International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

To Study the Time-Temperature Performance of Thermoelectric Refrigeration Using the Peltier Effect

Arshiya Tabassum

Guest Lecturer, Department of Physics, Adikavi Sri Maharshi Valmiki University, Raichur. Karnataka. India.

Abstract:
Thermoelectric cooling uses the Peltier effect to create a heat flux between the junctions of two different types of materials. This effect is commonly used in camping and portable coolers and for cooling electronic components and small instruments. Applying a DC voltage difference across the thermoelectric module, an electric current will pass through the module and heat will be absorbed from one side and released at the opposite side. One module face, therefore, will be cooled while the opposite face simultaneously is heated. On the other hand, maintaining a temperature difference between the two junctions of the module, a voltage difference will be generated across the module and an electrical power is delivered. The main objective of this study is to design and fabrication on "portable thermoelectric refrigerator" for the people (e.g. deserts) living in remote areas where electricity is still not available. The refrigerator could be used to store perishable items and facilitate the transportation of medications as well as biological material that must be stored at low temperature to maintain effectiveness. The design of the thermoelectric refrigerator is based on the principles of a thermoelectric module (i.e. peltier effect) to create a hot side and cold side. The cold side of the thermoelectric module is utilized for refrigeration purposes; provide cooling to the refrigerator space. On the other hand, the heat from the hot side of the module is rejected to ambient surroundings by using heat sinks and fans.

Keyword: Thermoelectric cooling, Portable thermoelectric refrigerator, Peltier effect.

1. Introduction:

In recent years, with the increasing awareness towards environmental degradation caused by CFCs and HCFCs from refrigerants in conventional refrigeration systems, it has become a subject of due concern. Besides, rural areas won't have to rely as much on power from the grid for their refrigeration and cooling needs, by using the battery to power the, **Thermoelectric refrigeration system**. Also, in situations where efficiency is a less important issue than small size, low weight and high reliability, thermoelectric refrigeration systems would be the preferred choice. Researchers are continuously striving towards the development of eco-friendly refrigeration technologies like thermoelectric, adsorption, magnetic and thermo acoustic refrigeration. Thermoelectric cooling uses the Peltier effect to create a heat flux between the junctions of two different types of materials. This effect is commonly used in camping and portable coolers and for cooling electronic components and small instruments. Mechanism of applying a DC voltage difference across the thermoelectric module, an electric current will pass through the module and heat will be absorbed from one side and released at the opposite side. One module face, therefore, will be cooled while the opposite face simultaneously is heated. On the other hand, maintaining a temperature difference between the two junctions of the module, a voltage difference will be generated across the module and an electrical power is delivered.

Thermoelectric Effects: The thermoelectric effect is the direct conversion of temperature differences to electric voltage and vice-versa. Moreover, Thermoelectric device creates a voltage when there is a different temperature on each side. Conversely, when a voltage is applied to it, it creates a temperature difference. An applied temperature gradient causes charge carriers in the material to diffuse from the hot side to the cold side**(Ref),**Correspond to classical gas that expands when heated. Therefore, The inducing a thermal current and their effect revealed. So far, "thermoelectric effect" encompasses three separately identified effects: Seebeck effect, Peltier effect and Thomson effect. When thermal heat generated whenever a voltage is applied across a resistive material is related, Though it is not generally termed a thermoelectric effect. The **Peltier–Seebeck** and **Thomson** effects are thermodynamically reversible whereas Joule heating is not.

2. Review of Literature:

1. Xi Hongxia, Lou Lingai and Fraisse Gilles, 2007, Three different materials were explored for the construction of the outer casing and frame of the device. These were aluminum, stainless steel and Hips. High impact polystyrene is desirable as it has a low thermal conductivity. It makes the device very light and portable while maintaining rigidity. It is readily available and reasonably priced. It is easy to work with it as it is easy to cut and drill Hips sheets. The outer casing and container would be made by first making a mold and applying a cloth coated with resin.
2. Hamidreza Najafi et.al 2013, they designed this project is to developed and simulated via MATLAB in order to determine the temperatures within the system. And they controlling the temperature of the photovoltaic cell and keep it under a specific limit for different conditions.
3. Attar, 2015, The Seebeck Effect- When there is a temperature difference in a thermoelectric material, an electric current is created due to movement of holes and electrons in the semiconductor materials. The effect that causes this behavior is called the Seebeck Effect.
4. V. Chaudari et.al 2018, they designed a refrigerator upholds a temperature above the freezing point of water. An appropriate temperature range for consumable food storing is between 3 to 5 °C (37 to 41°F). Currently, electricity is used to power refrigerators as a continuous source of energy.
5. G.Lavanya et.al designed the implementation of photo voltaic driven cooling and heating system. Refrigerator jacket works according to the atmospheric conditions. If the atmosphere is cooler than the required condition, then it gives the amount of warmness to the human body, without causing any side effects and vice versa. It entirely depends upon the principle of "Peltier effect".

3. This main objectives of this paper is-

Henceforth, the major challenges and solutions need to solve therefore, the present study entitled on **Time Temperature Performance study of Thermoelectric refrigeration using the Peltier effect. Further,** interest of the research required. Therefore the following objectives as follows

1. **Efficient Heat Transfer:**

- Utilize the Peltier effect to transfer heat from one side of a thermoelectric module to the other, thereby creating a temperature difference.

2. **Environmentally Friendly Operation:**
- Avoid the use of harmful refrigerants (like **CFCs or HFCs**) that are common in traditional vapor-compression systems.
3. **Compact and Lightweight Design:**
- Enable cooling solutions in applications where space and weight are critical, such as portable coolers, electronics, or medical devices.
4. **Precise Temperature Control:**
- Offer accurate and rapid control of temperature for sensitive applications (e.g., scientific instruments, laser systems).
5. **Low Maintenance and High Reliability:**
- Provide solid-state operation with no moving parts, leading to silent operation, minimal wear and tear, and longer lifespan.
6. **Reversible Operation:**
- Easily switch between cooling and heating by reversing the polarity of the electric current.
7. **Scalability and Integration:**
- Enable modular and scalable designs that can be integrated into various products or systems.

4. Methodology:

In this project we are used methods of working on time-temperature performance study of Thermoelectric refrigeration using peltier effect, it covers both hardware and software aspects.
- Here, Peltier module converts electric energy into a temperature gradient using Peltier effect, heat sink and cooling fan dissipates heat from hot side to maintain thermal balance, here cold side plate absorbs cooling effect for refrigeration.

Software Implementation:
- Here, microcontroller reads temperature data via analog/digital input, it controls relay to turn Peltier ON/OFF, and we set temperature threshold(e.g., 6 degree celcius).LCD is used for real time temperature display.

System Components Overview:

Component	Function
Peltier Module (TEC)	Creates cooling effect using electricity (Peltier effect).
Microcontroller	Brain of the system (e.g., Arduino, PIC, STM32, etc.).
Relay	Acts as an electrical switch to turn TEC module ON/OFF.
Digital Thermometer	Measures the temperature (e.g., DS18B20 sensor).
LCD	Displays current temperature and status.

Component	Function
Power Supply	Powers the microcontroller, TEC, and other components.


TEC-12706


Relay Module


Heat Sink


Digital Thermometer


Cooling Fan


Bread board


I2C LCD Display

ARDUINO UNO


Power supply

A relay is essentially an electrically operated switch. It uses a small electrical current to control a much larger electrical current. This allows one circuit to turn another circuit on or off, even if they're at completely different voltage levels.

Power Pins:
GND is the common ground connection.
VCC is the power supply pin. You connect this to the 5V pin on your Arduino.

Control Pin:
IN pin is the control input for the relay. One important thing to know is that the input is active-LOW. This means when you set the pin to LOW (0V), it turns the relay ON. When you set it to HIGH (5V), it turns the relay OFF.

Output Terminals:
COM is the common terminal. Connect one side of the device you want to control to this pin.
NC (Normally Closed) is connected to COM when the relay is deactivated. Use this if you want your device to be ON by default and OFF when the relay activates.
NO (Normally Open) is disconnected from COM when the relay is deactivated. Use this if you want your device to be OFF by default and ON only when the relay activates
.Wiring a One-Channel Relay Module to an Arduino
Now that we understand how the relay module works, it's time to put it to use! Let's connect it to an Arduino and use it to control a lamp.

Basic Connections:
First, let's connect the relay module to the Arduino:
Connect the VCC pin on the relay module to the 5V pin on your Arduino
Connect the GND pin to the Arduino's GND pin
Connect the IN pin on the relay module to the digital pin 6 on the Arduino

Connecting the Lamp:
Now we'll connect the relay module to the AC-powered lamp. Before you begin, make absolutely sure the lamp is unplugged and the power source is switched off! This is extremely important for your safety.

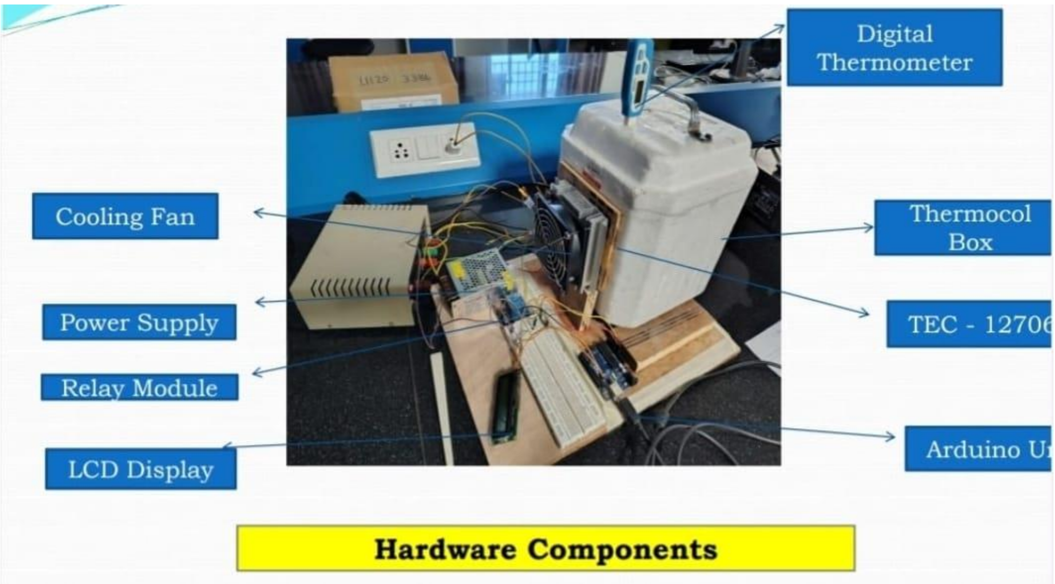
Follow these steps:
Carefully cut the live wire of the lamp's power cord Take the end of the wire coming from the wall outlet and connect it to the COM (Common) terminal on the relay
Connect the other end of the cut wire (the one going to the lamp) to one of the following terminals:
NO (Normally Open) terminal: Lamp will be OFF by default and turn ON when the relay is activated
NC (Normally Closed) terminal: Lamp will be ON by default and turn OFF when the relay is activated
For this project, we want the lamp to be off until we turn it on, so connect one wire to COM and the other to NO.

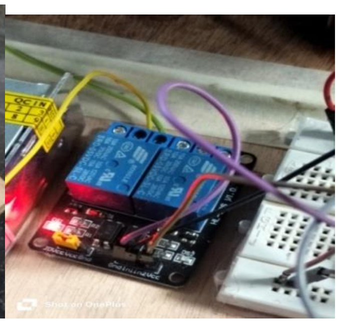
The following table lists the pin connections:

Relay Module	Arduino
VCC	5V
GND	GND
IN	6

5. Results and Discussion:

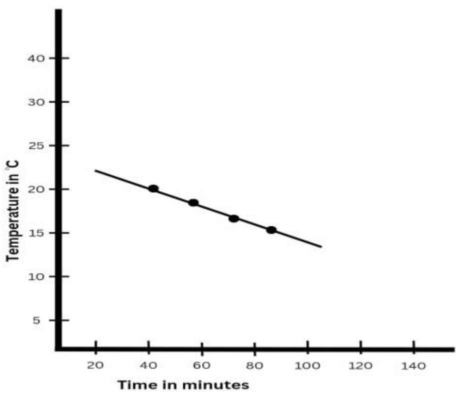
The system is built around an Arduino Uno microcontroller, which serves as the central processing unit, coordinating the operation of a thermoelectric cooling module and various sensors. The cooling is achieved using a Peltier module (TEC1-12706)**,** which transfers heat from the cold side to the hot side when powered, allowing precise temperature control within a small chamber. The hot side of the module is equipped with a heat sink and fan to efficiently dissipate heat into the environment, while the cold side absorbs heat from the internal space. A temperature sensor**,** such as an LM35 or DS18B20, continuously monitors the internal temperature, providing real-time data to the microcontroller. The Arduino processes the sensor data, applies necessary calibrations, and controls the cooling operation by switching the Peltier module on or off through a relay. A 5–12V power supply powers the system, delivering sufficient energy to both the microcontroller and the thermoelectric cooler. System information, including current temperature and operational status, is displayed on an I2C LCD, which also allows for real-time monitoring of environmental parameters such as humidity, wind speed, rainfall, air quality, and light intensity. The software is developed in Embedded C using the Arduino IDE**,** ensuring seamless integration of sensors, cooling control, and display output. The modular design of the system allows for easy addition of new sensors or upgrades in the future, making it versatile for a range of environmental monitoring and cooling applications. Overall, the system provides reliable, real-time temperature control and data collection while maintaining user-friendly display and operational efficiency.





Initial temperature	Set point temperature	Time taken to reach set point	Time taken for temp reduction in the refrigerator from the set point
1) 28.5^0 C	20^0C	45 minutes	5 minutes
	19^0C	60 minutes	6 minutes
	18^0C	75 minutes	8 minutes
	17^0C	87 minutes	11 minutes

Temperature v/s Time Graph



Our Project, put forth an effort to develop the refrigeration system using thermoelectric Peltier module in which the use can be able to maintain as well as control the Time and TEC module temperature in the refrigerator box.

The thermoelectric refrigerator successfully reduced the internal temperature from **28.50°C** to **20.0°C** and **19.0°C** respectively.

The system took:

45 minutes to cool to **20.0°C**
60 minutes to cool to **19.0°C**
75 minutes to cool to **18.0°C**
87 minutes to cool to **17.0°C**

After reaching the set point, the refrigerator continued to reduce the temperature by **1°C** in **5 minutes, 6 minutes, 8 minutes and 11 minutes** in the above cases.

And graphically representation of the thermo electric cooler with temperature v/s time graph gives the information about how we change the set point temperature with respect to time it will shows that when the temperature decreases the time will be increases

6. Conclusion:

Reviewing all the concerned Research Papers and Articles it can be thus concluded that by selecting the appropriate modules, sensor, controller and components one can precede to actual fabricate an eco-friendly less power consuming Thermo electric Refrigerator.

Efficiency Declines with Lower Set Points:

The time required to reach **lower temperatures increases** as the cooling gradient becomes smaller. This is typical for Peltier-based systems where the cooling rate slows near the module's minimum effective temperature range.

Consistent Cooling Performance After Set Point:

The **time taken to reduce temperature by an additional 1°C** after reaching the set point it will be change (**5 minutes,6,8 and 11 minutes**), indicating there is a changing in sub-cooling capability and effective microcontroller regulation.

Suitability:

The system is **suitable for controlled cooling** applications where moderate cooling and stable temperature maintenance are required, such as vaccine storage, portable cooling, or electronics cooling.

7. Applications:

1. High reliability and minimal mechanical wear.
2. No use of harmful refrigerants (e.g., CFCs or HFCs).
3. Small form factor.
4. Ideal for portable or space-constrained applications like mini-fridges, coolers, or electronics.
5. Can finely adjust temperature using electronic control.
6. Can act as both a cooler and a heater by reversing the current.
7. Unlike conventional refrigeration systems that use refrigerants like CFCs or HFCs, Peltier coolers are environmentally benign.

References:

1. Attar (2015). "Studying the Optimum Design of Automotive Thermoelectric Air Conditioning," Kalamazoo.
2. G. Lavanya1, S. Venkanteshwarlu2, A. Nagaraju3, G. Prasanthi4 (29 JAN 2013). “Cooling and Heating of Refrigerator Jacket by Using Peltier Effect”.
3. Hamidreza Najafi, Keith A Woodbury “ Optimization of a cooling system based on peltier effect for photovoltoic cell”.
4. V Chaudhari, M.Kulkarni, S. Sakpal, A. Ubale and A Sangale(2018). “ Eco-Friendly Refrigerator using Peltier Device”.
5. Xi Hongxia, Lou Lingai and Fraisse Gilles (2007). ”Development and applications of solar-based thermoelectric technologies”, Renewable and Sustainable Energy Reviews,11(5):923-936.