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Eight Channel Temperature Monitoring using Thermocouple Sensors (Type K) Based on Internet of Thing using ThinkSpeak Platform

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ABSTRACT A laboratory incubator is a tool used to incubate offspring. A very important factor in the Incubator procedure is the optimal temperature conditions for the growth of microorganisms. An incubator is equipped with a temperature controller so that the temperature can be adjusted according to the breed to be raised. In this case, the incubators use an oven-like dry heat. The purpose of this study was to test and analyze the accuracy of the thermocouple sensor of an incubator in a laboratory incubator calibrator. The design method used was the 8 MAX 6675 module, the 8 K type Thermocouple module, Arduino Mega, and SD Card data storage. Temperature measurements were carried out using a Type K thermocouple sensor. The thermocouple sensor has 8 channels which function to measure the temperature at each chamber point of the incubator. Furthermore, the temperature was stored in the SD card for data analysis and the data can be processed in graphical form. Benchmarking was done using a temperature data logger. This was done so that the design results were below the standard comparison tool. The measurement results on the module compared to the comparison tool obtained the largest error value, namely 3.98% on channel T6 at 35°C with ordinary incubator media. Meanwhile, the smallest error on ordinary incubator media was at point T6 by 37°C, which is 0.06 %. In addition, at 35ºC, the temperature of the incubator fan had the largest error of 2.98% and the smallest error of 0.86%. In this case, the design of this module is very important for monitoring bacterial growth, where setting the temperature sensor at each point can provide a good picture of the temperature distribution.

INDEX TERMS Incubator laboratory, Thermocouple, Calibration, IoT.

I. INTRODUCTION

A laboratory incubator is a tool used to incubate a breed [1]. Incubators provide optimum temperature conditions for microorganisms to grow [2]. It also has a temperature regulator so that the temperature can be adjusted according to the breed to be incarnated. Incubators take advantage of hot-dry-like ovens [3][4][5]. In some types of incubators, humidity is provided by providing water in the incubator during the microbial growth [6]. This allows a wet environment that slows down the dehydration of the medium, thereby avoiding biased environmental conditions [7]. Laboratory or bacteria incubators generally use temperatures between 35°C and 37°C for testing the total Coli bacteria, which is a total group of aerobic facultative anaerobic bacteria, gram-negative, rod-shaped, does not form spores that can ferment lactose by producing acid and gas at that temperature and the time [8][9][10][11].

Meanwhile, previously conducted research by Laura Valdes-Mora validated a laboratory incubator using a thermocouple data logger and wireless. This study used a measurement tool that has been calibrated, while the data compared were the result of measurements from a thermocouple datalogger and wireless with 2 conditions in the incubator (filled condition and empty condition). In this case, the thermocouple used was a type T thermocouple [12]. Furthermore, Dadan Saepul Rahman, designed a vaccine refrigerator monitoring device with a microcontroller at a temperature of 2°C to 8°C, where the researcher has communicated with the pc [13]. However, the research has several disadvantages including did not use wireless monitoring yet. Another research project was carried out by Rizkiyatussani who designed a temperature calibrator tool with 5 (five) channels or 5 (five) temperature distribution points equipped with data storage on micro-SD. The researchers used a type K thermocouple sensor with temperature measuring points of 50°C, 100°C, and 150°C. The lack of analysis was at 50°C, 100°C, and 150°C, while the temperature needed for the incubation process was 35°C and 37°C. In addition, the study has not used wireless technology yet [14]. Furthermore, Aninda Zakia Febriyanti also designed a temperature calibrator [15], where this tool used type K thermocouple sensors. The advantages of this tool was that it already used 5 (five) sensors and data storage using EEPROM. Meanwhile, the lack of the study was the same as previous researchers, namely the absence of wireless technology, and the temperature examined was not the temperature needed for bacterial incubation which is 35°C and 37°C [16]. In another study, a simple and low-cost humidity/temperature calibration system with a data logger was designed by Yasser A. Abdelaziz, with the temperature range started from 5°C to 50°C and from 50% RH to 98% RH for humidity. The lack of the design is that it was not equipped with a wireless data transmission system [17]. Furthermore, Olivia Ratna Yunita designed a temperature calibrator device with a thermocouple using an air medium and a stationer with a temperature of 30°C and 100°C. The advantages of this tool is that it displayed real-time graphics with pl-DAQ application. Meanwhile, the lack of the research is that the temperature media used was at 30°C of the room temperature and the use of wireless connections is still limited by distance [18]. Puspasari Fitri also has studied temperature and humidity comparison tests using an Arduino-based DHT22 sensor with a thermos-hygrometer [19]. The study reviewed the growing technological developments to facilitate temperature and humidity measurement using Arduino-based DHT22 sensors. Based on these results, accuracy was considered good and acceptable because it is in accordance with the DHT22 sensor sheet data, while the measured humidity must have a range between 2-5% and ± 5°C [20]. This analysis has the advantage of using standard thermos-hygrometer as the comparison tool of temperature deficiencies measured at room temperature. Meanwhile, the disadvantage of this research is the absence of controlled media temperature and thermocouple sensors analysis to examine the performance of two temperature sensors. For detecting the excess room temperature, this researcher used room temperature conditioning that is Air conditioning. In this case, the lack of the research is that they have not examined thermocouple sensor on controlled temperature media at a temperature of 35.37°C [21]. Yoga Alif Kurnia Utama in 2016 performed his research on comparing the skin of temperature sensors. This research has used four temperature sensors namely LM35 sensor, DHT11, DHT22 and DS18B20, while the weaknesses of this study is that the thermocouple sensors in controlled temperature media has not been revealed [22].

Based on the background related to the previous studies above, current research was done aiming to test or analyze the accuracy of the type k thermocouple temperature sensor by sending data using the internet network. Therefore, it is expected that by setting and placing the temperature sensor, it can monitor the optimal distribution of temperature distribution on bacterial growth [23]. Furthermore, the contributions of this research are to provide a good impact on bacterial growth, to monitor the bacterial growth using remote control system through a temperature regulation, and become a reference for temperature calibrator design.

II. MATERIALS AND METHODS

A. *EXPERIMENTAL SETUP*

The study collected the research data at 8 points in the media incubator laboratory with temperatures at 35°C and 37°C. In addition, this research also compared the modules and the manufacturer's thermometer. This research used max6675 [24] as the signal amplifier thermocouple sensor, where the

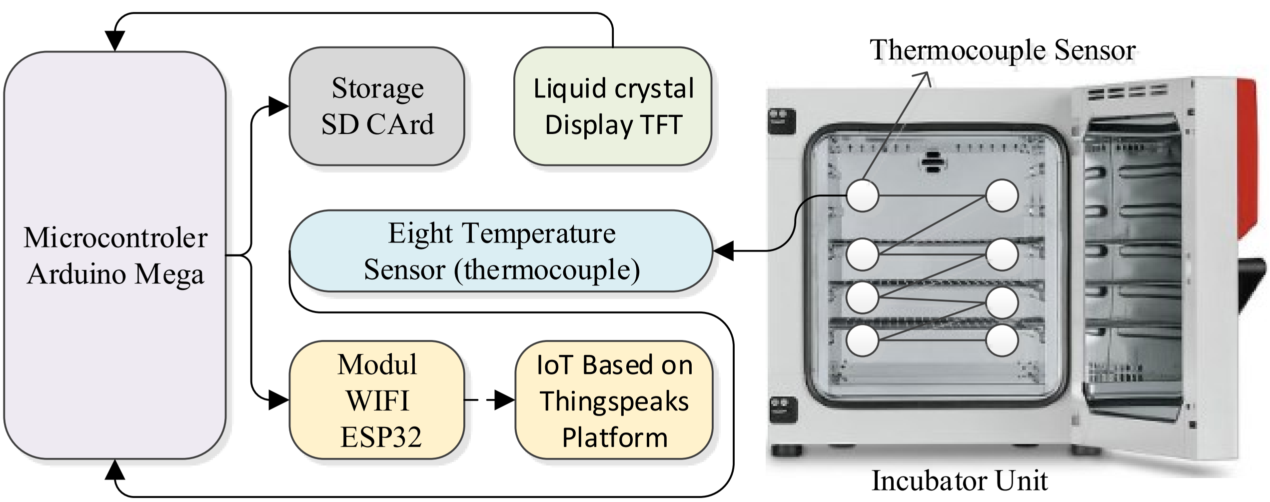

FIGURE 1 The diagram block of the system circuit

thermocouple used type K [25], Arduino Mega as the microcontroller, and esp8266 as the data senders [26][27]. In this study, after the design was completed, the module was tested using an incubator media and compared to data loggers whose results were displayed by android phones on each measuring point. FIGURE 1 The thermocouple works with an electric voltage at the junction point of two dissimilar metals (hot point/measurement point). The other end of the metal is often called the reference point (cold point), where the temperature is constant, while the other is a metal conductor which detects hot temperatures. Input data generated from sensors were then processed in the microprocessor program to become digital data that were further stored in the SD card. Furthermore, the Wi-Fi module worked as input was delivered in the IoT program via the internet network.

B. THE DIAGRAM BLOCK

The system starts working when the on button is pressed and the temperature sensor has been plugged into the device. The temperature sensor will detect the temperature of the device and then goes into the amplifier or signal conditioning signal used so that the results of the sensor output (analog / very small) can be readable. After the series of conditioning signal amplifiers continued to the microcontroller for data processing and displayed to the LCD then the Wi-Fi module of ESP 8266 will send the data to the application or IoT provider to display the temperature sensor data in the form of decimal temperature display and the results of the sensor reading can be stored with the storage of the Io*T [28].*

C. THE FLOWCHART

The flowchart is a data flow that starts from the beginning, processes, stores data, and forms data information that shows temperature monitoring on the module, as shown in the FIGURE 2.

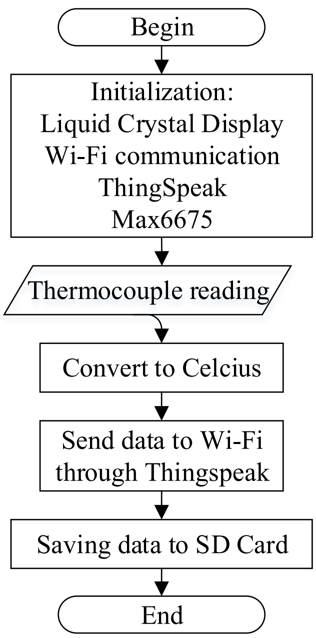

FIGURE 2 The flowchart of the system

When the device is watered, it initializes the temperature reading. After that, the sensor will be processed by the microcontroller and displayed the temperature data with LCD. TFT temperature is felt to be as stable as then by using the star storage button/ stop data will be stored by using the sd card managed by *the Excel* application [29]. The reading data from the sensor is also sent using the wifi module and displayed in the *blink* application by *internet of things provider* downloaded at play store[30].

D. System circuit

This series of microprocessor programs used Arduino to develop temperature sensor system settings for monitoring incubator equipment settings that are very much needed in bacterial cultivation, as described in the circuit below. FIGURE 3.

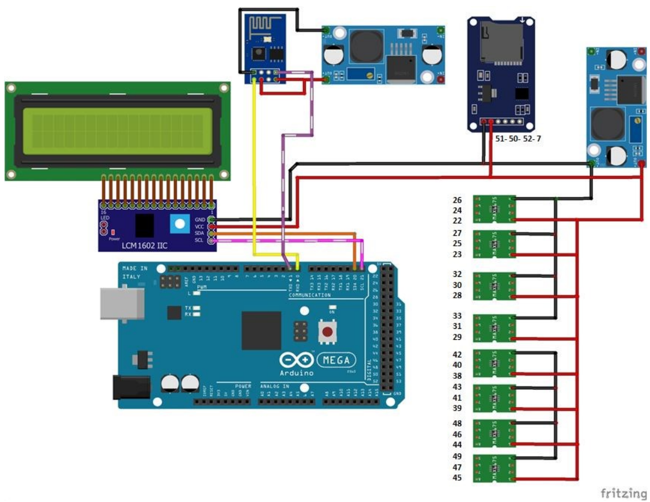

FIGURE 3. Thermocouple system circuit

An important part of this development is the thermocouple and max6675 circuit described in Figure 3 (thermocouple circuit), this circuit is used for a thermocouple sensor that reads the temperature in Celsius. Therefore, digital data processing requires an Arduino program.

III. RESULT

An incubator is a tool for incubating or incubating microbes at a controlled temperature (generally above ambient temperature) and is equipped with a temperature controller and a timer. The smaller the size of the incubator, the more susceptible the temperature changes when the incubator door is opened. Sensor placement was also regulated so that the temperature uniformity is inside by paying attention to the pattern of placement of heating elements or the presence of a temperature-spreading fan. Before testing the tool, the module was tested using a direct temperature calibrator with a comparison device and a data logger recording tool for UPTD Health Laboratory equipment,

The steps and procedures for using the Module are as follows:

1. Calibrator Module. The Calibrator Module is a microcontroller programming circuit that was supplied using 9-volt power connected to a thermocouple sensor.
2. The programming of thermocouple sensor temperature readings is in Celsius units on incubator equipment
3. The reading results from the Thermocouple sensor will be displayed on the character LCD in the form of Celsius temperature data which is read by the average reading at each point where the temperature sensor is placed (as in the list of programs in the journal attachment).

The above algorithm is a form of the Celsius reading from a thermocouple sensor, for "sensor1 = thermo1. read Celsus();" This is the celsius reading on the first thermocouple sensor. Meanwhile, "sensor2 = thermo2.read Celsus();"is the Celsius reading on the second thermocouple sensor, and so on up to the eighth thermocouple.The program above functions as a module data repository. My files = SD. open("save. txt", FILE_WRITE); This program is for storing data in the form of text files on the SD card. Meanwhile, my file. print("Sensor 1:"); my file. print(sensor1); my file. print("Celsius"); is for the file to be stored in txt form with the example sensor display1 = 35ºC.

In the program listing above, there are two parts, namely the introduction of constant value that contains components, the identity of Blynk account information (char SSID, ssid pass). In this case, in order to connect IoT devices with Blynk servers, it required authentication security code sent from Blynk server to email via Project Setting on the AUTH TOKEN menu or character on programming, as well as information about the Wi-Fi network used. The sensor values was in the form of float data that will be sent to the Blynk server using (blynk.virtualWrite(V1,sensor1) and will be displayed in the Blynk application that has been set into an android-based mobile phone. TABLE 1 describes the

TABLE 1
Average values and SD modules against com*parators tools with a temperature of 35⁰and 37⁰*

Setting (°C)	Average Module (°C)	Average Comparison Tool (°C)	SD Module	SD Comparison Tool	Setting (°C)	Average Module (°C)	Average Comparison Tool (°C)	SD Module	SD Comparison Tool
35.0	34.89	34.62	0.25	0.02	**37.0**	36.88	36.53	0.24	0.06
35.0	35.00	34.15	0.34	0.05	**37.0**	37.16	36.34	0.31	0.03
35.0	34.11	34.42	0.22	0.02	**37.0**	36.50	36.45	0.26	0.04
35.0	35.40	34.83	0.29	0.02	**37.0**	37.33	36.82	0.26	0.01
35.0	33.87	34.85	0.21	0.01	**37.0**	35.90	35.81	0.28	0.04
35.0	34.74	33.60	0.25	0.00	**37.0**	36.35	36.33	0.23	0.04
35.0	34.84	34.10	0.23	0.00	**37.0**	36.71	36.12	0.19	0.01
35.0	35.29	34.34	0.29	0.02	**37.0**	37.03	36.52	0.22	0.04

TABLE 2
The average value of the SD module against the incubator fan comparison at 35⁰ and 37⁰

Setting (°C)	Average Module (°C)	Average Comparison Inkubatpr Fan (°C)	SD Module	SD Comparison Inkubator Fan (⁰C)	Setting (°C)	Average Module (°C)	Average Comparison Inkubator Fan (°C)	SD Module	SD Comparison Incubator Fan (⁰C)
37.0	37.05	36.68	0.28	0.06	**35.0**	35.08	34.52	0.25	0.02
37.0	37.02	36.45	0.23	0.03	**35.0**	35.06	34.76	0.34	0.05
37.0	37.57	36.65	0.31	0.04	**35.0**	35.65	34.62	0.22	0.02
37.0	36.95	36.51	0.23	0.01	**35.0**	35.35	34.70	0.29	0.02
37.0	37.03	36.54	0.29	0.04	**35.0**	35.36	34.51	0.21	0.01
37.0	37.11	36.77	0.18	0.04	**35.0**	35.17	34.75	0.25	0.00
37.0	37.20	36.39	0.29	0.01	**35.0**	35.39	34.59	0.23	0.01
37.0	37.38	36.75	0.22	0.04	**35.0**	35.19	34.62	0.29	0.02

comparative data between the temperature of the module with the comparison device at a setting temperature of 35°C, 37°C as well as its error comparison. Based on the table, above it can be seen that the results of the comparison of the readings between the module and the comparison tool from the laboratory have the largest error of 2.98 at the T3 sensor and the smallest error of 0.86 at T2. In this case, the temperature of the incubator fan was 35°C and 37°C, where the biggest error of the incubator fans the biggest was 2.50 on the T3 sensor and the smallest error was 0.94 on the T6 sensor. Meanwhile, in the non-fan incubator at 35°C, the biggest error was 3.39 on the T6 sensor and the smallest error was -2.81 on the T5 sensor. Furthermore, at 37°C, the biggest error in the incubator was 2.26 on the T2 sensor and the smallest error was 0.06 on the T6 sensor. TABLE 2 describes the comparative data between module temperatures in fan laboratory incubators at temperature settings of 35°C and 37°C, as well as the standard deviation comparison.

Based on the table above, it can be seen that the results of the comparison between module readings on laboratory incubator readings have the largest error of 2.98 on the T3 sensor and the smallest error of 0.86 at T2. Meanwhile, at the incubator fan temperature of 35°C and at 37°C, the biggest error was 2.50 on the T3 sensor and the smallest error was 0.94 on the T6 sensor. The data were collected twenty-five times on fan-type incubator media and further averaged as well as compared to the manufacturer's equipment so that the level of accuracy was obtained with a temperature setting of 37.0° C at each sensor placement point, namely the sensor point T1 to point T8.

IV. DISCUSSION

The design has been examined and tested completely in this study and the sensor reading program for each channel on the module can be run properly. The type K and MAX6675 thermocouple circuits were already running well and the ESP module can be connected to a predetermined network. The results of temperature readings in each thermocouple sensor (channel) were displayed on a 4x20 LCD and were further stored in the mini–SD Card.

Based on the results of the measurement data, it was seen that the results of temperature accession in incubator devices are close to the comparison temperature. The results of the module measurement using a multi-channel comparison tool obtained largest error value of 3.98% on channel T6 at the temperature of 35 °C with ordinary incubator media. Meanwhile, the smallest error was on ordinary incubator media at T6 point at 37°C, which is 0.06%. Furthermore, in terms of the fan incubator at 35°C, the largest error was 2.98%, while the smallest error was 0.86%, which is caused by several factors, one of which is uneven temperature differences due to the distance between the heat source and the placement of different sensors. Measurement results from different incubators have varying accuracy from each measuring point as well as fan and fan less incubators both have different levels of accuracy and vary with module measurements and compared by standard tools. This study is a significant improvement because in the previous study entitled Temperature Calibrator Using Thermocouple Based on Microcontroller [15], there was no use of wireless technology, and the temperatures examined were not the temperatures required for bacterial incubation, which were 35°C and 37°C. In practical system, the incubator temperature calibration tool needs to use low temperatures for the utilization of bacterial breeding, as well as the Internet of Things wireless connection to make it easier to see or monitoring the temperature on the media before data collection to increase efficiency [31].

Despite the improvement obtained in this study, the result of the error value between the module and the comparator is still large because the data displayed is directly from the sensor reading output. In addition, the comparison sensor is a data logger type, so that it has a weakness in the forms of different specifications from the thermocouple sensor. Lastly, the use of tools is less efficient because the tools are still not portable.

V. CONCLUSION

The aim of this study was to analyze the accuracy of the thermocouple sensor with two types of comparison devices, namely a temperature calibration device and a laboratory incubator at 35°C and 37°C, using a temperature sensor, namely a type K thermocouple with an internet connection network (IoT) and an SD card to store the temperature data. The results of this study indicated the accuracy of the sensor in analyzing the temperature of both the comparison device and the incubator. Furthermore, in the future, this research can be used as a reference for the use of sensors for temperature measurements in incubator units that require high accuracy. However, it also needs continuous testing, especially the resistance of temperature readings for a long time.

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