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Baby Incubator Monitoring Center for Temperature and Humidity using WiFi Network

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ABSTRACT Monitoring the condition of premature babies inside the baby incubator is very necessary. Babies who are born prematurely with a birth age of less than 38 weeks have a higher risk of death and difficulty to adapt outside the womb due to immaturity of the organ system. Premature babies need continuous monitoring by the nurse to find out the baby's body condition remains stable in temperature and humidity to match the conditions in the womb. The purpose of this research to develop a baby incubator temperature and humidity monitoring system quickly and practically. As technology develops, the monitoring process that was initially carried out by looking directly at the baby incubator display, now developed with various innovations that make it easier to monitor premature babies. The baby incubator temperature and humidity monitoring center module via the WIFI network uses a temperature sensor and DHT 22 which will be sent via WIFI ESP 32 and the values obtained will be displayed on the Nextion TFT display. Based on the measurement results obtained the largest temperature error value of 2.083% at the incubator client 1 temperature at the measurement point 32 ° C. The results showed that the device has an average error suitable for use, because based on ECRI 415-20010301-01, the maximum allowable error limit is ± 1 ° C. The results of this study can be implemented to make it easier for nurses to monitor premature babies to avoid neglect.

INDEX TERMS Baby Incubator, Temperature, Humidity, Wireless, ESP32.

I. INTRODUCTION

Baby incubators are medical devices used to provide intensive care or protection for babies who have premature births and low birth weight. Normal infants are born with a gestational age of about 38-40 weeks with a body weight of around 2500-4000 grams, but in premature infants the age of the womb is only 37 weeks or a body weight of less than 2500 grams of baby [1][2]. Baby incubators help doctors monitor all the different aspects around the baby's environment, and make conditions similar to those in the mother's womb. Baby incubators help maintain the lives of premature babies and reduce infant mortality rates [3][4]. Various problems can be caused by premature birth. Premature babies have a higher risk of death compared to babies born at term. This is because they have difficulty adapting to life outside the womb due to the immaturity of their organ systems [5][4]. Newborns lose four times more heat than adults, resulting in a decrease in temperature. In the first 30 minutes the baby can experience a temperature drop of 3-4 °C.. In a room with a temperature of 20-25 °C baby's skin temperature drops around 0.3 °C per minute. The decrease in temperature is caused by heat loss by conduction, convection, evaporation and radiation. The baby's ability is not perfect in producing heat so the baby is very susceptible to experiencing hypothermia [6]–[9]. To avoid hypothermia, premature babies will be placed in a baby incubator to keep the baby's temperature and humidity stable. The temperature of the baby incubator is kept within normal limits around 32 °C to 36 °C and the temperature of the baby's skin is kept at normal temperatures around 36 °C to 37 °C. Besides this humidity is also responsible for providing warmth to the breath and moist air entering the baby's lungs. The relative humidity needed> 70% [7], [10]–[12]. Humidity needs to be maintained also to help the stability of the baby's body temperature [13]. The baby incubator in the neonate room requires intensive monitoring from medical personnel to see the temperature and humidity. If the temperature of the incubator is hotter it can cause the baby's skin to burn, and if it is colder than the temperature needed it can cause hypothermia. Infants who experience heat loss (hypo-termia) are at high risk for getting sick or dying [8]. Neo-natal mortality in Indonesia is 47% of infant mortality and 3.5% of neonatal deaths due to hypothermia [14]. So that nurses at all times must monitor directly into the room to ensure the temperature at the incubator remains in accordance with the setting temperature. Every baby in an incubator has special care and is monitored at a certain time. However, negligence often occurs in monitoring the baby who is in the incubator, 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 the servant The hospital is negligent in monitoring the temperature of the incubator, causing premature babies to die due to such negligence [15].

Baby incubator monitoring was once made by Shaib et. al with the title Monitoring Baby Incubator Through a Wireless Computer Network, the device was delivered using Xbee Pro [4]. Weaknesses in this tool are data processing and display processes using a computer. It was also made by Azkiyak et. al proposed a temperature and humidity monitoring basedon on the ATmega328 Microcontroller for Incubator Baby design, the delivery process still uses HC-12 wirelles but the device still uses wires [1]. So it requires a long cable if you want to take measurements outside. Then once made by Hannouch et. al proposed a monitoring baby incubator via wireless equipped nursecall, the delivery process is still using HC-11 and display using a computer [13]. Sendra et. al had made temperature and humidity monitoring application based on Internet for Baby Incubators, but this device still uses a PC display [16]. In 2013, Shabaan proposed a temperature and humidity monitoring device based on internet for baby incubator, but this device still uses Character LCD to display the parameters [17].

Based on these problems, the aims of this study is to design a temperature and humidity monitoring center for baby incubators based on a WIFI network". This device can be used to facilitate the temperature and humidity monitoring of the incubator quickly and practically. This Article is composed of: Chapter 1 introduction, Chapter 2 Materials and Methods, Chapter 3 Results, Chapter 4 Discussion, Chapter 5 Conclusion, and Chapter 6 Reference

II. MATERIALS AND METHODS

A. EXPERIMENTAL SETUP

This study was used in preterm infants with births of less than 37 weeks. Data retrieval is done with 6 trials.

B. MATERIALS AND DEVICE

This study uses temperature sensors (Dallas, DS18b20, China) to measure skin temperature in infants. Humidity sensor (DHT-22, SE-RHT03, China) is used to measure the temperature and humidity of a baby incubator. Microcontroller (ESP32, ESP32, China) for processing data [18]–[21]. LCD (Nextion, FT NX4827T043, China) for displaying temperature and humidity data [22]. Use the battery as a power supply (Toshiba, Li-ion, China). Charger module (Eshinede, AL540954336142, China) for battery charging. Thermohygrometer (Goldgood, HTC-6, China) is used as a comparison tool.

C. EXPERIMENT

In this study, the researchers measured the temperature and humidity values in the baby's incubator and skin temperature in premature babies.

D. THE DIAGRAM BLOCK

In (**Fig. 1**), the baby incubator temperature sensor, skin sensor and humidity sensor on the device will read according to the baby incubator temperature, the baby's skin temperature, and the humidity present in the baby incubator. The data will be read by and will be transmitted wirelessly by ESP 32 which has been designated as a client. The data is sent to another ESP 32 which is set as an access point. Data received by the ESP 32 access point will be obtained and the results will be displayed on the display.

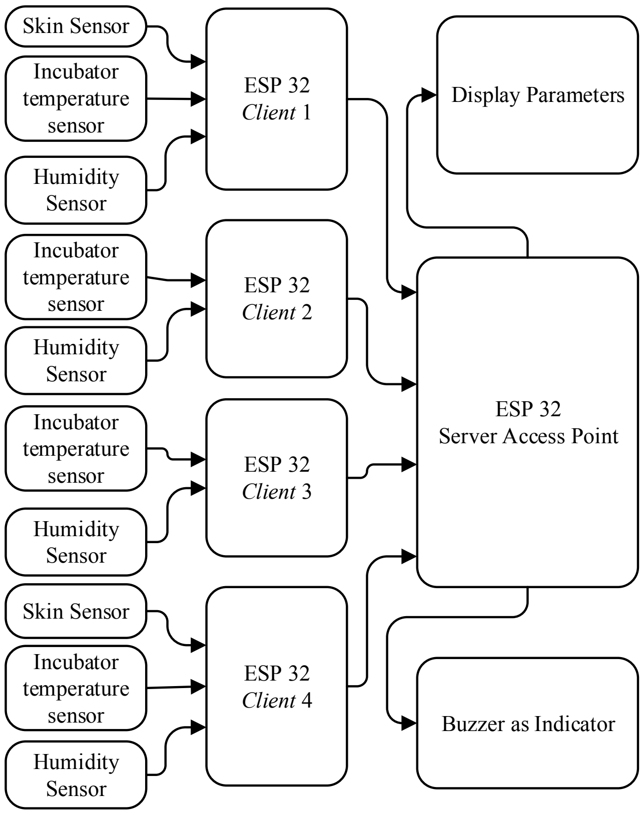

Fig 1. The diagram block

E. THE FLOWCHART

In (**Fig. 2**), when the On button is pressed, ESP32 will initialize the LCD. Then the sensor will read the temperature and humidity. The data obtained will be sent through ESP32 which has been set up as a client to ESP32 which has been set as an access point server. Data will be received by the ESP32 server access point and will be processed on ESP32. If the received skin temperature matches the specified set point, it will be displayed on the TFT LCD. If it does not match, the buzzer will light as a sign that the skin temperature does not match the set point. And the value of the skin temperature that is not appropriate will also be displayed on the TFT LCD.

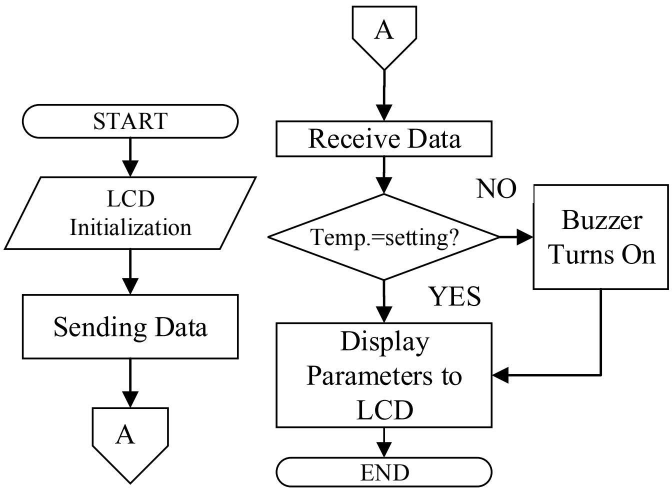

Fig 2. The Flowchart

F. CIRCUIT

1) DHT-22 AND DS18B20 CONNECTION

In (**Fig. 3**), DHT-22 is connected to the ESP-32 circuit by connecting the sensor pin data outputs to digital ESP32. In (**Fig. 4**) DS18b20 is connected to the ESP-32 circuit by connecting the sensor pin data outputs to digital ESP32.

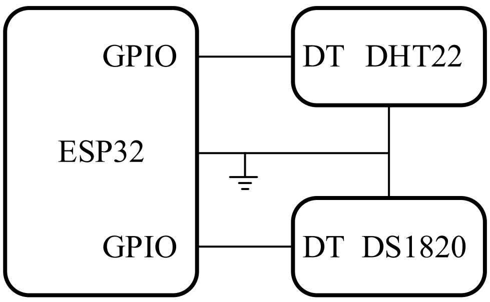

Fig 3. DHT-22 Connection

2) BLUETOOTH CONNECTION

In (**Fig. 5**) Nextion circuit TFT LCD which is connected to an ESP-32 by connecting pin ESP32 TX to Nextion TFT LCD pin, ESP32 pin RX to TX Nextion TFT LCD pin.

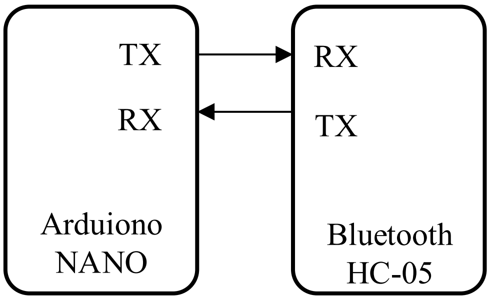

Fig 4. Nextion connection

III. RESULTS

A. RESULTS OF MEASUREMENTS

In (**Fig. 6**), researchers measured the incubator temperature and humidity values using a baby incubator and the baby's skin temperature using phantom gel [23]–[26], and the results were compared with the standard.

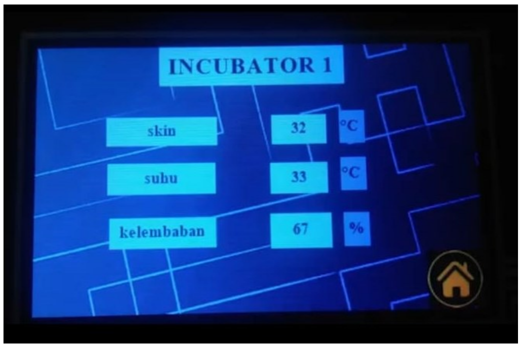

Fig 5. Results of measurements

B. TEMPERATURE MEASUREMENT RESULT FOR CLIENT 1 AND CLIENT 2

In (**TABLE I**), the results of the comparison between modules and comparator clients 1 and 2 at a temperature of 35 ° C. Data is collected when the temperature has begun to stabilize. Data collection was carried out with 6 measurements at each temperature. This instrument was compared with a thermohigrometer comparison device. From the measurement results of temperature 35 ° C obtained the smallest error value at the skin temperature of client 2 with a value of 0.191% for the highest error value at the incubator temperature of client 1 and client 3 with 0.333%.

TABLE I. TEMPERATURE MEASUREMENT RESULT FOR CLIENT 1 AND CLIENT 2

No	Client 1				Client 2			
	Incubator Temp. (°C)		Skin Temp. (°C)		Incubator Temp. (°C)		Skin Temp. (°C)	
	A	P	A	P	A	P	A	P
1	35	34.9	34.8	34.9	35	35	34.9	35
2	35.2	35	35	35	35.1	35.1	35	35.1

3	35	34.9	34.7	34.9	35	34.9	34.9	34.9
4	35.1	35	34.9	35	35.1	35	34.9	35
5	35.2	35.1	35	35.1	35	34.9	34.8	34.9
6	35.1	35	35	35	35.2	35	35	35
Mean	35.1	34.98	34.9	34.98	35.06	34.98	34.91	34.98
SD	0.089	0.075	0.126	0.075	0.082	0.075	0.075	0.075
Error %	-0.333 %		0.238 %		-0.238 %		0.191 %	

C. TEMPERATURE MEASUREMENT RESULT FOR CLIENT 3 AND CLIENT 4

In (**TABLE II.**), the results of the comparison between modules and comparator clients 3 and 4 at a temperature of 35 ° C. Data is collected when the temperature has begun to stabilize. Data collection was carried out with 6 measurements at each temperature. This instrument was compared with a thermohigrometer comparison device. From the measurement results of temperature 35 ° C obtained the smallest error value at the skin temperature of client 2 with a value of 0.191% for the highest error value at the incubator temperature of client 1 and client 3 with 0.333%.

TABLE II. TEMPERATURE MEASUREMENT RESULT FOR RESPONDEN

Data	Client3		Client 4	
	Incubator Temp. (°C)		Incubator Temp. (°C)	
	Design	Cal.	Design	Ca.
1	35	34.9	35.1	35
2	35.1	35	35	35
3	35.2	35.1	35	34.9
4	35.1	35	35.1	35
5	35	34.9	35.3	35.1
6	35.2	35	35	34.9
mean	35.100	34.983	35.083	34.983
SD	0.089	0.075	0.117	0.075
Error %	-0.333 %		-0.286 %	

IV. DISCUSSION

In previous studies discussing making baby incubator monitoring tools with various sensors and delivery methods, but in previous studies there are still many shipping methods that must use a PC and router. Therefore, to follow up on the previous research as mentioned above, the research was carried out to make a temperature and humidity monitoring tool for baby incubators via a WIFI network.

V. CONCLUSION

After making the Baby Incubator Temperature and Humidity Monitoring Center module via a WIFI network using ESP-32 displayed on the TFT LCD, it is concluded that the device is suitable for use, because based on ECRI 415-20010301-01, the maximum allowable error limit is ± 1 ° C The testing of this tool is done by comparing the module with a standard measurement tool that produces a value of 2.090% at incubator 1 client temperature at a measurement point of 32 ° C. The results of this study can be implemented on an infant incubator to test premature babies and help neglect. Further development of this research can use temperature sensors and humidity sensors which have a higher level of accuracy

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APPENDIX

A. *Listing program for Client*

This program to include the library ESP32, DHT22, temperature sensor, to connect with ESP32. In addition, the above program is an initialization to set ESP32 as a client.

```
#include <esp_now.h>
#include <WiFi.h>
#include <OneWire.h>
#include <DallasTemperature.h>
#include "DHT.h"
#define DHTPIN 15
#define DHTTYPE DHT22

//-------------------------------------------------------------------
--------------
#define ONE_WIRE_BUS 4
#define CHANNEL 1
#define SENDCHANNEL 1
#define WIFI_DEFAULT_CHANNEL 1


OneWire oneWire(ONE_WIRE_BUS);
DallasTemperature sensors(&oneWire);
DHT dht(DHTPIN, DHTTYPE);

uint8_t  ba[] = {0xA4, 0xCF, 0x12, 0x75, 0x92, 0x80};
esp_now_peer_info_t peer;

void initESPNow();
void configDeviceAP();
void addPeer(uint8_t *peerMacAddress);
void onDataSent(const uint8_t *ba, esp_now_send_status_t
status);
void onDataRecv(const uint8_t *mac_addr, const uint8_t
*data, int data_len);
int atur1 = 0;
int atur = 0;
typedef struct struct_message1 {
  float suhu1;
  float kelembapan1;
} struct_message1;

struct_message1 client1;
```

B. *Program for sensors*

The temperature sensor is connected to pin 4 and the DHT-22 sensor to pin 15. When the client succeeds in sending data to the access point server, "Sent with success" will appear on the serial monitor. When unable to send data, a "Error sending the data" message will appear. Sensor readings will be updated every 2000ms.

```
void loop()
{
  float h = (dht.readHumidity());
  float t = dht.readTemperature();
  float ta = t;
  addPeer(ba);
  client1.suhu1 = h;
  client1.kelembapan1 = t;

  esp_err_t result = esp_now_send(ba, (uint8_t *) &client1,
sizeof(client1));
  if (result == ESP_OK) {
    Serial.println("Sent with success");
  }
  else {
    Serial.println("Error sending the data");
  }
  delay(2000);
}
```

C. *Listing program for connection and delivery process*

This program is for the connection process between client and server. As well as programs to find out whether the client and server have connected or failed to connect.

```
void configDeviceAP()
{
  String Prefix = "Slave:";
  String Mac = WiFi.macAddress();
  String SSID = Prefix + Mac;
  String Password = "123456789";
  bool result = WiFi.softAP(SSID.c_str(), Password.c_str(),
CHANNEL, 0);
  if (!result)
  {
    Serial.println("AP Config failed.");
  }
  else
  {
    Serial.println("AP Config Success. Broadcasting with
AP: " + String(SSID));
  }
}
void addPeer(uint8_t *peerMacAddress)
{
  peer.channel = SENDCHANNEL;
  peer.ifidx = WIFI_IF_AP;
  peer.encrypt = 0;
  memcpy(peer.peer_addr, peerMacAddress, 6);
  esp_err_t addStatus = esp_now_add_peer(&peer);
  if (addStatus == ESP_OK)
  {
```

```
    // Pair success
    Serial.println("Pair success");
  }
  else if (addStatus == ESP_ERR_ESPNOW_NOT_INIT)
   {
    Serial.println("ESPNOW Not Init");
   }
   else if (addStatus == ESP_ERR_ESPNOW_ARG)
   {
    Serial.println("Add Peer - Invalid Argument");
   }
   else if (addStatus == ESP_ERR_ESPNOW_FULL)
   {
    Serial.println("Peer list full");
   }
   else if (addStatus == ESP_ERR_ESPNOW_NO_MEM)
   {
    Serial.println("Out of memory");
   }
   else if (addStatus == ESP_ERR_ESPNOW_EXIST)
   {
    Serial.println("Peer Exists");
   }
   else
   {
    Serial.println("Not sure what WENT WRONG");
   }
  }

// callback when data is sent from Master to Slave
void onDataSent(const uint8_t *ba, esp_now_send_status_t
status)
{
  char macStr[18];
  snprintf(macStr, sizeof(macStr),
"%02x:%02x:%02x:%02x:%02x:%02x",
           ba[0], ba[1], ba[2], ba[3], ba[4], ba[5]);
Serial.print("Last Packet Sent to: ");
  Serial.println(macStr);
  Serial.print("Last Packet Send Status: ");
  Serial.println(status == ESP_NOW_SEND_SUCCESS ?
"Delivery Success" : "Delivery Fail");
}
  Serial.print("Last Packet Sent to: ");
  Serial.println(macStr);
  Serial.print("Last Packet Send Status: ");
  Serial.println(status == ESP_NOW_SEND_SUCCESS ?
"Delivery Success" : "Delivery Fail");
}
```