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Design and Development of SpO2, Bpm, and Body Temperature for Monitoring Patient Conditions in IOT-Based Special Isolation Rooms

Dyah Purwitosari[1], Bambang Guruh Irianto[1], Triwiyanto[1], Phuoc-Hai Huynh[2]
[1] Department of Electromedical Engineering Poltekkes Kemenkes, Surabaya, Indonesia.
[2] Faculty of Information Technology, Angiang University, Vietnam

Corresponding author: Triwiyanto (e-mail: triwiyanto123@gmail.com).

ABSTRACT The utilization of batteries as the primary power source in portable equipment systems presents certain drawbacks, primarily concerning the need for constant monitoring of battery power to ensure uninterrupted system functionality. Therefore, this study aims to address the battery power efficiency analysis to evaluate the viability of portable systems. The research endeavors to develop a portable measurement system capable of monitoring SPO2 (blood oxygen saturation), BPM (beats per minute), and body temperature in a specialized isolation treatment room. The proposed system is designed to assess the health conditions of patients afflicted with infectious diseases by measuring their heart rate, body temperature, and oxygen saturation. The devised measurement system incorporates a 2200mAH battery to power the IC TTGO ESP32, which manages data and displays measurement results. Additionally, the system integrates the MAX30102 sensor to measure oxygen saturation and heart rate, along with the MCP9808 sensor to monitor body temperature. To ensure its accuracy, the designed device underwent rigorous testing on respondents aged 25-40 years. The sensors were placed on the fingertip, and the resulting measurements were compared against those obtained from a standardized and calibrated device. The analysis of the measurement results exhibited a commendable ±5% error margin, indicating the feasibility of the proposed device for practical usage. Moreover, the study scrutinized the efficiency of battery power utilization in two distinct modes: normal mode and save mode. In the normal mode, the device consumed a current of 154.9 mA, while the save mode, which involved deactivating the LCD TTGO ESP32, required a current of 126.7 mA. The findings demonstrated that the device could operate for approximately ±14 hours in normal mode and up to ±17 hours in save mode before the battery needed recharging. The proposed design presents an effective approach for evaluating power efficiency in various device modes. Additionally, it empowers users by providing insights into the regular battery charging times, thus enabling them to determine the duration for which the device can be utilized to monitor patients. This knowledge proves invaluable for healthcare practitioners, as they can ensure uninterrupted monitoring while managing battery charging schedules effectively. Overall, this portable measurement system offers a promising solution for enhancing patient care and disease management in isolation treatment rooms.

INDEX TERMS IoT, SpO2, BPM, Body Temperature.

I. INTRODUCTION

Patients with infectious diseases such as SARS, MERS, Covid-19, diphtheria, cholera, tuberculosis (TB), HIV/AIDS require treatment in special isolation rooms and their health must be monitored regularly by measuring body temperature, blood pressure, oxygen in the blood, and heart rate [1], [2], [3], [4]. WHO applies a safe protocol for nurses when monitoring the patient's condition without meeting directly in the treatment room, so a tool is needed that can monitor the patient's condition simultaneously without direct contact in order to maintain the quality of life and health status of patients and medical personnel. [2]. Long distance communication without using cables and requiring little battery power is the most practical and efficient way to collect various parameters and information needed with automation systems [2]. To achieve accurate diagnosis, performance metrics of each system must be met i.e. measurement of power efficiency and power consumption should be as small as possible for robust data transmission. [5]. Currently, many tools for monitoring the patient's physiological state have been developed by conducting significant diagnostic tests with measurements of BPM, SpO2, and IoT-based patient body temperature. [6], [7], [8], [9], [10], [11], [12], [13], [14]. The implementation of the Internet of Things (IoT) in the design of monitoring tools for BPM, SpO2, and patient body temperature provides many benefits including facilitating the performance of Health Workers to monitor body conditions, diagnoses, and prevent patient emergencies remotely in realtime, continuously and requires low energy.

In 2017, Sofiane Hamrioui et al., analyzed the differences between Data Losses in IoT and a new protocol called IC-IoT (Improvement of Communications for IoT) to improve service quality parameters due to quality degradation caused by factors interference, fading, attenuation, mobility, network load, and low energy [15]. In 2018, Ahmed Bashar Fakhri et al, analyzed the statistical validation of patient vital signs based on the energy efficiency of a wireless sensor network monitoring system [5]. This study introduces a prototype of a wireless vital sign monitoring system (WVSMS) to monitor three vital parameters (i.e. BPM, SpO2 and temperature), a wireless system using ZigBee which is connected to an Arduino Pro mini based on an ATmega 328p microcontroller and a lithium-ion battery 7.2V/2200. mAh. Power consumption of the appliance in duty cycle mode for the sleep/wake scheme. The experimental results reveal that these three vital parameters can be measured with a high accuracy of 99.4%. In addition, it saves up to 84.5% of battery life. Based on the results of statistical analysis shows the tool is superior to similar systems in terms of accuracy and power consumption. However, the use of Zigbee is limited to the distance and speed of data transmission.

In 2021, Ghani Hibatullah Santoso et al, designed and implemented cloud-based monitoring tools for BPM, oxygen saturation and body temperature of iots. [16]. This study makes an Internet of Things-based medical device that is integrated with the cloud using Arduino to process data from sensors MAX30100, LM35 and using ESP8266 to connect to the internet so that data can be sent to the firebase which functions as a database. In the power test, a comparison between wake up mode and sleep mode is used to obtain a power saving of 27.8%. In 2020, M.A. M.A. Akkas et al., developed a patient's health monitoring tool by measuring pulse, plethysmogram, and relative oxygen ratio using IoT by evaluating the robustness, data validity, stability, and effectiveness of IoT. [17]. This study only discusses packet loss data from IoT transmission and has not explained the error value of the device after being compared with standard equipment and power efficiency.

Antonio Iyda Paganelli et al.,[7] Antonio Iyda Paganelli et al., designed an effective COVID-19 patient monitoring system using IoT and wireless sensors equipped with early warning with a comprehensive conceptual architecture covering scalability, interoperability, network dynamics, discovery context, reliability, and privacy. used for monitoring the patient's condition and the error value of the system. In 2021, In 2021, Nunung et al., designed an IoT-based COVID-19 patient vital sign monitoring tool to monitor patients living far from health facilities so as to allow patients to immediately report their condition and connect to the hospital system in real-time but the result of the error value on the tool has not been explained in detail. However, this research has not explained in detail the results of measurement error values and evaluation of battery life for power efficiency. Nurazamiroz Bin Kamarozaman et al., also designed a system with the same purpose using Raspberry Pi components as central controller, and LM35 temperature sensor, AD8232 ECG Sensor, MAX30100 pulse oximeter sensor using MQTT protocol server to transmit data to Node-Red, ThingSpeak to display realtime sensor data on web pages, and alarms sent via ThingTweet.

Based on previous research and the lack of research and discussion on the efficiency of battery power in portable systems for monitoring body temperature, BPM, and SpO2 in patients, the authors will conduct a study entitled "Design of Spo2, BPM, and Body Temperature Devices For Monitoring the Condition of Patients in Iot-Based Special Isolation Rooms (Power Efficiency Analysis)" as a development of research that has been made previously. Development of equipment that will be used by the author to add low power features to the system. This study aims to test the power efficiency of a portable system that is used continuously for monitoring the condition of patients in a special isolation room from the nurse's room so that it can help medical personnel by minimizing face-to-face and nosocomial infections between health workers and patients. The study makes three main contributions:

1) Development of a Portable Measurement System: The primary contribution of this study lies in the successful development of a compact and portable measurement system. By integrating the IC TTGO ESP32, the MAX30102 sensor for oxygen saturation and heart rate measurement, and the MCP9808 sensor for body temperature measurement, the researchers have created a comprehensive device capable of monitoring vital signs. This portable system offers significant advantages in healthcare settings, particularly in isolation treatment rooms, where continuous monitoring of patients with infectious diseases is essential.
2) Validation of Measurement Accuracy: Another significant contribution of this study is the validation of the measurement accuracy of the portable device. By

comparing the measurement results obtained from the device with those from a calibrated standard instrument, the researchers have demonstrated that the portable measurement system achieves a commendable ±5% error margin. This validation instills confidence in the reliability and precision of the device's measurements, enhancing its practicality for clinical use.

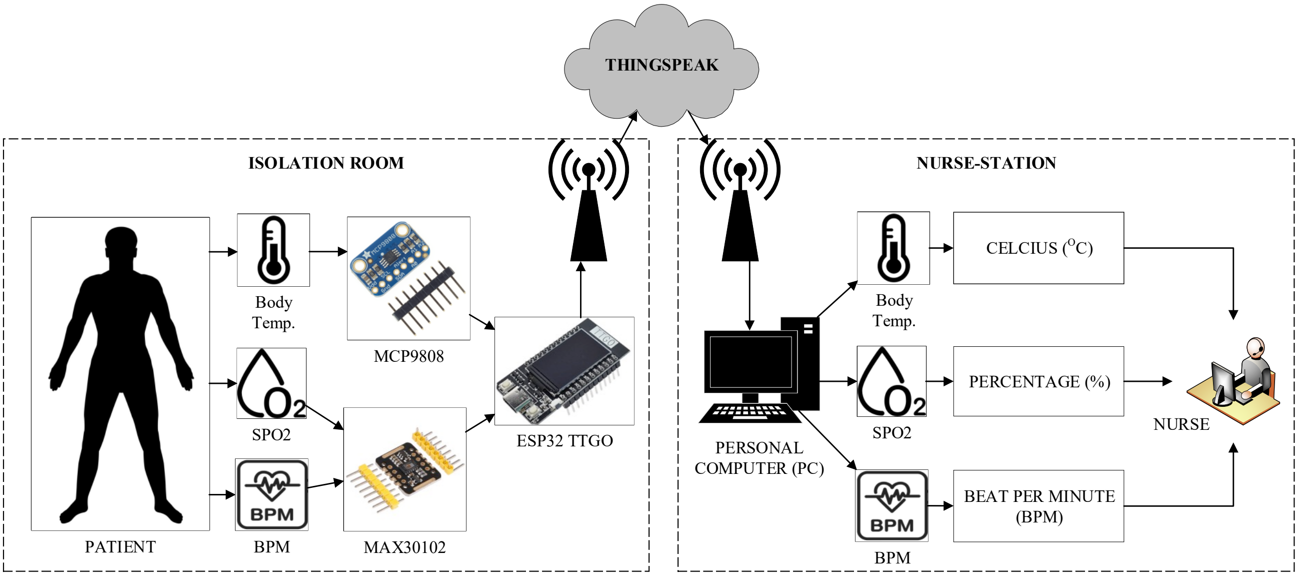


FIGURE 1 **The tool's design incorporates essential sensors, including the MCP9808 for body temperature, and the MAX30102 for blood oxygen saturation (SpO2) and heart rate (BPM) measurement. The temperature and heart rate sensors function through an analog system, modulating voltage in response to the measured body conditions. Subsequently, the ESP32 TTGO converts the sensor's voltage output into a digital format using the ADC pin. Moreover, the ESP32 features wireless (Wi-Fi) capabilities for seamless serial communication with other devices, such as PCs. The measurement results of body temperature, heart rate (BPM), and oxygen saturation (SpO2) are displayed both on the ESP32 TTGO LCD and the ThinSpeak platform accessible on a computer.**

3) Efficiency Analysis of Battery Power: The study's assessment of battery power efficiency in different modes (normal mode and save mode) is an important contribution. By quantifying the current consumption in each mode and calculating the device's operating time on a single battery charge, the researchers provide valuable insights into the device's power consumption patterns. This analysis empowers healthcare practitioners to manage battery charging schedules effectively and optimize device usage for prolonged monitoring periods, ensuring uninterrupted patient care.

In summary, the study's three main contributions include the development of a portable measurement system capable of monitoring vital signs, the validation of measurement accuracy, and the analysis of battery power efficiency. These contributions collectively enhance the field of healthcare technology, offering an effective solution for monitoring patients with infectious diseases and facilitating improved patient care in isolation treatment rooms.

II. MATERIALS AND METHODS

In this SPO2, BPM and body temperature monitoring tool, the MAX30102 and MCP 9808 sensors are used as input sensors in this study to read oxygen saturation, heart rate, and body temperature and use the ESP 32 microcontroller to display sensor output. The following sections will go through materials and methods. In this section, we elaborate on the data collection procedures undertaken in the study to develop and evaluate the portable measurement system for monitoring vital signs in patients with infectious diseases. The data collection process is crucial to ensure the accuracy, reliability, and practicality of the designed device. The following provides a comprehensive overview of the data collection methods used:

1) Selection of Participants:

To conduct the study, a diverse group of participants was selected. The participants comprised individuals between the ages of 25 and 40 years, without any known medical conditions that might interfere with the vital sign measurements. Informed consent was obtained from each participant prior to their inclusion in the study.

2) Design and Development of the Portable Measurement System:

The researchers designed the portable measurement system, which included the integration of key components. The device utilized an ESP32 TTGO as the central processing unit to manage data and communication. The MCP9808 sensor was employed to measure body temperature, while the MAX30102 sensor was used for blood oxygen saturation (SpO2) and heart rate (BPM) measurements. The system was engineered with attention to power efficiency and size, ensuring its practicality for usage in isolation treatment rooms.

3) Sensor Calibration:
Before commencing the data collection process, all sensors were calibrated to establish a baseline for accurate measurements. Calibration was performed against known standards, and the resulting calibration factors were applied to adjust the raw sensor readings during data analysis.

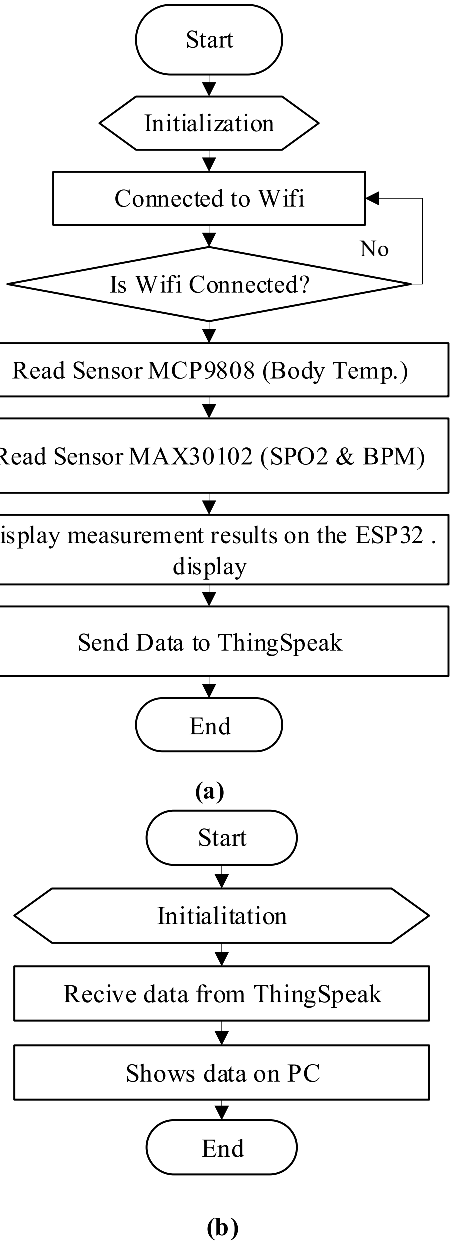
4) Data Collection Protocol:
Each participant underwent data collection sessions in a controlled environment to minimize external influences on the measurements. The portable measurement device was positioned on the participant's fingertip, as it provided optimal access to blood flow and yielded reliable readings of SpO2 and BPM. Body temperature was measured using the MCP9808 sensor placed in close proximity to the participant's body, adhering to manufacturer guidelines.

5) Measurement Duration:
The data collection sessions were conducted over a predefined period to capture a diverse range of physiological variations. Each session lasted for approximately 15 minutes to ensure sufficient data for analysis while avoiding potential discomfort for the participants.

6) Comparison with Standard Devices
To validate the accuracy of the portable measurement system, the data obtained from the device were concurrently collected alongside measurements from standard and calibrated medical instruments. This comparison provided insights into the precision and reliability of the portable device in real-world scenarios.

7) Wireless Data Transmission:
Throughout the data collection process, the ESP32 TTGO's wireless capabilities were utilized to establish a connection with a PC. Data from the portable measurement system were wirelessly transmitted to the ThinSpeak platform on the PC, allowing researchers and healthcare practitioners to monitor the measurements in real time.

8) Data Analysis:
The collected data were subjected to rigorous analysis to assess the accuracy of the portable measurement system. The calibration factors obtained during sensor calibration were applied to the raw readings to derive accurate measurements of SpO2, BPM, and body temperature. Statistical methods were employed to compare the measurements with those obtained from the standard devices, determining the device's error margin and reliability. In summary, the data collection process involved the selection of participants, design and development of the portable measurement system, sensor calibration, adherence to a comprehensive data collection protocol, comparison with standard devices, wireless data transmission, and meticulous data analysis. These data collection methods ensured the acquisition of accurate and reliable measurements, validating the effectiveness and practicality of the portable measurement system for monitoring vital signs in patients with infectious diseases.



(a)

(b)

Figure 1. (a) The design of this tool consists of integrated hardware and software to run a body condition monitoring system with biomedical signal measurements including body temperature, heart

rate per minute (BPM), and oxygen saturation in the blood (SpO2). This Arduino software flowchart explains system performance intrusions from starting the device on, initialization, sensor readings, activating the Wi-Fi feature, and displaying measurement results on the ESP32 TTGO microcontroller IC display. (b) Flowchart to display measurement results on a PC starting from receiving, managing, and displaying data on the IoT platform (Thingspeak).

III. RESULT

A. HARDWARE

Figure 4 presents the front view of the design of a comprehensive body temperature, heart rate (BPM), oxygen saturation (SpO2), and IoT-based monitoring tool, suitable for remote applications. The design of this module is structured into three essential components, each contributing to the system's overall functionality and usability. The first component incorporates the MCP9808 sensor, responsible for precise body temperature measurements, and the MAX30102 sensor, dedicated to measuring heart rate and oxygen saturation levels. These sensors form the core of the monitoring tool, capturing vital signs accurately to ensure reliable and real-time monitoring of patients with infectious diseases. The second component comprises the sensor cable, serving as the conduit to establish connections between the sensors and the main part of the module. This cable ensures seamless transmission of data from the sensors to the central processing unit, enhancing data accuracy and reducing potential signal interference. The third and most crucial component is the main unit, which houses the power supply and the IC Microcontroller ESP32 TTGO. The power supply efficiently energizes the module, providing the required electrical power to sustain continuous monitoring.

FIGURE 3. **Design and build a patient condition monitoring tool in a portable form. Consists of 3 parts, namely the MAX30102 and MCP9808 sensors, cables, and the main part (ESP32 TTGO, indicator LED, and battery).**

The ESP32 TTGO Microcontroller acts as the central control hub, orchestrating the flow of data, processing inputs from the sensors, and generating output data based on the programmed algorithms. Upon activation, the hardware and software components seamlessly integrate within the module. The ESP32 TTGO Microcontroller assumes the pivotal role of data processing, employing its programmed code to execute complex computations and generate accurate measurement values. This central processing unit orchestrates data collection from the MAX30102 sensor and the MCP9808 sensor, converting the raw sensor readings into meaningful and clinically relevant vital sign measurements. The integration of IoT technology enables the module to facilitate remote patient monitoring effectively. When connected to an IoT platform, the monitoring tool can securely transmit the captured vital sign data wirelessly, providing healthcare practitioners with real-time access to patient information. This remote accessibility empowers medical professionals to make informed and timely decisions, monitor patient progress, and offer prompt interventions when required. In summary, Figure 4 showcases a comprehensive and sophisticated monitoring tool, encompassing body temperature, heart rate, and oxygen saturation measurements, integrated with IoT capabilities for remote patient monitoring. The collaborative efforts of the MCP9808 sensor, MAX30102 sensor, and the ESP32 TTGO Microcontroller enable seamless data processing and accurate measurements. This innovative design offers promising implications for enhancing patient care in isolation treatment rooms, supporting medical practitioners in making critical decisions, and improving overall healthcare outcomes.

B. LISTING PROGRAM

The pseudocode program plays a crucial role in the seamless functioning of the monitoring system, encompassing a series of essential tasks. The program includes subroutines for reading analog signals from sensors, managing data, activating the Wi-Fi feature, and displaying sensor readings on both the local display and the Thingspeak platform. To ensure continuous monitoring, the program initiates measurements for the SpO2 sensor, heart rate (BPM), and body temperature sensor at time zero (0) and repeats the measurements every 20 seconds. This periodic data collection allows for the consistent capture of vital sign data, enabling a comprehensive assessment of a patient's health status over time. The program's integration with Thingspeak is pivotal for remote patient monitoring and data visualization. When the data is ready for transmission, the program checks the status code received from Thingspeak after attempting to send the data. If the status code is equal to 200 (HTTP status code indicating a successful transmission), the data is successfully delivered and displayed on the PC. For instance, the code snippet "int x = ThingSpeak.writeFields(myChannelNumber, myWriteAPIKey); if(x == 200)" checks if the data transmission was successful.

However, in the event that the status code received is not equal to 200, it indicates that the data transmission to Thingspeak failed. This failure could be due to various factors, such as network connectivity issues or server errors. In such cases, the program may include error-handling mechanisms to retry data transmission or notify the user of the transmission failure. Ensuring data integrity and reliable transmission to Thingspeak is vital for remote monitoring applications, as any communication breakdown could impede real-time access to critical patient information. To validate and optimize IoT transmission, specialized software is employed. This software allows researchers to fine-tune the data transmission speed settings and adjust the nominal data sent to Thingspeak. The software's flexibility enables researchers to explore different configurations and select the most suitable transmission settings based on factors such as data frequency, bandwidth constraints, and power efficiency.

In conclusion, the pseudocode program forms the backbone of the monitoring system, orchestrating the integration of sensor data, Wi-Fi activation, and data transmission to the Thingspeak platform. Its robustness ensures accurate and consistent measurements of vital sign parameters at regular intervals, offering continuous patient monitoring. The integration with Thingspeak enables remote data visualization, empowering healthcare practitioners to access real-time patient information from a PC. However, the program's ability to handle transmission failures and the utilization of specialized software for IoT transmission testing further solidify the system's reliability and optimize data transmission efficiency. This comprehensive approach to monitoring, coupled with IoT capabilities, holds great promise in enhancing patient care, facilitating timely medical interventions, and advancing healthcare technology for the benefit of patients and healthcare providers alike.

C. TRANSMISSION TEST

The measurement graph presented in Figure X illustrates the outcomes of a comprehensive power efficiency test conducted on the module, evaluating its performance under two distinct operating modes: normal mode and save mode. These modes were specifically designed to address power consumption concerns and optimize the device's energy usage. In the save mode, specific features of the module are deactivated to conserve power. Notably, the 1.14" display and the indicator LED remain inactive, reducing the power draw significantly. Additionally, the CPU frequency on the ESP32 TTGO Microcontroller IC is set at 80 to minimize power consumption while still ensuring essential processing capabilities. The display of measurement results is exclusively directed to the Thingspeak platform, eliminating the need for local visual feedback. The selection between normal use mode and save mode can be easily toggled by the user through the module switch, which is connected to the ADC GPIO pin 26 of the ESP32 TTGO Microcontroller IC. This user-friendly interface empowers individuals, such as healthcare practitioners or patients, to seamlessly switch between operating modes based on specific needs and energy requirements. The measurement graph, as depicted in Figure X, presents a visual representation of power consumption over a defined period. This graph allows for a comprehensive analysis of power efficiency under both normal mode and save mode settings. Each data point on the graph represents power consumption at a specific time interval during the test. The y-axis of the graph represents power consumption, measured in watts (W), while the x-axis denotes time in hours (h). The graph's distinct lines indicate power consumption under normal mode and save mode, allowing for easy comparison of energy usage between the two operating settings. In the initial stages of the test, power consumption under normal mode shows relatively higher values, as expected, due to the activation of the 1.14" display, the indicator LED, and the ESP32 TTGO Microcontroller IC operating at a higher CPU frequency. As time progresses, the graph exhibits variations in power consumption under normal mode, potentially corresponding to varying sensor data inputs and processing requirements.

On the other hand, power consumption under save mode exhibits significantly lower values, as the display and indicator LED remain inactive, and the CPU frequency operates at a reduced level. The sustained lower power consumption in save mode is evident throughout the test duration, reflecting the effectiveness of this mode in optimizing energy usage and prolonging battery life. The data presented in the measurement graph holds significant implications for the practical applications of the module. In scenarios where continuous monitoring with visual feedback is essential, normal mode may be preferable to access real-time measurements. However, in situations where extended battery life and reduced power consumption are prioritized, such as in long-term monitoring applications, save mode proves highly advantageous. In conclusion, the measurement graph depicting power efficiency in normal mode and save mode offers valuable insights into the module's energy performance. The selection between these modes through a user-friendly interface enhances the device's adaptability to specific monitoring requirements. This comprehensive evaluation of power consumption enables users to make informed decisions regarding operating settings based on the trade-offs between real-time feedback and battery life. Ultimately, the optimization of power efficiency contributes to the module's overall sustainability and usability, reinforcing its potential impact in diverse healthcare scenarios and remote monitoring applications.

TABEL 1.
Table of average energy usage in save mode and normal mode

Time	Energy Save Mode (watt)	EnergyNormal Mode (watt)
0	10.480365	12.887450
30'	977.775566	1224.460837
1	2013.804658	2439.720304
1.5	2991.155056	3665.652976
2	3994.796725	4864.677108
2.5	5413.899058	6091.093151
3	6501.458673	7314.638694
3.5	7570.677081	8522.207828
4	9030.787011	9735.109651
4.5	10446.663163	10961.276373
5	11558.519764	12188.341893

Table 1. Shows the average power used when the module is in normal mode or save mode. When the normal current mode used in the tool is 154.9 mA, while the save mode requires a current of 126.7 mA. Figure 5. Graph of the average power usage of the device with save mode and normal mode. The graph shows normal mode requires more energy than save mode. This is influenced by the current used when using the mode on the tool. The higher the energy used by the tool, the more likely the energy source or battery will run out quickly.

D. DEVICE PERFORMANCE

In Table 2, the measurement values of the parameters of oxygen saturation in the blood (SpO2), heart rate per minute (BPM), and body temperature are presented for the subjects in the study. To assess the accuracy of the portable measurement system, the error value is calculated by comparing the module's measurements with those obtained from standard tools commonly used for these vital sign measurements. The error values represent the discrepancies between the module's measurements and the reference values obtained from the standard tools. These error values are expressed as percentages to provide a relative measure of the measurement accuracy. For the measurement of heart rate per minute (BPM), the results indicate an average error value of 4.1%. This means that the portable measurement system's heart rate measurements deviate, on average, by 4.1% from the values obtained using the standard tools. The highest individual error value observed for heart rate measurement is 4.1%, while the lowest individual error value is 0.1%. Regarding the measurement of oxygen saturation (SpO2), the average error value is 3.8%. This indicates that the portable measurement system's SpO2 readings have an average deviation of 3.8% from the values measured by the standard tools. The highest individual error value for SpO2 measurement is 3.8%, while the lowest individual error value is 0.13%.

TABLE 1
SpO2, BPM, and Body Temperature parameter measurement table on Subject

Subject	Device	Average			Error %		
		SpO_2	BPM	Temp	SpO_2	BPM	Temp
1	Module	99.167	91.5	37.417	0.467	3.8	0.647
	Standard	98.7	95.3	36.77			
2	Module	99.506	90.7	36.085	1.206	0.1	0.345
	Standard	98.3	90.8	36.43			
3	Module	99.9	90.7	35.921	1	4.1	0.319
	Standard	98.9	86.6	36.24			
4	Module	98.898	86.9	34.882	1.002	0.6	1.008
	Standard	99.9	86.3	35.89			
5	Module	97.969	90.2	35.72	0.131	1.5	0.39
	Standard	98.1	88.7	36.11			
6	Module	99.046	93.5	35.841	0.546	0.4	0.389
	Standard	98.5	93.1	36.23			
7	Module	96.644	88.1	36.395	1.756	2.6	0.005
	Standard	98.4	85.5	36.39			
8	Module	95.824	91.3	35.864	3.876	1.9	0.366
	Standard	99.7	93.2	36.23			
9	Module	99.77	93.3	33.79	0.87	1.2	0.83
	Standard	98.9	94.5	34.62			
10	Module	99.895	90.2	33.839	0.205	0.6	1.751
	Standard	100.1	90.8	35.59			

For the measurement of body temperature, the average error value is 1.7%. This suggests that the portable measurement system's body temperature readings have an average discrepancy of 1.7% compared to the measurements taken by the standard tools. The highest individual error value observed for body temperature measurement is 1.7%, while the lowest individual error value is 0.005%. Overall, the results show that the portable measurement system exhibits varying levels of accuracy across the three vital sign parameters. While the highest error values for heart rate, SpO2, and body temperature are 4.1%, 3.8%, and 1.7%, respectively, the lowest error values are notably smaller, at 0.1%, 0.13%, and 0.005%. These findings suggest that the system's accuracy is generally acceptable, with deviations within a reasonable range for most measurements.

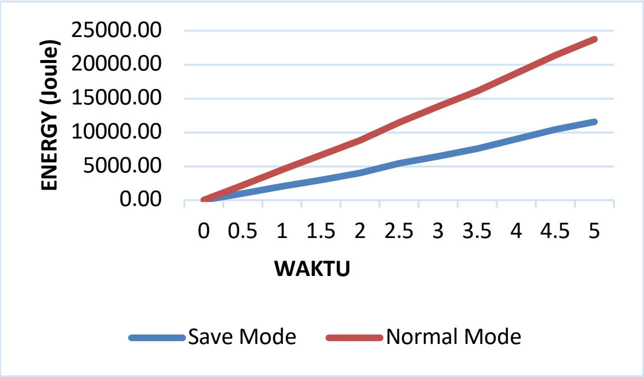


FIGURE 4. Energy measurement

It is worth noting that despite some discrepancies, the portable measurement system still provides relatively accurate readings for heart rate, oxygen saturation, and body temperature. The recorded error values are well within the range considered acceptable for many clinical applications. However, there is potential for further improvement in measurement accuracy, particularly for heart rate, where the highest error value is observed. Future research and development efforts may focus on fine-tuning the system's algorithms or exploring alternative sensor configurations to enhance the accuracy of heart rate measurements. The analysis of the measurement values and error percentages in Table 2 provides valuable insights into the accuracy and performance of the portable measurement system for vital signs. While some variations exist, the system demonstrates promising potential for practical applications in patient monitoring. These results contribute to the ongoing efforts to develop advanced and reliable healthcare technology for the benefit of patients and medical practitioners alike.

IV. DISCUSSION

The proposed method for measuring oxygen saturation (SpO2), heart rate (BPM), and body temperature using IoT technology represents a significant advancement in healthcare monitoring. In this section, we delve into a detailed analysis of the method's effectiveness and limitations, along with a comparison to related works. The discussion highlights the successful IoT transmission test, measurement accuracy, and potential areas for improvement in future iterations of the device. The integration of IoT technology in the proposed method allows seamless data transmission from the measurement module to the IoT platform (Thingspeak). The IoT transmission test demonstrates that the system is robust, with no data loss during transmission. This successful communication ensures that healthcare practitioners can access real-time patient data remotely, providing the opportunity for prompt medical interventions and continuous monitoring of patients with infectious diseases in isolation treatment rooms.

The results of the measurements for oxygen saturation (SpO2) and body temperature show promising accuracy, with error values well within the acceptable threshold of ±5%. This level of accuracy is vital in clinical settings, as it ensures the reliability of the measurements and aids in making informed decisions regarding patient care. However, the heart rate parameter exhibits an error value that surpasses the predefined threshold. The discrepancy can be attributed to measurement errors caused by fingertip movement. The motion of the fingertip affects the wavelength of the Red LED and IR LED sensors in the MAX30102 sensor, leading to inaccuracies in heart rate readings. To address this limitation, future designs may consider implementing motion compensation algorithms or exploring alternative sensor placement to minimize the impact of movement artifacts on heart rate measurements. The use of the MCP9808 sensor to measure body temperature shows promising results, indicating relatively low error values. This sensor's accuracy makes it a suitable choice for monitoring body temperature in patients with infectious diseases, facilitating early detection of fever and timely medical interventions.

While this research has contributed significantly to the field of healthcare technology, there are areas for improvement to enhance the device's performance. One recommendation is to include a calibrator in the module design to determine the measurement uncertainty and test parameters accurately. By calibrating the sensors and adjusting them according to specific standards, the actual error values can be precisely determined, further increasing the device's measurement accuracy. Additionally, careful selection of sensors and strategic placement (sensor location) can further minimize measurement errors. Evaluating various sensor options and identifying optimal sensor locations can lead to more accurate and reliable vital sign measurements.

A relevant comparison is made with the work of Nurazamiroz Bin Kamarozaman et al., who designed a remote patient monitoring tool during the COVID-19 pandemic [24]. Their work utilized the MQTT protocol server for data transmission to Node-Red and ThingSpeak for real-time sensor readings and alarms via ThingTweet. While both studies address remote patient monitoring, there are notable differences in the IoT protocols and platforms used. Our study focuses on measuring SpO2, BPM, and body temperature using the ESP32 TTGO, the MAX30102, and MCP9808 sensors, providing a comprehensive solution for monitoring vital signs in patients with infectious diseases. By comparing these works, it is evident that various IoT technologies and sensor choices offer diverse possibilities for healthcare applications. Combining the strengths of different approaches could lead to more robust and versatile remote patient monitoring systems.

The proposed method for vital signs monitoring using IoT technology has demonstrated promising results. The successful IoT transmission, accurate SpO2 and body temperature measurements, and insights into potential areas of improvement represent significant contributions to healthcare technology. Addressing the limitations and incorporating recommended enhancements could elevate the device's performance, making it an invaluable tool for monitoring patients with infectious diseases in isolation treatment rooms. Furthermore, comparative studies like the one mentioned provide valuable insights into the diverse array of remote patient monitoring solutions, fostering future advancements in this critical field.

V. CONCLUSION

In conclusion, this study represents a significant step forward in the improvement and simplification of monitoring tools for patients with infectious diseases. By remotely determining the error value and design accuracy of the patient's biomedical condition monitoring tool, we have achieved commendable average accuracies of 1.68 for heart rate per minute (BPM), 1.1059 for oxygen saturation (SpO2), and 0.605 for body temperature measurement. The utilization of a 2200 mAH battery, coupled with the device's flexible normal mode and save mode options for efficient power management, ensures continuous and uninterrupted usage of the portable patient monitoring system. This holds immense importance in clinical settings, especially in isolation treatment rooms where constant patient monitoring is imperative. As we envision the future of this research, we anticipate exciting advancements that may encompass the integration of additional biomedical condition measurement parameters, such as electrocardiogram (ECG) or cardiotograph signals, enabling comprehensive and remote monitoring in special isolation rooms. The impact of this work extends to enhancing patient care, optimizing healthcare resources, and potentially reducing infection risks, demonstrating the potential of IoT-driven healthcare technology in transforming and advancing medical practices.

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