Recovery-Monitoring Knee Brace

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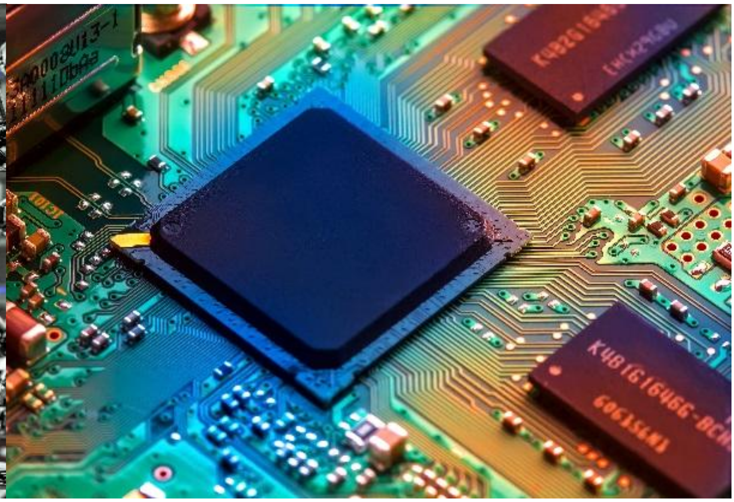
ECE 445 Fall 2017



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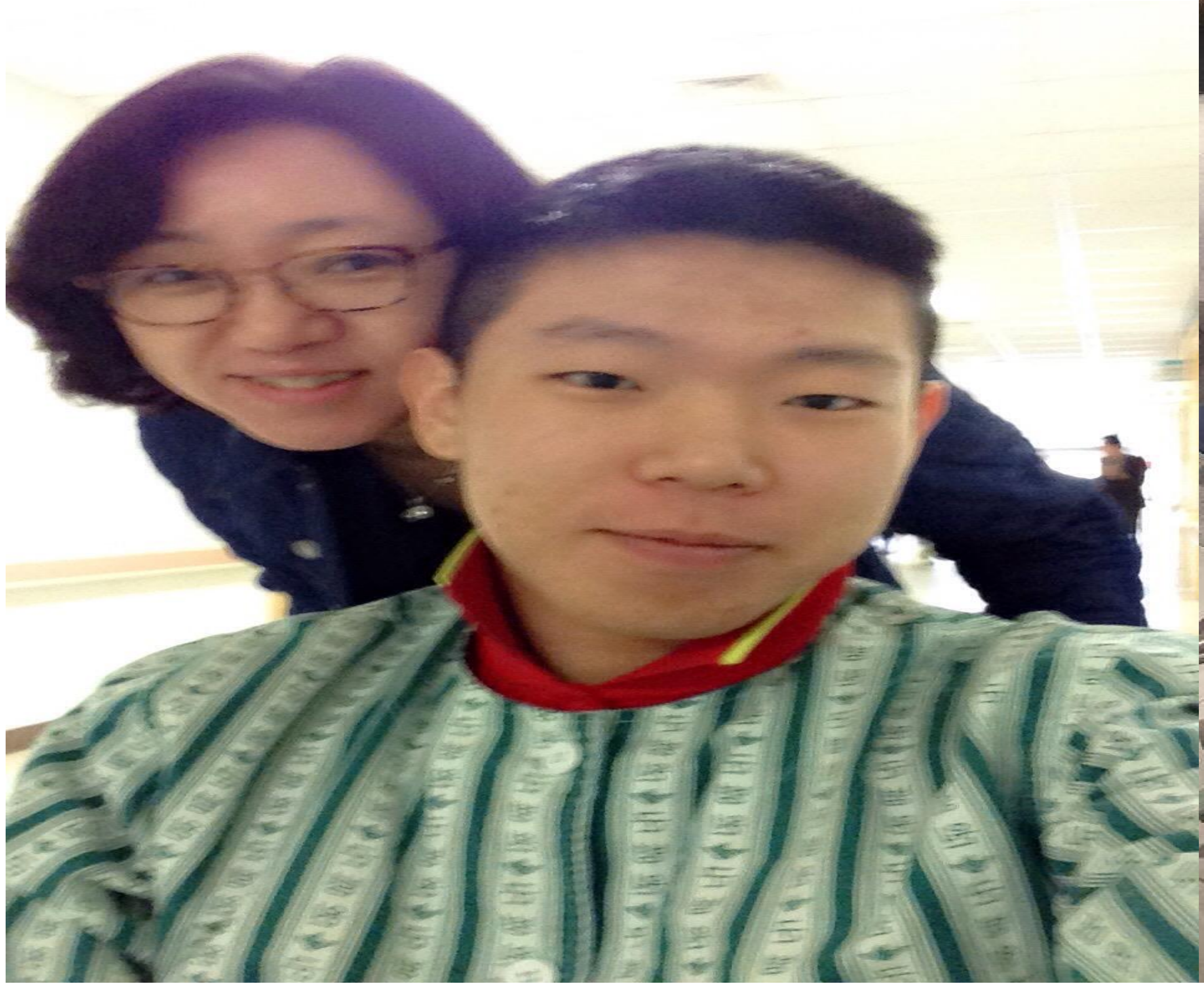
Story Behind



Anterior Cruciate Ligament Injury

- “In the United States there are between 100,000 and 200,000 ACL ruptures per year, with an annual incidence in the general population of approximately 1 in 3500…”

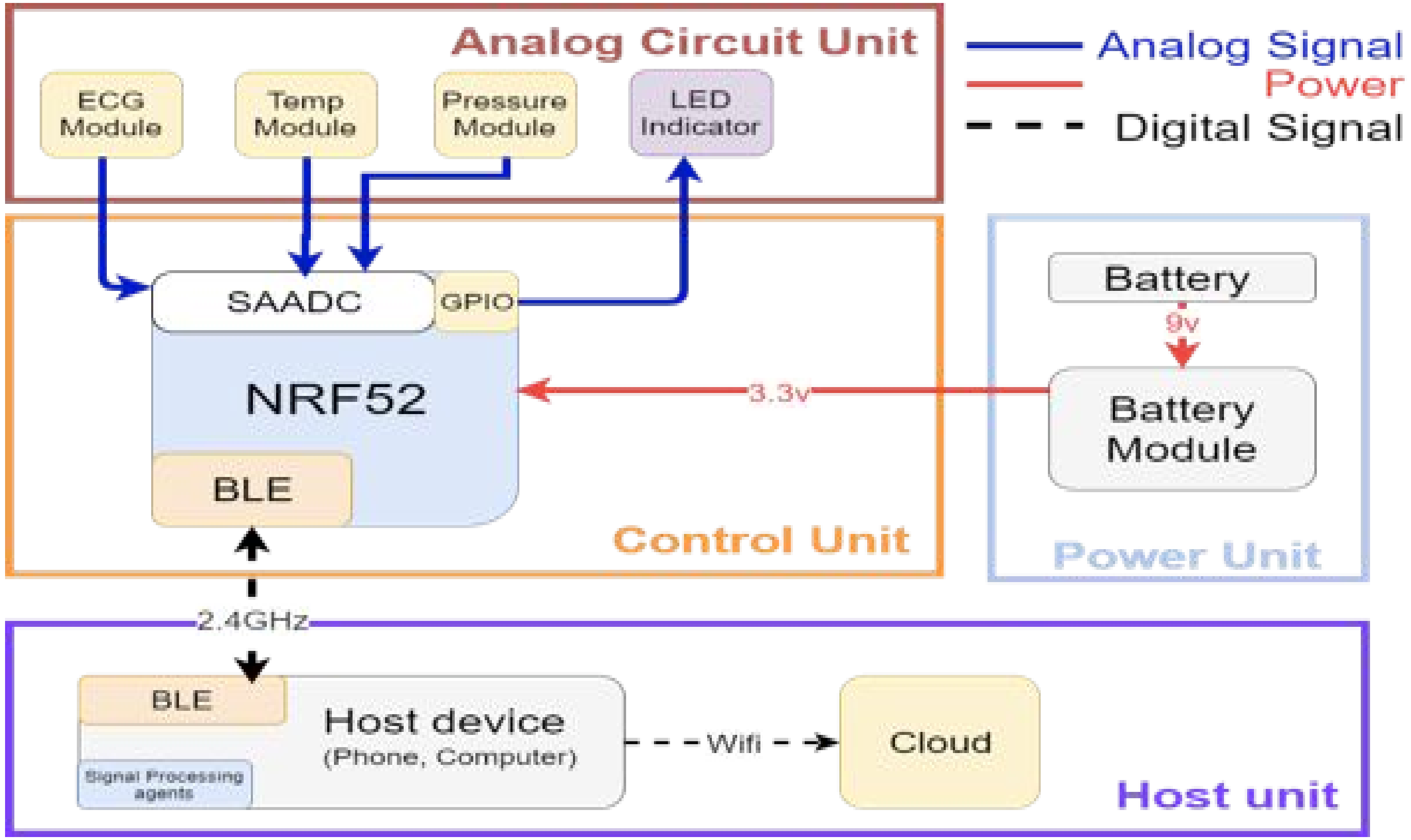
Introduction

- Assist patients in the recovery stage
- Provide feedback so both doctors and patients can keep track of the progress

Objective

- Notify user about maintaining secure fit
- To help refrain from excessive leg use
- Monitor injury via swelling

Block Diagram

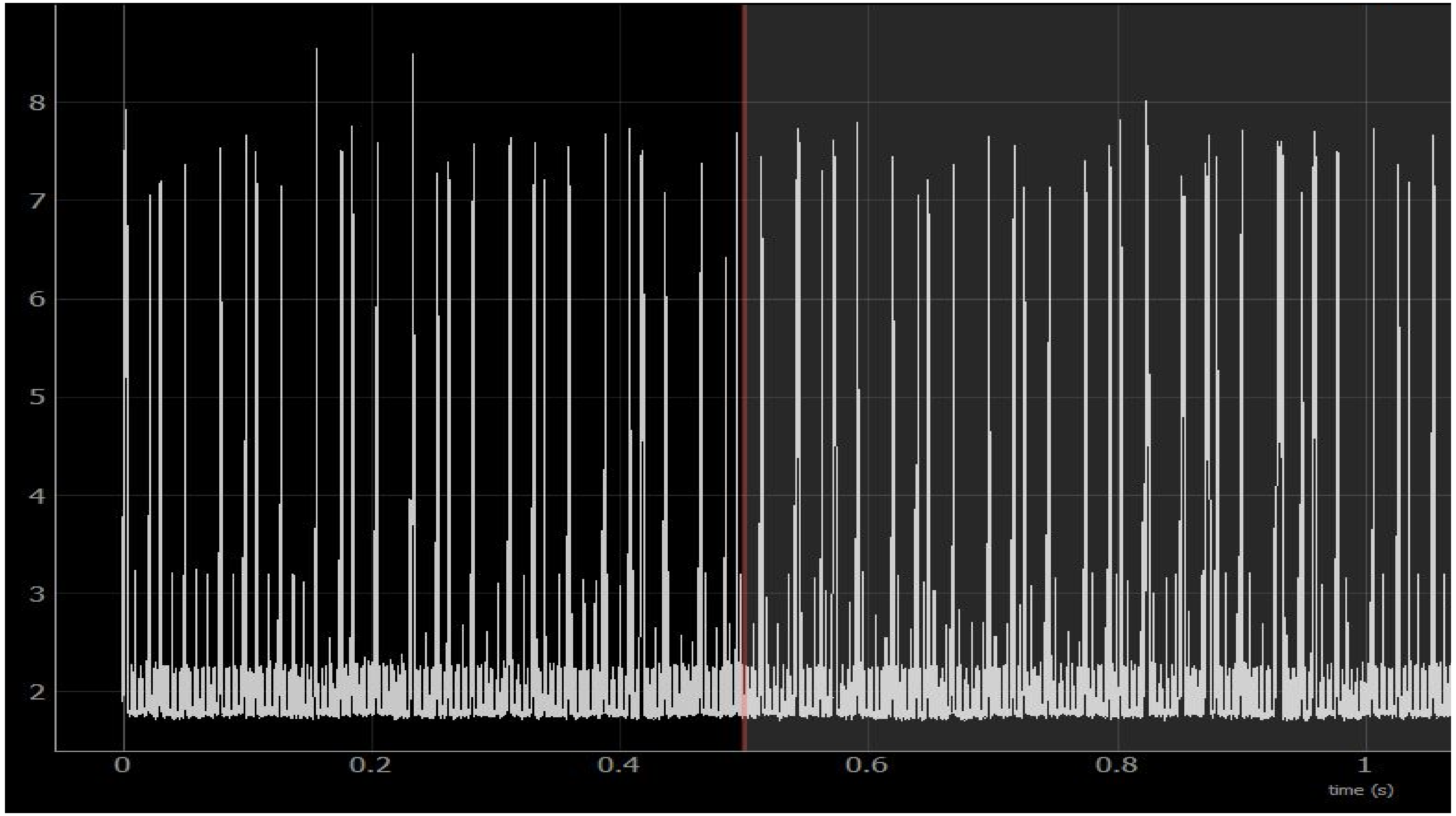


ECG: Electrocardiography
SAADC: Successive Approximation A/D Converter
GPIO: General-purpose input/output
NRF52: Name of our microcontroller
BLE: Bluetooth Low Energy

Micro Controller - NRF52

- Bluetooth low energy SoC
- ADC
- Timer
- GPIO

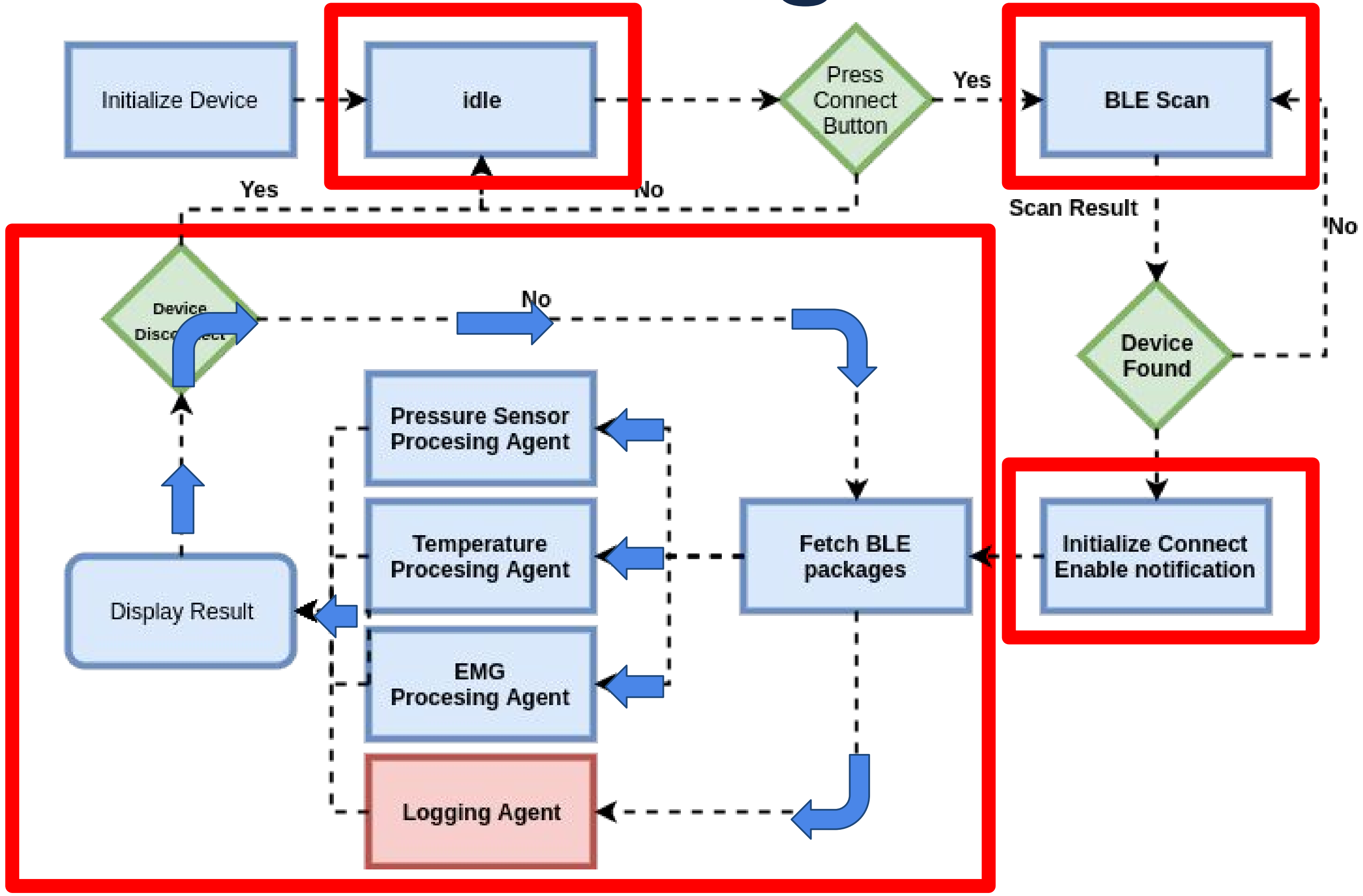
Power Test



Active : 2.11 mA

Passive: 25 uA

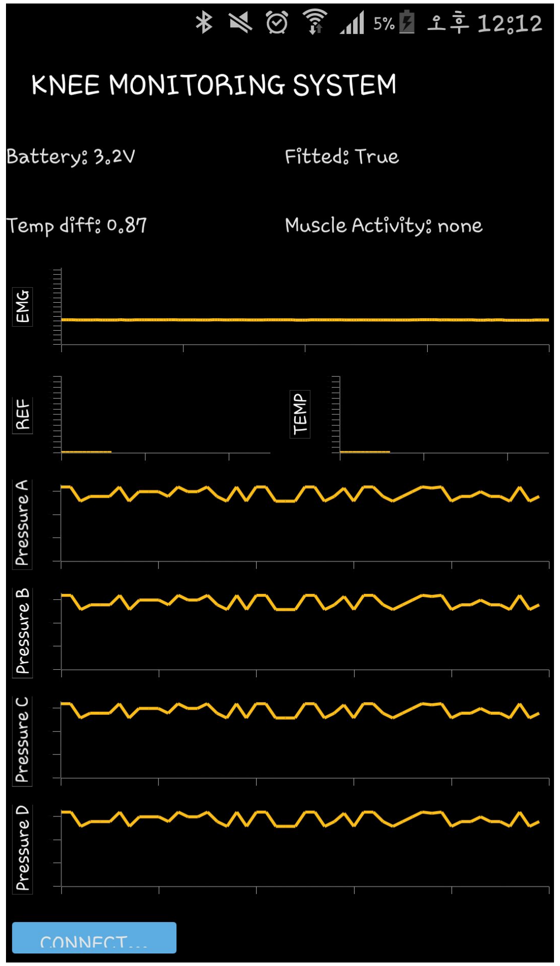
Host Software Diagram



Host User Interface

PC Tablet

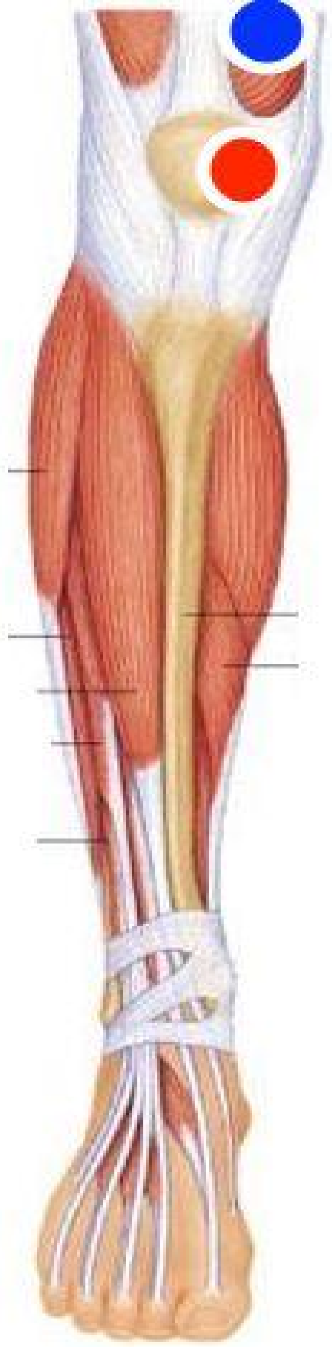
Phone App



Temperature Sensor

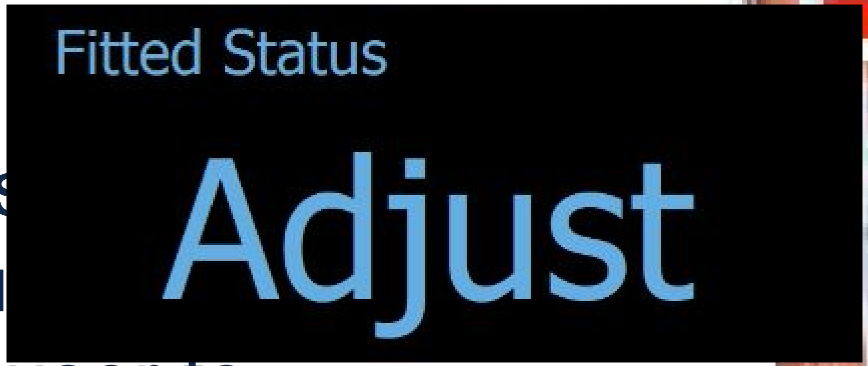
- Red: Knee Temperature
- Blue: Reference Temperature

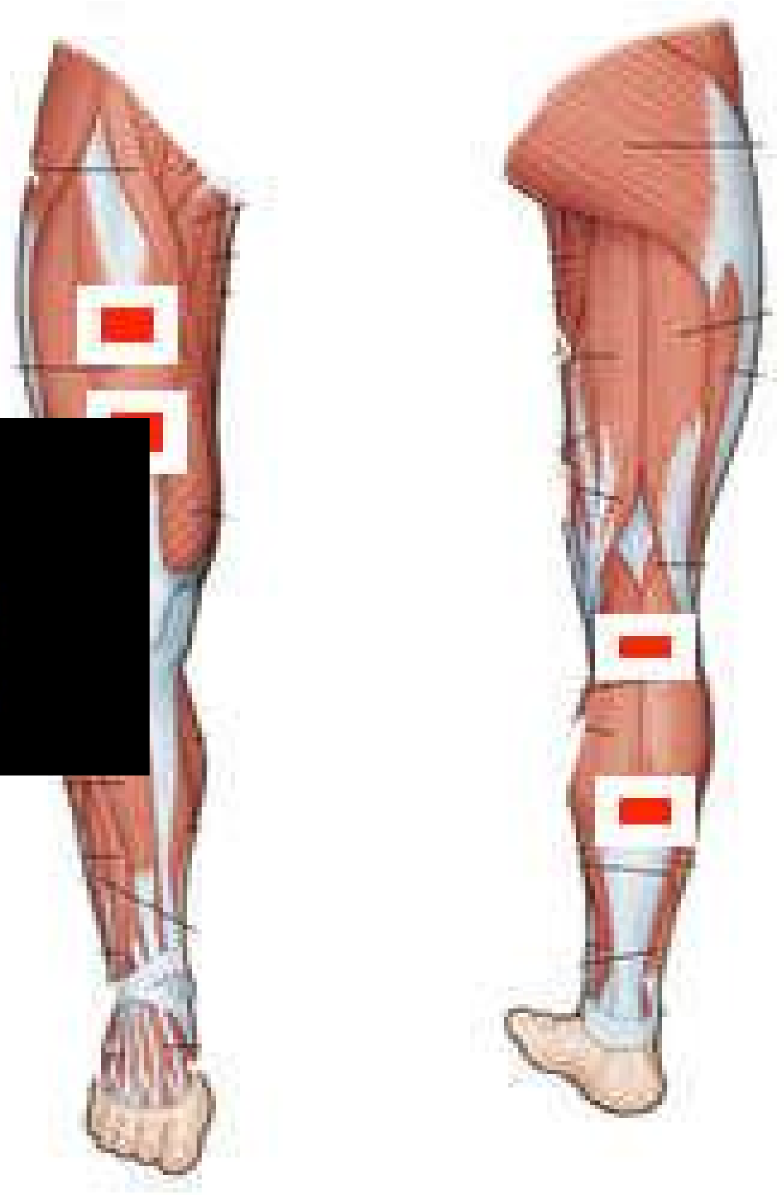
- Compare Reference to Knee temperature to determine swelling.



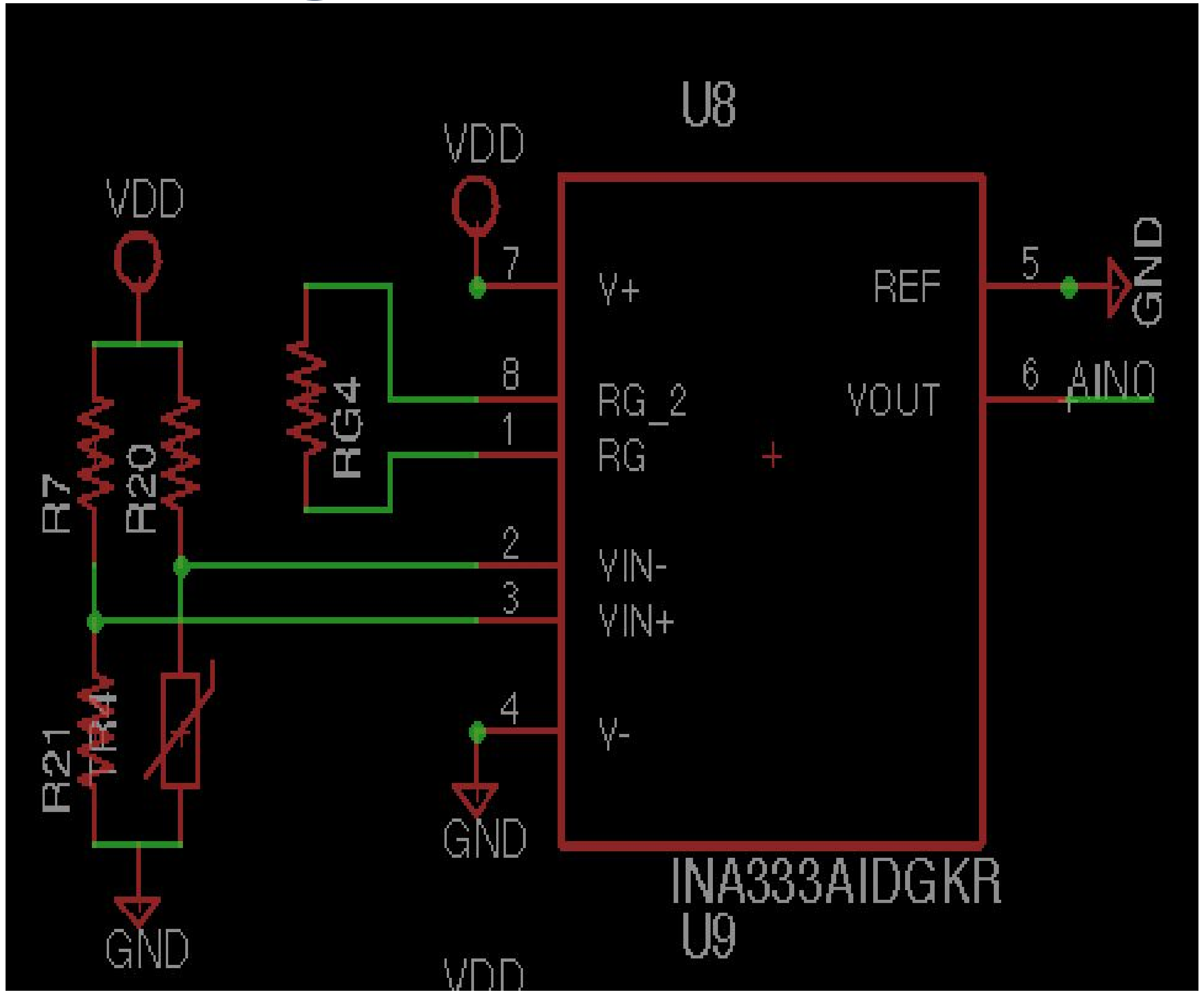
Pressure Sensor

- Attached Pressure sensor under the strap.
- When one of the press
sensor voltage goes u
threshold voltage, tell user to
adjust the strap.





Design: Temperature/Pressure Sensor



- Bridge Circuit Implementation Using Resistance sensor.

$$V_{out} = V_{in}\left(\frac{R_7}{R_{21} + R_7} - \frac{R_{sensor}}{R_{20} + R_{sensor}}\right)$$

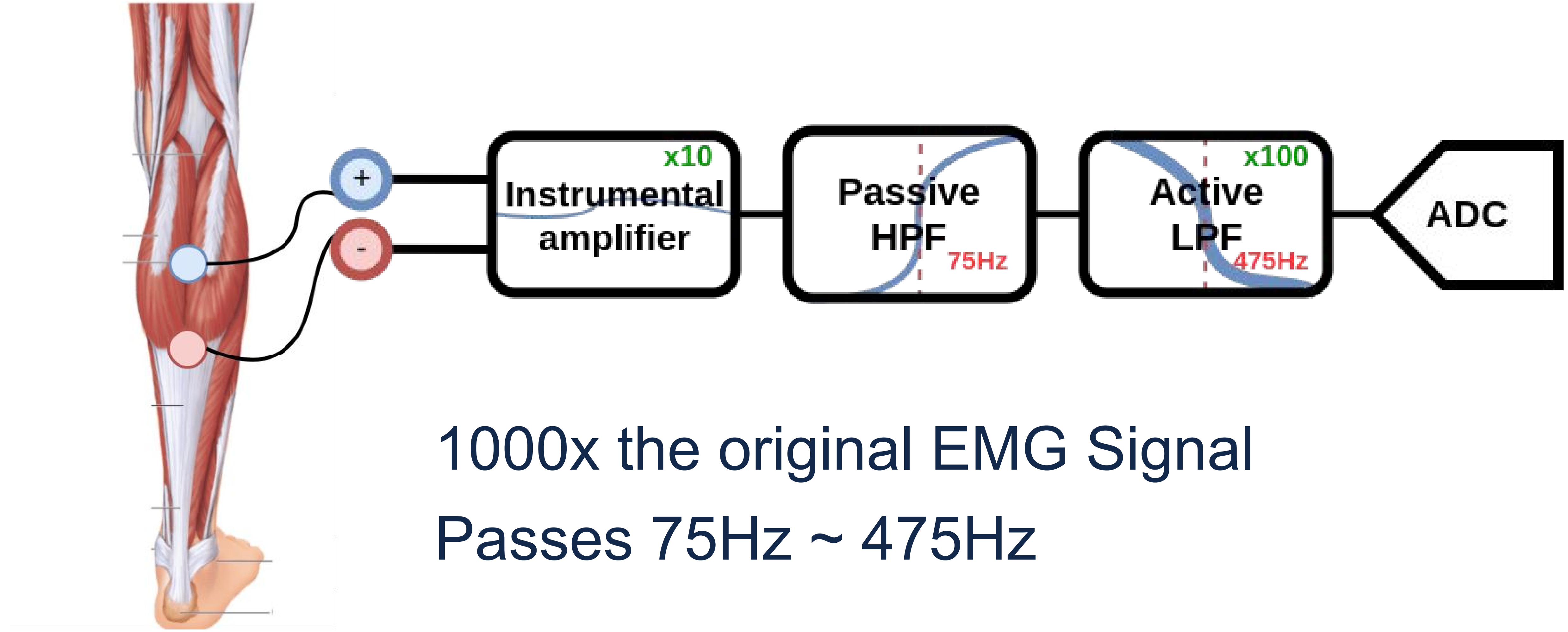
Why Bridge Circuit

- Easily find unknown resistance using different resistor values that are precisely chosen.
- Distribute current to each resistor
  - can prevent excessive current flow into sensor
  - stabilizes the heat increase.

Electromyography (EMG)

- Muscle generate electric potential when muscle cells are physically and neurologically activated.
- Techniques that captures and evaluates these muscle cells' signal.

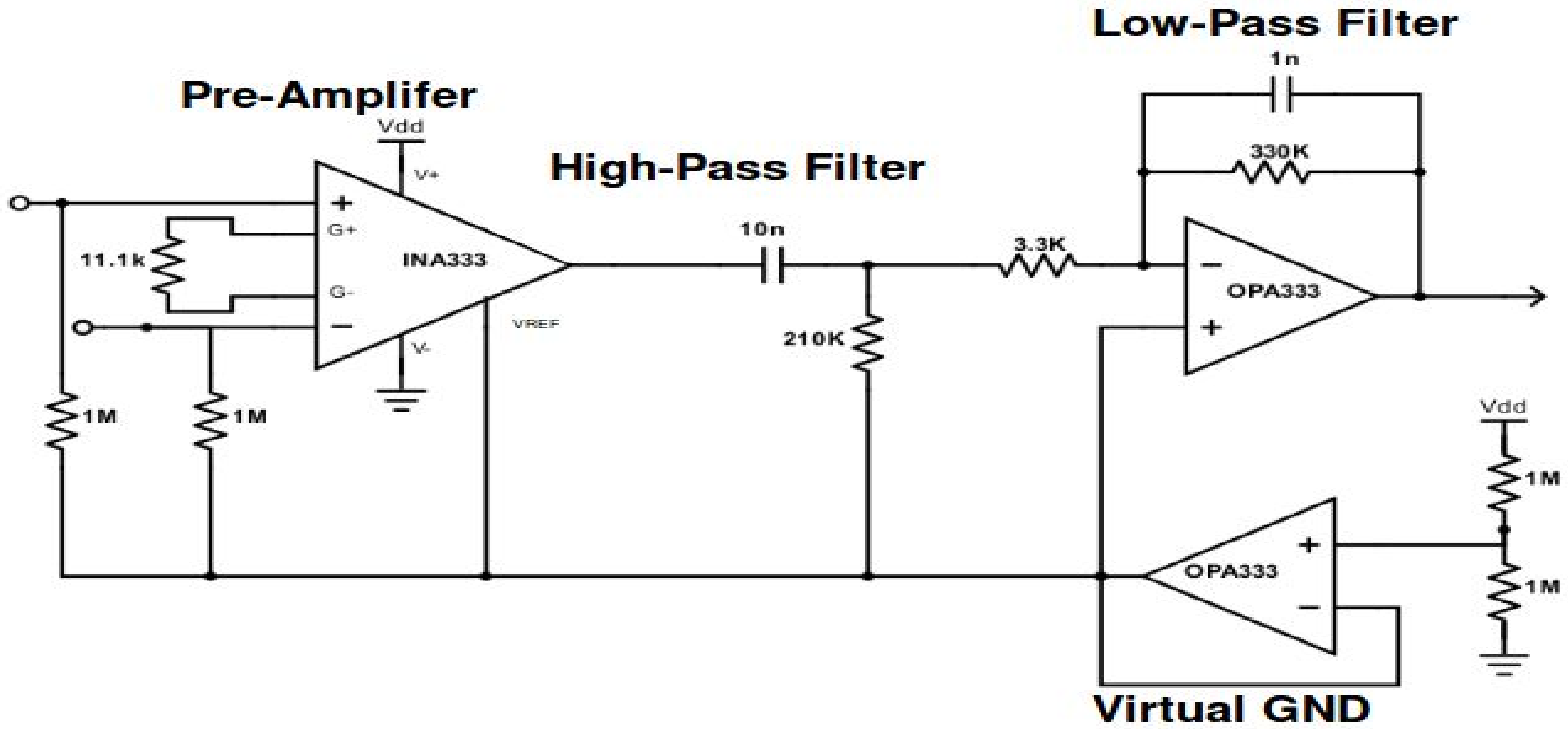
EMG Sensor



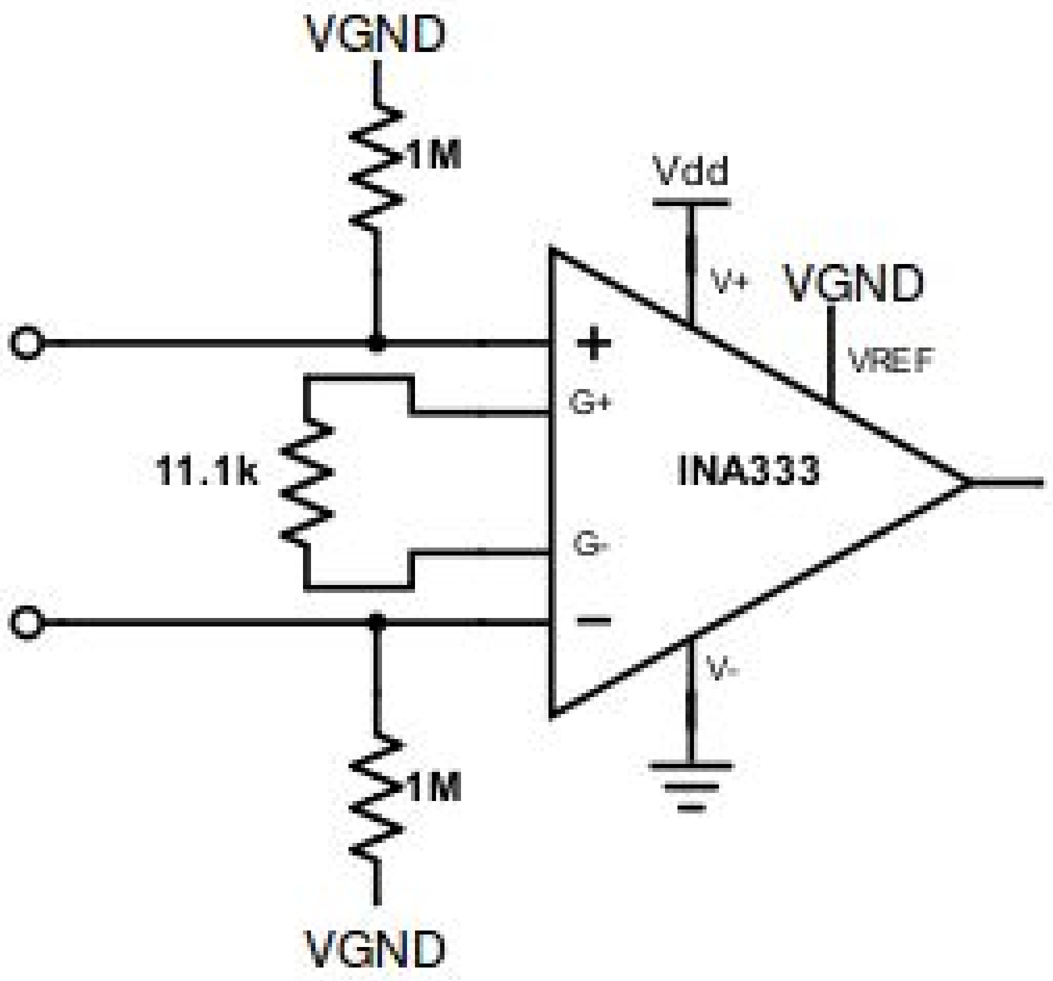
1000x the original EMG Signal

Passes 75Hz ~ 475Hz

EMG Sensor: Circuit



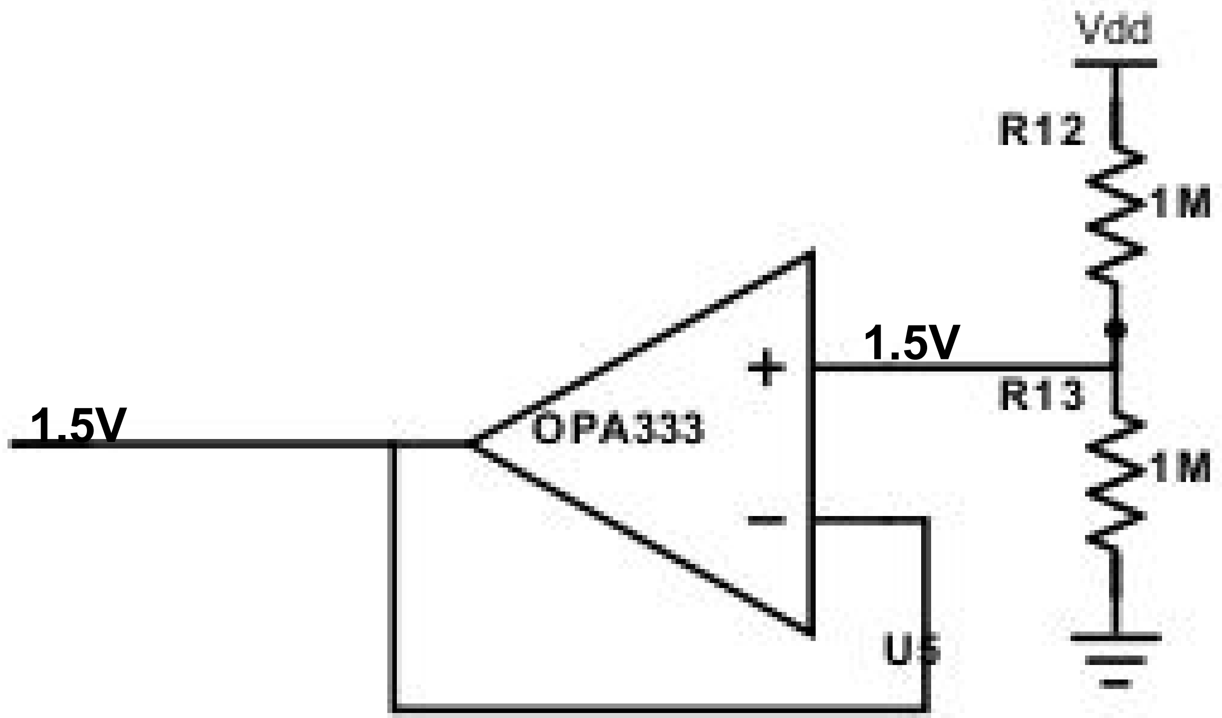
EMG Sensor: Circuit



- Pre-amplify the circuit, maintaining stability

$$G = 1 + (100k\Omega / R_G)$$

EMG Sensor: Circuit

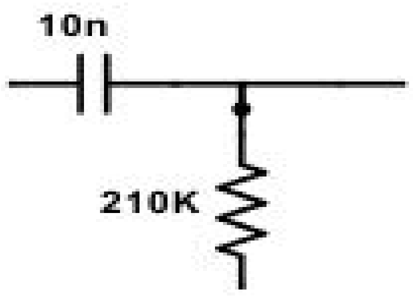


- Provide Stable Virtual Ground
  - High impedance

$$V_{out} = V_{in}$$

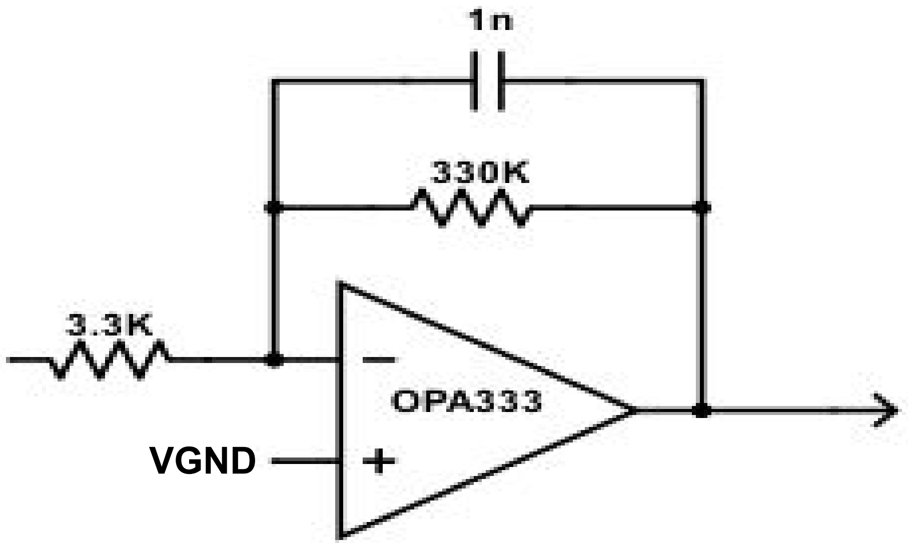
EMG Sensor: Circuit

Passive HPF



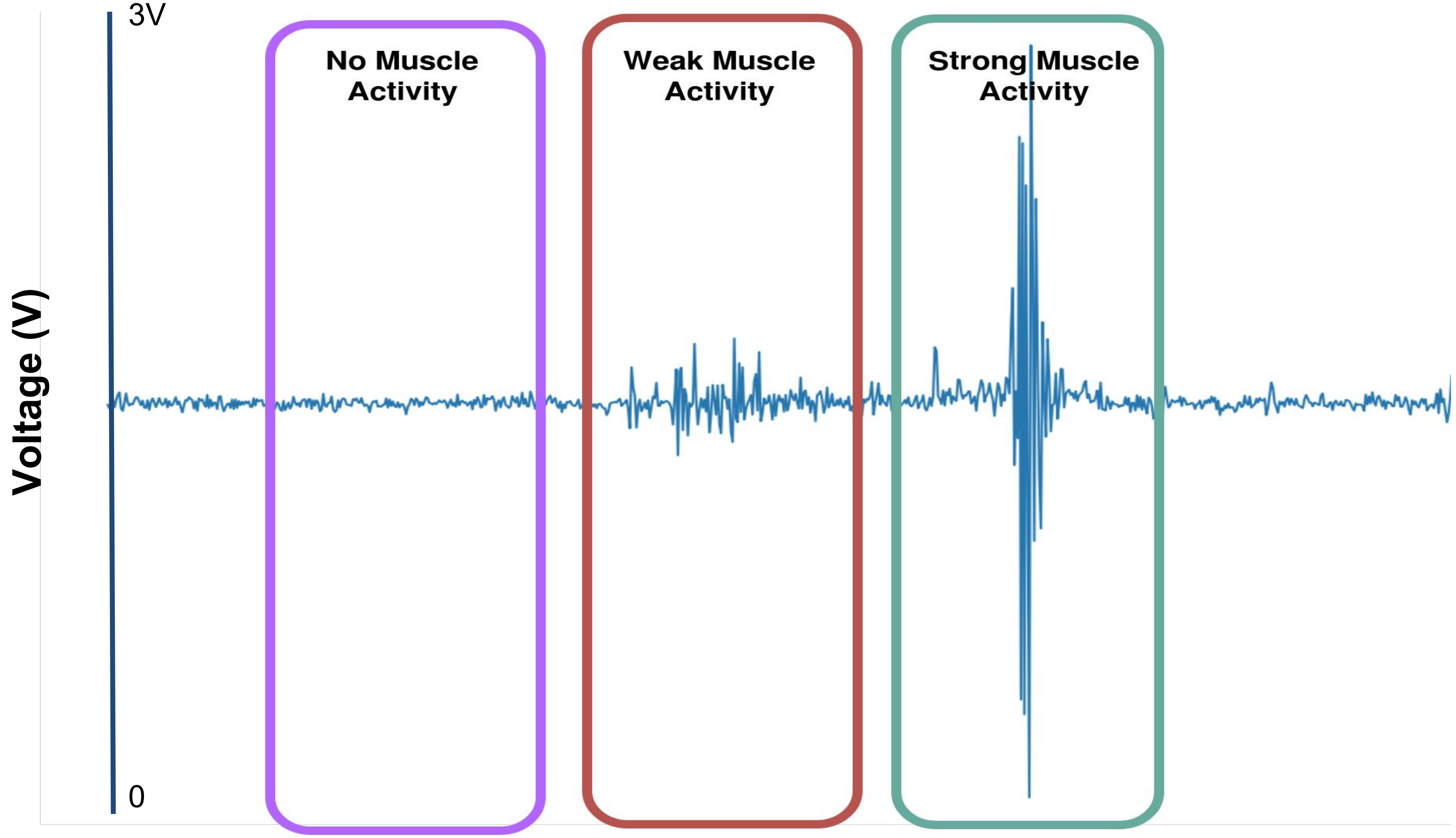
$$f_c = \frac{1}{2\pi CR} hertz$$

Active LPF



$$gain = -\frac{R_2}{R_1}$$

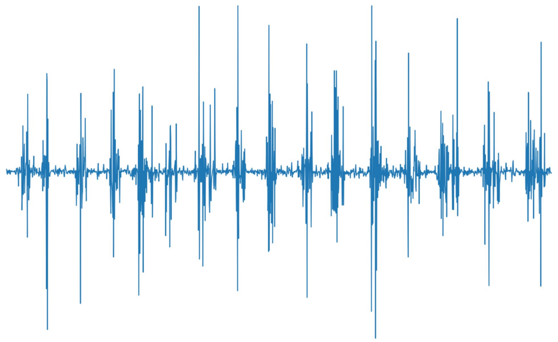
EMG Sensor: Signal Processing Goal

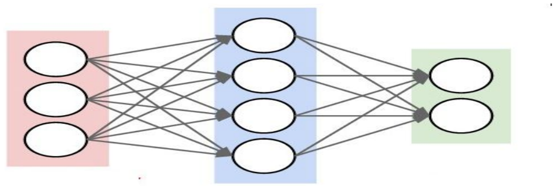


- Detect different types of Muscle movements
- Provide doctors with history of patients activities

EMG Sensor: Signal Processing 1

Nueral Network





- Strong Muscle Activity
- Weak Muscle Activity
- No Muscle Activity

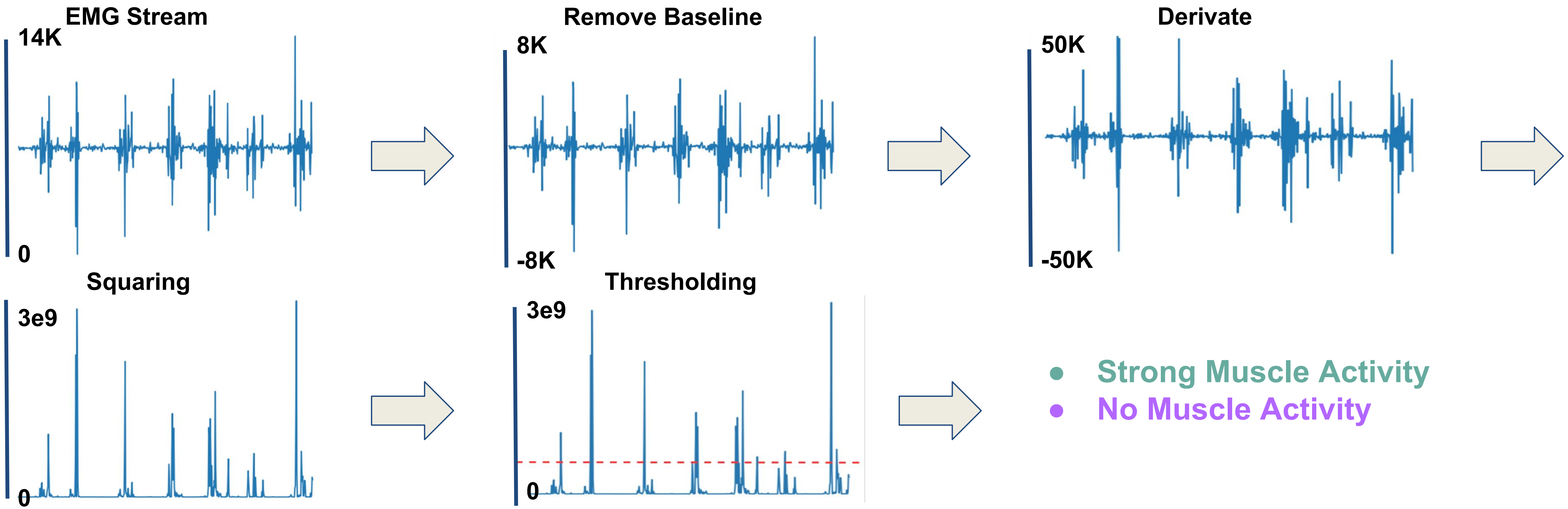
200 data points

3 Layers
4 Width

3 Labels

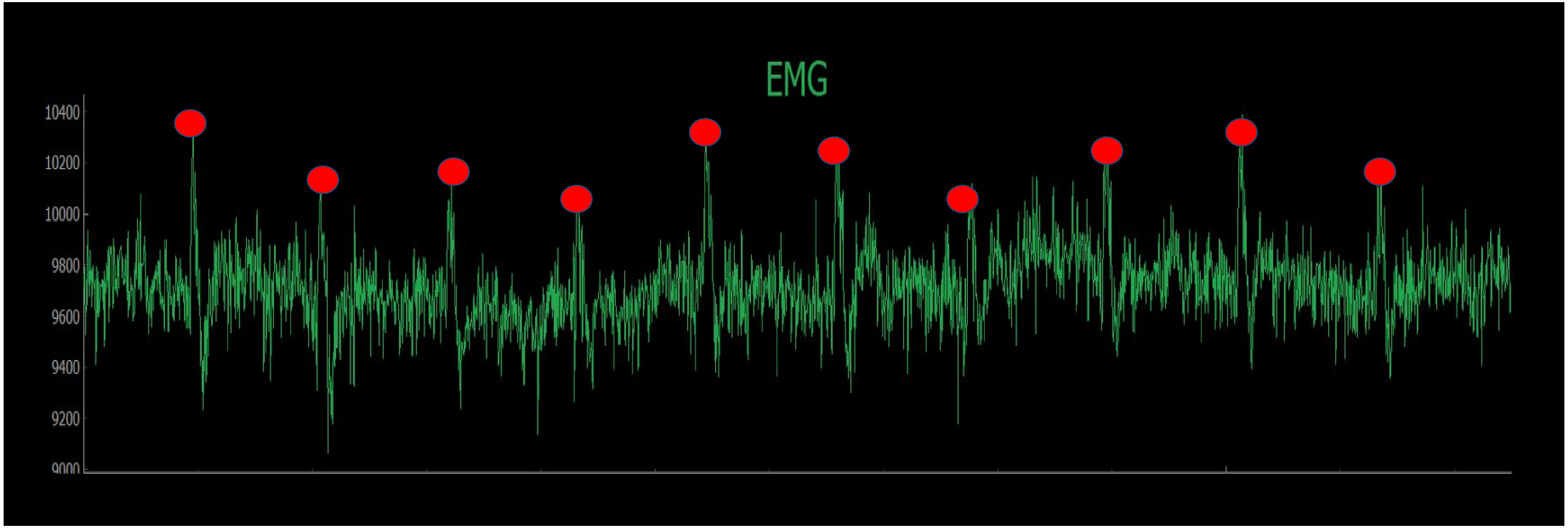
EMG Sensor: Signal Processing 2

Digital Signal Processing

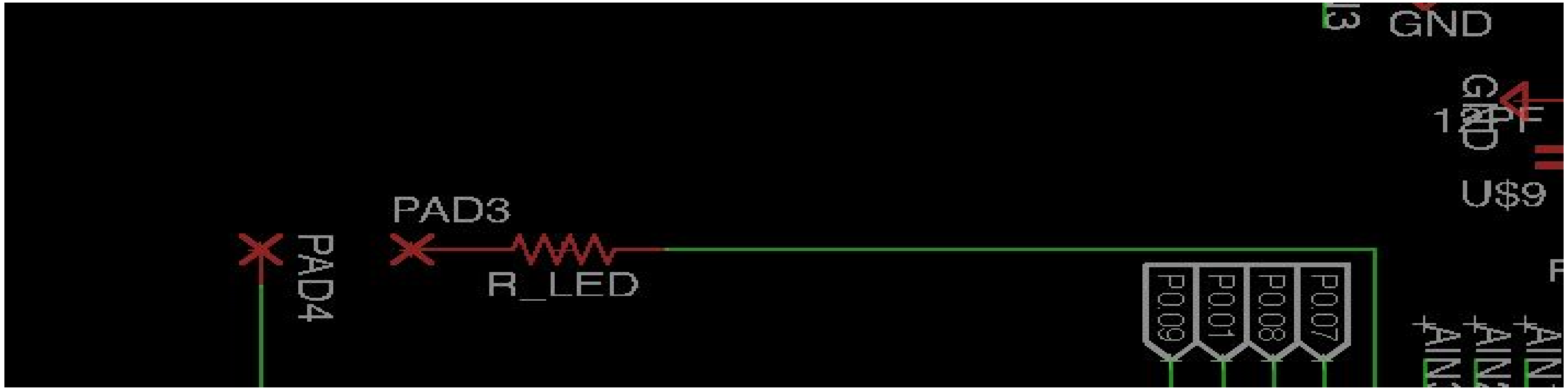


- Strong Muscle Activity
- No Muscle Activity

EMG Sensor: ECG?

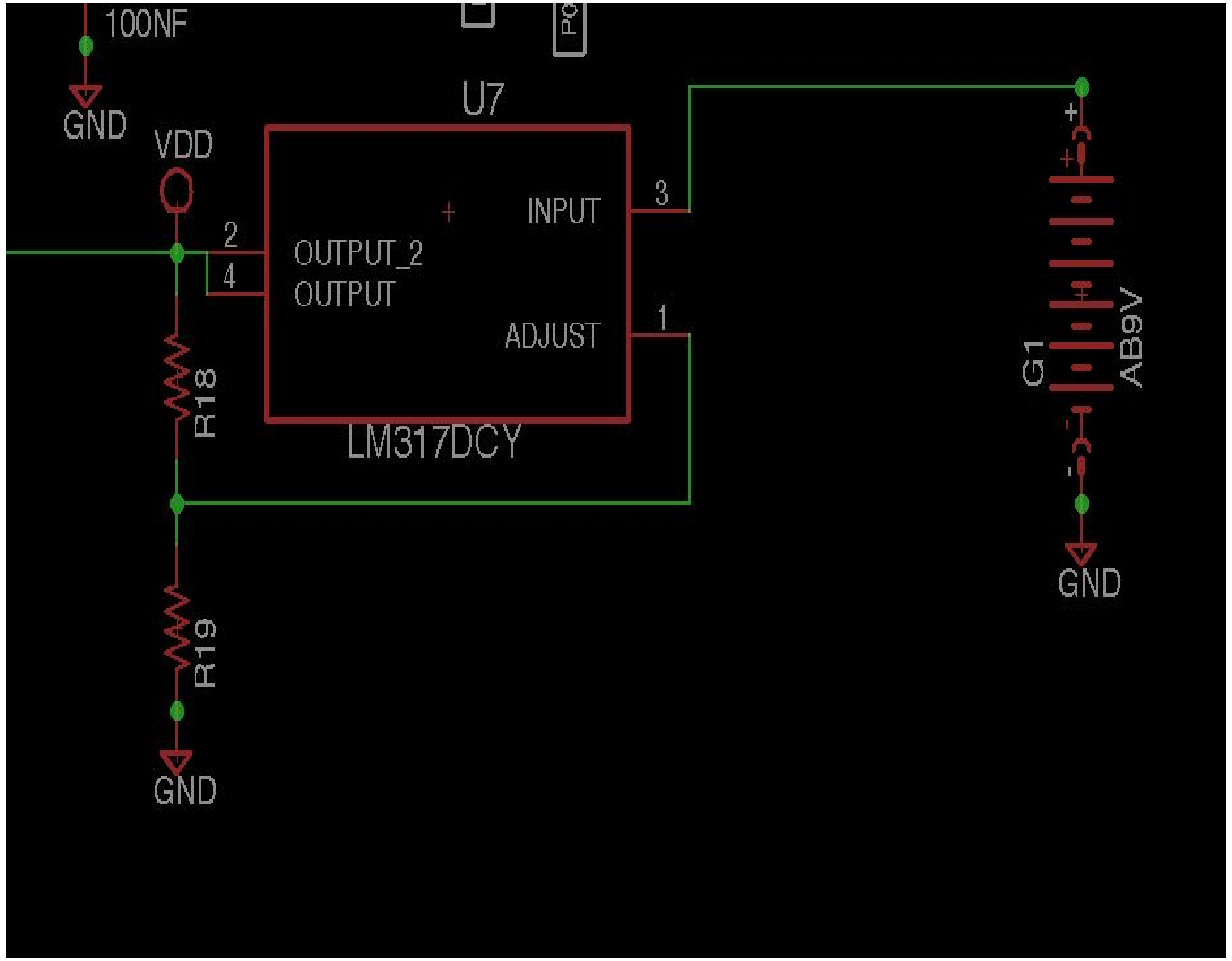


Design: LED Circuit



- nRF52 controls the duty cycle of the LED to ensure that the device is connected into the HOST device via bluetooth.

Design: Power Circuit

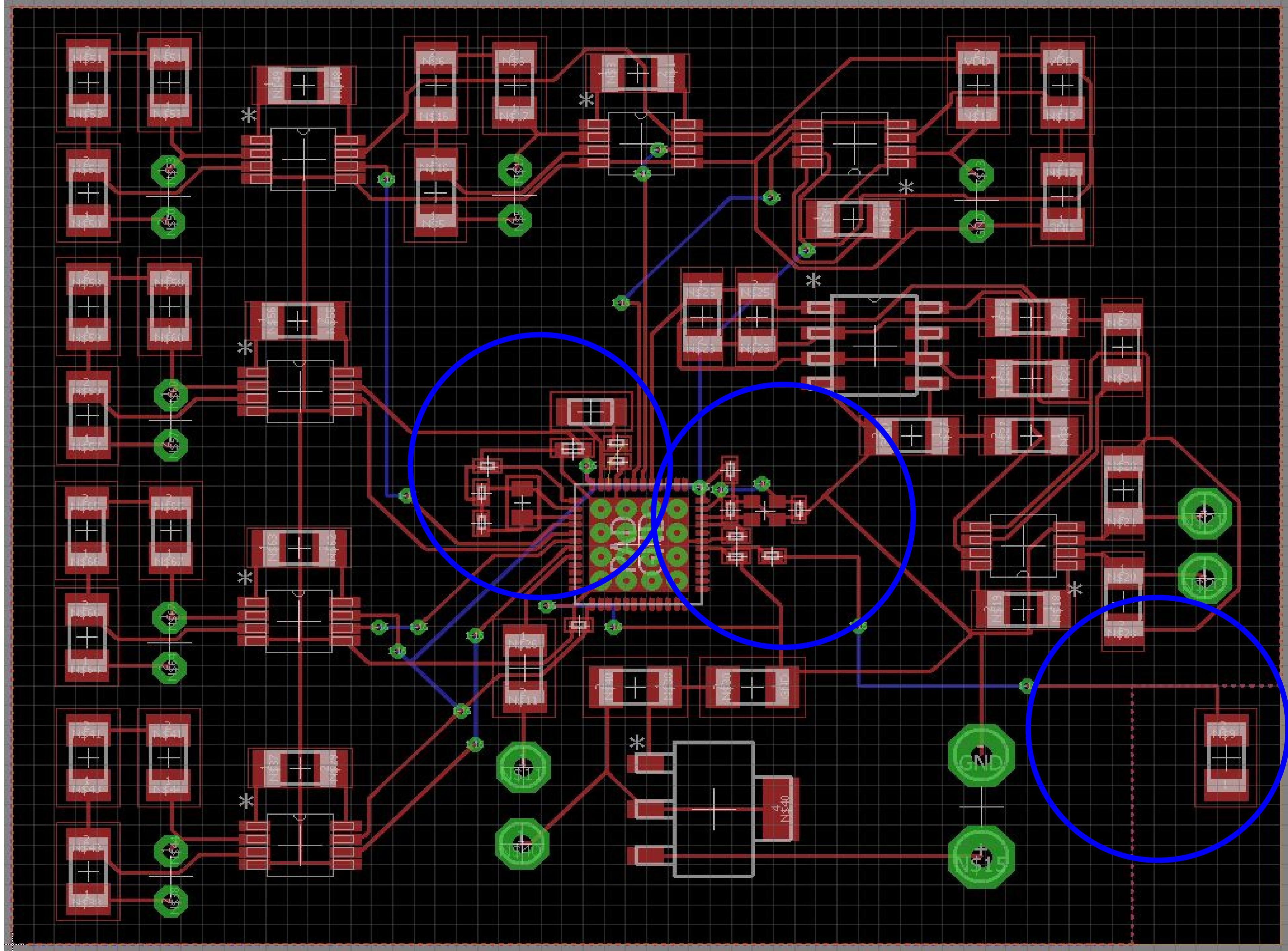


- Simple voltage regulator circuit using LM317 chip.

$$V_{out} = V_{REF}\left(1 + \frac{R_2}{R_1}\right) - 10V$$

Try & Error

- Unstable crystal and antenna location
- Nordic provided reference PCB layout for nRF52



Conclusion

- EMG sensors distinguish between different usage strengths
- Pressure sensors work together to provide feedback
- Use difference in temperature to assess swelling
- Post signal processing using captured bio-signals

Future Directions

- Mount on a flexible substrate for better aesthetic appeal
- Optimize circuitry/sensors for ideal signal output
  → choose different parts?
- Expand implemented system into other medical usage → arm, back, neck or any other body parts which need protection