Jurnal Teknokes
International: Rapid Review: Open Access Journal Vol. 16, No. 3, Sept. 2023, pp. 121–129 e-ISSN 2407-8964; p-ISSN 1907-7904

Manuscripts received July 18, 2023; revised August 10, 2023; accepted August 12, 2023; Publish date: 25 September 2023
Digital Object Identifier (**DOI):** https://doi.org/10.35882/teknokes.v16i1.516

How to quote: Farhel Gading Mahendra,Triana Rahmawati, Abd. Kholiq, and Muhammad Umer Farooq Mujahid, " Baby Incubator with Room Temperature and Skin Temperature Monitoring Via IoT-Based WIFI Network", Jurnal Teknokes, vol. 16, no. 3, pp. 121–129, September. 2023.

Baby Incubator with Room Temperature and Skin Temperature Monitoring Via IoT-Based WIFI Network

Farhel Gading Mahendra[1], Triana Rahmawati[1], Abd. Kholiq[1], and Muhammad Umer Farooq Mujahid[2]
[1] Department of Electromedical Engineering Poltekkes Kemenkes, Surabaya, Indonesia
[2] University of Health Sciences, Lahore, Pakistan

Corresponding author: Triana Rahmawati (e-mail: triana@poltekkesdepkes-sby.ac.id).

ABSTRACT Newborns require special attention to the labor process, this affects the health of the baby itself. Similarly, with premature babies who have a high level of sensitivity to the surrounding environment, one of the biggest causes of death in premature babies is hypothermia, therefore adjustments are needed starting from room temperature and skin in the baby incubator. The purpose of this study is to develop a monitoring system that will facilitate the performance of nurses in monitoring the parameters of the baby incubator. Related to this, an incubator device is needed that can be monitored remotely. This module uses a wifi network system for data transmission. Using the ESP32 module assembled into a module for monitoring and control which will then be displayed on the LCD and in the blynk as a monitoring display. Data transmission will be communicated using an external WIFI network and the monitoring results of each sensor will be displayed on Blynk. The highest error values were 1.24% for incubator room temperature parameters and 1.15% for skin temperature parameters. The results showed that there were still inaccuracies in some parameter readings, one of the factors that read inaccurate parameters was sensor sensitivity. This research is expected to help medical personnel to facilitate monitoring the condition of premature babies in baby incubators.

INDEX TERMS Baby Incubator, Blynk, Temperature, ESP32

I. INTRODUCTION

The use of technology in the field of communication has a very big change felt by humans today. With internet connectivity, everything becomes easier and faster. This is used by technology developers to explore the benefits of this internet network. [1][2] The Internet of Things is a concept that aims to expand the benefits of continuously connected internet connectivity, along with the ability to control, share data, and so on. The use of this concept is generally applied to several fields that require continuous data information such as monitoring or control. There are already many medical devices that have applied technology in it, one of which is a baby incubator [3][4] [5]

Baby incubators are medical equipment used to provide intensive care or protection for babies who have premature birth and low birth weight. By providing temperature heating that matches the temperature when the baby is in the mother's womb and provides protection against germs such as viruses and bacteria from the outside environment against. Normal babies are born with a gestational age of about 38-40 weeks with a body weight of about 2500-4000 grams, but in premature babies the gestational age is only 37 weeks or weighs less than 2500 grams of babies[6][7][8][9]. Hypothermia is the leading cause of newborn pain and death in developing countries. Premature babies have a higher risk of death compared to full-term babies. This is because they have difficulty adapting to life outside the womb due to the immaturity of their organ systems. [10][11][12].

Hypothermia occurs due to a decrease in body temperature caused by various circumstances, mainly due to high oxygen demand and a decrease in room temperature. Maintaining body temperature within normal limits is essential for the survival and growth of newborns. [13][14][10] Consequently, it is essential to maintain a warm temperature of approximately 35°C – 36°C inside the incubator since babies possess less fat tissue, making them susceptible to hypothermia or low body temperature. Additionally, the incubator's humidity must be regulated to account for exhalation.. [15][16][17][7] An essential requirement in incubator development is the implementation of a monitoring system for temperature and humidity control. Presently, manual monitoring of chamber temperature and skin temperature is still being conducted. [18][16][19]. Manual monitoring causes nurses or midwives to often enter the nursery to check the temperature of the incubator for periodic periods. This condition can cause data reading errors. In this system, monitoring of humidity measurements is also developed so, that the baby's respiratory system remains in optimal condition [20] [21][3] [22]

Based on library search results, several research studies have been conducted to monitor baby incubators using different communication methods. This article summarizes the findings from each study, highlighting their advantages and limitations. The first study et al. focused on using Bluetooth as a communication medium to send data for monitoring baby incubators. They successfully obtained display results from the LCD and the MIT APP application interface. The MIT APP application effectively displayed data received from the microcontroller via Bluetooth HC-05. However, a drawback of this method is the limited range of connectivity between Bluetooth devices. With a barrier, the maximum distance achieved was 8 meters, and without obstructions, it was 10 meters. This limitation may restrict monitoring in larger spaces or areas with obstacles. [2][20]

The next research et al. explored web monitoring methods for remote monitoring based on Esp32. The web monitoring results were satisfactory in displaying data received from the microcontroller. However, the method exhibited delays in sending data, which could impact real-time monitoring. Such delays might lead to inaccuracies in the displayed information, potentially affecting critical decision-making in the care of premature infants. A third researcher conducted a study using the Think Speak display method as an Internet of Things (IoT)-based data storage web server. The study found that the design of the tool used was appropriate, resulting in accurate moisture readings displayed on the Thing Speak web server. However, the research identified limitations related to the network's quality of service, which could affect the duration of web statuses. Unreliable network connectivity may hinder real-time monitoring and could lead to data gaps or inaccuracies. [23][24][25].

The latest study utilized Borland Delphi's programming method as a visual application to monitor baby incubator parameters. The measurement results of each parameter were displayed in the Delphi application over a WIFI network. While this method provided real-time data monitoring, it encountered a limitation in terms of the maximum distance of the WIFI signal capabilities. At distances of 4 to 6 meters, data transmission could become unreliable or disconnected, potentially affecting the effectiveness of monitoring in certain settings. [16][17]

Overall, each research study has contributed valuable insights into monitoring baby incubators through different communication methods. The Bluetooth method offers direct and immediate communication but is limited by its range. The web monitoring method provides remote accessibility, but data delays could be a concern. The IoT-based data storage web server approach offers accurate readings but relies heavily on network quality. The Borland Delphi's programming method allows visual monitoring but faces limitations due to WIFI signal distance.

As future research and development continue, it is essential to address these limitations and explore ways to improve the communication methods for baby incubator monitoring. Potential areas of improvement may include optimizing Bluetooth connectivity for longer ranges, reducing data delays in web monitoring, enhancing network robustness for IoT-based systems, and investigating alternative communication technologies that could overcome WIFI signal limitations. By addressing these challenges, researchers can contribute to more efficient and reliable baby incubator monitoring systems, ultimately improving neonatal care and outcomes. Based on the literature search described above, it can be concluded that there are still many previous researchers who have not been able to display measurement results on the android display.

In this study, an IoT-based Baby Incubator was developed, incorporating Chamber Temperature and Skin Temperature Monitoring through a WIFI network. The primary objective is to provide healthcare professionals, including doctors, midwives, and nurses, with a convenient means of monitoring infants and their incubators. The researchers utilized the DHT22 sensor to measure room temperature inside the incubator and the DS18B20 sensor to monitor the baby's body temperature. The study's outcomes are expected to contribute valuable knowledge to readers by presenting a design for a baby incubator device capable of remotely tracking room and skin temperatures via smartphones. This innovation aims to simplify the monitoring process for healthcare providers, ensuring the well-being of infants and enhancing the efficiency of neonatal care.

Understand the results of room temperature and skin temperature in baby incubators normally and abnormally. The research findings presented above encompass the development of a Baby Incubator with Chamber Temperature and Skin Temperature Monitoring through an IoT-based WIFI Network, contributing to the advancement of medical technology. The objective is to enable data parameters reading through Android devices, addressing the issue faced by prior researchers who were unable to display measurement results on android screens. This innovative approach significantly benefits doctors, midwives, and nurses by providing them with convenient remote monitoring of both room temperature and the baby's skin temperature via smartphones. It offers a crucial tool for

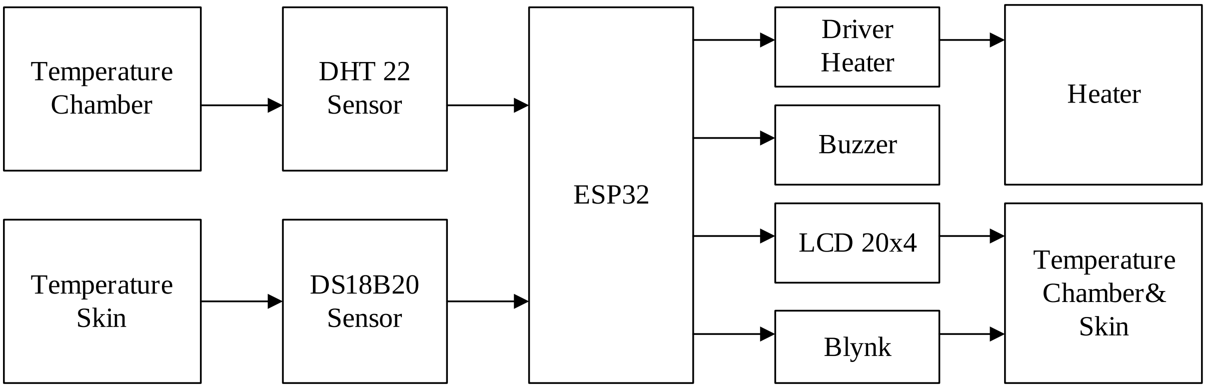

FIGURE 1 System Block Diagram baby incubator module that uses dht sensor as chamber temperature reader and ds18b20 sensor as skin temperature reader. Heater driver to turn on the heater so that the room temperature can match the settings. 20x4 LCD as a display on the module and Blynk as a platform to be displayed on Android as a monitoring display

healthcare professionals to efficiently oversee the well-being of infants and their incubators from a distance, thus enhancing patient care.

This research aims to serve as a valuable resource for readers by showcasing the potential of a baby incubator device that caters to the real-time monitoring needs of healthcare practitioners. The device's capability to detect normal and abnormal room and skin temperatures in baby incubators provides crucial insights, ultimately contributing to the advancement of neonatal care and safety.

II. MATERIALS AND METHODS

In FIGURE 1 this study researchers made a system block diagram on the module according to the parameters made, consisting of chamber temperature parameters and skin temperature as System Block Diagram to give readers an idea of how the tool flow is made.

From this study, it can be seen that this module is able to monitor room temperature, the temperature of the skin, the level of humidity, and the ambient noise inside the infant incubator. This module consists of DSB1820, DHT22 and Analog V.2 Sound Sensor sensors plus ESP32 module via WIFI communication in sending data. Sensor readings will be processed by ESP32 which functions as an access point module then the data will be sent to the blynk application.

This module is made to be able to transmit values from parameters in the module so that it can be monitored remotely. This module is equipped with a display on the blynk that can display monitoring charts in real time, to see graphs of room temperature changes in baby incubators.

The DSB1820 sensor will work at a voltage of 3.7V and the digital data output from the skin temperature measurement will go to pin D18 ESP32. The DHT22 sensor will also work at a voltage of 3.7 V and the digital data output from the room temperature measurement results will go to pin D5 ESP32. Then ESP 32 will also process data from all sensors so that it can be received by ESP 32 which functions as a server. This module is also equipped with a buzzer that functions as an alarm, where this bell will sound if the module detects a measurement difference between temperature settings and measurement results with a tolerance of ± 1 ° C.

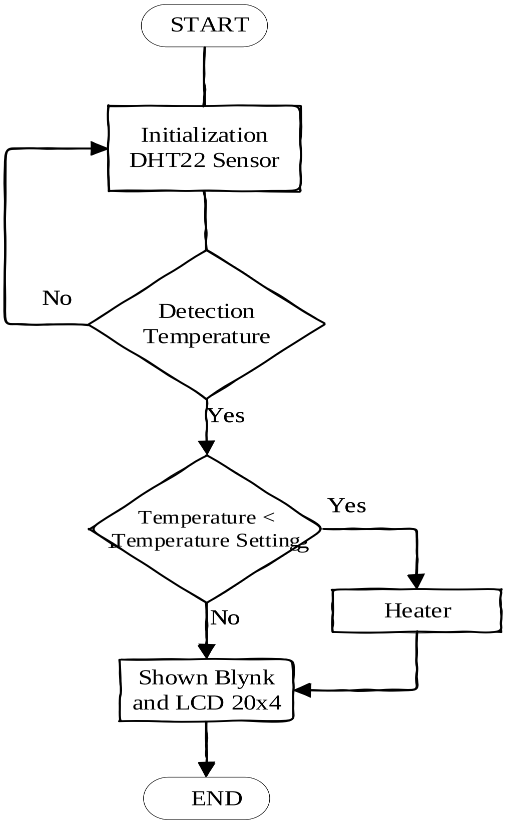

FIGURE 2 System Flowchart from baby incubator module with monitoring via IoT-based wifi network with 20x4 lcd display and blynk.

Data collection is carried out using a standard Incubator Analyzer tool, with the aim of ensuring that the reading values of all sensors both room temperature, skin temperature, humidity and noise match the sensor readings of standard calibration tools. The research design of this tool model uses a pre-experimental method with the type of After Only Design research. In this design, researchers only looked examining the outcomes without prior assessment of the conditions is avoided in this case, as there is already a control group in place, although no randomization has been carried out. The disadvantage of this design is that it does not know the initial state, so the results obtained are difficult to conclude.

The baby incubator temperature sensor and humidity sensor on the device will read according to the baby incubator setting temperature, skin temperature, noise and humidity in the baby incubator. The data will be read and will be sent directly by ESP 32 which has functioned as monitoring. Then the data will be sent to Android which then the data received by ESP 32 will be processed and the results will be displayed on the Android display in the form of graphs for chamber temperature parameters and decimal numbers for skin temperature.

The researcher has developed a baby incubator device equipped with a skin temperature sensor, which is employed to monitor the infant's body temperature within the incubator. therefore, the author made a program flow chart as in FIGURE 2. When the on button is pressed, initialization will occur. Then the sensor will work to read room temperature, skin temperature, humidity, and noise. Next, the sensor reads the data digitally. Then the data obtained will go to the microcontroller and the data will be processed by ESP32. Furthermore, the ESP32 data that has been processed will be transferred to Android via wifi network. Then the received parameter data value will be displayed on the android display with the application.

Average a is the value or result of dividing the amount of data taken or measured by the amount of data taken or the number of measurements aimed at determining the validity of the tool as written in Eq. (1) below:

$$\text{SD} = \sqrt{\frac{\sum(xi-\bar{x})^2}{(n-1)}} \tag{1}$$

Information:
X = average
X1, ..., Xn = data value
n = lots of data

Standard deviation is a metric that expresses the extent of diversity or the magnitude of the average standard deviation within a dataset. The standard deviation (SD) The Eq. (2) for uncertainty is displayed:

$$\text{SD} = \sqrt{\frac{\sum(xi-\bar{x})^2}{(n-1)}} \tag{2}$$

Where xi represents the desired quantity of values, x represents the average of measurement outcomes, and n denotes the total number of measurements taken. Uncertainty (UA) refers to the doubt that may arise in any measurement result [23][24][25]. The Eq. (3) for uncertainty is displayed as follows:

$$UA = \frac{SD}{\sqrt{n}} \tag{3}$$

UA represents the uncertainty value of the overall measurement, while SD denotes the resulting standard deviation, and n stands for the number of measurements. The term '%error' signifies a system error. A smaller Error value corresponds to the average difference among the data points. These errors may indicate disparities between the standard and the design or model. The Eq. (4) for calculating the error is provided:

$$\%\text{ERROR} = \frac{(x_n - \text{x})}{x_n} \times 100\% \tag{4}$$

Where X_n represents the recorded measurement from the engine calibrator, and X denotes the measured value from the design.

III. RESULTS

In FIGURE 3 is the result of a monitoring module design consisting of ESP32 assembled into one with DHT 22 sensor which functions as a room temperature and humidity sensor, DS18B20 sensor as a skin sensor, and analog sound sensor V.2 as a noise sensor. In FIGURE 4 is what the Blynk app looks like. Data transmission from the module to the Blynk app is done using an external wifi network in the room.

FIGURE 3. Modified module from the TESENA brand which is equipped with monitoring of temperature, humidity, and noise parameters through an IoT-based WiFi network.

The study introduces a specialized module tailored for monitoring the environment inside a baby incubator. It incorporates various sensors, namely DSB1820, DHT22, and Analog V.2 Sound Sensor, in addition to an ESP32 module for WIFI communication. By utilizing this setup, the module effectively gathers and transmits data, allowing for remote monitoring through the Blynk application. Its core objective lies in the continuous surveillance and recording of essential parameters within the baby incubator, encompassing room temperature, skin temperature, humidity, and noise levels. This innovative solution holds the potential to enhance the safety and care provided to infants in neonatal units, offering real-time insights to medical personnel and caregivers, ultimately contributing to better infant health outcomes. By continuously monitoring these parameters, medical staff can ensure a stable and conducive environment for the baby's growth and development.

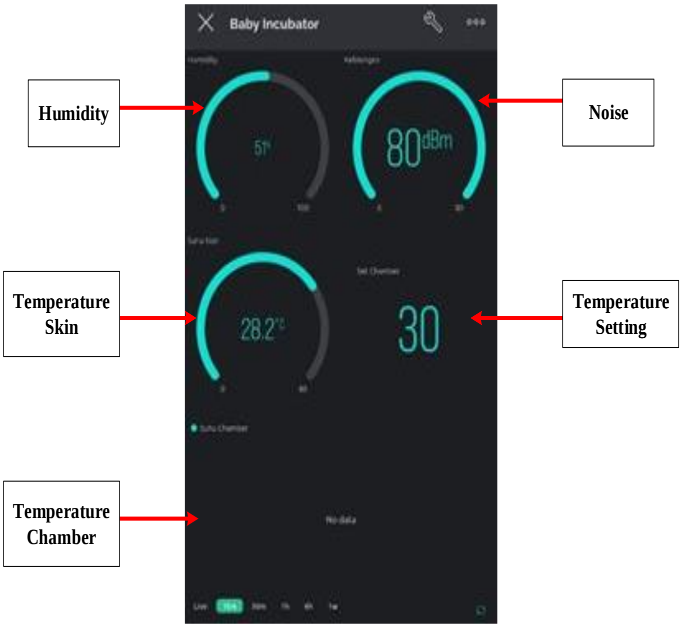

FIGURE 4. **Results Display of temperature, humidity and noise parameters on android with blynk platform.**

The DSB1820 sensor is responsible for measuring skin temperature. It operates at a voltage of 3.7V, and its digital data output is connected to pin D18 of the ESP32. Meanwhile, the DHT22 sensor is used for room temperature measurements and also operates at a voltage of 3.7V, with its digital data output connected to pin D5 of the ESP32. The ESP32 acts as the central processing unit for the module. It processes data from all sensors and serves as the access point module for WIFI communication. This enables seamless data transfer to the Blynk application, where real-time monitoring charts are displayed. The charts allow medical personnel to visualize temperature changes inside the incubator and take necessary actions promptly. To ensure the safety of the baby, the module is equipped with an alarm system, implemented using a buzzer. The buzzer serves as an alert mechanism, activating when the module detects a measurement difference between the temperature settings and the actual measurements exceeding a tolerance of ±1 °C. This ensures that any significant deviations from the desired environment trigger immediate attention. For validation and accuracy, data collection is performed using a standard Incubator Analyzer tool. By comparing the sensor readings with the values obtained from the calibrated tool, the module's accuracy and reliability are verified. This validation process is crucial to ensure that the module provides accurate and dependable readings, vital for the health and well-being of the baby. In conclusion, the proposed study introduces an advanced module that ensures comprehensive and reliable monitoring of crucial parameters within a baby incubator. This module integrates room temperature, skin temperature, humidity, and noise monitoring, while also offering real-time data visualization through the Blynk app. Such capabilities empower medical personnel to establish a secure and stable environment, promoting optimal newborn growth. Moreover, the module includes integrated alarms and validation mechanisms, enhancing safety and dependability. As a result, it becomes an indispensable asset in neonatal care, safeguarding the well-being and development of newborns as they progress towards reaching their full potential.

TABLE 1
Temperature Measurement Results in The setting 32°C

Temperature Setting 32°C	Incu Analyzer (°C)	Module (°C)
Data 1	32.2	32
Data 2	32.3	32.1
Data 3	32.3	32.1
Data 4	32.4	32.2
Data 5	32.3	32.1
STDV	0.07	0.07
UA	0.031	0.031
ERROR %	0.6	

TABLE 1 shows the results of temperature measurements on the module and incu analyzer in the incubator with a temperature setting of 32°C and measurements are carried out with 5x data capture using the DHT22 sensor with an error value of 0.6%.

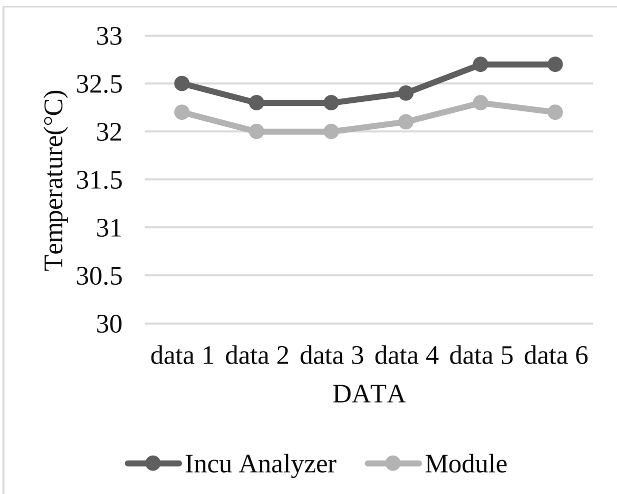

FIGURE 1. **Graph of Temperature Measurement Results in The setting 36°C**

FIGURE 5 is the result of plotting from the module and INCU analyzer at a setting temperature of 32°C

TABLE 2
Temperature Measurement Results in The setting 34°C

Temperature Setting 34°C	Incu Analyzer (°C)	Module (°C)
Data 1	33.9	34
Data 2	34.2	34.3
Data 3	34.2	34.2
Data 4	34.3	34.4
Data 5	34.2	34.3
STDV	0.151	0.151
UA	0.067	0.067
ERROR(%)	0.58	

TABLE 2 shows the results of temperature measurements on the module and incu analyzer in the incubator with a temperature setting of 34°C and measurements are carried out with 5x data capture using the DHT22 sensor with an error value of 0.58%.

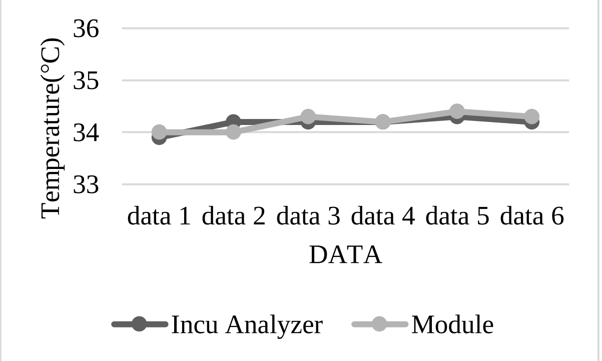

FIGURE 2. Graph of Temperature Measurement Results in The setting 36°C

FIGURE 6 is the result of plotting from the module and INCU analyzer at a setting temperature of 34°C

TABLE 3
Temperature Measurement Results in The setting 36°C

Temperature Setting 36°C	Incu Analyzer (°C)	Modul (°C)
Data 1	35.9	36.3
Data 2	35.6	359
Data 3	35.9	36.3
Data 4	36	36.5
Data 5	36	36.5
STDV	0.209	0.244
UA	0.093	0.109
ERROR%	1.15	

TABLE 3 shows the results of temperature measurements on the module and incu analyzer in the incubator with a temperature setting of 36°C and measurements are carried out with 5x data capture using the DHT22 sensor with an error value of 1.15%.

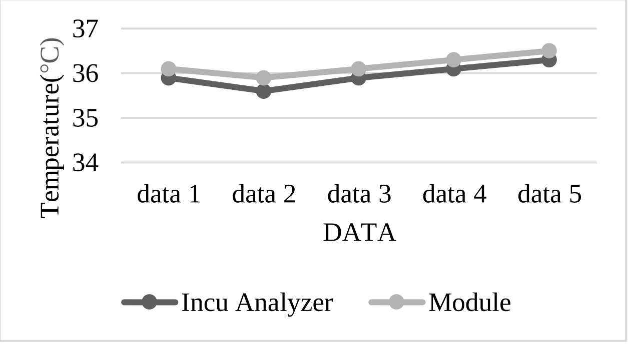

FIGURE 3. Graph of Temperature Measurement Results in The setting 36°C

FIGURE 7 is the result of plotting from the module and INCU analyzer at a setting temperature of 36°C.

TABLE 4
Skin Temperature Measurement Results

Measurement	Thermometer (°C)	Module (°C)
Data 1	32.7	32.9
Data 2	33	32.8
Data 3	32.5	32.2
Data 4	33.9	34.1
Data 5	33.3	33
Data 6	32.7	32.2

TABLE 4 shows the results of temperature measurements of thermometers and modules in incubators with measurements made as much as 5x data collection using the DS18B20 sensor.

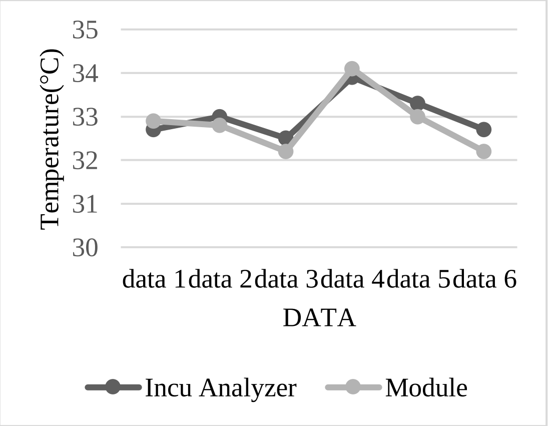

FIGURE 4. Skin Temperature Measurement Results Graph in The setting 36°C

FIGURE 8 is the result of plotting *thermometers* and standard modules.

TABLE 5
Skin Temperature Measurement Results

Measurement	Thermometer (°C)	Module (°C)
Middle	33.01	32.86
Error %	0.45	

TABLE 5 contains error data derived from the measurements obtained using the tool. The error value mentioned above was obtained by collecting data from the baby incubator skin sensor in comparison with a standard thermometer. The data collection process involved six measurements on each respondent. directly comparing the results with the thermometer comparison device to determine the error value presented in the table.

Through an analysis of the measurement outcomes. it was determined that there is a module error of 0.45%. Despite this. the results obtained still indicate relatively high error values when compared to the thermometer's measurement results. which serve as the reference. However. it is important to note that the error values obtained are still within an acceptable threshold. However. in the process of retrieving data there is a slight delay and not too real time. this is because a lot of data is sent so that the module sends data alternately with other parameter measurement data. so, there is a high difference between the incu reading and the module we make.

TABLE 6
Set Point DHT 22 Measurement Results in the setting 32°C

Temperature Chamber (°C)	Output sensor (V)	Enter SSR (V)	Output SSR (V)	Heating Conditions	Skin Temperature (°C)
31.7	1.55	3.3	220	Above	32
31.4	1.53	3.3	220	Above	31.9
32	1.56	0	0	OFF	32.2
32.6	1.59	0	0	OFF	32.6
31.8	1.55	3.3	220	Above	32
32.4	1.58	0	0	Above	32.5

TABLE 6 The above data can be used to see the sensor setpoint value. The purpose of reading setpoints as in the table above used in this study is to see the condition of other components as the chamber temperature value obtained by the module made by the researcher changes so that its conformity with the actual value can be accounted for by measurements made as much as 6x.

TABLE 7
Set Point DHT 22 Measurement Results in the setting 34°C

Temperature Chamber (°C)	Output sensor (V)	Enter SSR (V)	Output SSR (V)	Heating Conditions	Skin Temperature (°C)
33.4	1.63	3.3	220	Above	33.6
33.8	1.65	3.3	220	Above	34
34.2	1.67	0	0	OFF	34.5
34	1.66	0	0	OFF	34
34.4	1.68	0	0	OFF	34.2
33.8	1.65	3.3	220	Above	34

TABLE 7 The above data can be used to see the sensor setpoint value. The purpose of reading setpoints as in the table above used in this study is to see the condition of other components as the chamber temperature value obtained by the module made by the researcher changes so that its conformity with the actual value can be accounted for by measurements made as much as 6x.

TABLE 8
Set Point DHT 22 Measurement Results in The setting 36°C

Temperature Chamber (°C)	Output sensor (V)	Enter SSR (V)	Output SSR (V)	Heating Conditions	Skin Temperature (°C)
35.9	1.76	3.3	220	Above	36.2
36.1	1.77	0	0	OFF	36.4
36.1	1.77	0	0	OFF	36.6
35.7	1.77	3.3	220	Above	36
36.3	1.78	0	0	OFF	36
36.5	1.79	0	0	OFF	36.3

TABLE 8 The above data can be used to see the sensor setpoint value. The purpose of reading setpoints as in the table above used in this study is to see the condition of other components as the chamber temperature value obtained by the module made by the researcher changes so, that its conformity with the actual value can be accounted for by measurements made as much as 6x.

IV. DISCUSSION

In this study. researchers compared the results of mattress temperature readings on modules made by researchers with Fluke INCU II. The presented error value is obtained from gathering data in the baby incubator. where it was operated at three different temperature points: 32°C. 34°C. and 36°C. The data collection process commenced once the temperature had reached a stable state. Data was collected through up to 5 measurements at each temperature setting. These measurements were directly compared using the incu analyzer comparison tool to obtain error values. which are listed in the table above. The error value recorded for the temperature setting of 32°C was 0.6% in the module. Similarly. the module recorded an error value of 0.58% at the temperature setting of 34°C. and an error value of 1.15% at the temperature setting of 36°C. According to the measurement data. the obtained outcomes exhibit a relatively high level of error when compared to the reference values provided by the incu analyzer. yet they remain within the acceptable threshold. However. in the process of retrieving data there is a slight delay and not too real time. this is because a lot of data is sent so, that the module sends data alternately with other parameter measurement data. so, there is a high difference between the incu reading and the module we make. Based on the measurement data. the results obtained are still quite high error values from the thermometer measurement results that function as a comparison and are still within the threshold. However. in the process of retrieving data there is a slight delay and not too real time. this is because a lot of data is sent so that the module sends data alternately with other parameter measurement data. so, there is a high difference between the incu reading and the module that we made. Standard deviation in Fluke INCU II calibration refers to a measure of variation in the measurement data. While uncertainty (Ua) serves to see how much deviation (accuracy) the baby incubator module in carrying out its function. The smaller the standard deviation and standard uncertainty value. the more accurate the measurement results and the more consistent the measurement results obtained

Based on library search results, several research studies have been conducted to monitor baby incubators using different communication methods. This article summarizes the findings from each study, highlighting their advantages and limitations. The first study et al. focused on using Bluetooth as a communication medium to send data for monitoring baby incubators. They successfully obtained display results from the LCD and the MIT APP application interface. The MIT APP application effectively displayed data received from the microcontroller via Bluetooth HC-05. However, a drawback of this method is the limited range of connectivity between Bluetooth devices. With a barrier, the maximum distance achieved was 8 meters, and without obstructions, it was 10 meters. This limitation may restrict monitoring in larger spaces or areas with obstacles. [2][20]

The next research et al. explored web monitoring methods for remote monitoring based on Esp32. The web monitoring results were satisfactory in displaying data received from the microcontroller. However, the method exhibited delays in sending data, which could impact real-time monitoring. Such delays might lead to inaccuracies in the displayed information, potentially affecting critical decision-making in the care of premature infants. A third researcher conducted a study using the Think Speak display method as an Internet of Things (IoT)-based data storage web server. The study found that the design of the tool used was appropriate, resulting in accurate moisture readings displayed on the Thing Speak web server. However, the research identified limitations related to the network's quality of service, which could affect the duration of web statuses. Unreliable network connectivity may hinder real-time monitoring and could lead to data gaps or inaccuracies. [23][24][25]

The latest study utilized infant incubator intelligent control system based on internet of things. The measurement results of each parameter were displayed in the Delphi application over a WIFI network. While this method provided real-time data monitoring, it encountered a limitation in terms of the maximum distance of the WIFI signal capabilities. At distances of 4 to 6 meters, data transmission could become unreliable or disconnected, potentially affecting the effectiveness of monitoring in certain settings. [16][17]

Based on the table in Chapter IV. it can be seen that the standard deviation obtained can be said to be good. because the result of the standard deviation value is not more than the average value of the measurement of the baby incubator module. This shows that the average measurement module value can be used as a measurement representation of the overall data. The evidence from the standard deviation confirms that the least amount of variation (standard deviation) is observed in configuration 32. registering a value of 0.07. across all the collected measurement data. However. this module has a weakness. namely the high value of temperature overshoot when it will reach the setting temperature. Based on the measurement data. the results obtained are still quite high error values from the thermometer measurement results that function as a comparison, n and are still within the threshold. However. in the process of retrieving data there is a slight delay and not too real time. this is because a lot of data is sent so that the module sends data alternately with other parameter measurement data. so, there is a high difference between the incu reading and the module we make.

In this study. a Baby Incubator was made with Chamber Temperature and Skin Temperature Monitoring through an IoT-based WIFI Network making it easier for doctors. midwives and nurses to monitor the condition of babies and their baby incubators. Similarly. for the standard uncertainty value (Ua) in the table above. the best accuracy result is 0.032 at a temperature setting of 32. Standard deviation in Fluke INCU II calibration refers to a measure of variation in the measurement data. While uncertainty (Ua) serves to see how much deviation (accuracy) the baby incubator module in carrying out its function. The smaller the standard deviation and standard uncertainty value. the more accurate the measurement results and the more consistent the measurement results obtained.

IV. CONCLUSION

In this study. a Baby Incubator was made with Chamber Temperature and Skin Temperature Monitoring via IoT-based WIFI Network. This method aims to make it easier for doctors. midwives and nurses to monitor the condition of babies and their baby incubators.

After making and studying the literature as well as planning. testing tools and data collection. the author can conclude that a Baby Incubator tool can be made by monitoring through an IoT-based WIFI network with a display on the Blynk application. This tool can work to send data via external WIFI connected to ESP32 as a microcontroller receiver and data processor judging from the parameters that can be monitored through the blynk application on Android. Based on the data measurement results. the highest error value is obtained from the measurement room temperature parameter at the temperature setting of 36°C. which is 1.15% with an incu analyzer. The highest error of measuring skin temperature parameters at 32°C was 0.46%. Sensor placement affects measurement results and errors The value obtained is seen from the high overshoot value. This tool still cannot be implemented in patients because the overshoot chamber temperature is still high.

Because of the numerous existing factors. the module designed by the author is considerably imperfect. both in terms of its physical shape planning and performance. The recommendations made by the researcher for its improvement in this study are as follows. The use of new sensors for more stable and accurate temperature readings. whether used at low temperatures or high temperatures. The display for parameters is too small so, it can be overridden to use a larger display to be clearly visible. The display on Android is made more attractive by using other applications.

REFERENCE

[1] M. Manoj and K. Ojha, “An Overview of Smart Home System Based on Internet of Things,” *Samvakti J. Res. Bus. Manag.*, vol. 2, no. Anon, p. 65, 2021, doi: 10.46402/2021.02.18.

[2] T. Hussain, K. Muhammad, S. Khan, A. Ullah, M. Y. Lee, and S. W. Baik, “Intelligent Baby Behavior Monitoring using Embedded Vision in IoT for Smart Healthcare Centers,” *J. Artif. Intell. Syst.*, vol. 1, no. 1, pp. 110–124, 2019, doi: 10.33969/ais.2019.11007.

[3] IEEE SA, “IEEE Standards Activities in the Internet of Things (IoT) Overview,” no. November, pp. 1–4, 2018.

[4] E. Clasen, K. Land, and T. Joubert, “Micro-incubator for bacterial biosensing applications,” in *Fourth Conference on Sensors, MEMS, and Electro-Optic System*, Feb. 2017, p. 100360G. doi: 10.1117/12.2245443.

[5] M. Taştan and H. Gökozan, “Real-time monitoring of indoor air quality with internet of things-based e-nose,” *Appl. Sci.*, vol. 9, no. 16, 2019, doi: 10.3390/app9163435.

[6] M. V. Pedersen, T. C. K. Andelius, H. B. Andersen, K. J. Kyng, and T. B. Henriksen, “Hypothermia and heart rate variability in a healthy newborn piglet model,” *Sci. Rep.*, vol. 12, no. 1, pp. 1–9, 2022, doi: 10.1038/s41598-022-22426-3.

[7] J. O. Davidson, G. Wassink, L. G. van den Heuij, L. Bennet, and A. J. Gunn, “Therapeutic hypothermia for neonatal hypoxic-ischemic encephalopathy - Where to from here?,” *Front. Neurol.*, vol. 6, no. SEP, 2015, doi: 10.3389/fneur.2015.00198.

[8] M. K. Zarkani, “Design and implementation of Laboratory incubator,” Ministry of Higher Education & Scientific Research University of Kerbala, Republic of Iraq, 2020.

[9] “A Multifunction Infant Incubator Monitoring System with Phototherapy and ESP-32 Based Mechanical Swing | International Journal of Science, Technology & Management.” [Online]. Available: https://ijstm.inarah.co.id/index.php/ijstm/article/view/93

[10] E. H. Yayan PhD and M. Zengin MSc, “A Key Point in Medical Measurements: Device Calibration and Knowledge Level of Healthcare Professionals,” *Int. J. Caring Sci.*, vol. 13, no. 2, pp. 1346–1354, 2020, [Online]. Available: https://www.proquest.com/scholarly-journals/key-point-medical-measurements-device-calibration/docview/2462488451/se-2%0Ahttps://media.proquest.com/media/hms/PFT/1/EqjgH?_a=ChgyMDIyMDYyMzAyMjEwMDY2Mzo2MDM2NTQSBTk3ODM1GgpPTkVfU0VBUkNIIg0zNi43My4xMDIuMjIwKgc

[11] “Jagadeesh P, Karthick Kumar Reddy G, Venkatramana Reddy S (2014) Design and development of an inexpensive temperature controller for an infant incubator. Int J Adv Res Electr Electron Instrum Eng 3(6):10194 (An ISO 3297: 2007 Certified Organization). Copy.” [Online]. Available: http://www.ijareeie.com

[12] “Patil DS, Aher AS, Nahata AS (2016) PIC microcontroller based efficient baby incubator. Int J Mod Trends Eng Res. www.ijmter.com e-ISSN No: 2349-9745, Date: 28–30 Apr 2016 @IJMTER-2016, All rights Reserved.” [Online]. Available: http://www.ijmter.com

[13] D. Singh, P. Kumar, and S. C. Prasad, “Calibration of thermocouples for low temperature applications,” in *2016 International Conference on Recent Advances and Innovations in Engineering (ICRAIE)*, 2016, pp. 1–4. doi: 10.1109/ICRAIE.2016.7939485.

[14] S. M. Lawal, M. Umar, and I. Muhammad, “Design and Performance Evaluation of an Automatic Temperature Control System in an Incubator,” *Int. J. Appl. Electron. Phys. Robot.*, vol. 2, no. 1, pp. 8–12, 2017, doi: 10.7575/aiac.ijaepr.v.2n.1p.8.

[15] “View of Development of Incubator Analyzer Based on Computer with Temperature And Humidity Parameters.pdf.”

[16] S. Kolhe, M. S. Mishra, and M. S. Shah, “Improved Design of IoT based Infant Incubator Monitoring and Control System,” *Int. Res. J. Eng. Technol.*, no. May, pp. 2837–2842, 2021, [Online]. Available: www.irjet.net

[17] T. Huang and L. Sun, “Design and implementation of the infant incubator intelligent control system based on internet of things,” *Open Autom. Control Syst. J.*, vol. 7, no. 1, pp. 2223–2229, 2015, doi: 10.2174/1874444301507012223.

[18] “View of PROTOTYPE BABY INCUBATOR DENGAN SISTEM MONITORING BAK AIR BERBASIS INTERNET OF THINGS (IOT).pdf.”

[19] M. Kalilani, N. Shyan Lai, and R. Abdulla, “IOT based neonatal incubator for the developing world and conflict zones,” *J. Appl. Technol. Innov.*, vol. 5, no. 4, pp. 2600–7304, 2021.

[20] S. Purwanti, A. Febriani, Mardeni, and Y. Irawan, “Temperature monitoring system for egg incubators using raspberry Pi3 based on internet of things (IoT),” *Journal of Robotics and Control (JRC)*, vol. 2, no. 5. pp. 349–352, 2021. doi: 10.18196/jrc.25105.

[21] “View of Development of Rain Detector System using ESP32 With Alarm and Blynk Application.pdf.”

[22] K. Lezama-García *et al.*, “Strategies for Hypothermia Compensation in Altricial and Precocial Newborn Mammals and Their Monitoring by Infrared Thermography,” *Vet. Sci.*, vol. 9, no. 5, pp. 1–20, 2022, doi: 10.3390/vetsci9050246.

[23] F. Kristya, S. Luthfiyah, I. D. G. Hari Wisana, and M. Thaseen, “Baby Incubator Monitoring Center for Temperature and Humidity using WiFi Network,” *J. Electron. Electromed. Eng. Med. Informatics*, vol. 3, no. 1, pp. 8–13, 2021, doi: 10.35882/jeeemi.v3i1.2.

[24] W. A. Jabbar, H. K. Shang, S. N. I. S. Hamid, A. A. Almohammedi, R. M. Ramli, and M. A. H. Ali, “IoT-BBMS: Internet of Things-Based Baby Monitoring System for Smart Cradle,” *IEEE Access*, vol. 7, pp. 93791–93805, 2019, doi: 10.1109/ACCESS.2019.2928481.

[25] F. Fahmi, W. Shalannanda, I. Zakia, and E. Sutanto, “Design of an IoT-based smart incubator that listens to the baby,” *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 1003, no. 1, 2020, doi: 10.1088/1757-899X/1003/1/012153.