North South University

Department of Electrical and Computer Engineering

Junior Design Project Report

Portable ECG & Pulse Oximeter Device with HeartPal App

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ABSTRACT:

Development and Evaluation of a Portable ECG Machine with Pulse Oximeter and “HeartPal” App for Heart Health Monitoring.

A Portable ECG Machine with Pulse Oximeter and "HeartPal" App is a device designed to provide a convenient and effective way of monitoring heart health for people on the go. This device combines the functionality of an ECG machine and a pulse oximeter, which are the key components of a comprehensive heart monitoring system. It can be used by healthcare professionals in hospitals, clinics, and emergency settings, as well as by patients at home. The accompanying app, "HeartPal" allows users to record and track their heart health data, providing a comprehensive overview of their cardiovascular health over time. Therefore, the portable device and the app have many advantages over traditional ECG machines, including their ease of use, portability, and real-time monitoring capabilities. It has the potential to promote awareness of heart health and the importance of regular heart monitoring.

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Chapter-1

Introduction:

1.1: Information: Our project aimed to design and develop an innovative medical device that integrates both ECG and pulse oximeter functionalities, along with a dedicated mobile application called HeartPal.
The device is developed using the latest technologies and industry standards and tested for accuracy and reliability. The accompanying app, HeartPal, allows users to record and track their heart health data, providing a comprehensive overview of their cardiovascular health over time. Results showed that the device and app were easy to use, accurate, and reliable.

1.2: Background: Cardiovascular diseases (CVDs) are the leading cause of death worldwide, with 17.7 million deaths in 2015, representing 31% of all global deaths. CVDs are a major public health concern globally, with low- and middle-income countries being the most affected, with 80% of CVD deaths occurring there [1]. Bangladesh has seen a rise in noncommunicable chronic diseases like cardiovascular diseases, leading to increased mortality rates.
A portable ECG machine with a pulse oximeter and the app will act like a medical device that allows users to monitor their heart activity and oxygen saturation levels in real-time. The device will consist of a small, portable ECG machine that is connected to a pulse oximeter and an app. The pulse oximeter will measure the oxygen saturation of the blood, while the app displays the ECG results and provides analysis and interpretation of the results.

1.3: Motivation: The development of portable ECG and pulse oximeter devices is driven by the need for convenient and accessible monitoring of vital signs, particularly for individuals with cardiovascular or respiratory conditions. These devices allow for early detection and monitoring of abnormal heart rhythms, providing timely medical intervention. They offer convenience and mobility, enabling individuals to monitor their heart health anywhere, anytime. It also plays a crucial role in remote patient monitoring, allowing healthcare providers to assess heart rhythm and oxygen saturation levels remotely.
Overall, the motivation behind these devices is to provide individuals with the means to monitor their cardiovascular health conveniently and facilitate remote healthcare in an increasingly connected world.

1.4: Project Goal:

This project aims as follows:

1. To build a portable and compact ECG machine with a pulse oximeter.
2. To develop an accompanying app that is easy to use, accurate, and affordable.
3. To potentially help in the early detection and prevention of cardiovascular disease

4. To promote awareness of heart health and the importance of regular heart monitoring.

1.5: Benefits: The portable ECG machine with pulse oximeter and app has many features and benefits that make it an attractive option for healthcare professionals and patients.

- One of the primary advantages of this device is its **portability**. The device will be small and lightweight, making it easy to transport and use in a variety of settings. This allows healthcare professionals to monitor patients in their homes, at work, or during transportation.
- Another advantage of the project is its **ease of use**. The device is designed to be user-friendly, with simple instructions for performing ECG tests and connecting the device to the app. The app will provide real-time monitoring of the ECG results, making it easy to identify any abnormalities or changes in heart activity.
- By using the portable ECG machine with pulse oximeter and app, patients can monitor their heart activity and oxygen saturation levels on their own, without having to visit a hospital or clinic. This can be particularly useful for patients with chronic conditions such as heart disease or arrhythmias, who may need to monitor their heart activity regularly [2].

Chapter -2

Literature Review:

2.1: Heart health monitoring and ECG machines: An electrocardiogram (ECG) is a non-invasive medical test that measures the electrical activity of the heart. It is also called an electrocardiogram or an EKG. It is a graph of voltage versus time. Very significant intervals and sections between waves are used to describe ECG [3].

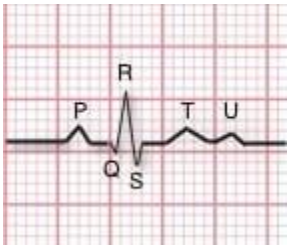


Fig 01: ECG Graph

The first upward of the ECG tracing is the P wave. It indicates atrial contraction. The QRS complex begins with Q, a small downward deflection, followed by a larger upwards deflection, a peak (R); and then a downwards S wave. This QRS complex indicates ventricular depolarization and contraction. Finally, the T wave, which is normally a smaller upwards waveform, representing ventricular re-polarization.

The test is commonly used to diagnose and monitor heart-related conditions such as arrhythmias, heart attacks, and heart failure. Traditionally, ECG tests have been performed in hospitals and clinics using large, stationary machines [4]. However, the development of portable ECG machines has made it possible to perform ECG tests in a variety of settings, including patients' homes.

2.2: Pulse oximeters and oxygen saturation measurement: The pulse oximeter works by emitting two different wavelengths of light, typically red and infrared, through a translucent part of the body, such as a fingertip or earlobe. The light passes through the tissue and blood, and is detected by a photodetector on the other side of the device.

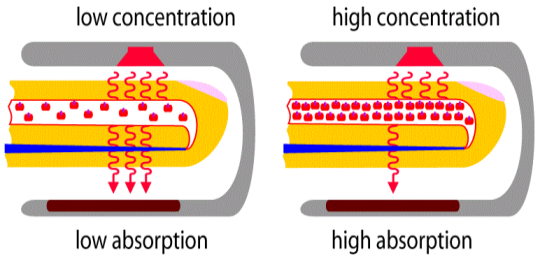


Fig 02: How Pulse Oximeter Works

Oxygenated blood absorbs more infrared light and allows more red light to pass through it, while deoxygenated blood absorbs more red light and allows more infrared light to pass through it. [5] The pulse oximeter measures the ratio of the amount of red light to infrared light that passes through the tissue, and calculates the oxygen saturation level based on this ratio.

The pulse oximeter also measures the person's pulse rate, by detecting the changes in blood volume that occur with each heartbeat. The device uses this information to calculate the person's pulse rate, which is displayed on the device along with the oxygen saturation level.

2.3: Advancements in wearable medical devices: Wearable medical devices are small, portable, and often unobtrusive, making them ideal for use in a variety of settings, from hospitals to homes. Some of the advancements in wearable medical devices include:

- Miniaturization: Wearable devices have become smaller and more compact over time, making them more comfortable for patients to wear for extended periods.
- Connectivity: Many wearable medical devices are now equipped with wireless connectivity, allowing data to be transmitted in real-time to healthcare providers, caregivers, and family members.
- Sensors: Wearable devices are now equipped with a range of sensors, including ECG sensors, pulse oximeters, blood pressure monitors, and glucose sensors, enabling the continuous monitoring of patients' vital signs.
- Artificial Intelligence (AI): Wearable devices are now being integrated with AI technology, enabling the real-time analysis of data and providing insights into patients' health conditions.

As technology continues to advance, we can expect to see further improvements in wearable medical devices, leading to improved patient outcomes and better healthcare delivery.

Chapter -3

Technical Details and Methodology:

3.1: Datasheet: Datasheet of the major component used in our project below:

Bluetooth module (HC-05):

- Operating Voltage: 4V to 6V (Typically +5V).
- Operating Current: 30mA.
- Range: <100m.
- Works with Serial communication and TTL compatible.

Arduino Uno:

- Operating Voltage: 5v.
- Input Voltage: 7-12v.
- DC Current per I/O Pin: 20 mA.
- DC Current for 3.3V Pin: 50 mA.
- Flash Memory: 32 KB of which 0.5 KB used by bootloader.

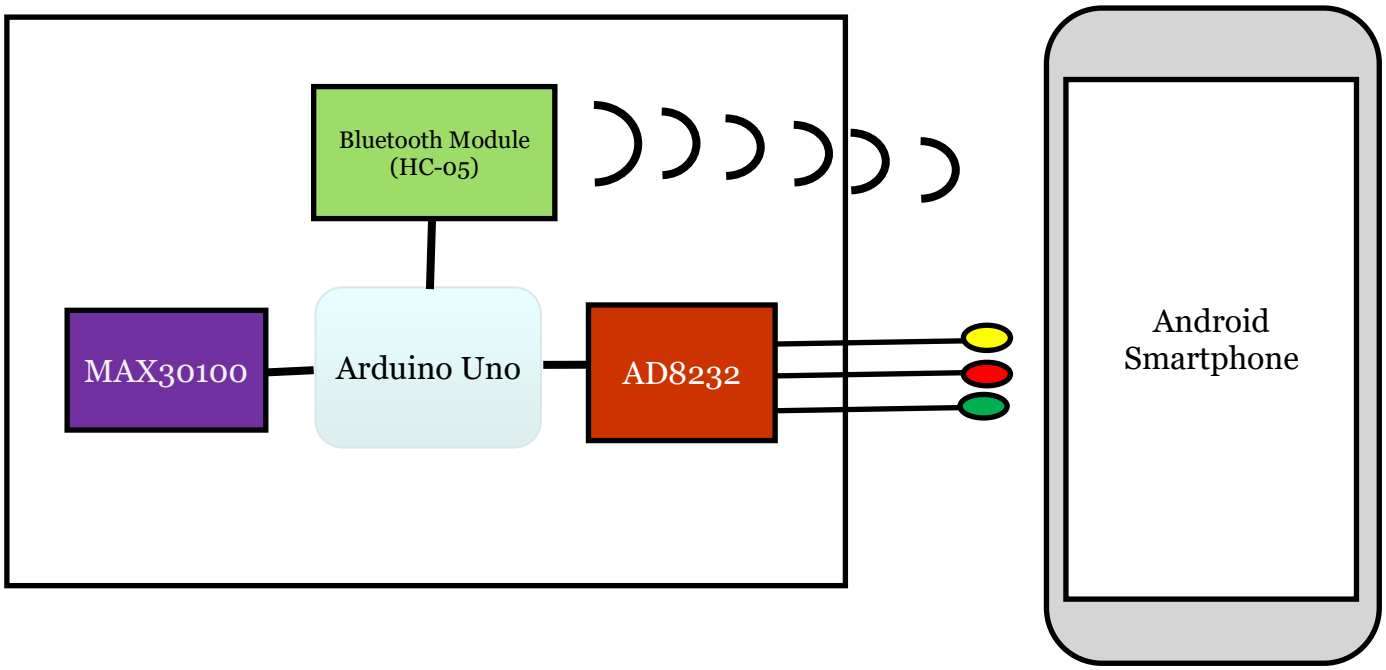
AD8232:

- Power supply voltage: 2.0 V to 3.5 V
- Power consumption: < 170 µA
- Bandwidth: 0.5 Hz to 40 Hz
- Input impedance: > 2 GΩ

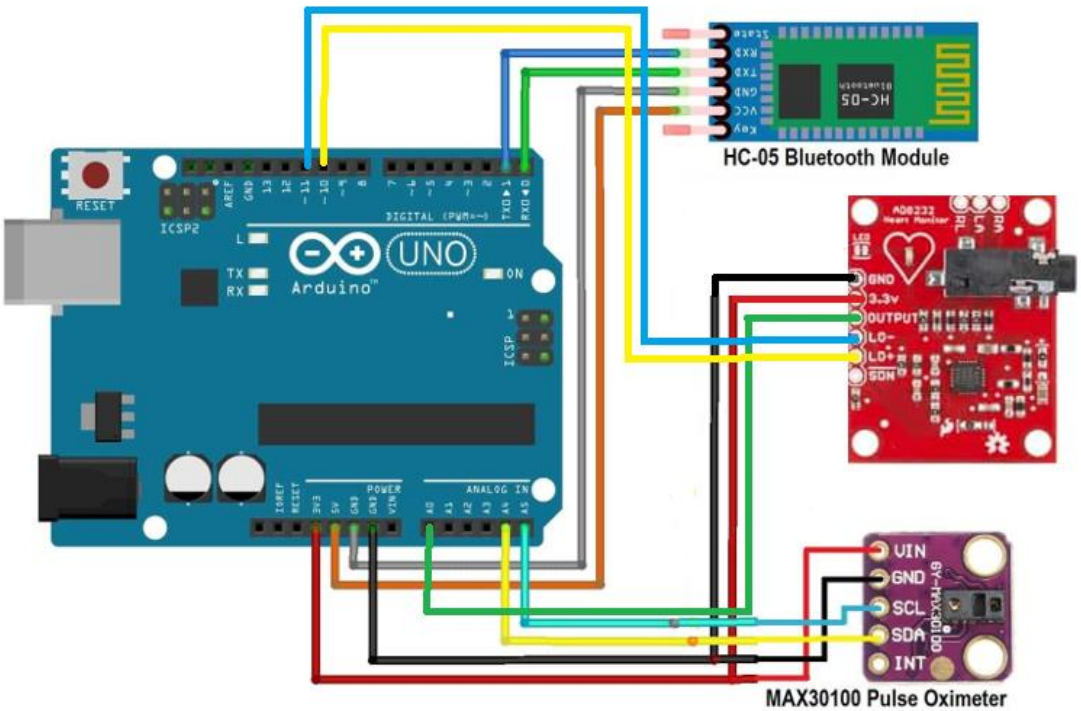
Max30100 Module:

- Supply Voltage: VDD = 1.8 V to 3.3 V
- Operating Current: Active: 600 µA & Shutdown: < 1 µA
- LED Drive Current: Programmable from 0 mA to 50 mA
- Photodiode Input Current: 100 pA to 1 mA
- Sampling Rate: Programmable from 50 Hz to 1,000 Hz
- LED Pulse Width: Programmable from 200 µs to 1,600 µs
- Operating Temperature Range: -40°C to +85°C

3.2: Block Diagram:



3.3: Circuit Diagram:



3.4: Connections:

- Here is the connection of Bluetooth HC-05 Pins to Arduino Uno:

Bluetooth HC-05	Arduino Uno
Rx	1
Tx	0
GND	GND
+5v	5V

Table I: HC-05 and Arduino Uno connections

- Here is the connection of AD8232 Pins to Arduino Uno:

AD8232	Arduino Uno
GND	GND
3.3V	3.3V
Output	A0
LO+	10
LO-	11

Table II: AD8232 and Arduino Uno connections

- Here is the connection of GY-MAX30100 Pins to Arduino Uno:

MAX30100	Arduino Uno
GND	GND
Vin	3.3V
SCL	A5
SDA	A4

Table III: GY-MAX30100 and Arduino Uno connections

Chapter -4

Investigation/Experiment, Result, Analysis

4.1: Component Description: The major components we used in this project are:

i. Arduino Uno
ii. AD8232 single lead ECG sensor with Biomedical sensor pad
iii. HC-05 Bluetooth module
iv. MAX30100 Heart Rate Sensor
v. Breadboard
vi. Jumper wires

Arduino Uno: The most important component for this project is Arduino. Arduino-UNO is a microprocessor that will collect data and present it according to user requirements [7]. A code will be generated for the implementation and operation of the Arduino.

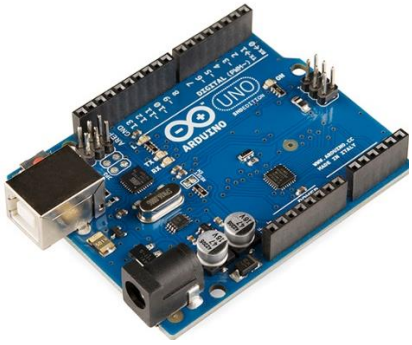


Fig 03-Arduino Uno

Bluetooth HC-05 module: Another essential part of this project is the Bluetooth module. An android device is connected with HC-05 Bluetooth module. Android phone converts the received data into string of data. This string of data was sent to HC-05 Bluetooth module and then to Arduino Uno.

Fig 04- Bluetooth module (HC-05)

MAX30100 Pulse Oximeter and heart rate sensor:

The sensor is an integrated pulse oximetry and heart-rate monitor sensor solution. It combines two LED's, a photo detector, optimized optics, and low-noise analog signal processing to detect pulse and heart-rate signals. It operates from 1.8V and 3.3V power supplies and can be powered down through software with negligible standby current, permitting the power supply to remain connected at all times.

Fig 05- MAX30100 module

AD8232 ECG Sensor: The AD8232 is an integrated signal conditioning block for ECG and other biopotential measurement applications. It is designed to extract, amplify, and filter small biopotential signals in the presence of noisy conditions, such as those created by motion or remote electrode placement. ECGs can be extremely noisy, the AD8232 Single Lead Heart Rate Monitor acts as an op-amp to help obtain a clear signal from the PR and QT Intervals easily. This AD8232 sensor has been used in a lot of ECG studies [8] [9].

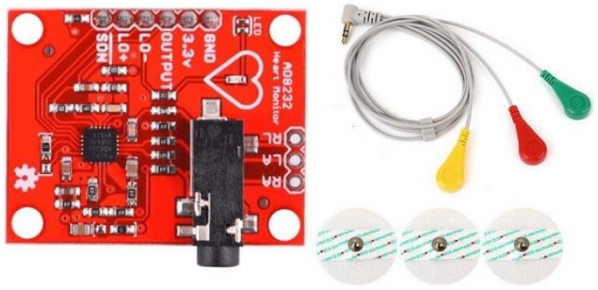


Fig 06- Bluetooth module (HC-05)

4.2: Appendix: Here are the codes for our project:

Code for AD8232 module and Bluetooth:

```
#include <SoftwareSerial.h>
SoftwareSerial btSerial(0, 1); // RX, TX

int in = A0;

void setup() {
  Serial.begin(9600);
  btSerial.begin(9600);

  pinMode(in, INPUT);
  pinMode(10, INPUT); // Setup for leads off detection LO +
  pinMode(11, INPUT); // Setup for leads off detection LO -
}

void loop() {
  if ((digitalRead(10) == 1) || (digitalRead(11) == 1)) {
    Serial.println('!');
  }
  else {
    float val = analogRead(in);
    Serial.println(val);
  }
  //Wait for a bit to keep serial data from saturating
  delay(1);
}
```

Code for Max30100 module and Bluetooth:

```
#include <SoftwareSerial.h>
#include <Wire.h>
#include "MAX30100_PulseOximeter.h"
```

```
#include "MAX30100.h"
#define REPORTING_PERIOD_MS 1000

SoftwareSerial BTserial(0, 1); // RX | TX

const long baudRate = 9600;
char c=' ';
boolean NL = true;

MAX30100 sensor;
PulseOximeter pox;

uint32_t tsLastReport = 0;

// Callback (registered below) fired when a pulse is detected
void onBeatDetected()
{
    Serial.println("Beat!");
}

void setup()
{
   Serial.begin(9600);
    BTserial.begin(baudRate);
    Serial.print("BTserial started at "); Serial.println(baudRate);
    Serial.println(" ");
        Serial.print("Initializing pulse oximeter..");

    // Initialize the PulseOximeter instance
    // Failures are generally due to an improper I2C wiring, missing power supply
or wrong target chip
    if (!pox.begin()) {
        Serial.println("FAILED");
        for(;;);
    } else {
        Serial.println("SUCCESS");
    }
    sensor.begin(); //Get raw values
    sensor.setMode(MAX30100_MODE_SPO2_HR);

    pox.begin();
}

void loop()
{
```

```
    /*-------------MAX30100--------------------*/
    // Make sure to call update as fast as possible
    sensor.update();
    pox.update();
    // Asynchronously dump heart rate and oxidation levels to the serial
    // For both, a value of 0 means "invalid"
     pox.setOnBeatDetectedCallback(onBeatDetected);
    if (millis() - tsLastReport > REPORTING_PERIOD_MS) {
        Serial.print("Heart rate:");
        Serial.print(pox.getHeartRate());
        Serial.print("bpm / SpO2:");
        Serial.print(pox.getSpO2());
        Serial.println("%");

        tsLastReport = millis();
    }
    // Read from the Bluetooth module and send to the Arduino Serial Monitor
    if (BTserial.available())
    {
        c = BTserial.read();
        Serial.write(c);
    }
    // Read from the Serial Monitor and send to the Bluetooth module
    if (Serial.available())
    {
        c = Serial.read();
        BTserial.write(c);
        // Echo the user input to the main window. The ">" character indicates
the user entered text.
        if (NL) { Serial.print(">");  NL = false; }
        Serial.write(c);
        if (c==10) { NL = true; }
    }
}
```

Merged code for MAX30100, AD8232 And HC-05 Bluetooth Module:

```
#include <SoftwareSerial.h>
#include <Wire.h>
#include "MAX30100_PulseOximeter.h"
#include "MAX30100.h"

#define REPORTING_PERIOD_MS 1000
```

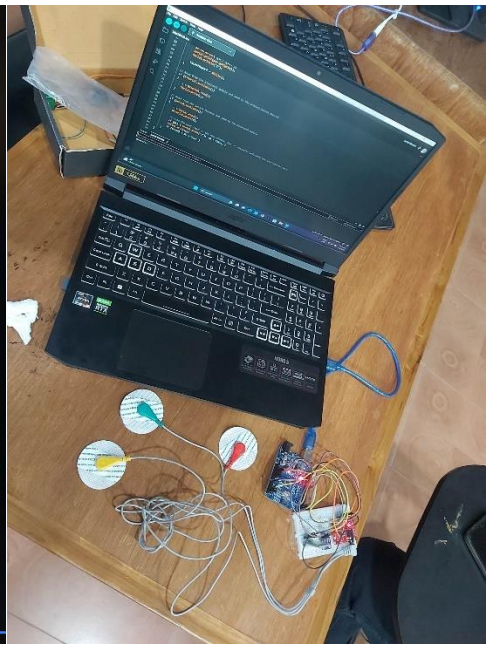
```
SoftwareSerial BTserial(0, 1); // RX | TX

const long baudRate = 9600;
char c = ' ';
boolean NL = true;

MAX30100 sensor;
PulseOximeter pox;

uint32_t tsLastReport = 0;
bool fingerOnSensor = false;

// Callback (registered below) fired when a pulse is detected
void onBeatDetected()
{
  Serial.println("Beat!");
  fingerOnSensor = true;
}

void setup()
{
  Serial.begin(9600);
  BTserial.begin(baudRate);
  Serial.print("BTserial started at "); Serial.println(baudRate);
  Serial.println(" ");
  Serial.print("Initializing pulse oximeter..");

  // Initialize the PulseOximeter instance
  // Failures are generally due to an improper I2C wiring, missing power supply,
or wrong target chip
  if (!pox.begin()) {
    Serial.println("FAILED");
    for (;;);
  } else {
    Serial.println("SUCCESS");
  }
  sensor.begin(); // Get raw values
  sensor.setMode(MAX30100_MODE_SPO2_HR);
  pox.begin();
  pinMode(A0, INPUT); // Set A0 as input for AD8232 ECG sensor
}

void loop()
{
  /*-------------MAX30100---------------------*/
```

```
  // Make sure to call update as fast as possible
  sensor.update();
  pox.update();
  // Asynchronously dump heart rate and oxidation levels to the serial
  // For both, a value of 0 means "invalid"
  pox.setOnBeatDetectedCallback(onBeatDetected);

  if (fingerOnSensor && millis() - tsLastReport > REPORTING_PERIOD_MS) {
    Serial.print("Heart rate:");
    Serial.print(pox.getHeartRate());
    Serial.print("bpm / SpO2:");
    Serial.print(pox.getSpO2());
    Serial.println("%");

    tsLastReport = millis();
  }
  /*-------------AD8232---------------------*/
  float ecgValue = analogRead(A0);

  if (!fingerOnSensor) {
    float ecgValue = analogRead(A0);
    Serial.println(ecgValue);
  }
  // Read from the Bluetooth module and send to the Arduino Serial Monitor
  if (BTserial.available())
  {
    c = BTserial.read();
    Serial.write(c);
  }
  // Read from the Serial Monitor and send to the Bluetooth module
  if (Serial.available())
  {
    c = Serial.read();
    BTserial.write(c);
    // Echo the user input to the main window. The ">" character indicates the
user entered text.
    if (NL) { Serial.print(">");  NL = false; }
    Serial.write(c);
    if (c == 10) { NL = true; }
  }
}
```

A laptop is used for writing the code into the Arduino IDE software and also test the coding whether it is correctly uploaded or not.

4.3: Data Processing: The Arduino UNO is a microcontroller board that is used for building electronic projects. The Bluetooth HC-05 module allows for wireless connectivity between the ECG machine and other devices. The MAX30100 Heart Rate Sensor is a pulse oximeter and heart rate sensor that can be used to measure heart activity [6]. The AD8232 single lead ECG sensor is used to measure the electrical activity of the heart. Biomedical sensor pads are used to attach the sensors to the skin. A laptop is used to power the Arduino. A breadboard and jumper wires are used to connect the various components together.

4.4: Experimental Setup:



Chapter-05

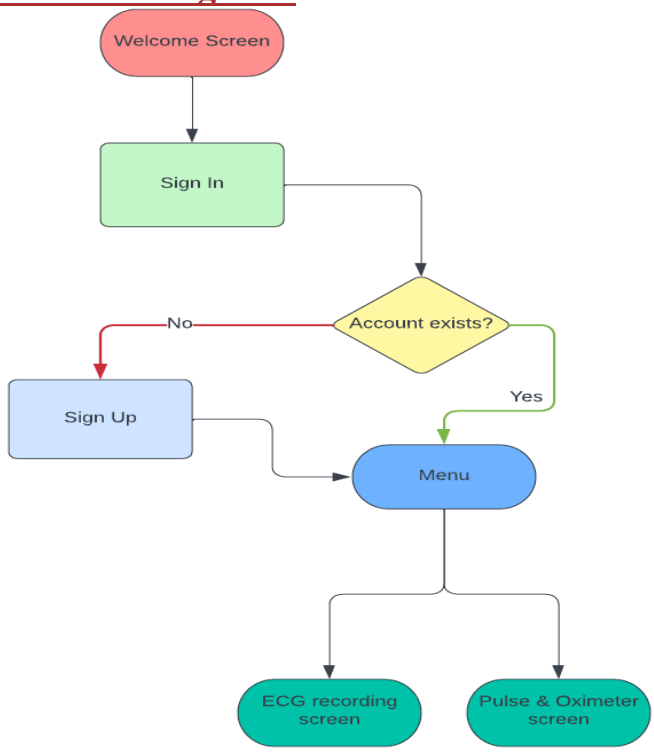
Android App Details

5.1: Introduction: HeartPal is an innovative mobile application designed to revolutionize the way individuals monitor and manage their heart health. Developed with a focus on convenience, accessibility, and accuracy, the app provides users with a comprehensive platform for tracking and analyzing their electrocardiogram (ECG) readings. With just a compatible smartphone and a portable ECG device, users can effortlessly record and monitor their heart's electrical activity anytime, anywhere.

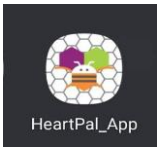
5.2: Software Tools:

1) Arduino IDE
2) MIT App Inventor
3) Firebase

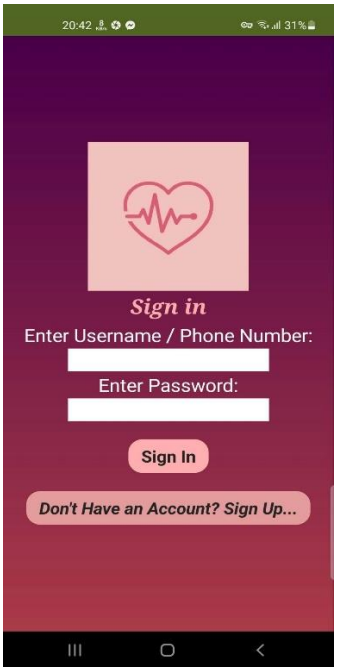
5.3: HeartPal App Interface Diagram:



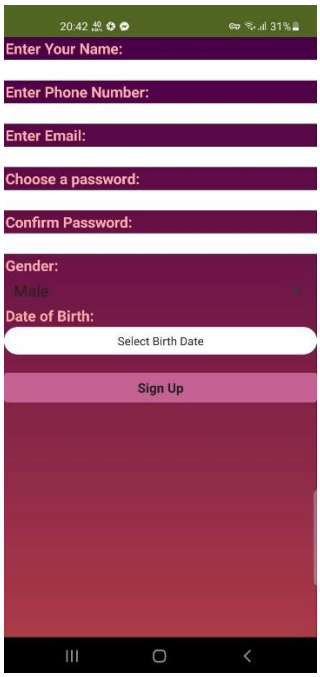
5.3: HeartPal App's UI Interface Designs:



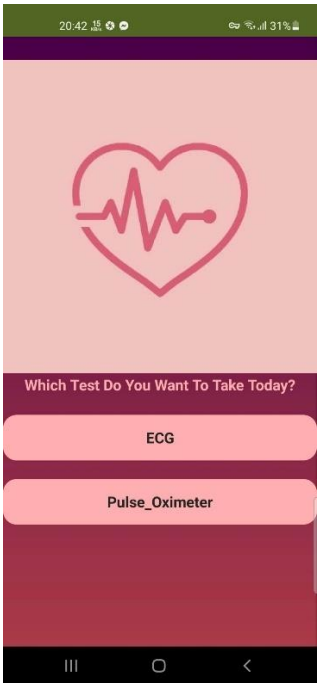
Welcome Screen



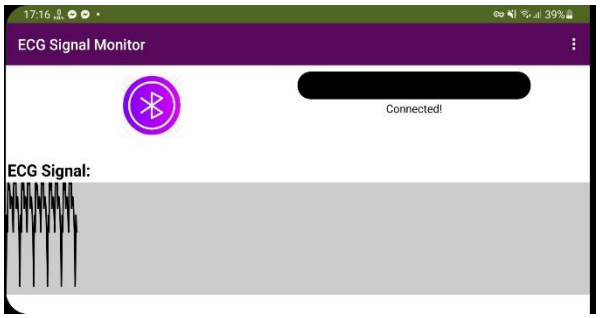
Login Page



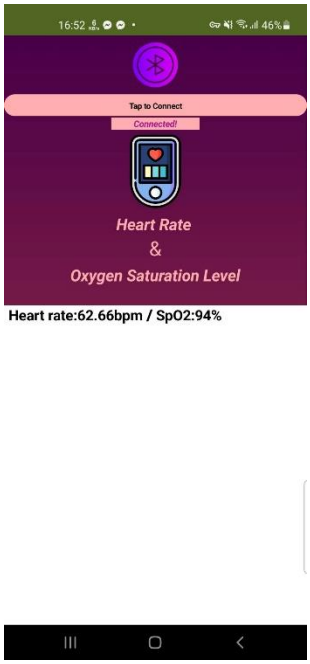
Sign Up page



Menu



ECG signal Monitor Screen



Pulse Oximetry Screen

Chapter -6

Working Sheets:

6.1: Work Breakdown Structure: The estimated time distribution for our project was as below:

Week 1: Project research, collecting data, project proposal, learning about different perspective for building the project.

Week 2: Hardware components collecting and setup.

Week 3: Reviewing hardware device setup front-end, designing front-end.

Week 4: Reviewing front-end, designing front-end.

Week 5: Reviewing database, storing data in the database.

Week 6: Reviewing backend, back-end coding.

Week 7: Connecting front-end, back-end and database.

Week 8: Testing device, debugging source code, testing project performance.

Week 9: Analyzing project performance, Report writing.

Week 10: Project demonstration and Presentation

6.2: Financial Plan & Cost: The total cost was around 2510 BDT. Here is a list:

Components	Costs	Quantity
Arduino Uno	**700**	**1**
Bluetooth HC-05	**340**	**1**
AD8232 ECG sensor with Biomedical sensor pad	**900**	**1**
Breadboard	**70**	**1**
Jumper wires	**30**	**15**
MAX30100 module	**470**	**1**

Table IV: Costings for the project

Chapter- 7

Project Summary:

7.1: Problem Faced & Solution: While implementing our project we faced some types of problem. During the upload process, we need to disconnect the RX and TX pins of the Bluetooth HC-05 module. While uploading code to an Arduino board, the RX (Receive) and TX (Transmit) pins are used for serial communication between the computer and the Arduino. The reason the Bluetooth TX pin needs to be disconnected is because in the serial system the idle state is HIGH so the 5v from the Bluetooth module will confuse the Arduino and prevent it detecting serial signals from the PC.

It is unfixable, buying another Bluetooth module will not change anything, and it is not a bug. It is an inconvenience.

7.2: Limitations: Despite its many advantages, the portable ECG machine with pulse oximeter and app can have some limitations.

- One of the primary limitations is its accuracy. While the device is designed to be accurate and reliable, it may not provide the same level of accuracy as traditional ECG machines. This is particularly true for patients with complex cardiac conditions, who may require more sophisticated monitoring equipment.
- Another limitation of the device is its cost. While the portable ECG machine with pulse oximeter and app is more affordable than traditional ECG machines, it can still be expensive for some patients. This may limit its accessibility for patients who cannot afford the device or who do not have health insurance coverage. But we will try our best from our side to reduce the total cost further.

7.3: Future Development Opportunities: The future development of our project on the Portable ECG device with pulse oximeter and HeartPal app holds tremendous potential for advancing heart health monitoring and patient care. Here are some key aspects to consider for its future development:

- ***Integration of Artificial Intelligence:*** Exploring the integration of artificial intelligence (AI) into our project. AI algorithms can be trained on large datasets to develop predictive models for identifying and diagnosing heart conditions. By leveraging AI, the portable

ECG device and HeartPal app can provide real-time alerts and personalized recommendations for users based on their unique health profiles, helping them make informed decisions about their cardiac health.

- ***Enhanced Data Analytics:*** Investing in further research and development to refine the data analytics capabilities of the HeartPal app. This could involve implementing advanced algorithms and machine learning techniques to analyze ECG and pulse oximeter data more accurately. The goal is to provide users with comprehensive insights into their heart health, including identifying patterns, detecting abnormalities, and predicting potential cardiac events.
- ***Remote Monitoring and Telemedicine:*** Expanding the capabilities of the HeartPal app to support remote patient monitoring and telemedicine. This would involve enabling healthcare providers to securely access and analyze patient data remotely, facilitating real-time consultations, and allowing for proactive interventions based on the captured ECG and pulse oximeter readings. Integrating video conferencing or chat features within the app would further enhance the telemedicine aspect.
- ***Wearable Technology Integration:*** Considering integrating the portable ECG and pulse oximeter functionalities into wearable devices, such as smartwatches or fitness trackers. This would provide users with a more seamless and continuous monitoring experience, allowing for long-term data collection and analysis. Additionally, wearable devices could leverage other sensors (e.g., accelerometer, gyroscope) to provide more comprehensive insights into physical activity and its impact on heart health.
- ***Collaboration with Healthcare Professionals:*** Forging partnerships with healthcare professionals, research institutions, and medical organizations. Collaborating with experts in cardiology and other relevant fields can help validate and enhance the accuracy of our device and app. It can also open avenues for clinical trials, feedback, and validation studies, ensuring that our project meets the highest standards of quality and effectiveness.

7.4: Conclusion:

The Portable ECG Machine with Pulse Oximeter and App can be a valuable tool for promoting heart health and regular heart monitoring. The device and app are designed to be affordable, easy to use, and accurate, making heart monitoring accessible to a wider range of people. By providing users with a comprehensive overview of their heart health data, the app will promote awareness of heart health and the importance of regular heart monitoring [10]. Overall, this project can be a valuable addition to the field of heart monitoring and is expected to have a positive impact on the health and wellbeing of its users.

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