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IO-Based Heart Rate And Blood Oxygen Measurement Monitoring System

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ABSTRACT

The development of Internet of Things (IoT) technology has driven innovation in the healthcare sector, particularly in real-time and remote monitoring of vital body conditions. This research aims to design and implement an IoT-based heart rate and blood oxygen level (SpO_2) monitoring system using the MAX30100 sensor and the ESP8266 microcontroller. This system was developed to overcome the limitations of conventional monitoring methods that still rely on specialized equipment and direct observation by medical personnel. The MAX30100 sensor is used to measure heart rate and blood oxygen levels based on the principle of pulse oximetry, then the data is processed by the microcontroller and sent to a cloud server via a Wi-Fi connection. The measurement data is displayed in real-time on the Blynk application so that it can be accessed by users anytime and from anywhere. System testing includes heart rate accuracy testing, SpO_2 testing by comparing sensor results to a standard pulse oximeter, IoT connection stability testing, and device durability testing for 6 hours. The test results show that the MAX30100 sensor is capable of producing accurate heart rate and SpO_2 data with small differences compared to standard devices. Furthermore, the IoT connection demonstrated a stability rate of up to 99% without system disruptions. Therefore, this system is considered reliable and suitable for use as a real-time and continuous IoT-based health monitoring solution.

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1. Introduction

The rapid advancement of information and communication technology has brought substantial changes to various aspects of human life, including the healthcare sector. Technological innovations have not only increased efficiency and convenience in daily activities but have also enabled the development of intelligent systems capable of addressing complex health-related challenges[1]. In recent years, the integration of digital technology into healthcare services has become increasingly important, particularly in supporting preventive healthcare and continuous patient monitoring[2]. One area that has gained significant attention is the application of technology for monitoring vital health parameters, especially among vulnerable populations such as elderly individuals and patients with chronic diseases[3].

Monitoring physiological parameters is essential for assessing an individual's health condition. Among the most important indicators are heart rate and blood oxygen saturation (SpO_2), which provide valuable information about cardiovascular and respiratory performance. Abnormalities in these parameters may indicate underlying health issues, including heart disease, respiratory disorders, and other medical conditions that require immediate intervention. Therefore, continuous monitoring of these vital signs is necessary to facilitate early detection and timely medical response[4].

Despite the importance of health monitoring, conventional monitoring methods still present several limitations. Most traditional systems rely on periodic examinations performed in healthcare facilities using specialized equipment operated by trained medical personnel. As a result, health assessments are often conducted only at specific times, making it difficult to obtain continuous data regarding a patient's condition. This limitation may delay the identification of sudden changes in physiological status and reduce the effectiveness of preventive healthcare measures[5].

The emergence of the Internet of Things (IoT) has created new opportunities for developing smart healthcare solutions. IoT technology enables interconnected devices to collect, process, and transmit data automatically through internet networks. By leveraging IoT, health monitoring systems can provide real-time data acquisition and remote accessibility, allowing users and healthcare providers to monitor health conditions anytime and anywhere. Furthermore, the collected data can be stored in cloud-based databases, enabling long-term tracking of patient health records and supporting more informed medical decision-making[6].

One of the sensors widely utilized in IoT-based health monitoring applications is the MAX30100 sensor. This sensor is capable of measuring both heart rate and blood oxygen saturation with relatively high accuracy through optical sensing technology. When integrated with the ESP8266 microcontroller, which features built-in Wi-Fi connectivity, the sensor can transmit measurement results directly to cloud servers and display them through web-based or mobile applications. Such integration offers an efficient and cost-effective solution for continuous health monitoring[7],[8].

Previous studies, including research conducted by Ratna S., demonstrated that IoT-based health monitoring systems are capable of providing accurate and real-time heart rate measurements. Building upon these findings, the present study aims to develop an IoT-based health monitoring system utilizing the MAX30100 sensor and ESP8266 microcontroller for real-time monitoring of heart rate and blood oxygen saturation. The proposed system is expected to enhance accessibility, improve monitoring efficiency, and support early detection of health abnormalities through web and mobile platforms[9],[10].

2. Research Method

2.1 Research Flowchart

Figure 1. shows a flow diagram, often known as a flow chart, which outlines the procedures that need to be followed in a study[11]..

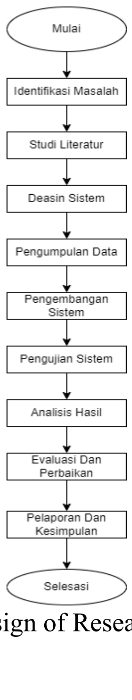

Figure 1. Design of Research Flowchart

2.2 System Block Diagram

Data collection can be seen from the block diagram itself, which is a tool design and production technique used to determine the overall operating principles of the tool being tested[12]. The block diagram is illustrated in Figure 2.

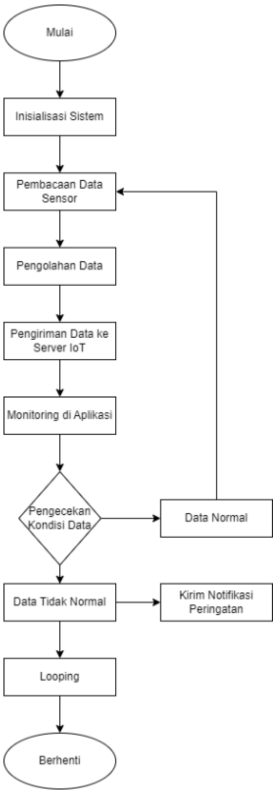

Figure 2. Design Block Diagram

a. The process begins with the Start stage, which is the initial stage of the system's operation.
b. The system initializes the system to prepare the sensors, microcontroller, and network connection.
c. Next, sensor data is read to obtain heart rate and blood oxygen levels.
d. The data obtained then enters the data processing stage by the microcontroller.
e. The processed data is sent to the IoT server at the data transmission stage.
f. The transmitted data is then displayed at the monitoring stage in the application.
g. The system checks the data condition to determine whether it is normal.
h. If the data is normal, the system returns to the sensor data reading process repeatedly.
i. If the data is abnormal, the system sends a warning notification.
j. The system then enters a loop to continue monitoring.
k. The process ends at the stop stage when the system is stopped.

2.3 Hardware Design

An Internet of Things (IoT)-based heart rate and blood oxygen monitoring system requires hardware and software integration to support real-time health monitoring. Hardware design involves combining components capable of efficiently detecting, processing, and transmitting data so that the system can perform optimally in monitoring the user's health[13].

The main components of this system consist of a MAX30100 or MAX30102 sensor, which measures heart rate and blood oxygen levels (SpO_2) using pulse oximetry principles, and an ESP32 microcontroller as the data processing center. The sensor communicates with the microcontroller via an I2C or SPI interface, and the processed data is then sent via a Wi-Fi connection to a cloud platform or monitoring application such as ThingSpeak, Blynk, or Adafruit IO to support real-time remote monitoring [14].

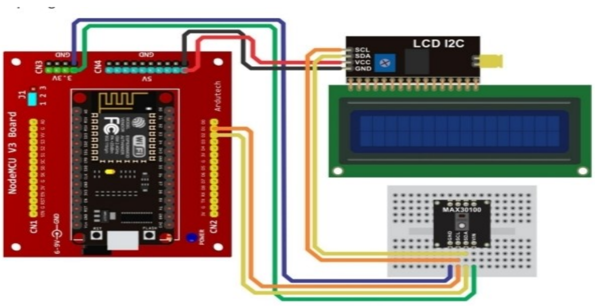

Figure 3. Hardware components

Table 1. Component Paths

Component	Pin Node MCU	Pin Modul	Fungsi
MAX30100	D1	SCL	12C Communication Clock Line
MAX30100	D2	SDA	12C Communication Data Line
MAX30100	G.3V	VIN	Sensor Power Supply
MAX30100	GND	GND	Circuit Ground
LCD 12C	D1	SCL	LCD Communication Clock Line
LCD 12C	D2	SDA	LCD Communication Data Line
LCD12C	5V	VCC	LCD Power Supply
LCD12C	GND	GND	Circuit Ground

2.4 Software Design

To ensure that data collected by the hardware (sensors and microcontrollers) can be processed, analyzed, and delivered effectively and in a timely manner, software design is a crucial part of an Internet of Things-based heart rate and blood oxygen monitoring system[15]. The software will be used in this design to process sensor data in real time, connect it to a cloud platform for health monitoring, and notify the user or medical staff when measurement values deviate from the norm. Furthermore, this system will be built with user convenience and data security in mind[16],[17].

Figure 4 displays the ESP8266 program design flowchart, shown below.

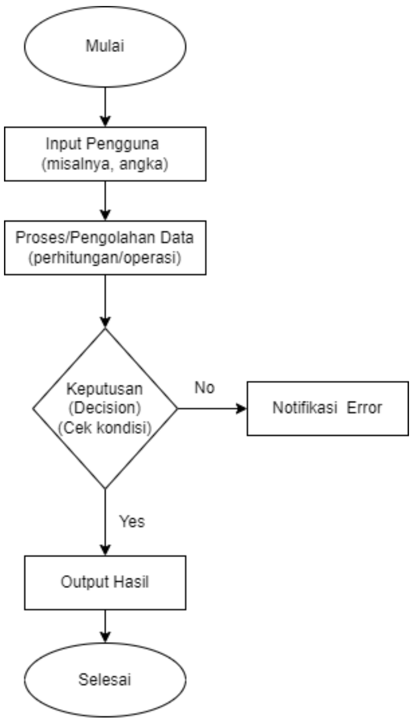

Figure 4. Design the Flowchart of the esp8266 Program Flow[18]

2.5 Testing Methods

It is crucial to employ a thorough and organized testing procedure when evaluating an IoT-based blood oxygen and heart rate monitoring system. From data collection on the hardware (sensors) to accurate data transmission to the cloud platform for real-time monitoring, thorough testing will ensure the system operates as intended. Furthermore, because the collected data is critical to user health, testing must ensure the system is accurate and reliable across a variety of scenarios. The goal of performance testing is to measure how well the system collects and processes sensor data. It is crucial to ensure that the sensors in an IoT-based system can provide accurate data and process it quickly, especially for blood oxygen and heart rate readings[19],[20].

3. Result and Discussion

3.1 Design Results for an IoT-Based Heart Rate and Blood Oxygen Monitoring Device

The design results of the previously developed technique, modified to accommodate the position of various components in an Internet of Things-based heart rate and blood oxygen monitoring system, are shown in Figures 5 and 6. Users or operators can operate this device using a smartphone because it is designed to connect to the internet. Figure 5 shows the design of the system that regulates oxygen and heart rate when the device is turned off[21].

Figure 5. Display of Heart Rate and Oxygen Monitoring Device Off[22]

The design of the active heart rate and oxygen monitoring system is shown in Figure 6.

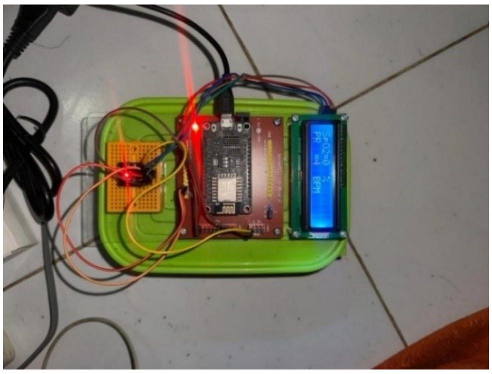

Figure 6. Display of Heart Rate and Live Oxygen Monitoring Device

3.2 Blynk IoT Smartphone Design Results

The developed system is integrated with the Blynk application, which serves as a user-friendly monitoring interface accessible through smartphones. By utilizing the Blynk platform, users can observe heart rate and blood oxygen saturation (SpO_2) data in real time without requiring direct interaction with the hardware device. The measured data from the MAX30100 sensor is transmitted via the ESP8266 microcontroller through a Wi-Fi network and displayed instantly on the Blynk dashboard[23]. Various widgets available in the application, such as gauges, value displays, charts, and notification panels, can be configured according to monitoring requirements[24]. These features enable users to track their health conditions more effectively and conveniently from any location with internet access. In addition, the application provides a visual representation of physiological data, making it easier for users to understand changes in their health status over time. Therefore, the proposed system offers a reliable, efficient, and accessible IoT-based health monitoring solution that supports continuous observation of vital signs[25]. The implementation result of the Blynk-based monitoring interface is presented in Figure 4.3.

Figure 7. Blynk Design display

3.3 Test Results of an IoT-Based Heart Rate and Blood Oxygen Monitoring System

Table 3.3 displays the test results for the IoT-based Heart Rate and Blood Oxygen Monitoring System.

Table 2. Testing

No.	Types of Testing	Description	Test Results	Information
1.	Heart Rate Testing	View heart rate results from the MAX30100 sensor	Heart Rate: Sp02 96% BPM (sensor) and PR 73 BPM	Succeed
2.	SpO2 Testing	SpO2 sensor with pulse oximeter sensor MAX30100	SpO2: 97% (sensor) vs 96% (*pulse oximeter*) MAX30100	Succeed
3.	IoT Connection Stability Testing	Testing the connection stability between the ESP8266 and the Blynk application	Stable Connection: 99% online time And tested within 6 hours	Succeed
4.	Device Durability Testing	Testing the stability and durability of the device during long-term use (within 6 hours)	Stable: No crashes or glitches	Successful in 6 hours of testing time

To evaluate the performance of the developed health monitoring system, several testing procedures were conducted, including sensor accuracy testing, IoT communication testing, and system durability testing. These evaluations were carried out to ensure that the system could provide accurate measurements, maintain stable data transmission, and operate reliably for extended periods[26].

The accuracy test focused on the performance of the MAX30100 sensor in measuring heart rate and blood oxygen saturation (SpO_2). Measurements obtained from the sensor were compared with those generated by a standard commercial pulse oximeter, which served as the reference instrument. The testing results indicated that the MAX30100 sensor successfully measured a heart rate of 73 beats per minute (BPM) and blood oxygen saturation values ranging from 96% to 97%. When compared with the reference device, the observed differences were minimal and remained within an acceptable margin of error. These findings demonstrate that the MAX30100 sensor is capable of providing reliable and accurate physiological measurements. The high level of agreement between the sensor readings and the reference instrument confirms the suitability of the sensor for implementation in IoT-based health monitoring applications[27].

In addition to sensor accuracy, communication performance was assessed by evaluating the stability of the Internet of Things (IoT) connection established between the ESP8266 microcontroller and the Blynk application. This test was conducted to determine the system's ability to transmit data continuously and in real time over a wireless network. During the testing period, physiological data collected by the sensor were sent to the Blynk platform and displayed on a smartphone interface. The results showed that the communication link remained stable throughout the testing process, achieving an average connection success rate of approximately 99%. Over six consecutive hours of operation, no significant interruptions, delays, or data losses were observed. This indicates that the ESP8266 microcontroller effectively maintained network connectivity and supported reliable real-time data transmission[28].

Furthermore, a durability test was performed to assess the overall stability and reliability of the monitoring system during prolonged operation. The device was operated continuously for six hours under normal working conditions. Throughout the testing period, the system functioned as expected without experiencing software crashes, hardware malfunctions, unexpected resets, or communication failures. The sensor readings continued to be transmitted and displayed correctly, demonstrating consistent system performance. These results indicate that the developed IoT-based health monitoring system possesses a high degree of operational reliability and is suitable for long-term, real-time monitoring of heart rate and blood oxygen saturation. Consequently, the system can be considered a dependable solution for continuous health monitoring applications in both personal and healthcare environments[29],[30].

4. Conclusion

Based on the test results, it can be concluded that the developed Internet of Things (IoT)-based heart rate and blood oxygen (SpO_2) monitoring system is able to work accurately and reliably. The MAX30100 sensor shows heart rate and SpO_2 measurement results that are close to a standard pulse oximeter, while the connection between the ESP8266 microcontroller and the Blynk application is proven to be stable with a success rate of up to 99% during the 6-hour test. In addition, the device is able to operate continuously without experiencing interruptions or crashes, making this system suitable for use in real-time and remote health monitoring.

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