

Water-Bath Calibration Device with Data Storage Using Six Thermocouple Sensor

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Article Info	Abstract
Article History: Received May 19, 2020 Revised July 14, 2020 Accepted July 21, 2020	Uneven temperature distribution in the water-bath chamber can cause the temperature conditions in the chamber are not the same. Temperature, humidity, atmospheric pressure, and dust particles are the main factors that adversely affect the accuracy of the water bath's temperature. Therefore, the purpose of this study is to design a calibration device for water-bath with six-channel temperature sensors. In this study, the system able to detect temperatures at each point. The K-type thermocouple sensor is used to detect the temperature at each chamber point with the help of the MAX6675 module as a signal conditioning amplifier. The sensor readings will be displayed on a personal computer using a USB cable, and the sensor readings can be stored on a personal computer in the TXT format so that the data can be reprocessed using Microsoft Excel for further calibration purposes. This study aims to facilitate the calibration process and the processing of calibration data. Based on the obtained measurements, a temperature error for 40 °C channel one 1.4 %, channel two 1.8%, channel three 0.4%, channel four 0.2%, channel five 0.2% and channel 6 0.2%. Furthermore, the accuracy for temperature setting of 50 °C for channel one 2.25%, channel two 2.26%, channel three 2.00%, channel four 2.44%, channel five 2% and channel six 1.6%. Moreover, the accuracy for setting temperature 60 °C for channel one is 0.3%, channel two 0.6%, channel three 0.5%, channel four 1.5%, channel five 2% and channel six 1.8%. Based on the test results, this design has the lowest error of 0.2% and the highest error of 2.44%. The results of this research can be implemented as a water bath calibrator device to maintain the temperature stability of the instrument.
Keywords: Calibration Chamber Temperature K-Type Thermocouple Water-bath	
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I. INTRODUCTION

Water baths in laboratories generally use temperatures between + 5 °C to + 99.9 °C [1]. Temperature, humidity, atmospheric pressure, and dust particles are the main factors that adversely affect the accuracy of the water bath's temperature. Therefore, a water bath needs calibration before use [2]. The calibration process that requires a container or space with certain media is called Enclosure in the world of calibration. According to PERMENKES NO. 43 of 2013 monitoring the temperature of the Water Bath is the same as monitoring the temperature of the refrigerator and oven. Bath calibration is used in various types of media, namely water, alcohol, oil, and others [3]. The calibration results can be in the form of determining the value of the measuring scale against the appointment or determination of correction [4]. Based on reality, Water Bath calibration is done

by using 1 Thermometer, which is placed in several points alternately so that the results of the measurement of 9 points cannot be known in real-time[5].

The water bath calibration device has been made by several researchers. In Mohammad Rofi's research, a Water Bath with Nine Channels Sensor was made. This study uses a K type thermocouple sensor. The advantages of this study are using 9 sensors to be used when calibration, but in this study still has drawbacks that the device is not equipped with data storage and for display only in the form of numbers not with graphics[5]. In the research of Sandeep P. Nalavade's, Abhishek D. Patange, Chandrakant L. Prabhune, Sharad S. Mulik and Mahesh S. Shewale also made a device entitled Development of the 12 Channel Temperature Acquisition System for Heat Exchanger Using MAX6675 and Arduino Interface to read temperatures

use 12 type K thermocouple sensors. The advantages of this device use 12 type K thermocouple sensors making it easier to measure temperature, but this device is not used in the calibration field only used for temperature measurements[6]. In the research of R. A. Koestoer, Y.A. Saleh, I. Roihan, Harinaldi with his research entitled A Simple Method For Calibration Of Temperature Sensors DS18B20 Waterproof In Oil Bath Based On Arduino Data Acquisition System. The sensor used by DS18B20 in the oil bath media, but this study is only used in the oil bath not in the Water Bath, besides the DS18B20 sensor has an error rate of 2% much greater than the K type thermocouple sensor[7]. The DS18B20 sensor has a 2% error rate explained in the research of Imam Abdul Rozaq and Noor Yulita DS[8]. In the research of Aninda Zakia Febriyanti, Temperature Calibrator Using Thermocouple Based on Microcontroller. A calibration device that uses 5 K type thermocouple sensors equipped with data storage on the Arduino EEPROM, but this research has a weakness that is the display only displays the numbers so that temperature monitoring cannot be in real-time[9]. In the 4 Channel Sterilizer Calibrator study by Syafiq Naufal Syayakti, research on a sterilizer calibration device that uses 4 K type thermocouple sensors. This research has the disadvantage that there is no storage for measured data and only displays numbers for measurement results[10]. In the research of Rizkiyatussani Five Channel Temperature Calibrator Using Thermocouple Sensors Equipped with Data Storage, this study was used in a sterilizer that uses a K type thermocouple sensor and is equipped with data storage. However, this research still has shortcomings; namely, the display only displays the numbers[11]. In the study of Self-Calibrating Enabled Low Cost, Two Channel Type K Thermocouple Interface for Microcontrollers by Hesham H. Shaker, A.A. Saleh, Azza H. Ali, and M. Abd Elaziz researched automatic calibration on 2 channel type K thermocouple sensors which were powered by LM358 IC. IC LM358 is used to implement two differential amplifiers with a gain factor equivalent to 200 (<122 to guarantee more accuracy)[12]. In the research of Devendra Singh, Sumer Chand Prasad, and Pravin Kumar with the title Calibration of Thermocouples for Low-Temperature Applications on thermocouple calibration for low-temperature applications. This study uses a K type thermocouple sensor with oil bath media. The temperature readings on the thermocouple sensor are not much different from the temperature set in the oil bath[13]. In the Thermocouples calibration and analysis of the influence of the length of the sensor coating by M Noriega, R Ramírez, R López, M Vaca, J Morales, H. Terres, A Lizardi, S Chávez explained the thermocouple calibration using LAB VIEW software. In the thermocouple calibration process using water media. This research has the advantage of using software VIEW LAB for monitoring. However, this device in monitoring does not display the results of the calibration with graphs[14].

Based on some of the research described above, several things need to be completed through a study. Calibration activities to establish under certain conditions the relationship between the value of the amount indicated by the measuring instrument or measurement system, or the value stated by the

measuring material or reference material, and the related value realized by the standard. Equipment calibration is carried out at the beginning when new equipment is installed and tested for function, and subsequently must be done periodically at least once a year, or by the manufacturer's guidelines for infrastructure and medical devices as well as regulatory provisions according to manufacturer's instructions. Calibration to determine a device is said to be feasible or not feasible to use on a device. Research on the Water Bath calibration device that has been done by several researchers has a weakness, namely the sensor used DS18B20, which still has an error rate of 2% than the type K thermocouple, which has a special error rate of 0.4%. The sensitivity of type K thermocouples is around $41 \mu\text{V} / \text{K}$ [15]. Type-k has a longer life Type J as in Type J Fe (iron) wires oxidize rapidly, especially at higher temperatures. Type K Thermocouple Sensors have a temperature range of -270°C to 1260°C [16]. Type K thermocouple experiences a nonlinearity between the output voltage and the temperature at around 150°C . For a small measurement range, the relationship between temperature and voltage is linear. Besides, type K thermocouples are relatively cheaper and easier to find on the market. Type k thermocouples use max6675 to convert K-type thermocouple signals into digital signals (development of 12 channels). MAX6675 has a resolution of 0.25°C [17]. Besides, there are still weaknesses from several studies that have been described; namely, the appearance of the calibration results are still in the form of numbers without any appearance in graphical form. In reality, in the field, calibration of devices equipped with graphical displays is needed more, especially calibrations related to temperature measurements, because to facilitate the user in monitoring the temperature of the calibrated instrument. From some of the studies described, some studies are not equipped with calibration data storage. Calibration data storage is needed in the field because users in performing the calibration cannot simultaneously monitor and record the calibration results. Besides, data storage makes it easy for users to input data on existing calibration worksheets. Based on these things, the author wants to make a water bath calibration device that is equipped with storage on a personal computer to facilitate the user in processing the calibration data for further calibration purposes—also equipped with a graph display for calibration results.

This Article is composed of: section 1 described introduction, section 2 indicated Material and Methods, section 3 showed Result, section 4 discussed the results, and section 5 conclude the study.

II. MATERIAL AND METHOD

A. Experimental Setup

In this research method using the alabtech brand water bath in the measurement temperature of 40°C , 50°C , and 60°C . Using the enclosure calibration method at 6 measurement points. Measurement in this calibration is done 10 times every minute

B. Materials and Device

This study uses a type k Thermocouple(K, Thermocouple, Indonesian) sensor to read the temperature in the chamber water bath. MAX6675 module as a signal conditioning amplifier from a type K thermocouple sensor before entering the Microcontroller. Arduino Nano(Version 3.0, Arduino, Italy) is used to process data read by modules. Delphi 7 software to display temperature values. The device used four batteries as a power supply. A digital thermometer (Central Electric) was used as a comparison device.

C. Experiment

In this study, researchers measured the value of average and calibrated space errors. For data retrieval steps, 6 sensors are installed at 6 points that have been determined by AS2853 standards and then make changes to the stable space, then do temperature data storage.

D. The Diagram Block

When the ON button is pressed, all the circuits on the device will get voltage. The sensor will detect the temperature of the appliance, then enter the signal conditioning amplifier (Analog Signal Conditioner). A Signal conditioning amplifier is used so that the results from a very small sensor output can be read. After the signal conditioning amplifier circuit proceeds to the Microcontroller for data processing. They were sent to a PC to display the temperature sensor data. On the PC is displayed on delphi7 software. Display in the form of graph and number plots. Then do several data storage in the form of TXT (Fig. 1).

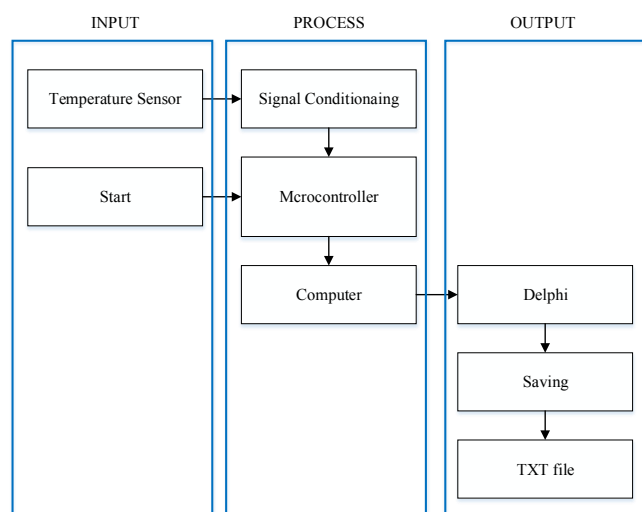


Fig 1. The diagram block of the calibration water bath

E. The Flowchart

When the appliance is turned on, the device initializes the temperature. When going to detect temperature on the Water Bath device, press the start button on the device. After the start button is pressed, the sensor will do the temperature reading on the Water Bath device. Then the ADC data is processed by reading the temperature sensor on Arduino. After processing data on Arduino, it will be sent to a PC via USB to be displayed on Delphi software in the form of graphics and numbers. If the measurement has been completed, you can press the reset button on the device to do the measurement again (Fig. 2).

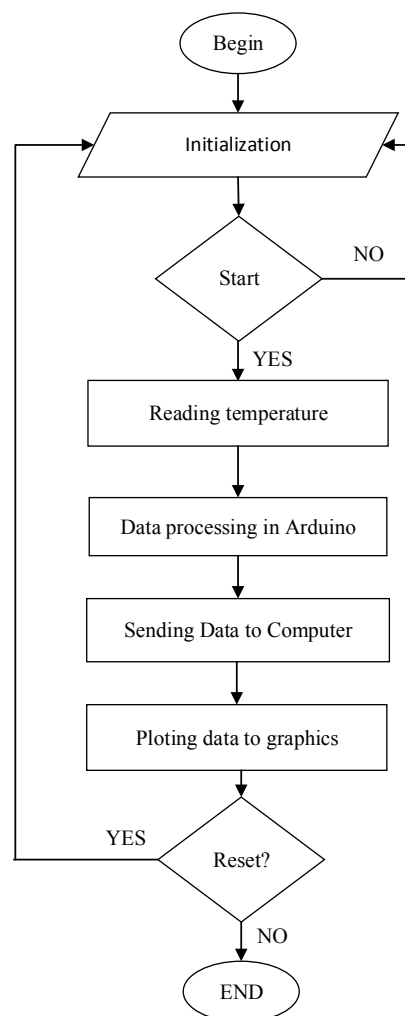


Fig 2. The flowchart of the Arduino program

The device will save when the save button on the Delphi display is pressed; the device will automatically save for 10 minutes by taking data every 1 minute so that in 10 minutes, 10 data is obtained. The device is connected to the PC using a USB cable, after which the Delphi software will initialize the PORT. After that, the results of

reading the data will be displayed on Delphi software. After completing the measurement, the data will be stored as a number in the form of a TXT(Fig. 3)

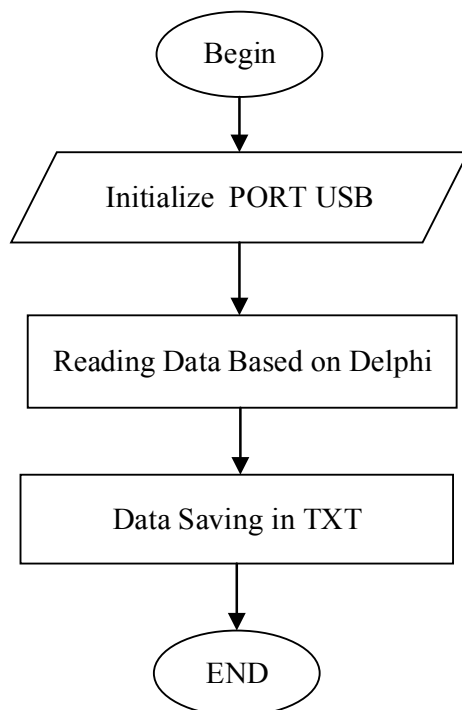


Fig 3. The flowchart of the data storage

III. RESULTS

A. Results of Microcontroller Design

Water Bath calibration module with storage controlled using a button. This sensor requires 5v power, ground, and generates digital data. The push-button there is a start button, reset button, save button on delphi7 display(Fig. 4 and Fig. 5).

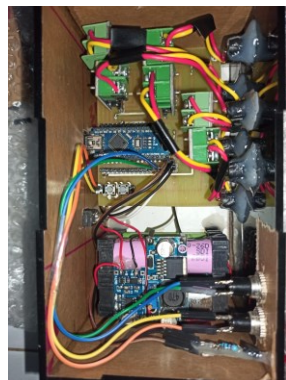


Fig 4. Microcontroller design

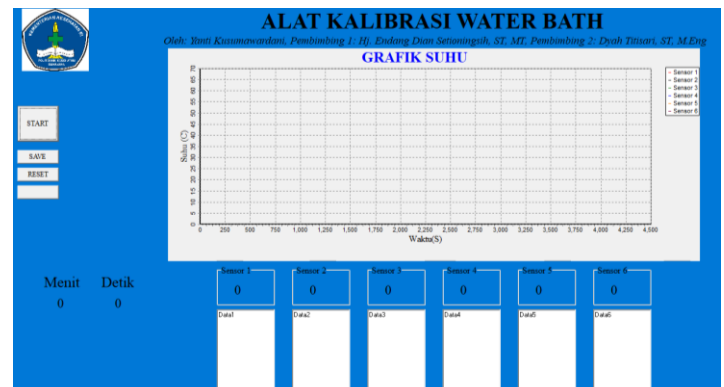


Fig 5. Display in the PC using Delphi7 software

B. Pseudo Code: Module MAX6675

IF ((analogRead(A0)==1023)) **THEN**

```

Serial.print ('a');
suhu = thermo1.readCelsius();
sensor1 = suhu * 100;
adc1=sensor1/100;
adc2=sensor1%100;
Serial.print (char(adc1));
Serial.print (char(adc2));
  
```

```

suhu = thermo2.readCelsius();
sensor1 = suhu * 100;
adc1=sensor1/100;
adc2=sensor1%100;
Serial.print (char(adc1));
Serial.print (char(adc2));
  
```

```

suhu = thermo3.readCelsius();
sensor1 = suhu * 100;
adc1=sensor1/100;
adc2=sensor1%100;
Serial.print (char(adc1));
Serial.print (char(adc2));
  
```

```

suhu = thermo4.readCelsius();
sensor1 = suhu * 100;
adc1=sensor1/100;
adc2=sensor1%100;
Serial.print (char(adc1));
Serial.print (char(adc2));
  
```

```

suhu = thermo5.readCelsius();
sensor1 = suhu * 100;
adc1=sensor1/100;
  
```

```

adc2=sensor1%100;
Serial.print (char(adc1));
Serial.print (char(adc2));

suhu = thermo6.readCelsius();
sensor1 = suhu * 100;
adc1=sensor1/100;
adc2=sensor1%100;
Serial.print (char(adc1));
Serial.print (char(adc2));
Serial.print ('b');
delay(1000);

```

ENDIF

The above program is used to transmit data from sensor readings. Data will be sent from Arduino to delphi7 software to be displayed on the Personal Computer in the form of numbers and graphs. The above program also converts ADC data into bits and then sent together to Delphi in the form of char or characters.

C. Pseudo Code: Graphic Display Initialization

DO:

```

PRINT "Temperature from sensor 1", temp1
PRINT "Temperature from sensor 2", temp2
PRINT "Temperature from sensor 3", temp3
PRINT "Temperature from sensor 4", temp4
PRINT "Temperature from sensor 5", temp5
PRINT "Temperature from sensor 6", temp6

```

```

PLOT "Chart from sensor 1", temp1
PLOT "Chart from sensor 1", temp1
PLOT "Chart from sensor 1", temp1
PLOT "Chart from sensor 1", temp1
PLOT "Chart from sensor 1", temp1
PLOT "Chart from sensor 1", temp1

```

ENDDO

The above program is used to input data on the label on the Delphi 7 software display so that the sensor reading data appears on the label. Besides, the above program is used to display data in graphical form.

D. Pseudo Code: Data Storage

```

IF SaveDialog1.Execute THEN
button5.Caption:='SAVE';
mode:=1;
Timer1.Enabled:=true;
ENDIF

```

IF mode=1 THEN

savedialog2.filter:='Text File (.txt)|*.txt';

IF SaveDialog2.Execute THEN

AssignFile(myFile,SaveDialog2.FileName);

ReWrite(myFile);

akandisimpan:=True;

mode:=2;

ENDIF

The program functions to save the data in the form of a text file. When button5 is pressed, then the PC display will appear to give the name of the file to be saved. When the file has been given the next name, the program will run a timer.

E. Pseudo Code: Running a Timer

LOOP:

sec :=sec+1;

IF sec > 59 THEN

sec := 0;

min := min+1;

ENDIF;

menit.Caption:=inttostr(min);

detik.Caption:=inttostr(sec);

ENDLOOP;

The above program is used for a timer when data will be stored. The timer will work when data storage starts running. The timer will be displayed in a table that is already in the Delphi software.

F. Sensor Reading

In (Fig. 6) the data stored in txt at 40 ° C for 10 minutes so that 10 data are obtained in each channel. The data stored in the form of txt is converted into Microsoft Excel to be displayed in graphical form.

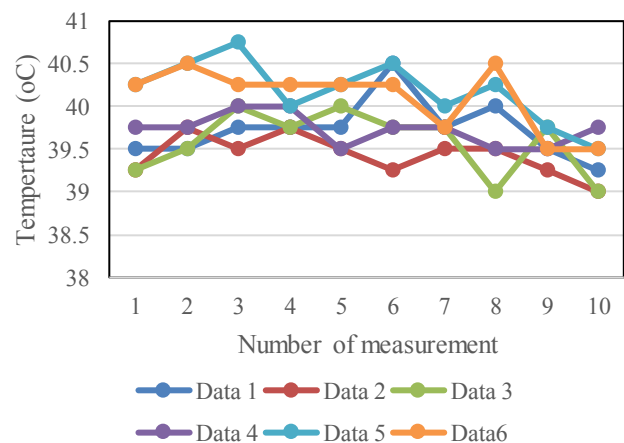


Fig 6. The reading results on the sensor at a temperature of 40°C.

In (Fig. 7) the data stored in txt at 50 ° C for 10 minutes so that we get 10 data in each channel. The data stored in the form of text is converted into excel to be displayed in graphical form. For data at 50 ° C there are only 8 temperature data per channel because there is still an error in data storage on the water bath calibration device.

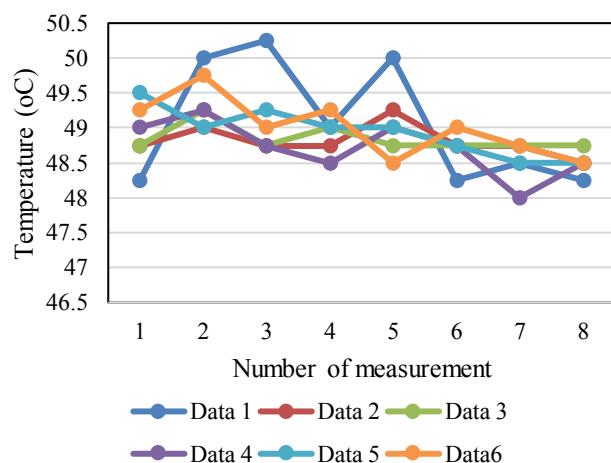


Fig 7. The reading results on the sensor at a temperature of 50°C

In (Fig. 8) the data stored for 10 minutes so that 10 data are obtained in each channel. The data stored in the form of text is converted into Excel to be displayed in graphical form. For data at 60 ° C there are only four temperature data per channel because there is still an error in data storage on the water bath calibration device.

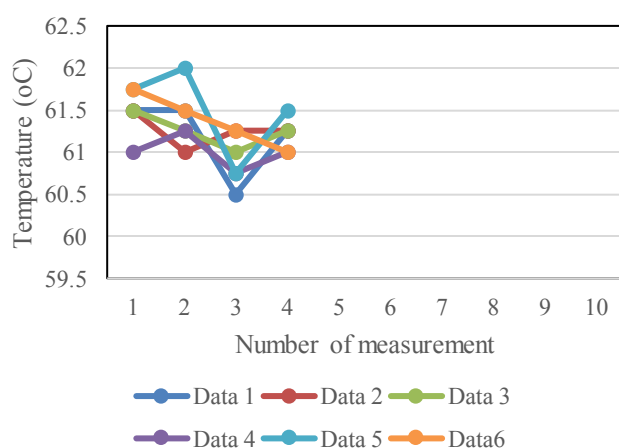


Fig 8. The reading results on the sensor at a temperature of 60°C

G. The Error value from temperature calibration

In **Table I** the data stored from the measurement results at a temperature setting of 40 ° C. Data was collected on Alabtech brand Water Bath. Data is collected when the temperature has begun to stabilize. Retrieval of data storage is done every 1 minute in 10 minutes so that in ten minutes, there are ten temperature data stored. The device is compared to a digital thermometer comparison device. From the results of the temperature measurement of 40 ° C, the smallest error value is obtained in channels 4.5 and 6 with a value of 0.2%, while for the highest error value in channel 2 with a value of 1.8%.

TABLE I. TEMPERATURE SETTING 40°C

Channel	Device	Mean	Error	SD	U95
1	Calibrator	39.73	1.4%	0.34	0.11
	Design	40.29		0.35	0.11
2	Calibrator	39.43	1.8%	0.24	0.08
	Design	40.16		0.46	0.15
3	Calibrator	39.58	0.4%	0.37	0.12
	Design	39.75		0.43	0.14
4	Calibrator	39.73	0.2%	0.18	0.06
	Design	39.81		0.45	0.14
5	Calibrator	40.18	0.2%	0.37	0.12
	Design	40.26		0.44	0.14
6	Calibrator	40.1	0.2%	0.38	0.12
	Design	40.11		0.43	0.14

In **Table II** the data stored from the measurement results at a temperature setting of 50 ° C. Data was collected on Alabtech brand Water Bath. Data is collected when the temperature has begun to stabilize.

TABLE II. TEMPERATURE SETTING 50°C

Channel	Device	Mean	Error	SD	U95
1	Calibrator	49.06	2.25%	0.89	0.32
	Design	50.19		0.35	0.13
2	Calibrator	48.81	2.26%	0.22	0.08
	Design	49.94		0.24	0.09
3	Calibrator	48.84	2%	0.19	0.07
	Design	50		0.35	0.13
4	Calibrator	48.72	2.44%	0.39	0.14
	Design	49.94		0.24	0.09
5	Calibrator	48.94	2%	0.35	0.13
	Design	49.8		0.21	0.08
6	Calibrator	49	1.6%	0.42	0.15
	Design	49.8		0.21	0.08

Retrieval of data storage is done every 1 minute in 10 minutes so that in 10 minutes, there are ten temperature data stored. The device is compared to a digital thermometer comparison device. From the results of the temperature

measurement of 50 ° C the smallest error value is obtained on channel 6 with a value of 1.6%, while for the highest error value on channel 4 with a value of 2.44%.

In **Table III**, the data stored from the measurement results at a temperature setting of 60 ° C. Data was collected on Alabtech brand Water Bath. Data is collected when the temperature has begun to stabilize. Retrieval of data storage is done every 1 minute in 10 minutes so that in 10 minutes, there are ten temperature data stored. The device is compared to a digital thermometer comparison device. From the results of the measurement of temperature 60 ° C obtained the smallest error value on channel 5 with a value of -2% for the highest error value on channel 1 with a value of -0.3%.

TABLE III. TEMPERATURE SETTING 60°C

Channel	Device	Mean	Error	SD	U95
1	Calibrator	61.19	0.3%	0.31	0.16
	Design	60.98		0.31	0.16
2	Calibrator	61.25	0.6%	0.2	0.1
	Design	60.88		0.39	0.19
3	Calibrator	61.25	0.5%	0.2	0.1
	Design	60.93		0.3	0.15
4	Calibrator	61	1.5%	0.2	0.1
	Design	60.1		1	0.5
5	Calibrator	61.5	2%	0.54	0.27
	Design	60.25		0.44	0.22
6	Calibrator	61.38	1.8%	0.32	0.16
	Design	60.28		0.28	0.14

VI. DISCUSSION

In **Table I**, **Table II**, and **Table III** show the measurement of Temperature values in a room water bath where these values can be used to determine whether a water bath is suitable or not. The smallest error value is 0.2%, and the biggest error value is 2.4%. In some studies, calibration tools have been made using the same method. Research on 4 Channel Sterilizer Calibrator using a type k thermocouple sensor [11]. But in this study still has shortcomings, namely the measurement results obtained with the smallest error of 0.2% and the largest error value of 4.4%. In this study, not equipped with data storage for data retrieval results. In performing calibration of data storage for the results of data, retrieval is very necessary because to facilitate the user in processing the next calibration data. Besides this study only displays the results of measurements in the form of numbers without displaying in the graphical form such as in (**Fig. 5**).

VII. CONCLUSION

This water bath calibration device cannot be determined as feasible or not feasible because there is no standard comparison

device yet. The results of measurement data compared with digital thermometer obtained error values at temperature 40 ° C channel 1 1.4%, channel 2 1.8%, channel 3 0.4%, channel 4 0.2%, channel 5 0.2% and channel 6 0.2%. At 50 ° C channel 1 2.25%, channel 2 2.26%, channel 3 2.00%, channel 4 2.44%, channel 5 2% and channel 6 1.6%. At 60 ° C channel 1 0.3%, channel 2 0.6%, channel 3 0.5%, channel 4 1.5%, channel 5 2% and channel 6 1.8%. Based on the results of research in this module for the next researcher, it is recommended to use another signal conditioning amplifier module because when using MAX 6675 sensor read resolution is 0.25 ° C.

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