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Design and Implementation of Smart Patient Monitoring System (SPMS) using ESP32

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***Abstract:** Continuous monitoring of vital physiological parameters is essential for timely diagnosis and effective healthcare management, especially for elderly patients, chronic cases, and individuals under home care. Traditional patient monitoring systems are often bulky, expensive, and confined to hospital environments, limiting their accessibility and continuous usage. This project presents the design and implementation of a Smart Patient Monitoring System (SPMS) using an ESP32 microcontroller. The system continuously measures vital parameters such as body temperature, heart rate, ECG signals, and environmental conditions, and displays the data on a local OLED screen. The ESP32's built-in Wi-Fi capability enables real-time data transmission to a cloud platform for remote monitoring. Threshold-based alert mechanisms are incorporated to notify caregivers during abnormal physiological conditions, enhancing patient safety. The proposed system is compact, low-cost, and suitable for bedside and home-care applications. The modular design allows future expansion with additional sensors and advanced analytics, making it a scalable solution for modern healthcare monitoring.*
***Keywords:** Esp32, ECG Signals, Heart Rate, Wi-Fi , Healthcare*

I. INTRODUCTION

The rapid advancement of embedded systems, sensor technologies, and the Internet of Things (IoT) has significantly transformed modern healthcare by enabling intelligent and continuous patient monitoring. The increasing prevalence of chronic diseases, cardiovascular disorders, respiratory illnesses, and age-related health conditions has created a growing demand for efficient and real-time health monitoring solutions beyond conventional hospital settings. Traditional patient monitoring methods rely heavily on periodic manual observations by healthcare professionals, which are labor-intensive, time-consuming, and may fail to detect sudden physiological abnormalities promptly. To address these limitations, the Smart Patient Monitoring System integrates multiple biomedical sensors with an embedded microcontroller to continuously acquire and process vital physiological parameters, including body temperature, heart rate, oxygen saturation (SpO_2), electrocardiogram (ECG) signals, and environmental conditions. The collected data are transmitted through IoT-based wireless communication, enabling remote access by physicians and caregivers for continuous supervision irrespective of geographical location. Such remote monitoring is particularly beneficial for home-based healthcare, elderly patients, and individuals residing in rural and underserved regions where immediate medical assistance is often unavailable. Furthermore, the system incorporates automated threshold-based alert mechanisms to identify abnormal physiological conditions at an early stage, thereby facilitating timely medical intervention and reducing the risk of severe complications. By providing continuous real-time monitoring, remote accessibility, automated alerts, and reliable health data acquisition, the Smart Patient Monitoring System enhances patient safety, improves clinical decision-making, reduces healthcare costs, minimizes the workload of medical personnel, and contributes to the development of efficient, scalable, and patient-centric healthcare services.

II. EXISTING SYSTEM

Existing patient monitoring systems are primarily designed for use in hospitals and clinical environments. These systems consist of advanced medical equipment that continuously measures vital parameters such as heart rate, ECG, blood pressure, and oxygen saturation. While hospital-based monitoring systems provide accurate and reliable data, they are often expensive, bulky, and require trained medical personnel for operation and maintenance. As a result, their use is generally limited to intensive care units and specialized medical wards. In many cases, conventional monitoring systems rely on wired connections and centralized control units, which restrict patient mobility and comfort. Patients are required to remain within a specific range of monitoring equipment, making long-term or home-based monitoring inconvenient. Additionally, these systems often generate large amounts of data that require manual interpretation by healthcare professionals, increasing the workload and chances of delayed response during emergencies. Another limitation of existing systems is the lack of remote accessibility. Most traditional monitoring setups do not support real-time data transmission over the internet, making it difficult for doctors to monitor patients from distant locations.

This becomes a major drawback for patients who require continuous observation but cannot remain hospitalized for long durations. Due to these limitations, existing patient monitoring systems are not suitable for affordable, continuous, and remote healthcare monitoring. This creates a need for a smart, IoT-based solution that is compact, cost-effective, and capable of providing real-time monitoring with automated alerts and remote access

III.PROPOSED SYSTEM

A. Overall System Architecture

The proposed Smart Patient Monitoring System is an Internet of Things (IoT)-enabled embedded healthcare platform designed to provide continuous, real-time monitoring of multiple physiological parameters. The system integrates biomedical and environmental sensors with an ESP32 microcontroller to acquire, process, display, and transmit patient health data with minimal human intervention. The ESP32 serves as the central processing unit, coordinating sensor communication, data processing, threshold evaluation, local visualization, and wireless communication. Physiological parameters including body temperature, heart rate, oxygen saturation (SpO_2), electrocardiogram (ECG), and ambient humidity are continuously monitored to provide a comprehensive assessment of the patient's health status. The measured data are displayed locally on a 1.3-inch OLED display and simultaneously transmitted to an IoT cloud platform through the ESP32's built-in Wi-Fi module, enabling remote monitoring by healthcare professionals. Furthermore, a buzzer-based alert mechanism is incorporated to provide immediate notification whenever any monitored parameter exceeds predefined clinical threshold values. The proposed system offers ***a*** compact, low-cost, scalable, and energy-efficient solution suitable for hospital wards, home healthcare, and remote patient monitoring applications**.**

B. Hardware Architecture

The hardware implementation of the proposed Smart Patient Monitoring System consists of an ESP32 development board, biomedical sensors, an OLED display, and an alert module interconnected to achieve continuous health monitoring. The ESP32 functions as the central controller owing to its high processing capability, integrated Wi-Fi connectivity, multiple GPIO interfaces, and low power consumption. A DS18B20 digital temperature sensor is employed to monitor body temperature accurately, while the MAX30102 sensor measures heart rate and oxygen saturation using photoplethysmography. Cardiac electrical activity is monitored using the AD8232 ECG sensor, which provides analog ECG signals for real-time cardiac analysis. A DHT11 sensor is incorporated to measure ambient humidity, allowing environmental conditions surrounding the patient to be monitored simultaneously. The acquired physiological information is displayed on a 1.3-inch OLED display, providing immediate visualization for caregivers. An active buzzer is connected to a digital output pin of the ESP32 to generate audible alerts whenever abnormal physiological conditions are detected. The hardware architecture is designed to ensure reliable operation, low implementation cost, portability, and ease of deployment in healthcare environment.

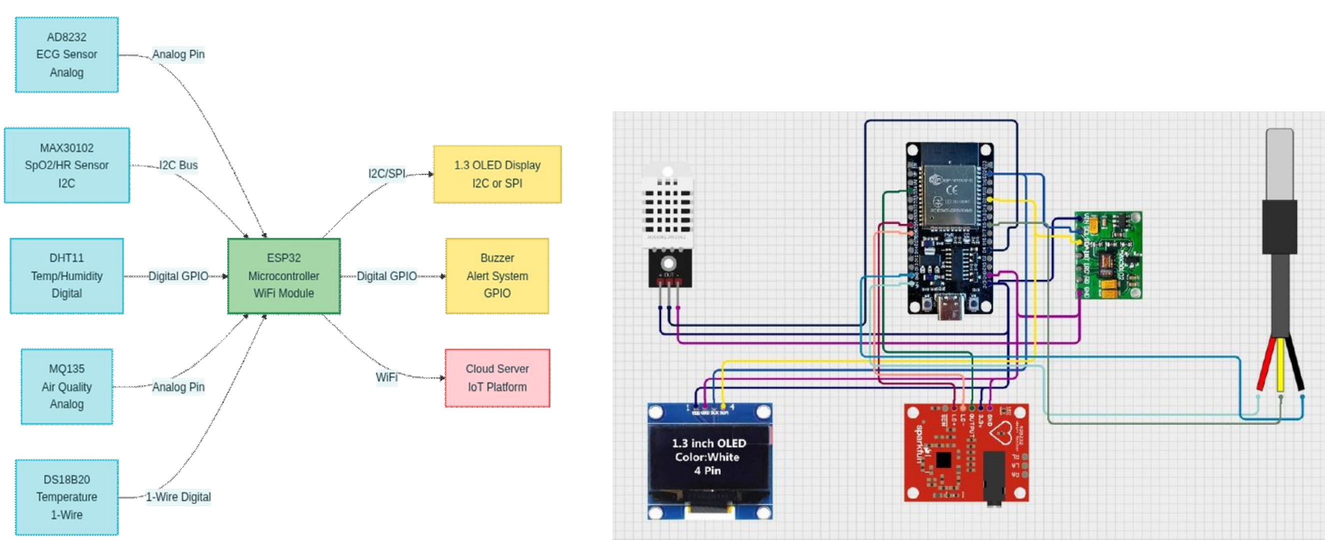


Fig 1: Block diagram and circuit diagram of the system

C. Sensor Data Acquisition and Processing

The sensor data acquisition process involves continuous collection of physiological and environmental parameters through multiple sensing modules interfaced with the ESP32 microcontroller. The DS18B20 communicates with the controller using the One-Wire protocol to provide high-resolution body temperature measurements. The MAX30102 pulse oximeter communicates through the I²C interface and continuously measures heart rate and oxygen saturation by analyzing variations in light absorption caused by blood flow. The AD8232 ECG module captures the electrical activity of the heart through surface electrodes and provides analog ECG signals that are sampled by the ESP32 using its analog-to-digital converter (ADC). The DHT11 sensor acquires ambient humidity data through a digital communication interface. Following data acquisition, the ESP32 performs preprocessing, noise reduction, threshold comparison, and parameter conversion before displaying the processed values on the OLED display. Simultaneously, the processed data are transmitted through the integrated Wi-Fi module to an IoT cloud platform, enabling secure remote access and continuous monitoring by healthcare professionals.

D. Physiological Parameters and Sensor Working Principle

The proposed Smart Patient Monitoring System continuously measures multiple physiological and environmental parameters to provide a comprehensive assessment of the patient's health condition. Each parameter is acquired using a dedicated sensor selected based on its measurement accuracy, reliability, and compatibility with the ESP32 microcontroller.

1) Body Temperature Measurement: Body temperature is monitored using the DS18B20 digital temperature sensor, which operates based on semiconductor temperature-sensing technology. The sensor converts temperature variations into a digital signal and communicates with the ESP32 through the One-Wire communication protocol. Continuous monitoring of body temperature assists in the early detection of fever, hypothermia, and infection-related abnormalities.
2) Heart Rate and Oxygen Saturation Measurement: Heart rate and blood oxygen saturation (SpO_2) are measured using the MAX30102 pulse oximeter sensor. The sensor operates on the principle of photoplethysmography (PPG), in which red and infrared light emitted by integrated LEDs passes through body tissue. Variations in the reflected light intensity caused by pulsatile blood flow are detected by a photodiode. The ESP32 processes these optical signals to estimate heart rate in beats per minute (BPM) and oxygen saturation as a percentage, providing continuous assessment of cardiovascular function.
3) Electrocardiogram (ECG) Measurement: The AD8232 ECG module is employed to acquire the electrical activity of the heart. Surface electrodes attached to the patient's body detect low-amplitude bioelectric signals generated during cardiac depolarization and repolarization. The AD8232 amplifies and filters these signals before providing an analog output to the ESP32 analog-to-digital converter (ADC). The acquired ECG waveform facilitates the identification of cardiac rhythm abnormalities and supports continuous cardiac monitoring.
4) Ambient Humidity Measurement: The DHT11 sensor measures ambient humidity using a capacitive humidity sensing element integrated with a digital signal processing circuit. Changes in the surrounding humidity alter the capacitance of the sensing element, which is converted into digital data and transmitted to the ESP32. Monitoring environmental humidity contributes to improved patient comfort and enables assessment of environmental conditions that may influence patient health.

E. Working Principle of the Proposed System

The overall operation of the Smart Patient Monitoring System consists of four sequential stages: sensor initialization, physiological data acquisition, data processing, and remote monitoring. Initially, the ESP32 microcontroller initializes all connected sensors, the OLED display, and the Wi-Fi communication module. After successful initialization, each sensor continuously acquires its respective physiological or environmental parameter and transmits the measured data to the ESP32 through the appropriate communication interface.

The ESP32 receives the sensor data, performs signal conditioning, parameter conversion, and threshold evaluation using predefined clinical limits. The processed physiological parameters, including body temperature, heart rate, oxygen saturation (SpO_2), ECG waveform, and ambient humidity, are displayed in real time on the OLED display to facilitate local monitoring by caregivers. Simultaneously, the ESP32 utilizes its integrated Wi-Fi module to upload the processed data to an IoT cloud platform, enabling remote visualization and continuous patient monitoring by healthcare professionals.

During system operation, the measured parameters are continuously compared with predefined threshold values. Whenever any physiological parameter exceeds its permissible range, the ESP32 immediately activates the buzzer to generate an audible warning while simultaneously transmitting the abnormal measurements to the cloud platform for prompt medical attention.

This continuous cycle of sensing, processing, visualization, threshold analysis, alert generation, and cloud communication enables early detection of physiological abnormalities, enhances patient safety, and supports timely clinical decision-making. The proposed architecture therefore provides a reliable, low-cost, and scalable solution for continuous healthcare monitoring in hospital, home-care, and telemedicine applications.

F. Software Implementation

The software architecture of the proposed Smart Patient Monitoring System is designed to ensure reliable acquisition, processing, visualization, and transmission of physiological data in real time. The ESP32 microcontroller executes the embedded software that coordinates communication with multiple biomedical sensors, processes the acquired measurements, evaluates predefined threshold conditions, and manages both local and remote monitoring functions. The software is developed using a modular programming approach to facilitate efficient sensor integration, improve code maintainability, and support continuous system operation with minimal computational overhead. By synchronizing sensor acquisition, signal processing, display updates, and wireless communication, the software enables uninterrupted monitoring while maintaining low power consumption and real-time responsiveness.

1) Embedded Software Architecture

The embedded software is implemented on the ESP32 microcontroller using the Arduino Integrated Development Environment (Arduino IDE). During system initialization, the firmware configures the communication interfaces, including One-Wire, I^2C, analog-to-digital converter (ADC), and digital input/output ports, required for interfacing with the DS18B20, MAX30102, AD8232, DHT11 sensors, OLED display, and buzzer. After successful initialization, the firmware enters a continuous execution loop in which physiological data are periodically acquired, processed, and converted into meaningful health parameters such as body temperature (°C), heart rate (BPM), oxygen saturation (SpO_2), ECG waveform, and ambient humidity (%RH). The processed data are subsequently displayed on the OLED screen while simultaneously being prepared for wireless transmission. The modular implementation ensures accurate sensor synchronization, reliable data acquisition, and efficient execution without interrupting continuous patient monitoring.

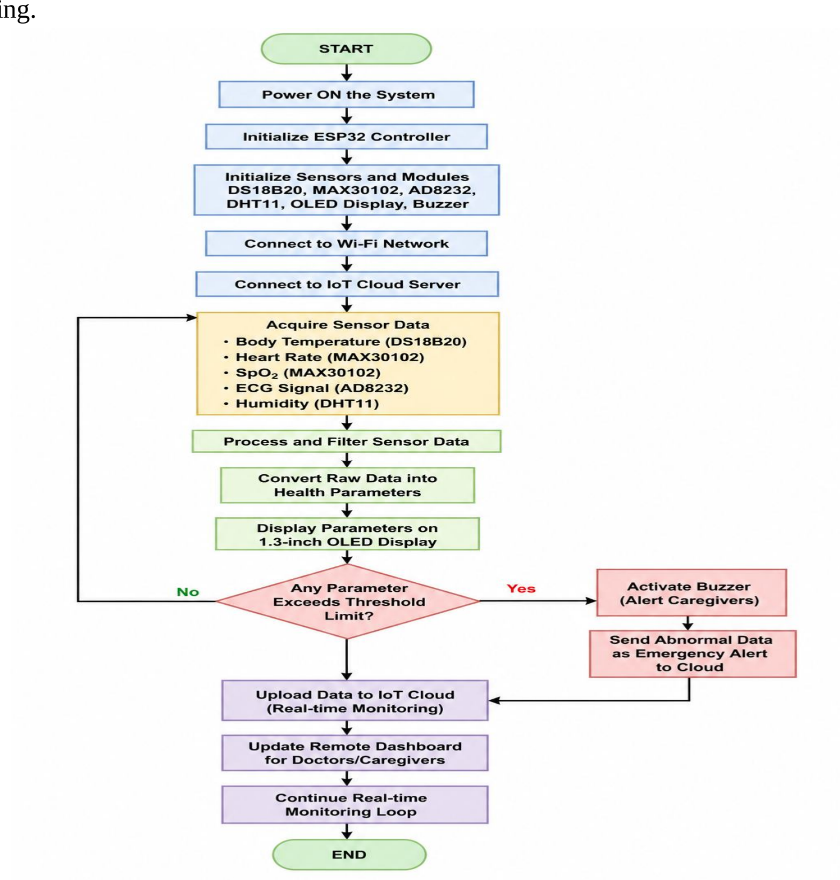


Fig 2: Flow chart of the system

2) Alert Generation and Decision Algorithm

Following data acquisition, the embedded software compares each physiological parameter with predefined clinical threshold values to determine the patient's health status. When all measured values remain within the permissible operating range, the system continues routine monitoring and periodically updates the OLED display and cloud database. If any physiological parameter exceeds its predefined threshold, the ESP32 immediately activates the buzzer to generate an audible alert for nearby caregivers. Simultaneously, the abnormal sensor readings are transmitted to the IoT platform, enabling healthcare professionals to observe the patient's condition remotely and initiate timely medical intervention. This automated decision-making mechanism enhances system reliability while reducing dependence on continuous manual observation.

3) IoT Communication and Remote Monitoring

The ESP32 utilizes its integrated IEEE 802.11 Wi-Fi interface to establish communication with the IoT cloud platform. After local processing, the physiological parameters are formatted into structured data packets and transmitted periodically through the wireless network. The uploaded data include body temperature, heart rate, oxygen saturation (SpO_2), ECG signals, and ambient humidity, enabling continuous cloud-based monitoring of patient health. Remote accessibility allows healthcare professionals and caregivers to observe physiological trends irrespective of geographical location, thereby supporting telemedicine applications and long-term patient supervision. The combination of local monitoring, cloud synchronization, and automated alert generation significantly improves response time during emergency situations and enhances the overall effectiveness of the healthcare monitoring system.

4) Software Development Environment

The embedded firmware was developed using the Arduino Integrated Development Environment (Arduino IDE), which provides an integrated platform for code development, compilation, debugging, and firmware uploading to the ESP32 microcontroller. The development environment supports C/C++ programming and offers extensive libraries for biomedical sensors, OLED displays, and wireless communication, thereby simplifying software implementation and hardware integration. The hardware interconnections and circuit schematic were designed using the Fritzing software package, which facilitates clear visualization of component connections and supports accurate documentation of the electronic hardware architecture. The combined use of Arduino IDE and Fritzing ensured efficient software development, hardware verification, and system integration throughout the implementation process.

IV. RESULTS AND DISCUSSIONS

The proposed Smart Patient Monitoring System was successfully implemented and experimentally evaluated under normal operating conditions to assess its functionality, reliability, and real-time performance. Experimental results demonstrated successful integration of the ESP32 microcontroller with the DS18B20, MAX30102, AD8232, and DHT11 sensors, enabling continuous acquisition of body temperature, heart rate, oxygen saturation (SpO_2), electrocardiogram (ECG) signals, and ambient humidity. The acquired physiological parameters were processed efficiently by the ESP32 and displayed on the 1.3-inch OLED display with negligible latency, providing immediate visualization of the patient's health status. Simultaneously, the processed data were transmitted to the IoT cloud platform through the ESP32's integrated Wi-Fi module, enabling seamless remote monitoring by healthcare professionals. The threshold-based alert mechanism functioned reliably by activating the buzzer whenever any physiological parameter exceeded predefined safe limits, thereby facilitating prompt medical attention during abnormal conditions. The system exhibited stable operation throughout continuous testing without communication failures or sensor synchronization issues, demonstrating its suitability for long-term healthcare monitoring. Although the proposed prototype is not intended to replace advanced clinical monitoring equipment, it provides an accurate, portable, and cost-effective solution for preliminary health assessment, remote patient supervision, and home-based healthcare applications. The integration of embedded sensing, wireless communication, real-time data visualization, and automated alert generation highlights the feasibility of the proposed architecture for IoT-enabled healthcare systems and establishes its potential for deployment in telemedicine, elderly care, and chronic disease monitoring.

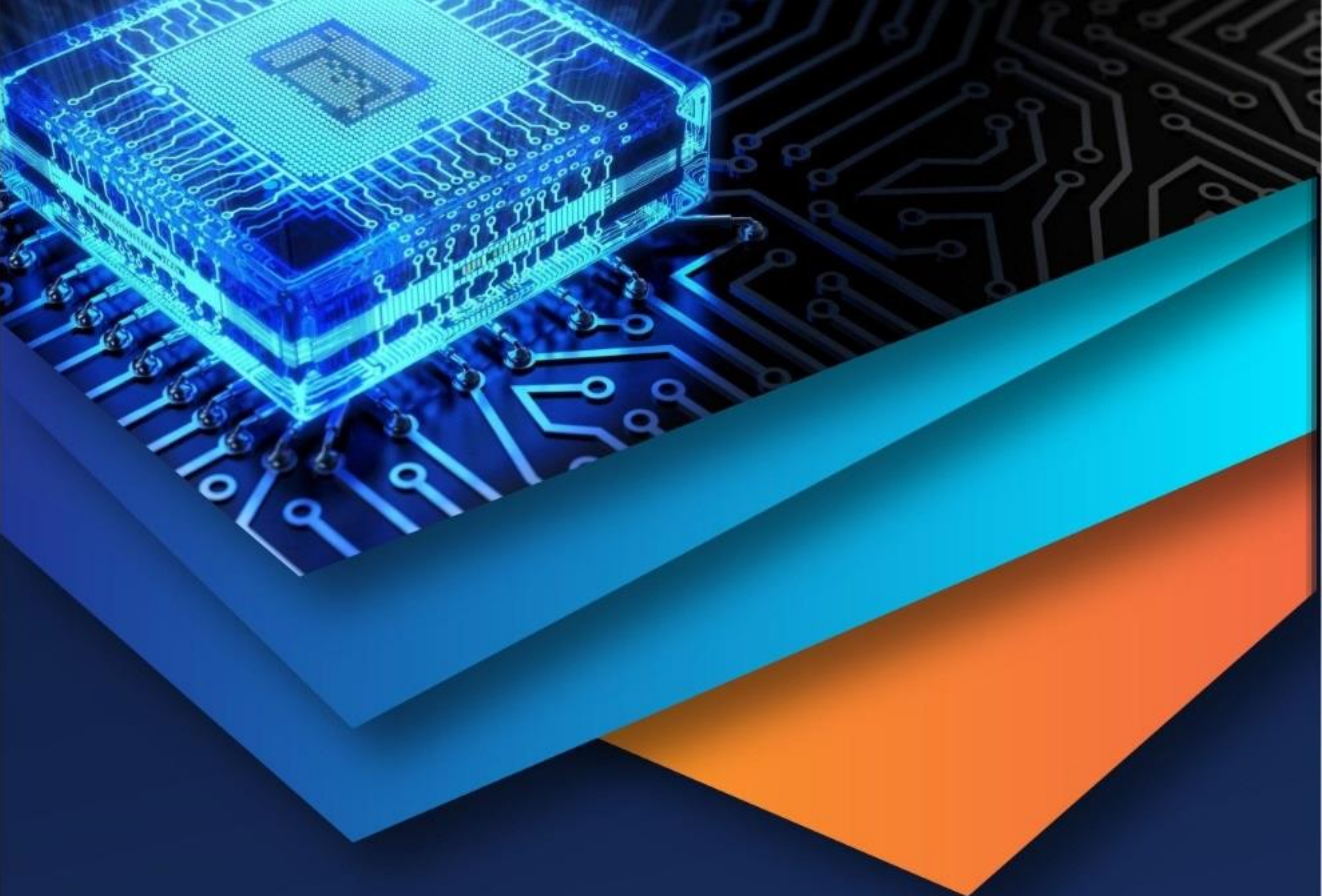
V. CONCLUSION

The Smart Patient Monitoring System has been successfully designed and implemented using the ESP32 microcontroller and various biomedical sensors. The system is capable of continuously monitoring vital health parameters such as body temperature, heart rate, oxygen saturation, ECG signals, and humidity.

The measured values are displayed in real time, and an alert mechanism is used to notify caregivers whenever abnormal health conditions are detected. The integration of IoT technology enables remote monitoring of patient health data, allowing doctors and caregivers to access information from distant locations. This improves response time during medical emergencies and enhances patient safety. The system is designed using low-cost components, making it affordable and suitable for continuous operation in both hospital and home-care environments. The successful implementation of the Smart Patient Monitoring System demonstrates its reliability and effectiveness as a basic healthcare monitoring solution. The project highlights the importance of IoT-based embedded systems in modern healthcare applications and shows potential for further enhancement in future developments.

REFERENCES

[1] Mamdiwar SD, Akshith R, Shakruwala Z, Chadha U, Srinivasan K, Chang CY. Recent advances on IoT-assisted wearable sensor systems for healthcare monitoring. Biosensors (Basel). 2021;11(10):372. doi:10.3390/bios11100372.
[2] Abdulmalek S, Albogamy FR, Alotaibi SS, et al. IoT-based healthcare-monitoring system towards improving quality of life: A review. Healthcare (Basel). 2022;10(11):1993.
[3] Ferdous J, Roy B, Hossen M, Islam MM. Implementation of IoT-based patient health monitoring system using ESP32 web server. Int J Adv Res. 2023;11(6):716-726. doi:10.21474/IJAR01/17119.
[4] Vyas H, Shukla H, Jivani MN. A portable IoT-based health monitoring framework using ESP32 for isolated and home-based patient care. J Electron Autom Eng. 2025;4(2):240-245. doi:10.46632/jeae/4/2/31.
[5] Mnaathr SH, et al. Design of a remote monitoring system for patients in real time based on the Internet of Things (IoT). Int J Eng Manuf. 2023;13(5):1-10.
[6] Ya'acob N, Amin MZ, Aziz NF, et al. Design and implementation of a wireless health monitoring system for real-time patient data using ESP32. In: Proceedings of the IEEE 15th Control and System Graduate Research Colloquium (ICSGRC); 2024.
[7] Chougule AV, Bailakkanavar SR, Kale SM, et al. Optimizing space and time complexity for IoT-infused health monitoring system. In: Proceedings of the IEEE International Conference on Advances in Computing, Communication and Networking (ICAC2N); 2024.
[8] Rahman KKM, Mohamed NN, Zidan R, Alsarraj I, Hasan B. IoT-based wireless patient monitor using ESP32 microcontroller. In: Proceedings of the 24th International Arab Conference on Information Technology (ACIT). IEEE; 2023.
[9] Monitoring vital signs with IoT devices. IFAC-PapersOnLine. 2025;59(24):470-475. doi:10.1016/j.ifacol.2025.11.910.
[10] Mounika K, Akram SV. Wireless IoT-based continuous ECG monitoring using ESP32 and ThingSpeak-based performance analysis across age groups. Sens Actuators A Phys. 2025. doi:10.1016/j.sna.2025.117392.



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