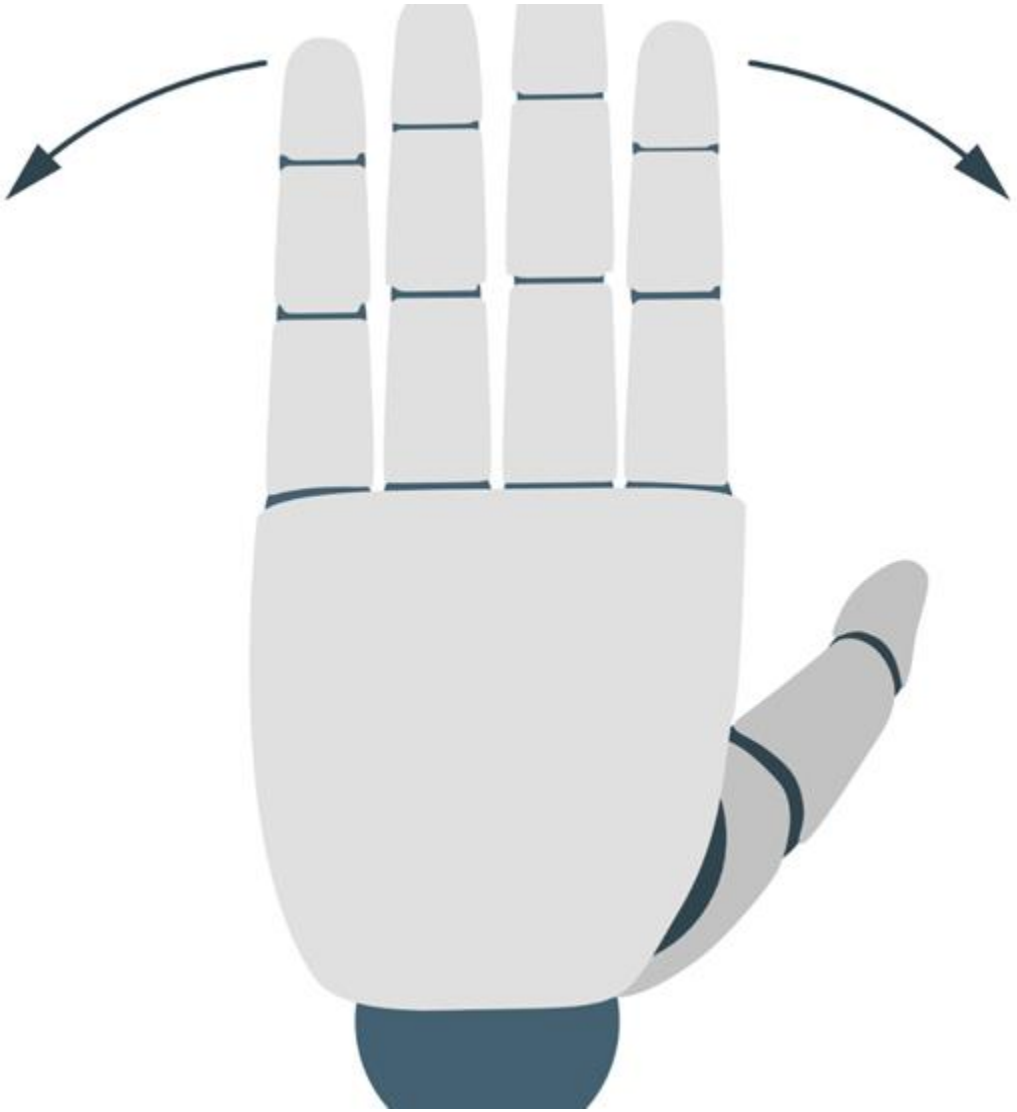
ETH zürich

Workshop Unit 7
Sensor Integration

TA Habib Ben Abda

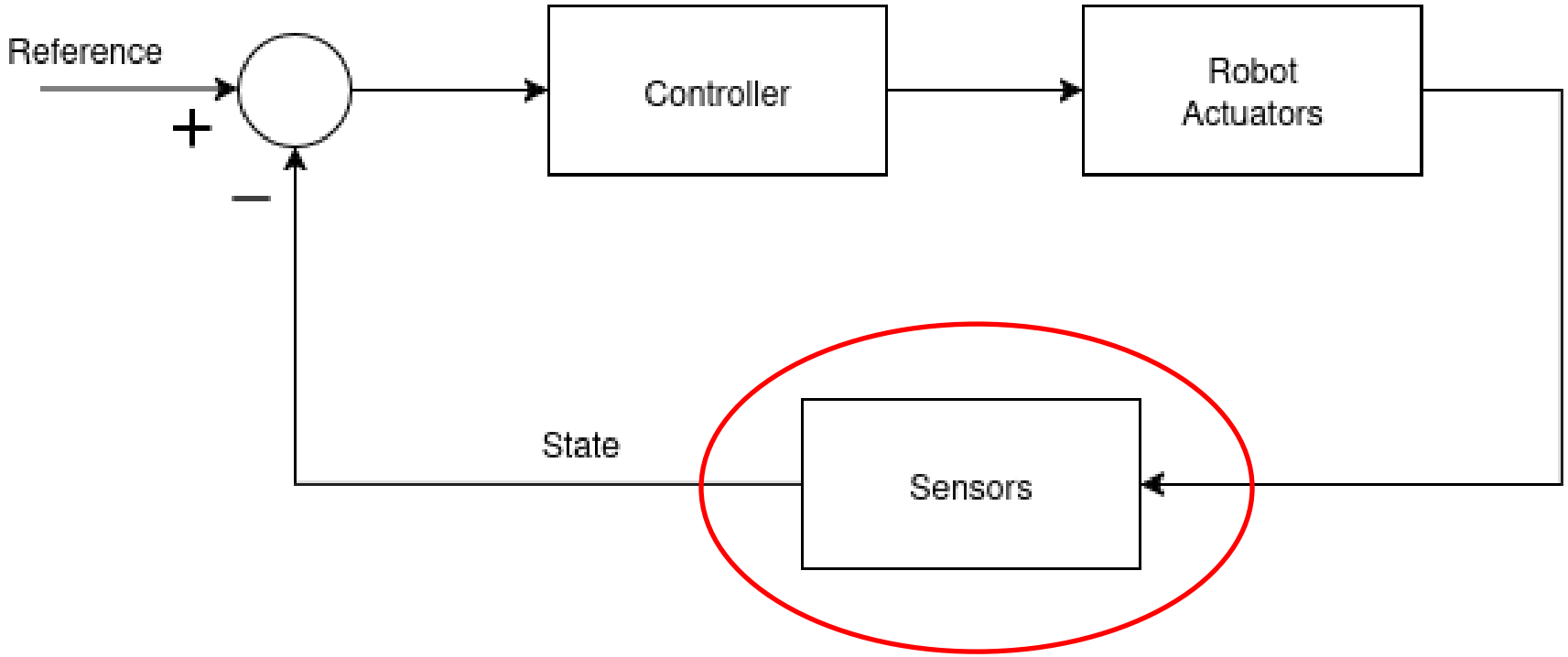
08.10.2025



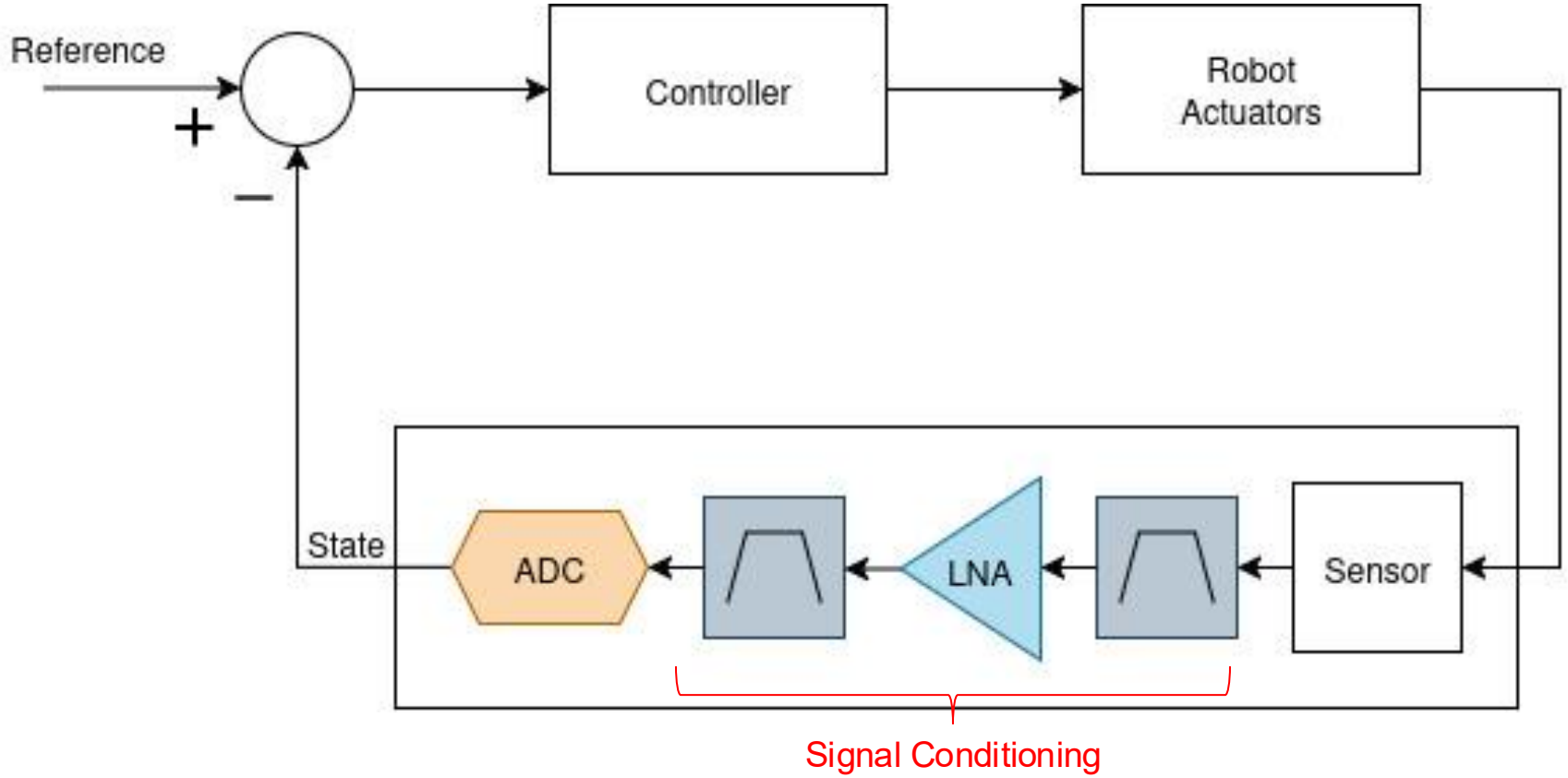
SoftRobotics Laboratory

Closed Loop Controller

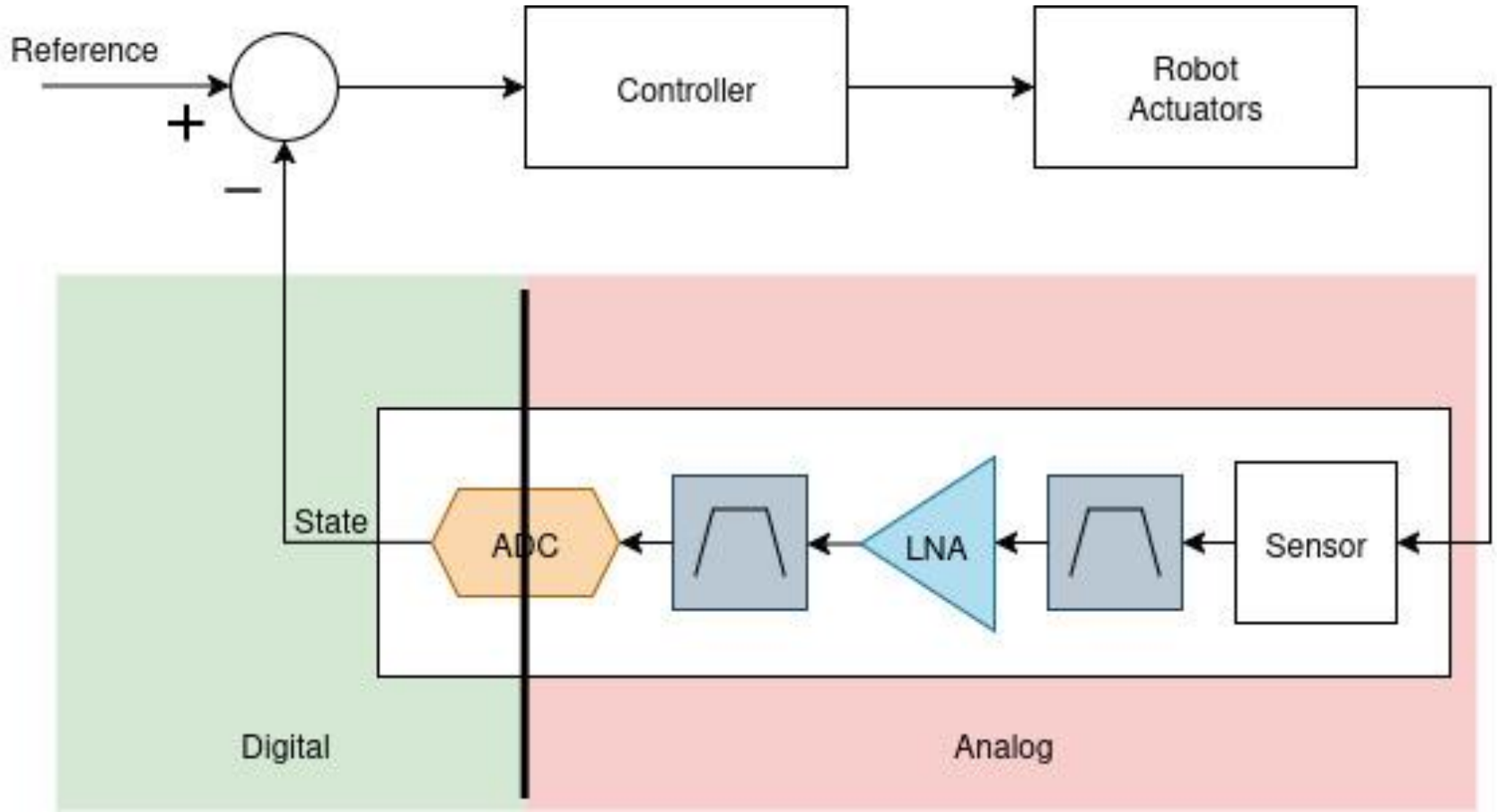
Robot = Sensors + Actuators



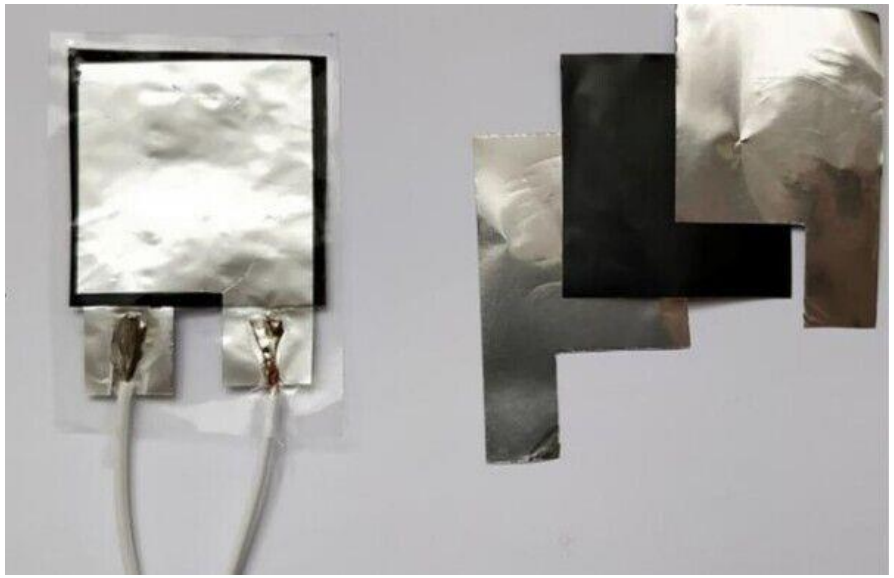
Closed Loop Controller

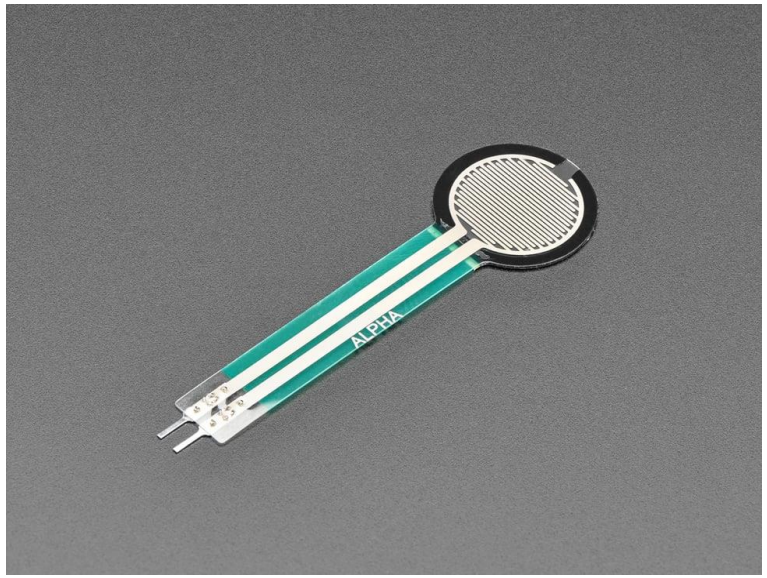


Closed Loop Controller



DIY sensors VS. Off-the-shelf sensor





Sensor VS. Sensor module

Example:

BOSCH

BMP390

Digital pressure sensor

Sensor VS. Sensor module

Example:

6.3. Connection diagram I²C

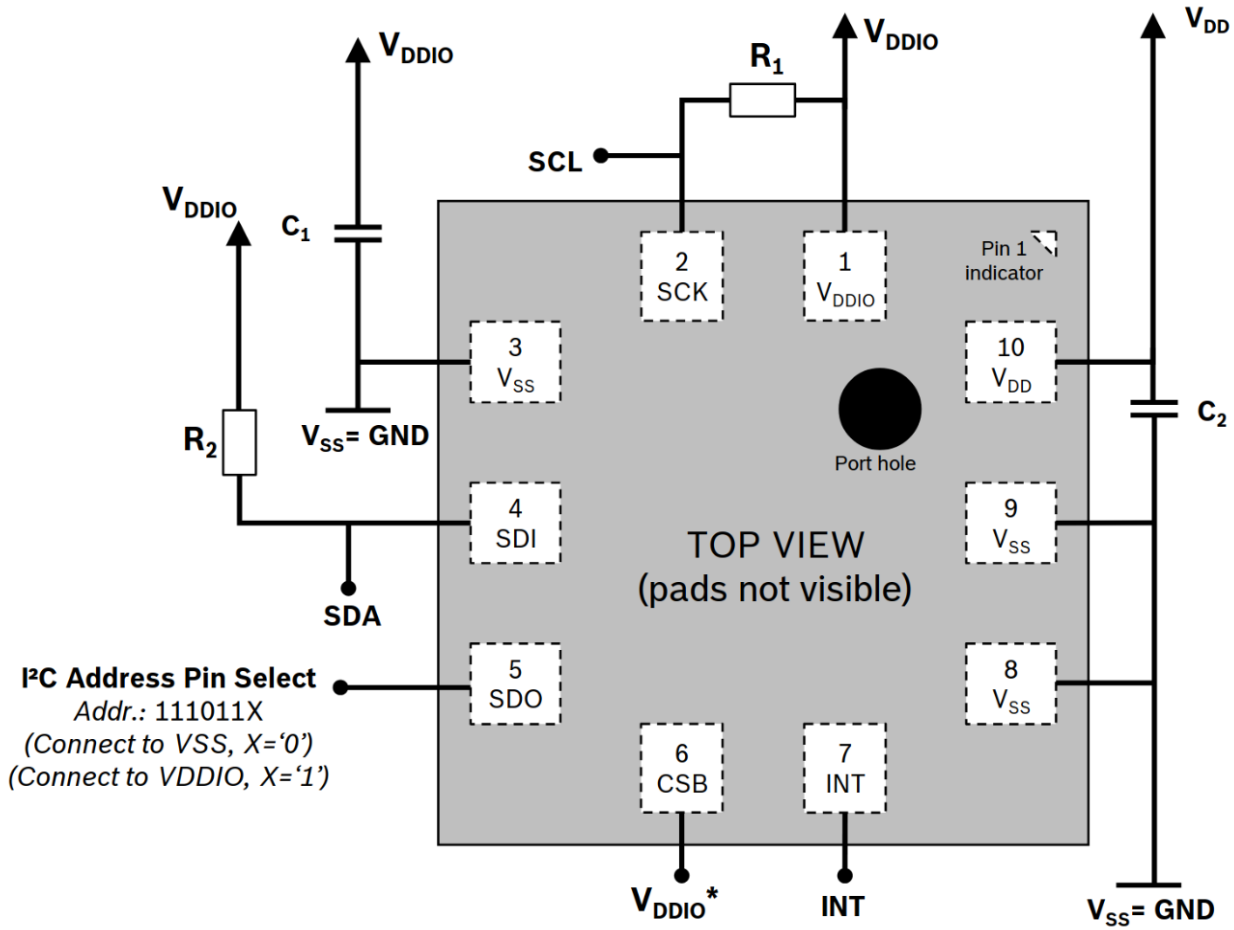


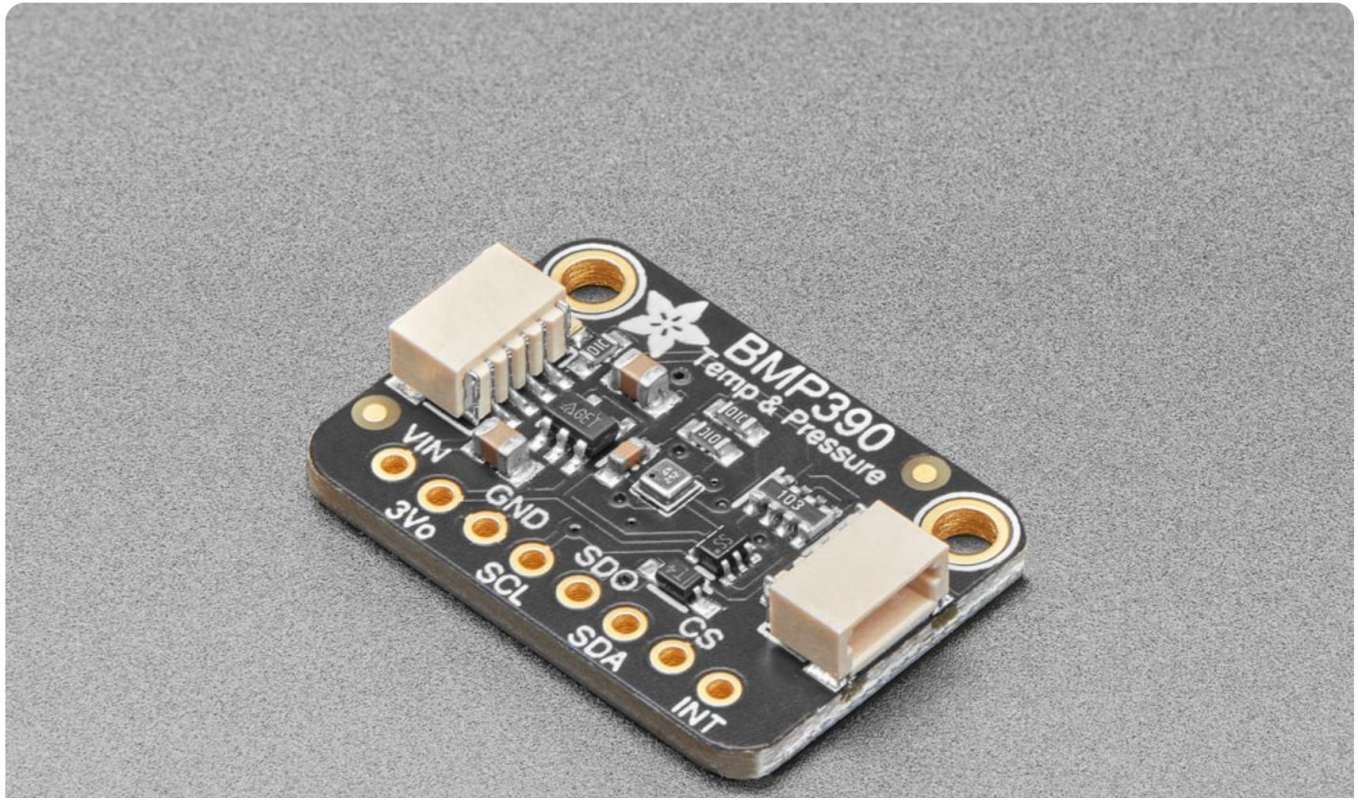
Figure 25: I²C connection diagram (Pin1 marking indicated)

Sensor VS. Sensor module

Example:

adafruit Products Gift Ideas What's New

Sensors / Barometric Pressure / Adafruit BMP390 - Precision Barometric Pressure and Altimeter



Adafruit BMP390 - Precision Barometric Pressure and Altimeter - STEMMA QT / Qwiic

Product ID: 4816

$10.95

In stock

1 Add to Cart

☐ **Also include 1 x STEMMA QT / Qwiic JST SH 4-pin to Premium Male Headers Cable ($0.95)**

☐ **Also include 1 x STEMMA QT / Qwiic JST SH 4-pin Cable - 100mm Long ($0.95)**

Qty	Discount
1-9	$10.95
10-99	$9.86
100+	$8.76

Add to Wishlist

Analog to Digital Converters (ADC)

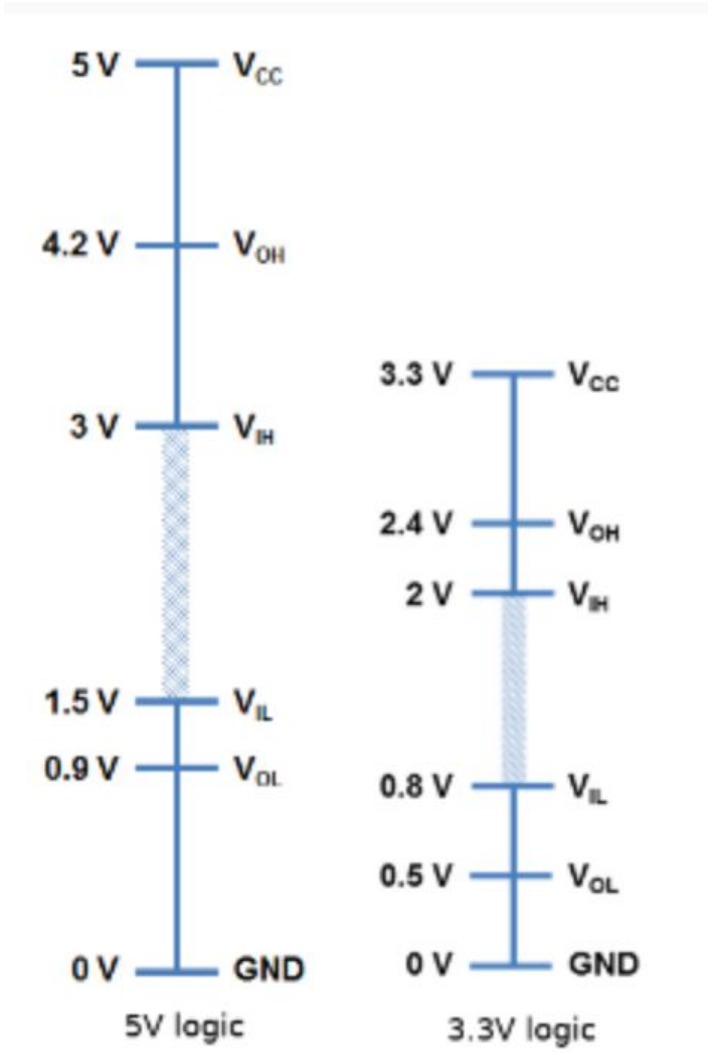
1. Resolution

    - Number of bits (12-bit → 4096 levels)
    - Effective number of bits (ENOB)
    - Inversely proportional to sampling rate

2. Sampling rate

    - Nyquist: $f_s = 2 \times f_N$

Signal Range

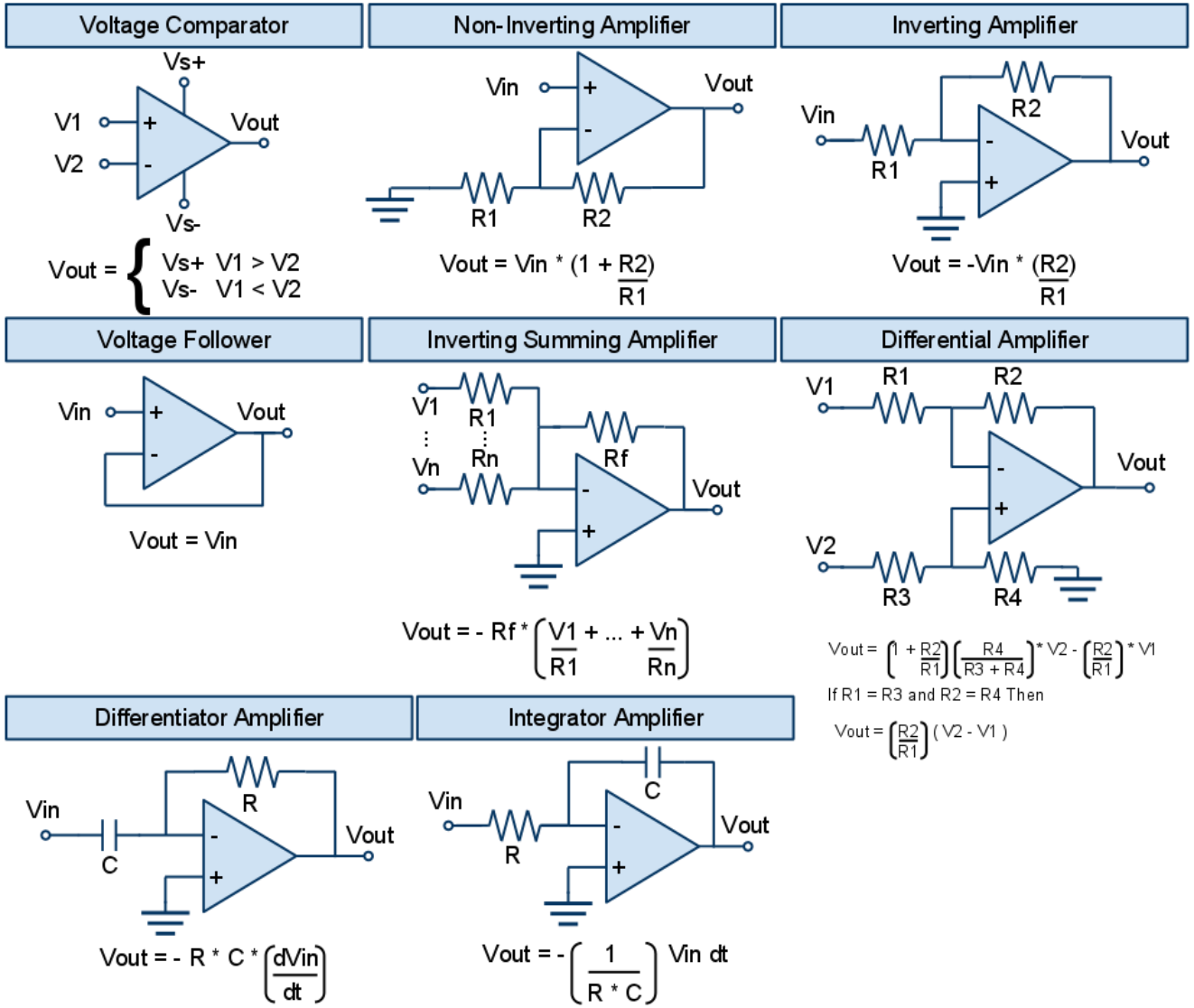


Signals are usually encoded as voltage:

- All the voltages are referenced to a common potential (usually denoted as ground, GND)
- Commonly used 5V, 3.3V, 1.8V systems

https://learn.sparkfun.com/tutorials/logic-levels/arduino-logic-levels

Basic Operational Amplifier Configurations



Reddit, r/EngineeringStudents

FSR

FSR® 400 Series Data Sheet

Force Sensing Resistors®

Features and Benefits

- Actuation force as low as 0.2N and sensitivity range to 20N
- Cost effective
- Ultra thin
- Robust; up to 10M actuations
- Simple and easy to integrate

Description

Interlink Electronics FSR® 400 Series is part of the single zone Force Sensing Resistor® family. Force Sensing Resistors, or FSR's, are robust polymer thick film (PTF) devices that exhibit a decrease in resistance with increase in force applied to the surface of the sensor. This force sensitivity is optimized for use in human machine interface devices including automotive electronics, medical systems, industrial controls and robotics.

The FSR 400 Series sensors come in seven different models with four different connecting options. A battery operated demo is available. Call us for more information at +1 805-484-8855.

FSR® 400 Short
5mm Circle x 20mm

FSR® 400
5mm Circle x 38mm

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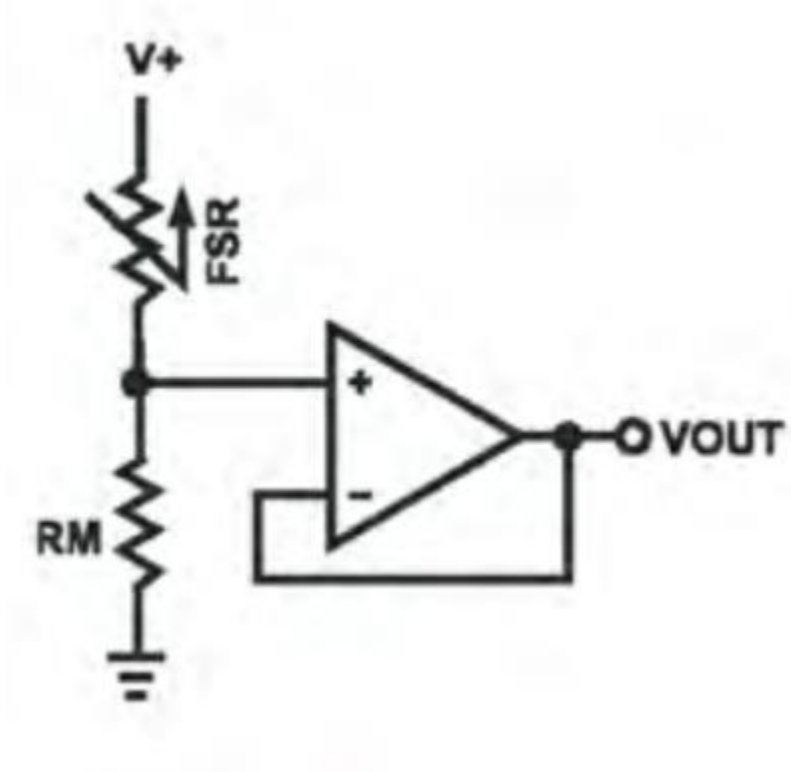
https://cdn2.hubspot.net/hubfs/3899023/Interlinkelectronics%20November2017/Docs/Datasheet_FSR.pdf

Voltage divider



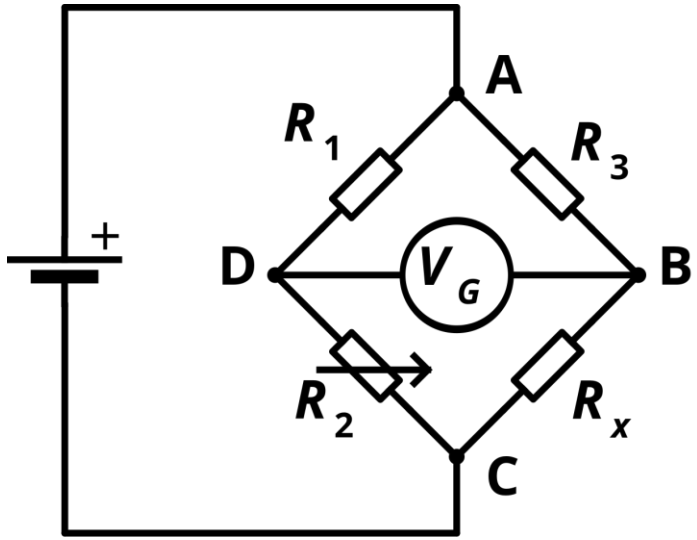
$$V_{OUT} = \frac{R_M V +}{(R_M + R_{FSR})}$$

Wheatstone Bridge

- Measures **small resistance changes** as differential voltage → cancels noise and drift.
- Reduces **effects of supply variation**.
- High sensitivity when bridge is near balance.

At balance ($V_G = 0$):

$$\frac{R1}{R2} = \frac{R3}{Rx}$$

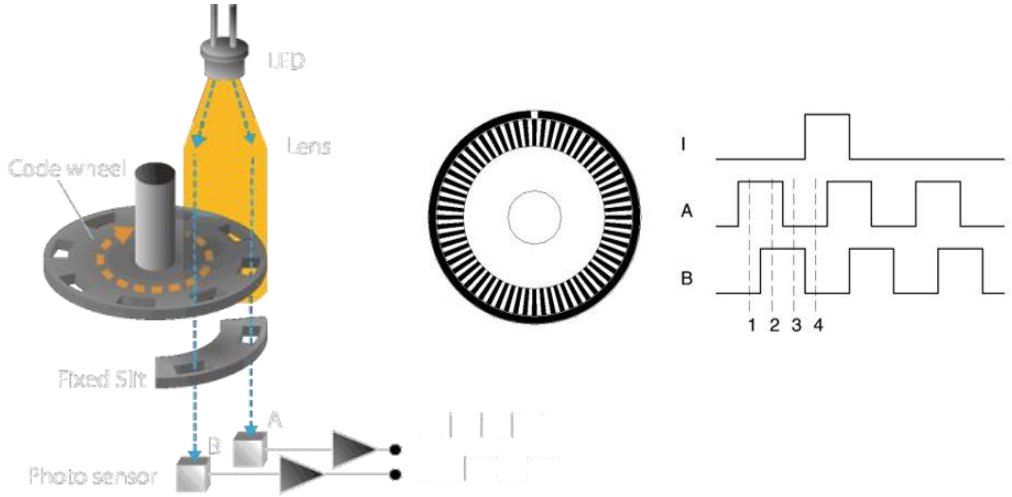


Relative measurement & Absolute measurement

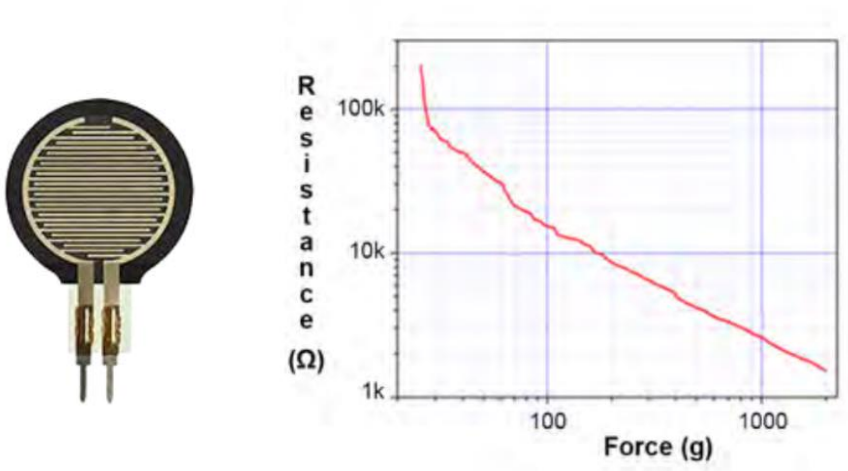
Challenges with absolute measure:

- Requires **high calibration accuracy**
- Requires **stable references**
- Sensitive to **drift, noise, and environmental variations**
- Achieving long-term stability is **expensive and complex**

Linear system vs Non-linear system

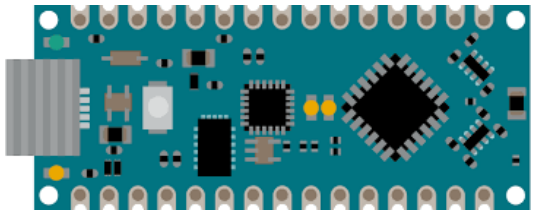


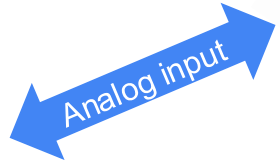
Rotary Encoder

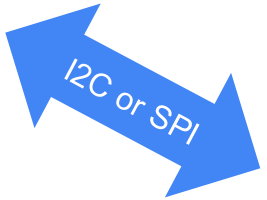


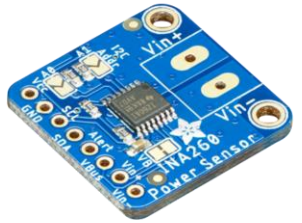
Force Sensitive Resistor

Potential Setup





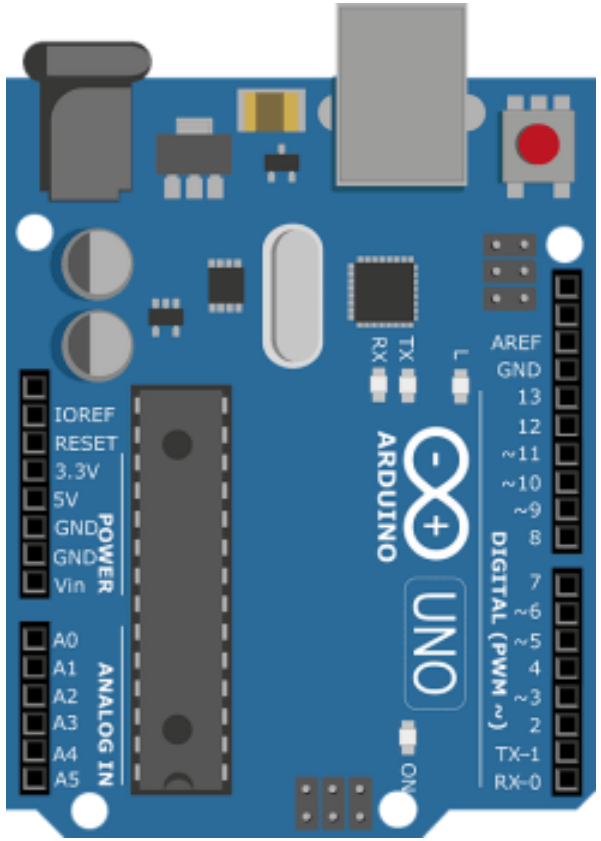




Why use a µC board?

- GPIO: analog and digital
- I2C, SPI
- UART
- PWM
- Voltage Supply & Ground

Additional modules:
- SD card
- BLE
- Sensors
- ...

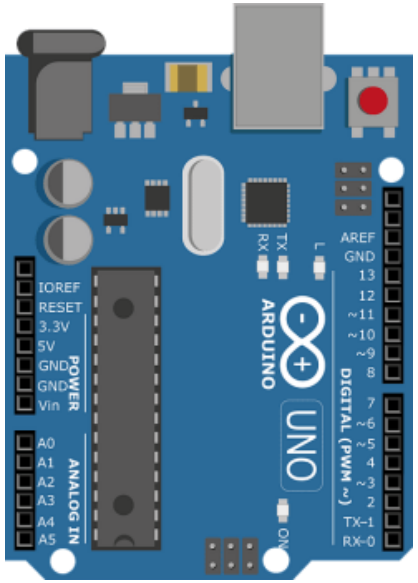


Arduino-style embedded programming

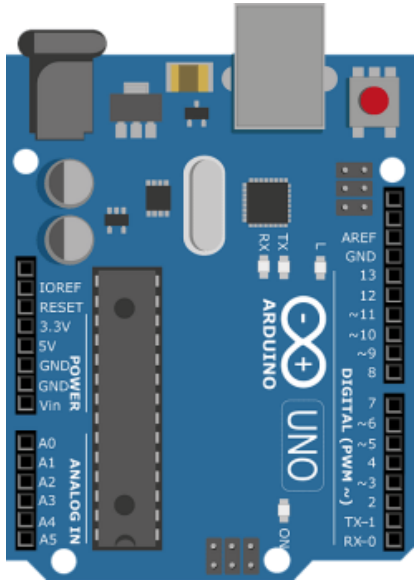
```
#include <Arduino.h>

void setup() {
    Serial.begin( 9600 );
}

void loop() {
    Serial.println( "Hello world!" );
    delay( 500 );
}
```



Boards



Arduino

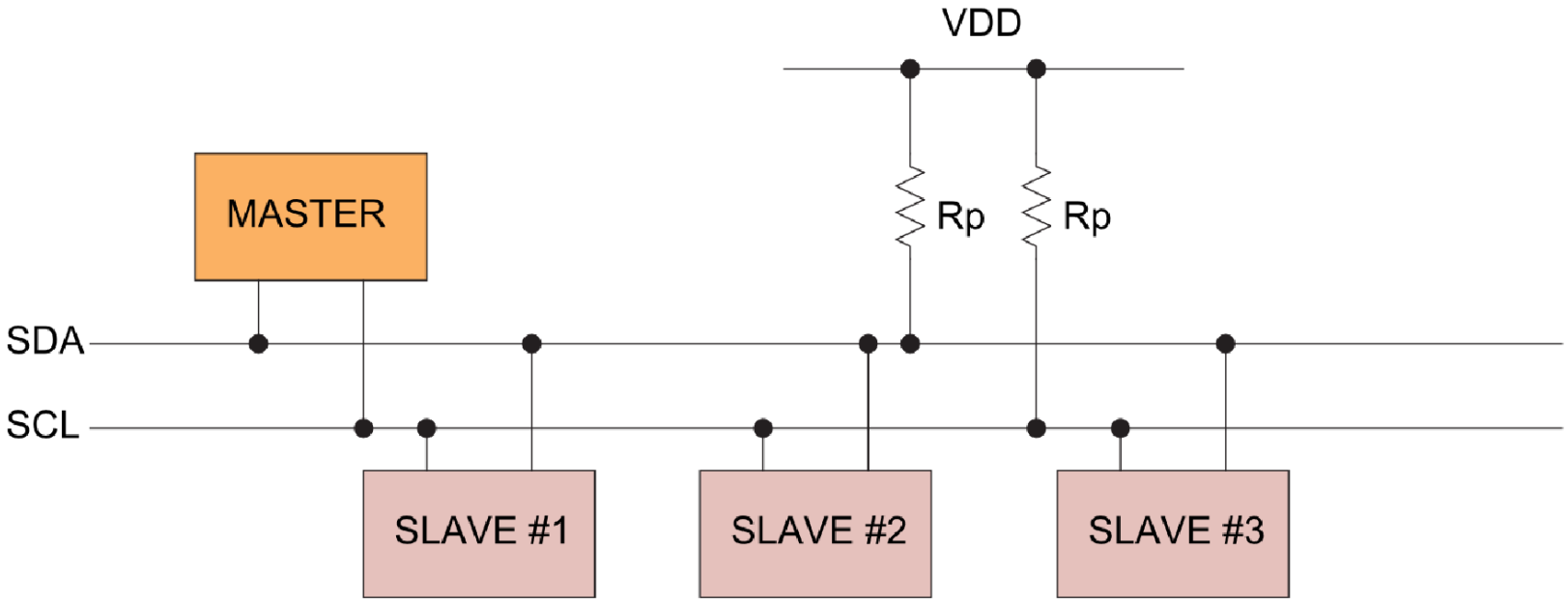
Teensy

STM32

I2C

2 wire serial bus

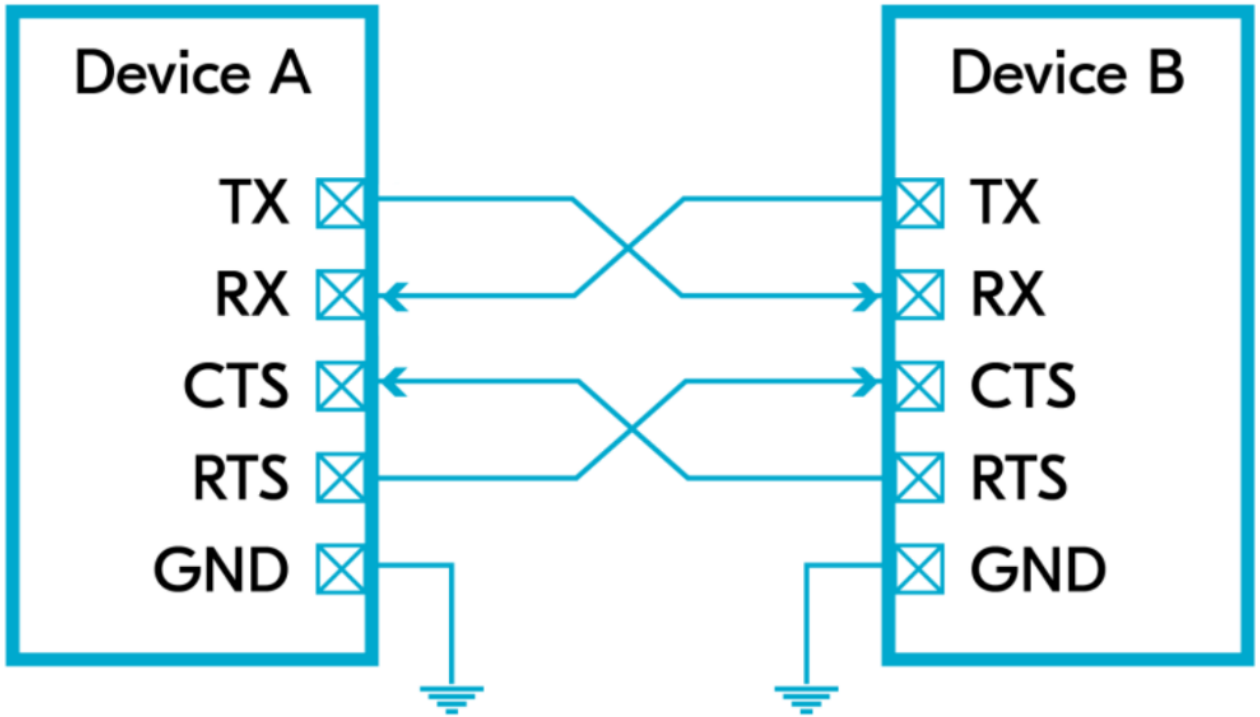
Unique address for each device



https://www.analog.com/en/resources/technical-articles/i2c-primer-what-is-i2c-part-1.html

UART

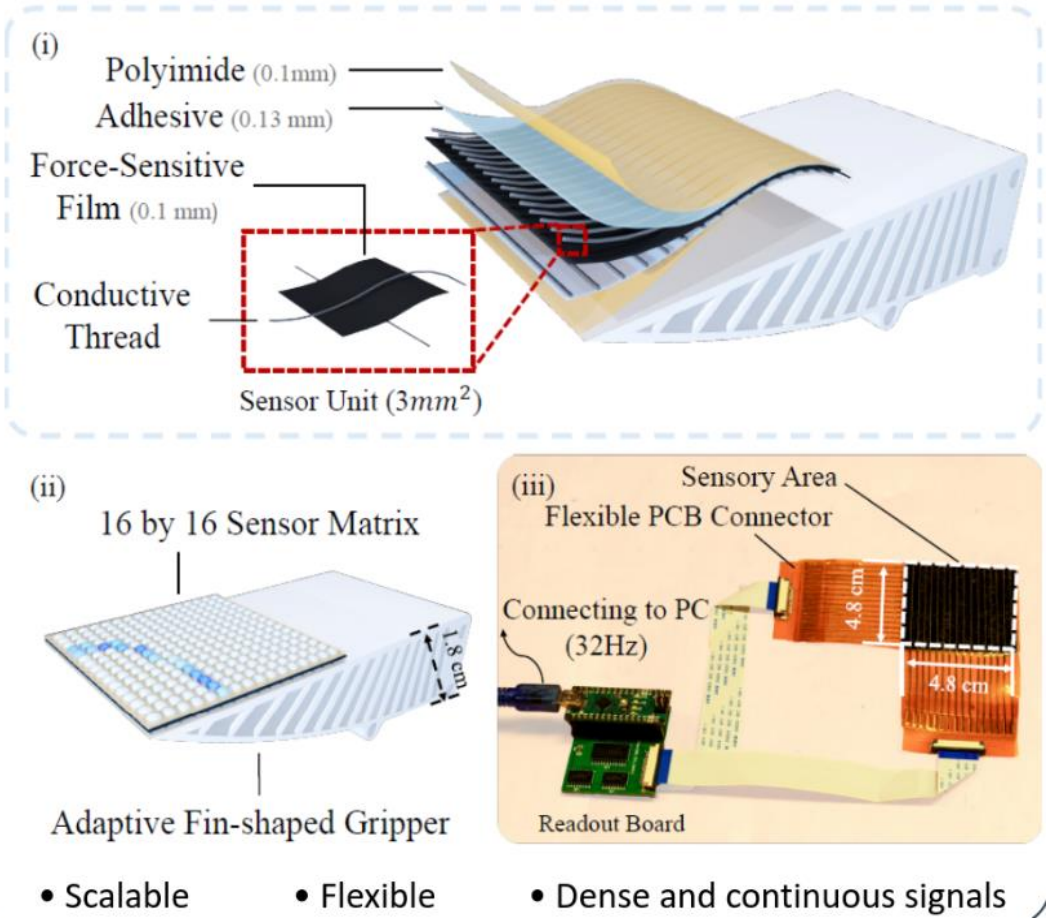
Data streaming set by baud rate : 9600, 57600, 115200, 921600

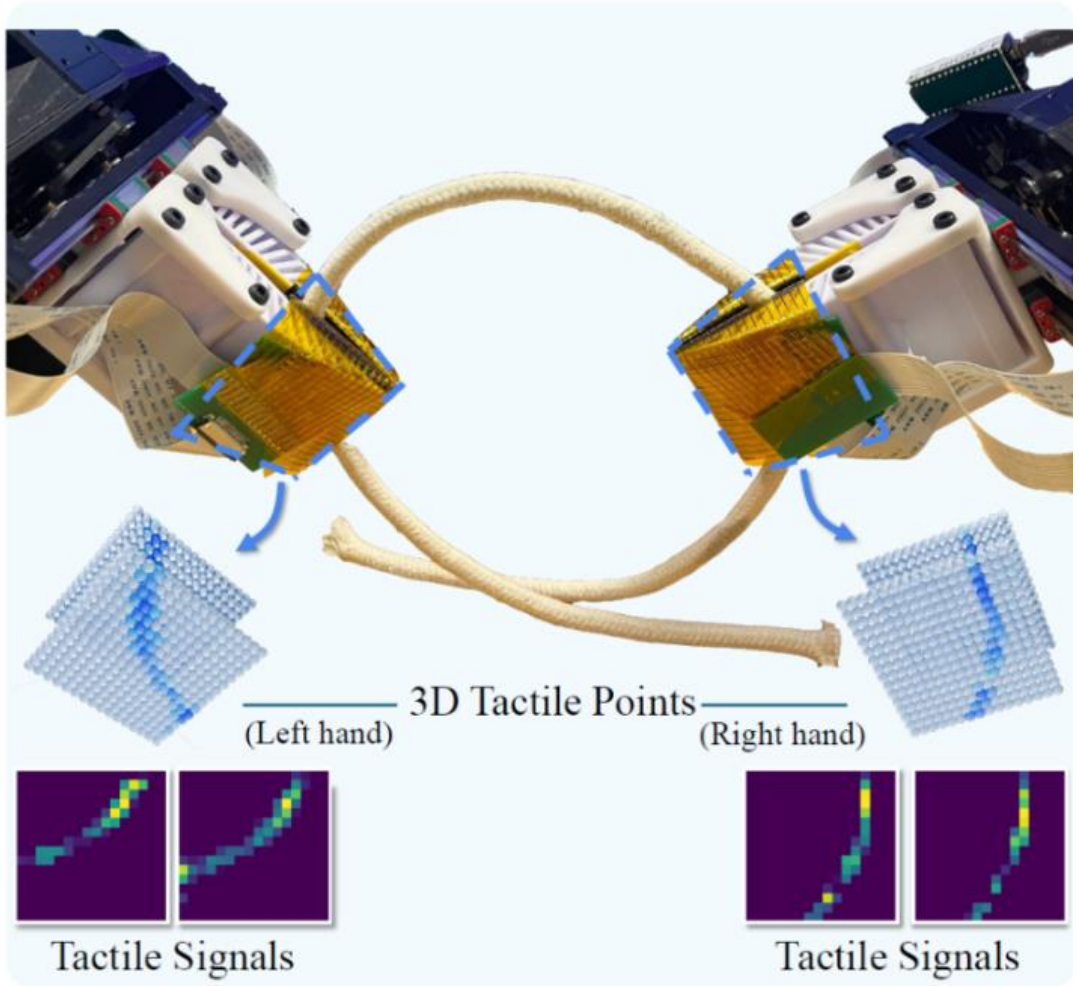


UART connection with hardware flow control

https://academy.nordicsemi.com/courses/nrf-connect-sdk-fundamentals/lessons/lesson-4-serial-communication-uart/topic/uart-protocol/

Example by Binghao Huang





Finite number of channels

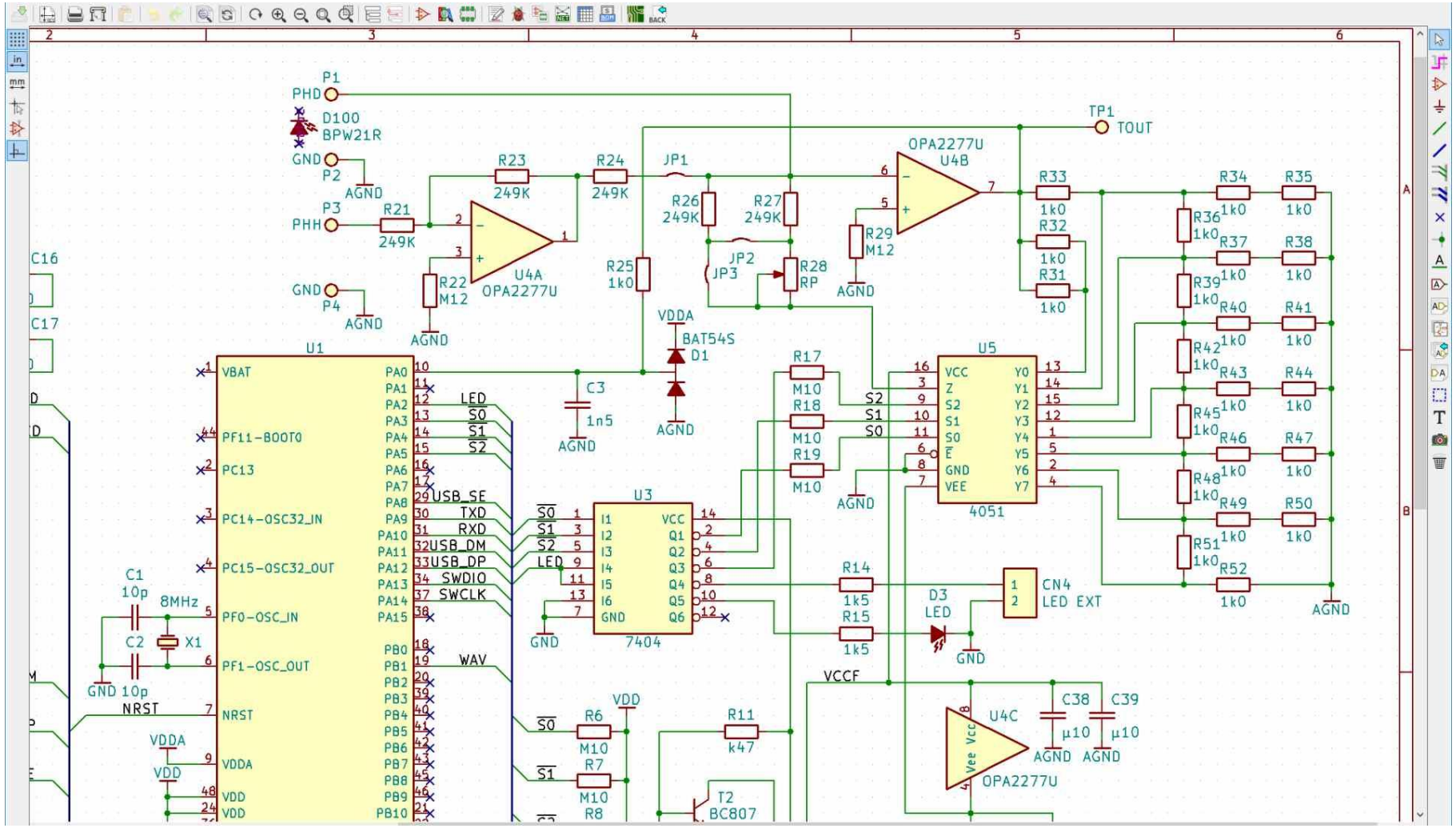
- Limited number of ADC channels
- Communication bottleneck
- Cross talk

Typical solutions:

- Multiplexing
- Bus sharing
- Multithreading
- System partitioning

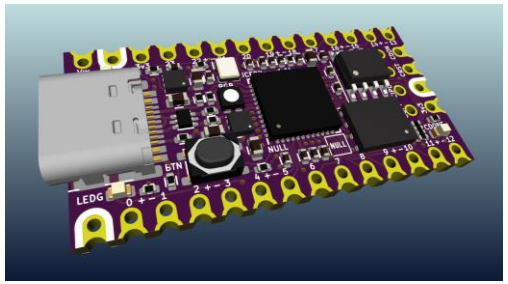
PCB design Tutorial - Kicad

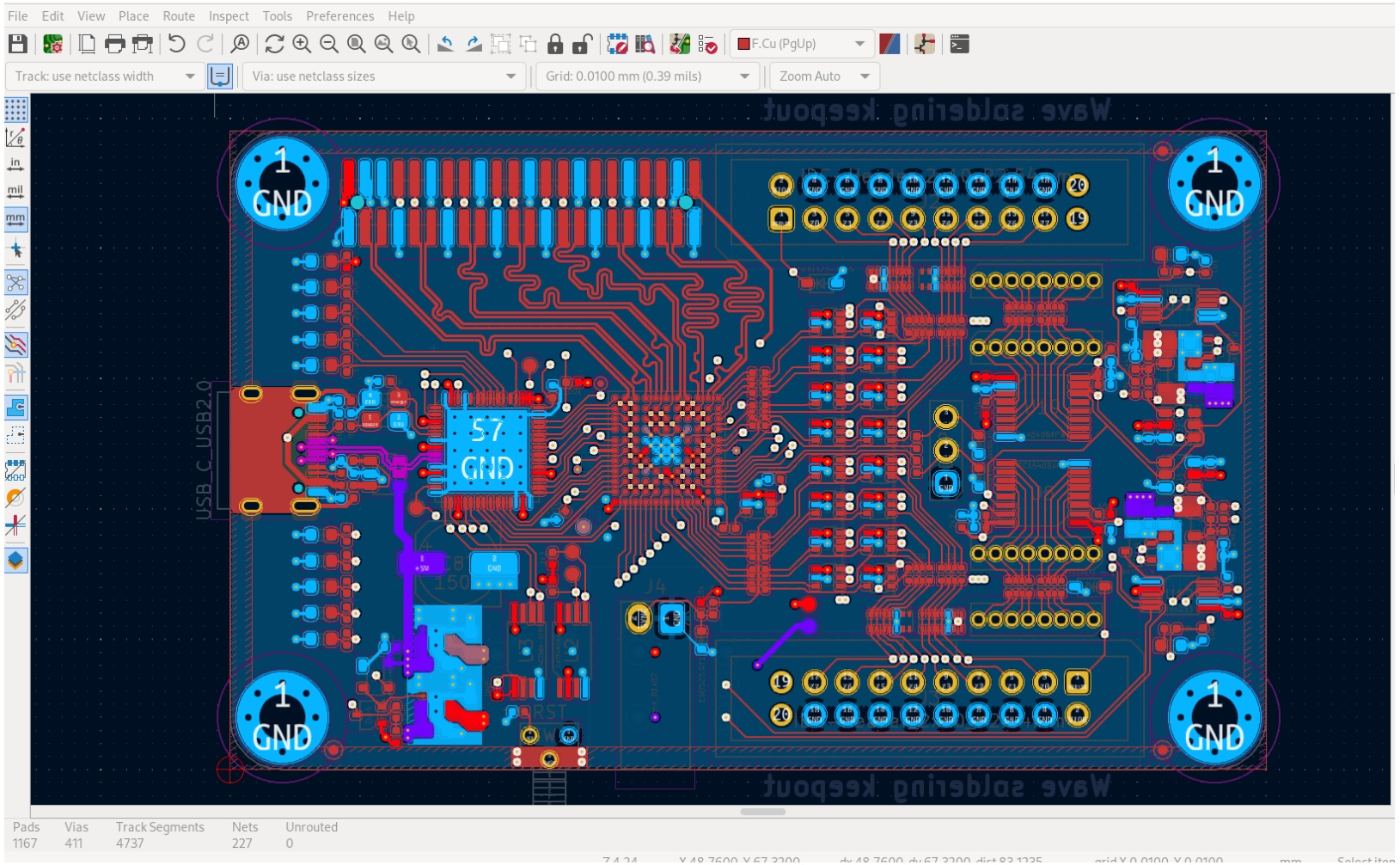
Step 1: Schematic



PCB design Tutorial - Kicad

Step 2: Layout

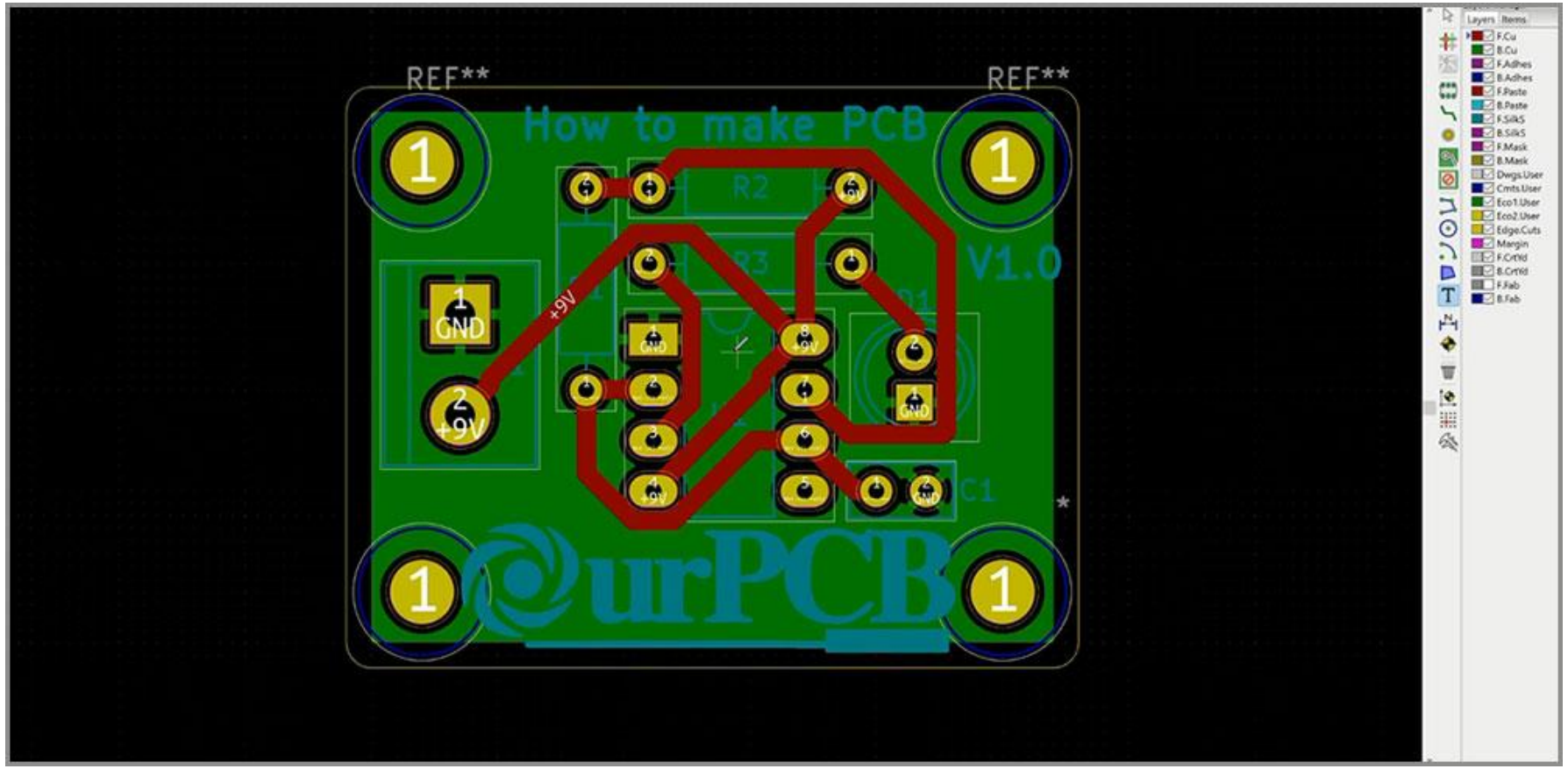




https://en.wikipedia.org/wiki/KiCad
https://www.kicad.org/

PCB design Tutorial - Kicad

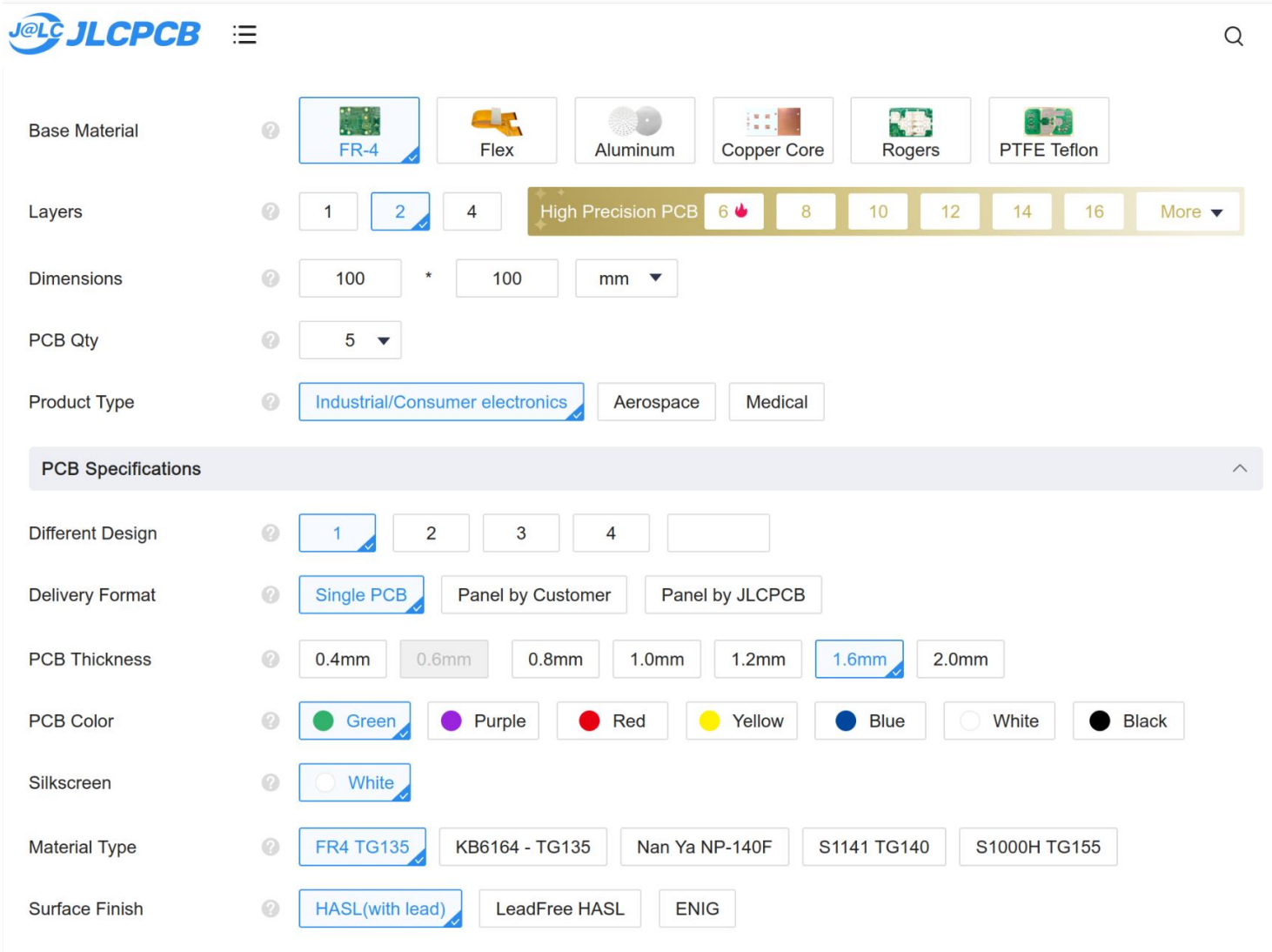
Step 3: generate **Gerber files** (equivalent to .stl in CAD)

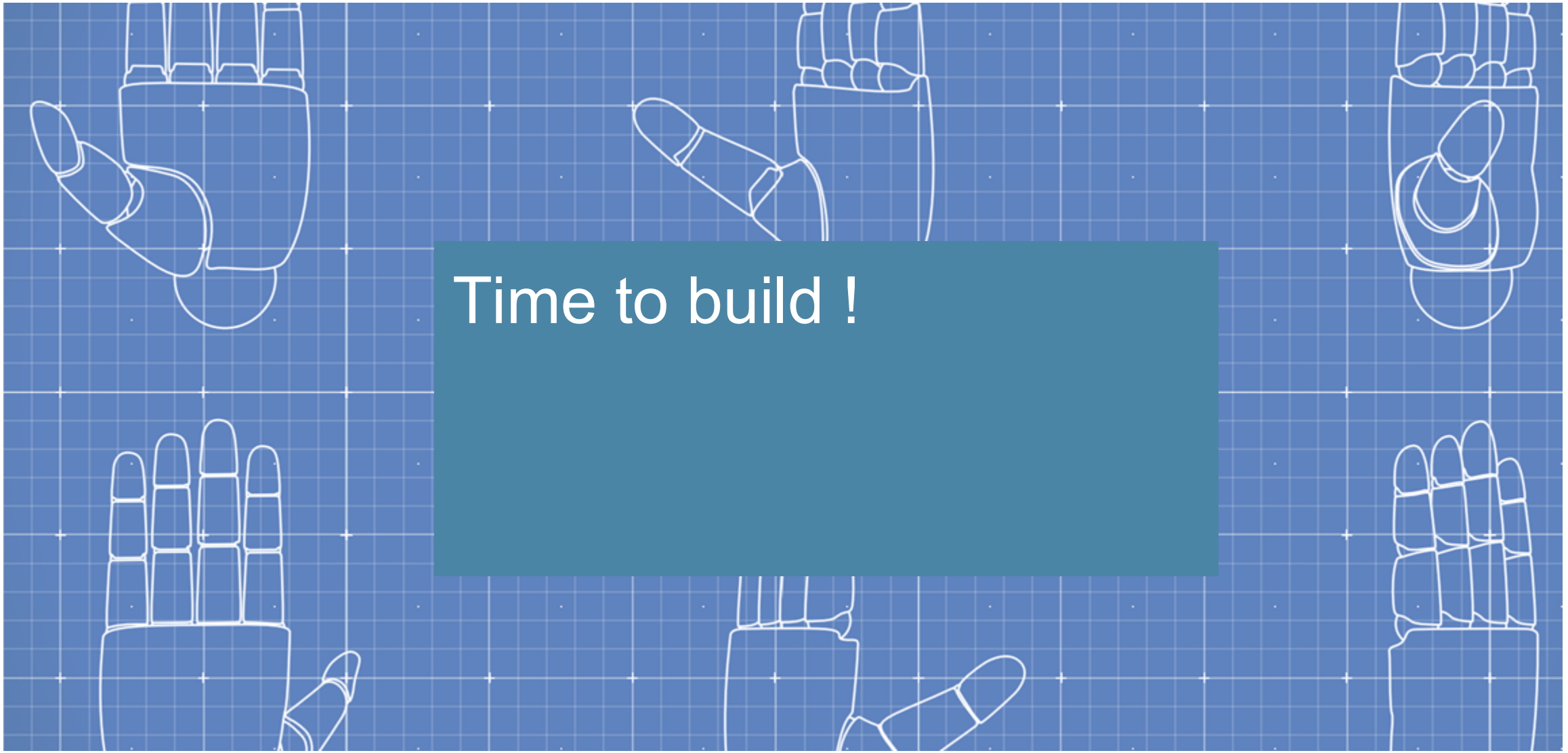


https://www.ourpcb.com/gerber-files.html

PCB design Tutorial - Kicad

Step 4: Order PCB from manufacturer




Time to build !