Five Channel Temperature Calibrator Using Thermocouple Sensors Equipped With Data Storage

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***Abstract*— A temperature calibration device is a tool used to measure the accuracy of a temperature-related device such as a Sterilizer. This temperature calibration device is needed when the temperature in the Sterilizer is not linear. In this calibration tool, the sensor used is a type-k thermocouple that is inserted into the media to be measured then the temperature results will be read. This tool is designed using pre-experimental methods with the type of after only design research. In this tool is equipped with storage on the micro sd card and also conversion mode to convert temperature results from Celsius to Reaumur, Fahrenheit, and Kelvin. Temperature results will be displayed on a 4x20 LCD and processed using Arduino UNO. This module can be used in medical equipment calibration laboratories. After testing the thesis module with a comparison device from BPFK, the biggest error is obtained at 1% at 50 ° Celsius, 100 ° Celsius, and 150 ° Celsius. The smallest percentage of error is 0% at 50 ° Celsius and 150 ° Celsius. It can be concluded that the tool "Temperature Calibrator (5 Channels) Using Thermocouple Equipped with Data Storage.**

Keywords—Sterilizer; Temperature; SD Card

I. INTRODUCTION

Dry Sterilizer requires exposure at a temperature of 150 °C to 170 °C for 1-4 hours. (Hadada, 2009). Sterilizer ingredients such as glass materials can be sterile at a temperature of 170 °C, if the temperature is not set according to the material requirements of medical devices it is feared that it will have an impact on non-sterile medical devices. Therefore, calibration is needed. The calibration tool uses a thermocouple sensor to detect the temperature in the Sterilizer.

The thermocouple is a type of temperature sensor used to detect or measure temperature through two types of metal conductors, whose working principle is that each end of a conductor metal is combined to give rise to a "thermo-electric" effect. One type of conductor metal contained in a thermocouple will function as a reference with a constant temperature (fixed), while a metal conductor functions as a conductor metal that detects hot temperatures (Dickson Kho, 2015).

The standard temperature unit used in the world, in general, there is two kinds, namely Fahrenheit and Celsius units. The Fahrenheit scale uses the number 32° to indicate the freezing point and 212° for the boiling point of pure water at atmospheric pressure. As for the Celsius unit, use the number 0° at freezing and 100° for the boiling point of pure water at atmospheric pressure. At the international physics association congress held in 1954, a new standard for the temperature unit was determined as kelvin. This provision takes place at an external air pressure of 1 atmosphere with an ice melting temperature of 273.15 K and a water boiling point temperature of 373.15 K. This means that in that year there is a standard change in temperature from degrees Celsius to kelvin. (Core Laboratory, 2012).

In connection with the functions of the above-mentioned tools, currently on the campus of the Electromedical Engineering Department, Poltekkes Kemenkes Surabaya, the process of calibration is carried out using a combination of temperature calibration devices with thermocouple as a temperature measuring device with non-linear temperature detection results. According to the author's observation that the process of calibration activity performance is less effective because the process of measuring data is done twice the work.

The temperature calibrator with thermocouple and Thermo hygrometer by Mochammad Sofyan, 2016 is equipped with the conversion of temperature units on temperature gauges, but there is no data storage. Furthermore, the temperature calibrator with thermocouple and Thermo hygrometer equipped with data storage has been made by Aviliana Kusuma Bintari, 2017 but still uses 1 channel and the storage media still uses EEPROM.

Based on the identification of the above problems, the author intends to make a Temperature Calibrator (5 Channel) Using Thermocouple Equipped with Data Storage, which can measure the temperature of the device and the temperature data is stored on the SD Card.

II. Materials and Methods

A. Experimental Setup

This study uses Sterilizer with a volume of 0.14 m³ and uses 5 thermocouple sensors k-type to use the temperature at the sterilizer

1) Materials and Tool

This study uses a type-k thermocouple sensor. The type-k thermocouple sensor is installed in accordance with the stipulated conditions. Arduino UNO microcontroller is used to read temperature and convert temperature. The MAX 6675 module is used to convert thermocouple digitally. Micro SD Card is used to store temperature data manually. Sterilizer (Electro-Mag M6040P) is used as a temperature measurement medium. Temperature calibrator (OMEGA OM-CP-OctTemp2000) is used as a comparison with the thesis module.

2) Experiment

In this study, the researcher compiled a module that reads the temperature on the sterilizer using a type-k thermocouple sensor. The body temperature reading results are displayed on the LCD in the thesis module. The temperature reading results can be saved with a micro SD card. The researcher conducted several tests including comparing the measurement results in the thesis module with the temperature calibrator available in the BPFK with temperature settings (50,100 and 150).

B. The Diagram Block

When power on / off is on, the entire circuit will get voltage. The sensor will detect the temperature of the device which then enters the ATMEGA 328P IC, then appears on the LCD of the 4x20 character resulting from the temperature measurement of the tool. While the conversion button pressed, the temperature measurement results which initially have Celsius temperature units will be converted into Fahrenheit, Reaumur, and Kelvin temperature units. The measurement results will be saved using the SD Card program when pressed the save button. The reset button functions to reset it back to the initial look.

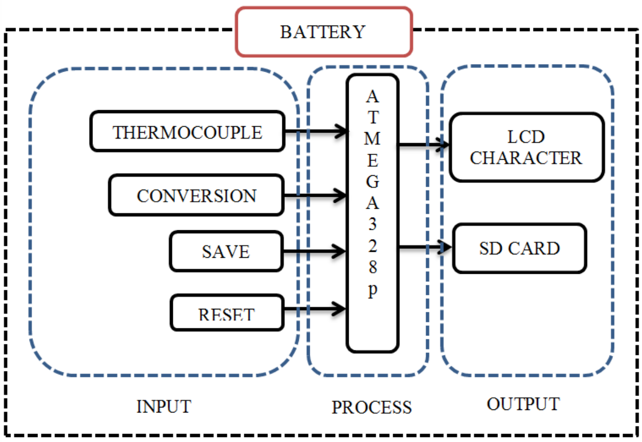

Fig. 1. The diagram block

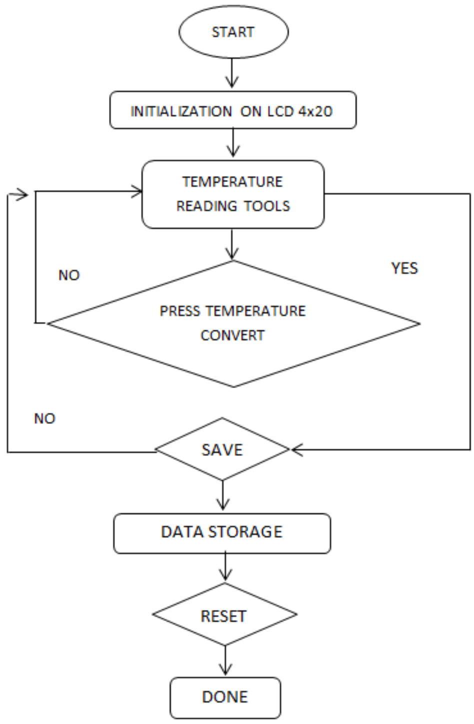

Fig. 2. The Flowchart

C. The Flowchart

When starting then initialization occurs from initializing the input-output microcontroller and LCD interface 4X20. Then after the initialization process is complete, the LCD will display the temperature reading value on the device. When the temperature converter button is pressed, the temperature unit displayed on the LCD display will change and when the save button is pressed, the temperature reading will stop then the data will be stored on the SD Card. When the reset button is pressed, the initial display returns.

D. The Analog Circuit

The important part of this development is the module that illustrates in Figure. 3 (MAX 6675). This module is used to process temperature output. Therefore for digital processing using Arduino.

1) Max 6675

This MAX6675 module is formed from cold-junction compensation, which digitizes the output of a K-type thermocouple signal. Data output has 12-bit resolution and supports SPI microcontroller communication in general. This module is used to convert thermocouple digitally.

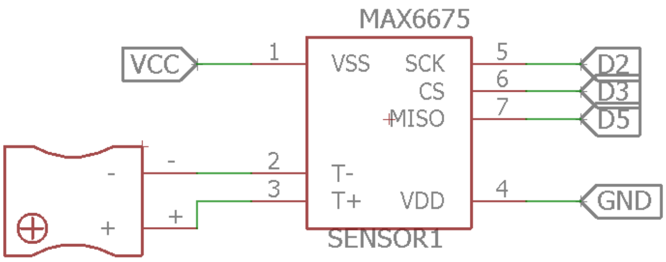

Fig. 3. Max 6675

2) MicroData Storage Module

The storage module used in this tool is a micro SD card. This storage module is used to store temperature reading data. For communication between Arduino and micro SD Card modules, it takes 6 pins, Gnd, Vcc, Miso, Mosi, Clk, and Cs. The connection between the micro SD Card and Arduino modules is shown in Fig. 4.

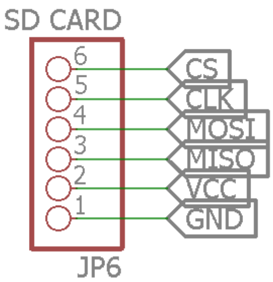

Fig. 4. Micro SD Card

III. RESULTS

In this study, the thesis module has been tested using a temperature calibrator at BPFK (OMEGA OM-CP-OctTemp2000) using a media Sterilizer (Elektro-Mag M6040P). The results show that the tool is suitable for use.

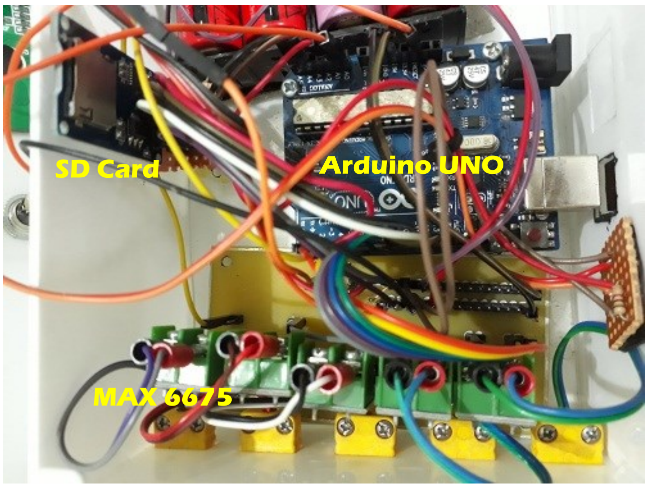

Fig. 5. The Temperature Calibrator Design

1) The Temperature Calibrator Design

Photograph of the digital part of the thesis module is shown in Figure. 5 The digital part consists of an Arduino UNO microcontroller which is the main board of the thesis module device, the MAX 6675 module is used to digitally convert thermocouple and SD card memory modules to store temperature reading data manually.

2) The Listing Program for Arduino

```
if(mark > 3){
mark = 0;
}
//======================Celcius========================//
 if(mark == 0){
   lcd.setCursor(6,0);// set cursor at character 0, line 0
   lcd.print("T1:");
   lcd.print(thermo1.readCelsius()); // print temperature in Celsius
   lcd.print(" ");

   lcd.setCursor(0,1);// set cursor at character 0, line 0
   lcd.print("T2:");
   lcd.print(thermo2.readCelsius()); // print temperature in Celsius
   lcd.print(" ");

   lcd.setCursor(11,1);// set cursor at character 0, line 0
   lcd.print("T3:");
   lcd.print(thermo3.readCelsius()); // print temperature in Celsius
   lcd.print(" ");

   lcd.setCursor(0,2);// set cursor at character 0, line 0
   lcd.print("T4:");
   lcd.print(thermo4.readCelsius()); // print temperature in Celsius
   lcd.print(" ");

   lcd.setCursor(11,2);// set cursor at character 0, line 0
   lcd.print("T5:");
   lcd.print(thermo5.readCelsius()); // print temperature in Celsius
   lcd.print(" ");
   lcd.setCursor(6,3);
   lcd.print("Celcius  ");
 }
//========================Reaumur======================//
 if(mark == 1){
   lcd.setCursor(6,0);// set cursor at character 0, line 0
   lcd.print("T1:");
   lcd.print(thermo1.readCelsius()* 0.8); // print temperature in Celsius
   lcd.print(" ");

   lcd.setCursor(0,1);// set cursor at character 0, line 0
   lcd.print("T2:");
   lcd.print(thermo2.readCelsius()* 0.8); // print temperature in Celsius
   lcd.print(" ");

   lcd.setCursor(11,1);// set cursor at character 0, line 0
   lcd.print("T3:");
   lcd.print(thermo3.readCelsius()* 0.8); // print temperature in Celsius
   lcd.print(" ");

   lcd.setCursor(0,2);// set cursor at character 0, line 0
   lcd.print("T4:");
   lcd.print(thermo4.readCelsius()* 0.8); // print temperature in Celsius
   lcd.print(" ");
```

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```
    lcd.setCursor(11,2);// set cursor at character 0, line 0
    lcd.print("T5:");
    lcd.print(thermo5.readCelsius()* 0.8); // print temperature in Celsius
    lcd.print(" ");
    lcd.setCursor(6,3);
    lcd.print("Reaumur  ");
  }
//=====================Fahrenheit=======================//
  if(mark == 2){
    lcd.setCursor(6,0);// set cursor at character 0, line 0
    lcd.print("T1:");
    lcd.print(thermo1.readCelsius()*1.8+32); //print temperature in Celsius
    lcd.print(" ");

    lcd.setCursor(0,1);// set cursor at character 0, line 0
    lcd.print("T2:");
    lcd.print(thermo2.readCelsius()*1.8+32);//print temperature in Celsius
    lcd.print(" ");

    lcd.setCursor(11,1);// set cursor at character 0, line 0
    lcd.print("T3:");
    lcd.print(thermo3.readCelsius()*1.8+32);// print temperature in Celsius
    lcd.print(" ");

    lcd.setCursor(0,2);// set cursor at character 0, line 0
    lcd.print("T4:");
    lcd.print(thermo4.readCelsius()*1.8+32);// print temperature in Celsius
    lcd.print(" ");

    lcd.setCursor(11,2);// set cursor at character 0, line 0
    lcd.print("T5:");
    lcd.print(thermo5.readCelsius()*1.8+32);// print temperature in Celsius
    lcd.print(" ");
    lcd.setCursor(6,3);
    lcd.print("Fahrenheit");
  }
//=========================Kelvin========================//
  if(mark == 3){
    lcd.setCursor(6,0);// set cursor at character 0, line 0
    lcd.print("T1:");
    lcd.print(thermo1.readCelsius()+273);// print temperature in Celsius
    lcd.print(" ");

    lcd.setCursor(0,1);// set cursor at character 0, line 0
    lcd.print("T2:");
    lcd.print(thermo2.readCelsius()+273);// print temperature in Celsius
    lcd.print(" ");

    lcd.setCursor(11,1);// set cursor at character 0, line 0
    lcd.print("T3:");
    lcd.print(thermo3.readCelsius()+273);// print temperature in Celsius
    lcd.print(" ");

    lcd.setCursor(0,2);// set cursor at character 0, line 0
    lcd.print("T4:");
    lcd.print(thermo4.readCelsius()+273);// print temperature in Celsius
    lcd.print(" ");

    lcd.setCursor(11,2);// set cursor at character 0, line 0
    lcd.print("T5:");
    lcd.print(thermo5.readCelsius()+273);// print temperature in Celsius
    lcd.print(" ");
    lcd.setCursor(6,3);
    lcd.print("Kelvin   ");
  }
```

3) Save the Temperatur to Micro SD Card

In order for the Calibrator to store the temperature read by the sensor, a micro SD card is needed to store the temperature. The Listing Program is displayed in Program Listing 2.

Listing Program 2. Program to save the temperature in micro SD Card

```
if (!SD.begin(4))
{
Serial.println("initialization failed!");
return; }
Serial.println("initialization done.");
// open the file. note that only one file can be open at a time,
// so you have to close this one before opening another.
myFile = SD.open("test.txt", FILE_WRITE);
// if the file opened okay, write to it:
if (myFile) {
myFile.println(" =========== ");
myFile.print("T1=");
myFile.println(val1);
myFile.print("T2=");
myFile.println(val2);
myFile.print("T3=");
myFile.println(val3);
myFile.print("T4=");
myFile.println(val4);
myFile.print("T5=");
myFile.println(val5);
myFile.println(" =========== ");
}
```

4) The Error of Temperature value

The validation of the temperature value shown in the LCD display of the thesis module is compared with the calibrator at BPFK. Errors are shown in Table I.

TABLE I. THE ERROR MEASUREMENT BETWEEN THE MODULE OF THE SKRIPSI WITH CALIBRATORS IN BPFK.

Temp Setting (°C)	Channel	Error (%)
50	1	1%
	2	1%
	3	1%
	4	0%
	5	1%
100	1	1%
	2	1%
	3	1%
	4	1%
	5	1%
150	1	1%
	2	0%
	3	1%
	4	0%
	5	0%

IV. Discussion

After comparing the results between modules and measuring instruments, the average error is 1% which is still within the tolerance range. When testing data storage, it can still be stored on a micro SD card manually. It can be concluded that manual data storage is still ineffective because users pay more attention when retrieving data when the temperature at the sterilizer is stable to be stored on a micro SD Card.

V. Conclusion

This study has shown the development of a temperature calibrator to ensure the temperature results in Sterilizer according to the setting. This study was built using an Arduino microcontroller and uses the MAX6675 module. This study has proven that its accuracy is appropriate for calibrating Sterilizer and recording data can be read from SD card memory. In the future, this research can be used in medical equipment calibration laboratories.

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