# HOMEFLOW

# Project Overview

**Project**

Design a smart wearable device to monitor user health

**Product**

A smartwatch that monitors health metrics and environmental conditions

**Goal**

To improve the well-being of all users

# Team Members

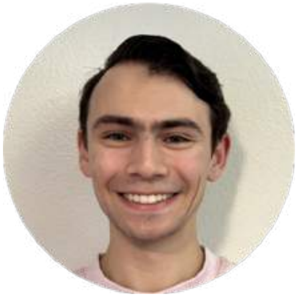
Ben Cruttenden

Brandon Lee

Julian Frank

Snehith Nayak

Harshita Gangaswamy



# Table of Contents

# Project Features

## Sensors

- Pulse oximetry
- Body temperature
- Motion
- Noise level
- Weather

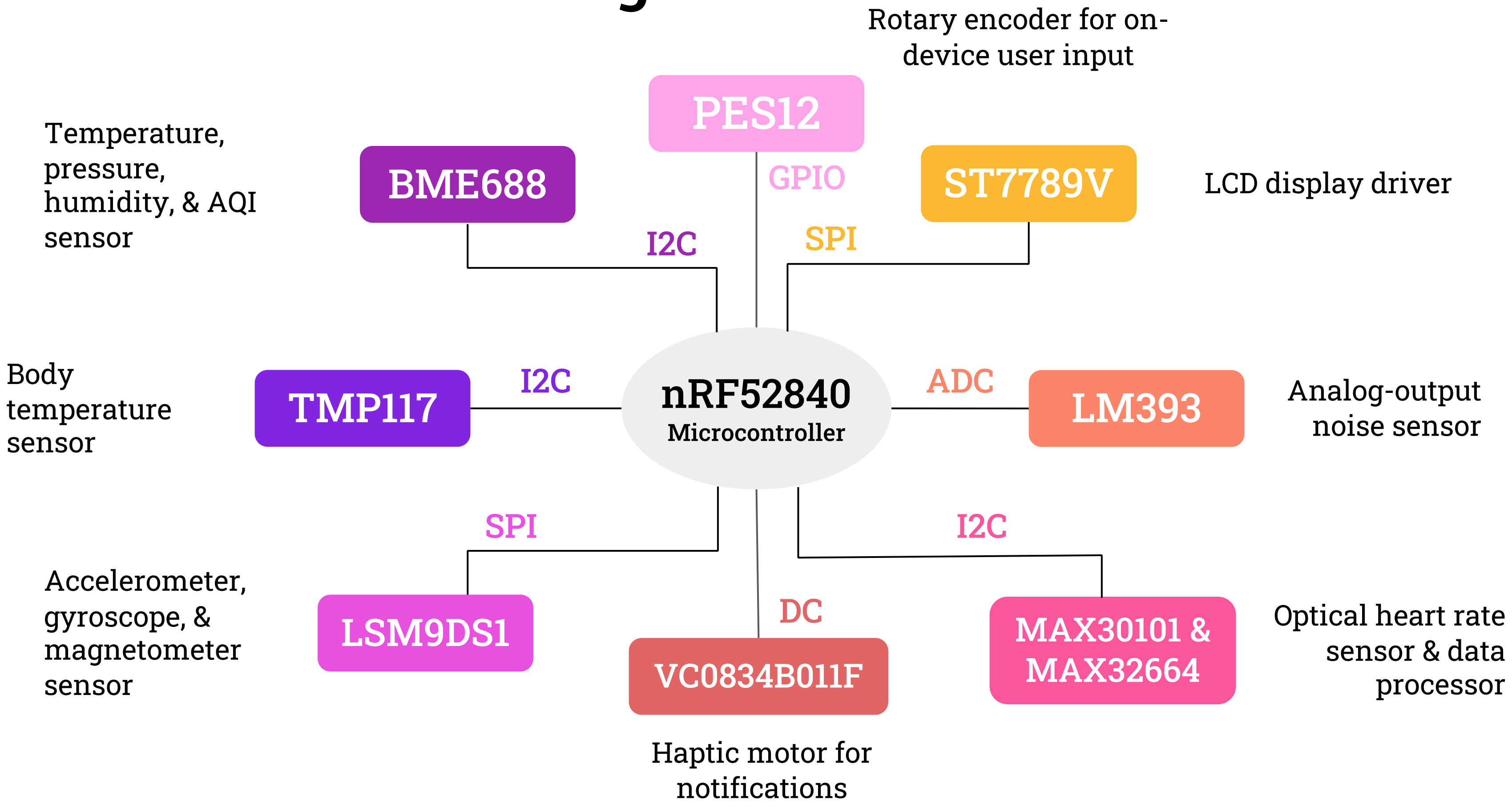
## Outputs

- Medical metrics
- Air quality and environmental safety
- Step counting
- Alerts

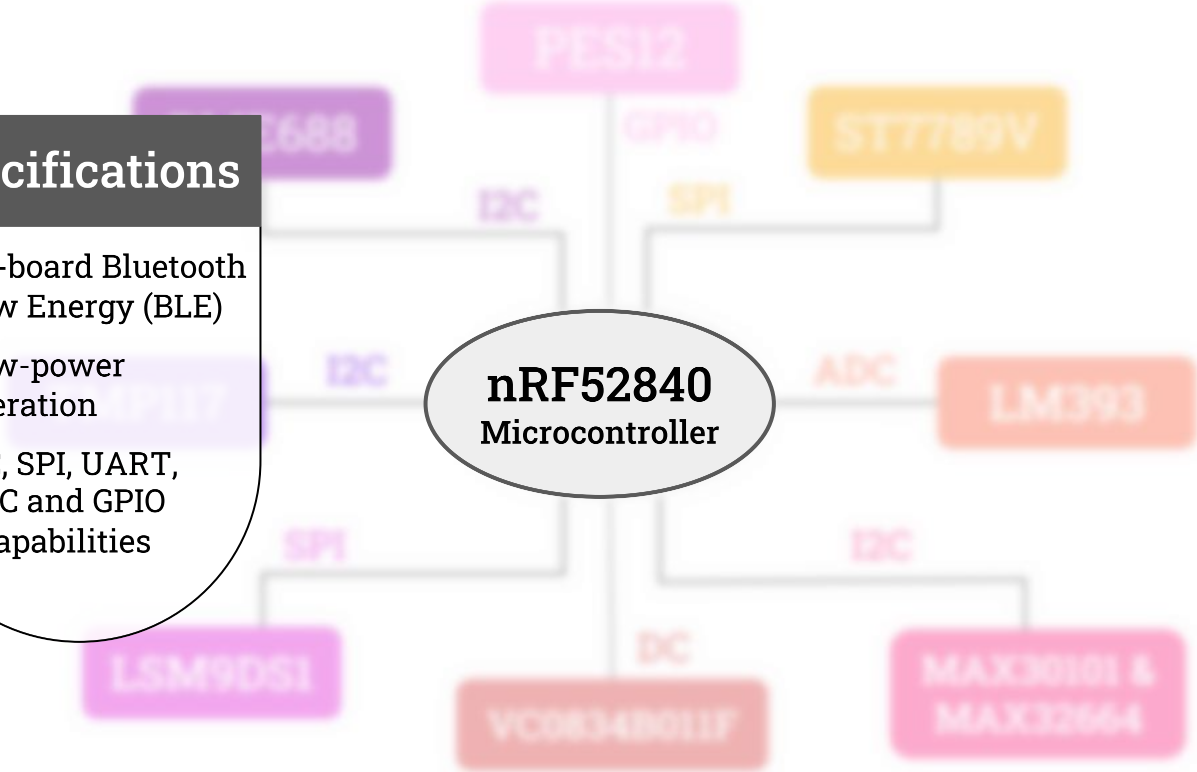
## User Interface

- Wearable:
  - LCD display
  - Rotary encoder
- Mobile application:
  - Data visualizations
  - Databasing

# Wearable Block Diagram



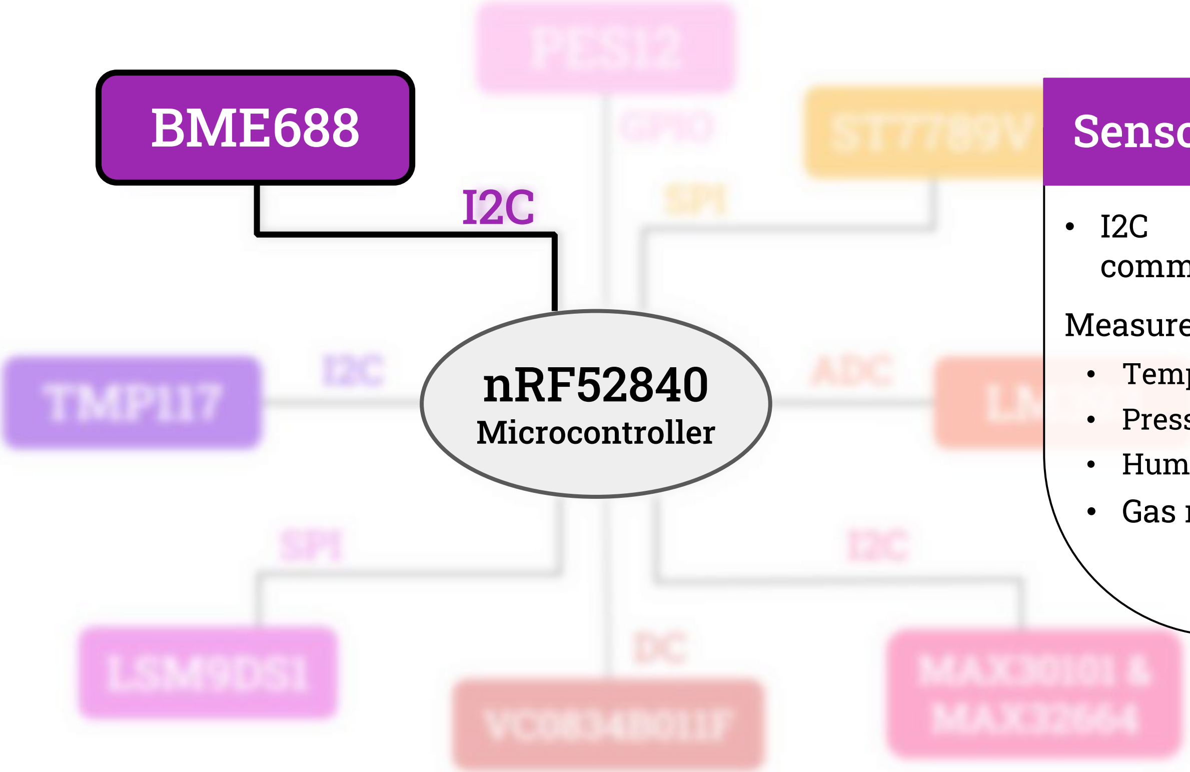
# Microcontroller




## Specifications

- On-board Bluetooth Low Energy (BLE)
- Low-power operation
- I2C, SPI, UART, ADC and GPIO capabilities

# Weather Sensor



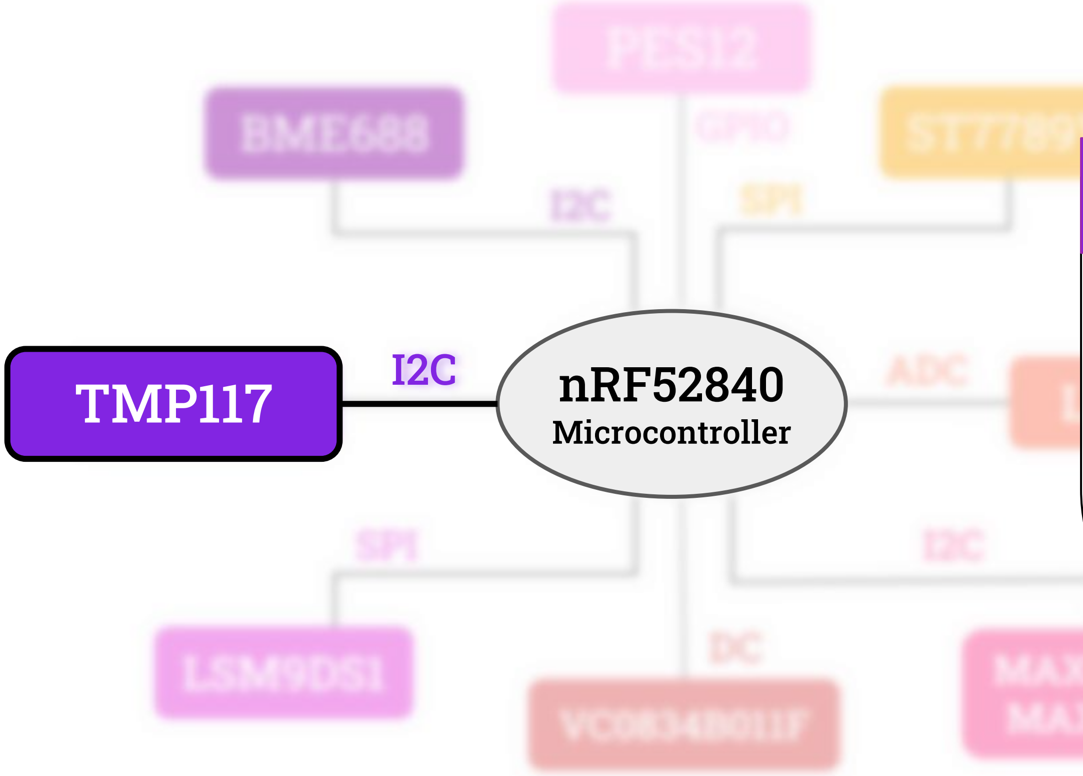

## Sensor Details

- I2C communication

Measures:

- Temperature
- Pressure
- Humidity
- Gas resistance

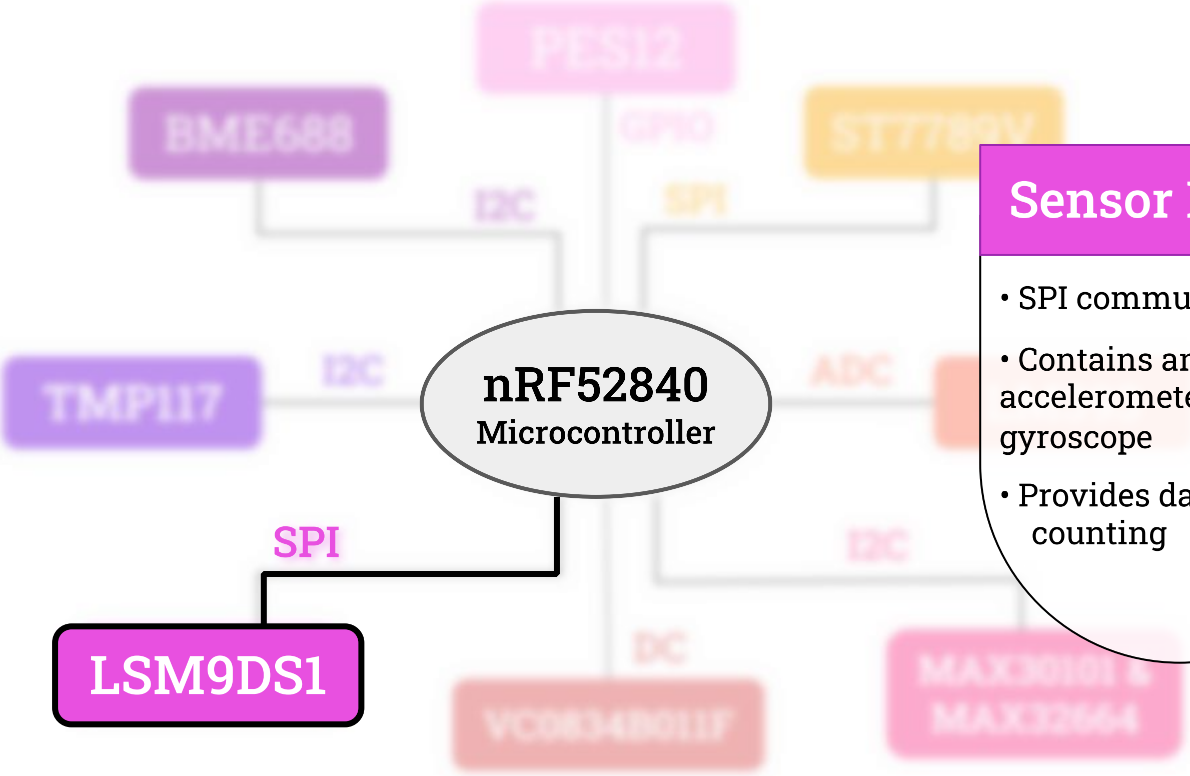
# Medical Thermometer




## Sensor Details

- I2C-compatible
- Measures temperature via contact with skin
- Medical-grade

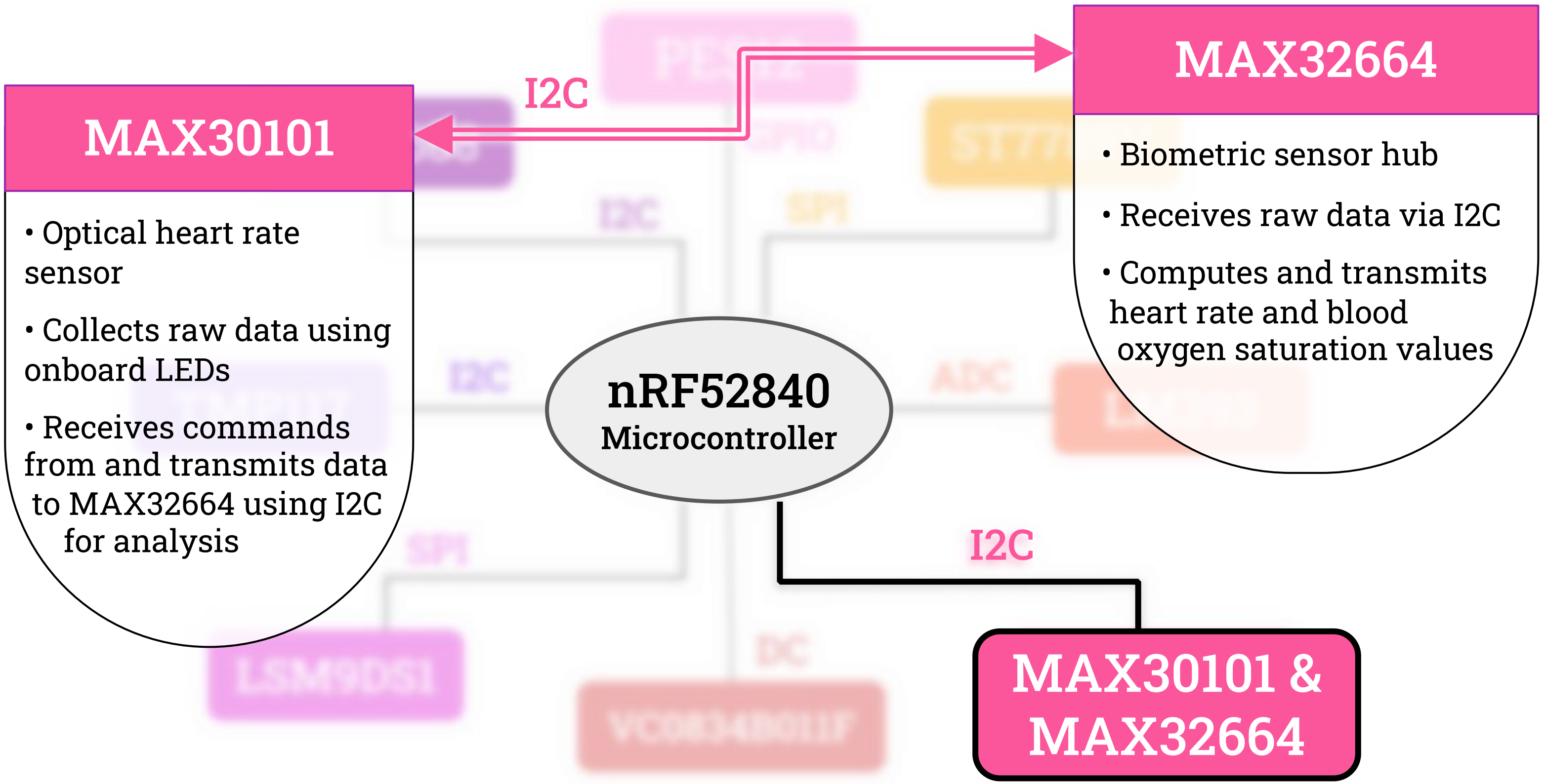
# Inertial Measurement Unit (IMU)




## Sensor Details

- SPI communication
- Contains an accelerometer and gyroscope
- Provides data for step counting

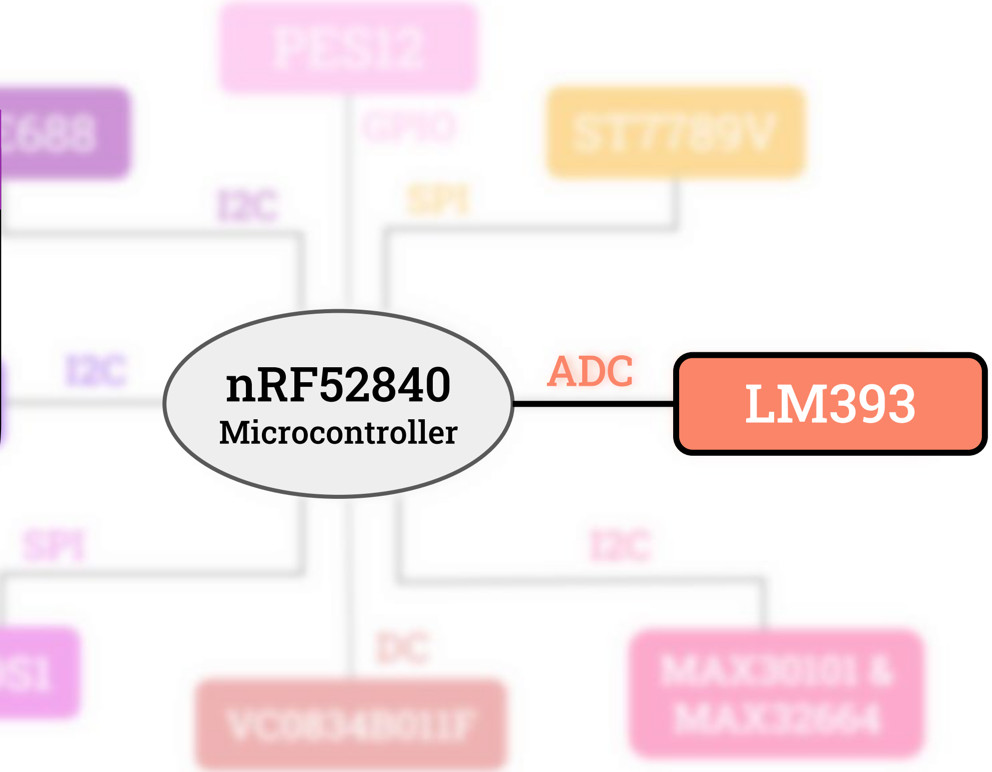
# Heart Rate / Blood Oxygen Sensor



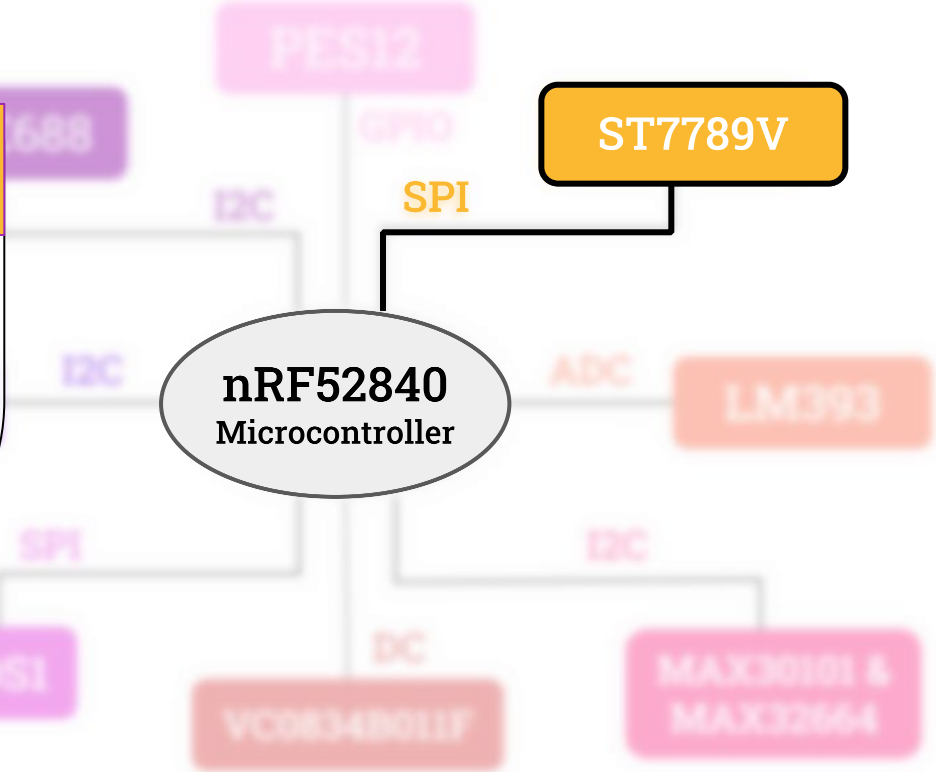
# Volume Sensor

## Sensor Details

- Microphone that measures sound level
- Outputs noise intensity as analog voltage
- Omnidirectional



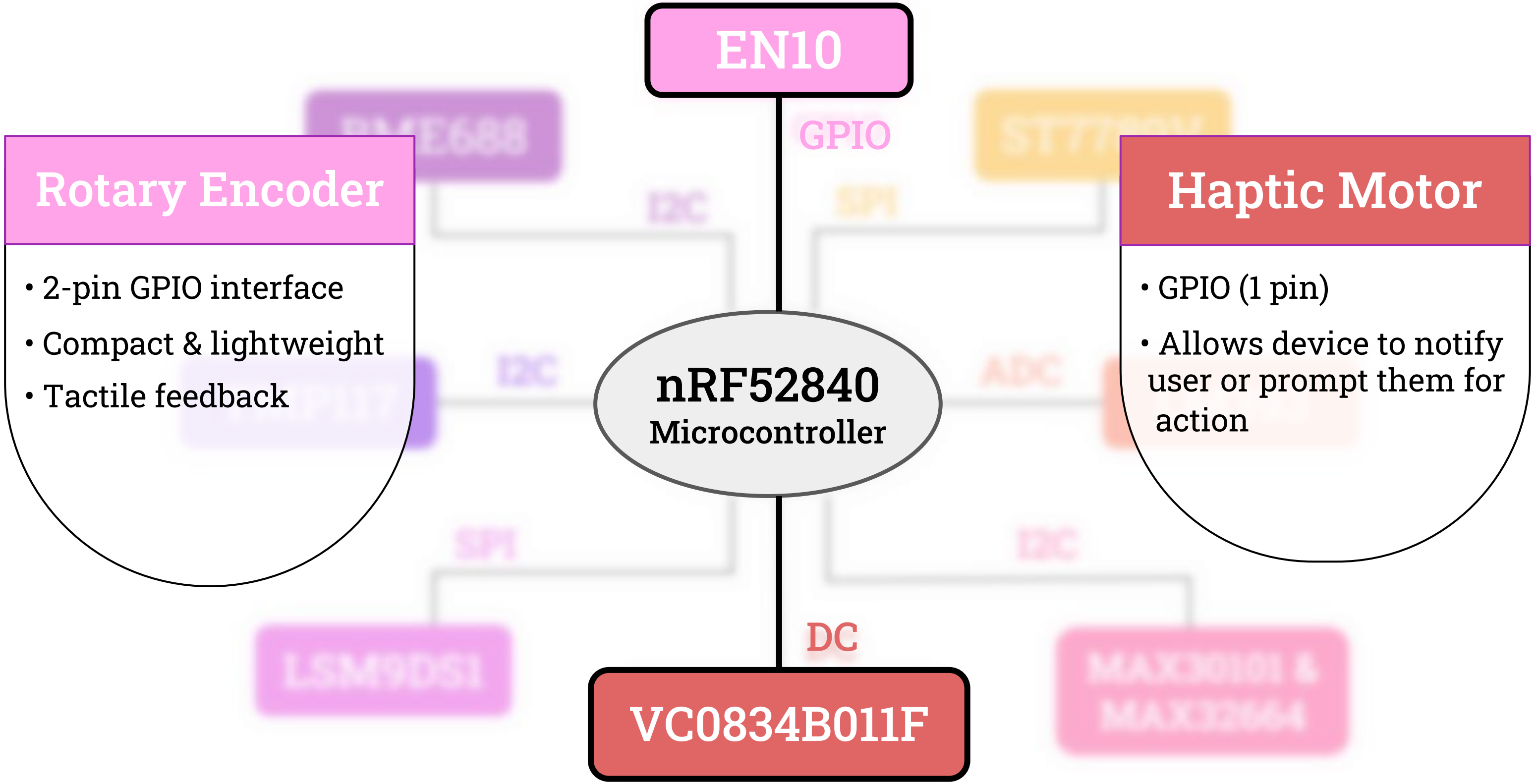
# Display Module



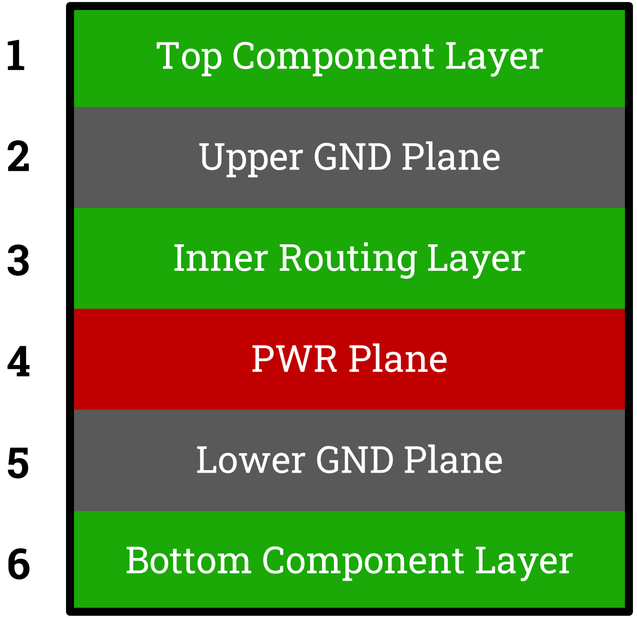

## Sensor Details

- SPI communication
- 18-bit color depth
- Compatible with LCD displays up to 240x320 resolution

# UI Components



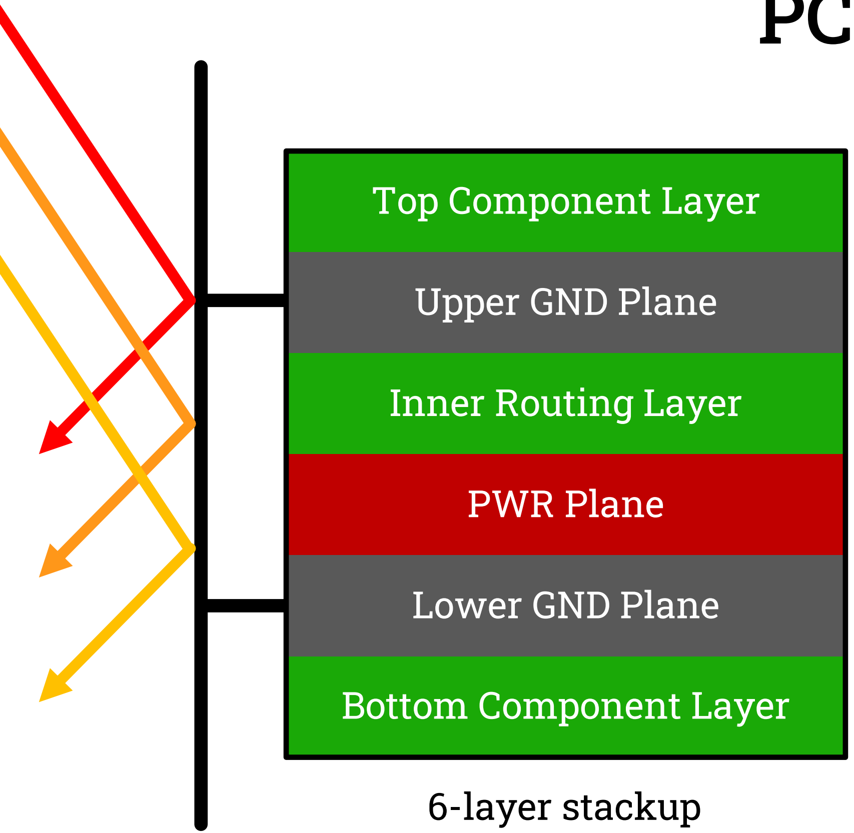
# PCB Design




6-layer stackup

- 6-layer design and dimensions of 35 x 50 mm

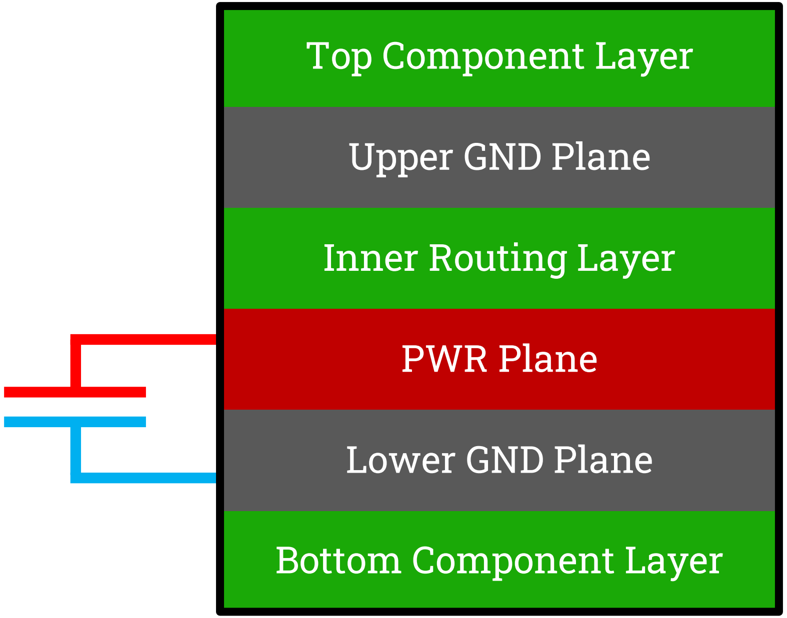
# PCB Design




6-layer stackup

- 6-layer design and dimensions of 35 x 50 mm
- **EMI shielding with GND planes**

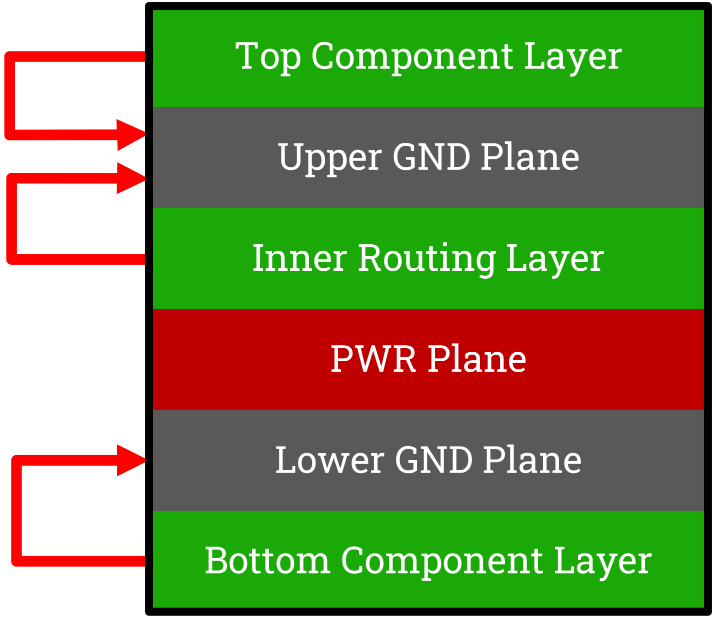
# PCB Design




6-layer stackup

- 6-layer design and dimensions of 35 x 50 mm
- EMI shielding with GND planes
- **Embedded capacitance:**
  - Alternative to decoupling capacitors for noise reduction
  - Utilizes capacitance between PWR and GND planes

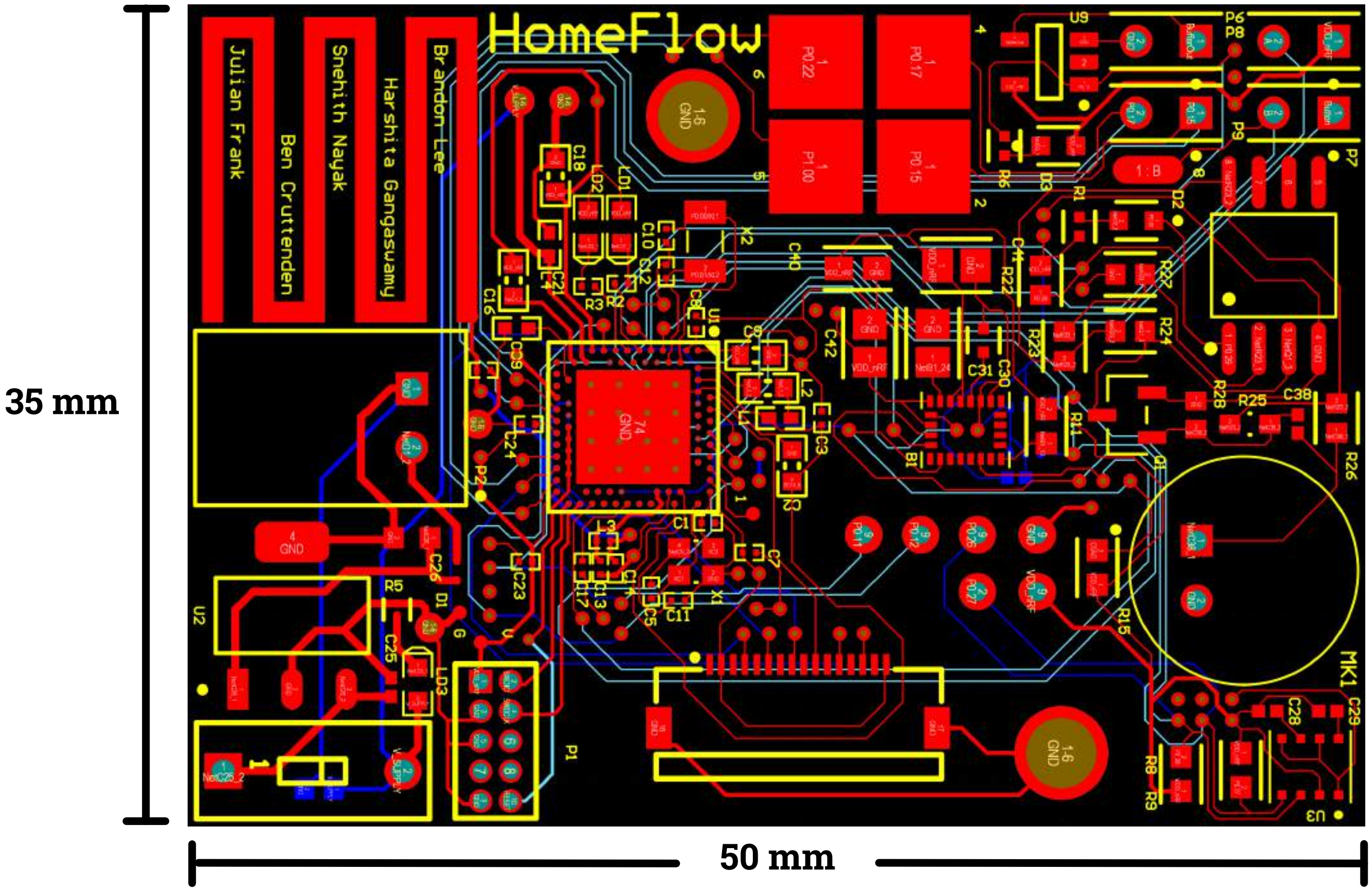
# PCB Design




6-layer stackup

- 6-layer design and dimensions of 35 x 50 mm
- EMI shielding with GND planes
- Embedded capacitance
  - Alternative to decoupling capacitors for noise reduction
  - Utilizes capacitance between PWR and GND planes
- **Reference planes**
  - Provides a direct return path for currents from signal layers
  - Helps to reduce EMI output and further mitigate noise

# PCB Layout


HomeFlow
Julian Frank
Snehith Nayak
Ben Cruttenden
Harshita Gangaswamy
Brandon Lee
35 mm
50 mm

# PCB Layout

Noise sensor

Weather sensor

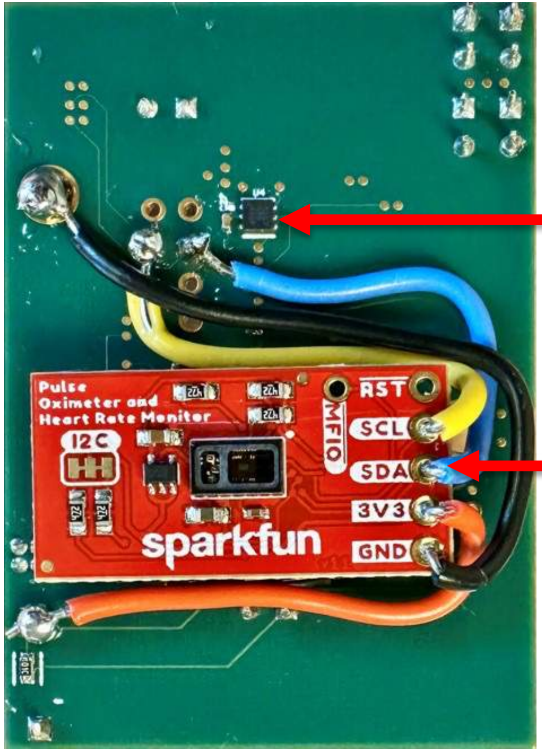
IMU

Display connector

Microcontroller

BT Antenna

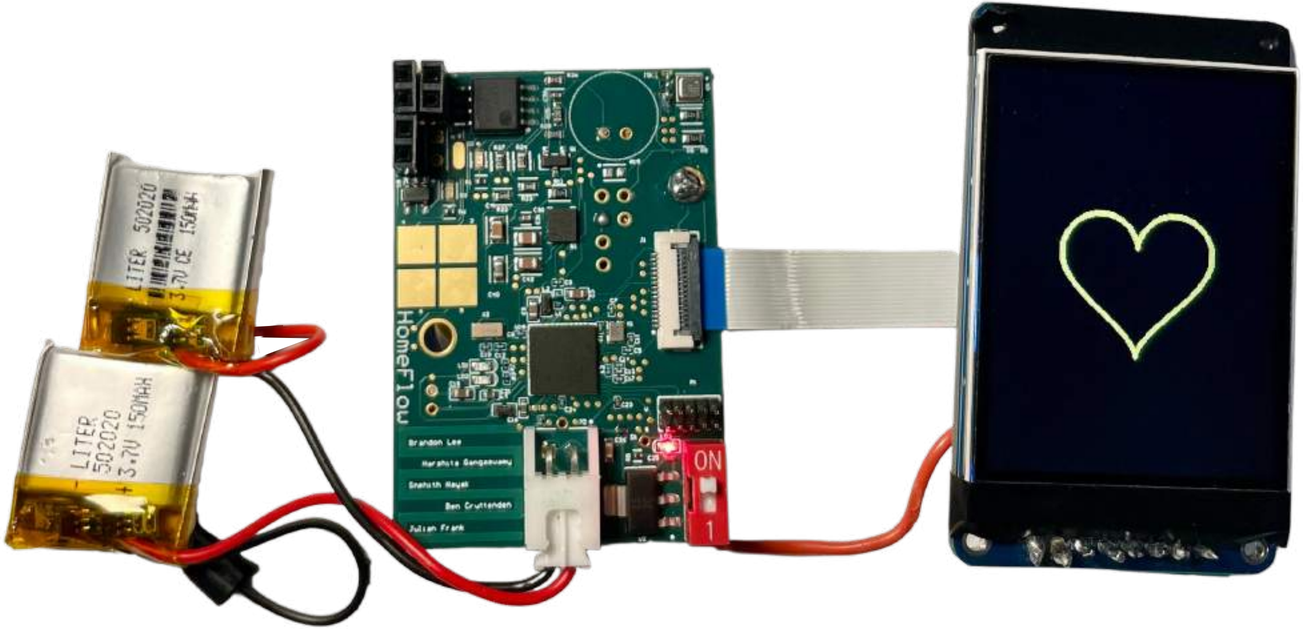
Battery connector

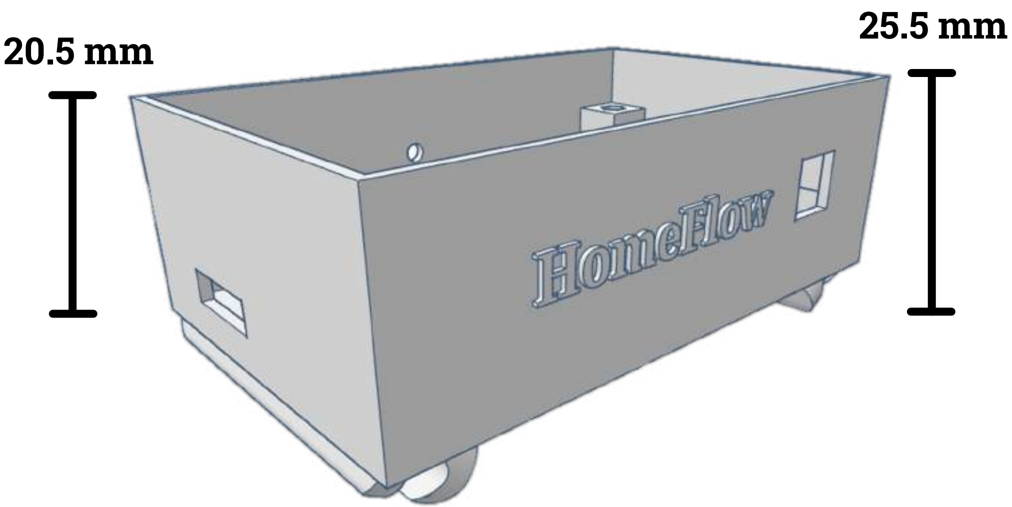

Body temperature sensor

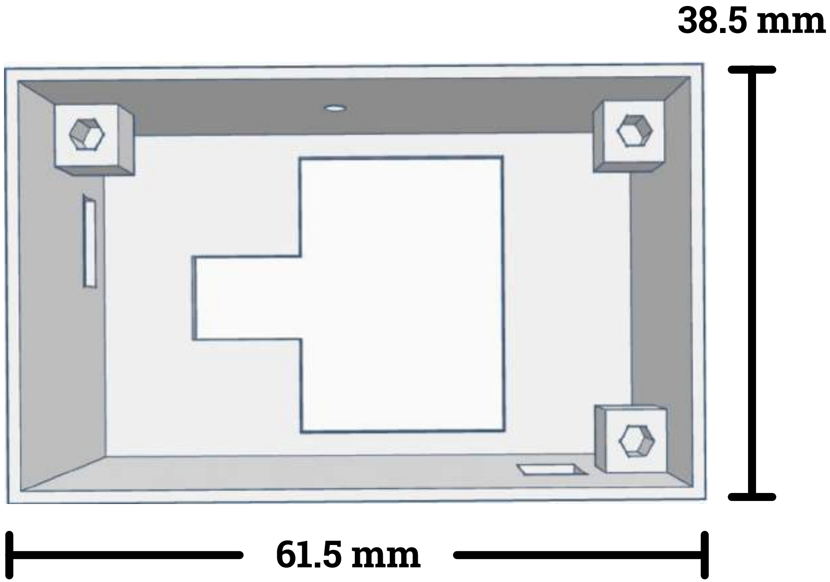
Heart rate & pulse oximetry sensor

# Hardware Construction

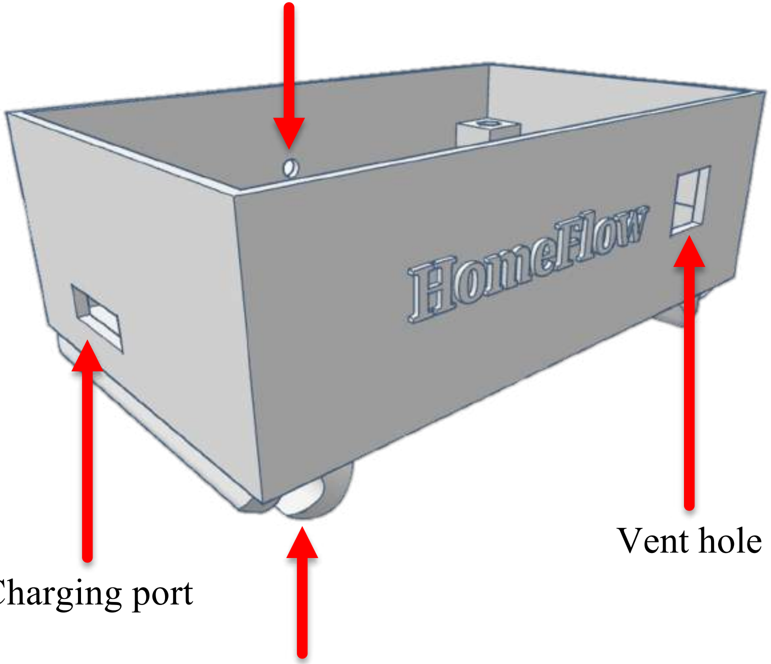


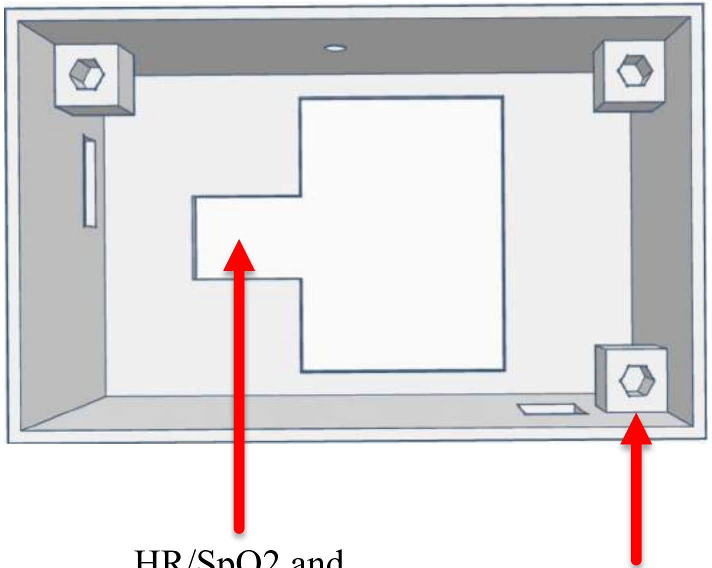
# Enclosure Design



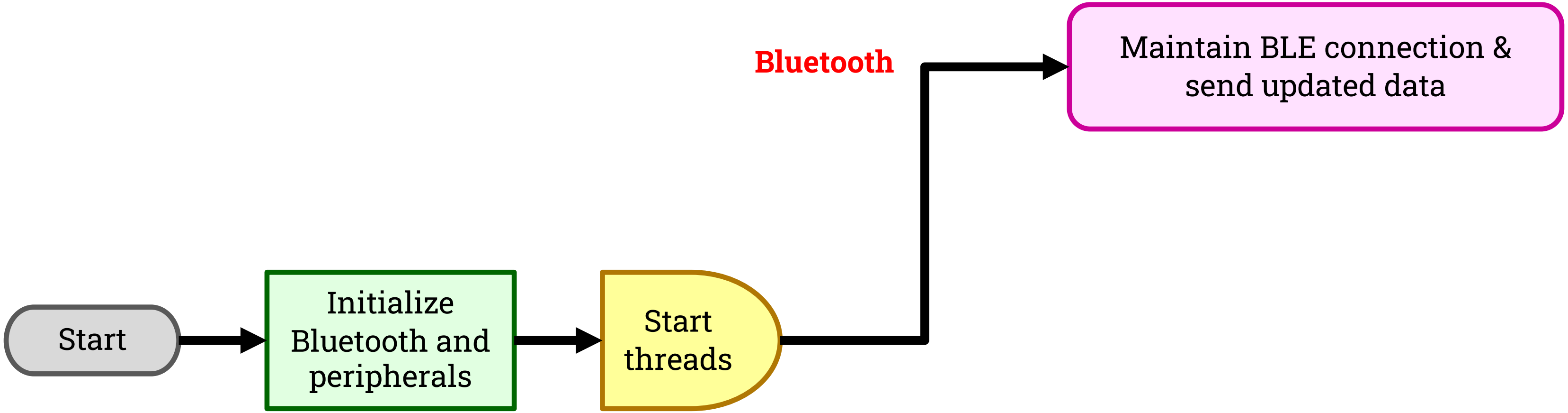
# Enclosure Design



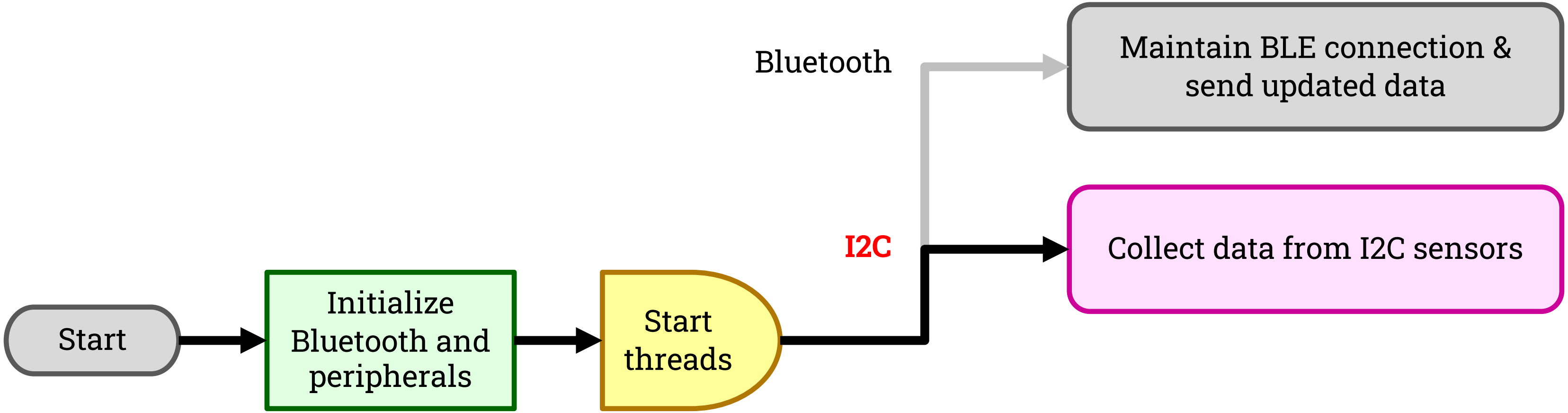



# Embedded Software Design

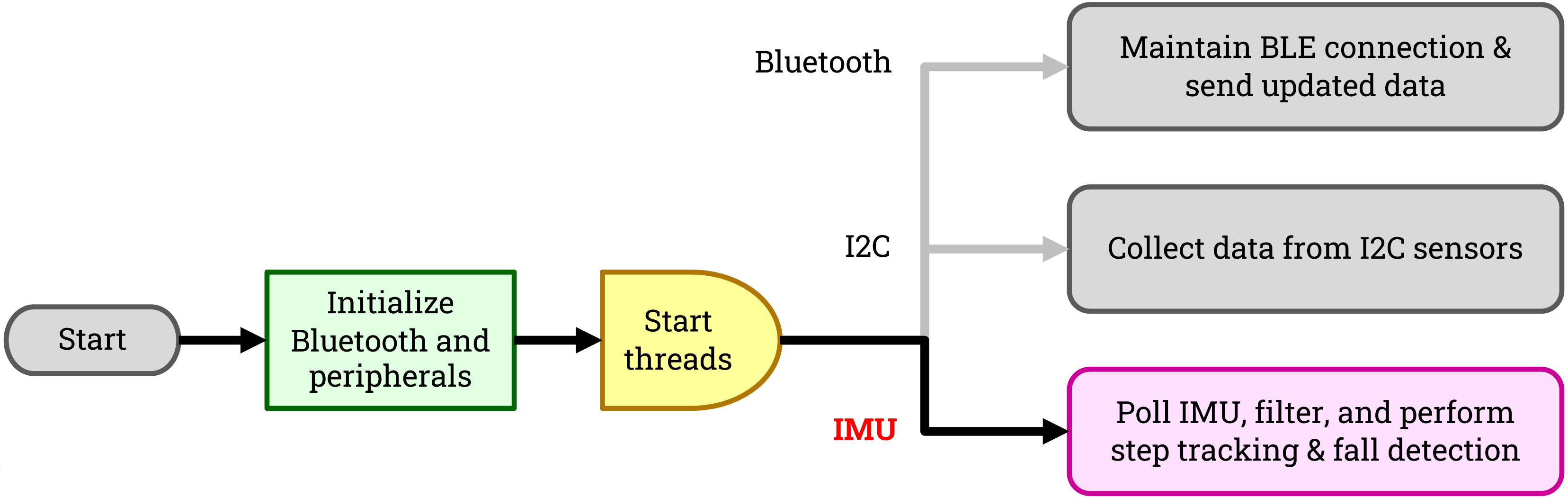
# Embedded Software Flow

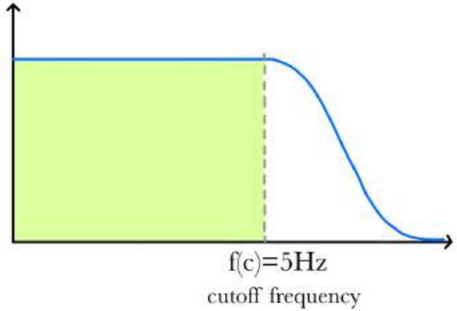


# Embedded Software Flow



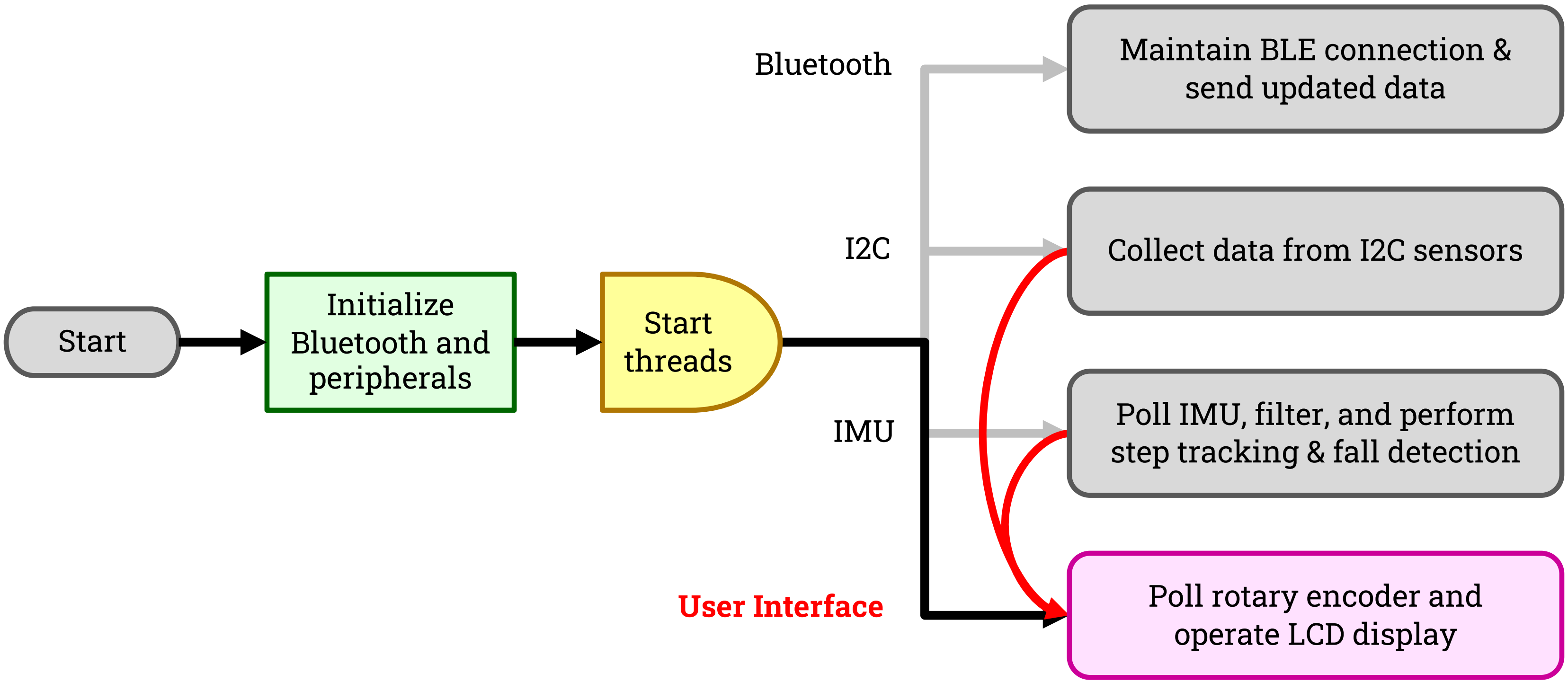
# Embedded Software Flow



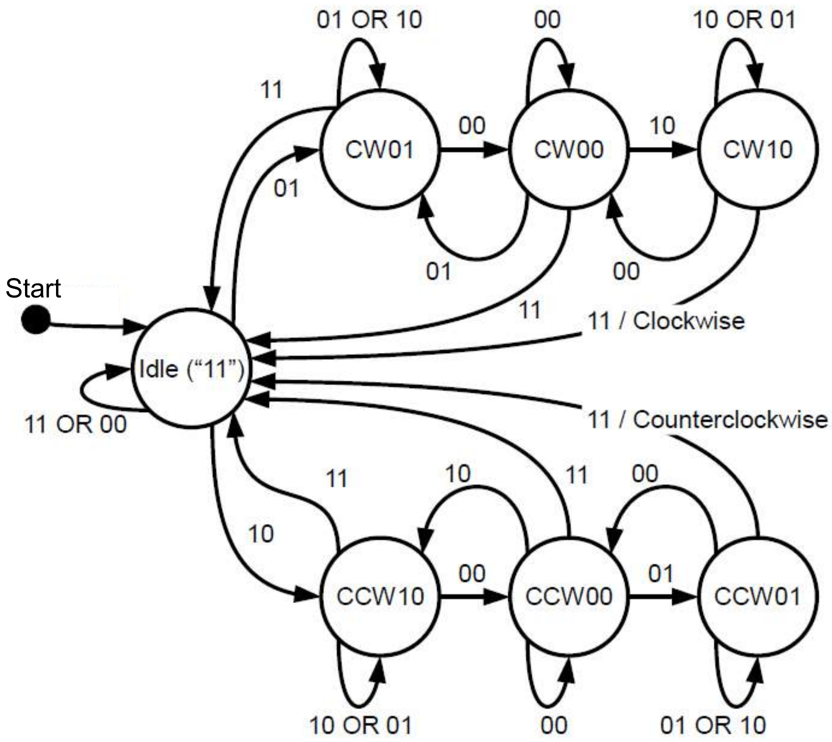




$$V_{out}[n] = \frac{T}{T + RC} V_{in}[n] + \frac{RC}{T + RC} V_{out}[n-1]$$

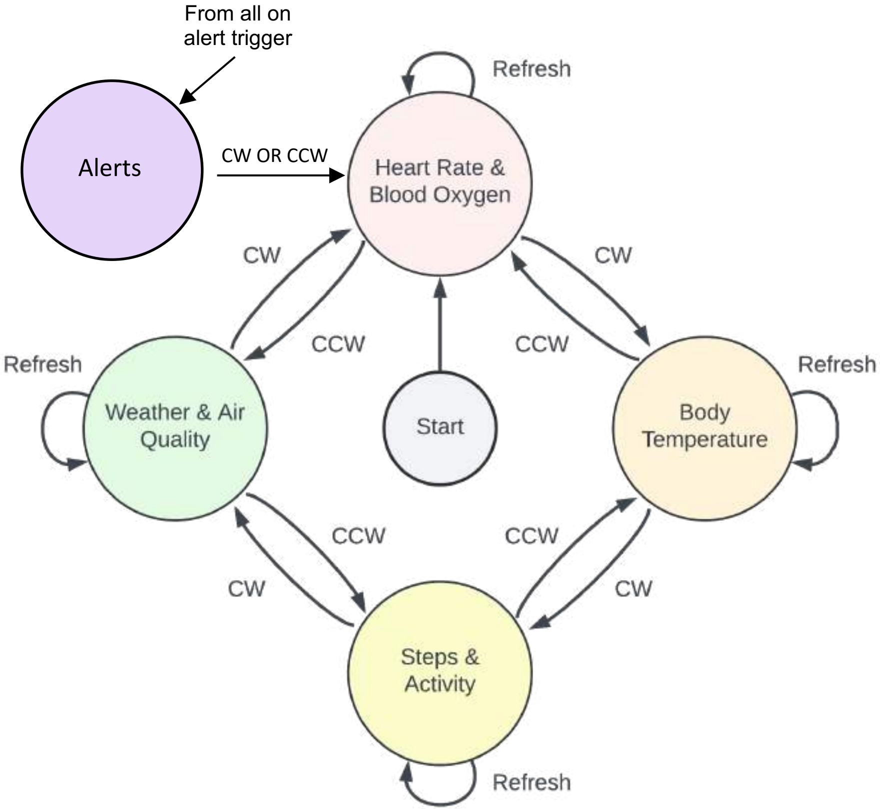
# Embedded Software Flow



# UI State Machines




Rotary encoder debouncing




Wearable user interface

# Wearable User Interface





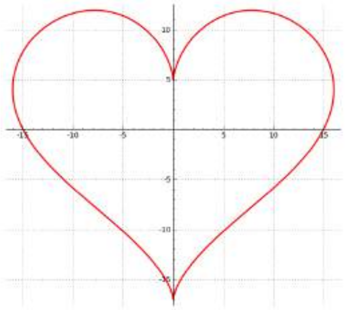
# Custom Display Drivers

```
const uint8_t font[85][5] = {
    // Digits 0-9
    {0x3E, 0x51, 0x49, 0x45, 0x3E}, // 0
    {0x00, 0x42, 0x7F, 0x40, 0x00}, // 1
    {0x42, 0x61, 0x51, 0x49, 0x46}, // 2
    {0x21, 0x41, 0x45, 0x4B, 0x31}, // 3
    {0x18, 0x14, 0x12, 0x7F, 0x10}, // 4
    {0x27, 0x45, 0x45, 0x45, 0x39}, // 5
    {0x3C, 0x4A, 0x49, 0x49, 0x30}, // 6
    {0x03, 0x71, 0x09, 0x05, 0x03}, // 7
    {0x36, 0x49, 0x49, 0x49, 0x36}, // 8
    {0x06, 0x49, 0x49, 0x29, 0x1E}, // 9
    // Uppercase Alphabet A-Z
    {0x7E, 0x09, 0x09, 0x09, 0x7E}, // A
```

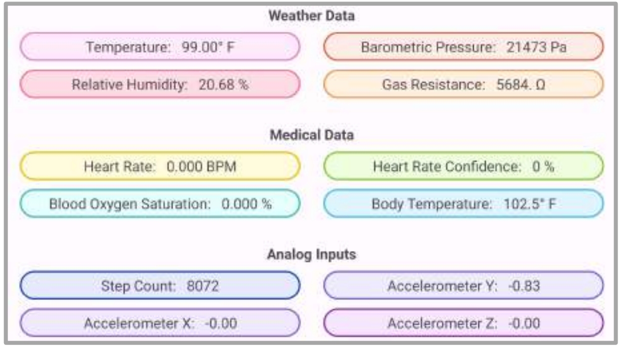
- Optimize pixel drawing with buffers
- Customizable font with digit/text drawing
- Parametric equations to draw shapes

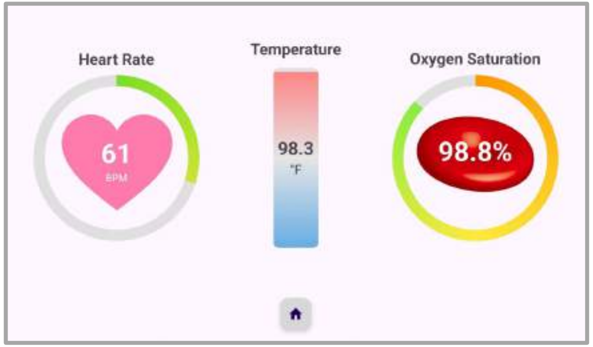
$$x = 16\sin^3 t$$

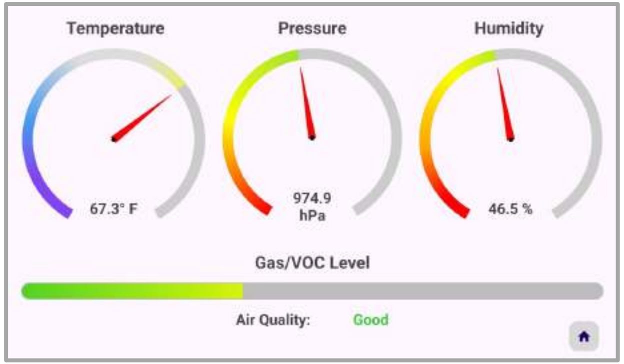
$$y = 13\cos t - 5\cos(2t) - 2\cos(3t) - \cos(4t)$$

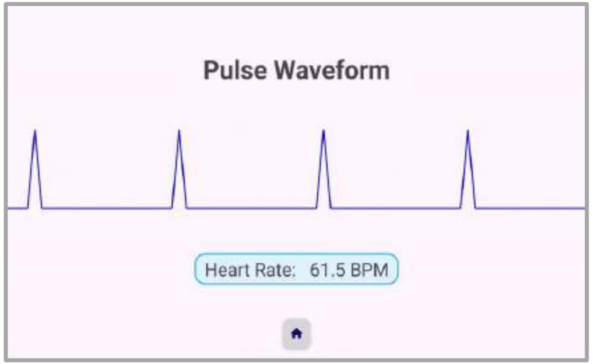


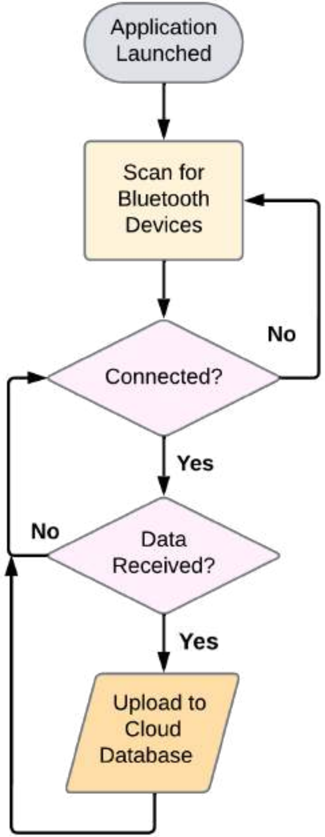
# Android Application



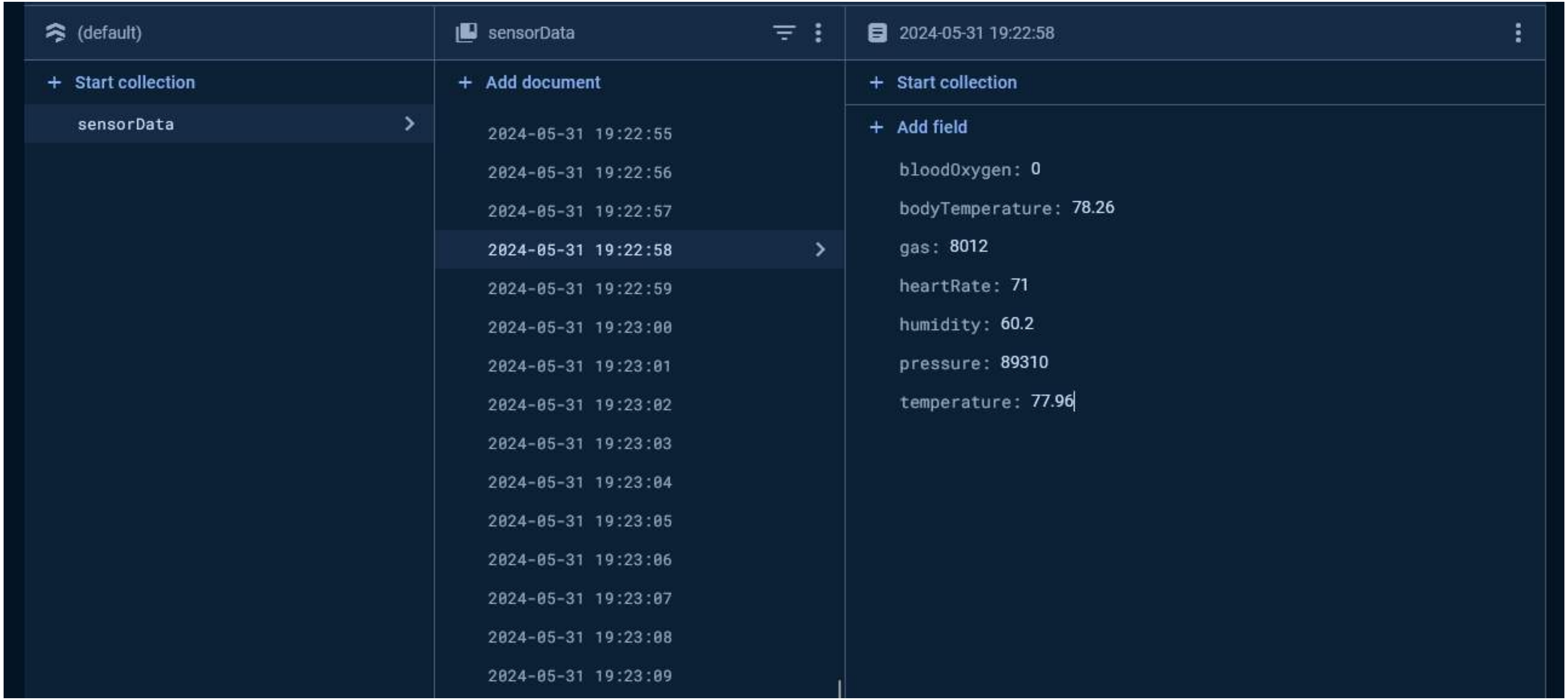



# Firebase


(default)
Start collection
sensorData
sensorData
Add document
2024-05-31 19:22:55
2024-05-31 19:22:56
2024-05-31 19:22:57
2024-05-31 19:22:58
2024-05-31 19:22:59
2024-05-31 19:23:00
2024-05-31 19:23:01
2024-05-31 19:23:02
2024-05-31 19:23:03
2024-05-31 19:23:04
2024-05-31 19:23:05
2024-05-31 19:23:06
2024-05-31 19:23:07
2024-05-31 19:23:08
2024-05-31 19:23:09
2024-05-31 19:22:58
Start collection
Add field
bloodOxygen: 0
bodyTemperature: 78.26
gas: 8012
heartRate: 71
humidity: 60.2
pressure: 89310
temperature: 77.96

# Final Product

# Thank You!

Special thanks to:  Our sponsor IFT, and to
Dr. Yoga Isukapalli and Brian Li for the guidance

# Questions?

# Operating Characteristics

- Power consumption:
  - HR sensor and LCD display OFF: 0.15 W
  - LCD display OFF: 0.22 W
    - LCD power draw would be cut by 33% if run of 3.3V instead of 5V
  - All peripherals ON: 1.48 W
- Battery life:
  - 30 minutes with everything enabled
  - Numerous potential improvements
- Operating temperature:
  - ~110 °F on average


Total capacity:

2 * 0.555 Wh = **1.11 Wh**

# Marketability

- Modular → easily repairable
- Medical focus provides superior data without unnecessary features
  - No calibration required
- Total cost per device: $145.34
  - PCB parts: $46.74
  - HR/SpO2 sensor: $40.00
  - PCB manufacturing and assembly: $58.60
  - Easy improvements: Include HR sensor on PCB, use cheaper IMU, eliminate some weather data, order larger batches of both PCBs and parts
- Seamless databasing and data viewing by medical personnel

# I2C Communication Code Sample

```
float get_body_temp() {
    uint8_t BT_ADDR = 0x48;
    uint8_t write_data1[1] = {0x00};

    // Writing 2 bytes to the sensor
    int ret = i2c_write(i2c0_dev, write_data1, 1, BT_ADDR);
    if (ret < 0) {
        return 0; // Error writing to sensor
    }

    // Reading 2 bytes from the sensor
    uint8_t data_buffer[2];
    ret = i2c_read(i2c0_dev, data_buffer, sizeof(data_buffer), BT_ADDR);
    if (ret < 0) {
        return 0; // Error reading from sensor
    }

    // Raw temp output
    uint16_t temperature = (data_buffer[0]<<8)+(data_buffer[1]);
    float final_temp_F = (temperature / 128.0)*1.8 + 32;

    return final_temp_F;
}
```

# Difficulties and Future Plans

- Including HR/SpO2 sensor on PCB proved too expensive
  - Total PCB cost was ~$500 when soldering sensor on
  - Directly using SMD components would cost $2000 minimum
- Operating temperature can exceed comfortable values
  - Microcontroller has limited power
  - HR/SpO2 sensor and display are drawing more power than necessary
- Potential improvements:
  - Make all components SMD
  - Remedy noise sensor sensitivity issues
  - Add heat management components
  - Reduce size of PCB and enclosure