Summer Internship

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Introduction

In the following I will document the process of the Analog Devices Summer Internship 2023. The project aims to lead us through all the departments of the company: Hardware, Hardware Description Language(HDL), Embedded Linux and Software Applications in order to gain some knowledge regarding them all. It revolves around an accelerometer and the main purpose is to aquire data from the sensor and manage to process it using software. The PCB containing the accelerometer connects to an FPGA that will contain a Linux image, allowing us to read the data through SPI and use it to create a user application.

Hardware

1. Power supply

The entire circuit will be supplied using a USB type C, but since this works on 5V

and we need 3.3V, some step-down is required. For this purpose we have chosen a voltage regulator, more specifically the ADP1715.

TYPICAL APPLICATION CIRCUITS

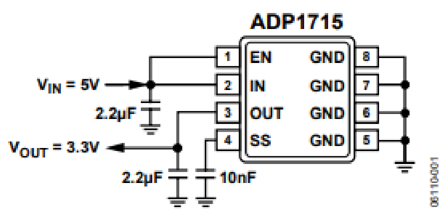


Figure 1. ADP1715 with Fixed Output Voltage, 3.3 V

2. Accelerometer

Since the main component is an accelerometer, we will start by choosing one. This is a MEMS (micro electro mechanical system) that can detect the change in acceleration on the X, Y, and Z axis and can be used to measure the inclination of an object, as well as shock or vibration.

It gives this information as a changing voltage in a certain range that we can find out more about in the datasheet. We were given the ADXL327 to work with.

SENSITIVITY (RATIOMETRIC)[2]	Each axis				
Sensitivity at X_{OUT}, Y_{OUT}, Z_{OUT}	V_S = 3 V	378	420	462	mV/*g*
Sensitivity Change Due to Temperature[3]	V_S = 3 V		±0.01		%/°C
ZERO *g* BIAS LEVEL (RATIOMETRIC)					
0 *g* Voltage at X_{OUT}, Y_{OUT}	V_S = 3 V	1.3	1.5	1.7	V
0 *g* Voltage at Z_{OUT}	V_S = 3 V	1.2	1.5	1.8	V

Figure II: ADXL327 voltage output

We can see in its datasheet that it will output 1.5V when not stimulated and ± 420mV/g otherwise, depending on the orientation of the inclination. Below we can observe how the 3 axis are represented.

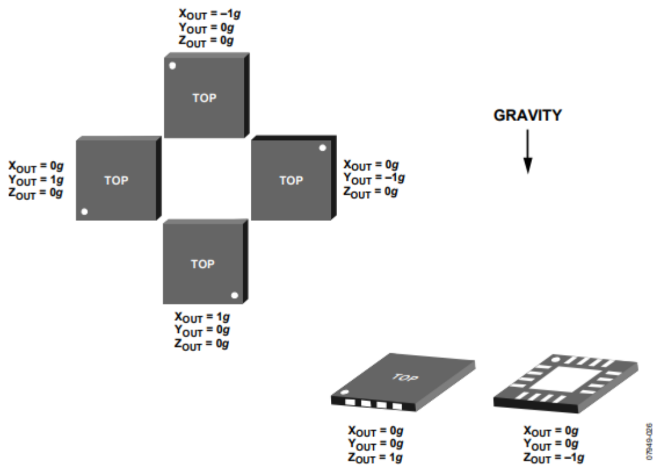


Figure 24. Output Response vs. Orientation to Gravity

3. Differential Amplifiers

We would like to make the 1.5V offset disappear and separate the measurements for the positive and negative values of each axis. This can easily be achieved with the help of differential amplifiers. These circuits are able to amplify the difference between 2 voltages, so they are perfect for our needs.

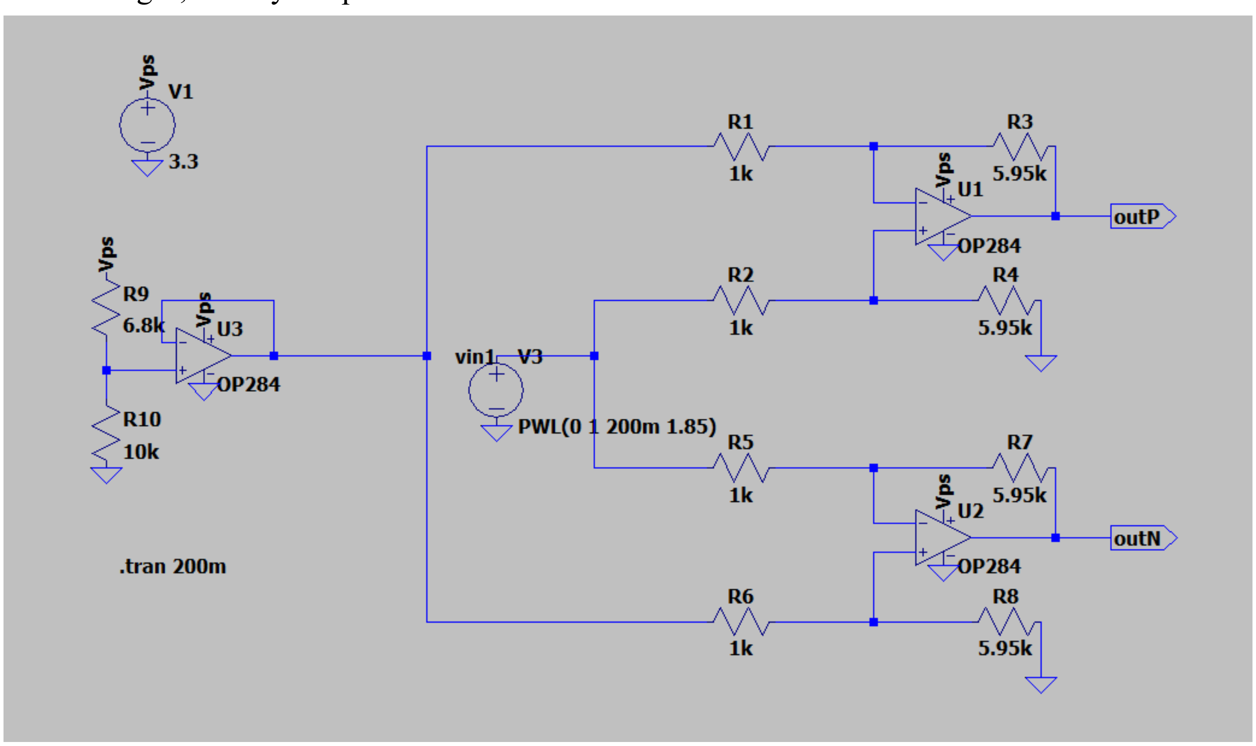
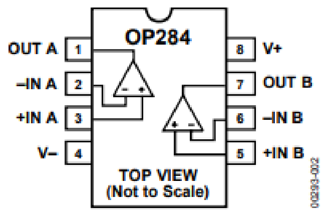
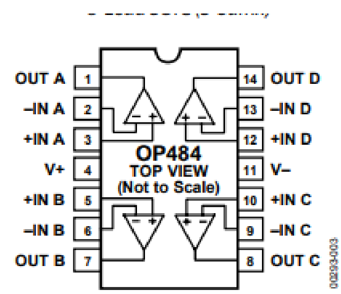


Figure III: LTSpice differential amplifier schematic

However, this schematic suffered slight modifications before being placed on the PCB. Instead of the 2 resistances and the voltage follower on the left side we ended up using a simple potentiometer to get the precise offset of each axis and also the resistor values became 1Meg and 5.49Meg in order to set the gain better. As a summary, these amplifiers will receive 3 signals of 1.5V ± 420mV and will output 6 signals of 0-2.5V.

Since we need 6 OpAmps, we will use one OP484 and one OP284. We have chosen these particular OpAmps as they are suitable for an ADC input buffer.





4. Analog to Digital Converter

In order to process this signal digitaly we shall use an ADC, more specifically the AD5592R. This is an 8-Channel, 12-Bit, Configurable ADC/DAC with On-Chip Reference and SPI Interface.

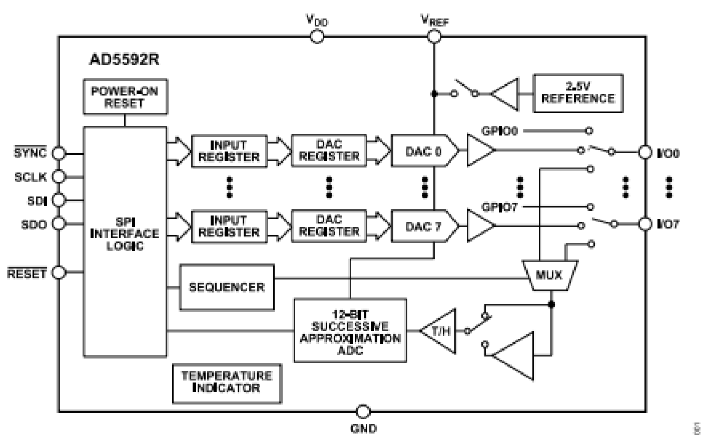
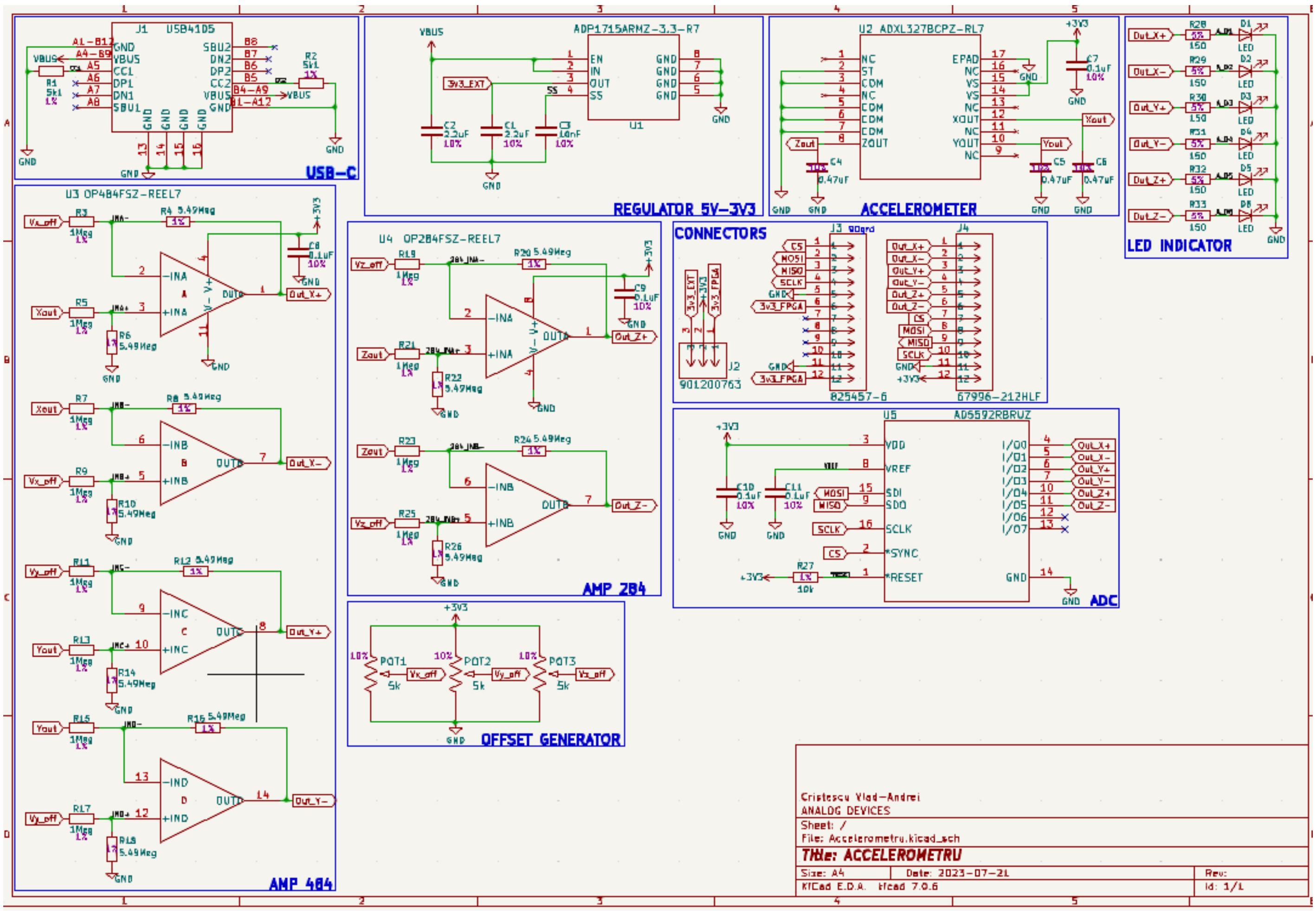


Figure 1. AD5592R Functional Block Diagram

Since this chip has an internal 2.5V reference, we have adjusted the gain of the differential amplifiers to suit this perfectly. In essence, the ADC will receive the 6 outputs of the amplified signal of the accelerometer and transform a 0-2.5V value to a 0-4095 number of bits ($4095 = 2^{12} - 1$) for each axis (X+, X-, Y+, Y-, Z+, Z-).

5. Final Schematic



Here is how the schematic looks like in the end with all the added necessary components. Every supply received a bypass capacitor, the ADXL requires capacitors on all the outputs and we also added an LED for each axis on the PCB as a visual representation that the board works like we expect it to. Also we added 3 connectors: one to allow us to choose wheter we want to supply the PCB through the USB or the FPGA by simply adding a jumper to short the pins together; one PMOD connector that inserts in the FPGA to transmit or receive the SPI signals; and lastly a sniffing connector to make the debugging easier and to connect to Scopy and visualize the signals.

6. PCB Layout

The layout and routing was done in KiCad and the footprints were chosen for 0603 packages for all the passive components. The PCB has been designed with 2 layers.

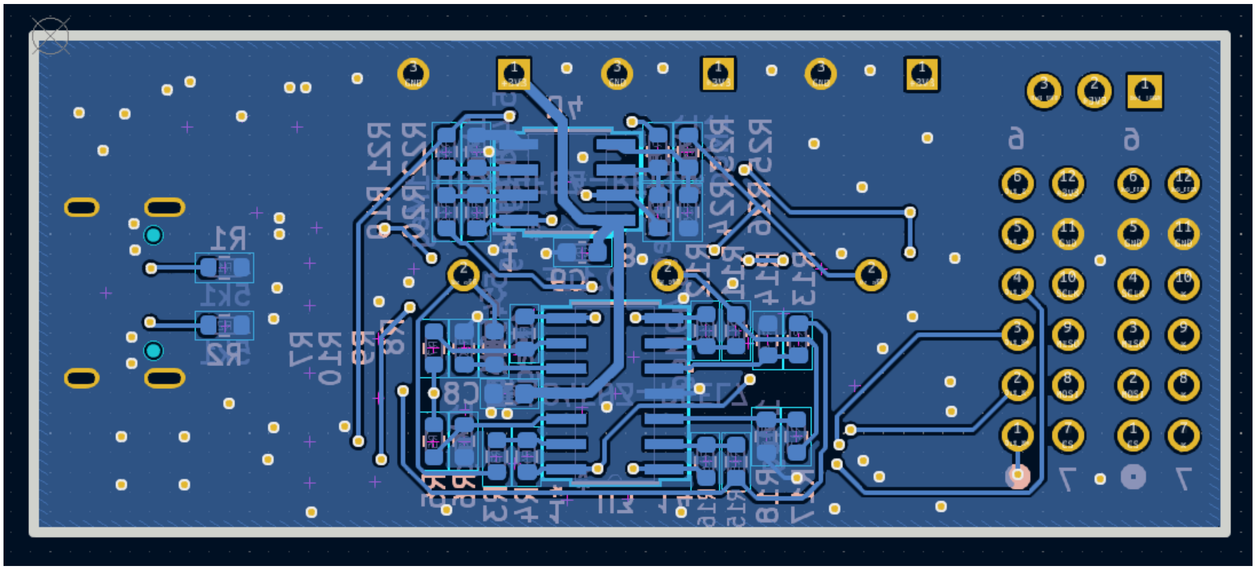


Figure III: Back layer layout

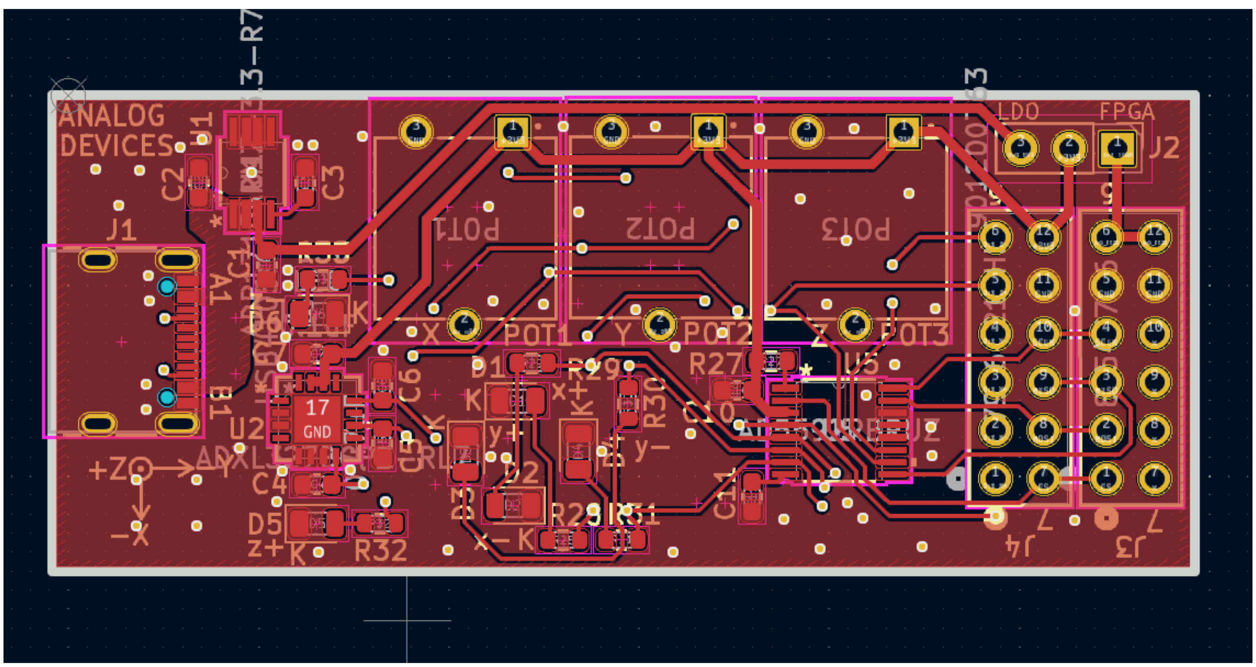


Figure IV: Front layer layout

7. 3D Model

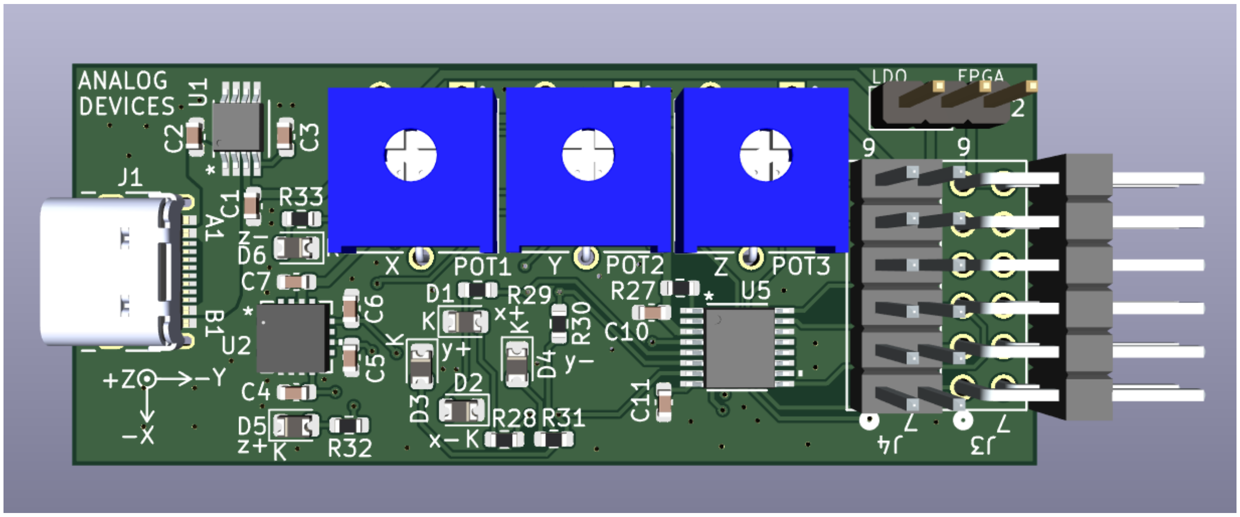


Figure V: 3D Top view

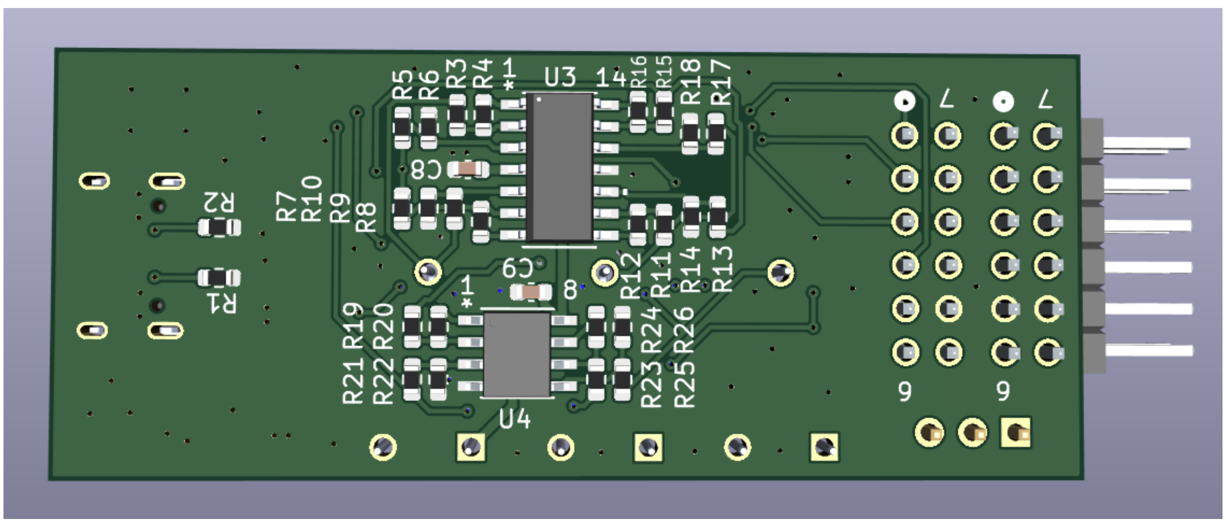


Figure VI: 3D Bottom view

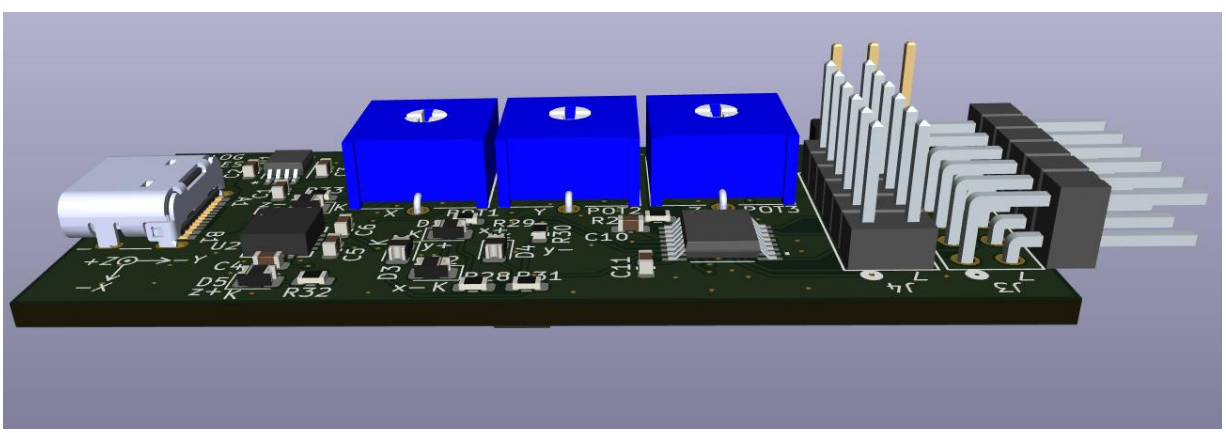


Figure IIIII: 3D Side view