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Comparative Analysis of PID Temperature Control System on Infant Warmer

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ABSTRACT Infant Warmer is a life aid used to relieve heat in normal and premature babies who are unable to maintain their own body temperature in a new environment. Related to this matter, current research was carried out aiming to design a baby warmer using the DS18B20 sensor to analyze the efficiency and effectiveness between PID and fuzzy temperature control. This study used a temperature setting of 34°C, 35°C, and 36°C. The device used for reference from standard measurements was standard baby warmers. When the PID controller used in the microcontroller detected the set temperature difference value with the actual temperature, the difference in value was further inputted to the PID control. The results of this study obtained an error value of 0.05%. The error value became the PWM input on the PID controller which then processed the error value and determined the output value for the heater. Furthermore, the temperature sensor read the actual temperature value and compared it again with the temperature setting, where the PID controller continued to process the error value and determined PWM output value until the actual temperature is equal to the set temperature or the error value is zero.

INDEX TERMS Infant warmer, DS18B20, PID, Fuzzy, TFT Nextion

I. INTRODUCTION

Millions of babies born in the world with premature condition or born in less than 32-34 weeks a year and about one million of these babies died from complications of premature birth.[1] Normal babies are generally born at 37 weeks or 9 months of age and weigh 3 kg. However, there are also many mothers who give birth at less than 37 weeks of gestation; in this case, these babies are referred to as premature babies.[2][3] Premature babies or babies born less than 32-34 weeks can be physically distinguished from normal babies, in which premature babies have different physical appearances, namely thinner skin and easily visible blood vessels.[4][5] The body temperature of a premature baby will drop dramatically after being born from his mother and may develop hypothermia. The baby's low temperature results in metabolic processes and results of respiratory rate, heart work, low blood pressure, and loss of consciousness so that if left untreated it can lead to death.[5][6] Premature babies have a slightly lower chance of survival than normal babies. In this case, premature babies can experience two complications, namely, short-term complications and long-term complications. Short-term complications in premature babies are in the form of respiratory distress syndrome which further often ends in death. Meanwhile, long-term complications in premature babies are blindness, deafness, paralysis, and mental retardation.[7][8] Thus, a tool in the form of a baby incubator is needed to reduce the very high mortality rate.[9][10]

Infant Warmers are baby aids that are used to provide comfort and warmth to normal or premature babies who are unable to maintain their own body temperature in a new environment.[11][12] In the care of normal and premature babies, it is necessary to provide an artificial heat effect on the baby in order to minimize the baby's body temperature so that it is the same as in the womb and can help the baby's growth process and organs that have not developed fully. Babies need a temperature that is in accordance with the temperature inside the mother's womb, which is between 34ºC - 37ºC. This is intended to adjust the baby's body temperature with its environment. [13][14] An infant warmer is a baby heating device that is set at a certain temperature by using a main component only, namely a heater and a temperature sensor to read the actual temperature. Maintaining the stability of the temperature of the Infant warmer due to the influence of environmental temperature is very important so that the user does not have to be bothered in carrying out an action on a newborn.[15][16]

Hugo A, Viktor M, and Alexander S have conducted related study on the Implementation of PID controller using Arduino by using NTC (Negative Temperature Coefficient) sensors. This study used an NTC temperature sensor and Arduino as the PID controller by receiving a pulse width modulated square wave (PWM) input signal with a duty cycle that can be set and calculated according to the difference between the set temperature and the actual temperature. The weakness in this study is that the sensor was categorized as poor in detecting changes in temperature occurred.[17] In the following year, Akif R, Inten F, Alfian P, Osmalina, Nur Rahma, and Suhariningsih conducted a similar study. The research focused on the Design and Implementation of PID Controller for Laboratory Scale Infant Incubator Temperature Using the FOPDT Model by receiving a signal input from the LM35 temperature sensor and using the First Order Plus Dead Time (FOPDT) System as the controller method. The drawback of this study is that the temperature sensor used had a reading with poor accuracy.[18] Furthermore, Zain-Aldeen S and Farahan S also carried out a study in 2017 at Southern Technical University Iraq, where they applied PID by receiving a signal from the LM35 temperature sensor and using Arduino Mega as the microcontroller and displaying it on a 20x4 LCD. The weakness of this research is that the temperature sensor was not good because it still produced an error value and still used a 4x20 LCD.[19] Furthermore, Aiguo Jin, Haixiao Wu, Haosheng Zhu, Hua Hua and Yanhai Hu also implemented a study in 2021 at Ningbo University China in designing a temperature control system for baby radian warmers using a PID filter-fuzzy Kalman. This research used an NTC temperature sensor and a fuzzy PID control. In this case, this tool worked by receiving an input signal from a pulse width modulated square wave (PWM) which was calculated according to the difference between the set temperature and the actual temperature. The drawback in this study is that the temperature sensor was not good at detecting changes in temperature occurred [20]

These studies only modified the infant warmer [21], such as updating the components, sensors, displays, and others. This modification was done in order to create a more advanced and more sophisticated infant warmer so that it can be controlled in a flexible way. However, it still does not change the main parameters of an infant warmer, namely temperature parameters.[22][23]

However, no previous research projects have been done through a comparative study of a temperature controller used by an infant warmer. Therefore, no information obtained regarding which temperature controller is accurate for making an infant warmer. Therefore, we need an accurate temperature controller to be applied on infant warmers. The purpose of this study was to find out which temperature controller is accurate for the infant warmer between PID or FUZZY temperature control.

II. MATERIALS AND METHODS

This study was conducted to compare 2 controllers, those are PID and Fuzzy.

A. DATA COLLECTION

PID Control System (Proportional - Integral - Derivative controller) is a controller used to determine the precision of an instrumentation system with the characteristics of the presence of feedback on the system. [24] The PID control system consists of three control methods, namely P (Proportional), I (Integral), and D (Derivative) controls, each of which has advantages and disadvantages. In its implementation, each method can work alone or a combination of them. In designing the PID control system, what needs to be done is to set the parameters of P, I or D so that the system output signal response to a certain input is as desired. Therefore, an effective method was proposed for robust proportional–integral–derivative (PID) controller that were easily implementable on commonly used equipment such as programmable logic controller (PLC) and programmable automation controller (PAC). The method was based on a two-loop model following controller (MFC) system containing a nominal model of the controlled plant and two PID controllers.[25]

1. PROPORTIONAL CONTROL

The characteristics of Proportional control action are to reduce the rise time, increase overshoot, and reduce steady-state error. The characteristics of proportional controllers must be considered when the controller is applied to a system:

- If the value of Kp is small, the proportional controller is only able to correct a small error, so it will produce a slow system response.
- If the value of Kp is increased, the system response shows the faster it reaches the set point and the state is stable.
- However, if the value of Kp is enlarged so that it reaches an excessive value, it will cause the system to work unstable, or the system response will oscillate [26].

2. INTEGRATIVE CONTROL

Integral controller can improve and eliminate overshoot, but improper selection of integral constant can cause high transient response that can cause system instability. Due to the characteristics that cause the response to be slow, in general the integral constant is paired proportionally to the PI controller. The equation shows the integral control output signal.[27]

3. DERIVATIVE CONTROL

The effect of derivative control on the system is:

- Providing a damping effect on the oscillating system so that it can increase the value assignment.
- Fixing the transient response, as it takes action when an error changes.
- Derivatives only change when there is an error change, so when there is a static error the Derivative does not act. So Derivatives should not be used alone. Equation (3) shows the control derivative output signal.

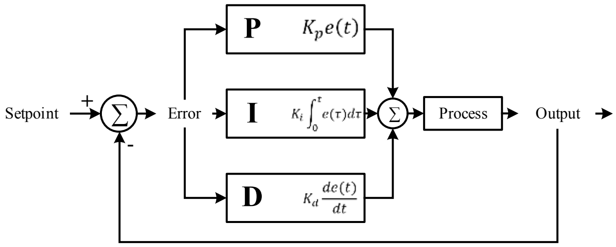

FIGURE 1. PID Control

In this study, researchers compared PID and Fuzzy controllers using the DS18B20 temperature sensor. The DS18B20 is a single bus digital temperature sensor from the American Dallas Company. DS18B20 consists of 64 digits ROM engraved by laser, component temperature sensitivity, and non-volatile temperature alarm trigger (TH and TL Device). The DS18B20 can perform 9 bit to 12 bit temperature reading communicating with microprocessor by single bus port with test ranging from -55 Celsius to +125 Celsius, and the additional value is 0.5 centigrade. The DS18B20 temperature sensor can also be used for setting the upper and lower thresholds with a power supply input between 3.0 v to 5.0 v. The DS18B20 Temperature sensor can get power directly from the data line and does not require an external power supply[28].

FIGURE 2. Module Infant Warmer.

This research used an Arduino microcontroller based on a microcontroller-based main board module that used IC ATMega 328. This type of Arduino has 14 input/output pins of which 6 pins could be used as PWM outputs, 6 analog inputs, 16 MHz crystal oscillator, USB connection, power jack, head ICSP, and reset button. Meanwhile, the 6 analog pins could be used as an output if additional digital output is needed, in addition to the 14 pins available [29]. Furthermore, on Arduino, the analog pins could be turned into digital by changing the pin configuration in the program [30][31][32].

Nextion is a Human Machine Interface (HMI) solution that combines an onboard processor and touch screen memory with Nextion Editor software for the development of GUI HMI projects[33]. The Tft Nextion device will serve as an interface between the user and the device, enabling visualization of the results on the screen as well as changes to settings via the touch screen, thereby facilitating solution development and communication with the device being used [34][35]. In this case, when the tool was first turned on, namely the selection of the Temperature setting at 34, 35, and 36, next step conducted was selecting the controller to be used, namely PID or Fuzzy. After all have been selected, the TFT Nextion screen will display Temperature, Skin Temperature, Temperature settings, current controller settings used as well as Display temperature graph. With the graph, the user could see the increase and decrease in the temperature of the Infant Warmer

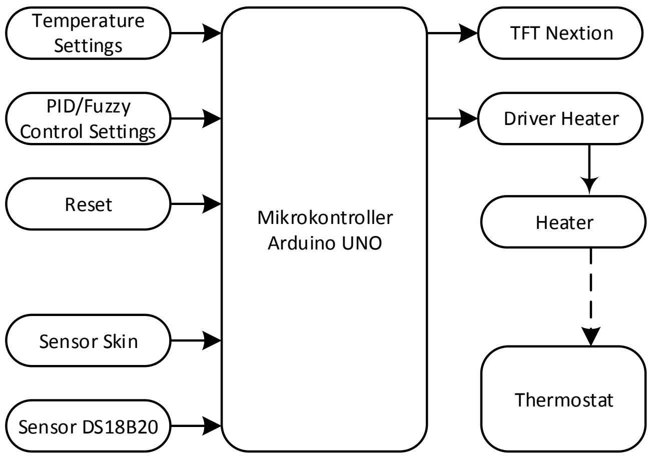

FIGURE 3. System block diagram using Arduino Uno microcontroller, ds18b20 temperature sensor and TFT Nextion as the display.

B. ANALYSIS DATA

The temperature measurement was repeated 6 times. The mean value of the measurement was obtained using the following equation:

$$\text{Rata} - \text{rata } (X') = \frac{X1+X2+\ldots+Xn}{n} \quad (1)$$

Where X1,X2… is the value of the measured data and n is the number of data. Error (Mean Deviation) is the difference between the mean of each data. Error is:

$$\%ERROR = \frac{X-X'}{X} \text{ x } 100\% \quad (2)$$

Where x is the desired data value and x' is the average value of the measured data

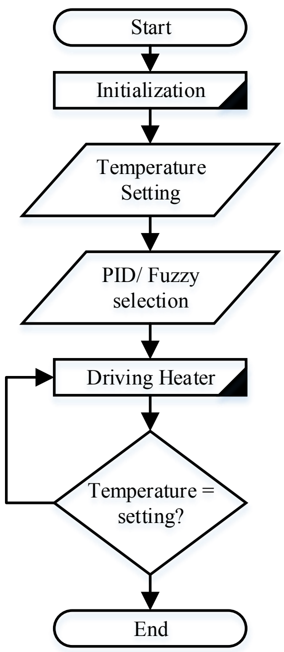

FIGURE 4. Flowchart of the Ds18b20 sensor detecting the temperature on the Infant warmer then the microcontroller receives temperature input and processes it using the selected control. Then, the microcontroller output in the form of PWM which will regulate the Heater output.

III. RESULT

As a result of research in the manufacture of an infant warmer device, a comparison of the results of the module measurements was made with a comparison tool. In this case, the comparison tool used was the HTC-2 Thermometer with the following specifications, device name, thermometer, HTC-2 Brand, size of : 9 cm X 11 cm X 2 cm, Power of 2600-2800 mAh, and weight of 500gr.

TABLE 1
Measurement Results of PID controller and Fuzzy controller

Control	Tools Used	Setting temperature	Data Retrieval				
			1	2	3	4	5
PID	Device	34°	33.38	33.75	33.94	34.00	33.75
	Thermo		33.7	33.7	33.8	33.8	33.6
	Device	35°	34.81	34.75	34.75	34.94	35.00
	Thermo		34.7	34.6	34.7	34.8	34.8
	Device	36°	35.81	35.81	35.94	36.00	35.75
	Thermo		35.7	35.8	35.8	35.9	35.6
Fuzzy	Device	34	33.88	33.94	33.94	33.88	33.88
	Thermo		33.7	33.8	33.9	33.8	33.7
	Device	35	34.94	34.81	34.81	34.88	34.88
	Thermo		34.8	34.7	34.7	34.8	34.7
	Device	36	35.81	35.81	35.8	35.94	35.88
	Thermo		35.7	35.6	35.8	35.7	35.7

Based on the results of 6 data collections, the temperature reading of the tool with PID controller was able to reach the setting temperature but the control results still experienced Oscillation. Meanwhile, the Fuzzy controller worked well and was more stable in controlling the Heater.

The results of PID and Fuzzy controlled at temperature settings of 34˚, 35˚ and 36˚ showed as follow. Based on the comparison carried out illustrated on the two graphs, the time fuzzy controller took to reach a steady state was 2.5 seconds, while the time the PID controller took to reach a steady state was 2.8 seconds. Hence, it can be concluded that Fuzzy controller achieved a steady state faster than PID. In addition Fuzzy controller did not have Overshoot either, while PID had an Overshoot at 0.6 second. Based on the results of the comparison of the two graphs, both the fuzzy controller and PID controller almost had the same steady state with the time used for the fuzzy controller of 3.4 seconds and for the PID controller of 3.2 seconds. However, fuzzy controller did not experience overshoot while PID experienced an overshoot at 0.06 seconds (FIGURE 5).

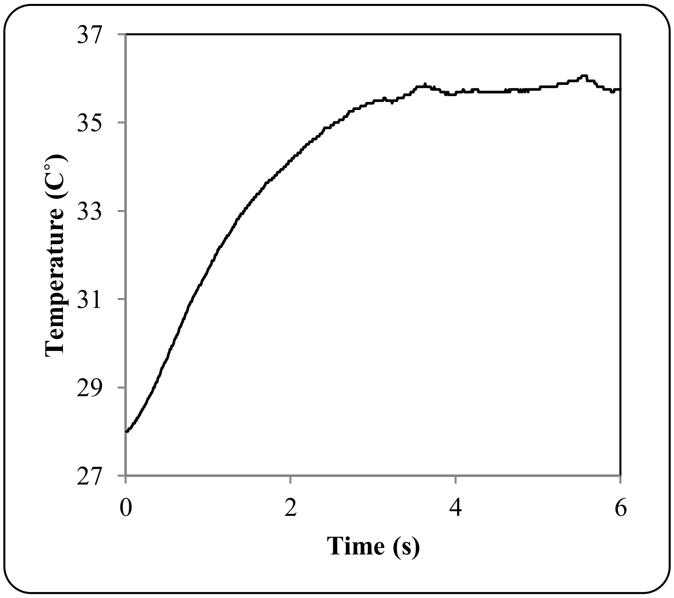

FIGURE 5. PID controller chart at 36˚C . temperature setting

TABLE 2
Measurement Results of Response Time to Reach Steady State on PID controller and Fuzzy Controller

Controller	Temperature Setting	Mean(s)
PID	34°	2.8016
	35°	3.4016
	36°	4.4200
Fuzzy	34°	2.5066
	35°	3.2416
	36°	4.2366

Based on the comparison of the two graphs, the time the fuzzy controller took to reach to a steady state takes 4.2 seconds, while the time PID controller took to reach a steady state is 4.4 seconds. It can be concluded that fuzzy controller reached a steady state faster than PID controller. In addition, fuzzy controller did not experience overshoot, while PID had an overshoot at 0.6 seconds. Furthermore, the oscillation generated by PID controller was higher than by Fuzzy controller. Based on the results of 6 data collections as presented on the table above, Fuzzy controller was faster in reaching the temperature setting than the PID controller

TABLE 3
Measurement Results of Overshoot on PID controller and Fuzzy controller

Controller	Temperature Setting	Mean
PID	34°	0.01
	35°	0.02
	36°	0.02
Fuzzy	34°	0
	35°	0
	36°	0

Overshoot

Based on the results of 6 data collections, the PID controller had an Overshoot of 0.06˚, while the Fuzzy controller did not have an Overshoot.

IV. DISCUSSION

Based on the performance of the system in this circuit when testing the DS18B20 sensor, there was a temperature deviation when calibration was carried out. During the checking, it turned out that there was a problem between the sensor and heater distances that were not close enough, so adjustments were made between the sensor and heater distances. In addition, there were several communication errors on the TFT Nextion display between Arduino and TFT Nextion, particularly in the Arduino program. Furthermore, overlap between PID and Fuzzy programs also occurred. The solution was to change the program by creating a different Void for each Controller program. In this case, several weaknesses were discovered this study, namely the oscillation values obtained were still high and the time used to reach the setting temperature was relatively long because this module only used 1 heater. The performance of the system in the program when the author conducted a function test on the system program, the error occurred when the tool was moved from the lower lab to the upper lab. Furthermore, during the PID controller testing, it did not work after checking the circuit. It turned out that there were some loose wires when the tool was moved.

V. CONCLUSION

This study aims to design a baby warmer using the DS18B20 sensor to analyze the efficiency and effectiveness between PID and fuzzy temperature controller. In this case, this study uses a temperature setting of 34°C, 35°C, and 36°C. Based on the results of the discussion and the purpose of making the module made by the author, it could be concluded that an Infant Warmer device could be made using DS18B20 as a sensor as well as PID and Fuzzy as the controller. The DS18B20 sensor is the skin temperature with a difference of 0.10C reading against a thermometer that uses a TFT Nextion display.

The tool can be used as long as possible and at any time by using PID or Fuzzy controller through the Arduino program using the temperature setting of 34˚C, 35˚C, and 36˚C. In addition, PID or Fuzzy controller could also be used, in addition to the Nextion TFT screen display. The implication of this research is as a basis for research to proceed to further research. Where, in future research, researchers want to use an incu analyzer so that the results are more accurate and optimize the PID controller so that the oscillation value is not too high.

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