Team HeartRestart

ECE 445 Team 27

FA 25

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In one year alone, 436,000 Americans die from a cardiac arrest.

- Globally, cardiac arrest claims more lives than colorectal cancer, breast cancer, prostate cancer, influenza, pneumonia, auto accidents, HIV, firearms, and house fires combined.

More than 350,000 cardiac arrests occur outside of the hospital each year.

- Half of all US workers cannot locate an AED at work.
- In the hospitality industry, 66 percent of employees cannot locate an AED.

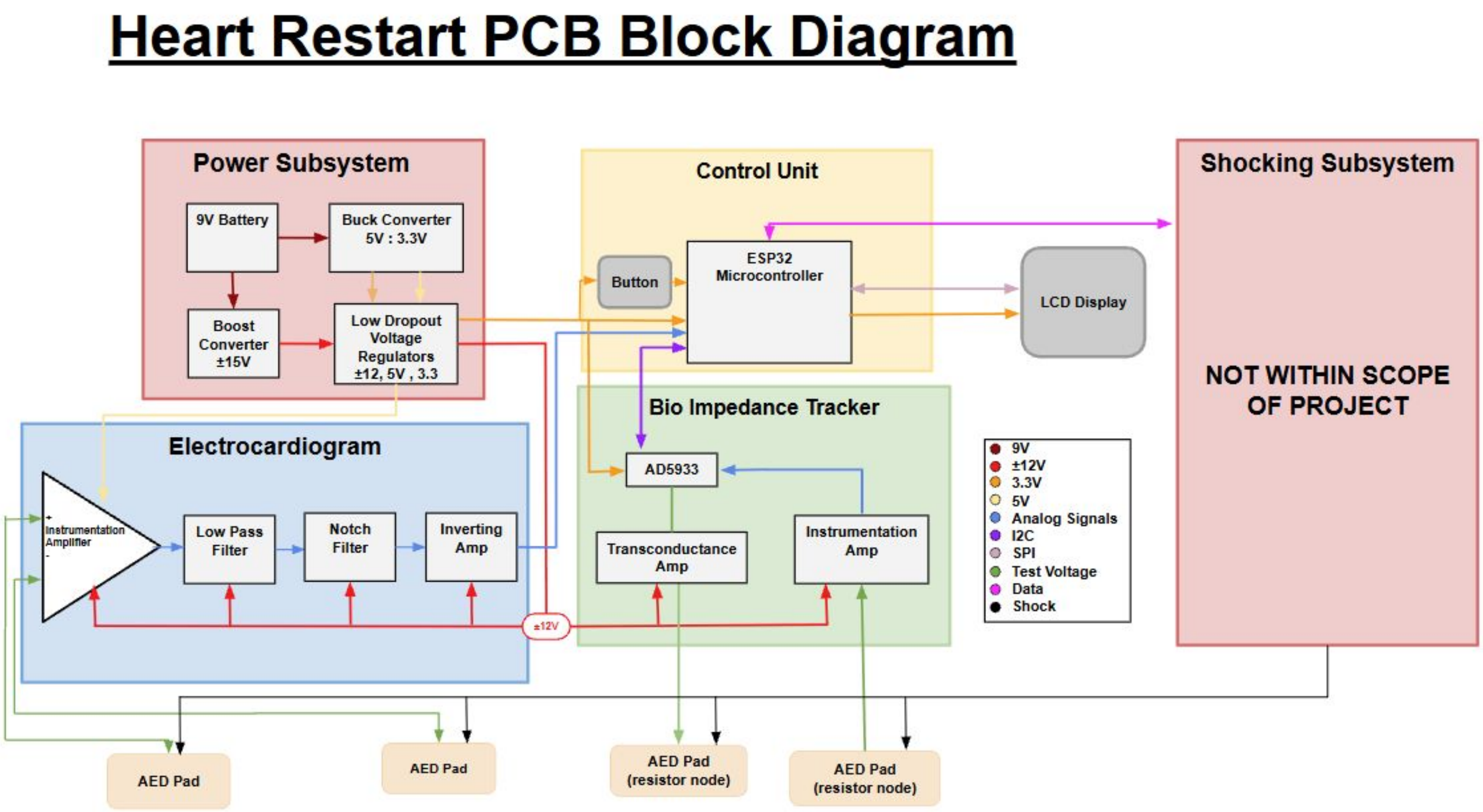
Survival Rate of One Shock: 13.3%

- Most defibrillators **lack** impedance sensing
  - Bulky and expensive with sensing
- Only one defibrillator in ambulances

Survival Rate of Two Shocks: 30.4%

- Double Sequential External Defibrillators (DSED)
  - Shocks **twice** in sequence milliseconds apart
- Implement impedance sensing in a **single** unit
- Allow ambulances administer double shock

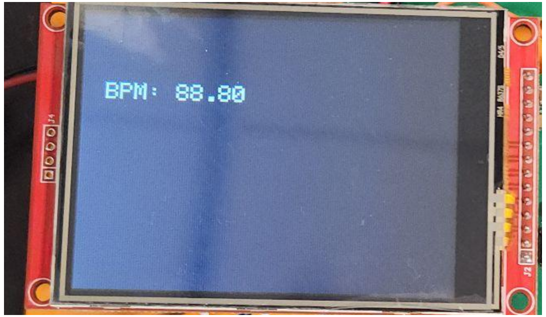
Block Diagram

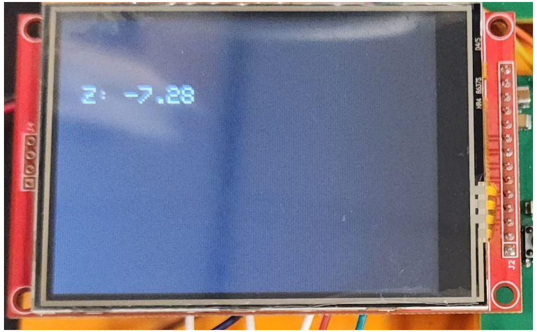


Impedance Accuracy: ±5%

Heart Rate Accuracy: ±2%

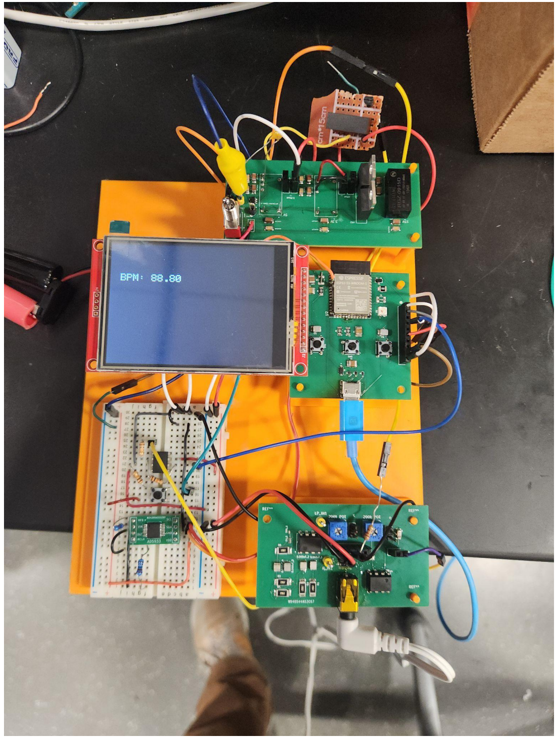
Display patient impedance & heart rate on an LCD screen (240 x 320 Pixels) @ 1Hz



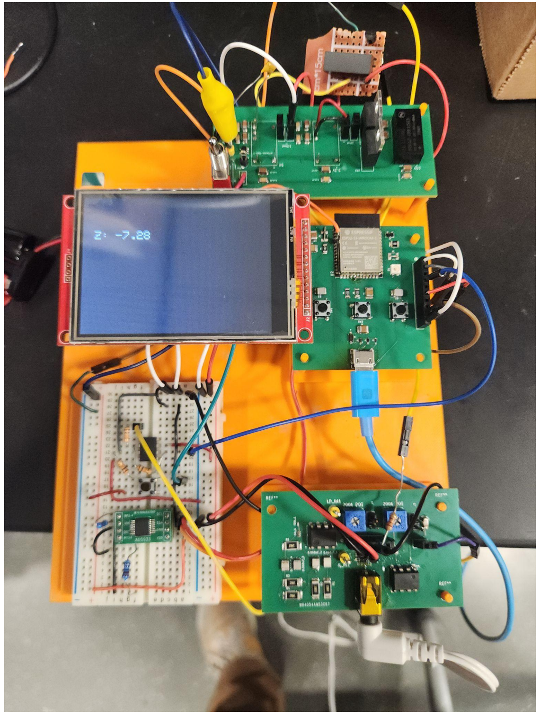


Final Design

ECG Mode



Impedance Mode



Power Distribution Board

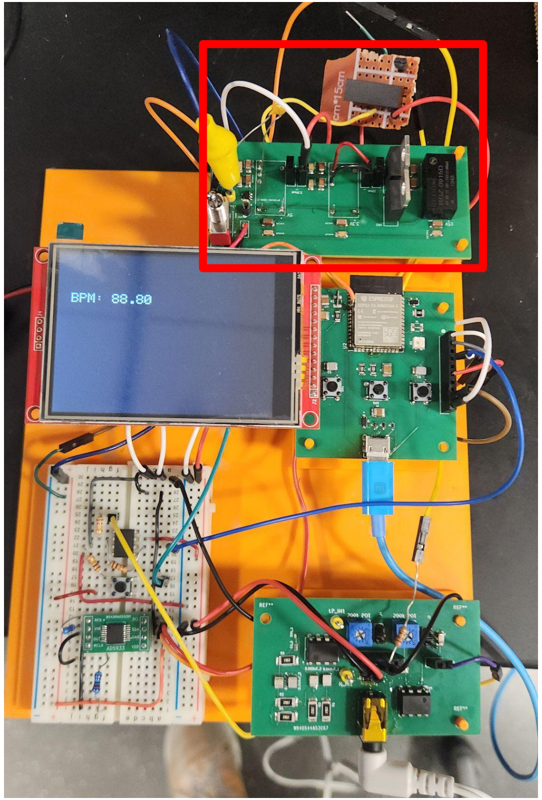
Goal: Supply adequate power to the microcontroller and sensors

Execution:

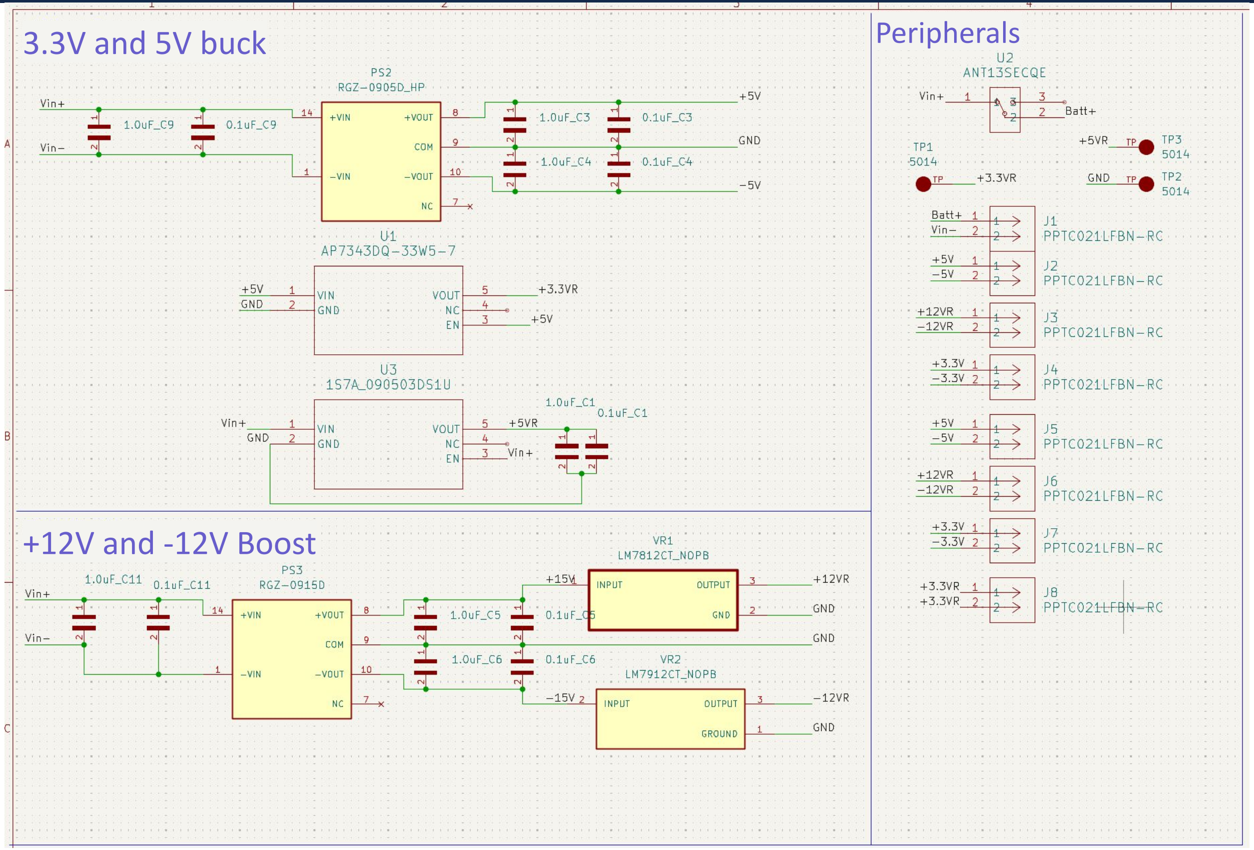
- Step-down converters
- Tailored to ESP32 microcontroller
- All power from standard 9 V battery

<u>Subsystem Requirement:</u>

- Supply 3.3 V and 0.5 A to microcontroller
- Supply power to active components in sensors



Power Schematic



ECG Module

Electrocardiogram Sensor

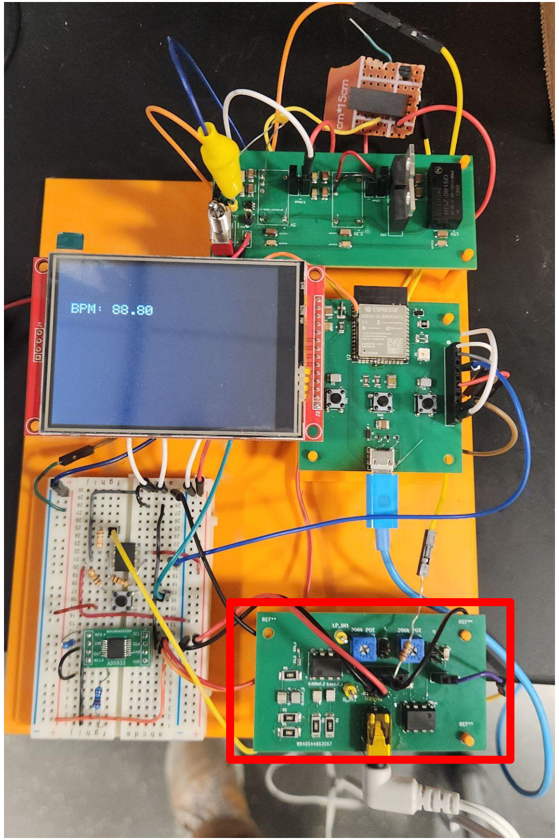
Goal: Measure Patient's Heart Rate and send information to microcontroller

Execution:

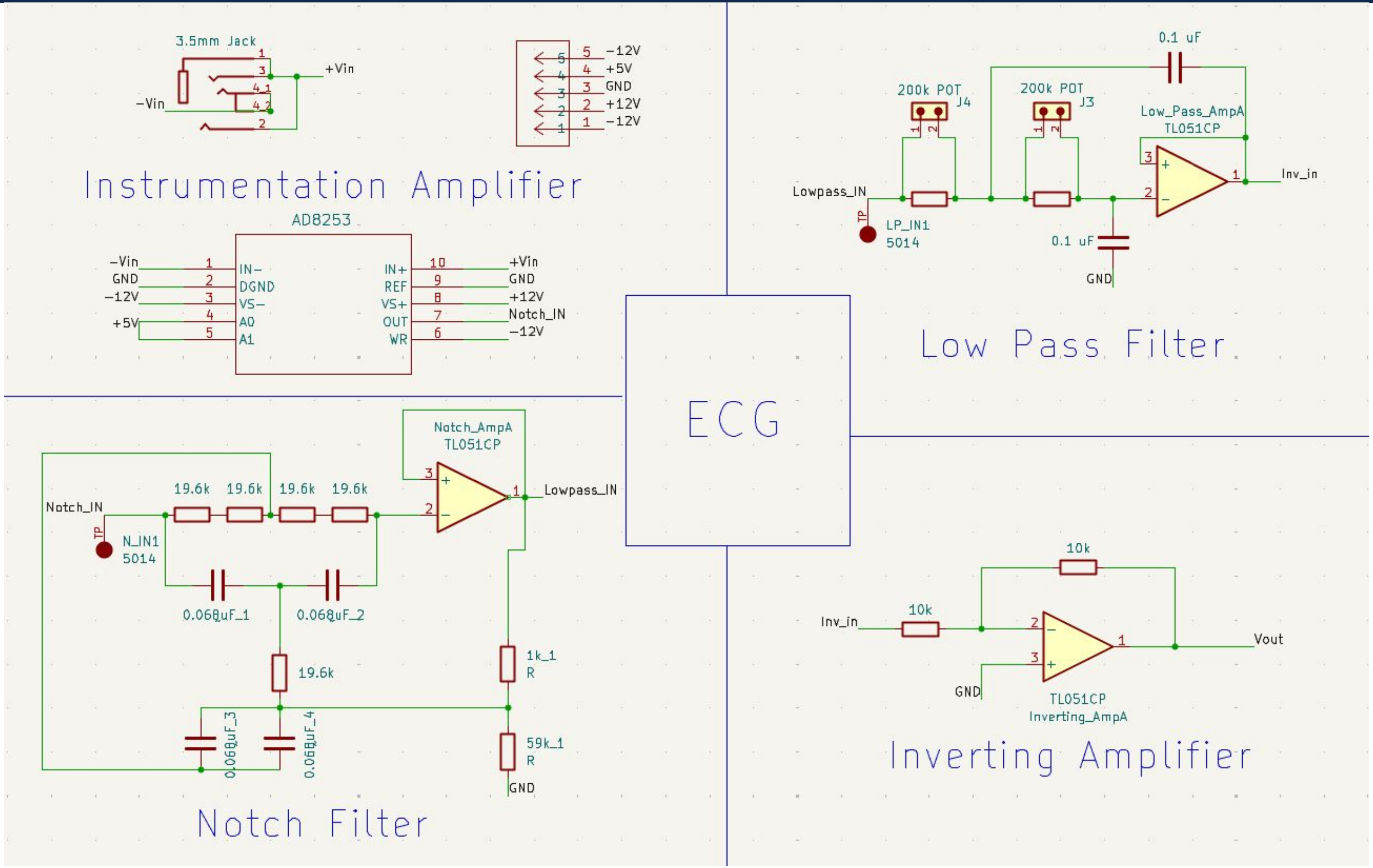
- Capture Heart Rate signals using standard AED pads
- Amplify the signals using a differential Amplifier
- Filter out noise utilizing low pass and notch filters
- Export processed signal to microcontroller to be displayed

<u>Subsystem Requirement:</u>

- Measure the heart rate and be accurate to within ± 2%.
- Filter out high frequencies and making the signal readable.



ECG Schematic



Impedance Sensor

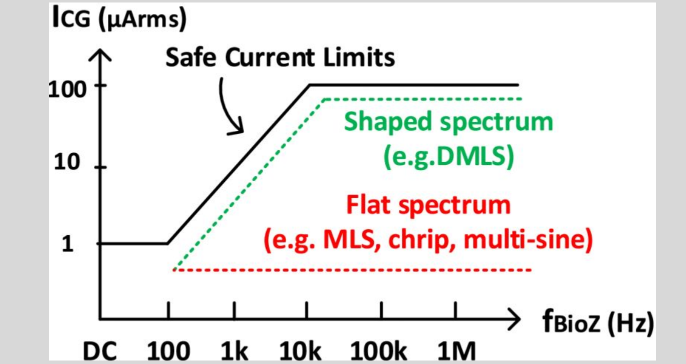
Goal: Measure the patients Bio-Impedance

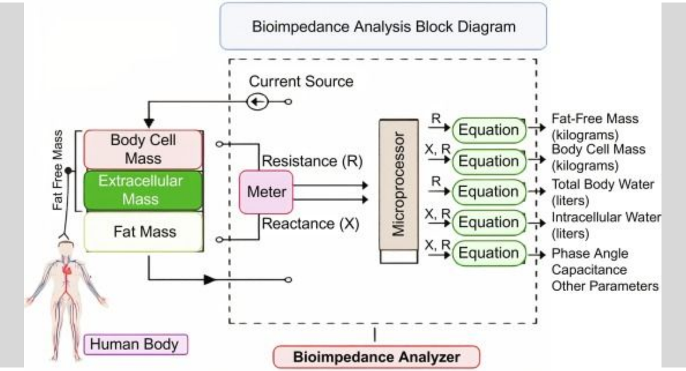
Execution:

- Communicate with medical team to understand current effect on the heart
- Send a controlled current through patient
- Capture sent current on the other end to determine Z
- Amplify the signal to be readable by microcontroller

Subsystem Requirement:

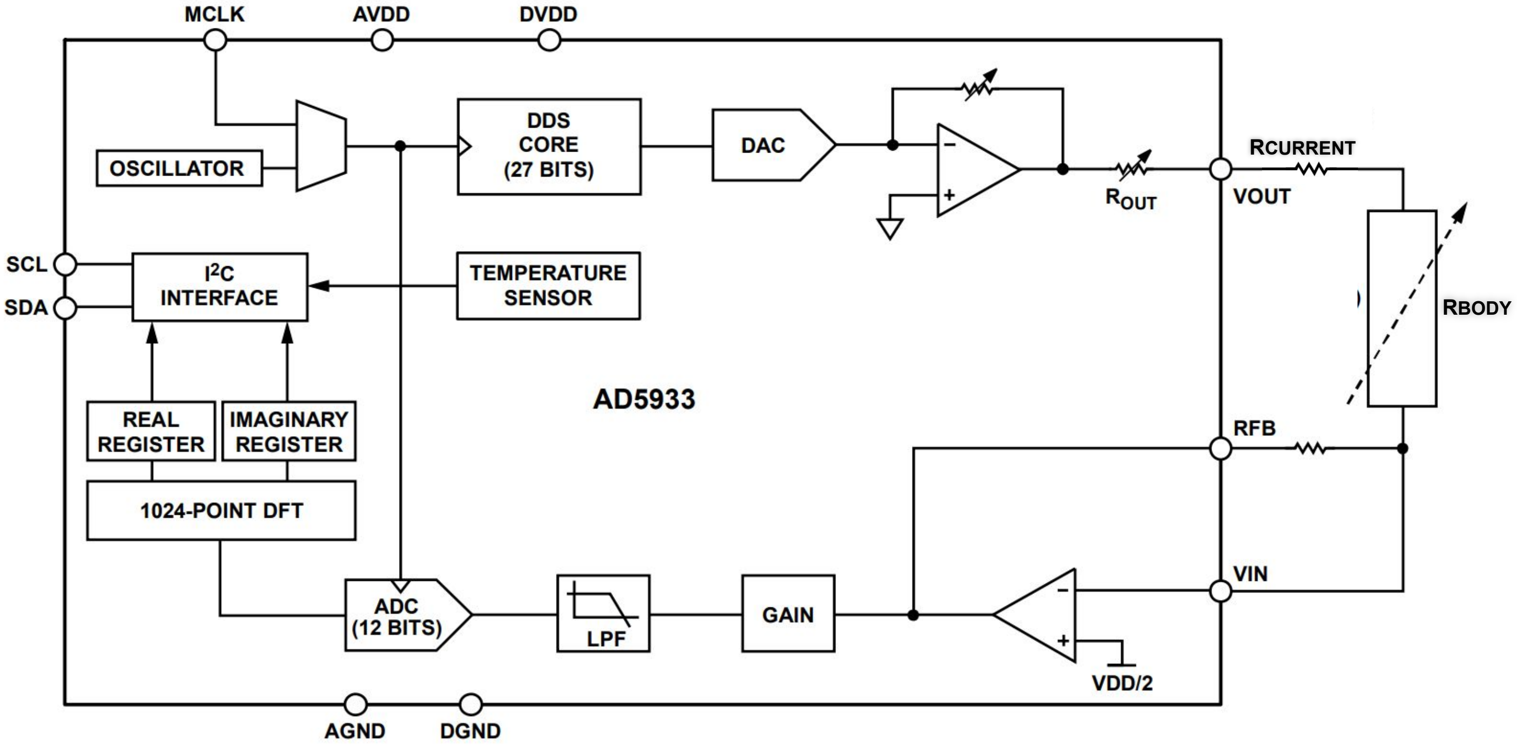
- Restrict current within health safety limits (<100 uA)
- Measure the body impedance to within ± 5%





Traditional Bio Z trackers

Impedance Schematic



ESP32 Microcontroller

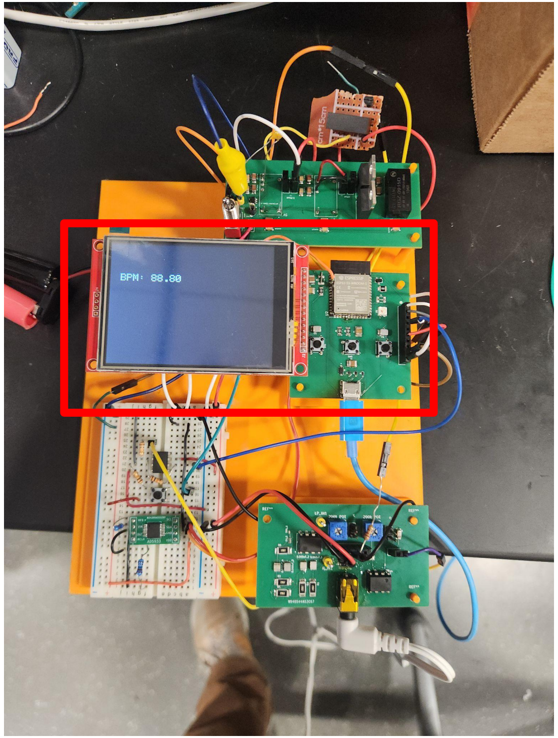
Goal: Process analog signals from ECG and Impedance modules and display via LCD

Execution:

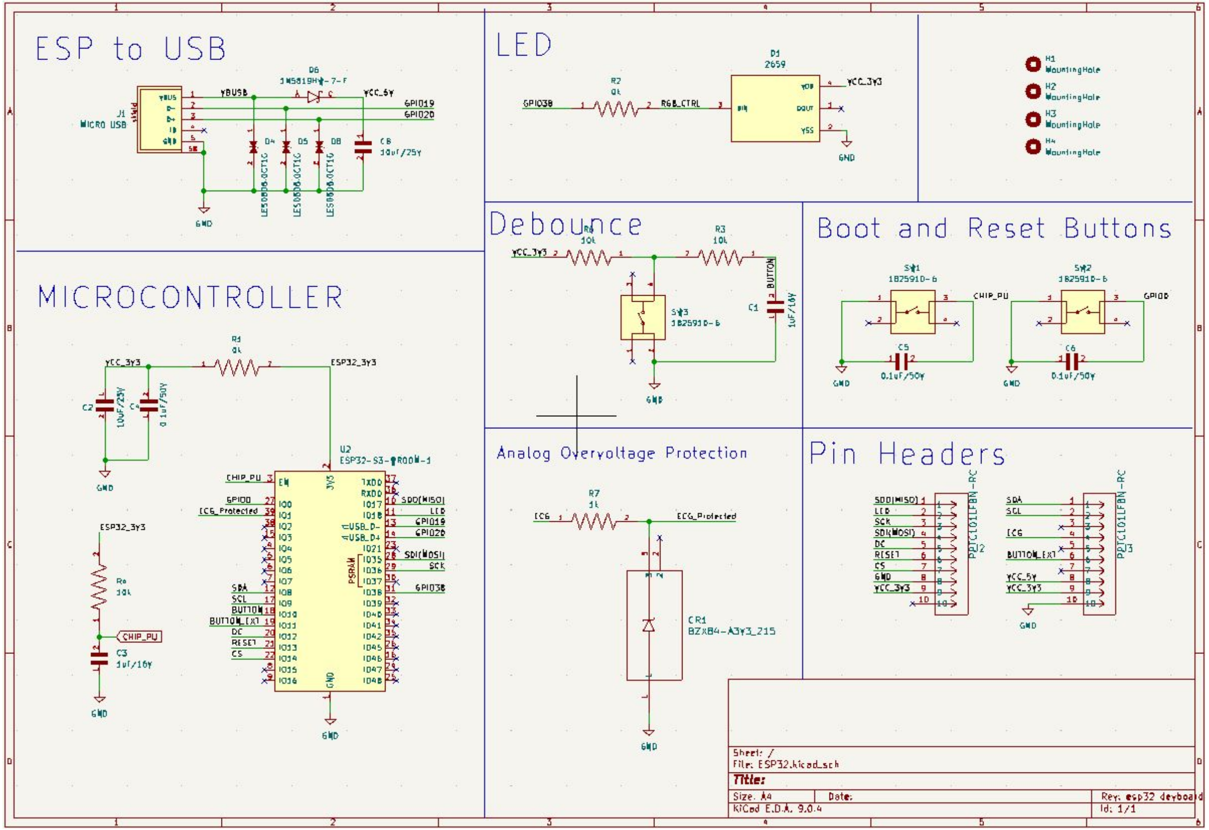
- ESP32-S3-WROOM-1 Microcontroller
- Pan–Tompkins QRS detection algorithm
- Libraries to handle LCD and AD5933 integration

Subsystem Requirement:

- Calculate heart rate
- Calculate average Impedance
- Display data to LCD in real-time



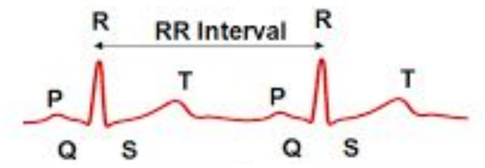
Control Unit Schematic



How do we calculate Heart Rate?

Pan–Tompkins QRS detection algorithm

Used in medical devices since 1985

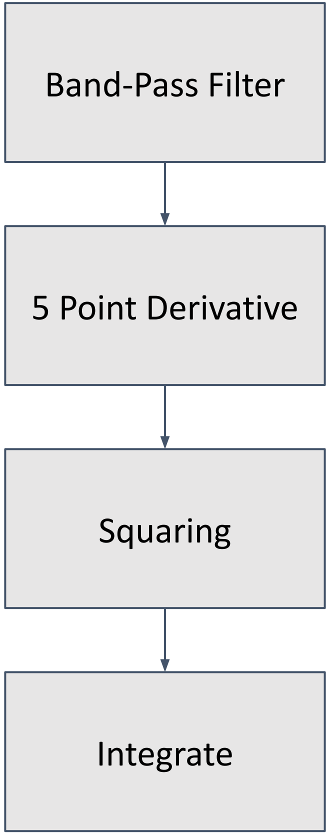


Steps to isolate heartbeat peaks

- Band-pass filter (5-15Hz) removes noise outside of ECG range
- Derivative → Squaring → Integration
- Result: a clean signal where each heartbeat (QRS) peak stands out

Adaptive Threshold & Heart Rate Calculation

- Peaks recognized when the signal crosses an adaptive threshold
- Threshold continuously adjusts based on the max value in the last 300 samples
- Time between beats (RR interval) is measured
- Heart rate = average of the last 10 RR intervals



Conclusion

Reflection

- Overall, we are proud of what we accomplished
- Challenges and lessons learned highlight our growth and learning

Potential improvements for the future

- Handle input voltages > 3.3 mV or negative by scaling filter outputs and adding a diode rectifier to ensure positive voltage to the ESP
- Order extra AD5933 chips initially to avoid delays due to accidents or shipping
- Choose parts that are easier to solder by hand
- Be more careful in designing PCBs through verification
- Get all modules onto one PCB package
- Implement more fail-safe precautions around delicate / expensive elements

References

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[2] D. Park, Y. Park, C. Kim, Y.-C. Kim, and Y. Lee, “Impedance spectroscopy analysis of dielectric properties of materials,” Sensors and Materials, vol. 29, no. 3, pp. 359–366, 2017. Available: https://pmc.ncbi.nlm.nih.gov/articles/PMC5875053/

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