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PID Temperature Control of Baby Incubator Transport Battery Efficiency

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ABSTRACT Transport baby incubators are used to keep babies warm and safe while in transport using battery voltage sources or DC electricity, which are portable and can be used without getting a supply of electrical energy. The problem that often occurs with this tool is the limited battery power system. causes a risk to the infant in the event of power failure or battery exhaustion. We aim to evaluate the battery efficiency of Baby Incubator Transport using a PID temperature controller. The evaluation is done by comparing and analyzing the battery voltage of the device to the standard device, as well as considering the setting temperature and duration of use of the device so that it can provide convenience in evacuating babies in an emergency. The tool uses the PID method to control temperature and maximize battery power. In this design, researchers only look at the efficiency of the PID method on temperature control and the battery to be used. This module will have a display that will display the battery voltage value, battery voltage percentage, skin temperature, chamber temperature, humidity, and temperature control that has been selected in the form of a graph. Compared with the digital multimeter measuring instrument. From the results of data collection, it can be concluded that the PID method has a faster rise time to reach the setting temperature, while the fuzzy method has a longer rise time to reach the setting temperature. However, the PID method requires more battery power than the Fuzzy method. The measurement results between the display and the measuring device have a difference of 3.1% at 34°C, at 35°C it is 3.9%, and at 36°C it is 4.7%. The biggest error is at a temperature of 36ºC, the smallest is at a temperature of 34ºC. Based on the results of the observation analysis of battery power consumption, it is found that the smaller the battery energy, the smaller the current issued, as well as the voltage issued. But if the load is large, the current is inversely proportional to the center, the battery voltage decreases while the current increases.

INDEX TERMS Baby Incubator Transport, Battery Efficiency, PID Control

I. INTRODUCTION

Baby incubator transport is a life support tool to keep premature babies or sick babies warm and safe while being transported to the NICU in a hospital environment[1]. The main element of the NICU is the incubator, a system that provides warmth to the baby and allows for easy monitoring and intervention. The baby's health is maintained and monitored through the unit, which is equipped with various types of monitors. Due to their high cost, incubators are often limited in health facilities in rural areas. Therefore, there is a need for portable incubators that can be used while the baby is traveling to or between care facilities[2][3]. Baby incubator transport uses a portable battery voltage source or DC electricity, which can be used in various places and unlimited time without having to be in a location or place that gets electricity. Batteries have a time limit and usage power and cannot be reused when energy has run out. For the battery to be recharged, it is necessary to charge with an AC voltage source.

A baby incubator is a medical device used to provide intensive care to babies who are born prematurely and have a low birth weight[4][5][6]. Premature is the term for babies who are born before reaching 37 weeks of gestation. Births at this stage are at risk of growth and developmental problems due to under-gestation, as well as low body weight. This can lead to the potential for serious illnesses or disabilities, with a high tendency to experience pain that can even lead to death[7][8]. Premature babies tend to have lower activity levels, less responsiveness, higher sensitivity, and more reluctance to gaze when compared to babies born at the right time[9]. A major challenge for babies born prematurely is their inability to regulate their body temperature[10]. Babies are protected from bacteria and germs from the outside environment by providing heating at a temperature that matches the temperature when the baby is in the mother's womb. Therefore, the room temperature must remain stable and follow the baby's temperature[11][12][13].

Low power is a trend to maximize battery consumption [14]. Most portable systems consume more power due to limited battery life [15][16][17]. Energy delivery, analog-digital conversion, signal processing, and data communication are activities that typically require biomedical electronic devices that have relatively low power consumption requirements[18][19]. The need for compact, efficient, and frequently used devices is very high [20].

Some researchers have developed and modified incubators for babies[21][22]. Nyoman Someyasa and Didit Rudiyanto (2012) made a prototype research baby incubator transport equipped with the detection of infant skin temperature and humidity in the chamber (temperature sensor also charger circuit) using experimental methods. This study used On-Off control[23]. Wisnu Kusuma Wardanai et al (2019) have conducted research modifying baby incubators equipped with temperature control and refill series. This study used On-Off control and the battery can last for an average of 160 minutes when used[24].

Dara Pratiwi (2020) developed a PID-based Infant Incubator with Kangaroo Mode (Control PID Room Temperature &; Skin Temperature). Because the heater wattage is too small, the method's response to heater performance is rather slow, and this study using PID control still found weaknesses[25]. Furthermore, research conducted by Abdul Latif and his colleagues (2021) discussed the creation of a temperature and humidity control system in baby incubators. The results of this study show that the system can operate well. However, using an on-off system can lead to a fairly high-temperature overshoot[26]

From the identification results in previous research, the author plans to develop "PID Temperature Control of Baby Incubator Transport Battery Efficiency" which aims to evaluate battery efficiency in Baby Incubator Transport using a PID temperature controller. The evaluation is done by comparing and analyzing the battery voltage on the device compared to the standard device, as well as considering the setting temperature and duration of use of the device so that it can provide convenience in the process of evacuating babies in an emergency because it can be used anywhere and anytime without having to be in a location that gets electricity supply. The contribution of this study is as follows:

a. Determine the most effective and efficient temperature control system for infant incubator transportation.
b. Extend battery life to ensure optimal continuity of operation in the use of baby incubator transportation tools
c. Improve the efficiency and accuracy of the infant incubator transportation device in maintaining the ideal temperature to provide more stable and safe environmental conditions for premature babies.

II. MATERIALS AND METHOD

In ongoing research, the authors suggest the required portion through materials and methods as follows:

A. DATA COLLECTION

The author will use a digital multimeter to test the module to evaluate the capabilities that have been designed. After module testing is complete, the next step is to deposition and analyze the results to assess the performance of the module created. This study also aims to analyze the quality of battery efficiency by applying the PID method during a test period lasting 1 hour.

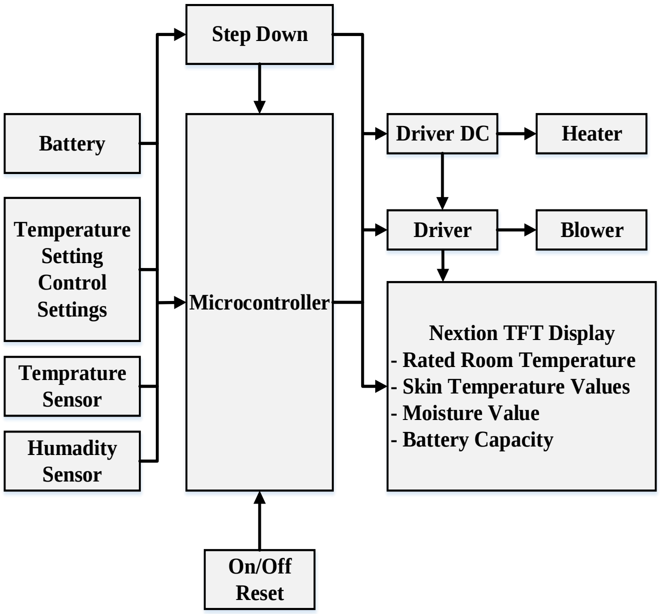

FIGURE 1. The system will be controlled using the Arduino Mega256 module

FIGURE 1 shows the entire diagram of the battery system block used to supply voltage to the microcontroller which will activate the skin sensor, temperature sensor, humidity sensor, and display. The voltage from the battery will also be lowered (step down) to supply drivers to heaters and blowers. The display here uses Nextion TFT which will display temperature settings and control setting options. The microcontroller will process the temperature read by the temperature sensor and control the temperature according to the selected control by turning on the heater and blower. Then the presentation of the heating work will be displayed on the NExtion TFT screen along with the values of room temperature, skin sensor, humidity, and battery capacity.

The flow chart shown in FIGURE 2 shows how it works. When the device is on, the process of initializing the temperature sensor and microcontroller data transmission (Arduino mega) with TFT Nextion occurs. TFT will then display temperature setting options to control the work of the heater. The temperature of the baby incubator will also be displayed on the Nextion TFT along with the graph. The heater will turn off when the temperature inside the baby incubator is close to or according to the specified temperature and will start turning on again when the temperature in the room drops below the temperature specified by the PID control.

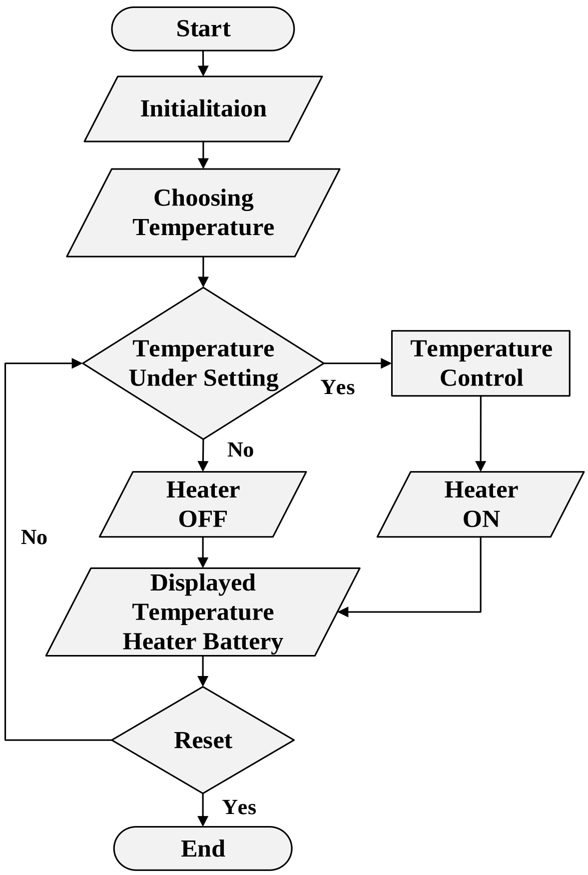

FIGURE 2. System flow chart to test battery efficiency. The data will be processed by Arduino Mega256 and displayed on a personal computer.

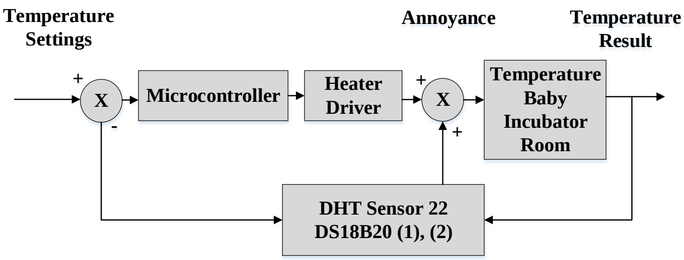

FIGURE 3. *PID Control System*

The design of the PID Control System can be seen in FIGURE 3. In the description of the figure, the temperature setting is used as input on the microcontroller with the PID system to control the heater, then after the temperature is stable the test is carried out by providing interference to test the PID system[27][28][29][30].

B. *DATA ANALYSIS*

In this research, data analysis was carried out using the average calculation method to evaluate the average battery voltage resulting from five measurement trials on a baby incubator for one hour at various temperatures, namely 34ºC, 35ºC, and 36ºC. Measurements were made by comparing the results from the module with existing standard tools, in this case, using a digital multimeter. Each measurement aims to record variations in battery voltage under different temperature conditions. Furthermore, the average of the measurement results is calculated for each of these temperatures.

The error value, which is the difference between the measured value and the true or expected value, is used to measure the accuracy of a measurement tool. In this context, the error is calculated from the average difference in measurement results between the module and the standard tool, which indicates how far the measurement results of the baby incubator module differ from the standard which is considered the correct value. The function of the error is to give an idea of the accuracy of a measurement tool in producing values that match the standard. The smaller the error value, the closer the measurement results are to the expected value or standard. Thus, error can be used as a marker of the quality or accuracy of a measurement tool.

III. RESULT

Testing and data collection were carried out five times using a digital Multimeter and the results were displayed on the PC screen. The results of battery life and error measurements tested at various temperature settings are contained in TABLE 1 below.

TABLE 1

Data error from the comparison between module and standard.

Temperature Setting (ºC)	Module (volt)	Standard (volt)	Error (%)
34	11.25	11.62	0.031
35	10.79	11.23	0.039
36	9.51	9.98	0.047

TABLE 1 displays the average value of the remaining battery power measurement on the tested transport incubator. The average value is obtained from 5 times taking data at each temperature setting, at 34º, 35º, and 36º. Then the error value is obtained by measuring the remaining battery power in the transport incubator. The error value is obtained from the average comparison minus the average module divided by the average comparison and multiplied by 100%. The error value is set at a temperature of 34º, 35º, and 36º and data collection begins when the temperature has stabilized.

TABLE 2

Result of estimated energy used by batteries.

Temperature Setting (ºC)	Power Consumption for 1 Hour (%)
34	30,41
35	36,04
36	32,92

TABLE 2 measurements of the power consumption of operating the baby incubator for one hour at each temperature setting show an interesting pattern. At a temperature setting of 34ºC, the measurements showed that the power usage for heating was 54.625 Wh, with stabilized power usage reaching 47.58 Wh, totaling 102.205 Wh. The final result of the calculation revealed that the power consumption reached 30.41%, while the heating period lasted for 48 minutes before reaching a stable temperature.

Meanwhile, at a temperature setting of 35ºC, the power usage for heating reached 110 Wh, with a stable power usage of 11.11 Wh, totaling 121.11 Wh. The final power consumption was 36.04%, with the same heating period of 48 minutes. At a temperature setting of 36ºC, the power consumption for heating was 33 Wh, with a stable power consumption of 77.62 Wh, totaling 110.62 Wh. The final result shows a power consumption of 32.92%, with a heating period of 15 minutes before reaching a stable temperature at the same time.

IV. DISCUSSION

During the 1-hour test, there was a decrease or increase in the battery graph showing the working heating load. SSR is used as a bridge between PWM and heater power input. ON/OFF control is required to minimize overshoot. Overshoot can mean that the heater's performance stops when it reaches the set temperature, at that time the heater stops and cannot cool down suddenly so the temperature will rise. This is called overshoot, and the temperature will stabilize afterward. This overshoot generates excessive heat. To minimize this, it is necessary to control On/Off controlled by PID, so that the heater stops working before reaching the temperature setting, and the overshoot will be at the temperature setting and will remain stable at that temperature. The PID method will affect how the heater works, which will be controlled On/Off. This will also affect battery power because it is inversely proportional to the heater load. After experimenting, a study was conducted for 1 hour to see how much battery power was left at each temperature setting.

The main limitations of this study, the battery power used is only 70%, while the battery life will be affected by its performance if the battery power used is above 70%. In this module, room temperature greatly affects the temperature in the room. Battery life will be affected by its performance if the battery voltage is at 9 volts. The reading of the voltage value measured in the module has a difference with the measurement results on the device display, where at a temperature of 34ºC of 0.031%, at a temperature of 35ºC of 0.039% and at a temperature of 36ºC is 0.047%. The biggest error is found in the measurement of temperature voltage 34 ºC.

The device can be used to help evacuate babies during emergencies because it uses batteries as the main source of power. This baby incubator transport can be used for mobility purposes. PID rise time is good and fast, but the power required for heater load is greater. To achieve a good and fast rise time, the power needed for the heater load is greater. That way, PID reaches the temperature set point or rise time faster. This research can be a solution for the baby incubator mobility system.

In previous research designed a baby incubator with an endurance of up to 160 minutes starting from the tool being turned on. Using batteries there is also a usage mode that can be switched automatically, if you want to use the battery then immediately switch to using electricity or vice versa[24]. Then the previous research also designed a baby incubator based on Proportional Integral and Derivative (PID) control using a thermistor sensor for baby skin temperature and an LM35 sensor for the temperature of the baby incubator room[25]. In this study designing a baby incubator transport to analyze the quality of battery efficiency using the PID method which has a durability of up to 2 hours. The sensors used are DS18B20-1 and DS16B20 sensors for the detection of high and low-temperature values in the chamber and will be used as skin sensors and DHT22 to detect humidity.

V. CONCLUSION

This study aims to evaluate the battery efficiency of Baby Incubator Transport using a PID temperature controller. The evaluation is done by comparing and analyzing the battery voltage on the device compared to the standard device, as well as considering the setting temperature and duration of use of the device to provide convenience in the process of evacuating the baby in an emergency. The baby incubator module circuit uses a DS1B20 sensor to regulate the heating condition with PID control. For control and display, a Nextion TFT is used that presents information such as battery capacity, temperature parameters, humidity, baby's skin temperature, as well as graphs of temperature, battery, voltage, and current. In testing the module, there is a difference in measurement results between the display and the measuring instrument. At 34ºC, the difference was 3.1%, at 35ºC it was 3.9%, and at 36ºC it was 4.7%. The largest error occurs at a temperature of 36ºC, while the smallest at a temperature of 34ºC. The results of the battery power consumption analysis show that the smaller the battery energy, the smaller the current and voltage released. However, if the load is large, the current and voltage are inversely proportional, where the battery voltage decreases and the current increases. The development of this research can be done by using a box with better air circulation and combining PID and Fuzzy methods to improve the quality of temperature control in baby incubators.

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