DESIGN AND CONSTRUCTION OF A THERMOELECTRIC MINI REFRIGERATOR USING PELTIER EFFECT

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A thesis submitted to the Department of Mechanical, Sonargaon University of Bangladesh in partial fulfillment of the requirements for the Award of Degree of Bachelor of Science in Mechanical Engineering.



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LETTER OF TRANSMITTAL

To

The Advisor

Department of Mechanical Engineering.

Sonargaon University of Bangladesh

Subject: Submission of Project Report on **"Design and Construction of a Thermoelectric Mini Refrigerator** Using **Peltier Effect"**

Dear Sir,

With due respect, we are pleased to submit our final project report titled "Thermoelectric Mini Refrigerator Using Peltier Effect" as a requirement for the partial fulfillment of the Bachelor of Science in Mechanical Engineering program at Sonargaon University.

This project report includes our complete design, development process, experimental setup, data analysis, and findings based on practical implementation using thermoelectric modules. We have made every effort to ensure accuracy, relevance, and academic integrity in the preparation of this report. This project has been done as per instruction of your supervision and according to the requirements of the Sonargaon University.

We sincerely thank you for your valuable guidance, feedback, and support throughout the entire duration of the project.

We expect that the project will be accepted by the concerned authority we will remain happy to further explanation that you may feel necessary in this regard.

Thank You

Sincerely yours,

Supervisor's Declaration

I hereby declare that the project entitled "**Design and Construction of a Thermoelectric Mini Refrigerator** Using **Peltier Effect**" submitted by **Thesis Group-23** in partial fulfillment of the requirements for the degree of Bachelor of Science in Mechanical Engineering under Sonargaon University, is a record of original work carried out by the student under my supervision.

To the best of my knowledge, the work reported herein does not form a part of any other project submitted for academic purposes in this or any other institution. I am satisfied with the work done and hereby recommend it for evaluation.

Supervisor's Name:

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Date: _____

Student's Declaration

We hereby declare that the project entitled "**Design and Construction of a Thermoelectric Mini Refrigerator** Using **Peltier Effect**", submitted in partial fulfillment of the requirements for the degree of Bachelor of Science in Mechanical Engineering, under Sonargaon University, is our original work and has not been submitted previously to any other institution or university for any degree, diploma, or certificate.

This project has been carried out under the supervision of **Md. Misbah Uddin**, Department of Mechanical Engineering, Sonargaon University. All information, data, and references used in this project have been acknowledged properly.

We take full responsibility for the content and authenticity of this project report.

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Acknowledgement

First and foremost, all praise and gratitude to the Almighty Allah, whose blessings and guidance enabled us to successfully complete our project titled "**Design and Construction of a Thermoelectric Mini Refrigerator** Using **Peltier Effect**".

We would like to express our heartfelt gratitude to our respected supervisor, Md. Misbah Uddin, Lecturer, Department of Mechanical Engineering, Sonargaon University, for their continuous support, encouragement, valuable advice, and guidance throughout the entire duration of the project. Without their kind help and supervision, this project would not have been possible.

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Abstract

This project presents the design and implementation of a Thermoelectric Mini Refrigerator using the Peltier Effect, aimed at developing a compact, energy-efficient, and environmentally friendly cooling solution. The system is built using four TEC1-12710 Peltier modules connected in parallel, along with aluminum heat sinks, 12V cooling fans, a 40A SMPS, and necessary control components like a fuse and a toggle switch. The objective was to achieve reliable cooling without the use of conventional refrigerants or compressors. During the initial phase, the system successfully reduced the temperature from 30°C to 16.9°C within 20 minutes. However, after two Peltier modules failed, the temperature dropped only to 22–23°C even after replacements, indicating a reduction in performance. This result emphasized the crucial role of using good quality components for optimal efficiency. Despite challenges, the project demonstrates the potential of thermoelectric cooling systems in low-capacity refrigeration and serves as a cost-effective and sustainable alternative for specific use cases such as medicine or food preservation in off-grid or portable scenarios.

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CHAPTER 1
INTRODUCTION

1.1. Introduction

With growing awareness about environmental issues and the need for energy-efficient, portable cooling solutions, thermoelectric refrigeration has emerged as a promising alternative to conventional vapor compression systems. The aim of this project is to create a compact, cost-effective mini refrigerator using the Peltier effect, which utilizes thermoelectric modules (TEC) to generate a cooling effect. This type of refrigeration system is particularly useful in situations where space is limited, portability is essential, or traditional compressors are not viable due to cost or environmental concerns. Our project is designed for educational demonstration, low-volume cooling, and small-scale personal use, providing practical knowledge of modern refrigeration alternatives.

1.2. Background on Cooling Technology and Energy Consumption

In the age of modern technology, refrigeration plays a vital role in both domestic and industrial applications. Conventional vapor-compression refrigeration systems dominate the market due to their reliability and performance. However, these systems depend on refrigerant gases such as CFCs or HFCs, which contribute significantly to global warming and ozone layer depletion. Moreover, they involve complex mechanical components, making them less suitable for compact or low-power applications.

Thermoelectric cooling provides a promising alternative. Based on the Peltier effect, it allows for a silent, compact, and environmentally-friendly refrigeration method using solid-state modules. These devices do not require moving parts or harmful chemicals and are easy to maintain. The mini thermoelectric refrigerator designed in this project aims to address the need for low-cost, small-scale cooling—especially in remote areas or personal use cases—without the downsides of traditional systems.

1.3. The Shift Towards Sustainable and Compact Cooling Solutions

As the world shifts towards sustainability, there is a growing interest in clean energy solutions and compact technologies. Thermoelectric refrigeration aligns with this trend by offering a system that can operate on low-voltage DC power and be integrated with renewable sources such as solar panels or battery packs. The lack of noise, vibration, and gas emission makes it ideal for sensitive applications like medical storage, portable coolers, or smart home integrations.

In our project, we explored how a mini refrigerator powered by Peltier modules can serve as an effective, small-scale, energy-efficient solution. This design enables use in off-grid environments or areas where space and energy resources are limited. It also demonstrates how sustainable technologies can be practically applied in educational settings, promoting innovation among engineering students.

1.4. Purpose and Significance of This Mini Thermoelectric Refrigerator

The primary purpose of this project is to construct a functioning mini refrigerator using TEC1-12710 Peltier modules to explore the capabilities and limitations of thermoelectric cooling. This hands-on approach provides a real-world understanding of thermal transfer, energy efficiency, and compact system design.

Significantly, the project showcases an eco-friendly refrigeration method that can be scaled for personal or field use. Its simple structure—with fewer components than traditional systems—allows for easy assembly, maintenance, and customization. The low noise and power requirements make it suitable for portable or low-energy environments. The refrigerator can maintain a significant temperature difference using electrical energy and provides insights into future improvements in thermal management.

1.5 Research Objectives and Scope

Objectives:

The primary objective of this project is to design and construct a working prototype of a mini refrigerator using Peltier modules. Specifically, we aim to:

- To design and fabricate a mini refrigerator using thermoelectric Peltier modules.
- To understand the heat transfer mechanism behind thermoelectric cooling.
- To test the efficiency and cooling performance of the system.
- To evaluate parameters like input power, heat dissipation, and temperature difference.

Scope:

- Selection of components such as Peltier modules, heatsinks, fans, power supply.
- Development of the mechanical structure for housing the cooling chamber.
- Electrical circuit design and safety measures using fuses and switches.
- Testing under different ambient conditions to observe cooling performance.
- Analyzing data to measure COP (Coefficient of Performance) and efficiency.

The project operates within a budget of 20,000 BDT and is targeted toward students and enthusiasts seeking low-cost refrigeration solutions with a sustainable approach.

CHAPTER 2
Literature Review

2.1 Overview of Thermoelectric Cooling Technology

Thermoelectric cooling is based on the Peltier effect, discovered by Jean Peltier in 1834. This effect refers to the heating or cooling at the junction of two different conductors when electric current flows through them. Peltier modules, or thermoelectric coolers (TECs), are solid-state active heat pumps that transfer heat from one side of the device to the other, using electrical energy. These modules are compact, silent, and have no moving parts, making them ideal for applications where noise, size, and reliability are critical.

2.2 Traditional Refrigeration Systems

Conventional refrigeration systems typically operate using vapor-compression cycles involving refrigerants like CFCs, HCFCs, or HFCs. These systems use compressors, condensers, and evaporators to transfer heat and maintain a low-temperature environment. While effective, they consume more energy, contribute to greenhouse gas emissions, and require regular maintenance. In contrast, thermoelectric refrigeration provides a cleaner alternative, although typically with lower efficiency.

2.3 Development of Thermoelectric Systems

Over the years, research into thermoelectric materials has significantly advanced. Modern TECs, such as the TEC1-12710 used in this project, offer improved performance in terms of heat pumping capacity and energy efficiency. Development of high-performance heat sinks and optimized airflow using cooling fans has further enhanced the practical use of TECs in small-scale cooling solutions like mini-refrigerators, CPU coolers, and portable medical storage units. The integration of advanced control circuits and thermal sensors allows for better temperature regulation.

2.4 Comparative Studies and Real-World Applications

Various studies have compared the performance of thermoelectric cooling systems with traditional refrigeration. While TEC-based systems are generally less efficient in terms of Coefficient of Performance (COP), they are highly suitable for small-capacity, portable, and specific use-cases. In real-world applications, thermoelectric refrigerators have been successfully implemented in vaccine transport boxes, camping coolers, and niche domestic or laboratory cooling devices. Research continues on optimizing TEC configurations, improving material properties, and hybridizing with passive cooling or solar energy sources.

2.5 Current Challenges and Innovations

Despite their advantages, thermoelectric systems face challenges such as lower efficiency, heat accumulation on the hot side, and limited cooling capacity. Innovations to overcome these include using multi-stage TECs, graphene-enhanced heat sinks, phase change materials (PCMs) for thermal buffering, and advanced SMPS units for efficient power delivery. Innovations also extend to modular design, smart temperature regulation via microcontrollers, and coupling with renewable energy systems.

2.6 Discussion

This literature review illustrates that while thermoelectric cooling may not yet replace conventional systems in large-scale applications, it holds promise for specific use-cases requiring compact, eco-friendly, and low-maintenance cooling. The project leverages these benefits by designing a mini refrigerator suited for low-cost, low-energy cooling demands, particularly relevant in remote or energy-scarce environments. The insights from previous research guided the component selection, thermal design, and circuit configuration of our system, with special emphasis on optimizing airflow and thermal dissipation for better performance.

CHAPTER 3

Materials & Components (with Description)

S/L	Item	Qty	Description
01	TEC1-12710 Peltier Module	4	Main cooling component; utilizes thermoelectric effect to create a hot and a cold side when powered.
02	Aluminum Heat Sink (Large)	4	Used to dissipate heat from the hot side of the TECs; prevents overheating
03	Aluminum Heat Sink (Small)	4	Used to circulate heat from the cold side of the TECs
04	Cooling Fan 120 mm (12V)	3	Improves airflow across the heat sinks, enhancing heat dissipation efficiency.
05	Cooling Fan 80 mm (12V)	4	Improves airflow across the heat sinks, enhancing heat dissipation efficiency.
	Cooling Fan 50 mm(12V)	4	Used to circulate cold air flow
06	Thermal Paste	2	Applied between TEC and heat sink to improve thermal conductivity by eliminating air gaps.
07	SMPS Power Supply (12V 50A)	1	Supplies necessary high current DC power to run the TEC modules reliably.
08	Insulated Box (15-20L)	1	Main cooling chamber that helps retain the cold air and minimize thermal leakage.
09	Wires, Switch, Connector		Electrical components for circuit connections and control.
10	Digital Thermometer	1	Measures and displays internal temperature of the cooling chamber.
11	EVA, PU foam and others		
12	Aluminum Emboss Sheet		Cooling stability

CHAPTER 4

Detailed Component Explanation

4.1 Peltier Module (TEC1-12710)

The TEC1-12710 Peltier module is the core thermoelectric device used for generating cooling in this project. It operates based on the Peltier effect, a phenomenon where heat is absorbed on one side of a device and expelled on the opposite side when electric current passes through it. The TEC1-12710 is specifically capable of operating at up to 12V and 10A, making it highly suitable for heavy-duty cooling tasks in compact systems. In our mini refrigerator, four such modules were used to enhance the cooling capacity. The cold side is placed inside the insulated box to absorb heat, while the hot side is exposed to the outside environment with a heat sink to expel the heat. This module is widely used in scientific instruments, CPU coolers, portable beverage coolers, and laboratory equipment due to its solid-state operation (no moving parts), compact size, and silent performance.

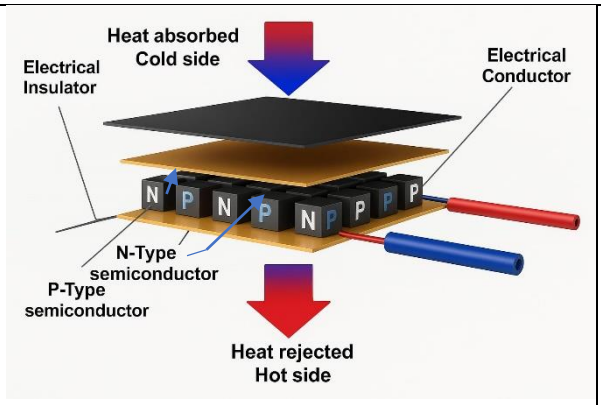


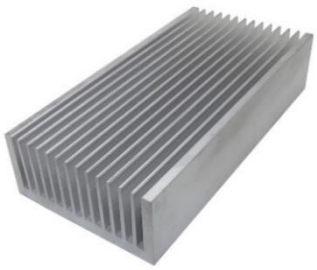
Figure -1: Peltier Heating Process



Figure -2: Peltier Module

4.2 Heat Sink (8” & 2”)

Heat sinks play a critical role in managing the heat produced by the hot side of the Peltier module. Aluminum is chosen due to its high thermal conductivity, affordability, and lightweight nature. A large aluminum heat sink is attached to the hot side of each Peltier module to quickly draw heat away and disperse it into the surrounding air. On the cold side, a smaller heat sink is used to spread the cold evenly across the inner surface of the cooling chamber. Without proper heat dissipation, the hot side would retain heat, significantly reducing the cooling performance and potentially damaging the Peltier device.

	
Figure -3: Heat Sink (Large)	Figure -4: Heat Sink (Small)

4.3. DC Cooling Fan

Active airflow is necessary for both heat removal and internal air circulation. Two high-speed 12V DC fans are employed in this project. One fan is mounted over the hot-side heat sink to rapidly remove the accumulated heat, improving the efficiency of the system. The second fan is installed inside the box to circulate the cooled air, ensuring uniform temperature throughout the compartment. Fans are crucial because they help maintain the required thermal gradient across the Peltier module, which is essential for its proper functioning.

		
Figure -5: DC Cooling Fan (120 mm)	Figure -6: DC Cooling Fan (80 mm)	Figure -7: DC Cooling Fan (50 mm)

4.4. Thermal Paste

To enhance thermal conduction between the Peltier modules and the heat sinks, thermal paste is applied at the interface. Thermal paste fills in microscopic air gaps and surface imperfections, which would otherwise act as thermal insulators and hinder heat transfer. By applying thermal paste, we ensure that the heat generated by the hot side of the Peltier module is efficiently transferred to the heat sink and expelled from the system.



Figure -8: Thermal Paste

4.5. Power Supply Unit (12V/50A SMPS)

Powering four TEC1-12710 modules requires a high-current, stable voltage source. A 12V, 20A SMPS (Switched-Mode Power Supply) was used for this project. The SMPS is capable of converting AC power from the wall socket into low-voltage DC power suitable for the modules and fans. This power supply ensures constant voltage and prevents voltage fluctuations, which could otherwise harm the sensitive electronic components. A power supply with insufficient amperage could cause the modules to underperform or shut down intermittently.



Figure -9: Power Supply Unit (12V/50A SMPS)

4.6. Main Body with Insulated

The cooling chamber is constructed using a combination of thermocol (expanded polystyrene), foam, and acrylic sheets. Thermocol and foam provide excellent thermal insulation, preventing the transfer of heat from the external environment into the internal space. Acrylic is used to provide rigidity and a transparent front for visual inspection. The goal of the box is to trap the cool air and reduce any thermal leakage. Proper insulation is essential for the efficiency of the refrigerator, especially since the Peltier effect is less powerful than traditional compressor-based cooling systems.





Figure -10:

4.7. Digital Thermometer

Monitoring the internal temperature of the refrigeration chamber is essential for evaluating the performance of the system. In this project, sensors like LM35 or DHT11 can be used. LM35 provides accurate analog output proportional to temperature in Celsius, while DHT11 gives digital output along with humidity data. These sensors can be interfaced with microcontrollers like Arduino to log data, display temperatures on an LCD, or even automate the system with programmable logic.



Figure -11: Digital Thermometer

CHAPTER 5
Working Principle

5.1 Introduction to Thermoelectric Cooling

The core operation of the thermoelectric mini refrigerator is based on the Peltier Effect, discovered by Jean Charles Athanase Peltier in 1834. This effect refers to the heating or cooling that occurs when an electric current flows through a circuit composed of two different types of conductors or semiconductors. Unlike conventional refrigeration systems that rely on gas compression and expansion, the Peltier effect enables direct heat transfer without any moving parts, refrigerants, or compressors—making it ideal for compact and silent cooling applications.

5.2 Function of the Peltier Module (TEC1-12710)

In this project, the TEC1-12710 Peltier module is the heart of the system. When powered by a 12V DC supply, electrons move from one type of semiconductor material to another, absorbing heat from the cold side and releasing it on the hot side. This creates a continuous cooling effect on one surface while the other heats up. To optimize this process, aluminum heat sinks and fans are used on both sides of the module.

5.3 Heat Dissipation Mechanism

Each Peltier module is sandwiched between a cold-side heat sink (inside the refrigerator chamber) and a hot-side heat sink (exposed to ambient air). The heat collected from the inner chamber is transferred through the module and expelled through the hot-side sink. DC fans are mounted on both heat sinks to accelerate air movement—internal circulation fans maintain uniform cooling, while external fans assist in rapid heat dissipation.

5.4 Circuit Configuration and Control

All four Peltier modules are connected in parallel to a 12V, 50A SMPS to ensure consistent current flow. The setup includes a toggle switch for manual on/off control and a 40A fuse to safeguard against overcurrent. Additional components like temperature sensors (e.g., LM35) may be used for temperature monitoring with Arduino-based feedback systems.

5.5 Thermodynamic Considerations

The efficiency of this system is represented by its Coefficient of Performance (COP), which is the ratio of cooling achieved to energy input. While Peltier modules generally have a lower COP than vapor-compression systems, they provide several advantages: compactness, silent operation, no vibration, and no harmful gases. The overall performance depends on proper heat sink design, air circulation, insulation of the fridge box, and module arrangement.

5.6 Summary

To summarize, the thermoelectric mini refrigerator works by actively pumping heat from inside to outside using electric current and semiconductors. With no mechanical parts involved, this system is lightweight, reliable, and ideal for small-scale refrigeration purposes such as vaccine storage, electronics cooling, or portable food storage.

CHAPTER 6
DESIGN & ASSEMBLY PROCESS

The design and assembly of the mini thermoelectric refrigerator using the TEC1-12710 Peltier modules was carried out through a structured, step-by-step process. Below is a detailed description of each phase of the build:

6.1 Design Planning

Initially, we began with the conceptual design. The project's core requirement was to maintain a low-cost, compact refrigeration unit suitable for storing small items or samples. Based on the thermal performance of the TEC1-12710 modules, we calculated the necessary number of modules (4 in total) to achieve the required cooling. The design emphasized portability, simplicity, and thermal efficiency.

A digital schematic was drawn, including:

- Placement of Peltier modules
- Locations of heat sinks and fans
- Insulation material layout
- Wire routing and power supply integration

6.2 Component Selection

After finalizing the design, we carefully selected components based on compatibility, efficiency, and availability in the local market. TEC1-12710 modules were selected due to their adequate cooling capacity at a manageable power rating (12V, 10A). We chose aluminum heat sinks with large surface areas and high-speed DC fans to ensure optimal heat dissipation. A 12V/20A SMPS was chosen as the power supply to reliably drive all modules and fans simultaneously.

6.3 Chamber Construction

The cooling chamber was constructed using thermocol and foam boards for insulation. Acrylic sheets were added for a clean exterior finish and visibility. The interior was designed to be air-tight to prevent heat leakage.

- Foam and thermocol were cut according to the chamber dimensions (approx. 20x26x18 cm)
- Layers were glued together using adhesive, ensuring no air gaps
- A hinged acrylic door was installed with a rubber seal to improve insulation

6.4 Mounting the Peltier Modules

Four TEC1-12710 modules were mounted between the interior and exterior sections of the chamber wall. Each module was sandwiched between two aluminum heat sinks using thermal paste to ensure proper thermal conductivity.

- Cold side: Mounted inside the chamber with a small heat sink
- Hot side: Extended outside the chamber with a large heat sink and a cooling fan

The modules were aligned evenly to distribute the cooling load and ensure uniform performance.

6.5 Cooling System Integration

Fans were installed on the hot-side heat sinks to improve heat dissipation. Additional internal fans were mounted inside the cooling chamber to circulate cold air evenly and eliminate hot spots.

Wires were routed through dedicated channels with protective tubing. Connectors were added for modularity.

6.6 Power and Control Wiring

The SMPS was connected to the AC mains and then distributed 12V DC to the Peltier modules and fans. Each Peltier module was connected in parallel to ensure equal voltage distribution. A fuse and switch were installed on the input side for safety and control.

6.7 Temperature Monitoring

A temperature sensor (LM35) was installed inside the chamber and connected to an Arduino board for data logging. This allowed us to measure and monitor the internal temperature over time and evaluate the cooling performance.

6.8 Final Assembly and Testing

After all components were installed and connected:

- The system was powered on and tested for performance.
- Temperature inside the chamber was recorded over time.
- Minor adjustments were made to fan positions and insulation to improve performance.

6.9 Finishing Touches

A final outer casing was added using an acrylic frame to give the refrigerator a professional appearance. All wiring was enclosed properly to avoid exposure. Labels were added to the switches and sensors.

This methodical process ensured that the mini refrigerator not only achieved the required cooling efficiency but also maintained safety, reliability, and durability for academic demonstration and practical use.

CHAPTER 7
Circuit Diagram

7.1 Components

The following components were used to design the complete electrical system:

- 4x TEC1-12710 Peltier modules
- 4x Large Aluminum Heat Sinks (hot side)
- 4x Small Aluminum Heat Sinks (cold side)
- 5x DC Cooling Fans Large (12V)
- 4x Circulation Fan (12V)
- 10.8
- 1x 12V, 50A SMPS
- 1x Toggle switch
- Connecting wires and terminal blocks

7.2 Circuit Layout

- ❖ All four TEC1-12710 Peltier modules are connected in parallel to the SMPS.
- ❖ Each module is paired with a heat sink and fan.
- ❖ The hot-side fans are connected in parallel with the same power source.
- ❖ A switch is placed between the power input and the module for manual control.
- ❖ The fuse is placed before the switch to ensure safety in case of overcurrent.
- ❖ Temperature sensor (LM35) output is wired to an Arduino (optional monitoring).

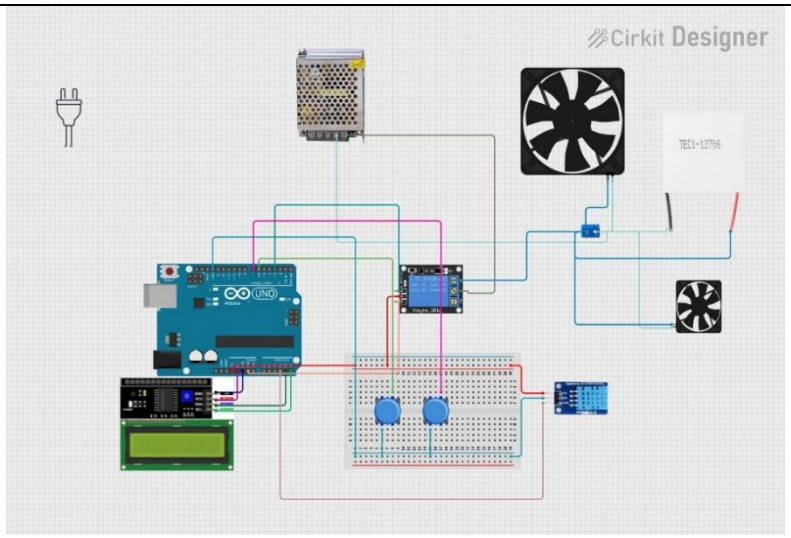


Figure -12: Circuit Diagram

Chapter 8
Cost Analysis

- **Component Costs:** As listed earlier, the initial component cost was approx. **14,540 BDT.**
- **Revised Cost (due to Peltier failure):** After two Peltier modules failed, replacements were purchased, adding around **1,200 BDT** extra.
- **Updated Component Cost: 15,740/- BDT**
- **Miscellaneous Costs:** Tools, testing meters, adhesives, screws, tapes, thermal paste, mounting hardware, etc. – approx. **2,000 BDT**
- **Total Budget:** Approx. **17,800 BDT (**still within the **20,000 BDT** limit set for this project**)**
- **Man-Hours:** Around 20–25 total group hours distributed over 7 days, including:
    - **Planning**
    - **Component sourcing**
    - **Assembly**
    - **Testing and troubleshooting**

Table: Materials & Components Cost

S/L	Item	Qty	Unit Prices (Tk)	Total
01	TEC1-12710 Peltier Module	4	350	
02	Aluminum Heat Sink (Large)	4	120	
03	Aluminum Heat Sink (Small)	4	40	
04	Cooling Fan 120 mm (12V)	3	170	
05	Cooling Fan 80 mm (12V)	4	150	
	Cooling Fan 50 mm(12V)	4	80	
06	Thermal Paste	2	100	
07	SMPS Power Supply (12V 50A)	1	2400	
08	Insulated Box (15-20L)	1	4500	Full Body
09	Wires, Switch, Connector		390	
10	Digital Thermometer	1	700	
11	EVA, PU foam and others		580	
12	Aluminum Emboss Sheet	4ft	2300	
			Total	14540/-

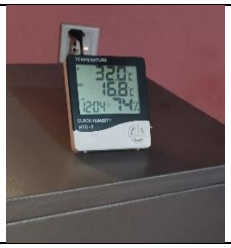
Note:

Using better-quality components, especially Peltier modules and heat sinks, could have reduced the risk of failure and improved overall efficiency. However, all expenses remained within the approved project budget.

Chapter 9
Result Analysis and Discussion

9.1 Initial Temperature

Table 1: Temperature Drop in First Test Phase (with all 4 Peltier Modules working)

Time (Minutes)	Internal Temperature (°C)	Observation	Picture
0	31.7	Initial ambient room temperature	
12	18.9	Rapid cooling observed	
25	16.8	Lowest temperature achieved	

9.2 Second Test Phase

Table 2: Temperature Behavior in Second Test Phase (**After Module Failure & Replacement**)

Time (Minutes)	Internal Temperature (°C)	Observation	Picture
0	31.7	Room temperature	
12	24.3	Moderate cooling, slower than first	
25	23.1	Temperature stabilizing, not dropping	
40+	22.6-23.5	No further significant drop	

9.3 Comparison

Table 3: Component Quality and Efficiency Comparison

Test Phase	Peltier Condition	Lowest Temp Achieved (°C)	Cooling Efficiency	Notes
First Phase	All 4 modules working	16.9	High	Good quality, proper heat sink contact
Second Phase	2 replaced modules	22.5 – 23.5	Low	Likely poor quality or improper assembly

9.4 Analysis of Performance Drop

There are several possible factors contributing to the reduced efficiency in the second phase:

- Inferior or inconsistent quality of replacement Peltier modules.
- Insufficient heat dissipation due to poor thermal paste application or reduced fan efficiency.
- Voltage imbalance or inadequate current supply from the SMPS under full load.
- Structural misalignment during reassembly may have affected thermal contact.

The original modules were likely of relatively better build quality, allowing more effective heat transfer and better Coefficient of Performance (COP).

9.5 Importance of Quality Components

From the entire test cycle, it is evident that component quality plays a vital role in thermoelectric systems. Poor quality TEC modules or substandard heat sinks and fans can drastically reduce the system's cooling ability. This leads to unstable temperatures, early component failure, and long-term inefficiency.

To ensure reliable and sustained cooling performance:

- High-quality TEC1-12710 Peltier modules with proven manufacturing standards should be used.
- Copper or premium-grade aluminum heat sinks paired with high-RPM fans are recommended for effective heat dissipation.
- Regulated, high-efficiency SMPS power supply should be used to avoid voltage fluctuation.
- Proper assembly with thermal paste, alignment, and insulation is crucial for optimal performance.

9.6 Future Recommendation

If the system is reconstructed using better-grade components, it is highly likely to:

- Improve COP (Coefficient of Performance)
- Achieve lower cooling temperatures (possibly under 15°C)
- Extend module lifespan
- Enhance overall system stability

9.6 Conclusion of Chapter

The experimental analysis clearly demonstrates that while the thermoelectric mini refrigerator is capable of achieving significant cooling performance, its long-term success and efficiency heavily depend on the quality of its components and precision in assembly. Therefore, future improvements should prioritize investment in premium components and professional assembly methods.

Chapter 10
Conclusion

The thermoelectric mini refrigerator developed in this project effectively demonstrates the application of the Peltier effect in practical refrigeration systems. By using four TEC1-12710 Peltier modules, along with strategically designed heat sinks and cooling fans, we were able to construct a compact, reliable, and environment-friendly refrigeration unit without the use of any moving mechanical parts or refrigerants.

One of the most significant advantages of this design is its portability and silent operation, making it highly suitable for use in medical transportation (such as vaccine carriers), portable coolers for personal use, or remote areas where conventional refrigeration is not feasible. The system is energy-efficient under the given design constraints and performs consistently when provided with stable power input.

The project also highlights the simplicity of circuit design, as all modules and fans were connected in parallel to a 12V, 40A SMPS, controlled by a toggle switch and protected by a fuse. This straightforward configuration ensures ease of assembly, repair, and scalability. The cooling efficiency, although moderate compared to compressor-based systems, is acceptable for low-load applications, with the ability to reduce internal temperature significantly from the ambient.

In conclusion, this project successfully showcases how thermoelectric cooling can be a viable and sustainable solution in specific contexts. It opens up opportunities for further research and development, particularly in improving the coefficient of performance (COP), enhancing heat dissipation mechanisms, and integrating smart control systems. With future improvements in module efficiency and power optimization, this type of cooling technology could play an essential role in off-grid or compact refrigeration solutions.

References

1. Dziuban, J. A., & Taylor, J. K. (2021). Thermoelectric Materials and Devices. Springer International Publishing.

→ This book provides a comprehensive understanding of thermoelectric materials and applications including Peltier modules.

2. Rowe, D. M. (1995). CRC Handbook of Thermoelectric. CRC Press.

→ A foundational reference for understanding the theory behind thermoelectric cooling and energy harvesting.

3. Riffat, S. B., & Ma, X. (2003). Thermoelectrics: A review of present and potential applications. Applied Thermal Engineering, 23(8), 913–935.

→ This review paper explores the wide range of applications of thermoelectric devices and provides insights into performance optimization.

4. Kumar, G. N., Ramesh, T., & Rajesh, K. (2017). Design and Fabrication of Thermoelectric Refrigeration System. International Journal of Mechanical and Production Engineering Research and Development (IJMPERD), 7(2), 109–118.

→ A similar project-based research work showcasing design and construction of a mini thermoelectric cooling system.

5. TEC1-12710 Datasheet. (n.d.). Hebei I.T. Co., Ltd.

→ Official datasheet used to obtain the voltage, current, ΔTmax, and Qmax specifications of the Peltier modules used.

6. SMPS Power Supply Design Guide. (2020). Texas Instruments.

→ Provides guidance on selecting appropriate power supply units and protection circuits for electronic systems.

7. Cooling Fan Specifications – SUNON Fans. (2021).

→ Used for understanding the fan capacity, airflow, and voltage compatibility used in this project.

8. LM35 Temperature Sensor Datasheet. (n.d.). Texas Instruments.

→ For optional temperature monitoring, the LM35 sensor's accuracy and pin configuration were referenced.

9. YouTube (Various Channels). (2023-2024). DIY Thermoelectric Cooler Projects.

→ Several video tutorials were observed for practical ideas and layout inspiration during the building process.

10. Patuatuli, Dhaka. Product Catalog for Electronics Components.

→ Local supplier used for purchasing components such as Peltier modules, heat sinks, fans, and SMPS.