FDQ-30002: R3aktor Core RTD
RTD Temperate Sensor Data Acquisition Board

Overview

R3aktor Core RTD integrates a RTD temperature sensor measurement front-end with an Arduino compatible core to provide a complete measurement and logging solution in a compact package.

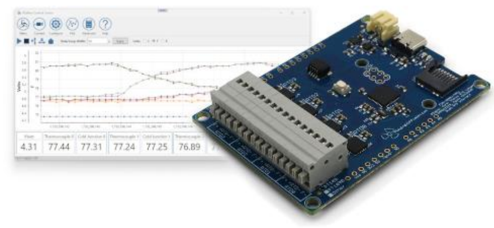
R3aktor ships with full-featured firmware and can record data to the included 4GB SD card or connect to a PC using the free R3aktor Control Center software for live data monitoring, recording, and offline analysis. Its small size, low power consumption, and integrated Li-Po battery charger make it ideal for compact and battery-powered applications.

Features

- Preprogrammed and compatible with R3aktor Control Center PC software.
- 4 RTD inputs (15-bit resolution)
- Li-Po battery charger.
- Micro-SD card slot
- 32-bit SAMD21G18 Processor with 256K Flash and 32k RAM.
- QWIIC compatible I2C connector.
- 1 User controllable LED.
- 1 Analog output (10-bit DAC).
- 13 Analog Inputs including battery voltage monitor (12-bit ADC).
- 29 Digital inputs.
- 15 PWM outputs.
- Regulated 3.3V output.
- Pin compatible with Arduino Uno R3 devices. Electrically compatible with 3.3V compliant shields.

Kit Includes

- FDQ-30002-(x) RTD data acquisition board
- 4 GB SD card



Typical Applications

- High sensor count applications
- Resistance Measurement
- Automotive temperature sensing
- Industrial instrumentation and thermal management
- Commercial and industrial ovens
- Brewing controls
- Hobby applications

Description

R2aktor Core features a 32-bit SAMD micro packaged into an Arduino Uno R3 form factor. High-resolution RTD temperature and resistance measurements are provided via MAX31865 measurement ICs. Calibration for PT100 and PT1000 temperature sensors is built it, or resistance may be reported directly. R3aktor is further extended by a micro-SD card slot and integrated single-cell lithium battery charger.

Each R3aktor ships with full featured firmware and is ready for use out of the box. In cases where custom firmware or additional features are needed, R3aktor may be programmed by the end user through the standard Arduino IDE.

Electrical Limits and Specifications

Name	Description	Min	Nominal	Max	Unit
V_{Supply}	Supply Voltage	3.3	-	5.5	V
$T_{Ambient}$	Ambient Temperature	-40	-	85	°C
I_{Supply}	Supply Current (No additional shields)[1]	13	31	100	mA
I_{Shield}	Regulated 3.3V power available for shields and external loads	-	-	500	mA
V_{Chrg}	Li Battery Charge Voltage	-	-	4.2	V
I_{Chrg}	Li Battery Charge current	-	-	500	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	100	-	-	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)

RTD Sensor and Resistance Measurement

R3aktor Core RTD incorporates the high-performance MAX31865 to provide precise resistance measurements. This IC features a 15-bit ADC (Analog-to-Digital Converter), which ensures high linearity and fine measurement resolution (approximately 0.05 °C for temperature readings).

While optimized for platinum resistance temperature detectors (RTDs), R3aktor can measure alternate resistive sensors including:

- **PT100 and PT1000 RTD Sensors:** Ideal for high-accuracy temperature sensing.
- **Thermistors**: PTC or NTC resistive temperature sensors
- **Load Cells & Strain Gauges**: measuring force and pressure.
- **Photoresistors**: light sensing applications.
- **Gas Concentration Sensors**: environmental monitoring.

Resistance is determined by applying a small current in series though the sensor to be measured and a reference resistor (0.10% tolerance). It is this reference resistor that ultimately determines the sensor measurement range. A 400 Ohm resistance is used for PT100 R3aktor Core variants and a 4K Ohm resistor is used for PT1K variants.

Wiring and Connections

The R3aktor Core offers flexible wiring options to suit different sensor types and applications. It supports 2, 3, and 4-wire connections, which are essential for mitigating the effects of lead resistance in long wire runs. For added convenience, the board includes solderable jumpers that allow for 2 and 3-wire connections to be made directly on the PCB, eliminating the need for external jumper wires (see Figure 1).

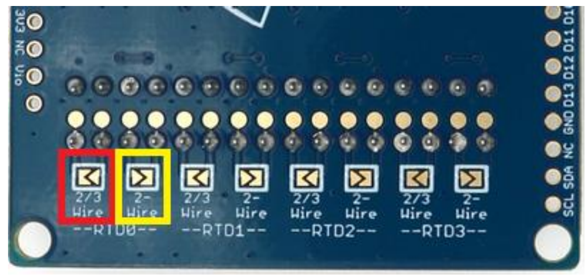


Figure 1 – Solder jumper locations for 2 and 3 wire sensor connections

No wire or solder jumpers are required for four-wire (Kelvin) sensor connections. For three-wire connections, connect the RTD- and F- pins by either soldering across the respective '2/3 Wire' jumper on the bottom of the board (red box, Figure 1) or connect a short length of wire (red wire, Figure 2). For two wire connections, solder across both jumpers (yellow and red, Figure 1) or uses two short lengths to connect the RTD+ and F+ pins and the RTD- and F- pins on the push in connector (yellow and red wires, Figure 2).

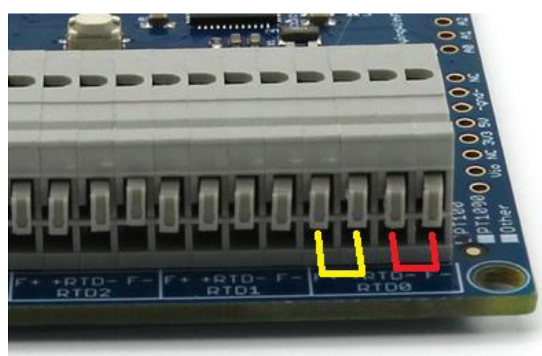


Figure 2 - Jumper wire locations for 2 and 3 wire sensor connections

Fault detection

RTD and resistive sensor fault detection is provided by the MAX31865. R3aktor Core can detect the following faults:

- Sensor open circuit
- Sensor leads (RTD+ and RTD-) shorted together
- Sensor leads (RTD+ or RTD-) shorted to voltage outside common-mode measurement range

Temperature Measurement 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 = 3.90830×10^{-3}
b = -5.775×10^{-7}
c = -4.18301×10^{-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.

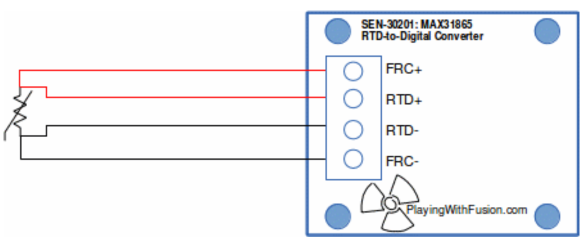


Figure 3 - Example 4-Wire RTD Connection

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.

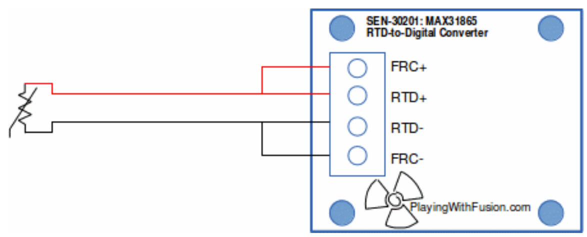


Figure 4 - Example 2-Wire RTD Connection

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.

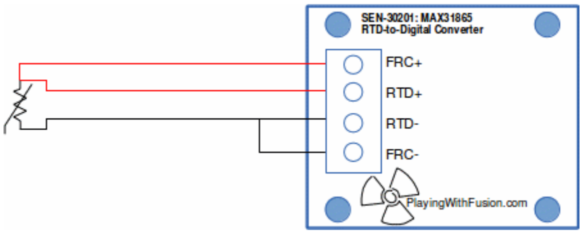


Figure 5 - Example 3-Wire RTD Connection

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.

Measuring Load Cells

While the MAX31865 IC is designed for a Kelvin connection (4-wire) to measure the absolute resistance of a single element, it can still be used with a load cell, which is typically configured as a Wheatstone bridge. To measure the resistance of a load cell with R3aktor Core, you must measure the resistance of one leg of the bridge at a time, rather than the differential voltage output of the entire bridge.

The PT1K R3aktor Core variant should generally be used as the most common resistance range for load cells and strain gauges is 350 Ohms. The Kelvin connection provided by the R3aktor Core's 4-wire configuration allows for precise measurement of this resistance without the errors introduced by lead wires.

Battery Powered Operation

The R3aktor Core may be powered by applying 3.3V – 5.5V to either:

- The USB-C VBUS pin
- The positive terminal of the battery JST connector
- The VBUS pin on the right side of the R3aktor Core PCB

A single cell, 3.7V lithium battery may be connected to the two-pin JST connector at the bottom of the PCB, next to the USB-C connector. R3aktor powers on immediately upon battery connection.

Users must ensure connected batteries include appropriate battery management/protection as no under-voltage limit is enforced by the R3aktor.

Battery charging occurs when 5V is applied to VBUS (R3aktor pin or USB-C connector) via the integrated MCP73831 charge controller. The controller is pre-configured to charge the battery up to 4.2 V at 500mA. The charge LED (located to the right of the JST battery connector) will light when the battery is charging. The LED will turn off when the battery is fully charged.

The charge LED state is undefined when no battery is connected. This LED may flicker on some boards without a battery

Integrated SD Card

R3aktor includes a micro-SD card slot and is compatible with SD cards which support SPI mode and 3.3V operation. Most SD cards support these requirements. If R3aktor is unable to read a particular SD card, attempt to use a card from another manufacturer

SD cards with more than 2 TB of storage in particular do not support SPI mode.

Custom Firmware using Arduino IDE

R3aktor comes pre-loaded with firmware that allows it to connect to the Control Center PC software and preform simple logging and data acquisition.

Alternate firmware may be written using the Arduino IDE. See the Playing with Fusion product page for *instructions* to add the required board support package and MAX31865 driver library

The factory default firmware may be reloaded at any time using Control Center.

Individual MAX31865 ICs are accessed via a 4-wire SPI interface with individual Chip-Select lines.

RTD Channel	Chip Select Pin (Arduino digital input)
RTD0	2
RTD1	3
RTD2	4
RTD3	5

Table 2 - MAX31865 Chip Select pin assignments

Ordering Options & Related Parts

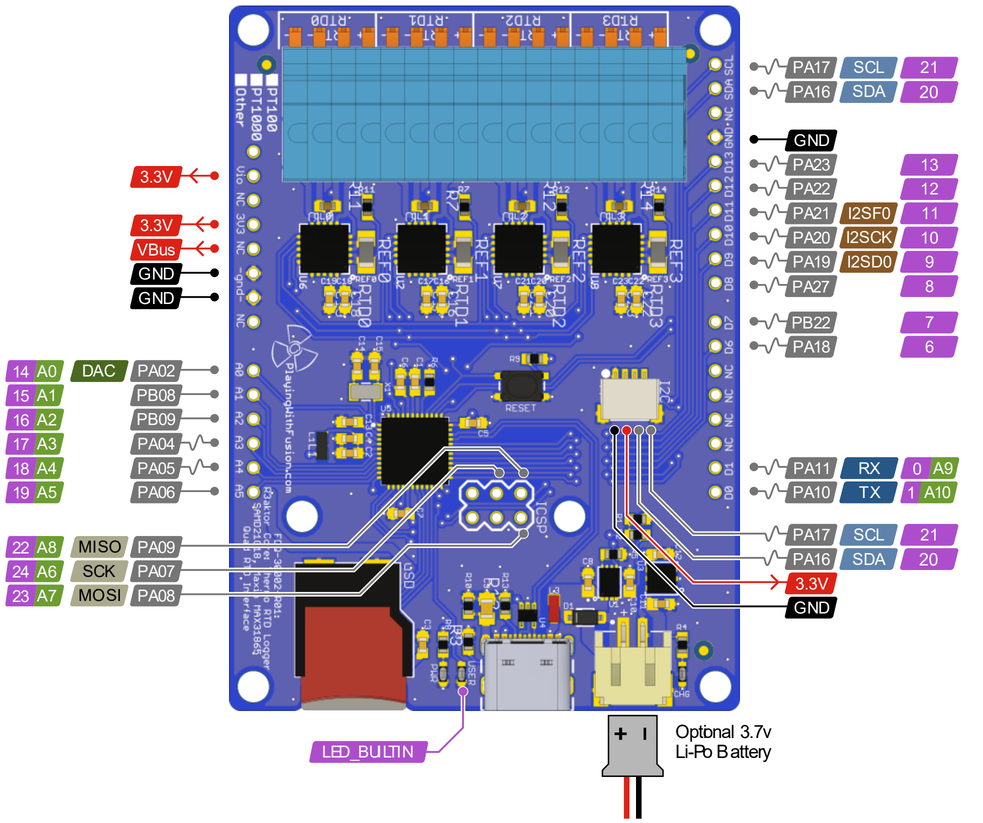
FDQ-30001-J: R3aktor Core - J-type Thermocouple
FDQ-30001-K: R3aktor Core - K-type Thermocouple
FDQ-30001-T: R3aktor Core - T-type Thermocouple
FDQ-30001-W: R3aktor Core - Universal TC

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

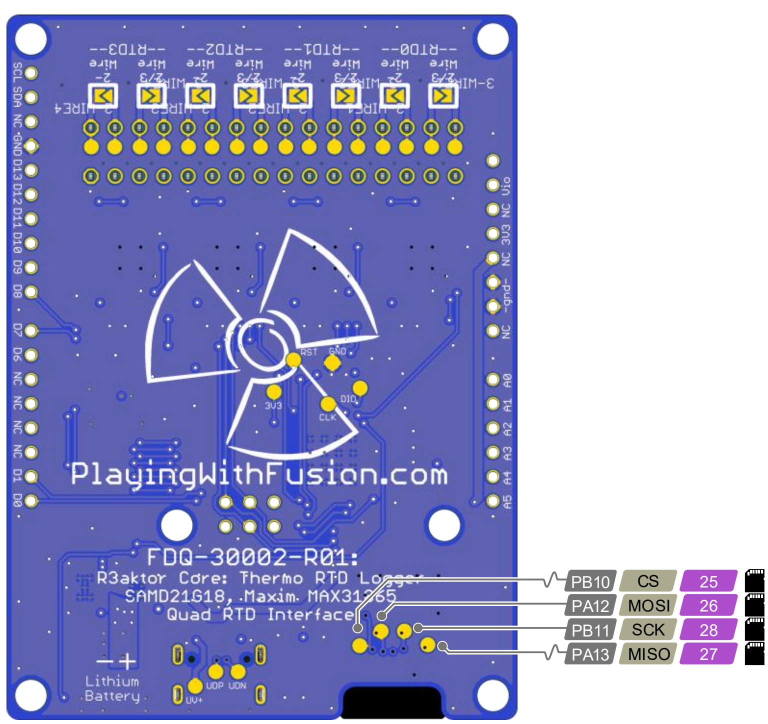
SEN-30012-J: Quad J-type Thermocouple Shield
SEN-30012-K: Quad K-type Thermocouple Shield
SEN-30012-T: Quad T-type Thermocouple Shield
SEN-30012-ST: Quad Screw-terminal TC Shield
SEN-30012-W: Quad Universal Thermocouple Shield

SEN-30203-PT100: Quad PT100 RTD Shield
SEN-30203-PT1K: Quad PT1000 RTD Shield

Pinout

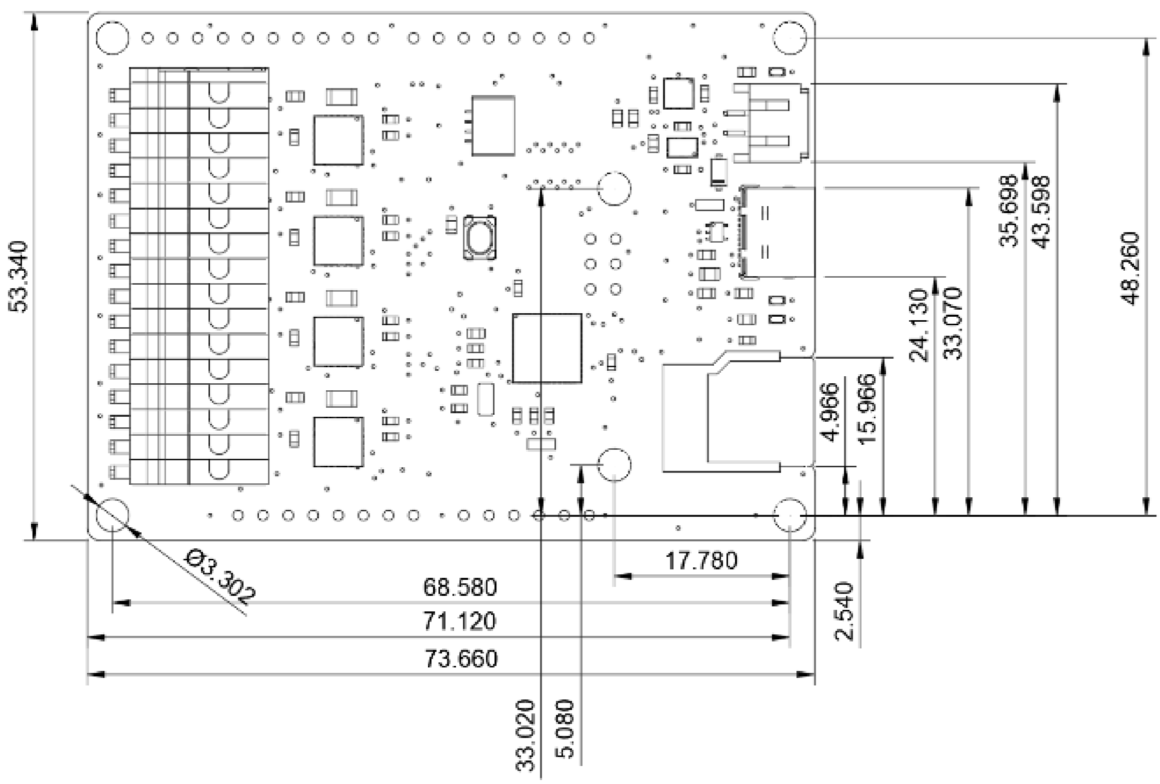


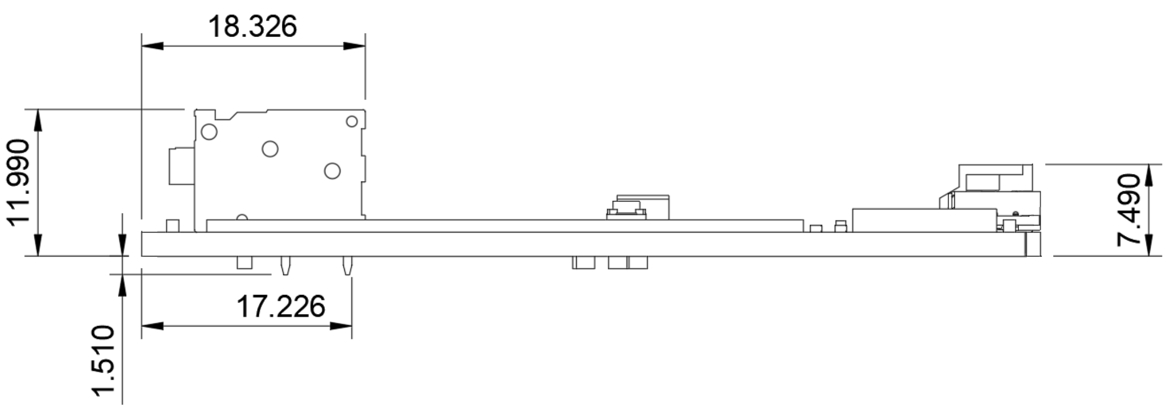
3.3V
3.3V
VBus
GND
GND
14 A0
DAC
PA02
15 A1
PB08
16 A2
PB09
17 A3
PA04
18 A4
PA05
19 A5
PA06
22 A8
MISO
PA09
24 A6
SCK
PA07
23 A7
MOSI
PA08
PA17
SCL
21
PA16
SDA
20
GND
PA23
13
PA22
12
PA21
I2SF0
11
PA20
I2SCK
10
PA19
I2SD0
9
PA27
8
PB22
7
PA18
6
PA11
RX
0 A9
PA10
TX
1 A10
PA17
SCL
21
PA16
SDA
20
3.3V
GND
LED_BULTIN
Optional 3.7v
Li-Po Battery



PlayingWithFusion.com
FDQ-30002-R01:
R3aktor Core: Thermo RTD Logger
SAMD21G18, Maxim MAX31865
Quad RTD Interface
Lithium
Battery
PB10
CS
25
PA12
MOSI
26
PB11
SCK
28
PA13
MISO
27

Appendix 1: Mech Drawing (Top/Side Views)





Revision History

Date	Author	Notes
08/06/2025	J. Leonard	First revision published