Jurnal Teknokes
International: Rapid Review: Open Access Journal **Vol. 16, No. 2, June 2024, pp. 84-92** **e-ISSN 2407-8964; p-ISSN 1907-7904**

RESEARCH ARTICLE OPEN ACCESS

Manuscript received January 18. 2024; revised March 10. 2024; accepted March 12. 2024; date of publication June 25. 2024
Digital Object Identifier (**DOI**): https://doi.org/10.35882/teknokes.v16i2.539

How to cite: Citra Nur Astrif, Triwiyanto Triwiyanto, and Vugar Abdullayev. "Development of a Low-Cost and Portable Device for Monitoring Heart Rate, Blood Oxygen Saturation, and Body Temperature in Infants Incubator ". Jurnal Teknokes. vol. 16. no. 2. pp. 84–92. June. 2024.

Development of a Low-Cost and Portable Device for Monitoring Heart Rate, Blood Oxygen Saturation, and Body Temperature in Infants Incubator

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ABSTRACT The risk of newborn infant mortality is commonly associated with hypothermia. Hypothermia is a health disorder and a leading cause of death in newborns. caused by an imbalance in the baby's body temperature. Hypothermia is caused by a decrease in body temperature, which can result from various conditions, including high oxygen requirements and a decrease in room temperature, among other factors. Hypothermia occurs due to a decrease in body temperature resulting from various conditions. especially high oxygen requirements and a decrease in room temperature. The purpose of this study is to monitor the health status of newborns. Monitoring the body temperature and oxygen saturation levels in newborns can help detect abnormalities in infants at an early stage. This research is expected to assist patients using a baby cube in providing care for newborns with hypothermia symptoms. The Baby Cube utilizes the DS18B20 sensor for temperature measurement and the MAX3102 sensor for heart rate and oxygen saturation. The data is then processed using the ESP32 microcontroller. and the results are displayed on an LCD screen. The comparative tools used in this study are the standard thermometer and pulse oximeter. The results of this research indicate that the smallest measurement error value is found in the SpO2 measurement of data collection 10. which is 0.1%. The largest measurement error value is found in the SpO2 measurement of data collection 2. which is 5.6% based on the obtained data. However. the measurement results are still within the tolerance limit of ±10%.

INDEX TERMS Baby Cube. Hypothermia. DS18B20. MAX3102

I. INTRODUCTION

Hypothermia in neonates is a common problem worldwide. In Ethiopian hospitals. 67% of newborns admitted to the special care unit from outside the hospital experience hypothermia[1]. There is evidence to suggest that rapid postnatal hypothermia is highly dangerous for newborns[2]. Elevating the chances of suffering from illness and death. Roughly half of all infant fatalities happen within the neonatal phase, which encompasses the first month after birth[3]. Newborns develop hypothermia when their body temperature decreases as a result of heightened oxygen requirements and exposure to cold room temperatures. It is vital to ensure that newborns maintain their normal body temperature for their survival[4]. Hypothermia can lead to the narrowing of blood vessels, anaerobic metabolism, increased oxygen demand, hypoxemia, and ultimately, death[5]. Neonatal mortality rates surpass those of other age groups, with the majority of newborn deaths occurring in Indonesia during the initial month of life. Effective management of hypothermia is crucial to avoid complications and fatalities in newborns[6]. Vigilant monitoring of newborns' health is vital to identify health issues, particularly in infants. The ongoing monitoring and advancements in medical care have notably enhanced survival rates for critically ill newborns in the Neonatal Intensive Care Unit (NICU). Providing care and closely monitoring vital signs, including body temperature, heart rate, and oxygen saturation, need to be continuously monitored for early diagnosis and appropriate medical intervention[7][8]. Monitoring vital signs is essential because any measurement outside the normal range can pose a high risk to the patient's survival[9]. Monitoring oxygen saturation levels in newborns can help in early detection of congenital abnormalities or infectious diseases with maternal suspicion. Oxygen saturation (SpO2) is a vital sign that plays a crucial role in supplying oxygen to the body. As oxygen saturation indicates the ability of hemoglobin to bind to oxygen, it serves as a crucial indicator for identifying and addressing the risks of oxygen deficiency. This deficiency can potentially result in organ damage and even death. Knowing the oxygen saturation levels in newborns is important as low levels may indicate potential concerns[10]. Oxygen saturation is the ability of hemoglobin to bind with oxygen and is expressed as the degree of saturation (SaO2). The highest saturation level is 100%. When oxygen saturation is at 100%, it indicates that all hemoglobin is bound with oxygen. Conversely, the lowest saturation level of 0% signifies that no oxygen is bound by hemoglobin. A normal oxygen sturation level is considered to be above 95%. The percentage of hemoglobin saturation reflects the amount of oxygen carried by hemoglobin in comparison to its maximum capacity to carry oxygen. Monitoring oxygen saturation helps observe the stability of infants and provides immediate information. Oxygen saturation values are important to monitor as they indicate the adequacy of oxygen in the baby's body[11]. Decreased oxygen saturation can result in oxygen transport failure. Since the majority of oxygen in the body is bound to hemoglobin, it plays a critical role in transporting and delivering oxygen to various tissues and organs. The normal range for oxygen saturation is between 95% and 100%. When oxygen saturation levels fall below 85%, it signifies an insufficient oxygen supply to the tissues and necessitates further evaluation to address the potential issue. Low oxygen saturation (less than 70%) is a dangerous condition[12].

In 2013. Sri Wahyuni Dwi designed a device titled Modification of Baby Incubator (Temperature Control and Heart Rate Reflection). The device works by controlling the temperature inside the incubator box based on the reflected heart rate[13]. The device only provides temperature and BPM readings. In such circumstances, the baby retains the ability to perceive noise from the surrounding environment, which may result in restlessness and discomfort. In 2015. Khusnul Khuluq designed a device titled Baby Cube Equipped with Classical Music and Baby BPM. Based on observations. Khusnul Khuluq believed that the functionality of the Baby Cube needed improvement. particularly in enhancing the effectiveness of therapy for infants born with abnormal conditions. such as by adding classical music. In 2020. Artdieansyah Nur Wiaam designed a device titled Design and Construction of Temperature Control System and Skin Sensor on Baby Cube. This Baby Cube experienced uneven temperature distribution caused by inadequate fan direction. Therefore. precise temperature control is required[14][15].

Previous research has discussed the design and construction of a temperature control system and skin sensors on a baby cube. The baby cube box had limitations, including uneven temperature distribution at various points within the box and suboptimal driver circuitry. This can be overcome by implementing proper temperature distribution control on the fan to ensure even heating and increasing the wattage of the lamp. The driver circuitry of the baby cube device is enhanced and optimized through coding

Baby cube is a medical device designed as a place for newborn babies. Nevertheless, not all babies are in normal conditions, and some may experience hypothermia. Previous designs of the baby cube device might have encountered challenges in effectively managing hypothermic infants (Sri Wahyuni Dwi Lestari, 2013). The earlier version of the baby cube was equipped with temperature and BPM monitoring capabilities and was subsequently enhanced and improved by further development efforts (Khusnul Khuluq. 2015) with the addition of classical music and BPM. It was then continued by (Artdieansyah Nur Wiaam. 2022) with the design of a temperature control system and skin sensors on the baby cube. Baby Cube is a simple baby box designed with standard specifications using a light bulb to heat the room. However, the temperature distribution within the room might not be uniform across all locations. Baby care is not optimal as the baby's body temperature is measured manually. In an effort to improve the survival rate of newborns who require treatment with a baby cube. the author will develop a device by adding control for oxygen saturation (SpO2) and heart rate (BPM) for the care of newborns exposed to infectious diseases. This device is expected to support intensive care for infants with low cost, suitability and user-friendliness can be restated as appropriateness and ease of use, respectively. Based on this problem background. the author aims to create a device called "Design and Construction of Baby Cube Equipped with Body Temperature Monitoring. Heart Rate. Oxygen Saturation. and Room Temperature Control." The author intends to develop this device with a focus on BPM and SpO2 parameters indispensable for measuring heart rate and oxygen saturation in newborn infants[16]. This research is expected to assist patients using a baby cube in providing care for newborns exposed to infectious diseases or suspected cases where the mother has an infectious disease. Regarding the advancement of the device's design mentioned in the previous heading, "Design and Construction of Temperature Control System and Skin Sensor in Baby Incubator." the author will further expand the previous title by adding variables such as heart rate and oxygen saturation for hypothermic infants exposed to infectious diseases or infants born to mothers suspected or diagnosed with infectious diseases[17]. The contribution of the device created by the author includes. Temperature Control and Body Temperature Monitoring in Baby Cube: The device is designed to control the room temperature inside the baby cube. ensuring it remains within a safe and comfortable range for infants[18]. Additionally, the device can accurately and real-time monitor the baby's body temperature. Heart Rate (BPM) and Oxygen Saturation (SpO2) Monitoring The device is equipped with sensors that allow the measurement of the baby's heart rate and oxygen saturation. This enables comprehensive monitoring of the baby's health condition. Temperature Adjustment from 34°C to 37°C: The device has the capability to adjust the room temperature inside the baby cube within a safe and optimal range for infant care. The adjustable temperature range is between 34°C and 37°C. Use of ESP32 Microcontroller[19][20]. The device utilizes the ESP32 microcontroller as the system's core. Comparison with Room Thermometer[21]. The device can also compare temperature measurement results with a room thermometer. This allows for monitoring and validation of temperature measurements performed by the device against a well-established measuring device[22]. Device Testing: The device has undergone testing to ensure functionality and reliability. Testing has been conducted to assess temperature control capabilities. The accuracy of measuring heart rate and oxygen saturation levels, along with the device's performance in different scenarios, are crucial aspects. Through the incorporation of these features, the device created by the author brings benefits in monitoring the health and temperature of infants inside the baby cube. Additionally, it offers extensive control and monitoring capabilities, ensuring effective care for infants facing hypothermia or potential exposure to infectious diseases.

II. MATERIALS AND METHOD

This research was conducted at the Biomedical Engineering Campus, Surabaya City 10 Biomedical Engineering students will participate in the data collection process, with each participant contributing one data set for body temperature. Furthermore, heart rate and oxygen saturation data will also be collected from each of the participants. 10 data sets were collected from each participant. The study also controlled the temperature within the baby cube box. starting from 34˚C. 35˚C. 36˚C. and 37˚C.

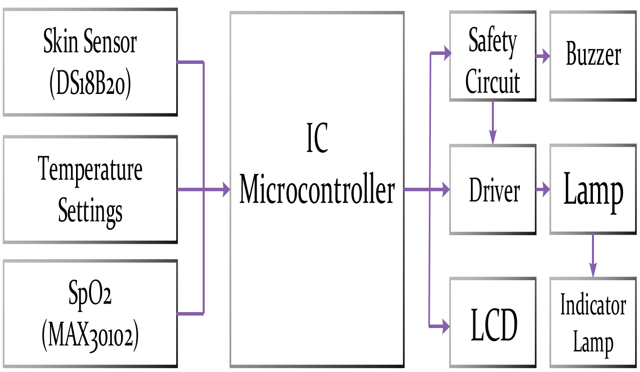

FIGURE 1. The system block diagram in the study on Baby Cube with DS18B20 Sensor and MAX30102 Sensor Using Safety Circuit illustrates the interconnections and components within the system.

In this study, the temperature control setting in the baby cube box serves as the independent variable. The dependent variables in this study consist of the body temperature values recorded by the DS18B20 sensor, as well as the heart rate (BPM) and oxygen saturation (SpO2) values measured by the MAX30102 sensor. The ESP32 microcontroller board serves as the controlled variable in this study.

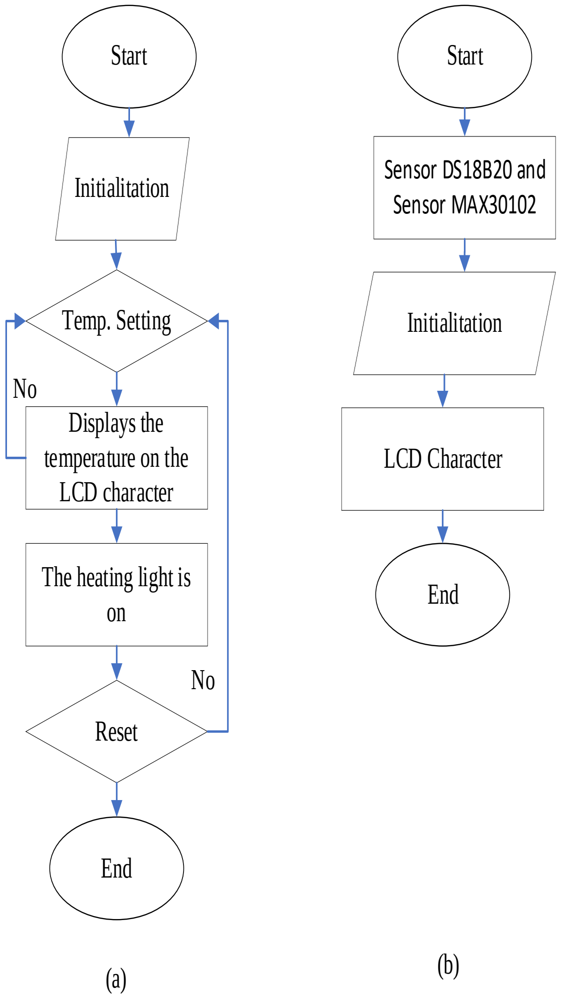

FIGURE 2. The system flowchart in the study on Baby Cube with DS18B20 Sensor and MAX30102 Sensor Using Safety Circuit illustrates the sequential steps and interactions within the system.

This research utilizes the DS18B20 body and ambient temperature sensors. The MAX30102 sensors used for measuring heart rate (BPM) and oxygen saturation (SpO2). The data is processed using the ESP32 microcontroller. The data collected from the DS18B20 and MAX30102 sensors is presented on an LCD display. **FIGURE 1** Illustrates a block diagram comprising three primary sections: input, process, and output. The input segment includes the DS18B20 temperature sensor modules responsible for measuring body and ambient temperature, as well as temperature settings and the MAX30102 sensor module for heart rate (BPM) and oxygen saturation (SpO2). In the process section, the ESP32 microcontroller plays a vital role. Upon receiving data from the sensors, the ESP32 processes the information before presenting it on the LCD display. The output section is represented by the LCD display, which shows the processed results obtained from the sensors. processed by the microcontroller.

Refer to **FIGURE 2** (a) Upon activating the baby cube device, an initialization process is initiated for the temperature sensor, and data transmission from the ESP32 begins. Subsequently, the LCD will exhibit the displayed results. The light bulb will turn off if the temperature inside the baby cube box approaches the set temperature or the temperature set on the box button. Furthermore, the device will be automatically reactivated if the room temperature drops below the pre-set threshold. The process is considered complete when the temperature reaches the desired level. If the desired temperature is not reached, the user is required to set the temperature again. (b) When the start button is pressed, an initialization process commences to read data from the SpO2 sensor, BPM sensor, and room temperature using the microcontroller. Once the sensors are read, the obtained results will be displayed on the character LCD, marking the completion of the process.

A. DATA ANALYSIS

The data collection involves measuring each parameter, namely Body Temperature and SpO2, with a total of 10 data points. It is repeated once for body temperature and repeated 10 times for SpO2. The average value of the measurements is obtained by calculating the mean or the average **Eq. (1)** The average, commonly referred to as the mean, is determined by dividing the sum of all values within a dataset by the total number of data points present in that set.:

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

In a dataset with n measurements, let x represent the mean (average). The individual measurements are denoted as x1 for the first measurement, x2 for the second measurement, and xn for the nth measurement. The standard deviation (SD) is a measure that quantifies the extent of variation or spread around the mean within the dataset. The formula used to calculate the standard deviation (SD) is as follows: **Eq. (2)**:

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

In the context of the measurements, let xi denote each individual measurement value. The average value obtained from all the measurements is represented by x, and n signifies the total number of measurements conducted. Uncertainty (UA) refers to the degree of doubt or variability inherent in each measurement result. The formula for calculating uncertainty (UA) is as follows: **Eq. (3)**:

$$UA = \frac{SD}{\sqrt{n}} \quad (3)$$

UA represents the uncertainty value of the total measurement. SD denotes the resulting standard deviation, and n indicates the number of measurements taken. The % error (percentage error) is a measure of system error that quantifies the disparity between the observed or measured values and the expected or theoretical values. A lower % error indicates a smaller average difference between each data point and its corresponding theoretical value. The % error serves to emphasize discrepancies between the standard (expected) values and the actual measurements obtained from the design or model. The formula used to calculate the % error is as follows: **Eq. (4)**.

$$\mathrm{ERROR} = \frac{(x_n - \mathrm{x})}{x_n} \times 100 \quad (4)$$

The formula calculates the ratio of the standard deviation to the mean, multiplies by 100 to express the error as a percentage. A lower % error indicates that the measured values are closer to the expected values, demonstrating a higher degree of accuracy and a smaller deviation from the theoretical model.

III. RESULT

In this study, the measurement results of the body temperature module and the SpO2 module will be compared with a thermometer and pulse oximeter as a benchmark to determine the accuracy of the body temperature module and the SpO2 module in the research being conducted. The thermometer measures body temperature, while the pulse oximeter measures oxygen saturation in hypothermic infants. **FIGURE 3** and **FIGURE 4** The front and back views of the baby cube, equipped with an ESP32 microcontroller, DS18B20 sensors, MAX30102 sensors, and lamp driver circuits, are illustrated. Measurements will be displayed on the LCD and the temperature can be adjusted according to the user's desired setting.

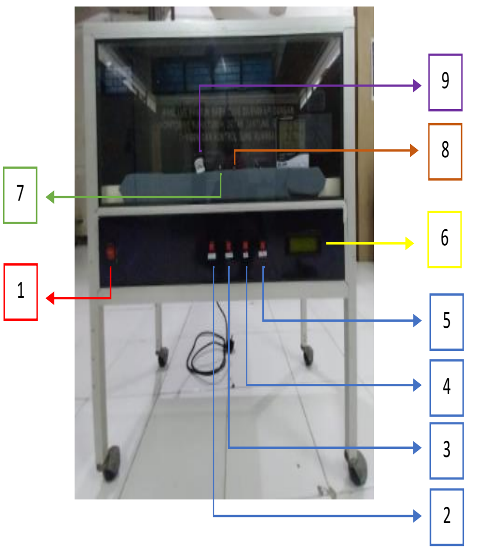

FIGURE 3. The front view of the Baby Cube module presents readings for body temperature, heart rate, and oxygen saturation.

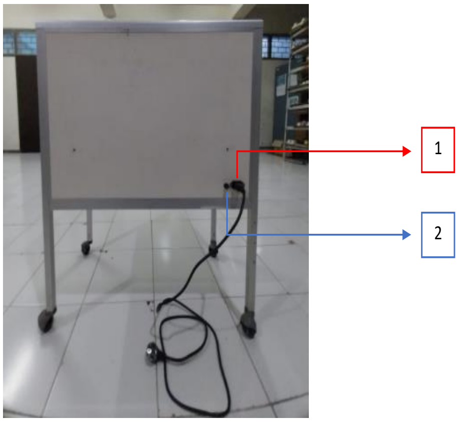

FIGURE 4. The back view of the Baby Cube module shows readings for body temperature, heart rate, and oxygen saturation.

TABLE 1
Front View Tool Module Description

No	Description
1	Power ON/OFF
2	Reset button
3	Down button
4	Up button
5	Start button
6	LCD
7	Skin Sensor
8	Room Sensor
9	Pulse refers to heart rate (BPM) and oxygen saturation (SpO2)

In the front view of the baby cube **TABLE 1** there is a power on/off to turn on the tool module. a reset button to return to the initial display. The front view of the baby cube displays a down button for lowering the room temperature setting and an up button for increasing the room temperature setting. It also features a start button to set the desired temperature, with an LCD serving as the device's display. The baby cube includes a skin sensor that measures body temperature in infants, and the tool module box houses a room temperature sensor. Additionally, the pulse measurement uses a MAX30102 sensor to detect oxygen levels in infants.

TABLE 2
Rear View Tool Module Description

No	Description
1	Power Cable
2	Fuse

On the rear view of the baby cube **TABLE 2** there is an electric cable as a conductor of electricity to provide voltage to the tool module. The device incorporates fuse functions designed to interrupt the electric current in case of a short circuit or excessive current, which can lead to hazardous incidents like fires.

The digital part of the device is composed of an ESP32 microcontroller, serving as the central board, accompanied by the DS1820 sensor and the MAX30102 sensor. The data collection process for the module took place at the Electromedical Engineering Campus of Poltekkes Kemenkes Surabaya. 10 data collections were conducted to measure each parameter, which includes Body Temperature and SpO2. The Body Temperature measurement was performed once. while the SpO2 measurement was repeated 10 times

TABLE 3
Error values for body temperature

Measurement	Body Temperature Module	Thermometer(°C)
Mean	33.97	34.4
Difference	0.36	
Error	1%	

Error in this study refers to the disparity between the actual value and the measured value of the module, specifically related to body temperature, using the units employed in the research. **TABLE 3** The above data can be utilized to compare the values obtained from the module's measurements with those obtained from a standard device, such as a thermometer. The purpose of using a comparator in this study is to ensure that the values obtained by the module created by the researcher can be accountable in terms of their conformity with the true values. The module's average body temperature measurement is recorded as 33.97˚C, while the thermometer comparator registers it as 34.34˚C. Based on these findings, a temperature difference of 0.36 is observed, resulting in an error of 1%.

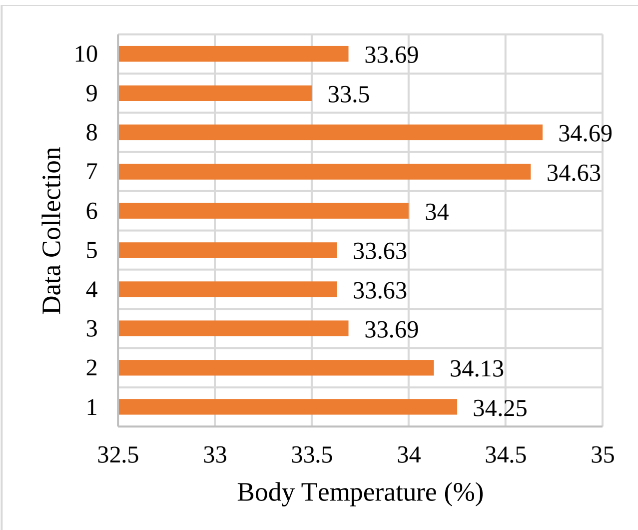

FIGURE 5. Graph depicting the overall error results of the SpO2 module.

In **FIGURE 5** The measurements obtained from the data collection were found to be within the acceptable tolerance range. These measurements were conducted on 10 data collection with 1 measurement each. The measurements obtained from the body temperature module were compared to those of a commercially available device. The thermometer was employed to make observations by examining the values.

After conducting tests using the thermometer to compare with the body temperature module, an error value of 1% was determined. This result was calculated based on the values obtained from the testing of all ten data collection. The data was processed and resulted in the diagram.

TABLE 4
Error values for oxygen saturation (%)

Data Collection	Error (%)
1	1.6
2	5.6
3	1.8
4	0.8
5	1.2
6	2
7	1
8	1.2
9	0.4
10	0.1

It can be seen from the **TABLE 4** Measurements were obtained from 10 data sets, with each data set comprising 10 individual measurements that were then averaged to produce the final result. After analyzing the measurement data, the deviation between the average measurement and the reference tool, the Pulse Oximeter, was assessed. The largest error value among the measurements in the data collection was found to be 5.6%, while the average measurement value was 1.57%.

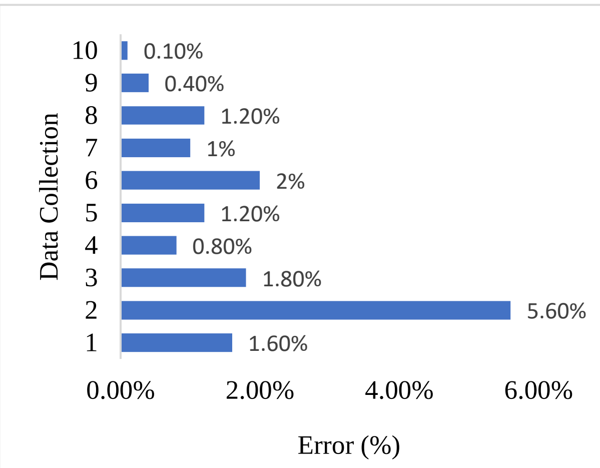

FIGURE 6. Graph the overall error results of the SpO2 module.

In **FIGURE 6** Based on the measurement results obtained from the data collection, it was observed that the measurements fell within the acceptable tolerance range. These measurements were performed on 10 data collections, with each collection consisting of 10 measurements. The SpO2 module's measurements were compared to those of a commercially available device, and the Pulse Oximeter was utilized to observe the SpO2 values.

From the testing of the SpO2 module using the Pulse Oximeter. an average error value of 1.57% was obtained. This result was calculated based on the values obtained from the testing of all ten data collection. The data was processed and resulted in the diagram. The largest error value obtained was 5.6%.

IV. DISCUSSION

After collecting data and performing measurements on the baby cube module, data collection and analysis were carried out to evaluate the module's stability and accuracy. In this study, the main objective is to assess the module's alignment with the compared instruments, namely the thermometer and pulse oximeter. The study aims to evaluate the module's performance and accuracy in comparison to these two instruments. After conducting experiments in this study to obtain body temperature values with 10 data collection and data collection conducted once. The module recorded an average body temperature of 33.98°C, whereas the thermometer recorded a temperature of 34.34°C. The temperature difference obtained was 0.36°C, with an error of 1%. The DS18B20 sensor read the data well and showed a minimal difference compared to the comparator. It should be noted that this sensor's readings are slower compared to those of the thermometer. During the experiment to obtain SpO2 values, data was collected from 10 data sets, and a total of 10 data collections were performed. The resulting data was then compared with the SpO2 values obtained from a Pulse Oximeter. The results were deemed satisfactory since they fell within the SpO2 measurement threshold of 2. Therefore, the SpO2 module can be considered effective and suitable for use. The measurements were performed 10 times and then averaged. Based on the measurement data, the variance between the average measurement and the comparator Pulse Oximeter was determined. The data collection revealed that the highest error value among the measurements was 5.6%, and the average measurement error across all data sets was 1.57%. Among the data collections, data collection 2 exhibited the highest error value of 5.6%, while data collection 10 displayed the lowest error value of 0.1%. The weakness of this sensor lies in its reliance on the correct positioning of the finger on the skin to obtain stable results.

Essentially, the method employed in this baby cube device is quite similar to previous studies, with the inclusion of additional variables like heart rate and oxygen saturation. The inclusion of these variables from previous research was aimed at improving the tool's capability to effectively monitor infants. Specifically, the vital signs of infants during hypothermia treatment were considered. The baby cube device shares a similar design and functionality with the previous author's work concerning temperature control. It incorporates temperature settings of 34˚C, 35˚C, 36˚C, and 37˚C for precise regulation of room temperature[23]. The author offers temperature control settings for the baby cube by adjusting the light driver, allowing precise regulation of room temperature. The comparison with previous research lies in the addition of heart rate and oxygen saturation parameters. with body temperature parameters and room temperature controls that are still the same as the previous authors[24]. Additionally, there are enhancements in the monitoring settings for heart rate and oxygen saturation[25].

The Baby Cube device can be constructed with the incorporation of heart rate and oxygen saturation parameters using MAX30102 as the sensor for heart rate and oxygen saturation, along with a character LCD display for visualization. The temperature settings of 34˚C, 35˚C, 36˚C, and 37˚C can be implemented in this baby cube. The device utilizes an ESP32 microcontroller for control. A safety limit control with a digital thermostat and a buzzer can be incorporated. The limitation of this device is the relatively fast reading from the MAX30102 sensor. The position of the finger also affects the reading. Unstable and inaccurate readings can occur due to an improper finger position. Despite efforts made by the author in creating the module, various factors contribute to its imperfections, including aspects of the physical design and performance. The researcher suggests some improvements for future research. The author explores the utilization of the PID (Proportional-Integral-Derivative) method to achieve uniform heat distribution in all temperature settings, including T1, T2, T3, and T4. Implementing a better heater driver to achieve temperature stability. Using a more tightly sealed box and a more modern display. Maximizing the accuracy of heart rate and oxygen saturation readings. The first mentioned drawback is the lack of adequate planning and construction regarding heat circulation in the module. This indicates that the system has not been properly designed to regulate optimal room temperature. Improper heat circulation can have negative impacts on the performance and reliability of the module. Moreover, this approach may lead to potential issues like overheating or excessive temperature rise. Further analysis is essential in this context, and improvements or enhancements may be necessary in the design or cooling system to address these concerns. The second drawback mentioned is that the readings of the MAX30102 sensor are relatively fast and can be influenced by improper finger placement. When the finger is not properly positioned on the sensor, the acquired readings become unstable and imprecise. The MAX30102 sensor is typically used for monitoring pulse and blood oxygen levels, and accurate results are crucial in medical applications. To tackle this concern, adjustments or the implementation of new methods might be necessary to guarantee appropriate finger placement when using the sensor. This will lead to more consistent and accurate results. It is important to note that the mentioned drawbacks are specific to the module created by the author. The appropriate solutions to address these limitations will vary depending on the context, purpose, and specifications of the module. To improve the quality and performance of the module, the author may need to implement enhancements or improvements in the planning, construction, and functionality of the device.

This research has several advantages in maintaining the quality of life for hypothermic infants and is designed in a simple and user-friendly manner. Maintaining the quality of life for hypothermic infants. The objective of this research is to improve the quality of life for infants experiencing hypothermia, a condition characterized by body temperature falling below the normal range. In this pursuit, the research proposes a solution to address this issue. Through the implementation of a highly efficient approach, the designed system has the capability to regulate the infant's body temperature at a safe level and mitigate the risk of complications associated with hypothermia. One of the key strengths of this research is its straightforward and uncomplicated design. A simple design facilitates the use and implementation of the system by medical professionals or nurses. Additionally, a simple design can reduce production costs and allow for easier access to the required equipment. The simplicity of the design enhances the overall user-friendliness and affordability of the solution proposed in this research. Additionally, the study places significant emphasis on ensuring a user-friendly approach. The system designed with this principle is intended to be easy to use and operate by medical professionals. Characteristics such as an intuitive interface, clear instructions, or easily understood mechanisms can aid medical personnel in operating the system accurately and efficiently. User-friendliness is essential to ensure the success and adoption of the system in everyday medical practice. These advantages result in significant potential impact for improving the quality of life for hypothermic infants. The simple and user-friendly design also enables the widespread use and easy implementation of the system in various medical settings.

V. CONCLUSION

Taking into account the discussions and the module's intended purpose, it can be deduced that the Baby Cube device can be created by integrating various specific components and features. One of these features includes the utilization of the DS18B20 temperature sensor to monitor both the body temperature of the baby and the room temperature. This sensor provides high accuracy readings with a difference of less than 1˚C compared to standard thermometers and thermohydrometer comparators. This is crucial for accurately monitoring the baby's body temperature and maintaining optimal room temperature. The Baby Cube device is equipped with a character LCD display that provides clear and easy-to-read information about body and room temperature. With the aid of this display, medical professionals or parents can effortlessly and swiftly monitor the temperature. Moreover, alongside the temperature sensor, the baby cube device can also be equipped with the MAX30102 sensor to monitor the baby's heart rate and oxygen saturation levels. This information is crucial for closely monitoring the baby's health, particularly in situations that necessitate intensive care. The Baby Cube device offers temperature adjustment with multiple levels, specifically 34˚C, 35˚C, 36˚C, and 37˚C. This enables users to customize the temperature according to the baby's needs. The Baby Cube device utilizes the ESP32 microcontroller for control and data processing. This microcontroller has sufficient capabilities to control the module functions and process data efficiently. Safety limit control, the Baby Cube device can also include a digital thermostat and an alarm as part of the safety limit control. This functionality allows the detection of excessively high temperatures or temperatures that exceed the safe limits, thereby enabling the system to issue necessary warnings or take preventive actions. Given these characteristics, the Baby Cube device emerges as a comprehensive and valuable option for the supervision and well-being of infants. Nonetheless, it is crucial to highlight that the integration and effectiveness of the module demand meticulous preparation, development, and fine-tuning to guarantee its appropriateness and dependability in medical contexts. The author's main findings are based on previous research. specifically (Artdieansyah Nur Wiaam. 2022) on body and room temperature parameters and (Sri Wahyuni Dwi Lestari. 2013) on baby heart rate parameters. The author added the oxygen saturation parameter because the sensor can monitor both heart rate and oxygen saturation to maximize the device's functionality. The author proposes several enhancements for future investigations, one of which involves investigating the application of PID (Proportional-Integral-Derivative) methods to achieve uniform heat distribution across all temperature settings, namely T1, T2, T3, and T4. Implementing better heating drivers for temperature stability. Using a more tightly sealed box and a more modern display. Maximizing the accuracy of heart rate and oxygen saturation readings.

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