not contain any of the restricted substances in concentrations/applications not permitted by the RoHS Directive.

Carl Haapaoja, Director of Quality Assurance

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