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Design of Temperature and Humidity Monitoring Baby Incubator Based on Internet of Things

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ABSTRACT

Babies who are born prematurely need intensive care and a fairly stable level of warmth given that the baby is not accustomed to adapting to temperatures outside the mother's womb, which is an incubator. The incubator serves to maintain the warmth and humidity of the baby's body. There are still many incubators that are conventional in nature which means that the temperature and humidity are not controlled to be constant. While the automatic incubator is very expensive. Temperature and humidity control monitoring system is very much needed in an incubator because at the moment there is still a lot of temperature monitoring done manually. Thus the monitoring and control system of temperature and humidity of the incubator is designed which can be automatically monitored from a considerable distance based on the Internet of Things (IoT). This system consists of 2 parts, namely the main device and monitoring device. The sensor used is DHT11 for temperature and humidity, and DS18B20 sensor for mattress temperature. On the web will be displayed monitoring temperature, humidity in real-time and as a controller when the incubator is in manual mode. Monitoring can be done in real-time and manual controlling can be done on the web and also displayed on the LCD. If the temperature and humidity do not match what is specified, the heater or DC fan will turn on.

Key words: Baby incubator, Internet of Things, Monitoring.

1. INTRODUCTION

The use of technology in the field of communication has had a profound change that is felt by humans today. With internet connectivity, everything becomes easier and faster. Internet of Things is a concept that aims to expand the benefits of connected internet connectivity, along with the ability to control, share data, and so on. The use of this concept is generally applied in several fields that require continuous data information such as monitoring or controlling.

The importance of monitoring critical infant patients in intensive care is something that encourages health technology to be able to provide convenience, speed and accuracy in overcoming problems that arise while infant patients are treated [1]. Babies born between 28 and 36 weeks of pregnancy are called premature babies. Babies who are born prematurely need intensive care and a level of warmth that is quite stable considering that the baby is not used to adapting to temperatures outside the mother's womb, with an incubator. The incubator functions to keep the baby's body warm and moist. The working principle of the baby incubator is to regulate and stabilize the temperature in the incubator room to match the temperature required by premature babies [2].

There are still many incubators that are conventional, meaning that temperature and humidity are not controlled to be constant. Meanwhile, automatic incubators are very expensive. A temperature and humidity control monitoring system is needed in an incubator because at this time a lot of temperature monitoring is done manually. Manual monitoring causes the nurse or midwife to frequently enter the nursery to check the temperature of the incubator at regular intervals. This condition can make nurses or midwives exhausted, which can lead to data reading errors [3, 4].

Thus a system for monitoring and controlling the temperature and humidity of the incubator is designed which can be automatically monitored remotely using internet access [5-7]. Because internet access can give us some benefit to remote monitoring in some case like other study [8-10]. This system planning aims to facilitate the monitoring and control of temperature and humidity of the incubator without having to be in the location of the incubator.

2. RESEARCH METHOD

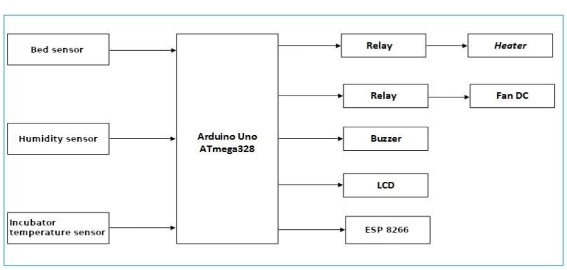
This section will explain how the system created can be useful to perform functions such as the objectives stated in the introduction. This system consists of a hardware system, a software system, communication between them, and the data classification step. In this paper, we will explain how each hardware component is connected. Also explained the process of how the communication between hardware and software data exchange.

2.1 Hardware System Architecture

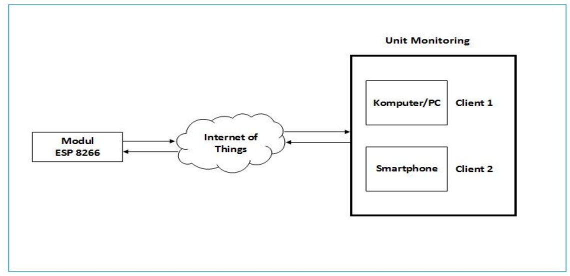
The hardware components that are compiling into a hardware system used in this study are shown in Figure 1. In Figure 1, we can see that we can group them into 2 parts. The parts are main device and monitoring device. The main equipment is a device consisting of: Arduino Uno ATmega328, ESP 8266 module, DHT11 sensor, DS18B20 temperature sensor, relay, heater, DC Fan, character LCD.

Arduino Uno ATmega328 functions as the main controller and processor in the system that reads sensors, input-output, manages the system, and sends data. DHT11 sensor functions to measure the temperature and humidity of the baby's incubator room. DS18B20 temperature sensor functions to measure the temperature of the mattress (baby bed protector). Heater functions as a space heater for a baby incubator. For the heater (heater) use lights because the lights can provide even heat to the room and are safe to use. The DC fan functions as a baby incubator room cooler. Character LCD display functions to display readings of all sensors. ESP 8266 module, the Wi-Fi module functions as an additional device for the microcontroller so that it can connect directly to Wi-Fi and establish a TCP/IP connection. So that data will be sent via this module using a Wi-Fi network and so that the data can be accessed via the web.

The monitoring device functions to monitor and monitor the actual condition of the system that occurs in real time. The main devices and monitoring devices can be connected wirelessly or using cables depending on the conditions and design desires, but in designing this system, wireless communication will be used.



(a)



(b)

Figure 1: Hardware systems architecture. (a) Main device (b) Monitoring device

2.2 Software Embedded

Software embedded in the hardware system is carried out using the Arduino IDE program. At the beginning of initials, the program is calling the library from the DHT11 sensor and DS18B20 sensor, declaring Wi-Fi profiles, server addresses, and other variables. Next is to connect to a Wi-Fi network. If the ESP8266 microcontroller is not connecting to a Wi-Fi network, it will be re-connecting. If it is successfully connecting to a Wi-Fi network, continuous data reading is performing on the "void loop(){}" function on the Arduino programming. The temperature and humidity readings are from the DHT11 sensor with float data types. The mattress temperature reading is from the DS18B20 sensor with float data types. After the data obtained, then try to connect the server. If it is not connected, it will reread the sensors data and re-connect with the server. If it is connected, the sensors data will convert into a form of data string. Sensor data will be seen on the web in tabular form. The hardware processing flow is shown in Figure 2.

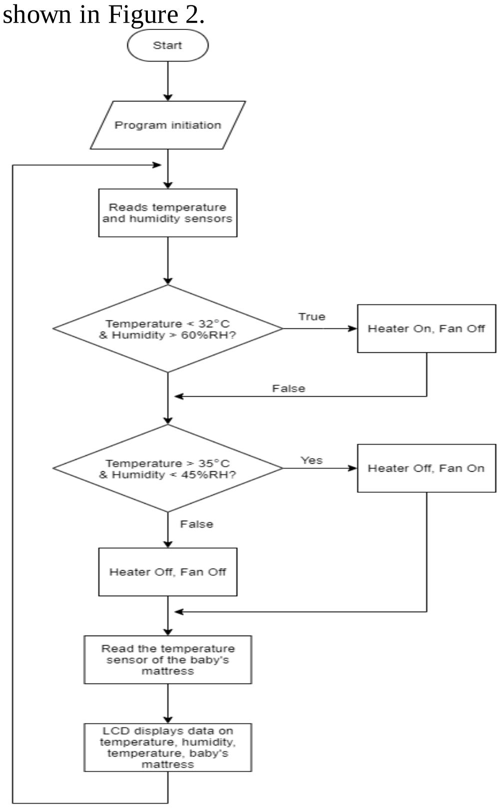


Figure 2: Software process flow

3. RESEARCH METHOD

3.1 Testing the reading accuracy of the DS18B20 Sensor

We can see in Table 1 and Table 2, comparison of DS18B20 sensor with a digital thermometer and a mercury thermometer.

Table 1. Digital Thermometer Test Results and DS18B20 Sensor Temperature

No.	Calibrated digital thermometer (°C)	DS18B20 temperature (°C)	Error	Error (%)
1	26,15	25,98	0,17	0,65
2	28,73	28,52	0,21	0,73
3	29,2	29,01	0,19	0,65
4	31,92	31,57	0,35	1,09
5	33,43	33,33	0,1	0,29
6	34,5	34,3	0,2	0,57
7	36,46	36,35	0,11	0,3
8	37,12	36,89	0,23	0,61
Average % error				0,61

Table 2. Mercury Thermometer Test Results and DS18B20 Sensor Temperature

No.	Calibrated mercury thermometer (°C)	DS18B20 temperature (°C)	Error	Error (%)
1	27,8	28,19	0,39	1,4
2	29,1	29,31	0,21	0,72
3	30,3	30,63	0,33	1,08
4	31,2	31,56	0,36	1,15
5	32,4	32,75	0,35	1,08
6	32,8	33,06	0,26	0,79
7	34,4	34,75	0,35	1,01
8	35,3	35,63	0,33	0,93
Average % error				1,02

It can be calculated the error value (error) of each temperature condition being tested. Thus, the average total error obtained from tests carried out on the DS18B20 sensor is 0.61% with a digital thermometer and 1.02% with a mercury thermometer. So, the accuracy rate of the DS18B20 temperature sensor circuit for digital thermometers on the market is 99.39% and the DS18B20 sensor accuracy rate for mercury thermometer is 98.98%.

Table 3. DS18B20 Temperature Sensor Voltage Test Results

No.	Sensor DS18B20	
	Temprature (°C)	Output (volt)
1	29	4,931
2	30	4,932
3	31	4,933
4	32	4,934
5	33	4,936
6	34,1	4,937
7	35,1	4,938
8	36	4,939

Based on Table 3, it can be seen that the test is carried out when the temperature value changes, the increase in the temperature value affects the output voltage value of the DS18B20 sensor. Every 1 °C increase, the sensor output voltage increases by 0.001 Volt, this is in accordance with the sensor datasheet. So that it can be said that the sensor works stably.

3.2 Testing the reading accuracy of the DHT11 Sensor

We can see in Table 4 and Table 5, comparison of DHT11 sensor with a digital thermometer and a mercury thermometer.

Table 4. Digital Thermometer Test Results and DHT11 Sensor Temperature

No.	Calibrated digital thermometer (°C)	DHT11 temperature (°C)	Error	Error (%)
1	26,6	27	0,4	1,5
2	27,7	28	0,3	1,08
3	28,7	29	0,3	1,04
4	29,6	30	0,4	1,35
5	30,5	31	0,5	1,63
6	31,5	32	0,5	1,58
7	33,4	34	0,6	1,79
8	34,5	35	0,5	1,44
Average % error				1,42

Table 5. Mercury Thermometer Test Results and DHT11 Sensor Temperature

No.	Calibrated mercury thermometer (°C)	DHT11 temperature (°C)	Error	Error (%)
1	26,4	26	0,4	1,51
2	27,4	27	0,4	1,45
3	29,3	29	0,3	1,02
4	30,5	30	0,5	1,63
5	31,5	31	0,5	1,58
6	32,3	32	0,3	0,92
7	33,4	33	0,4	1,19
8	34,5	34	0,5	1,44
Average % error				1,34

The accuracy rate of the DHT11 temperature sensor circuit for digital thermometers on the market is 98.58% and the accuracy of the DHT11 sensor for mercury thermometers is 98.66%. Furthermore, testing the DHT11 sensor voltage. Voltage measurement using a multimeter measuring instrument. The results of the DHT11 sensor output voltage test can be seen in Table 6.

Table 6. DHT11 Temperature Sensor Voltage Test Results

No.	Sensor DHT11	
	Temprature (°C)	Output (volt)
1	30	4,936
2	31	4,937
3	32	4,938
4	33	4,940
5	34	4,941
6	35	4,942
7	36	4,944
8	37	4,945

In Table 6. the measurement results of the DHT 11 sensor show that the increasing temperature value affects the output voltage value of the DHT11 sensor. Every 10C increase, the sensor output voltage increases ± 10 mV, as when the temperature of 36 ° C has a voltage of 4.944 V and when the temperature rises to 37 °C to 4.945 V, this is in accordance with the sensor datasheet. And vice versa when the temperature drops, the voltage also drops so that it can be concluded that temperature and voltage are directly proportional.

Table 7. DHT11 Temperature and Humidity Test Result when experimented every 18 second

No	When heated		When chilled	
	Temperature (^{O}C)	Humidity (%)	Temperature (^{O}C)	Humidity (%)
1	30	64	34	59
2	31	63	34	60
3	32	62	33	61
4	32	61	32	63
5	33	59	31	64
6	34	58	31	65
7	34	56	30	67
8	35	55	30	69
9	35	53	29	72
10	36	52	28	73

In Table 7, the test results of the DHT11 sensor with heated and cooled conditions can be seen that when heated the temperature will always increase while the humidity decreases, while when cooled down the temperature starts to fall and humidity continues to rise so it can be concluded that room conditions affect temperature and humidity and temperature is inversely proportional to humidity.

3.3 System output testing

Following the test results, the output of the system can be seen in Table 8. The relay will turn on/off to control the on/off of the heater and DC fan. The heater will work when the temperature is <32 °C and humidity > 60% RH. DC fans will run when > 35 °C and humidity < 45% RH.

Table 8. System output testing

No.	Testing	Expected output	Test result output
1.	when the temperature < 32 ° C and humidity > 60% RH	*Heater* : on	✔
		Fan DC : off	✔
		Buzzer : on	✔
2.	when the temperature > 35°C and humidity < 45% RH	*Heater* : off	✔
		Fan DC : on	✔
		Buzzer : on	✔
3.	when the temperature is 32°C - 35°C and humidity 45%RH – 60%RH	*Heater* : off	✔
		Fan DC : off	✔
		Buzzer : mati	✔

3.4 Monitoring Web

This web monitoring test is performed to ensure that the sensor data that has been sent by the ESP 8266 Wi-Fi module to the localhost server can be accessed through the web monitoring that has been designed. On the web there are home menus, profiles, monitoring, controlling, reports. Monitoring web can see in Figure 3, Figure 4 and controlling web can see in Figure 5.

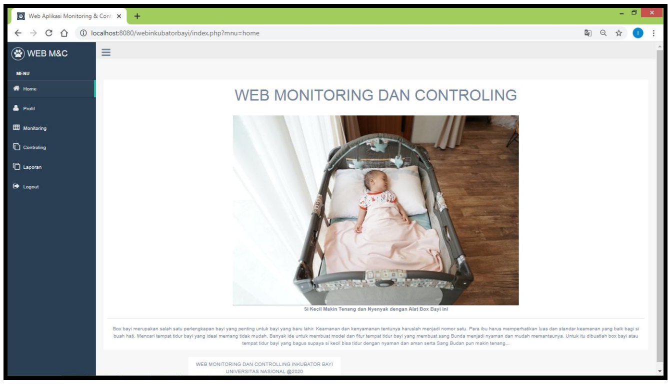


Figure 3: Home view on the web

On the web there are home menus, profiles, monitoring, controlling, reporting and logout. When you open the web for the first time it will appear in the home menu. Data from sensors other than displayed on the LCD can be seen on the web in the monitoring menu. In the monitoring menu, there is a choice of date, month, year and a table of incubator data. #A mode is an automatic incubator mode and #M is an incubator mode manually. On the web there are home menus, profiles, monitoring, controlling, reporting and logout. When you open the web for the first time it will appear in the home menu. Data from sensors other than displayed on the LCD can be seen on the web in the monitoring menu. In the monitoring menu, there is a choice of date, month, year and a table of incubator data. #A mode is an automatic incubator mode and #M is an incubator mode manually.

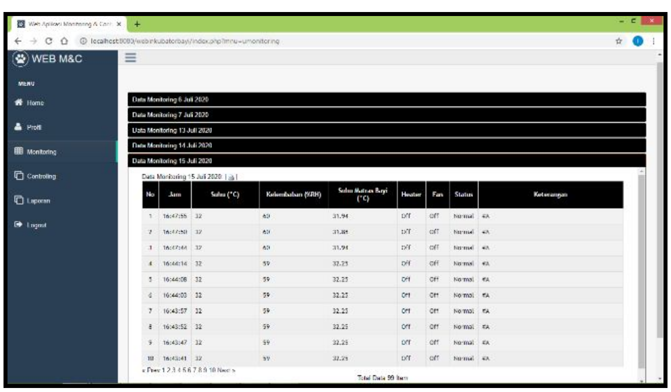


Figure 4: Display monitoring on the web

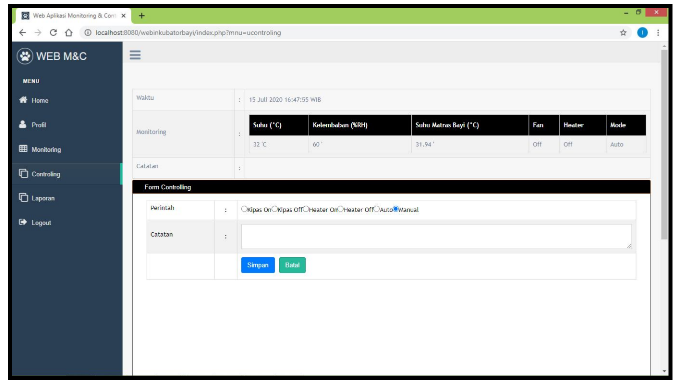


Figure 5: Display controlling on the web

For incubator system mode, auto or manual can be selected in the controlling menu. When auto mode is activated, the incubator system will function automatically, the heater and DC fan will be activated according to certain conditions. Meanwhile, when manual mode is activated, to turn on or turn off the heater and DC fan is done manually, which is selected in the controlling menu. Data on the web will also be stored in a database and you can get the results of recording data stored in a pdf file.

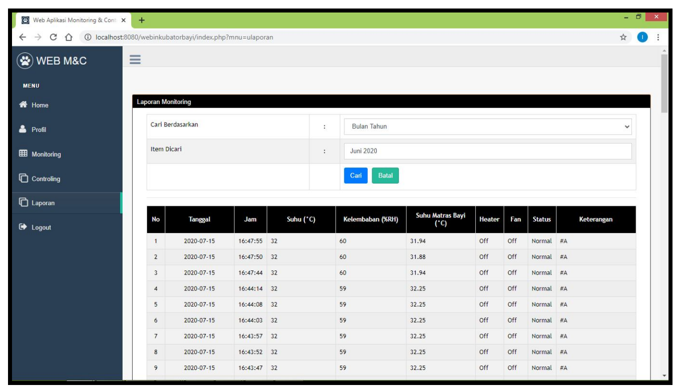


Figure 6: Display reports on the web

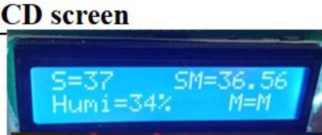
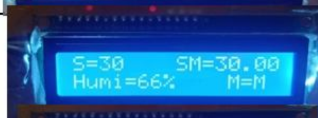
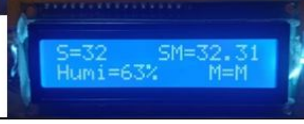
3.5 Overall systems testing

When automatic mode is activated then the heater and DC fan will turn on/off automatically. On the web are displayed data of temperature, mattress temperature, humidity, status in real-time for monitoring. The data from the DHT11 and DS18B20 sensor inputs displayed on the LCD will be the same as those displayed on the web. That means data is sent to a web database. We can see in Table 9, overall system test results in auto mode.

Table 9. Overall System Test Results in Auto Mode

No	Condition	LCD display	Output
1.	when the temperature is <32°C and humidity >60% RH		Heater : On Fan DC : Off Buzzer : On
2.	when the temperature is <35°C and humidity <45% RH		Heater : Off Fan DC : On Buzzer : On
3.	when the temperature is 32°C - 35°C and humidity is 45%RH-60%RH		Heater : Off Fan DC : Off Buzzer : Off

Table 10. Overall System Test Results in Manual Mode

No	Condition	LCD screen
1.	Fan DC : ON	
2.	Heater : ON	
3.	Heater : OFF Fan DC : OFF	

From Table 10. at the time of manual mode the baby incubator system is working well and as expected. To enable auto or manual mode can be selected on the web. When manual mode is enabled the DC fan and heater can be controlled either on or off the web.

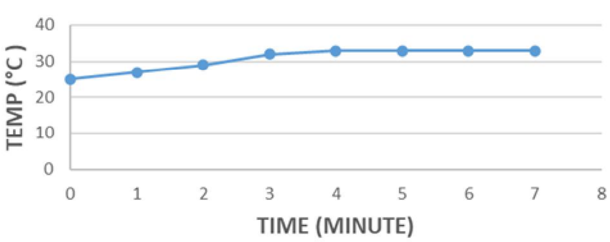


Figure 7: System response graph to reach a temperature of 32 ° C

From Figure 7. above to reach a temperature of 32 °C is reached in the 3rd minute. The time reached to that temperature is affected by the ability of heating the lamp to quickly reach the desired temperature quickly and accurately. The smaller the ability of the lamp to provide heat can affect the temperature response in the incubator.

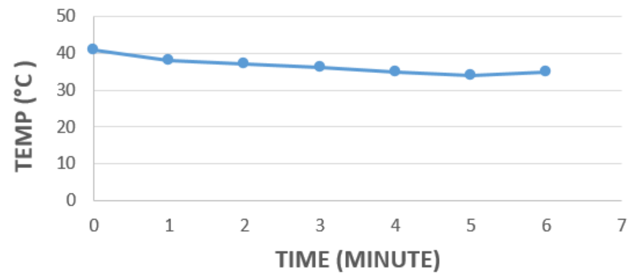


Figure 8: System response graph to reach a temperature of 35 °C

From Figure 8. to reach a temperature of 35 °C is reached in the 4th minute. The time reached to that temperature is affected by the cooling ability of the fan in removing hot air quickly and accurately. The smaller the fan's ability to dissipate heat can affect the temperature response in the incubator.

3.6 System response testing

This system response test is performed to determine the characteristics of the system to low temperature changes, namely the ability of the system to return to the set point temperature values.

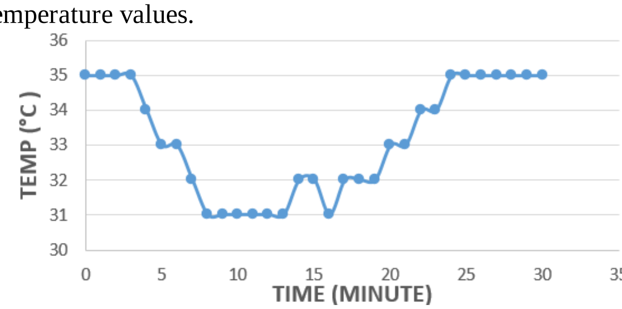


Figure 9: Low Temperature Response Graph

From Figure 9. it can be seen that in the 5th minute after a piece of ice cubes the temperature drops to 31 °C. In these conditions the heater (lamp) continues to work to heat the room while the fan does not turn on at all. The temperature of the incubator room continues to increase after heating is done to reach the set point temperature, the time required to reach a temperature of 35 °C is about 17 minutes. This is due to the length of the ice melting process due to the radiation process from the heating lamp.

After that, test was performed after the incubator room temperature was at 32 °C for 5 minutes. Then heating with a hair dryer in the incubator room.

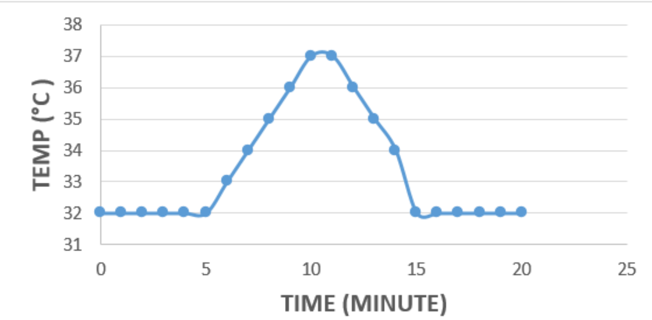


Figure 10: Low Temperature Response Graph

In Figure 10, shows a graph of the response to sudden temperature changes after heating in the 5th minute. It is shown that the temperature rises to 35 ° C after heating for 3 minutes. This condition causes the heater (lamp) to turn off and the fan to remove the hot flame. The system time to return to the 32 ° C value is about 7 minutes. The length of the temperature control process is influenced by the size of the fan in removing hot air.

4. CONCLUSION

Based on the results obtained in this study, we can conclude the following. The DS18B20 sensor can work well to measure the mattress temperature sensor with a percentage error rate in the reading of the temperature sensor of 0.98% to the digital thermometer and 1.23% to the mercury thermometer. The DHT11 sensor can work well in the design and development of temperature and humidity monitoring systems in baby incubators with a percentage error rate in temperature readings of 1.26% on digital thermometers and 1.42% on mercury thermometers. While the percentage error rate in reading humidity is 1.09%. The time required by the system to reach a temperature of 35 ° C after the incubator gets a low temperature is 17 minutes. The time required by the system to reach a temperature of 32 ° C after the incubator gets a high temperature is 7 minutes. Monitoring can be done in real-time and manual control can be done on the web and also displayed on the LCD. If the temperature and humidity do not match the set, then the DC heater or fan will turn on.

REFERENCES

1. Surasmi, A., Handayani, S., dan Kusuma, H.N. **Perawatan Bayi Risiko Tinggi**. Jakarta: Penerbit Buku Kedokteran EGC, 2003.
2. Sen, G. T., & Yuksekkaya, M. **Desing and Test of an Incubator Analyzer**. 2018 2nd International Symposium on Multidisciplinary Studies and Innovative Technologies. 2018.
3. Radhika, B., Rao, V R. **Incubator Baby Parameter Sensing and Monitoring**. *International Journal of Innovative Technology and Exploring Engineering (IJITEE)*, Vol. 8 Issue 7, May 2019.
4. Sendra, S., Romero-Diaz, P. **Smart Infant Incubator Based on LoRa Networks**. *IEEE* 978-1-5386-9120-5/18. 2019
5. Prinyakupt, J., & Roongprasert, K. **Verification Device for Temperature and Relative Humidity Inside the Infant Incubator via IoT**. *2019 12th Biomedical Engineering International Conference (BMEiCON).* 2019.
6. Ashish, B. **Temperature monitored IoT based smart incubator**. 2017 International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud) (I-SMAC). IEEE 978-1-5090-3243-3/17. 2017.
7. S. Meystre. The Current State of Telemonitoring : A Comment on the Literature, vol. 11, no. 1, pp. 63–69. 2005.
8. Azman, N., Wicaksono, S.R., Sinaga, E. Offline-First Sleep Assessment (OFFSA) Internet of Things Polysomnography Sleep Assessment Framework for Sleep Monitoring in Rural Environment. *International Journal of Recent Technology and Engineering (IJRTE)*, Vol. 8 Issue 4, November 2019.
9. Azman, N., Ghani, M. K. A., Wicaksono, S.R., Salahuddin, L. **The Development of IoT Tele-Insomnia Framework to Monitor Sleep Disorder**. *International Journal of Advanced Trends in Computer Science and Engineering*, Vol. 8 Issue 6, November 2019.
10. Azman, N., Ghani, M. K. A., Wicaksono, S.R., Kurniawan. B., Repi, V. V. R. **Insomnia analysis based on internet of things using electrocardiography and electromyography**. *Telecommunitaction, Computing, Electronics and Control*, Vol. 18 Issue 13, June 2020.