Design, Fabrication and Performance Analysis of a Peltier Module-Based Water Cooling and Heating System

A Thesis

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Of

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APPROVAL

This is to certify that the project "**Design, Fabrication and Performance Analysis of a Peltier Module-Based Water Cooling and Heating System**'', by Md. Shohanur Rahman (ID: ME2203028006), Md. Nuruzzaman Shahadat (ID: ME2203028034), Md. Mahedi Hasan (ID: BME1503007002), Nahid Hasan (ID: ME2203028079), Thousif Hassan (ID: ME2203028030) has been carried out under our supervision. The project has been carried out in particle fulfillment of the requirements of the degree of Bachelor of Science (B.Sc.) in Mechanical Engineering of years of 2026 and has been approved as to its style and contents.

Signature of the Supervisor

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DECLARATION

We do hereby solemnly declare that, the work presented here in this project report has been carried out by us and has not been previously submitted to any University/ Organization for award of any degree or certificate

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We further undertake to indemnify the university against any loss or damage arising from breach of the foregoing obligation.

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ABSTRACT

This project presents the design and implementation of an innovative Water Purifier System employing a Peltier Module for both cooling and heating functionalities. The system integrates advanced filtration components, including Activated Carbon, Mineral Sand Ball, Zeolite & Silica Gel, and a Ceramic Filter, along with a Pump Motor for water circulation and a Heat Sink for efficient heat dissipation. The filtration process begins with the ceramic filter, removing larger particles, followed by activated carbon to adsorb impurities and enhance water taste. Mineral sand balls contribute beneficial minerals, while zeolite and silica gel provide additional purification. The heart of the system lies in the Peltier Module, capable of cooling or heating the water as needed, offering a versatile solution for diverse applications. A carefully designed water circulation system, powered by the pump motor, ensures that water passes through each filtration stage and interacts with the Peltier Module for optimal treatment. The heat sink plays a crucial role in maintaining the efficiency and longevity of the Peltier Module by dissipating the generated heat. This integrated water purifier system aims to deliver purified water with improved taste, reduced impurities, and the flexibility of temperature control. The combination of cooling, heating, and multi-stage filtration makes it suitable for various environments, offering a sustainable and efficient solution for enhancing water quality. The project aligns with the growing demand for innovative water treatment technologies, addressing the need for clean and customized water solutions in different contexts.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1
INTRODUCTION

1.1 Introduction

Water is an essential resource for sustaining life, and ensuring access to clean and temperature-controlled water is crucial for both domestic and industrial applications. Traditional water heating and cooling systems rely on large-scale infrastructure, which can be inefficient and energy-intensive. To address this challenge, thermoelectric modules, specifically Peltier modules, offer a compact, energy-efficient solution for water heating and cooling.

Peltier modules operate on the principle of the thermoelectric effect, where an electric current passing through a thermoelectric material creates a temperature gradient. This phenomenon allows for both cooling and heating within a single system, making it highly versatile for applications requiring temperature control. The use of Peltier modules for water purification and temperature regulation is gaining traction due to their reliability, solid-state operation, and ability to function without moving parts or refrigerants.

This project aims to design and construct a purified water cooling and heating system utilizing Peltier technology. The system consists of a dual-chamber setup, where water is cooled and heated separately, controlled by digital temperature regulators. The purified water storage mechanism ensures that users have access to clean drinking water at their desired temperature. Additionally, the system is designed to be cost-effective and energy-efficient, making it suitable for residential, office, and laboratory environments.

By integrating filtration mechanisms, the system ensures that water is not only temperature-regulated but also free from contaminants. The implementation of this project contributes to advancing sustainable and eco-friendly solutions for daily water consumption needs. The findings and construction of this system can pave the way for further research into thermoelectric applications in water treatment and temperature management. This document outlines the methodology, construction, testing, and evaluation of the proposed system, ensuring a comprehensive understanding of its design and functionality.

1.2 Objective

- To design a compact Peltier module-based water cooling and heating system.
- To fabricate a functional prototype using thermoelectric technology.
- To analyze the performance of the Peltier module in heating and cooling.

1.3 Proposed Method / System

The proposed system consists of a thermoelectric water cooling and heating mechanism that utilizes a Peltier module, a water reservoir, a heat dissipation system, and a microcontroller-based control unit. The Peltier module operates based on the thermoelectric effect, where heat is absorbed on one side and released on the other when an electric current pass through it. This property allows the system to provide both hot and cold water efficiently.

The methodology involves several key components:

1. **Water Reservoir –** A container holds the purified water, ensuring a constant supply for the system.

2. **Peltier Module –** Responsible for heat transfer, cooling one section of the water while heating the other.

3. **Heat Dissipation System –** Includes aluminum heat sinks and cooling fans to enhance heat transfer and improve efficiency.

4. **Microcontroller and Sensors –** A microcontroller regulates the operation of the Peltier module based on inputs from temperature sensors, ensuring precise control.

5. **Power Supply –** Provides the necessary electrical energy for system operation.

6. **Thermal Insulation –** Prevents heat loss, enhancing energy efficiency.

7. **User Interface –** Consists of an LCD display and control buttons for user operation and monitoring.

The system will be tested under various environmental conditions to evaluate its efficiency, stability, and energy consumption. By analyzing performance metrics such as temperature variations, power usage, and response time, improvements will be made to enhance system reliability and sustainability. The final prototype aims to deliver an eco-friendly, cost-effective solution for instant access to purified hot and cold water.

1.3 Organization of book

This book is structured to provide a comprehensive understanding of the study and construction of a purified water cooling and heating system using Peltier modules. It is organized into the following chapters:

- **Chapter 1:** Introduction – Covers the background, objectives, and scope of the project.
- **Chapter 2:** Literature Review – Discusses existing water purification and thermoelectric temperature control technologies.
- **Chapter 3:** System Design – Details the components, design specifications, and working principles of the proposed system.
- **Chapter 4:** Implementation and Construction – Describes the step-by-step process of building the system, including materials used.
- **Chapter 5:** Experimental Results and Discussion – Presents test results, performance analysis, and system efficiency.
- **Chapter 6:** Conclusion and Future Work – Summarizes findings and suggests improvements for further research.

Each chapter builds upon the previous one, ensuring a logical flow of information that aids in understanding the principles, design, and execution of the project. This organization ensures clarity and provides a structured approach to comprehensively studying the system's development and application.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

The literature review explores existing research, technologies, and methodologies relevant to the development of a purified water cooling and heating system using a Peltier module. It provides a comprehensive understanding of prior studies on thermoelectric cooling and heating, water purification methods, and energy efficiency considerations. By analyzing past work, this chapter identifies gaps in research and highlights key advancements that contribute to the project's framework. The review further establishes the theoretical foundation required for designing and implementing an effective and sustainable water cooling and heating system.

2.2 Literature Review

Zhang H. Y., Mui Y. C., and Tarin M. (2010) conducted significant research on thermoelectric cooling systems and their thermal performance in Applied Thermal Engineering. Their study mainly focused on improving the efficiency of Peltier-based cooling devices through better heat transfer techniques. They explained that thermoelectric modules work effectively when proper heat dissipation methods such as heat sinks and cooling fans are used. The researchers also highlighted that thermoelectric systems are environmentally friendly because they do not use harmful refrigerants. Their findings proved that Peltier modules are suitable for compact cooling and heating applications due to their small size, noiseless operation, and low maintenance requirements [1].

Najmie M. S. and Fadzly M. K. (2019) presented research on thermoelectric water cooling systems in AIP Conference Proceedings. Their work emphasized energy-efficient cooling methods using Peltier modules. The study analyzed temperature variation and system stability under different operating conditions. They observed that integrating a proper water circulation system with thermoelectric modules improves heat transfer efficiency and provides better cooling performance. Their research also discussed the importance of thermal insulation and controlled power supply for achieving stable operation. The authors concluded that Peltier technology can be effectively used in portable and small-scale water cooling systems because of its simplicity and eco-friendly characteristics [2].

Haris N. I., Wahab M., and Talip A. (2014) studied the practical applications of thermoelectric technology in portable temperature control systems, published in Applied Mechanics and Materials. Their research focused on the advantages of thermoelectric devices over traditional cooling methods. They found that Peltier modules require fewer mechanical parts, resulting in lower maintenance and quieter operation. The study also highlighted the reliability and durability of thermoelectric systems in long-term applications. According to their findings, thermoelectric cooling systems are highly suitable for portable and low-capacity heating and cooling applications where compact design and energy efficiency are important factors [3].

2.3 Summary

The literature review highlights advancements in Peltier-based water cooling and heating systems, emphasizing efficiency improvements, energy optimization, and IoT integration. Future research aims to overcome existing limitations through innovative techniques and materials.

CHAPTER 3
HARDWARE ANALYSIS

3.1 Required Components List

Water Purifier Section:

1. Ceramic Filter
2. Mechanical float switch valves
3. Plastic Box

Cooling and Heating Section:

1. SMPS
2. Buck Converter
3. Pump Motor
4. Peltier Module
5. Heat Sink
6. Digital Temperature Meter

3.2 Ceramic Filter

A ceramic filter is a porous water filtration device that removes impurities and contaminants from water by using natural filtration mechanisms. These filters are widely used in water purification systems due to their efficiency, affordability, and ease of maintenance.

Ceramic filters function by allowing water to pass through a network of microscopic pores while trapping suspended solids, bacteria, and other harmful microorganisms. The porous structure of ceramic material acts as a natural barrier, effectively removing particles larger than the pore size, typically ranging from 0.1 to 0.5 microns. Some ceramic filters are also coated with silver to enhance bacterial disinfection properties.

Figure 3.l: Ceramic Filter

One of the key advantages of ceramic filters is their long lifespan. With proper maintenance, including periodic cleaning to remove accumulated impurities, these filters can last for several years. Additionally, ceramic filters do not require electricity, making them a sustainable and cost-effective solution for clean drinking water, especially in remote or underdeveloped areas.

The integration of ceramic filters in water purification systems is beneficial for removing bacteria, sediment, and certain chemical contaminants. However, they may not effectively eliminate dissolved solids, heavy metals, or viruses, requiring additional filtration stages such as activated carbon or UV treatment for comprehensive purification.

In the Peltier-based purified water cooling and heating system, the ceramic filter serves as a crucial component in ensuring water quality. It acts as a pre-filtration stage before the water undergoes temperature regulation, maintaining high purity levels and preventing contaminants from affecting system performance. The combination of ceramic filtration with advanced purification technologies enhances the overall efficiency and effectiveness of the water treatment process.

3.3 Mechanical float switch valves

Mechanical float switch valves are crucial components in water management systems, designed to regulate water levels in tanks, reservoirs, and purification systems. These valves operate based on a simple yet effective floating mechanism that rises or falls with the water level, automatically controlling the flow of water.

Figure 3.2: Mechanical float switch valves

The primary function of a mechanical float switch valve is to prevent overflow and maintain a steady water level. When the water level reaches a predetermined point, the float mechanism triggers the valve to either open or close, allowing or stopping water flow accordingly. This process ensures efficient water management without requiring electrical components, making it highly reliable and cost-effective.

Mechanical float switch valves are typically made from durable materials such as stainless steel, brass, or high-quality plastic, ensuring longevity and resistance to corrosion. They are widely used in water filtration systems, agricultural irrigation, industrial applications, and household water tanks.

One of the key advantages of these valves is their automatic operation, which minimizes human intervention and reduces the risk of water wastage. Additionally, they require minimal maintenance, as they do not rely on electrical power or complex control systems.

In the Peltier-based purified water cooling and heating system, mechanical float switch valves play a vital role in maintaining an optimal water level within the system. By ensuring a consistent water supply, these valves contribute to the system's efficiency and longevity. They also help prevent dry running of the pump and protect components from potential damage due to fluctuations in water levels.

Overall, integrating mechanical float switch valves into the water cooling and heating system enhances its reliability, sustainability, and ease of operation, making it an essential component in modern water management solutions.

3.4 Plastic Container Box

A plastic container box is an essential component used as a water tank in the Peltier-based purified water cooling and heating system. These containers serve as storage units for purified water, ensuring a continuous supply for the system's cooling and heating functions.

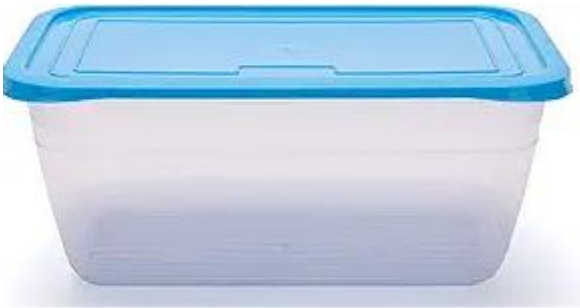

Figure 3.3: Plastic Container Box

Plastic water tanks are widely chosen due to their lightweight nature, durability, and resistance to corrosion. Unlike metal containers, plastic does not react with water, preventing contamination and ensuring the safety of stored water. High-density polyethylene (HDPE) or food-grade plastic is commonly used for water storage, as it is non-toxic and does not leach harmful chemicals into the water.

The use of a plastic container box enhances the portability and adaptability of the system. Its design allows for easy installation and integration with components such as float switches, filters, and pumps. Additionally, plastic containers are cost-effective, making them a practical choice for small-scale water management solutions.

In this project, the plastic container box ensures that water remains uncontaminated while being efficiently cooled or heated. Proper insulation of the container helps maintain temperature levels, optimizing the performance of the Peltier module. By selecting a suitable plastic container, the system achieves a balance between affordability, efficiency, and safety in water storage and regulation.

3.5 Switch Mode Power Supply (SMPS)

A switched-mode power supply (switching-mode power supply, switch-mode power supply, switched power supply, SMPS, or switcher) is an electronic power supply that incorporates a switching regulator to convert electrical power efficiently. Like other power supplies, an SMPS transfers power from a DC or AC source (often mains power) to DC loads, such as a personal computer, while converting voltage and current characteristics. Unlike a linear power supply, the pass transistor of a switching-mode supply continually switches between low-dissipation, full-on and full-off states, and spends very little time in the high dissipation transitions, which minimizes wasted energy.

A hypothetical ideal switched-mode power supply dissipates no power. Voltage regulation is achieved by varying the ratio of on-to-off time (also known as duty cycles). In contrast, a linear power supply regulates the output voltage by continually dissipating power in the pass transistor. This higher power conversion efficiency is an important advantage of a switched-mode power supply. Switched-mode power supplies may also be substantially smaller and lighter than a linear supply due to the smaller transformer size and weight.

Figure 3.4: SMPS

Switching regulators are used as replacements for linear regulators when higher efficiency, smaller size or lighter weight are required. They are, however, more complicated; their switching currents can cause electrical noise problems if not carefully suppressed, and simple designs may have a poor power factor. Switched-mode power supplies are classified according to the type of input and output voltages.

The four major categories are:

- AC to DC
- DC to DC
- DC to AC
- AC to AC

A basic isolated AC to DC switched-mode power supply consists of:

- Input rectifier and filter
- Inverter consisting of switching devices such as MOSFETs
- Transformer
- Output rectifier and filter
- Feedback and control circuit

The input DC supply from a rectifier or battery is fed to the inverter where it is turned on and off at high frequencies of between 20 KHz and 200 KHz by the switching MOSFET or power transistors. The high-frequency voltage pulses from the inverter are fed to the transformer primary winding, and the secondary AC output is rectified and smoothed to produce the required DC voltages. A feedback circuit monitors the output voltage and instructs the control circuit to adjust the duty cycle to maintain the output at the desired level.

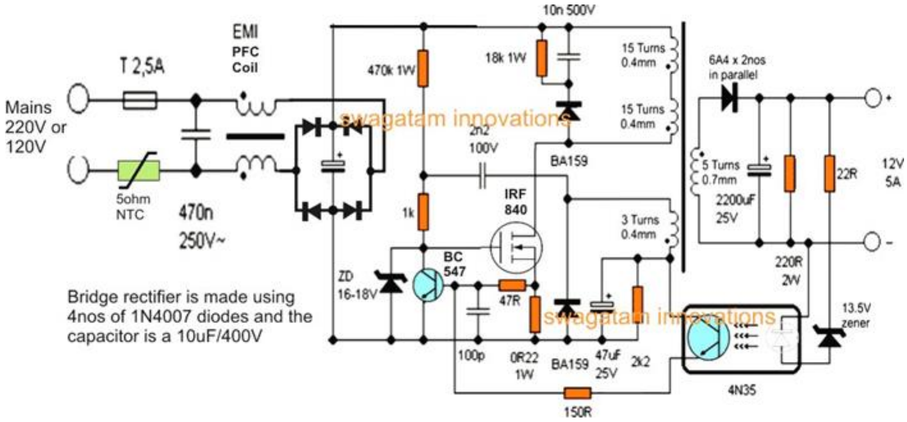

Figure 3.5: SMPS Circuit

Basic working concept of an SMPS

A switching regulator does the regulation in the SMPS. A series switching element turns the current supply to a smoothing capacitor on and off. The voltage on the capacitor controls the time the series element is turned. The continuous switching of the capacitor maintains the voltage at the required level.

Design basics

AC power first passes through fuses and a line filter. Then it is rectified by a full-wave bridge rectifier. The rectified voltage is next applied to the power factor correction (PFC) pre-regulator followed by the downstream DC-DC converter(s). Most computers and small appliances use the International Electrotechnical Commission (IEC) style input connector. As for output connectors and pin outs, except for some industries, such as PC and compact PCI, in general, they are not standardized and are left up to the manufacturer.

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Advantages of switched-mode power supplies:

- Higher efficiency of 68% to 90%
- Regulated and reliable outputs regardless of variations in input supply voltage
- Small size and lighter
- Flexible technology
- High power density
- Disadvantages:
- Generates electromagnetic interference
- Complex circuit design
- Expensive compared to linear supplies

Switched-mode power supplies are used to power a wide variety of equipment such as computers, sensitive electronics, battery-operated devices and other equipment requiring high efficiency. Linear voltage IC regulators have been the basis of power supply designs for many years as they are very good at supplying a continuous fixed voltage output. Linear voltage regulators are generally much more efficient and easier to use than equivalent voltage regulator circuits made from discrete components such a zener diode and a resistor, or transistors and even op-amps.

These two types of complementary voltage regulators produce a precise and stable voltage output ranging from about 5 volts up to about 24 volts for use in many electronic circuits.There is a wide range of these three-terminal fixed voltage regulators available each with its own built-in voltage regulation and current limiting circuits. This allows us to create a whole host of different power supply rails and outputs, either single or dual supply, suitable for most electronic circuits and applications.

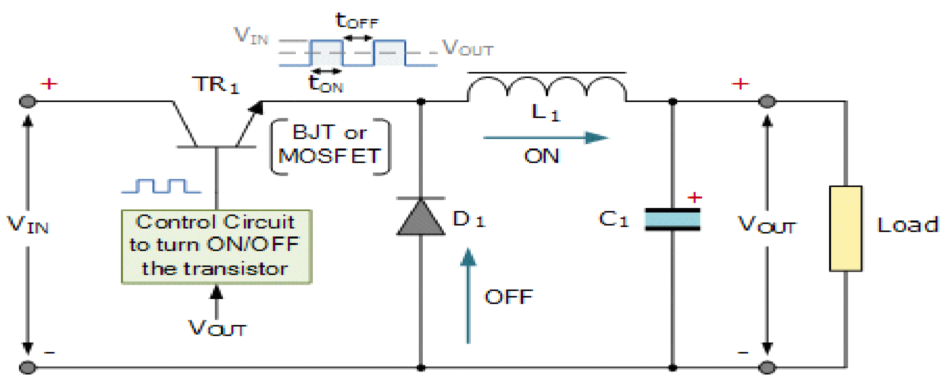

Figure 3.6: SMPS Circuit Connection

Most d.c. power supplies comprise of a large and heavy step-down mains transformer, diode rectification, either full-wave or half-wave, a filter circuit to remove any ripple content from the rectified d.c. producing a suitably smooth d.c. voltage, and some form of voltage regulator or stabiliser circuit, either linear or switching to ensure the correct regulation of the power supplies output voltage under varying load conditions. Then a typical d.c. power supply would look something like this:

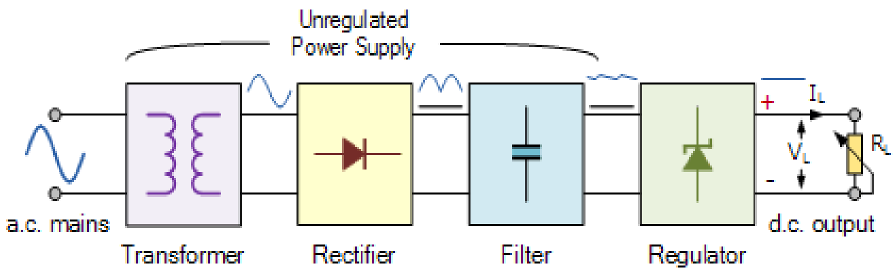

Figure 3.7: DC Power supply way

These typical power supply designs contain a large mains transformer (which also provides isolation between the input and output) and a dissipative series regulator circuit. The regulator circuit could consist of a single zener diode or a three-terminal linear series regulator to produce the required output voltage. The advantage of a linear regulator is that the power supply circuit only needs an input capacitor, output capacitor and some feedback resistors to set the output voltage.

3.6 Buck Converter

A buck converter (step-down converter) is a DC-to-DC power converter which steps down voltage (while drawing less average current) from its input (supply) to its output (load). It is a class of switched-mode power supply (SMPS) typically containing at least two semiconductors (a diode and a transistor, although modern buck converters frequently replace the diode with a second transistor used for synchronous rectification) and at least one energy storage element, a capacitor, inductor, or the two in combination.

To reduce voltage ripple, filters made of capacitors (sometimes in combination with inductors) are normally added to such a converter's output (load-side filter) and input (supply-side filter). It is called a buck converter because the voltage across the inductor “bucks” or opposes the supply voltage.

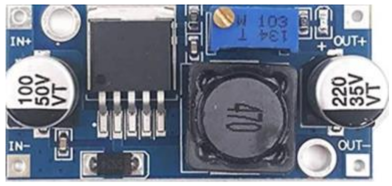

Figure 3.8: DC -DC Buck Converter

DC-DC Buck Converter Step Down Module LM2596 Power Supply is a step- down(buck) switching regulator, capable of driving a 3-A load with excellent line and load regulation. These devices are available in fixed output voltages of 3.3 V, 5 V, 12 V, and an adjustable output version. The LM2596 series operates at a switching frequency of 150kHz, thus allowing smaller sized filter components than what would be required with lower frequency switching regulators.

Specifications of DC-DC Buck Converter Step Down Module LM2596 Power Supply:

- Conversion efficiency: 92%(highest)
- Switching frequency: 150KHz
- Output ripple: 30mA9maximum)
- Load Regulation: ± 0.5%
- Voltage Regulation: ± 0.5%
- Dynamic Response speed: 5% 200uS
- Input voltage:4.75-35V
- Output voltage:1.25-26V(Adjustable)
- Output current: Rated current is 2A, maximum 3A (Additional heat sink is required)
- Conversion Efficiency: Up to 92% (output voltage higher, the higher the efficiency)
- Switching Frequency: 150KHz
- Rectifier: Non-Synchronous Rectification
- Module Properties: Non-isolated step-down module (buck)
- Short Circuit Protection: Current limiting, since the recovery
- Operating Temperature: Industrial grade (-40 to +85) (output power 10W or less)

3.7 Pump Motor

This is a low cost, small size Submersible Pump Motor which can be operated from a 2.5 6V power supply. It can take up to 120 liters per hour with very low current consumption of

220mA. Just connect tube pipe to the motor outlet, submerge it in water and power it. Make sure that the water level is always higher than the motor. Dry run may damage the motor due to heating and it will also produce noise.

Figure 3.9: Pump Motor

Feature:

- Operating Current : 130 ~ 220mA
- Flow Rate : 80 ~ 120 L/H
- Maximum Lift : 40 ~ 110 mm
- Continuous Working Life : 500 hours
- Driving Mode : DC, Magnetic Driving
- Material : Engineering Plastic
- Outlet Outside Diameter : 7.5 mm
- Outlet Inside Diameter : 5 mm

3.8 Peltier Module

A Peltier cooler, heater, or Thermoelectric heat pump is a solid-state active heat pump which transfers heat from one side of the device to the other, with consumption of electrical energy, depending on the direction of the current.

Figure 3.10: Peltier Cooler

The TEC1-12706 40x40 mm Thermoelectric Cooler 0~6A Peltier Module is the simple application of Peltier Thermoelectric Effect. Thermoelectric coolers also are known as TEC or Peltier Module create a temperature differential on each side. One side gets hot and the other side gets cool. Therefore, they can be used to either warm something up or cool something down, depending on which side you use. You can also take advantage of a temperature differential to generate electricity.

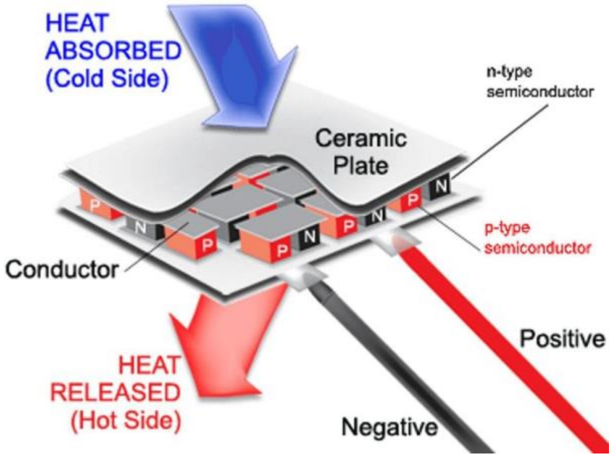

Figure 3.11: Construction of Peltier

Two unique semiconductors, one n-type and one p-type, are used because they need to have different electron densities. The semiconductors are placed thermally in parallel to each other and electrically in series and then joined with a thermally conducting plate on each side. When a voltage is applied to the free ends of the two semiconductors there is a flow of DC current across the junction of the semiconductors causing a temperature difference. The side with the cooling plate absorbs heat which is then moved to the other side of the device where the heat sink is. Thermoelectric Coolers, also abbreviated to TECs are typically connected side by side and sandwiched between two ceramic plates. The cooling ability of the total unit is then proportional to the number of TECs in it. This Peltier works very well as long as you remove the heat from the hot side. After turning on the device, the hot side will heat quickly, the cold side will cool quickly. If you do not remove the heat from the hot side (with a heat sink or other device), the Peltier will quickly reach stasis and do nothing. We recommend using an old computer CPU heatsink or another block of metal to pull heat from the hot side. We were able to use a computer power supply and CPU heat sink to make the cold side so uncomfortable we could not hold our finger to it.

A Thermoelectric cooling (TEC) module is a semiconductor-based electronic component that functions as a small heat pump. By applying the DC power source to a TEC, heat will be transferred from one side of the module to the other. It creates a cold and hot side. They are widely used in industrial areas, for example, computer CPU, CCDs, portable refrigerators, medical instruments, and so on. Also Known as Thermoelectric cooling modules, Thermoelectric modules, Peltier modules, Thermoelectric cooling module.

Features:

- Small module.
- Easy transition between the hot side to the cool side and vice-versa just by reversing the polarity of supply.
- Quality tested cooling cells.
- Solid state, vibration free, noise-free.
- Simple to install and operate.
- Should use with a heat sink.

3.9 Heat Sink

A heat sink (also commonly spelled heat sink) is a passive heat exchanger that transfers the heat generated by an electronic or a mechanical device to a fluid medium, often air or a liquid coolant, where it is dissipated away from the device, thereby allowing regulation of the device's temperature. In computers, heat sinks are used to cool CPUs, GPUs, and some chipsets and RAM modules. Heat sinks are used with high-power semiconductor devices such as power transistors and optoelectronics such as lasers and light emitting diodes (LEDs), where the heat dissipation ability of the component itself is insufficient to moderate its temperature.

Figure 3.12: Heat Sink

Description

- Aluminum Water Cooling Block for CPU Heat sink Cooler Peltier Plate 80x40x12mm
- Internal flow channel extrusion forming

- Brazing parts into a whole
- Leak rate of less than 5X10-6 mbar.l/s parts
- Internal fin thickness 0.5MM
- Connection: 9 mm id tubes
- Processing: vacuum aluminum brazing
- Surface treatment: silver oxidation
- Applicable to computer CPU water, industrial inverter driver, laser head cooling, industrial control cabinet cooling, Thermoelectric Cooler
- Size:80 (D) x 40 (W) x 12 (H) MM

3.10 Push Button Switch

The Push Button Switch - Small (4Pin) is a compact and versatile electronic component commonly used in various circuit applications. It features four pins, typically arranged in a 2x2 configuration, and operates in a momentary manner, meaning it closes the circuit when pressed and opens it once released.

The 4-pin design offers additional functionality compared to traditional 2-pin push-button switches. The four pins generally include two pairs of contacts: one pair for the normally open (NO) state and another pair for the normally closed (NC) state. This allows for more versatile control in electronic projects, enabling different behaviors, such as toggling between on/off states or creating more complex input systems.

Figure 3.13: Push Button Switch

These small push button switches are commonly used in Arduino projects, DIY electronics, and other embedded systems, often serving as input devices to trigger actions like activating LEDs, motors, or other components. Due to their small size, they can be integrated easily into tight spaces or compact designs, making them ideal for projects with limited space.

3.11 Digital Temperature Meter

A thermometer is a device that measures temperature or a temperature gradient (the degree of hotness or coldness of an object). A thermometer has two important elements: a temperature sensor (e.g. the bulb of a mercury-in-glass thermometer or the pyrometric sensor in an infrared thermometer) in which some change occurs with a change in temperature.

Figure 3.14: Digital Temperature Meter

some means of converting this change into a numerical value (e.g. the visible scale that is marked on a mercury-in-glass thermometer or the digital readout on an infrared model). Thermometers are widely used in technology and industry to monitor processes, in meteorology, in medicine, and in scientific research. Some of the principles of the thermometer were known to Greek philosophers of two thousand years ago.

As Henry Carrington Bolton (1900) noted, the thermometer's "development from a crude toy to an instrument of precision occupied more than a century, and its early history is encumbered with erroneous statements that have been reiterated with such dogmatism that they have received the false stamp of authority." The Italian physician Santorio Santorio (Sanctorius, 1561-1636) is commonly credited with the invention of the first thermometer, but its standardization was completed through the 17th and 18th centuries.

In the first decades of the 18th century in the Dutch Republic, Daniel Gabriel Fahrenheit made two revolutionary breakthroughs in the history of thermometry. He invented the mercury-in-glass thermometer (first widely used, accurate, practical thermometer) and Fahrenheit scale (first standardized temperature scale to be widely used).

Specification

- Temperature range: -50~ +110°C
- Using environment: Temperature: -5~ +50°C Humidity: 5%~80%
- Accuracy: ±1°C
- Size: 47*28*14mm

CHAPTER 4
METHODOLOGY

4.1 Methodology

The methodology of this project involves the design, fabrication, and testing of a Peltier module-based water cooling and heating system. The process begins with converting AC 220V input power into regulated DC 12V using an SMPS. This DC supply is then adjusted to required voltage levels through a buck converter to ensure safe and efficient operation of all components.

The Peltier module is installed between a heat sink and a water block. When electrical current flows through the module, it creates a temperature difference, producing a hot side and a cold side simultaneously. Proper heat dissipation is ensured by attaching a heat sink and cooling arrangement to maintain system efficiency.

Water circulation is achieved using pump motors, which direct water through the hot and cold channels of the system. Two push button switches are used to control the operation of hot and cold-water flow separately. When a switch is activated, the corresponding pump motor circulates water through either the heating or cooling section.

Finally, the system is tested under different conditions to evaluate temperature variation, response time, and overall performance, ensuring reliable and efficient operation.

4.2 Block Diagram

The block diagram of the Peltier module-based water cooling and heating system represents the overall structure and flow of power and water within the system. It consists of several interconnected functional blocks, including the power supply unit, control switches, Peltier module, pump motors, and water block.

The system begins with an AC 220V input source, which is supplied to the SMPS (Switched Mode Power Supply). The SMPS converts high-voltage AC into low-voltage DC (12V), making it suitable for electronic components. This DC output is then fed into a buck converter, which further regulates and steps down the voltage to the required level for safe and efficient operation.

The regulated DC power is distributed to the Peltier module and pump motors. The Peltier module acts as the core unit, generating both hot and cold surfaces when current flows through it. The hot side is used for heating water, while the cold side is used for cooling. A

heat sink is attached to the hot side to dissipate excess heat and maintain system efficiency.
Two push button switches are connected to control two separate pump motors. Push Switch-1 activates Pump Motor-1, which circulates water through the heating path to produce hot water. Similarly, Push Switch-2 activates Pump Motor-2, directing water through the cooling path to provide cold water.
The water block acts as the medium for heat exchange, allowing efficient transfer of thermal energy between the Peltier module and water. This block diagram clearly illustrates the working flow and interaction of all system components.

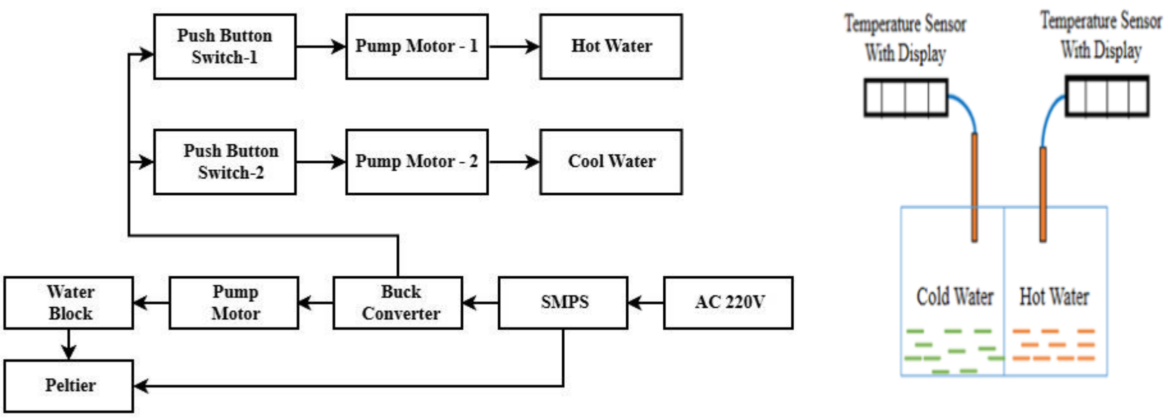

Figure 4.1: Block Diagram

4.3 Complete Project Prototype Image:

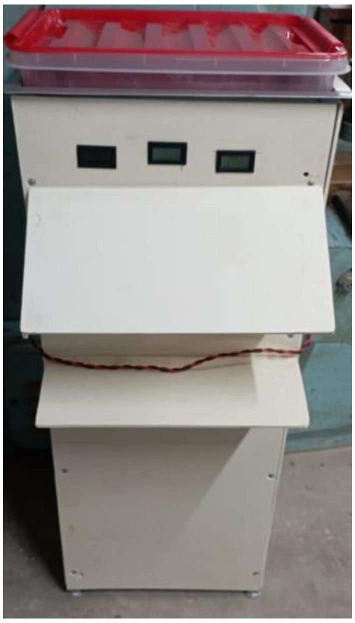

Figure 4.2: Complete Project Picture-1

Figure 4.3: Complete Project Picture-2

4.4 Working Principle

The working principle of the Peltier module-based water cooling and heating system is based on the thermoelectric effect. When a direct current (DC) passes through the Peltier module, it creates a temperature difference between its two sides. One side becomes cold by absorbing heat, while the other side becomes hot by releasing heat. This dual functionality allows the system to provide both cooling and heating using a single device.

Initially, AC 220V power is supplied to the system and converted into DC 12V using an SMPS. This voltage is then regulated through a buck converter to meet the operating requirements of the Peltier module and pump motors. Once powered, the Peltier module starts generating hot and cold surfaces simultaneously. A heat sink is attached to the hot side to dissipate excess heat and maintain proper temperature balance.

Water circulation is achieved using pump motors. When Push Switch-1 is pressed, Pump Motor-1 is activated, allowing water to flow through the hot side of the system. As a result, water absorbs heat and becomes hot. Similarly, when Push Switch-2 is pressed, Pump Motor-2 operates and directs water through the cold side, where heat is absorbed from the water, producing cool water.

The water block ensures efficient heat transfer between the Peltier module and the flowing water. Continuous circulation improves temperature uniformity and system performance, enabling effective and controlled heating and cooling.

4.5 Cost Analysis:

Table I: Cost Analysis.

No	Product Name	Specification	Qty.	Unit Price	Total Price	Market Price
01.	Water Purifier	Multi Cartridge	1	1500	1500	
02.	Water tap		2	100	200	
04.	SMPS	12V	1	990	990	
05.	Buck Converter	LM2596	1	120	240	
06.	Pump Motor	12V DC	3	150	450	
07.	Peltier Module	TEC-1 12706	4	300	1200	
08.	Heat Sink	80*40*12	2	520	1040	
09.	Temperature Meter		3	150	450	
10.	Others				1500	
Total =					8500/=	12,000/=

CHAPTER 5
RESULT AND DISCUSSION

5.1 Data Analysis

Observation

Table No. II: Time duration VS. Cold water temperature

SL	Time (Min)	Supply Temp.	Cold Temp.
1	0	25.6° C	25.6° C
2	15	25.6° C	21.3° C
3	30	25.7° C	21.1° C
4	45	25.7° C	21.0° C
5	60	25.7° C	20.3° C

Table No. 2: Time duration VS. Hot water temperature.

SL	Time (Min)	Supply Temp.	Hot Temp.
1	0	25.6° C	25.6° C
2	15	25.6° C	29.8° C
3	30	25.6° C	32.6° C
4	45	25.6° C	36.8° C
5	60	25.6° C	40.6° C

SL	Time (Min)	Supply Temp.	Cold Temp.	Hot Temp.
1	0	25.6° C	25.6° C	25.6° C
2	15	25.6° C	21.3° C	29.8° C
3	30	25.6° C	21.1° C	32.6° C
4	45	25.6° C	21.0° C	36.8° C
5	60	25.6° C	20.3° C	40.6° C

Note: Each Data has been taken after 15 minutes.

Calculation of Co-Efficient of Performance:

Hot and Cold-Water Chamber dimensions are given bellow.

L= 250 mm = 0.25 m

W=250 mm = 0.25 m

H=160 mm = 0.16 m

Chamber Volume, V=0.25x0.25x0.16

= 0.1 m3

Mass of Water in the Chamber, m= ρV

= 1000x.01

=10 kg

Qcold= MS x (Tn - Tmin)

= 10 x 4200 x (25.2 - 20.2)

= 210,000 J

=210 kJ

QHot= MS x (Tmax - Tn)

=10 x 4200 (40 - 25.2)

=621600J

=621.6 kJ

Here, Input Power

P=VI= 12x10 = 120 w

Input Power for Cooling = P x time

=120 x 15 x 60

=108000 J

=108 kJ x 0.8 (Peltier module efficiency: 80%)

=86.4 kJ

Input Power for Heating = P x time

=120 x 60 x 60

=432000 J

=432 kJ x 0.8 (Peltier module efficiency: 80%)

=345.6 kJ

Now Co-efficient of performance,

COP (cooling)= Qcold / Input Work

=210/86.4

=2.43

Now Co-efficient of performance,

COP (heating) = QHot / Input Work

=621.6/345.6

=1.8

5.2 Description

After completing all design objectives and planned procedures, the project was successfully fabricated and tested. The system was assembled using all required components, and the circuit was implemented carefully to ensure stable and efficient operation. Upon testing, the system performed smoothly according to the intended design, demonstrating reliable heating and cooling functions using the Peltier module.

• The successful implementation of this project confirms that integrating a Peltier module with a water system is a feasible solution for both heating and cooling applications. It validates the concept and demonstrates the practicality of thermoelectric technology in real-life use.

• The system showed effective thermal performance, where the cold side was able to reduce water temperature noticeably, while the hot side increased temperature efficiently. This proves that dual temperature control can be achieved within a compact system.

• Users can easily obtain temperature-controlled water by operating push button switches, making the system user-friendly and convenient for everyday use.

• The continuous water circulation using pump motors ensured uniform temperature distribution and improved overall system efficiency.

• The system also demonstrated stable performance over time, with minimal fluctuations, indicating good reliability.

Overall, the results confirm that the proposed system is efficient, cost-effective, and suitable for small-scale applications requiring both hot and cold-water supply.

5.3 Advantage

Our initiative undoubtedly has many benefits, some of the most significant of which are listed below:

- Comprehensive Water Treatment.
- Temperature Control.
- Improved Water Taste and Odor.
- Health Benefits
- User-Friendly Interface
- Efficient Water Circulation
- Innovation in Water Treatment

5.4 Application

Our project has many application areas and actually we need to use it in many places to verify the exact person which have the proper access. Some of the application areas of the project has been pointed out below:

- Residential Use.
- Office Environments.
- Healthcare Facilities.
- Educational Institutions
- Emergency and Disaster Relief
- Research Laboratories.

5.5 Limitation

It is a demo project so we found some limitation. In future we will work for reduce this kind of limitation. These limitations are –

- Energy Consumption.
- Initial Cost.
- Maintenance Requirements.
- Limited Temperature Range.
- Dependence on Ambient Temperature.
- Water Flow Rate.

5.6 Discussion

The developed Peltier module-based water cooling and heating system demonstrates a practical application of thermoelectric technology for small-scale temperature control. The system operates on the principle of heat transfer through the Peltier effect, where electrical energy is directly converted into a temperature difference. The experimental results show that the system is capable of producing both hot and cold water simultaneously, which confirms the effectiveness of the design.

One of the key factors influencing system performance is heat dissipation. The efficiency of the Peltier module largely depends on how effectively heat is removed from the hot side. In this project, the use of a heat sinks significantly improved performance by maintaining a temperature gradient across the module. However, it was observed that insufficient cooling on the hot side reduces overall efficiency and limits the cooling capacity of the system.

Water flow rate also plays an important role in system performance. Proper circulation ensures uniform heat exchange and prevents overheating or overcooling. The pump motors used in the system provided continuous water flow, which enhanced thermal transfer and stabilized the output temperature.

Despite its advantages, the system has some limitations. The coefficient of performance (COP) of thermoelectric systems is generally lower compared to conventional refrigeration systems. Additionally, the system consumes relatively high electrical power for the amount of heating or cooling produced. Ambient temperature also affects performance; as higher surrounding temperatures reduce cooling efficiency.

Overall, the project highlights that while Peltier-based systems are compact, eco-friendly, and easy to implement, further improvements in heat management, insulation, and power optimization are necessary to enhance efficiency and make the system more suitable for large-scale applications.

CHAPTER 6
CONCLUSION

6.1 Conclusion

To sum up, the Water Purifier System with Peltier Module Water Cooling and Heating is a state-of-the-art and creative method of treating water. The system solves the twin problems of supplying clean water and accurate temperature control by combining cutting-edge technology like the Peltier Module with multi-stage filtration. Its design and operation are based on theoretical foundations that span environmental science, fluid dynamics, thermoelectricity, and filtration processes. The thermoelectric qualities of the Peltier Module allow for both heating and cooling, which adds to the system's versatility in a range of applications. Water is thoroughly treated, pollutants are removed, and overall quality is improved by the extensive multi-stage filtering process, which includes ceramic filtration, activated carbon adsorption, mineralization, and zeolite & silica gel purification. In order to overcome current constraints and improve the Water Purifier System with Peltier Module Water Cooling and Heating's overall effectiveness and usability, further study, development, and invention in its theoretical elements are needed.

6.2 Future Scope

The model can be improved by making some changes in the program and components. Some suggestions are given below-

- **Integration of Smart Technologies:** Using smart technologies, such Internet of Things (IoT) connectivity, could allow the water purifier system to be monitored and controlled in real time.
- **Nanotechnology in Filtration:** Investigating how nanotechnology might be incorporated into filtration components could improve the system's capacity to eliminate even tinier impurities and particles, therefore enhancing the quality of the water.
- **Advanced Filtration Materials:** More sustainable and efficient water purification may result from research into cutting-edge filtration materials, such as bio-inspired materials.

- **Reference**

1. De França Doria M. 2010 Water policy 12 p 1-19.
2. Asyiqin N A, Fadzly M K and Amarul T 2019 AIP Conf. Proc. 2129 p. 020145
3. Costin D, Ion-Ene M and Neofit A 2010 Health, Sports and Rehabilitation Medicine 32.
4. Zhang H Y, Mui Y C and Tarin M 2010 Appl. Therm. Eng. 30 p 561–568.
5. Najmie M S and Fadzly M K 2019 AIP Conf. Proc. 2129 p. 020147
6. Radhwan H, Shayfull Z, Farizuan M R, Effendi M S M and Irfan A R 2019 AIP Conf. Proc. 2129 p 020153
7. Tan J X, Effendi M S M and Radhwan H 2019 AIP Conf. Proc. 2129 p 020162
8. Xin T J, Farizuan R M, Radhwan H, Shayfull Z and Fathullah M 2019 AIP Conf. Proc. 2129 p 020159.
9. Farahin K, Effendi M S M and Radhwan H 2019 AIP Conf. Proc. 2129 p 020163.
10. Farahin K, Farizuan M R and Radhwan H 2019 AIP Conf. Proc. 2129 p 020160
11. Hazelrigg, G. A. 2010 Research in Engineering Design 21 p 143-144
12. Ismalina H N, Amarul T, Yusra A Z N, Zahidah M N N, Rakeish K P, Nasuha M N T and Vikneswaran P 2018 AIP Conf. Proc. 2030 p 020021
13. Haris N I, Wahab M And Talip A 2014 Applied Mechanics and Material 465 p 725-729
14. Fadzly M K, Foo W T, Amarul T, Mardhiati M M and Fakhira W N 2019 AIP Conf. Proc. 2129 p. 020146.
15. Masniza Y, Zulfabli H M, Amarul T, Khairunnisa S N, Zilawati N A R N N, Nazera D and Ismalina H N 2019 AIP Conf. Proc. 2129 p 020056
16. Zulfabli H M, Ismalina H N, Amarul T, and Ahmad S 2019 AIP Conf. Proc. 2129 p 020055
17. Ismalina H N, Zulfabli H M, Amarul T, Idham M T M A, Fahmi A Z M I,Syuhadah M H N and Fatihah R F N 2019 AIP Conf. Proc. 2129 p 020054.