



# Integrated Health Monitoring System with ECG, SCG, SpO<sub>2</sub>, and Heart Rate Measurements using ESP32 and other Biosensors

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**Abstract:** Integrated health monitoring systems have gained significant attention in recent years due to their potential in providing real-time and continuous monitoring of various physiological parameters. This paper presents the design and implementation of an integrated health monitoring system using an ESP32 microcontroller and various biosensors, including ECG (AD8232), SCG (MPU6050), and SpO<sub>2</sub> (MAX30100). The system allows simultaneous ECG, SCG, SpO<sub>2</sub>, and heart rate measurements, providing comprehensive insights into cardiac activity and oxygenation levels. A graphical user interface (GUI) and serial communication are also incorporated to enable real-time visualization and analysis of the acquired signals. The research approach involved the development of a customized hardware setup and the utilization of signal processing techniques to extract relevant information from the acquired signals. Extensive experiments were conducted to evaluate the system's performance in capturing accurate and reliable measurements. The obtained results demonstrate the successful integration of multiple biosensors and the system's capability to provide synchronized and real-time monitoring of key physiological parameters. The significance of this research lies in its potential applications in healthcare, fitness tracking, and remote patient monitoring. By leveraging the capabilities of ESP32 and advanced biosensors, the proposed system offers a portable, non-invasive, and cost-effective solution for continuous health monitoring. The results highlight the system's effectiveness in capturing ECG waveforms, analyzing SCG signals for mechanical insights, and measuring SpO<sub>2</sub> levels accurately. In conclusion, this paper's integrated health monitoring system offers a robust platform for real-time monitoring of ECG, SCG, SpO<sub>2</sub>, and heart rate measurements. The developed system and its associated methodologies hold promise for advancing healthcare technologies and improving the quality of patient care. Future work will focus on expanding the system's capabilities, refining the signal processing algorithms, and conducting clinical studies to validate its performance in diverse healthcare scenarios.

**Keywords:** Health monitoring, ECG, SCG, SpO<sub>2</sub>, Heart rate, MAX30100, MPU6050, ESP32, GUI, Serial communication.

## I. INTRODUCTION

Healthcare monitoring has undergone significant advancements in recent years, moving from traditional episodic data collection to continuous and comprehensive monitoring. This shift has become increasingly crucial in managing chronic diseases and improving patient outcomes. Integrated health monitoring systems have emerged as a promising solution to address the limitations of traditional monitoring methods by integrating multiple biosensors and technologies to capture and analyze various physiological parameters simultaneously.

The development of specialized biosensors has played a vital role in advancing integrated health monitoring. These compact devices, such as the AD8232 biosensor for ECG, the MAX30100 biosensor for SpO<sub>2</sub> and heart rate, and the MPU6050 biosensor for SCG, enable the accurate and real-time measurement of vital signs. These biosensors provide valuable insights into cardiac activity, oxygenation levels, and mechanical aspects of heart function.

Microcontrollers, such as the ESP32, have become essential components in integrated health monitoring systems. These small, low-power devices provide the computational capabilities required for data processing and analysis from multiple biosensors. Additionally, they enable wireless communication, allowing for real-time data transmission and remote monitoring.

Despite the progress made in biosensors and microcontrollers, there is still a need for integrated health monitoring systems that can accurately capture and synchronize multiple vital parameters. Existing solutions often rely on separate devices for measuring individual vital signs, leading to inconvenience and challenges in data management. The lack of synchronized measurements also hinders the ability to correlate different physiological signals accurately.

The research project aims to bridge this gap by designing and implementing an integrated health monitoring system that combines ECG, SCG, SpO<sub>2</sub>, and heart rate measurements. By integrating specific biosensors, such as the AD8232, MAX30100, and MPU6050, with the ESP32 microcontroller, the project seeks to provide synchronized and real-time measurements. Developing a graphical user interface (GUI) will facilitate data visualization and interpretation.

This project's outcomes can revolutionize healthcare management by enabling early detection of cardiac abnormalities, identification of oxygenation-related issues, and insights into the mechanical aspects of heart function. By improving patient outcomes through proactive interventions and personalized healthcare approaches, integrated health monitoring systems can significantly impact the field of healthcare.

## 1.1 Objective

The objective of this research project is to develop an integrated health monitoring system that addresses the limitations of existing systems. The key objectives include:

1. Integration of vital sign measurements: The project aims to combine ECG, SCG, SpO<sub>2</sub>, and heart rate measurements into a single device, eliminating the need for multiple devices and cables. This integration enhances user convenience and streamlines data management.
2. Synchronized measurements: The proposed system aims to capture vital signs simultaneously, enabling accurate correlation and analysis of different physiological signals. This synchronization provides a comprehensive view of an individual's health status and improves diagnostic capabilities.
3. Accuracy and reliability: By integrating specific biosensors and implementing calibration and synchronization techniques, the project ensures accurate and reliable measurements. This accuracy is essential for making informed healthcare decisions and interventions.

## 1.2 Proposed System

The proposed integrated health monitoring system combines ECG, SCG, SpO<sub>2</sub>, and heart rate measurements into a single device. By integrating specific biosensors (AD8232, MAX30100, MPU6050) with the ESP32 microcontroller, the system enables synchronized and accurate measurements of multiple vital parameters.

Key points:

1. Single-device convenience: The proposed system eliminates the need for multiple devices and cables, providing a streamlined and user-friendly experience for users.
2. Comprehensive health assessment: By capturing ECG, SCG, SpO<sub>2</sub>, and heart rate simultaneously, the system provides valuable insights into various aspects of cardiovascular health.
3. Synchronization for accurate analysis: The system synchronizes measurements to establish correlations and patterns between different physiological signals, aiding in early detection, accurate diagnosis, and treatment planning.
4. Reliable measurements: The integration of biosensors with the ESP32 microcontroller ensures calibration and synchronization, minimizing variability and improving the overall accuracy of the captured data.

## 1.3 Existing System

Existing health monitoring systems face several challenges and limitations, which the proposed integrated system aims to overcome. Here are the problems commonly encountered with existing systems:

1. Inconvenience for users: Existing systems often require users to use multiple devices to measure different vital signs. This can be cumbersome and time-consuming, requiring users to carry and manage multiple devices and cables.
2. Lack of synchronized measurements: Traditional systems measure different vital signs at different times, making it difficult to establish accurate correlations between physiological signals. Synchronized measurements are crucial for a comprehensive understanding of an individual's health status.
3. Variability and inconsistencies in data: Using separate devices for each vital sign may introduce variability and inconsistencies in the collected data. This can impact the reliability and accuracy of the measurements, leading to potential challenges in diagnosis and treatment decisions.
4. Complex data management: Managing and synchronizing data from separate devices can be complex and may require additional software or manual efforts. This can pose challenges in data integration, analysis, and interpretation.
5. Limited scope of measurement: Some existing systems focus on measuring only specific vital signs, neglecting the comprehensive assessment of an individual's health. This may lead to missed opportunities for early detection or identification of underlying health conditions.

## II. LITERATURE SURVEY

Remote healthcare has gained traction for its accessibility and effectiveness. Portable devices and biosensors have improved monitoring accuracy and convenience.

- AD8232 module: Used for ECG monitoring, known for sensitivity and low noise.
- MAX30100 module: Measures SpO<sub>2</sub> and heart rate accurately in real-time.
- MPU6050 module: Captures mechanical vibrations of the heart for SCG monitoring.
- ESP32 module: Enables data acquisition from biosensors and wireless communication.
- GUI: Enhances data visualization and analysis for informed decision-making.

[1] In their paper, Md Abdur Rahman presents Remote monitoring of heart rate and ECG using esp32 that project used ad8232 for ECG and pulse sensor for SPO2 and heartrate monitoring purposes, by using esp32 there they can transfer the data anywhere in the world.

[2] In their paper, Deepak Rai focuses on A Comprehensive Review on Seismocardiogram: Current Advancements on Acquisition, Annotation, and Applications, there they used ECG and SCG modules to collect mechanical and electrical activities of the heart.

### III. IMPLEMENTATION OF Integrated System for Health Monitoring

#### 3.1 Block Diagram

The proposed model operates based on a block diagram that outlines its functionality. The user/patient will be the subject, he himself can collect the basic body vitals like ECG, SCG, SPO2, and heart rate.

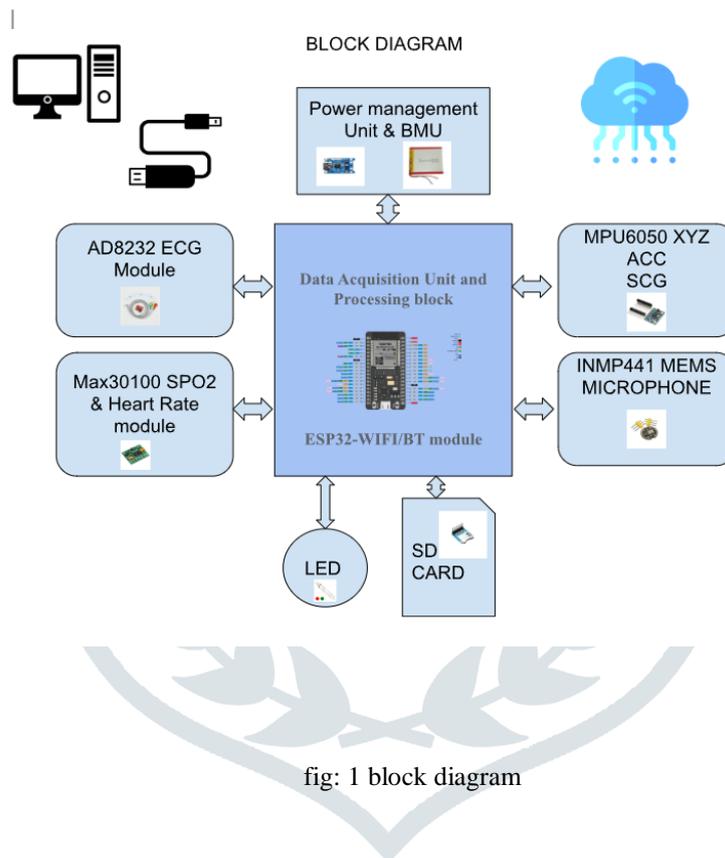
In the system, Esp32 is the core component it will acquire the data from different sensors process the data and send it to a PC or mobile using communication protocols, here in the hardware along with the main sensor there are other supporting modules like SD card, INMP441 MEMS microphone for future reference.

-AD8232 ECG module, this module will amplify the weak electrical signal of the heart and send the data to esp32, ESP32 inbuilt ADC will convert the raw ADC values into ECG signal.

-MAX30100 SPO2&Heart rate module, this module will be used to collect the spo2 and heart rate value using I2C communication.

-MPU6050 3-axis accelerometer & Gyroscope, by using this module we can get the mechanical vibrations of the heart, which is connected with ESP32 via I2C protocol.

-Power management unit, this section will take care of battery charging and protection, TP4056 module it has a type c port to charge the battery and it has an onboard over-current, voltage protection chip.



3.2 CIRCUIT DIAGRAM

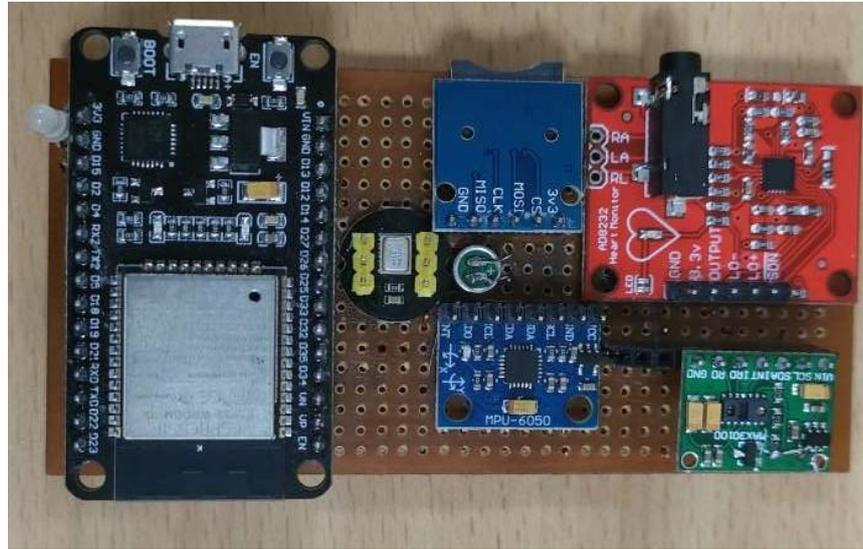


fig: 2 Circuit diagram

Everything is soldered on a single PCB, for protection purpose designed a 3D printed enclose and all sensors will be placed on the top of the PCB.

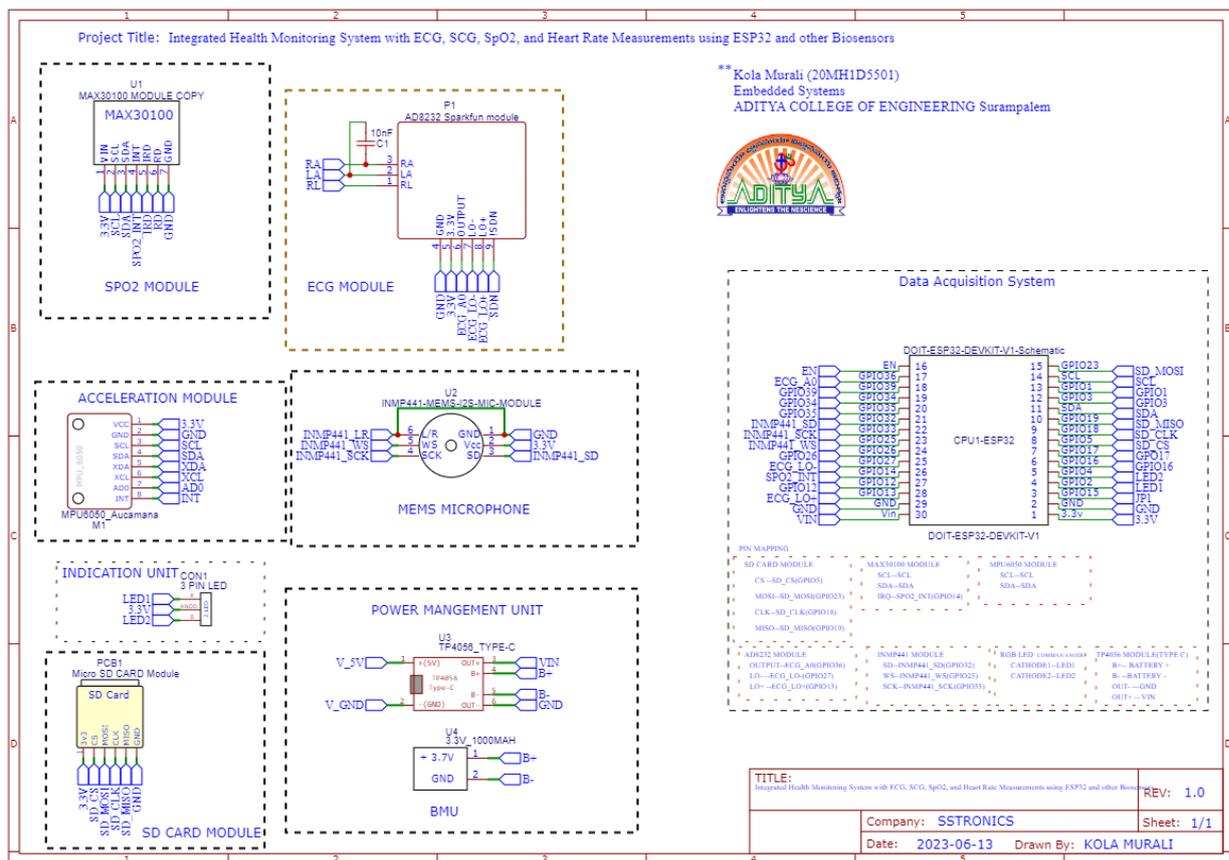


fig: 3 Schematic

IV. WORKING

4.1 Algorithm Implementation:

The firmware written in c used Arduino IDE for development.

1. first esp32 will turn on and initiate the pins and default settings
2. Control will go to the GUI; from GUI we can control the operations.
3. when serial data is available, based on the string received from the GUI, it will start the operation.
4. after the operation completes again go back to the same loop and wait for a new string from GUI.

## 4.2 Working

It is a standalone device, which means it can be handheld so the end user can use it themselves to collect the body vitals.

1. first, we have to connect the device's USB cable to PC, through the USB cable the board will get the power. it is an optional battery unit, using any type c charger we can charge the battery.
2. Open the Health monitoring app (GUI) on the laptop.
3. select the com port and select the device. click on connect button.
4. once successfully connected with the device we can start the monitoring process.
5. In the GUI window there are 4 Buttons, SPO2, ECG, Heartrate, and SCG.
6. If the user presses the ECG button, the user needs to connect the ECG electrode before starting the test and once the user clicks on the ECG button the waveform will appear on the screen, backend algorithm will remove the noise and calculator the heartrate from ECG wave and save it as a wave file.
7. if the user clicks on SPO2 or the heart rate button user needs to place the finger on the max30100 sensor top surface, so it will calculate the spo2 and heart rate and display the values.
8. if the user clicks on the SCG button it will collect the data from the MPU6050 sensor, the user needs to place either sensor on the body's surface tightly otherwise the values may be wrong.

## V. RESULT

### 5.1 PROJECT KIT

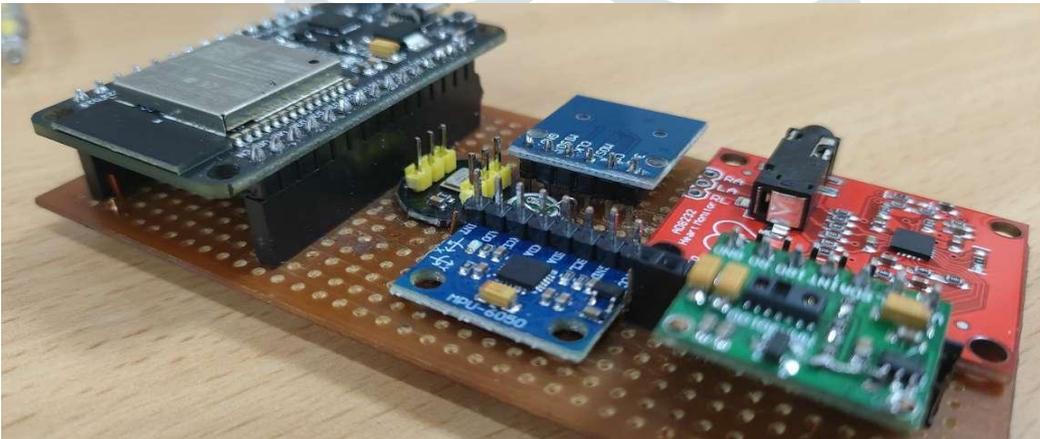
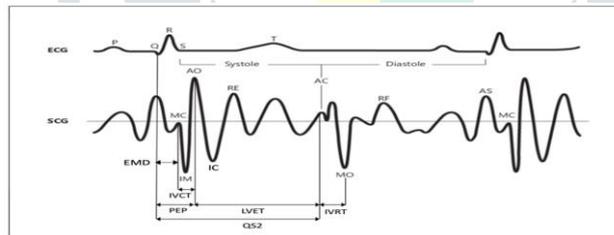


fig: 4 Project kit

### 5.2 Results



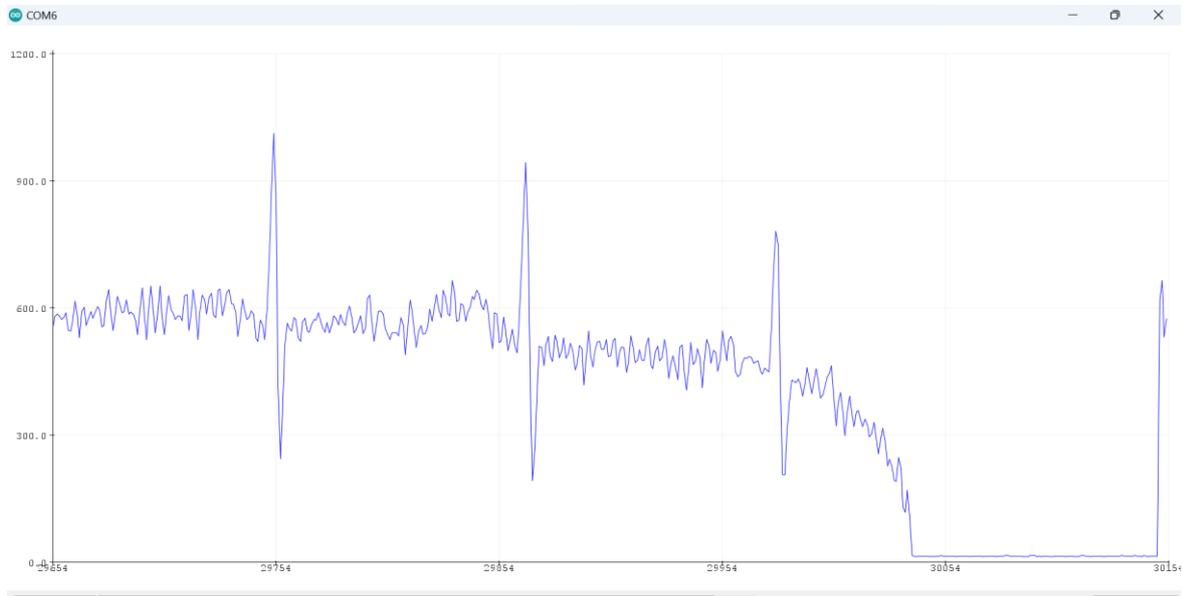


fig: 5 Output 1 ECG wave r-r interval

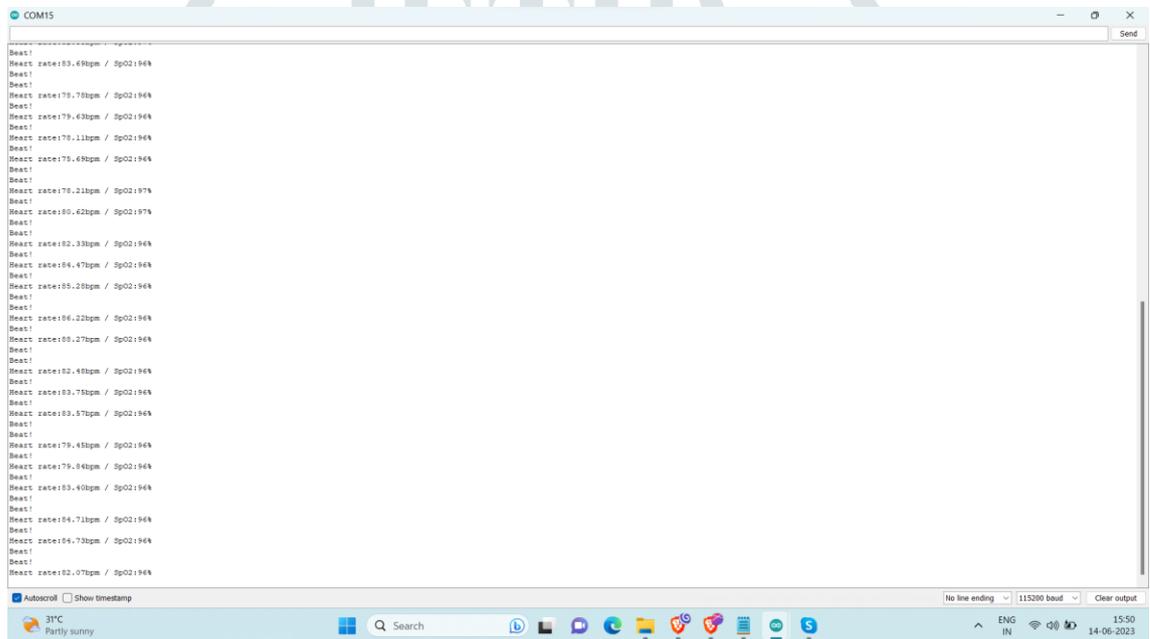


fig: 6 output 2 spo2 & heat rate

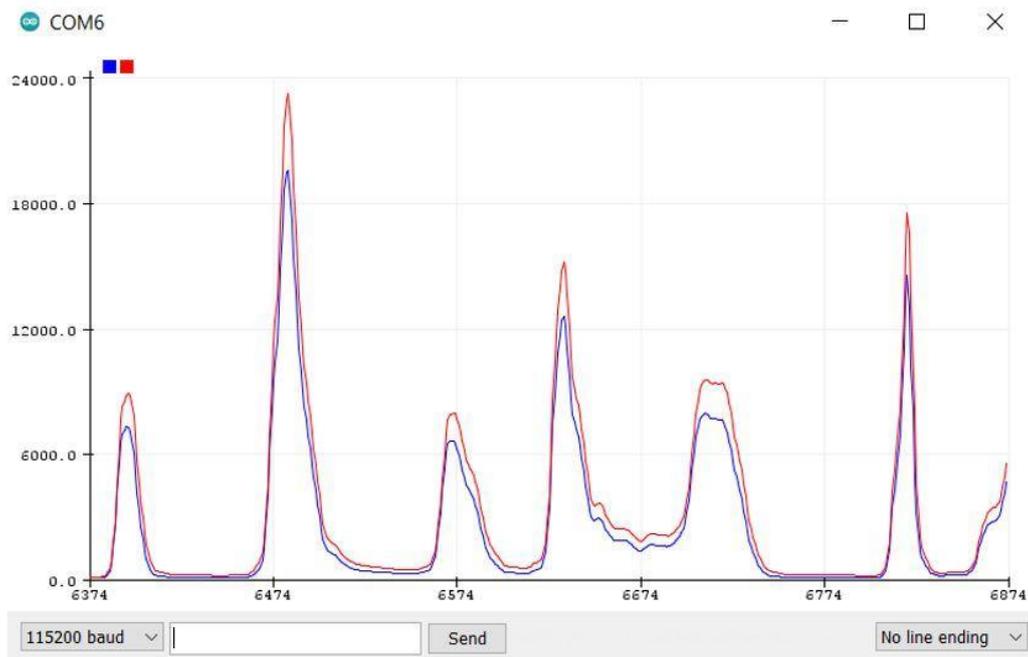


fig: 7 Output 3 spo2 waveform

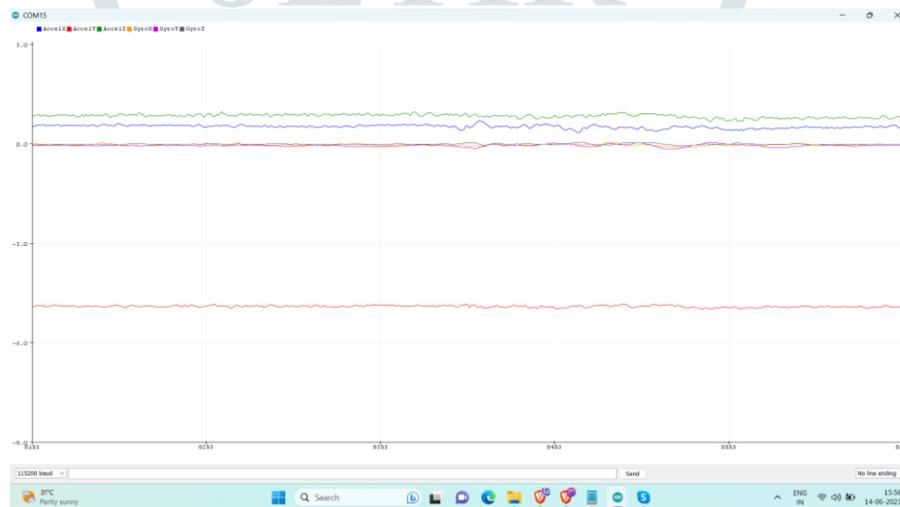


fig: 8 output 4 scg



fig: 9 output 5 gui

With this hardware we can square the ECG, SCG, SPO2, and Heart rate, by using GUI we can do the post-processing of the data, the results will be displayed on the GUI screen, and data will be stored in the local database, later we can do the preprocessing of the data like analyzing the recorded data.

## VI. CONCLUSION & FUTURE SCOPE

### Conclusion:

1. The integrated health monitoring system effectively captured and analyzed ECG, SCG, SpO2, and heart rate measurements.
2. The system provided valuable insights into individuals' health status and physiological functioning.
3. ECG analysis accurately assessed the cardiac activity and provided information for cardiovascular health monitoring.
4. SCG analysis measured mechanical signals associated with heart function, enhancing understanding of heart activity.
5. SpO2 analysis accurately measured blood oxygen saturation levels, which is crucial for assessing respiratory health.
6. The system enables continuous monitoring, early detection of abnormalities, and proactive healthcare management.
7. Future work includes system optimization, expansion of parameters, long-term monitoring, validation studies, advanced data analytics, user experience enhancements, telemedicine integration, cost-effectiveness analysis, and addressing regulatory and ethical considerations.

### Future Work:

1. System optimization in hardware design, sensor technologies, and signal processing algorithms.
2. Integration of additional physiological parameters for a comprehensive health assessment.
3. Long-term monitoring studies with larger sample sizes to detect trends and predict outcomes.
4. Rigorous validation studies in clinical settings to establish reliability and accuracy.
5. Incorporation of data analytics and machine learning techniques for interpretation and prediction.
6. Enhancing user experience and interface design based on user feedback.
7. Integration with telemedicine platforms and remote monitoring technologies.
8. Cost-effectiveness analysis and consideration of regulatory and ethical aspects.

In conclusion, the integrated health monitoring system project has achieved its objectives, provided valuable insights and set the stage for further research and application of integrated health monitoring systems in healthcare.

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