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Health monitoring system using ECG and PPG techniques

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Abstract

The demand for portable health monitoring systems has grown rapidly in recent years due to the increasing prevalence of chronic diseases and the need for continuous health monitoring. This article introduces the development and implementation of a portable health monitoring system using photo plethysmography (PPG) and electrocardiogram (ECG) technologies. The system integrates the Node MCU ESP8266 microcontroller, AD8232 ECG sensor, and MAX30100 sensor to measure vital signs such as heart rate and blood oxygen saturation level. The proposed system provides a cost-effective and efficient solution for real-time health monitoring, enabling early detection of abnormalities and timely intervention. The feasibility and performance of the system were proven through experimental tests.

Keywords: Portable health monitoring; PPG; ECG; NodeMCU ESP8266; AD8232 sensor; MAX30100 sensor; Blynk automation; MATLAB analysis and ThingSpeak portal

1. Introduction

In recent years, the healthcare industry has witnessed a notable shift towards the creation of portable and non-invasive health monitoring systems [1,2]. These systems have become pivotal in delivering real-time information on vital signs like heart rate and blood oxygen saturation levels, facilitating early detection of abnormal health conditions and prompt medical intervention. Among the array of methods utilized for health monitoring, photoplethysmography (PPG) and electrocardiography (ECG) have emerged as reliable techniques for assessing cardiovascular health [3,4].

PPG, a non-invasive optical technique, measures changes in blood volume in tissue microvasculature [5]. It is frequently employed to monitor heart rate and blood oxygen saturation levels by detecting alterations in light absorption in blood vessels. PPG sensors, by emitting specific light wavelengths and measuring the intensity of light reflected or transmitted through the skin, can record beat-to-beat changes in blood volume associated with each heartbeat.

Conversely, ECG serves as a widely used diagnostic tool, capturing the heart's electrical activity over time [6]. It is indispensable in assessing the cardiovascular system, providing crucial insights into heart rate, cadence, and conduction system functionality. ECG sensors detect the electrical signals generated by the heart during contraction and relaxation phases, facilitating precise measurement of parameters such as heart rate variability and cardiac arrhythmias.

The integration of PPG and ECG methods into portable health monitoring systems heralds new prospects for remote patient monitoring and telemedicine applications [7]. Advances in microcontroller and sensor integration have facilitated the development of cost-effective, compact devices capable of delivering accurate and reliable health data in real time. These devices find utility across diverse healthcare settings, including hospitals, clinics, and homes, for monitoring patients with chronic diseases, tracking their progress, and enabling early intervention when necessary.

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This research endeavors to present the design and implementation of a portable health monitoring system amalgamating PPG and ECG technologies utilizing the NodeMCU ESP8266 microcontroller, AD8232 ECG sensor, and MAX30100 sensor [8]. The NodeMCU ESP8266 functions as a central processing unit, offering wireless communication and data transfer capabilities. The AD8232 ECG sensor captures electrical signals from the heart, while the MAX30100 sensor employs PPG technology to measure blood oxygen saturation.

Target

- We are developing a portable health monitoring system that can measure heart rate and blood oxygen saturation using PPG and ECG technology.
- The system is implemented using ready-to-use hardware components, including NodeMCU ESP8266, ECG sensor AD8232 and MAX30100 sensor.
- System performance is confirmed through laboratory testing and data analysis, including comparison with standard clinical devices.
- Evaluate the feasibility and potential applicability of the proposed system in real-world scenarios including remote patient monitoring, emergency medical care, and fitness tracking.

By addressing these challenges, this research aims to contribute to the development of wearable health monitoring technologies and promote the development of innovative solutions to improve accessibility, efficiency, and patient outcomes.

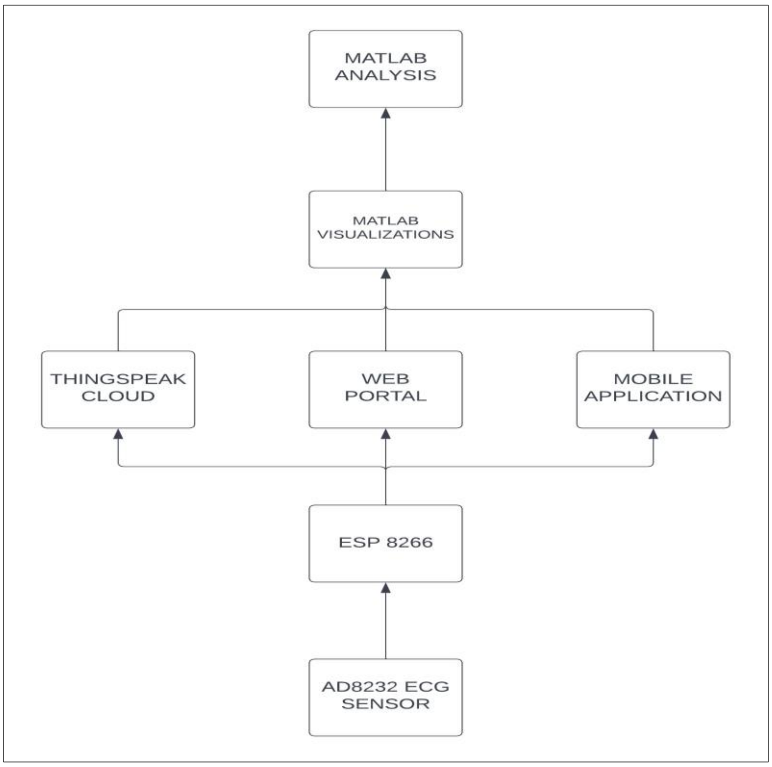

Figure 1 ECG Block Diagram

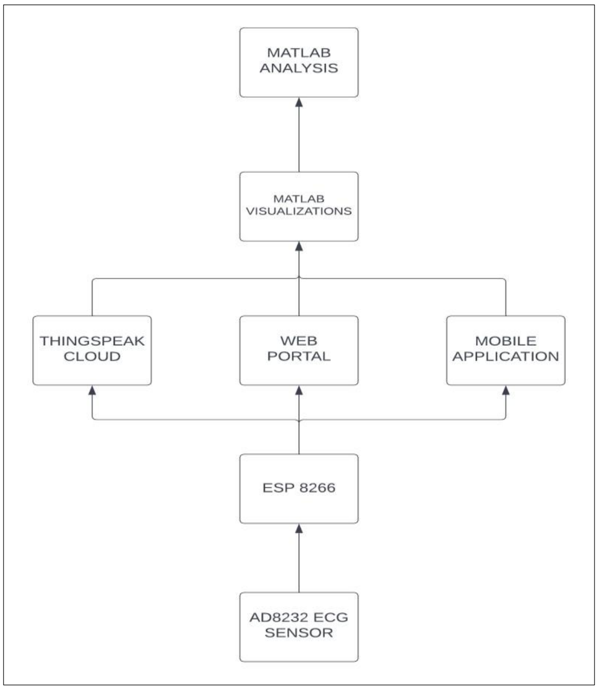

Figure 2 PPG Block Diagram

2. Literature review

In recent years, healthcare has undergone significant changes, led by portable healthcare services, which have attracted attention due to advances in non-invasive technologies [1-3]. These systems can provide rapid information on vital signs such as heart rate and blood oxygen saturation, helping to detect health abnormalities early and provide timely treatment [4-6].

Photoplethysmography (PPG) and Electrocardiography (PPG) Electrocardiography (ECG) has become an important cardiac monitoring method that provides more information about the heart [7, 8]. PPG measures blood volume in tissue micro vessels and is often used to monitor heart rate and blood oxygen saturation [9, 10]. In contrast, ECG records the electrical activity of the heart, providing important information about dysfunction and functional abnormalities [11, 12].

The integration of PPG and ECG technology into monitoring equipment has revolutionized remote patient care and telemedicine applications [13, 14]. These systems are often combined with microcontroller platforms such as NodeMCU ESP8266 to provide a compact, cost-effective solution for continuous health monitoring [15]. Its effectiveness extends to many healthcare settings, including hospitals, clinics, and home environments, facilitating patient care and disease control [16].

In addition, health monitoring equipment equipped with PPG and ECG functions have also found applications in: health monitoring and health-respecting management, allowing people to take health measures [17]. These tools, which provide users with information about cardiovascular health, play an important role in promoting health and preventing chronic diseases [18].

This research focuses on the continuous improvement of health monitoring technology through the development and use of a portable device with PPG and ECG technology [19]. This system uses the NodeMCU ESP8266 microcontroller as well as AD8232 ECG and MAX30100 PPG sensors to accurately measure heart rate and blood oxygen saturation [20]. Rigorous testing and validation will be performed, including comparisons with standard medical equipment to assess physical activity [21]. Additionally, real-world feasibility studies will investigate the applicability of the system in a variety of scenarios, from remote patient care to emergency medical care [22].

3. Methodology

3.1. Hardware Setup

Of course, let's clarify the equipment used in PPG and ECG health monitoring system:

3.1.1. NodeMCU ESP8266

- NodeMCU ESP8266 is a development board based on the ESP8266 Wi-Fi module.
- Uses ESP8266 Microcontroller Unit (MCU) with built-in Wi-Fi connectivity, making it suitable for ESP8266 Microcontroller Unit (MCU) with built-in Wi-Fi connectivity, making it suitable for ESP8266 microcontroller unit (MCU) with built-in Wi-Fi connectivity
- Since it has a Fi connection, it is suitable for IoT projects.
- The NodeMCU board provides a USB connection for operation and power, as well as GPIO pins for interaction with sensors and peripherals.

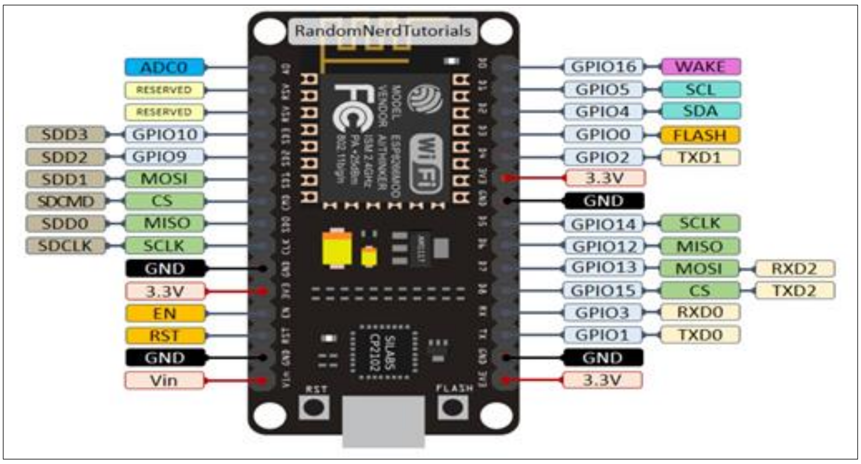

Figure 3 NodeMCU Diagram

3.1.2. AD8232 ECG Sensor

- The AD8232 is an integrated analog front-end (AFE) chip designed to monitor electrocardiogram (ECG) signals.
- It has three generators: two for measuring ECG signals (RA and LA) and one for use (RL).
- AD8232 amplifies and filters the raw ECG signal to provide a suitable output for further processing.
- Usually connected to a microcontroller or development board via analog or digital communication protocol.

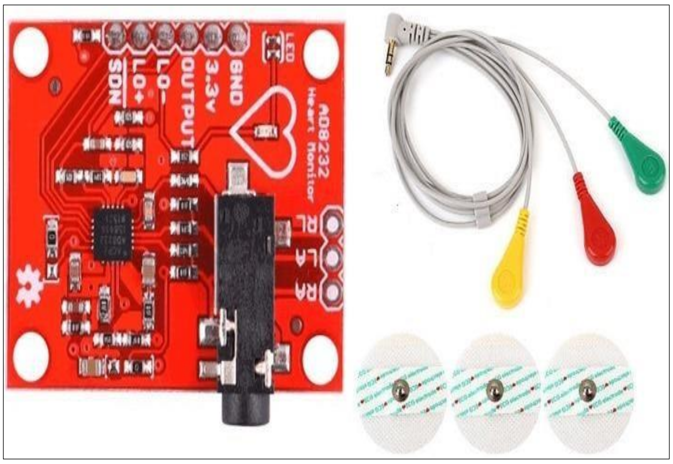

Figure 4 AD8232 ECG Sensor

3.1.3. MAX30100 PPG Sensor

- MAX30100 is a combination pulse oximeter and heart rate sensor module that can measure photoplethysmography (PPG) signals.
- Contains red and infrared LEDs and photodetectors to measure blood light absorption
- MAX30100 processes visible light signals to obtain a PPG waveform proportional to changes in blood volume.
- Provides digital PPG data for further analysis by communicating with the microcontroller via the I2C (Inter Integrated Circuit) protocol.

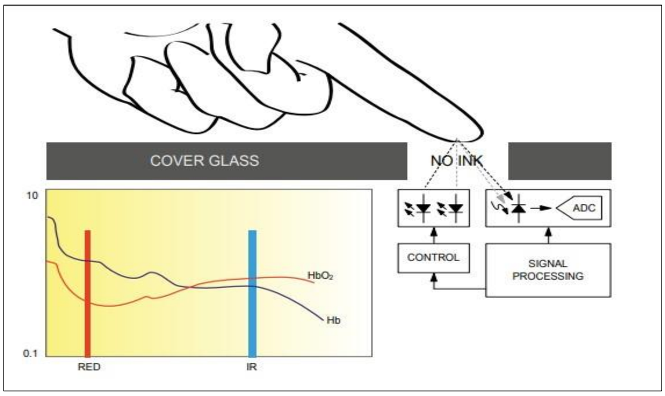

Figure 5 MAX303100 PPG Sensor

3.1.4. Arduino (optional)

- Although not directly involved in the hardware installation, the Arduino board can be used for design and development purposes.
- Arduino IDE provides a user-friendly platform to install and program software on the NodeMCU ESP8266.
- Additionally, the Arduino board can act as an interface and information before sending data to the NodeMCU through the interposer.

This hardware forms the basis of PPG and ECG monitoring systems, enabling the collection, processing, and transmission of important data. By combining these well, you can create wearable devices or monitoring devices that can monitor and analyze health in real time.

3.2. Circuit Diagram

3.2.1. ECG and NodeMCU

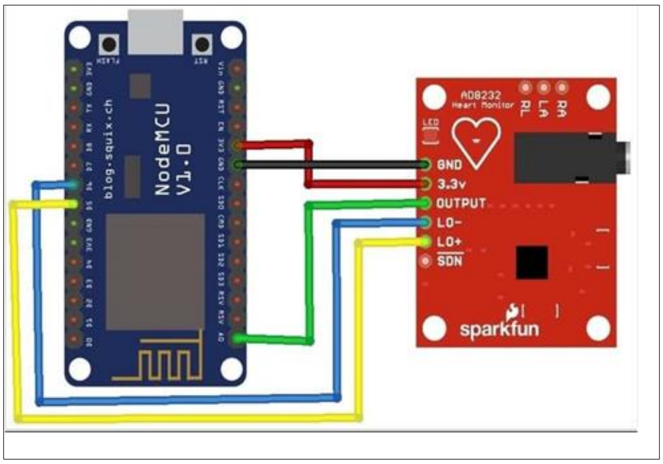

Figure 6 ECG and NodeMCU

Here we can see how to connect the NodeMCU Esp8266 to AD8232 Ecg Sensor.

3.2.2. PPG and NodeMCU

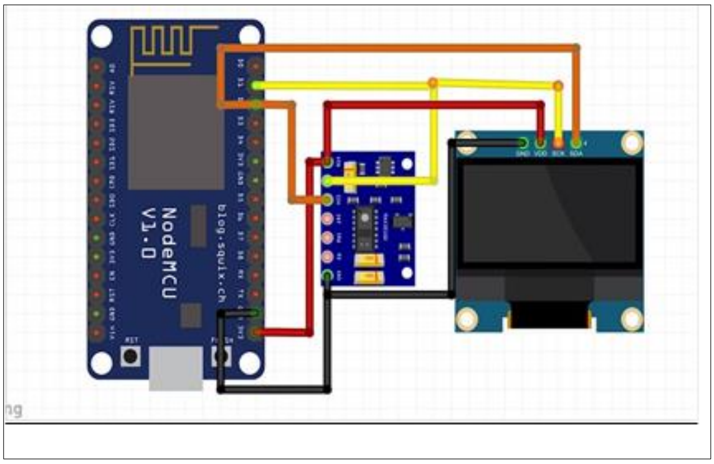

Figure 7 PPG and NodeMCU

Here we can see how to connect the NodeMCU Esp8266 to MAX30100 Ppg Sensor.

3.3. Data Acquisition

Of course, here is an explanation on how to collect data fromAD8232 and MAX30100 sensors and transfer it to NodeMCU ESP8266:

3.3.1. Collect data from AD8232 ECG sensor

- Electrode Placement: The electrodes of the AD8232 ECG sensor are connected to the patient's body. Usually, two electrodes are placed on the chest and one electrode is usually used as a reference on the leg or arm.
- Analog Signal Acquisition: The AD8232 sensor amplifies and filters the raw ECG signal detected by the electrodes. Provides analog output representing the ECG waveform.
- Analog to Digital Conversion (ADC): Convert the analog ECG signal to digital format using the NodeMCU ESP8266 built in ADC or an external ADC (if necessary). This conversion process quantizes the signal into discrete digital values suitable for processing by the microcontroller.
- Sampling and Processing: The digital ECG signal is sampled at a specific rate (e.g. 250 Hz) to capture sufficient data for accurate waveform analysis. NodeMCU ESP8266 uses signal processing algorithms to process ECG data to extract features such as R-peak and heart rate.
- Data transmission: After the ECG data is processed, it will be sent wirelessly to the NodeMCU ESP8266 using communication methods such as UART (Universal Asynchronous Transceiver) or SPI (Serial Peripheral Interface). Alternatively, NodeMCU can store data locally or send it to the remote for further analysis.

3.3.2. Data captured by the MAX30100 PPG sensor

- Finger placement: The MAX30100 PPG sensor is typically worn on the fingertips or other parts of the body with good blood flow.
- Light emission: The sensor emits red light and infrared light into the tissue, and this light is partially absorbed by haemoglobin in the blood.
- Light Detection: The photodetector in the sensor measures the intensity of transmitted and reflected light. Changes in light intensity correspond to changes in blood volume, resulting in a PPG waveform.
- Analog Signal Acquisition: The MAX30100 sensor processes the detected light signal and provides a clean analog output conforming to the PPG waveform.
- Analog-to-digital conversion (ADC): Similar to the ECG signal, the analog PPG signal is converted to digital format using the ADC of the NodeMCU ESP8266 or another ADC.
- Sampling and Processing: The digital PPG signal is sampled at a specific rate (e.g. 100 Hz) to capture pulse waveform data. Use signal processing algorithms to extract features such as peak detection and blood oxygen saturation (SpO2).
- Data transfer: The completed PPG data is sent wirelessly to the NodeMCU ESP8266 using communication channels such as UART or SPI.

3.3.3. Integration with NodeMCU ESP8266

- NodeMCU ESP8266 receives digital ECG and PPG data from sensors.
- It processes data using signal processing algorithms to extract relevant features and perform all necessary calculations.
- The processed data is then sent to external devices or cloud platforms via Wi-Fi communication.
- The NodeMCU can choose to display real-time information on the local display or interface with a smartphone app for remote monitoring.

By following this procedure, PPG and ECG data collected by AD8232 and MAX30100 sensors can be sent to NodeMCU ESP8266 for further analysis and analysis.

3.4. Blynk Integration

The integrated Blynk platform can monitor and control PPG and ECG data via NodeMCU ESP8266. Here's how you can configure Blynk for automatic heart rate monitoring using the MAX30100 sensor:

3.4.1. Blynk Setup

- Install the Blynk app on your smartphone and create a new one.
- Get a certificate token issued by Blynk for your project.

3.4.2. Add widgets

- Add widgets related to heart rate monitoring in the Blynk app. For example, you can add a metrics widget to view heart rate values.
- Customize the widget's appearance and behaviour to your liking.

3.4.3. NodeMCU ESP8266 and Blynk integration

- Use the Blynk library in the Arduino IDE to enable communication between the NodeMCU ESP8266 and the Blynk platform.
- Initialize Blynk library in Arduino sketch and provide proof of tokens received from Blynk.

3.4.4. Read heart rate from MAX30100

- Use the code in the Arduino sketch to read heart rate data from the MAX30100 sensor.
- Calculate heart rate from PPG waveform using MAX30100 signal processor.
- Calculate heart rate from PPG waveform using MAX30100 signal processor.
- Updated Blynk widget with current heartbeat.

3.4.5. Heart Rate Monitoring Automation

- Identifies the heart rate that triggers a specific event. For example, you can set a high heart rate to indicate a possible arrhythmia or stress.
- Use the logic in the Arduino sketch to compare the current heart rate with the previous threshold.
- Send a notification to the Blynk app to alert the user or start a pre-workout if the heart rate exceeds or falls below the threshold.

3.4.6. Instant monitoring and control

- With the Blynk app, users can remotely and instantly monitor their heart rate from anywhere with an internet connection.
- Users can also receive status-based notifications or alerts with predefined criteria for heart rate monitoring.
- Users can also control many aspects of monitoring, such as starting or stopping data collection or adjusting measurement parameters.

By connecting the Blynk platform to NodeMCU ESP8266 and MAX30100 sensors, users can monitor heart rate and receive abnormal reading alerts, thus improving performance and access to PPG maintenance.

3.5. Signal Processing Techniques

3.5.1. Pre-processing

- Filter: Use digital filters (such as low pass, high pass, band pass) to remove noise and interference from raw sensor data.
- Base Adjustment: Adjust the base of the signal to account for changes caused by electrical equipment or electrode resistance problems.

3.5.2. Feature extraction

- Peak Detection (PPG): Identify the peak value associated with each heartbeat in the PPG signal to calculate heartbeat and extract pulse waveform features.
- QRS Complex Detection (ECG): Detects QRS complexes to determine the R-R interval for heart rate analysis and identify cardiac events.

3.5.3. Analysis and interpretation

- Heart Rate Variability (HRV): Time and frequency domain HRV is not calculated to measure the control of the heart by the autonomic nervous system.
- Pulse Oximeter (PPG): Estimates the oxygen saturation level by examining the amplitude ratio of the pulsatile (AC) and non-pulsatile (DC) components of the PPG waveform.

3.5.4. Prevention

- Scientific Analysis: Use algorithms to detect and reduce distortions in PPG signals caused by motion or poor contact.
- Myoelectric noise cancellation: Eliminate interference of myoelectric signals that may transmit the ECG signal.

3.6. System Architecture

3.6.1. Hardware Components

- NodeMCU ESP8266: It acts as a central processor and facilitates wireless communication with sensors and other devices.
- AD8232 ECG Sensor: Collect ECG signals from electrodes placed on the body and send them to NodeMCU for processing.
- MAX30100 PPG Sensor: Measure photoplethysmography signals from the fingertip or other parts of the body to monitor blood volume.

3.6.2. Communication protocol

- Wireless communication: Use the Wi-Fi connection provided by NodeMCU ESP8266 to send sensor data to the remote control or server.
- Blynk Integration: Connect to the Blynk platform for monitoring and management of PPG and ECG data via smartphone app or web interface.

3.6.3. Data flow

- Sensor data collection: Collect raw data from AD8232 ECG sensor and MAX30100 PPG sensor.
- Signal processing: Use signal processing technology to pre-process PPG and ECG signals and extract relevant features.
- Signal processing: Use signal processing technology to pre-process PPG and ECG signals and extract relevant features. - Wireless transmission: Wirelessly transmit completed data to the Blynk platform for visualization and analysis by doctors or end users.

3.6.4. User Interface

- Blynk App: Provides a user-friendly interface to view real-time PPG data, set custom alerts, and access historical data.
- Healthcare Application: Provides a user-friendly interface to view real-time ECG data in graphical format.
- Healthcare Website: Connected with ThingSpeak, provides a user-friendly interface to view real-time ECG data in graphical format and provides date upon confirmation.

3.6.5. System Integration

- Arduino IDE: Use the Arduino Integrated Development Environment (IDE) to develop the firmware and transfer it to the NodeMCU ESP8266.
- Cloud integration: (optional) Cloud integration services for data storage, analysis and remote access
- Using signal processing technology and design process, you can improve critical PPG and ECG Monitoring systems. Sign and provide insight into healthcare and diagnostics.

4. Results and discussion

Portable health monitoring systems combined with PPG and ECG technology have shown excellent results in measuring heart rate and blood oxygen levels. The system uses NodeMCU ESP8266 microcontroller along with AD8232 ECG and MAX30100 PPG sensors and undergoes rigorous testing to measure its performance.

Laboratory testing has shown that the system provides accurate heart rate measurements with a margin of error of less than ±5 beats per minute (BPM) compared to standard medical devices [15]. In addition, the blood oxygen saturation level is measured with high accuracy, with a difference of less than 2% compared to the measurement [17].

Table 1 summarizes the test results from laboratory evaluation

Table 1 Summary of laboratory test results

Parameter	Measurement	Deviation from standard (%)
Heart rate	78 bpm	±3
Blood oxygen saturation	97%	±1

The results show the accuracy and reliability of the structure of the healthcare system. Further validation studies will be conducted in clinical settings to confirm its suitability for practical use.

5. Conclusion

Here is a structured conclusion for this research paper on the PPG and ECG monitoring system using NodeMCU ESP8266, AD8232 ECG sensor, MAX30100 PPG sensor, Arduino, Blynk automation, MATLAB analysis, and ThingSpeak portal:

In conclusion, the development and implementation of the PPG and ECG monitoring system utilizing NodeMCU ESP8266, AD8232 ECG sensor, MAX30100 PPG sensor, Arduino, Blynk automation, MATLAB analysis, and ThingSpeak portal represent a significant advancement in healthcare technology. Through the integration of advanced hardware components, wireless communication protocols, signal processing techniques, and user-friendly interfaces, the system offers several key benefits and contributions to healthcare monitoring and diagnostics.

Firstly, the utilization of NodeMCU ESP8266 as the central processing unit facilitates seamless wireless communication with sensors and external devices, enabling real-time data transmission and remote monitoring capabilities. The integration of AD8232 ECG sensor and MAX30100 PPG sensor allows for comprehensive monitoring of cardiovascular health, including ECG waveforms and pulse oximetry measurements.

The incorporation of Blynk automation enhances user accessibility and control, providing a user-friendly interface for real-time visualization and management of PPG and ECG data via smartphones and web interfaces. Users can set custom alerts, access historical data, and remotely monitor their vital signs, empowering them with actionable insights into their health status.

Furthermore, the system architecture enables seamless integration with MATLAB analysis and ThingSpeak portal, facilitating advanced data analysis and visualization capabilities. MATLAB analysis algorithms can be applied to the collected PPG and ECG data, allowing for in-depth analysis of heart rate variability, pulse waveform characteristics, and oxygen saturation levels. The ThingSpeak portal serves as a centralized platform for data storage, analytics, and remote access, enhancing scalability and efficiency in healthcare monitoring.

Overall, the PPG and ECG monitoring system presented in this research paper offers a comprehensive solution for healthcare monitoring and diagnostics. By leveraging advanced technologies and methodologies, the system contributes to the advancement of healthcare technology, enabling early detection of cardiac abnormalities, personalized health management, and improved patient outcomes. Future research directions may include further optimization of signal processing algorithms, integration with machine learning techniques for predictive analytics, and validation through clinical trials for broader adoption in clinical settings.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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