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DEVELOPMENT OF A PORTABLE DIGITAL SYSTEM FOR VITAL SIGN MEASUREMENT USING MULTI-SENSOR INTEGRATION

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ABSTRACT The designed module has dimensions of 85.50mm x 54.94mm with a Nextion LCD (85.50mm x 54.94mm). Portable vital sign monitoring devices play an important role in supporting home-based healthcare and early detection of clinical abnormalities. This study presents the development of a compact digital system capable of measuring five vital parameters —blood pressure, oxygen saturation, heart rate, respiration rate, and body temperature—using an integrated multi-sensor architecture. Blood pressure is measured using the MPX5050GP sensor with the oscillometric method; oxygen saturation and heart rate are obtained from the MAX30100 PPG sensor; and body temperature is measured using the DS18B20 digital sensor. Functional testing was performed to evaluate sensor response and operational stability. The system successfully displayed all vital parameters on the Nextion LCD. The findings demonstrate the feasibility of integrating multiple physiological sensors into a portable module for basic vital sign assessment. Further work is recommended to conduct clinical validation and optimize measurement accuracy.

INDEX TERMS vital sign, blood pressure, oxygen saturation, heart rate, respiration rate, body temperature

I. INTRODUCTION

The rapid advancement of technology has greatly influenced various sectors, particularly healthcare, where medical devices are continuously evolving to improve patient care [1]. In modern hospitals, technological innovations extend beyond diagnostic and therapeutic equipment to include patient monitoring systems. One essential tool in this regard is the vital sign monitor, which enables continuous, real-time monitoring of a patient's physiological conditions. Effective monitoring of vital signs is a crucial aspect of clinical practice, especially for patients with unstable conditions, as it provides healthcare professionals with the data needed to make timely, accurate medical decisions [2].

Vital signs are fundamental indicators of a patient's physiological status and are routinely used to assess general health, detect early signs of deterioration, and support diagnosis [3]. The primary parameters of vital signs include blood pressure, heart rate, oxygen saturation, and body temperature. Blood pressure, expressed in systolic and diastolic values, reflects cardiovascular function, with the normal average in adults being approximately 120/80 mmHg [3]. Heart rate, measured in beats per minute (BPM), indicates cardiac activity, where normal values range from 60 to 100 BPM. Oxygen saturation (SpO2) represents the ratio of oxygenated hemoglobin to total hemoglobin, with normal values ranging between 95% and 100%. Values below 85% generally indicate insufficient oxygen supply.

Meanwhile, body temperature, which usually ranges between 36.5°C and 37.5°C, serves as an important indicator of metabolic and immune activity. Deviations from the normal range may signal conditions such as hypothermia or hyperthermia. These four parameters form the core of patient monitoring and are therefore essential to be measured comprehensively.

Several studies have previously attempted to develop vital sign monitoring devices. For instance, Firmansyah Noviandi (2019) designed a monitoring device using Arduino Mega, capable of measuring oxygen saturation and heart rate, with the results displayed on a 16x2 LCD [4]. Linawati (2020) further extended this by developing an IoT-based monitoring system using the MAX30100 sensor, the NodeMCU ESP8266, and the Blynk application, enabling oxygen saturation and heart rate monitoring via Android smartphones [5]. More recently, Angger Nur Habib (2022) developed a monitoring device for three parameters—body temperature, oxygen saturation, and heart rate—using the DS18B20 sensor and a 2.4-inch TFT display [6]. While these studies contributed to advancing patient monitoring technologies, most remained limited in scope, either in the number of vital parameters measured or in the ability to store and transmit data for further use.

Considering these limitations, there remains a need for the development of a more comprehensive monitoring device capable of simultaneously measuring all four vital signs. In response to this need, the present study aims to design and develop a digital vital sign monitor based on Arduino Mega, incorporating the MAX30100, MPX5050GP, and DS18B20 sensors. The device features a 3.2-inch Nextion display for real-time visualization, an ESP32 module for wireless data transmission to smartphones, and a data storage system to ensure continuous and accessible patient monitoring. By integrating these components, the proposed system aims to provide a more effective, user-friendly solution for healthcare professionals in both clinical and remote monitoring settings.

Vital signs are key physiological parameters used to determine health status, particularly in medically unstable patients or those at risk of cardiopulmonary complications. They are essential for assessing responses to clinical interventions [7]. Non-invasive blood pressure measurement using the oscillometric method employs an inflatable cuff on the upper arm, where pressure oscillations are detected and processed to yield systolic and diastolic values, offering a reliable, clinically accepted alternative to invasive techniques [8]. Normal oxygen saturation measured by pulse oximetry ranges from 95–100%, while levels below 85% indicate inadequate oxygen supply and may reflect clinically significant hypoxemia requiring prompt intervention [9]. Heart rate, commonly measured at the wrist in beats per minute, reflects oxygen utilization and metabolic demand, making it a valuable indicator of cardiovascular function and overall physiological status [10].

In transmission mode, light passes through tissue. It is detected by a photodiode on the opposite side of the LED, producing strong signals but limited to sites such as the finger or earlobe. In contrast, in the reflectance mode, scattered light is detected, allowing PPG devices to be used at more flexible sites, such as the wrist [11]. Body temperature reflects the balance between metabolic heat production and environmental heat loss, typically ranging from 36°C to 38°C, with heat dissipation influenced by conduction from the core to the skin and transfer to the environment [12], [13]. Gas exchange of oxygen and carbon dioxide occurs in the alveoli of the lungs, enabling cellular respiration with oxygen derived from the 21% available in the atmosphere [14]. Respiratory rate is affected by factors such as age, sex, activity, body temperature, and position, ranging from 40–60 brpm in newborns to 12–20 brpm in adults, with gradual increases in the elderly [15].

The oscillometric method measures blood pressure by analyzing cuff pressure oscillations during inflation and deflation, unlike the auscultatory method, which relies solely on Korotkoff sounds [16]. The MPX 5050 is a pressure sensor that converts gas or liquid pressure into electrical signals, functioning as a transducer for monitoring and control applications, including indirect measurement of variables such as flow, velocity, and fluid level [17]. A solenoid is an electromechanical device that converts electrical current into linear motion by using a coil and an iron core; efficiency is often improved with partial-voltage or smaller coils [18]. The MAX30100 is a reflectance-mode sensor that determines blood oxygen saturation by detecting the differential absorption of red and infrared light by hemoglobin, providing digital outputs that update every 0.5–1 second [19]. The DS18B20 is a digital temperature sensor with 9–12-bit resolution, an operating range of –55 °C to 125 °C, ±0.5 °C accuracy, and a unique 64-bit code that enables multiple sensors on a single 1-Wire bus, making it suitable for distributed monitoring [20].

II. SYSTEM DESIGN AND METHODOLOGY

A. OVERALL SYSTEM ARCHITECTURE

The direct current (DC) power supply with a 5-volt output serves as the primary source of power for the entire circuit system. In this experimental setup, four different sensor systems are integrated and operated simultaneously. The Arduino Mega microcontroller functions as the central processing unit, receiving and analyzing data from the MPX5050GP pressure sensor, the DS18B20 temperature sensor, and the MAX30100 heart rate and oxygen saturation sensor.

The examination process begins with the measurement of blood pressure, which is conducted manually but presented digitally. A cuff is attached to the patient's arm, and once the start button is pressed, the automatic pump begins inflating the cuff. As pressure increases, blood flow in the artery is temporarily obstructed by the cuff's tight compression. Subsequently, the valve gradually releases the pressure in a controlled manner. During this gradual release, the force exerted by the cuff on the artery decreases. At the moment the first pulse is detected, the MPX5050GP pressure sensor registers a slight pressure fluctuation. This value, processed by the Arduino Mega, is defined as the systolic pressure. As the cuff pressure continues to drop, the pulse signal eventually disappears, and the corresponding pressure value is identified as the diastolic pressure. The block diagram is shown in fig. 1.

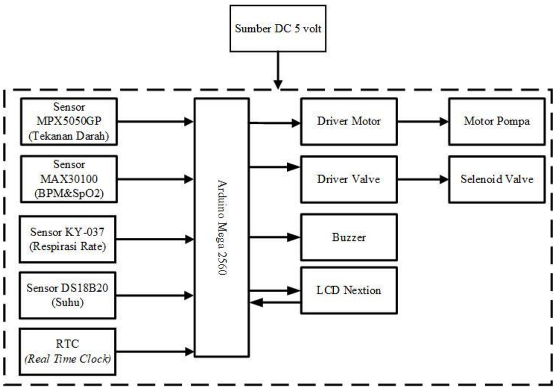

Figure 1: Block Diagram of the system.

Following the blood pressure measurement, the DS18B20 digital temperature sensor is placed under the patient's armpit to measure body temperature. Once the temperature is recorded, the data is transmitted to the microcontroller for digital processing and display. Immediately afterward, the patient is instructed to place one finger on the HR Finger Sensor, which employs the MAX30100 module to measure both oxygen saturation (SpO_2) and heart rate. The sensor begins operation by detecting and calculating pulse signals, which the Arduino then processes.

In the subsequent step, respiratory activity is measured using a mouthpiece connected to a condenser microphone and the KY-037 sound sensor module. During exhalation, airflow generates acoustic signals that are captured by the microphone and processed to determine the respiratory rate, expressed as breaths per minute.

All sensor outputs are transmitted to the Arduino Mega, which serves as the system's "brain." The microcontroller processes the analog voltage signals, converts them into digital data, and manages the overall system workflow. Importantly, the system has been designed with an alert mechanism. When sensor readings exceed the pre-set thresholds, the Arduino automatically triggers a buzzer to warn the user or healthcare provider. This integrated design enables the device to perform multi-parameter monitoring—blood pressure, body temperature, oxygen saturation, heart rate, and respiratory rate—within a single system, making it potentially useful for patient health assessment in both clinical and non-clinical settings.

B. HARDWARE AND SOFTWARE DESIGN

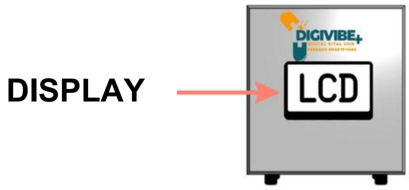

Figure 2 Front Module Design

From Fig. 2, it can be observed that the front view of the device design is equipped solely with a Nextion Editor LCD, model NX4024T032, measuring 3.2 inches. This display serves as the system's main interface, providing a clear visualization of measurement results and enabling users to interact with the device efficiently.

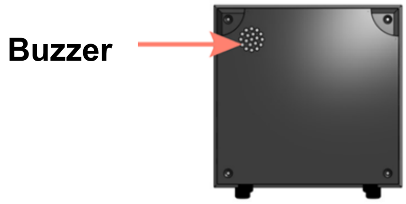

Figure 3 Back Module Design

From Fig. 3, it can be seen that the rear view of the device design includes an opening that serves as an outlet for the buzzer or alarm sound. This feature serves as an auditory indicator, enabling the device to provide immediate alerts to users in response to specific measurement conditions or system notifications.

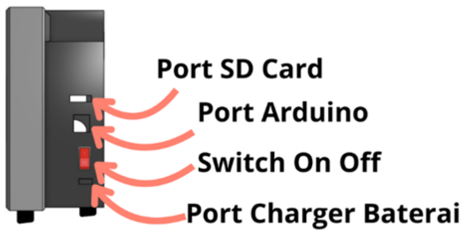

Figure 4 Right Side Module Design

From Fig. 4, the right side of the device design is shown to contain four functional ports. The first is the SD Card port, which is used to insert and remove the SD card from the module. The second is the Arduino port, which allows connecting an Arduino cable when uploading code to the module. The third is the On/Off switch, which controls power and turns the device on and off. The fourth is the battery charging port, which connects the charger cable to recharge the battery when the power supply is depleted. Together, these components ensure operational flexibility, ease of maintenance, and reliable power management for the device.

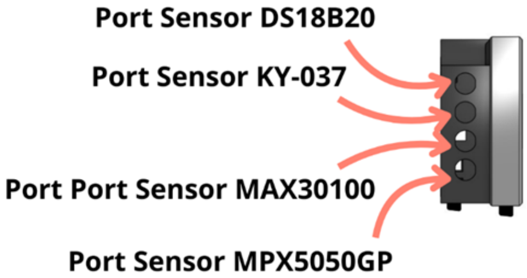

Figure 5 Left Side Module Design

As shown in Fig. 5, the left side of the device design features four dedicated sensor ports. These include the DS18B20 sensor port for body temperature measurement, the KY-037 sensor port for respiratory rate detection, the MAX30100 sensor port for monitoring both heart rate and oxygen saturation, and the MPX 5050GP sensor port for measuring blood pressure. The integration of these ports enables the device to comprehensively capture multiple vital parameters, thereby enhancing its functionality as a reliable digital vital-sign monitoring system.

Figure 6 Log In Page on LCD

Fig. 6 presents the design layout of the LCD display, which includes a dedicated section for entering patient identification data. This feature allows users to record essential patient information directly in the system, ensuring that all measurement results are appropriately associated with the corresponding patient profile. Such integration not only improves data organization but also supports accurate documentation and long-term monitoring of patient health records.

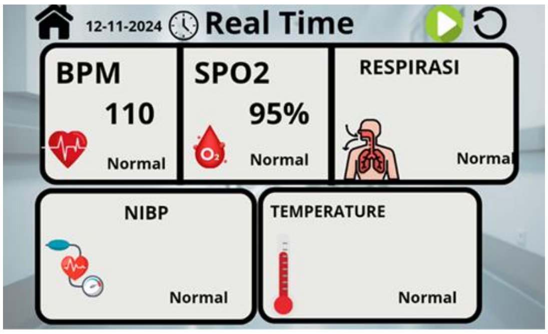

Figure 7: Main Page on LCD

In Fig. 7, the main interface of the LCD design is illustrated, displaying the measurement results from various sensors. The parameters presented on this screen include heart rate (BPM), oxygen saturation (SpO_2), respiratory rate, non-invasive blood pressure (NIBP), and body temperature. This centralized display enables users to conveniently monitor multiple vital signs in real time, thereby enhancing the system's usability and clinical relevance.

C. INTEGRATION AND PROTOTYPING

Fig. 8 presents the circuit schematic of the developed Digital Vital Sign Monitoring Device (DIGIVIBE), illustrating the integration of various sensors, microcontrollers, display units, and power management modules.

The system is built around the Arduino Mega 2560, which serves as the central microcontroller, acquiring and processing data from the connected sensors. The DS18B20 temperature sensor is connected to the Arduino's digital input pin to measure body temperature. The KY-037 sound sensor is interfaced with the Arduino to capture respiratory signals. For cardiovascular parameters, the MAX30100 sensor is employed to simultaneously measure heart rate (BPM) and blood oxygen saturation (SpO_2), with its output pins connected to the Arduino for digital data communication. Additionally, the MPX5050GP pressure sensor is utilized to measure non-invasive blood pressure (NIBP), and its analog signal is routed to the Arduino's analog input for further processing.

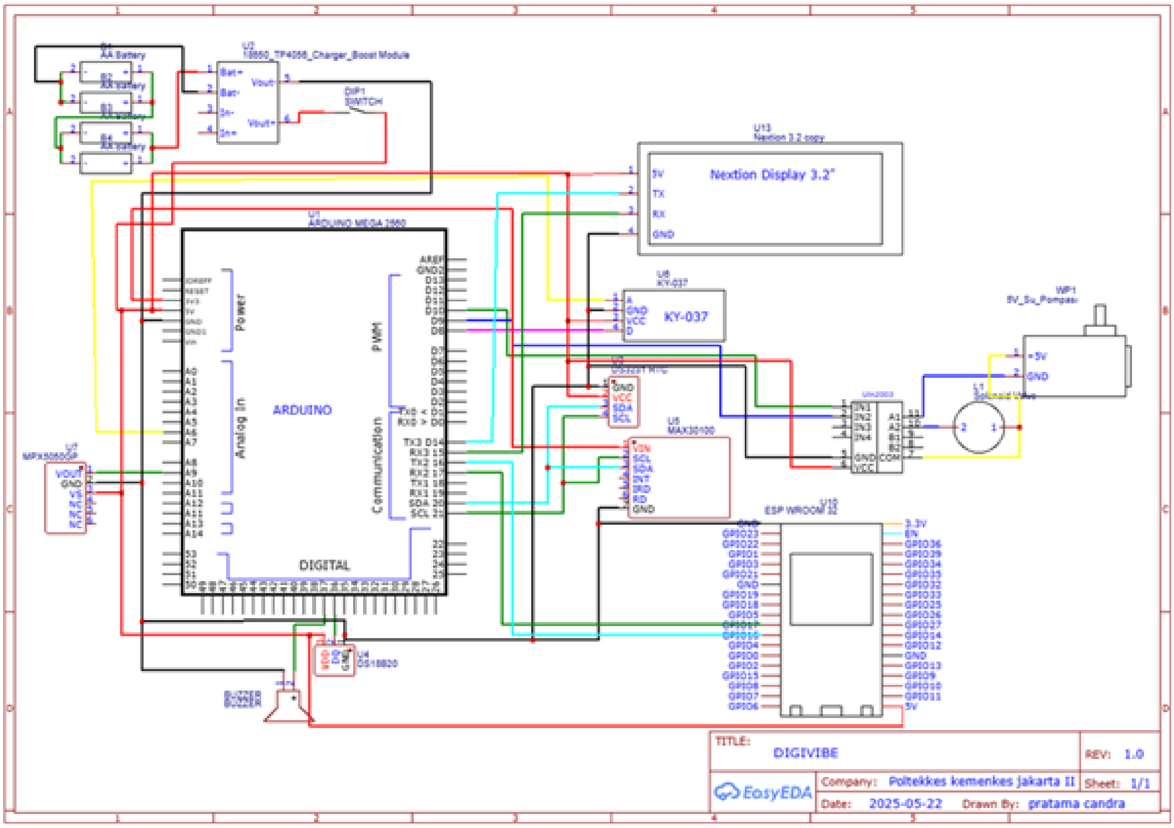

Figure 8: **Overall Circuit Block Diagram**

The processed data from the Arduino is transmitted to the ESP-WROOM-32 (ESP32) module, which functions as the wireless communication unit. This module enables real-time data transfer to the TagoIO platform via Wi-Fi, allowing remote monitoring of vital signs via a web-based application.

For local visualization, the device incorporates a Nextion Display (3.2" NX4024T032) connected to the Arduino, providing an interactive graphical interface that displays real-time measurement results and allows basic device operation. The system is also equipped with an SD Card module, integrated via the Arduino's communication port, which stores measurement data for future reference and analysis.

The power supply is managed by a Li-ion battery system, regulated through a TP4056 charging and boost module, which ensures stable power delivery to all components, including the Arduino, ESP32, sensors, and display. An external on/off switch is included to control device operation. At the same time, a buzzer is integrated at the output stage to provide audio alerts or alarms when specific threshold values are exceeded.

Overall, this schematic illustrates the seamless integration of hardware components into a unified system capable of acquiring, processing, storing, and transmitting vital sign data, thereby supporting both local and remote monitoring applications.

III. RESULT AND DISCUSSION

A. *PROTOTYPE RESULTS*

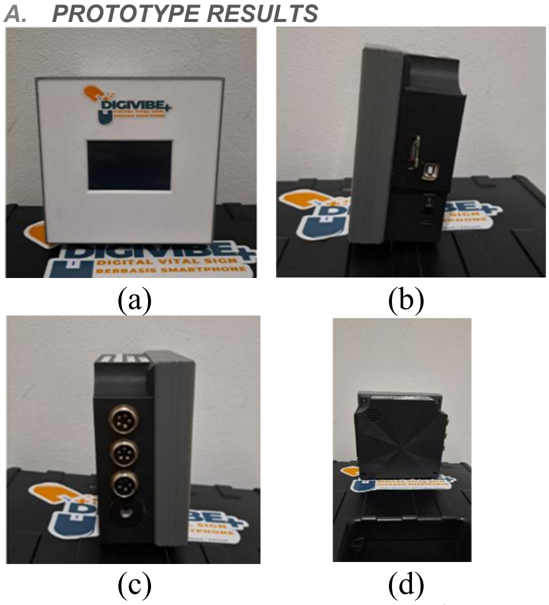

Figure 9 **Module Device (a) Front, (b) Right, (c) Left, (d) Behind**

The prototype result can be seen in Fig. 1. Figure 9 (a) shows that a 3.2" Nextion LCD is used as the display interface, which also functions as the control panel for operating the device. The (b) is the right side of the device, which shows four functional ports. The first port is the SD Card port, which is used for inserting and removing the SD card from the module. The second is the Arduino port, which allows connection of the Arduino cable when uploading code to the module. The third is the On/Off switch, which controls powering the device on and off. The fourth is the battery charging port, which is used to connect the charger cable for recharging the battery when the power is depleted.

Fig. 9. (c) shows the physical appearance of the left side of the device, which contains four sensor ports with specific functions. The first is the DS18B20 sensor port, used for body temperature measurement. The second is the KY-037 sensor port, which measures respiratory activity. The third is the MAX30100 sensor port, which monitors both heart rate and oxygen saturation. Finally, the fourth is the MPX 5050GP sensor port, which is utilized for blood pressure measurement. These ports allow the integration of multiple vital sign sensors, enabling the device to perform comprehensive physiological monitoring.

The design of displays on the TFT Nextion 3.2' can be seen in the figure. 2. Fig. 2 illustrates the initialization display on the LCD, which serves as the initial interface shown when the device is first powered on. This initialization stage is crucial, as it confirms that the system and its microcontroller have successfully started operation, ensuring that all modules and sensors are activated adequately before performing any measurements. By presenting a standardized starting screen, the LCD not only indicates that the power supply and internal circuits are functioning correctly but also provides the user with an intuitive confirmation that the device is ready for use. Such initialization displays are commonly implemented in medical monitoring systems to enhance the user experience and reliability, thereby reducing the risk of misoperation at the start of the examination process.

Figure 10 Homescreen

Figure 11 Data Input Screen

Fig. 10 and Fig. 11 present the second display page on the device's LCD. This page appears when the user navigates from the initialization screen to the next interface. The second display contains essential patient information, which serves as a preliminary data entry step before proceeding to physiological measurements. Displaying patient identity data on the LCD is an important feature in medical monitoring devices, as it ensures that the examination results can be accurately associated with the correct individual. In addition, this interface minimizes the risk of misplaced or misinterpreted data, particularly in scenarios where multiple patients are examined sequentially. By incorporating this feature, the system not only improves usability and traceability but also aligns with best practices in digital health record management.

Figure 12: Result Monitoring Screen

Fig. 12 illustrates the third display page on the device's LCD, which presents the measurement results obtained from the integrated sensors. On this screen, the system displays multiple physiological parameters, including respiratory rate, body temperature, heart rate (beats per minute), non-invasive blood pressure (systolic/diastolic), and oxygen saturation (SpO_2). Each parameter is represented not only by numerical values but also accompanied by visual icons to enhance readability and facilitate quick interpretation by the user.

In addition to displaying physiological data, the interface provides essential operational features, including data acquisition ('Read Data'), data storage ('Save'), and a refresh function to repeat or update the measurement process. Furthermore, the interface includes a date and time display, which is critical for accurate medical record keeping and traceability.

The structured display layout ensures that healthcare providers and users can easily access comprehensive monitoring results in real time. By combining numerical data, visual elements, and operational controls into a single interface, this display design enhances user-friendliness, reduces the risk of misinterpretation, and supports the integration of patient data into digital health management systems.

B. SPECIFICATION

Device Name	DIGIVIBE
Power Supply	Lithium Ion Battery
Display	3.2" Nextion Editor, NX4024T032 Series
Microcontrollers	ESP32 and Arduino Mega
Blood Pressure Sensor	MPX 5050GP
Oxygen Saturation Sensor	MAX30100
Heart Rate Sensor	MAX30100
Body Temperature Sensor	DS18B20
Device Dimensions	180 mm (length) × 130 mm (height) × 100 mm (width)

The DIGIVIBE device integrates multiple vital sign sensors with dual microcontroller units (an ESP32 and an Arduino Mega) to ensure accurate data acquisition and efficient processing. Equipped with a 3.2" Nextion display, the system provides a straightforward and interactive user interface. The device's compact dimensions make it portable and practical for continuous monitoring applications.

C. PERFORMANCE EVALUATION

To assess the reliability and effectiveness of the developed device, a series of performance evaluations was conducted. The evaluation focused on measuring each sensor's accuracy, the efficiency of data transmission, and the overall functionality of the system for real-time monitoring. These tests were carried out under controlled conditions to ensure the results are valid and can serve as a benchmark for further development.

1) Analysis of Temperature Accuracy Test Data

The measurement results indicate the accuracy of 98,3%. This outcome demonstrates that the system can provide reliable temperature measurements with high precision, further validating its effectiveness in supporting continuous vital-sign monitoring applications. The measurement result is shown in Fig. 13.

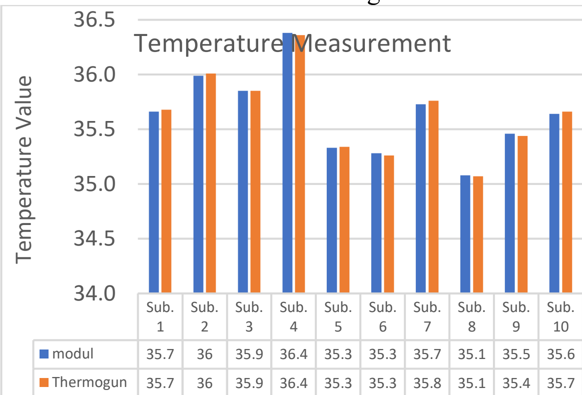

Figure 13 **Temperature Measurement**

2) Analysis of Oxygen Saturation Accuracy Test Data

As presented in Fig. 14, the measurement results indicate that the accuracy level of the developed Digital Vital Sign Monitoring Device equipped with data storage for the Oxygen Saturation parameter is 96%. This outcome demonstrates that the system can provide reliable Oxygen Saturation measurements with high precision, further validating its effectiveness in supporting continuous vital sign monitoring applications.

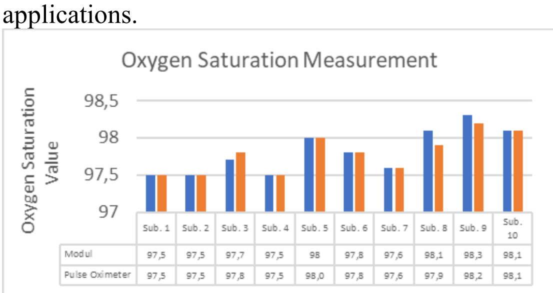

Figure 14 **Oxygen Saturation Measurement**

3) Analysis of Heart Rate Accuracy Test Data

As presented in Fig. 15, the measurement results indicate that the accuracy level of the developed Digital Vital Sign Monitoring Device equipped with data storage for the heart rate parameter is 97%. This outcome demonstrates that the system is capable of providing reliable heart rate measurements with a high degree of precision, further validating its effectiveness in supporting continuous vital sign monitoring applications.

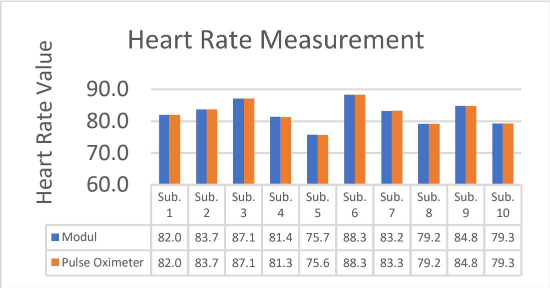

Figure 15 **Heart Rate Measurement**

4) Analysis of Systolic Blood Pressure Accuracy Test Data

As shown in Fig. 16, the measurement results indicate that the accuracy of the developed Digital Vital Sign Monitoring Device equipped with data storage for the systolic blood pressure parameter is 94%. This finding confirms that the device can deliver accurate systolic blood pressure readings, reinforcing its potential for comprehensive vital sign monitoring.

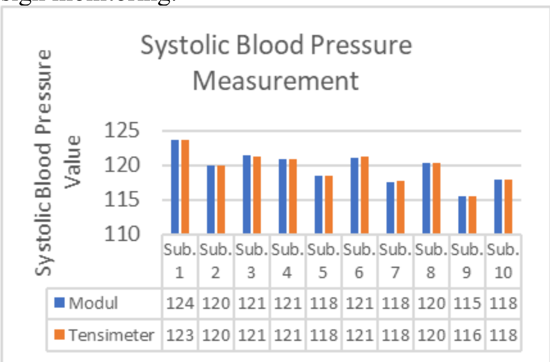

Figure 16 **Systolic Blood Pressure Measurement**

5) Analysis of Diastolic Blood Pressure Accuracy Test Data

As presented in Fig. 17, the measurement results indicate that the accuracy level of the developed Digital Vital Sign Monitoring Device equipped with data storage for the diastolic blood pressure parameter is 93%. This demonstrates that the system can provide consistent and reliable diastolic blood pressure measurements, supporting its applicability in clinical and monitoring settings.

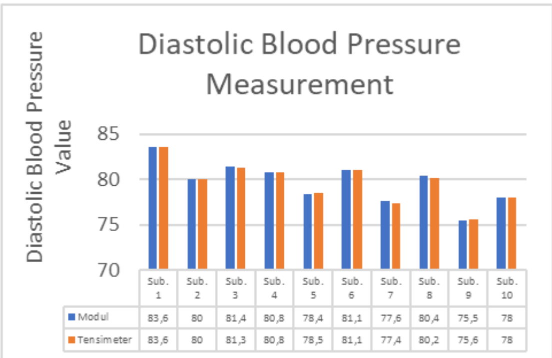

Figure 17 **Diastolic Blood Pressure Measurement**

6) Analysis of Respiratory Rate Accuracy Test Data

As presented in Fig. 18, the measurement results indicate that the accuracy level of the developed Digital Vital Sign Monitoring Device equipped with data storage for the respiratory rate parameter is 89%. Although slightly lower than other parameters, this level of accuracy is still within an acceptable range, indicating that the device is effective for continuous respiratory monitoring.

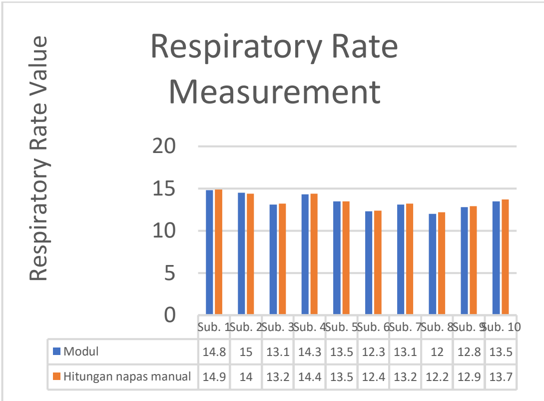

Figure 18 **Respiratory Rate Measurement**

IV. CONCLUSION

A portable digital system for vital sign measurement using multi-sensor integration was successfully designed. The device's performance evaluation demonstrated high accuracy across multiple physiological parameters. The results of temperature, respiration rate, heart rate, oxygen saturation, and blood pressure measurements: 98.3%, 89%, 97%, 96%, and 94%, respectively. Overall, the findings validate that the developed device can serve as an effective and reliable measurement for digital vital sign monitoring.

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