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Pulse Oximeter Design for SpO2 and BPM Recording on External Memory to Support the Covid-19 Diagnosis

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ABSTRACT COVID-19 (coronavirus disease) is an acute respiratory illness induced by exposure to coronavirus 2 in 2019 (SARS-CoV-2). WHO confirms that there were 1.8 million registered deaths in 2020 and that there were 3.5 million recorded deaths in 2021. People who are infected with SARS-CoV-2 without symptoms should have a pulse oximeter. Early detection of low oxygen levels in the blood can lead to fewer complications. Continuously decreasing oxygen saturation, if not controlled, will cause hypoxia (an abnormal respiratory circulation system condition that causes breathlessness). In normal conditions, oxygen levels and heart rate are related. When a person has a shortage of oxygen (breathlessness), their heart rate increases to supply the oxygen. Regulating heart rate can aid in the prevention of disorders such as arrhythmia, coronary heart disease, and hypertension. A pulse oximeter is used to measure the oxygen saturation in the blood and the patient's heart rate (BPM) with non-invasive methods. Conventional pulse oximeters do not support users by not having features such as medical records, which are required for further examination by a doctor. The purpose of this research is to make a pulse oximeter with external storage capability. The difference in wavelength between the red and infrared LED lights that will be captured by the photodiode is measured. SpO_2 and HR values will be generated as a result of comparative measurements. Using a MAX30102 sensor to detect SpO_2 and heart rate, and an Arduino Mega256 to process data for display on the TFT Nextion with Memory Card storage. By comparing the module to a conventional pulse oximeter, data was collected 10 times for each respondent. The maximum SpO_2 error value is 0.43%, whereas the BPM parameter has the largest error value of 2.02% and the smallest error value of 0.01% based on the data collected. A significant error value is caused by finger movement. The module is usable, based on the results, because the maximum error tolerance for a pulse oximeter is 1% SpO_2 and 5% BPM, according to the 2001 Ministry of Health Ministry's Guidelines for Testing and Calibrating Medical Devices.

INDEX TERMS Pulse Oximeter; Oxygen Saturation; Heath Rate, MAX30102, Memory Card.

I. INTRODUCTION

On March 11, 2020, the World Health Organization proclaimed Covid 19 a worldwide epidemic [1]. The detection of reported Covid patients is divided into clinical manifestations of disease based on severity, notably mild sickness such as mild pneumonia, followed by severe disease with signs of respiratory frequency 30 times per minute and total oxygen saturation of 93 %. COVID-19 patients may encounter this as a result of inflammation or inflammation in the lungs, which leads to heavy breathing [2]. There's a consequence of inflammation or inflammation in the lungs, which leads to heavy breathing, and the last one is a critical-level condition, namely respiratory failure. We should be aware of the indicators of COVID-19 illness with personal control, as the symptoms have previously been mentioned [3]. We can exert control by utilizing a thermometer to measure our body temperature and a pulse oximetry instrument to monitor oxygen levels in our blood. Infected people with SARS-CoV-2 who are asymptomatic and self-isolated at home should have a pulse oximeter [4]. In COVID-19 patients with respiratory failure, measuring oxygen saturation can help evaluate the respiratory rate and avoid intubation (insertion of a tube into the airway to support breathing) [5]. Low oxygen saturation, also known as hypoxemia, can cause symptoms such as chest pain, breathing difficulty, cough, headache, fast heartbeat, confusion, and blue skin [6]. People who have hypoxemia may also not feel any symptoms. COVID-19 patients may have this syndrome, called as happy hypoxia [7], [8]. Whether it causes symptoms or not, hypoxemia can interfere with the work of organs and body tissues. If left unchecked, this can cause damage to vital organs, such as the heart, brain, and kidneys, and risk causing dangerous complications [9]. The percentage of hemoglobin that binds oxygen in the blood compared to the total amount of hemoglobin in the body is referred to as oxygen saturation. Adults have a normal oxygen saturation around 95-100%. Values under 90% are considered low oxygen saturation, neding an external oxygen supply [10]. To measure the percentage of oxygen bound by hemoglobin in the blood, oxygen saturation (SO2) is referred to as SATS in medicine [11]. Two alternative tests can be used to measure the oxygen saturation in the blood. There are two types of methods: invasive and non-invasive [12]. Pulse oximetry is an effective technique for monitoring the patient for small or sudden changes in oxygen saturation [13]. Hypoxia (low oxygen saturation) conditions make the heart beat faster because the heart needs more oxygen. So, the heart tries to pump more blood than normally [14]. According to the World Heart Federation, heart disease kills more than 17 million people each year [15]. The heart rate is a vital human organ that is commonly used to evaluate a person's health[16]. If first aid is given when an abnormal heartbeat condition is detected, death from this condition can be avoided [17]. By monitoring the heart rate regularly, we will be able to prevent several diseases such as arrhythmia (irregular heartbeat), coronary heart disease, hypertension, or simply knowing our stress levels and sleep quality every day [18]. An adult normal human heart rate ranges from 60-100 beats per minute, which is in good health [19]. A pulse oximeter is one of the SpO_2 and BPM monitoring tools [20]. The pulse oximeter only analyzes arterial blood and the tissues that surround the blood [21]. An oximeter is one technique of using a tool to measure the level of oxygen saturation in a patient's blood (arterial), which is also linked with a heart rate monitor to help with the physical checkup without a blood test analysis [22]. The primary advantage of this sensor pulse oximeter, which includes optical sensors for medical applications, is its inherent safety [23]. To find out oxygen levels in the body can be done by analyzing blood gases, which requires blood samples. Measuring oxygen saturation with an oximeter can be done easily at home and done non-invasively [24]. One of the main considerations is low cost and ease of operation [25][26]. Pulse oximetry is able to recognize the difference in the absorbance of red (R) and near-infrared (IR) light in hemoglobin [27]. Oxyhemoglobin (O2Hb) can absorb more IR light than deoxyhemoglobin (HHb). This is consistent with the macroscopic appearance of arterial blood. High levels of O2Hb will appear bright red because not much red light is absorbed. On the other hand, venous blood appears less red because higher HHb levels cause it to absorb a lot of red light [9]. There are 2 wavelengths: red (660 nm) and near-infrared (940 nm) [27][21]. A light sensor (photodiode) on the other hand detects light that has passed through body tissues. If the light absorption of O2Hb and HHb differ, pulse oximetry can measure the number of Hb bound to oxygen [28]. When the light absorption of O2Hb and HHb differs, pulse oximetry may be used to calculate the amount of Hb bound to oxygen [28][13]. In conditions where oxygen saturation is low, HHb levels increase, and light absorption increases, resulting in a high ratio. Meanwhile, when oxygen saturation is high, O2Hb levels rise, increasing IR light absorption and lowering the R-value [30][31]. Monitoring for SpO_2 and BPM parameters is very important. If symptoms appear, then action must be taken quickly so that the patient's condition does not worsen. There are 2 types of sensors in a pulse oximeter: reflectance and transmittance [12]. This reflecting method can be used in anatomical areas where two surfaces are not required to be in close contact, more accurate and stable reading regardless of the patient's size or age. The signal noise in the reflecting system is lower than in the transmitting system. However, setting up the reflectance system needs a significantly greater amount of light [29]. The difference in oxygen levels is calculated by the microprocessor and converted into a digital value [31]. Elita Kartini of Electrical Engineering Poltekkes Surabaya created a gadget called Fingertip Pulse Oximeter Shown PC in 2016. This was created to let doctors monitor the state of a patient even while they are located away from the patient. However, it has a limited distance that the LP2303 module cable can cover is restricted. This device employs a transmittance model with sensor fingers containing very sensitive red and infrared light [32]. Umi Salamah et al. from the Physics study program, Faculty of Mathematics and Natural Sciences, Ahmad Dahlan University, Yogyakarta, created a research device titled Design of Pulse Oximetry Using Arduino as Detection of Oxygen Saturation in Blood at the same year. It's designed to monitor the patient's oxygen saturation signal. This utility was created on a Personal Computer using Arduino as the data programming platform. However, due to the usage of the Arduino Mega, which is large, and the delivery of the cable has a limited range, making it difficult to carry everywhere, this device has a large physical shape and is not simple [33]. Over the next two years, Fuad Ughi from Biomedical Engineering at German University produced a monitoring tool in the shape of a pulse oximeter, with the title Proof-of-Concept Simulation of Oxygen Saturation Levels for Pulse Oximeter Evaluation. The tool is a modified transmittance oxisensor with a light sensor. This pulse oximeter can detect a pulse. However, the graph it displays is erratic, and the oxygen saturation values are not as intended. This might be due to the addition of a light sensor to the built-in sensor, leading to one of the sensors' readings being less suggested by Fuad [34]. I Putu Anna Andika from Electrical Engineering Poltekkes Surabaya created a similar module in 2019 with the title Portable Pulse Oximeter. The Atmega 2560-16AU Microcontroller IC is utilized to process data read by the reflectance sensor, and a TFT LCD is used as a display to display parameter values.

The feature of this tool is that it is powered by two batteries, which allows for more mobility and longer battery life. The Department of Electrical Engineering at the Ministry of Health Surabaya's Health Polytechnic student, Novan Prastyo Aji, finished a final project titled Reflectant Pulse Oximeter Using the Max30100 Sensor in 2020. Overall, this tool works and can be effectively used. Based on the results of the identification of the problem above, the author wants to make a tool called Measuring Oxygen Concentration and Heart Rate Equipped with External Storage. The tool that will be made by the author is in the form of a portable reflectance pulse oximeter that can measure heart rate and oxygen levels in the blood equipped with indicators indicating if the results are abnormal by examining the patient's fingers for BPM and SpO_2 data collection, which will be stored on the memory Card as a medical record. Benefit of Medical Records Patient name, date and time, history (at least complaints and health history), results of physical examination and medical support, diagnosis, management plan, treatment, and actions, and other services offered to patients are all included in the medical record [35].

II. MATERIALS AND METHODS

The pulse oximeter was used as a comparison device in this study by the researchers. The MAX30102 sensor is used as an input sensor in this study to read oxygen saturation and heart rate, and a step up and charger module, rtc, memory card, and microcontroller Arduino Mega for transferring data to the TFT Nextion. The following sections will go through the materials and methods.

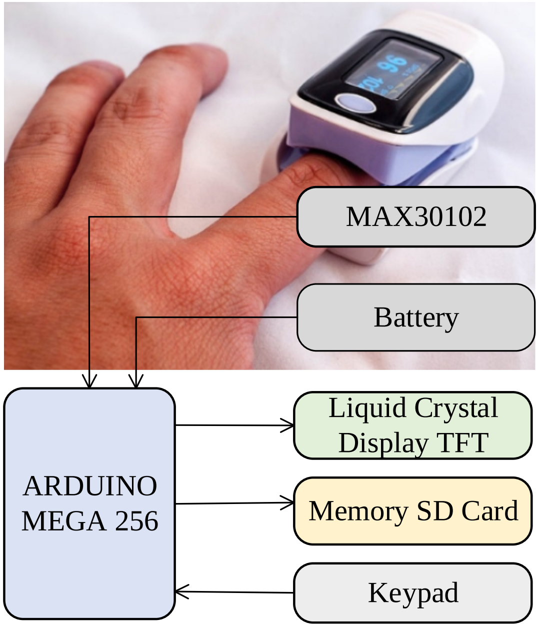

FIGURE 1 The Diagram Block of the Pulse Oxymeter

A. DATA COLLECTION

The testing was performed on the Electrical Engineering campus, with data collected from a variety of respondents. Five healthy adults were tested in this study. Subjects were sampled at random, and data collection was repeated 10 times. Respondents will place their fingers directly on the sensor to get the percentage of oxygen saturation and BPM measurement. This study uses materials and tools. The Arduino Mega256 microcontroller is used to process sensor data, add the rtc, connect with a memory card, and display it on the Nextion TFT. After the design is finalized, the module test of this tool is carried out directly using a respondent's finger in this study. Fingers were placed on the MAX30102 as a sensor, and any finger from the left or right hand was tested on the sensor at the module. When using the module, it's not recommended to move the fingers because finger movement impacts the results and effects reading time. In around 12 seconds, the module will display the measurements. By connecting the tool module's Rx and Tx pins to the Arduino module, the results could be shown in Nextion, and the storage results could be accessed by a card reader to read a TXT output file.

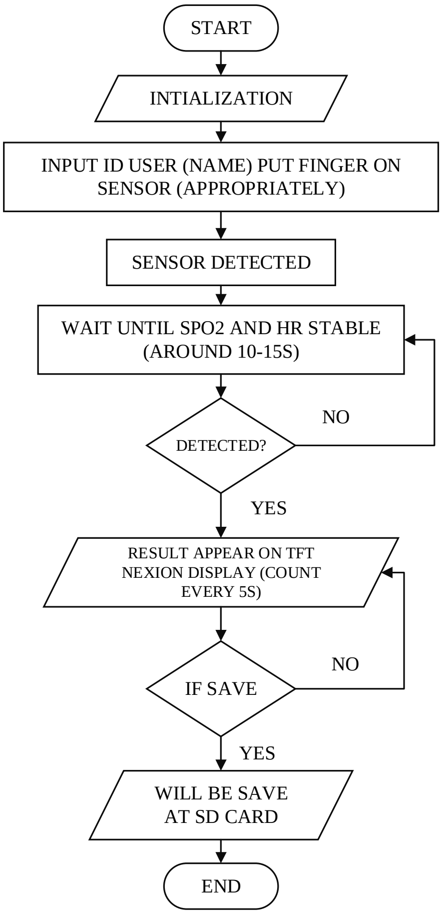

FIGURE 2 The Flowchart of the Module

FIGURE 1 shows the entire system's block diagram. The battery supplies voltage to all the circuit blocks. The patient will place his finger on the sensor that will be used as a sensor input on the module. The sensor's output data will be processed by data processing on the microcontroller. The processed data will also be included in the RTC for processing the measurement time data collection. In the Arduino mega256, the incoming data processing occurs from the difference in wavelengths between the red and infrared LED lights. SpO_2 and BPM measurement results will be displayed on the device display as numbers and saved on the SD Card in a txt file when the save button is tapped.

FIGURE 2 shows a flow chart. The initialization process will begin when the module is powered on. In the tool, the user enters data in the form of a name. If the data is correct, the entry will be displayed for inspection. When the patient places his finger on the module, the data from the output sensor is processed to determine the SpO2 and BPM values displayed. Wait 10–15 secs after the results are shown to get stable results. When the save icon on the display is pressed, the microcontroller will also use the RTC to measure time, and the results will be saved to the SD card in the form of a TXT file.

B. DATA ANALYSIS

Data collection for 5 objects was carried out 10 times. Data is collected, and the measurement value is taken using a conventional oximeter. The formula (1) gets the measurement's average value:

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

where x represents the mean (average) value for measurement, x1 represents the first measurement, x2 is the second measurement, and xn represents the n measurement A standard deviation is a value that shows the amount of variation in a data set or a standard measure of variation from the mean. Equation (2) shows the standard deviation (SD) formula:

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

SD is the calculated standard deviation, and shows the quantity of measurement. The percentage error represents the system's mistake. The lower the value The difference between the means of each data set is defined as an error. The error might represent the difference between the standard oxymeter and the module. Equation shows the error formula (3).

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

where xn is the comparation measurement. The x represents the value obtained from the module.

III. RESULT

Data were measured using the respondent's fingers in this test. Data on 5 respondents was taken by comparing the module with conventional pulse oximetry. The entire circuit design results are shown in FIGURE 3. The module design includes a battery as a power supply, a step-up charger module, an RTC, an Arduino Mega256 module as a data processor, and data communication from the TFT Nextion to the memory card. While FIGURE 4 shows the display results on the TFT nextion, FIGURE 5 shows the storage results in the form of txt files.

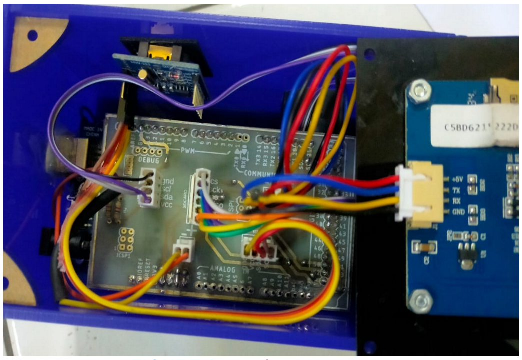

FIGURE 3 The Circuit Module

FIGURE 6 TFT Nextion Display

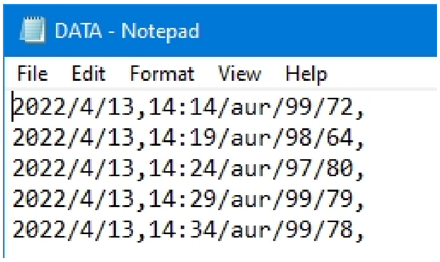

FIGURE 7 Notepad View of a Txt File

TABLE 1
SpO_2 Respondent Measurement Result

Tool	Respondent	Mean SpO_2
Module	1	98,1
	2	98,1
	3	97,9
	4	97,6
	5	97,5
Calibrator	1	98,1
	2	97,7
	3	97,7
	4	98
	5	97,7

Based on TABLE 1 The mean column takes data from the data collection 10 times per respondent, creates the module and comparison tool's average value. SpO_2 rates are determined by comparisons using a pulse oximeter put on a finger.

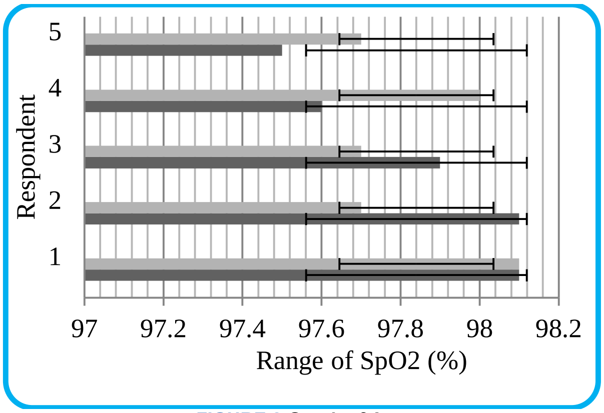

FIGURE 8 **Graph of Average**

The data at FIGURE 8 are descibed on TABLE 1 and error values on TABLE 3 are calculated using the SpO_2 value. Based on this data, respondent's mean was 98,1 %, 98,1 %, 97,9 %, 97,6 %, and 97,5% for module.

TABLE 2
BPM Respondent Measurement Result

Device	Respondent	Mean HR
Module	1	79,2
	2	91,6
	3	86,6
	4	93,9
	5	82
Calibrator	1	80
	2	91,3
	3	84,9
	4	92,6
	5	82,1

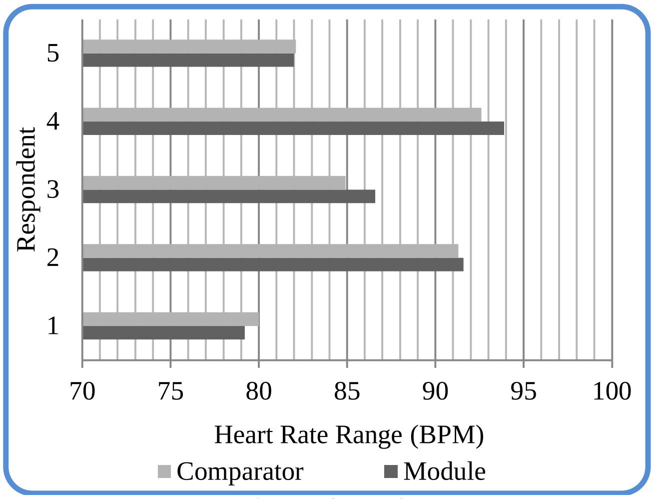

FIGURE 9 **Graph of Heart**

Based on TABLE 2 the mean of the HR column takes data to occur at or during the same time with SpO_2, from the data collection 10 times per respondent, and creates the module and comparison tool's average value. HR rates are determined by comparisons using a conventional pulse oximeter as on the FIGURE 9.

TABLE 3 **Error each Parameter**

Parameter	Respondent	Error (%)	Standart Deviation
SpO_2	1	0	0,56
	2	0,42	0,73
	3	0,21	0,87
	4	0,43	0,69
	5	0,28	0,7
Heart Rate	1	0,01	3,55
	2	0,32	2,31
	3	2,002	5,6
	4	1,4	2,02
	5	0,12	3,23

The error-values on TABLE 3 for the BPM measure are ±0.01% , ±0.32% , ±2.002% , ±1.4% , and ±0.12% . for the highest error value of 2.02% and the lowest error value of 0.01%. The result of the average comparison minus the module. The comparison divides the result. The module measurement results are affected by the finger movement factor. Furthermore, all error values for this module are less than 5%, meaning that the module satisfies the standard error at 5% and is good enough to gain the BPM value and the maximum SpO_2 error value is 1% of the SpO_2 value, and all error values for this module are less than 1%, meaning all data fulfills the error standard.

FIGURE 10 shows a graph of the error results for each respondent. The SpO_2 parameter has the largest error value of ±0.43% and the smallest error value of ±0%. Meanwhile, for the BPM parameter, the largest error value is ±2.02% and the smallest error value is ±0.01%. This is the result of the comparison average minus the module, result is divided by the comparison. The finger movement factor affects the module measurement results

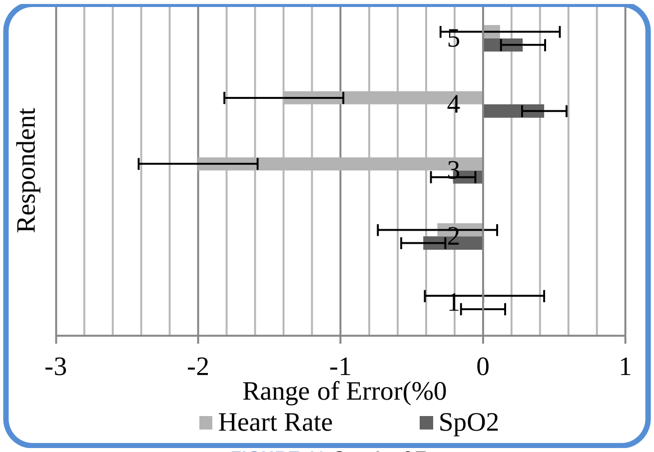

FIGURE 10 **Graph of Error**

IV. DISCUSSION

The module has undergone measurement and testing. This module includes a Max30102 sensor, which is used to measure

SpO_2 and BPM values. The sensor's output is red and infrared LED data, which is converted into SpO_2 and BPM values by the Arduino microcontroller. Before the sensor gets the patient's finger input, the patient enters data in the form of a name. The data will then be sent into the microcontroller, which will determine the ratio between red and infrared LEDs based on the wave difference. As light sources, infrared and red LEDs are placed in parallel to the photodiode and act as light sensors. The photodiode receives a signal or change in the form of infrared light. Data from MAX30102 will be processed by the microcontroller, which will then calculate the heart rate (BPM) and oxygen saturation levels. After the measurement of the two parameters, the results will be displayed as a value for BPM and a percentage of SpO_2. The module includes a memory card module as a data storage medium for the module's measurement results, as well as an RTC 1307 module to detect when measurements were taken. The module has a TFT Nextion display that can present results and normal values in real-time. The TFT Nextion was chosen because it is more effective, does not require additional buttons to execute module operations, and has a larger and clearer display. The saving of results and time is supposed to help doctors' or health practitioners' diagnostic processes in monitoring the patient's condition. Data will be saved in the form of user data, which contains the following information such as, name, results of SpO_2 and Hearth Rate, date, and time measurements in txt format. This module was tested on five adult participants who were of different genders. A module and a comparison tool are used to get data (conventional oximeter). Measurements were tested ten times for each data collection, in line with the oximeter inspection SOP, with a module and comparison tool. Data was collected with the highest SpO_2 error value of 0.48% and the lowest error value of 0%. Meanwhile, the smallest error value for the BPM parameter with comparison is 0.9 %, and the largest error value is 2.82 %. This module has limitations, which still takes a long time to read BPM, has limited saving characters, and is without a finger clip.

V. CONCLUSION

The purpose of this study was to monitor the patient's condition by using the percentage of oxygen saturation and the heart rate value. The results showed that the module works well, with SpO_2 resulting in the least error of 0.48 percent and the smallest error of 0% when tested using pulse oximetry. The results of the smallest heart rate (BPM) test are 0.01 % and the largest is 2.002 %, with a time to reach stability of around 10-15 s. For future studies, researchers can use a better SpO_2 circuit or module to get more stable measurement results that are not reliant on finger movement. Using more recent microcontroller technical advances, as well as a more compact design for easy mobility.

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