DESIGN & FABRICATION OF A THERMOELECTRIC REFRIGERATION SYSTEM

A report submitted to the Department of Mechanical, Sonargaon University of Bangladesh, in partial fulfillment of the requirements for the award of the degree of Bachelor of Science in mechanical engineering.

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APPROVAL

This is to certify that the project work entitled, "Design & Fabrication of Thermoelectric Refrigeration System" has been carried out by Md Mahfuzur Rahman (ID: ME2202027226), Kishor Mahmud (ID: ME2202027215), Suwaib ibn Sharif (ID: ME2002021008), Uzzal Mondal (ID: ME2202027193) and Joy Dey (ID: ME2202027131) thereby declared that the work presented here is original work done by me and has not been published or submitted elsewhere for the requirement of a degree of Bachelor of Science (B.Sc.) in Mechanical Engineering in the year of 2026 Program in the Department of Mechanical Engineering, Sonargaon University of Bangladesh (SU) has been carried out under by 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 the 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

The Thermoelectric Refrigeration System with Peltier Effect project aims to design and construct a compact and efficient cooling system utilizing the Peltier effect. This solid-state Thermoelectric cooling system is designed to maintain a controlled low temperature for various applications. The core components include a Peltier module, a Switched-Mode Power Supply (SMPS) for power regulation, a water cooling block as a heat sink, a pump motor for efficient heat dissipation, and a temperature sensor with a display for real-time monitoring. The Peltier module, functioning as the cooling element, is powered by the SMPS, which provides stable and adjustable DC power. The Peltier module transfers heat from one side to another, achieving cooling on the cold side and heating on the hot side. A water cooling block enhances heat dissipation from the hot side, while a pump motor circulates water to maintain efficient cooling. A temperature sensor positioned strategically measures the system's temperature, and the data is displayed in real time for monitoring and control.

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CHAPTER 1
INTRODUCTION

1.1 Introduction

The Peltier effect is used in Thermoelectric refrigeration (TEC), which is the direct conversion of electrical energy into heat and cold. Thermoelectric refrigeration has many benefits over traditional compressors, which include small size, no noise, long life, precise temperature control, and no need for refrigerant. Because of these advantages, it has a high application value in refrigeration, electronic device cooling, LED lamp cooling, and medical device temperature control. However, its cooling capacity is limited, the coefficient of performance (COP) is lower than that of compressors, and this obstacle has prompted researchers to pursue new ways to elevate efficiency. Researchers have conducted extensive research to try to improve the cooling performance of Thermoelectric modules. In general, there are two ways to improve Thermoelectric cooling efficiency.

Change the inherent properties of the materials inside the TEC module, such as changing the geometry and length of thermocouples, segmenting P-type and N-type thermocouples, or researching the constituent materials of thermocouples to improve the figure of merit. However, when the TEC is in use, its inherent internal properties cannot be changed, which requires another method to improve its cooling performance. Based on the existing Thermoelectric modules, improve the thermal design and optimization of the Thermoelectric refrigeration system. He et al. stated that improving heat dissipation conditions can improve the cooling performance of Thermoelectric cooling units and the system's COP value.

When optimizing Thermoelectric cooling modules, the hot side heat dissipation conditions should be prioritized. For the heat dissipation of TEC equipment, the most commonly used cooling methods are air cooling, heat pipe cooling, liquid cooling, phase change material cooling, and so on. Liu et al. established five different cooling methods and explored the effects of different cooling methods on the COP of Thermoelectric refrigeration modules through experiments. The better the cooling performance, the higher the average COP of the Thermoelectric device.

Riffat et al designed a phase change material heat sink and found that good heat dissipation performance can increase the refrigeration performance of the entire system. Astrain et al. proposed a phase change siphon principle Thermoelectric cooling module hot side heat dissipation device. Through analytical calculations, computational fluid dynamics simulation, and experimental verification, phase change siphon heat dissipation can increase the refrigeration performance by 32%. Karwa et al. designed a low-thermal-resistance water-cooled heat sink. Through CFD simulation and 3D printing technology, the experimental test results proved that the water-cooled heat sink had a low thermal resistance value, which further improved the refrigeration performance of the Thermoelectric refrigeration module.

Cuce et al. used comprehensive experimental methods to investigate the effect of nano-fluid heat dissipation on the cooling performance of Thermoelectric refrigeration modules and discovered that different types of nano-fluids have better thermal conductivity than pure water. The COP of Thermoelectric cooling is enhanced by enhancing the hot-end's heat dissipation performance. Summarizing the above techniques, researchers are more interested in improving the Thermoelectric refrigeration system's thermal performance than changing the Thermoelectric material's internal structural parameters when it comes to improving the refrigeration performance of Thermoelectric devices. Experiments have shown that high-performance heat sinks can optimize the Thermoelectric refrigeration system's performance, but increase energy consumption.

1.2 Background Study

On the other hand, in the above research, the efficiency of the Thermoelectric system is improved through the design of a new type of heat dissipation system, but the new type of system designed requires additional space and thermal budget. For this reason, plate fined heat sinks are a good choice. Researchers have conducted extensive research on the plate-fin heat sink and further optimized the radiator. For example, the shape of the fins becomes cylindrical, conical, rectangular, trapezoidal, irregular, and arranged irregularly to improve their heat dissipation performance. In this regard, a new type of finned heat sink is designed for use in the heat dissipation of the hot-end of the Thermoelectric refrigeration system. As far as the author knows, this new type of finned radiator has not been studied by previous researchers.

To improve the performance of the Thermoelectric cooler, this study proposes two new types of hot-end heat sinks under the premise that the external dimensions of the hot-end heat sink of the Thermoelectric cooling module remain unchanged. The new heat sink enhances the general system's heat dissipation performance, further improving the Thermoelectric device's refrigeration performance. It also has the advantage of consuming less power and taking up less space. Finally, experiments are conducted to verify the effectiveness of the new heat sink in improving the cooling performance of the Thermoelectric refrigeration system under different working conditions.

1.3 Objective

We have some specific objectives for this project, and they are listed below:

- To Study about Design and Construction of a Thermoelectric Refrigeration System.
- To study the working principle of thermoelectric (Peltier) modules in real conditions
- To develop a low-cost and educational prototype for academic use
- To analyze the cooling effect of the Thermoelectric Refrigeration System.

1.4 Structure of the Project

This Project is organized as follows:

Chapter 1 Introduction: The first chapter contains the statement of the introduction, our background study for the project, objectives of the study, methodology used in the project, and the project outline.

Chapter 2 Literature Review: The chapter two contains our literature review.

Chapter 3 Hardware and Software Analysis: Chapter three describes the theoretical model. Here we mainly discuss hardware and software development of our project, etc.

Chapter 4 Methodology: Here, we mainly discuss the proposed system architecture in detail, including a block diagram, circuit diagram, project working principle, complete project image of our project, etc.

Chapter 5 Results and Discussion: Chapter five deals with the results, advantages, and discussion about our project's advantages and application.

Chapter 6 Conclusion: all about our project conclusion, limitations, and future scope.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

In this section, topics related to the design and Construction of a Thermoelectric Refrigeration System are included. These provide a sampling of problems appropriate for the application of the Thermoelectric Refrigeration System. The references are summarized below.

2.2 Literature Review

Jincan Chena et al.,[1]:- According to non-equilibrium thermodynamics, cycle models of single-stage and two-stage semiconductor Thermoelectric refrigeration were experimentally investigated. By using the three important parameters which governs performance of the Thermoelectric refrigerator, i.e., coefficient of performance (COP), the rate of refrigeration, and the power input, the development of general expressions performances of the two-stage Thermoelectric refrigeration system took place. It was concluded that the performance of a thermoelectric refrigerator depends on the temperature ratio of the heat sink to the cooled space. When this ratio is small, the maximum value of COP of a two-stage Thermoelectric refrigeration system is larger than the COP of a single-stage Thermoelectric refrigeration system; however maximum rate of refrigeration is smaller than that of a single-stage Thermoelectric refrigeration system. Hence, it is convenient to use single stage Thermoelectric refrigerator when the ratio is small. When the temperature ratio is large, two stage Thermoelectric refrigerator is observed to be superior to a single stage by both parameters, i.e. maximum value of COP and the maximum rate of refrigeration.

X.C. Xuan et al., [2]:- In this paper, Two stage Thermoelectric refrigerator was investigated with two design configurations. Two configurations were pyramid style and cuboid style, as shown in the respective figures. In a pyramid-style configuration top side is the coldest as the current is unidirectional. In a cuboid-style configuration, current can be alternated, causing the top and bottom sides to be switched between heating and cooling modes. To obtain optimization methods, other multi-stage designs can be used. The point of maximum cooling capacity and maximum COP were taken into consideration during the investigation for optimization of the two-stage TE coolers. It was concluded that the value lies between 2.5 and 3 for both parameters, which is the optimum limit of the ratio of the number of thermo-electric modules of two stages in a pyramid-style TE cooler, and the optimum limit of the ratio of electric current between stages of cuboid style TE cooler. The maximum temperature difference of the pyramid-style cooler is greater than single stage cooler.

Jun Luo et al., [3]:- Using finite time Thermodynamics theory performance of a Thermoelectric refrigeration system with multiple elements was analyzed. To improve and maximize the cooling load and coefficient of performance (COP), optimization of the ratio of the heat transfer surface area of the high temperature side to the total heat transfer surface area of the heat exchangers was done. The analysis of the number of parameters which affects optimum performance of the Thermoelectric system was done. The parameters were the number of Thermoelectric refrigerating elements, the See back coefficients, internal heat conductance, the heat source temperature, and internal electrical resistance. As well as the analysis of other parameters like the influences of total heat transfer surface area and working electrical current on the optimum performance was done. They concluded that the cooling load and coefficient of performance (COP) of the TE system are greatly influenced by total heat transfer surface area and working electrical current. These results can be used for designing and manufacturing practical Thermoelectric refrigerators.

D. Astrain et al.,[4]:- In this paper, a device using phase change material based on the thermosyphon principle was developed. This device was used and tested as a heat dissipater for the hot side of the TE cooler. Performance of the TE cooler with this device was compared with that of the TE cooler with a conventional heat dissipater made up of fins. It was concluded that with the help of a developed phase-changing device, it is possible to reduce thermal resistance between the hot side of the TE cooler and the atmosphere up to 23.8% at 293 K ambient temperature and 51.4% at 308 K ambient temperature, compared to a commercial finned heat sink. Decrease in thermal resistance ultimately causes heat to dissipate more effectively from the heat sink of the TE cooler, therefore improving the COP of the TE cooler. At the same values of temperatures, it was observed that COP increases by 26% and 35%, respectively.

Yuzhuo Pan, et al, [5]:- The author of this paper designed and analyzed an Irreversible multi-couple Thermoelectric refrigerator, which operates between two reservoirs maintained at constant temperature. The effect of other factors, like external and internal irreversibility of the thermoelectric refrigerator, on performance was also studied. They have specified many important parameters which affects coefficient of performance (COP) of the system. Results obtained from experiments lead to knowledge of information about the performance characteristics of a real multi-couple Thermoelectric refrigerator. This information may be used to manufacture and design a thermoelectric refrigerator that will perform at its optimum level.

Hongxia Xi et al, [6]:- In this paper, Author done survey on solar-based driven Thermo electric technology. A brief history of the development of solar-based driven Thermo electric technology was presented. It's today's status and drawbacks present in current Technologies were reviewed. Applications, future scope, and advantages over conventional technology were also discussed. In this paper, they have discussed two main modes, which are solar based Thermoelectric power generation and refrigeration. The current status of both Technologies was described. Problems related to this technology and their possible solutions were presented. Ultimately, these Technologies with some more development may lead to solve demand of Environment protection and energy conservation.

Suwit Jugsujinda et al, [7]:- In this paper, they have fabricated a thermoelectric refrigerator using a thermoelectric cooler. Thermoelectric refrigerator (25 × 25 × 35 cm3) and Thermoelectric cooler (4 × 4 cm2). This system was applied to 40 W electric power without any cooling fan as a heat dissipater at the heat sink. They have measured the temperature of this system at ten different points. It was concluded that these experiments results into temperature of the cold side of the thermoelectric cooler being decreased from 30°C to -4.2°C for 1 hour and decreased to -7.4°C for 24 hours, with the heat plate temperature being 50 °C. The temperature of the cold side of the thermoelectric refrigerator decreased from 30°C to 20°C for 1 hour and decreased further over 24 hours. 3 and 2.5 are the maximum values of the coefficient of performance (COP) of the thermoelectric cooler and Thermoelectric refrigerator, respectively.

S.A.Omer et al, [8]:- This paper presents some results of a thermoelectric refrigeration system using phase change materials (PCM) integrated with thermosyphones. They investigated two models of Thermoelectric refrigeration systems, one with conventional finned devices as a heat dissipater and the other with phase change material (PCM) as a heat dissipater. After the results, they have concluded that the coefficient of performance (COP) and effectiveness of the Thermoelectric refrigeration system with Phase Change Material (PCM) is higher than conventional one. They have also compared the thermoelectric refrigeration system of two kinds, one is using phase change materials (PCM) without a thermal diode and the other integrated with a thermal diode (Thermosyphones). Results show that thermosyphones used prevent leakage of heat during power off. Overall, they have concluded system can work with the help of renewable energies like solar energy, producing electricity. It is suited for medicine and food storage.

2.3 Summary

This project involves the creation of an efficient Thermoelectric refrigeration system using Peltier modules, a Switched-Mode Power Supply (SMPS), a water cooling block, a pump motor, and a temperature sensor with a display. The Peltier modules are powered by the SMPS to create a temperature difference, with one side getting hot and the other cold. A water cooling block and pump motor efficiently dissipate the heat generated by the hot side of the Peltier modules. A temperature sensor continuously monitors the target space or device, and a display provides real-time temperature feedback for precise control. This integrated system offers controlled and stable cooling, making it suitable for various applications such as electronics cooling, beverage chilling, or temperature-sensitive devices.

CHAPTER 3

HARDWARE AND SOFTWARE ANALYSIS

3.1 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.

Figure 3.1: SMPS

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. 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.

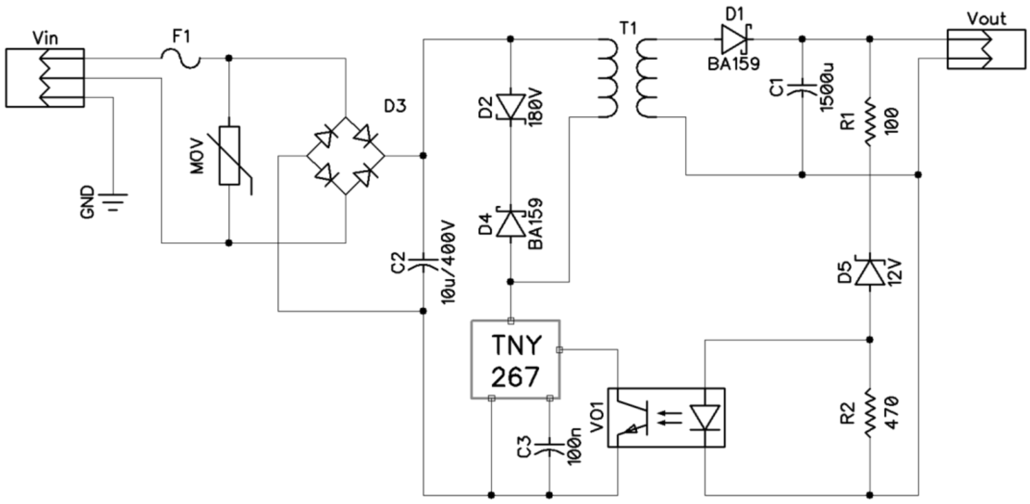


Figure 3.2: Basic working concept of an SMPS

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 on. 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 pinouts, except for some industries, such as PC and compact PCI, in general, they are not standardized and are left up to the manufacturer.

There are different circuit configurations known as topologies, each having unique characteristics, advantages, and modes of operation, which determine how the input power is transferred to the output. Most of the commonly used topologies, such as flyback, push-pull, half-bridge, and full-bridge, consist of a transformer to provide isolation, voltage scaling, and multiple output voltages. The non-isolated configurations do not have a transformer, and the power conversion is provided by the inductive energy transfer.

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.

Switch Mode Power Supply

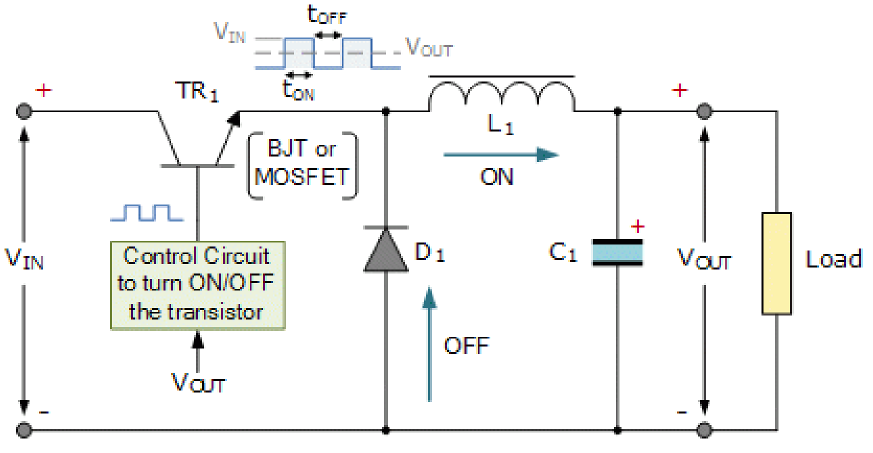


Figure 3.3: SMPS Diagram

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 as a zener diode and a resistor, or transistors and even op-amps. The most popular linear and fixed output voltage regulator types are by far the 78… positive output voltage series, and the 79… negative output voltage series. 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. There are even variable voltage linear regulators available as well, providing an output voltage that is continually variable from just above zero to a few volts below its maximum voltage output. Most d.c. Power supplies comprise a large and heavy step-down mains transformer, diode rectification, either full-wave or half-wave, and 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 stabilizer circuit, either linear or switching, to ensure the correct regulation of the power supply's output voltage under varying load conditions. Then a typical d.c. Power supply would look something like this:

Typical DC Power Supply

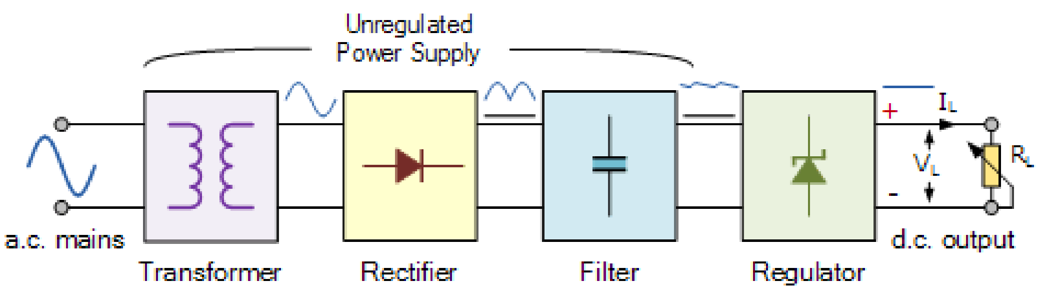


Figure 3.4: DC Power Supply Way

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, an output capacitor, and some feedback resistors to set the output voltage.

3.2 Peltier

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

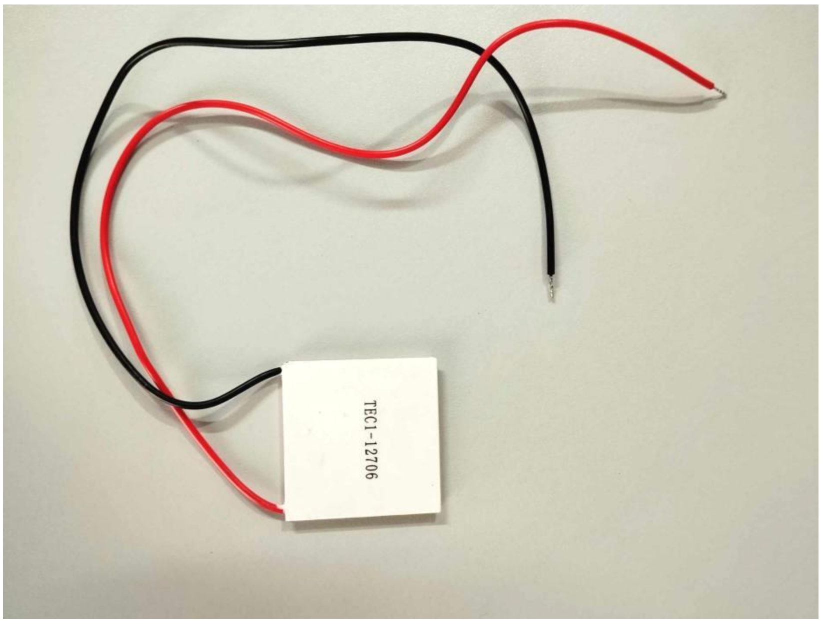
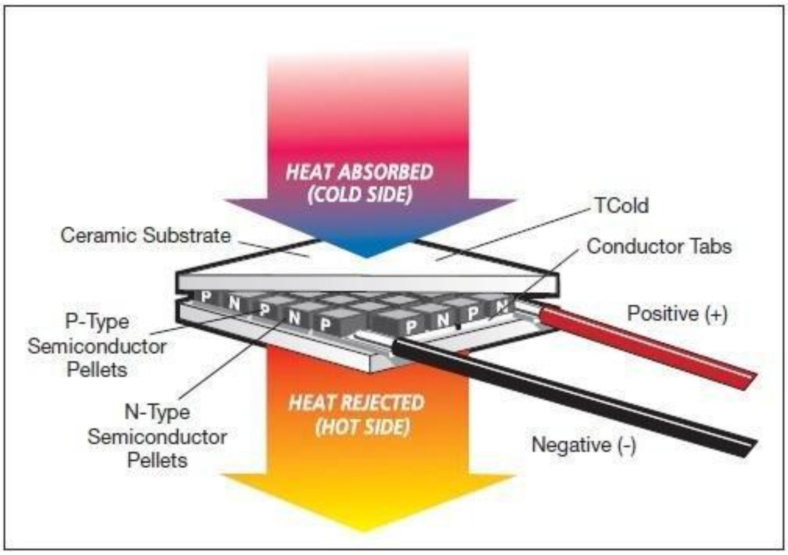


Figure 3.5: Peltier Cooler

The TEC1-12706 40x40mm Thermoelectric Cooler 0~6A Peltier Module is the simple application of the Peltier Thermoelectric Effect. Thermoelectric coolers, also known as TEC or Peltier modules, 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.



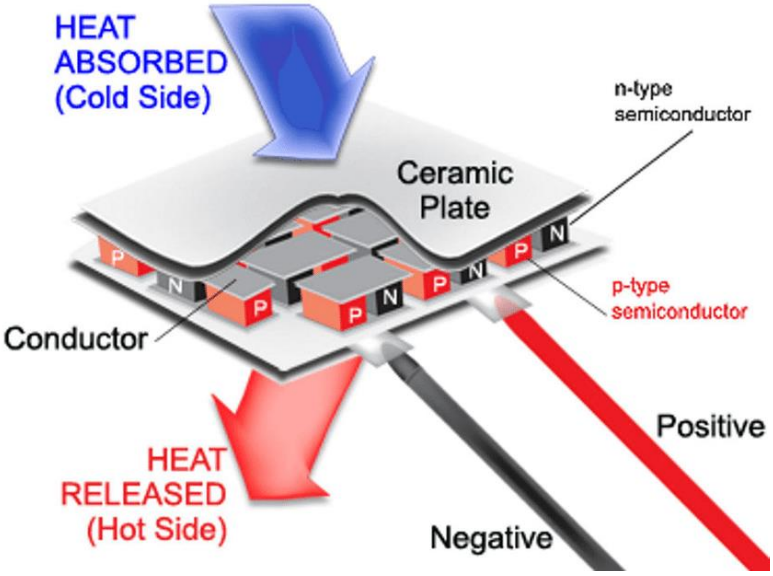


Figure 3.6: Construction of Peltier

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 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, and 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 that 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 a hot side. They are widely used in industrial areas, for example, computer CPUs, 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 and the cool side and vice versa, just by reversing the polarity of the supply.
- Quality-tested cooling cells.
- Solid state, vibration-free, noise-free.
- Simple to install and operate.
- Should be used with a heat sink.

3.3 Aluminum Water Cooling Block Heat Sink

A heat sink (also commonly spelled heat sink) is a passive heat exchanger that transfers the heat generated by an electronic or 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 3.7: 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, and Thermoelectric Cooler
- Size:80 (D) x 40 (W) x 12 (H) MM

3.4 Plastic Pipe

Plastic pipe is a tubular section, or hollow cylinder, made of plastic. It is usually, but not necessarily, of circular cross-section, used mainly to convey substances that can flow, liquids and gases (fluids), slurries, powders, and masses of small solids. It can also be used for structural applications; hollow pipes are far stiffer per unit weight than solid members.

Product Description

- Product Name: clear PVC tubing
- Material: PVC
- Size: from 1/8inch (ID 3mm) to 2 inches (ID 50mm)
- Wall Thickness: From 1mm to 4mm
- Color : clear / blue / red / yellow / black / green / orange, etc.
- Working Pressure : From 2bar (30psi) to 4bar (60psi)
- Temperature Range: From -5 to 65 degrees C.

Application

Suitable for low pressure transfer of various Fluids and air, such as fuel, water, light chemicals, oxygen, gas for watering systems, peristaltic pumps, electrical and thermal insulation, analytical systems in plant equipment, laboratories, watering system and many other low-pressure industry applications.


Figure 3.8: Plastic Pipe

3.5 Digital Thermometer

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 temperature change.

Figure 3.9: Digital Temperature Sensor

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 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 (the first widely used, accurate, practical thermometer) and the Fahrenheit scale (the first standardized temperature scale to be widely used).

Figure 3.10: Digital Temperature Sensor Display

Specification

- Temperature range: -50~ +110°C
- Using environment: Temperature: -5~ +50°C Humidity: 5%~80%
- Accuracy: ±1°C
- Size: 47*28*14mm
- Weight: 22g
- Color: Black and white

3.6 High Speed Pump

Figure 3.11: High Speed Pump

Feature

- Pump Operating Voltage: 12V
- Power: 8W Max
- Working Pressure: 160Psi (10.5 Bar) Cutoff
- Cutoff Automatic Switch
- Flow (MAX): 10L/min
- Pressure Adjustable Copper Head Water Spray
- Water Pressure Limit: Adjustable
- Sprayers Size: 20cm
- Spray Distance: 9 m
- Thread Diameter: 1.5cm
- Main Material: Copper, Plastic
- Power supply Voltage: 12V DC
- Power supply Current: 5A

3.7 Easy EDA Software

Easy EDA is a web-based EDA tool suite that enables hardware engineers to design, simulate, share publicly and privately, and discuss schematics, simulations, and printed circuit boards. Other features include the creation of a bill of materials, Gerber files, pick and place files, and documentary outputs in PDF, PNG, and SVG formats. Easy EDA allows the creation and editing of schematic diagrams, SPICE simulation of mixed analogue and digital circuits, and the creation and editing of printed circuit board layouts and, optionally, the manufacture of printed circuit boards.

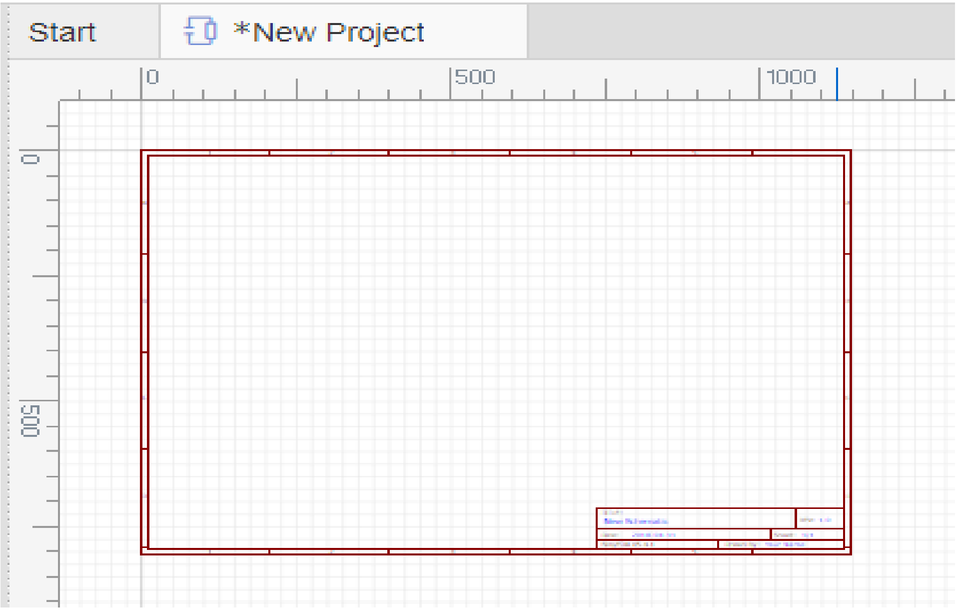


Figure 3.12: Easy EDA Software Interface

Subscription-free membership is offered to the public, plus a limited number of private projects. The number of private projects can be increased by contributing high-quality public projects, schematic symbols, and PCB footprints, and/or by paying a monthly subscription. Registered users can download Gerber files from the tool free of charge, but for a fee, Easy EDA offers a PCB fabrication service. This service is also able to accept Gerber file inputs from third-party tools.

CHAPTER 4
METHODOLOGY

4.1 Our methodologies for the project

Our methodologies for the project:

- Creating an idea for **a Thermoelectric Refrigeration System**. And designing a block diagram & circuit diagram to know which components we need to construct it.
- Collecting all the components of our system.
- Setting up all the components on a PCB board & then soldering. Lastly, assembling all the blocks on a board and running the system & for checking purposes.

4.2 Working Step Chart

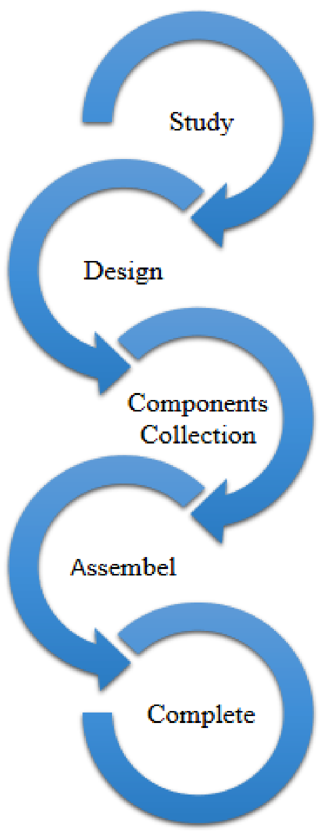


Figure 4.1: Working Step Chart

4.3 Block Diagram

The way the whole project works is that we take 220V AC power from the supply voltage and then feed it to a Switch Mode Power Supply, or in short SMPS module. The SMPS simply converts the 220V AC to a pure DC of 12V 10Amp. We will use this 12V DC output from the SMPS to run our controller, motor, and other units.

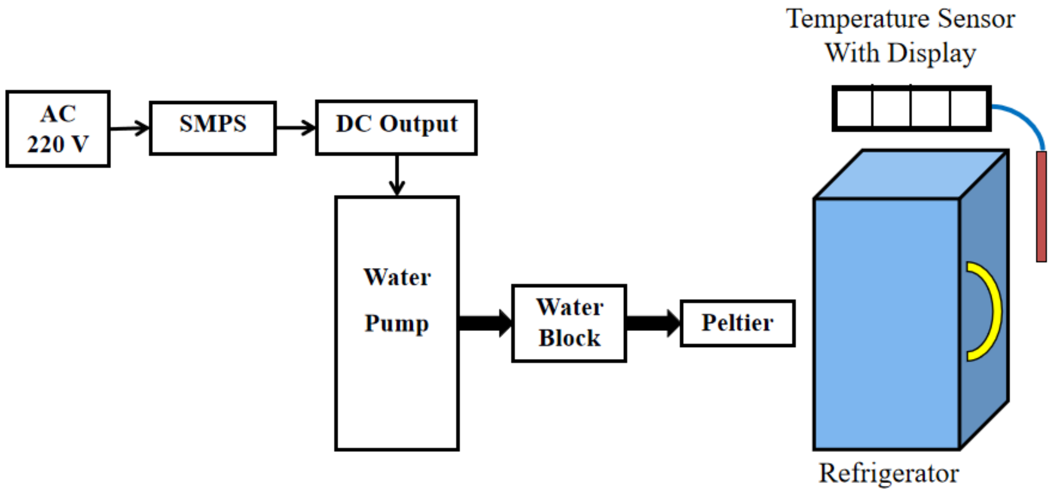


Figure 4.2: Block Diagram of Our System

4.4 Schematic Diagram

The schematic diagram here represents the electrical circuit and the components of the project. Here we have used standardized symbols and lines.

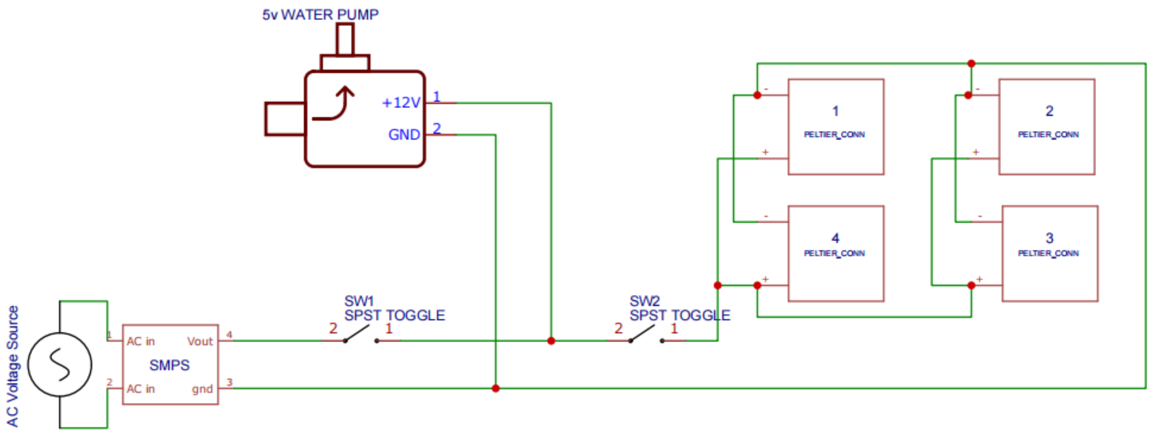


Figure 4.3: Schematic Diagram of the Project

4.5 Working Principle

Our main power supply for this system is AC 220 volts. This power is connected to the SMPS. The main function of SMPS is to convert AC to DC. Since all our instruments in this project are DC, we need DC power. This SMPS will supply a fixed 12V DC, 10Amp in this system. Here we use a Peltier, a water block, a temperature sensor, an aluminium sheet, etc. Firstly, we turn on the power button of the system. The motor will rotate the tank of water. After that, water goes in water block, then the water passes through the peltier, and the system produces cool inside this system. This is the main function of our system.

4.6 Our Final System View

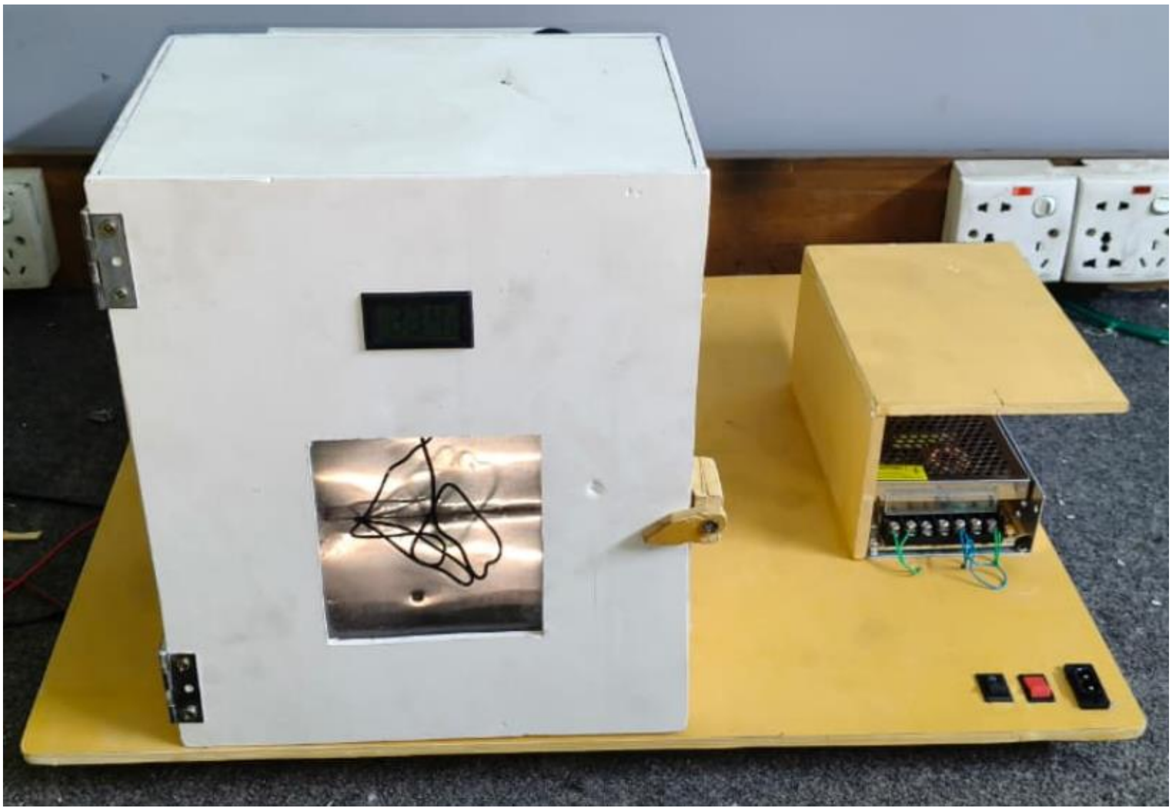


Figure 4.4: Our Final System Overview (Front View)

4.7 Cost Analysis

Sl.no	Particulars	Specification	Qty.	Unit Price (Taka)	Total Price (Taka)
1	SMPS	12V	1	1290	1300
2	Peltier	TEC-12706	4	500	2000
3	Water Cooling Block Heat Sink	40*80*12mm	2	550	1100
4	Pump Motor	DC 12V	1	400	400
5	Digital Temperature Meter		1	250	250
6	Others				1850
				Total	6900/=

4.8 Math Equation

We Know

$Q_C = MC_P \Delta T$
$P_{in} = V.I$

Where,

V =Volatge

I = Current

We Know

$$Cop = \frac{Q_c}{P_{in} \times t}$$

Where,

Q_c = Cooling Capacity

P_{in} = input Eletric Power

CHAPTER 5
RESULT AND DISCUSSION

5.1 Project Outcome

After finally completing this project, we ran it & we observed the output of this project. We can see that it is working well as expected. After making our project, we observe it very carefully. It works as we desire. Our project gives output perfectly, and all the equipment are work perfectly. We check how much it works, and we get perfect output from this project.

- The Peltier module effectively produced a noticeable temperature difference between the hot and cold sides
- Continuous water circulation through the cooling block improved heat dissipation from the hot side
- The internal chamber temperature decreased steadily after system activation
- The temperature sensor provided accurate real-time temperature monitoring on the display
- Aluminum heat spreading enhanced overall thermal performance
- The system operated without noise and mechanical vibration
- Cooling performance was stable under continuous operation
- The project proved the feasibility of thermoelectric cooling for small-scale refrigeration applications

5.2 Performance Experimental Data

S.L	Parameter	Value
1.	Supply voltage, V	12V
2.	Current per Peltier	2A
3.	Number of Peltier	4
4.	Total current	10A
5.	Total input power, $P_{in} =$ V.I	10*12=120W
6.	Initial Temp (cold side)	25°C
7.	Final temp (cold side)	8°C
8.	Temperature drop ΔT	17°C
9.	Mass of Water	0.5 kg
10.	Total Time	15 Min. = .25 Hour

We Know

Cooling Capacity Q_C $= MC_P \Delta T$

$= 0.5 \times 4.186 \times 17$

$= 35.581$ Kj

$= 9.88$ Wh

Where,

Qc = Cooling Capacity

Pin = input Electric Power

$$\text{Cop} = \frac{Q_c}{P_{in} \times t}$$

$$= \frac{9.88}{120 \times .25}$$

$= 0.32$

When, we use a Fan (10w), we get ⟶

S.L	Parameter	Value
1.	Supply voltage, V	12V
2.	Current per Peltier	2A
3.	Number of Peltier	4
4.	Total current	10A
5.	Total input power, P_{in} = V.I+10w	(10×12) + 10W = 130W
6.	Initial Temp (cold side)	25°C
7.	Final temp (cold side)	4°C
8.	Temperature drop ΔT	21°C
9.	Mass of Water	0.5 kg
10.	Total Time	15 Min. = .25 Hour

We Know

Cooling Capacity Q_C = $MC_P \Delta T$

= 0.5 ×4.186×21

= 43.953 Kj

= 12.21 Wh

Where,

Qc = Cooling Capacity

Pin = input Electric Power

$$\text{Cop} = \frac{Q_c}{P_{in} \times t}$$

$$= \frac{12.21}{130 \times 0.25}$$

= 0.37

Again we use a Fan (10w), we get ⟶

S.L	Parameter	Value
1.	Supply voltage, V	12V
2.	Current per Peltier	2A
3.	Number of Peltier	4
4.	Total current	10A
5.	Total input power, $P_{in} =$ V.I+10w	$(10 \times 12) + 10W = 130W$
6.	Initial Temp (cold side)	25°C
7.	Final temp (cold side)	2°C
8.	Temperature drop ΔT	23°C
9.	Mass of Water	1 kg
10.	Total Time	40 Min. = .66 Hour

We Know

Cooling Capacity $Q_C = MC_P \Delta T$

$= 1 \times 4.186 \times 23$

$= 96.278$ Kj

$= 26.743$ Wh

Where,

Qc = Cooling Capacity

Pin = input Electric Power

$$\text{Cop} = \frac{Q_c}{P_{in} \times t}$$

$$= \frac{26.743}{130 \times .66}$$

$= 0.31$

5.3 Discussion

In this experiment, a thermoelectric refrigeration system using Peltier modules was studied to analyze its cooling performance. From the results, the coefficient of performance (COP) without a fan was found to be about 0.32, which is reasonable for a thermoelectric cooling system. When a fan was added to improve heat dissipation at the hot side, the COP increased to approximately 0.37. This clearly indicates that effective heat rejection plays a vital role in enhancing the performance of thermoelectric systems.

However, when a larger mass of water (1 kg) was cooled over a longer period, the COP decreased to about 0.31. This reduction occurred due to increased heat losses to the surroundings, longer operating time, and reduced efficiency of Peltier modules at higher temperature differences.

Overall, thermoelectric refrigeration systems are compact, environmentally friendly, and noise-free, but their efficiency is relatively low compared to conventional refrigeration systems. With better heat sinks, insulation, and airflow management, their performance can be significantly improved.

5.4 Advantage

There are many advantages of our project because of its accuracy. Some of the advantages are pointed out below:

- Creates a comfortable and productive work environment.
- Improve the inside refrigeration Air Quality.
- Energy-efficient cooling solution.
- Environmentally friendly.
- Less skilled technicians are sufficient to operate.
- Installation is simplified greatly.
- Simple construction
- Silent operation due to the absence of moving compressors
- Ease of operation.

5.5 Application

Some of the application areas of the project have been pointed out below:

- Small-scale refrigeration for food, medicine, or lab samples
- Temperature-controlled storage for chemical or biological samples
- Portable mini-fridges and beverage coolers

5.6 Limitations

Although the project has many advantages, it also has some limitations, which are given below:

- Limited cooling capacity compared to conventional refrigeration systems
- This project can now be used only for small-scale purposes

CHAPTER 6
CONCLUSION

6.1 Conclusion

The Thermoelectric Refrigeration System based on the Peltier effect successfully demonstrates a compact, efficient, and eco-friendly cooling solution for small-scale applications. By utilizing the Peltier module, the system effectively transfers heat from the cold side to the hot side, achieving controlled cooling without the need for compressors or refrigerants. The integration of a Switched-Mode Power Supply (SMPS) ensures stable and adjustable DC power, which is essential for the reliable operation of all components. The water cooling block, combined with a pump motor, enhances heat dissipation from the hot side, preventing overheating and maintaining consistent performance. Real-time temperature monitoring through the sensor and display allows precise observation of the system's efficiency and stability.

This project highlights the advantages of solid-state cooling, including silent operation, low maintenance, and environmental safety. Although the system has limitations in cooling capacity and efficiency under extended operation, it proves highly effective for educational, laboratory, and small refrigeration purposes. Overall, the project demonstrates the practical application of thermoelectric technology and provides a foundation for future improvements in portable, energy-efficient, and sustainable cooling solutions.

6.2 Future Scope

We are thinking about adding many features to our project in the future to get more desirable outcomes. Some of the steps that we are thinking about taking are given below:

- Integration with solar or renewable energy sources for off-grid cooling
- In the future, we will add coolant liquid.
- In the future, we are thinking about adding more features to the system, such as an automatic heat sensor, deep fridge system.
- In the future, we are thinking about making the system IoT-enabled so that the whole system can be observed or ON/Off.

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