Wireless ECG
ECE 445 Team 9

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Wireless ECG - Introduction

**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
PROBLEM

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

Existing Products:
e.g. Apple watch, ZioPatch, BardyDX CAM

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

- Easily Replaceable 9V Battery
- ON/OFF Switch
- Retractable ECG Patch Wire
- Power Indicator (LED)
- Extra patch (for adhesion purpose)
- RL electrode
Design
Initial Design

Hub device with four nodes (Ground at the bottom of device)

Display ECG waveform on monitor

Attach to body
Make sure ground node is installed

Install nodes at appropriate locations

Bluetooth
Block Diagram

Subsystems:

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

- Voltage biasing and heart signal processing chip are combined
- ADC and microprocessor can be combined with ESP32 chip
- Device installation 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

**Images:**
- RL node placed at the center
- RL node placed at the RL corner
Design Changes and Improvements

- New Skin Patch Module (ECG Patch)
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 Regulator Output

At Voltage Input of ES32

At Voltage Input of AD8232
2. Skin Patch Module

**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 accommodate people with different body sizes.
**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).
4. Data Transmission Module

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)
4. Data Transmission Module (cont.)

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
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)
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.
Thank you!