Jurnal Teknokes
International: Rapid Review: Open Access Journal **Vol. 15, No. 2, June 2022, pp. 117-123** **ISSN: 2407-896**

RESEARCH ARTICLE **OPEN ACCESS**

Manuscript received February 10, 2022; Revised March 17, 2022; accepted April 1, 2022; date of publication June 20, 2022
Digital Object Identifier (DOI): https://doi.org/10.35882/teknokes.v15i2.246

How to cite Anita Miftahul Maghfiroh, Farid Amrinsani, Singgih Yudha Setiawan, Rafi Maulana Firmansyah, and Shubhrojit Misra, "Infant Warmer using Digital Scales for Auto Adjustment of PID Control Parameters", Jurnal Teknokes, vol. 15, no. 2, pp. 117–123, June. 2022.

Infant Warmer using Digital Scales for Auto Adjustment of PID Control Parameters

Anita Miftahul Maghfiroh[1], Farid Amrinsani[1], Singgih Yudha Setiawan[1], Rafi Maulana Firmansyah[1], and Shubhrojit Misra[2]

[1] Departement of Electromedical Engineering Poltekkes Kemenkes. Surabaya, Indonesia
[2] Department of ECE and CSE, National Institute of Technology Durgapur, India

Corresponding author: Singgih Yudha Setiawan1 (e-mail: singgihyudha91@poltekkesdepkes-sby.ac.id)

ABSTRACT Babies need temperatures that match the temperature of the mother's womb, which is between 35°C – 37°C. The latest research on infant warmer device used fuzzy method as a system for controlling temperature in infant warmers. The problem raised in the previous research is that the temperature was not evenly distributed throughout the bed at each predetermined temperature setting. When it reached the setting temperature, the warmer continued to turn on so that the bed got hotter. Therefore, the purpose of the current research is to make an infant warmer device equipped with digital scales with a temperature setting of 35^0C- 37^0C using PID control to stabilize the temperature and ensure that the heat is evenly distributed on the bed. In addition, skin temperature is also added, allowing the nurses know at which level of patient's body temperature is when observations should be made. The infant warmer in this module used an arduino microcontroller which is displayed in 7 segments, the skin sensor used is the DS18B20 temperature sensor to read the skin temperature, while the infant warmer temperature sensor used is LM35 as a PID control system. The results of the current research in making the device module were compared with the measurement results of the comparator. It was revealed that current research has obtained smallest error of 0% in temperature setting of 35^0C. For the comparison with the incu analyzer, the smallest error was obtained at the temperature setting of 37^0C with an error value of 0% on the T5 measurement. Meanwhile, the difference in skin temperature against the thermometer is 0.1^0C. The results showed that the temperature distributed on the module had different error values. Hence, this research can be implemented on the PID control of infant warmer system to improve the performance of infant temperature stability.

INDEX TERMS Infant Warmer, baby scale, temperature, skin temperature, PID Control.

I. INTRODUCTION

After the baby is born, the temperature of the baby's internal body and skin can decrease by about 0.1°C-0.3°C per minute. However, this incident can be prevented through therapeutic measures using an infant warmer as the first treatment after the baby is born [1]. Hypothermia or lack of body temperature below normal threshold is a significant problem that often occurs in newborns [2][3]. There are more than 20 million premature and low birth weight babies born every year. Among them, 95% of premature and low birth weight babies are born in developing countries. In addition, there are 3 million babies who die in the first 28 days after birth [2].

During the neonatal period, infants have the highest risk of health problems because the baby's body is still vulnerable [4]. Infant warmer is a life support equipment used to provide relief from the effects of heat on normal and premature babies who are unable to maintain their own body temperature in a new environment. For the treatment of normal and premature babies, GE health care makes infant warmer equipment, including panda warmer and giraffe warmer who are placed in neonatal intensive care units (NICU) [5].

Furthermore, the research was further redeveloped by Brahminindya Resi Kanastriloka and Maimunah Novita Sari in 2018 with the title of Infant Warmer equipped with phototherapy. The device used is Arduino Uno as the data processor and LCD as a temperature display. The weakness of this device is that the users found difficulties in seeing the temperature indicator on the LCD, so they must come closer;

the mechanics of the phototherapy lamp are too heavy so it is difficult to move; and the use of a digital sensor to reduce the temperature reading error value [6]. Anggraeni Dara Pratiwi also conducted a study entitled proportional integral and derivative-based infant incubator equipped with kangaroo mode researchers using a PID control system. In addition, this device also used ATMega 328 minimum system which processes the analog data from the LM 35 and thermistor sensor with a temperature setting of 32°C to 37°C. However, this device had weaknesses in the PID response to heater performance because the heater wattage is too small so the PID response is a little slow [7]. Subsequent research was carried out by I. W. Aris Wiyadnyana Putra. W. Widhiada. and I. N. Suarnadwipa entitled PID system control for temperature and humidity stability in an arduino microcontroller-based infant incubator. This device used a PID system with a trial and error tunning method using a DHT 22 sensor and an LM 35 sensor as the skin sensor [8][9][10]. The drawback of this study is that the DHT 22 sensor is less sensitive than other sensors. Furthermore, a PID controller-based smart incubator device was also developed. This device used a DHT-22 sensor as the temperature sensor and LM 35 sensor as the skin sensor [11]. In addition, this device also employed C programming language with IDE software and is processed on Arduino Mega as Economical Control System in Power Consumption. Furthermore, another study was also carried out on PID temperature controller infant incubator using RTD, explaining that the PID algorithm method that controls PWM also control the heater [12] to keep the heater at the desired temperature setting. In addition, this device also used the PT100 RTD sensor. Howeve, this device has additional parameters that were still lacking to observe in infants [13]. In 2012, further research was carried out by Sulistya Anggara Wira bhuwana with the title of digital baby warmer equipped with phototherapy unit and used a fuzzy logic system. The drawback of this study is that the fuzzy logic method is not precise for its control, in addition to the device which was not equipped with scales for observing the baby [11][15][16]. This study aims to create and design an infant warmer using a DC heater equipped with a battery so that when there is a blackout from PLN, this device can still be used. However, this device has a weakness in the forms of excessive use of battery [12]. Another study also designed such device by using DHT11 sensor as the sensing element and the control method were actuated by lightbulbs. The controller used microcontroller atmega16 as the processor whose output determines the amount of power supplied to the lightbulb by employing pulse width modulation and MOSFET triggered circuit [7]. In this case, PID control system is used by some researchers as control of industrial equipment [11][14][18][19]. Gunawan Osman et al had also made an infant warmer using an android-based temperature monitoring system. This system is actually quite helpful for users to unify the temperature on the infant warmer [20][21][22]. However, the temperature control has a fairly excessive level. In addition, the baby's after birth weight is also very important as one of the measures to know whether the baby conditions is normal or not [17][18][25].

Based on the identification results of the existing problems, the authors have not found any other researchers who paid attention to the importance of monitoring baby's weight. Therefore, the authors wanted to develop and overcome these shortcomings by conducting a research project on on making infant warmers using the LM35 sensor for baby temperature and DS18B20 sensor for skin temperature entitled Baby Warmer with Digital scales using a PID system to control the temperature of the infant warmer. The purpose of this research is to make an infant warmer equipped with digital scale with a temperature setting of 35 to 37^0C using PID control to stabilize the temperature and ensure an even distribution of heat on the bed. In addition, this device is also equipped with APGAR Timer of up to 20 minutes and a digital scale for an easy observation of the babies. In this case, the addition of skin temperature aims to let nurses know what the patient's body temperature during the observation.

II. MATERIALS AND METHODS

A. EXPERIMENTAL SETUP

This study employed temperature values at the range of 35^0C, 36^0C, and 37^0C by taking measurements at T1, T2, T3, T4, and T5 for 10 times for data collection.

1) MATERIAL AND TOOL

This research used ATMega 2560 and Arduino Uno microcontroller to process the data. Meanwhile, the output of the microcontroller is displayed on the 7segment cathode. Furthermore, this study also used LM35 sensor to read the room temperature and DS18B20 sensor to read the patient's skin temperature by using a 1200 watt power heater element.

2) EXPERIMENT

In this study, the LM 35 sensor was used to sense the temperature in the infant warmer room using a PID system design as the temperature control in order to suppress the excess level. Meanwhile, the DS18B20 sensor was used to sense the baby's body temperature. The results of the LM35 sensor design was then compared with the incu analyzer by taking 10 data within 1 hour. Furthermore, the DS18B20 sensor was compared with a contact body temperature thermometer with 6 data retrieval on the human body.

B. THE DIAGRAM BLOCK

The microcontroller, in this case, was used to process the temperature and time settings that have been inputted as temperature controller settings. The data were further sent to the microcontroller and then forced to control the heater according to the predetermined temperature between 35°C – 37°C. Operating the infant warmers, is first carried out by selecting the desired temperature setting by pressing the setting button. The start button will then indicate that the microcontroller has started processing the work of the infant

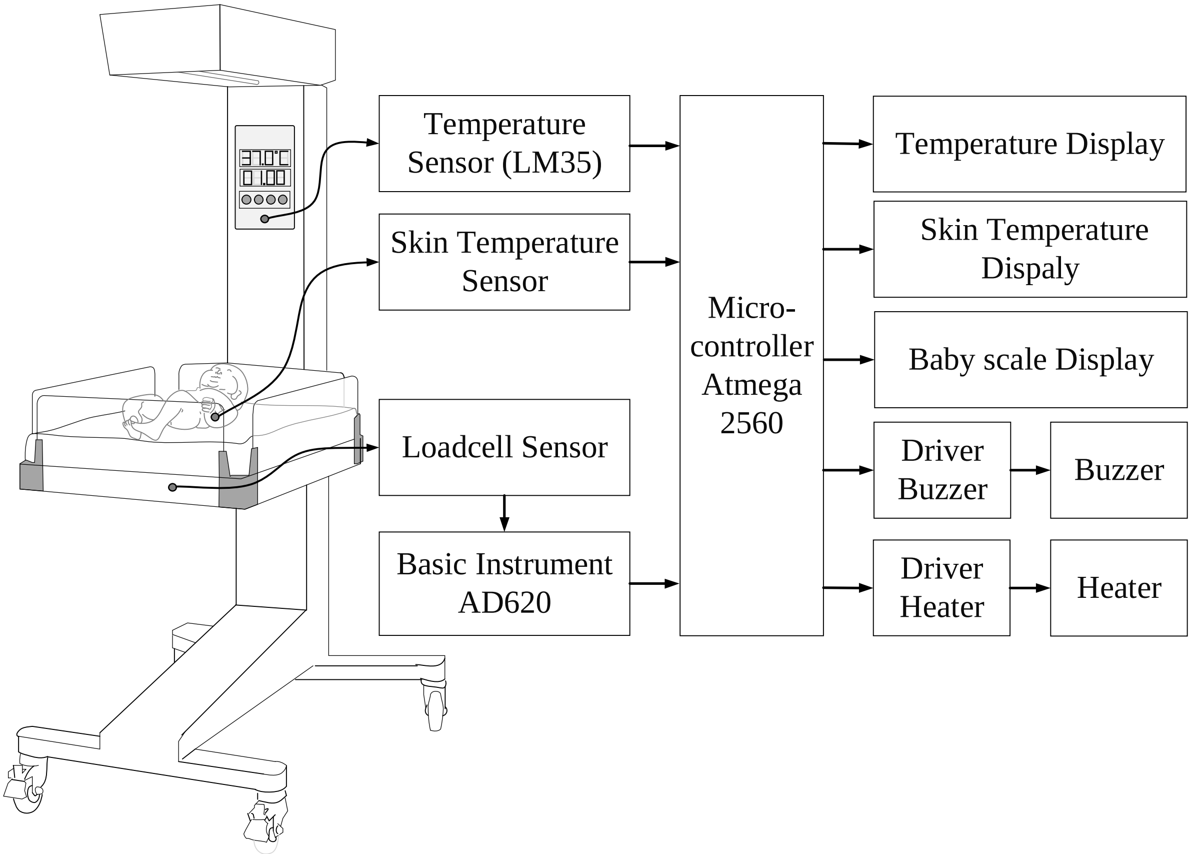


FIGURE 1. The block diagram of the infant warmer system, input temperature sensors, skin sensors, and loadcell sensors that are processed by a microcontroller which will display the results from these sensors by seven segments; the temperature conditions in the infant warmer are controlled by the PID system.

warmer. Reset button is used to stop program performance and sensor readings. The APGAR timer is used to assign the newborn's APGAR score. If the Room Temperature Sensor does not read the temperature or the temperature is excessive, the thermostat will turn off the heater. These steps are further illustrated in FIGURE 1.

C. THE FLOWCHART

The controll program was built based on the flowchart as shown in FIGURE 2. At the beginning (when the start button is pressed), the microcontroller performs initialization and then the user sets the temperature so that the microcontroller detects the difference value between the set point temperature and the actual temperature. The difference value will be then input to the PID control. The PID control processes the error value and determines the output value for the heater. In this case, the PID works simultaneously to quickly get the V set for integral to speed up the work response and derivatives to reduce the response or hold the riple to be stable. For example, when the actual temperature is 25℃ and the desired temperature is 35℃, it will send fedback to the PID so that the PID output will control the heater until the temperature setting is reached and stabile. Then the temperature sensor will read the actual temperature value and compare it with the temperature setting. Furthermore, the PID control will continue to process the error value and determine the output value so that the actual temperature is the same as the temperature setting (error value = 0). If the temperature is stable, the APGAR timer is activated by the user. The APGAR timer buzzer sounds at 1, 5, 10, 15, and 20 minutes. Then, the buzzer is turned off using a reset alarm. If this is finished then the process ends.

D. THE ANALOG CIRCUIT

The base leg of the transistor is controlled using a microcontroller. When given logic of 1 is given, then it turns on the 7 segments command. The 7segment leg of a, b, c, d, e, f, and g are controlled directly by the microcontroller. When the segment a is given logic 0, then it turns on segment a. The 7segment circuit is a circuit to drive 7segment so that it can be controlled by the microcontroller easily as shown in (APENDIX).

1) CIRCUIT OF SEVEN SEGMENT

The intended solenoid valve driver range as shown in (APENDIX), that is used for the selection of flow rate of the occlusion and drain modes. Each solenoid valve will be

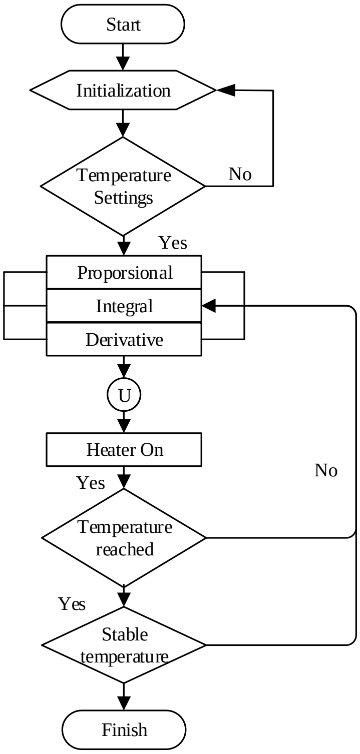


FIGURE 2. The Flowchart of PID Control. First, the temperature is set, which will then be controlled by the PID system. When the temperature is the same as the temperature setting or has not reached the temperature setting, then the heater will be on and vice versa. If the temperature is stable, then the process is complete.

connected to a series of solenoid valves. The initial condition of soloneoid valve is Normally Close so that when given solenoid voltage, the valve will open.

2) DS18B20 CIRCUIT

The output issued by the DS1820 sensor is a configuration of numbers 1 and 0, which indicate a certain temperature. The amount of data bit output voltage also depends on the amount of voltage that is input to the sensor. This ds18b20 sensor circuit requires a pullup resistor to be able to read the data value from the DS18B20 sensor in order to display the temperature data as shown in (APENDIX).

III. RESULT

In this study, the function test was carried out directly with a comparison tool using the Incu Analyzer II (Fluke) by testing the DS18B20 sensor using a contact thermometer comparison (omron). The results of the data collection show that the results are suitable to be used in patients who need an infant warmer. The proposed design is shown in (APENDIX), illustrating the analog digital part of this design, while (APENDIX) is infant warmer box design.

1) DESIGN MODULE

Photo of the analog and digital parts of the infant warmer shown in (APENDIX). In this case, the analog consists of LM35 sensor, a DS18B20 sensor, and a 7 segments circuit. In analog circuit, there is a pull up resistor for the DS18B20 sensor and a seven segment circuit using a transistor. Furthermore, the digital components consist of Arduino Uno and Arduino Mega as the processors of a controller. Thus, the PID process occurs in a program. (APENDIX) is the front view of the infant warmer box design.

2) THE LISTING PROGRAM FOR ARDUINO

The heater control uses which will work when the range is 0 to 255. If the PID is less than 1, then the PID will still show 0 and if the PID is more than 255 then the PID will still show 255. This aims to limit if the PID shows a number (-) or above 255. Before the PID control process occurs, there is a PID formula in the program. In this case, the error value is obtained from the setpoint minus the actual temperature, while P is the error value multiplied by the predetermined Kp. The heat value is obtained from the error value added to the error value of x. So, the error value x is the same as the the error value. Then, i= Ki multiplied by the value of heat. Then d=Kd* (error - errorx). After that, the results of each PID are added up based on EQUATION 1. shown in PSEUDOCODE 1

$$\frac{C_D(s)}{D(s)} = \frac{G_2(s)}{1+G_1(s)G_2(s)H(s)} \quad (1)$$

Where Cd(s) is the response to interruption (disturbance), D(s) is the interference (interruption) effect test

PSEUDOCODE 1. PID program.

```
void mulai(){
analogWrite(pwmout.pid);
  error = setpoint - suhu;
  p = error * kp;
  sumerr = error + errorx;
  i = ki * sumerr;
  d = kd * (error - errorx) ;
  pid = p + i + d;
errorx = error;
IF(pid < 1){
  pid = 0;
  }
  IF(pid > 255){
  pid = 255;
  }
}
END
```

3) THE MEASUREMENT RESULT WITH INCU ANALYZER

Based on the ten temperature readings, the device module reads the lowest temperature value at 34.28^{0}C, while the highest value at 34.9^{0}C. Meanwhile, the Incu Analyzer reads the lowest value at T5 at 34.81^{0}C and the highest value at 35.07^{0}C. The measurement result was shown in TABLE I, TABLE II, FIGURE 3, and FIGURE 4. Furthermore, from 10 temperature readings, the device module reads the lowest temperature value at 35.9^{0}C and the highest value at 36.2^{0}C. Meanwhile, the Incu Analyzer reads the lowest value at T5 of 35.99^{0}C and the highest value at 36.17^{0}C.

TABLE 1

Temperature setting of 35⁰C compared with the INCU Analyzer using five sensor points, namely T1, T2, T3, T4 and T5. Measurement was done 5 times at each point.

	T1	T2	T3	T4	T5
Mean	34.28	34.21	34.84	33.7	34.99
Standard Deviation	0.13	0.11	0.26	0.04	0.08
%Error	0.02	0.02	0.01	0.03	0.02
UA	0.04	0.03	0.08	0.01	0.02

Based on the measurement results that are explained in Table 1, it can be concluded that the temperature measurement at 35 ^{0}C was considered feasible since the error value is less that the standard determined, which is 5%.

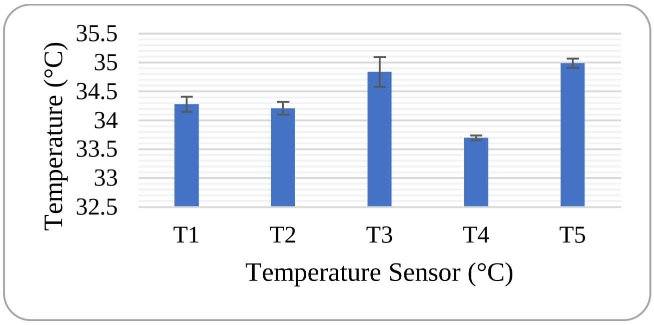


FIGURE 3. **Comparison between temperature settings of 35⁰C and the INCU Analyzer with the average value and error.**

Figure 3 explains that the graph used is the mean and error values at the measurement of temperature setting of 35^{0}C.

TABLE 2.

Temperature Setting of 36⁰C compared with the INCU Analyzer using five sensor points, namely T1, T2, T3, T4 and T5. Measurement was done 5 times at each point.

	T1	T2	T3	T4	T5
Mean	34.56	34.84	35.60	34.30	36.10
Standard Deviation	0.18	0.04	0.13	0.21	0.05
%Error	0.04	0.03	0.01	0.04	0.01
UA	0.05	0.01	0.04	0.06	0.01

Based on the measurement results that are explained in Table 2, it can be concluded that the temperature measurement at 36^{0}C was considered feasible since the error value is less that the standard determined, which is 5%.

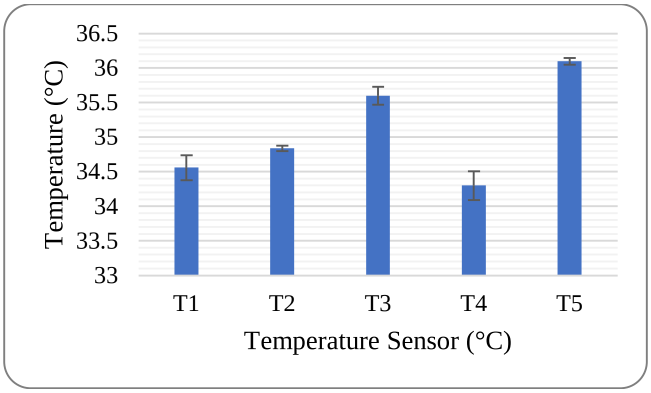


FIGURE 4. **Comparison between temperature settings of 36⁰C and the INCU Analyzer with the average value and error.**

Figure 4 explains that the graph used is the mean and error values at the measurement of temperature setting of 36^{0}C.

TABLE 3

Temperature Setting of 37⁰C compared with the INCU Analyzer using five sensor points, namely T1, T2, T3, T4 and T5. Measurement was done 5 times at each point.

	T1	T2	T3	T4	T5
Mean	35.52	35.07	35.88	34.81	37.07
Standard Deviation	0.24	0.04	0.29	0.24	0.07
%Error	0.04	0.05	0.03	0.06	0.00
UA	0.07	0.01	0.09	0.07	0.02

Based on the measurement results that are explained in Table 3, it can be concluded that the temperature measurement at 37^{0}C was considered feasible since the error value is less that the standard determined, which is 5%.

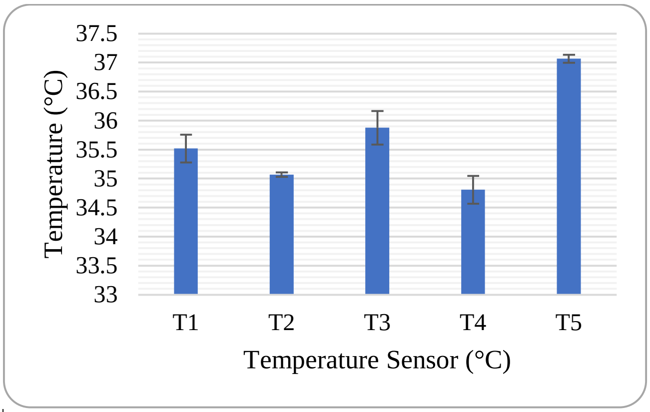


FIGURE 5. **Comparison between temperature settings 37⁰C and the INCU Analyzer with the average value and error**

Figure 5 explains that the graph used is the mean and error values at the measurement of temperature setting of 37^0C.

IV. DISCUSSION

Measurements have been done on the module using an incu analyzer and a contact thermometer. In this case, the measurement devices were used for 10 times in order to get constant results. Based on the measurement results of the temperature setting, each temperature setting has a different value. At the temperature setting of 35^0C, the error value obtained from the device module is 0.00%, where 0.02% for T5, 0.03% for T4, 0.01% for T3, 0.02% for T2, and 0.02% for T1. This indicates that when the temperature setting was 35^0C, the voltage obtained was 0.38 Vdc and the mean value of the module is around 35.00. Then, at the temperature setting of 36^0C, the error values in the device module are 0.01%, where T5 is 0.01%, T4 is 0.04%, T3 is 0.01%, T2 is 0.03%, and T1 is 0.04%. This indicates that during the temperature setting of 36^0C, the voltage obtained was 0.39 Vdc and the mean value of the module is about 36.06. Furthermore, during the temperature setting of 37^0C, the error value of the device module is 0.01%, where T5 is 0%, T4 is 0.06%, T3 is 0.03%, T2 is 0.05%, and T1 is 0.04%. This indicates that when temperature setting is 37^0C, the voltage obtained is 0.40 Vdc and the mean value of the module is about 37.01. Therefore, when the testing is done in an open room and on the skin temperature first, the error between the module and the thermometer is 0.1 with an error value of 0.03%. For the second measurement, the error between the module and the thermometer is 0 with an error value of 0%. Meanwhile, at the third measurement, the error between the module and the thermometer is 0.1 with an error value of 0.03%. At the fourth measurement, the error value between the module and the thermometer is 0.1 with an error value of 0.03%. Furthermore, at the fifth measurement, the error between the module and the thermometer is 0.1 with an error value of 0.03%. The sixth measurement obtained the error between the module and the thermometer of 0.2 with an error value of 0.05%. So the average error is about 0.1 with an average error value of 0.03%.

Compared to the previous studies, current research obtained different results at each temperature setting and skin temperature. The previous research used fuzzy method, which obtained the largest error value at T1 by 0.06% at a temperature setting of 34^0C, T1 by 0.06% at a temperature setting of 35^0C, and T1 by 0.06% at a temperature setting of 36^0C, and T1 by 0.07% at a temperature setting of 37^0C. Meanwhile, this study used PID control method, which obtained the largest error value at T4 by 0.03% at a temperature setting of 35^0C, T4 by 0.04% at a temperature setting of 36^0C, and T4 by 0.06% at a temperature setting of 37^0C. In terms of the skin temperature at previous study, the mean value of the difference between the module and the thermometer is around 0.6^0C, while this research obtained mean value of the difference between the module and the thermometer of 0.1^0C. Based on the results of the data that have been studied by previous researchers and the results of the current research, it can be concluded that the current research has a smaller error value than the previous research [7]. Therefore, the implementation is that this device can be used at an open room temperature with 3 temperature settings and PID control which is equipped with a temperature sensor for the body using 7 segments that are clearly visible even from 2 meters of vision.

In addition, it also can be concluded that the device module designed that has been compared with the calibrator has several weaknesses. First is the distance of the sensor, where if the distance is too close, it will affect the results of the heater control. Second is the time of the device that still uses many microcontrollers and has not been equipped with phototherapy for therapy in infants.

In addition, the baby's weighing system of this device is also less than optimal and the placement of the sensor is not right so that it affects the readings on the baby's weight results.

V. CONCLUSION

The purpose of this research is to make an infant warmer equipped with digital scales with a temperature setting of 35 to 37^0C using PID control to stabilize the temperature and ensure the evenly distribution of the heat on the bed. This research obtained smallest error value in the measurement, where at the temperature setting of 35^0C the error value is 0%, while at temperature settings of 36^0C and 37^0C, the error values are 0.01%, respectively. For the comparison with the incu analyzer, the smallest error was obtained at the setting temperature of 37^oC with an error value of 0% on the T5 measurement and the largest error at the setting temperature of 37^0C with an error value of 0.06% is on the T4 measurement. Based on the measurements that have been done, it can be concluded that the distance of the sensor placement to the heater can affect the control results on the heater driver. Therefore, a good heater driver can improve the heater control and temperature readings on the display. In addition, the use of a temperature sensor that can read the temperature linearly is also needed because it will affect the results. For further research, future researchers should improve the scale system and the accuracy of the PID control system to reduce excess.

REFERENCES

[1] E. M. Mccall, F. Alderdice, H. L. Halliday, S. Vohra, and L. Johnston, “Interventions to prevent hypothermia at birth in preterm and/or low birth weight infants,” *Cochrane Database Syst. Rev.*, vol. 2018, no. 2, 2018, doi: 10.1002/14651858.CD004210.pub5.

[2] World Health Organization, “Who compendium of innovative health technologies for low-resource settings 2011-2014.,” p. 143, 2016.

[3] J. Uwamariya *et al.*, “Safety and effectiveness of a non-electric infant warmer for hypothermia in Rwanda: A cluster-randomized stepped-wedge trial,” *EClinicalMedicine*, vol. 34, p. 100842, 2021, doi: 10.1016/j.eclinm.2021.100842.

[4] I. K. O. Azizah, “Kematian Neonatal di Kabupaten Grobogan,” *Higeia*

J. Public Heal. Res. Dev., vol. 1, no. 3, pp. 84–94, 2017.

[5] A. Erisnawati, "The Effectiveness of Early Initiation of Breastfeeding (IMD) in Reducing the Incidence of Hypothermia in Newborn at Ngimbang Lamongan Hospital in 2021," vol. 14, pp. 46–52, 2022.

[6] R. Fadilla *et al.*, "A Multifunction Infant Incubator Monitoring System with Phototherapy and ESP-32 Based Mechanical Swing," *Int. J. Sci. Technol. Manag.*, vol. 1, no. 4, pp. 371–381, 2020, doi: 10.46729/ijstm.v1i4.93.

[7] N. F. Hidayati, Endro Yulianto, and Abd. Kholiq, "Baby Incubator Based on PID Control With Kangaroo Mode (Kangaroo Mode and Humidity)," *J. Electron. Electromed. Eng. Med. Informatics*, vol. 1, no. 2, pp. 13–17, 2019, doi: 10.35882/jeeemi.v1i2.3.

[8] H. B. D. L. Mathew, Ashish Gupta, "Controlling of Temperature and Humidity for an Infant Incubator Using Microcontroller," *Int. J. Adv. Res. Electr. Electron. Instrum. Eng.*, vol. 04, no. 06, pp. 4975–4982, 2015, doi: 10.15662/ijareeie.2015.0406012.

[9] A. K. Theopaga, A. Rizal, and E. Susanto, "Design and implementation of PID control based baby incubator," *J. Theor. Appl. Inf. Technol.*, vol. 70, no. 1, pp. 19–24, 2014.

[10] J. Prinyakupt and K. Roongprasert, "Verification Device for Temperature and Relative Humidity Inside the Infant Incubator via IoT," *BMEiCON 2019 - 12th Biomed. Eng. Int. Conf.*, pp. 1–6, 2019, doi: 10.1109/BMEiCON47515.2019.8990351.

[11] W. Widhiada, I. N. G. Antara, I. N. Budiarsa, and I. M. G. Karohika, "The Robust PID Control System of Temperature Stability and Humidity on Infant Incubator Based on Arduino at Mega 2560," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 248, no. 1, 2019, doi: 10.1088/1755-1315/248/1/012046.

[12] M. H. Iqbal and W. S. Aji, "Wall Following Control System with PID Control and Ultrasonic Sensor for KRAI 2018 Robot," *Int. J. Robot. Control Syst.*, vol. 1, no. 1, pp. 1–14, 2021, doi: 10.31763/ijrcs.v1i1.206.

[13] Z. S. A. Rahman and F. S. A. Hussain, "Smart Incubator Based on PID Controller," *Int. Res. J. Eng. Technol.*, vol. 4, no. 3, pp. 2501–2509, 2017, doi: 10.13140/RG.2.2.21917.77282.

[14] M. S. A. Nampira, A. Kholiq, and Lamidi, "A Modification of Infant Warmer with Monitoring of Oxygen Saturation, Heart Rate and Skin Temperature," *J. Electron. Electromed. Eng. Med. Informatics*, vol. 3, no. 1, pp. 19–25, 2021, doi: 10.35882/jeeemi.v3i1.4.

[15] A. H. Muosa, "Wireless Controland Monitoring Systemfor Premature Infant IncubatorEnvironment," *J. Coll. Educ. pure Sci.*, vol. 7, no. 4, pp. 28–39, 2017.

[16] W. Widhiada, T. G. T. Nindhia, I. N. Gantara, I. N. Budarsa, and I. N. Suarndwipa, "Temperature stability and humidity on infant incubator based on fuzzy logic control," *ACM Int. Conf. Proceeding Ser.*, no. April, pp. 155–159, 2019, doi: 10.1145/3330482.3330527.

[17] H. Suwoyo, C. Deng, Y. Tian, and A. Adriansyah, "Improving a wall-following robot performance with a PID-genetic algorithm controller," *Int. Conf. Electr. Eng. Comput. Sci. Informatics*, vol. 2018-Octob, pp. 314–318, 2018, doi: 10.1109/EECSI.2018.8752907.

[18] A. Nayak and M. Singh, "Study of Tuning of PID Controller By Using Particle Swarm Optimization," *Int. J. Adv. Eng. Res. Stud.*, vol. IV, no. Jan.-March, pp. 346–350, 2015.

[19] E. Ambitiously, "PID Theory Explained - NI," pp. 1–7, 2020, [Online]. Available: http://www.idc-online.com/technical_references/pdfs/electrical_engineering/Introduction_to_Second_Order_Systems.pdf%0Ahttp://engineering.electrical-equipment.org/panel-building/introduction-to-second-order-systems.html.

[20] L. M. Silalahi, G. Osman, F. A. Silaban, I. U. V. Simanjuntak, and A. D. Rochendi, "Design An Infant Warmer With Android-Based Temperature Monitoring," *J. Informatics Commun. Technol.*, vol. 3, no. 2, pp. 67–73, 2021, doi: 10.52661/j_ict.v3i2.86.

[21] J. Bethanney Janney, S. KrishnaKumar, P. B. AnuShree, V. Rayshma, and S. Suresh, "Deisgn of mobile infant incubator with comforting pillow," *Int. J. Eng. Technol.*, vol. 7, no. 2, pp. 6–9, 2018, doi: 10.14419/ijet.v7i2.25.12353.

[22] E. W. Sinuraya and R. J. Pamungkas, "Design of Temperature Control System for Infant Incubator using Auto Tuning Fuzzy-PI Controller," *Int. J. Eng. Inf. Syst.*, vol. 3, no. 1, pp. 33–41, 2019.

[23] M. Y. Çelik and Z. Ciğdem, "Kırılgan bebek algısı ölçeği: Geçerlik ve güvenirlik çalışması," *J. Psychiatr. Nurs.*, vol. 11, no. 3, pp. 188–194, 2020, doi: 10.14744/phd.2020.92678.

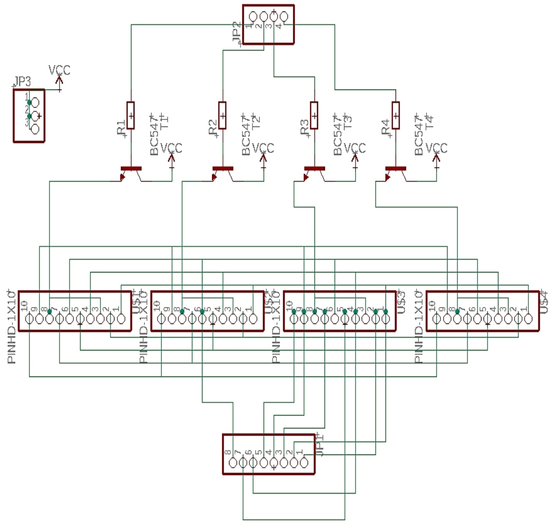
[24] S. Thorstensson, E. Hertfelt Wahn, A. Ekström, and A. Langius-Eklöf, "Evaluation of the Mother-to-Infant relation and feeling scale: Interviews with first-time mothers' for feelings and relation to their baby three days after birth," *Int. J. Nurs. Midwifery*, vol. 4, no. 1, pp. 8–15, 2012, doi: 10.5897/IJNM11.041.

[25] S. Matthey, R. Črnčec, A. Hales, and A. Guedeney, "A description of the modified alarm distress baby scale (m-ADBB): An instrument to assess for infant social withdrawal," *Infant Ment. Health J.*, vol. 34, no. 6, pp. 602–609, 2013, doi: 10.1002/imhj.21407.

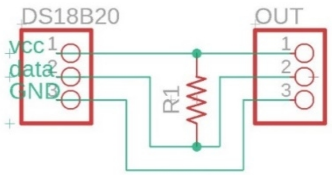
APENDIX

a. Schematic+Board:
https://drive.google.com/drive/folders/13iylYgpucehQRqm0mMDQuZl1bATPqTPz?usp=sharing

b. Listing Program :
https://drive.google.com/drive/folders/1RM5iLuNIPfAqjQx-5PAltXM75PVIfnx1?usp=sharing



Circuit of Seven Segment




```
void setsuhu(){
IF (digitalRead(7)==HIGH){
  a++;
  delay(100);
}
IF (a==3){
  a=0;
}
IF (a==0){
  tigalima();
}
IF (a==1){
  tigaenam();
}
IF (a==2){
  tigatujuh();
}
void tigalima(){
  digitalWrite(10. 1);
  digitalWrite(11. 0);
  digitalWrite(12. 0);
setpoint=50.0;
}
void tigaenam(){
digitalWrite(11. 1);
digitalWrite(10. 0);
digitalWrite(12. 0);
setpoint=51.0;
}
void tigatujuh(){
digitalWrite(12. 1);
digitalWrite(11. 0);
digitalWrite(10. 0);
setpoint=52.0;
}
```

Pseudocode: 1. Program Temperature Setting.

After the device is ON, the initial display is the skin temperature, room temperature, and the temperature setting indicator. Then to start the process, user needs to press the start button and select the temperature point required for the observation process. In this device, the temperature setting ranges from 35^0C to 37^0C as shown in **Pseudocode:** 1.

Pseudocode: 2. Program Sensor LM35.

```
#define  LM35_pin  A0
int  temp;
temp = 10 * analogRead(LM35_pin) / 9.3;  // read
analog voltage and convert it to °C ( 9.3 =
1023/(1.1*100) )
 delay(1000);  // wait 1 second
```

The above program is used to read the LM35 sensor. LM35 is an analog temperature sensor whose output is a voltage and then converted to Celsius for every 10^oC increase is 10mV for the LM35 pin, initialized to pin A0 as shown in **Pseudocode: 2**

Pseudocode: 3. Program Sensor DS18B20.

```
#include <OneWire.h>
#include <DallasTemperature.h>
#define ONE_WIRE_BUS 2
suhu = sensors.getTempCByIndex(0);
temp = suhu;
sensors.requestTemperatures();
```

Initialization in the temperature program contains the DS18B20 temperature sensor library which is a serial communication using one data line. Tthe data/output leg of the DS18B20 temperature sensor is initialized at pin 2 as shown in **Pseudocode:** 3