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.v16i4.615

How to cite: Navira Anggraini, Bambang Guruh Irianto, I Dewa Gede Hari Wisana, Triwiyanto and Ashish Kumbhare, "Monitoring SpO2, Heart Rate, and Body Temperature on Smartband with Data Sending Use IoT Displayed on Android ", Jurnal Teknokes , vol. 16, no. 4, pp. 200-207, December. 2023.

Monitoring SpO2, Heart Rate, and Body Temperature on Smartband with Data Sending Use IoT Displayed on Android

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

ABSTRACT The patient's health must not deteriorate if treatment is not started right away if they show indications of a disease. Monitoring is the most important thing that needs to be done to ascertain the patient's state, especially for those with lung illness who have asthma and pneumonia with moderate symptoms. SpO2, BPM, and body temperature are vital signs that can be used as indicators of a person's degree of health. The main goal of this project was to create wearable devices index finger then a wrist-worn devices that can measure SpO2, Heart rate, and body temperature in real time, regardless of distance, and alert users' smartphones when a patient's condition is abnormal. The body temperature is measured using the MLX90614 sensor, positioned on the wrist, whereas the Oxygen saturation and Heart rate are measured with MAX30100 sensor, placed on the index finger. The ESP32 Microcontroller processes the sensor data after which the results are displayed on the TFT Display GC9A01 and to Ubidots application on a smartphone or computer. When the SpO2, BPM, and Temperature values drop below the predetermined range, Ubidots sends an alert message to the associated email address on the smartphone or computer. In comparison to BPM, which had the lowest error is 0.06% and highest at 5.65%, and temperature, which had the least error value of 0.1% and the most 0.88%, SpO2 had the lowest error is 0.2% and biggest error at 1.6%. MAX30100 sensor, which serves as a processor for SpO2 and Heart rate values on the index finger, delivers a good response when utilized by respondents, according to the smart band's manufacturer. The results of data measurement can also be shown on LCD TFT GC9A01 and Ubidots applications. This device will be kept in a hospital, clinic, or utilized on its own at home. Additionally, regardless of the distance, this application is anticipated to assist families or medical personnel in keeping track of the health of senior patients.

INDEX TERMS Smartband, Ubidots, MAX30100, SpO2, LCD TFT GC9A01

I. INTRODUCTION

Monitoring patients is a crucial element of the healthcare system, serving as a vital aspect of both hospital and home-based care [1]. If a patient exhibits symptoms of an illness, prompt action must be done to ensure that the patient's health doesn't deteriorate [2][3]. One method of keeping track of the patient's healthy is the vital signs examination [4][5]. The human body has many vital signs that reveal extremely important functions, including heart rate, body temperature, oxygen saturation, blood pressure, and respiratory rate [6] . On this occasion, three of them will be discussed important signs that can be a parameter of health level are heart rate, oxygen saturation, and body temperature. The normal heart rates for adults usually fall within the range of 60 to 100 beats per minute. A normal heart rate might aid in the transportation of oxygen throughout the body. SpO2 (oxygen saturation) is a health indicator that measures the amount of oxygen in the bloodstream [7]. This medical examination is necessary to determine whether or not a person's condition is deficient in oxygen, anemia, pneumonia, anemia, apnea, and heart failure patients can benefit greatly from Covid-19. [8][9]. Normal oxygen saturation is between 95% - 100%, if the oxygen saturation level is below 94% then it is called hypoxemia [10]. Even when ambient factors alter, a healthy body can maintain a steady body temperature [11]. A patient's average body temperature determines how quickly their heart pumps blood throughout their body, which means that even a small fluctuation in body temperature can severely damage cardiac function [4]. In COPD patients, respiratory problems will occur which will be more frequent, when lung function worsens and the disease progresses, the risk of hypoxia will also increase, one of the symptoms of hypoxia is shortness of breath and faster heart rate [12]. Hypoxemia occurs due to airflow limitation due to narrowing of the airways, as a result the supply of oxygen entering the tissues is disrupted and the blood in the arteries is deprived of oxygen resulting in a decrease in oxygen saturation[13]. A person is said to be suffering from hypoxemia if the oxygen saturation in the blood is less than 90%, while someone is said to have a normal SpO2 if they have a SpO2 percentage of 95-100%[14]. In COPD patients with hypoxemia, it is recommended to monitor oxygen saturation continuously so that when oxygen desaturation occurs it can be immediately known [15].

Therefore, an oxygen saturation monitoring tool is needed for patients with COPD, heart disorders, and sleep apnea (not breathing during sleep) to see whether the distribution of oxygen to the body's tissues is still in a pretty good condition [16]. As well as tools that are easy to install and operate because most COPD sufferers are elderly patients, namely >40 years. This monitoring utilizes IoT (Internet of Things), which is a network connecting a network of various objects that have the same IP (Internet Protocol) address and identity, so they can communicate and exchange information [17]. It is envisaged that this method will enable the patient's family to monitor their condition and their vital signs for 24 hours while they are away from the treatment area [18][19]. By using an IoT platform called Ubidots, Ubidots has SMS and email notification services with triggers that are created based on sensor data that the user previously set [3]. Apart from notifications, monitoring can also be done anywhere and at any time without any distance apart so that doctors or nurses do not need to directly supervise patients all the time. The doctor or nurse can easily view the patient's result measurement parameters simply utilizing a cellphone [20][21].

In a previous study by Milad Mizher Rahma from the Iraqi Computer Informatics Authority Department of Computer Science Information Institute for Higher Studies the title "A Wearable Medical Monitoring And Alert System Of Covid-19 Patients" This tool makes use of the DS18B20 temperature sensor, whose sensor readings are still affected by the temperature around the sensor, and displays the heart rate and body temperature values from patients provided with delivery notifications on the selected IoT applications if conditions are abnormal. [22] . In the same year, Tito Alberto Nuncira Gacharna from Colombia. made a device entitled “Development of Smartband to Monitor from Home the Vital Signs for Patients with Sars Cov 2 Through A Mobile Application from The Central Military Hospital (Homil) Bogota 2020.” Nevertheless, this instrument retains its limitations, as its transmission is confined to Bluetooth, capable of solely transferring information to Android devices within a maximum range of 46.5 meters. Furthermore, the size of the wristband remains somewhat large due to its continued utilization of a character LCD screen [10]. After that, Pandu Arsy Filonanda from the Electromedical Engineering department improved it in 2021 under the name Smartband Monitoring of BPM and Temperature on Wrist Shows Android. The tool is currently utilizing the LCD of the ESP32 TTGO T-Display, to display BPM utilizing SEN0203 and MAX86141 sensors. This tool's objective is to assist medical professionals or patient families in identifying early COVID-19 signs, monitoring continually, and minimizing direct patient interaction [4].

The authors found several weaknesses in previous research, so they will finish the smart band parameters. Therefore, in this research Monitoring SpO2, BPM, and Temperature on Smartband with Data Sending Using IoT Display Android. The purpose from the research was to develop a wrist monitoring device that can track oxygen saturation, body temperature, and heart rate in real time and from a distance. The Ubidots app can be used to monitor this device afterwards, and it will be linked to an email in order to notify nurses or the family of patients if anything is out of the ordinary. So, the purpose of the research is to developing innovative monitoring tools for vital body conditions to determine whether a person is experiencing normal or abnormal body conditions. Checking a condition of patients at clinics, health centers, or hospitals still require patients to reach places that are sometimes far apart. This ineffectiveness is felt especially in the elderly who need companions such as family for examinations. In addition, elderly patients often forget the results of examinations of vital body conditions, moreover the results of examinations cannot be monitored regularly.

II. METHOD

The SpO2 Simulator was used as a calibrator for this study, which was carried out at the Department of Electromedical Engineering, Diagnostic Laboratory, Health Polytechnic Ministry of Health Surabaya. A pre-experimental After Only Design research design was used to construct the module. Within this configuration, a control group has indeed been established; however, the researcher solely employs a single experimental group. This group is observed for outcomes devoid of quantitative assessment or acknowledgment of the initial conditions.

The independent variable in the module is blood oxygen saturation, because it is not controlled and depends on other circuits. The dependent variable is a variable that can change due to the influence of the independent variables. The MAX30100 sensor is the module in question, and it functions by detecting the blood's oxygen saturation level. The controlled variable in module is the IoT-based measurement results (*Internet of Things)*, because it is controlled and controlled by the ESP32 microcontroller board.

computed. These measurements will be shown as numbers on the TFT Display 1.28inch LCD Module RGB 240x240 GC9A01 and simultaneously relayed via Wi-Fi to the Ubidots app that is loaded on the patient's smartphone. The smartphone's Ubidots application will provide notifications and monitoring information. If on the patient's body is found to be inaccurate or the oxygen saturation level drops below 95%, an email notification will be sent to the designated nurse or doctor.

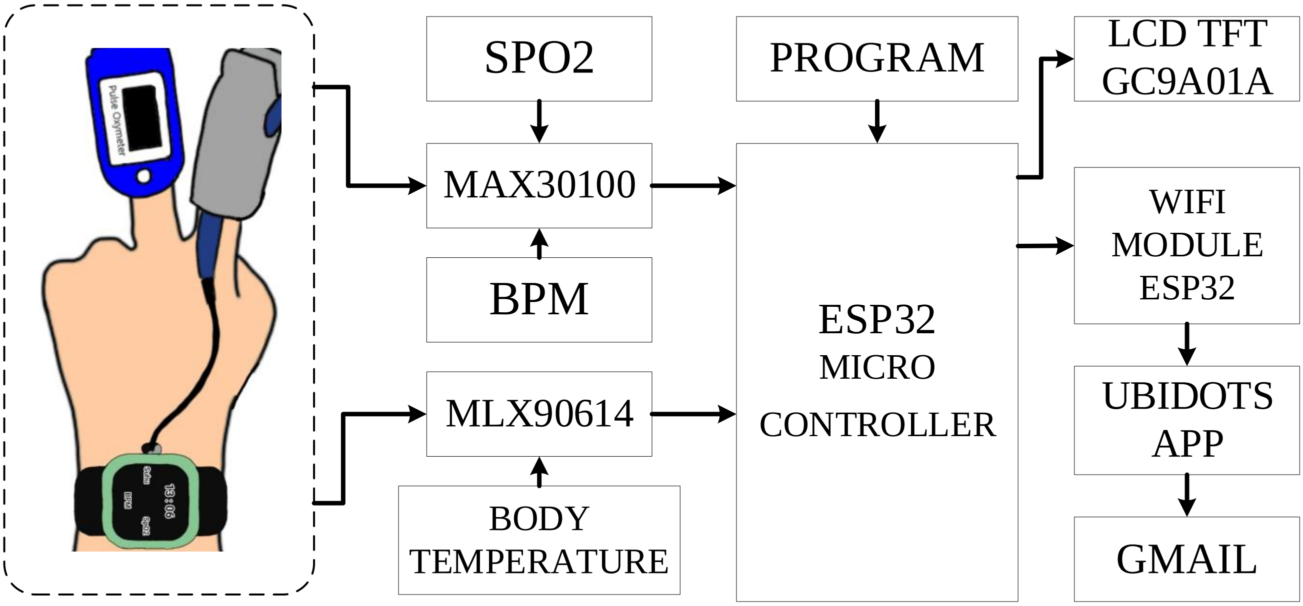

FIGURE 1. Smart band system block diagram for research using the MAX30100 and MLX90614 sensors

This sentence explains FIGURE 1 when the patient wears the Smart band and presses the on/off switch, the system activates. The patient's wrist is fitted with a smart band that has MAX30100 and MLX90614 sensors. The reading outcomes from the MAX30100 and MLX90614 sensors will then be processed by the ESP32 microcontroller. Then SpO2, BPM, and Body Temperature values will be shown on the TFT Display 1.28inch LCD Module RGB 240x240 GC9A01. The data will subsequently be transmitted over Wi-Fi from the ESP32 to the Ubidots application, which is loaded on patients' smartphones. The Ubidots application will send notifications and messages in the form of monitoring results of SpO2, BPM, and Body Temperature to the registered nurse or doctor's email to take further action if the results of monitoring parameters on the patient's body don't match with the normal range.

Refer to FIGURE 2 After pressing the start button, the initialization procedure starts. While the MAX30100 sensor measures heart rate and oxygen saturation, the MLX90614 sensor measures body temperature. The ESP32 microcontroller will proceed to process the data after that, Additionally, the data measurements of parameters will be

A. DATA ANALYSIS

Data collection for the parameter SpO2 will be done on 10 respondents, and everything will be performed five times. The measurement's mean or average is used to calculate its average value by using Eq. (1). The mean is computed by dividing the sum of all values by the overall data count within the collection:

$$\overline{x} = \frac{x1+x2...+xn}{n} \tag{1}$$

In this context, x1 denotes the initial measurement, x2 represents the subsequent measurement, and Xn signifies a collection of n measurements. x represents the mean (mean) for the n-measurements. Standard deviation is a measurement of the standard deviation of the mean or a number that represents the amount of variance in a set of data. The formula for standard deviation (SD) can be seen in Eq. (2):

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

In this scenario, n represents the quantity of measurements, xi corresponds to the desired values counted, and x stands for the mean of the measurement outcomes. A doubt known as uncertainty (UA) can be seen in each

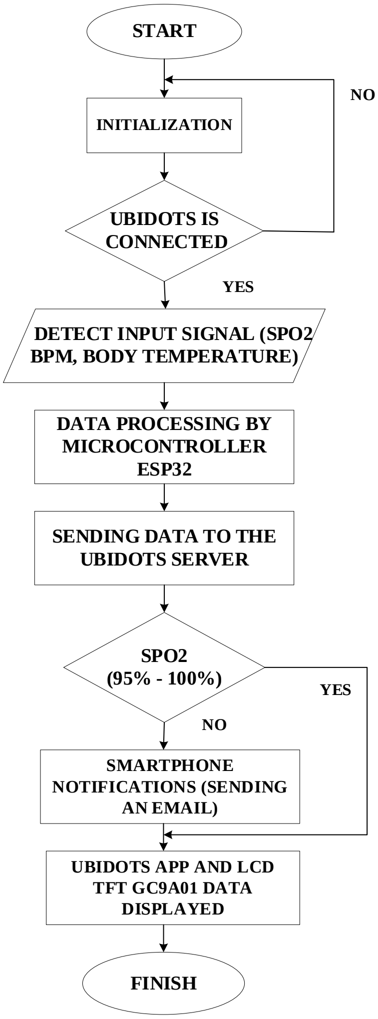

FIGURE 2. The system flowchart on the Smartband

measurement's outcome [23][24][25]. In Eq. (3), the uncertainty formula is displayed:

$$UA = \frac{SD}{\sqrt{n}} \tag{3}$$

where n represent the quantity of measurements, SD is the total measurement's standard deviation, and UA denotes the measurement's overall level of uncertainty. A system error is indicated by % error. The average difference between each data point is the lower Error value. Errors might be a symptom that the design or model deviates from the standard. In Eq. (4), the error formula is displayed.

$$\%ERROR = \frac{(x_n - x)}{x_n} \times 100\% \tag{4}$$

where Xn is the machine calibrator's measured value. X is the design's measured value.

III. RESULT

A digital thermometer and a pulse oximeter were used in this study's direct testing of the module. FIGURE 3 and FIGURE 4 Microcontroller ESP32, a battery lithium, an LCD TFT circuit, and a sensor configuration make up the microcontroller circuit. The power supply circuit incorporates a lithium battery, which will be connected to a voltage-up module.

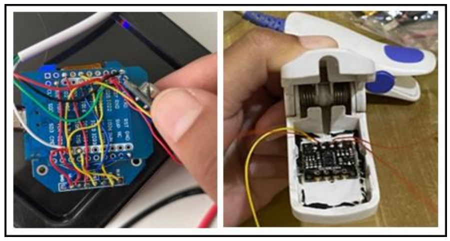

FIGURE 3 Smart band module display with oxygen saturation, heart rate, and body temperature

FIGURE 4. Smart band Module Design with MAX30100 Sensor and MLX90614 Sensor and using LCD TFT 1.28inch GC9A01A

The digital part of the device is composed of the main board, the ESP32 microcontroller, the MAX30100 Heart rate and Oxygen saturation sensor, MLX90614 as a noncontact body temperature sensor. According to the study's findings, when used by respondents, MAX30100 sensor, which serves act as processor for SpO2 and Heart rate data, reads with a good response. 10 Respondents had their data collected five times, each time with a 10-second delay. Data of SpO2 had minimum error is 0.2% and the greatest error is 1.6%, according to the findings of comparing the MAX30100 module's accuracy to a comparator for pulse oximeters. The steps for testing module on respondent:

1. Respondents use the smart band module in accordance with the SOP for using the tool.
2. Responses were compared using a pulse oximeter on the middle finger and the module on the forefinger.

3. Each Respondent will collect data 5 times with an interval of 10 seconds for SpO2 data collection.
4. After a ten-second interval, this module will exhibit the SpO2 measurements and then compare them to the readings reported by the fingertip pulse oximeter.

TABLE 1
Data measurements of SpO2 on smart band module

Respondent	Mean (%)	STD	Error SpO2 (%)
Respondent 1	97	0	0.4
Respondent 2	98.6	0.54	0.2
Respondent 3	99.8	0.44	0.8
Respondent 4	99	0	1
Respondent 5	98.6	0.89	1.2
Respondent 6	97.4	1.14	0.4
Respondent 7	99.6	0.54	1.6
Respondent 8	98.8	0.44	1.6
Respondent 9	97.4	0.54	0.8
Respondent 10	97.4	0.54	0.4

The module produced an average of 97% to 99.6% when SpO2 data from 10 Respondents were collected using as many as 5 data pickups at intervals of 10 seconds, as shown in TABLE 1. Given that these data showed that SpO2 had the minimum value error was 0.2% and maximum value error was 1.6%, the error value can be linked to the patient's movement.

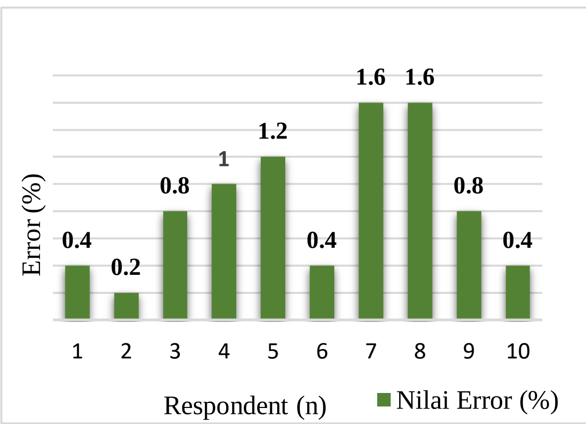

FIGURE 5. **Graph of the error value of SpO2 from average on 10 Respondents.**

Based on these data results shown at FIGURE 5, The overall quality of the smart band can be inferred as satisfactory based on the cumulative error value it produces. Just that the seventh and eighth measurements of SpO2 had two really big errors, the error value is 1.6%, however, this inaccuracy may differ from that of other individuals and may be brought on by patient movement, variances in posture during data collection, and the state of the patient's hands during the monitoring procedure.

TABLE 2
Data measurements of SpO2 on pulse oximeter

Respondent	Mean (%)	STD	Error SpO2 (%)
Respondent 1	97.4	0.54	0.4
Respondent 2	98.8	0.44	0.2
Respondent 3	99	0	0.8
Respondent 4	98	0	1
Respondent 5	97.4	0.89	1.2
Respondent 6	97	0	0.4
Respondent 7	98	0	1.6
Respondent 8	97.2	0.44	1.6
Respondent 9	96.6	0.54	0.8
Respondent 10	97	0	0.4

The error in this study's module with units is the difference between its measured value and its actual value. The collection of SpO2 data from 10 Respondents was carried out as many as 5 data collections with intervals of 10 seconds using the module yielded an average of 96.6% - 99%, as shown in TABLE 2. Based on these data, SpO2 had the smallest value error was 0.2% and biggest value error was 1.6%. These patient's mobility, variations in location during data collection, and the state of the patient's hands during the monitoring procedure can all contribute to the error.

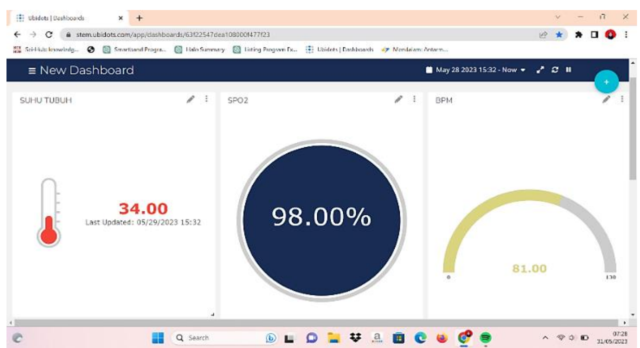

FIGURE 6 **Displaying data value of monitoring on Ubidots application**

FIGURE 6 illustrates how the outcomes of this monitoring are shown in the Ubidots application, where parameters of smart band monitoring. The Ubidots application has the benefit of having appealing graphics and being simple to use. Ubidots also has real-time and raw data visual so that make an easier for doctor and nurse to know how the condition of patient healthy. Besides that, Ubidots also provides notification facilities in the form of email, telegram, SMS, and even though voice calls. At least, Ubidots can installed on smartphone or open the website on the pc so because that many reasons we choose this application.

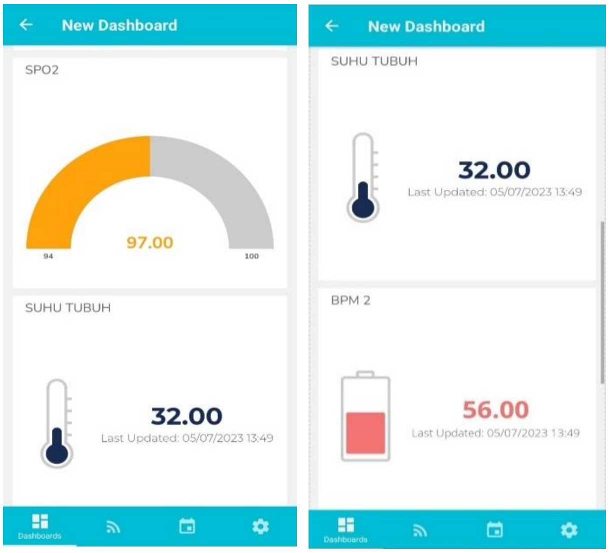

FIGURE 7 Displaying data value of monitoring on Ubidots application at Smartphone

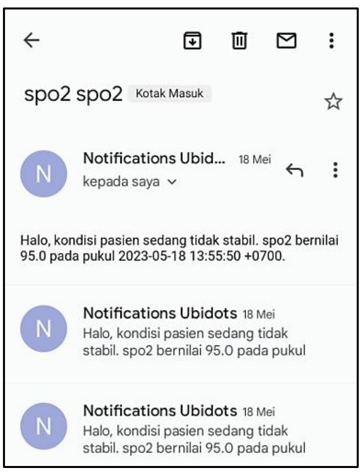

FIGURE 8 Displaying data value of monitoring if the measurement abnormal, then ubidots will send the email to smartphone

FIGURE 8 is a notification display in the form of an email on a smartphone. This notification will appear 1 minute after the smartband detects parameters with abnormal results. For setting the range of parameter values found in the ubidots application, so there is no need to add new programs into coding.

IV. DISCUSSION

According to the research findings, the MAX30100, which works as a sensor for SpO2 and Heart Rate measurements on the index finger, provides a decent reaction when utilized by respondents. Data was collected on 10 respondents, 5 times each respondent with a 10-second interval. The SpO2 data had this lowest error is 0.2% and greatest error is 1.6%, according to the findings of assessing the accuracy from the MAX30100 module against a pulse oximeter comparator. The erroneous value can be produced by the patient's mobility, changes in position during data collection, and the patient's hands' state during the monitoring process.

In a previous study by Milad Mizher Rahma from the Institute for Higher Studies Iraqi Computer Informatics Authority, Iraq the title "A Wearable Medical Monitoring And Alert System Of Covid-19 Patients" This tool makes use of the DS18B20 temperature sensor, whose sensor readings are still affected by the temperature around the sensor, and displays the heart rate and body temperature values from patients equipped with delivery notifications on the selected IoT applications if conditions are abnormal [22]. In the same year, Tito Alberto Nuncira Gacharna from Colombia. made a device entitled “Development of Smartband to Monitor from Home the Vital Signs for Patients with Sars Cov 2 Through A Mobile Application from The Central Military Hospital (Homil) Bogota 2020.” Nevertheless, this instrument retains its limitations, as its transmission is confined to Bluetooth, capable of solely transferring information to Android devices within a maximum range of 46.5 meters. Furthermore, the size of the wristband remains somewhat large due to its continued utilization of a character LCD screen [10]. After that, Pandu Arsy Filonanda from the Electromedical Engineering department improved it in 2021 under the name Smart band Monitoring of BPM and Temperature on Wrist Shows Android. This LCD from the Microcontroller ESP32 TTGO T-Display is already used by this tool to display BPM utilizing the SEN0203 and MAX86141 sensors. This tool's objective is to assist medical professionals or patient families in identifying early COVID-19 signs, monitoring continually, and minimizing direct patient interaction [4].

However, this inaccuracy may differ from that of other individuals and may be brought on by patient movement, variances in posture during data collection, and the state of the patient's hands during the monitoring procedure. The measurement results on the module lack visuals, the MAX30100 sensor is still on the index finger, and the size of the box is still too large, causing the measurement value to fluctuate whenever the patient's wrist moves, according to an analysis of the instrument. This study has many weaknesses where this thing can make a development in future for the next research. Among them is the smart band hasn’t data measurement of monitoring in graphical form, there is a box that connects to the index finger and the need to use a more accurate sensor when placed on the wrist, and the size of the box is too large.

This device will be kept in a hospital, clinic, or utilized on its own at home. Additionally, regardless of the distance, this application is anticipated to assist families or medical personnel in keeping track of the health of senior patients. So, the research can be improved by adding measurement findings in graphical form, doing away with the case that connects to the index finger in favor of a more precise sensor that is worn on the wrist, and once again shrinking the box size.

V. CONCLUSION

This study's goal was to create a SpO2 monitoring smart band with an ESP32 microcontroller, LCD TFT GC9A01, and Internet of Things-based data transmission. After making the SpO2 Monitoring tool, BPM, and Temperature on Smart band by sending data using IOT android display it can be concluded that:

In this smart band, the series of modules that have been made consist of several parts, namely the ESP32, MAX30100, and TFT LCD circuits. The MAX30100 circuit functions to detect SpO2 and BPM values on the index finger. ESP32 functions as a microcontroller (data processing) and module*WiFi*. Finally, there is a series of LCDs, where the LCD is used, namely LCD TFT 1.28 inch.

For MAX30100 Sensor readings, there is a program that functions to obtain SpO2 data from the sensor by processing the ADC value generated by the RED LED and IR LED. Meanwhile, to display data to the LCD there is a program that functions to display monitoring results on the LCD, arrange the design, position, and color of the letters on the display. In order for the device to connect with Ubidots, there is a program that functions to initialize communication with the server, connect the device to a Wi-Fi network, publish data to Ubidots, and process communication with the Ubidots server repeatedly while the microcontroller is still running.

According to the study's findings, when respondents utilize the MAX30100, which serves as a processor for SpO2 and heart rate information, it responds well. Data collection was carried out on 10 Respondentts 5 times per Respondentt with an interval of 10 seconds. The MAX30100 module's accuracy was compared to the SpO2 data gathered from a comparator pulse oxymeter, and the results show that the minimum value error was 0.2% and the maximum value error was 1.6%.

The research can be improved by adding measurement findings in graphical form, doing away with the case that connects to the index finger in favor of a more precise sensor that is worn on the wrist, and once again shrinking the box size.

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