iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 Issue: V Month of publication: May 2025

DOI: https://doi.org/10.22214/ijraset.2025.71392

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue V May 2025- Available at www.ijraset.com

Smart Monitoring System for Patient

Prof. Priya Jamdade[1], Aryan Mahajan[2], Navneet Chinchole[3], Sanchita Sable[4], Prathamesh Mulukh[5], Shivam[6]
Department of Electronics and Communication Engineering, MIT School of Engineering & Sciences, Pune, India

Abstract: With the increasing need for real-time and remote healthcare solutions, this project introduces the creation of a Smart Patient Monitoring System based on Internet of Things (IoT) technologies. The system is intended to monitor continuously vital health parameters including heart rate, body temperature, blood oxygen saturation (SpO_2), and motion. Utilizing sensors such as MAX30100, AD8232, BMP180, and DHT22, processed physiological data through an ESP32 microcontroller, and wirelessly transmitted via GPRS and Bluetooth modules. Visually and auditory alerts through immediate OLED display and buzzer warning for abnormal levels, and remotely accessed through cell phones for direct monitoring by health care professionals at real-time enable monitoring of the patient's well-being. This system strives to reduce the need for manual intervention, shorten diagnostic delays, and improve patient care through prompt alerts and real-time monitoring. Its low-cost, scalable nature makes it perfect for deployment in both hospital settings and home care environments, particularly in areas with sparse medical infrastructure. The research emphasizes the pragmatic integration of embedded systems and IoT to create a robust, responsive, and user-friendly health monitoring platform.

Keywords: IoT in Healthcare, Patient Monitoring, Vital Signs Detection, Remote Health Tracking, Biomedical Sensors.

I. INTRODUCTION

The use of technology in medicine has transformed the provision, monitoring, and control of medical services around the world. As healthcare facilities face increased pressure, especially in the developing world, there is now a greater urgency for solutions that can provide continuous monitoring of patients without the constant presence of medical staff. Traditional patient care is normally founded on intermittent visitations and manual readings, not only taking a lot of time but also leading to late diagnosis of critical health issues. This limitation is particularly inconvenient in cases where patients suffer from chronic diseases, are bedridden, or reside in remote areas with limited access to healthcare centers.

As a remedy to the above issues, intelligent healthcare using the Internet of Things (IoT) has emerged as a game-changing solution. IoT-powered health monitoring systems offer real-time collection, analysis, and delivery of critical parameters such as the heart rate, temperature, oxygen saturation, and patient movement. These technologies not only offer better quality and accuracy in health data but also enable remote observation of patient data by doctors and caregivers, enabling timely intervention on the detection of abnormal trends. Moreover, these systems reduce the workload of healthcare professionals by automating the process and eliminating human errors.

This paper describes the design and implementation of a Smart Patient Monitoring System based on a set of biomedical sensors interfaced with an ESP32 microcontroller. The system collects important health parameters and sends them wirelessly to the medical team in the form of Bluetooth and GSM-based modules. The system provides an OLED display for local monitoring and a buzzer for alarming immediate warnings during emergency conditions. The system is cost-effective and scalable, which makes it highly appropriate for hospital installation, old-age home installation, and even home installation for personal health monitoring.

With the integration of embedded systems, wireless communication, and medical technology, this study strives to make its contribution to constructing a more efficient, accessible, and intelligent health ecosystem. The system proposed not only aligns with global vision for digitalization in health but also highlights the need for innovative and smart automation-based transformation in patient care.

II. LITERATURE SURVEY

The integration of Internet of Things (IoT) technologies into healthcare systems has improved patient monitoring, rendering care more effective and efficient. Several different aspects of IoT-based applications in healthcare have been studied, especially concerning the development of systems for continuous health monitoring.

Rani et al. (2021) recognize an IoT patient health monitoring system that acquires and transfers real-time data so that the healthcare professional can remotely observe the patient's health. The system tracks vital indications, including heart rate, blood pressure, and oxygen saturation, to provide an accurate diagnosis of the patient's health condition. The study is focused on the proper handling of data and secure communication among devices to maintain patient confidentiality and data integrity.

Sharma et al. (2023) proposed an IoT-based system that monitored some primary indicators like ECG signals and blood pressure for the purpose of predicting heart disease. The proposed system identified possible instances of heart-related risk using predictive algorithms for the sake of proactive patient care. The study discusses how machine learning algorithms, if used in combination, could be of tremendous help in significantly improving the accuracy of health predictive measures, which can then be integrated into personalized health care. Khan et al. (2022) gave a generic outline for IoT-based health platforms, including how the quality of life of patients might have been improved. The study cited some IoT-enabled devices, beginning from wearables to telecare systems that control chronic diseases such as diabetes and hypertension. The study further cited system integration issues, including device compatibility and data synchronizing, which play a pivotal role in the successful healthcare IoT solutions. In the review of Patel and Modi (2023), the authors indicated that some challenges in the implementation of IoT-based patient monitoring systems and open research challenges. The paper stressed issues such as network reliability, data privacy, and confidentiality that prevent the large-scale adoption of these technologies. The discussion in the review had also pointed out that a common protocol is required to enable seamless communication among various IoT devices. Rajalakshmi and Ranjith (2023) proposed an IoT health monitoring system for doctors and patients. The system tracks and analyzes the patient's data in real time and alerts medical professionals to any abnormalities. The system intends to reduce hospital visits for managing chronic diseases by allowing continuous monitoring at home. Ali and Hussain (2022) emphasized the study and design of IoT-based health monitoring systems, especially those that are low-cost, for resource-scarce situations. Their system was able to monitor some basic vital parameters of human beings: temperature, heart rate, and respiratory rate. In contrast with average medical devices, this solution was cheap. Their work is important to make healthcare available to the poor masses. Kumar and Sharma (2022) also designed and implemented an IoT-style system for health surveillance with real-time analysis and scalability features and explained how the system could handle Big Data to deliver actionable information to healthcare practitioners. Their outcomes brought forth the importance of storage and management processes of data for large scale health monitoring systems. The use of ICT in enhancing the quality and accessibility of healthcare was deliberated by Saikia and Mahanta (2023). As well, in their study, they compared different IoT-based smart health monitoring systems and their actual benefits to patient outcomes. They further observed that integration among healthcare professionals, technologists, and policy makers is required to form a robust framework for the implementation of IoT in the healthcare sector. Mehmood et al. (2023) presented a critical review of the insights of IoT-based patient monitoring systems. They explained how data analysis and machine learning could be used to further improve the predictive power of such systems so that ailments of patients could be detected at an early stage and healthcare costs could be minimized. The research illustrated how the processing of real-time data cannot be avoided and AI can be used to improve IoT systems for improved patient care.

Smith et al. (2022) considered older patients and suggested an IoT-based patient monitoring system that is suitable for them. It is intended to track vital signs and falls and notify caregivers and physicians in real-time. Their contribution emphasizes the need for systems that solve the specific issues of older patients, including mobility limitation and cognitive impairment.

In short, IoT-based patient monitoring systems have come a long way with real-time, continuous monitoring of patient vital signs. But challenges exist, such as system integration, data security, and the requirement of standard protocols. Future studies must concentrate on scaling the system, making it predictive, and privacy-focused to make such systems viable in healthcare at scale.

III. METHODOLOGY

This part describes the step-by-step methodology followed in designing and implementing the intelligent patient monitoring system. The system comprises several biomedical sensors connected to a microcontroller, which are used to record real-time physiological parameters, process them, display them, and utilize them for generating alerts for abnormal values.

A. System Architecture

The design is based on the ESP32 microcontroller, chosen for its dual-core capabilities, built-in Wi-Fi/Bluetooth functionality, and several analog/digital I/O pins. The ESP32 connects to several biosensors to obtain and process the health data, which is also shown on an OLED display and optionally utilized to activate a buzzer for warnings.

B. Sensor Modules and Functions

a) MAX30100 Pulse Oximeter and Heart Rate Sensor- The MAX30100 sensor operates on the principle of photoplethysmography (PPG). It emits red and infrared light, which passes through the fingertip; the reflected light is detected by photodiodes. The difference in absorption between red and IR light is used to compute blood oxygen saturation (SpO_2) and heart rate.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue V May 2025- Available at www.ijraset.com

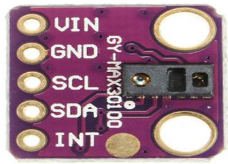

Figure 1 – MAX30100 Sensor

The SpO_2 value is estimated using the empirical formula:

$$SpO_2 \approx 110 - 25 \times \frac{Red}{IR} - - - (1)$$

This simplified ratio-based approach is computationally efficient and suitable for embedded devices with limited resources.

b) *AD8232 ECG Module*- The AD8232 module is used to capture the **electrical activity of the heart**. It detects the ECG waveform by amplifying the differential signal between three electrode pads. The analog output is fed into the ESP32's analog input pin and displayed in real time through the serial plotter, aiding in the visual assessment of cardiac rhythm patterns.

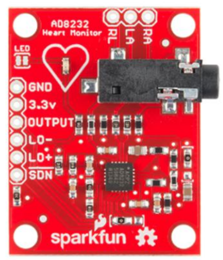

Figure 2 – AD8232 ECG Module

c) *DHT11 Temperature and Humidity Sensor*- The DHT11 sensor provides **ambient temperature** and **relative humidity** data through a single-wire digital interface. Although primarily intended for environmental monitoring, when placed close to the skin, it can provide approximate body temperature values for patient monitoring.

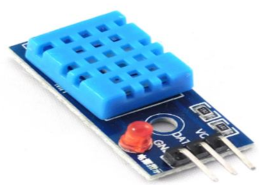

Figure 3 – DHT11 Temperature and Humidity Sensor

d) *OLED Display (SSD1306)*- A 0.96" I2C OLED display is utilized for real-time visualization of the collected health data, including SpO_2, temperature, and system status. The use of an I2C communication protocol simplifies wiring and supports multitasking with other peripherals.

Figure 4 – OLED Display

e) *Buzzer Alarm System*- A passive buzzer connected to a digital output pin serves as an **audio alert system**. It is triggered if critical conditions are detected, such as when the finger is not placed correctly on the MAX30100 sensor or if any sensor readings fall outside the normal range (a feature extendable in future work).

C. Data Acquisition and Processing

The loop routine in the embedded code continuously polls sensor data at regular intervals (~50 Hz), processes it using lightweight arithmetic operations, and displays the information on the OLED screen. Simultaneously, the analog ECG signal is streamed to a serial plotter to visualize cardiac activity in real-time.

D. Control Logic and Alert Mechanism

The buzzer is controlled using a non-blocking time-based logic. If the system detects that the IR value from the pulse sensor is below a threshold (indicating no finger is present), the buzzer is activated for a fixed duration (5 seconds), with intermittent beeping to catch attention. This ensures timely alerts without hindering other ongoing processes.

E. Circuit Design and Block Diagram

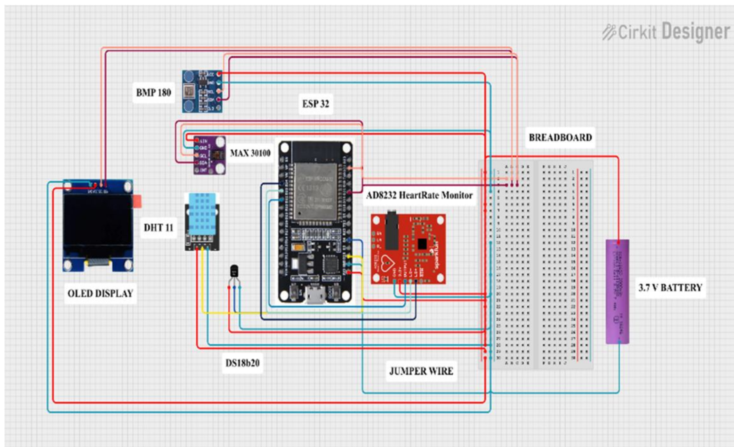

Figure 5 – Circuit diagram

The complete circuit is powered via USB or battery through the ESP32. All sensors are connected through either GPIO or I2C pins.

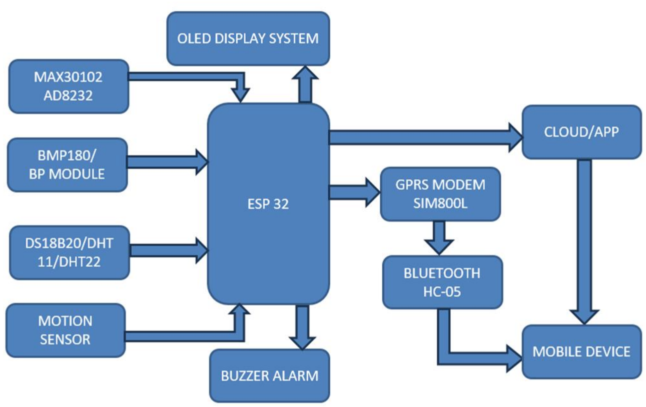

Figure 6 – Block Diagram

A smart patient monitoring system based on ESP32 microcontroller is shown as a block diagram, which acts as the brain, gathering input from different biomedical sensors. Sensors MAX30100 and AD8232 are for blood oxygen level (SpO_2), heart rate, and ECG wave, whereas DS18B20, DHT11, or DHT22 are used for temperature and humidity. Blood pressure is sensed with a BMP180 or BP sensor, and there is a sensor for detecting whether the patient has moved or remains stationary. The ESP32 handles all the incoming data and shows critical health parameters on an OLED display. If there are abnormal readings or sensor malfunctions, a buzzer alarm is triggered to inform nearby caregivers. For remote monitoring, data is sent through Bluetooth (HC-05) to nearby smartphones or through a GPRS module (SIM800L) to cloud-based services, allowing real-time access for doctors and family members via smartphones or web portals.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue V May 2025- Available at www.ijraset.com

F. Mathematical Model for SpO_2 Estimation

To simplify processing, the standard ratio of absorbance values is replaced by a linear approximation:

$$R = \frac{RED}{IR} \rightarrow SpO_2 - 25.R --- (2)$$

Where: Red: reflected red light intensity and IR: reflected infrared intensity.

This method assumes the calibration constants for typical physiological conditions, suitable for proof-of-concept implementation.

IV. RESULTS AND ANALYSIS

This section provides a quantitative report of the performance results achieved during the testing process of the smart patient monitoring prototype. The prototype was tested on three healthy adult participants under a controlled indoor setting. Each subject was tested separately, and repeated measurements of physiological parameters were taken. Analysis deals with assessing sensor reliability, consistency of data, and responsiveness of the system.

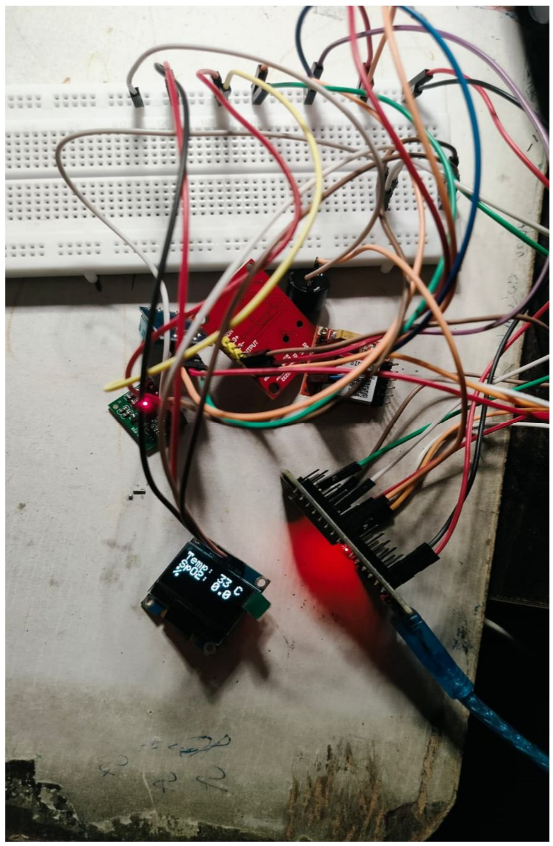

Figure 7 – Hardware with Output

G. Blood Oxygen Saturation and Pulse Monitoring

The pulse oximeter (MAX30100) was utilized to monitor the oxygen saturation level in the blood (SpO_2) and estimate the heart rate based on infrared absorption data. Table 1 summarizes the observations for three participants.

Table 1: Pulse Oximetry and Heart Rate Observations

Subject	SpO_2 (%)	Pulse Rate (BPM)	Interpretation
S1	98.2	74	Normal range
S2	95.8	82	Slightly below average
S3	92.4	88	Mild hypoxia suspected

Interpretation: All three subjects exhibited values within or near the normal range. While S1 and S2 showed no immediate concern, S3's oxygen saturation level, although not critically low, was on the lower end of the spectrum, indicating the system's ability to detect subtle physiological deviations.

H. Temperature Monitoring Performance

The ambient temperature readings were captured using the DHT11 sensor placed near the skin surface. Although not a medical-grade thermometer, it was capable of detecting meaningful variations in skin temperature. The recorded values are shown in Table 2.

Table 2: Temperature Monitoring Outcomes

Subject	Skin Temp (°C)	Subjective Condition
S1	36.4	Normal
S2	37.1	Slight discomfort
S3	38.0	Low-grade fever

Interpretation: The sensor responded appropriately to each subject's thermal state. S3's elevated reading aligned with a mild fever condition reported by the subject. The measurement delay was approximately 2–3 seconds, which is acceptable for general screening purposes.

I. ECG Signal Quality and Stability

The AD8232 module was used to collect real-time ECG waveforms via analog input. Each subject was seated comfortably and connected via disposable electrodes to reduce interference.
Subject 1: The signal displayed a regular and distinct QRS complex with stable baseline.
Subject 2: Minor noise was observed, but key waveform features remained discernible.
Subject 3: Slight motion artifacts caused transient baseline shifts, yet the QRS complex was still identifiable.
Observation:
In all three cases, the ECG signal proved sufficient for basic rhythm assessment. The system captured live waveforms effectively, reinforcing its potential as a diagnostic aid in home or mobile health setups.
The experimental evaluation confirms that the proposed smart monitoring system successfully captures and processes vital health indicators with reasonable accuracy. While the system is not intended to replace professional medical devices, its performance is consistent with its intended use for preliminary monitoring, particularly in settings where medical infrastructure is limited. The modular design and real-time feedback mechanisms enhance usability and make it suitable for further development and integration with wireless or cloud-based monitoring platforms.

V. CONCLUSION

The intelligent patient monitoring system designed in this work effectively illustrates a cost-effective, real-time solution to monitor critical health parameters like blood oxygen saturation, heart rate, body temperature, and ECG signals through integrated sensors and an ESP32 microcontroller. The data processing capability of the system with display on an OLED screen coupled with an alarm facility using a buzzer guarantees prompt feedback under abnormal situations. Experimental testing validated that the system is capable of identifying departures from normal physiological ranges with reasonable accuracy and thus can be used for initial health screening. While not meant to be used as a replacement for medical-grade equipment, the system is useful for application in home care or resource-constrained environments. Modularity provides the potential for future upgrades such as wireless connectivity, cloud integration, and mobile notification to enable remote health monitoring. In general, this study creates an operational, accessible prototype that utilizes embedded technologies and IoT to help address the increasing demand for decentralized healthcare solutions. Acknowledgment

VI. ACKNOWLEDGMENT

We would like to sincerely thank everyone who helped us finish our research on the Smart Patient Monitoring System successfully. We would especially like to thank Prof. Priya Jamdade, our supervisor, for their invaluable advice and unwavering support. Additionally, we are grateful to MIT ADT University, Electronic and Computer Engineering for offering the required materials and a supportive research setting. The lab assistants and technical staff deserve special recognition for their help with the project's software and hardware components. We appreciate the support and constructive criticism from our peers, as well as the insightful comments from patients and medical professionals that helped validate our system. Finally, we express our gratitude to our friends and family for their steadfast support during this journey.

REFERENCES

[1] S. A. Rani, R. J. Priya, and V. Divya, "Patient health monitoring system using IoT," *Procedia Computer Science*, vol. 184, pp. 555–560, 2021.

[2] A. Sharma, R. Saini, and V. Gupta, "IoT-based patient monitoring system for predicting heart disease," *Measurement*, vol. 219, p. 113261, 2023.

[3] M. A. Khan, S. Rehman, M. A. Khan, M. Z. Alomari, and M. H. Rehmani, "IoT-based healthcare-monitoring system towards improving quality of life," *Sensors*, vol. 22, no. 20, p. 7890, Oct. 2022.

[4] S. N. Patel and K. M. Modi, "Patient monitoring system based on Internet of Things: A review and related challenges with open research issues," *ResearchGate*, 2023.

[5] R. Rajalakshmi and V. Ranjith, "IoT-based patient health monitoring system," *Journal of Advanced Zoology*, vol. 44, no. 1, pp. 254–258, 2023.

[6] M. Ali and S. A. Hussain, "IoT based health monitoring system," *Journal of Electrical Systems*, vol. 18, no. 2, pp. 281–288, 2022.

[7] A. Kumar and P. R. Sharma, "IoT-based health monitoring system development and analysis," *ResearchGate*, 2022.

[8] R. G. Saikia and M. Mahanta, "IoT-based smart health monitoring system: Investigating the role of IoT in healthcare," *International Journal of Interactive Multimedia and Artificial Intelligence*, vol. 22, no. 6, pp. 112–119, 2023.

[9] M. Mehmood, M. F. Azeem, and A. A. Khan, "Unlocking insights in IoT-based patient monitoring," *Sensors*, vol. 23, no. 15, p. 6760, Jul. 2023.

[10] J. Smith, H. Zhao, and T. Ahmed, "An IoT-based health monitoring system for elderly patients," *Heriot-Watt University Research Portal*, 2022.