

## Real Time Heart Rate And Oxygen Value Monitoring Using Arduino Uno Based MAX30102 Sensor Module

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| Article Information                                                                                                                                                                                                                   | ABSTRACT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
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| <b>Article History</b><br><br><b>Received</b> : June 18, 2025<br><b>Revised</b> : July 06, 2025<br><b>Published</b> : July 26, 2025<br><br><b>Keywords:</b><br>Arduino;<br>BPM;<br>Real time;<br>Sensor MAX30102;<br>SpO <sub>2</sub> | The development of medical technology has produced efficient and easy-to-use medical devices, such as real-time heart rate and oxygen level monitors using Arduino with MAX 30102 sensors. This tool functions to monitor heart rate and oxygen levels in real time with a high level of accuracy, so it is useful for people with heart rhythm disorders and respiratory disorders such as hypoxemia. The data obtained is processed by the Arduino microcontroller and displayed on the LCD screen, the LED indicator lights up if the results are outside the normal limits. Based on testing, this tool has a low error value of 0.05% for BPM and 0.02 for SpO <sub>2</sub> and an accuracy value of 99.95% for BPM and 99.98% in one person tested, while in 6 different people the error value is 0.63% for BPM and 0.09% for SpO <sub>2</sub> and an accuracy value of 99.37% for BPM and 99.91% for SpO <sub>2</sub> compared to medical standards for different objects. The sensors used are Arduino Uno and MAX30102, which results in more accurate measurements compared to existing device designs. It is hoped that this tool can be a practical solution for routine health monitoring, especially for individuals who need regular monitoring. |

## INTRODUCTION

The heart functions to pump oxygen-rich blood throughout the body; therefore, its performance greatly depends on the stability of oxygen levels in the blood. Disorders such as arrhythmias can hinder blood circulation, reduce oxygen distribution, and lead to hypoxemia a condition where oxygen saturation drops below 90%, posing serious risks to vital organs (Handayani, 2021; Hidayatulah et al., 2015; *Indonesian Lung Association, 2011.Pdf*, n.d.; Pranandito & Hendry, 2023; Purba & Simanullang, 2024)

With advances in medical technology, health monitoring including heart rate (BPM) and blood oxygen saturation (SpO<sub>2</sub>) has become more accessible and essential in detecting conditions such as arrhythmias and hypoxemia. However, conventional medical devices such as electrocardiography (ECG) are costly and impractical for personal use. Technologies like Photoplethysmography (PPG), used in optical sensors, provide a non-invasive and affordable alternative. Microcontrollers such as Arduino enable the development of portable, affordable, and accurate monitoring devices. The MAX30102 sensor has proven effective in detecting biological signals in real-time with low power consumption.

Increased public awareness of personal health has also driven demand for simple, independent-use health monitoring device (Aprilia & Solliu, 2020; Hidayatulah et al., 2015;

Indriani et al., 2014; Jannah et al., 2024; Siahaan et al., 2022; Yulian & Suprianto, 2017). This study aims to design a real-time prototype of a BPM and SpO<sub>2</sub> monitoring device based on Arduino and the MAX30102 sensor, which is accurate and user-friendly. This innovation is expected to serve as an accessible alternative for the general public in supporting independent cardiovascular health monitoring.

## RESEARCH METHODS

In heart failure cases, oxygen levels decrease more severely due to inefficient blood supply. Table 1 presents the medical standard for SpO<sub>2</sub>, emphasizing that higher muscle activity increases oxygen demand. Therefore, simultaneous monitoring of heart rate and oxygen saturation is essential for early detection of cardiovascular disorders. Table 2 outlines the standard for heart rate (BPM). Several factors contribute to arrhythmias, including electrolyte imbalances, medication side effects, excessive caffeine and nicotine intake, arterial heart issues, or a history of cardiac surgery (Indriani et al., 2014; Sudaryanto, 2017). Individuals with arrhythmias may experience tachycardia (rapid heartbeat), bradycardia (slow heartbeat), or no symptoms at all, as arrhythmias can be asymptomatic (Smaha, 2004; Stout et al., 2019). Continuous heart monitoring is crucial for early identification of health conditions, as blood is constantly circulated to all organs.

**Table 1** SpO<sub>2</sub> Medical Standard

| No | Category                          | SpO <sub>2</sub> |
|----|-----------------------------------|------------------|
| 1  | Noormal Oxygen level              | 95%-100%         |
| 2  | Mild Hypoxemia (Oxygen Level)     | 91%-94%          |
| 3  | Moderate Hypoxemia (Oxygen Level) | 86%-90%          |

Source : (*Indonesian Lung Association, 2011.Pdf*, n.d.)

**Table 2.** BPM Medical Standard

| No | Category                         | BPM          |
|----|----------------------------------|--------------|
| 1  | Infant (0-1 month)               | 70-190       |
| 2  | Infant (1-12 month)              | 80-160       |
| 3  | Children (1-10 years)            | 70-130       |
| 4  | Adolescents & adults (>10 years) | 60-100       |
| 5  | Athletes                         | 40-60        |
| 6  | Tachycardia (faster heartbeat)   | >100 (adult) |

Source : (*Indonesian Heart Association, 2016.Pdf*, n.d.)

The sequential stages undertaken in the design and development of the proposed device are depicted in Figure 1, providing a comprehensive overview of the research methodology. The stages carried out include identifying the problem, namely by conducting a literature review to collect information regarding the background that will be used in designing the system. Literature searches are carried out through various media and journals to obtain information, review data and theories relevant to this research, and find elements of novelty (Nurahman et al., 2021; Rochmad, 2022; Sulista et al., 2021). Furthermore, a device design is carried out which includes software and hardware. During this phase, the tool is tested to evaluate the performance and compatibility of the designed system, as well as to collect research data that will be analyzed to confirm whether the research objectives have been successfully met.

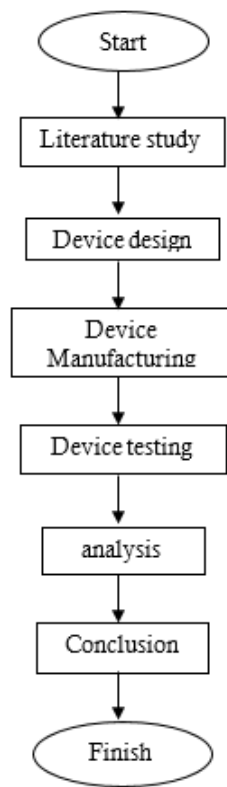


**Figure 1.** Research Flow Chart

The flowchart in figure 1 illustrates the stages of a research and device development process, beginning with the *Start* phase, followed by a *Literature Study* to gather relevant theories and references. Next is the *Device Design* stage, where the device is conceptualized based on the literature review, and then *Device Manufacturing*, which involves assembling or building the device according to the design. After construction, the device undergoes *Device Testing* to verify its functionality and accuracy. The results from testing are then evaluated in the *Analysis* phase to assess the device's performance, forming the basis for the *Conclusion*, which summarizes the outcomes of the entire process. Finally, the process ends with the *Finish* stage, marking the completion of the research and development activity.

## Device Design

This study aims to design and develop a prototype of an Arduino-based heart rate and blood oxygen level monitoring device, utilizing the MAX30102 sensor which has physical dimensions of 5.6 mm in length, 3.3 mm in width, and 1.5 mm in height, reflecting its compact form factor suitable for embedded applications. The design process for this device includes several stages to ensure functionality in monitoring heart rate and oxygen levels. First, the design and wiring of the device.

In general, design refers to the planning or design process before creating an object, system, component, or structure. This planning or design is important so that the object or system created has useful value and function, the following is the design and wiring of a heart rate and oxygen level monitoring device (Awanda Aerin Maesyarani et al., 2024; Muthmainnah & Tabriawan, 2022).

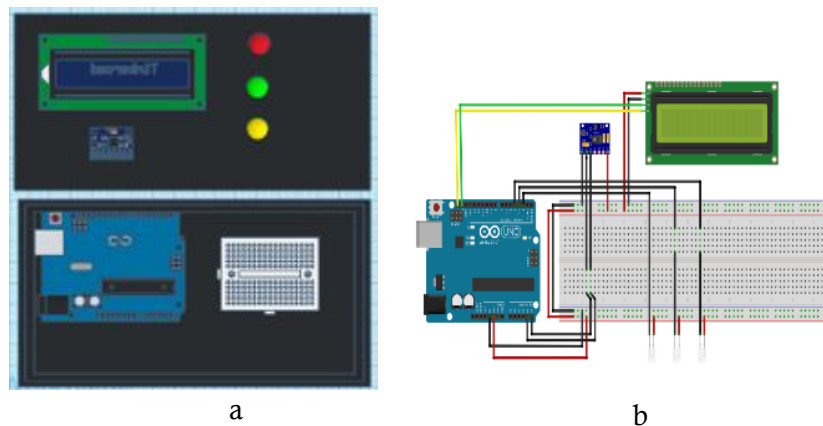


**Figure 2.** (a)Device Design, (b) Device wiring

Design of a device to monitor blood oxygen levels and heart rate based on Arduino using the MAX30102 sensor with the PPG (Photoplethysmography) method, a non-invasive optical method used to measure changes in blood volume in body tissue (Hidayatulah et al., 2015). The method operates by capturing variations in light absorption or reflection caused by blood flow within capillaries, enabling the quantification of heart rate in beats per minute (BPM) and blood oxygen saturation ( $SpO_2$ ), both of which are critical physiological indicators for evaluating cardiovascular and respiratory health. For the design of hardware used in heart rate and oxygen saturation monitoring devices (Siahaan et al., 2022; HADIANTO, 2021).

## Coding

For coding on the heart rate monitoring device and blood oxygen levels, the Arduino IDE application is used. Before starting the programming process, the initial step that must be taken is to install the Library on the Arduino IDE for the MAX30102 sensor and 16x2 I2C LCD as shown in the figure 3 below (Rossano et al., 2018; Riyanto, n.d ).

```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include "MAX30105.h"
#include "spo2_algorithm.h"
```

**Figure 3.** Library in Arduino IDE

## How the Device Works

The heart rate and oxygen level monitoring device has a work system flow, the work system flow of this device has a fairly important role to ensure that all interconnected components function properly, the following is the work system flow of the heart rate and oxygen level monitoring device figure 4.

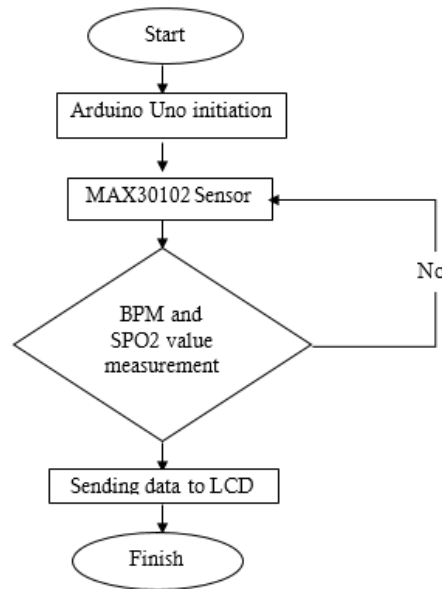


**Figure 4.** Flowchart of the Device Working System

The flowchart illustrates the working process of a heart rate and oxygen saturation monitoring system using Arduino Uno and the MAX30102 sensor. The process begins with the *Start* node, followed by the *Arduino Uno initiation*, which initializes the microcontroller. Next, the *MAX30102 Sensor* is activated to detect pulse and oxygen levels. The system then proceeds to the *BPM and SpO<sub>2</sub> value measurement* step, where it checks for valid readings. If the sensor fails to obtain proper values, the process loops back and retries the measurement. Once valid values are detected, the data is transmitted in the *Sending data to LCD* step to be displayed. The flow then ends at the *Finish* stage, marking the completion of one measurement cycle.

## Device Testing

Testing of the heart rate monitoring device and oxygen level readings is performed to assess how accurately and reliably the device can measure both vital signs during operation. This evaluation aims to assess the precision of the device in reading BPM and oxygen levels (SpO<sub>2</sub>) in real-time, whether the components on this device are functioning properly. Device accuracy is the level of closeness or conformity between the measurement results and the actual values, this test aims to see the accuracy of the device for monitoring heart rate (BPM) and oxygen saturation (SpO<sub>2</sub>) whether the components on this device are functioning properly. For device accuracy, it can be determined by comparing the device made with a conventional device that is already on the market. In this design, the author compares it with the SMH01 Oximeter.



**Figure 5.** Reference oximeter SMH01



**Figure 6.** SMH01 Oximeter as a Comparison

The level of accuracy of this device can be determined using the following equation (Diani et al., 2025; Nurahman et al., 2021; Nur'aidha & Kumarajati, 2024).

$$\text{Error (\%)} = \left| \frac{\text{reference device results} - \text{design device results}}{\text{reference device results}} \right| \times 100\% \quad (1)$$

Meanwhile, to get the accuracy value, you can search using the equation

$$\text{Accuracy (\%)} = 1 - \left| \frac{\text{reference device results} - \text{design device results}}{\text{reference device results}} \right| \times 100\% \quad (2)$$

$$\text{Accuracy (\%)} = 100 (\%) - \text{Error}(\%) \quad (3)$$

## RESULTS AND DISCUSSION

The device design results demonstrate that heart rate and blood oxygen saturation can be reliably monitored through the integration of an Arduino Uno microcontroller with the MAX30102 optical sensor. In this design, there are several steps that need to be taken, the process of preparing the device and materials, assembly, programming, and testing the device, including its design, can be seen below.

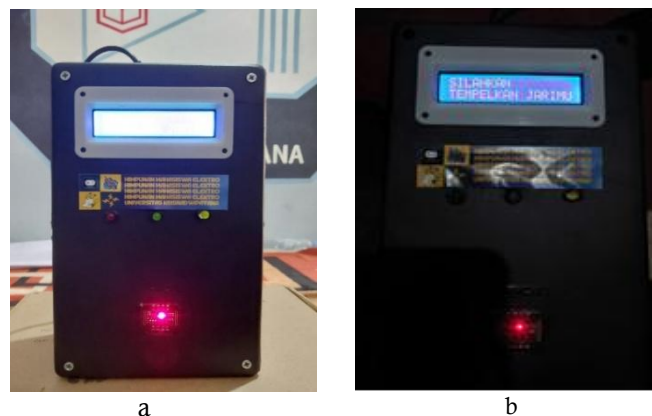


**Figure 7.** (a) Device Design Results and (b) If the Sensor Does Not Read the Object

In figure 7a is a device that has been designed and figure 7b when the MAX30102 sensor does not detect blood flow with a bpm value: -999 and SpO<sub>2</sub>: -999 and there will be a notification to the user which will be displayed on the LCD.

## Device Testing on One Person

This test was conducted 6 (six) times on the same person to evaluate the stability and accuracy of the device. Table 3 below is the result of the trial of the heart rate device and oxygen level values and comparing it with the SMH01 Oximeter.

**Table 3.** Device Testing Result

| No     | Oximeter SMH-01 (reff) |                  | Design Result |                  | Error%<br>(BPM) | Error%<br>(SpO <sub>2</sub> ) |
|--------|------------------------|------------------|---------------|------------------|-----------------|-------------------------------|
|        | BPM                    | SpO <sub>2</sub> | BPM           | SpO <sub>2</sub> |                 |                               |
| 1      | 93                     | 98               | 97            | 99               | 0,04            | 0,01                          |
| 2      | 88                     | 96               | 88            | 96               | 0               | 0                             |
| 3      | 93                     | 97               | 92            | 96               | 0               | 0                             |
| 4      | 98                     | 99               | 99            | 98               | 0,01            | 0                             |
| 5      | 100                    | 96               | 100           | 96               | 0               | 0                             |
| 6      | 100                    | 96               | 100           | 97               | 0               | 0,01                          |
| Number |                        |                  |               |                  | <b>0,05%</b>    | <b>0,02%</b>                  |

In the table above, testing is carried out to see whether the designed device is stable and accurate compared to the conventional Oximeter SHM-01 device, this test is carried out by researchers as users of the device and each test with a time interval of 5 minutes. This test is repeated 6 (six) times to minimize external interference that can affect the test results, the results of this trial test show the percentage of error from testing the device value obtained from the results of testing the device at BPM 0.05% and SpO<sub>2</sub> 0.02%.

Measurements using a single individual tend to be more stable because the individual's physiological variables remain consistent, reducing the potential for biological variation between subjects such as temperature, body position, and physical activity. Therefore, using a single individual for initial testing is effective in generating homogeneous, accurate, and reliable data before conducting broader testing on multiple subjects.

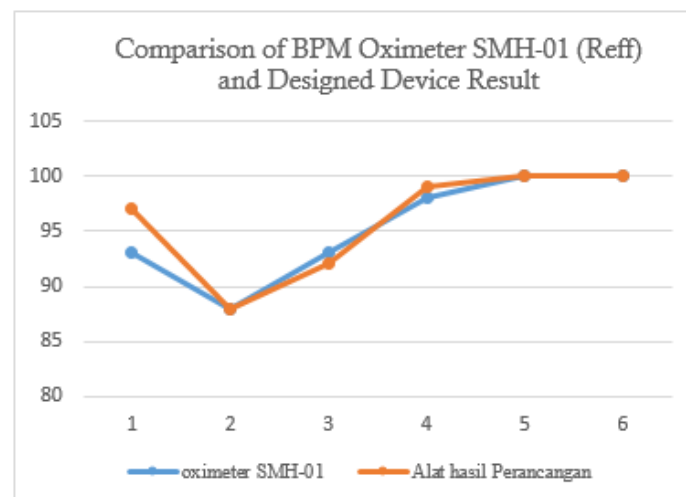


**Figure 8.** Comparison Chart of BPM Between SMH-01 Oximeter and Designed Device

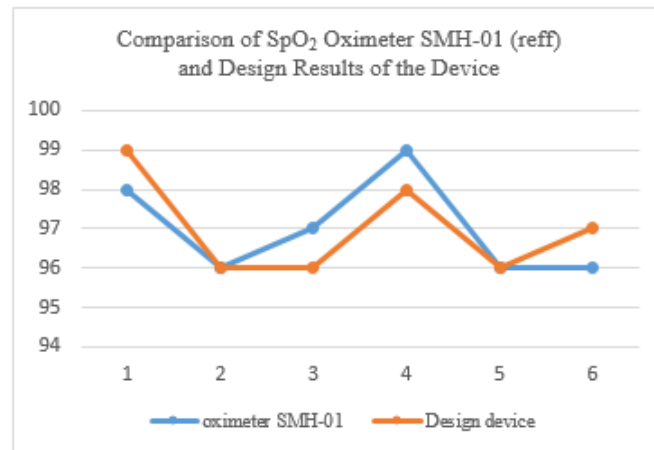


**Figure 9.** Comparison Graph of SpO<sub>2</sub> Between SMH-01 Oximeter and Designed Device

### Device Testing on Different Persoan/Object

This measurement is done by taking data from several different person to find out the heart rate value (BPM) and the blood oxygen level value SpO<sub>2</sub>. This measurement was conducted using the designed device on several individuals as test object, results of heart rate (BPM) and oxygen saturation (SpO<sub>2</sub>) presented in Table 4.

**Table 4.** Device Test Results

| Object | <i>Oximeter SMH-01 (reff)</i> |                  | <i>Design Result</i> |                  | <i>Error % (BPM)</i> | <i>Error % (Sp0<sub>2</sub>)</i> |
|--------|-------------------------------|------------------|----------------------|------------------|----------------------|----------------------------------|
|        | BPM                           | Sp0 <sub>2</sub> | BPM                  | Sp0 <sub>2</sub> |                      |                                  |
| 1      | 71                            | 100              | 65                   | 100              | 0,06                 | 0                                |
| 2      | 62                            | 98               | 65                   | 98               | 0,03                 | 0                                |
| 3      | 65                            | 95               | 75                   | 95               | 0.1                  | 0                                |
| 4      | 83                            | 99               | 68                   | 95               | 0.15                 | 0,04                             |
| 5      | 65                            | 99               | 87                   | 95               | 0.22                 | 0,04                             |
| 6      | 87                            | 96               | 80                   | 95               | 0,07                 | 0,01                             |
| Number |                               |                  |                      |                  | <b>0,63%</b>         | <b>0,09%</b>                     |

This test was carried out on six different people the results of this trial test show the percentage of error from testing the device value obtained from the results of testing the device at BPM 0.63% and SpO<sub>2</sub> 0.09%. for BPM accuracy of 99.37% and SpO<sub>2</sub> of 99.91%.

The differences in SpO<sub>2</sub> and BPM measurement results among the six subjects are natural and influenced by several factors, including individual physiological conditions such as fitness level, lung capacity, and cardiovascular health. Variations in physical activity before measurement, body position during testing, and environmental conditions can also affect the results. In addition, minor differences in sensor placement, finger temperature, or unintentional movement may impact the accuracy of readings. These variations highlight the importance of testing the device on multiple subjects to ensure its reliability and accuracy across different user conditions.

From the data above, a comparison graph can be made between the SMH-01 oximeter and the designed device.

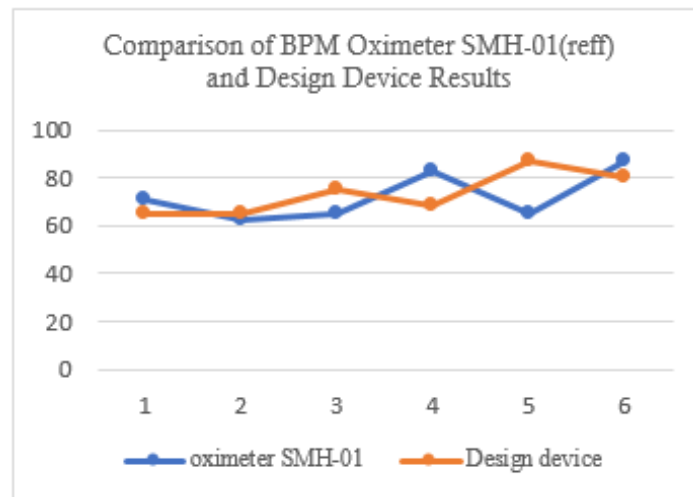


**Figure 10.** BPM Comparison Graph Between SMH-01 Oximeter and Designed Device

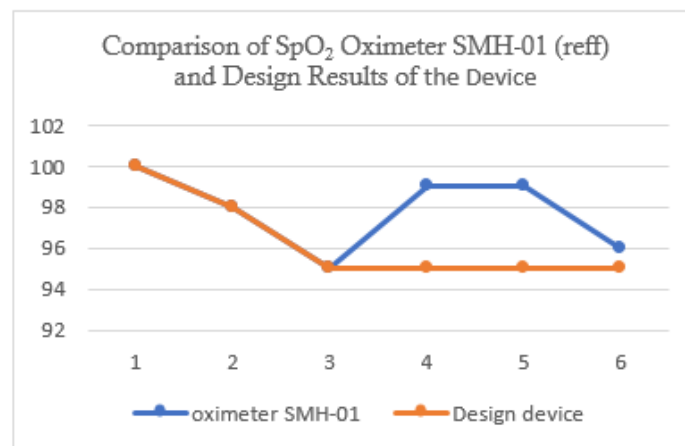


**Figure 11.** SpO<sub>2</sub> Comparison Graph Between SMH-01 Oximeter and Designed Device

In a study conducted by Ummi Anisyah in 2022, BPM and SpO<sub>2</sub> measurements were carried out using IoT-based components such as Arduino Uno with ESP8266 MCU nodes and MAX30100 sensors, with results sent via Telegram. The measurement results showed a BPM accuracy of 96% and SpO<sub>2</sub> accuracy of 98.6% (ANISYAH, 2022). Similarly, a study by Mohamad Aldi Adrian in 2021 used Arduino Uno, ESP8266, DS18B20, and MAX30100 sensors to measure body temperature, BPM, and SpO<sub>2</sub> (Adrian et al., 2021).

The results show that the device has high accuracy and low error rates, in a single person, BPM error was 0.05% and SpO<sub>2</sub> 0.02%, with accuracy of 99.95% and 99.98% respectively. In six different individuals, BPM error was 0.63% and SpO<sub>2</sub> 0.09%, with accuracy of 99.37% and 99.91%. These results indicate that the device outperforms previous studies due to its low error and high accuracy.

On the designed device has more accurate results, this is due to the use of a more stable Arduino Uno for local data processing, so the risk of crash or lag is smaller than the ESP8266 which is more vulnerable when used multitasking (processing + WiFi). As well as the use of the MAX30102 sensor which is an improvement on the MAX30100, which offers better sensitivity, lower noise levels, and stronger resistance to environmental light interference. This results in more

accurate and stable BPM and SpO<sub>2</sub> measurements, especially in varying lighting conditions or when there is little movement.

## CONCLUSION

The results of the study obtained an error value of 0.05% for BPM and 0.02 for SpO<sub>2</sub> and an accuracy value of 99.95% for BPM and 99.98% in one person tested, while in 6 different people an error value of 0.63% for BPM and 0.09% for SpO<sub>2</sub> and an accuracy value of 99.37% for BPM and 99.91% for SpO<sub>2</sub> were obtained. The results of this study indicate that this system can effectively monitor cardiovascular parameters within clinically acceptable limits, making it a practical solution for personal health monitoring, especially for those at risk of arrhythmia or hypoxemia.

further research, this device can be further developed by adding other functions such as measuring blood pressure, temperature, and blood sugar levels, and integrating it with the Internet of Things (IoT), enabling remote monitoring via mobile phones or laptops. Most importantly, it has strong potential to be developed into a self-operated digital health device that can support independent health monitoring.

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