Overview

SEN-30203 is a quad-channel, high precision and high accuracy Resistance Temperature Device (RTD) interface board based on the Analog Devices MAX31865. It supports all three RTD types, including 2-, 3-, and 4-wire devices, and handles multiple fault conditions. SEN-30203 is stocked in two common calibration values for optimal measurement of PT100, and PT1000 RTDs. PT500 and alternate resistance ranges are available upon request. A wide, 3.0V - 5.5V supply and DIO voltage range makes it possible to interface with the high-speed 4-wire SPI interface using a wide variety of microcontrollers and development boards.

Features

- Quad-channel MAX31865 RTD-to-Digital Converter
- Compatible with R3aktor Core
- Wide 3.0V - 5.5V supply and IO range
- 15-bit resolution (nominal 0.03125-°C)
- High speed, level shifted SPI interface
- PT100 and PT1000 parts stocked
- Supports 2-, 3-, and 4-wire RTDs
- ±45V Input protection
- Arduino Uno R3 shield form factor
- 0.15% absolute resistance accuracy
- Multi-fault detection: Open RTD, RTD shorts to out-of-range voltage, RTD shorted
- Programmable fault detection and temperature thresholds
- RTD connects spring loaded terminals
- Up to ~45Hz sampling rate

Kit Includes

- SEN-30203-(x) quad-channel MAX31865 Breakout, fully assembled

Typical Applications

- Replace thermocouples for improved precision and accuracy in < 850°C applications
- Medical equipment
- Industrial instrumentation and thermal management
- Commercial and industrial ovens
- Petrochemical thermal management
- Brewing controls
- Hobby applications

Description

RTDs are generally some of the most consistent and accurate temperature sensing devices used in ovens and chemical processing equipment. The MAX31865 from Analog Devices makes RTD interfacing simple by providing the excitation current needed to measure the resistance. SEN-30203 includes 0.1% reference resistors needed to perform the ratiometric reference measurement built-into the MAX31865 IC. These precision resistors are specifically optimized based on the RTD sensor to be used.

Three RTD wiring configurations are available, including 2-, 3-, and 4-wire devices, and MAX31865 has specific consideration for all of them. See the application section below for more details on using the SEN-30203 to read the different RTDs, as well as details on when to select 2- vs 3- or 4-wire devices.

SEN-30203 compliments high accuracy RTDs with an overall 0.15% full-range resistance accuracy, which includes the onboard reference resistor. This resistance is turned into a temperature value using one of three common methods, described in the application section below.

A high-speed, 3.0V - 5.5V compatible 4-wire SPI interface is used to configure and update readings from the device. The SEN-30203 shield is pin compatible with Arduino Uno R3 devices and is electrically compatible with 3.3V and 5.0V microcontrollers. Multiple SEN-30203 boards can be connected to a single microcontroller by modifying the factory selected CS (chip-select) connections while sharing the rest of the SPI signals.

A 9-pin straight header with 0.1" (2.54mm) spacing is also provided to allow a user to build a system on anything from a breadboard to a custom carrier PCB. Multiple SEN-30203 boards can be connected to a single microcontroller by adding extra CS connections while sharing the rest of the SPI signals.

R3aktor Compatible

The SEN-30012 is compatible with the R3aktor Core line of data acquisition products including the Control Center PC software. Simply install the SEN-30012 shield on top of a R3aktor Core and begin measuring data. No programming required when using the factory supplied R3aktor firmware.

Electrical Limits and Specifications

Name	Description	Min	Nominal	Max	Unit
V_{Supply}	Supply Voltage	3.3	-	5.5	V
$T_{Ambient}$	Ambient Temperature	-40	-	80	°C
I_{Supply}	Supply Current[1]	0	8	14	mA
	RTD Temperature Resolution		15		Bits
			0.05		°C/bit
	Resistive Measurement Resolution[2] (PT100) (PT1K)		0.0123 0.1221		Ω/bit
	Resistive Measurement Range[2] (PT100) (PT1K)	0 0		400 4000	Ω
t_{sample}	Minimum sample period	47	-	-	ms

Table 1 - Electrical Limits and Specifications

[1] Expected current load with 3.3V supply voltage. Higher supply current as supply voltage increases due to onboard 3.3V LDO

[2] Measurement range and resolution is dependent on the R3aktor Core variant (PT100 or PT1k)

Application & Guide

RTDs provide greater measurement consistency, accuracy, and repeatability than their thermocouple counterparts. For example, IEC 751 Class A RTDs have a base resistance tolerance of ±0.06% (±0.1°C @0°C) and full-range tolerance of ±0.45% (±1°C @600°C). For a thermocouple to approach this accuracy “Special Limits of Error” thermocouple wire is needed, and even then, the thermocouple will age and lose accuracy when exposed to high temperatures.

On the other hand, RTDs cannot handle the wide temperature range of many thermocouple types. For example, a K-type thermocouple may measure from -260°C to 1380°C. If the end application is limited to -200°C - 800°C and an RTD in a suitable form factor is available, an RTD is often the best fit for the application.

There are two main user-defined components that affect accuracy of an RTD measurement. First is the method chosen for converting resistance-to-temperature. It is possible to use a linear approximation to the RTD response curve, which is typically only used over a narrow range of temperatures and around 0°C. As stated in the MAX31865 datasheet, Temperature(°C) ≈ (ADC code / 32) - 256. Since the resistance curve “bends down” from a linear approximation, error increases as temperature gets farther away from 0°C. At -100°C the error is -1.4°C, and at +100°C error is -1.7°C. It is also possible to linearize around an expected operating point or region or interest to minimize error at, say, 37°C, normal human body temperature, or 100°C, the temperature at which water boils. RTDs are most widely available with α values (average slope between 0°C and 100°C) of 0.00385 or 0.00392.

Improvements to simple linearization assumptions can be made by:

a. Using lookup tables to correct for nonlinearity
b. Using the Callendar-Van Dusen equation relevant to your specific RTD.

Both of methods can reduce the error to within the accuracy bands of the RTD itself. Per the MAX31865 datasheet, the Callendar-Van Dusen equation is as follows:

$$R(T) = R_0(1 + aT + bT^2 + c(T - 100)T^3)$$

Equation 1 - Callendar-Van Dusen equation

Where:

T = temperature (°C)
R(T) = resistance at T
R_0 = resistance at T = 0°C

For IEC 751-complaint RTDs (α = 0.00385)

a = 3.90830 x 10^{-3}
b = -5.775 x 10^{-7}
c = -4.18301 x 10^{-12} (-200°C - 0°C)
c = 0.0 (0°C - 850°C)

The second user-defined accuracy limit depends on which RTD wiring type is selected. As mentioned, 2-, 3-, and 4-wire RTDs are available, and R3aktor can measure each. Key to selecting the right type lies in understanding how RTDs are ‘read.’ As the name implies (Resistance Temperature Device), the resistance of an RTD element changes with respect to temperature. By passing a small, known current through the device and measuring the voltage drop, resistance can be determined.

4-wire RTD connection

The most precise way to do this is using a 'Kelvin' connection at the device, which uses four wires to accomplish the measurement task. Two leads, F+ and F- connections on a 4-wire RTD, pass the current to the RTD. Two additional leads, RTD+ and RTD-, connect to F+ and F-, respectively, at the RTD element. This is shown below.

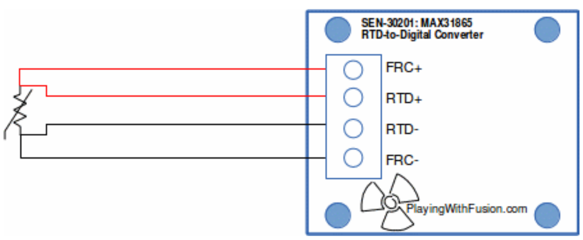


Figure 1 - Example 4-Wire RTD Connection

A high-impedance sink (ADC or multimeter) reads the voltage differential across the RTD+ and RTD- leads and multiplies by the known current flowing to get resistance. In principle, F+ and F- leads are not even required to have the same length or resistance to get an accurate measurement on a 4-wire device, which makes it good for virtually any lead length (assuming cost and wiring challenges are not big factors). Which takes us to the other options.

2-Wire RTD Connection

4-wire RTDs have several benefits, largely surrounding the precision domain. However, 2-wire RTDs have fewer wires to run and connect than 3- or 4-wire RTDs, which make running wires cheaper and simpler in applications where precision can be sacrificed.

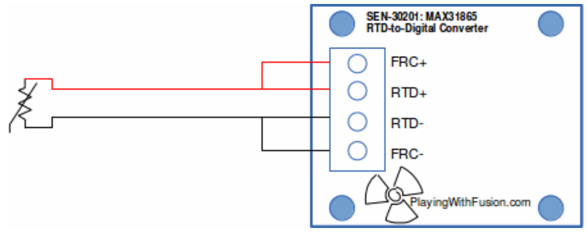


Figure 2 - Example 2-Wire RTD Connection

Some applications naturally see minimal degradation in measurement with 2-wire probes. For instance, when RTD probe is within inches or a few feet of the sensor board. In this case, wire resistance is not high enough to interfere with (offset) the reading of the RTD element. In other cases, precision requirements are low enough that using even long wires is not an issue.

3-Wire RTD Connection

3-wire RTDs exist, as well. True to their name, they have three wires that need to be connected to R3aktor.

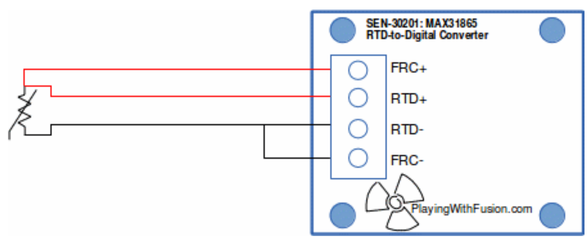


Figure 3 - Example 3-Wire RTD Connection

3-wire devices run on an assumption that the F+ wire is identical in spec (resistance) to the RTD- wire. The voltage differential between F+ and RTD+ is subtracted from the measurement between RTD+ and RTD- to get an accurate reading. Hence, the 3-wire RTD has the precision benefits of the 4-wire device (though requires an assumption about identical lead resistances) with the benefit of one fewer wire to connect.

In summary, 4-wire RTDs typically offer the highest accuracy, regardless of distance between RTD and measurement equipment, whereas 2-wire devices may help to reduce system cost.

Chip-select Configuration

Individual MAX31865 ICs are accessed via a 4-wire SPI interface with individual Chip-Select lines. Table 2 lists the factory default chip select pin assignments when the SEN-30203 is used as an Arduino shield.

RTD Channel	Chip Select Pin (Arduino digital input)
RTD0	6
RTD1	7
RTD2	8
RTD3	9

Table 2 - MAX31865 Chip Select pin assignments

The default chip select pin assignments may be modified by removing the zero-Ohm jumper resistors (yellow box in Figure 4) and then soldering jumper wires between the MAX31865 CS vias (orange box) to the Arduino pin vias (red boxes).

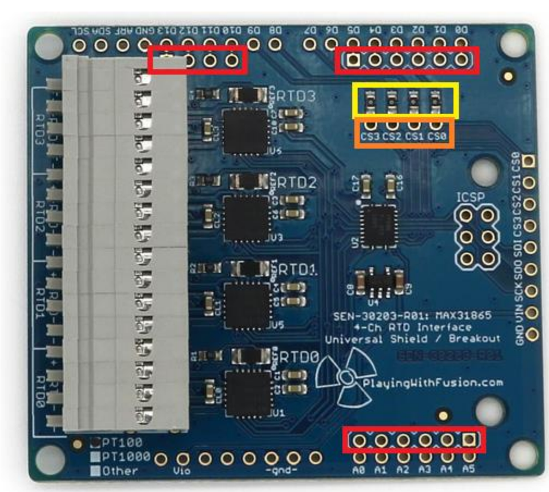


Figure 4 - Chip-select jumper locations

QuickStart

SEN-30203 is designed for rapid setup and integration. We have provided several code examples on our GitHub Page designed to get you up and running quickly. Start by plugging SEN-30203 into your microcontroller board by soldering headers or fly-wires to power and SPI pins between SEN-30203 and your micro. Next, download the desired PwFusion example code, set your RTD type, flash the board, and start measuring! Please note: be sure to set your baud rate to match the Serial.begin() statement in the setup() routine.

Advanced User

The PwFusion library can be used to change additional settings of the MAX31865 based on descriptions in the datasheet. Things like temperature fault thresholds can be set with our example code. It is highly recommended to spend some time with the MAX31865 datasheet once you have gotten the SEN-30203 up and running to ensure optimal performance in your application.

Common Issues

- Not installing all required connections.
  - Vin, GND, SDO/SDI/SCK (MISO, MOSI, SCK) and both CS connections are required for proper function
- Temperature range not wide enough
  - Consider switching to a thermocouple device (see related parts below)
- Contact us for help selecting the right sensing solution for your needs

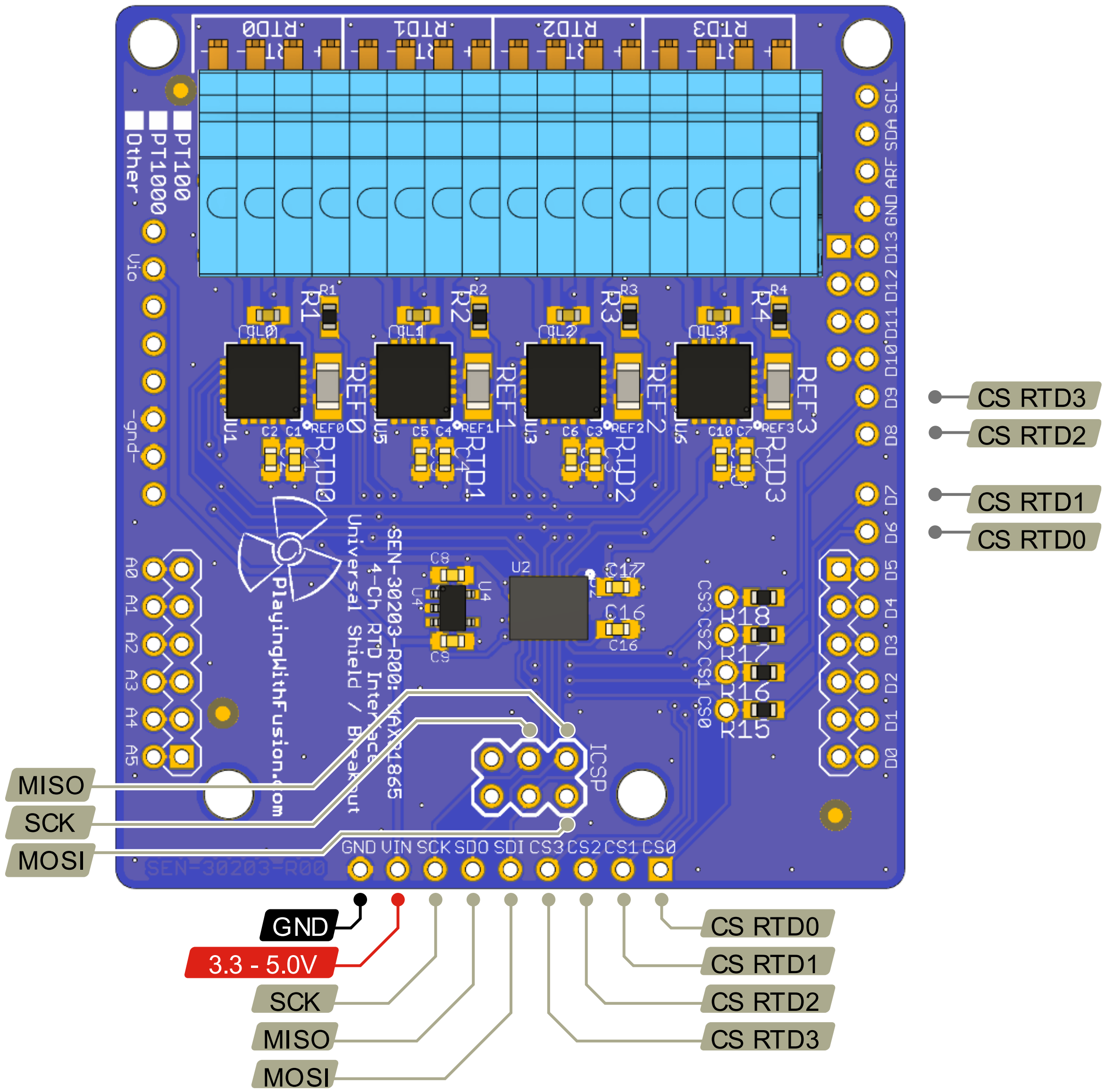
Ordering Options & Related Parts

FDQ-30001-J: R3aktor Core - J-type Thermocouple
FDQ-30001-K: R3aktor Core - K-type Thermocouple
FDQ-30001-T: R3aktor Core - T-type Thermocouple
FDQ-30001-W: R3aktor Core - Universal TC

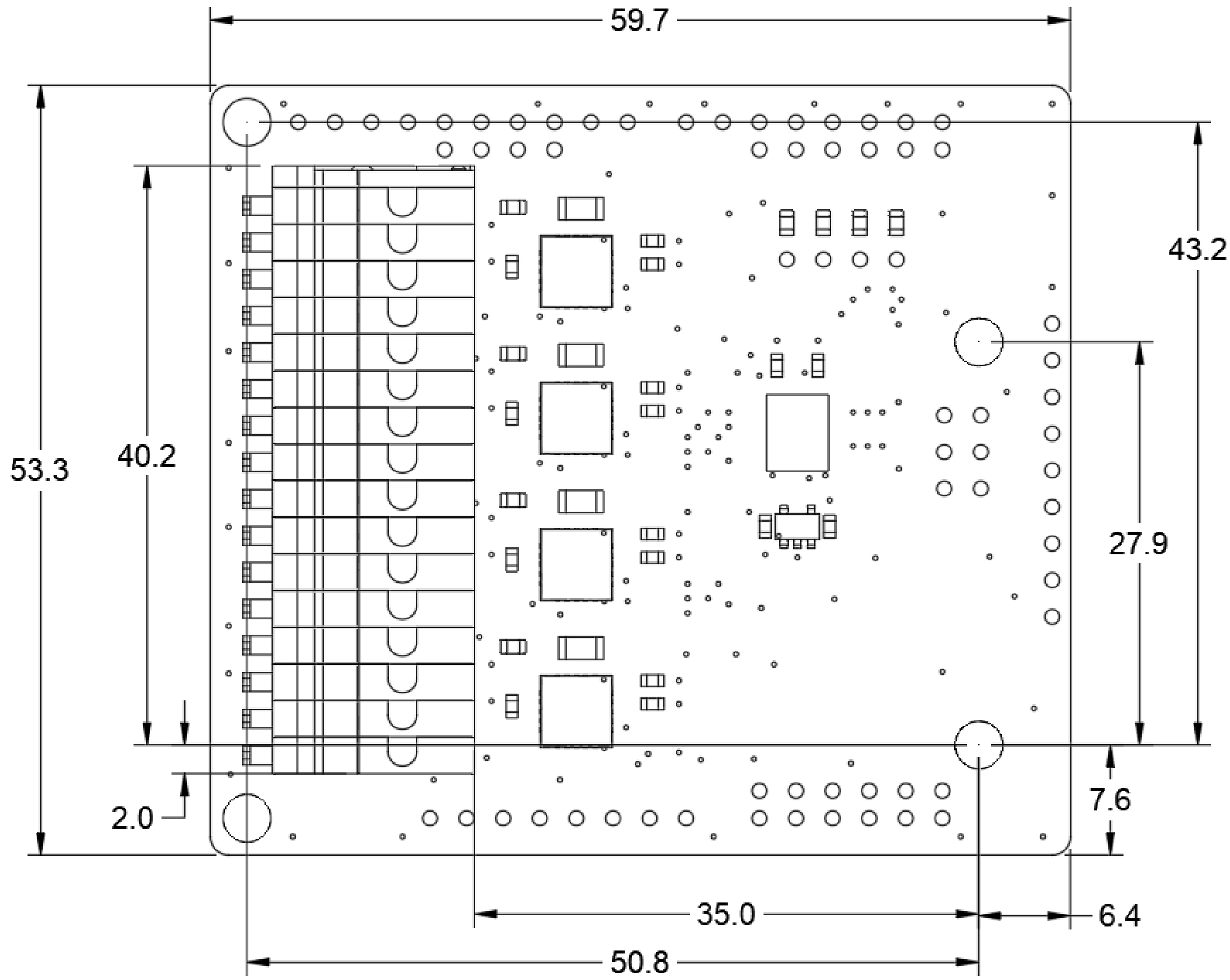
FDQ-30002-PT100: R3aktor Core – PT100 RTD
FDQ-30002-PT1K: R3aktor Core – PT1000 RTD

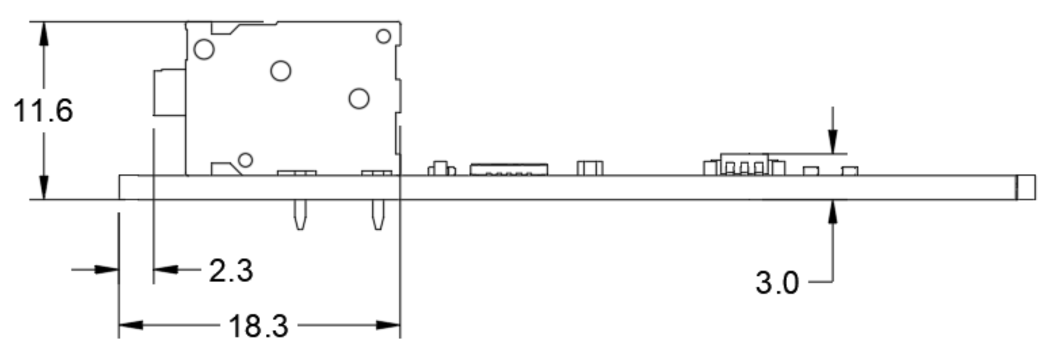
SEN-30201-PT100: Single-channel PT100 breakout
SEN-30201-PT1K: Single-channel PT1000 breakout
SEN-30202-PT100: Dual-channel PT100 breakout
SEN-30202-PT1K: Dual-channel PT1000 breakout
SEN-30203-PT100: Quad PT100 RTD Shield
SEN-30203-PT1K: Quad PT1000 RTD Shield

Pinout


CS RTD3
CS RTD2
CS RTD1
CS RTD0
MISO
SCK
MOSI
GND
3.3 - 5.0V
SCK
MISO
MOSI
CS RTD0
CS RTD1
CS RTD2
CS RTD3

Appendix 1: Mech Drawing (Top/Side Views)





Revision History

Date	Author	Notes
08/07/2025	J. Leonard	First revision published