Manuscript received May 27, 2026; revised May 30, 2026; accepted June 17, 2026; date of publication June 20, 2026
Digital Object Identifier (DOI): 10.1109/ELECTROMEDIC.v1.i1.1

Design and Development of a Portable 8-Channel Water Bath Calibrator with Data Logging Capability

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ABSTRACT The purpose of this research is to create an 8 Channel Portable Water Bath Calibrator equipped with data storage to make it easier for technicians to perform calibrations. The method used is in the form of research and development with a data collection technique in the form of comparing the temperature values read between the writing tool and the comparison tool by PT. Tera Accuracy Partners at the points that have been standardized by the calibration company, namely at temperatures of 40ºC, 60ºC, and 80ºC taken in ten measurements. The results obtained from the measurements that have been carried out are that the largest deviation of temperature measurement between the water bath calibrator and the comparator is located at the temperature measurement of 40°C with a deviation value of 0.34°C. Meanwhile, the smallest deviation value of temperature measurement between the calibrator and the comparator is located at the temperature measurement of 60°C and 80°C, which is 0.02°C. The largest error percentage is in the measurement of 40°C with a value of 0.92% on T2 and the smallest percentage of measurement error is in the measurement of 80°C with a value of 0.14% on T5 and the accuracy of this tool is 99.89%. In addition, the data storage system on the 8-channel water bath calibrator can be read on a PC in CSV file format. Thus, the system created by the author can be useful in the field of calibration, especially in water bath tools that utilize 8 sensors for temperature readings with a data storage system.

INDEX TERMS Water Bath, Calibration, Data Logging, Calibrator Equipment

I. INTRODUCTION

A water bath is a laboratory equipment that contains water or a special liquid that can maintain the temperature under certain conditions for a specified time [1], [2]. The function of *the water bath* is to create a constant temperature in the *chamber* as an incubation tool [3] . The *water bath* works by heating the water with a *heater* to a predetermined temperature, the *water bath* is used at a low temperature of 30ºC - 90ºC[4].

The use of *water baths* in the laboratory is very often used, so calibration must be carried out so that the performance of the tool remains in good condition. The parameter that is calibrated in the *water bath device* is the temperature in the *chamber*, to ensure that the temperature in each *water bath chamber* is the same, so this calibration activity is very important to be carried out to ensure whether the tool is suitable for use or not [5]. Calibration is carried out by comparing the measuring instruments and measuring materials to be calibrated with traceable and traceable standards to national or international standards, whereas the calibration objectives can be determined by conventional truth deviations, measuring instrument values or nominal dimensional deviations that should be the measuring material [6], [7].

Several studies related to temperature calibration tools have been conducted previously by Oktatianto [8], designing an IoT-based 6-channel Blood Bank Refrigerator Calibrator using a DS18B20 sensor with a display on a smartphone but not yet equipped with data storage. Ratna [9], develop temperature calibrators are based on K-type thermocouples with Excel graph display but still produce quite high errors of up to 14.9%. Kusumawardani [10] designed a 6-channel water bath calibrator with a low error of 0.2% and a high of 2.4%, but the device had to be connected to a computer, so it was less practical.[11] create a 4-channel sterilization calibrator with an error of 0.2–4.4%, but a limited number of measuring points. Meanwhile, [12] designed a 8-channel water bath calibrator with an with an automatic storage system. From the study, it can be concluded that most of the research is still limited to a small number of measurement points and has not been equipped with data storage features.

Water bath calibration is usually carried out using a dip thermometer that is dipped alternately at several points, which of course takes the technician's time in calibrating the tool. On the other hand, the storage of measurement results that are carried out manually often poses a risk of human *error* in data recording, which can affect the validity of calibration results and according to relevant research, there is no data storage feature. Therefore, the author created an *8 Channel Water bath* Calibrator tool at 8 *water bath chamber* points so that the *water bath* temperature value can be known evenly and quickly to increase time efficiency in the measurement process. This prototype is designed to *be portable*, which uses a voltage supply from the battery so that with a portable design, this tool can be easily used in various work sites. In addition, the feature of automatically storing calibrated results into a Micro SD card allows users to store, transfer, and process data more easily and accurately in CSV file format, thus minimizing the risk of errors in data recording. It also allows for better documentation as well as ease in the analysis and reporting of calibration results.

II. METHOD

The 8-channel water bath calibrator is composed of several electronic circuits that are integrated with each other to produce a complex tool that can operate as it should.

A. System Block Diagram

The water bath calibrator uses a display of test parameters on an LCD which is composed of several electronic circuits that are integrated with each other to produce a complex tool that can operate as it should. The block diagram used to create the water bath calibration tool is shown in Fig. 1.

Based on fig.1, it can be explained that an 8-channel DS18B20 temperature sensor is placed at 8 points of the water bath chamber which is used to measure the temperature of the water bath chamber. The 8-channel DS18B20 sensor will generate a digital signal[13] . Furthermore, the digital signal will be processed by the microcontroller into a temperature value in units of Celsius and a temperature value of 8 channels will be displayed on the LCD Character 20x4. The entire circuit will be supplied using a 5V voltage battery.

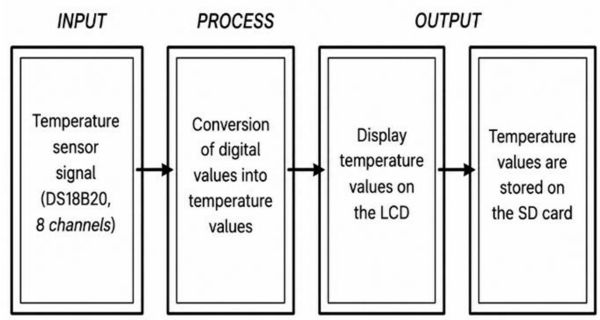

Figure. 1. System diagram blocks

B. Flowchart

The designed system is seen in the prototype working process flow diagram, shown in Figure 2

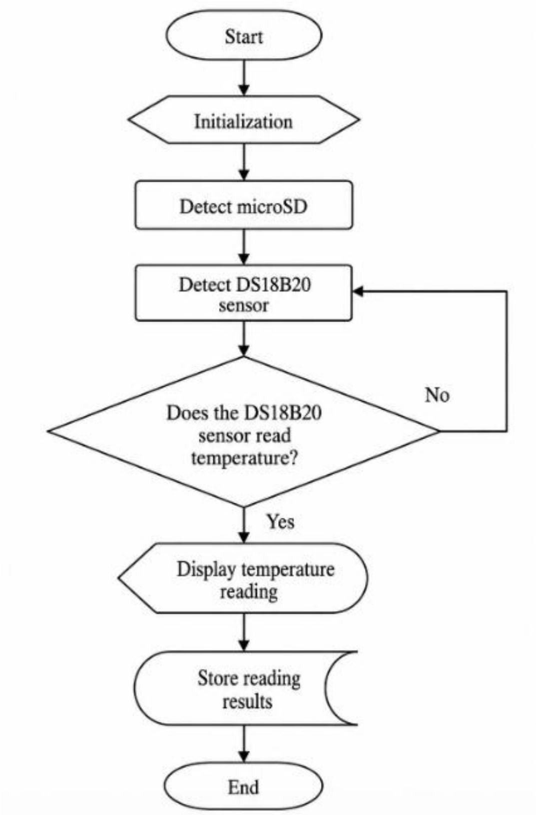

Figure 2. Flowchart

Based on Fig. 2, the process starts when the tool is turned on and then initializes. After the microcontroller has initialized, the microcontroller also detects the presence of a microSD chip. Furthermore, all sensors will DS18B20 read the temperature of the water medium in the water bath chamber. The data from the sensor will be processed by a microcontroller in the form of a degree value of degrees Celsius. The temperature reading results of the eight sensors will be displayed on the LCD screen. In addition, the reading results will also be stored in microSD storage and read on a laptop or PC in CSV file format[14].

C. Design Visual

A visual design prototype is a graphical representation of a tool that includes design elements such as color, shape, proportion, texture, and layout to convey information about the tool clearly and visually appealing. The visual design of the prototype can help in clarifying the functions and features of the prototype, as well as reinforce the visual impression of the water bath calibrator. Fig. 3 shows the visual design of the water bath calibrator

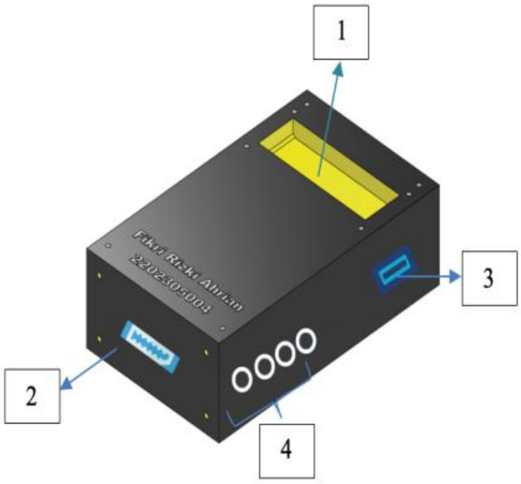

Figure 3. Visual design

Description:

1. 20x4 LCD: Functions to display calibration data
2. SD *card* slot: Serves as a place to insert SD *card*
3. *USB port:* Serves to charge the appliance
4. *Sensor socket*: Serves as a place DS18B20 installation between the sensor and the appliance

D. Testing Method

The test and data collection on this prototype used the Thermocouple Temperature Data Logger calibrator as a comparison tool. The way of calibration is that the sensor from the prototype is immersed in a water bath medium at temperatures of 40 ºC, 60ºC, and 80ºC which is taken in ten measurements. In addition, a calibration check is also carried out from SD Card storage by attaching the SD Card to a laptop or personal computer (PC).

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III. RESULTS

Temperature measurement is carried out by dipping all DS18B20 sensors that are spread into the water bath chamber. The results of the temperature reading by the sensor will be compared with a comparison calibrator, namely the Multichannel Thermocouple Temperature Data Logger brand Madge-Tech. Chamber temperature measurements were carried out at temperature settings of 40ºC, 60ºC and 80ºC. Data collection was carried out 10 times.

A. Measurement Results at 40ºC

The temperature measurement of the water bath chamber with a temperature setting of 40ºC was carried out 10 times [15] to determine the consistency of the calibrator that has been made in calibrating the temperature of the water bath whose value is compared to the measurement results of the comparator. To make it easier for readers to see the difference between the measurement results of the calibrator that has been made by the author and the comparison tool, a comparison diagram is made. Figure 4 shows a diagram of the results of the 40ºC temperature measurement between the calibrator and the comparator.

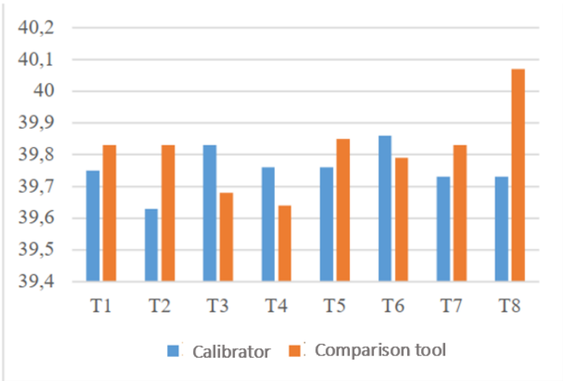

Figure 4. Temperature measurement 40ºC

Based on Fig. 4, it is known that the percentage of calibrator errors obtained is ± 1% with the largest error value of 0.92% at T2 and the smallest error value of 0.33% at T6 calculated using the error formula. In addition, the value of the largest deviation of temperature measurement between the calibrator and the comparator was analyzed using the average formula and deviation, located at T8 with an average value of temperature measurement by the calibrator of 39.73ºC while in the comparator it was 40.07ºC. The value of the smallest deviation of temperature measurement between the calibrator and the comparator was located at T6 with an average value of measurement by the calibrator of 39.86ºC while in the case of the comparator is 39.79ºC. This difference in measurement can be caused by the specifications of the components used in the calibrator. In addition, the exact position of the sensor when the measurement is taken can be a factor in the difference in measurement.

B. Temperature Measurement Results 60°C

The temperature measurement of the water bath chamber with a temperature setting of 60ºC was carried out 10 times to determine the consistency of the calibrator [15] that has been made in calibrating the temperature of the water bath whose value is compared to the measurement results of the comparator. To make it easier for readers to see the difference between the measurement results of the calibrator that has been made by the author and the comparison tool, a comparison diagram is made. Figure 5 shows a diagram of the results of the 60ºC temperature measurement between the calibrator and the comparator.

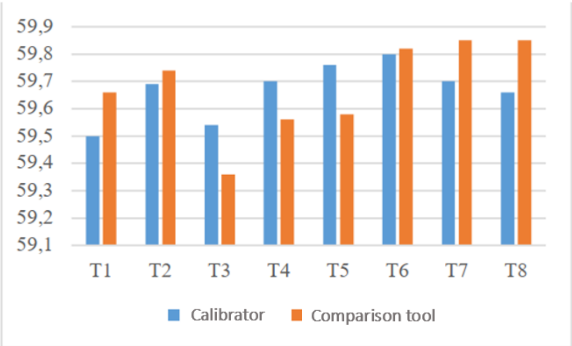

Figure. 5. Temperature measurement 60ºC

Based on Fig. 5, it is known that the percentage of calibrator errors obtained is ± 1% with the largest error value of 0.83% at T1 and the smallest error value of 0.33% at T6 calculated using the error formula. In addition, the value of the largest deviation of temperature measurement between the calibrator and the comparator was analyzed using the average formula and deviation, located at T8 with an average value of temperature measurement by the calibrator of 59.66ºC while in the comparator it was 59.85ºC. The value of the smallest deviation of temperature measurement between the calibrator and the comparator was located at T6 with the average value of measurement by the calibrator of 59.80ºC while in the case of the calibrator the comparator is 59.82ºC. This difference in measurement can be caused by the specifications of the components used in the calibrator. In addition, the exact position of the sensor when the measurement is taken can be a factor in the difference in measurement.

C. Measurement Results at 80ºC

The measurement of the temperature of the water bath chamber with a temperature setting of 80ºC was carried out 10 times [15] to determine the consistency of the calibrator that has been made in calibrating the temperature of the water bath whose value is compared to the measurement results of the comparator. To make it easier for readers to see the difference between the measurement results of the calibrator that has been made by the author and the comparison tool, a comparison diagram is made. Figure 6 shows a diagram of the results of the 80ºC temperature measurement between the calibrator and the comparator.

Based on Fig. 6, it is known that the percentage of calibrator errors obtained is ± 1% with the largest error value of 0.61% at T7 and the smallest error value of 0.14% at T5 calculated using the error formula. In addition, the value of the largest deviation of temperature measurement between the calibrator and the comparator was analyzed using the average formula and deviation, located at T4 with an average temperature measurement by the calibrator of 79.83ºC while in the comparator it was 79.55ºC. The smallest deviation of temperature measurement between the calibrator and the comparator was located at T5 with the average value of measurement by the calibrator of 79.88ºC while in the measuring device is 79.86ºC. This measurement difference can be caused by the specifications of the components used in the calibrator. In addition, the exact position of the sensor when the measurement is taken can be a factor in the difference in measurement.

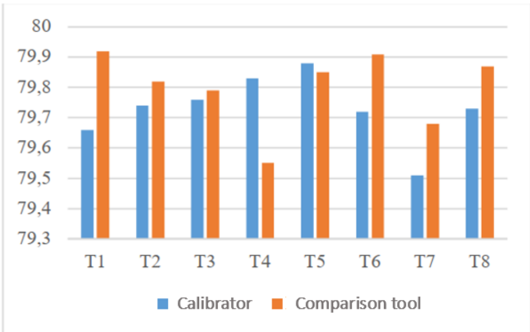

Figure. 6. Temperature measurement 80ºC

Furthermore, the error values obtained from each measurement at temperatures of 40ºC, 60ºC and 80ºC are shown in Fig. 7.

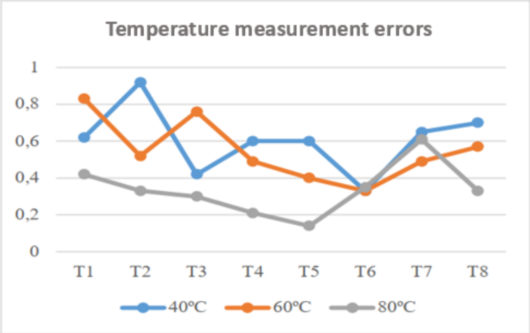

Figure. 7. Temperature measurement error

D. Data Retention

The 8-channel water bath calibrator is also equipped with automatic data storage using an SD Card that is compatible with the device that has been created and a personal computer (PC). Fig. 7 shows the calibration data results from the calibrator displayed on the PC.

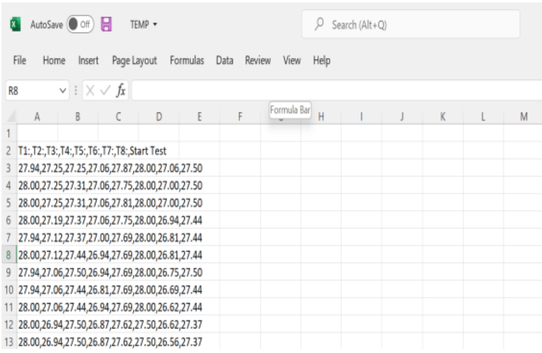

Figure 8. Calibration data storage results.

Based on Fig. 8 which shows the calibration results stored on the SD Card, it can be known that this storage mode can make it easier for technicians to carry out calibration activities without having to record the calibration data storage file on the calibrator is already in CSV format[14] .

IV. DISCUSSION

Based on Fig. 7, it is known that the largest error value when measuring 40ºC temperature is 0.92%. Then in the temperature measurement of 60ºC it has the largest error value of 0.83% and in the measurement of temperature 80ºC it has the largest error value of 0.61. It is seen that the percentage of errors decreases as the temperature increases. This could indicate that the sensor used has better accuracy at high temperatures than at low temperatures. In addition, the use of DS18B20 sensors in the water bath calibration system affects the time efficiency and accuracy of temperature distribution. With only one sensor, it is not possible to describe the overall temperature distribution in a water bath. The use of four sensors strikes a balance between efficiency and accuracy. Meanwhile, the use of eight sensors allows for more detailed monitoring of temperature distribution.

IV. CONCLUSION.

Based on the results obtained from the 8-channel water bath calibrator, it can be concluded that the design of the 8-Channel Portable Water Bath Calibrator module successfully integrates both hardware and software to support accurate and well-coordinated multichannel calibration. The system can handle multiple measurement channels simultaneously, enabling a more efficient and reliable calibration process.

The validation results indicate that the module performs well in terms of accuracy, reliability, and consistency in temperature measurement. Testing was conducted at 40°C, 60°C, and 80°C, showing that the highest measurement error of the DS18B20 sensor occurred at 40°C with a value of 0.92%, while the lowest error occurred at 80°C with a value of 0.14%. Additionally, the data storage function using a microSD card has been verified successfully, where the calibration data can be stored properly and accessed on a personal computer in CSV format.

For future development, the user interface can be improved by implementing a web-based or application-based system. This enhancement is expected to provide a more user-friendly and efficient way to monitor calibration results, ultimately improving the usability and overall performance of the system

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