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Design, Development, and Performance Analysis of an Innovative Mini Portable Cooling Cup

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Abstract

This study aims to design, develop, and evaluate the performance of a portable micro-cooling cup that utilizes a Peltier thermoelectric module for efficient beverage cooling. This innovative cooling cup presents a practical, low-energy alternative for maintaining cool drinks without the need for refrigeration systems. The Peltier module operates by creating a temperature differential when an electric current is applied, effectively reducing the beverage temperature within minutes. Key components of the cooling cup include the Peltier module, a heat sink, a fan to enhance heat dissipation, and a rechargeable power source for portability.Experimental results demonstrate that the cooling cup can lower the liquid temperature by as much as 15°C from its initial temperature for up to 10 minutes under optimal conditions. This technology is particularly advantageous for various scenarios such as outdoor activities and travel, where access to traditional cooling appliances is limited. The study also explores energy efficiency, durability, and user-friendliness, highlighting the potential of thermoelectric technology in small-scale, portable cooling systems. This innovative portable cooling solution has significant potential for both personal and commercial applications, addressing the increasing demand for convenient beverage chilling on the go.

Keywords
Peltier effect, Temperature, ergonomic design, cooling technology.

1. Introduction
In today's fast-paced and convenience-driven society, innovation is always growing to satisfy the needs of modern life. Personal accessories that improve comfort and ease in daily activities are an area where innovation is desired. As global temperatures rise and the importance of fitness and health increases, it is imperative to stay hydrated. But it might be difficult to keep liquids cold all day, especially when you're on the run. With time, conventional methods like adding ice or utilizing insulated bottles may become cumbersome, uncomfortable, or ineffectual. For those who like to keep their beverages delectably cold wherever they are, the Mini Portable Cooling Cup offers a creative alternative. In the mini portable cooling cup Peltier device and semiconductor are used in thermoelectric cooling technology. This technique lowers the temperature quickly. The design of the Mini Portable Cooling Cup is tasteful, small, and visually appealing. It is also lightweight, making it convenient to carry. The cup is constructed from durable, high-quality and eco-friendly materials. The cup is made of stainless steel, and the exterior shell is long-lasting and safe. The interior parts of the cup are tightly sealed, and the cooling element is situated at the bottom of this product. This guarantees the cooling cup's user-friendliness and safety. The ease of use of the Mini Portable Cooling Cup is one of its unique features. By offering a convenient and practical way to keep drinks cold anywhere, it enhances the

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user experience. It is a great item for anyone who likes innovation, sustainability, and convenience because of its small size, active cooling technology and environmentally friendly design. A great option for a range of activities is the Mini Portable Cooling Cup.

The Peltier technologies, including vapor compression and vapor absorption refrigeration, are harmful to the environment. Numerous studies are being conducted to identify alternative refrigeration technologies to mitigate environmental contamination. Thermoelectric cooling employs the Peltier effect to provide a thermal gradient between the connections of two dissimilar materials. This effect is frequently utilized in camping gear, portable coolers, and for the cooling of electronic components and small instruments. Magnetic refrigeration, also known as adiabatic demagnetization, is a cooling process that utilizes the magneto-caloric effect.

(Chua et al. 2013) . Thermo acoustic refrigeration employs sound waves in compressed gas to facilitate heat transfer and heat exchange. (Khadtare, Chavan, Wagh, Atkale, & Parkhe). Numerous Stirling cycle heat engines may operate in reverse to function as refrigerators, thereby serving a specialized role in cryogenics. (Peters 1974). Numerous studies have reported on the Peltier thermoelectric refrigeration technology. This thermoelectric cooling system offers numerous advantages, including compact dimensions, reduced weight, absence of refrigerants and moving components like compressors, and the capability to run on a DC power supply. This system is utilized in portable refrigerators and ice boxes; beverage can cool, picnic basket cooling, laser diode cooling, blood analysis, integrated circuit chip cooling, and industrial temperature regulation. (Verma, Chatterjee & Nagarajan 2009). Elavarasan E et al. created a tiny thermoelectric refrigerator with a 40-liter capacity, designed to sustain temperatures between 3°C and 23°C for a duration of thirty minutes. Prashant G. et al. (Liao et al. 2016) created a portable thermoelectric refrigeration device for medical purposes that can get a cooling efficiency of 40% to 60% relative to conventional refrigerators. Murat Gökçek and Fatih Şahin utilized a commercial refrigerator with a capacity of 0.063 m^3 as a thermoelectric cooling device and indicated that a high coefficient of performance may be attained with an appropriate heat sink (Egan, Stafford, Walsh, & Walsh 2009).

A tiny bovine embryo freezer, with a capacity of one cubic foot and weighing 15 kg, Model R206, is available for some biomedical purposes utilizing liquid nitrogen (Yamaguchi et al. 2017) employed a straightforward thermal resistance correlation to evaluate various cryogenic cooling solutions for electronics: a Linde air cycle, a Stirling cycle, a vapor compression refrigeration (VCR) cycle, a cascaded vapor compression refrigeration cycle, a vortex tube, and a liquid nitrogen system. The thermal resistance equation indicated that the coefficient of performance (COP) of the vapor compression refrigeration cycle diminished as the junction temperature decreased. Liquid nitrogen has been asserted as an appropriate method for the cryogenic cooling of electronics. Only two research in the literature report on refrigeration system models for electronic cooling. Neither model incorporated an examination of the heat spreader and the chip packaging (John et al. 2022). Bash created a vapor-compression system model for an optimal small-scale refrigeration cycle intended for electronics cooling applications.

A standard vapor compression system was also evaluated using a serpentine evaporator, an intercooler, a compressor, a plate fin-and-tube condenser, and a capillary tube expansion device. An alternate hot-gas bypass valve was employed to regulate the refrigerant flow from the compressor output to the evaporator intake and to manage the evaporator capacity. The hot-gas bypass valve further reduced moisture condensation on the evaporator surface when its temperature fell below the dew point. Bash's model presumed an isenthalpic process throughout the expansion phase and excluded the refrigerant pressure drop in both the evaporator and condenser; also, the air-side pressure drop across the condenser was not considered. The analysis of refrigeration inventory and the chip packaging was also excluded. A refrigeration test apparatus was constructed with a 400 W thermal load at 25°C. Experimental experiments were conducted at a constant condenser air flow rate of 0.031 m^3/s (65 CFM) and an evaporator temperature of 20°C. The model was validated against the test results: the accuracy of pressure and temperature forecasts was within ±10%, while the accuracy of COP predictions was within ±8% for heat loads ranging from 210 to 400 W (Yuan et al. 2015).

Different researchers have conducted considerable studies on thermoelectric coolers. One of the authors was Huang et al. (Najafi & Woodbury 2013) Chien et al. (Ding et al. 2021)examined the performance of a thermoelectric chiller powered by solar cells. Chien et al. employed nitrogen (NH_3-H_2O) in their refrigeration system, resulting in substantial electricity consumption and prolonged operational time. The fundamental components of the thermoelectric cooler are the n-type and p-type thermo-elements. A bottom-up modeling strategy involves constructing the model at the elemental level, assuming that both thermo-elements are identical save for the opposing direction of the Peltier–Seebeck effect (Zhao & Tan 2014). Thermoelectric technology has two primary applications.

Electricity generation utilizes waste energy and renewable sources. Rowe DM and Min Gao have assessed thermoelectric modules for energy generation (Zio & Compare 2013). The output performance, specifically power, of thermoelectric modules (TEMs) can be achieved by thermoelectric power generation (TEPG) systems utilizing either deliberately provided heat sources or waste heat sources (Alghoul et al. 2018). The TEC can function solely within a specific temperature differential range between the cold and hot sides, contingent upon the input electric current and the parameters of the thermoelectric material (Chein & Chen, 2005). Actually significant cost savings are possible by employing innovative design or maintenance strategy for a cooling cup (Alam, Rafiquzzaman, Ali, & Jubayer 2024).

The review highlights advancements in cooling technologies, focusing on thermoelectric cooling (TEC) for its compactness, DC power compatibility, and diverse applications such as portable refrigerators and medical devices. Alternative methods like magnetic refrigeration, thermo-acoustic cooling, and cryogenic systems offer potential but face limitations in portability and efficiency. Key research gaps include optimizing TEC for broader temperature ranges, addressing bulkiness in cryogenic systems, and improving the energy efficiency of solar-powered and small-scale cooling devices.

The research gaps for designing a mini cooling cup include the need for improved portability and power efficiency, as current TEC systems are not optimized for compact, battery-powered applications. Enhancements in temperature range optimization, heat dissipation mechanisms, and environmentally sustainable materials are essential for better performance and reduced environmental impact. Lastly, a user-centric design tailored for everyday consumer use, prioritizing ease of use, affordability, and functionality, remains largely unexplored. The structure of this study is organized into several sections. Section 2 reviews relevant literature, focusing. advancements in Peltier module-based cooling technologies. Section 3 describes the methods, including the assembly of the cooling cup with components like the Peltier module, heat sink, and power supply, while Section 3.1 covers the theoretical basis for these design choices. Section 4 analyzes data, detailing materials used, product specifications, and component dimensions. Section 5 presents results, including numerical power efficiency findings (64.94%) and temperature-time graphs for both the cool and hot sides of the Peltier module. Finally, Section 6 offers conclusions and future directions, highlighting opportunities for enhancing energy efficiency, adding Bluetooth or Wi-Fi features, and exploring lighter-weight designs for effective beverage cooling.

1.1 Objectives

The specific objectives of the study are:

i. To provide a compact and efficient way to keep a beverage cold.
ii. To improve portability.
iii. To achieve results in a short time.
iv. To maintain operating efficiency and protect the equipment.
v.To control intuitive controls for effortless operation.

2. Methods

The cooling system for a portable tiny cooling cup with a Peltier module (Figure 2) is designed by integrating the module such that its cold side is in direct touch with the cup's base, allowing it to chill the liquid inside. The Peltier module uses the thermoelectric effect, which generates a temperature differential when an electric current is applied. A heat dissipation system made up of a cooling fan and a heat sink is designed to manage the heat produced on the Peltier module's hot side (Figure. 1). The Peltier module's hot side is linked to the heat sink (Fig. 6), which is often made of a material with a high thermal conductivity, such as aluminum, to absorb heat. The fan then vigorously distributes this heat into the surrounding air. To further improve cooling effectiveness and minimize heat loss, insulating materials like foam or plastic casing are placed around the cooling cup.

To make sure it satisfies the right cooling requirements, the Peltier module (e.g.,) is selected based on a number of criteria, including cooling capacity, power consumption, size, and overall efficiency. To accompany the Peltier module, a fan and heat sink were selected; the fan's purpose was to provide enough airflow to adequately cool the hot side, while the heat sink's was to improve heat dissipation. The power supply is utilized to control the Peltier module and cooling fan, guaranteeing safe and effective operation and avoiding overheating. It is carefully chosen to ensure mobility and sufficient power delivery.

In order to improve thermal conductivity, thermal paste is applied between the Peltier module's cold side and the cooling cup's base. This is the first step in the manufacturing process.

The heat sink is securely affixed to the hot side of the Peltier module, with a cooling fan positioned on top to facilitate effective heat dispersion. An external power supply adapter (Fig. 7) is integrated within the system alongside a control circuit that manages power delivery and temperature regulation. Depending on the specific design requirements, this control system can range from a simple on/off switch to more complex configurations. As a result of these assembly processes, the cooling cup (Fig. 8) is made compact, portable, and efficient at cooling its contents using the Peltier module..

Figure 1. Heat sink with cooling fan

2.1 Theoretical basis for designing

Thermoelectric cooling principles form the basis of the design of a portable mini cooling cup featuring a Peltier module and heat sink. The Peltier module makes use of the Peltier effect, which occurs when an electric current causes a temperature difference between two sides, allowing one to cool while the other heats. While heat produced on the opposite side is distributed via a heat sink, the cooling side of the module needs to be in contact with the cup for best performance. Aluminum and other materials with high thermal conductivity enhance convectional heat dissipation and can be used in conjunction with a fan for active cooling to boost efficiency.

2.1.1 Peltier Module

The Peltier module, which operates on the thermoelectric principle, is the key component of design. When an electric current flows between the connections of two distinct conductors, heat is transferred from one to the other. This generates a cooling effect on one side while heating the other. (Figure. 3)

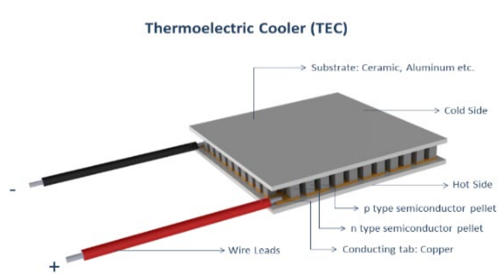

Figure. 2. Peltier Modules

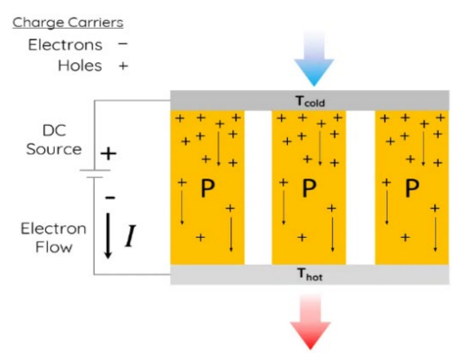

Figure. 3. Thermoelectric cooler (Peltier Effect)

2.1.2 Controlling the Voltage Supplied to the Peltier Module
In some applications, the Peltier module is engineered to consistently deliver optimal cooling performance. In these instances, a steady voltage is applied to the Peltier device, producing load current and cooling effects. Peltier modules are utilized in various applications to maintain an object's temperature consistently. These designs employ a thermal sensor, including a thermocouple, a solid-state temperature sensor, or an infrared sensor, to assess the object's temperature. The temperature data is relayed to the power supply via a thermal control loop, which modulates the voltage (or current) supplied to the Peltier module. The restricted loop bandwidth allows for diverse designs of the thermal control loop. Moreover, the polarity of the regulated voltage or current must be reversible for the temperature control system to simultaneously cool and heat the object (Figure. 4).

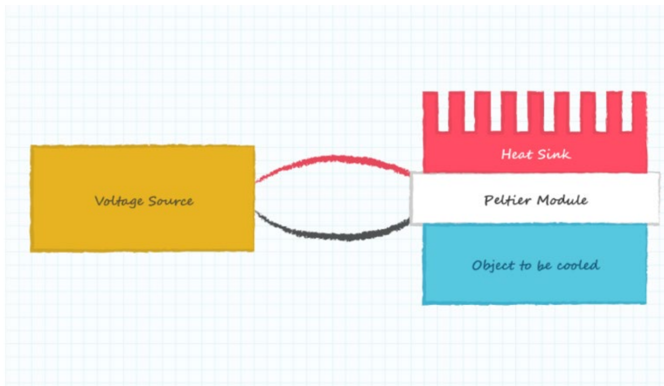

Figure 4. Peltier module system design with constant voltage

2.1.3 Accounting for All Heat Sources
Upon the application of an electrical current to a Peltier device, thermal energy is conveyed throughout the module. The electrical power utilized during operation induces thermoelectric modules to generate supplementary heat alongside the heat that is delivered. The thermal solution must disperse both the heat produced by the Peltier system and the heat delivered by the Peltier module. The electrical function of the Peltier device generates considerably more heat than it conveys in systems with a poor coefficient of performance (COP). The maximum operating system performance is determined by the interplay of ambient temperature and the efficacy of the heat sink solution (Figure 5).

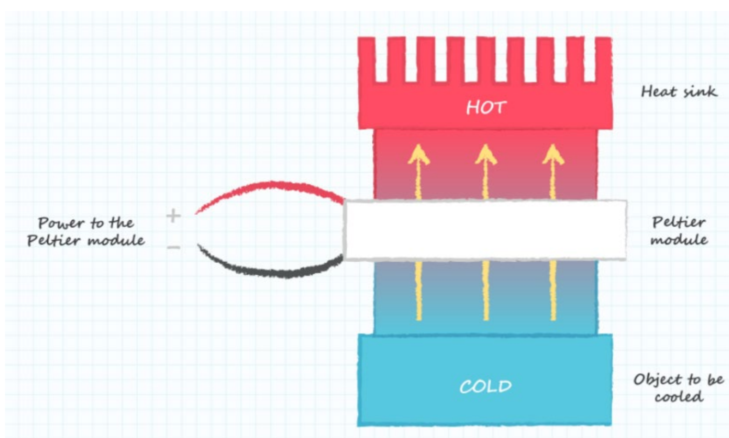

Figure 5. Typical heat flow through a Peltier module

2.2 Material

The cooling cup is an innovative device designed to rapidly lower the temperature of beverages. Utilizing advanced thermoelectric cooling technology, it offers a convenient and efficient solution for keeping drinks chilled. Perfect for personal use, it combines functionality with modern cooling methods. The following materials used in developing a mini portable cooling cup.

Peltier Module: Enables thermoelectric cooling.

Heat Sink with Cooling Fan: Dissipates heat for efficiency.
Aluminum Water Block: Distributes cold temperature effectively.
Power Supply: Provides consistent power.
Thermal Paste: Enhances heat transfer.
Electric Wire: Ensures proper connectivity.

2.2.1 Heat Sink: The heat sink's principal function is to disperse heat generated on the hot side of the Peltier module. Efficient heat dissipation keeps the cold side cool enough to chill the cup.

Figure 6. Heat Sink

2.2.2 Power Supply

The mini cooling cup likely uses thermoelectric cooling (Peltier module) and operates efficiently with a 12V DC power supply. The adapter converts AC to stable DC, ensuring optimal performance and protecting the device from power surges.

Figure **7.** Adapter DC12V 5A

2.3 Construction of Portable mini–Cooling Cup

A systematic approach for creating a portable mini-cooling cup:

Step 1. Cup Body Construction: A robust, insulated vessel is selected to contain the beverage. The container is sized and shaped to accommodate the cooling components.
Step 2. Peltier Module Installation: The Peltier module is placed at the bottom of the cup, with the cold side oriented toward the beverage and the hot side facing outward. Thermal paste is applied to ensure optimal thermal contact.
Step 3. Attachment of the Heat Sink and Cooling Fan: The heat sink is positioned for efficient heat dissipation and is fastened to the Peltier module's hot side. After that, the cooling fan is attached to the heat sink to increase cooling and airflow.

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Step 4. Thermal Paste Application: To enhance thermal conductivity and heat transfer, a thin layer of thermal paste is placed between the Peltier module and the heat sink.

Step 5. Configuration of Power Supplies: The AC from the wall outlet is transformed into the required DC voltage by connecting a 12V DC power supply. The Peltier module and fan are connected to the positive and negative terminals of the power supply.

Step 6. Electrical Wiring: The power supply, cooling fan, and Peltier module are connected via electrical connections. To avoid short circuits, all connections are insulated and fastened.

Step 7. Final Assembly and Testing: The parts are put together with care to guarantee strong connections. In order to test the cooling cup, the power supply is connected, and the Peltier module's ability to effectively cool the beverage is confirmed. Heat dissipation and fan operation are also examined.

Step 8. Modifications and Finalization: To maximize airflow or cooling efficiency, the necessary modifications are implemented. To guarantee longevity and safety, a protective casing may be put around the electrical components.

This method uses thermoelectric technology to efficiently cool liquids and produces a portable, fully functional mini-cooling cup.

Figure. 8. Construction of Portable mini–Cooling Cup

3. Data Analysis

Many relevant criteria have been met for designing a cooling cup. Various parameters have been set for using a Peltier module as a cooling device in this cooling cup. It takes 21 minutes for the temperature to drop to -2°C from indoor or outdoor temperatures. (Table 1) An active heat sink has been attached to the Peltier module to ensure it works efficiently. A cooling fan attached to the heat sink produces 22dB of sound to minimize noise. This product operates with 12V and 5A direct current at approximately 65% efficiency.

Table 1. Product Description

Parameter	***Description***
Initial Temperature (°C)	32.4
Cooling Temperature (°C)	-2
Cooling Time (minutes)	21 minutes
Circuit Connection Type	Parallel Circuit Connection
Power Supply (V/A)	12V/5A
Power Efficiency (%)	64.94%
Heat Sink Type	Active Heat Sink
Ambient Temperature (°C)	21°C (70°F)
Energy Consumption (Wh)	0.4 Wh
Noise Level (dB)	22 dB

Selecting small and light-weighted parts for the cooling device was the main concept to design a portable cooling cup. The measurements of weight and dimensions of every important part of this cooling cup are shown in Table 2. As a cooling device, a 40mm x 40mm square Peltier module was selected, with a height and weight of 3.6mm and 33 grams, respectively. The relative parts, like the fan with heatsink and power supply, were also small and lightweight for developing this product.

Table 2. Weight and Dimension of Materials

Material	***Weight (kg)***	***Dimension (mm)***
Peltier Module	.0033 kg	40*40*3.6 mm
Water Block	.0010kg	40*40*2mm
Heat Sink with Cooling Fan	0.170 kg	115*115*77 mm
Power Supply	0.23 kg	150*90*55 mm

4.Results and Discussion
4.1 Numerical Result

Table 3. Power Efficiency Measurement

Criteria	***Voltage (V)***	***Current (A)***	***Power (watts)***
Operating Condition	12	5	60
Maximum Capacity	15.4	6	92.4

A small-sized Peltier module has been used as a cooling device for this portable cooling cup. The Peltier module operates with 12V and 5A with a direct current power supply, but the maximum power consumption is 15.4V and 6A (Table 3). The power efficiency is lower due to operating it with low power, even though it can operate with high power.

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$$power\ efficiency = \frac{power\ of\ operating\ condition}{power\ of\ maximum\ capacity} \times 100\%$$
$$= \frac{12 \times 5}{15.4 \times 6} \times 100\%$$
$$= 64.94\%$$

From the calculation, the power efficiency of the Peltier module is 64.94% because it could operate at 92.4 watts but is currently operating at 60 watts. The Peltier module has been operated with low power to increase its lifespan. This may happen for several reasons, including restricting power to prevent overheating, enhancing energy efficiency, or functioning within designated temperature limits. It is crucial to recognize that although elevated power may enhance performance, it can also result in diminishing returns, including decreased efficiency in heat transmission and heightened energy losses as heat, particularly in thermoelectric systems such as Peltier modules.

4.2 Graphical Results

The Peltier effect allows these modules to transfer heat by moving it from the cold side to the hot side. However, this process generates additional waste heat in the system, which must be managed. If the heat isn't efficiently dissipated from the hot side, it accumulates and reduces the module's ability to maintain lower temperatures on the cool side.

Rapid Cooling Phase: The cool side starts at 32.2°C and drops quickly to approximately 10°C in the first 50 seconds. This indicates the Peltier module is initially very efficient at reducing temperature. (Fig. 9)
Slower Cooling Toward Freezing: After the rapid drop, the temperature gradually decreases to around 0°C, reaching freezing at about 623 seconds, and continues to dip to around -2°C by 1256 seconds. As the module approaches freezing temperatures, the cooling efficiency slows down. (Figure. 9)

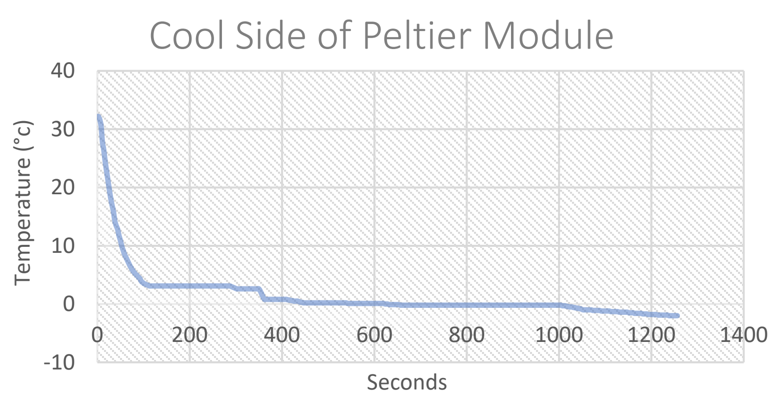

Figure 9. Temperature on the cool side of a peltier module over time

Stable Temperature Rise: The hot side begins at 32.47°C and experiences a much slower and steadier increase compared to the cool side's rapid temperature drop. By around 50 seconds, the temperature reaches approximately 38.4°C and stabilizes. (Fig. 10)
Slight Fluctuations: After reaching a peak of around 39.3°C at 71 seconds, the hot side's temperature remains relatively stable, fluctuating slightly between 38.8°C and 39.3°C over the remaining time. (Fig. 10)
Saturation Point: The heat on the hot side plateaus around 39°C and does not increase significantly, which shows the Peltier module's ability to dissipate heat reaches a certain equilibrium. (Fig. 10)

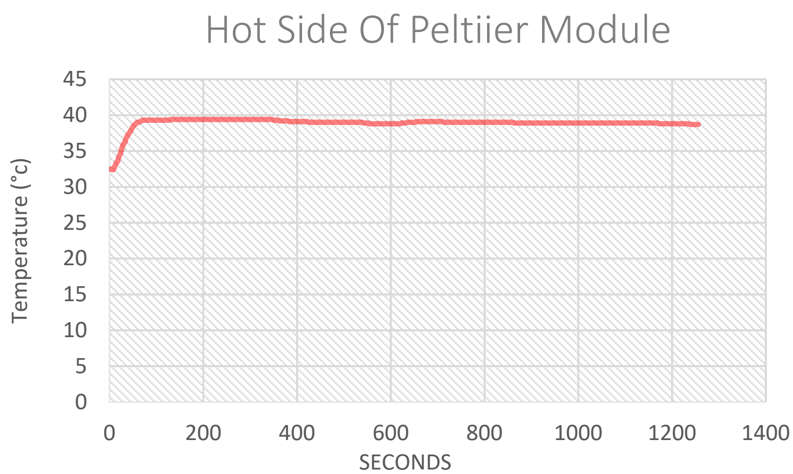

Figure 10. Temperature on the hot side of a Peltier module over time

For better cooling, it's crucial to optimize the heat dissipation from the hot side. Larger heatsinks and faster fans can help move the heat away from the hot side faster, reducing thermal saturation and allowing the cold side to become even cooler. Stacking Peltier modules won't help without improving heat management. Adding more modules would just compound the heat problem, as each module would generate its waste heat, making it harder to maintain a large temperature differential.

4.3 Validation

Table 4 delineates the validation parameters of the micro cooling cup, encompassing performance metrics (e.g., cooling duration), test categories (indoor and outdoor), execution time for each testing environment, acceptance standards for cooling duration, and pertinent reference papers.

Table 4. Validation of Mini Cooling Cup

Aspect	Description
Performance Characteristics	Cooling Time: The time required for the mini cooling cup to cool from an initial high temperature (e.g., 40°C) to a target temperature (e.g., 25°C).
Typology of Test	Product performance Test (Internal Validation)
	Environmental Testing: Testing under two conditions: Indoor (25°C, 17.32% humidity) and Outdoor (35°C, 17.32% humidity).
Executive Time	Indoor Test: Average cooling time 8.5 minutes (Trial range: 7-10 minutes)
	Outdoor Test: Average cooling time 20.67 minutes (Trial range: 20-21 minutes)
Acceptability Criteria	Indoor Test: Cooling time should be within 12-18 minutes of the target (15 minutes).
	Outdoor Test: Cooling time should be within 15-25 minutes.
	Cooling times outside these ranges may indicate a need of product adjustments.
Related Documents	Product Design Specification Document: Specifies the intended cooling time and design parameters.
	Testing Protocol Document: Describes the test methodology, including ambient conditions, trial procedure and temperature measurement methods.
	Product Development Reports: Include past iterations and changes made to the cooling mechanism or other relevant parts
	ISO Standards (if applicable): Any relevant industry or product testing standards that apply to cooling devices (e.g., temperature measurement methods).

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Table 5 delineates the testing parameters, desired cooling durations, observed result ranges, acceptability standards, and pass/fail outcomes for both indoor and outdoor assessments. The acceptance criteria delineate the permissible cooling time limits for each setting to ascertain whether the product fulfills performance standards.

Table 5. Performance Characteristics and Acceptance Criteria

Test Conditions	Cooling Time (Minutes)	Measured Result Range	Acceptance Criteria	Pass/ Fail
Indoor (25°C, 17.32% Humidity)	15 (Target)	7-10 minutes	Cooling time should be between 12-18 minutes.	Pass/Fail
Outdoor (35°C, 17.32% Humidity)	15 (Target)	20-21 minutes	Cooling time should be between 15-25 minutes.	Pass/ Fail

5. Conclusion

This paper presents the design and development of the Mini Portable Cooling Cup, a device that employs a Peltier module for efficient and portable beverage cooling. This innovation focuses on rapid cooling and boasts a compact, lightweight design, allowing users to enjoy their beverages at the ideal temperature in no time. The selection of a Peltier module as a small and lightweight temperature-regulating device proves to be highly effective. One notable advantage of the Peltier module is its lifespan of over 200000 hours, alleviating concerns about the reliability of a portable device.

When the Peltier module is in operation, one side becomes cold while the opposite side becomes very hot. To prevent damage to the Peltier module from overheating, an active heat sink is utilized to properly manage the hot side. Maintaining the Peltier module's operating temperature below 39.4 °C will contribute to its longevity.
In addition, incorporating Bluetooth or Wi-Fi functionality for wireless power and control can enhance user convenience by enabling remote monitoring and management via a smartphone app. Offering a fresh perspective on portable cooling, the Mini Portable Cooling Cup harmoniously combines portability, efficiency, and eco-friendliness. While the Peltier module is a compact cooling solution, it has a relatively low cooling capacity and requires more time to cool objects.

To advance deep and rapid cooling systems, the incorporation of nanotechnology heat insulators for temperature regulation, along with upgraded p-type and n-type connections, could be explored. This product presents an excellent option for customers seeking more efficient and enjoyable methods to chill their beverages on the go, thanks to the proposed enhancements that are set to redefine industry standards.

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Biographies

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