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PID Temperature Control on Blood Warmer Equipped with Patient Temperature and Blood Temperature

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ABSTRACT Blood, being a sensitive biological fluid, can undergo cellular and biochemical changes when subjected to temperatures that are too high or too low. Consequently, administering blood that is not at an appropriate temperature can result in hemolysis (the destruction of red blood cells), clotting issues, and even patient harm. Therefore, ensuring that the temperature of transfused blood remains within a specific range is crucial for the success and safety of the procedure, The objective of the described project is to enhance the success and safety of blood transfusion procedures by implementing a temperature control system using various sensors and control techniques. The methodology employed in this project, DS18B20 Sensor This sensor is used to measure the temperature of the blood being transfused. It provides accurate temperature readings, which are crucial for maintaining optimal conditions. MLX90614 Sensor, This sensor is utilized to adjust the temperature of the transfused blood according to the recipient's body temperature. It ensures that the introduced blood is compatible with the patient's internal environment. PID Control: The Proportional-Integral-Derivative control technique is implemented to regulate the heater that maintains the temperature of the blood. The PID parameters (Kp, Ki, Kd) are tuned to achieve precise control and response. Fuzzy Control: Fuzzy logic control is also employed for temperature regulation. While PID control is known for its rapid response and stability, Fuzzy control is utilized to handle potential non-linearities and complex relationships in the system. PID and Fuzzy control techniques are evaluated and compared in terms of their effectiveness in regulating blood temperature during transfusion.This study uses the DS18B20 Sensor to control the heater with PID and Fuzzy controls, the MLX90614 Sensor to adjust the temperature according to the patient's body temperature and the Optocoupler Sensor as an indicator when fluids run out. When using the PID control with Kp = 4, Ki = 1, and Kd = 4, the highest error value is 0.07 with an average error of 0.02, the resulting response time is faster and there is also a low overshoot with the result obtained an overshoot of 0.09, the results of the study are displayed on the TFT Nextion. The conclusion of the project highlights the successful implementation of temperature control strategies during blood transfusion procedures using advanced sensors and control techniques. The project's findings shed light on the effectiveness of different approaches and provide valuable insights for enhancing patient safety and improving transfusion outcomes.

INDEX TERMS Body Temperature, Blood Transfusion, DS18B20 Sensor, MLX90614 Sensor, Optocoupler Sensor, PID.

I. Introduction

Taking a patient's temperature is a tried-and-true technique of diagnosis that has stood the test of time in both the clinic and the daily lives of patients and their carers. The method and location used to take a temperature reading from the human body vary. Body temperature in humans varies greatly depending on the location where the reading is taken[1]. The hypothalamus regulates human core body temperature, which typically stays between 36.5 and 37.5 degrees Celsius. Most thresholds have a narrow temperature difference of only 0.2°C to 0.4°C. Central thermoregulation is suppressed by general and regional anaesthetics, increasing the interthreshold range to 2°C to 4°C and resulting in hypothermia. The clinical threshold for hypothermia is a core temperature of 36 degrees Celsius or less. Because of the high mortality rate they generate, In trauma patients, the "lethal triad" consists of hypothermia, acidosis, and coagulopathy. Risk of wound infection, abnormal clotting, and myocardial ischemia after surgery, and atrioventricular arrhythmias are all linked to intraoperative hypothermia. Large amounts of cold fluids or blood infusions are one of the causes of hypothermia. Your average body temperature may be lowered by roughly 0.25 degrees Celsius for every litre of room-temperature fluids you drink. Mild hypothermia may be induced by intravenous 30 minute infusion of 2 L of normal saline at 4°C without the use of extracorporeal circulation[2]. Premature newborns that experience hypothermia are more likely to develop coagulopathy, nosocomial infections, and die. Hypothermia increases the risk of coagulopathy, arrhythmias, blood transfusions, and death in adult trauma patients. Death rates are directly proportional to core body temperature, increasing exponentially below 32 degrees Celsius[3]. The most often used control strategy in real-world industrial settings is PID (proportional-integral-derivative)[4]. Since PID controllers have a straightforward design and can be derived without extensive mathematical computations, they find widespread application in industry. The analogue signal to the actuator is a total of three terms: maintains both transient and steady-state responsiveness via proportional, derivative, and integrated measurements of error. Modulating the behaviour of fast and slow, linear and nonlinear systems has been shown to be possible using this method. Using a well-tuned PID controller, it is possible to maintain a constant water temperature at the desired setpoint. [5]. In previous research, a Blood Warmer device was made with the title Automatic Blood and Infusion Warmer with PID system which has the advantage of being able to heat the heater on the device according to the patient's body temperature in the range (36°C - 38°C), without manual settings from the operator, and there is a PID control system on the heater to optimize the temperature of the liquid that will enter through the veins. The measurement results are displayed via a 4x16 Character LCD interface, with a DS18B20 sensor, with an Arduino program manager. It also has weaknesses, namely replacing the mechanics or temperature control system which can minimize the effect of ambient temperature on the output temperature results, adding a temperature monitoring data storage system so that it can know more detailed temperature increases and decreases, making smaller box designs and more orderly cable management. in order to ensure comfort in use.

The next researcher made a Blood Warmer device entitled A Development Of Portable Fluid Warmer For Surigical Hypothermia Patients which has the advantage of designing and developing an Intravenous fluid warmer for surgical patients to prevent hypothermia and the risk of infection due to cold. It makes the heart work harder. This can lead to myocardial hypoxia and heart failure. According to hypothermia, it was found that warm liquids can help prevent hypothermia, but liquid warmers have bulky dimensions and are expensive. Therefore, the development of a portable fluid warmer for surgical patients is proposed. Where this study also has drawbacks, namely the proposed prototype requires a longer heating time than a commercial device for 3 minutes, but the prototype cost is much lower than a commercial device, and the dimensions are also reduced [6]. The next researcher made a Blood Warmer with the title In order to save both time and money, it is desirable to maximise the efficiency with which the Blood Transfusion Warmer's heating component converts electrical energy into thermal energy. This can be accomplished by employing a closed-system approach. In this investigation, the blood bag was heated in an acrylic chamber 3 mm in thickness, creating a confined environment ideal for optimisation. In this investigation, a Peltier heating element was utilised. The DS18B20 temperature sensor is used to provide an input signal to the microcontroller, which then uses the driver to regulate the heating element. Its precision and speed of temperature heating response are both low, making it unsuitable for use in preparation for or performance of a blood transfusion. Because of the potential for harm caused by incorrect instruments or a sluggish reaction to heating, this is crucial for the effective treatment of blood transfusion situations. One of the variables that may lead to human mortality during the blood transfusion procedure is a blood temperature that is either too high or too low, which can cause the blood to become frozen or damaged. Some users also find that the electrical power needs of the best Blood Transfusion Warmers on the market are too high [7]. Using additional PID control (Proportional Integral Derivative), the next researcher developed a Blood Warmer tool titled Arduino AT Mega 2560-Based Robust PID Temperature and Humidity Control for Baby Incubator, which has the advantage of a faster system response for achieving the point setting value and can minimise the maximum overshoot of 5% and the average signal error of 5%. Due to the limitations of this investigation, PID control was used, a comparison value is obtained between the Maximum Overshoot without a load and the Maximum Overshoot with a load or an additional 2kg load, an unstable value is obtained. For the Maximum Overshoot with a load or an additional 2kg load, a large value is obtained due to the additional load [8]. The following scientist developed a PID-controlled blood

warmer dubbed An Automatic Grain Dryer Prototype. It takes this dryer 25 minutes to get the temperature up from 28°C to the intended temperature (SV), which is 38°C, using the PID technique as a temperature controller, which has the benefit that the PID method is also employed in this dryer. To regulate the DC motor that is linked to the valve's open and shut position, the ATmega16's built-in PID technique will send a signal to the motor driver circuit. The PID approach was tested empirically, yielding a steady-state error of 5.2% with constant values Kp=2, Ki=2, and Kd=10 at S0056=38oC. There are limitations to this research, such as the fact that drying the grain to a moisture percentage of 14.12% takes 54 hours and a lot of land. In response to these issues, scientists developed an automated grain dryer. The dryer's type K thermocouple temperature sensor and grain moisture content gauge were included to address issues with standard grain dryers. Using fire generated from LPG gas, heat is transferred to the furnace or grain drying chamber. The DC motor's shaft is coupled to a variable valve's open and closed position, allowing the user to regulate the flow of LPG gas to the nozzle [9].

The subsequent scientist developed a PID-controlled blood warmer device called the infant warmer. The goal of this study is to use PID control to stabilise the temperature and guarantee uniform heat distribution in baby warmers equipped with digital scales that allow for temperature adjustments between 35°C and 37°C. In addition, the patient's skin temperature is recorded for the nurse's reference. temperature is when the observation must be carried out. This study also has weaknesses, namely having to increase the system scale and accuracy of the PID control system to reduce excess [10]. The next researcher made a Blood Warmer using PID control with the title The PID controller's temperature monitoring and control system on the egg incubator has been successfully merged automatically with the PWM technique on the lamp, allowing for more efficiency in the hatching process. incandescent. The purpose of this research is to develop a PID-controlled autonomous aquaculture hatchery system that will allow for more consistent and accurate temperature regulation in plant incubators. Consequences of this study include the need for more accurate and precise sensors like the DHT 11 type, the introduction of an automatic rotating rack system, the installation of a UPS as backup power in the event of an electrical outage, and the introduction of a monitoring system. IoT-based online and adjusting adaptive controllers, fuzzy logic, and neural network (ANN) controls to lower steady-state error levels [11]. The next researcher made a Blood Warmer tool using the DS18B20 temperature sensor with the An automated dispenser design, built on an Arduino Mega with a DS18B20 temperature sensor, may save time and prevent accidents for the visually impaired who need to refill it with hot water. simply installing a DS18B20 sensor in the water and setting its temperature between 50 and 80 degrees Celsius. One limitation of this research is that it uses hot water to test the instrument, and the findings reveal that the water temperature in the glass varies by 1°C to 3°C depending on the setpoint (options for setpoint temperatures are 50°C, 70°C, and 80°C)[12]. The following scientist also used PID control to create a blood warmer, Named PID Controlled Infant Warmer Design Maintains Consistent Temperature. Using PID regulation, the temperature is stabilised and the heat is dispersed evenly throughout the bed, this study's digital scales for preventing hypothermia in newborns also measure skin temperature to help nurses keep tabs on their patients' core temperatures during observation. In order to enhance the effectiveness of a PID control baby warmer system in maintaining an optimal temperature for the infant, this study may be included into such a system. The results of the heater control and display temperature readings can be improved by using a good driver and a temperature sensor that can read linear temperatures, but these limitations also highlight the limitations of this study [13]. The next researcher made a Blood Warmer tool using the MLX90614ESF (Infrared Temperature) Sensor with the title Using the popular MLX90614 infrared temperature sensor, a proximity sensor ultrasonic, and RGB LEDs that offer fast feedback to the user, the project "Research on Infrared Body Temperature Measurement - Virus Spreading Prevention" has the advantages of being cost-effective and easy to use for fever screening. In addition, it also has weaknesses, namely the results obtained are still imprecise or still on the threshold [14]. The next researcher made a Blood Warmer tool using the DS18B20 Sensor with the title Hydroponic Plants' Peltier Tec1 12706 Automatic Water Temperature Control System Including Temp. Sensing Devices With the DS18B20 sensor's ability to accurately monitor water temperature, this study intends to develop a system for controlling water flow in hydroponic plant cultivation. The test findings demonstrate that hot water cools from 38.10 C to 30.31 C in under 4 hours, and then to 7.79 C, which is ideal for maintaining optimum plant development. Although the water temperature is below the optimal 28 C for hydroponic growing. This study has a weakness, namely by using the DS18B20 sensor the temperature sensor cannot produce a stable temperature where the temperature decrease is around 38.10˚C down to 30.31˚C down in 4 hours [15]. The next researcher, using the Optocoupler Sensor with the title Enhancement Precision in Infusion Dosing through Drip Optocoupler- and microcontroller-based infusion-set drop detection is a benefit of this sensor technology. The precise measurement of infusion rates and droplet volumes is contingent on this well-calibrated sensor. Both macro (20 drops/cc) and micro (60 drops/cc) drips benefit from this improved precision. The precision of the volume readings is between 95% and 99% for macro drip and between 94.5 and 97% for micro drip. The corresponding range of precision for velocity is 92.37–98.46%. The optocoupler test revealed that the required voltage to enable the microcontroller to detect liquid drips was 4.31 V. High, or 1 on the microcontroller, may be supplied via this voltage. Concerning the study's limitations, the optocoupler sensor readings may be processed by the Arduino microcontroller, shown on the OLED screen, and accompanied by a buzzer when the speed measurement suddenly changes. from 92.37 to 98.46% accuracy while reading quickly. The sensor's location in the chamber has a significant effect on the

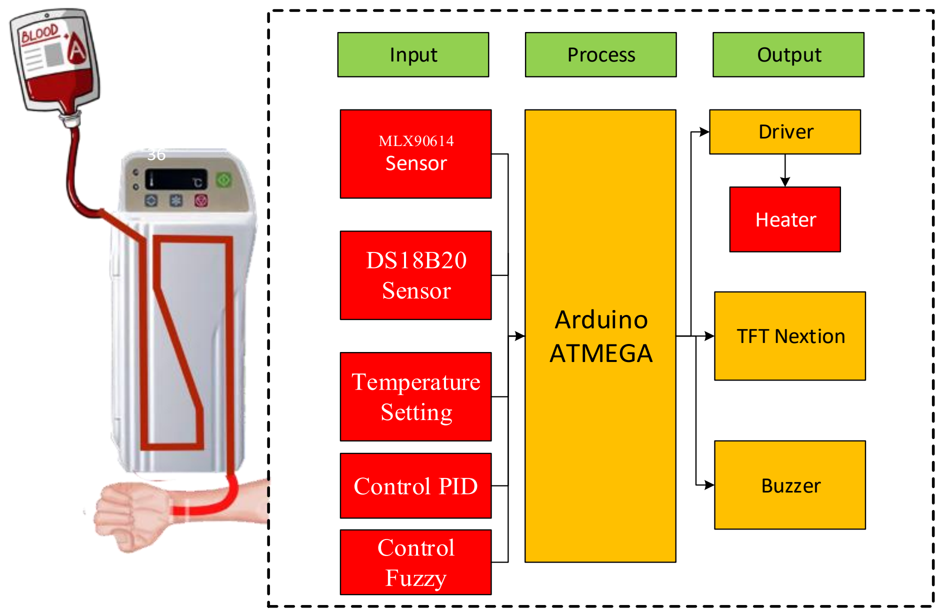


FIGURE 1. Block diagram of the blood warmer system. There are 2 sensors namely the DS18B20 sensor and the MLX90614 sensor which will then be processed by the microcontroller then the results of the sensor output will be displayed on the TFT Nextion. The Block Diagram above also uses 2 controls, namely Fuzzy Control and PID Control

measurement's precision. The infusion chamber might also be larger or smaller depending on the infusion set brand. To prepare for the future, we need to create an optocoupler sensor that can be installed reliably in all brands [16].

The problem your study aims to solve is to enhance the precision and adaptability of blood warming systems in medical settings through the implementation of PID control techniques, with the ultimate goal of improving patient safety and the effectiveness of medical procedures. contributions include improved patient safety, precise temperature regulation, optimized resource usage, and a potential impact on the advancement of medical device technology. These contributions collectively address critical challenges in medical settings and have the potential to revolutionize blood warming procedures for the betterment of patient care and treatment outcomes

II. Materials And Methods

A. Experimental Setup

This study used a Digital Thermometer and used the HTC-2 Thermometer as a comparison using a temperature setting of 36˚C - 37˚C adjusted to normal human body temperature.

1) Materials And Tool

The DS18B20 sensor detects blood temperature in the infusion tube via the heater, the MLX90614 sensor detects body temperature, and the optocoupler sensor indicates when the liquid has run out. A digital thermometer and an HTC-2 thermometer are used for comparison. An Arduino ATMEGA-2560 serves as the microcontroller, uses Liquid Glycerin as a blood substitute, uses a heater with a small wattage, uses the Nextion LCD as a display and uses the PID control as an automatic heater control.

2) Experiment

In this study using a temperature setting of 36˚C - 37˚C where the temperature setting adjusts the normal human body temperature by taking 6x experimental data at different times and the results obtained from the PID Control and Fuzzy Control are different then the results will be displayed on the LCD Nextion.

B. The Diagram Block

In FIGURE 1 The microcontroller input consists of the MLX90614 sensor as body temperature, the DS18B20 sensor as heater temperature. The microprocessor receives the inputted temperature control setting, processes it, and then operates to regulate the heater to maintain a constant 36°C - 37°C. For the blood warmer, first look at the patient's body temperature condition then select a temperature setting according to the patient's temperature condition by pressing the touchscreen on the TFT Nextion. Then select the desired control setting. Then the microcontroller processes the work of the blood warmer tool. The reset button is used to stop the process.

C. The Flowchart

In FIGURE 2 When the tool is started, the user must microcontroller initialization follows the selection of a temperature setting appropriate to the patient's body temperature. The user then chooses the PID control parameters to be utilised by the microcontroller to detect the temperature difference, turns on the heater to warm the blood in the chamber, and watches as the

TFT nextion shows both the patient's and the fluid's temperatures. The flow sensor will begin functioning after the set temperature has been attained. The heater will turn off if the flow sensor detects no flow rate after which the buzzer sounds when the liquid has run out.

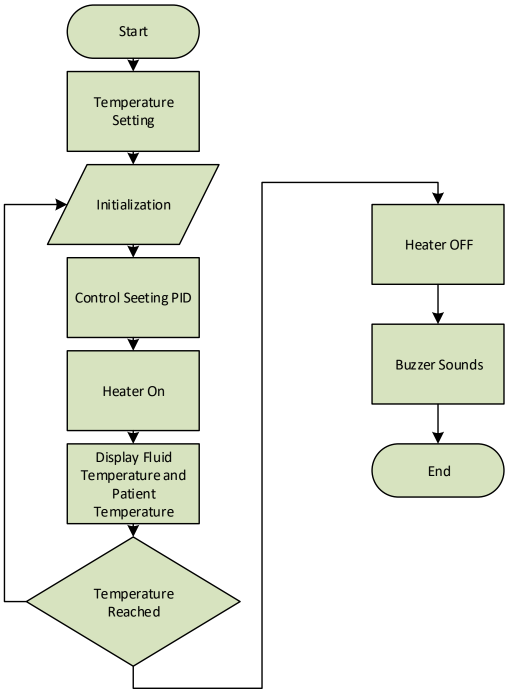


FIGURE 2. **The flowchart above is the flowchart of how the Blood Warmer works, where the temperature reading on the Blood Warmer is then processed by the microcontroller which will be displayed on the Nextion LCD**

D. System circuit

In FIGURE 3 The circuit above consists of the DS18B20 Sensor, MLX90614 Sensor, Optocoupler Sensor, Nextion and SSR Module. First of all, from the DC supply, enter the SSR module sequence (DC+, DC- and CH1), for CH1, enter pin 2 on Arduino. Then there are DS1 and DS2 sensors where this sensor has 3 legs namely VCC, GND and Data. For the Data pin, go to pin 3 on Arduino. Before entering Arduino pin 3, there is a resistor of 4K7.

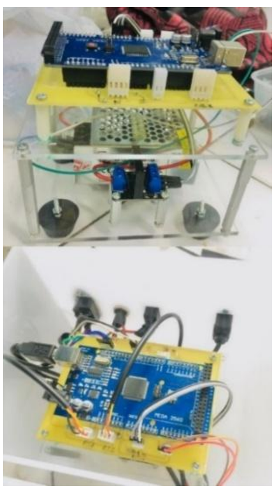


Figure 4. **Control Design in the Box**

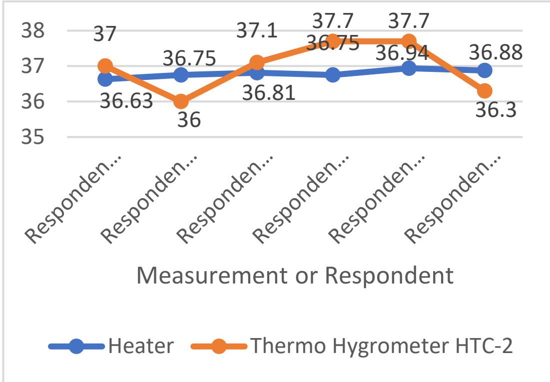


FIGURE 3. **Blood Warmer system circuit**

The DS18B20 Sensor (1) functions as a PID and Fuzzy heater control (according to patient temperature). Furthermore, the MLX90614 sensor has 4 legs namely Vin, GND, SCL, SDA. For the SCL and SDA pins, enter the SCL and SDA pins on Arduino. The MLX90614 sensor functions as a patient temperature monitoring. Then there is the Optocoupler Sensor which has 4 legs namely VCC, GND, A0 and D0. For A0, enter pin A0 on arduino. Optocoupler sensor serves as an indicator when the liquid runs out. Then there is also the Nextion display which has 4 legs namely +5V, TX, RX and GND. For pin TX, it goes to pin RX2 on arduino, whereas for pin RX goes to pin TX2 on arduino, and lastly, there is a buzzer which consists of 2 legs (+ and -) for feet + goes to pin 10 on arduino.

III. Result

In this study, the Blood Warmer tool has tested the sensor and the results of temperature measurements produced using the Digital Thermometer and HTC-2 Thermometer where the results will be displayed to Nextion. Here is the circuit design in the box : FIGURE 4 In this writing it is a circuit design in the box to adjust the temperature readings from the DS18B20 Sensor and MLX90614 Sensor. For programs on microcontrollers using Arduino ATMEGA2560 to run a tool then the temperature reading results will be displayed on the TFT Nextion.

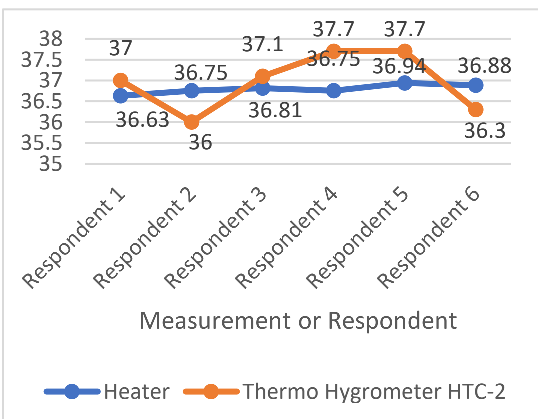


FIGURE 5. **PID control chart with temperature settings that adjust to normal human body temperature. For the PID control the temperature increase is not sequential but to reach the temperature setting it is accelerated compared to the Fuzzy control**

The following results of the temperature comparison of the measurement results with PID

TABLE 1
MLX90614 Sensor Measurement Against Digital Thermometer (PID Control)

Measure ment	MLX Tools Display (^{0}C)	Digital Thermo meter (^{0}C)	Mis take	Error (%)
Respondent 1	36,69	36,5	0,19	0,05
Respondent 2	36,75	36,3	0,45	0,01
Respondent 3	36,77	36,8	0,03	0,08
Respondent 4	36,71	36,8	0,09	0,02
Respondent 5	36,91	36,7	0,21	0,05
Respondent 6	36,85	36,6	0,25	0,06
Mean			0,20	0,03
Standard Deviation			0,06	0,13
Uncertainty(UA)			0,02	0,05

TABLE 1 Table 1 is a measurement table for the MLX90614 Sensor against a Digital Thermometer using PID Control. From the results of the data collection above, the data collection was taken 6x at different times, where the highest error value was obtained, namely Respondent 2 of 0.45 and the highest error value was obtained in Respondent 3 of 0.08.

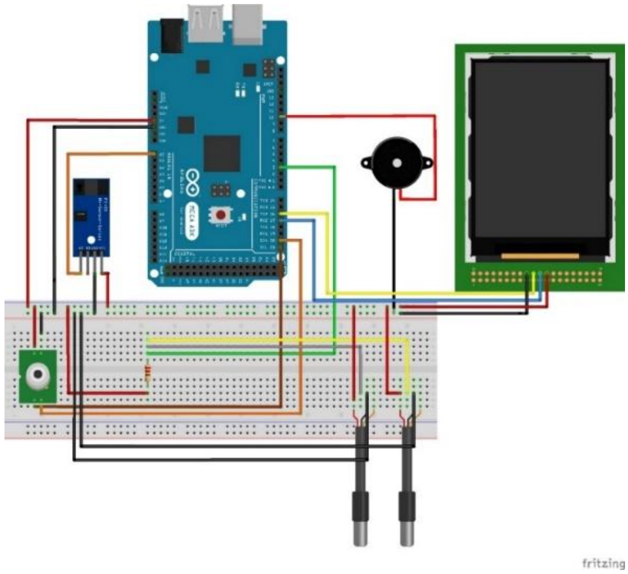
2). Fuzzy Control

The following results of the temperature comparison of the measurement results with Fuzzy

TABLE 2 *Thermometer (Fuzzy Control)*

Measure ment	MLX Tools Display (^{0}C)	Digital Thermom eter (^{0}C)	Mis Take	Error (%)
Respondent 1	36,85	36,5	0,35	0,09
Respondent 2	36,71	36,3	0,41	0,01
Respondent 3	36,59	36,6	0,01	0,02
Respondent 4	36,61	36,9	0,29	0,07
Respondent 5	36,81	36,5	0,31	0,08
Respondent 6	36,71	36,8	0,09	0,02
Mean			0,24	0,04
Standard Deviation			0,06	0,04
Uncertainty (UA)			0,02	0,01

TABLE 2 Table 2 is a measurement table for the MLX90614 Sensor against a Digital Thermometer using PID Control. From the results of the data collection above, the data collection was taken 6x at different times, where the highest error value was obtained, namely Respondent 2 of 0.41 and the highest error value was obtained in Respondent 1 of 0.09.



1). PID Control

The following results of the temperature comparison of the measurement results with PID

TABLE 3
DS18B20 Sensor Measurement Against HTC-2 Thermometer (PID Control)

Measure ment	MLX Tools Display (^{0}C)	Digital Thermo meter (^{0}C)	Mis take	Error (%)
Respondent 1	36,63	37	0,37	0,01
Respondent 2	36,75	36	0,75	0,02
Respondent 3	36,81	37,1	0,29	0,07
Respondent 4	36,75	37,7	0,95	0,02
Respondent 5	36,94	37,7	0,76	0,02
Respondent 6	36,94	36,3	0,64	0,01
Mean			0,61	0,02
Standard Deviation			0,25	0,1
Uncertainty (UA)			0,1	0,04

TABLE 3 Table 3 is a measurement table for the MLX90614 Sensor against a Digital Thermometer using PID. Control. From the results of the data collection above, the data collection was taken 6x at different times, where the highest error value was

obtained, namely Respondent 4 of 0.95 and the highest error value was obtained in Respondent 3 of 0.07.

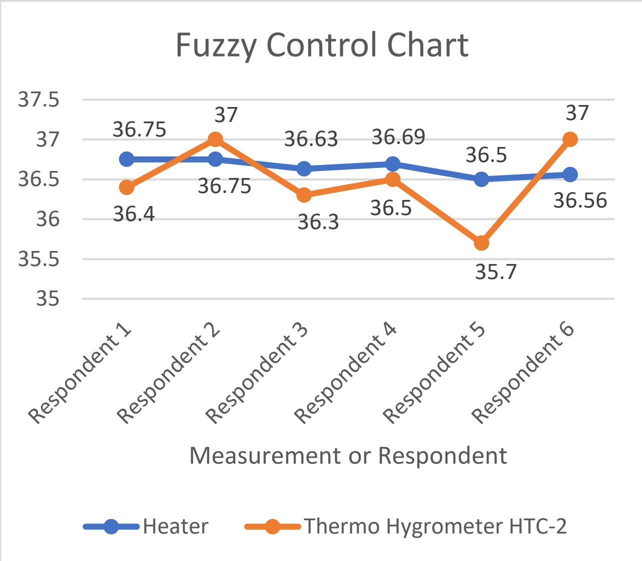


FIGURE 6. Fuzzy control chart with temperature settings which adjust to normal human body temperature. For Fuzzy control the temperature increases sequentially but cannot reach the setting temperature.

The following results of the temperature comparison of the measurement results with Fuzzy

TABLE 4
DS18B20 Sensor Measurement Against HTC-2 Thermometer (Fuzzy Control)

Measure ment	MLX Tools Display (^{0}C)	Thermo Hygro meter HTC-2 (^{0}C)	Mis take	Error (%)
Respondent 1	36,94	36,4	0,54	0,01
Respondent 2	36,75	37	0,25	0,06
Respondent 3	36,63	36,3	0,33	0,09
Respondent 4	36,19	36,8	0,61	0,01
Respondent 5	36	36,3	0,3	0,08
Respondent 6	36,56	37	0,44	0,01
Mean			0,41	0,04
Standard Deviation			0,14	0,03
Uncertainty (UA)			0,05	0,01

TABLE 4 Table 4 is a measurement table for the MLX90614 Sensor against a Digital Thermometer using PID Control. From the results of the data collection above, the data collection was taken 6x at different times, where the highest error value was obtained, namely Respondent 4 of 0.61 and the highest error value was obtained in Respondent 3 of 0.09.

TABLE 5
PID Control and Fuzzy Response Time

Control	Measurement or Respodent	Overshoot
PID	Respondent 1	0,06
	Respondent 2	0
	Respondent 3	0,04
	Respondent 4	0,04
	Respondent 5	0,03
	Respondent 6	0,09
FUZZY	Respondent 1	0,09
	Respondent 2	0,04
	Respondent 3	0,04
	Respondent 4	0,4
	Respondent 5	0,8
	Respondent 6	0,15

TABLE 6
PID Control Overshoot and Fuzzy

Control	MLX Tools Display (^{0}C)	Time to Reach Set Point (s)
PID	36,69	147 second
	36,75	186 second
	36,77	174 second
	36,71	172 second
	36,91	117 second
	36,85	177 second
FUZZY	36,85	179 second
	36,71	171 second
	36,59	185 second
	36,61	211 second
	36,81	194 second
	36,71	214 second

TABLE 5 From the results of the data collection above for the two controls, namely the PID Control and Fuzzy Control, it was taken 6x at different times, where the response time for the PID control was faster than the Fuzzy control. TABLE 6 From the results of the above data collection for the two controls, namely the PID Control and Fuzzy Control, it was taken 6x at different times, where the data collection for the Fuzzy control had a higher overshoot compared to the Fuzzy control.

IV. Discussion

After testing the Blood Warmer device where data was collected using a Digital Thermometer and Thermo Hygrometer HTC-2 with data collection 6 times each using PID control and Fuzzy control. For PID control using KP = 4, KI = 1 and KD = 4 where more optimal results are obtained such as not too large overshoot and to reach the set point faster than the Fuzzy control. The accuracy of sensors such as DS18B20 and MLX90614 can be affected by various factors such as sensor calibration, ambient conditions, and drift over time. Ensuring accurate and consistent temperature measurements is critical for the success of system.

When dealing with medical procedures, especially ones as critical as blood transfusions, system reliability and redundancy become essential. What measures are in place to handle sensor failures, control system malfunctions, or communication errors? Redundancy and fail-safe mechanisms are important to ensure patient safety. While this study evaluates the effectiveness of the control techniques in a controlled environment, translating these findings to real-world clinical settings requires rigorous validation. Collaborating with medical professionals and conducting clinical trials will help establish the practical benefits and safety of your system. Patient conditions can vary widely, including factors like age, weight, underlying health issues, and reactions to blood transfusions. How does your system adapt to these variabilities to ensure optimal temperature control for all patients?

V. Conclusion

To enhance the success and safety of blood transfusion procedures by implementing a temperature control system using various sensors and control techniques. the DS18B20 sensor (used to measure blood temperature) and the MLX90614 sensor (used to measure skin temperature) may be used to create a blood warmer. when compared to the digital thermometer, whose values would be shown on the TFT Nextion screen, a discrepancy of 0.2 0 C is seen. Two controls, PID Control, are used in the production of this instrument and Fuzzy Control where temperature settings can be adjusted according to the patient's normal body temperature, The findings of project The DS18B20 sensor provided accurate temperature measurements of the blood being transfused. This accuracy is essential for maintaining the blood within the optimal temperature range and preventing issues like hemolysis and clotting. The comparison between PID and Fuzzy control techniques highlighted their respective strengths. PID control demonstrated rapid response and stability, while Fuzzy logic control effectively handled non-linearities and complex relationships in the system. The tuning of PID parameters (Kp, Ki, Kd) with values such as Kp = 4, Ki = 1, and Kd = 4 resulted in a system with low error values, fast response time, and minimal overshoot. This fine-tuning contributed to maintaining precise temperature regulation during the transfusion. This project and its findings provide a strong foundation for potential future work and improvements in the field of blood transfusion procedures and medical technology

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