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Design and Development of a Bacteria Incubator Based on Arduino Mega Microcontroller with LCD Touch Screen Display

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Abstract: The bacterial incubator plays a crucial role in culturing microorganisms, particularly in biotechnology research and its applications. This research focuses on the development of a bacterial incubator system utilizing the Arduino Mega2560 microcontroller, operating within a temperature range of 35°C to 50°C. The system incorporates a BME280 sensor for temperature and humidity detection, a TFT touchscreen LCD for user interaction, and an integrated control mechanism for regulating both temperature and incubation duration. Performance testing involved comparing sensor readings from the prototype against standard measuring devices, yielding an average temperature deviation of 0.61%, indicating reliable and precise performance. The device also features automatic regulation of environmental conditions and real-time data visualization, ensuring consistent incubation settings based on predefined criteria. Overall, testing confirmed that the incubator performs effectively and aligns with the intended design parameters.

Keywords: Bacterial Incubator, Arduino Mega2560, BME280 Sensor, Automation, LCD TFT.

INTRODUCTION

Microorganisms can be classified based on their optimal growth temperature into psychrophiles, psychrotrophs, mesophiles, thermophiles, and hyperthermophiles. Psychrophilic bacteria grow optimally between 0°C and 20°C, while psychrotrophic bacteria can survive in temperatures ranging from 0°C to 35°C. Mesophiles thrive within the 20°C to 45°C range, thermophiles between 45°C and 65°C, and hyperthermophiles at temperatures above 90°C, with some capable of growing between 80°C and 113°C (Prescott, 2005). Thermophiles are generally defined as organisms that can grow at temperatures exceeding 45°C. In recent years, thermophilic organisms have garnered increasing scientific attention, especially following discoveries of bacterial species capable of surviving at or above the boiling point of water (Lestari, 2000).

Indonesia, as a tropical country, possesses a wide range of geothermal environments, such as volcanic mountain regions, hot springs, and fossil fuel and coal reserves. These varied ecological conditions support the high heterogeneity of thermophilic bacteria (Indrajaya, 2003). Thermophilic bacteria are known to produce thermostable enzymes, which are crucial for a variety of industrial and biotechnological applications. These include molecular biology research and diagnostics (such as enzymes involved in DNA and RNA processing), as well as the transformation of starch, food processing, waste treatment, paper manufacturing, and organic synthesis (Sutiamiharja, 2008).

Among microbial groups, bacteria are a notable source of amylase enzymes, and some of these bacteria are thermophilic in nature (Indrajaya, 2003). The use of thermophilic bacteria for amylase production offers several benefits, including reduced risk of contamination due to their high-temperature growth environment (Santos & Meire, 2003). In response to this scientific context, this study aims to design and construct a bacterial incubator system.

RESEARCH METHOD

Research Design

The research stages represent the sequence of steps undertaken by the author from the initial phase to the completion of the study. These stages are illustrated in the flowchart presented in Figure 1.

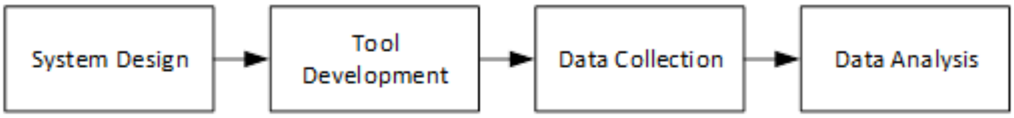

Figure 1. Research Procedure Flowchart

Overall Circuit Design

The complete circuit diagram of the Arduino Mega2560-based bacterial incubator is shown in Figure 2, which illustrates the integration of all components, including the power supply, controller, sensors, and output devices.

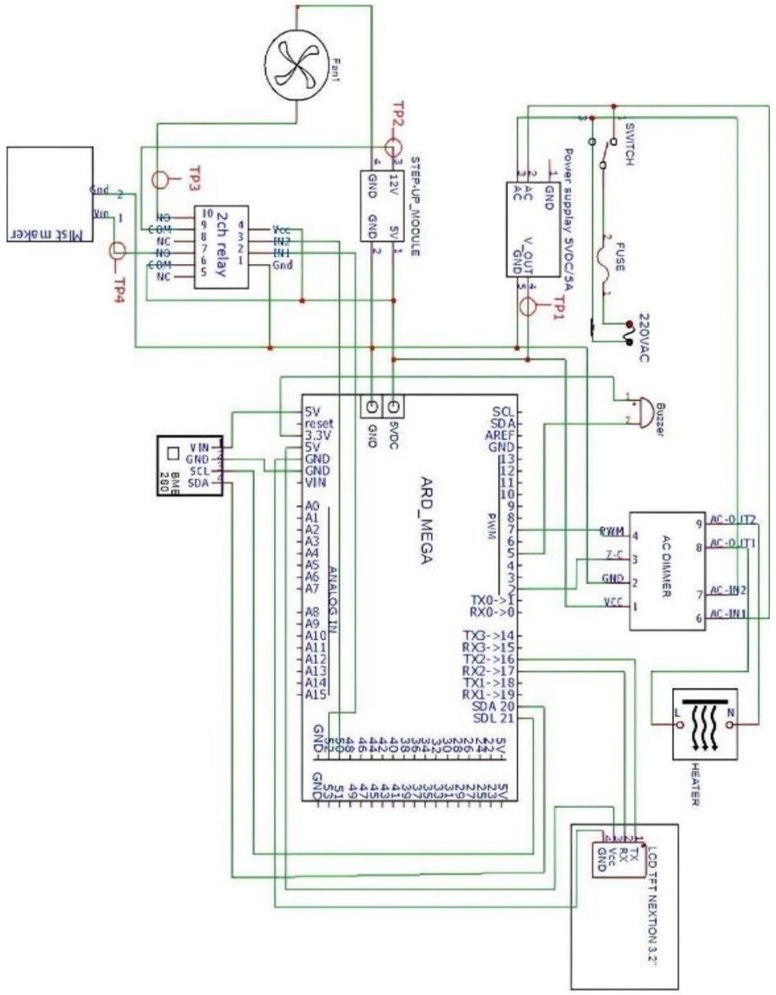

Figure 2. Complete Circuit Diagram of the Bacterial Incubator

The device workflow is illustrated in outlines the control logic and operational stages of the Arduino Mega2560-based bacterial incubator system.

Description of the flowchart:

1. Start
2. Initialization by powering on the system
3. Set temperature and timer parameters
4. When the "Start" button is pressed, both the timer and heater are activated
5. Check if the set temperature is reached:
    - If temperature is within the range of 35ºC – 50ºC → Fan turns ON
    - If not, the system continues to heat
6. When the timer reaches the configured duration → Timer OFF, Fan OFF, Heater OFF

7. Buzzer turns ON to indicate completion
8. End

Device Design

The physical design of the Arduino Mega2560-based bacterial incubator is presented in Figure 3, showing both front and rear views of the device.

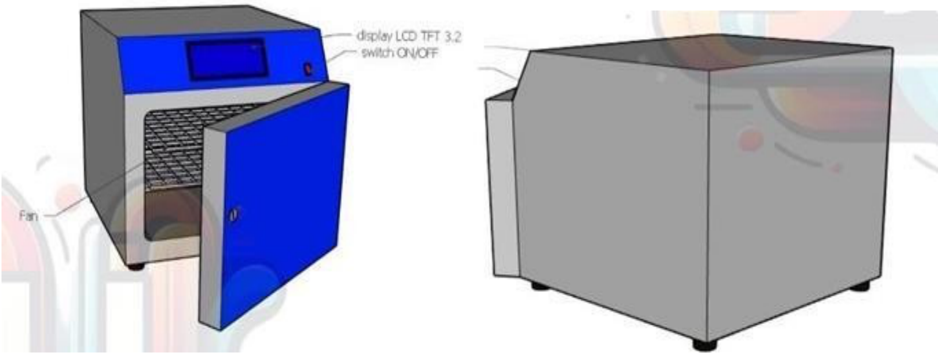

Figure 3. Incubator Device Design

Data Collection

Data collection in this study involves measuring voltages at key circuit points and conducting functional tests. These tests are documented both in the lab and field using a multimeter.

Measurement Points

To monitor the output of various components in the system, the following measurement points are defined:

1. Measurement Point 1 (TP1)
   Measures the output of the 5VDC power supply, taken at the output terminal.
2. Measurement Point 2 (TP2)
   Measures the output of the 5VDC to 12VDC step-up module, taken at its output terminal.
3. Measurement Point 3 (TP3)
   Measures the input voltage at the fan terminal to observe current flow when the fan is ON or OFF.
4. Measurement Point 4 (TP4)

Measures the input voltage at the mist maker terminal to detect the operating current when the mist maker is active or idle.

RESULT AND DISCUSSION

Preparation of Tools and Materials

Before conducting functionality testing and data collection, several tools were prepared to support the testing of the Arduino Mega2560-based bacterial incubator. These include:

1. Arduino Mega2560-based bacterial incubator
2. Digital multimeter
3. Basic electronics toolset

Measurement Results and Data Analysis

Measurement results were obtained from several predefined test points to determine whether the actual voltages match the theoretical design values. Data analysis was conducted by comparing measured values against standard datasheets to calculate the percentage of error for each component.

Measurement Point TP1 – Power Supply Output Voltage

Voltage at the output of the 5VDC power supply was measured using a digital multimeter. The results are presented in Table 1.

Table 1. TP1 – Output Voltage of Power Supply

Measurement Results			Reference (V)	Error %
Measurement	Measurement Voltage (V)	Average (V)		
1	5,02 VDC	5,013 VDC	5 VDC	0.26%
2	5,01 VDC			
3	5,01 VDC			

The power supply output voltage was 5.013V on average, resulting in an error percentage of 0.26%, which is within the acceptable ± 5% tolerance range.

Figure 4. TP1 Voltage Measurement Procedure

Measurement Point TP2 – Step-Up Module Output Voltage

The output of the 5VDC to 12VDC step-up converter was measured. Results are summarized in Table 2.

Table 2. TP2 – Output Voltage of Step-Up Module

Measurement Results			Reference (V)	Error %
Measurement	Measurement Voltage (V)	Average (V)		
1	11,98 VDC	12 VDC	12 VDC	0.25%
2	11.96 VDC			
3	11,98 VDC			

The average output was 11.97V, with a 0.25% error—also within acceptable range.

Figure 5. TP2 Voltage Measurement Procedure

Measurement Point TP3 – LCD Input Voltage

Measurements were taken at the input terminals of the Nextion LCD. Results are presented in Table 3.

Table 3. TP3 – Input Voltage of LCD

Measurement Results			Reference (V)	Error %
Measurement	Measurement Voltage (V)	Average (V)		
1	4,96 VDC	5 VDC	5 VDC	1.00%

The average reading was 4.95V, with a 1.00% error, still within the ±5% tolerance.

Figure 6. TP3 Voltage Measurement Procedure

Measurement Point TP4 – Fan Input Voltage

Fan input voltage was measured and recorded in Table 4.

Table 4. TP4 – Fan Input Voltage

Measurement Results			Datasheet (V)	Error %
Measurement	Measurement Voltage (V)	Average (V)		
1	11,83 VDC	11.84	12 VDC	1.33%
2	11.85 VDC			
3	11.85 VDC			

Fan voltage was stable at 11.84V with a 1.33% error, within tolerance.

Figure 7. TP4 Voltage Measurement Procedure

Measurement Point TP5 – Heater Input Voltage

The voltage supplied to the heater was measured using an AC setting on the multimeter. Results are shown in Table 5.

Table 5. TP5 – Heater Input Voltage

Measurement Results			Datasheet (V)	Error %
Measurement	Measurement Voltage (V)	Average (V)		
1	8,41 V	9 V	9 V	1.36%
2	8,41 V			
3	8,41 V			

The heater input voltage was recorded as 223V, with an error margin of 1.36%, within acceptable limits.

Figure 8. TP5 Voltage Measurement Procedure

Incubator Temperature and Humidity Test Results

The incubator was tested at three different temperature setpoints (35°C, 45°C, and 50°C) over 10-minute intervals. Sensor readings were compared to a standard measuring instrument, as shown in Table 6.

Table 6. Temperature and Humidity Function Test

Set Temp	Duration	Incubator Reading	Standard Reading
35°C	10 mins	35.2°C / 65% RH	35.0°C / 67% RH
45°C	10 mins	40.1°C / 45% RH	40.0°C / 46% RH
50°C	10 mins	50.5°C / 35% RH	49.9°C / 31% RH

Additional temperature accuracy testing was conducted across six trials:

Table 7. Temperature Accuracy Test Results

Trial	Set Temp (°C)	Measured (°C)	Standard (°C)	Error (%)
1	35	35.2	35.1	0.28
2	37	37.5	37.5	0.80
3	40	40.1	40.0	0.25
4	45	45.4	45.6	0.43
5	50	50.5	49.0	1.20
6	53	53.3	52.9	0.75
Average Error	-	-	-	**0.61%**

Based on the test data, the Arduino Mega2560-based bacterial incubator is capable of maintaining stable temperature and humidity levels. Real-time temperature values are accurately displayed on the TFT LCD touchscreen. The average error rate of 0.61% confirms the reliability of the system, making it suitable for laboratory applications including bacterial culture and biotechnology research.

CONCLUSION

This research successfully designed and developed a bacterial incubator based on the Arduino Mega2560 microcontroller equipped with a TFT touchscreen LCD interface. The system integrates key components including a BME280 sensor for temperature and humidity monitoring, a relay-controlled heater and fan, a step-up power module, and a real-time control interface.

The results of the voltage measurements at five key test points (TP1–TP5) demonstrate that all components operate within acceptable voltage tolerance limits (±5%). The system exhibited stable voltage outputs with minimal error, confirming the reliability of the hardware integration.

Functionality tests involving temperature and humidity control at setpoints of 35°C, 45°C, and 50°C showed that the incubator was capable of achieving and maintaining the target conditions effectively. The average temperature error across six test trials was recorded at only 0.61%, indicating high accuracy and system responsiveness.

The Arduino Mega2560-based incubator consistently displayed real-time values on the LCD and allowed for precise parameter configuration, ensuring a controlled environment suitable for bacterial culture. Given these results, the device is proven to be functional, stable, and suitable for laboratory applications in microbiology and biotechnology research.

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