Nine Channel Temperature Data Logger in Measuring the Effectiveness of the Sterilization Process of Medical Instruments with Dry Sterilization

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ABSTRACT Measuring the temperature on the dry sterilizer is very necessary because the temperature inside the dry sterilizer has the possibility that the temperature is not the same as the temperature that has been set and is displayed on the display. If the temperature in the dry sterilizer does not match the standard setting temperature for the sterilization process, then the sterilization process is said to be imperfect. The purpose of this study is to record and monitor whether the distributed temperature in the sterilization chamber corresponds to the setting temperature. The workings of the temperature data logger tool is that the type K thermocouple temperature sensor will detect the temperature which then enters the analog signal conditioning circuit which then enters the ATMegga 2560 which has been given a program and processed in such a way, then the temperature will be displayed on a 4x20 character LCD. Temperature measurement data will be saved to the SD Card every 10 seconds in the form of a TXT file. This research has been used to record 2 sterilizers and compared with the Madgetech OctTemp2000 data logger. Based on data measurements and comparisons, the average error was obtained at a temperature of 50°C with the smallest error value of 0.7% and the largest value of 3.9%. At a temperature of 100°C, the smallest error value is 1.6% and the largest is 10.5%. Then at a temperature of 120°C the smallest error value is 0.0% and the largest is 8.5%. This research can be used to help analyze the distribution of temperature in a room. With these measurement results, it can be said that this study still has a fairly high error value at several measurement points.

INDEX TERMS Data Logger, Thermocouple, Sterilizer

I. INTRODUCTION Measuring the temperature on the dry sterilizer is very necessary because the temperature inside the dry sterilizer has the possibility that the temperature is not the same as the temperature that has been set and is displayed on the display. If the temperature in the dry sterilizer does not match the standard setting temperature for the sterilization process, then the sterilization process is said to be imperfect. If the temperature is not reached, it causes microbes to remain on the sterilized material or equipment. However, if the temperature exceeds the setting temperature, it can damage the material or tools being sterilized. Sterilization is a process to kill living microorganisms by relying on heat [1]. Dry heat sterilization is the most effective method for killing microbes in glassware and many surgical instruments. Dry heat sterilization uses a heater from a dry element that is electrified so that there is a hot temperature that fills the room, where the temperature has been set according to the needs of the sterilization process. A process that provides information about recording temperature data in the
sterilizer is a data logger. Data Logger is an electronic device that records data from time to time, both integrated with sensors and instruments in it and external sensors and instruments. In short, a data logger is a tool for data logging. The data obtained from the temperature sensor is stored in a data logger, then the data is compared with the temperature on the display of the dry sterilizer.

This temperature data logger tool has been used several times, in 2010 Micky Virgo conducted a focused study with a system from a data logger, this study used the LM35 temperature sensor only as a data source [1]. In 2015 Dwinta Musseytarsih made a research data logger in this study using an LM35 temperature sensor with a temperature measurement range of 60°-100°C, temperature data is stored using an SD Card in the form of a CSV file[2]. Risky Bian Primaswara conducted a research in 2016. In this study the author uses 2 thermocouple temperature sensor channels with a range of 50°-170°C, the temperature read is stored on the SD Card and displayed on a PC[3]. Agus Dwi Korawan conducted a study in 2018. In this study the authors used 16 NTC 7.5 K thermistor sensors with temperature data storage using an SD Card, and data processing using ATMega2560 [4]. In 2020 Rismawati and Muhammad Sadli conducted a research on Temperature Sensor Data Logger using the Atmega16 Microcontroller [5], in this study there were 4 channels using the LM35 sensor and data storage via a USB module with txt and xls file formats.

In previous studies, some still use LM35 and NTC 7.5 K Probe thermistor as temperature sensors, where they are based on specifications that can only detect up to +/-100°C temperatures, some also still have a little channel. The purpose of this study is to record and monitor whether the distributed temperature in the sterilization chamber corresponds to the setting temperature.

The purpose of this study was to record and monitor whether the distributed temperature inside the sterilizer chamber matched the temperature setting. This study will have 9 temperature channels to measure 9 points in the room in accordance with the standard AS2853 in order to know the distribution of temperature in the room with detail, using a thermocouple type-k temperature sensor where the sensor can detect up to 200°C temperature, and this study equipped data storage on sd card with TXT file format so that users can easily access the data of temperature readings on PC (Personal Computer).

II. MATERIALS AND METHODS

A. EXPERIMENTAL SETUP
This research is a temperature recorder that provides 9 channels for measuring, using a type-k thermocouple temperature sensor, using an analog signal conditioning circuit and ATMega 2560 to process the output from the sensor, then the temperature will be displayed on a 4x20 character LCD. Temperature measurement data will be saved to the SD Card every 10 seconds in the form of a TXT file. To test this research, it is necessary to use a sterilizer and a comparison tool in the form of a data logger, place the sensors at the measuring points of the sterilizer room according to the standard, then set the temperature on the sterilizer and start recording the temperature.

1) MATERIAL AND TOOL
This study uses a type-k thermocouple as a temperature sensor, then a analog signal conditioning circuit consisting of a filter, buffer, and non-inverting amplifier circuit. Using ATMega2560 as data processing, 4x20 character LCD as display, and SD Card and RTC modules. The measuring instruments used in this research are avometer and data logger. The tools used in the experiment were a sterilizer with the Fortune ztp78e brand and Elektro-Mag M6040P. While the standard tool used as a comparison is the data logger Madgetech OctTemp2000.

2) EXPERIMENT
In this study, after the module is finished, an experiment will be carried out to record the temperature of the sterilizer for one hour, with temperature settings of 500°C, 1000°C, 1200°C. Using standard tools as a comparison. All sensors will be placed at points according to the specified standard, in the study using the AS2853 standard reference. Each result of recording temperature setting data will calculate the error values and make a graph to compare and validate the results of this study.

B. THE DIAGRAM BLOCK
In Fig 1, When the ON / OFF switch on the tool is ON, the entire circuit will get voltage from the battery. When the start button is pressed, the thermocouple temperature sensor that has been installed on the tool will detect the temperature and will be processed into the analog signal conditioning circuit. The output of the analog signal conditioning circuit is inputted to ATMega2560 for data processing and then displayed on a 4x20 LCD and the data will be stored in the SD Card.

C. THE FLOWCHART
In Fig 2 when the device is turned on, the initialization process will be carried out on the LCD and sensors. Then the thermocouple sensor will take temperature readings. The temperature reading results will be displayed on the device display and the temperature reading data will be stored in the
SD Card. After the temperature reading data is saved, the user can insert the SD Card into the PC to open a txt file, then when the txt file is opened, a table of measurement results will be shown.

FIGURE 2. The Flowchart

D. ANALOG CIRCUIT
The most important part of this study is on fig 3, that is analog signal conditioning circuit. Where there are a series of filters, buffers, and non-inverting amplifiers. The circuit serves to process the output of thermocouple sensors in the form of a small voltage of 0.004mV per increase of 1°C, then will be changed from voltage to temperature using Arduino.

FIGURE 3. Analog signal conditioning Circuit

1) LOW PASS FILTER
The low pass filter circuit on fig 4 serves to eliminate noise coming from the long sensor cable. In this fig 5 the filter circuit was designed with cut-off 3,387 and 1,592 Hz with the calculation:

\[ f = \frac{1}{2 \cdot R \cdot C} \]  

(1)

FIGURE 4. Low Pass Filter Circuit

2) BUFFER
The buffer circuit serves to support the received voltage so that when an output impedance of the circuit remains the same as the voltage received at the beginning.

\[ V_{out} = V_{in} \]  

(2)

FIGURE 5. Buffer Circuit

3) NON-INVERTING AMPLIFIER
The non-inverting amplifier circuit is an amplifier with the characteristics of its output as effective as its input. In this study, an amplifier with a gain of 311 times was used.

\[ V_{out} = 1 + \frac{R_f}{R_i} \]  

(3)

FIGURE 6. Non-Inverting Amplifier Circuit

III. RESULT
In this study, the data logger has been tested using a fortune ztp78e sterilisator and Elektro-Mag M6040P. The standard tool used for comparison is the Madgetech OctTemp2000 data logger.

FIGURE 8. Module Design

1) DESIGN MODULE
As in Fig 8 This module uses a type-k thermocouple as a temperature sensor, then a analog signal conditioning circuit consisting of a filter, buffer, and non-inverting amplifier circuit. Using AT Mega2560 as data processing, 4x20 character LCD as display, and SD Card and RTC modules.
The measuring instruments used in this research are ammeter and data logger.

2) THE LISTING PROGRAM FOR ARDUINO

In this study, the Arduino Mega microcontroller was used and the program was programmed through Arduino. The program on Arduino is shown in the program listing below.

**Pseudocode**: 1. ADC reading function using RMS formula

```c
int get_adc(int ampPin)
{
    int sampleDuration = 100;  // duration of sample
    int sampleCount = 0;       // count of samples
    unsigned long rSquaredSum = 0;  // sum of squared samples
    uint32_t startTime = millis();   // start time

    while((millis()-startTime) < sampleDuration)
    {
        int RawCurrentIn = analogRead(ampPin);  // read analog value
        rSquaredSum += RawCurrentIn;             // add to squared sum
        sampleCount++;                           // increment sample count
    }

    rSquaredSum = rSquaredSum / sampleCount;  // calculate RMS
    return (int) rSquaredSum;                 // return integer
}
```

**Pseudocode 1** is a listing for ADC readings of each analog signal conditioning series output using the average RMS formula and then converted.

**Pseudocode**: 2. Listing to convert ADC to temperature

```c
float nilai_suhu1 = get_adc(pin_ADC1);  // get ADC value of sensor 1
(nilai_suhu1 = (0.4889*nilai_suhu1) - 0.07);
float nilai_suhu2 = get_adc(pin_ADC2);  // get ADC value of sensor 2
(nilai_suhu2 = (0.467*nilai_suhu2) + 18.857);
float nilai_suhu3 = get_adc(pin_ADC3);  // get ADC value of sensor 3
(nilai_suhu3 = ( 0.4788*nilai_suhu3) + 14.139);
float nilai_suhu4 = get_adc(pin_ADC4);  // get ADC value of sensor 4
(nilai_suhu4 = (0.4829*nilai_suhu4) - 7.7189);
float nilai_suhu5 = get_adc(pin_ADC5);  // get ADC value of sensor 5
(nilai_suhu5 = (0.4871*nilai_suhu5) - 9.1896);
float nilai_suhu6 = get_adc(pin_ADC6);  // get ADC value of sensor 6
(nilai_suhu6 = (0.5067*nilai_suhu6) + 3.3444);
float nilai_suhu7 = get_adc(pin_ADC7);  // get ADC value of sensor 7
(nilai_suhu7 = (0.4881*nilai_suhu7) + 3.0716);
float nilai_suhu8 = get_adc(pin_ADC8);  // get ADC value of sensor 8
(nilai_suhu8 = (0.5499*nilai_suhu8) + 13.367);
float nilai_suhu9 = get_adc(pin_ADC9);  // get ADC value of sensor 9
(nilai_suhu9 = (0.4907*nilai_suhu9) - 2.3256);
```

Results of Temperature Measurements in Modules with Comparison Tools

**Table 1**

| Sensor | UA | Error (%) |
|--------|----|-----------|
| T1     | D  | 1.3       | 0.7       |
|        | P  | 0.6       |           |
| T2     | D  | 0.7       | 3.9       |
|        | P  | 0.3       |           |
| T3     | D  | 0.6       | 0.7       |
|        | P  | 0.3       |           |
| T4     | D  | 0.7       | 3.3       |
|        | P  | 0.6       |           |
| T5     | D  | 0.3       | 2.0       |
|        | P  | 0.7       |           |
| T6     | D  | 0.9       | 3.3       |
|        | P  | 0.3       |           |
| T7     | D  | 0.3       | 0.7       |
|        | P  | 0.0       |           |
| T8     | D  | 0.7       | 1.3       |
|        | P  | 0.3       |           |
| T9     | D  | 0.7       | 1.4       |
|        | P  | 0.7       |           |

**FIGURE 12**. Graph of Temperature Measurement Results In Module And setting temperature 50°C

Based on Table 1 and Fig 12 obtained the smallest average error value in the temperature data 50°C is 0.7% and the largest 3.9%. Where D is a data logger tool module, while P is a comparison tool Madgetech OctTemp2000.
| Sensor | UA | Error (%) |
|--------|----|-----------|
| T1     | D  | 0.3       | 4.7     |
|        | P  | 0.3       |
| T2     | D  | 0.7       | 3.6     |
|        | P  | 1.0       |
| T3     | D  | 0.3       | 5.1     |
|        | P  | 0.3       |
| T4     | D  | 0.3       | 7.4     |
|        | P  | 0.3       |
| T5     | D  | 0.3       | 5.8     |
|        | P  | 0.3       |
| T6     | D  | 0.0       | 5.8     |
|        | P  | 0.3       |
| T7     | D  | 0.3       | 10.5    |
|        | P  | 0.3       |
| T8     | D  | 0.0       | 4.1     |
|        | P  | 0.3       |
| T9     | D  | 0.3       | 1.6     |
|        | P  | 0.3       |

**Table 2**  
Measurement results at 100ºC

Based on table 2 and Fig 13 obtained the smallest average error value in the temperature data 100ºC is 1.6% and the largest 10.5%.

| Sensor | UA | Error (%) |
|--------|----|-----------|
| T1     | D  | 0.3       | 4.0     |
|        | P  | 0.3       |
| T2     | D  | 0.3       | 3.2     |
|        | P  | 0.3       |
| T3     | D  | 0.3       | 5.3     |
|        | P  | 0.0       |
| T4     | D  | 0.3       | 4.1     |
|        | P  | 0.6       |
| T5     | D  | 0.7       | 4.3     |
|        | P  | 0.6       |
| T6     | D  | 0.3       | 2.3     |
|        | P  | 0.3       |
| T7     | D  | 0.3       | 8.5     |
|        | P  | 0.3       |
| T8     | D  | 0.3       | 2.1     |
|        | P  | 0.0       |
| T9     | D  | 0.3       | 0.0     |
|        | P  | 0.3       |

**Table 3**  
Measurement results at 120ºC

Based on table 3 and Fig 14 obtained the smallest average error value in the temperature data 120ºC is 0.0% and the largest 8.5%.
IV. DISCUSSION
Temperature Data Logger research design has conducted experiments to record the temperature on the sterilizer with a temperature setting of 50ºC, 100ºC, 120ºC. While the standard tool used as a comparison is madgetech OctTemp2000 data logger. All sensors will be placed at points according to the specified standards, in the study using standard reference AS2853.

Based on measurement and comparison data, the average error was obtained at 50ºC with the smallest error value of 0.7% and the largest value of 3.9%. At 100ºC the smallest error value is 1.6% and the largest is 10.5%. Then at a temperature of 120ºC is the smallest error value of 0.0% and the largest is 8.5%. The result of the error in the measurement may be affected by the location of the sensor which may be very close to the heat source.

With the results of the calculation of errors, the shortcomings in this study is that it still has a high enough error value This study can be improved again in the analog signal conditioning circuit so that the error value is not too high. This research can be used to help analyze the distribution of temperature in a room.

V. CONCLUSION
The purpose of this study was to record and monitor whether the distributed temperature inside the sterilizer chamber matched the temperature setting. Based on measurement and comparison data, the average error was obtained at 50ºC with the smallest error value of 0.7% and the largest value of 3.9%. At 100ºC the smallest error value is 1.6% and the largest is 10.5%. Then at a temperature of 120ºC is the smallest error value of 0.0% and the largest is 8.5%. The development of this research can be done on Using another analog signal conditioning series, so that the error value is not high and modules that are used on any device are not just measurements on dry sterilizers.

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ATTACHMENT
- Schematic and listing program
  https://drive.google.com/drive/folders/1kcg0jU_8Y8vhAOA-ZxUF9iYuRyinihn?usp=sharing