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Vital Sign Monitoring Spo2 and BPM

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Abstract
The condition of the human body can be seen through vital signs on the human body. Blood oxygen saturation (SpO2) and heart rate (BPM) are part of human vital signs which are important for regular checks to determine human health status. This research was conducted to create a vital sign tool as a tool that can measure both vital signs simultaneously. The design of the tool is made with a fingertip accessory design that is placed on the patient's fingertip where there is a MAX30102 sensor which is tasked with detecting human SpO2 and BPM levels. Then the data will be processed by the ESP32 as a microcontroller and displayed on the Nextion screen. The results of the tool show that the average error data for measuring SpO2 is ±0.02% and the average error for measuring BPM is ±0,16%. By making this tool, it is hoped that it will make it easier to check human vital signs, especially measuring oxygen saturation and heart rate, so that human health conditions remain monitored.

Keywords
Vital Sign, SpO2, BPM, MAX30102, ESP32.

Specifications table

Hardware name	*Vital Sign Monitoring SpO2 and BPM (Photoplethysmograph Method)*
Subject area	• *Electronics System* • *Microcontroller System* • *Diagnostic Field* • *Photoplethysmography*
Hardware type	• *Electrical Engineering* • *Computer science* • *Mechanicl Engineering* • *Measurement and sensor*
Closest commercial analog	*This is a vital sign that can meassure SpO2 and BPM with fingertip design*
Open source license	*https://creativecommons.org/licenses/by-sa/4.0/*
Cost of hardware	90 USD
Source file repository	DOI 10.17605/OSF.IO/8PTFB
OSHWA certification UID	

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1. Hardware in context

Regularly checking vital signs is crucial for knowing the health of the human body. Heart rate (BPM) and oxygen saturation (SpO2) are two of vital signs that need to regularly check [1][2][3]. Deaths due to heart and blood vessel diseases remain the leading cause of death worldwide [2]. Normally, the human heart beats 60-100 times per minute [4][5]. The normal oxygen saturation value in humans ranges from 90% to 100% [6][7][8]. Therefore, monitoring BPM and SpO2 in the body is essential. This ensures an adequate oxygen supply so that all organs function properly [9][10]. Previously, measuring oxygen saturation in humans was done invasively by drawing a small amount of blood. However, with advancements in technology, a new non-invasive method called pulse oximetry has been developed[11]. Pulse oximetry uses two technologies: spectrophotometry and plethysmography (PPG) [12]. PPG measures blood volume changes non-invasively to determine oxygen saturation and heart rate. It utilizes sensors with red and infrared LEDs along with a photodetector to measure light absorption through a finger or body tissue [11][12].

In 2019, Dian Bagus Setyo Budi and colleagues developed a device using similar parameters, utilizing the MAX30100 sensor and Arduino UNO microcontroller. The device had an error rate of 2.96% for oxygen saturation and 2.86% for heart rate. From this research, it is hoped that future designs of the device will be made portable [13]. Then, in 2020, research by Arsa Rizky Imanda and colleagues focused on monitoring oxygen saturation, temperature, and heart rate. This study used the Grove Heart Rate Sensor for BPM, the MAX30100 sensor for SpO2, and the MPU6050 sensor for body temperature, with the ESP8266 microcontroller. In this study, it was found that the heart rate sensor produced a relatively high error value, which is 4.12%, the oxygen saturation sensor had an error rate of 1.27%, and the body temperature sensor had an error rate of 0.35% [14]. In 2021, Muhammad Irfan Pure do a study focused on a heart rate and SpO2 detection device using the photoplethysmograph method, the MAX30102 sensor, and the Raspberry Pi 3B microcontroller. The results showed an error rate of 1.1% for BPM and 0.9% for SpO2. Although the data accuracy is fairly high, with error rates below 4%, data collection was limited to marathon athletes, and the microcontroller used is relatively expensive [15].

From the descriptions above, the device's error results are already quite good. However, researchers aim to improve by using the MAX30102 sensor, which has better specifications and performance. Previously, the error values were nearly reaching 3%, with some even at 4%. However, the research using the MAX30102 sensor yielded results with smaller errors. Yet, in the previous study, the device was only tested on marathon athletes. Next, improving the device design for better portability is also necessary.

Based on the description above, in this study titled "Vital Sign Monitoring of SpO2 and BPM (Photoplethysmograph Method)" a vital sign monitoring device will be developed to monitor SpO2 and BPM using the MAX30102 sensor and ESP32 [16] microcontroller. The MAX30102 sensor offers advantages such as better and faster data transmission, sensitivity, and lower power consumption. The device will be designed to be as compact as possible for easy portability, and the monitoring results will be displayed on a Nextion LCD Display. This device will also operate using battery power, allowing it to be carried and used in emergency situations without electricity as long as the battery power is available.

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Fig.1. The hardware of the Vital Sign

Within the hardware shows in **Fig. 1**, specifically on the top right side, there is an accessory namely a fingertip probe which will be placed on the patient's finger. It includes the MAX30102 sensor integrated with the microcontroller and will be displayed on the screen. The MAX30102 sensor utilizes the PPG method [17][18][20], consisting of red and infrared LEDs acting as transmitters and a photodiode as a receiver [19][20][21][22]. There is a difference in color between oxygen-bound (oxygenated) and oxygen-unbound (deoxygenated) blood [23][24]. Oxygen-bound blood in humans tends to be bright red because hemoglobin contains iron, which is where oxygen binds [25][26]. When blood is deoxygenated, it tends to be darker and appears bluish in the blood vessels [27][28]. The device design consists of power supply, microcontroller, finger sensor containing the MAX30102 sensor, and Nextion LCD display. The design output is numerical values indicating the value of oxygen saturation (SpO2) and the value of heart rate (BPM), which will be displayed on the Nextion LCD screen. There is a power supply circuit where the device uses a total of 12 batteries. These batteries will be connected to a Battery Management System (BMS) and provide outputs of 4.2V and 5V . This setup allows the device to work without requiring electrical power, enabling it to be used in places without power sources for some time as long as the batteries are available. Based on usage during data collection, the device can last for two days with approximately 9 hours of usage per day. Additionally, the minimum duration required for recharging the batteries is at least two hours, depending on the battery's depletion level. The hardware result of the device can be seen in the **Fig.1**.

2. Hardware description

The hardware module consists of a fingertip sensor containing the MAX30102 sensor integrated with ESP32 and displayed on the Nextion LCD. The fingertip sensor will be used on the patient. The MAX30102 sensor will collect patient data using the PPG method based on blood volume changes. It simplifies the measurement process by just attaching the accessory to one of the patient's fingers. A more detailed diagram will be shown in the **Fig. 2**.

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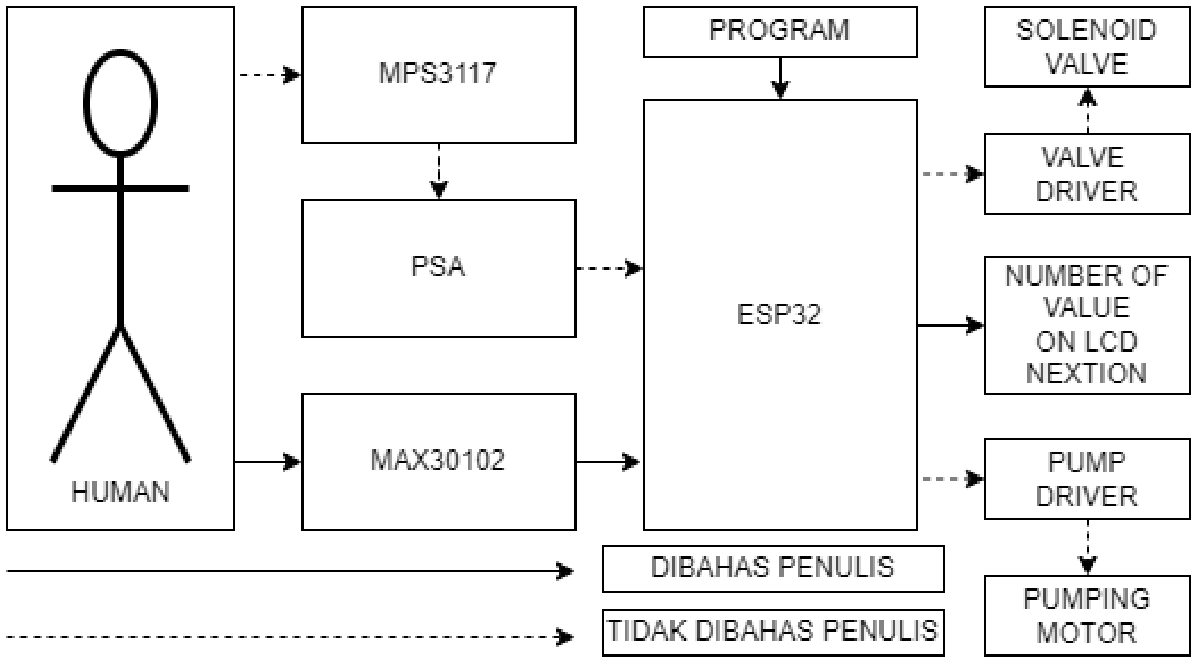

Fig. 2. The diagram block of the Vital Sign Monitoring SpO2 and BPM (*Photoplethysmograph Method*)

The patient will use the fingertip sensor containing the MAX30102 sensor for measuring SpO2 and measuring BPM. The fingertip design will minimize finger movement or displacement during readings. The MAX30102 sensor will measure SpO2 and BPM values using the Reflectance Photoplethysmograph method. The sensor data, in digital values, will be processed by the ESP32 microcontroller to convert them into SpO2 percentage and BPM values. Then, the processed data from the microcontroller will be displayed on the Nextion display as heart rate (BPM) and blood oxygen saturation (SpO2) values.

2.1. Vital Sign Hardware

The hardware for this device is designed using CorelDRAW application, as shown in **Fig. 3**. The box is made of acrylic material to ensure sturdiness and strength, with a thickness of 5mm. Additionally, it is shaped like a box with a display screen and buttons on the top and at the back of the device, there will be ports for the power cable and an ON/OFF switch. On the front side, there are ports for connecting accessories to the device.

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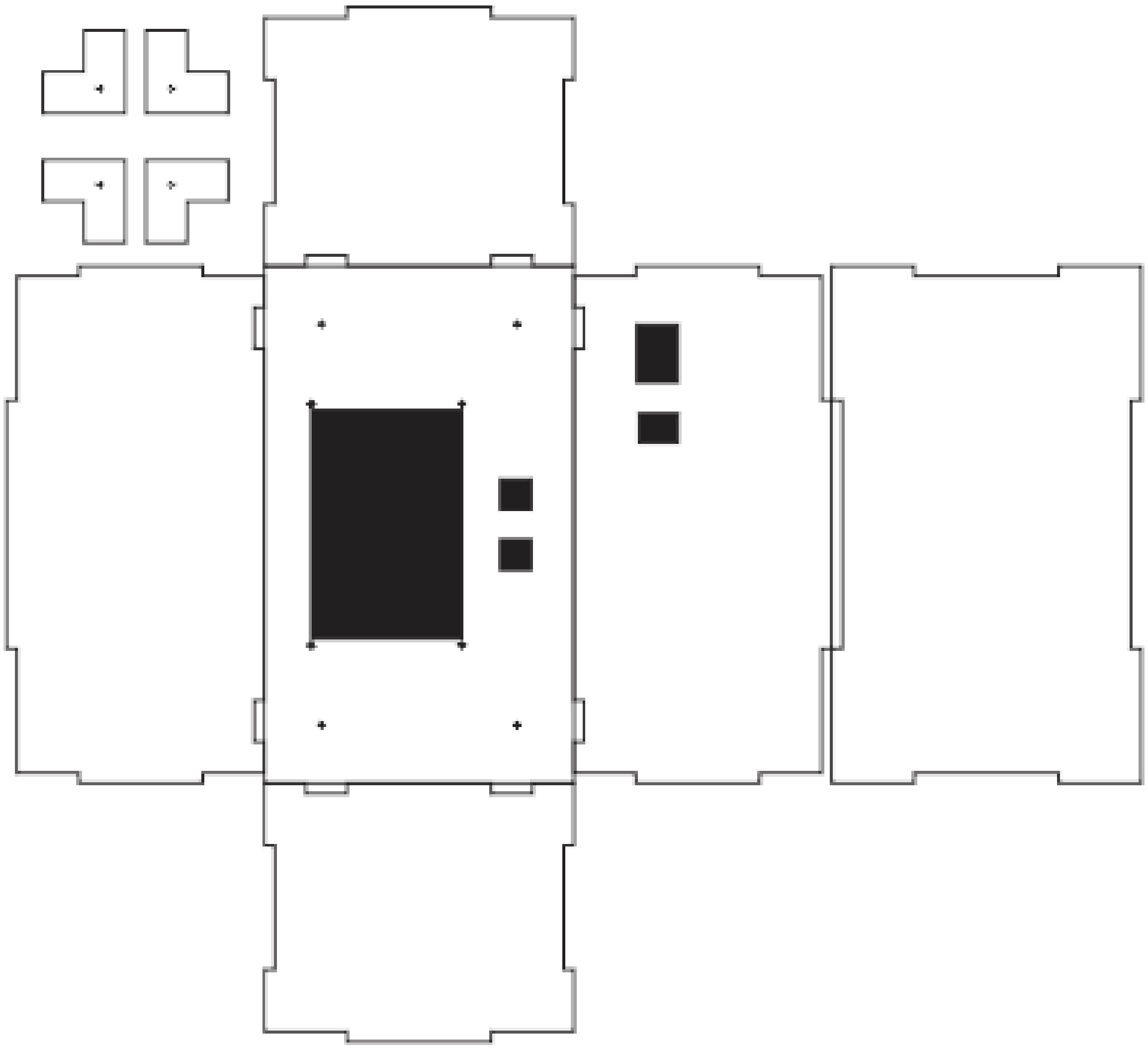

Fig. 3. Design of Vital Sign Using CorelDraw

After the acrylic is cut according to the CorelDRAW design like shown at **Fig. 3**, it will be assembled using Korean glue. Specifically, the top part of the device will be attached using screws with elbows for easy assembly and disassembly. The finished hardware of the device is shown in **Fig. 4**. In the top left part of **Fig. 4**, the top and front parts of the device are shown. At the top, there is a 4.3" Nextion LCD and two buttons for start and reset functions. Then, at the front, there are ports installed for connecting accessories to be attached to the patient. The accessories are shown in the bottom left side of **Fig. 4**. In the top right part of **Fig. 4**, there is a switch to power on and off the vital sign device, along with ports for the power cable. The power cable is used to connect the device to a power source for battery charging. Meanwhile, in the bottom right part of **Fig. 4**, it shows the inside of the box where the microcontroller board and power supply for the device are located.

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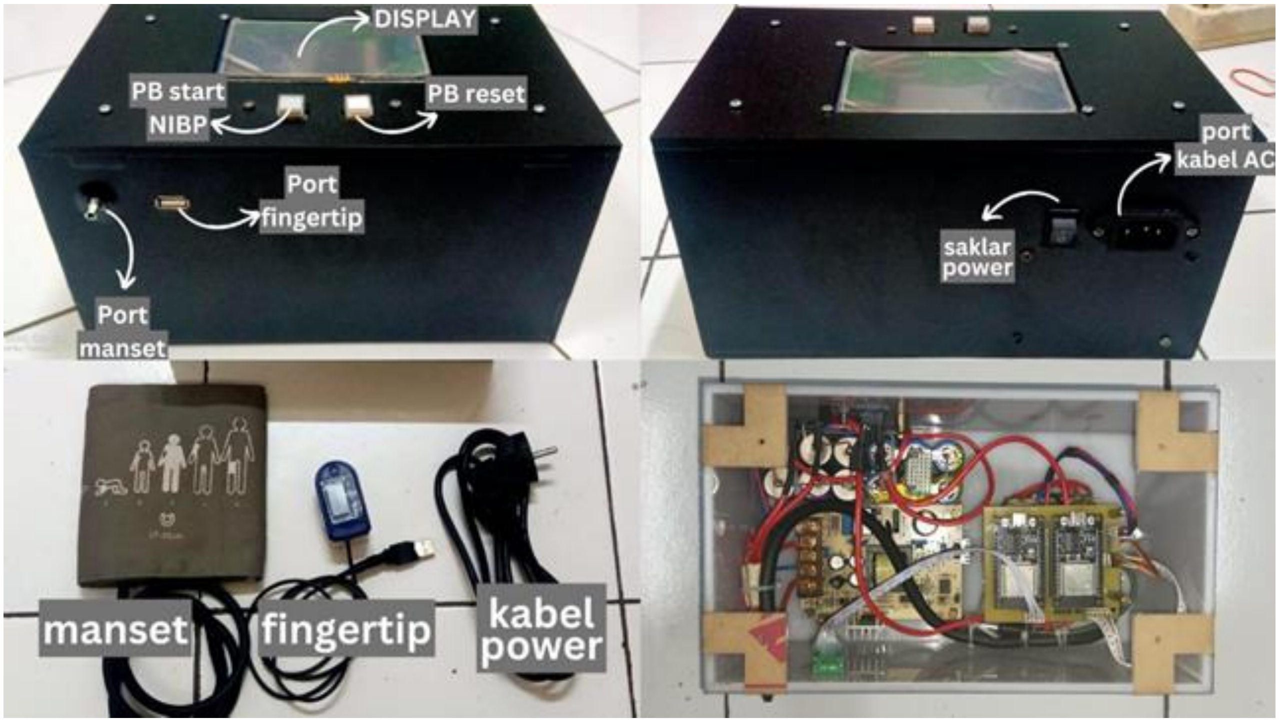

Fig. 4. The Hardware of The Vital Sign Monitor.

2.2. Hardware Circuit

The microcontroller board shown in the bottom right part of Fig. 4 indicates that there are two ESP32 modules. The first ESP32 is used for the SpO2 and BPM measurement algorithm, integrated with a fingertip sensor which includes the MAX30102 sensor. Meanwhile, the second ESP32 is the microcontroller integrated with the Nextion LCD. The ESP32 is equipped with WiFi, Bluetooth, and various other peripherals. It's a comprehensive microcontroller featuring a processor, storage, and GPIO (General Purpose Input Output) access. The ESP32 supports direct WiFi connections and is known for its robust performance. In terms of performance, the ESP32 tends to have better speed due to its dual-core microprocessor architecture. More detail about ESP32 shows at **Table 1.**

Table 1
Summary of the ESP32 Specifications

Items	Specifications
System On Chip (SOC)	The WiFi and Bluetooth modules are ESP32 FCC certified.
Size	39mm × 31mm
Voltage	RT9013 500mA
Input Voltage	3.0~5.5VDC
Analog-to-Digital Converter (ADC)	16 channels SAR ADC 12-bit
Digital-to-Analog Converter (DAC)	Two 8-bit DACs
Pulse-Width Modulation (PWM)	16 channels PWM pins
Touch Sensor	10 GPIOs feature capacitive sensing capabilities.
Universal Asynchronous Receiver-Transmitter (UART)	2
I2C, SPI, I2S	2/4/2

The device module utilizes two ESP32 modules that shows at **Fig. 5**. The first ESP32 is used for the SpO2 and BPM measurement algorithm, integrated with a fingertip sensor which includes the MAX30102 sensor. Meanwhile, the second ESP32 is the microcontroller integrated with the Nextion LCD. Each ESP32 receives a voltage of 5V. The input voltage

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for the Nextion display is also 5V from the step-up module. The MAX30102 sensor is connected to the ESP32 via the SDA, SCL, VIN, and GND pins.

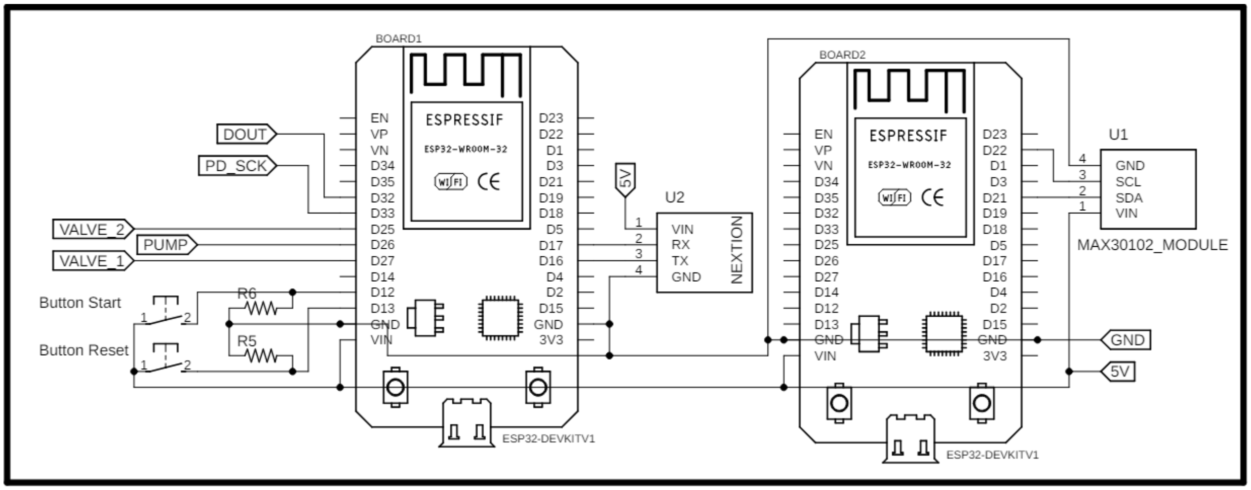

Fig. 5. Sensor System Circuit

The device module requires power supplied from a battery source. The battery in this device module is arranged in a 2-series system, which will produce a total voltage of 8.4V. In this circuit, a Battery Management System (BMS) is used to control charging and provide two different output voltages. These voltages are 5V and 4.2V. The 5V voltage is used to power the microcontroller, ESP32, while the 4.2V voltage is used to power the sensor and Nextion display. For more detail is shows in **Fig. 6.**

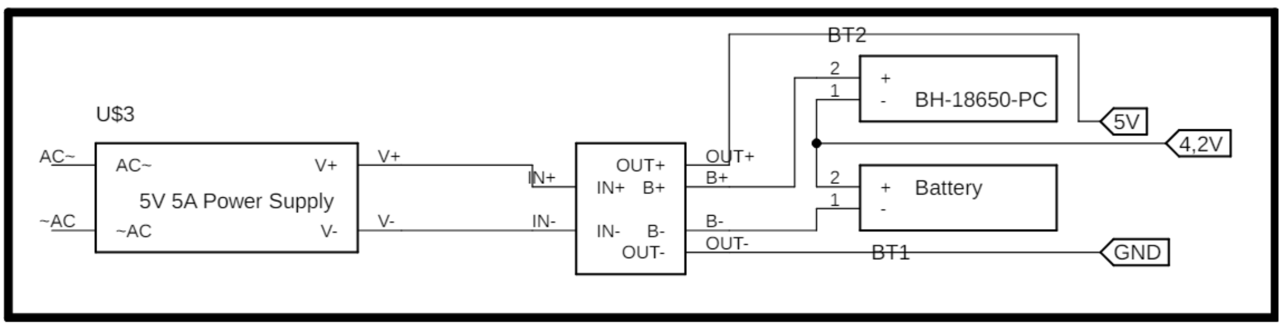

Fig. 6. Power Supply Circuit

2.3. ESP32 Software

The program is created using the Arduino IDE, where the ESP32 library needs to be installed beforehand to be used for developing algorithms for the ESP32 microcontroller. This software is designed for measure SpO2 and BPM. The algorithm will measure these two parameters using data obtained from the Photoplethysmography (PPG) method by the MAX30102 sensor. The calculation algorithm is obtained from the MAX30102 library sketch code available in the market. Flowchart in **Fig. 7** illustrates the algorithm flow used for this device. The process begins with the initialization of the ESP32 microcontroller. When the patient uses the fingertip module containing the MAX30102 sensor, the sensor will start detecting using the photoplethysmograph method. The photodiode or can be called photodetector will detect the light reflection produced from the LED reflection onto the patient's finger. To obtain accurate results, it will take some time, typically 10 to 15 seconds, to wait for the photodiode data to stabilize. Photodiode data is considered stable when the rise and fall of the analog signal have the same and consistent height. If the data is still erratic, meaning the signal levels are rapidly fluctuating randomly, a message will appear as a warning for the patient to reposition the fingertip sensor, as this usually happens when there is movement interfering with the sensor. Determining erratic and stable signals can be achieved by utilizing automatic thresholding. The threshold will automatically follow the generated PPG signal, and when significant changes are detected, the threshold value will differ from the sensor value. Once the data is stable, the ESP32 will process the data and display it on Nextion display in the form of SpO2 and BPM Values.

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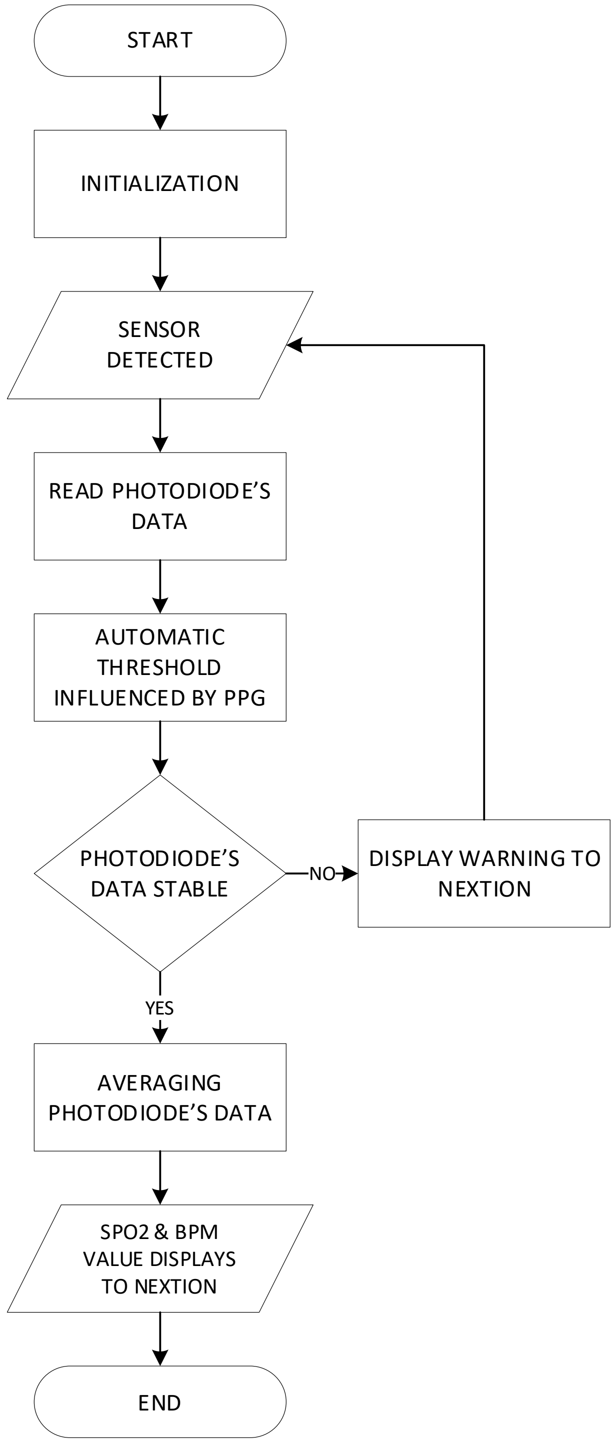

Fig. 7. Flowchart of Vital Sign Device Design

On the device module, a warning will appear if the patient's condition involves movement, causing instability in the finger condition. There is also a warning indicating that no finger is detected on the finger sensor. The determination of these conditions is done through the above program. This program will calculate the standard deviation of a data array from the pulses read by the sensor. The resulting value will vary depending on the data read by the sensor. If there is finger movement, the standard deviation value will also change according to the sensor data. The more movement the subject makes, the greater the standard deviation value. From that value will determine whether there is a finger present or movement in the subject's finger.

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2.4. Portable Design of Vital Sign Using MAX30102

The module uses the MAX30102 sensor to measure blood oxygen saturation (SpO2) and heart rate (BPM). Data were collected from ten respondents, each ten times. The test results show an average SpO2 of 96.66 with a standard deviation of 0.52. This indicates that the device provides good and homogeneous results. The SpO2 measurement error is ±0.02%, indicating good accuracy. The average BPM measured is 96.42 with a standard deviation of 14.01. BPM variation is larger compared to SpO2 due to the wider range of BPM data. The BPM measurement error is ±0.16%, also indicating good accuracy. In terms of error values, the MAX30102 is superior to the MAX30100. The power required by the MAX30102 is also less compared to the MAX30100 series used in previous studies. More details can be seen in **Table 2**. These results demonstrate that the module has good accuracy for measuring SpO2 and BPM. The device is designed to be portable, making it easy to carry anywhere. Additionally, since the device is powered by a long-lasting battery, approximately ±2 days with 12 hours of usage per day based on testing, it can be helpful when electrical power is not available.

Table 2
Comparison between MAX30102 and MAX30100

Feature	MAX30102	MAX30100	Difference
SpO2 Accuracy	±0.02% error	±1% error	MAX30102 offers higher accuracy.
BPM Accuracy	±0.16% error	±2% error	MAX30102 offers higher accuracy.
Power Consumption	Lower (optimized for battery-powered devices)	Higher	MAX30102 is more power-efficient.
Noise Performance	Lower noise, better signal-to-noise ratio	Higher noise	MAX30102 provides cleaner signal readings.
Motion Artifacts	Reduced sensitivity to motion artifacts	More sensitive to motion artifacts	MAX30102 performs better in dynamic conditions.
Sample Rate Support	Higher sample rate support	Lower sample rate support	MAX30102 supports faster sampling.
Integration	Enhanced algorithm and hardware integration	Basic integration	MAX30102 offers better integration.
Package Size	3.3 mm x 6.6 mm x 1.55 mm	Larger	MAX30102 is more compact.
LEDs	Two LEDs (Red + IR)	Two LEDs (Red + IR)	Similar LED configuration.
Operating Voltage	1.8V - 3.3V	1.8V - 3.6V	Slightly different voltage range.

2.5. Cost

The price of widely available portable vital sign monitors ranges between approximately 300USD-500USD like shows in **Fig. 7**. This cost is not affordable for everyone. Furthermore, monitoring vital signs, especially SpO2 and BPM, is essential. The device developed requires <100USD to obtain a vital sign monitor that can measure these two vital signs. Additionally, the design in this research is also open source or open for publicm making it easy to access and develop for future research advancements.

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Fig. 7 Mini vital signs monitor PC100

2.6. Summary

This vital sign device can be used to measure oxygen saturation and heart rate comfortably and efficiently. The result of this research are as follows:

(a) The hardware design is quite simple and portable.
(b) It can be used to measure two types of vital signs simultaneously.
(c) The device is comfortable and easy to use for both patients and operators.
(d) It is battery-powered, allowing for use even when electrical power is unavailable.
(e) It can be used for approximately 2 days with frequent usage.
(f) The charging time is quite fast, requiring only 2 hours to fully charge from an empty battery.

3. Design Files Summary

3.1. Design file

This section contains the results of the research design. It includes the design documentation for the board, the box design, and the software for the research instrument, as shown in **Table 3**.

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Table 3
Summary of Vital Sign Monitoring SpO2 and BPM (Photoplethysmograph Method) Design File

Design File Name	File Type	Open Source License	Location Of The File
Schematic Controller.sch	Schematic, eagle file	CC BY-SA 4.0	DOI 10.17605/OSF.IO/8PTFB
Board Controller.brd	Board, eagle file	CC BY-SA 4.0	DOI 10.17605/OSF.IO/8PTFB
Software Nextion.ino	Software, Arduino	CC BY-SA 4.0	DOI 10.17605/OSF.IO/8PTFB
Software SpO2 and BPM.ino	Software, Arduino	CC BY-SA 4.0	DOI 10.17605/OSF.IO/8PTFB
Design Box Vital Sign.cdr	CorelDraw	CC BY-SA 4.0	DOI 10.17605/OSF.IO/8PTFB

3.2. Schematic and Board
The schematic of the tool made by the Eagle application program V 9.1.0 (available in: Eagle) The schematic includes the circuitry of the microcontroller along with sensors, showing how they are interconnected. Drawing a schematic diagram that shows the connections between electronic components ensures that all components are correctly connected and meet the instrument's requirements The board design is the core of the research instrument, serving as the place where all electronic components are integrated.

3.3. Software
Software is the part that controls and operates the research instrument. In this study, Arduino application program (Version 2.3.3, visit the website: Arduino IDE) was used for developing the programs. In **Table 3**, there are two software types listed: one for SpO2 and BPM measurement, and another for Nextion interface. This separation is due to the device's utilization of two ESP32 microcontrollers, each containing different algorithmic implementations.

3.4. Box Design
The box design of the Vital Sign was made by an application called Corel Draw (available in the free version: corelDraw). he box design serves as the physical protection for the board and other electronic components. This design must be adjusted to the dimensions and shape of the box to be ergonomic and fit the size of the board and other additional components. The design also provides necessary holes or ports for cable connections, ventilation, and access to certain components for maintenance or replacement. The Design Box Vital Sign.cdr file shown in **Table 3**.

4. Bill of materials summary

In **Table 4** below are the stores that sell the components or materials needed to make the device. Prices are included as references to facilitate component search. Components or materials can be obtained anywhere; the table below is just an example or reference.

Table 4
Bill of materials of Vital Sign Monitoring SpO2 and BPM (Photoplethysmograph Method)

Designator	Component	Number	Cost per unit (USD)	Total cost (USD)	Source of materials	Material type
MK1, MK2	ESP32	2	3.29	6.58	ESP32	Semi-conductor
SW	Switch	1	0.11	0.11	SWITCH	Plastic, metal
PB1, PB2	Push Button	2	0.21	0.42	PUSH BUTTON	Plastic, metal
S1	MAX30102	1	1.64	1.64	MAX30102	Semi-conductor
O1	Oximeter	1	2.43	2.43	OXIMETER	Semi-conductor, plastic
N1	LCD Nextion 4,3”	1	60.78	60.78	NEXTION	Semi-conductor,

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						glass, plastic, metal
A1	Acrylic 25cmx25cm	1	12.16	12.16	ACRYLIC	Acrylic
BT1, BT2, BT3, BT4, BT5, BT6, BT7. BT8. BT9, BT10, BT11, BT12	Lithium Battery	12	2.86	34.32	BATTERY	Plastic, metal
PA1	Port AC Cable Power	1	1.52	1.52	PORT AC POWER	Plastic, metal
UM1	USB Male	1	0.97	0.97	USB MALE	Metal
UF1	USB Female	1	0.97	0.97	USB FEMALE	Metal
BMS1	BMS	2	0.49	0.97	BMS	Semi-conductor

5. Build instructions

5.1. Hardware Design

The equipment box is chosen to be made of acrylic material because it is sturdy and nice-looking, although compared to plastic, the weight of acrylic material will be slightly heavier. The design of the equipment is created using CorelDRAW application. It contains features to create shapes according to needs with precise measurements, making it easier for users to design something. CorelDRAW is a vector graphics editor developed by Corel Corporation, primarily used for graphic design, illustration, layout design, and photo editing tasks. It offers features such as vector illustration, page layout design, basic photo editing, typography tools, color management, effects and filters, compatibility with various file formats, extensions support, templates, multi-monitor support, collaboration tools, and cloud integration. The latest version, CorelDRAW Graphics Suite 2022, runs on Windows 10 and Windows 11.

5.2. Software Design

After the hardware fabrication is completed, the next step is to work on the program for the device. The vital sign software was developed using Arduino IDE application program Version 2.3.3. In this application, a program is developed to measure SpO2 (blood oxygen saturation) and BPM (heart rate). In the device module, a warning will appear if the patient's condition causes finger instability. There is also a notification indicating when there is no finger detected on the finger sensor. These conditions are determined by the above program, which calculates the standard deviation of a data array from the pulse read by the sensor. The resulting value varies depending on the sensor data. If there is finger movement, the standard deviation value will also change according to the sensor data. The more movements the subject makes, the larger the standard deviation value. These results will determine whether there is a finger detected or movement in the subject's finger. For measuring, the program will collects 100 samples of red and infrared (IR) data from the sensor. The gathered data will be stored in variables `spo2`, `validSPO2`, `heartRate`, and `validHeartRate`. Then, this data will be used by the function 'maxim_heart_rate_and_oxygen_saturation' to calculate and output the BPM and SpO2 values like shows in **Fig. 8**.

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Fig. 8 Program Calculation of SpO2 and BPM

5.3. Finished Design of Vital Sign

After the hardware and program development, the device is ready to be assembled. The device is rectangular-shaped with a display screen on the top. The 4.3" display screen makes it easy to read the measurement results. Assemble all parts of the box using adhesive. The top part of the box is attached using screws with brackets for easy opening and closing. Then, there is a Male USB port for connecting the fingertip sensor accessory to the device. Once everything is assembled as shown in **Fig. 9**, the device is ready for use.

Fig. 9 Hardware Result

6. Operation instructions

First, make sure the device is charged or has batteries installed. Then, attach the fingertip accessory to the device through the available port. Next, press the switch located at the back of the device for turning on the device. Wait until the display lights up and shows the SpO2 and BPM measurement screen. Then, place the accessory on one of the patient's fingers, ensuring the patient is sitting calmly or lying down. If the 'No Finger' message disappears, it indicates that the finger has been detected and measurement is in progress. After that, the measurement values will appear on the screen.

7. Validation and characterization

The data collection process involves measuring SpO2 and BPM for ten participants. The participants are aged >19 years old, consisting of seven male and three female participants. Measurements are conducted using the device and compared with the GE Medical B125 Patient Monitor. The data collection process is repeated ten times for each participant. All participants receive the same treatment. During the testing, the participants were seated. The device module, designed as a fingertip sensor, was placed on one of the participant's fingers, while the reference device was placed on another finger. Both devices (module and reference) displayed the measurement values on their respective displays. The measurement results from each participant were then recorded for further analysis. The process is visually represented in **Fig. 10.**

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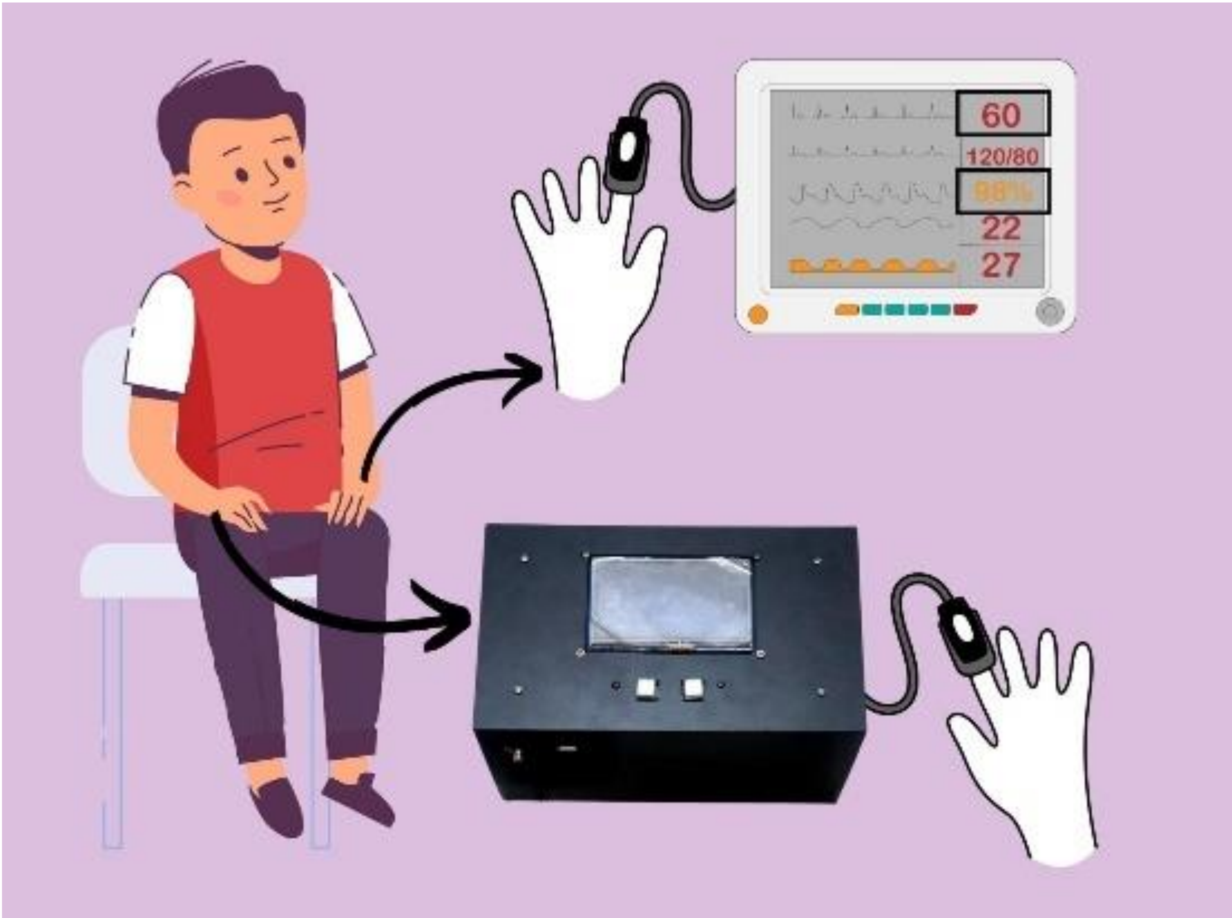

Fig. 10 Data Collection Visualization

Derived from the results in the **Table 5**, it can be observed that the standard deviation (STDEV) values from the device are small. Furthermore, the error value generated by the vital sign compared to the patient monitor, which is the reference device is also small, approximately ±0.02%. These values are obtained from calculations based on the average data of each participant.

Table 5
SpO2 Calculation

RESPONDENT	MEAN	
	PATIENT MONITOR SpO2 (%)	MODUL SpO2 (%)
A	95,80	95,80 ±0,00%
B	97,10	97,10 ±0,00%
C	96,80	97,20 ±0,41%
D	97,10	96,90 ±0,21%
E	96,70	96,20 ±0,52%
F	96,50	97,00 ±0,52%
G	96,90	96,80 ±0,10%
H	96,40	96,40 ±0,00%
I	96,20	96,00 ±0,21%
J	96,90	97,20 ±0,31%
MEAN	96,64	96,66
STDEV		0,52
ERROR (%)		±0,02

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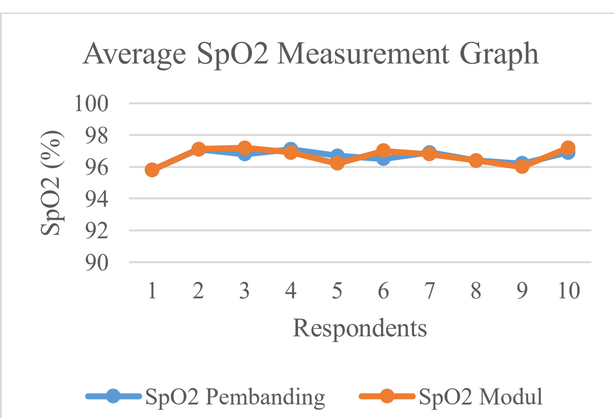
Derived from the results in the **Table 6**, it can be looked that the standard deviation (STDEV) values from the device are moderate. This indicates that the device module shows a reasonable level of variation in BPM measurement values. Furthermore, the error value generated by the module compared to the reference device is also small, approximately ±0.16%. These values are obtained from calculations based on the average data of each participant.

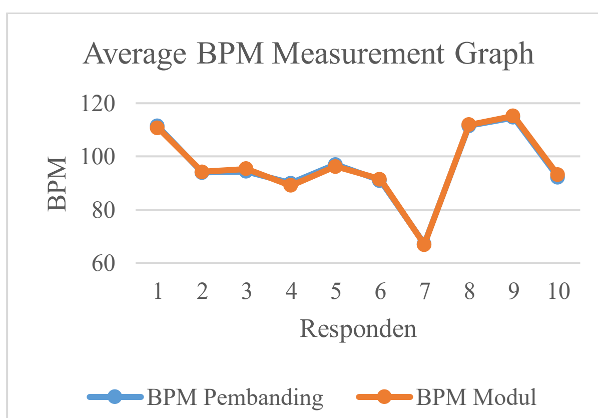
Table 6
BPM Calculation

RESPONDENT	MEAN	
	PATIENT MONITOR BPM	MODUL BPM
A	111,40	110,80 ±0,54%
B	93,90	94,20 ±0,32%
C	94,30	95,30 ±1,06%
D	89,90	89,10 ±0,89%
E	96,90	96,20 ±0,72%
F	90,90	91,50 ±0,66%
G	67,10	66,90 ±0,30%
H	111,50	111,90 ±0,36%
I	114,60	115,20 ±0,52%
J	92,20	93,10 ±0,98%
MEAN	96,27	96,42
	STDEV	14,01
	ERROR (%)	±0,16

During the SpO2 parameter testing on the device module, the average measured SpO2 value obtained was 96.66 (97) with a STDEV of 0.52. This indicates that the device provides good and relatively homogeneous results with slight variation around the average in SpO2 measurements. Then, the measurement error was analyzed by comparing the average results of the reference device with the vital sign device that has been created. The error data obtained is approximately ±0.02%, indicating that the device module has good accuracy in measuring the SpO2 parameter. In BPM measurement using the same steps with the device module, the average measured data result is 96.42 (96) with a STDEV of 14.01. This indicates that the device has a reasonable level of variation around the average in BPM measurements. The STDEV value in BPM is relatively larger compared to SpO2 because the data dispersion range of BPM is larger, ranging from 60 to 115 BPM, while SpO2 ranges from 90% to 100% among the ten respondents. Calculation of the error value was also performed by comparing the average results of the reference device with the vital sign device that has been created. The error data obtained is approximately ±0.16%, indicating that the device module has good accuracy in measuring the BPM parameter. The graph of the data results is shown in **Fig. 11**.



(a)



(b)

Fig. 11 Graph of SpO2 and BPM Measurement Data from 10 Respondents **(a) SpO2**, and **(b) BPM**

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All the above data were obtained from actual respondent measurements. Each of these data are processed to find the mean, STDEV, and error value. These values will later assist in concluding whether the module's performance is good or not. The formula used first is the mean formula. It is the result of dividing the sum of all the collected data by the number of data samples taken.

$$\overline{X} = \frac{\sum Xi}{n} \qquad (1)$$

Explanation:
$\overline{X}$ = Mean
$\sum Xi$ = Sum of all the collected data
n = The number of data samples taken (1,2,3,...n)

Standard deviation is a statistical measure that indicates how dispersed the data is within a dataset. It shows how far the data points are from the mean value. The smaller the STDEV value, the better the measured data because it indicates that the data is not far from the mean value. This affects the consistency, stability, and low risk possibility in the measurement.

$$STDEV = \sqrt{\frac{\sum(x-\bar{x})^2}{(n-1)}} \qquad (2)$$

Explanation:
STDEV = Standard deviation
x = Data value
$\bar{x}$ = Mean value
n = Number of data points

8. Conclusion

This module has been tested and works well. The sensor can read the oxygen saturation or SpO2, and heart rate or BPM using the photoplethysmograph. The microcontroller, ESP32 also can processes the data effectively. The display screen, Nextion, can show the measurement results for both parameters. This is indicated by the small error values, which are 0.02% for SpO2 and 0.16% for BPM. The cost required to build this device is also less than 90 USD. With this module, SpO2 and BPM measurements can be carried out more easily by simply using a finger sensor on a human finger. Additionally, since this device uses battery power, it can be useful in situations where there is no available electrical power. Furthermore, it is hoped that this research can serve as a reference for future research or studies on the use of the photoplethysmograph method for determining SpO2 and BPM values or other related topics.

Ethics statements

The author verified that the subjects provided informed consent. This study received approval from the Health Research Ethics Committee Poltekkes Kemenkes Surabaya, Indonesia following an ethical review, No.EA/2405/KEPK-Poltekkes_Sby/V/2024.

Credit author statement

Adinda Natasya: Methodology, Conceptualization, Software, Data collection, and Measurement. **Triana Rahmawati**: Mechanical Design and Validation. **Levana Forra Wakidi**: Electronics and Design.

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Declaration of interests

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The authors declare that there is no conflict of interest.

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