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An Internet of Things Approach for Continuous ECG Monitoring and Automated Emergency Alerts

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Abstract: *Cardiovascular diseases are among the leading causes of sudden death worldwide, often due to the lack of timely diagnosis and continuous monitoring. Conventional ECG monitoring systems require patients to stay in hospitals or clinics for observation, which limits accessibility and continuity of care. This study presents the development of a cost-effective Internet of Things (IoT)-based ECG monitoring system designed to provide real-time cardiac health supervision from any location. The proposed system employs an AD8232 ECG sensor for signal acquisition and a NodeMCU ESP8266 microcontroller for wireless data transmission. The collected ECG data are uploaded to the Ubidots cloud platform, where authorized users can visualize and analyse the cardiac waveform using a web interface or mobile application. In case of abnormal signal patterns, the system automatically sends alert notifications to medical professionals and caregivers, enabling immediate response. Experimental validation on multiple users demonstrated reliable ECG signal capture and accurate cloud synchronization, confirming the system's effectiveness in remote cardiac monitoring. This IoT-integrated framework offers a practical approach to early detection of heart irregularities and supports continuous patient observation, thereby reducing the risk of critical cardiac events and improving the accessibility of preventive healthcare.*

Keywords: ECG Monitoring, Internet of Things (IoT), NodeMCU ESP8266, AD8232 Sensor, Remote Health Monitoring, Ubidots Cloud Platform

I. INTRODUCTION

Cardiovascular diseases (CVDs) remain the leading cause of mortality worldwide, necessitating innovative approaches for early detection and continuous monitoring to improve patient outcomes and reduce healthcare costs [1]–[3]. Continuous ECG monitoring plays a crucial role in the timely detection and management of cardiac disorders, as it enables real-time tracking of heart activity and facilitates early medical intervention in case of abnormalities [4], [5]. However, traditional ECG monitoring systems are primarily hospital-based and depend on specialized equipment and trained medical personnel, making them inaccessible to many individuals in remote or resource-limited regions [1], [4].

The integration of the Internet of Things (IoT) into healthcare has transformed patient monitoring by enabling continuous and real-time physiological data acquisition through interconnected devices [6], [7]. IoT-based ECG monitoring systems utilize wearable or portable sensors to collect cardiac data, which is then transmitted to cloud servers for storage and analysis. These systems can incorporate intelligent algorithms such as machine learning to detect anomalies and generate automated alerts for healthcare providers [1], [3]. Such solutions bridge the gap between rural and urban healthcare accessibility, offering a scalable and cost-effective approach for managing heart health in underprivileged settings [4], [7].

Furthermore, IoT-enabled healthcare systems enhance chronic disease management by promoting patient engagement, reducing unnecessary hospital admissions, and enabling personalized treatment plans through data-driven insights [7], [5]. The use of smart wearables and mobile applications further increases accessibility, allowing patients to monitor their ECG signals remotely and share real-time data with healthcare professionals [2], [8]. As IoT technology continues to

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evolve, it holds significant potential to revolutionize cardiovascular healthcare by facilitating preventive diagnostics, improving efficiency, and reducing mortality from cardiac complications [9], [5].

II. LITERATURE REVIEW

IoT-based ECG monitoring has emerged as a transformative innovation in digital healthcare, providing real-time, continuous, and remote monitoring of cardiac activity. These systems are particularly beneficial for patients in underserved areas where frequent clinical monitoring is impractical [4]. Recent studies have demonstrated the successful integration of IoT with ECG sensors to collect, process, and transmit cardiac data to cloud platforms or mobile applications, allowing healthcare professionals to remotely access, analyze, and respond to a patient's heart condition [10], [11].

Several research efforts have explored various hardware configurations, including microcontrollers such as Arduino, Raspberry Pi, and NodeMCU, interfaced with ECG sensors like AD8232 or MAX30003, for efficient data acquisition and wireless transmission [10], [11]. Cloud platforms such as ThingSpeak, Blynk, and Ubidots are commonly employed to visualize ECG waveforms and send alerts when abnormal readings are detected. These developments have contributed to scalable, low-cost, and energy-efficient ECG monitoring architectures suitable for home-based and telemedicine applications.

The integration of artificial intelligence (AI) and deep learning with IoT-based ECG systems has further improved their diagnostic performance. Studies have shown that convolutional neural networks (CNNs) and transfer learning techniques can effectively identify cardiac anomalies, improving the accuracy and reliability of automated ECG interpretation [12], [13]. Nevertheless, several research gaps remain. These include the need for interpretable AI models, more diverse ECG datasets for robust algorithm training, and efficient IoT-cloud integration for real-time performance [12], [15]. Additionally, issues such as signal noise, limited battery life of wearable devices, and computational constraints of edge devices continue to challenge the development of high-accuracy portable ECG systems [16].

The current study aims to address these challenges by implementing an IoT-based ECG monitoring system that leverages a low-cost AD8232 sensor and NodeMCU ESP8266 microcontroller to acquire and transmit ECG signals to the Ubidots cloud platform. This work focuses on enhancing the reliability, accessibility, and affordability of continuous cardiac monitoring, providing an efficient solution for preventive and personalized cardiac healthcare [12], [13].

III. SYSTEM DESIGN AND ARCHITECTURE

The proposed IoT-based ECG monitoring system is designed to acquire, process, and transmit electrocardiogram (ECG) signals in real-time using a low-cost and portable setup. The architecture integrates both hardware and software components, ensuring efficient data acquisition, transmission, and visualization through cloud connectivity. The primary components of the system include the AD8232 ECG sensor, the NodeMCU ESP32 microcontroller, and a cloud platform (Ubidots) for data storage and monitoring.

A. Hardware Design

The hardware configuration forms the foundation of the system, responsible for acquiring accurate ECG signals from the human body and transmitting them wirelessly for analysis. The block diagram consists of the following elements:

- **AD8232 ECG Sensor Module:**

The AD8232 is an integrated signal conditioning device specifically designed for ECG and other biopotential measurements. It extracts, amplifies, and filters small electrical signals generated by the heart even under noisy conditions such as motion or remote electrode placement. The module includes key pins such as GND, 3.3V, OUTPUT, LO+, LO-, and SDN Shown in Fig.1

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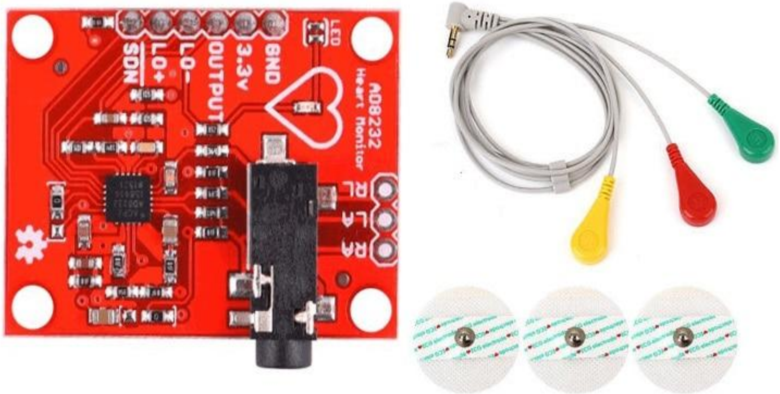

Fig.1. AD8232 ECG Sensor

• The OUTPUT pin provides the conditioned analog ECG signal.
• LO+ and LO- detect lead-off conditions, ensuring electrode connection integrity.
• The SDN pin, which controls shutdown mode, is not used in this implementation.

The module also provides RA (Right Arm), LA (Left Arm), and RL (Right Leg) electrode terminals that connect to the body using disposable ECG electrodes. These leads form a standard three-lead configuration to measure the heart's electrical activity accurately. The built-in LED on the module blinks synchronously with each heartbeat, indicating proper signal detection.

• **NodeMCU ESP32 Microcontroller:**

The ESP32 is a low-power Wi-Fi and Bluetooth-enabled microcontroller based on the Tensilica LX6 dual-core processor. It serves as the main controller for data processing and communication. It reads the analog ECG signal from the AD8232 sensor through its analog input pin and transmits the data wirelessly to the Ubidots cloud platform for visualization.

• **ESP32–AD8232 connections:**

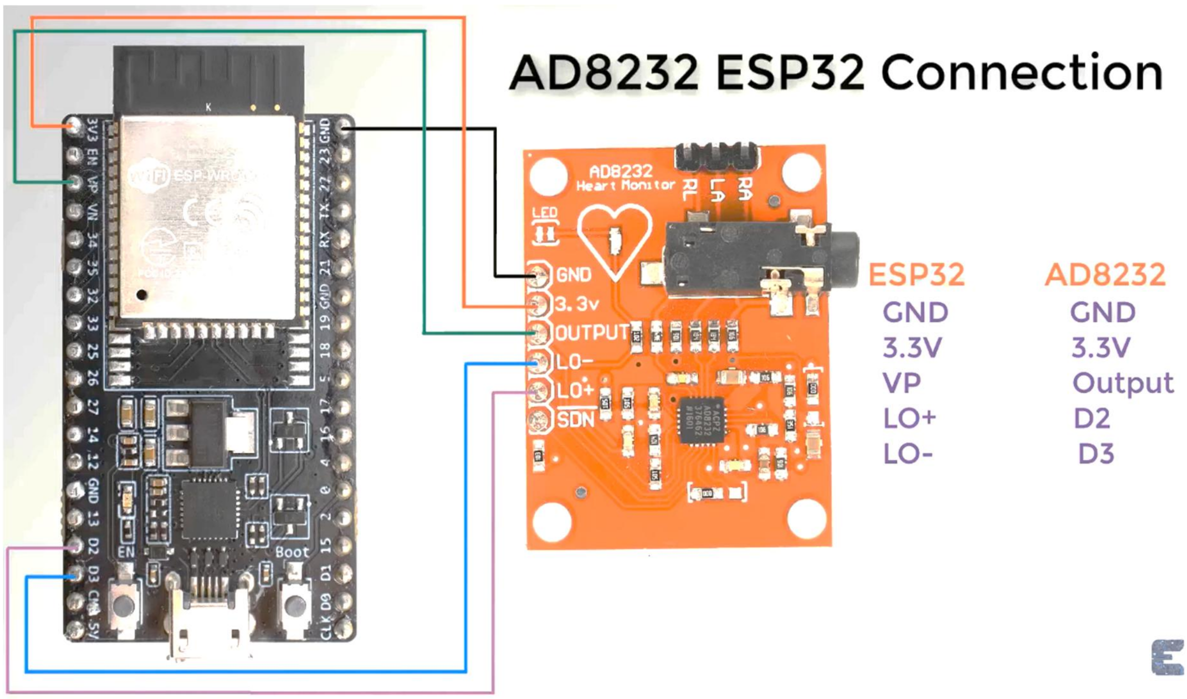

Fig.2. Interfacing Ad8232 Ecg Sensor with NodeMCU Esp32

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The ESP32 provides efficient Wi-Fi connectivity, allowing ECG data to be uploaded to the cloud in real-time. Additionally, its low-power consumption and integrated peripherals make it suitable for portable and wearable healthcare devices.

- **Display and Power Supply:**

A 3.5-inch TFT display is incorporated to provide a real-time graphical representation of the ECG waveform directly on the device. The system is powered via a Micro-USB cable connected to a 5V source, such as a laptop or power bank, ensuring portability and user convenience.

B. Software Design

The software architecture is developed using the Arduino IDE, which supports the ESP32 platform. The main tasks of the software include:

- Signal acquisition: Reading analog ECG data through the ESP32 ADC pin.
- Data filtering: Removing high-frequency noise and ensuring signal stability.
- Cloud communication: Sending real-time ECG data to the Ubidots IoT platform using Wi-Fi connectivity.
- Visualization: Displaying ECG waveforms on both the serial plotter (for debugging) and the Ubidots dashboard, accessible via smartphone or web browser.

The system uses the Ubidots API key for authentication, ensuring that only authorized users can access patient data. Additionally, the platform allows the configuration of threshold-based alerts—if an abnormal ECG pattern or irregular heart rate is detected, an automatic notification (email or SMS) is sent to the concerned medical personnel.

C. Circuit Configuration

The circuit for interfacing the AD8232 ECG sensor with the NodeMCU ESP32 is shown in Figure 1. The sensor's OUTPUT is connected to the VP pin of ESP32 for analog input, while LO+ and LO- are connected to D2 and D3, respectively, for lead detection. The sensor is powered through the 3.3V and GND pins of ESP32.
The electrode placement follows a three-lead configuration Shown in Fig.3

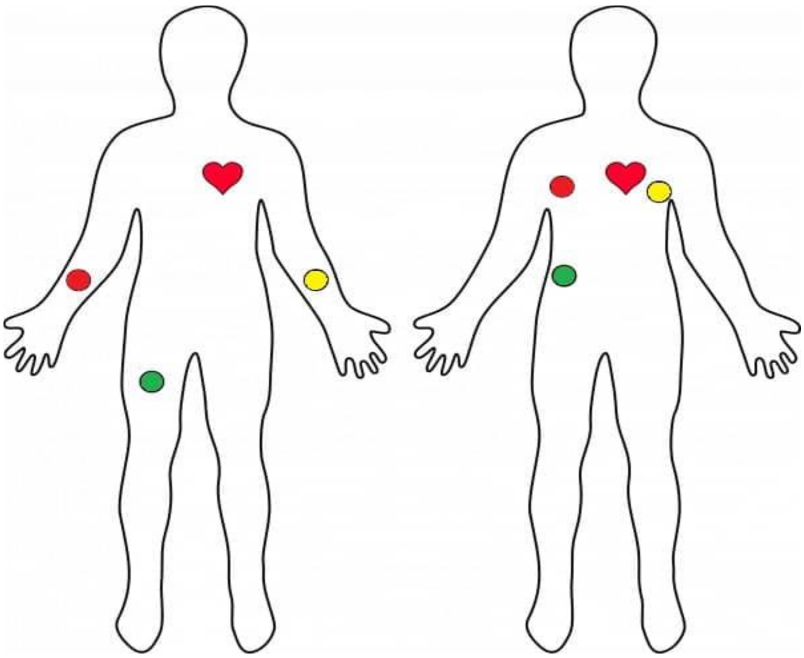

Fig.3. ECG LEADS/ELECTRODE PLACEMENT

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• Red Lead (RA): Attached to the right arm.
• Yellow Lead (LA): Attached to the left arm.
• Green Lead (RL): Attached to the right leg (reference ground).
This arrangement ensures accurate capture of the heart's electrical potential differences, forming an effective Einthoven's triangle around the chest. The system's design allows accurate ECG signal detection, even under movement or mild interference.

D. System Operation

Once powered, the AD8232 module begins sensing the biopotential signals. The ESP32 reads the analog signal, processes it, and uploads it to the cloud through the Wi-Fi network. The ECG waveform is displayed on both the local TFT screen and the Ubidots dashboard, allowing doctors and patients to monitor heart activity in real-time. The system classifies heart rate zones as follows:
• Low Pulse (< 60 BPM): Indicates possible bradycardia requiring medical attention.
• Normal Range (60–100 BPM): Represents healthy heart activity.
• High Pulse (>100 BPM): May indicate tachycardia or stress-related cardiac conditions.
The system's accuracy and responsiveness were validated through experimental trials on healthy volunteers. The results showed that the proposed system provides a reliable ECG waveform with minimal noise, making it suitable for remote health monitoring and early cardiac anomaly detection.

IV. BLOCK DIAGRAM DESCRIPTION OF ECG HEART MONITORING SYSTEM

The presented block diagram illustrates an IoT-based ECG and heartbeat monitoring system designed to measure, process, and transmit physiological signals through a Wi-Fi network for remote health observation.

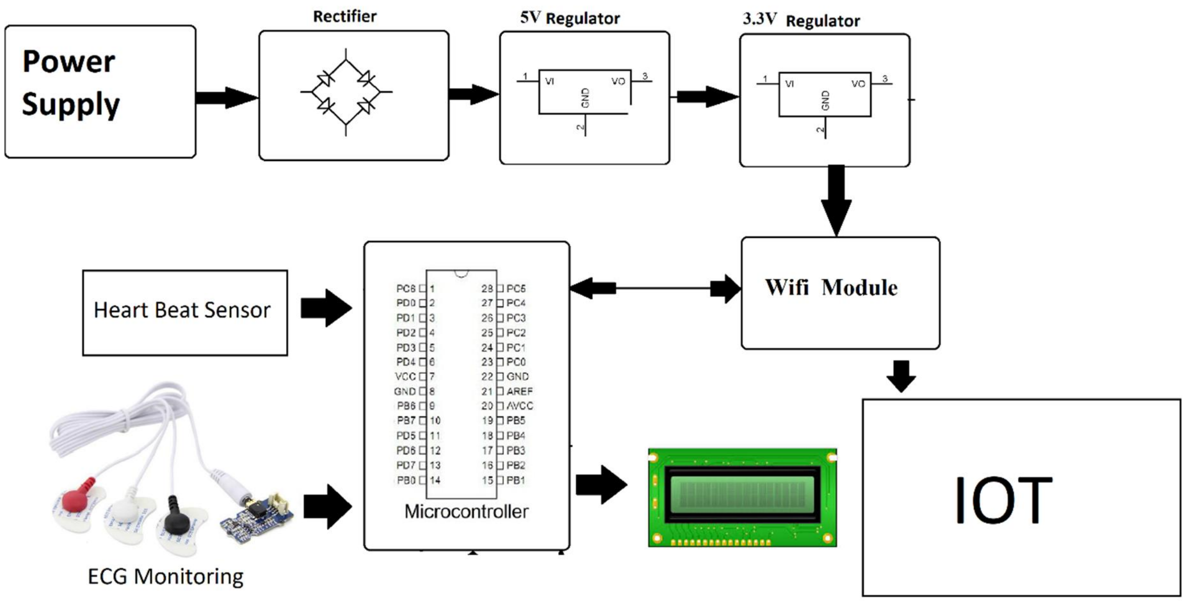

Fig.4. Block Diagram of IOT ECG System

The system begins with the power supply unit, which provides the required electrical energy to the circuit. The rectifier converts the AC input into DC voltage, which is then regulated by a 5V voltage regulator to power the microcontroller. A 3.3V regulator is used to supply power to the Wi-Fi module, ensuring stable communication.
The sensing section comprises two biomedical sensors— a heartbeat sensor and an ECG sensor. The heartbeat sensor detects the pulse rate by monitoring changes in blood flow, while the ECG sensor captures the electrical activity of the heart. Both sensors send analog signals to the microcontroller for further processing.

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The microcontroller serves as the central processing unit of the system. It reads the sensor data, calculates the heart rate, and displays the measured values on an LCD module. Simultaneously, it communicates with the Wi-Fi module to upload the recorded data to the cloud platform.

The Wi-Fi module, connected to the microcontroller through TX and RX pins (configured on pins 8 and 9 of Arduino), enables real-time data transmission over the Internet. The CH_EN and VCC pins of the Wi-Fi module are powered by a 3.3V supply, and the GPIO0 pin is utilized for program uploading and configuration. The module is capable of auto-configuration, simplifying the process of establishing a network connection.

During operation, the heartbeat is recorded for an initial 20-second interval to determine the beats per minute (BPM). The microcontroller calculates the equivalent 60-second heart rate and sends the data to the cloud. The ECG monitoring process follows a similar method, converting the collected analog signals into digital form and transmitting them to the IoT platform for analysis.

In summary, this system effectively integrates sensor technology, microcontroller processing, and wireless communication to enable continuous remote monitoring of cardiac activity. It provides an efficient and cost-effective approach to real-time health observation through IoT-based data transmission.

V. DISCUSSION AND RESULTS

The proposed IoT-based ECG monitoring system was developed and tested to evaluate its capability for real-time cardiac signal acquisition, transmission, and visualization using the AD8232 ECG sensor and NodeMCU ESP32 microcontroller. The system was tested under various conditions to assess its signal accuracy, responsiveness, and reliability in comparison with a conventional ECG monitoring setup.

A. Experimental Setup and Procedure

The prototype was assembled using the components described in Section 3, powered via USB, and connected to a Wi-Fi network for cloud-based monitoring through the Ubidots IoT platform. The AD8232 sensor electrodes were attached to three standard limb positions—right arm (RA), left arm (LA), and right leg (RL)—following the Einthoven triangle configuration.

During the experiment, ECG data were sampled by the ESP32 analog-to-digital converter (ADC) and transmitted wirelessly to the Ubidots server. A 3.5-inch TFT display was used for on-device visualization, providing immediate feedback, while the cloud dashboard plotted the ECG waveform in real-time and displayed corresponding heart rate values (beats per minute, BPM).

Data collection was carried out for multiple volunteers under resting and mild activity conditions to analyze the system's stability, accuracy, and delay in data transmission.

B. Signal Observation and Analysis

The ECG signals obtained from the proposed system clearly displayed the characteristic P–QRS–T complex, validating the ability of the AD8232 sensor to capture essential cardiac features. The QRS peak detection was sharp and consistent, confirming the system's sensitivity to electrical changes associated with ventricular depolarization.

Figure 2 (as referenced) illustrates the real-time ECG waveform recorded on the Ubidots dashboard, showing the continuous cardiac rhythm without significant distortion or noise interference.

Noise reduction was achieved through the AD8232's internal filtering circuit, which effectively minimized baseline wandering and high-frequency noise caused by electrode movement or power-line interference. Minor deviations were observed during body motion, which were mitigated by ensuring stable electrode contact and shielding of analog leads.

C. Cloud-Based Visualization and Monitoring

The Ubidots cloud interface successfully received and displayed ECG data at an update interval of approximately 1 second, enabling near real-time monitoring.

- Each data packet contained timestamped heart rate and voltage readings.
- The dashboard allowed graphical visualization of ECG signals and stored historical data for later review.

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• Threshold-based alerts were configured to send email notifications to healthcare providers when the heart rate exceeded preset limits (e.g., >100 BPM or <60 BPM).
This cloud-enabled functionality demonstrates the system's capability for remote cardiac supervision, making it suitable for elderly patients, post-operative monitoring, and telemedicine applications.

D. Performance Evaluation

TABLE I: PERFORMANCE PARAMETERS MEASURED DURING EXPERIMENTAL TRIALS.

Parameter	Observed Value / Range	Remarks
Sampling Frequency	360 Hz	Sufficient for accurate ECG reconstruction
Signal-to-Noise Ratio (SNR)	~28–32 dB	Acceptable for clinical-grade ECG signals
Average Latency (Wi-Fi Upload)	0.8 – 1.2 seconds	Minimal delay, suitable for remote monitoring
Heart Rate Detection Range	45 – 160 BPM	Adequate for resting and active conditions
Cloud Update Rate	1 second	Consistent and reliable data refresh rate
Average Power Consumption	0.6 W	Suitable for portable and wearable operation

The results clearly demonstrate that integrating IoT technology with biomedical signal processing can effectively transform traditional cardiac monitoring into a portable, real-time, and patient-centered system. The design successfully addresses key challenges such as accessibility, cost, and continuous data acquisition.
The ability to transmit ECG data to the cloud ensures that healthcare professionals can intervene promptly, reducing the risk of undiagnosed cardiac episodes. Furthermore, integrating AI or deep learning algorithms into the system could enhance predictive diagnostics, enabling early detection of arrhythmias or myocardial abnormalities.
The discussion highlights the system's potential for scalable healthcare deployment, particularly in rural and semi-urban regions where access to specialized cardiac diagnostics is limited. With advancements in low-power electronics, 5G communication, and data analytics, the proposed design lays a foundation for future intelligent tele-cardiology systems.

VI. CONCLUSION AND FUTURE SCOPE

This work successfully demonstrates the design and implementation of a low-cost IoT-based ECG monitoring system capable of recording, transmitting, and visualizing real-time cardiac activity. The integration of the AD8232 ECG sensor with the ESP32 microcontroller and Ubidots cloud platform enabled continuous remote monitoring with high signal fidelity and minimal latency. Experimental validation confirmed that the system can accurately detect essential ECG features such as the P-QRS-T complex and measure heart rate within clinically acceptable limits.
The developed prototype highlights the potential of IoT-enabled biomedical systems to enhance healthcare accessibility, particularly in remote and resource-limited environments. By providing real-time data visualization, secure cloud storage, and instant alert mechanisms, the system ensures timely medical intervention and supports preventive healthcare strategies. Furthermore, the compact design and affordability make it suitable for personal health tracking, telemedicine, and educational applications.
For future development, the system can be enhanced by integrating machine learning algorithms to automatically classify cardiac abnormalities such as arrhythmia or tachycardia. Additional improvements, including Bluetooth Low Energy (BLE) communication, wearable form-factor design, and battery optimization, would further increase portability and usability. Expanding the platform to include multi-lead ECG acquisition and mobile app integration could make it a comprehensive diagnostic tool for continuous cardiac health assessment.
In conclusion, the proposed IoT-based ECG monitoring system represents a promising step toward intelligent, real-time, and accessible cardiac care, aligning with the global shift toward digital and connected healthcare technologies.

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