“Automated Arduino and peltier Based Smart Cooling system”

A report submitted to the Department of Mechanical Engineering. Sonargaon University in fulfillment of the requirements for the course

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May 2026

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DECLARATION

I hereby declare that this project, titled "**Automated Arduino and peltier Based Smart Cooling system**" is the result of my original work conducted independently in the laboratories of the Department of Mechanical Engineering, Sonargaon University.

This project is submitted in partial fulfillment of the requirements for the degree of Bachelor of Science in Mechanical Engineering (ME). It has not been submitted, either wholly or in part, for any other academic award, diploma, or qualification at this or any other institution. I affirm that the project work was carried out with due diligence and in accordance with the highest standards of academic integrity. All relevant ethical and safety guidelines were followed throughout the course of this research. I take full responsibility for the content, originality, and reliability of the information and findings presented in this document.

Signature of the Supervisor

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The project entitled **"Automated Arduino and peltier Based Smart Cooling system"** submitted by MD. MASUD RANA ID: 2103025223, ALI NEWAZ NILOY ID: 2203028088, DRUBA MAJUMDAR ID: 2203028007, SAIFUL ISLAM ID: 2203028056, SHAHIN ALAM ID: 2201026102 has been done under my supervision and accepted as adequate in partial fulfillment of the requirements for the degree of **Bachelor of Science in Mechanical Engineering** in **May, 2026.**

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On behalf of

Md. Masud Rana

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ABSTRACT

The Automated Arduino and peltier Based Smart Cooling system is a smart and energy-efficient cooling system designed using thermoelectric technology. The system primarily utilizes Peltier Module to achieve cooling based on the principle of heat transfer when electric current is applied. Two Peltier modules are used to enhance cooling performance, where the cold side is placed inside the chamber and the hot side is cooled externally using heat dissipation methods. To improve cooling efficiency, two cooling fans are employed for proper air circulation, while a mini water pump assists in removing heat from the hot side through a liquid cooling mechanism. The internal temperature and humidity of the chamber are continuously monitored using a DHT11 Sensor, and the data is processed by an Arduino Uno. A potentiometer is used to set the desired temperature within a range of 0°C to 50°C, allowing the user to easily control the system according to requirements. Based on the comparison between the set temperature and the measured temperature, the Arduino automatically controls the operation of the Peltier modules, fans, and water pump through relay modules. When the temperature exceeds the set value, the system turns ON, and when it falls below the set value, the system turns OFF, ensuring efficient energy usage. Additionally, a Motor Driver is incorporated to handle the high current requirements of the Peltier modules (rated at 12V, 6A), ensuring safe and stable operation. The system is powered by a 220V AC supply, which is converted into 12V DC using an SMPS, and further regulated to 5V using a buck converter for low-power components. An I2C LCD display is used to show real-time temperature, humidity, set temperature, and system status, providing a user-friendly interface. Overall, the system offers an efficient, compact, and reliable solution for maintaining controlled temperature environments in small-scale applications.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

With the rapid advancement of modern technology, the demand for automated and energy-efficient cooling systems has significantly increased in various fields such as laboratories, food preservation, medicine storage, and electronic device cooling. Maintaining a stable and controlled temperature environment is essential for ensuring product quality, system reliability, and operational safety. Conventional cooling systems, although effective, often consume high power and lack precise control and automation features. To address these challenges, the Automated Arduino and peltier Based Smart Cooling system has been developed as a compact and intelligent cooling solution. This system is based on thermoelectric cooling technology using the Peltier Module, which operates on the principle of heat transfer when electric current flows through it. In this project, two Peltier modules are used to enhance cooling efficiency, where the cold side is utilized inside the chamber and the hot side is cooled externally using heat dissipation techniques. The system is controlled by an Arduino Uno, which processes real-time data from a DHT11 Sensor to monitor the internal temperature and humidity of the chamber. A potentiometer is used to set the desired temperature within a range of 0°C to 50°C, allowing flexible user control. Based on the comparison between the set temperature and the measured temperature, the Arduino automatically controls the operation of the cooling components. When the temperature inside the chamber exceeds the predefined value, the system activates two Peltier modules, cooling fans, and a mini water pump through relay modules to initiate the cooling process. Additionally, a Motor Driver is used to safely drive the Peltier modules (rated at 12V, 6A), ensuring stable and efficient operation under high current conditions. [1,2]

The fans ensure proper air circulation inside the chamber, while the water pump assists in dissipating heat from the hot side of the Peltier modules, thereby improving overall efficiency. Once the temperature drops below the set value, the system automatically turns

OFF the devices, ensuring energy conservation. [3] The entire system is powered by a 220V AC input, which is converted into 12V DC using an SMPS, and further stepped down to 5V through a buck converter to operate low-power components. An I2C-based LCD display provides real-time information such as temperature, humidity, set temperature, and system status, making the system user-friendly and easy to monitor. [4]

This project demonstrates an effective integration of thermoelectric cooling, sensor-based monitoring, automatic control, and efficient power management to create a reliable and high-performance cooling chamber suitable for small-scale applications.

1.2 Problem Statement

In many laboratory, industrial, and small-scale storage applications, maintaining a stable and controlled temperature environment is essential for preserving materials, ensuring system reliability, and achieving accurate results. However, most conventional cooling systems are not suitable for precise and automated temperature control. These systems often rely on manual operation or simple thermostatic control, which lacks accuracy, flexibility, and efficiency.

One of the major problems with traditional cooling systems is the absence of real-time monitoring and automatic control. Without continuous temperature feedback, it becomes difficult to maintain a consistent cooling environment, especially when external temperature conditions vary. This can lead to overheating or overcooling, both of which may damage sensitive components or stored materials. Another limitation is inefficient energy usage. Conventional cooling systems often run continuously or operate at fixed power levels regardless of the actual cooling requirement. This results in unnecessary power consumption, increased operational cost, and reduced system efficiency. Additionally, many low-cost cooling systems do not include proper heat management techniques. In thermoelectric systems, ineffective heat dissipation from the hot side reduces overall performance and cooling efficiency. Without proper cooling methods such as heat sinks, fans, or liquid cooling, the system cannot perform optimally. User control is also limited in traditional systems. Most systems do not provide an easy way to set and adjust the desired temperature according to specific requirements. The absence of a simple and flexible control interface makes these systems less user-friendly. the lack of integrated sensing and display systems makes monitoring difficult. Users cannot easily observe real-time temperature, humidity, or system status, which reduces system reliability and usability. To overcome these challenges, the Automated Arduino and peltier Based Smart Cooling system is developed as an intelligent and efficient solution. The system uses Peltier Module for cooling, combined with proper heat dissipation techniques using fans and a water pump. A DHT11 Sensor continuously monitors temperature and humidity, while an Arduino Uno processes the data and automatically controls the system. A potentiometer allows users to set the desired temperature within a range of 0°C to 50°C, providing flexible and user-friendly control. Relay modules are used to switch the cooling devices ON or OFF based on real-time temperature conditions, ensuring energy-efficient operation. By integrating automatic control, real-time sensing, and efficient cooling techniques, this project addresses the limitations of conventional systems and provides a cost-effective, reliable, and user-friendly solution for temperature-controlled applications.

1.3 Background of the Study

Temperature control and environmental regulation play a vital role in modern industries, laboratories, agriculture, and food storage systems. Maintaining a stable temperature ensures product quality, enhances equipment performance, and increases the lifespan of temperature-sensitive materials. In developing countries like Bangladesh, conventional cooling systems are widely used, but they often lack automation, precision, and energy efficiency. Traditional cooling systems generally rely on manual control or basic thermostats, which are not capable of maintaining consistent temperature conditions. These systems require continuous human supervision and often fail to respond quickly to environmental changes. As a result, temperature fluctuations can occur, leading to product spoilage, reduced efficiency, and potential system damage. In Bangladesh, where the climate is predominantly hot and humid, the need for efficient cooling solutions is even more critical. Sectors such as food preservation, agriculture, pharmaceuticals, and electronics frequently deal with temperature-sensitive materials. However, many low-cost and locally available cooling systems do not provide accurate temperature control, real-time monitoring, or automatic response mechanisms. Another major issue is energy inefficiency. Conventional cooling systems often operate continuously without considering the actual cooling demand, leading to excessive power consumption and increased operational costs. Additionally, improper heat dissipation in many systems reduces cooling performance and affects long-term reliability. Thermoelectric cooling technology, using devices like the Peltier Module, offers a compact and efficient alternative to traditional refrigeration methods. These modules provide solid-state cooling without the need for refrigerants, making them environmentally friendly and suitable for small-scale applications. However, their efficiency depends heavily on proper heat management and intelligent control. To address these limitations, the Cooling System has been developed. This system integrates thermoelectric cooling with automatic control using an Arduino Uno. A DHT11 Sensor is used to continuously monitor temperature and humidity inside the chamber. The system allows users to set a desired temperature between 0°C and 50°C using a potentiometer. Based on real-time sensor data, the Arduino automatically controls the operation of Peltier modules, cooling fans, and a mini water pump through relay modules. This ensures efficient cooling performance while minimizing energy consumption. An LCD display provides real-time information about temperature, humidity, set temperature, and system status, making the system easy to monitor and operate. By combining automatic control, efficient heat dissipation, and user-friendly design, this project provides a practical and cost-effective solution for maintaining controlled temperature environments. [4,5]

1.4 Objectives

This project aims to develop an automated and efficient cooling system capable of maintaining controlled temperature conditions for various applications such as laboratories, food storage, and electronic equipment cooling. The main objectives of this project are as follows:

I. To design and develop a Automated Arduino and peltier Based Smart Cooling system that can automatically maintain a desired temperature range between 0°C and 50°C using Peltier Module, cooling fans, and a water pump for stable and uniform cooling.

II. To implement an automatic control mechanism using Arduino Uno that compares the set temperature with the measured temperature and controls the cooling components accordingly.

III. To continuously monitor the internal environment of the chamber using a DHT11 Sensor for accurate feedback and system control.

IV. To allow users to easily set the desired temperature between 0°C and 50°C using a potentiometer for flexible and customizable operation.

CHAPTER 2

LITERATURE REVIEW

2.1 Related Research

Recent advancements in sensor technology and microcontroller-based automation have significantly improved temperature control and environmental monitoring systems. Researchers have widely used sensors such as the DHT11 Sensor to obtain real-time temperature and humidity data for maintaining stable environmental conditions. These sensors, when integrated with microcontrollers like the Arduino Uno, enable automatic decision-making by comparing measured values with predefined settings and controlling cooling devices accordingly. This approach reduces human intervention and increases system accuracy and efficiency in temperature regulation.

2.2 Temperature and Humidity Monitoring System

A study by Rahman et al. (2021) presented a microcontroller-based temperature and humidity monitoring system using the DHT11 Sensor and Arduino Uno. The system continuously measured environmental parameters and displayed real-time data on an LCD screen. The researchers highlighted the importance of continuous monitoring and automatic response in maintaining stable environmental conditions. The system demonstrated improved accuracy and reduced human intervention by automatically controlling output devices based on sensor readings. This study provides a strong foundation for developing automated cooling systems without relying on complex networking technologies [1,6].

2.2.1 Thermoelectric Cooling System Using Peltier Module

study conducted by Kumar and Singh (2022), a thermoelectric cooling system was developed using a Peltier Module for small-scale cooling applications. The system utilized temperature sensors and a microcontroller to regulate cooling performance automatically. Heat dissipation was enhanced using heat sinks and cooling fans to improve the efficiency of the Peltier module. The researchers concluded that thermoelectric Automated Arduino and peltier Based Smart Cooling system are compact, energy-efficient, and suitable for applications requiring precise temperature control. This research directly supports the design and implementation of the Cooling System, which also uses Peltier modules along with proper heat management techniques for effective cooling. [2,5]

2.2.2 Automated Cooling System with Sensor Feedback and Relay Control

A study by Hasan et al. (2020) proposed an automated cooling system that used temperature sensors, relay circuits, and transistor-based switching for controlling fans and cooling elements. The system automatically adjusted cooling intensity based on sensor feedback to maintain a stable environment. The authors highlighted the importance of using buck converters and regulated SMPS units for maintaining consistent voltage levels to prevent damage to sensitive components. This research supports the IoT-Based Smart Cooling Chamber project's use of transistor and relay-based control for efficient automation and protection. [3]

2.2.3 IoT-Based Smart Cold Storage for Agricultural Applications

In a study by Chowdhury et al. (2023), an IoT-based smart cold storage system was developed to preserve fruits and vegetables under controlled environmental conditions. The system employed ESP32 microcontrollers, DHT sensors, and Wi-Fi-based communication to transmit real-time temperature and humidity data to a cloud dashboard. The project also included alert notifications for abnormal temperature fluctuations. The authors emphasized scalability and adaptability for rural applications in developing countries. This research directly supports the objectives of the IoT-Based Smart Cooling Chamber, which aims to deliver an energy-efficient and remotely accessible cooling solution for diverse industries.[4]

2.3 Sensor Technologies in Smart Cooling Systems

Sensor technologies play a crucial role in Automated Arduino and peltier Based Smart Cooling system by enabling accurate monitoring and control of environmental conditions such as temperature and humidity. In the Cooling System, sensors provide continuous feedback to ensure that the system maintains the desired cooling performance. The integration of sensors allows the system to respond automatically to changes in environmental conditions, improving accuracy, reliability, and energy efficiency without the need for constant manual supervision. In this project, the DHT11 Sensor is used to measure the temperature and humidity inside the chamber in real time. The sensor sends data to the Arduino Uno, which processes the information and determines whether the cooling system needs to be activated or deactivated. Based on the sensor feedback, the Arduino controls the operation of the Peltier modules, cooling fans, and water pump through relay modules, ensuring stable temperature conditions and efficient energy usage. Unlike complex systems, this project focuses on a simple yet effective sensor-based control mechanism without the need for internet connectivity or advanced monitoring platforms. The use of a reliable and low-cost sensor like DHT11 makes the system practical and suitable for small-scale applications. In future improvements, more advanced sensors with higher accuracy can be incorporated to enhance system performance and support more precise environmental control in industrial or laboratory settings.

2.3.1 Importance of Safety in Automated Cooling Systems

Safety is a critical aspect of automated Temperature Controlled Cooling Chamber, especially when electrical components and temperature-sensitive devices are involved. Improper operation or system faults can lead to overheating, component damage, or failure of the cooling system, which may affect the stored materials. In the Cooling System, maintaining stable operation and protecting system components are essential for reliable performance. The system must ensure that temperature control operates accurately without causing excessive load on devices. The use of proper control mechanisms and protective components helps maintain system integrity. The Arduino Uno ensures controlled operation by automatically switching devices ON and OFF based on sensor feedback. Additionally, safe handling of power supply and proper insulation of electrical connections prevent short circuits and overheating. Ensuring system safety not only protects the equipment but also increases the reliability and lifespan of the overall cooling system.

2.3.2 Types of Safety and Protection Measures

Various safety and protection measures are implemented to ensure the reliable operation of the cooling system. These measures include physical protection, electrical safety, and operational control mechanisms:

1. **Physical Protection Measures**: All components such as the Arduino Uno, sensors, relay modules, and wiring should be properly enclosed within a protective casing. This prevents accidental damage, dust accumulation, and external interference. Proper mounting of components also ensures stable and long-term operation.
2. **Electrical Protection Measures**: The system uses a 220V AC input, which is converted to a safe 12V DC using an SMPS and further regulated to 5V through a buck converter. Proper insulation, fuses, and voltage regulation help protect components from voltage fluctuations and short circuits. Relay modules are used to safely control high-power devices like Peltier modules, fans, and pumps.
3. **Automatic Control and Monitoring**: The DHT11 Sensor continuously monitors the internal conditions of the chamber. Based on this data, the Arduino automatically controls the cooling system, preventing overheating or excessive cooling. This automatic operation reduces human error and improves system efficiency.

2.3.3 Challenges in Implementing Safety and Reliability Measures

Implementing effective safety and reliability measures in automated cooling systems presents several challenges. One of the main issues is maintaining stable operation under varying environmental and power conditions. In regions where voltage fluctuations are common, unstable power supply can affect system performance and may damage sensitive components. Another challenge is efficient heat management. In thermoelectric systems using Peltier Module, improper heat dissipation from the hot side can reduce cooling efficiency and potentially damage the module. Therefore, proper use of heat sinks, cooling fans, and water-cooling systems is essential. Cost is also an important factor, as adding protective components and improving system reliability can increase overall expenses. Designing a system that balances cost, safety, and performance is crucial. Regular maintenance, proper circuit design, and careful component selection help overcome these challenges and ensure a reliable and efficient cooling system.

2.4 Control System, and Efficiency in Automated Cooling System

The Automated Arduino and peltier Based Smart Cooling system operates based on continuous interaction between sensors, control units, and cooling components to maintain stable environmental conditions. Instead of relying on internet-based communication, the system uses direct hardware integration for real-time monitoring and control. This approach ensures reliable performance, faster response time, and independence from network connectivity, making the system suitable for low-cost and practical applications.

2.4.1 Sensor-Based Environmental Monitoring

In this system, environmental monitoring is achieved using a DHT11 Sensor, which continuously measures the temperature and humidity inside the chamber. The sensor sends real-time data to the Arduino Uno, enabling accurate detection of environmental changes. This continuous monitoring ensures that the system can respond immediately when the temperature exceeds or falls below the desired level.

2.4.2 Local Display and User Interaction

Instead of cloud-based monitoring, the system uses an I2C LCD display to provide real-time information directly to the user. The display shows current temperature, humidity, set temperature, and system status (ON/OFF). A potentiometer allows the user to set the desired temperature between 0°C and 50°C. This simple and effective interface makes the system user-friendly and easy to operate without requiring internet connectivity.

2.4.3 Automatic Control and System Efficiency

The cooling system operates automatically based on a feedback control mechanism. The Arduino compares the measured temperature with the user-defined set value and controls the cooling devices accordingly. When the temperature rises above the set value, the system activates the Peltier Module, cooling fans, and water pump through relay modules. Once the temperature drops to the desired level, the system turns OFF these components to conserve energy. This automatic ON/OFF control improves energy efficiency and reduces unnecessary power consumption.

2.5 Automation and User Interaction in Smart Cooling System

Automation and user interaction are essential for improving the performance and usability of temperature-controlled cooling systems. In the Cooling System, automation ensures accurate temperature regulation with minimal human intervention, while user interaction allows easy monitoring and control of system parameters. By integrating sensors, a microcontroller, and display units, the system achieves reliable operation, energy efficiency, and user-friendly control.

2.5.1 Automation in Cooling Chambers

Automation in the cooling chamber eliminates the need for manual temperature control by using sensor-based feedback and microcontroller processing. The system continuously monitors environmental conditions using a DHT11 Sensor and sends the data to the Arduino Uno. When the measured temperature exceeds the user-defined value, the controller automatically activates the cooling components such as Peltier modules, fans, and the water pump through relay modules. Once the temperature returns to the desired level, the system turns OFF the devices to conserve energy. This automatic control loop ensures stable temperature conditions, reduces human error, and improves overall system efficiency.

2.5.2 User Interaction Features

User interaction in this system is achieved through simple and effective hardware interfaces. A potentiometer is used to set the desired temperature within a range of 20°C to 50°C, allowing flexible control based on user requirements. An I2C LCD display provides real-time information such as temperature, humidity, set temperature, and system status. This allows users to easily monitor the system without the need for complex interfaces or internet connectivity. The combination of physical control (potentiometer) and visual feedback (LCD) makes the system easy to operate and suitable for practical applications.

2.6 Summary

This chapter has reviewed the fundamental concepts and existing research related to temperature-controlled cooling systems. It highlighted the limitations of conventional cooling methods, including lack of automation, poor energy efficiency, and insufficient monitoring capabilities. The study also discussed the importance of sensor-based systems and microcontroller-driven automation in improving temperature regulation and system performance. Key technologies such as the DHT11 Sensor, Arduino Uno, and Peltier Module were analyzed, demonstrating their effectiveness in developing compact and efficient cooling solutions. The role of proper heat dissipation, power management, and relay-based control was also emphasized to ensure system stability and reliability. Furthermore, the chapter explained the importance of automation and user interaction in maintaining consistent environmental conditions. It showed how real-time monitoring, automatic control mechanisms, and simple user interfaces can significantly enhance system usability and reduce energy consumption. Safety considerations and system reliability were also discussed as essential factors in designing an effective cooling system. Overall, this literature review provides a strong foundation for the development of the Cooling System, supporting the use of sensor-based monitoring and microcontroller control to achieve an efficient, reliable, and cost-effective temperature regulation system.

CHAPTER 3

COMPONENTS & METHOLOGY

3.1 Methodology

The development of the Automated Arduino and peltier Based Smart Cooling system follows a structured methodology that integrates thermoelectric cooling with automatic control to achieve efficient and stable temperature regulation. The system is designed by combining three main units: sensing unit, control unit, and cooling unit. The cooling process is based on the Peltier Module, where two modules are used to improve cooling performance. The cold side of the modules is placed inside the chamber to absorb heat, while the hot side is positioned outside and connected to heat sinks, cooling fans, and a water cooling mechanism for effective heat dissipation. During hardware implementation, the Arduino Uno acts as the central controller, coordinating all system operations. A DHT11 Sensor is installed inside the chamber to continuously measure temperature and humidity. Two cooling fans are used one for circulating cool air inside the chamber and another for removing heat from the hot side of the Peltier modules. A mini water pump further enhances heat removal through liquid cooling. A potentiometer allows users to set the desired temperature between 0°C and 50°C, and the Arduino compares this set value with real-time sensor data. Based on this comparison, relay modules and a Motor Driver are used to control the high-current Peltier modules (12V, 6A), fans, and pump, ensuring safe and efficient operation. The system is powered using a 220V AC supply, which is converted into 12V DC through an SMPS. A DC-DC Buck Converter is used to step down the voltage to 5V for low-power components such as the Arduino, sensor, and LCD display. An I2C LCD provides real-time feedback, displaying temperature, humidity, set temperature, and system status for user convenience. After assembly, the system undergoes testing and calibration to ensure accurate sensor readings and proper control response. Performance evaluation is carried out under different temperature conditions to analyze cooling efficiency, response time, and system stability. The results demonstrate that the system operates reliably and provides an effective, energy-efficient solution for maintaining controlled temperature environments. Additionally, the system demonstrates consistent performance under continuous operation, ensuring reliable long-term usage. The integration of automatic control and efficient heat management improves overall system effectiveness and reduces manual intervention. This methodology also provides a strong foundation for future enhancements, such as advanced control techniques and integration with smart monitoring systems.

3.2.1 Designed Model block diagram

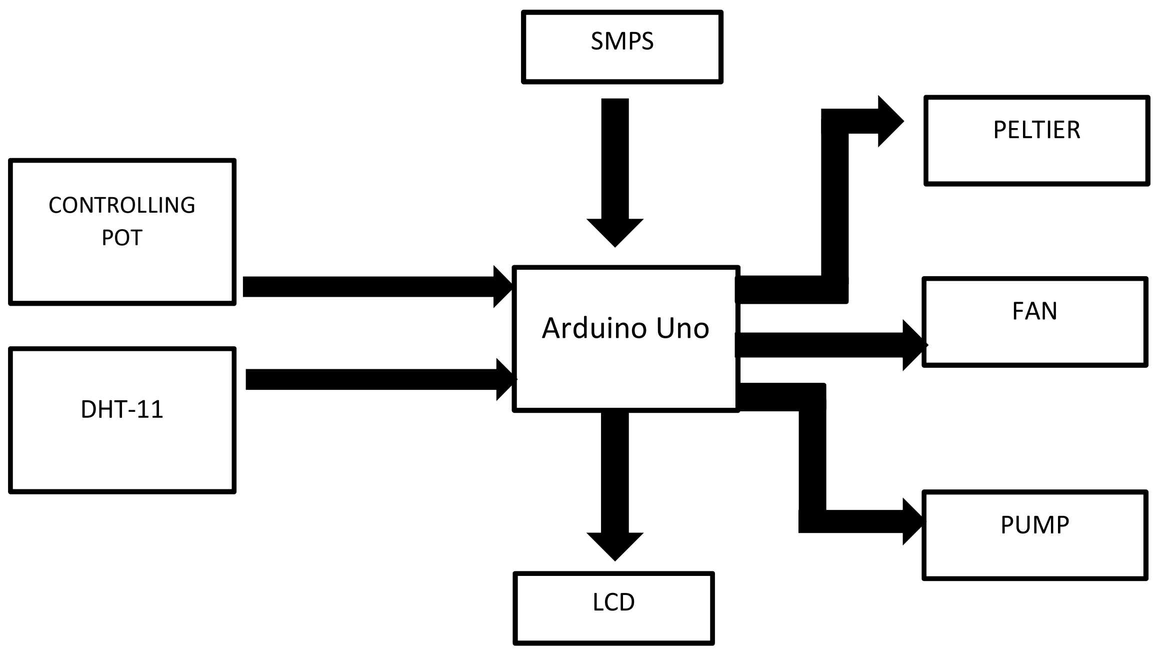


Figure 3.1: Designed model block diagram

The block diagram of the Automated Arduino and peltier Based Smart Cooling system, shown in Figure 3.1, represents the overall structure and working flow of the system. At the center of the design is the Arduino Uno, which acts as the main control unit. It receives input signals from the controlling potentiometer and the DHT11 Sensor. The potentiometer is used to set the desired temperature, while the DHT11 sensor continuously monitors the temperature and humidity inside the chamber and sends real-time data to the Arduino for processing. Based on the comparison between the set temperature and the measured temperature, the Arduino controls the cooling system automatically. The output section consists of Peltier Module, cooling fans, and a mini water pump, which are operated through relay modules. When the temperature exceeds the predefined value, the Arduino activates these components to start the cooling process. Once the temperature reaches the desired level, the system automatically turns OFF the devices to conserve energy and maintain stability. The LCD display provides real-time feedback by showing temperature, humidity, set temperature, and system status, allowing users to easily monitor the system. The entire system is powered by an SMPS, which supplies 12V DC, and a buck converter is used to regulate voltage for low-power components. This block diagram clearly illustrates how different units interact with each other to achieve an efficient, automated, and reliable temperature control system. Additionally, the block diagram highlights the smooth coordination between input, processing, and output units to ensure efficient system performance. The Arduino continuously processes incoming data and responds instantly to any change in temperature, ensuring a fast and accurate control action. Proper integration of power supply, sensing, and control components enhances system stability and reduces the chances of malfunction. This organized structure not only simplifies system understanding but also makes troubleshooting, maintenance, and future modifications easier, thereby increasing the overall reliability and practicality of the cooling chamber.

3.2.2 Circuit Diagram

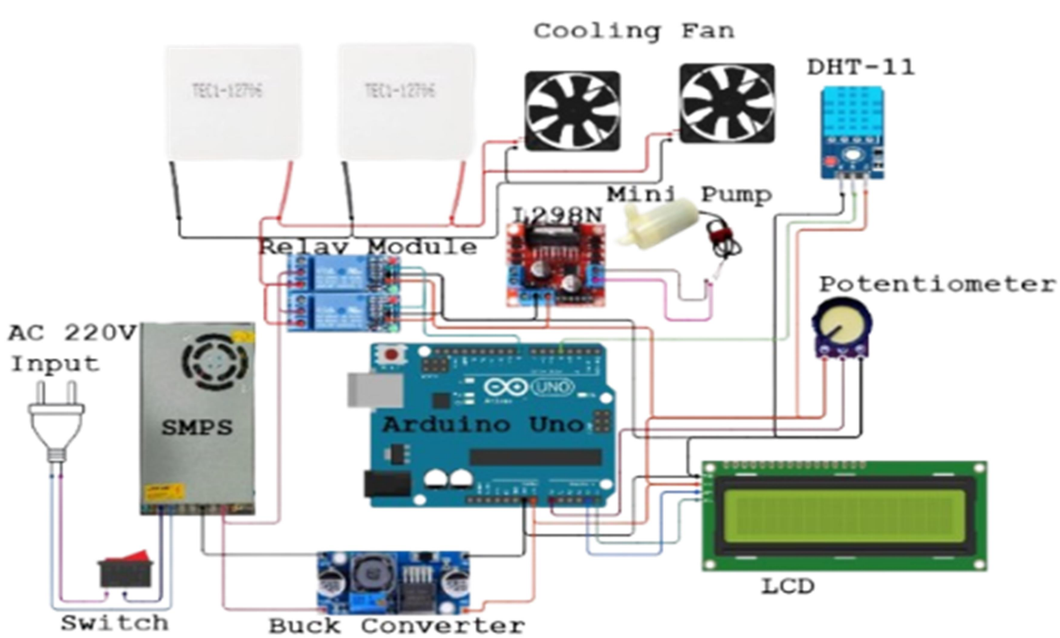
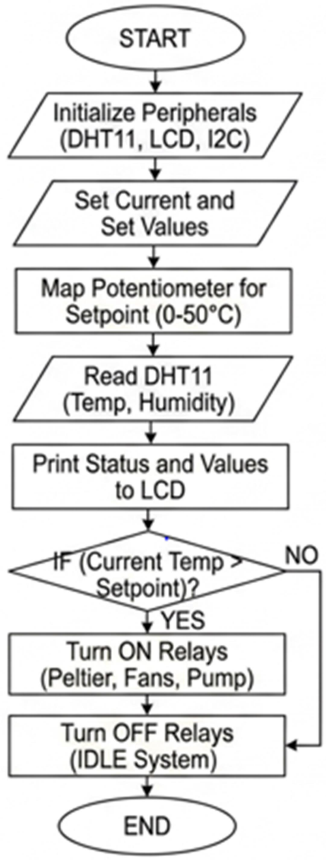


Figure 3.2: Designed model circuit diagram

The circuit diagram of the Automated Temperature Controlled Cooling Chamber, shown in Fig. 3.2, illustrates the electrical connections between all components required for system operation. At the core of the circuit is the Arduino Uno, which acts as the main control unit. It receives input from the DHT11 Sensor, which continuously measures the temperature and humidity inside the chamber. The sensor sends real-time data to the Arduino, enabling it to analyze the current environmental condition. A potentiometer is connected to the Arduino to allow the user to set the desired temperature between 0°C and 50°C. The Arduino compares this set value with the measured temperature and generates appropriate control signals. Based on this comparison, relay modules are activated to control the cooling components. The relays act as switching devices that safely operate high-power elements such as the Peltier Module, cooling fans, and the mini water pump. When the temperature exceeds the predefined value, the Arduino sends a signal to the relay module to turn ON the cooling system. Once the temperature drops to the desired level, the Arduino automatically turns OFF the relay, thereby stopping the cooling devices and conserving energy. An I2C LCD display is connected to the Arduino to provide real-time output, displaying temperature, humidity, set temperature, and system status for easy monitoring. The entire system is powered by a 220V AC supply, which is converted into 12V DC using an SMPS. A buck converter is used to step down the voltage to 5V for the Arduino, sensor, and display components, ensuring stable and safe operation.



3.2.3 Flow Chart

Figure 3.2.1: Flowchart

3.2.3 List of the components

- Arduino Uno
- Liquid Crystal Display (LCD) 16*2
- SMPS
- Relay
- Pump
- Fan
- Peltier
- Motor Driver
- Potentiometer

- Buck Converter
- DHT11
- Switch
- Bread Board
- Jumper wire

3.3 Arduino Uno

The Arduino Uno is an open-source microcontroller board based on the ATmega328P microcontroller, as shown in Fig. 3.3. It is widely used in embedded systems and automation projects due to its simplicity, flexibility, and ease of programming. The board provides both digital and analog input/output pins, allowing it to interface with a variety of sensors, actuators, and other electronic components. The Arduino Uno can be programmed using the Arduino IDE (Integrated Development Environment) via a USB Type-B cable. The board consists of 14 digital I/O pins, among which 6 can be used as PWM (Pulse Width Modulation) outputs, and 6 analog input pins for reading analog signals. It operates at 5V and can be powered through a USB connection or an external power supply ranging from 7V to 12V. The Arduino Uno comes with a pre-installed bootloader, which allows users to upload programs directly without requiring any external programmer. It supports multiple communication protocols such as UART, SPI, and I2C (TWI), making it suitable for interfacing with various peripherals and modules.

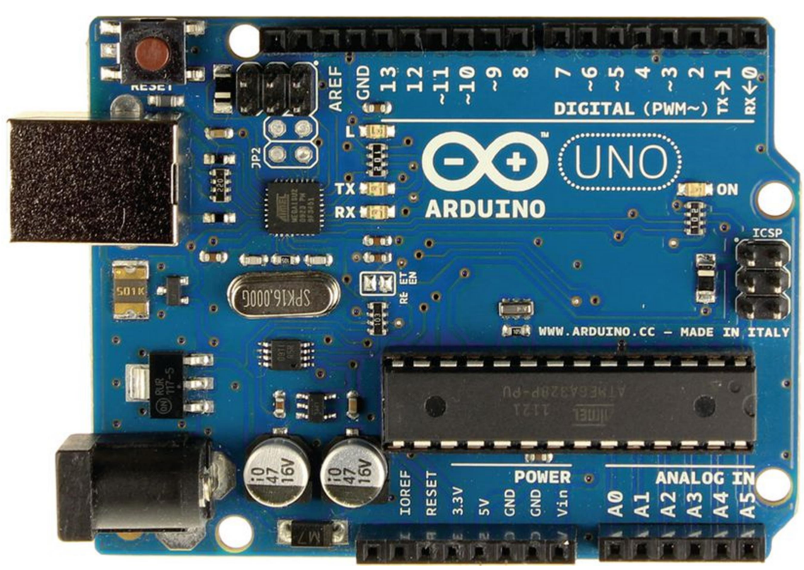


Figure 3.3: Arduino Uno

In this project, the Arduino Uno acts as the central control unit. It receives temperature and humidity data from the DHT11 Sensor and compares it with the user-defined temperature set using a potentiometer. Based on this comparison, the Arduino controls the operation of cooling components such as the Peltier Module, cooling fans, and mini water pump through relay modules. It also updates the LCD display with real-time system information, ensuring effective monitoring and automatic control of the cooling chamber.

Specifications:

Operative Voltage: 5V and 3.3V

Input Voltage: 5-12V (5V model) and 3.3-12V (3.3V model)

Digital I/O Pins: 14 Pins (6 are PWM output pins)

Analog Input Pins: 6 pins

DC Current per I/O Pin: 20 mA

Flash Memory: 32 kB (0.5 kB is taken by bootloader)

SRAM: 2 Kbytes

EEPROM: 1 Kbytes

Clock Speed: 16 MHz (5V model) and 8 MHz (3.3V model)

Table 3.1: Arduino Uno Configuration

Pin Group	**Pin Name**	**Description**
Power Source	VCC, GND, and RAW	VCC provides +5V, GND is ground, VIN is external input (7–12V)
Communication Interface	RX, TX, SDA, SCL	UART for serial communication, I2C (TWI) for peripherals.
Digital I/O Pins	D0 – D13	Used for digital input/output operations.
Analog Input	A0 – A5	Used for analog signal input (10-bit resolution).

PWM Pins	D3, D5, D6, D9, D10, D11	Used for PWM signal generation.
RESET	RESET	Resets the controller.

The **table-3.1** above describes the major pin groups and their functions in the Arduino Uno. These pins enable communication, data processing, and control of connected devices. Due to its versatility and reliability, the Arduino Uno is an ideal choice for implementing automation systems like the Automated Temperature Controlled Cooling Chamber.

3.4 Liquid Crystal Display (LCD) 16*2

The 16x2 LCD Display, shown in Fig. 3.4, is a widely used output device in microcontroller-based projects for displaying real-time information in a compact and readable format. It is capable of displaying 16 characters per line across two lines, making it suitable for showing parameters such as temperature, humidity, set values, and system status. The LCD is based on the HD44780 controller, which enables easy communication with microcontrollers like the Arduino Uno. The display can operate in either 4-bit or 8-bit data mode. In 4-bit mode, only four data lines are used along with control signals, reducing the number of required connections, whereas in 8-bit mode, all eight data lines are used for faster data transfer. In this project, an I2C interface is used with the LCD, which significantly reduces wiring complexity by using only two communication lines (SDA and SCL) along with power connections. In the Automated Arduino and peltier Based Smart Cooling system, the LCD plays an important role in user interaction by displaying real-time values such as temperature, humidity, set temperature, and system ON/OFF status. This allows the user to easily monitor the system without the need for additional devices, making the system simple and user-friendly.

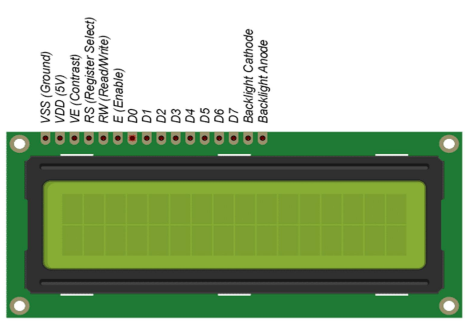


Figure 3.4: LCD 16*2

Features

- Based on HD44780 controller
- Displays 16 characters × 2 lines
- Character initiator ROM
- 160 different 57-dot matrix character patterns
- The display includes internal RAM for data storage and character generation ROM
- It supports 160 different 5x7 dot matrix character patterns
- Microcontrollers can access both display data RAM and character generator RAM
- The LCD offers various functions such as cursor positioning, display on/off, and character blinking.

Table 3.2: Pin Description of 16×2 LCD

PIN	Sign	Function
1	VSS	GND
2	VDD	+5V
3	V0	Contrast Adjustment
4	RS	H/L Register select signal
5	R/W	H/L Read/write signal
6	E	H/L Enable signal
7–14	DB0–DB7	H/L Data Bus Lines
15	A	Backlight Anode (+)
16	K	Backlight Cathode (–)

Table 3.2 shows the pin configuration and functions of the 16×2 LCD. Pins 1 and 2 provide power supply, while Pin 3 is used to adjust display contrast. Pins 4 to 6 are control pins used for command and data operations. Pins 7 to 14 serve as data lines for communication, and Pins

15 and 16 are used to power the backlight. In this project, the use of an I2C module simplifies these connections, making the system more efficient and easier to implement.

3.5 Switched-Mode Power Supply (SMPS)

The Switched Mode Power Supply, illustrated in Fig. 3.5, is a vital component of the Automated Temperature Controlled Cooling Chamber, responsible for providing a stable and efficient DC power source to all system components. The SMPS converts the 220V AC input into a regulated 12V DC output, which is used to power high-current devices such as the Peltier modules, cooling fans, and the mini water pump. For low-power components like the Arduino Uno, DHT11 Sensor, and LCD display, a buck converter is used to step down the voltage from 12V to 5V, ensuring safe and stable operation. Unlike traditional linear power supplies, the SMPS operates using high-frequency switching techniques, which significantly improve efficiency and reduce power loss. This results in less heat generation and better energy utilization, making it suitable for continuous operation. The compact size and lightweight design of the SMPS allow easy integration into the system without increasing overall complexity. The SMPS also ensures consistent voltage output even under varying load conditions, which is essential for maintaining reliable system performance. By delivering a stable and regulated power supply, it protects sensitive electronic components from voltage fluctuations and enhances the overall durability

and efficiency of the cooling system. The SMPS also ensures consistent voltage output even under varying load conditions, which is essential for maintaining reliable system performance.

Figure 3.6: SMPS

3.6 Submersible Water Pump (DC 3–6V)

The DC Submersible Water Pump, shown in Fig. 3.6, is an important component of the Automated Arduino and peltier Based Smart Cooling system, used to enhance heat dissipation from the hot side of the cooling system. This mini pump operates within a DC voltage range of 3–6V and is responsible for circulating water through the cooling setup, helping to remove heat efficiently from the Peltier module. In this project, the water pump works in combination with a water block and radiator system. As the Peltier Module generates heat on its hot side, the pump circulates water to absorb and transfer this heat away from the system. This continuous flow of water significantly improves cooling efficiency and prevents overheating, ensuring stable operation of the thermoelectric module. The pump is compact, lightweight, and

designed with waterproof materials, making it suitable for long-term use in enclosed systems. It typically offers a flow rate of approximately 80–120 liters per hour with low power consumption, ensuring energy-efficient operation. The magnetic driving mechanism allows quiet and smooth performance, which is beneficial for maintaining a noise-free environment. For safe and effective operation, the pump must always remain submerged in water to avoid dry running, which can damage the motor and reduce its lifespan. Overall, the submersible water pump plays a crucial role in maintaining efficient heat management, improving system reliability, and enhancing the overall performance of the cooling chamber.

Figure 3.6: Pump (DC 3–6V)

3.7 Fan

The DC Cooling Fan, illustrated in Fig. 3.7: is an essential component of the Automated Arduino and peltier Based Smart Cooling system, used to maintain proper airflow and enhance cooling efficiency. It operates on a DC power supply (typically 12V) and helps in circulating air within the system. Proper airflow ensures uniform temperature distribution inside the chamber, preventing uneven cooling and improving overall system performance. In this project, two

cooling fans are used for different purposes. One fan is placed inside the chamber to distribute the cool air generated by the Peltier Module evenly, while the other fan is attached to the heat sink on the hot side to remove excess heat. Both fans are controlled automatically by the Arduino Uno through relay modules, ensuring efficient operation, energy saving, and stable temperature control within the chamber.

Figure 3.7: Fan

3.8 Relay

The Relay Module is an important component in the Automated Temperature Controlled Cooling Chamber, used to control high-power devices using low-voltage signals from the microcontroller. A relay acts as an electrically operated switch, allowing the Arduino Uno to safely control components such as the Peltier modules, cooling fans, and the mini water pump. This ensures proper isolation between the control circuit and the high-power load, protecting sensitive electronic components from damage. In this project, two relay modules are used to control different parts of the cooling system. When the temperature inside the chamber exceeds the set value, the Arduino sends signals to activate the relays, which turn ON the cooling components. Once the desired temperature is achieved, the relays automatically switch OFF the devices to save energy and maintain system stability. The relay modules operate on 5V DC and provide reliable, fast switching, making them suitable for automated control systems. Their use ensures safe operation, efficient power management, and precise temperature

regulation within the cooling chamber.

Figure 3.8: Relay

3.9 Peltier Module

The Peltier Module is a thermoelectric device that operates based on the Peltier effect, where a temperature difference is created when electric current flows through it. One side of the module becomes cold while the opposite side becomes hot. In the Automated Arduino and peltier Based Smart Cooling system two Peltier modules are used to provide efficient and faster cooling performance. The cold sides of the modules are placed inside the chamber to absorb heat, while the hot sides are positioned outside and connected with heat sinks, cooling fans, and a water cooling system to dissipate heat effectively. The Peltier modules operate on a 12V DC power supply and are controlled by the Arduino Uno through relay modules. When the chamber temperature exceeds the set value, the modules are activated automatically to reduce the temperature inside the chamber. Each Peltier module has an approximate surface area of 40 mm × 90 mm, providing sufficient contact area for effective heat transfer and cooling performance. Using two modules improves cooling capacity and ensures more uniform temperature distribution inside the chamber. Peltier modules are compact, noise-free, and environmentally friendly, making them suitable for small-scale cooling applications. Their

integration in this system enhances efficiency, stability, and overall cooling performance.

Figure 3.9: Peltier Module

3.10 Buck Converter

The DC-DC Buck Converter is a power management device used to reduce a higher DC voltage to a lower, stable output voltage required by electronic components. In the Cooling System, the buck converter steps down the 12V DC output from the SMPS to 5V DC, which is suitable for operating low-power components such as the Arduino Uno, DHT11 Sensor, and the LCD display. This ensures that all sensitive components receive a safe and regulated voltage supply. The buck converter operates using high-frequency switching techniques, which makes it highly efficient with minimal power loss compared to linear regulators. It helps maintain a constant output voltage even when there are fluctuations in the input supply. This stable voltage regulation improves system reliability, prevents damage to components, and enhances overall performance. The use of a buck converter also ensures efficient power distribution within the system, contributing to energy savings and long-term durability of the Automated Arduino and

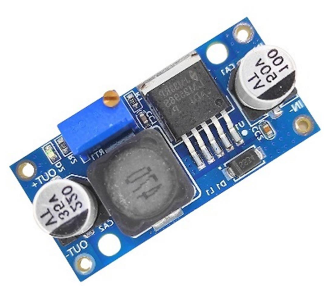


Figure 3.10: buck converter

3.11 Potentiometer & Jumper wire

A potentiometer is a variable resistor used to adjust voltage levels in a circuit. In this project, it is used to set the desired temperature of the cooling chamber (0°C–50°C). By rotating the knob, the resistance changes, which varies the input voltage to the Arduino Uno. The Arduino reads this value and uses it as the reference temperature to control the cooling system automatically. And The Jumper Wire is a simple but essential component used to establish electrical connections between different parts of a circuit without the need for soldering. These wires are commonly used in breadboards and prototype circuits, allowing quick and flexible connections between components such as the Arduino Uno, sensors, relay modules, and display units.

Jumper wires make it easy to modify, test, and troubleshoot the circuit during the development stage of the project. Jumper wires are available in three main types: male-to-male, male-to-female, and female-to-female, depending on the type of connection required. The male ends have exposed pins that can be inserted into sockets or breadboards, while female ends are designed to receive male pins. Although they come in different colors, the colors are mainly used for identification and do not affect functionality. In this project, jumper wires are used to interconnect all components efficiently, ensuring a neat, organized, and reliable circuit setup.

Figure 3.11: Potentiometer & Jumper wire

3.12 Design Specification

- **Microcontroller**: Arduino Uno operating at 16 MHz, equipped with digital and analog I/O pins. It serves as the central control unit, processing data from sensors, comparing it with the set temperature, and controlling relays, Peltier modules, fans, and the water pump.
- **Display:** 16x2 LCD Display with I2C interface, used to display real-time temperature, humidity, set temperature, and system status ("Cooling ON" or "OFF"). The I2C module reduces wiring complexity and simplifies communication with the Arduino.
- **Power Supply**: The system operates using a 220V AC input converted to 12V DC through an SMPS. A DC-DC Buck Converter is used to step down the voltage to 5V for powering low-voltage components such as the Arduino, sensors, and LCD. This ensures stable and efficient power distribution.
- **Cooling Mechanism:** Two Peltier Module units are used to generate cooling. The cold sides are placed inside the chamber, while the hot sides are connected to heat sinks, cooling fans, and a water cooling system for effective heat dissipation.
- **Relay Module:** Two relay modules are used to control high-power devices such as the Peltier modules, cooling fans, and water pump. The relays provide electrical isolation and allow automatic switching based on temperature conditions.
- **Sensors:** DHT11 Sensor is used to continuously monitor temperature and humidity inside the chamber and send real-time data to the Arduino for processing.
- **User Input:** A potentiometer is used to set the desired temperature within the range of 0°C to 50°C, allowing flexible and user-defined control of the system.
- **Software**: The system is programmed using the Arduino IDE with C/C++ language. The program includes logic for sensor data processing, temperature comparison, and automatic control of the cooling system without requiring internet connectivity.

3.13 Summarization

This chapter provides a detailed overview of the design and development process of the Automated Arduino and peltier Based Smart Cooling system, explaining its architecture, components, and overall functionality. It begins with the system's block diagram, illustrating how the Arduino Uno, DHT11 Sensor, Peltier modules, relay modules, and LCD display work together to maintain a controlled cooling environment. The circuit diagram further explains the electrical connections among the components, ensuring proper signal flow and reliable operation of the system. The chapter also highlights the role of the power supply system, including the SMPS and DC-DC Buck Converter, in providing stable and regulated voltage to all components. Key hardware elements such as the Peltier Module, cooling fans, and water pump have been carefully integrated to achieve efficient heat removal and uniform temperature distribution. The use of a potentiometer for setting the desired temperature and an LCD for real-time monitoring ensures a simple and user-friendly interface. Overall, this chapter demonstrates how sensor-based automation and proper system design enable effective temperature control, energy efficiency, and reliable performance, forming a strong foundation for system implementation and analysis in the next chapter.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Discussion

This section provides a detailed discussion of the key aspects of the Automated Arduino and peltier Based Smart Cooling system, focusing on component selection, system architecture, circuit design, and programming logic. The project integrates essential hardware components such as the Arduino Uno, DHT11 Sensor, relay modules, Peltier Module, cooling fans, water pump, and an LCD with I2C interface to create an automated and efficient temperature control system.

1. **Component Selection**: The components were carefully selected to ensure compatibility, efficiency, and reliability. The Arduino Uno acts as the central controller, processing sensor data and executing control logic. The DHT11 sensor provides real-time temperature and humidity data, enabling accurate monitoring of the chamber environment. Relay modules are used to control high-power devices such as Peltier modules, fans, and the water pump. The LCD display provides instant feedback on

system parameters, while the SMPS and buck converter ensure stable voltage supply for all components.

2. **System Architecture**: The system is designed for automatic temperature regulation and user-friendly operation. The Arduino Uno continuously receives data from the sensor and compares it with the user-defined temperature set through a potentiometer. Based on this comparison, it controls the cooling components accordingly. The use of dual Peltier modules improves cooling efficiency, while fans and the water cooling system enhance heat dissipation. The architecture is simple, reliable, and suitable for small-scale cooling applications.

3. **Circuit Design and Integration**: The circuit is designed to ensure proper communication, stable power distribution, and safe operation. The Arduino Uno is connected to the DHT11 sensor, relay modules, potentiometer, and LCD display through appropriate pins. The SMPS provides 12V DC power, while the DC-DC Buck Converter steps it down to 5V for low-power components. Each cooling device is controlled through relay modules to maintain electrical isolation and prevent damage due to high current or voltage fluctuations.

4. **Programming Logic**: The system is programmed using the Arduino IDE in C/C++ language. The program continuously reads temperature data from the sensor and compares it with the set value provided by the potentiometer. When the temperature exceeds the desired level, the Arduino activates the relay modules, turning ON the Peltier modules, fans, and water pump. Once the temperature falls below the set point, the system automatically turns OFF the devices to save energy. This control logic ensures stable and efficient temperature regulation without manual intervention.

Overall, the Automated Arduino and peltier Based Smart Cooling system demonstrates an effective integration of hardware and software to achieve automatic temperature control. The system's compact design, energy efficiency, and reliable performance make it suitable for applications such as food preservation, laboratory use, and small-scale cooling systems. Its simplicity and flexibility also allow future improvements and scalability for more advanced applications.

4.2 Results

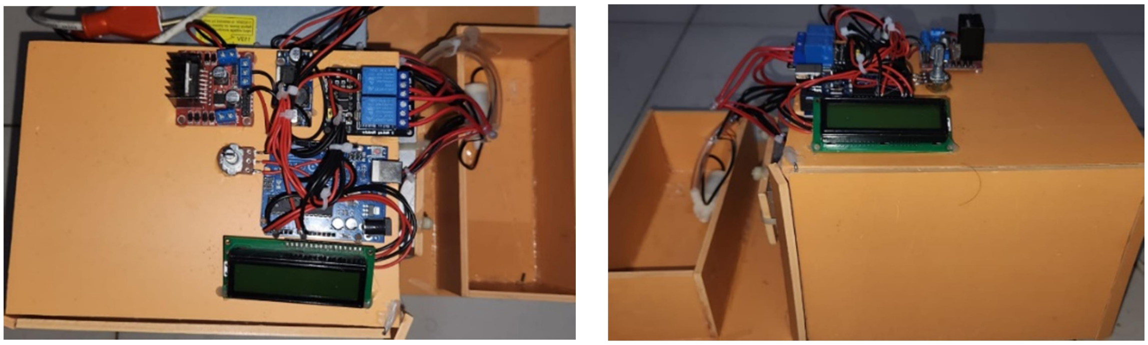


Figure 4.1: Project Picture

Figure 4.1 shows the complete setup of the Automated Arduino and peltier Based Smart Cooling system. The system consists of a thermally insulated cooling box integrated with two Peltier Module, cooling fans, and a mini water pump for effective heat exchange and temperature control. The Arduino Uno acts as the central control unit, connected to components such as the DHT11 Sensor, LCD with I2C display, relay modules, potentiometer for temperature setting, and a motor driver for handling high current loads. A 12V SMPS power supply provides the main operating voltage, while a DC-DC buck converter regulates voltage for low-power components. All components are neatly assembled to ensure proper operation, efficient cooling, and ease of monitoring. This setup successfully demonstrates an automated system capable of maintaining controlled temperature conditions with reliable and efficient performance.

Figure 4.2: Display Result for T-1

Figure 4.2 shows the real-time output displayed on the 16x2 LCD Display of the Automated Arduino and peltier Based Smart Cooling system. The display indicates the measured temperature (T = 30.90°C), humidity (H = 78.00%), and the user-defined set temperature (Set =

20.00°C). From this observation, it is clear that the current temperature inside the chamber is higher than the desired set value. As a result, the control system, managed by the Arduino Uno, activates the cooling components such as the Peltier Module, fans, and water pump to reduce the temperature. This figure demonstrates the system's ability to monitor environmental conditions in real time and automatically respond to maintain the desired temperature efficiently.

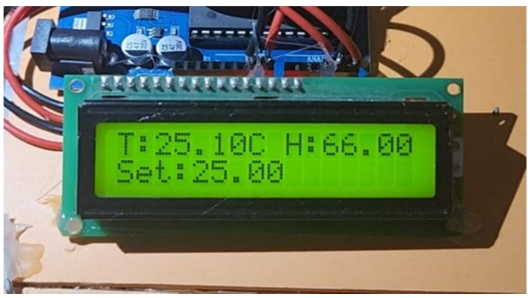


Figure 4.3: Result For T-2

Figure 4.4: Result For T-3

Figures 4.3 and 4.4 show the real-time output displayed on the 16x2 LCD Display of the Automated Arduino and peltier Based Smart Cooling system under different operating conditions. In Figure 4.3, the measured temperature is T = 25.10°C, humidity H = 66.00%, and the set temperature is 25.00°C, indicating that the system has almost reached the desired temperature and is maintaining a stable condition. At this stage, the Arduino Uno controls the cooling components to operate minimally or turn OFF to conserve energy. In Figure 4.4, the temperature rises slightly to T = 28.*10*°C while the set value remains 25.00°C and humidity is H = 64.00%. As a result, the system automatically reactivates the Peltier Module, fans, and water pump to bring the temperature back to the desired level. These results demonstrate the system's ability to dynamically respond to temperature variations and maintain controlled environmental conditions efficiently.

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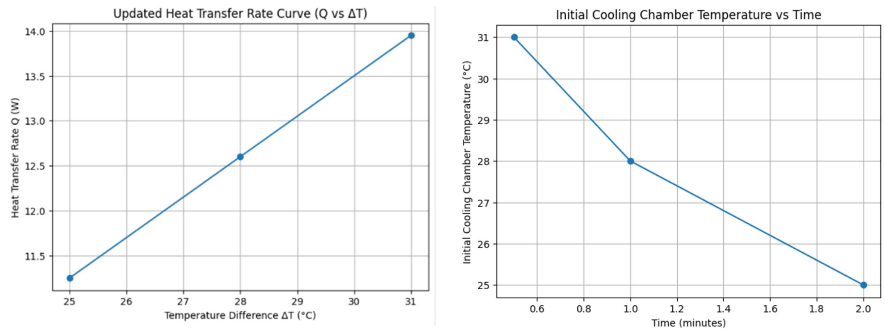

Figure 4.5 Cooling Performance Curve of the System (Q vs Time)

The Initial Cooling Chamber Temperature vs Time graph shows how the chamber temperature decreases gradually after the cooling system is activated. The continuous reduction in temperature over time confirms the effective performance of the Peltier modules, cooling fans, and water cooling mechanism in maintaining a controlled cooling environment.

Figure 4.5 illustrates the relationship between the temperature difference (ΔT) and the heat transfer rate (Q) of the Automated Arduino and peltier Based Smart Cooling system . The graph shows that the heat transfer rate increases as the temperature difference between the hot side and cold side of the Peltier modules increases. At ΔT = 25°C, the heat transfer rate is approximately 11.25 W, while at ΔT = 28°C and 31°C, the heat transfer rates increase to about 12.60 W and 13.95 W respectively. This indicates that a larger temperature difference results in faster heat transfer and improved cooling performance.

4.2.2 Data Analysis Table：

SL No.	Temperature (°C)	Humidity (%)	Time (minutes:seconds)
1	29.40	94	1.34
2	25.10	73	1.56
3	24.90	71	2.26
4	22.40	82	2.52

5	21.10	76	4.03

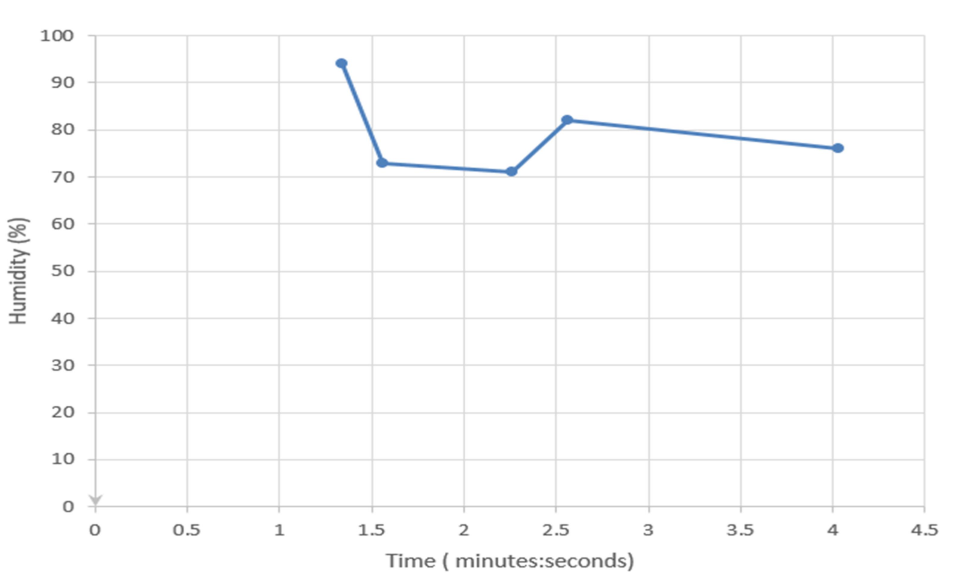

Figure 4.6 Time vs Humidity Curve

Figure 4.6 shows the variation of humidity inside the Automated Arduino and peltier Based Smart Cooling system over time. Initially, the humidity level is high at around 94%, then gradually decreases as the cooling system operates. A slight increase in humidity is observed during the middle stage due to temperature reduction and air circulation inside the chamber. Finally, the humidity stabilizes around 76%, indicating that the system can maintain a controlled internal environment effectively.

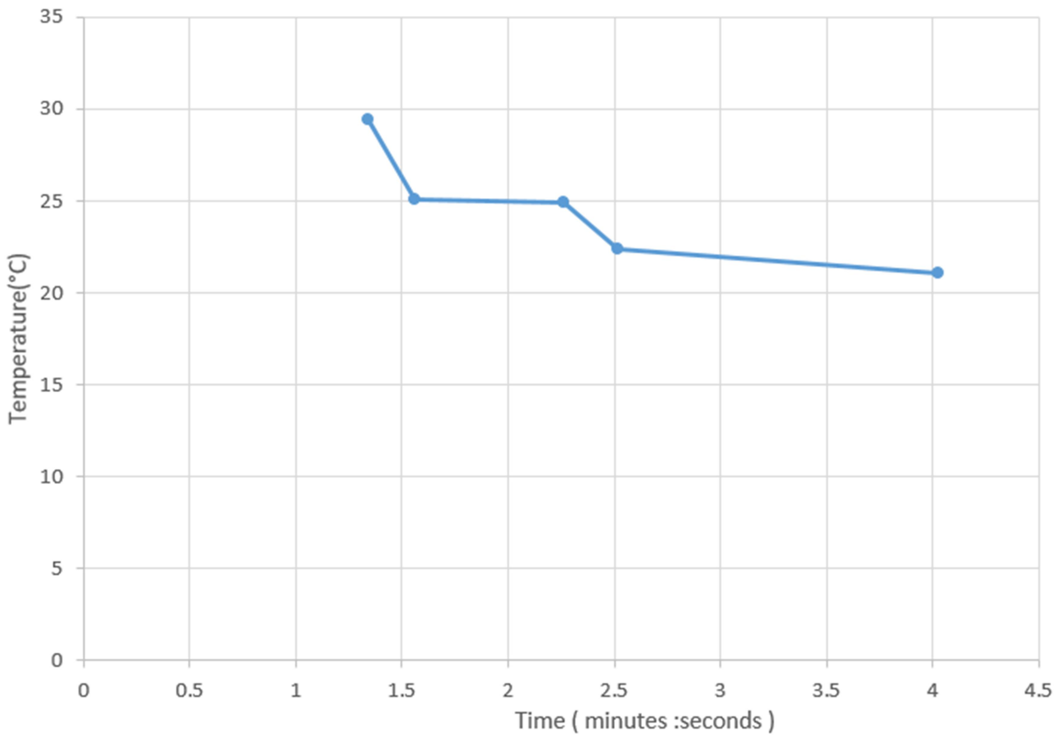

Figure 4.5 Time vs Temperature Curve

Figure 4.7 Illustrates the decrease in temperature inside the cooling chamber with respect to time. At the beginning, the chamber temperature is approximately 30°C, and it gradually drops to nearly 21°C as the Peltier modules, cooling fans, and water pump operate continuously. The smooth downward trend confirms that the cooling system effectively removes heat and maintains stable temperature control. This result demonstrates the efficiency and reliability of the Automated Arduino and peltier Based Smart Cooling system.

4.3 Outcome Analysis

The performance of the Cooling System is evaluated using the heat transfer equation:

$$Q = hA(T_{hot} - T_{cold})$$

- ✓ Q = Heat transfer rate (W)
- ✓ h = Heat transfer coefficient (considering 60% efficiency and forced cooling)
- ✓ A = Area of Peltier module = 40 mm × 80 mm = 0.0032 m^2

- ✓ $(T_{hot} - T_{cold})$ = Temperature difference (ΔT)

The calculated values are obtained by considering the combined operation of two Peltier modules, dual cooling fans operating at 3000 rpm, and the water cooling mechanism, which together improve the overall heat dissipation performance of the system. During experimental testing, the cooling time and temperature difference were recorded at different intervals. At 30 seconds, the temperature difference was 31°C, producing a heat transfer rate of approximately 12.4 W. After 1 minute, the temperature difference decreased to 28°C, resulting in a heat transfer rate of about 11.2 W. At 2 minutes, the temperature difference further reduced to 25°C, and the heat transfer rate became approximately 10.0 W. From the obtained results, it is observed that the heat transfer rate gradually decreases with time as the chamber temperature approaches the desired set temperature. Initially, the system removes heat rapidly because the temperature difference is high. As cooling continues, the temperature inside the chamber stabilizes, reducing the cooling load and heat transfer requirement. This decreasing trend confirms that the cooling system is functioning efficiently and moving toward thermal equilibrium. The integration of dual Peltier modules, high-speed cooling fans, and water cooling significantly improves cooling efficiency, resulting in faster temperature reduction and more stable chamber performance.

4.4 Advantages

- ❑ **Energy Efficiency**: The Automated Arduino and peltier Based Smart Cooling system reduces power consumption by activating cooling components such as Peltier Module, fans, and the water pump only when the temperature exceeds the preset value. This automatic control minimizes energy waste and lowers operating costs.
- ❑ **Real-Time Monitoring**: The DHT11 Sensor continuously monitors temperature and humidity inside the chamber, ensuring accurate environmental data for proper system control.
- ❑ **Automatic Control:** The system operates without manual intervention using the Arduino Uno. It continuously compares the current temperature with the user-defined set value and automatically turns ON/OFF the cooling system, ensuring stable temperature control.

- **User-Defined Temperature Control:** A potentiometer allows users to easily set the desired temperature within the range of 0°C to 50°C, providing flexibility and customization according to application requirements.
- **User-Friendly Display:** A 16x2 LCD Display with I2C interface provides real-time information such as temperature, humidity, set temperature, and system status, making it easy for users to monitor the system.
- **Efficient Cooling Performance**: The use of dual Peltier modules along with fans and water cooling improves heat dissipation and ensures faster and more uniform cooling inside the chamber.
- **Safe and Reliable Operation:** Relay modules provide electrical isolation between low-power control circuits and high-power devices, protecting system components from voltage fluctuations and ensuring safe operation.
- **Compact and Cost-Effective Design:** The system is built using affordable and easily available components, making it economical and suitable for small-scale applications.
- **Stable Power Management:** The SMPS and DC-DC Buck Converter ensure a stable and regulated power supply, improving system reliability and component lifespan.
- **Uniform Temperature Distribution:** The use of dual cooling fans ensures proper air circulation inside the chamber, allowing the cooled air from the Peltier Module (12v & 6A) to spread evenly. This prevents temperature variations and maintains a consistent cooling environment throughout the chamber
- **Easy Maintenance and Scalability**: The modular design allows easy troubleshooting and component replacement. The system can also be upgraded with additional features or sensors for advanced applications.

4.5 Disadvantages

- **Dependence on Continuous Power Supply:** The Automated Arduino and peltier Based Smart Cooling system requires a stable power source to operate components such as the Peltier Module, fans, and sensors. Power interruptions or voltage fluctuations can disrupt the cooling process and affect system performance.
- **Limited Cooling Capacity:** Peltier modules are suitable for small-scale cooling applications but are less efficient compared to conventional compressor-based systems.

They may struggle to maintain very low temperatures in larger chambers or under heavy thermal loads.

- **Heat Dissipation Issues:** The hot side of the Peltier module generates significant heat, which must be removed efficiently. If the heat sink, cooling fan, or water pump does not perform properly, it can reduce cooling efficiency and may lead to overheating.
- **High Power Consumption Under Load:** Although designed for efficiency, the simultaneous operation of multiple Peltier modules, fans, and the water pump can increase power consumption, especially during continuous cooling conditions.
- **Component Sensitivity:** Devices such as the Arduino Uno, sensors, and relay modules can be sensitive to heat and moisture, which may affect long-term durability if proper insulation and protection are not ensured.
- **Initial Setup Complexity:** Proper circuit connections, calibration of the DHT11 Sensor, and programming of the system require technical knowledge, making the setup process challenging for beginners.
- **Maintenance Requirements:** Regular maintenance is necessary, including cleaning fans, checking electrical connections, and ensuring proper operation of cooling components to maintain system efficiency.
- **Efficiency Limitations:** Compared to traditional refrigeration systems, thermoelectric cooling has lower efficiency, which can limit its performance in high-temperature environments or demanding applications.

Chapter 5

CONCLUSIONS AND RECOMMENDATION

5.1 Conclusion

The Automated Arduino and peltier Based Smart Cooling system successfully demonstrates an efficient and reliable method for maintaining a controlled temperature environment using thermoelectric cooling technology. The system integrates key components such as the Arduino Uno, DHT11 sensor, Peltier modules, cooling fans, water pump, relay modules, and LCD display to achieve automatic temperature regulation. The use of a potentiometer allows users to set the desired temperature between 0°C and 50°C, making the system flexible and user-friendly. From the experimental results and outcome analysis, it is observed that the system effectively reduces temperature over time and maintains stability by automatically controlling the cooling components. The heat transfer analysis and performance curve confirm that the cooling process follows a decreasing trend as the system approaches the set temperature, ensuring energy-efficient operation. The combination of dual Peltier modules, forced air cooling (fans), and water cooling significantly improves heat dissipation and enhances overall system performance. Moreover, the system operates with good reliability and stability due to proper power management using SMPS and buck converters. The LCD display provides real-time monitoring, making the system easy to operate and understand. Although the cooling capacity is limited compared to traditional refrigeration systems, the design proves to be compact, cost-effective, and suitable for small-scale applications such as laboratory use, food preservation, and electronic cooling. In conclusion, the project successfully achieves its objectives by providing an automated, energy-efficient, and user-friendly cooling solution. It also demonstrates the practical implementation of thermoelectric cooling and microcontroller-based automation, making it a valuable contribution to modern smart cooling system development.

5.2 Limitations of the Work

While the Automated Arduino and peltier Based Smart Cooling system demonstrates effective performance and reliable operation, several limitations were identified during the design and testing phases that may affect its efficiency in certain conditions:

- **Limited Cooling Capacity:** The Peltier modules used in this system are suitable for small-scale cooling applications. However, they are less efficient compared to conventional compressor-based systems and may not provide sufficient cooling for larger chambers or high thermal loads.
- **High Power Consumption:** Peltier modules require significant electrical power, especially when two modules operate simultaneously. This can increase overall energy consumption, particularly during continuous operation.

- **Heat Dissipation Challenges:** The hot side of the Peltier modules generates a large amount of heat. If heat sinks, cooling fans, or the water cooling system are not properly maintained, the efficiency of the cooling process may decrease.
- **Sensor Accuracy Limitation:** The DHT11 sensor provides basic temperature and humidity readings, but its accuracy and response time are limited compared to advanced sensors. This may affect precise temperature control in sensitive applications.
- **Manual Control Dependency:** The system uses a potentiometer for setting temperature manually, which does not allow remote control or data logging like IoT-based systems, limiting advanced monitoring capabilities.

5.3 Future Recommendation

To further improve the performance and capabilities of the Automated Arduino and peltier Based Smart Cooling system, several enhancements can be considered for future development. The use of more accurate and faster sensors, such as DHT22 or digital temperature sensors, can improve measurement precision and system responsiveness. Replacing or upgrading the existing Peltier modules with higher-efficiency thermoelectric modules or hybrid cooling systems can significantly enhance cooling capacity while reducing power consumption. Additionally, improving the heat dissipation system by using advanced heat sinks, liquid cooling blocks, or higher-speed fans can increase overall system efficiency. In terms of control and monitoring, the system can be upgraded by integrating IoT technology, allowing remote monitoring, data logging, and control through a mobile or web-based application. This would provide greater flexibility and user convenience. The inclusion of a digital interface instead of a manual potentiometer can enable more precise temperature setting and control. Moreover, incorporating backup power systems such as batteries or solar panels can ensure uninterrupted operation during power failures. Advanced control techniques, such as PID (Proportional-Integral-Derivative) control algorithms, can also be implemented to achieve more accurate and stable temperature regulation. These improvements would make the system more intelligent, energy-efficient, scalable, and suitable for real-world industrial and laboratory applications.

REFERENCES

[1] Sánchez, C., Dessì, P., Duffy, M., & Lens, P. N. (2020). OpenTCC: An open source low-cost temperature-control chamber. *HardwareX*, *7*, e00099.

[2] Meshcheriakov, Evgenii. "Climate Chamber Control System Automation Using PLC." (2024).

[3] Merentsov, N. A., et al. "Automatic control system for operation modes and calibration of technological parameters of evaporation cooling apparatuses." *Journal of Physics: Conference Series*. Vol. 1515. No. 2. IOP Publishing, 2020.

[4] Potter, George F. "An apparatus for automatically changing the temperature of a chamber." *American Journal of Botany* 7.1 (1920): 39-43.

[5] Sunny, Ali Imam, et al. "Low-cost IoT-based sensor system: A case study on harsh environmental monitoring." *Sensors* 21.1 (2020): 214.

[6] Xiao, Chengdi, Hailong Liao, Yan Wang, Junhui Li, and Wenhui Zhu. "A novel automated heat-pipe cooling device for high-power LEDs." *Applied Thermal Engineering* 111 (2017): 1320-1329.

[7] Irshad, K., Almalawi, A., Khan, A. I., Alam, M. M., Zahir, M. H., & Ali, A. (2020). An IoT-based thermoelectric air management framework for Smart building applications: A case study for tropical climate. *Sustainability*, *12*(4), 1564.

[8] Fetisov, Vadim, Yury V. Ilyushin, Gennadii G. Vasiliev, Igor A. Leonovich, Johannes Müller, Masoud Riazi, and Amir H. Mohammadi. "Development of the automated temperature control system of the main gas pipeline." *Scientific Reports* 13, no. 1 (2023): 3092.

[9] Patel, Chandrabhan, et al. "IoT-driven monitoring and controlling to improve performance of thermoelectric air conditioning system." *Journal of Building Engineering* 95 (2024): 110081.

[10] Islam, M. T., Parvez, S., Mia, S., Das, S., & Halim, M. A. (2023). *IOT Based Engine Cooling System* (Doctoral dissertation, Sonargoan University (SU)).

[11] Cheng, Li, Parveen Dhillon, W. Travis Horton, and James E. Braun. "Automated laboratory load-based testing and performance rating of residential cooling equipment." *International Journal of Refrigeration* 123 (2021): 124-137.

[12] Nattappan, A., Ganesan, S. P., Thiagarajan, V., & Ranganathan, K. (2022). Design of automation control thermal system integrated with parabolic trough collector based solar plant. *Thermal Science*, *26*(2 Part A), 947-954.

[13] Hatzopoulos, Argyrios T., Kyriakos Tsiakmakis, Vasileios Delimaras, Fotios T. Stoupas, Vassilios D. Vassios, and Maria S. Papadopoulou. "Automated Controlled Chamber for Measuring Plant Growth." *Int. Rev. Electr. Eng. IREE* 18 (2023): 252.

[14] Metiboba, Charity Temiloluwa, et al. "Automation of an evaporative cooling system for agricultural produce." *Int. J. Adv. Eng. Manag* 7 (2025): 628-636.

[15] Chaudhuri, Subhasis, Rajeev Kumar Singh, Kuntal Patwari, Susanta Majumdar, Asim Kumar Ray, Arun Kumar Prasad Singh, and Nirbhar Neogi. "Design and implementation of an automated secondary cooling system for the continuous casting of billets." *ISA transactions* 49, no. 1 (2010): 121-129.

[16] Parab, Abhishek S., Amol Joglekar, and Abhishek S. Parab. "Implementation of home security system using GSM module and microcontroller." *International Journal of Computer Science and Information Technologies* 6.3 (2015): 2950-2953..

[17] Rix, J. E., Weber, J. K. R., Santodonato, L. J., Hill, B., Walker, L. M., McPherson, R., ... & Volin, K. J. (2007). Automated sample exchange and tracking system for neutron research at cryogenic temperatures. *Review of scientific instruments*, *78*(1).

[18] Skarbierz, Wojciech, et al. "Energy-Efficient Cooling System Control in Ship Engine Rooms Using an Intelligent Integrated Automation, Control, and Monitoring System (IACMS)." *Energies* 19.3 (2026): 734.

[19] Das, Ananya, Sanjib Moulick, and Subhra Debdas. "Developing an Energy Efficient and Sustainable IoT-Enabled Indoor-Air Cooling System Using Earthen Materials." *Engineering, Technology & Applied Science Research* 15.5 (2025): 26607-26611.

[20] Pratama, Arya, and Solly Aryza. "Analysis of an Automated Control System for Air Conditioner Temperature In Industrial Production Rooms Using a Fuzzy Logic Method Based on Production Load and Environmental Temperature Detection." *International Journal of Economic, Technology and Social Sciences (Injects)* 6.1 (2025): 331-342.

[21] Anderson, Brent. *Development and Design of a User Interface for a Computer Automated Heating, Ventilation, and Air Conditioning System*. No. FERMILAB-D0-EN-515. Fermi National Accelerator Laboratory (FNAL), Batavia, IL, 1999.

[22] So, P. T. C., Gruner, S. M., & Shyamsunder, E. (1992). Automated pressure and temperature control apparatus for x-ray powder diffraction studies. *Review of scientific instruments*, *63*(2), 1763-1770.

[23] Tapiador, Jed I., and Alvin Y. Chua. "A novel automated wind chiller hybrid cooling system for a cold storage room application." *International Journal of Mechanical Engineering and Robotics Research* 7.6 (2018): 662-668.

[24] Huang, Xiang, Yongmei Lu, and Tianwei Qiang. "Study on the semi-centralized evaporative cooling air-conditioning system's automation." *2011 International Conference on Electrical and Control Engineering*. IEEE, 2011.

[25] Ershad, Hamed, and Richard Fertell. "Automated life stand advances nanotechnologies the reliability, aging tests of a flow instrument used to measure, monitor, and, control the chamber temperature." *2016 13th International Multi-Conference on Systems, Signals & Devices (SSD)*. IEEE, 2016.

[26] Nuñez Alvarez, José Ricardo, et al. "Automation of the air conditioning system for aseptic rooms of pharmaceutical production." *International journal of power electronics and drive systems* 14.3 (2023): 1479-1488.

[27] Wang, Hong, et al. "Capillary compression induced outstanding n-type thermoelectric power factor in CNT films towards intelligent temperature controller." *Nature Communications* 15.1 (2024): 5617.

[28] Wittwer, C. T., G. C. Fillmore, and D. R. Hillyard. "Automated polymerase chain reaction in capillary tubes with hot air." *Nucleic acids research* 17.11 (1989): 4353-4357.

[29] Goyette, B., et al. "Design and implementation of an automated controlled atmosphere storage facility for research." *Canadian Biosystems Engineering* 44.3 (2002): 35-40.

[30] Nagy, Jefte, et al. "Automation of Thermal Processes in a Datacenter. Experimental Control Using Cloud Based Platform and PLC." *2024 International Conference on Advanced Scientific Computing (ICASC)*. IEEE, 2024.

[31] Möhler, Ottmar, et al. "The portable ice nucleation experiment PINE: a new online instrument for laboratory studies and automated long-term field observations of ice-nucleating particles." *Atmospheric Measurement Techniques Discussions* 2020 (2020): 1-43.

APPENDIX

```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include <DHT.h>

// DHT setup
#define DHTPIN 2
#define DHTTYPE DHT11
DHT dht(DHTPIN, DHTTYPE);

// LCD setup (address may be 0x27 or 0x3F)
LiquidCrystal_I2C lcd(0x27, 16, 2);

// Pins
#define POT_PIN A3
#define RELAY_PIN 3
#define MOTOR_PIN 4

void setup() {
 Serial.begin(9600);

 dht.begin();
 lcd.init();
 lcd.backlight();

 pinMode(RELAY_PIN, OUTPUT);
 pinMode(MOTOR_PIN, OUTPUT);

 digitalWrite(RELAY_PIN, LOW);
 digitalWrite(MOTOR_PIN, LOW);
}

void loop() {
 // Read temperature & humidity
 float temp = dht.readTemperature();
 float hum = dht.readHumidity();

 // Read potentiometer and map to temperature (20°C - 50°C)
 int potValue = analogRead(POT_PIN);
 float setTemp = map(potValue, 0, 1023, 20, 50);

 // Check sensor reading
 if (isnan(temp) || isnan(hum)) {
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Sensor Error!");
  delay(1000);
  return;
 }
```

```
  // Control Logic
  if (temp >= setTemp) {
    digitalWrite(RELAY_PIN, HIGH);  // Relay ON
    digitalWrite(MOTOR_PIN, HIGH);  // Motor ON
  } else {
    digitalWrite(RELAY_PIN, LOW);   // Relay OFF
    digitalWrite(MOTOR_PIN, LOW);   // Motor OFF
  }

  // Display on LCD
  lcd.clear();

  lcd.setCursor(0, 0);
  lcd.print("T:");
  lcd.print(temp);
  lcd.print("C H:");
  lcd.print(hum);

  lcd.setCursor(0, 1);
  lcd.print("Set:");
  lcd.print(setTemp);

  delay(1000);
}
```