RESEARCH ARTICLE **OPEN ACCESS**

Manuscript received September 28, 2023; revised October 02, 2023; accepted October 12, 2023; date of publication December 25, 2023
Digital Object Identifier (DOI):https://doi.org/10.35882/teknokes.v16i4.614

How to cite: Melva Mahardika, Bambang Guruh Irianto, I Dewa Gede Hari Wisana, Triwiyanto, and Yagnik Rathod, "Monitoring SpO2,BPM and Temperature on Smaartband with Data Sending Using IoT Android Display ", Jurnal Teknokes , vol. 16, no. 4, pp. 185–192, December. 2023.

Monitoring SpO2, BPM, and Temperature on Smartband with Data Sending Using IoT Android Display

Melva Mahardika[1], Bambang Guruh Irianto[1], I Dewa Gede Hari Wisana[1], Triwiyanto[1], and Yagnik Rathod[2]

[1] Department of Electromedical Engineering, Health Polytechnic Ministry of Health Surabaya, Surabaya, Indonesia
[2] Department of Computer Engineering, Government Engineering College, Dahod, India

Corresponding author: I Dewa Gede Hari Wisana (e-mail: dewa@poltekkesdepkes-sby.ac.id).

"This work was supported in part by the Department of Electromedical Engineering, Health Polytechnic Ministry of Health Surabaya"

ABSTRACT No matter if a patient is receiving care at home or in a hospital, monitoring them is an essential part of healthcare. Currently, many hospitals use a manual method to measure body temperature, oxygen saturation, and heart rate, necessitating physical visits from nurses to patients' rooms to get data. This approach, however, turns out to be less effective and time-consuming. This research aims to develop a wearable device placed on a patient's wrist is the main goal of this project. Body temperature, oxygen saturation, and heart rate are the three vital sign metrics that this gadget will be able to continuously monitor in real-time. Additionally, Ubidots integration will enable the device to deliver notifications based on the data gathered.The contribution of this research is the development of IoT-based wearable devices for remote monitoring, which aims to improve the quality of health service monitoring. The tool is expected to facilitate remote monitoring for medical personnel and patient families. This research method uses MAX30100 as digital sensors to monitor heart rate, oxygen saturation and MLX90614 as a sensor to detect body temperature. The results of this research can display data on the Ubidots application and send notifications to email. The results showed that the SpO2 sensor had the lowest error rate of 0.2% and the highest mistake rate of 1.6%. The error rates displayed by the BPM sensor varied, with the lowest being 0.6% and the largest being 5.68%. For body temperature measurements, the minimum error rate recorded is 0.002%, while the maximum error rate is 0.016%. This research shows that it is time to develop further into a sophisticated health monitoring tool to improve the quality of health services.

INDEX TERMS Smartband, MAX30100, MLX90614, BPM, Temperature

I.INTRODUCTION

In the medical world, monitoring the patient's condition is an important matter in healthcare settings, such as hospitals, and in home care, keeping an eye on a patient's health is crucial. A person's vital signs, such as BPM, SpO2, and body temperature, are crucial markers of how well they are doing. When a patient exhibits illness-related symptoms that need rapid attention, prompt monitoring is essential because postponing treatment could make their condition worse [1][2]. A person's pulse can be felt to assess their heart rate, which is the simplest method. This approach is frequently used by medical professionals, who measure their patients' pulse rates for 15 seconds before multiplying the results by four to determine their heartbeats per minute [3][4]. The quantity of oxygen taken in by the blood through the lungs is known as SpO2, which is connected to hemoglobin. Grave effects, such as fainting or even death, can result from oxygen levels falling below normal ranges [5][6][7]. One method for determining oxygen saturation is oximetry. The balance between heat produced and released is represented by body temperature, which is a reflection of internal body heat [8][9]. Monitoring a person body temperature is the balance between heat generated and heat released.The level of a person's body temperature is an indicator to see whether a person's condition is healthy or sick. Measurement of body temperature is usually measured using a thermometer [10].

Above typical limits, a considerable drop in blood oxygen levels can offer serious risks, including the possibility of passing out or even dying. Body temperature is a measure of heat in the human body [11]. This body temperature is the balance between heat generated and heat released. The level of a person's body temperature is an indicator to see whether a person's condition is healthy or sick. Measurement of body temperature is usually measured using a thermometer [12]. Risk increases significantly when blood oxygen concentration falls below normal, you can experience fainting until death . Various methods are available for measuring oxygen saturation, with oximetry being one of the techniques commonly utilized[13]. Body temperature is a measure of heat in the human body. This body temperature is the balance between heat generated and heat released. The level of a person's body temperature is an indicator to see whether a person's condition is healthy or sick [14]. A thermometer is often used to measure body temperature because it helps determine how hot the human body is. Monitoring body temperature is crucial for assessing a person's health because it might indicate the presence of a fever or other illnesses.[15]. The level of a person's body temperature is an indicator to see whether a person's condition is healthy or sick [16][17][18]. The measurement of heat within the human body is called body temperature[12][13]. It comes about as a result of a precise balance between the heat produced by metabolic processes and heat released [19][20]. The level of a person's body temperature is an indicator to see whether a person's condition is healthy or sick [21][22]. Measurement of body temperature is usually measured using a thermometer [23].

In its use, Doctors frequently utilize an electrocardiogram (ECG) to monitor and measure heart's electrical activity and a thermometer to measure body temperature. This tool is very helpful for patients in diagnosing the disease they are suffering from. However, the use of electrocardiograms and thermometers used by medical personnel in hospitals or health centers is still being done repeatedly and requires concentration to get an accurate value, given the changes in heart rate and body temperature that keep on changing. This of course raises several problems, including the time it takes for medical personnel to determine the results of the diagnosis, the increase in patients will increase the burden on doctors in conducting patient examinations, and the amount of costs that must be incurred by the manager in completing the equipment for each medical personnel [24][25] .

There are several studies related to monitoring SpO2, heart rate, and body temperature to make the monitoring process more effective. Eryanda Bima Mahendra from the Electromedical Engineering Poltekkes Ministry of Health Surabaya created it in 2019 and it was exhibited as a smartwatch that conducted research on SpO2 and BPM. This tool is made to provide continuous monitoring of the patient's heart rate which can be displayed on an Android device. However, this tool still has a drawback, namely the distance that can be reached only Bluetooth is only 30 meters. In 2020, a researcher named Bagus Marten Giri from Electromedical Engineering created a smartband possessing the capability of monitoring BPM and body temperature. If abnormal conditions were detected, the device could send notifications through email as well as the Blynk program. However, the study revealed some limitations, particularly concerning the sensors and data collection process. The Ds18b20 temperature sensor used in the study was influenced by external or ambient temperatures, measurements. Additionally, there was still a need for a connection to be placed on the finger during BPM data retrieval. In the same year, In order to measure pulse rate and body temperature in people, Diah Eka Savitri from Syarif Hidayatullah State Islamic University Jakarta created a solution that makes use of Internet of Things (IoT) technology. However, this tool still has drawbacks where delivery can only use Bluetooth which can only send data to Android with a maximum distance of 46.5 and the shape of the bracelet is still too big because it still uses a character LCD screen and still uses jumpers. Then one year later in 2021 it will be perfected by Pandu Arsy Filonanda from Electromedical Engineering continue tool development. The tool is designed to monitor BPM and body temperature on the wrist, and is equipped with a display via an Android device. This tool already uses the LCD from ESP32 TTGO, which can display BPM measurements from the SEN0203 sensor, is incorporated into the developed tool. Additionally, it makes use of the MLX90614 sensor as a temperature sensor to make sure that the temperature being measured accurately reflects body temperature and is unaffected by the temperature of the environment. The following year it was developed by Yusita Indhira Prameswari Candra Putri Anwar and Fani Ferina Sani from Electromedical Engineering with the title Smartband Monitoring BPM and SpO2 Based on IoT (Internet of Things). This tool displays BPM and SpO2 values and is displayed on the blynk application using the MAX86141 sensor. The primary goal of creating this tool was to help medical professionals or patient families identify COVID-19 signs early, enabling continuous monitoring while reducing direct patient interaction.

To develop previous research, the authors created a tool Monitoring SpO2, BPM, and Temperature on Smartband with Data Sending Using IoT Android Display . This research aims to develop a wrist monitoring device that can track heart rate, oxygen saturation, and body temperature. This tool allows for real-time monitoring and remote tracking of the patient's vital signs. This tool can later be monitored with the Ubidots application and will be connected to an email with the aim of sending notifications to nurses or doctors and the patient's family if things are not normal. It is expected that with the presence of this smartband, monitoring will be enhanced, providing a useful and effective means for accurately diagnosing and detecting the health conditions of patients. Moreover, with the integration of IoT technology, it enables easy and flexible

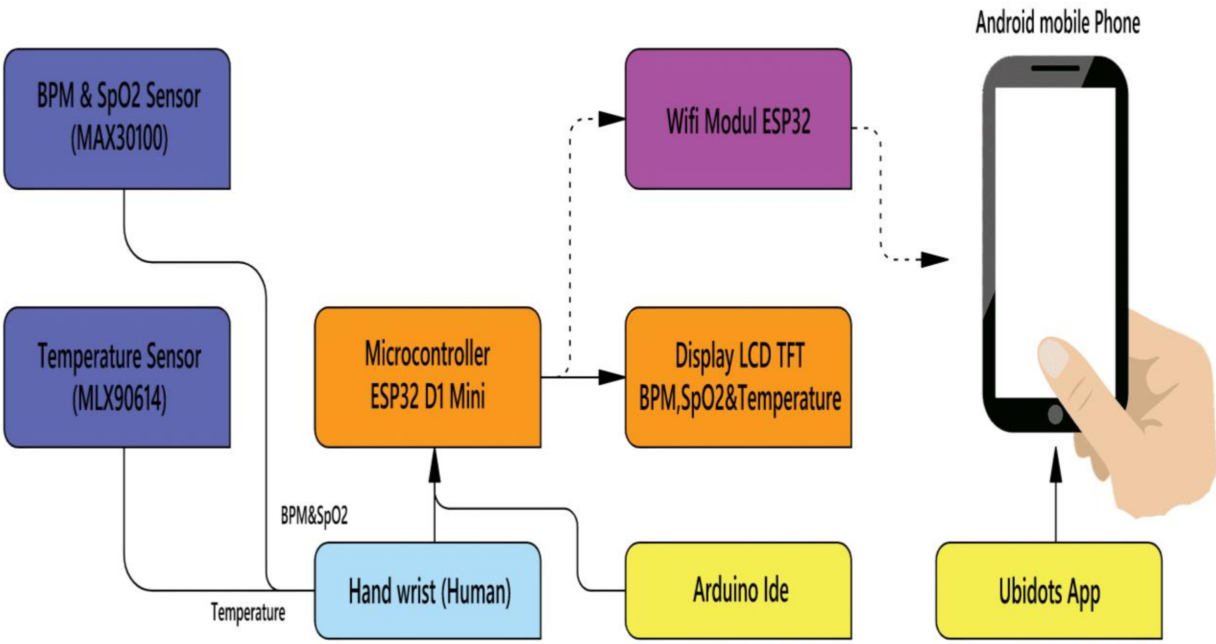

FIGURE 1. System Block Diagram in Research with MAX30100 Sensor and MLX90614 sensor

monitoring through the Ubidots application. Therefore, this research contributes to improving the quality of health monitoring between patients' families and medical professionals.

On the block diagram in FIGURE 1. In this study the MAX30100 sensor detects SpO2, BPM and MLX90614 detects body temperature. The ESP32 microcontroller will process the data gathered from the MLX906014 sensor and the MAX30100 sensor, the BPM and SpO2 measurement values will be displayed on a 1.28 inch TFT display. ESP32 will also send processed data to the Ubidots application installed on the patient's smartphone by sending data using a Wi-Fi connection. If the patient's SpO2, BPM, and temperature values are abnormal, the Ubidots application will send a message in the form of BPM, SpO2, body temperature monitoring results to email.

a. MAX30100
   Functions to detect measurements of SpO2 and BPM.
b. MLX90614
   Functions to detect body temperature.
c. LCD TFT
   The LCD TFT is employed to display the processed values of SpO2, BPM, and body temperature, which are obtained through the microcontroller.
d. ESP32 WEMOS
   Processes the data readings from the MAX30100 and MLX90614 sensors.
e. UBIDOTS
   Receives the processed data and displays it on a smartphone.

II. METHODS

The research was designed as an experiment with the main objective of creating an innovative Smartband for monitoring vital signs, including SpO2 (oxygen saturation), BPM (heart rate), and body temperature. The Smartband was developed using state-of-the-art Internet of Things (IoT) technology to enable seamless connectivity and efficient data transfer. The IoT-enabled Smartband is accompanied by an Android application that complements the monitoring process, allowing healthcare professionals and caregivers to access and track real-time vital sign data from the Smartband remotely.

A. DATA COLLECTION

The BPM, SpO2, and body temperature Data of 10 respondents, 5 women and 5 men, all over the age of 20, was used to collect information on BPM, SpO2, and body temperature. Each participant's data was collected 10 times with a comparison and data collection interval of 5 seconds. A SpO2 simulator was used as a calibrator for the SpO2 and BPM measurements during the research, which was conducted at the Department of Biomedical Engineering Technology Campus in Surabaya. The next section allows you to see how the module is designed. The design of the module can be observed in the subsequent section **FIGURE 2.**

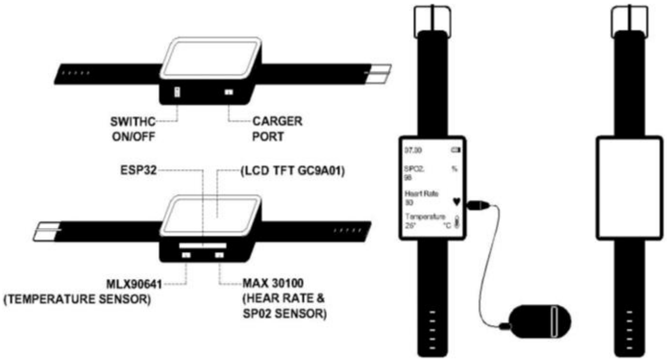

FIGURE 2. **Monitoring SpO2, BPM, and Temperature on Smartband with Data Sending Using IoT Android Display**

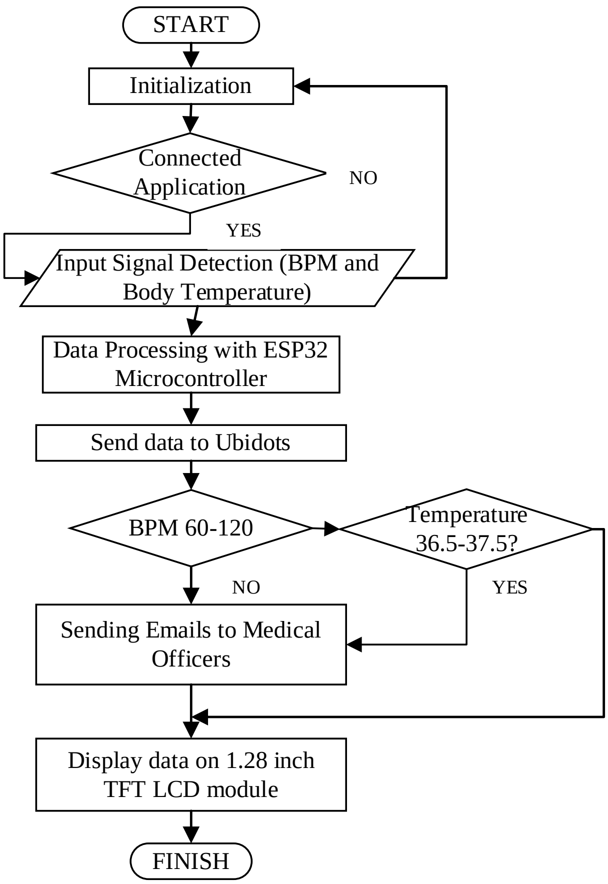

FIGURE 3. **The system flowchart Monitoring SpO2, BPM, and Temperature on Smartband with Data Sending Using IoT Android Display**

In this study, two sensors, namely the MAX30100 sensor and the MLX90614 temperature sensor, are utilized to gather the necessary data. The data collected from these sensors will be subsequently processed using the microcontroller ESP32. The processed data will then be used to determine the BPM (heart rate) and Temperature Output values. The final results of the BPM and temperature measurements will be displayed on the TFT LCD Display, then will be sent to the Ubidots application. This paragraph can explain FIGURE 3. There are 3 main parts in a block diagram, namely input, process and output. In the input section there are Max30100 to detect BPM and SpO2 and MLX90614 to detect Temperature sensors. In the process section of this study, a microcontroller is employed to data processing phase. Once the data is received from the sensors (MAX30100 and MLX90614), the microcontroller undertakes the necessary computations and adjustments the efficiency of data handling so that the data is ready to be sent. And finally in the output section there is an android application and a display which functions to display the results from the sensors that have been processed on the microcontroller.

When the start button is pressed on the microcontroller flow chart as shown in FIGURE 2, the initialization process begins. The MAX30100 sensor is activated to detect heart rate and oxygen saturation, while the MLX90614 sensor is utilized to measure body temperature on the wrist. The temperature, heart rate, and oxygen saturation readings will all be shown as numerical figures on the TFT display after they have been acquired. Furthermore, a WiFi connection will be used to send these values to the Ubidots app that is downloaded and installed on the patient's smartphone.

B. DATA ANALYSIS

Five repetitions of each comparison were made in order to measure each parameter, including temperature and BPM. Eq (1) was utilized to calculate the average measurement value by utilizing the mean or average. By dividing the sum of all values by the total number of data points in the set, the average is obtained :

$$\overline{x} = \frac{x1 + x2......+ xn}{n} \quad (1)$$

As the average of each measurement (x1, x2,..., xn), the mean (x) for n measurements is computed. One way to quantify the degree of variation within a data collection or the measure of the deviation from the mean is to use the standard deviation. There are also reference devices used to compare the measurement results. In this study, a pulse oximeter is used as a reference for the MAX30100 module, which detects BPM (heart rate), and a thermogun is used as a reference for the MLX90614 module, which detects body temperature. These reference devices have been calibrated and are known for their measurement accuracy. Eq (2) represents the formula for determining the standard deviation (SD):

$$\text{SD} = \sqrt{\frac{\sum(xi-\overline{x})^2}{(n-1)}} \quad (2)$$

The overall measurement uncertainty value (UA), the consequent standard deviation (SD), and the number of measurements (n). The average difference of each data point is shown by the %error, which represents the system error. Errors can show differences between a model or design and a standard. Eq (3) presents the error formula.

$$\%\text{ERROR} = \frac{(x_n - x)}{x_n} \times 100\% \quad (3)$$

where xn is the measured value of the engine calibrator. X is the measured value of the design.

III. RESULTS

The module was evaluated and tested in this study by contrasting it with a thermometer and an oximeter. FIGURE 4 is a microcontroller circuit consisting of Wemos D1 Mini, TFT LCD, battery lithium. A lithium battery is needed for order to power supply the data collection device.which will enter the ESP32 Wemos module.

TABLE 1
The avarage BPM for 10 Respondents with MAX30100 and pulse Oximetry

Subject	Avarage MLX90614 (Temp)	Avarage Thermogun (Temp)	Standard Deviation	Error %
R 1	36.6	36.5	0.54	0.27
R 2	36	36.32	0	0.88
R 3	36	36.32	0	0.88
R 4	36.2	36.4	0.4	0.54
R 5	36	36.3	0	0.82
R 6	36	36.28	0	0.77
R 7	36.2	36.14	0.4	0.16
R 8	36	36.32	0	0.88
R 9	36	36.44	0.54	0.1
R 10	36	36.28	0.44	0.22
Average	**36.1**	**36.4**	**0.23**	**0.27**

FIGURE 4 **Smartband module display with heart rate, SpO2, and body temperature.**

Pulse oximetry and a thermogun were used to capture BPM and body temperature data, which were then compared with the values from the MAX30100 and MLX90614 modules. Five measurements of each respondent's body temperature and BPM were made. Nikai average BPM and body temperature were then calculated and compared with the average values of MAX30100 and MLX90614 in 10 respondents.

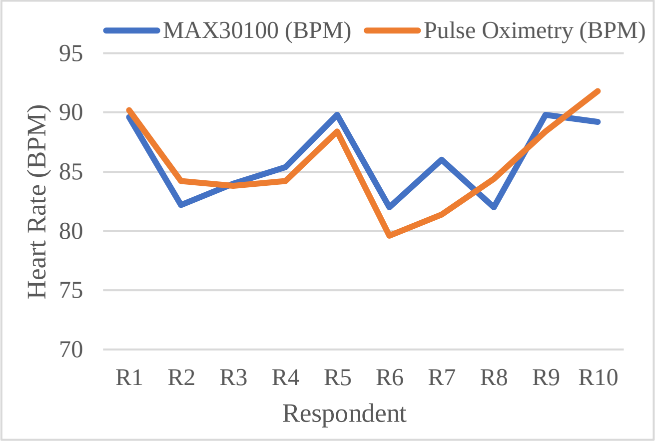

FIGURE 5. **Graph mean value of BPM between MAX30100 and pulse oximetry**

TABLE 2
The avarage Temperature for 10 Respondents with MLX90614 and thermogun

Subject	Average MAX30100 (BPM)	Avarage Pulse Oximetry (BPM)	Standard Deviation	Error %
R 1	89.6	90.2	2.9	0.06
R 2	82.2	84.2	0.8	2.3
R 3	84	83.8	2	0.23
R 4	85.4	84.2	1.8	1.4
R 5	89.8	88.4	1.09	1.58
R 6	82	79.6	1.2	3.01
R 7	86	81.4	1.2	5.65
R 8	82	84.4	1.8	2.84
R 9	89.8	88.4	2.4	0.6
R 10	89.2	91.8	3.6	2.83
Avarage	**85**	**83.54**	**1.9**	**2.03**

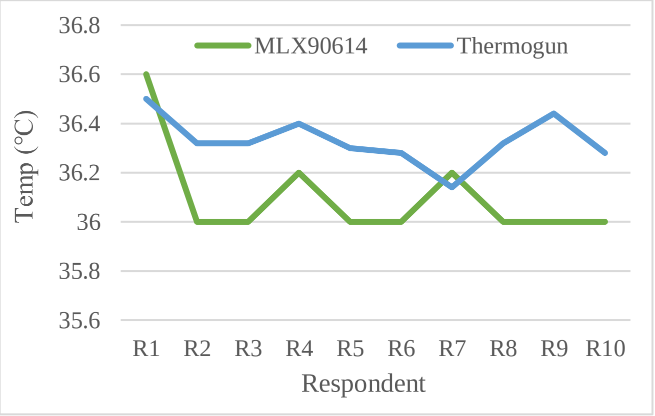

FIGURE 6. Graph mean value of Temperature between MLX90614 and Thermogun

The average BPM and body temperature values that have been calculated and compared with the comparison pulse oximeter for the MAX30100 and the thermogun for the MLX90614 module which were performed on 10 respondents are presented graphically in the table TABLE 1, TABLE 2, FIGURE 5, FIGURE 6. The error values and standard deviations, presented in TABLE 1 and FIGURE 5, were computed by comparing the average BPM values acquired from the MAX30100 and pulse oximetry measurements. The analysis revealed that the smallest error value in BPM data was 0.67 percent, indicating a high level of accuracy between the two measurement methods. On the other hand, the largest error value recorded was 5.65 percent, suggesting some variation in readings between the two techniques. However, it is noteworthy that the overall average error value of 2.2 percent signifies the data icapability is highly comparab pulse oximetry.

In TABLE 2 and FIGURE 6, the error values for body temperature measurements are presented. The smallest error value observed is 0.27 percent, while the largest is 1.2 percent, with an average error value of 0.7 percent. Nonlinearity in BPM and body temperature values within the module could be attributed to factors such as patient hand movements and improper placement of the module on the patient's wrist during measurements. Despite these potential challenges, the module demonstrates promising accuracy and reliability for monitoring body temperature.

TABLE 3
Error and Standard Deviation of BPM and Temperature

Subject	BPM		Temperature	
	Standard Deviation	Error %	Standard Deviation	Error %
R 1	2.9	0.67	0.54	0.27
R 2	0.8	2.37	0	0.88
R 3	2	0.23	0	0.88
R 4	1.8	1.42	0.4	0.55
R 5	1.09	1.58	0	0.82
R 6	1.2	3.02	0	0.77
R 7	1.2	5.65	0.4	0.17
R 8	1.8	2.85	0	0.88
R 9	2.4	1.58	0.54	1.2
R 10	3.6	2.9	0.44	0.77
Avarage	**1.9**	**2.2**	**0.23**	**0.791**

In FIGURE 7 presents the error values for temperature measurements and BPM measurements. On the orange graph there is an error result from BPM and on a yellow graph there is an error result from Temperature.

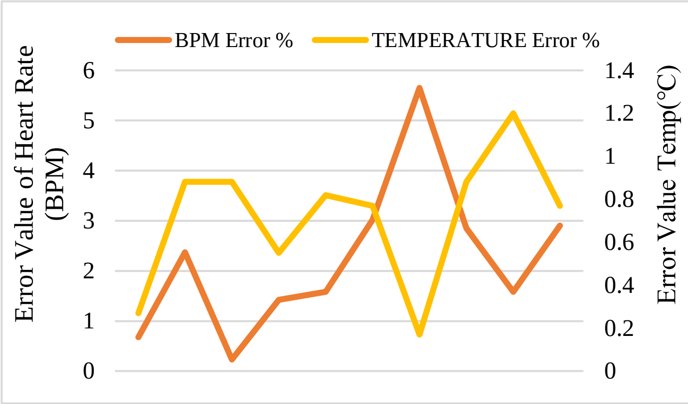

FIGURE 7. Graph mean value of Temperature between MLX90614 and Thermogun

IV. DISCUSSION

From the test results, analysis of BPM and body temperature values shows the accuracy and reliability of the Smartband module. The data shows that the lowest error observed in the Smartband module for BPM measurement is only 0.06%. On the other hand, the highest error recorded for the BPM measurement was 2.84%, indicating some degree of deviation between the Smartband module reading and the reference value, but still within the acceptable range. Regarding body temperature measurement, the Smartband module shows impressive accuracy, with the lowest error of 0.1%. The highest error in measuring body temperature for the Smartband module is 0.88%, which is relatively small, further confirming the module's effectiveness in assessing body temperature accurately. With a good error value within acceptable limits, the Smartband module is proven to be used to monitor real-time vital signs in healthcare.

Researchers Fani Ferina and Yusita Indihira from the Surabaya Ministry of Health Poltekkes conducted a study on Smartband Monitoring of SpO2 and BPM Based on IOT in 2022.[1] The device made use of the ESPTTGO T-Display, a microcontroller and display, integrated WiFi, and the MAX86141 sensor for BPM and SpO2 readings. This concept included a 3.7 V lithium battery for power supply and attempted to reduce the requirement for extra tools and materials. In addition, this tool also has the advantage of only using a watch that is placed on the wrist to place the sensor without connecting the sensor to the index finger. This is what makes this smartband more practical.[2]

During the data analysis, there are nonlinearities were observed and these can be attributed to various factors. One significant factor is the movement of the patient during the measurement process. Patients may involuntarily move their wrists, leading to fluctuations in the readings obtained by the sensors. Furthermore, the distance between the object being measured and the sensor on the patient's wrist can affect the results. Any discrepancy in the distance could lead to variations in the intensity of infrared light received by the sensor, consequently impacting the accuracy of the readings. Upon analysis, were some shortcomings were found in this instrument, especially with regard to the measurement outcomes are unstable if there is movement in the patient due to the very sensitive sensor, besides one of the deficiencies identified in this tool is that it requires a connection to the finger in order to retrieve BPM data and SpO2 and measurement results on the module are not equipped with graphs that only display measurements in numbers. The research results of the aforementioned tool indicate the development of a portable device, the measurement results can be monitored on the Ubidots application and there is an email notification if the measurement results are not normal.

After conducting tests on the Smartband module using the MAX30100 and MLX90614 sensors, calibration was performed using the SpO2 calibrator and thermogun. The module's performance was evaluated by obtaining average data and error values. The data collection process involved measuring 10 respondents, comprising both men and women, and repeating each measurement five times at five-second intervals.During the testing phase, the module's readings were compared against the values obtained from the SpO2 calibrator and thermogun to determine the level of accuracy and reliability in measuring vital signs such as SpO2, BPM, and body temperature. Moreover, the error values provided insight into the discrepancies between the module's measurements and the calibrated values. the study aimed to ensure consistency and validate the accuracy of the Smartband module's readings.

IV. CONCLUSION

The main objective of this research is to create a Smartband equipped with SpO2, BPM, and Temperature monitoring capabilities that can be wearable monitored on an Android phone through a WiFi connection. By successfully completing the manufacturing process and conducting an in-depth literature review, the study can draw the following conclusions :

Oxygen saturation and heart rate values are generated from the MAX30100 module which is located on the patient's index finger. The MLX90614 module which can be used to determine body temperature is placed on the wrist. The Ubidots application on Android can display the values of SpO2, BPM and body temperature in continuous time and are remotely monitorable. The Ubidots application can send notifications via linked email if the values of SpO2, BPM and temperature are abnormal.

Based on the conducted tests, the smartband module results error recorded in the smartband module for heart rate measurements was only 0.06% and the highest error observed in the smartband module for heart rate measurements was 2.84%. Regarding body temperature measurements, the smartband module in the lowest error being 0.1%. Additionally, the highest error observed in body temperature measurements for the smartband module was 0.88%. The obtained results demonstrate the smartband module's effectiveness in providing reliable and heart rate and temperature measurements. The results acquired from the testing of the smartband module, which the measurement results with those obtained from the Oximeter and Thermogun comparison tools, are considered satisfactory and capable of performing their intended functions. In order to monitor patient conditions on a daily basis without disturbing patients, this study's portable device design makes it very appropriate for application. It is hoped that this device would be widely utilized by medical professionals to monitor patient health and identify normal and abnormal circumstances with the right repairs and enhancements

REFERENCES

[1] I. D. G. H. W. Wisana, P. C. Nugraha, F. Amrinsani, F. F. Sani, Y. I. Anwar, and S. Palanisamy, “Smartband for Heartbeat and Oxygen Saturation Monitoring with Critical Warning to Paramedic via IoT,” *J. Teknokes*, vol. 15, no. 3, pp. 161–166, 2022, doi: 10.35882/teknokes.v15i3.317.

[2] P. A. Filonanda, D. Gede, H. Wisana, and P. C. Nugraha, “Smart-band BPM and Temperature Based on Android Using Wi-Fi Communication,” *J. Teknokes Multidiscip. Rapid Rev. Open Access J.*, vol. 14, no. 2, pp. 62–67, 2021, doi: 10.35882/TEKNOKES.v1i1.3.

[3] A. Hendryani, D. Gunawan, M. Rizkinia, R. N. Hidayati, and F. Y. Hermawan, “Real-time stress detection and monitoring system using IoT-based physiological signals,” *Electr. Eng. Informatics*, vol. 12, no. 5, pp. 2807–2815, 2023, doi: 10.11591/eei.v12i5.5132.

[4] A. N. Ejin, H. T. Yew, M. Mamat, F. Wong, A. Chekima, and S. K. Chung, “Internet of things based real-time coronavirus 2019 disease patient health monitoring system,” *Int. J. Electr. Comput. Eng.*, vol. 12, no. 6, pp. 6806–6819, 2022, doi: 10.11591/ijece.v12i6.pp6806-6819.

[5] M. Y. Nurhadiansyah, R. Widyatra Sudibyo, and M. Z. Samsono Hadi, “Body Temperature and Heart Rate Monitoring System Using Fuzzy Classification Method,” *Int. J. Artif. Intell. Robot.*, vol. 4, no. 2, pp. 86–96, 2022, doi: 10.25139/ijair.v4i2.5290.

[6] A. Sagahyroon, H. Raddy, A. Ghazy, and U. Suleman, “Design and implementation of a wearable healthcare monitoring system,” *Int. J. Electron. Healthc.*, vol. 5, no. 1, pp. 68–86, 2009, doi: 10.1504/IJEH.2009.026273.

[7] J. Karnadi, I. Roihan, A. Ekadiyanto, and R. A. Koestoera, “Development of a Low-cost Arduino-based Patient Monitoring System for Heartrate, Oxygen Saturation and Body Temperature Parameters,” *J. Appl. Sci. Eng. Technol.*, vol. 1, no. 1, p. 26, 2022, doi: 10.47355/aset.v1i1.15.

[8] C.-H. Huang and J.-W. Guo, “Design of Reflectance Pulse Oximeter and BPM using the Max30100 Sensor in Early Detection of Hypoxemia in Patients with Cardiovascular Disorders,” *Int. J. Adv. Heal. Sci. Technol.*, vol. 1, no. 1, pp. 1–6, 2021, doi: 10.35882/ijahst.v1i1.1.

[9] M. D. Stephenson, A. G. Thompson, J. J. Merrigan, J. D. Stone, and J. A. Hagen, “Applying Heart Rate Variability to Monitor Health and Performance in Tactical Personnel: A Narrative Review,” *Int. J. Environ. Res. Public Health*, vol. 18, no. 15, 2021, doi: 10.3390/ijerph18158143.

[10] B. Annapurna, A. Manda, A. C. Raj, R. Indira, S. P. Kumari, and V. Nagalakshmi, “Max 30100/30102 Sensor Implementation to Viral Infection Detection Based On Spo2 and Heartbeat Pattern,” *Ann. Rom. Soc. Cell Biol.*, vol. 25, no. 2, pp. 2053–2061, 2021, [Online]. Available: https://www.annalsofrscb.ro/index.php/journal/article/view/1150

[11] J. H. Wibowo, H. G. Ariswati, I. D. Gede, H. Wisana, and S. Misra, “Analysis of Heart Rate and Body Temperature Data Retrieval in

Smartband Design with Android Applications Using the Multiplexing Method," *J. Teknokes*, vol. 16, no. 1, pp. 7–13, 2023.
[12] A. Zaky, P. C. Nugraha, and A. Pudji, "Bed Measuring Estimate Blood Volume and Cardiac Output With TFT Display Equipped With Data Storage (SpO 2 and BPM)," *Indones. J. Electron. Electromed. Eng. Med. Informatics*, vol. 2, no. 1, pp. 6–12, 2020, doi: 10.35882/ijeeemi.v2i1.2.
[13] Y. Devis, Y. Irawan, Junadhi, F. Zoromi, Herianto, and M. R. Amartha, "Monitoring System of Heart Rate, Temperature and Infusion in Patients Based on Microcontroller (Arduino Uno)," *J. Phys. Conf. Ser.*, vol. 1845, no. 1, 2021, doi: 10.1088/1742-6596/1845/1/012069.
[14] K. T. Douglas, T. T. James, and K. H. Jennifer, "Implementation of Heart-Rate and Pulse Oximetry Monitoring Device With Wireless Temperature Sensor," *Int. J. Acad. Eng. Res. Theory (IJAERT*, vol. 1, no. 1, pp. 1–7, 2021, [Online]. Available: http://perfectengineeringassociates.comhttp//ijari.org.ng
[15] M. A. Mohd Takiyuddin, I. H. Abd Halim, T. R. Razak, and M. F. Mohd Fuzi, "Remote Patient Monitoring System For Covid-19 Patient Using Wi-Fi-Based Pulse Oximeter Reading Sensor," *J. Comput. Res. Innov.*, vol. 7, no. 2, pp. 101–110, 2022, doi: 10.24191/jcrinn.v7i2.290.
[16] A. Abu Bakar, S. S. A. Rahim, A. R. Razali, E. Noorsal, R. Radzali, and A. F. Abd Rahim, "Wearable Heart Rate and Body Temperature Monitoring Device for Healthcare," *J. Phys. Conf. Ser.*, vol. 1535, no. 1, 2020, doi: 10.1088/1742-6596/1535/1/012002.
[17] S. Syaifudin, T. Triwiyanto, D. A. Harditamara, and F. Masood, "Pulse Oximeter Design for SpO2 and BPM Recording on External Memory to Support the Covid-19 Diagnosis," *J. Teknokes*, vol. 15, no. 3, pp. 147–153, 2022, doi: 10.35882/teknokes.v15i3.303.
[18] A. A. Pathare, D. B. Kshirsagar, S. G. Wadekar, and M. N. S. Deshmukh, "SMART I ROBOT FOR HEALTHCARE SYSTEM BY USING SW FRAMEWORK AND IOT," *Int. J. Res. Appl. Sci. Eng. Technol.*, no. 05, pp. 2862–2867, 2023.
[19] N. Venu and S. R. Allanki, "INTERNET OF THINGS BASED PULSE OXIMETER FOR HEALTH MONITORING INTERNET OF THINGS BASED PULSE OXIMETER FOR HEALTH," *Int. J. Acad. Eng. Res. Theory (IJAERT*, no. October, 2022, doi: 10.14704/NQ.2022.20.5.NQ22781.
[20] I. K. Hanoon and M. I. Aal-Nouman, "Cloud-based COVID-19 Patient Monitoring using Arduino," *3rd 2021 East Indones. Conf. Comput. Inf. Technol. EIConCIT 2021*, pp. 292–296, 2021, doi: 10.1109/EIConCIT50028.2021.9431881.
[21] P. Jahnavi, B. S. Krishna, K. L. Shanmuk, and Y. Chakrapani, "COVID-19 VENTILATOR AND HEALTH MONITORING DEVICE," *Int. J. Res. Appl. Sci. Eng. Technol.*, no. 06, pp. 5464–5468, 2022.
[22] R.Yoganapriya, P.Deepthi, and M.Dhinakaran, "IoT Based Covid Patient Health Monitoring System," *Int. J. Eng. Technol. Manag. Sci.*, vol. 7, no. 1, pp. 82–87, 2023, doi: 10.46647/ijetms.2023.v07i01.015.
[23] B. Lucas, A. Mahamuni, V. Kulal, A. Gupta, and K. Deorukhkar, "Affordable Real-Time Heart Rate, ECG & SpO2 Monitoring System Using Internet of Things (IoT)," *Int. J. Res. Appl. Sci. Eng. Technol.*, vol. 10, no. 11, pp. 1852–1858, 2022, doi: 10.22214/ijraset.2022.47731.
[24] D. B. Ellebrecht, D. Gola, and M. Kaschwich, "Evaluation of a Wearable in-Ear Sensor for Temperature and Heart Rate Monitoring: A Pilot Study," *J. Med. Syst.*, vol. 46, no. 12, 2022, doi: 10.1007/s10916-022-01872-6.
[25] A. N. Costrada, A. G. Arifah, I. D. Putri, I. K. A. Sara Sawita, H. Harmadi, and M. Djamal, "Design of Heart Rate, Oxygen Saturation, and Temperature Monitoring System for Covid-19 Patient Based on Internet of Things (IoT)," *J. Ilmu Fis. | Univ. Andalas*, vol. 14, no. 1, pp. 54–63, 2022, doi: 10.25077/jif.14.1.54-63.2022.