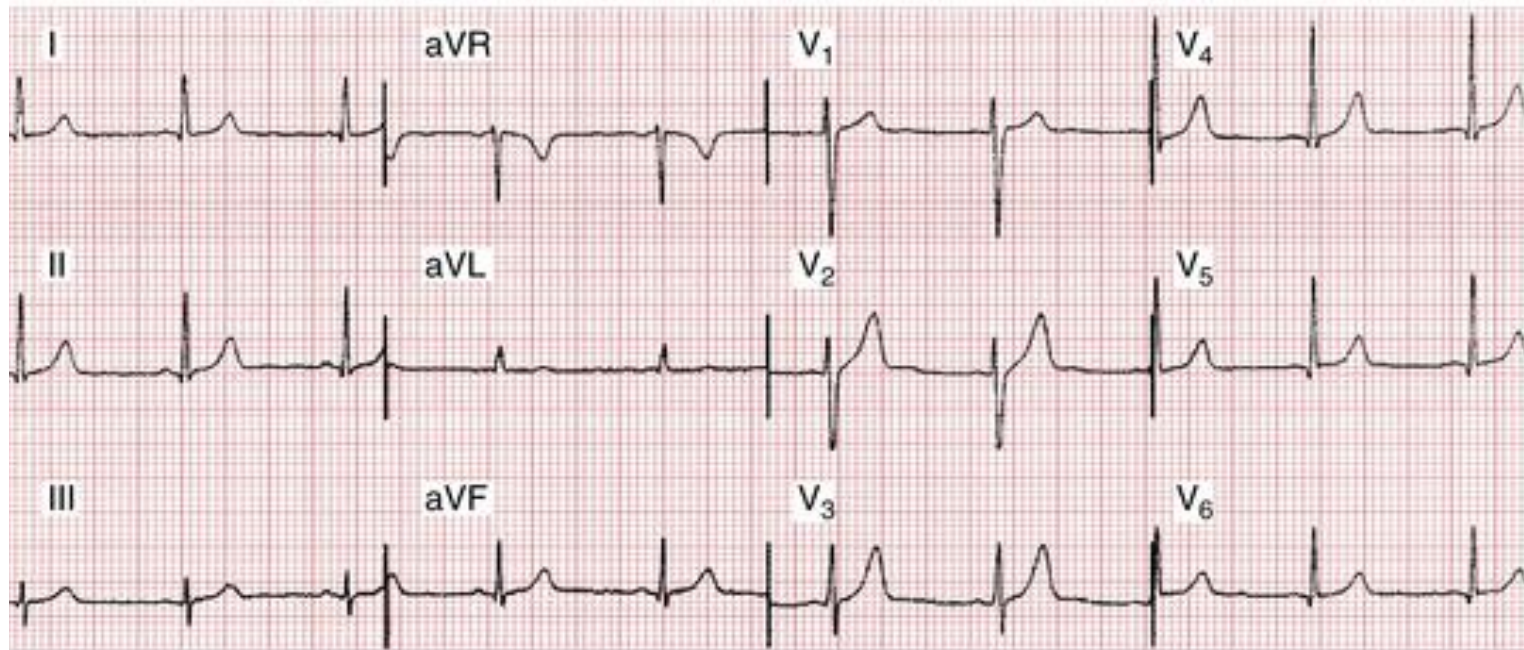# Wireless ECG

ECE 445 Team 9

Spring 2022
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Electrocardiogram

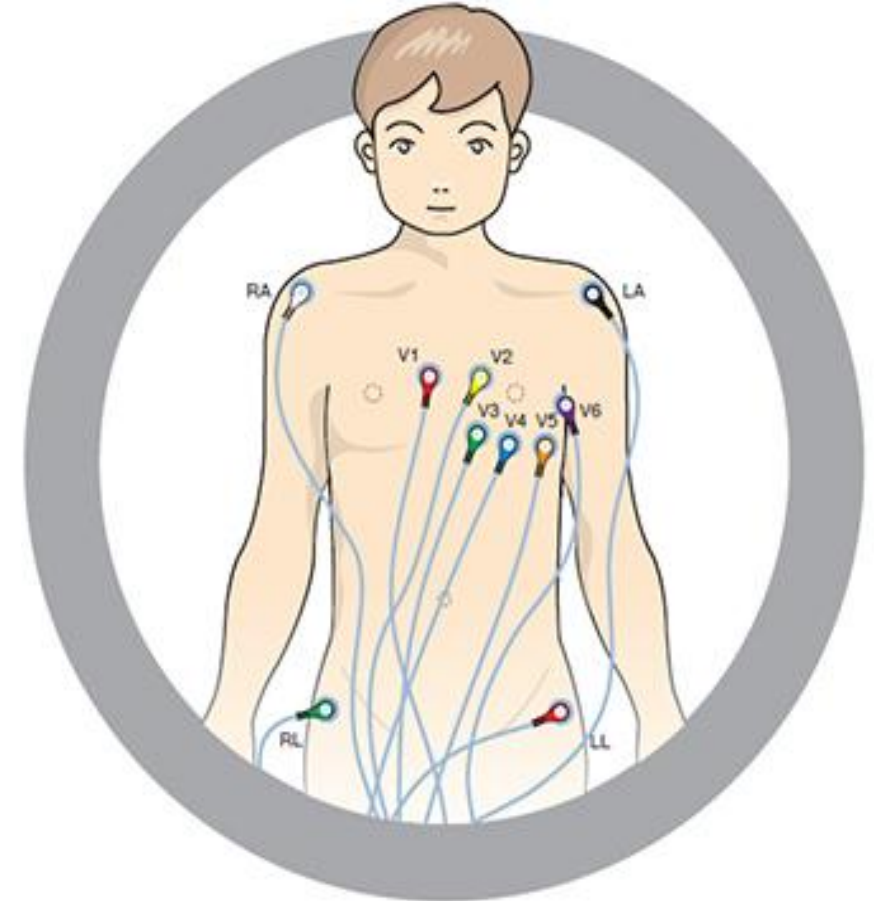- Visualizing the electrical activity of the heart, represented on a graph

Used for diagnosis with
- Chest pain
- Irregular heartbeats
- Heart-related issues e.g. shortness of breath, dizziness
- Overall health of the heart before/after a surgery

Project Objective : Partial Wireless Implementation of 12-Lead ECG (3-Lead)

- Conventional 12-Lead ECG involves measurements from 10 electrodes
  - 10 electrodes : V1~V6, RA, LA, RL, LL
  - 12 lead measurements: I, II, III, aVR, aVL, aVF, V1~V6
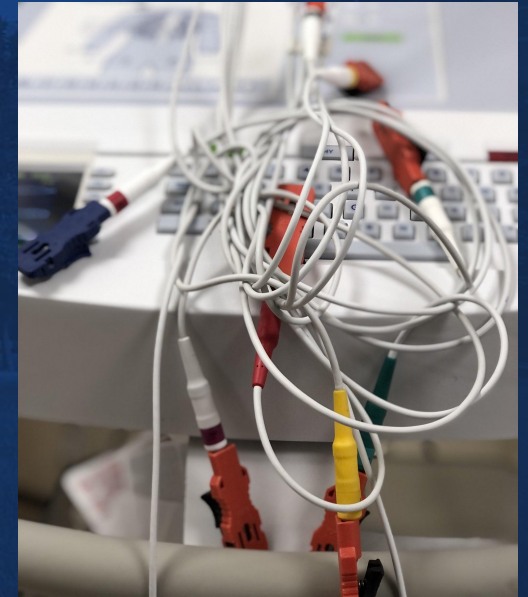 - lead number ≠ electrode number

Conventional

PROBLEM

Conventional 12-lead ECG:
- Too many wires to deal with
    - 10 electrode wires all connected to a device
- Inconvenient and inefficient

10 wires

PROBLEM

Existing Products:

e.g. Apple watch, ZioPatch, BardyDX CAM

- Measure one lead only
- Inefficient to replace
- Limited functionality

Apple watch   **ZioPatch**   **BardyDX CAM**

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Convenience:

- Three nodes measure body's surface biopotential (with RL reference node)

- A central hub converts analog signals into digital data

- Data transfers to the monitor through Bluetooth interface

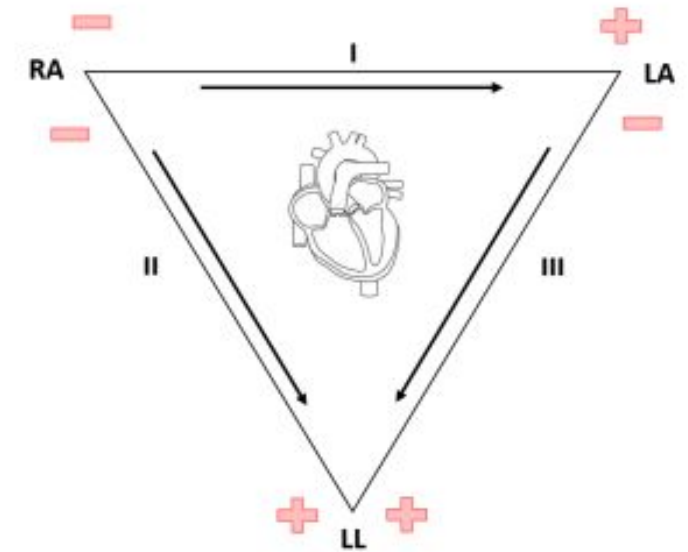- Retractable cable minimizes inevitable wire usage

Replaceability:

- The metal device is reusable and traditional ECG patches are replaceable

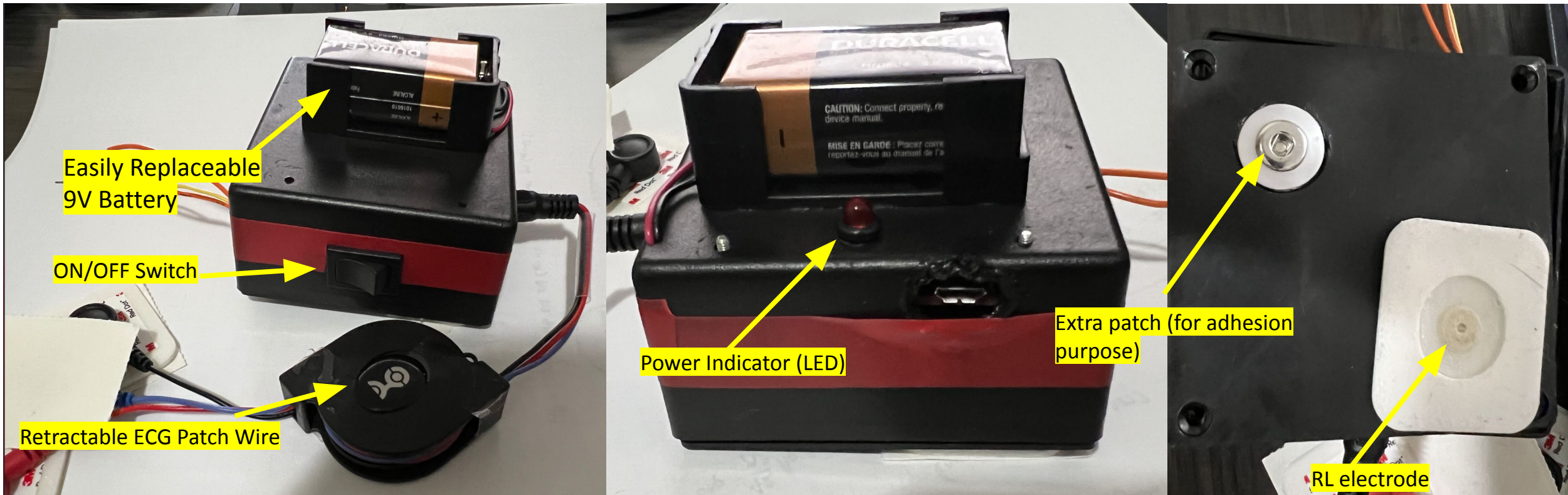## Project goal : Obtain 3-lead ECG with wireless implementation

- Four electrode placements : RA, LA, RL, LL
  - RL electrode removes artefact from ECG (noise)
- Two lead measurements : Lead I and III
- Lead II = Lead I + Lead III
  - Using Einthoven's Equilateral Triangle
- Wireless Implementation : Transmit digital data using Bluetooth
  - ESP32
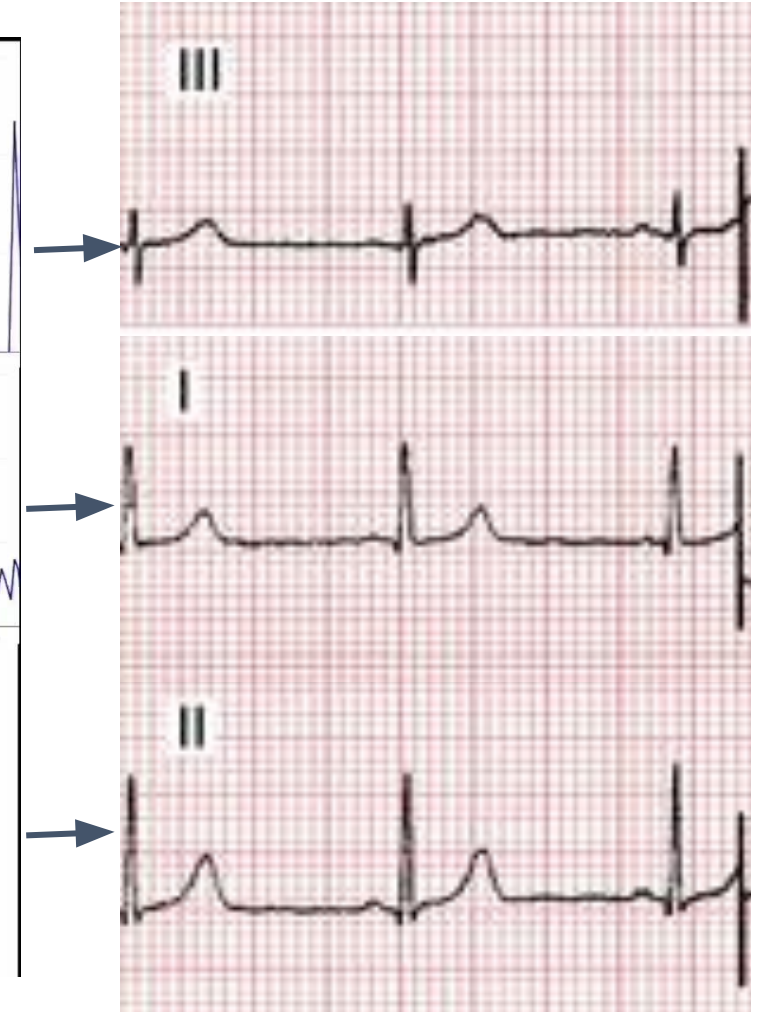
Einthoven's Equilateral Triangle

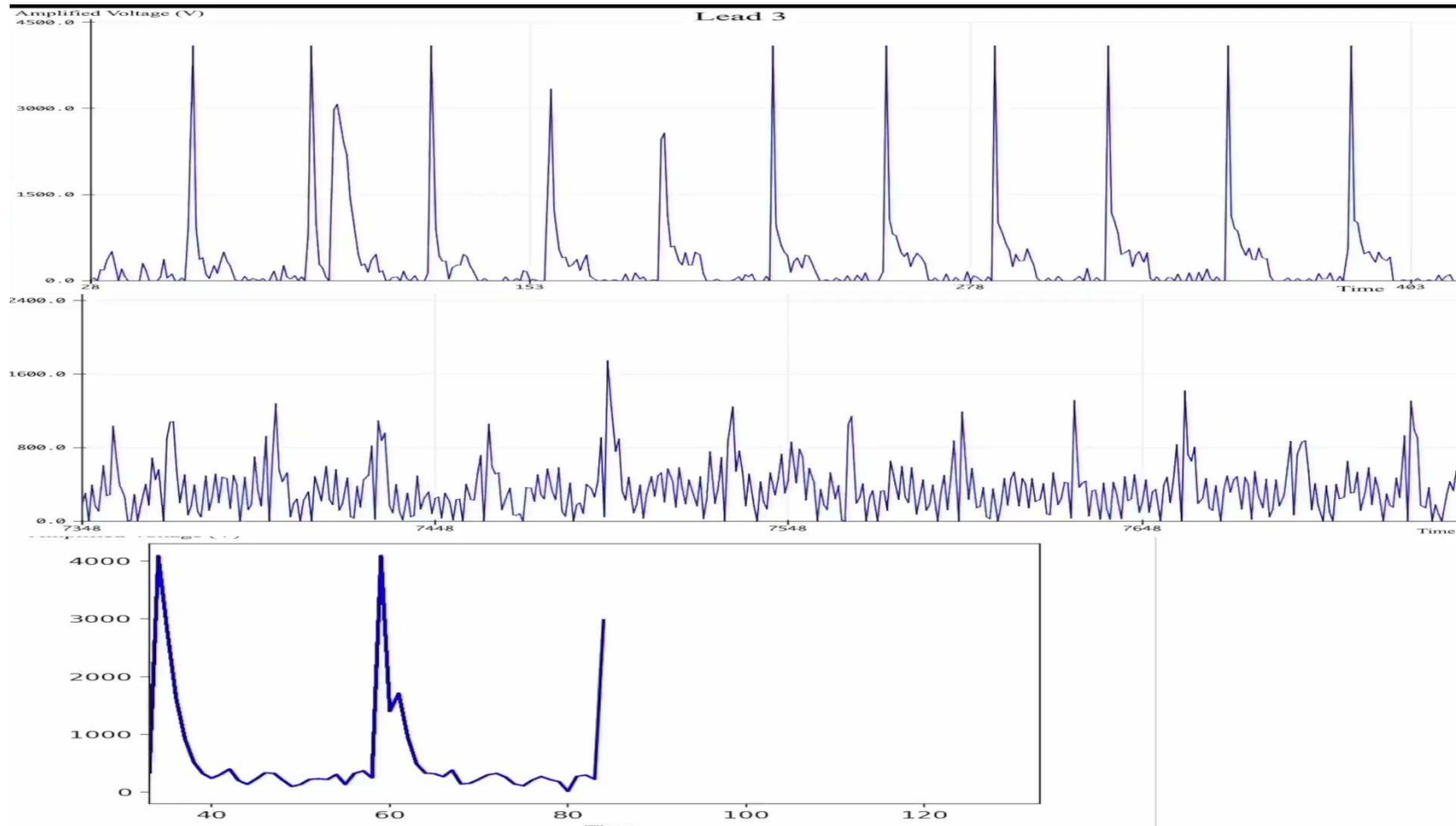| LEAD	Positive Electrode	Negative Electrode
I	LA	RA
II	LL	RA
III	LL	LA

Easily Replaceable 9V Battery

ON/OFF Switch

Retractable ECG Patch Wire

Power Indicator (LED)

Extra patch (for adhesion purpose)

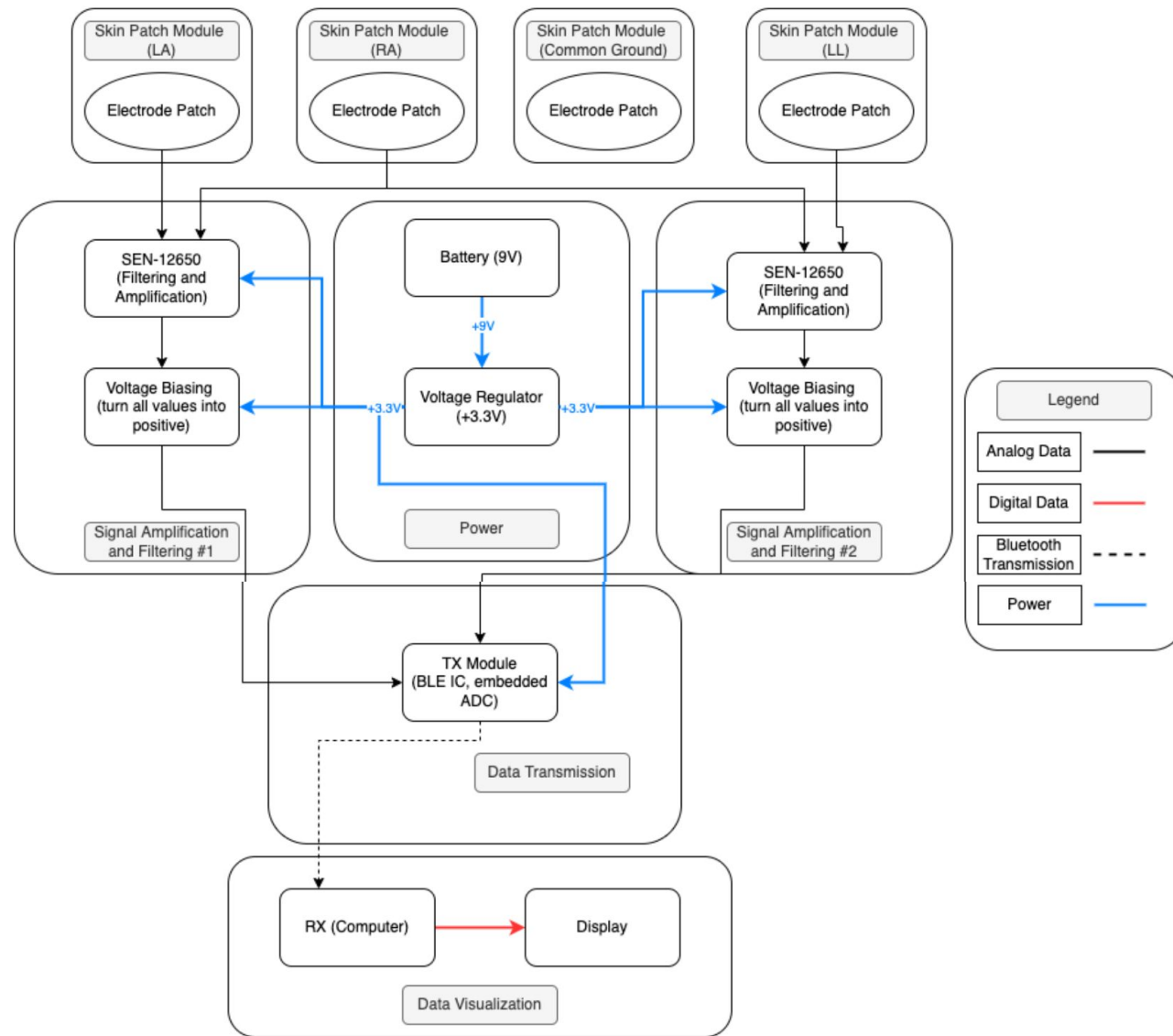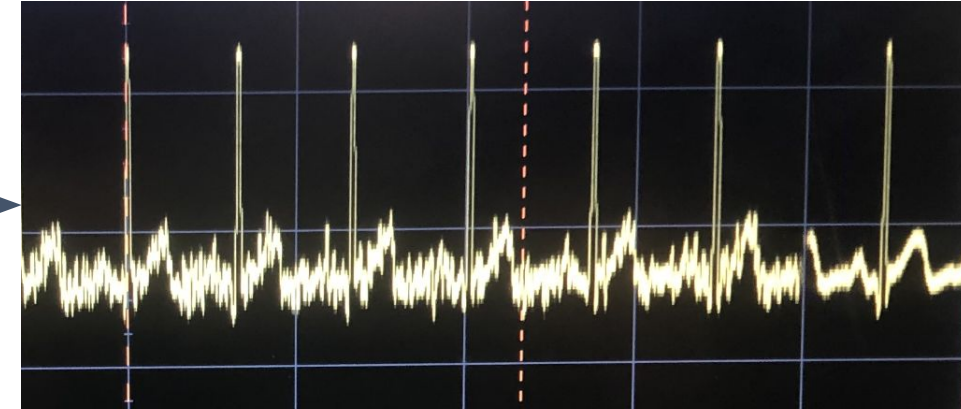RL electrode

Design

Initial Design

Block Diagram

Subsystems:

- Skin Patch Module
- Signal Amplification and Filtering Module
- Power Module
- Data Transmission Module
- Data Visualization Module

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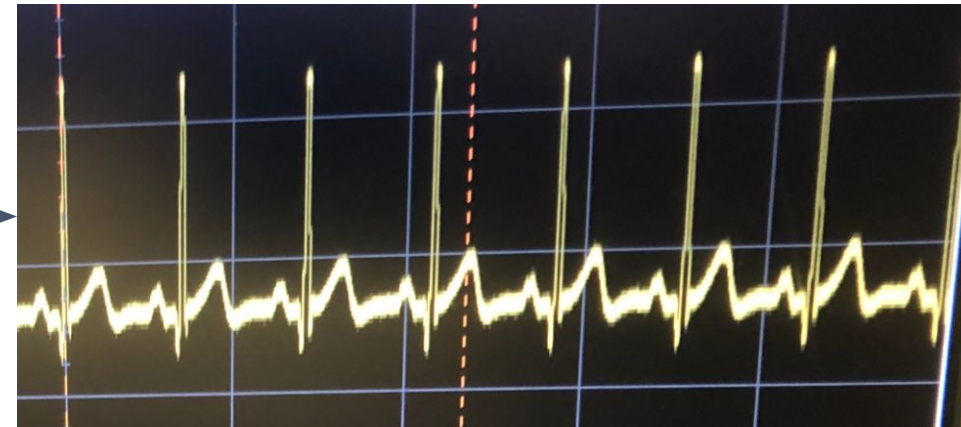
Design Changes and Improvements

- Voltage biasing and heart signal processing chip are combined
- ADC and microprocessor can be combined with ESP32 chip
- Device installment location changed from center of the body to bottom right corner
  - RL electrode can be attached at the bottom of the device
  - still maintain one less wire
  - less noise when the RL electrode is further away from the heart

RL node placed at the center

RL node placed at the RL corner

Design Changes and Improvements

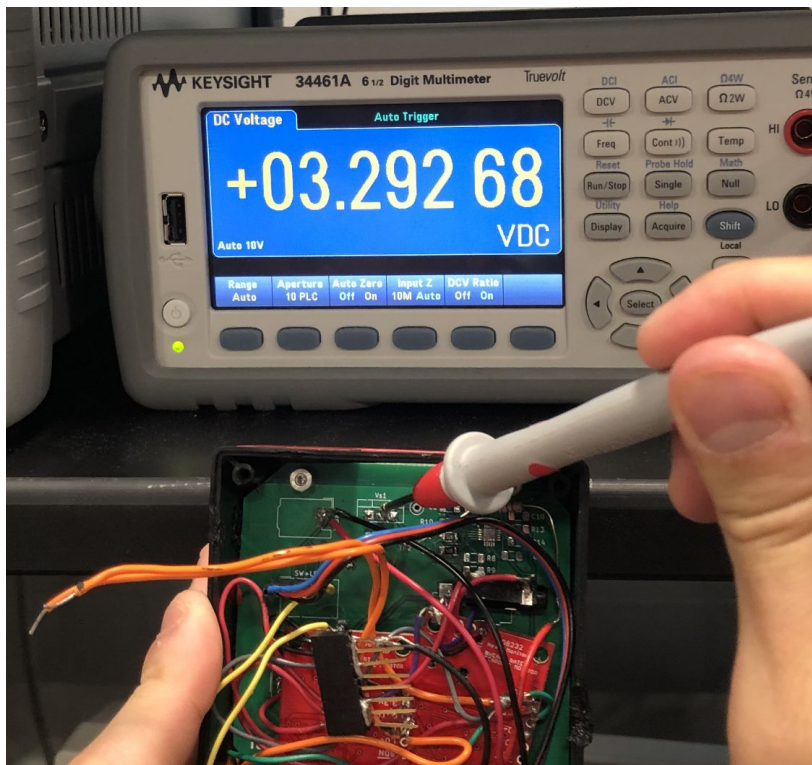- New Skin Patch Module (ECG Patch)

Old

New

Requirements & Verification

1. Power Module
2. Skin Patch Module
3. Signal Amplification and Filtering Module
4. Data Transmission Module
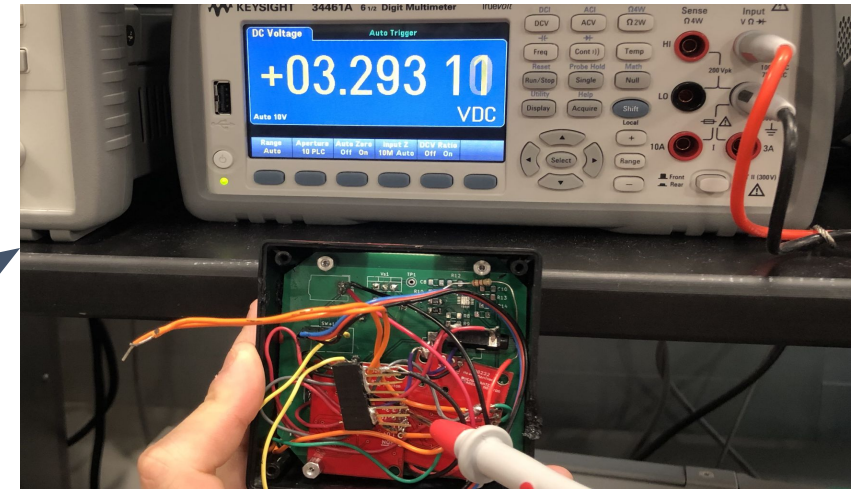5. Data Visualization Module

1. Power Module

Requirement: A 9V-battery should supply a stable voltage (3.3V) to the data transmission module (ESP32) and signal amplification module (AD8232)

At Voltage Input of AD8232

At Voltage Regulator Output

At Voltage Input of ESP32

Requirement: Skin patches should be strong enough to stick the entire device on the body even if the user is standing

Requirement: Cables must be retractable and should be able to accomodate people with different body sizes

3. Signal Amplification and Filtering Module

Requirement: The analog amplifier should amplify the signal to provide higher resolution for the ADC input, while not exceeding the maximum value of the input of ADC (3.3V).

Requirements

1. The module should successfully transmit the data from the hub to the computer, using the Bluetooth module of the microcontroller

Verification

1. It can successfully transmit the sample data to the computer (data visualization module)

334	305
335	112
336	127
337	255
338	0
339	26
340	214
341	86
342	253
343	286
344	197
345	203
346	0
347	1871
348	1587
349	1194
350	848
351	868
352	534
353	399
354	400
355	209
356	68
357	145
358	115
359	240

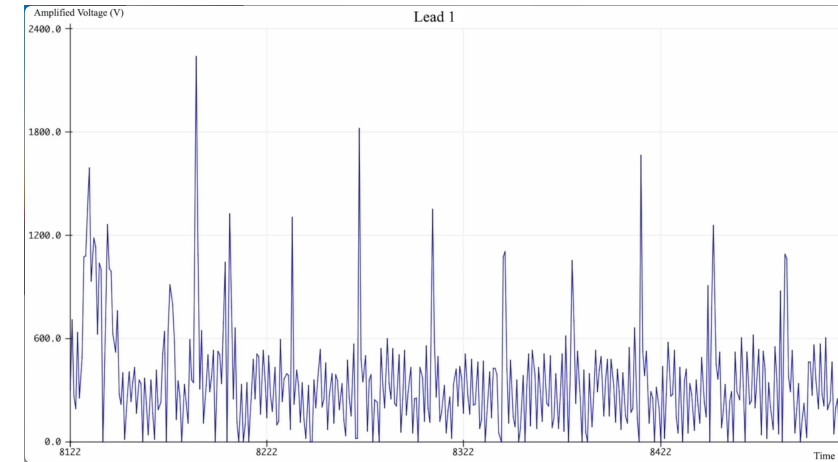| 465	182
466	136
467	0
468	3
469	0
470	0
471	0
472	242
473	4095
474	1367
475	1070
476	754
477	851
478	496
479	481
480	648
481	457
482	671
483	643
484	267
485	114
486	0
487	0
488	14
489	0

Lead 1   **Lead 3**
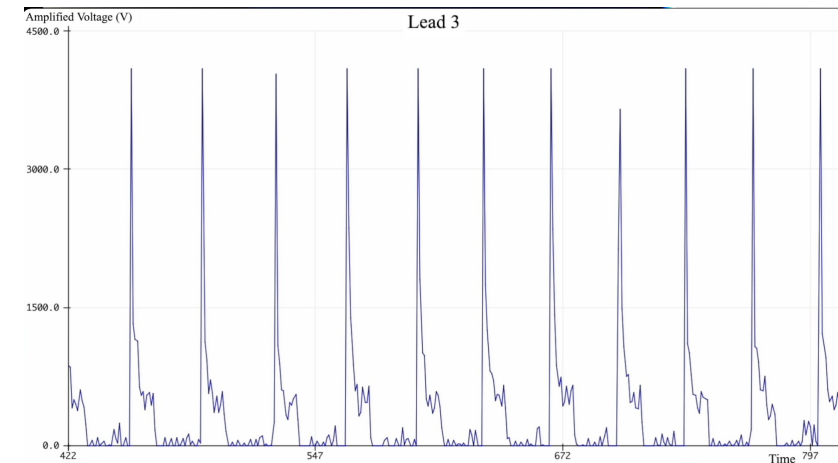
Requirements

2. The module should deliver the data from the hub to the computer
   in 5m distance between the hub and computer
   without any barriers in between.

Verification

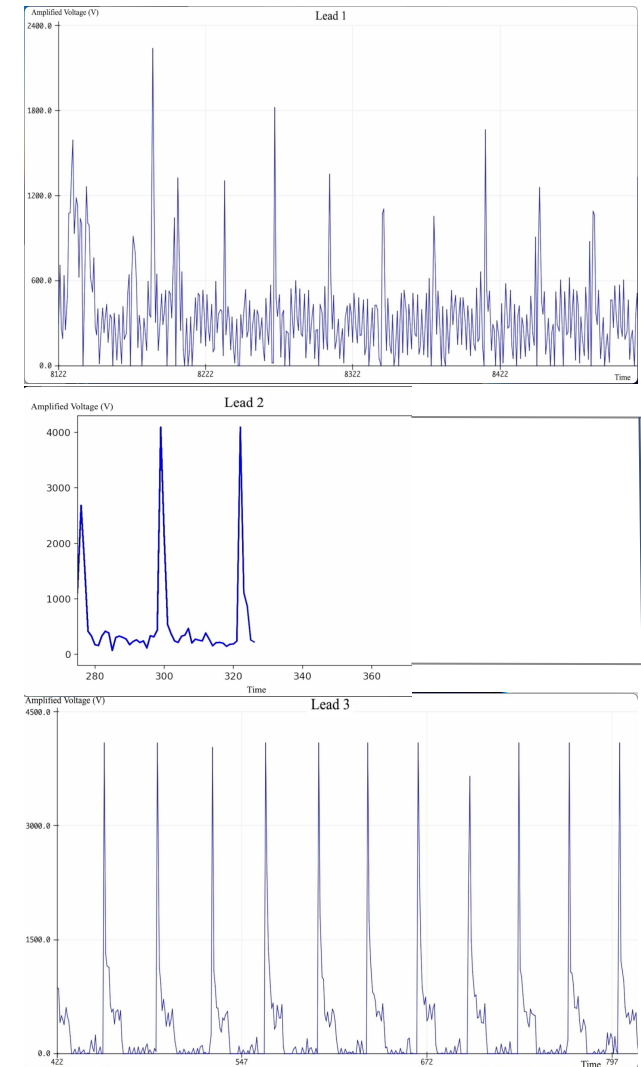2. Successfully received the data from a distance

Lead 1

Lead 3

Requirements

- This module should successfully display 3 graphs.

Verification

- Was able to display graphs of the data on the computer in real-time

Lesson Learned

- PCB design and soldering

- Combination of software and hardware

- All things about ECG

Major Takeaways

- Communication

- Time Management
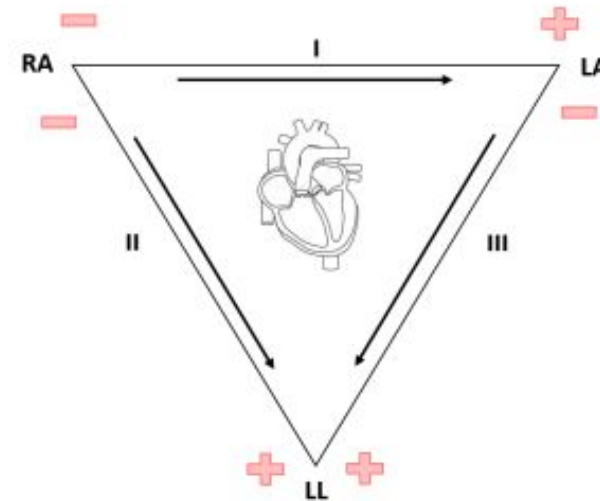
- Design and presentation experience

Improvement

- Improve PCB design to save more space inside the hub - more compact size

- Decreasing noise

- Update code to have more accurate signal plots

- Improve Bluetooth to increase the valid distance between devices and the board

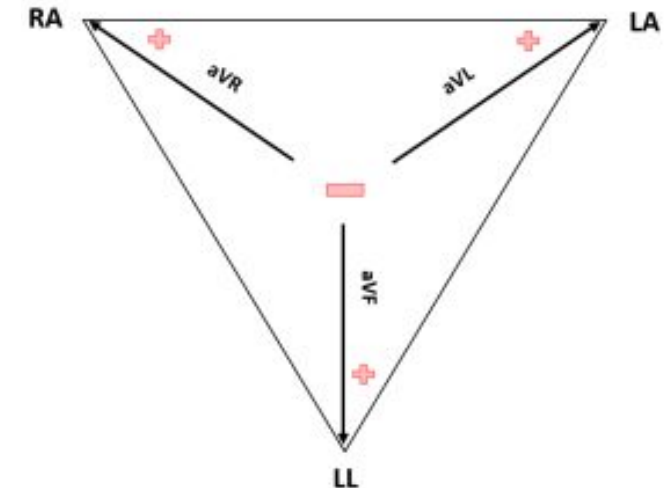- Possible improvements to patches (Quality and comfort)

Future Work

Next step: expand into a 6-lead device
- add aVR, aVL, aVF leads (augmented limb leads)
  - one extra electrode placement
- Would require 3 more signal processing chips and 3 more inputs to the microprocessor
  - Challenge: Battery life, product size and weight, etc.

Einthoven's Equilateral Triangle

LEAD	Positive Electrode	Negative Electrode
I	LA	RA
II	LL	RA
III	LL	LA

LEAD	Positive Electrode
aVR	RA
aVL	LA
aVF	LL

Thank you!

The Grainger College of Engineering

UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN