Vital Signs Monitoring Bracelet: IoT-Based Solution for Heart Rate, Blood Oxygen, and Body Temperature

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***Abstract*– The failure to promptly identify critical health conditions through vital sign monitoring can result in fatalities within the healthcare sector. Vital signs, including heart rate, blood oxygen levels and body temperature, are of paramount importance in the assessment of a patient's health status and the guidance of subsequent medical interventions. However, traditional vital signs monitoring techniques are constrained by mobility and reliance on bulky and costly equipment. To address these challenges, remote sensor readings supported by internet technology can enhance the capabilities of doctors in terms of monitoring. However, the Ministry of Communication and Information in Indonesia has highlighted that a significant number of healthcare facilities in the country face challenges in terms of internet access. In order to overcome these connectivity challenges, a study proposes the deployment of Internet of Things (IoT)-based health monitoring wristbands named SMBRONO (Smart Bracelet Monitoring). The aforementioned wristbands are capable of remotely tracking vital signs and, in the absence of an internet connection, transmitting sensor data to a designated website via LoRa (Long Range) technology. This solution offers a remote monitoring system for health applications, offering a longer transmission distance and a lower cost than other options such as Wi-Fi or Bluetooth. This technology ensures the uninterrupted transfer of data over extended distances, thereby enabling patients to move freely without the need for constant connectivity to large devices. This innovation has the potential to enhance remote patient monitoring in regions with constrained internet availability.**

***Keywords*– health, monitoring bracelet, website, sensor**

I. Introduction

Recently, death cases have often occurred in the health or medical sector. One of them is the delay in knowing the condition of a person's body. We can determine the condition of a person's body with various sensors. To determine the condition of the body in the health sector, we can use heart rate variables and oxygen levels in the blood. These two variables are very important to monitor because they can indicate a person's health condition. However, the monitoring methods currently used often have limitations, such as a lack of mobility and dependence on large and expensive equipment [1]. To make monitoring easier for doctors, technology is needed to view sensor reading results remotely, such as on the internet.

However, there are still some hospitals that do not have internet access. According to Kominfo, as of October 2020, there were 3,126 hospitals and 10,133 hospitals and health centres in Indonesia that did not have internet access. This is an obstacle to reaching patients from a distance. [2].

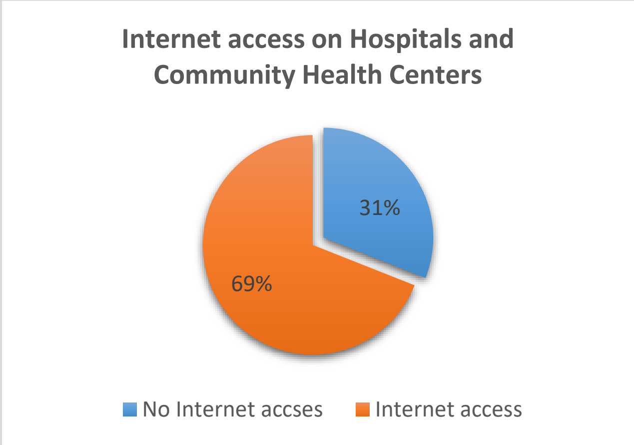

Fig. 1. Data on Hospitals and Community Health Centers Without Internet Access

In health monitoring it is very important to be connected to network applications. Continuity with the network must be guaranteed for data transmission over long distances. It also allows the patient to move freely without being constantly connected to a large device or having their mobility limited [3][4] .

In the previously utilised monitoring system, patients were obliged to attend the hospital in person. In some cases, the patient's condition precluded their ability to reach the health centre promptly. However, the integration of heart rate monitoring and blood oxygen levels with the website through this health bracelet provides patients and doctors with a more convenient means of monitoring health conditions. Patients can monitor their health conditions independently and convey the data to doctors for analysis, while doctors can monitor in real time and provide appropriate advice or instructions. This is closely related to the ease of Internet of Things technology.[5][6].

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Therefore, a heart rate and blood oxygen level monitoring system was developed that can be integrated with websites. With this system, it is hoped that it can increase the efficiency and effectiveness of monitoring a person's health condition and provide wider access for patients and doctors to control health conditions[7][8].

II. Methodology

In carrying out research, researchers arrange the stages carried out to achieve research objectives. The preparation of the research stages can be seen in the form of a flowchart as follows.

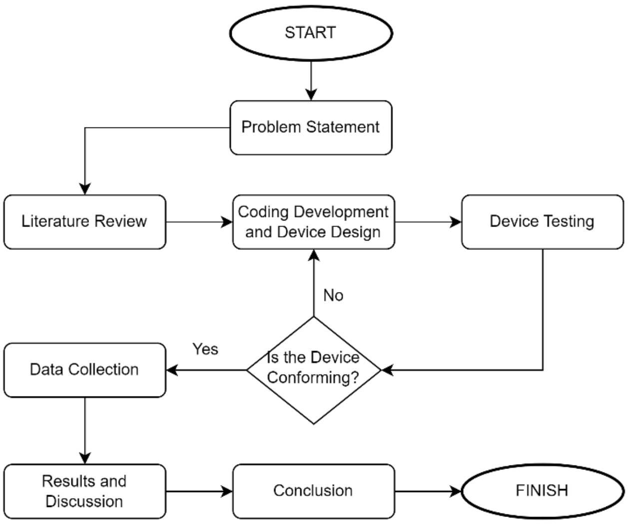

Fig. 2. Data on Hospitals and Community Health Centers Without Internet Access

Based on the Figure 2 above, the first stage is the initial stage of research, which aims to determine the problem or problems that will be solved by the researcher. The second stage is the literature study stage, researchers search for information and data through available sources such as scientific journals, books, or articles related to the research topic being conducted. The third stage is making programs and designing tools. This stage involves creating a program and designing tools that will be used to answer the problem formulation that has been determined. After the program and tools have been created, the next stage is to test the tools that have been created. This testing aims to ensure that the tool or system created functions properly and meets the stated objectives. After the tool or system is tested and declared to be functioning well, the final stage is to collect data. Data collection is carried out to collect information and data needed to answer the problem formulation and research objectives that have been set. Data collection includes heart rate variables in BPM units and blood oxygen levels (SpO2) in percent units (%) with the MAX30100 sensor and ESP32 microcontroller as controllers[9]. Then the sensor reading results will be sent to the Thingspeak platform as a database.[10]

III. Result And Discusiion

A. Program Algorithm

In order to create an electrical circuit for the Website Integrated IoT Health Monitoring Bracelet along with the bracelet and component box, researchers have created a program (coding) for this tool using the Arduino IDE in the C++ language. The program algorithm (coding) can be seen in the following flowchart.[11]

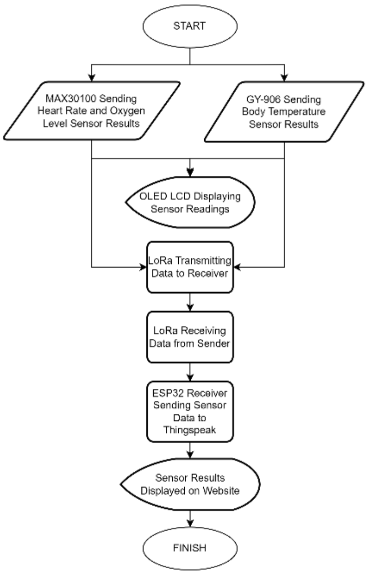

Fig. 3. Alogrithm flowchart

The programming algorithm in this tool is that the ESP32 first reads the MAX30100 and GY906 sensors, the results of which are heart rate variables in bpm units, blood oxygen levels in percent units, and body temperature in Celsius units. The sensor reading results are sent from the 'Sender' to the 'Receiver'. After the sensor reading results sends the data to the ESP32, which will then be forwarded to Thingspeak via the Internet. Thingspeak receives the sensor reading results and stores them in graphic form. These graphics will later be sent to the application and website so that we can view the application and website online.[12]

B. Circuit Schematics and Wiring

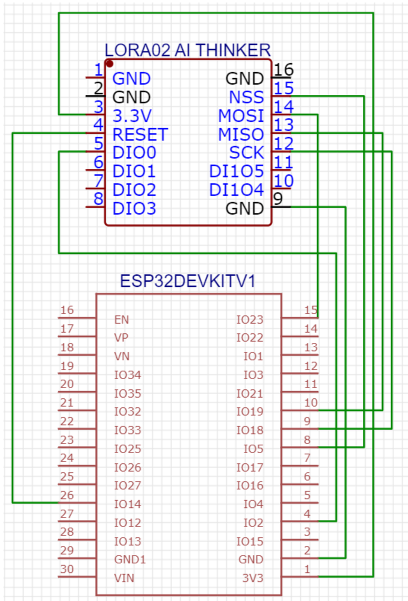

Fig. 4. Receiver Cricuit Scematic

In this circuit schematic, there are only two important components of this receiver, namely the LoRa Ra02 Ai Thinker module and the ESP32 microcontroller. This LoRa module uses SPI (Serial Peripheral Interface) communication with a microcontroller. With this communication, the LoRa module connects the 3.3V, GND, MOSI, MISO, NSS, and SCK pins. The important pins on LoRa are NSS, which functions for SPI Chip Select, MOSI, as SPI Data Input, MISO, as SPI Data Output, SCK, which functions for SPI Clock, RST, for Reset, and DIO0 for Digital I/O. The wiring can be seen in the figure 4.

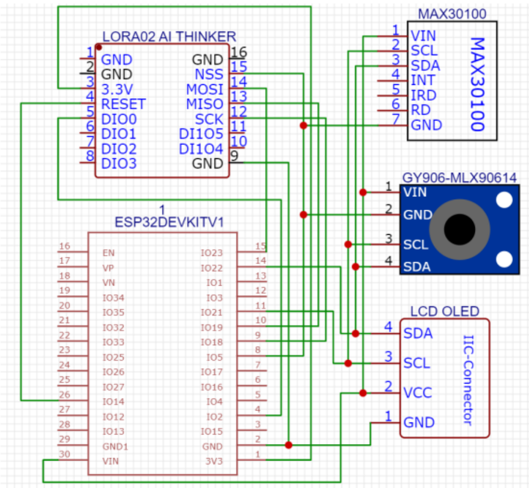

Fig. 5. Sender Cicruit Scematic

In this circuit schematic, there are only three important components of this sender: the LoRa Ra02 Ai Thinker module, the MAX30100 [13][14] as a sensor for heart rate and blood oxygen levels, the OLED LCD to display sensor reading results directly, and the ESP32 microcontroller. This LoRa module uses SPI (Serial Peripheral Interface) communication with a microcontroller. With this communication, the LoRa module connects the 3.3V, GND, MOSI, MISO, NSS, and SCK pins. The Oled LCD and MAX30100 sensor use I2C communication (SDA and SCL); this I2C communication must connect the SDA and SCL pins on the component with the microcontroller. The wiring can be seen in Figure 5.

C. Hardware and Microcontroller Design

In this study, the hardware called SMBRONO (Smart Bracelet Monitoring) is designed in the form of a bracelet device using electronic components such as the MAX30100 sensor to measure heart rate and blood oxygen levels, the GY906 sensor to measure body temperature, ESP32 is used as a microcontroller. Each component is connected according to the predetermined design. The SMBRONO monitoring bracelet is divided into two, namely the sending device which functions as a meter and sends data, and the receiving device which functions as a data receiver. The following are some images of the results of the hardware design on SMBRONO.

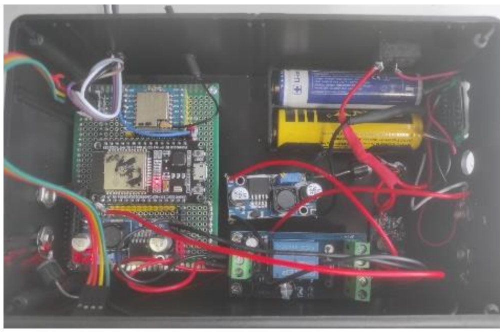

Fig. 6. Appearance of the SMBRONO *Sender Device*

Figure 7 above is the display inside the SMBRONO sender device. This device has components such as a MAX30100 sensor, a GY906 sensor, an ESP32 microcontroller, a LoRa (Long Range) module, and a battery. In use, the sender device is a device used by the patient or user. Apart from that, this device is also supported by an UPS (Uninterruptible Power Supply), which means it can continue to be used even when it is not connected to electricity.

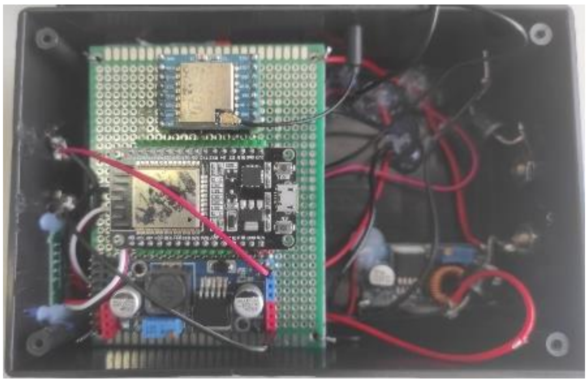

Fig. 7. Appearance of the SMBRONO *Receiver Device*

Figure 8 above is the display inside the SMBRONO receiver device. The receiver device has components such as an ESP32 microcontroller, LoRa module, and battery. In its use, the receiver device is a device used by doctors, nurses, and other medical personnel involved in using SMBRONO. Just like the sender device, the receiver device is also supported by an UPS (Uninterruptible Power Supply), which means this device can continue to be used even when it is not connected to electricity.

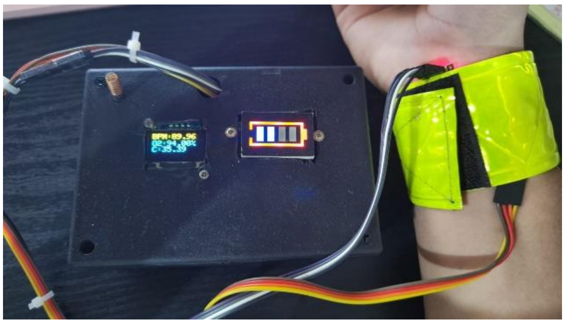

Fig. 8. Display of SMBORNO usage

The image above is a display of SMBORNO on patients or users. The bracelet on the sender device has a

MAX30100 sensor and a GY906 sensor installed; these two sensors function to measure the user's vital information. The sensors on the bracelet will read vital information on the patient's or user's body and then send the sensor data to the sender device, displayed on the OLED layer on the device. The bracelet on SMBRONO can be adjusted according to the circumference of the patient's or user's hand, and then the cable that connects the bracelet to the sender device can be adjusted to the length according to needs.

D. Experiment

The experiment aims to see whether the tool is functioning properly according to its purpose or not. Testing of the tool was carried out to view sensor reading results, send sensor reading results via LoRa Sender, receive sensor reading results via LoRa Receiver, and display sensor reading results on the website. The sensor reading results on the website can certainly be accessed via various electronic devices, such as cellphones and laptops.

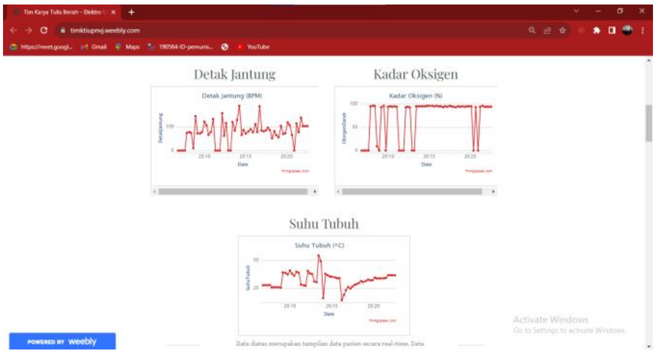

Fig. 9. SMBRONO website

The image above is a display of the SMBORNO website. The test carried out is in the form of data conformity between the sensor reading results and the data displayed on the website. The data displayed is data received and consists of heart rate data (in Beats Per Minute), blood oxygen level data (in percentage), and body temperature (in degrees Celsius). The data displayed on the website will continue to be updated if the tool is used, and the data displayed will also be collected in a database.

On the website, there are three graphs with different variables. The first graph (top left) is a graph displaying data from the MAX30100 sensor readings in the form of heart rate. The Y-axis shows the BPM (Beat Per Minute) of the human body. Meanwhile, the X axis shows the time (in hours) when the BPM was detected. It can be seen on the heart rate graph; it reads BPM 0 at some times. This is because SMBRONO is not used by users.

The second graph (top right) is a graph displaying data from the MAX30100 sensor readings in the form of oxygen saturation in the blood. The Y-axis shows the oxygen saturation in the blood (in percentage). Meanwhile, the X axis shows the time (in hours) when the BPM was detected. It can be seen on the heart rate graph that the oxygen saturation reading is 0 several times. This is because SMBRONO is not used by users.

The third graph (bottom center) is a graph displaying data from the GY906 sensor readings in the form of the user's body temperature. The Y-axis shows the user's body temperature (in degrees Celsius). Meanwhile, the X axis shows the time (in hours) when the BPM was detected. It can be seen on the heart rate graph that the body temperature is below 25 °C several times. This is because SMBRONO is not used by users.

E. Data Collection

Data collection is carried out to determine the health condition of the human body by collecting data on the user's heart rate, blood oxygen levels, and body temperature. Data collection is carried out when SMBORONO is worn on the user's arm and turned on. This data collection aims to determine the level of accuracy of the sensors used, namely the MAX30100 sensor and the GY906 sensor. Sensor accuracy analysis is an important process in assessing the extent to which a sensor can provide accurate and reliable results in measuring certain parameters. The formula used to measure error and accuracy on the sensor is

$$Error = \frac{|measured - real|}{real} x100\% \qquad (1)$$

By using equation (1), we obtained result below.

$$Accuracy = 1 - Error \qquad (2)$$

After looking at the calculations, we can get the accuracy and error values from the MAX30100 and GY906 sensors.

1) Accurate of Heart Rate Variables

In measuring heart rate variables, the measurement results from the MAX30100 sensor are compared with the measuring instrument that is generally used, namely the oximeter. Is carried out by taking 10 data samples when SMBRONO is used on the user's arm. The data taken is the user's heart rate (beats per minute). Table I shows the results of heart rate testing for the object being measured.

TABLE I. MEASUREMENT OF ERROR AND ACCURACY VALUES FOR THE MAX30100 HEART RATE VARIABLE SENSOR

HEART RATE (BPM)					
Trial	(BPM) sensors	Oximeter Measuring Instrument (BPM)	Difference	*Errors* (%)	Accuracy (%)
1	94.9	93	1.9	2.04%	97.96%
2	95.65	93	2.65	2.85%	97.15%
3	94.38	93	1.38	1.48%	98.52%
4	89.28	93	3.72	4.00%	96.00%
5	88.12	94	5.88	6.26%	93.74%
6	92.33	94	1.67	1.78%	98.22%
7	94.42	93	1.42	1.53%	98.47%
8	92.72	93	0.28	0.30%	99.70%
9	95.21	93	2.21	2.38%	97.62%
10	96.87	94	2.87	3.05%	96.95%
Average *error* and accuracy (%)				2.57%	97.43%

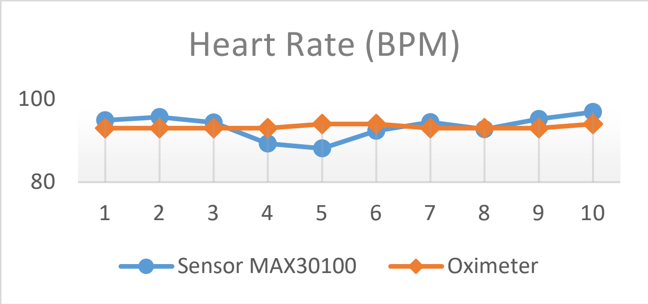

Fig. 10. User's Heart Rate Graph on the MAX30100 Sensor and Oximeter

Based on the calculations carried out, the results obtained were the average error value and the average accuracy value of the MAX30100 sensor in detecting heartbeats in Table I above. The error value on the MAX30100 sensor is the difference between the measured value on the MAX30100 sensor and the measured value on the oximeter measuring instrument of 2.57%. The accuracy value on the MAX30100 sensor is the level of similarity between the measured value on the MAX30100 sensor and the measured value on the oximeter measuring instrument of 97.43%.

2) *Accurate of Oxygen Levels in Blood Variables*

In measuring variable oxygen levels in the blood, the measurement results from the MAX30100 sensor are compared with the measuring instrument that is generally used, namely the oximeter. Is carried out by taking 10 data samples when SMBRONO is used on the user's arm. Table II shows the results of testing blood oxygen levels for the objects being measured.

TABLE II. MEASUREMENT OF ERROR AND ACCURACY VALUES FOR THE MAX30100 HEART RATE VARIABLE SENSOR

Blood Oxygen Levels (SpO2)					
Trial	(SpO2) sensor	Oximeter Measuring Instrument (SpO2)	Difference	*Errors* (%)	Accuracy (%)
1	97	95	2	2.11%	97.89%
2	96	95	1	1.05%	98.95%
3	96	94	2	2.13%	97.87%
4	98	94	4	4.26%	95.74%
5	95	96	1	1.04%	98.96%
6	96	95	1	1.05%	98.95%
7	96	95	1	1.05%	98.95%
8	97	95	2	2.11%	97.89%
9	97	96	1	1.04%	98.96%
10	97	95	2	2.11%	97.89%
Average *error* and accuracy (%)				1.79%	98.21%

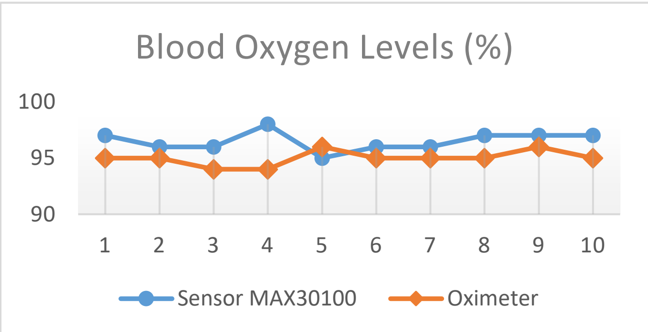

Fig. 11. User's Blood Oxygen Levels Graph on the MAX30100 Sensor and Oximeter

Based on the calculations carried out, the results obtained were the average error value and the average accuracy value of the MAX30100 sensor in detecting blood oxygen levels in Table II above. The error value on the MAX30100 sensor is the difference between the measured value on the MAX30100 sensor and the measured value on the oximeter measuring instrument of 1.79%. The accuracy value on the MAX30100 sensor is the level of similarity between the measured value on the MAX30100 sensor and the measured value on the oximeter measuring instrument of 98.21%.

3) *Accurate of Body Temperature Variables*

In measuring body temperature variables, the measurement results from the GY906 sensor are compared with the measuring instrument that is generally used, namely a thermometer. Is carried out by taking 10 data samples when SMBRONO is used on the user's arm. Table III shows the results of body temperature testing for the object being measured.

TABLE III. MEASUREMENT OF ERROR AND ACCURACY VALUES FOR THE GY906 BODY TEMPERATURE VARIABLE SENSOR

Body Temperature (°C)					
Trial	GY906 sensor (°C)	Thermometer Measuring Instrument (°C)	Difference	*Errors* (%)	Accuracy (%)
1	36.6	36.6	0	0.00%	100.00%
2	36.7	36.4	0.3	0.82%	99.18%
3	36.6	36.5	0.1	0.27%	99.73%
4	36.9	36.6	0.3	0.82%	99.18%
5	36.1	36.6	0.5	1.37%	98.63%
6	36.8	36.6	0.2	0.55%	99.45%
7	35.4	36.6	1,2	3.28%	96.72%
8	35.6	36.7	1.1	3.00%	97.00%
9	35.7	36.6	0.9	2.46%	97.54%
10	35.3	36.5	1,2	3.29%	96.71%
Average *error* and accuracy (%)				1.59%	98.41%

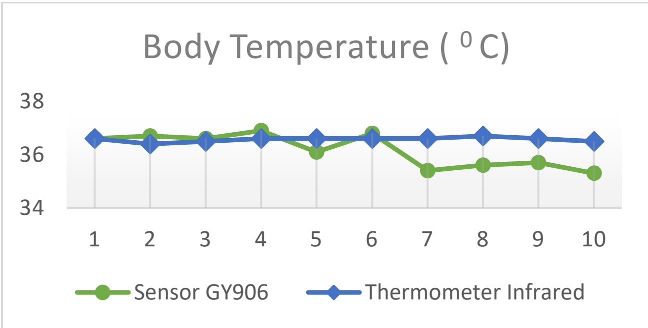

Fig. 12. User's Body Temperature Graph on the MAX30100 Sensor and Oximeter

The results of the calculations are presented in Table 4.6 above. They show the average error value and the average accuracy value of the GY906 sensor in detecting body temperature. The error value for the GY906 sensor is defined as the difference between the measurement value obtained from the GY906 sensor and the measurement value obtained from the thermometer measuring instrument, which was found to be 1.59%. The accuracy value of the GY906 sensor is the level of similarity between the measurement value on the GY906 sensor and the measurement value on the thermometer measuring instrument, which was found to be 98.41%. In this measurement, only the health bracelet device was considered in comparison with the manufacturer's thermometer.

IV. CONCLUSION

In this research, SMBRONO (Smart Bracelet Monitoring) is a tool to facilitate the process of monitoring body conditions remotely. There is a website that functions to display sensor reading data online; there is an OLED LCD on the tool that functions to display sensor reading results directly; and there is a Mini UPS Module (5 Volts) that functions as a backup power supply or energy source for this tool. This tool can facilitate the process of monitoring body conditions, including heart rate, oxygen levels in the blood, and body temperature. The accuracy produced by this tool is very high, with an average percentage accuracy of heart rate of 97.43%, oxygen levels in the blood of 98.21%, and body temperature of 98.41%. The following numbers can be said to be high, and the reading results of this sensor are very accurate. Therefore, this tool is an effective tool for monitoring a person's body condition and can replace other measuring tools.

In all of this research, it can be concluded that SMBRONO (Smart Bracelet Monitoring) Health Monitoring Bracelet Based on IoT Integrated Website is an effective solution for remote health monitoring. This bracelet provides easy access, measurement accuracy, and reliable data communication. The tools in this research have also been well tested, and the results are displayed directly on the website. This research makes an important contribution to the field of innovative health monitoring and has the potential to improve individual health management more effectively.

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