Jurnal E-Komtek
Vol. 9, No. 2 (2025) pp. 642-650
https://jurnal.politeknik-kebumen.ac.id/index.php/E-KOMTEK
p-ISSN : 2580-3719 e-ISSN : 2622-3066

Design and Construction of a NodeMCU-Based Heart Rate and Blood Oxygen Level Monitoring Device with Blynk Application Output

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https://doi.org/10.37339/e-komtek.v9i2.2927

Published by Politeknik Piksi Ganesha Indonesia

Artikel Info
Submitted:
17-12-2025
Revised:
26-12-2025
Accepted:
31-12-2025
Online first:
31-12-2025

Abstract

Health is a crucial aspect of human life that must be maintained and monitored regularly, especially during recovery periods or self-isolation. Real-time and remote body monitoring has become an essential need in today's digital era. This study aims to design and develop a heart rate and blood oxygen saturation monitoring device based on the Internet of Things (IoT) using the NodeMCU ESP8266 microcontroller integrated with the MAX30100 sensor and the Blynk application. The research method involves the design of an electronic system based on microcontrollers, software programming, and direct functional testing. The test results show that the device is capable of accurately detecting heart rate (BPM) and oxygen saturation (SpO_2), displaying the data on a 16x2 LCD, and transmitting it to the Blynk application in real-time via a WiFi connection. Therefore, the developed device has proven to function effectively as a practical and portable remote health monitoring system.

Keywords: *Heart rate; oxygen saturation; Internet of Things*

Abstrak

Kesehatan merupakan aspek penting dalam kehidupan manusia yang harus dijaga dan dipantau secara berkala, khususnya pada kondisi tertentu seperti masa pemulihan pasca sakit atau isolasi mandiri. Pemantauan kondisi tubuh secara real-time dan jarak jauh menjadi kebutuhan penting di era digital saat ini. Penelitian ini bertujuan untuk merancang dan membangun alat pemantauan detak jantung dan kadar oksigen dalam darah berbasis IoT menggunakan mikrokontroler NodeMCU ESP8266 yang terintegrasi dengan sensor MAX30100 dan aplikasi Blynk. Metode yang digunakan dalam penelitian ini adalah perancangan sistem elektronik berbasis mikrokontroler, pemrograman perangkat lunak, dan pengujian fungsional secara langsung. Hasil pengujian menunjukkan bahwa alat mampu mendeteksi denyut jantung (BPM) dan kadar oksigen (SpO_2) secara akurat, menampilkan data pada LCD 16x2, serta mengirimkan data ke aplikasi Blynk secara real-time melalui jaringan WiFi. Dengan demikian, alat yang dikembangkan terbukti bekerja secara efektif sebagai sistem pemantauan kesehatan jarak jauh yang praktis dan portabel.

Kata-kata kunci: *Detak jantung; saturasi oksigen; Internet of Things*

1. Introduction

Heart rate and blood oxygen levels (SpO_2) are vital indicators that are crucial in assessing a person's health. Heart rate reflects the activity of the cardiovascular system, while SpO_2 levels indicate the efficiency of the respiratory system in distributing oxygen throughout the body's tissues. A normal heart rate in adults ranges from 60–100 beats per minute. A value below this range is called bradycardia, while a value above it is called tachycardia, both of which can indicate a health problem and require further medical attention. Meanwhile, normal SpO_2 levels are in the range of 95–100%. A decrease in oxygen levels below 90% (hypoxemia) can disrupt cell metabolism, reduce vital organ function, and potentially lead to organ failure if not treated promptly **[1]**.

Conventional heart rate and SpO_2 monitoring is generally carried out in health facilities using relatively expensive medical equipment that is not always available for continuous monitoring **[2]**. This situation presents a challenge, especially for patients with chronic illnesses, the elderly, or individuals requiring regular health monitoring. Therefore, a real-time, non-invasive, portable, and widely accessible health monitoring solution is needed.

Advances in optical sensor technology have enabled non-invasive measurement of heart rate and blood oxygen levels using photoplethysmography (PPG). This method utilizes infrared and red light emitted into body tissue and then measures changes in reflected light intensity due to variations in blood volume. One widely used sensor for this application is the MAX30100 **[7][8]**, which is able to measure heart rate and SpO_2 simultaneously with relatively low power consumption.

Although PPG technology offers convenience and efficiency, PPG-based devices still have a number of limitations, including sensitivity to user movement (motion artifact), less ergonomic device design, the influence of external factors such as skin pigmentation and environmental light intensity, as well as limitations in terms of power and data connectivity **[3][4].** These limitations may affect measurement accuracy and usability, particularly for long-term monitoring.

The concept of the Internet of Things (IoT) is present as a solution to improve the function and reliability of health monitoring systems **[12].** IoT allows medical devices to be connected to the internet network so that physiological data can be sent, stored and monitored in real-time remotely via digital platforms **[5][6]**. This approach allows both medical personnel and users to continuously monitor health conditions without having to be in the same location as the patient. This is particularly relevant in the context of modern healthcare, which emphasizes efficiency, early detection, and data-driven care.

Several previous studies have developed microcontroller-based heart rate and SpO_2 monitoring systems. Research by Prasetyo et al. (2020) developed a heart rate monitor based on an Arduino Uno and a pulse sensor [9], However, this system does not yet support real-time remote monitoring. Sari and Hidayat (2021) developed an SpO_2 monitoring system using the MAX30100 sensor with a local LCD display [10], but not yet integrated with the IoT platform. Another study by Rahman et al. (2022) utilized the ESP8266 for sending data to a web server [11], However, the user interface is still less interactive and not optimal for use on mobile devices.

Based on the literature review, it can be concluded that most previous research still suffers from limitations, both in terms of optimal IoT integration, ease of user access, interactive data display, and system portability. Furthermore, there are few studies that simultaneously integrate local display and remote monitoring using an application platform that is easy for the general public to use.

Therefore, this study aims to design and build an IoT-based heart rate and blood oxygen level monitoring device using a NodeMCU ESP8266 microcontroller, a MAX30100 sensor, and the Blynk application as a remote monitoring medium. This system is designed to display data locally via a 16x2 LCD and transmit data in real time to the user's smartphone via an internet connection. The NodeMCU ESP8266 was chosen because it is integrated with a Wi-Fi module, has a compact size, and supports the development of IoT systems at a relatively low cost.

Research is developing a fully integrated health monitoring system, including accurate data acquisition, informative local displays, and remote monitoring based on an easily accessible mobile application [15]. By combining the MAX30100 sensor, the NodeMCU ESP8266, and the Blynk application, this research is expected to overcome the limitations of previous research and produce a practical, portable, economical, and applicable health monitoring device.

The results of this research are expected to provide an alternative solution for self-monitoring health, support the implementation of IoT technology in the healthcare sector, and contribute to the development of a more responsive and efficient digital health system.

2. Method

The system is designed in the form of a block diagram and flowchart. The system consists of three main parts: input, process, and output. Input comes from the user's finger placed on the MAX30100 sensor. Optical data from the sensor is sent to the NodeMCU ESP8266 via the I2C protocol [13][14]. The NodeMCU serves as the main processing unit, calculating BPM and SpO2 values. The results are displayed on two outputs: a 16x2 I2C LCD for local display and the Blynk application for remote monitoring via WiFi.

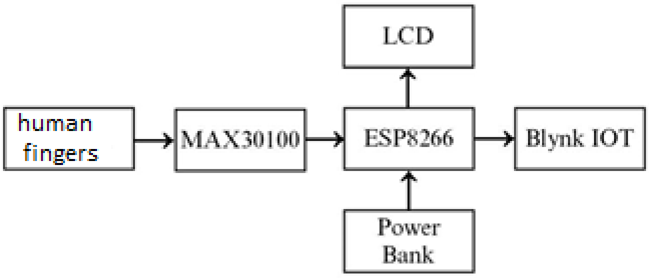

Figure 1. Block Diagram of Heart Rate and Oxygen Level Monitor

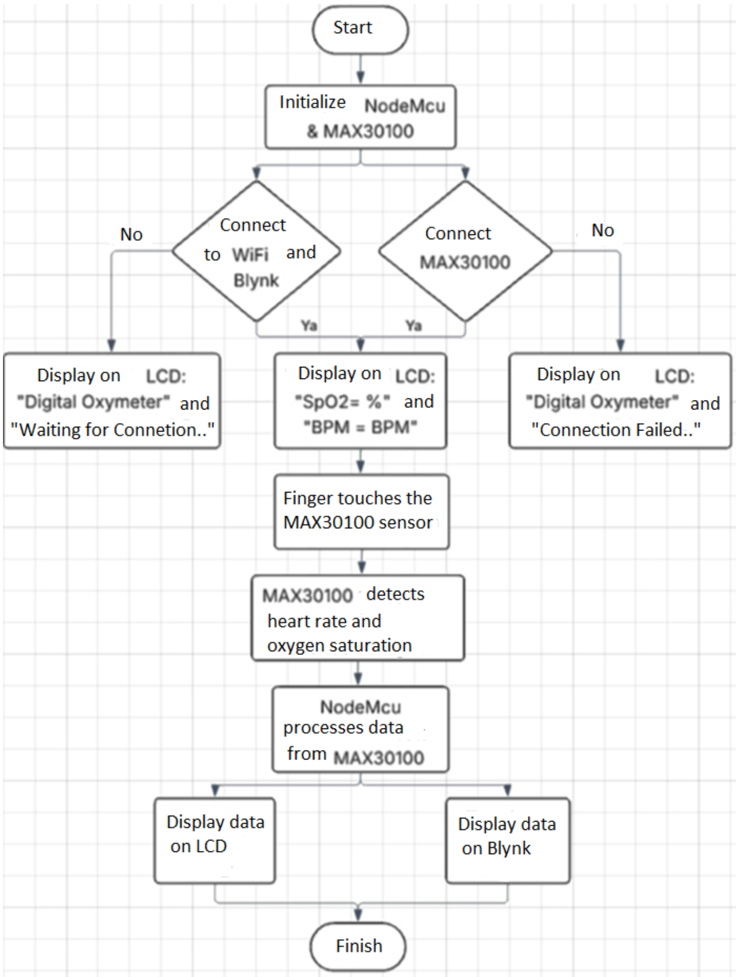

Figure 2. System Operational Flowchart

The heart rate and blood oxygen level monitoring system circuit is designed by connecting the main components to the NodeMCU ESP8266 microcontroller according to the I2C specification. The MAX30100 sensor is connected to the NodeMCU via four pins, namely the VIN pin is connected to the 3.3 V pin on the NodeMCU as a power supply source, the GND pin is connected to the NodeMCU ground (GND), the SDA pin is connected to D2 (GPIO4), and the SCL pin is connected to D1 (GPIO5) for data communication and clock based on the I2C protocol. The 16x2 I2C LCD module also uses the same I2C path, namely the SDA pin is connected to D2 (GPIO4) and the SCL pin to D1 (GPIO5). For its power supply, the LCD VCC pin is connected to the 5 V pin on the NodeMCU, while its GND pin is connected to the NodeMCU ground (GND). With this configuration, both the MAX30100 sensor device and the 16x2 LCD can communicate simultaneously over a shared I2C bus, allowing the microcontroller to read physiological data and display it in real-time on the LCD screen.

3. Results and Discussion

Based on the system test results, after the heart rate and blood oxygen level monitoring device was activated, the system automatically initialized the main components, namely the NodeMCU ESP8266 microcontroller, MAX30100 sensor, and I2C-based 16x2 LCD module. At this stage, the system also initiated a connection to the WiFi network and synchronized with the Blynk application-based remote monitoring platform. During the connection process, the LCD displayed the messages “Digital Oxymeter” and “Wait for Connection..”, indicating that the system was in the network communication preparation stage.

After the WiFi connection and the Blynk application are successfully connected, the system performs a verification process on the MAX30100 sensor. Test results show that if the sensor is detected and functioning properly, the system can proceed to the stage of reading heart rate data and blood oxygen levels. Conversely, if the sensor is not connected or experiencing interference, the LCD displays the message "Connection Failed..." and the system stops the measurement process. When all components are connected normally, the LCD displays the initial format of the measurement results as "SpO_2 = %" and "BPM = BPM", which are then updated in real-time according to the data obtained from the sensor.

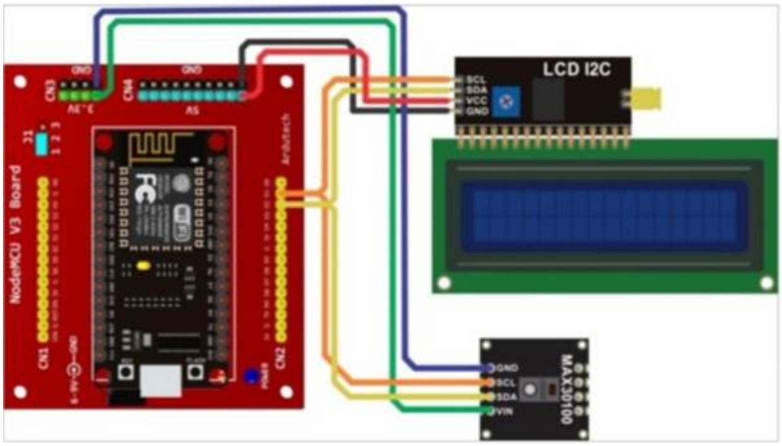

Figure 3. Overall circuit

Functional testing results showed that all key components—the NodeMCU, MAX30100 sensor, 16x2 LCD, and Blynk app—operated as designed. The system successfully initialized, connected to WiFi, and automatically transmitted data after power-on. Heart rate and oxygen saturation data were displayed in real time on both the LCD and the Blynk app dashboard.

Figure 4. Display of measurement results on a 16x2 LCD

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Figure 5. Display of measurement results in the Blynk application

The test results are displayed in tabular form. Data collection was conducted over three days, July 23-25, 2025, at 10:00 AM and 8:00 PM.

Table 1. Results of Heart Rate and Oxygen Saturation Monitoring Trials

No	Date	O'clock	SpO2(%)	BPM
1	23 July 2025	10:00	97	89
		20:00	96	76
2	24 July 2025	10:00	100	86
		20:00	94	86
3	25 July 2025	10:00	100	95
		20:00	94	90

This comprehensive test aimed to determine the sensor's capabilities by comparing the proximity of the MAX30100's measurement values to those of commercially available fingertip pulse oximeters. The test was conducted with 10 potential users to obtain a ratio of the sensor's values.

Table 2. Test Results by 10 Respondents

No	MAX30100		Fingertip Pulse Oximeter		Difference		Persentase error (%)	
	BPM	SpO2(%)	BPM	SpO2(%)	BPM	SpO2	BPM	SpO2
1	88	96	85	98	3	2	3,57	2,06
2	90	97	87	95	3	2	3,45	2,11
3	84	94	81	93	2	1	3,49	1,08
4	92	98	89	97	3	1	3,37	1,03
5	87	96	84	98	3	2	3,57	2,04
6	89	97	86	96	3	1	3,49	1,04
7	90	95	88	96	2	1	2,27	1,04
8	86	96	84	97	2	1	2,38	1,03
9	89	95	86	94	3	1	3,49	1,06
10	91	97	88	96	3	1	3,41	1,04
Average							**3,25**	**1,35**

Based on the data in Table 2, the average error percentage for heart rate measurements was 3.25% and for oxygen saturation was 1.35%. These error values are within the acceptable range for a microcontroller-based prototype, considering variations in finger position, skin pigmentation, and environmental conditions that can affect PPG sensor readings. These results indicate that the developed device is capable of providing fairly accurate measurements compared to reference devices.

This research successfully designed an IoT-based heart rate and oxygen saturation monitoring system. This system was realized by integrating a NodeMCU ESP8266, a MAX30100 sensor, a 16x2 I2C LCD, and the Blynk application. The device's accuracy level showed an average error percentage of 3.25% for BPM and 1.35% for SpO2 compared to commercial fingertip pulse oximeters. The system was able to transmit data in real time to the Blynk platform via a WiFi connection and display it locally on the LCD.

The main difference between this study and previous studies lies in the dual-output interface where in addition to using the IoT platform (Blynk vs Telegram), this system also provides a local display via a 16x2 I2C LCD. However, this system is still susceptible to motion artifacts, which is an inherent challenge in PPG (Photoplethysmography) technology. Conceptually, this study enriches the application of the Internet of Things (IoT) in the healthcare sector, by demonstrating that IoT not only functions as a data transmission channel, but also as a strengthening of accessibility and user independence in managing personal health.

4. Conclusion

This study successfully answered the three research questions formulated in the introduction. An IoT-based heart rate and oxygen saturation monitoring system has been successfully implemented using a NodeMCU ESP8266, MAX30100 sensor, 16x2 I2C LCD, and the Blynk application. The system is able to provide dual real-time data displays locally via LCD and remotely via smartphone, thereby increasing the reliability of information access compared to conventional IoT systems that rely entirely on internet connectivity. Based on testing on 10 respondents, the device demonstrated an acceptable level of accuracy for non-clinical use, with an average error percentage of 3.25% for BPM and 1.35% for SpO2 compared to commercial fingertip pulse oximeters. These values are within the tolerance range of PPG-based devices for general consumers, as reported in related literature.

The original contribution of this research lies in the integration of local and remote interfaces within a single, empirically validated, low-cost architecture—an approach rarely seen in similar studies at the diploma level. This feature not only overcomes the limitations of previous IoT systems but also strengthens the technology's role in supporting practical, affordable, and inclusive self-monitoring of health. Thus, this prototype serves not only as a measurement tool but also as a proof-of-concept that IoT-based health solutions can be effectively scaled beyond the clinical setting, opening up opportunities for early detection of critical conditions and increasing health awareness in the wider community.

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