

# Design and Implementation of an IoT-Based Web Server System for Real-Time Vital Signs Monitoring

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## ABSTRACT

The goal of this project is to develop and put into use a web server-based vital signs monitoring system for tracking health conditions in real time. The device is designed to enable medical personnel to remotely monitor blood pressure, body temperature, oxygen saturation (SpO<sub>2</sub>), and heart rate. The system architecture integrates Internet of Things (IoT) physiological sensors, a microcontroller for data gathering, and a web server for data storage and visualization. Authorized users can view sensor data on a web-based dashboard after it is wirelessly delivered to the server. Requirements study, system design, implementation, and testing were all part of the prototype process used to create the system. Sensor accuracy, data transfer stability, and web interface responsiveness were assessed by system testing. The average measurement error for heart rate was 2.57%, with an accuracy of 97.43%; for oxygen saturation (SpO<sub>2</sub>), it was 1.37%, with an accuracy of 98.63%; and for body temperature, it was 2.04%, with an accuracy of 97.96%, according to the test findings. The installation results show that the system is capable of low-latency, real-time monitoring and early notifications when critical metrics exceed normal limits.



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## 1. INTRODUCTION

Significant advancements in remote vital-signs monitoring systems have been fueled by the increased focus on an individual's physical health [1-3]. Heart rate [4], oxygen saturation (SpO<sub>2</sub>) [5-9], body temperature [10-12], and blood pressure [13-14] are examples of vital signs, essential physiological indicators used to evaluate a person's health [15-18]. These measures have typically been monitored in a clinical context, which can restrict ongoing observation and postpone the early identification of serious problems. As a result, there is increasing demand for reliable, real-time monitoring systems that enable healthcare delivery outside traditional hospital settings.

The integration of biomedical sensors [19] with networked systems for real-time health data collection [20-21] has been enabled by recent advancements in the Internet of Things (IoT). Through automated data collection, transmission, and analysis via networked devices, IoT-based healthcare systems provide ongoing monitoring [22]. These technologies, when paired with web server technology,

enable remote visualization and retrieval of health data via web-based dashboards [23], increasing accessibility for medical professionals and boosting decision-making effectiveness [24].

Despite these advancements, there are still several challenges in developing IoT-based vital signs monitoring systems, including reliability in real-world scenarios, data transmission latency, sensor accuracy, and system scalability. Sensor devices, communication protocols, and user interfaces appropriate for clinical applications are not fully integrated into many existing systems, which are still restricted to prototype-scale implementations. To get around these limitations, this study suggests developing and implementing an IoT-based web server system for real-time vital signs monitoring. The proposed system aims to enable remote healthcare services, improve early detection capabilities, and provide accurate, stable, and real-time visualization of physiological data. By increasing monitoring effectiveness and facilitating prompt clinical treatments, the suggested strategy is anticipated to progress smart healthcare systems.

## 2. RESEARCH METHOD

This research uses a research and development approach with a design-and-implementation model, focusing on the design, development, implementation, and testing of an IoT-based vital signs monitoring system integrated with a web server. This approach is used because the research aims not only to produce a prototype device but also to evaluate system performance based on sensor reading accuracy and the system's ability to perform real-time monitoring. The research stages include identifying system requirements, designing hardware and software, testing performance, collecting and analyzing data, and evaluating system feasibility.

### 2.1. Block Diagram

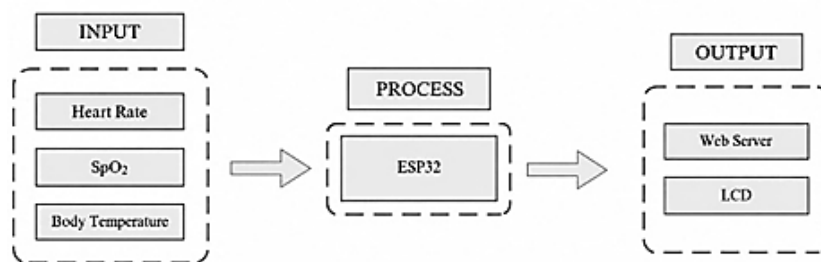


**Figure 1.** Block diagram of the vital signs monitoring

The three primary parts of a physiological health monitoring system input, processing, and output units are depicted in Figure 1. The input unit displays the physiological data of the patient as measured by the MAX30100 sensor (heart rate and SpO<sub>2</sub>) and the MLX90614 sensor (body temperature). An ESP32 microcontroller is used in the processing unit to process the data collected from the sensors. At this point, an ESP32-CAM is used to acquire, validate, and process data before sending it over the internet to the output system. The output device then uses a web server, an LCD, and a buzzer to show the data processing findings. A monitoring dashboard is used by the web server function to show data in real time.

### 2.2. Schematic Circuit Diagram

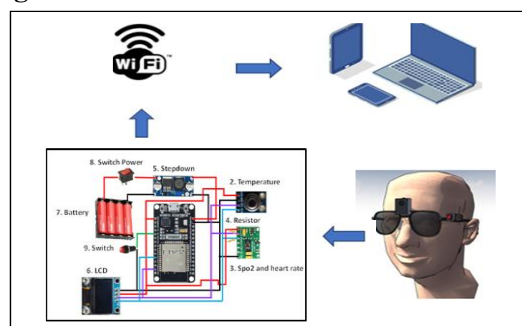


**Figure 2.** Schematic diagram of the vital signs monitoring system

Figure 2 shows a schematic of a vital signs monitoring circuit that is integrated with a web server. First, sensors installed on the device (part of the ESP32 circuit) are used to read body conditions such as heart rate, temperature and blood pressure. Next, the data is sent via a Wi-Fi connection to the internet. From the internet, data is forwarded to user devices such as laptops, computers or smartphones. On the user's side, the data is displayed on a monitoring display so that health conditions can be monitored in real time. Meanwhile, the image of a human head wearing glasses on the right side depicts a doctor recording patient or user data, with medical personnel monitoring the patient's condition.

### 2.3. Operating Principle of the Device

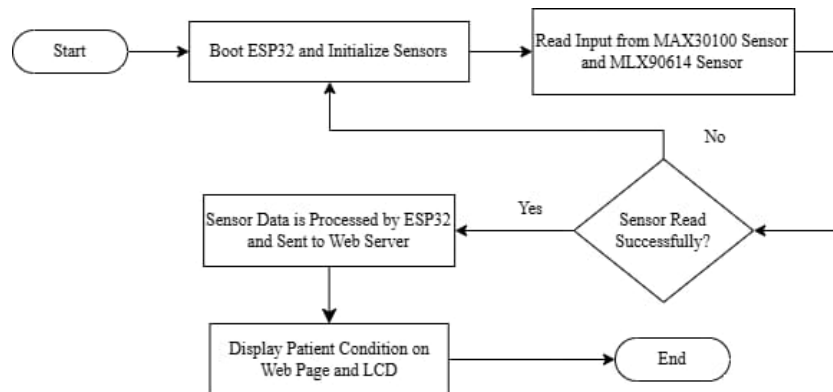


**Figure 3.** Flowchart of the working principle of the vital signs monitoring device

A flowchart illustrating the working concept of the vital signs monitoring device is shown in Figure 3. The ESP32 microcontroller boots up and initialises all of the system's embedded sensors to start the procedure. The ESP32 starts reading data from the MAX30100 and MLX90614 sensors once the initialisation process is complete. The system then performs validation to ensure the sensor data is accurately read. If the sensor reading fails, the system will return to the initialisation stage and repeat the reading until reliable sensor data is acquired. Nevertheless, the ESP32 handles the measurement data, including translating sensor readings and computing the required health parameter estimates, assuming all sensors have been correctly read.

After data processing is complete, the measurement results are transmitted via Wi-Fi to a web server for real-time display on a webpage for remote monitoring. As the device's local interface, the data is simultaneously shown on the LCD. To ensure the system is prepared to read and transmit data for the upcoming monitoring cycle repeatedly, this operation is performed continuously.

## 3. RESULTS AND DISCUSSION

### 3.1. Physical Form of the Device

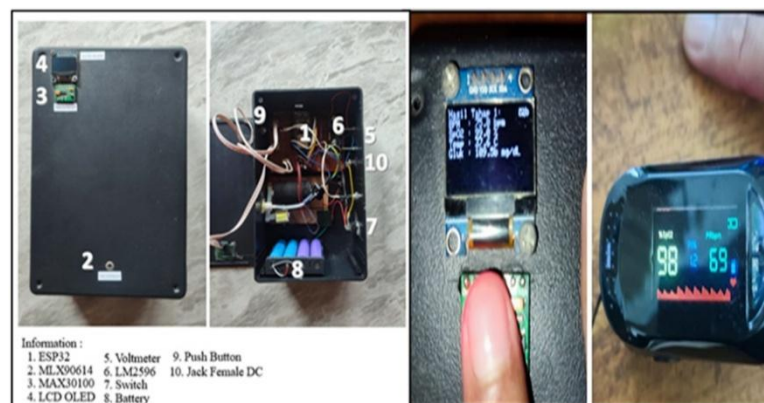


**Figure 4.** Design results of the vital signs monitoring system

Figure 4 shows the physical form of the vital signs monitoring system device developed in this study. The device is designed in a box shape, containing the main components: an ESP32, a DC pump, a solenoid valve, a Li-Ion battery, and a step-down module as a voltage regulator. On top of the device are an LCD screen for local display, a MAX30100 sensor for heart rate and SpO<sub>2</sub> measurements, and an MLX90614 sensor for body temperature measurements. Meanwhile, on the right side of the device, there is a three-mode switch (battery, off, and adapter), a push button for system reset, and a voltmeter for monitoring the input voltage. On the left side of the device, there is an air duct connected to the blood pressure cuff and a push button used for menu selection during the measurement process.

### 3.2. Heart Rate Testing

**Table 1.** Testing of the MAX30100 sensor for heart rate measurement

| Id_Number | Age | Heart Rate (BPM) |                | Error (%) |
|-----------|-----|------------------|----------------|-----------|
|           |     | MAX30100         | Pulse Oximeter |           |
| 001       | 55  | 79.40            | 75             | 5.87      |
| 002       | 67  | 73.10            | 75             | 2.53      |
| 003       | 59  | 92               | 90             | 1.33      |
| 004       | 75  | 86.4             | 85             | 1.65      |
| 005       | 60  | 73.7             | 75             | 1.73      |
| 006       | 73  | 68.70            | 71             | 3.24      |
| 007       | 67  | 73.3             | 75             | 2.27      |
| 008       | 56  | 83.60            | 86             | 2.79      |
| 009       | 55  | 67.20            | 66             | 1.82      |
| 010       | 57  | 98.10            | 96             | 2.19      |
| Average   |     |                  |                | 2.57      |

The heart rate measurement performance evaluation of the MAX30100 sensor compared to a pulse oximeter, a common medical device, is shown in Table 1. Ten respondents aged 55-75 participated in testing to evaluate the reliability of the IoT-based real-time vital signs monitoring system in practical use cases. The measurement findings demonstrate that, with only minor variations across all test samples, the heart rate readings derived from the MAX30100 sensor show a significant correlation with the pulse oximeter reference value. Respondent 001 had the largest mistake value (5.87%), while respondent 003 had the lowest error value (1.33%). The system's susceptibility to external influences, such as sensor-skin contact, motion artefacts, and individual physiological fluctuations, is indicated by variability in error across responses.

Overall, the system achieved 97.43% accuracy with an average error of 2.57%. This figure shows that the MAX30100 sensor operates in the high-accuracy range and can be used in an IoT-based real-time vital-sign monitoring system. These results also show that integrating the sensor with a web server and microcontroller maintains measurement consistency in multi-subject testing scenarios, which may facilitate its use in telemedicine and remote health monitoring systems.

### 3.3. Oxygen Saturation Testing

The results of oxygen saturation (SpO<sub>2</sub>) testing with the MAX30100 sensor and a reference instrument, a pulse oximeter, are displayed in Table 2. Ten participants aged 55-75 were tested to determine how well the sensor measured blood oxygen levels. According to the test results, responders 001, 004, and 009 showed an error value of 0%, meaning that the sensor readings matched the reference equipment. Respondent 008 had the greatest error value (4.30%), with a MAX30100 reading of 89% and a pulse oximeter reading of 93%. Several variables, including the location of the finger on the sensor, the stability of the skin-sensor contact, hand movement during the measurement, and the state of the respondents' peripheral blood circulation, can affect measurement findings. Overall, the system accuracy was 98.63% with an average error of 1.37% in SpO<sub>2</sub> measurements. These findings show that the

MAX30100 sensor is appropriate for use in an IoT-based web server system for Real-Time Vital Signs Monitoring and performs well in measuring oxygen saturation.

**Table 2.** Testing of the MAX30100 sensor for oxygen saturation measurement

| Id_Number | Age | Oxygen Saturation (%) |                | Error (%) |
|-----------|-----|-----------------------|----------------|-----------|
|           |     | MAX30100              | Pulse Oximeter |           |
| 001       | 55  | 98                    | 98             | 0         |
| 002       | 67  | 99                    | 97             | 2.06      |
| 003       | 59  | 94                    | 92             | 2.17      |
| 004       | 75  | 98                    | 98             | 0         |
| 005       | 60  | 99                    | 98             | 1.02      |
| 006       | 73  | 91                    | 90             | 1.11      |
| 007       | 67  | 99                    | 97             | 2.06      |
| 008       | 56  | 89                    | 93             | 4.3       |
| 009       | 55  | 99                    | 99             | 0         |
| 010       | 57  | 98                    | 99             | 1.01      |
| Average   |     |                       |                | 1.37      |

### 3.4. Body Temperature Testing

**Table 3.** Testing of the MLX90614 sensor for body temperature measurement

| Id_Number | Age | Temperature (C°) |                | Error (%) |
|-----------|-----|------------------|----------------|-----------|
|           |     | MAX30100         | Pulse Oximeter |           |
| 001       | 55  | 35,9             | 35,6           | 0,84      |
| 002       | 67  | 35,7             | 34,8           | 2,59      |
| 003       | 59  | 38,8             | 38,4           | 1,04      |
| 004       | 75  | 33,6             | 34,1           | 1,47      |
| 005       | 60  | 33,9             | 33,8           | 0,3       |
| 006       | 73  | 37,1             | 38,7           | 4,13      |
| 007       | 67  | 36,4             | 36,1           | 0,83      |
| 008       | 56  | 34,5             | 34,2           | 0,88      |
| 009       | 55  | 36,9             | 34,7           | 6,34      |
| 010       | 57  | 34,2             | 34,9           | 2,01      |
| Average   |     |                  |                | 2.04      |

The body temperature test results for 10 respondents aged 55-75 are shown in Table 3. To assess measurement accuracy, the system readings were compared with those of a reference device to calculate the error (%). The body temperature measurements from the system were mostly in line with those from the reference device, as shown in the table. Respondent 005 had the lowest error, at 0.30%, with a system reading of 33.9°C and a reference device of 33.8°C. With a system measurement result of 36.9°C and a reference device reading of 34.7°C, Respondent 009 had the largest error, 6.34%. The device measured body temperature with an average total error of 2.04%, yielding an accuracy of 97.96%. This chart demonstrates that the device has reasonably good temperature measurement capabilities and can monitor vital signs in real-time.

Several factors, such as sensor position, distance from the body surface, ambient temperature, respondent movement, and the stability of the data-reading process, can influence differences in measurement values. Overall, test results indicate that the system can provide relatively stable body temperature readings that are close to those of the comparison device.

### 3.5. Web Server Testing

Web server testing was conducted to ensure the system could automatically receive, store, and display patient examination data sent from ESP32-based devices. This testing included user authentication, patient data storage, sensor data transmission, and visualization of examination results on a web page.

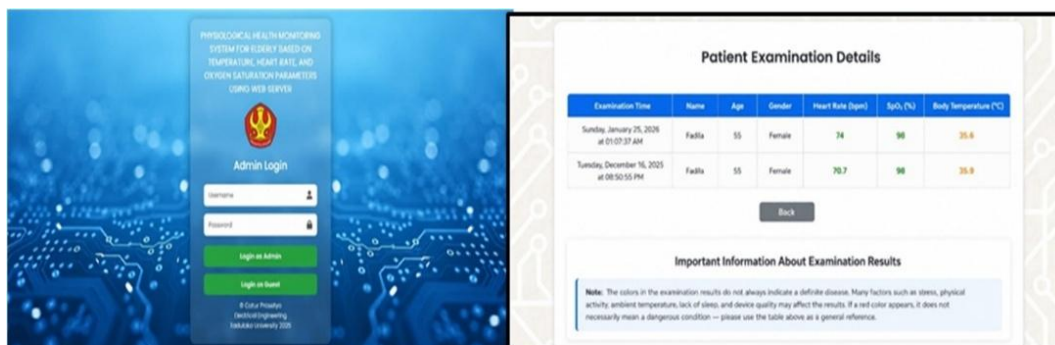


**Figure 5.** Web server interface for vital signs monitoring

The admin login page and the patient examination results page are the two primary sections of the web-based vital signs monitoring system depicted in Figure 5. The administrator or other authorised users use the system login page. The entry point for tracking and managing patient health data is this page. Before gaining access to the vital signs monitoring system, users must input their login and password.

The "Patient Examination Details" page displays real-time patient examination data. The displayed data include examination time, patient name, age, gender, and vital parameters such as heart rate, oxygen saturation (SpO<sub>2</sub>), and body temperature. Each measurement result is displayed in a table for easy reading and analysis. Additionally, an information note explains that the color or value of the examination result can serve as an indicator of the patient's overall health. This helps medical personnel monitor patient conditions more quickly and efficiently.

## 4. CONCLUSION

This study successfully designed and implemented an IoT-based web server system for real-time vital signs monitoring. The system integrates an ESP32 microcontroller, MAX30100 sensor, MLX90614 sensor, LCD, buzzer, Wi-Fi communication, and a web-based dashboard to acquire, process, transmit, store, and display physiological data in real time. The experimental results show that the proposed system achieved good measurement performance, with heart rate accuracy of 97.43% and an average error of 2.57%, SpO<sub>2</sub> accuracy of 98.63% and an average error of 1.37%, and body temperature accuracy of 97.96% and an average error of 2.04%. These results indicate that the developed device can provide relatively accurate and stable measurements compared with reference instruments. The web server testing also confirmed that patient examination data could be transmitted and displayed through the monitoring interface, enabling remote access to vital sign information. Therefore, the proposed system is feasible as a supporting tool for real-time patient monitoring and telemedicine applications. However, further development is recommended to improve measurement stability under movement conditions, expand clinical validation with more respondents, and enhance data security and system scalability for broader healthcare implementation.

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