Baby Incubator Monitoring Center for Incubator Temperature and Skin Temperature using WiFi Network

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Abstract: Premature infants with birth age less than 38 weeks who have a higher risk of death require continuous monitoring. Therefore, a temperature monitoring system is needed in the incubator. So the purpose of this research is to develop a baby incubator monitoring system that still uses the manual method to be faster and easier. This module has a wireless system and uses a Wi-Fi network for data transmission. By using several ESP32 modules assembled into a central system, where the data obtained from monitoring skin temperature from the DS18B20 sensor and incubator temperature monitoring data from the DHT22 sensor will be processed by the ESP32 which functions as a client and collected at one central point of the ESP32 which has been functioned as a server using the wifi network as data transmission. then the data collected on the server will be displayed on the nextion TFT display. Based on the overall measurement results using 2 baby incubators, the highest error value is 1.387% for the incubator temperature parameter and 3.911% for the skin temperature parameter. The results showed that the module that was made still contained errors in each measurement. The results of this study can be implemented to make it easier for nurses to monitor premature babies easily and quickly.
Keywords*:* Monitoring, Baby Incubator, Temperature, Skin Temperature, Wireless, ESP32

I. INTRODUCTION

Baby incubator is a medical device used for premature care. The function of the Baby incubator is to maintain the warmth and humidity of the baby's body, and prevent respiratory infections in infants and to isolate newborns or premature babies [1]. Normal babies are born with a gestational age of about 38-40 weeks and weigh around 2500-4000 grams, but premature babies are only 37 weeks pregnant or weigh less than 2500 grams [2]–[7]. Premature babies have a higher risk of death compared to babies born at term. This is because they have the ease of adapting to life outside the womb of the immaturity of their organ systems [3], [4], [6], [8], [9]. About half of the worldwide total, or 1.8 million babies each year, die for lack of a consistent heat [3]. Neo-natal mortality in Indonesia is 47% of infant mortality and 3.5% of neonatal deaths due to hypothermia[10]. Therefore, the Baby Incubator is needed in hospitals as an effort to reduce infant mortality, especially those born prematurely [11]. The temperature of the incubator needs to be kept warm around 35°C – 36°C because babies have less fat tissue so they are at risk of developing hypothermia or low body temperature [4], [7]–[9], [12], [13]. Therefore, the baby incubator in the neonate room requires intensive monitoring from medical personnel [14]. Nurses must monitor directly into the room at all times to ensure the temperature in the incubator remains in accordance with the setting temperature. This will increase the workload of medical personnel if they have to monitor several baby incubators [2]. A temperature monitoring system is very much needed in an incubator because at this time a lot of temperature monitoring is still done manually.[5], [11], [15]–[23]. Manual monitoring causes nurses or midwives to frequently enter the nursery to check the temperature of the incubator at regular intervals. This condition can make nurses or midwives tired, which can result in data reading errors[12]. In addition, there is often negligence in monitoring the baby, so that the temperature given to the baby is too hot or too cold due to the incubator heating system that is not maintained regularly and hospital staff are negligent in monitoring the baby's condition. Such negligence will cause the premature baby to die[24].

A baby incubator monitoring tool was made by Rizky Handayani Rayu (2014) with the title Monitoring Temperature and Humidity in an ATmega328 Microcontroller-Based Incubator, the delivery process still uses Bluetooth. In addition, Angga Irsyad Pradita (2016) has also made a baby incubator monitoring tool with the title Monitoring Baby Incubator Via Wireless Equipped with Nursecall. on the device that has been made, the data transmission system still uses HC-11 or bluetooth. In the two studies above, there are similarities, namely in the data transmission system that still uses Bluetooth. In addition to these studies, a baby incubator monitoring center was also created by Furi Kristya P (2019) with the title Baby Incubator Temperature and Humidity Monitoring Center using a wifi network.

Based on the weaknesses and limitations mentioned in previous researchers, among others, 1) Incomplete parameters, 2) The results of previous studies were less than perfect, so the purpose of this study was to create a baby incubator monitoring center tool using a wifi network by trying to improve previous research by addition of skin temperature parameters to be monitored. The use of this tool will be more effective because it can be used to make it easier for users to monitor incubator

temperature parameters and baby skin temperature parameters quickly and practically.

This article consists of: Chapter I contains an introduction, Chapter II contains Materials and Methods, Chapter III on Research Results, Chapter IV Discussion, and Chapter V Conclusions.

II. MATERIALS AND METHODS

A. Experimental Setup

This study used 2 baby incubators for data collection. and data collection was taken by repeating 10 measurements.

B. Materials and Device

This study used a temperature sensor (Dallas, DS18b20, China) as a sensor to measure the baby's skin temperature. and used a temperature sensor (DHT-22, SE-RHT03, China) as the sensor used to measure the incubator temperature. In addition to the two sensors, this study uses a microcontroller (ESP32, ESP32, China) to process data . and using a TFT LCD (Nextion, FT NX3224T028, China) to display data on the measurement results of skin temperature and incubator temperature parameters. And the last one uses a battery as a power supply (Sony, VTC4 18650, Japan). Power bank and charger module (powerbank module, 134N3P, China) for battery charging.

C. Experiment

In this study, after the design of the tool was completed, the instrument was tested using 2 baby incubators. At the calibration stage, the tool that has been made is tested using 1 baby incubator and directly compared the Incu Analyzer with 3 measurement points for temperature settings, at temperatures of 32ºC, 34ºC and 36ºC. then repeated 10 times at each point of measurement of the temperature setting.

D. The Diagram Block

in (**Fig. 1**) The baby incubator temperature sensor, skin sensor, humidity sensor, and noise sensor on the device will read according to the baby incubator temperature, baby skin temperature, humidity, and noise in the baby incubator. The data will be read and sent wirelessly by each ESP 32 which has functioned as a client. Then the data will be sent to another ESP 32 that has been set up and functioned as an server acces point. Then the data received by the ESP 32 access point will be processed and the results will be displayed on the display.

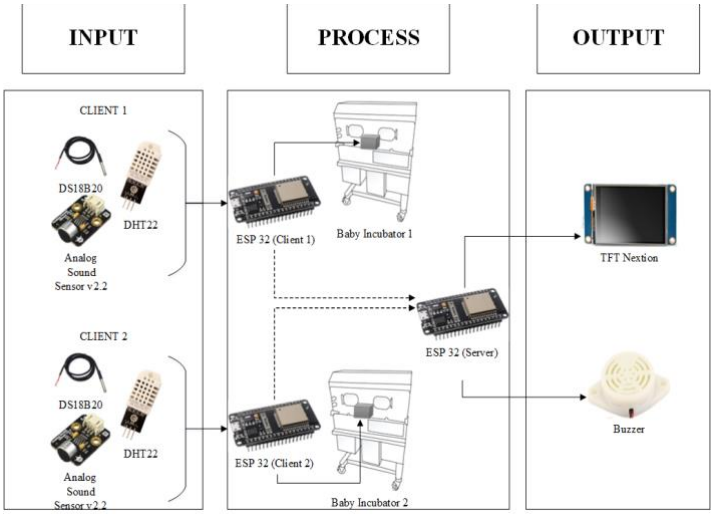

Fig. 1. The diagram block

E. The Flowchart

in (**Fig. 2**) when the On button is pressed, the tool will initialize. all sensors in each client will work to read the temperature of the incubator and skin temperature. then the data is received and processed by ESP32. after the data is processed, the ESP 32 will try to connect to the WiFi ESP 32 which has been set as a server. if not connected, the tool will automatically reconnect until the client and server are connected. and if the device is connected, data will be sent from the client to the server.

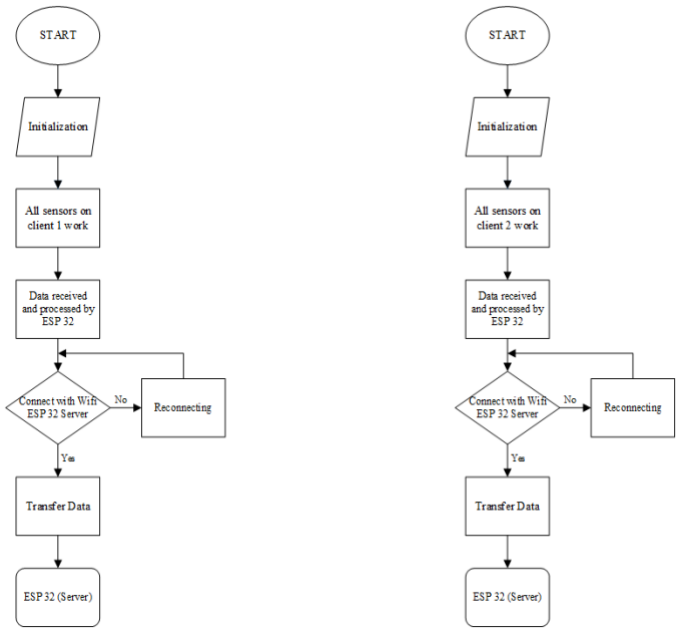

Fig. 2. Client Flowchart

in (**Fig. 3**) when the On button is pressed, the tool will initialize. then the server is connected to each client. and data that has been sent by each client is received by ESP 32 which has been set as an access point server. then the tool will display the monitoring results data. and if the parameters do not match the settings then the buzzer will work.

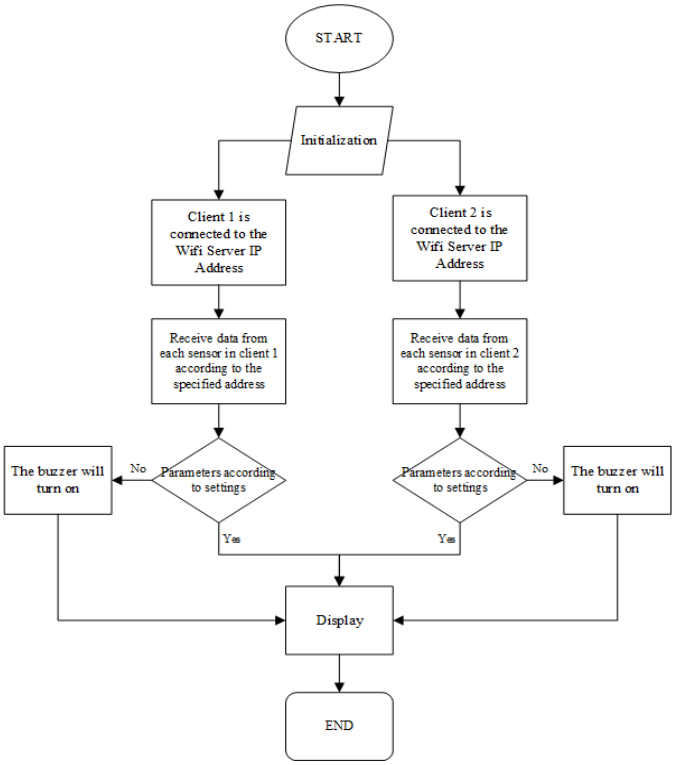

Fig. 3. Server Flowchart

F. Circuit

1) DHT-22 Connection

In **(Fig. 4),** DHT-22 is connected to the ESP-32 circuit by connecting the sensor pin data outputs to digital ESP32.

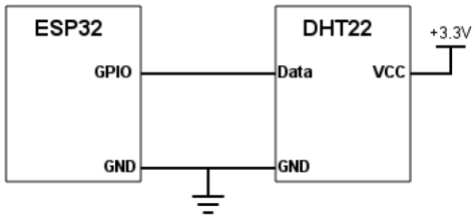

Fig. 4. DHT-22 Connection

2) DS18B20 Connection

In **(Fig. 5)** DS18b20 is connected to the ESP-32 circuit by connecting the sensor pin data outputs to digital ESP32.

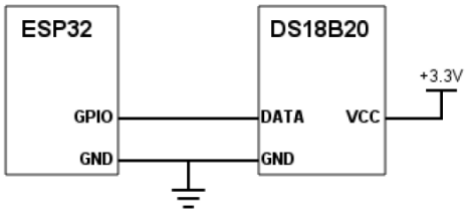

Fig. 5. DS18B20 Connection

3) Nextion Connection

In **(Fig. 6)** DS18b20 is connected to the ESP-32 circuit by connecting the sensor pin data outputs to digital ESP32.

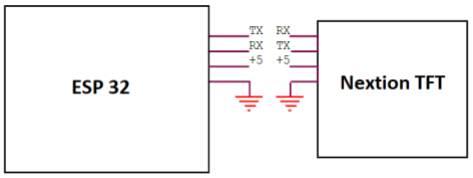

Fig. 6. Nextion Connection

III. RESULTS

A. Display Design

In **(Fig. 7)** is an image of the tool display design when the monitoring process is in progress.

Fig. 7. Display Design

B. The Listing Program for Client

1) Program for ESP 32 WiFi IP Addressing

The function of this program is for ESP 32 WiFi IP addressing.

```
1. IPAddress BISAServer1(192, 168, 4, 1);
2. IPAddress BISAServer1a(192, 168, 4, 1);
3. IPAddress BISAServer1b(192, 168, 4, 1);
4. IPAddress BISAServer1c(192, 168, 4, 1);
5. WiFiClient BISAClient1;
```

2) ESP 32 Wifi connection program

This program is contained in the void setup section. This function is to set up the wifi connection process between the client and server.

```
1. WiFi.mode(WIFI_STA);
2. WiFi.begin("BIASALAH");
3. CheckConnectivity();
```

3) Program to check wifi connectivity

This program functions to detect whether a WiFi connection is connected or not, if it is not connected, it is repeated continuously until the Client and Server are connected.

```
1. void CheckConnectivity(){
2. WHILE (WiFi.status() != WL_CONNECTED)
3. {
4. FOR (int i = 0; i < 10; i++)
5. {
6. Serial.print(".");
7. }
8. Serial.println("");
9. }}
```

4) Sensor reading and sending program

The program is a program for reading data by each sensor and sent to the server in turn according to a predetermined time.

```
1.  void kirim()
2.  {
3.  unsigned long currentMillis2 = millis ();
4.  IF (currentMillis2 - previousMillis2 >= 4000&&a==1)
5.    {
6.       float t = dht.readTemperature();
7.  IF (BISAClient1.connect(BISAServer1a, 8101))
8.    {
9.  stemperature = (String)t;
10. stemperature.toCharArray(tstr, 5);
11  BISAClient1.print (tstr);
12. Serial.println(tstr);
13. previousMillis2=millis();
14. a=2;
15. } }
16. unsigned long currentMillis = millis ();
17. IF (currentMillis - previousMillis >= 3000&&a==0)
18.   {
19.    sensors.requestTemperatures();
20. float skin = sensors.getTempCByIndex(0);
21. IF (BISAClient1.connect(BISAServer1, 8001)){
22. sskin = (String)skin;
23. sskin.toCharArray(sstr, 5);
24. BISAClient1.print (sstr);
25. Serial.println(sstr);
26. previousMillis=millis();
27. a=1;
28. }}
29.
```

C. The Listing Program for Server

1) Program for Addressing data on the server

The above program serves to provide an addressing code for each sensor reading data from the client that has been received by the server (so that the data is not mixed).

```
1.  #define     MAXSC
2.  WiFiServer  BISAServer1(8001);
3.  WiFiServer  BISAServer1a(8101);
4.  WiFiServer  BISAServer1b(8201);
5.  WiFiServer  BISAServer1c(8301);

6.  WiFiServer  BISAServer2(9001);
7.  WiFiServer  BISAServer2a(9101);
8.  WiFiServer  BISAServer2b(9201);
9.  WiFiServer  BISAServer2c(9301);

10. WiFiClient  BISAClient1;
11. WiFiClient  BISAClient2;
```

2) Nextion Serial Program

The program is in the void loop section, the program functions to run serial ESP 32 to Nextion so that the components in Nextion can work and the value of reading data can be displayed on Nextion TFT.

```
1.  terima1();
2.    Serial2.print("t1.txt=\"");
3.    Serial2.print(dskin + "C");
4.    Serial2.print("\"");
5.    Serial2.write(0xff);
6.    Serial2.write(0xff);
7.    Serial2.write(0xff);

8.    terima1a();
9.    Serial2.print("t0.txt=\"");
10.   Serial2.print(dtemperature + "C");
11.   Serial2.print("\"");
12.   Serial2.write(0xff);
13.   Serial2.write(0xff);
14.   Serial2.write(0xff);

15.   Terima2();
16.   Serial2.print("t5.txt=\"");
17.   Serial2.print(dskin2 + "C");
18.   Serial2.print("\"");
19.   Serial2.write(0xff);
20.   Serial2.write(0xff);
21.   Serial2.write(0xff);

22. terima2a();
23.   Serial2.print("t4.txt=\"");
24.   Serial2.print(dtemperature2 + "C");
25.   Serial2.print("\"");
26.   Serial2.write(0xff);
27.   Serial2.write(0xff);
28.   Serial2.write(0xff);
```

3) ESP 32 WiFi setup program

The program serves to set the wifi to be connected, and the program used for settings in order to start wifi access.

```
1.  void SetWifi(char* Name, char* Password){
2.    WiFi.disconnect();

3.    WiFi.mode(WIFI_AP_STA);
4.    Serial.println("WIFI Mode : AccessPoint Station");

5.    BISAssid      = Name;
6.    BISApassword  = Password;

7.    WiFi.softAP(BISAssid, BISApassword);
8.    Serial.println("WIFI < " + String(BISAssid) + " > ...
9.  Started");
10.   delay(1000);

11.   IPAddress IP = WiFi.softAPIP();
12.   Serial.print("AccessPoint IP : ");
13.   Serial.println(IP);

14.  // Starting Server
15.   BISAServer1.begin();
```

```
16.   BISAServer1a.begin();
17.   BISAServer1b.begin();
18.   BISAServer1c.begin();

19.   BISAServer2.begin();
20.   BISAServer2a.begin();
21.   BISAServer2b.begin();
22.   BISAServer2c.begin();
23.   Serial.println("Server Started"); }
```

4) Sensor Reading Data Receiver Program

The program is a program when the server is connected to client 1 and client 2, then the server will receive data readings of the incubator temperature parameters and skin temperature parameters from each client.

```
1.  void terima1(){
2.    WiFiClient BISAClient1 = BISAServer1.available();
      IF (BISAClient1.connected())
3.    {
4.      skin = BISAClient1.readStringUntil('sstr');
5.      dskin = (String)skin;
6.      Serial.println("suhu skin:" + dskin + "°C");
7.    }}

8.  void terima2()
9.  {
10.   WiFiClient BISAClient2 = BISAServer2.available();
11.   IF (BISAClient2.connected())
12.   {
13.     skin2 = BISAClient2.readStringUntil('cstr');
14.     dskin2 = (String)skin2;
15.     Serial.println("suhu skin2:" + dskin2 + "°C");
16.   }}

17. void terima1a()
18. {
19.   WiFiClient BISAClient1 =
20. BISAServer1a.available();
21.   IF (BISAClient1.connected())
22.   {
23.     temperature = BISAClient1.readStringUntil('tstr');
24.     dtemperature = (String)temperature;
25.     Serial.println("suhuu:" + dtemperature + "°C");
26.   }}

27. void terima2a()
28. {
29.   WiFiClient BISAClient2 =
30. BISAServer2a.available();
31.   IF (BISAClient2.connected())
32.   {
33.     temperature2 =
34. BISAClient2.readStringUntil('astr');
35.     dtemperature2 = (String)temperature2;
36.     Serial.println("suhuu2:" + dtemperature2 + "°C");
37.   }}
```

D. Measurement Results

1) Incubator Temperature Parameters

In (**TABLE I**), is the result of measuring the incubator temperature parameter at the temperature setting point of 32°C. Data is collected when the temperature has started to stabilize. Data collection was carried out with 10 measurements. during the measurement process this tool is compared with the incubator display. From the measurement results of the 32°C incubator temperature parameters, the smallest error value was obtained for client 1 with a value of 1.059% for the highest error value for client 2 of 1.153%.

TABLE I. RESULT OF MEASURING THE INCUBATOR TEMPERATURE PARAMETER AT THE TEMPERATURE SETTING POINT OF 32°C

Data	Client 1		Client 2	
	Incubator 1	Tool	Incubator 2	Tool
1	32.1°C	32.4°C	32.1°C	31.7°C
2	32.1°C	32.4°C	32.1°C	31.7°C
3	32.1°C	32.4°C	32.1°C	31.7°C
4	32.1°C	32.4°C	32.1°C	31.7°C
5	32.1°C	32.4°C	32.1°C	31.7°C
6	32.1°C	32.4°C	32.1°C	31.7°C
7	32.1°C	32.5°C	32.1°C	31.7°C
8	32.1°C	32.5°C	32.1°C	31.8°C
9	32.1°C	32.5°C	32.1°C	31.8°C
10	32.1°C	32.5°C	32.1°C	31.8°C
Average	32.1	32.44	32.1	31.73
Error %		1.059%		1.153%

In (**TABLE II**), is the result of measuring the incubator temperature parameter at the temperature setting point of 34°C. Data is collected when the temperature has started to stabilize. Data collection was carried out with 10 measurements. during the measurement process this tool is compared with the incubator display. From the measurement results of the 34°C incubator temperature parameters, the smallest error value was obtained for client 2 with a value of 0.588% for the highest error value for client 1 of 0.736%.

TABLE II. RESULT OF MEASURING THE INCUBATOR TEMPERATURE PARAMETER AT THE TEMPERATURE SETTING POINT OF 34°C

Data	Client 1		Client 2	
	Incubator 1	Tool	Incubator 2	Tool
1	34°C	34.2°C	34°C	33.8°C
2	34°C	34.2°C	34°C	33.8°C
3	34°C	34.2°C	34°C	33.8°C
4	34°C	34.2°C	34°C	33.8°C
5	34°C	34.2°C	34°C	33.8°C
6	34°C	34.3°C	34°C	33.8°C
7	34°C	34.3°C	34°C	33.8°C
8	34°C	34.3°C	34°C	33.8°C
9	34°C	34.3°C	34°C	33.8°C
10	34°C	34.3°C	34°C	33.8°C
Average	34	34.25	34	33.8

Error %		0.736%		0.588%

In (**TABLE III**), is the result of measuring the incubator temperature parameter at the temperature setting point of 36°C. Data is collected when the temperature has started to stabilize. Data collection was carried out with 10 measurements. during the measurement process this tool is compared with the incubator display. From the measurement results of the 36°C incubator temperature parameters, the smallest error value was obtained for client 2 with a value of 0.055% for the highest error value for client 1 of 1.387%.

TABLE III. RESULT OF MEASURING THE INCUBATOR TEMPERATURE PARAMETER AT THE TEMPERATURE SETTING POINT OF 36°C

Data	Client 1		Client 2	
	Incubator 1	Tool	Incubator 2	Tool
1	36.1°C	36.6°C	36°C	36.2°C
2	36.1°C	36.6°C	36°C	36.2°C
3	36.1°C	36.6°C	36°C	36.2°C
4	36.1°C	36.6°C	36°C	36.1°C
5	36.1°C	36.6°C	36°C	36.1°C
6	36°C	36.5°C	36°C	35.8°C
7	36°C	36.5°C	36°C	35.8°C
8	36°C	36.5°C	36°C	35.8°C
9	36°C	36.5°C	36°C	35.8°C
10	36°C	36.5°C	36°C	35.8°C
Average	36.05	36.55	36	35.98
Error %		1.387%		0.055%

2) Skin Temperature Parameters

In (**TABLE IV**), is the result of measuring the skin temperature parameter at the temperature setting point of 32°C. Data is collected when the temperature has started to stabilize. Data collection was carried out with 10 measurements. during the measurement process this tool is compared with the incubator display. From the measurement results of the 32°C skin temperature parameters, the smallest error value was obtained for client 1 with a value of 0.778% for the highest error value for client 2 of 1.246%.

TABLE IV. RESULT OF MEASURING THE SKIN TEMPERATURE PARAMETER AT THE TEMPERATURE SETTING POINT OF 32°C

Data	Client 1		Client 2	
	Incubator 1	Tool	Incubator 2	Tool
1	32.1°C	32.3°C	32.1°C	31.7°C
2	32.1°C	32.3°C	32.1°C	31.7°C
3	32.1°C	32.3°C	32.1°C	31.7°C
4	32.1°C	32.3°C	32.1°C	31.7°C
5	32.1°C	32.3°C	32.1°C	31.7°C
6	32.1°C	32.4°C	32.1°C	31.7°C
7	32.1°C	32.4°C	32.1°C	31.7°C
8	32.1°C	32.4°C	32.1°C	31.7°C
9	32.1°C	32.4°C	32.1°C	31.7°C
10	32.1°C	32.4°C	32.1°C	31.7°C
Average	32.1	32.35	32.1	31.7
Error %		0.778%		1.246%

In (**TABLE V**), is the result of measuring the skin temperature parameter at the temperature setting point of 34°C. Data is collected when the temperature has started to stabilize. Data collection was carried out with 10 measurements. during the measurement process this tool is compared with the incubator display. From the measurement results of the 34°C skin temperature parameters, the smallest error value was obtained for client 1 with a value of 3.824% for the highest error value for client 2 of 3.911%.

TABLE V. RESULT OF MEASURING THE SKIN TEMPERATURE PARAMETER AT THE TEMPERATURE SETTING POINT OF 34°C

Data	Client 1		Client 2	
	Incubator 1	Tool	Incubator 2	Tool
1	34°C	35.3°C	34°C	35.3°C
2	34°C	35.3°C	34°C	35.3°C
3	34°C	35.3°C	34°C	35.3°C
4	34°C	35.3°C	34°C	35.3°C
5	34°C	35.3°C	34°C	35.3°C
6	34°C	35.3°C	34°C	35.3°C
7	34°C	35.3°C	34°C	35.3°C
8	34°C	35.3°C	34°C	35.4°C
9	34°C	35.3°C	34°C	35.4°C
10	34°C	35.3°C	34°C	35.4°C
Average	34	35.3	34	35.33
Error %		3.824%		3.911%

In (**TABLE VI**), is the result of measuring the skin temperature parameter at the temperature setting point of 36°C. Data is collected when the temperature has started to stabilize. Data collection was carried out with 10 measurements. during the measurement process this tool is compared with the incubator display. From the measurement results of the 36°C skin temperature parameters, the smallest error value was obtained for client 2 with a value of 0.833% for the highest error value for client 1 of 2.358%.

TABLE VI. RESULT OF MEASURING THE SKIN TEMPERATURE PARAMETER AT THE TEMPERATURE SETTING POINT OF 36°C

Data	Client 1		Client 2	
	Incubator 1	Tool	Incubator 2	Tool
1	36.1°C	35.3°C	36°C	36.5°C
2	36.1°C	35.3°C	36°C	36.5°C
3	36.1°C	35.3°C	36°C	36.5°C
4	36.1°C	35.3°C	36°C	36.5°C
5	36.1°C	35.3°C	36°C	36.5°C
6	36°C	35.1°C	36°C	36.1°C
7	36°C	35.1°C	36°C	36.1°C
8	36°C	35.1°C	36°C	36.1°C
9	36°C	35.1°C	36°C	36.1°C
10	36°C	35.1°C	36°C	36.1°C
Average	36.05	35.2	36	36.3
Error %		2.358%		0.833%

IV. DISCUSSION

In previous studies, the manufacture of baby incubator monitoring tools with various delivery methods has been discussed, but in previous studies it is still lacking and can be further developed. In addition, the monitored incubator parameters are also incomplete. Therefore, to follow up on previous research as mentioned above, a study was carried out to create a baby incubator monitoring center tool using a WIFI network by adding parameters.

V. CONCLUSION

This research has demonstrated that the progress of monitoring baby incubator parameters, which is currently still being done manually, is faster and easier. This research is built based on microcontrollers from several ESP32 which have been assembled into a unified central system where the temperature monitoring data from the DHT22 and DS18B20 sensors will be processed by the ESP32 which functions as a client and collected at one central point of the ESP32 which has functioned as a server using a wifi network as delivery. the data. then the data that has been collected on the server will be displayed on the Nextion LCD display. Based on the overall measurement results using 2 baby incubators, the highest error value is 1.387% for the incubator temperature parameter and 3.911% for the skin temperature parameter. The results showed that the module that was made still contained errors in each measurement. The results of this study can be implemented to make it easier for nurses to monitor premature babies easily and quickly.

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ATTACHMENT

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