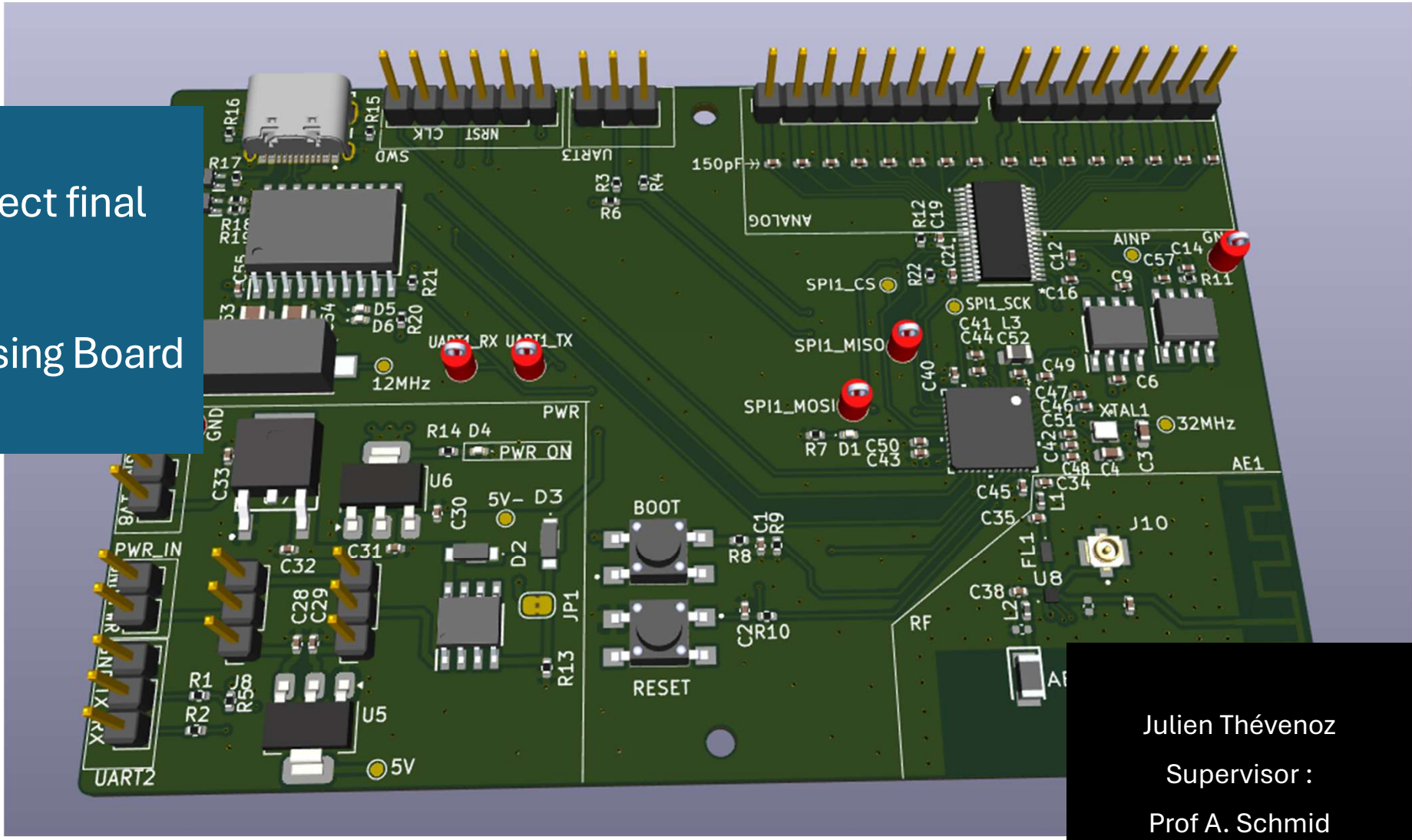
EPFL

Semester project final presentation: EMG-Bracelet Signal Processing Board



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Supervisor :

Prof A. Schmid

22.05.25

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Project motivation and goals

N-Pulse
New student association doing **biomedical** tech

Goal : **open source arm prosthesis** with seamless control (**EMG**, BCI, computer vision, ...)

Need for a device capable of EMG-signals real time analysis :
Lightweight, self-powered, many electrodes, enough computing power

Myo Armband (2)

CTRL-Kit (3)

Bought and discontinued by Meta

Design own **open-source** wearable EMG bracelet

Ui1

Slide 3

Ui1 "EMG analysis" implies it only does signal processing, but in our case it also does signal acquisition.=> I would simply say "EMG bracelet".

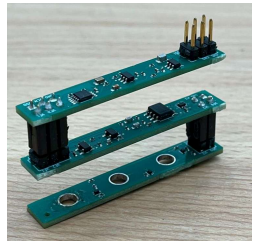
Utilisateur invité, 2025-05-21T22:29:21.107

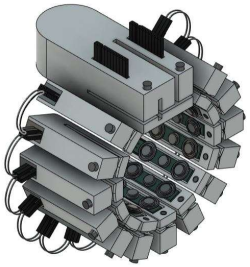
Project motivation and goals

Autumn 2024

«Development of an open-source EMG armband for Hand Gesture Estimation"
Semester project by **R. Danylovych** and **E. Massonnet** at labs INL & TNE

➔ Based on a design by eLiONS lab (Politecnico Torino) [1] [2]
➔ First prototype of EMG signal acquisition modules and bracelet architecture
BUT no time to develop module to analyze the signals





- Standalone, **wearable**, light , ajustable bracelet
- **Hand gesture detection** from EMG signals
- **Open-source** and documented

The **signal processing board** is a component of the **N-Pulse EMG Bracelet project** :

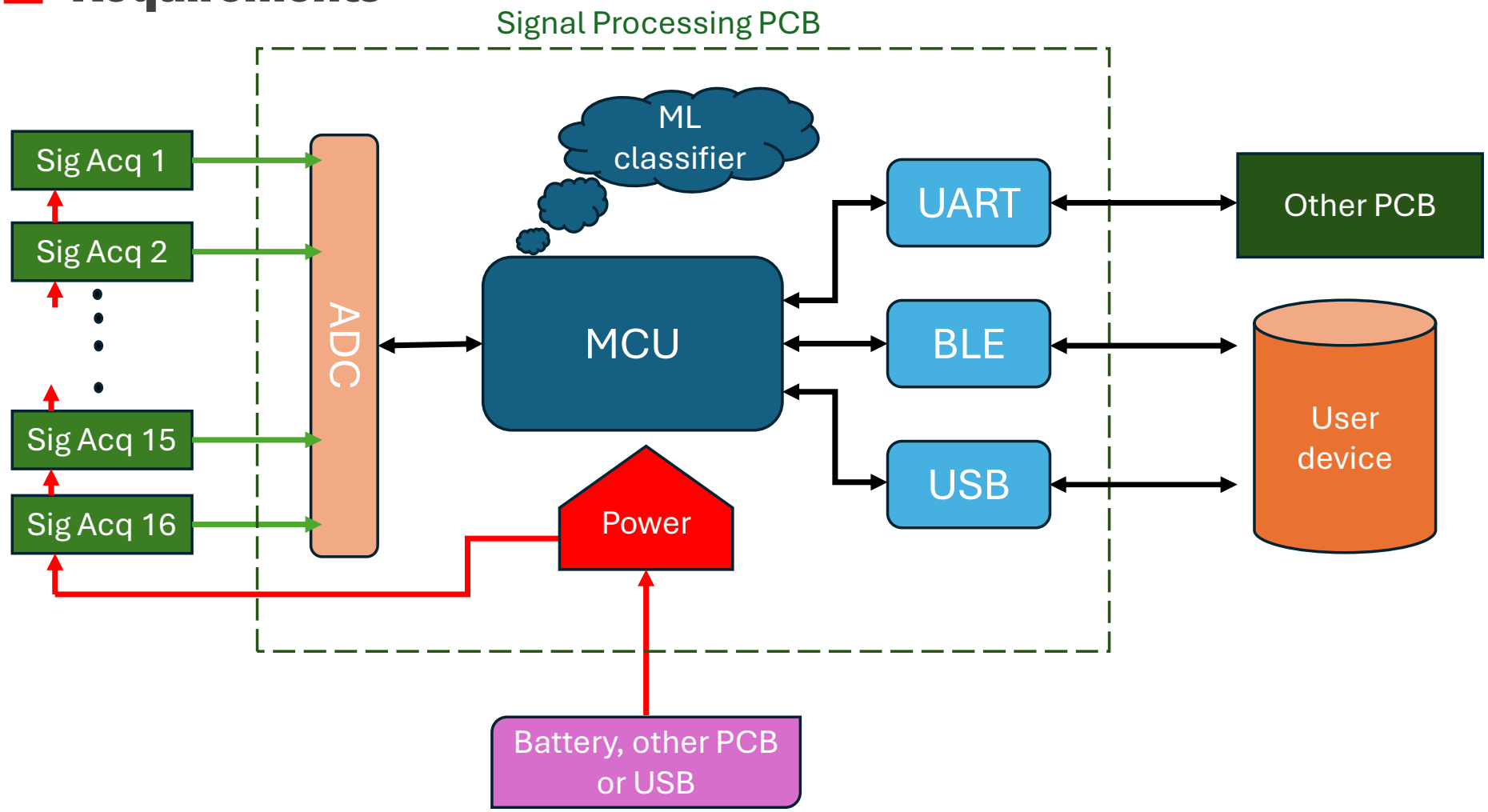
Spring 2025

Develop the hardware to analyze the EMG signals :

- Able to run **compact ML algorithm** such as [3] **on- board** and in **real time**
- Transmit results **wirelessly** and physically
- Central piece of the EMG bracelet (powers the rest)

ML Semester project proposition :
«EMG Signal Processing Board»

Requirements



Sig Acq = EMG signal acquisition modules (either **custom-made** or **commercial** *e.g. BioAmp EXG Pill*)

Requirements

MCU

Enough **FLASH**, **RAM** and **clock frequency** to run on-board ML algorithm in real-time.
Bluetooth capability.

Paper [3] proposes a model with ~7000 parameters to do hand gesture classification
➔ This amounts to ~55 kBytes (float double precision 8 Bytes).
Another paper proposes a model with 400'000 parameters [4] ~ 2.6 Mbytes, and then others with even more.
We want to base software on [3] and decided that a flash memory of 2 MB should be enough. For RAM, we calculated that 1s of data ~ 100kBytes.

ADC

16 channels @ 800 Hz each --> ADC sampling rate > 12 800 Hz.
But accounting for channel switching, non-ideal SigAcq modules etc ->
decided 100 Samples per Second strict minimum

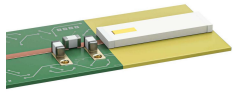
Design choice : board as prototype

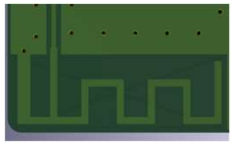
Complex PCB : many different functions and parts
No previous experience for this level of design by me or other N-Pulse members

Protoype board :
try different solutions together, allow insights into board behavior, keep doors open

(4)

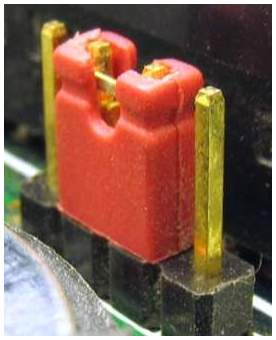
(3)

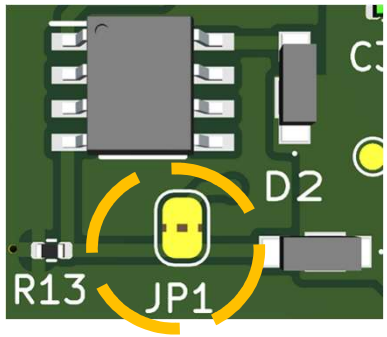




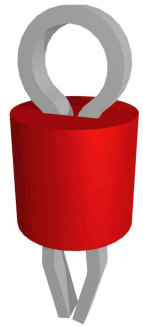
3 different antenna types :
External, Ceramic chip, Trace

(5)



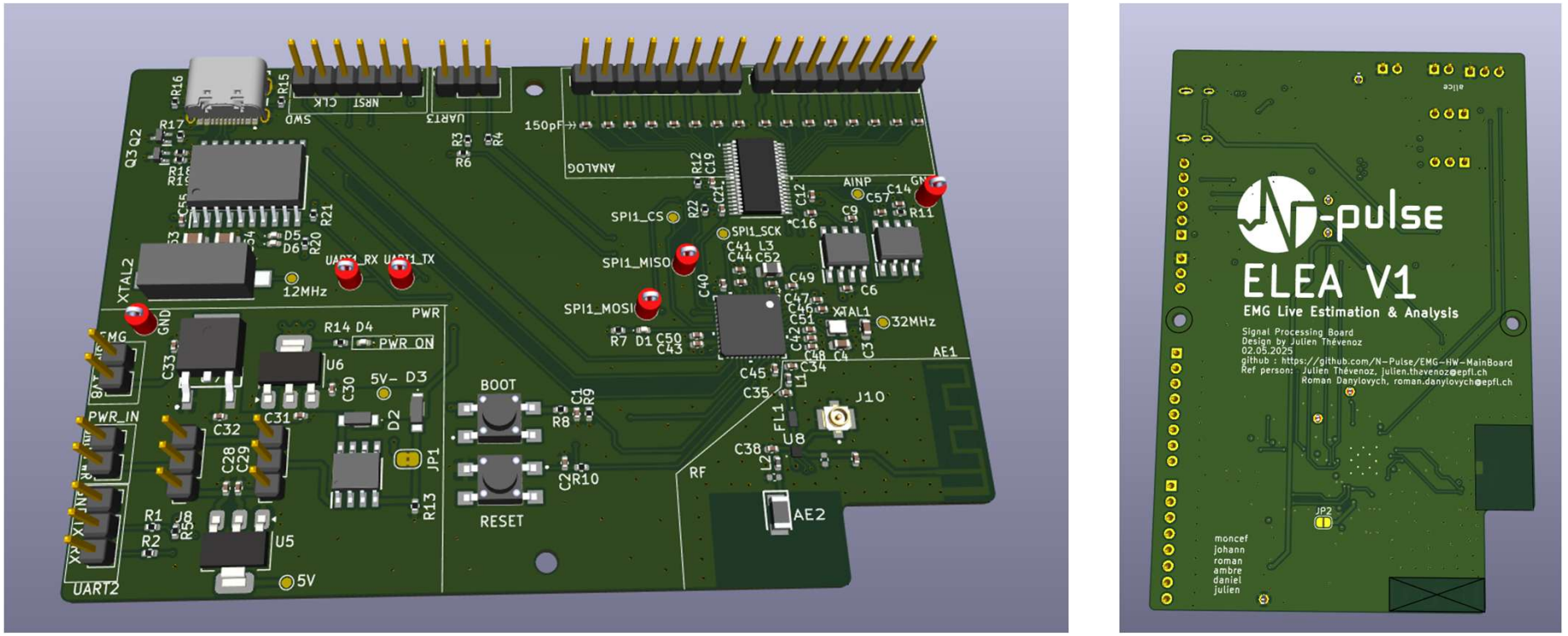


Pin header jumpers and solder bridge jumpers to provide easy (de)routing



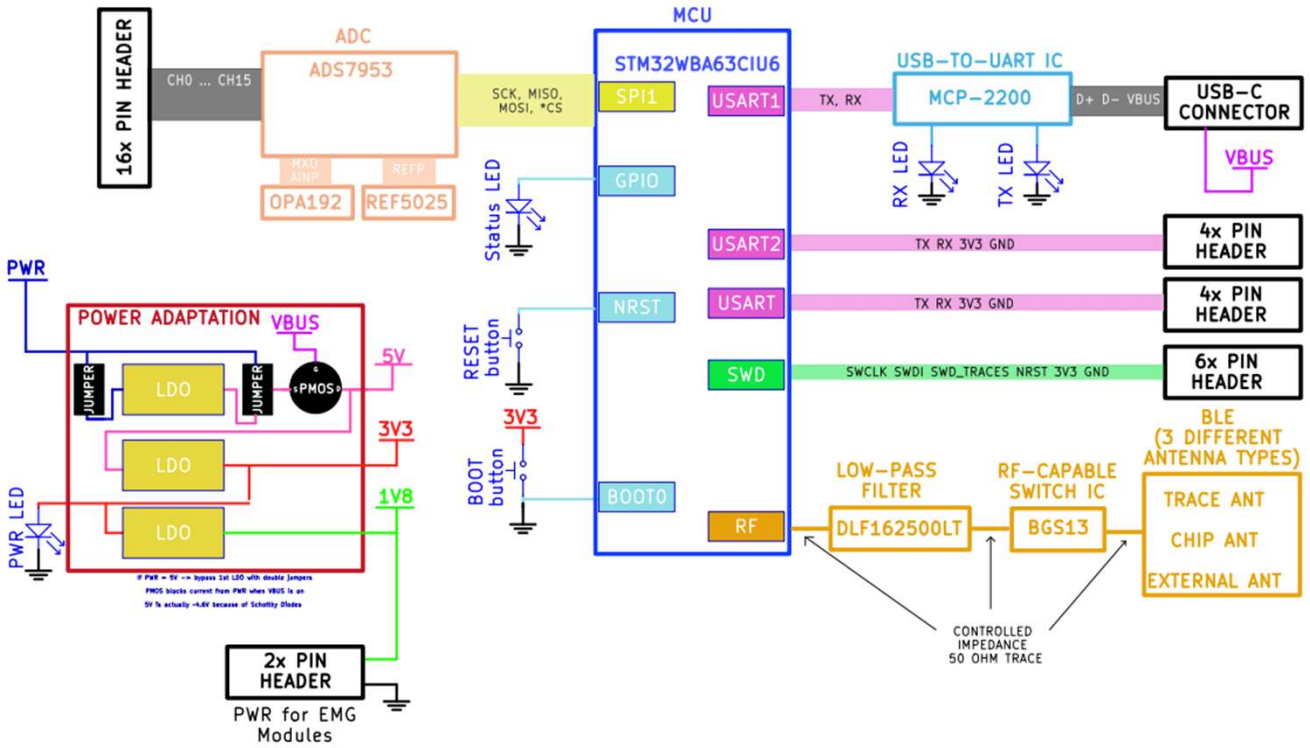
Test points to expose Important signals

Signal Processing Board : Version 1

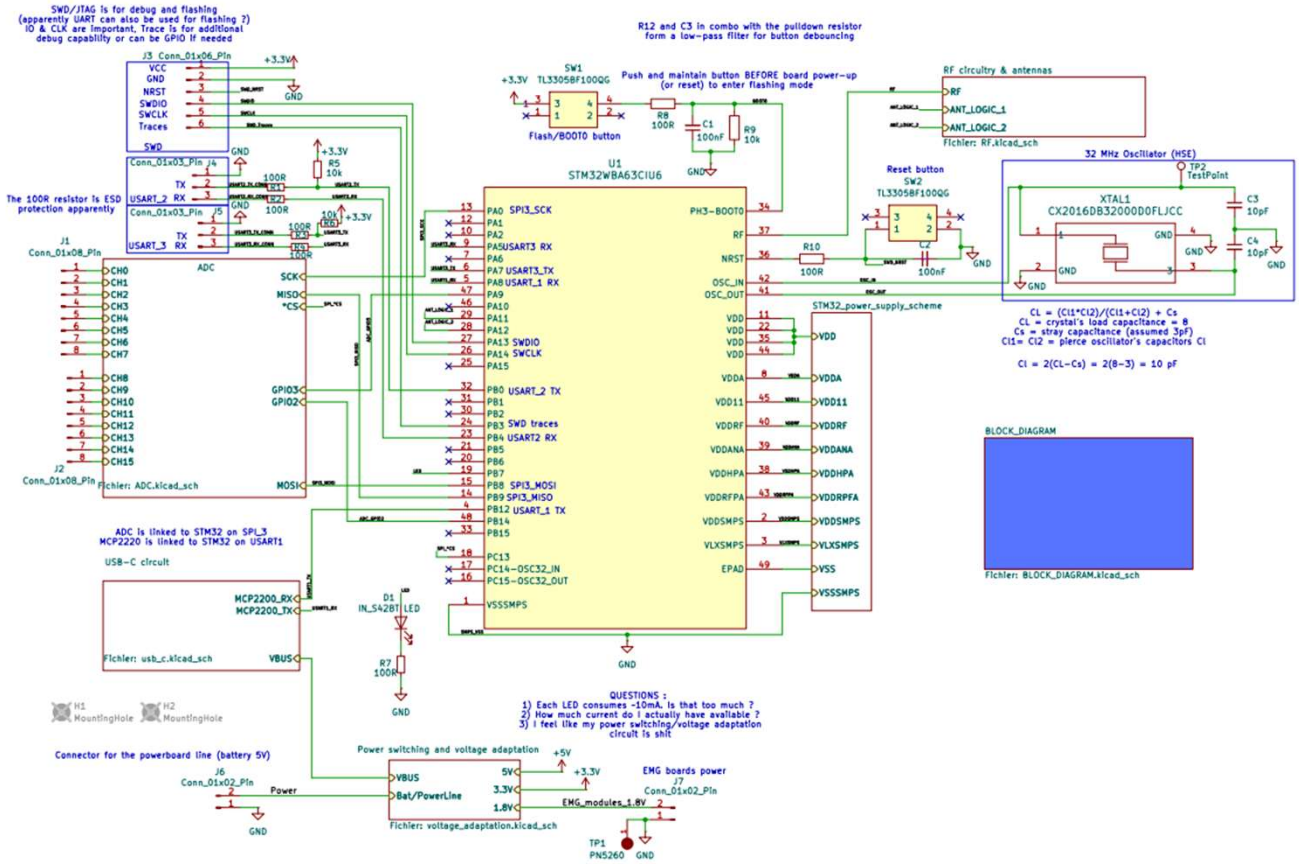


Front and back view of the PCB (KiCad 3D render)

Block diagram

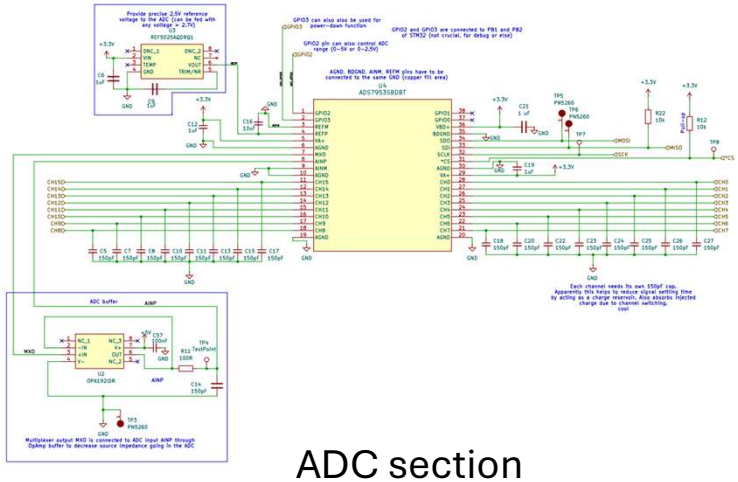


Schematic

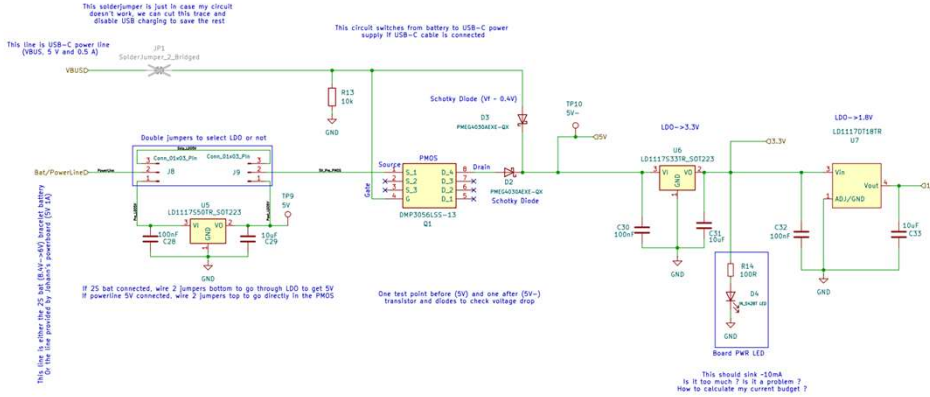


Electronic schematic main page

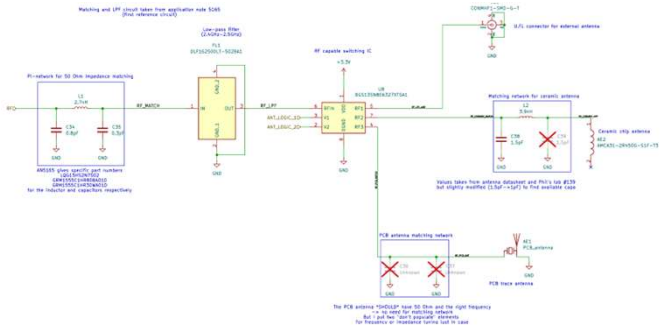
EPFL Schematic



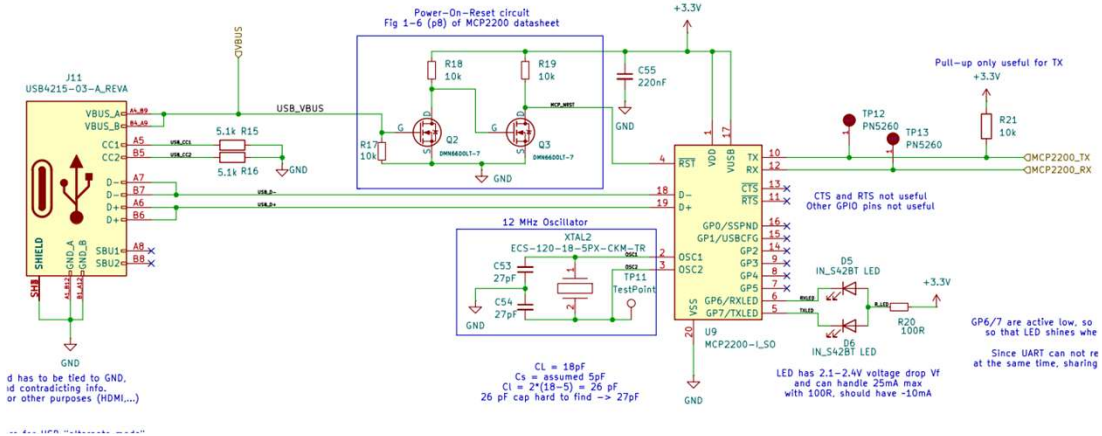
ADC section



Power section

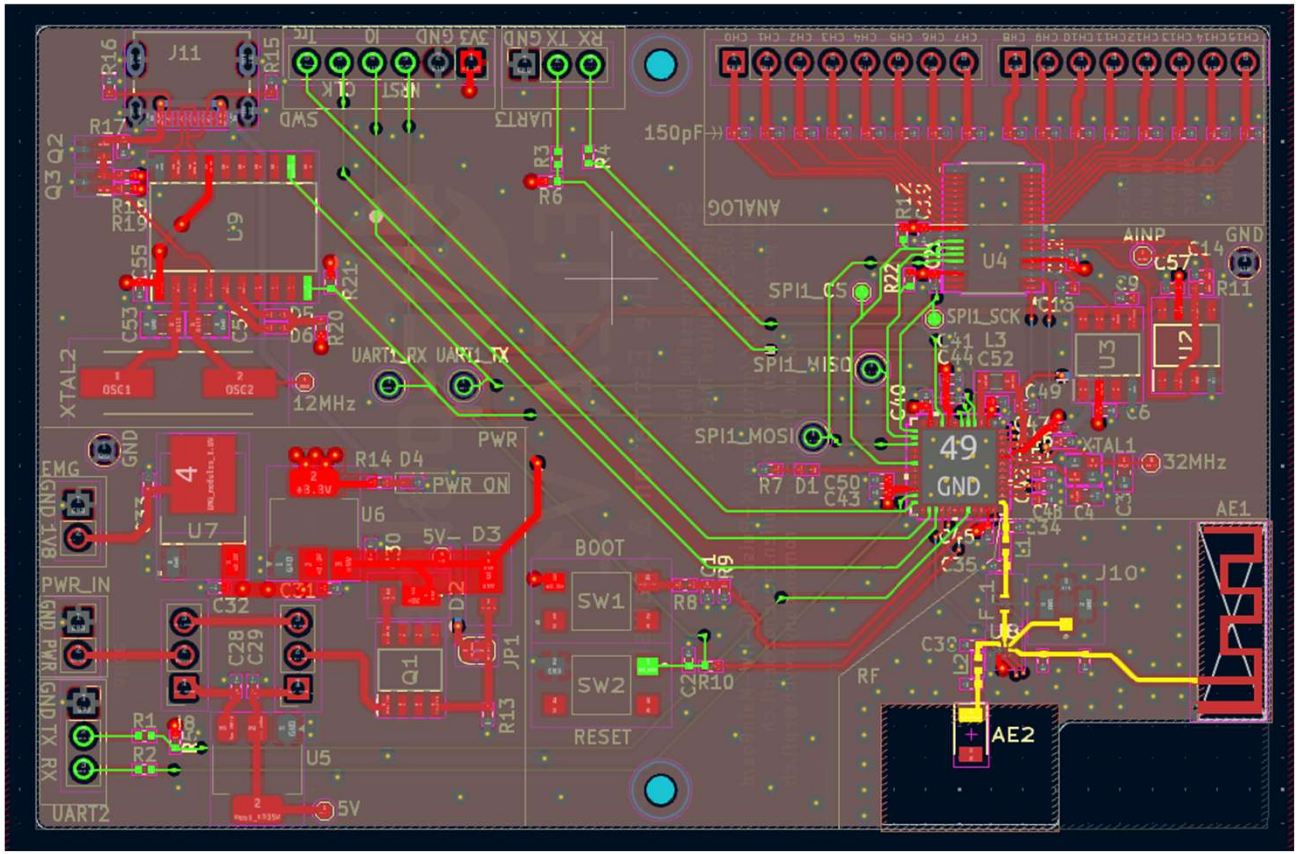


RF section



USB section

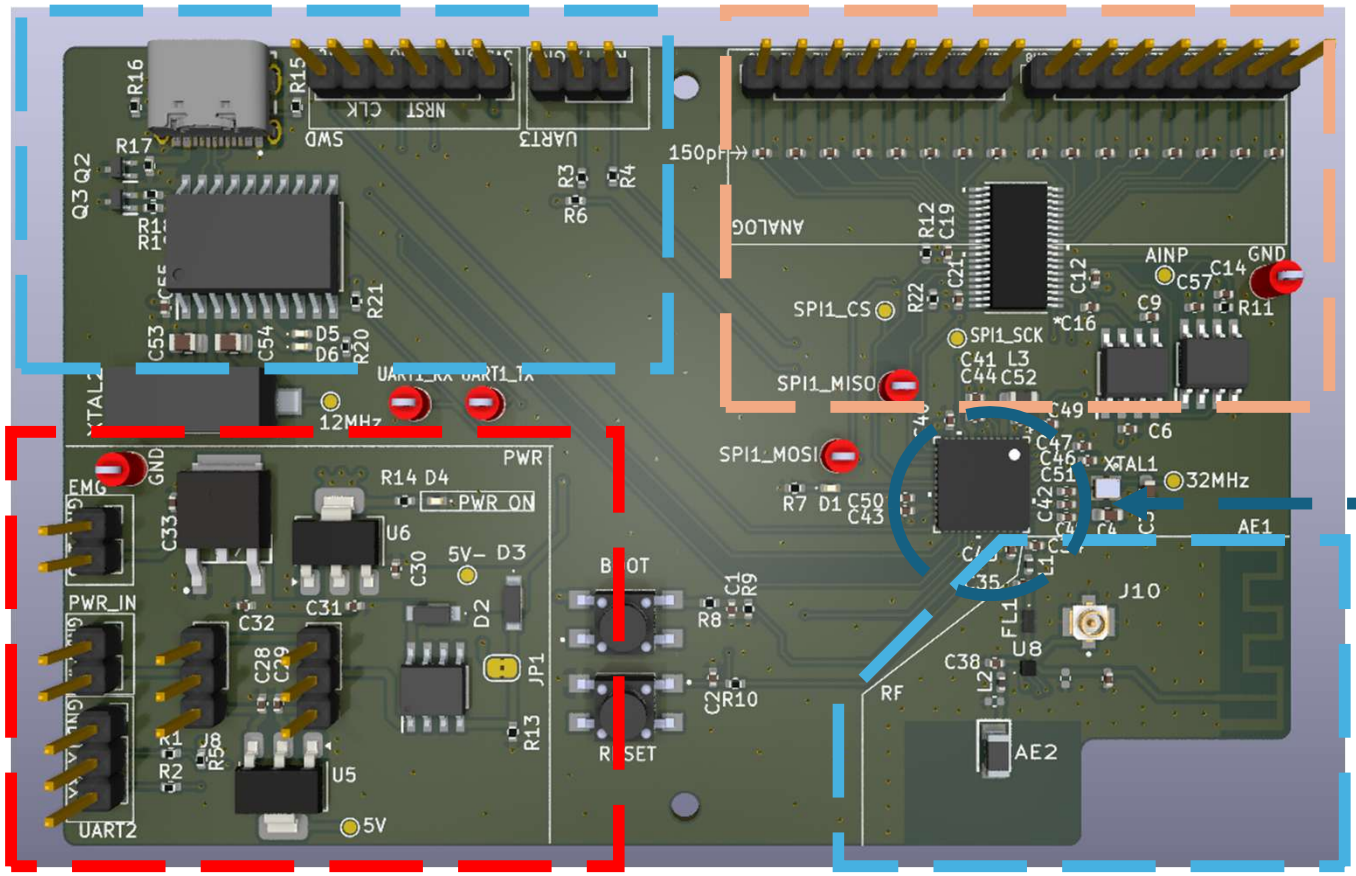
PCB LAYOUT – 4 LAYERS



PCB LAYOUT

USB-C, UART and SWD section

ADC section

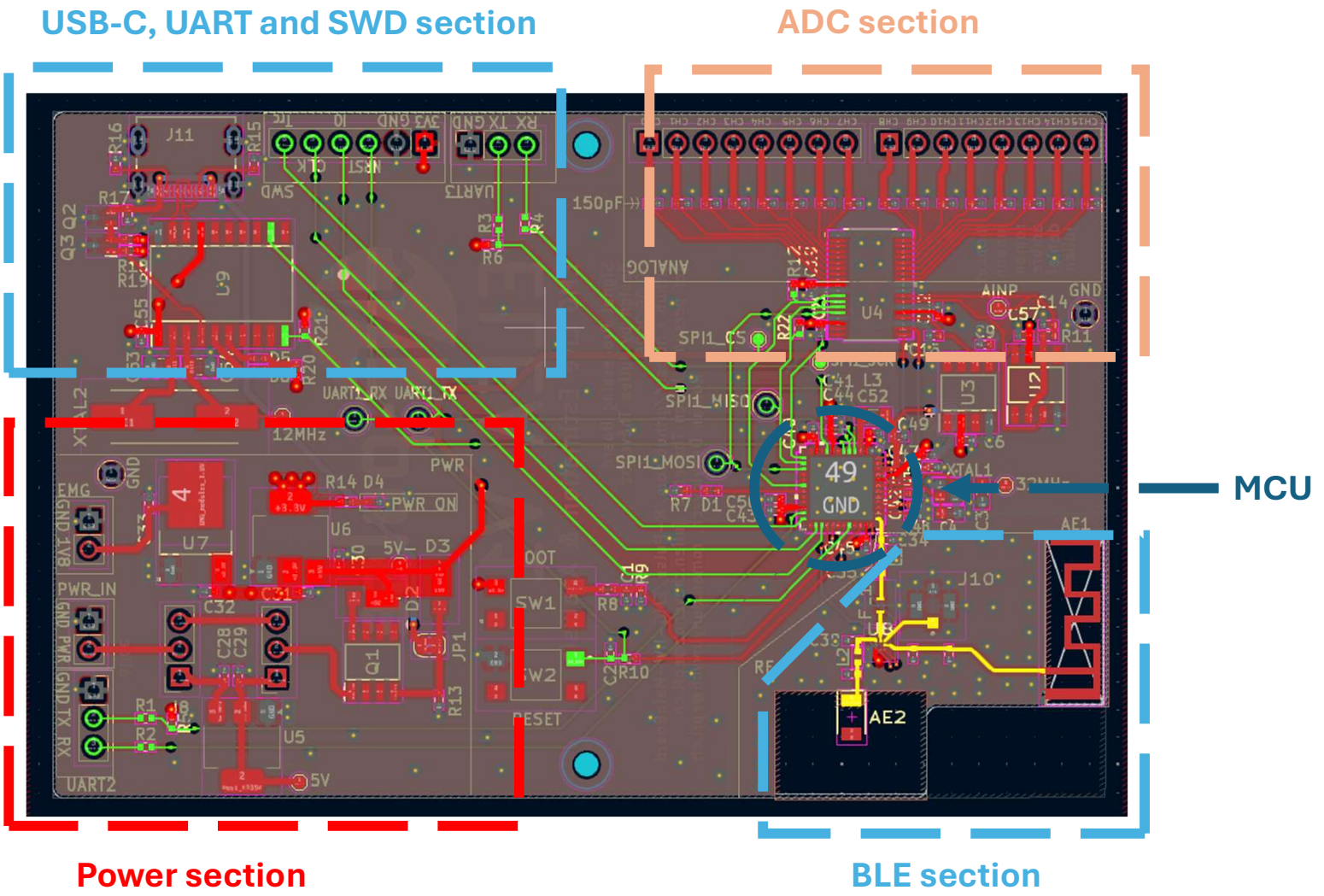


MCU

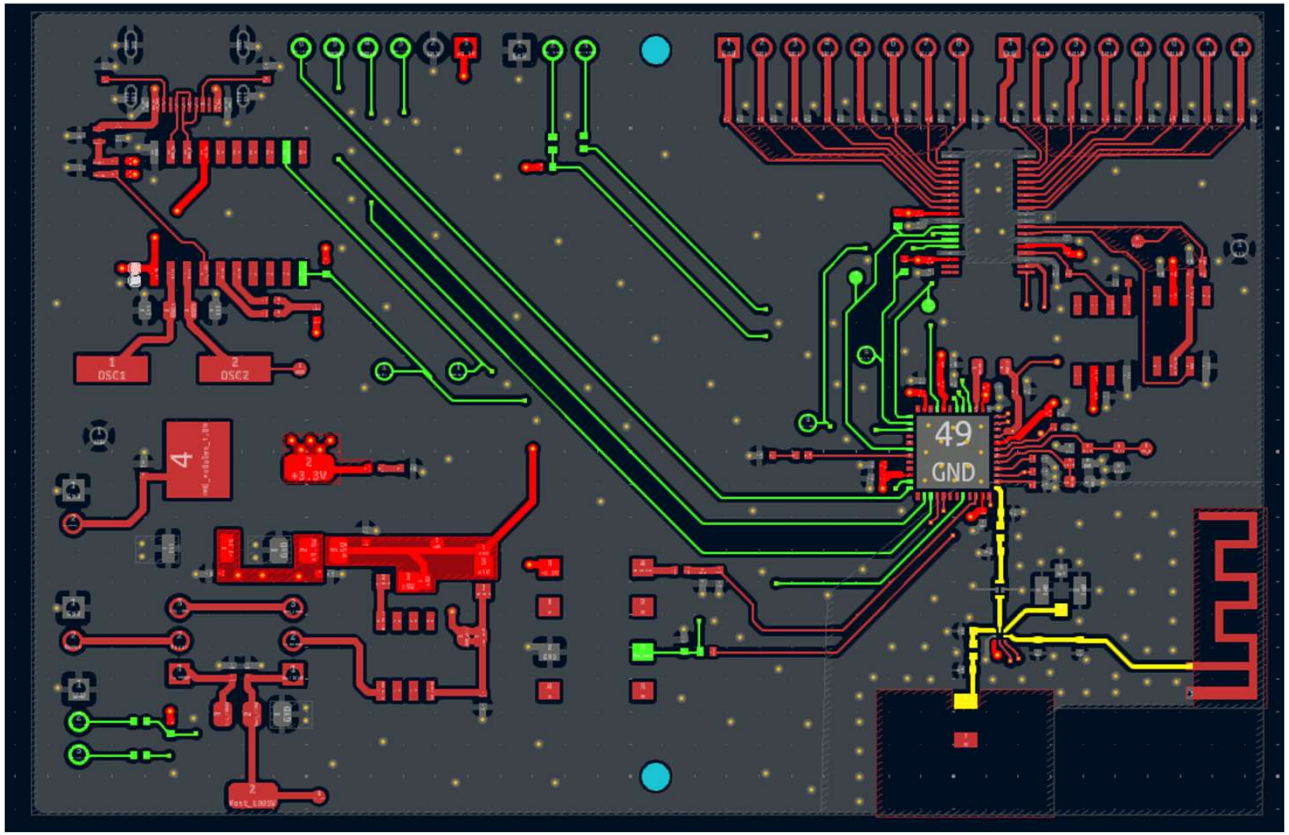
Power section

BLE section

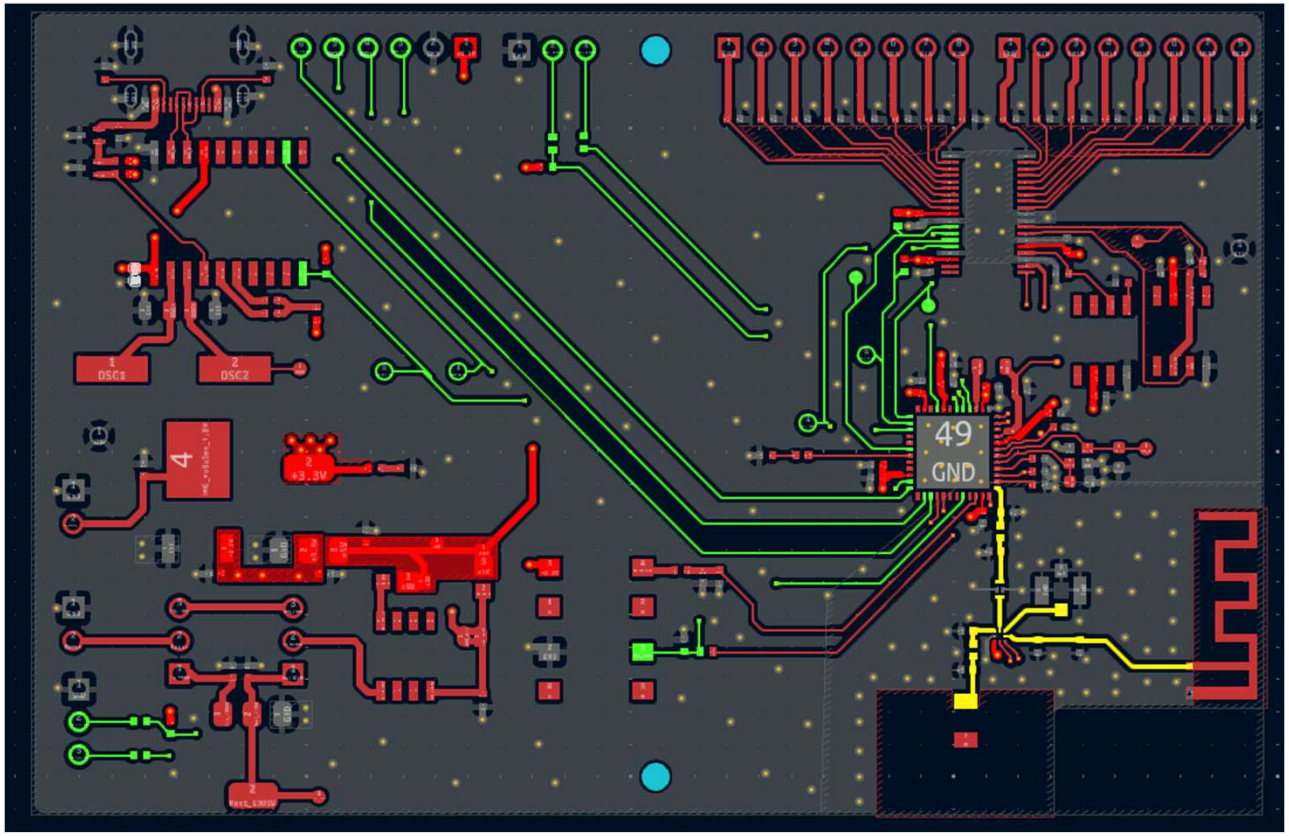
PCB LAYOUT


USB-C, UART and SWD section
ADC section
MCU
Power section
BLE section
J11
SWD
UART3
150pF
ANALOG
U4
AINP
GND
SPI1_CS
SPI1_MISO
SPI1_MOSI
12MHz
PWR
PWR_ON
U6
U7
5V
D3
SW1
SW2
RESET
JP1
Q1
U5
UART2
PWR_IN
EMG
XTAL1
AE1
AE2
J10
49
GND

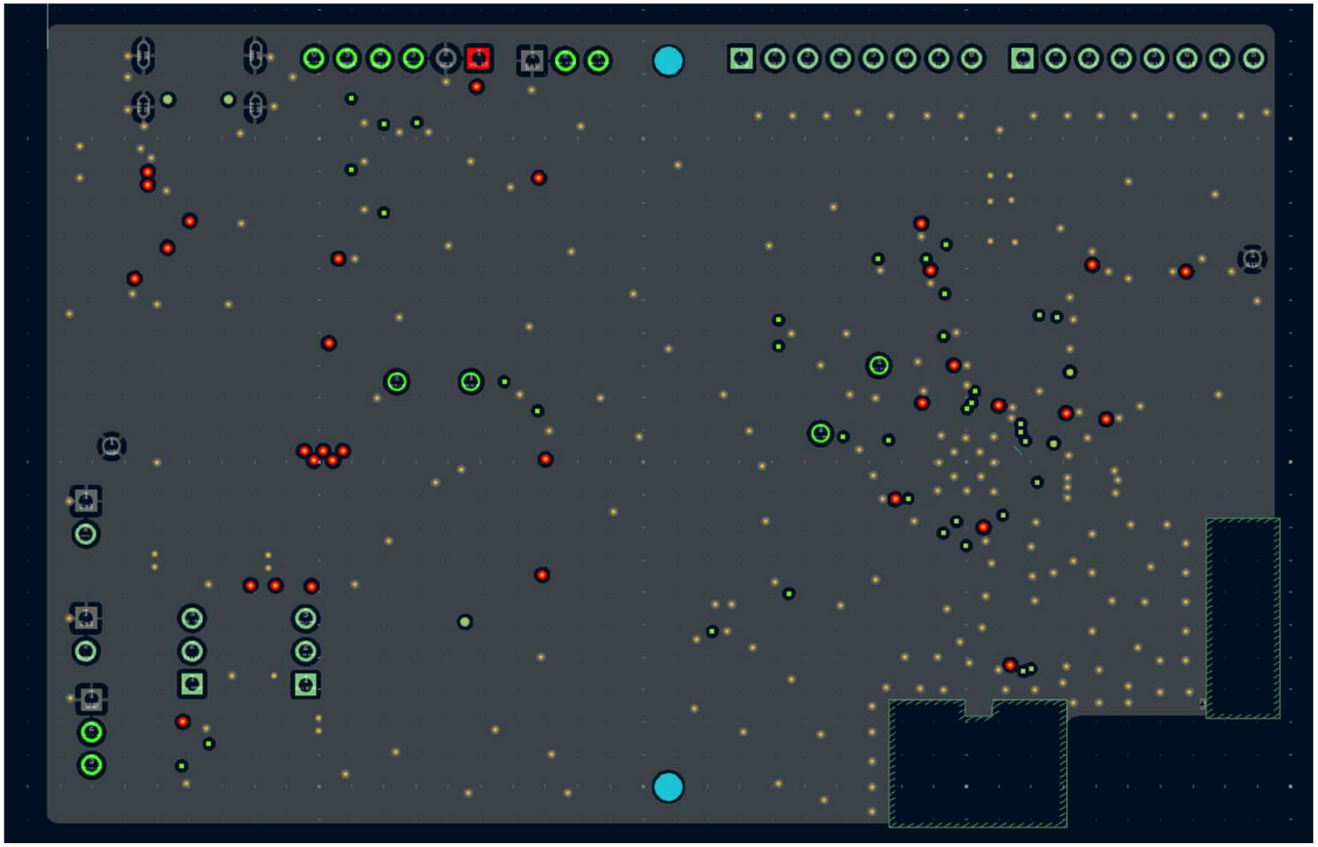
PCB LAYOUT – 4 LAYERS



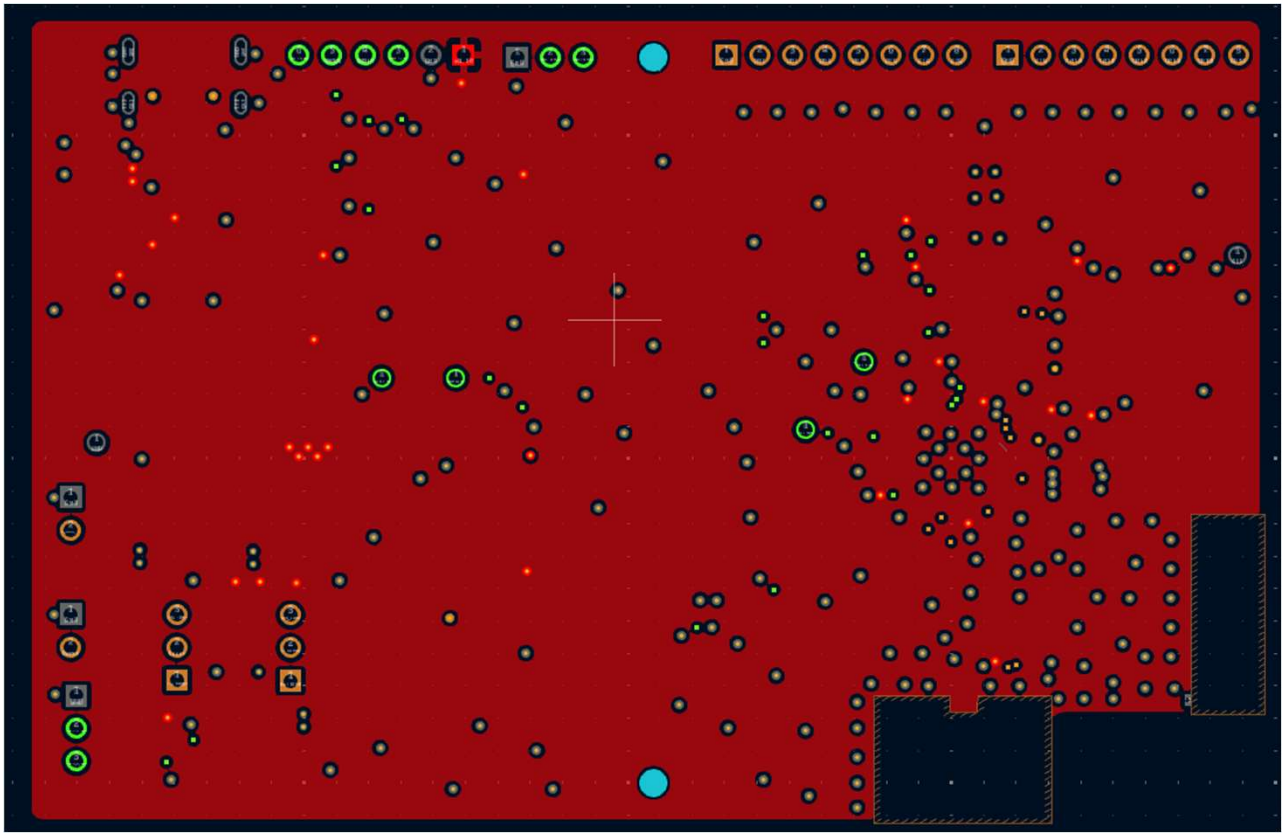
PCB LAYOUT – FRONT LAYER (SIGNAL, RF)



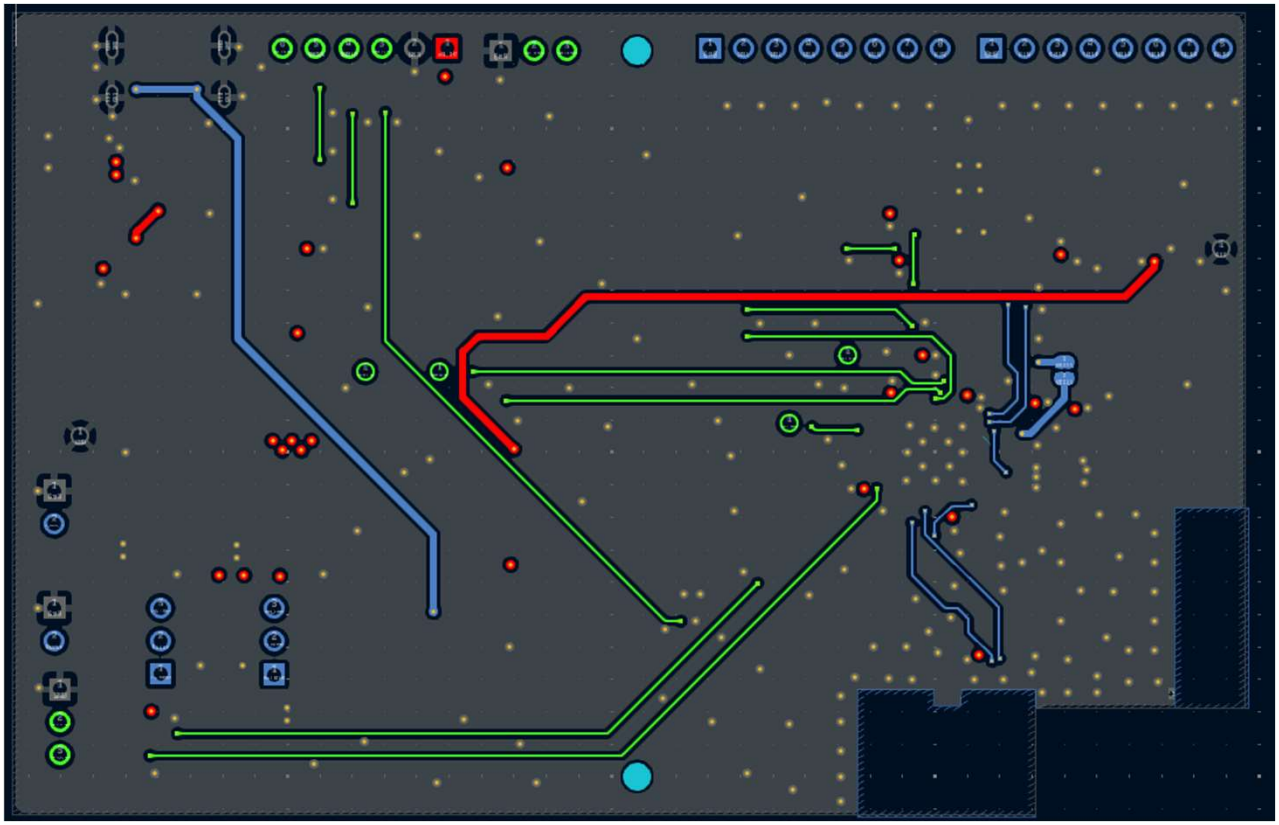
PCB LAYOUT – 2nd LAYER (GND)



PCB LAYOUT – 3rd LAYER (3.3V)



PCB LAYOUT – BOTTOM LAYER (SIGNAL)



Challenges

1) Some goals still slightly vague
2) No prior experience
3) Workload
4) RF

EPFL Self-teaching

Never took any PCB design class -> had to learn on the go.
Thankfully many very good resources online

Tutorials

Phil's Lab (a)
PCB & electronics design consultant with hundreds of in-depth video tutorials

Altium Academy (b)

Altium's official YT education channel

Forums

Official ST community forum (c)

ELECTRICAL ENGINEERING Electronics stack exchange (d)

In-person help

EPFL SPOT

Big thanks to Rafael, David & Leo

(a) https://www.phils-lab.net/
(b) https://www.youtube.com/@AltiumAcademy
(c) https://community.st.com/
(d) https://electronics.stackexchange.com/

Progress so far

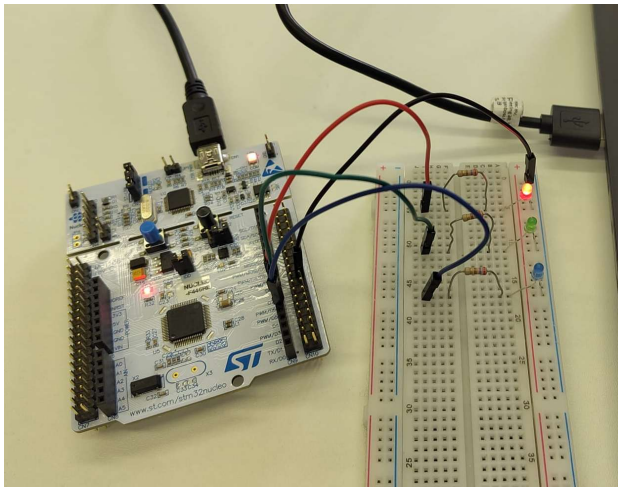
- Design
- List of improvement ideas for next iteration
- Extensive list of notes on conception process

- Assemble
- Test individual composants
- Shape improvement ideas and notes into a coherent tutorial

N-Pulse members

Demonstrations : UART communication

Goal : Use UART to command Nucleo Board (STM32) to switch LEDs on/off from PC



Setup

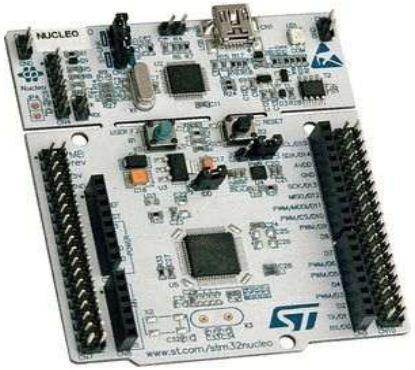
```
void HAL_UART_RxCpltCallback(UART_HandleTypeDef *huart)
{
    UNUSED(huart);
    // echo character first
    HAL_UART_Transmit(&huart2, rx_data, sizeof(rx_data), HAL_MAX_DELAY);

    if (rx_data[0] == 'R') {
        HAL_GPIO_WritePin(LED_R_GPIO_Port, LED_R_Pin, 1);
        HAL_GPIO_WritePin(LED_G_GPIO_Port, LED_G_Pin, 0);
        HAL_GPIO_WritePin(LED_B_GPIO_Port, LED_B_Pin, 0);
        HAL_UART_Transmit(&huart2, (uint8_t*)"ed\r\n", 4, HAL_MAX_DELAY);
    }
    else if (rx_data[0] == 'G') {
        HAL_GPIO_WritePin(LED_R_GPIO_Port, LED_R_Pin, 0);
        HAL_GPIO_WritePin(LED_G_GPIO_Port, LED_G_Pin, 1);
        HAL_GPIO_WritePin(LED_B_GPIO_Port, LED_B_Pin, 0);
        HAL_UART_Transmit(&huart2, (uint8_t*)"reen\r\n", 6, HAL_MAX_DELAY);

    }
    else if (rx_data[0] == 'B') {
        HAL_GPIO_WritePin(LED_R_GPIO_Port, LED_R_Pin, 0);
        HAL_GPIO_WritePin(LED_G_GPIO_Port, LED_G_Pin, 0);
        HAL_GPIO_WritePin(LED_B_GPIO_Port, LED_B_Pin, 1);
        HAL_UART_Transmit(&huart2, (uint8_t*)"lue\r\n", 5, HAL_MAX_DELAY);

    }
```

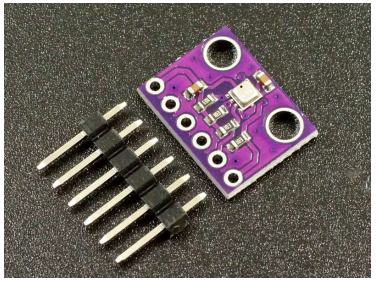
Code snippet : using interrupt callbacks to command LEDs in non-blocking way (in STM32CubeIDE)



ST Nucleo F446RE board (6)

Demonstrations : SPI communication with BME280 sensor

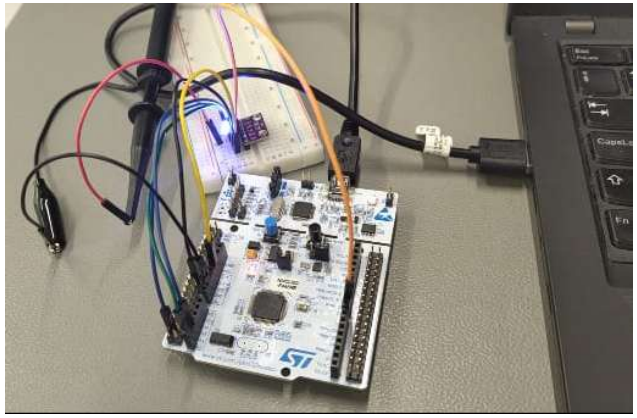
Goal : Use SPI to read from sensor & transmit it by UART to computer



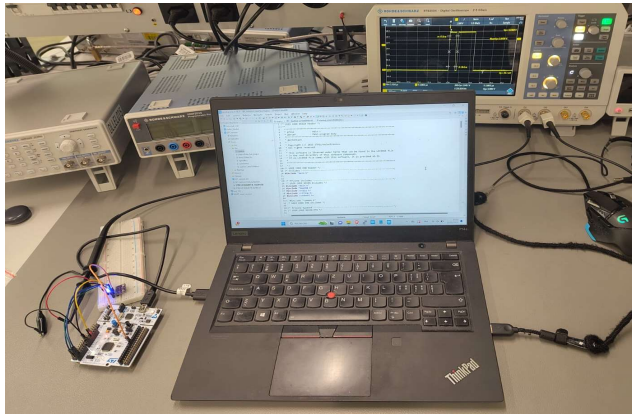
(7)

GY-BME280 temperature, humidity & pressure sensor

Unable to start comms :
init function return code = -4 (DEVICE NOT FOUND)



Setup



Setup with oscilloscope to check signals

Demonstrations : SPI communication with BME280 sensor

Sending command «read data in register»
0xF7 = 11110111

Recieve some signal. Yet not able to understand it. Also continues to receive even when MOSI is disconnected

Bug cause not found ☹

References

Images

(1) https://wearables.com/products/myo
(2) https://www.curtisbarbre.com/ctrl-kit
(3) https://www.analogictips.com/matching-service-optimizes-gsm-900-wifi-bluetooth-gps-gnss-zigbee-4g-lte-antenna-placement/
(4) https://www.te.com/en/product-L9000097-01.html
(5) https://en.wikipedia.org/wiki/Pin_header#/media/File:Jumper_on_motherboard.jpg
(6) https://media.distrelec.com/Web/WebShopImages/portrait_medium/23/3f/st-nucleo-30009233f.jpg
(7) https://protosupplies.com/product/gy-bme280-pressure-humidity-temperature-sensor-module/
(8) https://cdn.myportfolio.com/645ef5b2f82fdeaf819364ecd9d55d6c/249fac0f-5e46-40cb-a0d7-fa4df5d45ae8_car_4x3.jpg?h=e5b7b4d92b4ce4867a731d0a88e68f27

References

Papers

[1] A. Mongardi *et al*., "Hand Gestures Recognition for Human-Machine Interfaces: A Low-Power Bio-Inspired Armband," in *IEEE Transactions on Biomedical Circuits and Systems*, vol. 16, no. 6, pp. 1348-1365, Dec. 2022, doi: 10.1109/TBCAS.2022.3211424.

[2] F. Rossi, A. Mongardi, P. M. Ros, M. R. Roch, M. Martina and D. Demarchi, "Tutorial: A Versatile Bio-Inspired System for Processing and Transmission of Muhttps://cdn.myportfolio.com/645ef5b2f82fdeaf819364ecd9d55d6c/249fac0f-5e46-40cb-a0d7-fa4df5d45ae8_car_4x3.jpg?h=e5b7b4d92b4ce4867a731d0a88e68f27scular Information," in *IEEE Sensors Journal*, vol. 21, no. 20, pp. 22285-22303, 15 Oct.15, 2021, doi: 10.1109/JSEN.2021.3103608.

[3] Kalbasi, Mohammad & Shaeri, Mohammad & Mendez, Vincent & Shokur, Solaiman & Micera, Silvestro & Shoaran, Mahsa. (2024). A Hardware-Efficient EMG Decoder with an Attractor-based Neural Network for Next-Generation Hand Prostheses. 10.48550/arXiv.2405.20052.

[4] A. Ameri, M. A. Akhaee, E. Scheme, and K. Englehart, ”Regression convolutional neural network for improved simultaneous EMG control,”
Journal of Neural Engineering, vol. 16, no. 3, 2019, Art. no. 036015.

Questions

Thank you for listening

Questions ?