ELECTROMEDIC, Journal of Medical Electronic
Multidisciplinary : Rapid Review : Open Access Journal **eISSN:**

Manuscript received November 10, 2020; revised March 3, 2021; accepted April 21, 2021; date of publication April 28, 2021
Digital Object Identifier (DOI): 10.1109/ELECTROMEDIC.v1.i1.1

Design of an IoT-Based Patient Bracelet for Monitoring SpO_2, Heart Rate, and Body Temperature

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ABSTRACT Vitalsign examination is the most basic measurement of body function to determine clinical signs and is useful for strengthening the diagnosis of a disease, and functions in determining the appropriate medical care plan. Oxygen saturation, heart rate, and body temperature are some of the most basic vital sign parameters for paramedics in determining the physical condition of patients. The prototype aims to facilitate the measurement of heart rate, oxygen saturation, and temperature with one tool. Using this tool requires a finger as the basis for taking heart rate data, oxygen saturation, and the wrist for temperature. To support data accuracy in patients, the author uses the MAX30102 sensor to measure heart rate, oxygen saturation, and body temperature using DS18B20. For the output display using TFT LCD, and can display data in real time using the IP Address web-based protocol. Data retrieval is done by comparing the results of the module readings and comparison tools, namely pulse oximetry with oxygen saturation and heart rate parameters. Testing is done using the fingertips as input for prototype sensor data, and temperature on the wrist. While the sensor data on pulse oximetry is installed alternately in the same index finger position as the prototype sensor position. And for body temperature, data collection is done by comparing the reading results on the prototype with a digital thermometer. The results of the percentage of accuracy in testing using a pulse oximetry comparison tool with oxygen saturation parameters (SpO_2) of 99 %, the percentage of accuracy in the heart rate parameter (heart rate) of 97.99%, and the percentage of accuracy in the body temperature parameter of 97.75%.

INDEX TERMS SpO_2, BPM, Temperature, Max30102, DS18B20.

I. INTRODUCTION

Wearable technology in healthcare has undergone significant evolution in recent years, providing innovative solutions for more efficient and accessible health monitoring. Heart rate monitoring, blood oxygenation (SpO_2), and body temperature are vital parameters that are very important in health management, both for daily monitoring and for early detection of serious medical conditions. With the increasing development of technology, web-based patient bracelets have emerged as a promising solution for integrating health monitoring with digital platforms, offering convenience in data collection and real-time health analysis, making it easier for doctors and paramedics to monitor vital signs in patients in health facilities. [1].

In this millennial era, technological developments are experiencing a significant transformation, including in the health sector. One key innovation is the wearable Internet of Things (IoT), which offers the benefits of continuous internet connectivity. The use of IoT in wearable devices, such as smart watches and fitness bracelets, enables real-time health monitoring and early detection of deviations from normal health conditions. This technology supports telemedicine, facilitating remote diagnosis, monitoring, and intervention. This implementation shows the great potential of IoT in increasing the efficiency and effectiveness of health services, especially in remote areas. [2].

There are several parameters of vital signs in humans, one of which is body temperature, which can provide an initial indication of medical conditions such as infection or metabolic disorders. Continuous monitoring of body temperature can detect significant changes in health, such as fever or hypothermia. Bracelets equipped with temperature sensors, such as *Withings ScanWatch*, can provide real-time body temperature data, enabling more effective monitoring and rapid response to changing health conditions.

Plan Build. This tool is intended for monitoring *Vitalsign.* The patient is displayed on a TFT display screen and is based on *IoT* in heart rate monitoring, SpO_2, and body temperature. By utilizing Arduino technology integrated with IoT, the design of this patient bracelet will explore how this system can improve patient health monitoring, provide accurate data, and support better health management through easier access. [3].

A. VITALSIGN

Vital Sign is a basic physical examination known as vital signs or vital signs examination, which is one form of method carried out by personnel to determine system changes that occur in the patient's body and determine the patient's diagnosis. Changes in vital signs in a person's body can occur if they are in an unhealthy condition. Changes that occur in the patient's body indicate a health problem in the body system. Check vital signs or examine *vital signs.* This is usually very commonly done by doctors, midwives, and nurses to monitor the patient's progress, to see and assess the patient's condition. The act of checking vital signs is a form of monitoring the patient's condition. In examining vital signs, there are four main components in assessing a patient's condition, namely, blood pressure, temperature, respiration, and pulse.

This vital signs examination has a purpose, to help medical personnel in diagnosing patients or clients, formulating intervention plans and evaluating or assessing the success of vital signs, to determine the value of the patient's body temperature, to determine the pulse rate in the patient's body (rhythm, frequency and strength), to see and assess cardiovascular abilities, and to determine the frequency, rhythm and depth of breathing. [4].

B. SpO2

Oxygen saturation (SpO_2) is the ratio of the actual amount of oxygen bound by hemoglobin to the total ability of blood hemoglobin to bind oxygen. At low partial pressure of oxygen, most of the hemoglobin is deoxygenated, which means the process of distributing oxygenated blood from the arteries to the body tissues. *Pulse oximetry* functions to monitor blood oxygen saturation. This is done to ensure sufficient oxygen levels in the vessels. Usually used for patients who experience poor conditions. This tool displays heart rate frequency and oxygen saturation.[5]. \

Blood oxygen saturation (SpO_2) and heart rate are one of the body variables that are important to measure and monitor to determine the body's health condition. Oxygen saturation levels are the percentage of hemoglobin that binds oxygen compared to the total amount of hemoglobin in the blood. If the arterial oxygen level reading with an oximeter is below 90 percent, it indicates that the oxygen level in the blood is low, so the blood requires oxygen supplements.

Meanwhile, if the reading of the percentage of oxygen saturation levels is said to be normal in humans if it ranges from 95% to 100%, oxygen levels play an important role in the body's metabolic processes so that if humans lack oxygen levels, it can result in imperfect body metabolism, characterized by hypoxia, which is a dangerous condition that can quickly disrupt the function of the brain, liver and other organsas in Table 1 [6].

TABEL I
OXYGEN SATURATION RANGE

No.	**Category**	**SpO2 Range (%)**
1	Normal	95 – 100
2	A little low	91 – 94
3	Mild hypoxemia	86 – 90
4	Moderate hypoxemia	80 – 85
5	Severe hypoxemia	< 80

C. HEARTRATE

The pulse is a wave that is felt in the arteries caused by the pumping of blood by the heart towards the blood vessels. The pulse can be felt or palpated in arteries close to the surface of the body, such as the temporal artery which is located at the bend of the ankle, the brachial artery which is located in front of the crease of the elbow joint, the radial artery which is located in front of the wrist, and the carotid artery which is located at the level of the thyroid cartilage. The pulse frequency for normal people is the same as the heart rate. Heart rate frequency can easily be measured by measuring the pulse rate. Pulse rate is the propagation of the heart rate, which is calculated every minute by counting repetitions (times/minute), with a normal pulse rate of 60-100 times/minute.

Heart rate is the number of beats per unit of time, which is usually expressed in beats per minute (bpm). The number of human heartbeats is greatly influenced by the human body's temperature, because the speed at which the human heart pumps blood throughout the body depends on changes in the human's temperature. Heart rate *in* adults ranges between 60 – 100 bpm, however, Heart rate cannot be determined by each human being. This depends on physical activity, surrounding air temperature, body position (sleeping/standing), age level, emotions, and the drugs being consumed, as shown in Table II.[7].

TABLE II
NORMAL HEART RATE BASED ON AGE

Age Group	Normal Heart Rate (BPM)
Newborn baby (0-1 month)	70-190
Baby (1-11 months)	80-160
Children (1-2 years)	80-130
Children (3-4 years)	80-120
Children (5-6 years)	75-115
Children (7-9 years)	70-110
Teenagers (10-15 years)	60-100
Adults (16 years and above)	60-100

Factors that influence heart rate include physical condition, emotions, temperature, and medications. Individuals who exercise regularly tend to have a lower resting heart rate. Emotions such as anxiety, stress, or fear can increase heart rate, while a rise in body temperature also leads to an increased heart rate. Additionally, certain medications can either slow down or speed up the heart rate.

The number of heartbeats per minute, commonly known as beats per minute (bpm), is a widely used measure to assess whether a person's heart is healthy or not.

D. TEMPERATURE

Body temperature is a balance between the production and loss of heat from the body, which is measured in heat units called degrees. The temperature referred to is the hotness or coldness of a substance. Body temperature is the difference between the amount of heat produced by body processes and the amount of heat lost to the external environment. In measuring body temperature, there are two measurement scales, namely the *Fahrenheit scale*, which is denoted by °F (degree *Fahrenheit*), and Celsius scale, which is denoted by °C (degree *Celsius*). Human body temperature ranges between 36°C to 38°C. The location of body temperature measurement affects the value of body temperature, but it remains within the normal body temperature range, even though the final results vary. [8].

E. PHOTOPLETHYSMOGRAPHY (PPG)

PPG is a technology that allows measuring the amount of light absorbed by blood vessels, blood, and body tissue. The resulting signals can be translated into various physiological parameters, including variations in blood flow volume, heart rate variability, and blood pressure. As a result, PPG signals can provide diverse biological information and are useful for detecting and diagnosing various health problems. Apart from providing information about blood circulation and heart rate, PPG can also provide information related to detecting hypertension. The use of PPG has become an integral part of monitoring heart health *non-invasive*.

This technology provides important information about heart rate and relevant cardiovascular conditions. With PPG, detection of pulse changes in blood volume within the blood vessel network can be done with each heartbeat. PPG also provides simple diagnostic information, but it is an effective and necessary early examination method to determine whether a patient needs further treatment. However, to understand the information contained in a PPG signal, the signal needs to be displayed clearly so that the important information contained in it can be understood properly. Thus, a deep understanding of PPG signals and the ability to interpret them is key to gaining valuable insights into heart health and overall cardiovascular conditions.

Photoplethysmography (PPG) is a method that can be used to measure heart rate. PPG is a simple optical method that can detect changes in blood volume from the heart pumping non-invasively. The PPG method requires light with an adjustable wavelength so that the photodetector will change the light wave radiation to be the same as changes in the volume of flowing blood. The red LED emits light waves towards the blood, which will be partially absorbed by Hemoglobin in the blood, while the remainder of the light waves will be transmitted and received by the Photodetector. The remaining light waves are then compared with the initial value of the light waves before they are absorbed by the blood. With each pumping of blood by the heart throughout the body, a heartbeat also occurs, accompanied by pulse waves that propagate through the arteries to the ends of the capillaries.

PPG is a signal generated from a sensor using a method of *Photoplethysmography* (PPG), which is wave-shaped in reflectance mode. PD detects light that is re-scattered or reflected from tissue, bone, and/or blood vessels, as shown in Figure 1 below. Reflectance mode eliminates problems associated with sensor placement, and a variety of blood-borne measurement sites can be used. So users can use the PPG device wherever it is on the wrist or at the fingertips [9].

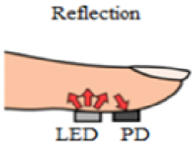

FIGURE 1 **PPG REFLECTION TYPE**[9]

The explanation of the PPG signal in Fig. 1 is as follows:

1. Systolic Point
   The peak point on this graph is called the systolic point. It represents the peak of the PPG wave, which occurs when the heart's ventricles contract and pump blood out of the heart (systole). At this moment, the blood volume in the arterial vessels increases, leading to a rise in the intensity of the PPG signal.
2. Diastolic Point
   The lowest point after the systolic point is called the diastolic point. It occurs after the heart's contraction (during diastole), when the heart relaxes and refills with blood. As the blood volume in the arteries decreases, the intensity of the PPG signal also decreases.
3. Cardiac Cycle
   A complete cardiac cycle includes the contraction phase (systole) and the relaxation phase (diastole), both of which are reflected in the PPG signal. On the graph, one cycle is represented by the duration from one systolic point peak to the next.

The PPG signal consists of an AC component, which reflects the dynamic fluctuations in blood volume related to the heartbeat. This is represented by the periodic waves on the graph (peaks and troughs). Meanwhile, the DC component is a stable baseline that represents the non-pulsatile component of blood[9].

F. SENSOR MAX30102

MAX30102, as seen in Fig. 2, is a sensor module output from Maxim Integrated. This sensor can measure heart rate and temperature at the same time. The components consist of a signal transmitter and receiver. The transmitter source emits infrared waves when the sensor is connected to a voltage source. The receiver is a photodetector that will measure heart rate through changes in the intensity of the light received. The advantage of the MAX30102 sensor is that it has low noise, so it is easy to calibrate. This sensor is widely used in monitoring systems, especially in the fitness sector. Monitoring heart rate and body temperature when exercising is important to determine health conditions. The MAX30102 sensor measures heart rate using the PPG working principle.

The sensor has an IR-LED as a wave transmitter and a photodiode as a signal receiver. When first turned on, the IR-LED will emit waves and expose the fingertips. At the fingertips, there will be changes in the volume of blood flowing when the heart pumps. Changes in light intensity received by the photodetector will be received and converted into beats or clocks.[10].

FIGURE 2 **SENSOR MAX30102**[10]

The working principle of the MAX30100 sensor when collecting data is that when the finger is placed on the sensor, light is emitted by the red LED and infrared LED, then the light waves emitted by the infrared LED will be absorbed by the blood, requiring the presence of a large amount of oxygen. If the oxygen in the blood is reduced, the red LED light wave will absorb more infrared light than the LED. Light waves that are not absorbed will be reflected and detected by the Photodiode.

G. SENSOR DS18B20

The DS18B20 sensor is a sensor used to detect a person's body temperature and is waterproof, as seen in Fig. 3. The output from the DS18B20 sensor is digital data, which is very popular because of its high accuracy, easy integration, and support for communication with the 1-wire protocol. The characteristics of this sensor include, it is used at a voltage of 3.3-5V, the error accuracy level is ±0.5℃ with a temperature range between -10℃ to 85℃, the red cable on the DS18B20 sensor is for VCC, the black cable on the DS18B20 sensor is for GND, the yellow cable on the DS18B20 sensor is for data, the cable diameter is 4mm with a length of 90cm. [11].

FIGURE 3 ***SENSOR DS18B20***[11]

H. ESP32

Fig. 4 shows that ESP-32 is a system-on-chip (SoC) based microcontroller developed by Espressif Systems. Launched as the successor to the popular ESP8266, the ESP32 offers significant improvements in terms of capabilities and features. With a design that integrates multiple components on a single chip, the ESP32 is a top choice for a variety of applications, especially in the development *Internet of Things* (IoT)[12].

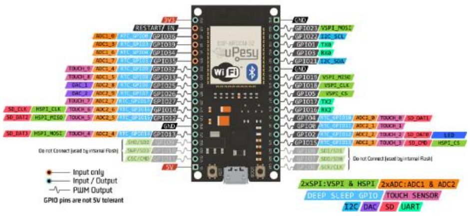

FIGURE 4 PIN ESP-32 ESP32[12]

Architecture and Processor

The ESP32 is equipped with two Xtensa LX6 processor cores that can operate simultaneously at frequencies up to 240 MHz. This dual-core processor is designed to improve computing performance and multitasking efficiency, allowing the ESP32 to handle multiple simultaneous tasks well. Both can function as independent cores or in shared processing mode, depending on application needs.

Memory

This microcontroller provides 520 KB of internal SRAM, which is used for data storage and runtime programming. In addition, the ESP32 supports the use of external Flash memory, which can reach a capacity of 16 MB. This external memory allows storage of large programs and user data, making it ideal for applications that require high memory capacity.

Connectivity

One of the ESP32's superior features is its integrated support for Wi-Fi and Bluetooth, including *Bluetooth Classic dan Bluetooth Low Energy* (BLE). The Wi-Fi feature supports the 802.11 b/g/n standard and allows the ESP32 to connect to a local network or the internet wirelessly. Bluetooth, in both Classic and BLE modes, facilitates communication with other devices, making the ESP32 especially suitable for applications that require wireless connectivity and data communications.

Input/Output dan Peripherals

The ESP32 offers up to 34 GPIO (General Purpose Input/Output) pins, which can be used for various functions. These pins support various modes, including input, output, PWM (Pulse Width Modulation), ADC (Analog-to-Digital Converter), DAC (Digital-to-Analog Converter), and more.

ADC: 18 12-bit ADC channels can be used to read analog signals from external sensors.

DAC: 2 channels of 8-bit DAC allow conversion of digital to analog signals.

UART, SPI, I2C: The ESP32 also supports serial communications via UART, SPI, and I2C, enabling integration with a variety of sensors and devices.

Power Management

The ESP32 is designed with advanced power management features. With deep sleep mode *(deep sleep mode)*, ESP32 can reduce power consumption significantly, making it suitable for applications that depend on battery resources. This mode allows the device to operate with minimal power when inactive, which is very important for the device *wearable* devices or IoT sensors that require low power.

I. Display TFT (Thin Film Transistor) GC9A01

Figure 5. shows the GC9A01 TFT LCD is an LCD that has a single chip SOC driver with 262,144 colors for a-TFT liquid crystal displays with resolution. The GC9A01 supports 8-/9-/12-/16-/18-bit parallel data bus MCU interfaces, 6-/12-/16-/18-bit data bus RGB interfaces, and 3-/4-line serial peripheral interfaces (SPI). The moving image area can be specified in the internal GRAM with the window address function. Defined window areas can be updated selectively, so that moving images can be displayed simultaneously regardless of the still image area. 240RGBx240 dot, consisting of a 360-channel source driver, a 32-channel gate driver, 129,600 bytes of GRAM for 240RGBx240 dot graphic display data, and power supply circuitry. GC9A01 Data Sheet The GC9A01 supports full color, 8-color display mode, and sleep mode for precise power control by software. These features make the GC9A01 an ideal LCD driver for medium-sized or small portable products such as digital cell phones, smartphones, MP3s, and PMPs, where long battery life is a primary concern.[13].

FIGURE 5 DISPLAY TFT GC9A01[13].

J. LITHIUM ION BATTERIES

Figure 6 shows that Lithium-ion batteries are a type of secondary rechargeable battery that can be recharged and are environmentally friendly batteries because they do not contain dangerous materials like previously developed batteries, namely Ni-Cd and Ni-MH batteries. [14].

FIGURE 6 LITHIUM ION BATTERIES[14]

K. INTERNET OF THINGS (IOT).

Internet of Things (IoT) is a concept that aims to expand the benefits of continuous connected internet connectivity, as in Fiig. 7. *Internet of Things* (IoT) can be used in buildings to control electronic equipment such as room lights, which can be operated remotely via a computer network. This research aims to build a remote control device by utilizing internet technology to carry out a mobile-based lighting control process. The research was carried out by building a prototype and a mobile-based application using the Python programming language. In the design of this tool, there is a display feature, namely displaying SPO2 data, heart rate, and user temperature simultaneously and in real time.

Internet of Things (IoT) is a global network connection infrastructure that connects physical and virtual objects through data exploitation, *capture,* and communications technology. IoT infrastructure consists of existing networks and the internet, and its developments. It offers object identification, sensor identification, and connection capabilities that form the basis for the development of independently existing cooperative services and applications, also characterized by a high degree of autonomy and *capturing* high event transfer, network connectivity, and interoperability. [15].

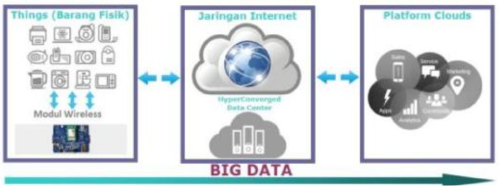

FIGURE 7 **Konsep Internet of Things (IoT)**[15].

The basic working principle of IoT devices is that objects in the real world are given a unique identity and can be reproduced in a computer system and can be represented in the form of data in a computer system. In the early days of implementing the IoT idea, the identifier used so that objects could be identified and read by computers was by using bar codes (*Barcode*), QR Code (QR Code), and Radio Frequency Identification (RFID). In its development, an object can be given an identifier in the form of an IP address and use the internet network to be able to communicate with other objects that have an IP address identifier.

Internet of Things, namely by utilizing a programming argument where each command produces an interaction between machines that are connected automatically without human intervention, and at any distance. The internet is the link between the two machine interactions, while humans only serve as direct regulators and supervisors of the working of these tools.

II. RESEARCH METHODS

A. RESEARCH DESIGN

A research design is a plan and structure of investigation that is structured in such a way that the researcher will be able to obtain answers to his or her research questions. The plan is an overarching scheme that includes a research program. This research uses software design and hardware design methods, which include electronic modules to casings made according to plans that can be wrapped around the user's wrist and are as light as shown in Fig. 8.

The author creates a research flow so that the research can work in an orderly manner according to the workflow created by the author in Figure 8.

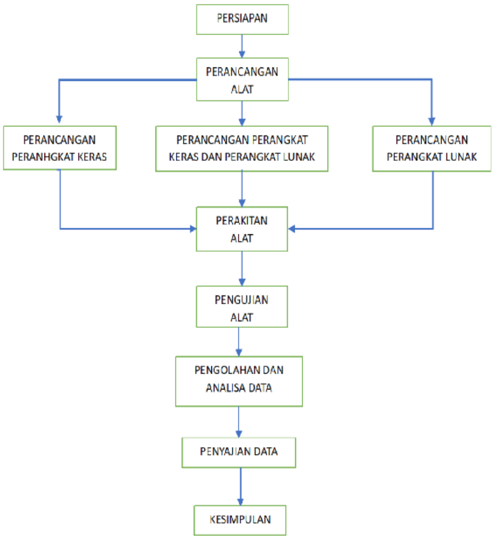

FIGURE 8 Research Flow

B. PROTOTYPE DESIGN PLAN

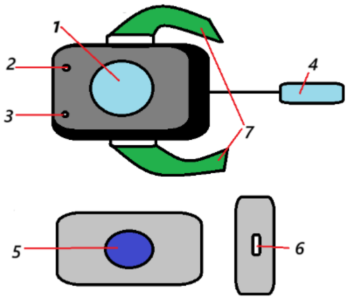

FIGURE 9 ***Front, Back, and Side Views***

Fig. 9 can be explained as:

1. TFT LCD display (touch layer).
2. Reset Button.
3. Standby button.
4. Sensor MAX30102 SpO2 dan Heartrate.
5. DS18B20 Temperature Sensor.
6. Mini USB Type-C connector.

7. Watch strap.

C. BLOCK DIAGRAM PLAN

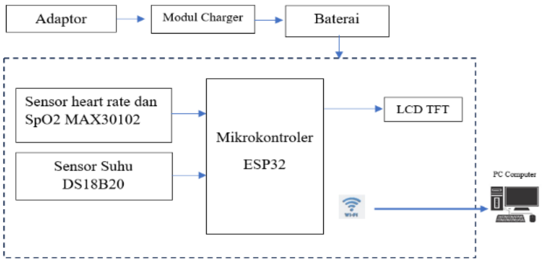

FIGURE 10 **Block Diagrams of Proposed System**

Fig.10 can be explained starts from the AC voltage which enters through the adapter and is converted into DC 5 volts and the Charger module as a module which functions to provide a supply to store electrical power into the 3.3 volt battery, the ESP32 Microcontroller supplies all components which require 3.3 volt voltage which activates the Max30102 sensor and the DS18B20 sensor.

D. FLOW CHART PLAN

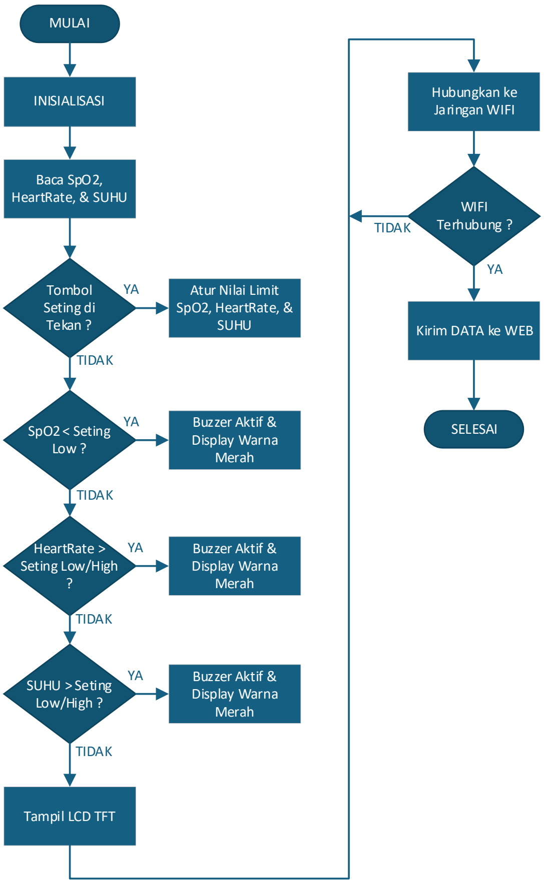

FIGURE 11 **Flowchart of the Prototype**

How the Flow Charts in Fig. 11 work can be explained as:

1. Start
2. Initialize input/output pins, sensors, and TFT LCD Display
3. Read Connected Sensors MAX30102 and DS18B20
4. Check whether the setting button is pressed, then the display will show the setting parameters for each sensor
5. Check whether the SpO value$_2$ is less than the low setting; the buzzer will sound, and the SpO display$_2$ will be red
6. Check whether the Heart Rate value is less than the low/high setting, then the buzzer will sound, and the Heart Rate display will be red
7. Check whether the temperature value is less than the low/high setting, then the buzzer will sound, and the temperature display will be red
8. SpO value$_2$, Heart rate, and Temperature are displayed on the TFT LCD
9. The process of connecting to a WIFI network
10. If Wifi is not available, the process of reconnecting to the network will be carried out
11. Date SpO$_2$, Heart rate, and Temperature are sent to the web base in real-time
12. Finished.

E. ELECTRONIC CIRCUITS DESIGN

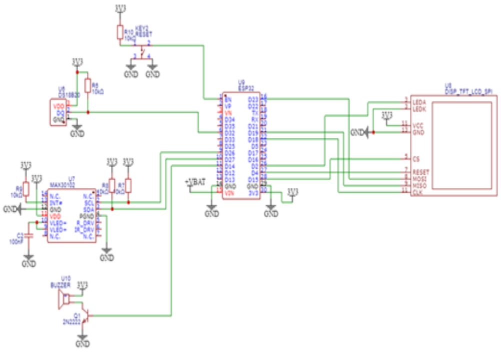

FIGURE 12 **Picture of the prototype Electronic Network**

The way the circuit works in Fig. 12 is when the circuits get a voltage according to the specifications required by the circuit, the ESP32 performs initialization to activate the sensors and activates WiFi which is useful for displaying the IP Address to be able to display on a cellphone or computer on a web-based basis, the sensors provide a signal to be displayed on the TFT LCD layer. On the TFT layer, SpO2, heart rate, and temperature alarm limits can be set, so that if the sensor gives a signal that exceeds the alarm limit, the ESP-32 gives a signal to the buzzer to be activated.

F. PROTOTYPE TOOL SPECIFICATIONS

The design specifications for the patient bracelet are as follows:

1. 3.7 VDC battery with 1500mAh power
2. TFT LCD screen (touch layer).
3. Microcontroller: ESP32
4. MAX30120 sensor for SpO2 and Heart rate.
5. DS18b20 sensor for temperature.
6. Can be displayed on computers and cellphones by accessing the IP Address displayed on the TFT screen.

III. RESULTS AND DISCUSSION

In this chapter, the author will explain the results of the analysis and discussion of the scientific papers that have been prepared. At this stage, the module has been completed, and several measurements have been carried out to complete this scientific paper. And the author will present data that has been taken in several measurements.

A. PHYSICAL FORM OF THE EQUIPMENT

FIGURE 13 **Physical Prototype and display on the web-based**

Figure 13 shows that the tool has been made according to plan. The image also shows a web-based display that uses a computer by calling the IP address in the web program on the computer or an Android cellphone.

B. DEVICE FUNCTION TESTING

Before carrying out testing and analysis on the prototype that has been created, a functional test on each prototype component needs to be carried out first.

TABLE III
FUNCTIONAL TESTS ON PROTOTYPE COMPONENTS

No.	Device Components	Test Results
1	Reset button	Works
2	Stanby button	Works
3	Buzzer	Works
4	Sensor MAX30102	Works
5	Sensor DS18B20	Works
6	LCD	Works
7	Charger module	Works
8	Battery	Works

Detailed testing carried out on the prototype in Table III is as follows:

1. Pressing the reset button, then the prototype re-initializes.
2. Pressing the standby button for 10 seconds, the prototype will turn off the screen display, with sleep mode turning off the LCD layer backlight.
3. Pressing any button, the buzzer makes a sound.
4. The MAX30102 sensor emits red light and infrared light.
5. The DS18b20 sensor works when it can display the temperature on the LCD layer.
6. The TFT LCD touch screen can display information according to the design plan and can be touched to enter the next menu.
7. The battery charger can charge the battery as indicated by the increase in battery voltage value shown on the LCD screen.
8. The battery can function after the Type-C charging cable is disconnected, so the power comes from the battery.

After carrying out thorough testing on the prototype components that have been made, the prototype can be tested to compare it with standard health equipment products.

C. STANDARD OPERATIONAL PROCEDURES (SOP)

Standard Operating Procedures (SOPs) are a series of written rules that regulate how a specific method or process must be carried out in a tool. SOPs are designed to achieve measurement quality and safety for equipment, users, and patients. Standard Operating Procedures (SOP) for the tools that have been designed are as follows:

1. Place the Unit on the user's wrist and tighten the strap.
2. Install the *finger sensor* on the user's finger.
3. Turn on the unit by pressing the Stayby button. Make sure the voltage on the battery indicator is at least 3V. If it is below this voltage value,

please charge the battery first with an adapter that has a Type-C connector cable.

4. Atur limit alarm SpO_2 by pressing the screen on the SpO indicator$_2$ until you enter the SpO Limit Settings menu$_2$, press up to increase the limit setting limit and down to decrease the limit setting, then press save to save the settings, after that press exit on the screen to exit the SpO limit setting menu$_2$.
5. Set the Heartrate alarm limit by pressing the screen on the indicator *heartrate* until you enter the Setting limits menu *heartrate*, press up to increase the limit setting limit and down to decrease the limit setting, then press save to save the settings, after that press exit on the screen to exit the limit setting menu *heartrate*.
6. Set the temperature alarm limit by pressing the screen on the temp indicator until you enter the temperature limit setting menu, press up to increase the setting limit limit and down to decrease the setting limit, then press save to save the settings, after that press exit on the screen to exit the temperature setting limit menu.
7. To display on the laptop and Android website, make sure the *IP Address is* the same as the unit shown on the patient wristband unit screen.
8. Use the patient bracelet unit as needed.

D. TESTING AND DATA ANALYSIS

The measurements in this study will compare the measurement results of *SpO_2, Heart rate,* and temperature. Testing is carried out by directly comparing the reading results from the *prototype, Pulse oximeter,* and *Thermometer* digital, where each parameter is read 10 times. Measurements were carried out by researchers with 10 measurements. Fig. 14 shows the activity of data collecting.

After measuring each parameter, the measurement results will be recorded. During testing, observations are made of the intermediate measurement results, *pulse oximetry* for *SpO_2* and *heart rate*, and a *digital thermometer* for temperature.

FIGURE 14: **Data Collection Activities**

Module testing was carried out using a comparison tool in the form of a calibrated pulse oximeter, namely the Beurer brand model PO30 with serial number 2022H12/002570. Each parameter was measured 10 times, namely SpO2 and Heart Rate (BPM), and temperature, using a comparison tool in the form of a digital thermometer. Module measurements were carried out on the index finger of the researcher's right hand, while the comparison tool was placed on the same finger in succession. For body temperature, the digital thermometer sensor was placed close to the prototype temperature sensor.

After measuring each parameter, the recorded data is documented. During testing, observations were made of the sensor response to readings and potential differences in measurement results for each parameter. The recorded measurement data is processed using a formula to analyze the accuracy of the module that has been designed. The results of this test are used as analysis material to determine the percentage accuracy of the module that has been developed.

E. SpO_2 DATA COLLECTION

SpO retrieval$_2$, by comparing the measurement results from the Pulse Oximeter against the *Prototype. The result is shown in Table IV.*

TABLE IV
TESTING SpO2 DATA RESULTS

No	Data Retrieval	Measurement results (%)		Error/Correction
		Pulse Oximetry	Prototype	
1	1	98	99	1
2	2	98	99	1
3	3	99	100	1
4	4	99	100	1
5	5	98	99	1
6	6	99	99	0
7	7	99	98	1
8	8	99	99	1
9	9	98	100	2
10	10	98	99	1
Rate-Rata		**98,5**	**99,2**	**1**
Error/correction value		**1 %**		
% Error		**1 %**		
% Accuracy		**99 %**		

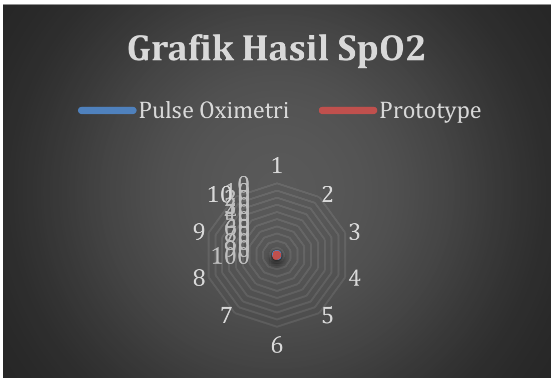

FIGURE 15 **GRAPHICS SPIDER CHART SpO2**

Fig. 15 shows the Radar graph (spider chart) showing the comparison of SpO₂ (Blood Oxygen Saturation) measurement results between the two methods:
Pulse Oximetry blue line, Prototype orange line
This radar graph has a circular axis with scale values increasing from the center outward, possibly representing SpO₂ values in the 0-100% range.
Each point on the graph shows the SpO₂ value measured using a standard Pulse Oximeter compared to the Prototype being tested.
If the two lines (blue and red) are very close or overlap, it means the prototype has accuracy close to standard equipment.
From the graphic image, it seems that the results from the prototype are quite close to the results from a standard pulse oximeter.
When measuring oxygen saturation *(SpO₂)* on *pulse oximetry* compared to the *prototype,* the average presentation error value is 1% with an accuracy level of 99%.

F. HEART RATE DATA COLLECTION

Taking the heart rate by comparing the measurement results from the Pulse Oximeter against the *Prototype is shown in Table V.*

TABEL V
TESTING HEART RATE DATA RESULTS

No	Data Retrieval	Measurement Results (BPM)		Error/Correction
		Pulse Oximetry	Prototype	
1	1	83	83	0
2	2	84	83	1
3	3	84	88	4
4	4	84	83	1
5	5	84	88	4
6	6	85	83	2
7	7	87	88	1
8	8	86	83	3
9	9	84	83	1
10	10	83	83	0
Rate-Rata		**84,4**	**84,5**	**1,7**
Error/correction value		**1,7 %**		
% Error		**2,01%**		
% Accuracy		**97,99 %**		

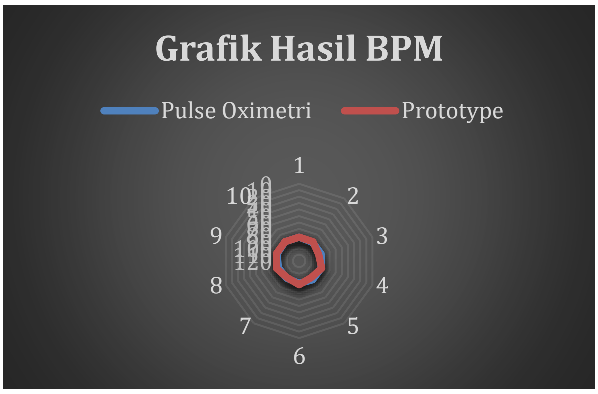

FIGURE 16 **GRAFIK SPIDER CHART HEART RATE**

Fig. 16 shows the heart *rate,* which displays the BPM measurement results (*Beats Per Minute*) of two different methods pulse oximeter and the *prototype*. This graph is in the form of a radar chart (*spider chart*) with 10 axes representing 10 different measurement samples, the two blue and orange lines almost coincide, indicating that the measurement results from the pulse oximeter and *prototype* have very similar values. Value Scale

The graph's radial axis has a BPM scale with values ranging from 0 to 120 BPM. The data points are in the range of 80-100 BPM, which corresponds to the normal range of human heart rate.
On heart rate measurement *(heart rate)* on *pulse oximetry* compared to the *prototype,* the average presentation error value is 2.01% with an accuracy level of 97.99%.

G. TEMPERATURE DATA COLLECTION

Retrieval of temperature data by comparing digital thermometers with prototypes, as shown in Table VI.
After measuring the temperature parameters, the measurement results will be recorded. During testing, observations are made of the intermediate measurement results *Prototype* against a digital thermometer. The results of this test are analyzed to determine the percentage of accuracy of the designed module.

TABLE VI
TESTING TEMPERATURE DATA RESULTS

No	Data Retrieval	Measurement Results (ºC)		Error/Correction
		Thermometer	Prototype	
1	1	36	37,3	1,3
2	2	36	37,4	1,4
3	3	36,6	37,3	0,7
4	4	36,6	37,2	0,6
5	5	36,5	37,4	0,9
6	6	36,2	37,4	1,2
7	7	36,3	37,4	1,1
8	8	36,6	36,9	0,3
9	9	36,6	36,9	0,3
10	10	36,6	37	0,4
Rate-Rata		**36,4**	**37,22**	**0,82**
Error/correction value		**0.82 %**		
% Error		**2,01%**		
% Accuracy		**97,75 %**		

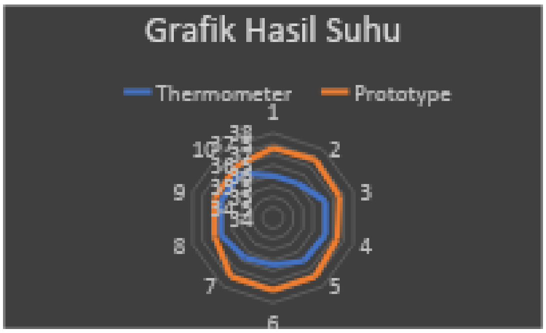

FIGURE 17 **GRAPHIC SPIDER CHART TEMPERATURE**

Fig. 17 compares temperature results between the Thermometer and the Prototype.

This graph is in the form of a spider chart, which is used to compare several variables in the form of a polygon centered on one center point. The radial axis shows the temperature value listed in number 34ºC, 35 °C, 36 °C, 37 °C, and 38 °C.

Showing that the results from the thermometer tend to be higher than the prototype, the shape of the two lines shows a similar pattern, which means the prototype has a measurement trend that is in line with the thermometer, but with slight differences in values. Fig. 17 shows that although the prototype follows the thermometer measurement pattern, there are differences that may be caused by factors such as sensor accuracy or tool calibration.

On temperature measurements on the *thermometer digital* compared to the *prototype,* the average presentation error value is 2.25% with an accuracy level of 97.75%.

IV. CONCLUSIONS

This study concludes that the MAX30102 sensor is capable of accurately measuring oxygen saturation (SpO_2) and heart rate, while the DS18B20 sensor effectively measures skin temperature. The prototype achieved high levels of accuracy when tested against standard comparison tools, with accuracy rates of 99% for SpO_2, 97.99% for heart rate, and 97.75% for temperature. Additionally, the device successfully transmits and displays real-time vital sign data—SpO_2, heart rate, and temperature—through a web-based interface using an IP address protocol programmed into the ESP-32 microcontroller. These results demonstrate the system's potential for reliable, real-time monitoring in digital health applications.

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