Overview

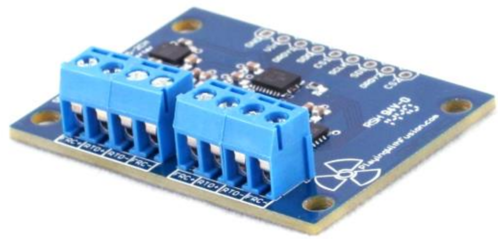
SEN-30202 is a dual-channel, high precision and high accuracy Resistance Temperature Device (RTD) interface board based on the Maxim Integrated MAX31865. It supports all three RTD types, including 2-, 3-, and 4-wire devices, and handles multiple fault conditions. SEN-30202 is stocked in two common calibration values for optimal measurement of PT100, and PT1000 RTDs. PT500 is 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

- Dual-channel MAX31865 RTD-to-Digital Converter
- 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
- ±50V Input protection
- Breakout form factor with straight header interface
- 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 with screw-terminal connectors
- Up to ~45Hz sampling rate

Kit Includes

- SEN-30202-(x) single-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 most accurate, temperature sensing devices used in ovens and chemical processing equipment. The MAX31865 from Maxim Integrated makes RTD interfacing simple by providing the excitation current needed to measure the resistance. SEN-30202 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 type you plan on using.

As such, SEN-30202 is offered in three variants to cover the most popular RTD options. See Table 1 below for configuration options.

Table 1: Orderable Parts

PwF Part No.	RTD Resistance @0°C
SEN-30202-PT100	100Ω
SEN-30202-PT1K	1,000Ω

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-30202 to read the different RTDs, as well as details on when to select 2- vs 3- or 4-wire devices.

SEN-30202 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. A 11-pin straight header with 0.1" (2.54mm) spacing allows a user to build a system on anything from a breadboard to a custom carrier PCB. Multiple SEN-30202 boards can be connected to a single microcontroller by adding extra CS connections while sharing the rest of the SPI signals.

Application & Guide

Generally speaking, 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). "Special Limits of Error" thermocouple wire is needed to compete with this standard RTD type, and even then, the thermocouple will age and lose accuracy when exposed to high temperatures. On the other hand, RTDs can't quite handle the wide temperature range of, say, a K-type thermocouple (-260°C - 1380°C). In short, if your application is limited to -200°C - 800°C and you can find an RTD in a suitable form factor, it is probably best to select the RTD for your application.

There are two main user-defined components that affect accuracy of an RTD measurement system when using SEN-30202. 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, or b) using the Callendar-Van Dusen equation relevant to your specific RTD. Both of these methods can reduce the error to within the accuracy bands of the RTD itself. Per the MAX31865 datasheet, the Callendar-Van

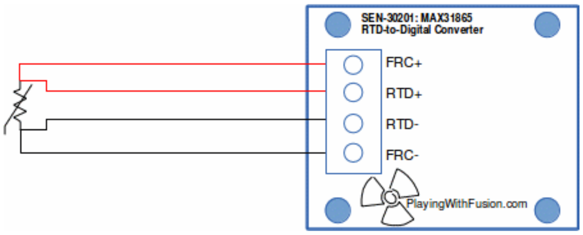
Dusen equation is as follows:

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

For IEC 751-complaint, α = 0.00385 RTDs,
T = temperature (°C)
R(T) = resistance at T
R_0 = resistance at T = 0°C
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 SEN-30202 is capable of measuring them all. 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. The most precise way to do this is using a 'Kelvin' connection at the device, which uses 4 wires to accomplish the measurement task. Two leads, Force+ and Force- connections on a 4-wire RTD, pass the current to the RTD. Two additional leads, RTD+ and RTD-, connect to Force+ and Force-, respectively, at the RTD element. This is shown below.

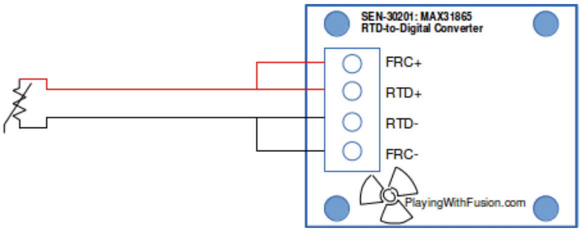
4-wire RTD connection



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, Force+ and Force- 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.

As mentioned, 4-wire RTDs have a number of benefits, largely surrounding the precision domain. However, 2-wire RTDs have fewer wires to run and connect than 3- or 4-wire RTDs (stating the obvious), which makes running wires cheaper and simpler in applications where precision can be sacrificed to some degrees. However, 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.

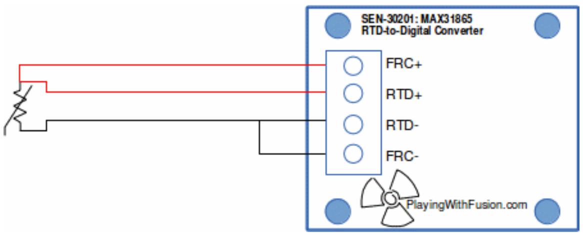
2-Wire RTD Connection



3-wire RTDs exist, as well. True to their name, they have three wires that need to be connected to the SEN-30202. 3-wire devices run on an assumption that the

Force+ wire is identical in spec (resistance) to the RTD- wire. The voltage differential between Force+ 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.

3-Wire RTD Connection



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.

QuickStart

SEN-30202 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-30202 into your microcontroller board by a) using a Qwiic-compatible cable or b) soldering headers or fly-wires to power and SPI pins between SEN-30202 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-30202 up and running to ensure optimal performance in your application.

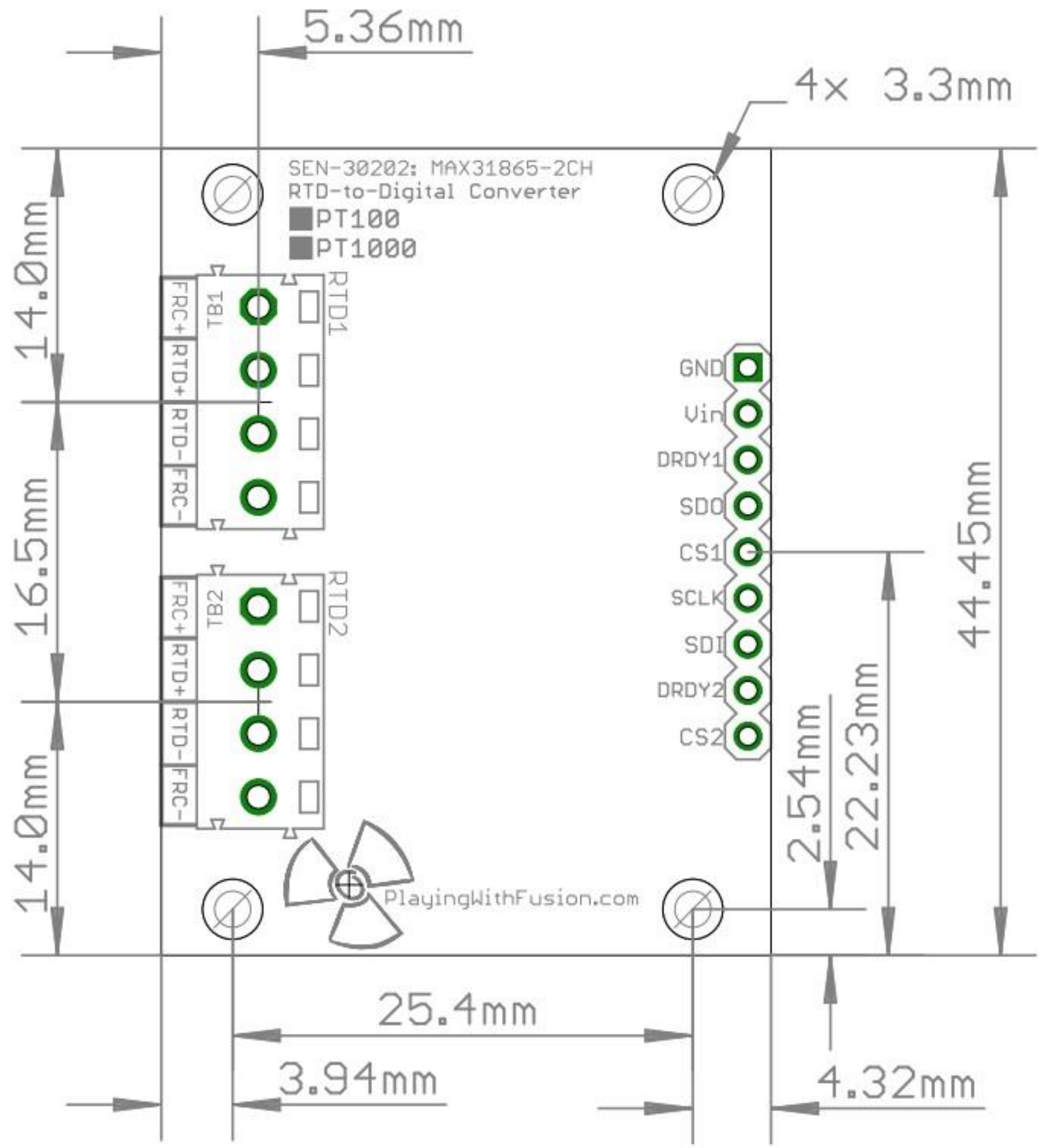
Common Issues

- 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

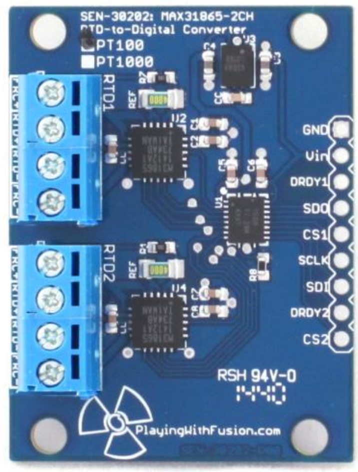
Ordering Options & Related Parts

SEN-30202-PT100: Dual-channel MAX31865 breakout, PT100 calibration, SPI interface
SEN-30202-PT1K: Dual-channel MAX31865 breakout, PT1000 calibration, SPI interface
SEN-30201: Single-channel MAX31865 breakout, SPI interface
SEN-30005: MAX31856 thermocouple device, SPI interface
SEN-30010: MCP9601 Thermocouple device, I2C interface
SEN-30007: Quad MAX31856 thermocouple shield, SPI interface

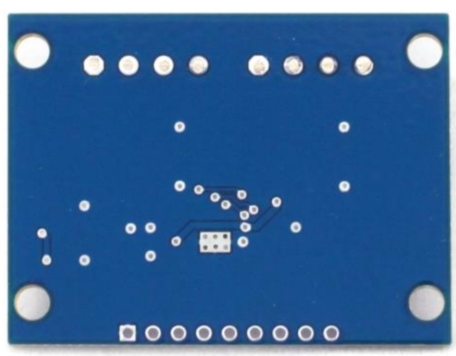
Appendix 1a: Mech Drawing (Top View)



Appendix 3a: SEN-30202, Front View



Appendix 3b: SEN-30202, Back View



Revision History

Date	Author	Notes
03/21/2021	J. Steinlage	Add pictures