# Design and Implementation of Air Conditioner Using Peltier Module

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## Abstract:

The greatest demand for energy efficiency cooling solutions has led to research on thermoelectric cooling systems as an alternative to traditional air conditioning systems. Traditional air conditioning systems are based on refrigerants that contribute to environmental separation and high energy consumption. In this article, we propose a thermoelectric string of bare skin cooling that optimizes cooling capacity and maintains low energy consumption at the same time. The system has been developed using multiple subcutaneous modules, heat dissipators and air current mechanisms to improve efficiency in the thermal sector. Microcontroller -based systems adjust the energy distribution to ensure optimal performance. Experimental tests analyze cooling capacity in different configurations and show that the system reaches effective cooling and at the same time minimizes energy consumption. The results show that this refrigerant, free, compact and ecological cooling system is suitable for live and small cultural applications, which offers a sustainable alternative to traditional air conditioning systems.

## Introduction:

The introduction of new technologies and innovations has significantly improved the quality of life, which makes various tasks and activities easier to execute. Cooling systems, in particular, have become increasingly essential in modern times, especially in regions with extreme heat. Traditional air conditioning systems depend on excessive electricity consumption, which leads to high energy costs and environmental concerns. However, recent advances in thermoelectric cooling technology offer an alternative of energy efficiency that eliminates the need for expensive refrigerants and compressor - based systems while maintaining effective temperature control [1]. People living in remote areas often fight with inappropriate cooling solutions, which forces them to trust inefficient methods, such as fans and water -based cooling techniques. Thermoelectric cooling technology presents a viable solution to these problems. This project uses a PELTIER module, which takes advantage of the thermoelectric effect to convert electricity into a temperature difference. The device facilitates heat transfer from one surface to another, creating a cooling effect, while a fan and heat dissipator work together to optimize thermal dissipation and guarantee soft operation. This ecological approach minimizes the dependence of traditional air conditioning systems and is particularly beneficial for areas with limited electricity supply [2]. Several studies have focused on thermoelectric cooling using Peltier modules, exploring their possible air conditioning applications. The research carried out by Allwin José, Alan D'Oouza, Sarvesh Dandekar, JITESH Karamchandani and Pavan Kulkarni examined the air conditioning depending on the Peltier effect, highlighting its environmental benefits due to the elimination of refrigerants, while indicating the need for efficiency improvements [3]. M. Majid M. Al-Khalidy and Ali Maki Isa Ahmed investigated a cold/hot air system enabled for IoT that integrates remote monitoring and automation [4]. Saket Kumar, Ashutosh Gupta, Gaurav Yadav and Hemend Pal Singh proposed a cooling and heating system based on the Peltier module with minimal moving parts, reducing maintenance while guaranteeing localized cooling [5]. Another significant study of Arjun Kumar GB, S. Sushma, Priyanka L, Vijay G and Thouqhir Pasha G focused on the air conditioning with solar energy using the Peltier module, which specifically attends to portable and remote applications [6]. Similarly, Abhishek Sharma, Apurv Pratap Singh, Ritesh Ranjan, Nithyashu Tiwari, Sandip Kumar and Anu Kumar developed a modified air cooler designed for high humidity conditions such as a profitable alternative to traditional air conditioning units [7]. Addhya SM, Karunakara P. Menon, Anjana M and Anupama introduced an intelligent air conditioning system that took advantage of IoT and Machine learning, which allows automated temperature control along with cooling based on Peltier [8]. Despite the significant progress in thermoelectric cooling technologies, several challenges persist in the development of an efficient air conditioning system that uses Peltier modules. The current research is predominantly focused on improving the efficiency of Peltier devices, but limited studies explore effective heat dissipation techniques to prevent thermal saturation. Although Peltier based cooling has been widely analyzed in small -scale applications, there is not enough research on the optimization of energy consumption for continuous operation in larger environments [9]. Another critical challenge is the absence of a standardized energy management system for PELTIER modules, since existing studies do not comprehensively address compensation between cooling performance and energy efficiency. In addition, hybrid cooling approaches, such as the integration of PELTIER modules with phase change materials or radiative cooling, remain sub -examination. In addition, most experimental research on air conditioners based on Peltier have been made in controlled environments, with minimal real world tests under different environmental conditions and humidity levels [10]. The thermoelectric air conditioning system that uses a PELTIER module offers an alternative of energy and ecological efficiency to conventional air conditioners that depend on refrigerants and compressors. The Peltier module generates a temperature difference, absorbing heat on the cold side and dissipating it on the hot side with the help of a heat dissipator and a cooling fan. A NODEMCU (ESP8266) microcontroller processes the temperature sensor data in real time to regulate energy entry, ensuring optimal cooling performance. In addition, its built-in Wi-Fi module allows IoT-based monitoring and control-based control through a smartphone application or web interface [11]. Designed for the continuous current (DC) operation, the system admits renewable energy sources, which makes it appropriate for residential applications, offices and industrialists. With a stable power supply, efficient heat dissipation and low maintenance requirements, this innovative solution provides a compact, intelligent and sustainable alternative to traditional air conditioning systems. Recent advances in thermoelectric cooling technology have provided energy efficiency alternatives to conventional air conditioning systems, which depend on high power consumption and cooling with environmental damage. The integration of solar energy into cooling systems has been explored as a sustainable solution to reduce the dependence of the electricity grid. A. MISHRA et al. [17] investigated the strategic placement of solar energy plants to improve energy efficieny and prevent blackouts, which aligns with the potential to integrate thermoelectric cooling with solar energy for sustainable air conditioning. In addition, automation plays a crucial role in improving efficiency and remote operation. R. Umamaheswari et al. [19] developed an automated system assisted by Arduino for cleaning the photovoltaic panel, showing the benefits of monitoring and control based on microcontrollers, a concept that can be extended to intelligent thermoelectric air conditioning systems. In addition, efficient energy management remains a challenge in thermoelectric cooling applications. U. M. Ramisetty and S. K. Chennupati [16] analyzed hybrid information and energy transfer techniques, which provide information on the optimization of energy use for the continuous operation of the air conditioning units based on PELTIER. These studies highlight the importance of renewable energy integration, automation and energy management optimized in the development of an intelligent, ecological and efficient thermoelectric air conditioning system.

## Proposed System of Air Conditioner Using Peltier Module:

The Peltier -based air conditioning system works in the thermoelectric effect, where heat is transferred between two surfaces when an electric current flows through the PELTIER module. This system consists of multiple Peltier modules, a heat dissipation mechanism and an air circulation system to improve cooling efficiency. The cooling effect occurs when the cold side of the slowest module absorbs the heat of the surrounding environment, while the hot side dissipates heat with a heat dissipator and a fan. To regulate performance, an energy management system is incorporated to control voltage and input current, which guarantees optimal functionality and better efficiency. A temperature and humidity sensor continuously monitors environmental conditions, allowing dynamic adjustments in cooling intensity based on real -time data. The system is controlled by a NODEMCU (ESP8266) microcontroller, which processes the sensor inputs and dynamically adjust the food supplied to the Peltier modules. To avoid overheating, aluminum heat dissipators and forced air cooling mechanisms efficiently dissipate excess heat, maintaining the stability and system performance. To improve energy efficiency, the system is equipped with a rechargeable battery and an optional solar energy integration, reducing the dependence on network electricity. The inclusion of IoT -based monitoring and remote control through an application for smartphones allows users to control cooling configuration and monitor system performance remotely. This compact and ecological thermoelectric cooling system offers an alternative to conventional air conditioners by eliminating the use of refrigerants, minimizing energy consumption and providing an efficient solution for cooling located in residential and small -scale commercial applications. The design and implementation of the system are illustrated in Fig. 1, which shows the block diagram of the proposed system.

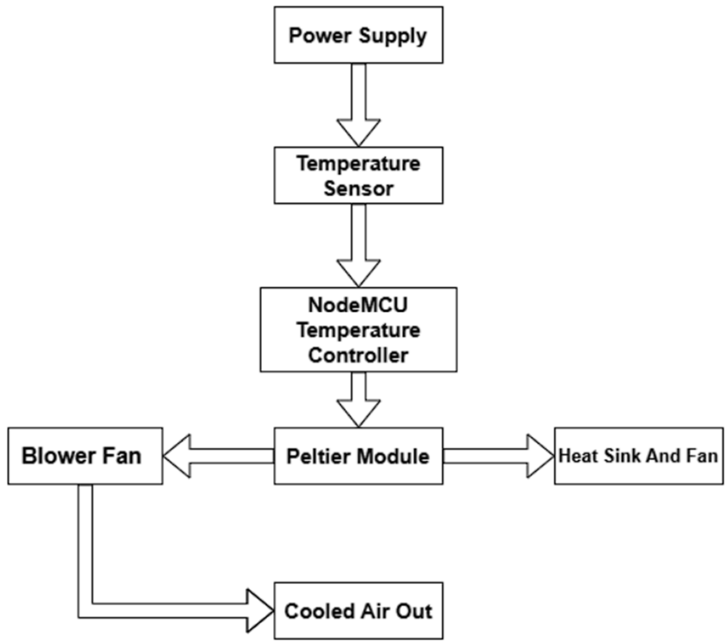


**Fig. 1: Block Diagram with Components**

## Components Explaination:

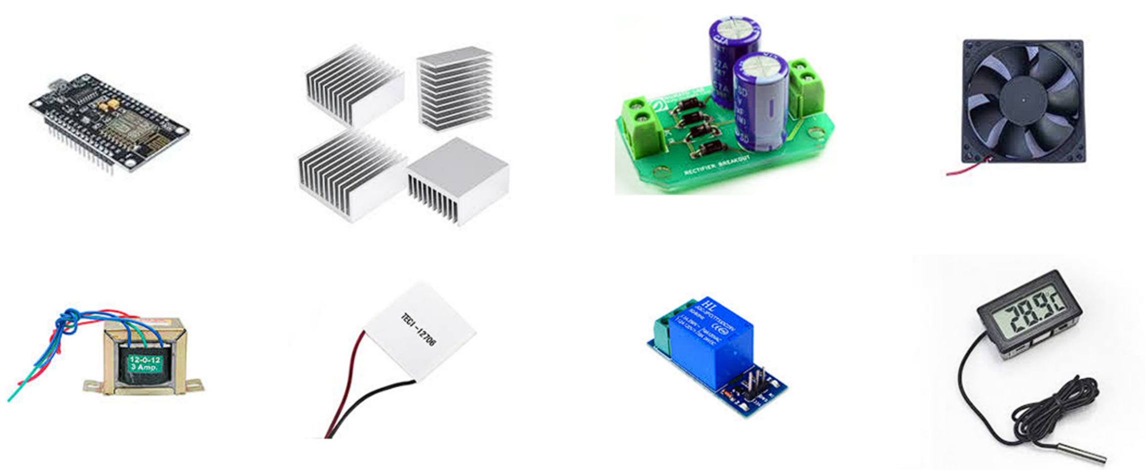

**Fig. 2 : Components Used in the Peltier Module Air Cooling System**

Fig. 2 shows the key hardware components used in the air conditioning using the Peltier module project. The Peltier module (TEC-12706) plays a crucial role in thermoelectric cooling when creating a temperature difference when it is feed. To improve heat dissipation, aluminum heat dissipators and cooling fan are used, avoiding overheating and efficiency improvement. The microcontroller, such as an ESP8266 or Arduino, manages system operations and controls the retransmission module, which changes or deactivates the cooling mechanism based on temperature readings. A digital temperature sensor continuously monitors the surrounding environment to maintain the desired cooling effect. In addition, a rectifier circuit converts AC to CC, ensuring a stable power supply to all components, with a transformer that decreases the voltage as necessary. These components work together to achieve effective cooling using thermoelectric principles.

## Work Flow / Flow Chart:

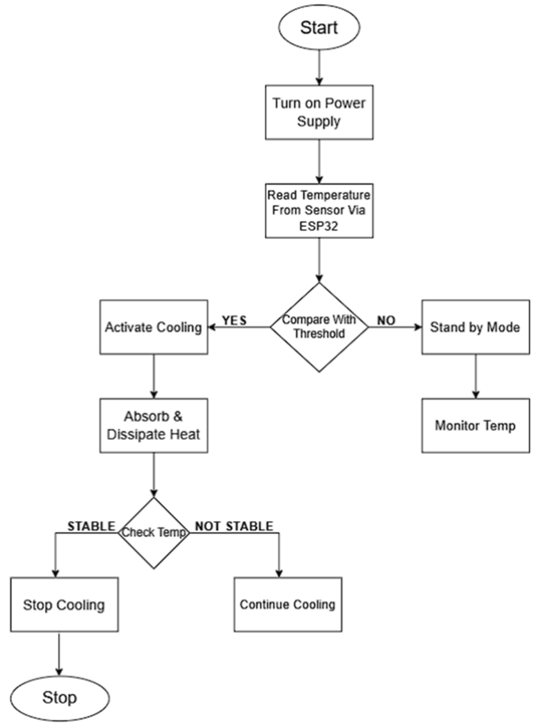


**Fig. 3: Flow Chart of Air Conditioner Using Peltier Module**

## Implementation:

The implementation of the Peltier air conditioning system begins with the initialization of basic components, including Peltier modules, heat disappoists, CPU fans, the temperature sensor, the NodeMC (ESP8266) microcontroller, the relay module and the supply unit. Nodemcu is scheduled to handle real automated monitoring and control to effectively optimize cooling performance. Once the system is turned on, the temperature sensor continuously measures the surrounding area temperature and the Nodemcu processes this data to determine if cooling is required on the basis of the user -defined threshold. If the measured temperature exceeds the threshold value, the system activates the cooling mechanism by lighting PELTIER modules, activate the CPU fans and heat dispersion fans for heat dispersion. The system dynamically adjusts the cooling intensity depending on the temperature in real time to maintain energy efficiency. The heat dispersion mechanism ensures that excess heat is effectively eliminated to avoid thermal saturation. To guarantee a stable operation, NODEMCU continuously monitors the battery level and when the energy is low, it automatically becomes an external power supply through the repeated transmission module and guarantees the continuous cooling capacity. The energy control system regulates energy distribution between system components, energy efficiency and performance balance. The IoT Internet control mechanism allows users to monitor and remotely adjust the cooling configuration using the application for smartphones. The real time temperature and system temperature and system status are shown in the interactive plate, allowing users to make the necessary adjustments as necessary. Figure 3 is represented. This automated cooling system, efficient in energy and compact, serves as a sustainable conventional air conditioning alternative, which makes it particularly suitable for commercial applications for residential and small scale.

## Performance Analysis and Mathematical Formulation:

### Cooling Power Calculation

$$Q = mC_p\Delta T \tag{1}$$

### Power Consumption Formula

$$P = V \times I \tag{2}$$

### Coefficient of Performance

$$COP = \frac{Q}{W} \tag{3}$$

Equalization (1) refers to the process of calculating cooling power, which determines the amount of heat absorbed by the cold side of the Peltier module. This is crucial to evaluate the efficiency of the cooling system and ensure that it can maintain the desired temperature in various environmental conditions. Equation (2) provides the formula to determine the total electrical power necessary to execute the PELTIER module and its connected parts. This equation is vital to evaluate energy efficiency and maximize system performance to reduce electricity consumption while guaranteeing efficient cooling. Equation (3) represents the COP, which quantifies the ratio of the cooling power of the entrance to the cooling power of the entire system. A higher COP value means a more effective system, which makes this equation crucial to assess the general efficiency of the thermoelectric air conditioning system.

## Results and Discussion:

**Fig. 4: Front View**

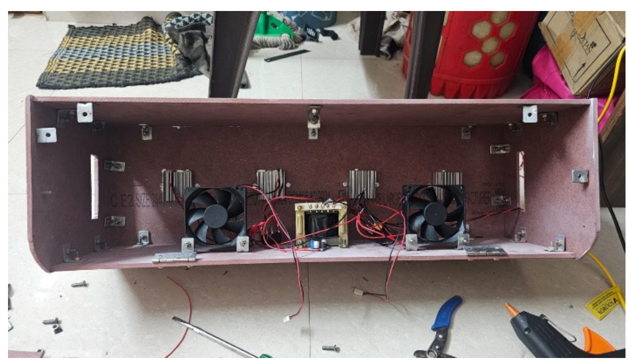

**Fig. 5: Internal Components**

Fig. 4. Assembly system: The air conditioning system based on Peltier final is shown with a digital temperature screen and a feed switch for operation. The closed design guarantees an efficient regulation of air flow, improving cooling performance. Fig. 5. Internal components: The internal structure includes more peltier modules, heat dissipators, cooling and wiring fans, allowing effective heat dissipation and system stability. The provision of optimized components improves energy efficiency and cooling performance. The results indicate that the PELTIER -based cooling system effectively reduces the temperature over time, although at a slower speed compared to the conventional CA, as shown in Table 1 and Figure 1. The efficiency analysis in Table 2 and Figure 2 reveals that cooling efficiency increases with energy consumption, but stabilizes beyond 70W, highlighting the operational limits of the system. In addition, COP values in Table 3 and Figure 3 show that maximum performance is achieved to the average range power levels (~ 150W), after which efficiency decreases slightly due to thermal saturation.

**Table 1: Cooling Performance Data**

| Time(minutes) | Peltier-Based AC (℃) | Conventional AC (℃) | $\Delta T$(℃) |
|---|---|---|---|
| 0 | 35 | 35 | 0 |
| 10 | 28 | 24 | 7 |
| 20 | 24.5 | 18 | 10.5 |
| 30 | 22 | 16 | 13 |
| 40 | 21 | 14 | 14 |
| 50 | 20.5 | 12 | 15.5 |

Table 1 compares the cooling efficiency of an AC based on PELTIER and a conventional AC. The Peltier system is gradually cools, reaching 20.5 ° C in 50 minutes, while the conventional CA reaches 12 ° C. This indicates that Peltier based cooling is slower but provides a sustainable alternative.

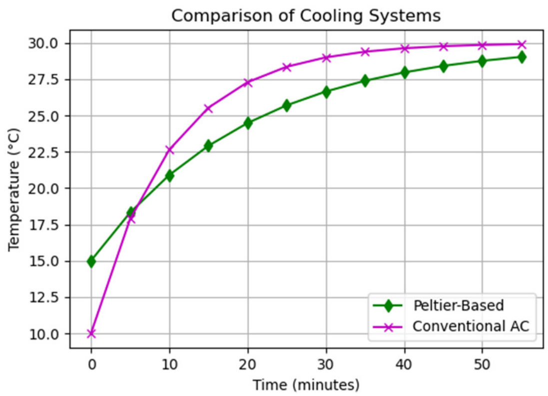


**Fig 6: Temperature vs. Time for Peltier vs. Conventional AC**

Figure 6 shows that the conventional CA cools the environment faster than the Peltier -based system. The temperature difference becomes remarkable after 20 minutes, since the conventional CA is significantly more efficient. The graph highlights the slowest cooling speed of thermoelectric cooling.

**Table 2: Power Consumption**

| Power Consumption(W) | Cooling Efficiency(%) |
|---|---|
| 10 | 2 |
| 30 | 15 |
| 50 | 45 |
| 70 | 75 |
| 90 | 95 |

Table 2 presents the relationship between power input and cooling efficiency. Efficiency increases with power but stabilizes beyond 70W, showing diminishing returns. This suggests that an optimal power range must be maintained for efficiency.

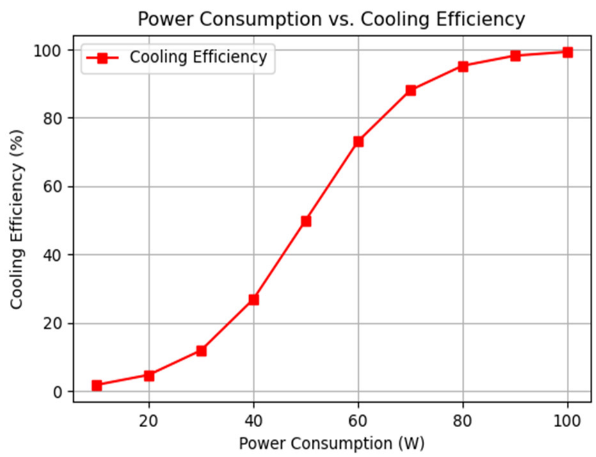


**Fig 7: Power Consumption vs. Cooling Efficiency**

Fig. 7 illustrates that efficiency improves with power input but plateaus after 70W. Beyond this, additional power does not significantly enhance cooling performance. The graph emphasizes the need for controlled power consumption.

## Table 3: Coefficient of Performance

| Power Input (W) | Cooling Power (W) | COP |
|---|---|---|
| 50 | 15 | 0.30 |
| 100 | 35 | 0.35 |
| 150 | 55 | 0.37 |
| 200 | 70 | 0.35 |

Table 3 shows that COP increases with power input, peaking at 0.37 at 150W. Beyond this, efficiency declines due to thermal saturation. This suggests an optimal power limit for maximizing efficiency.

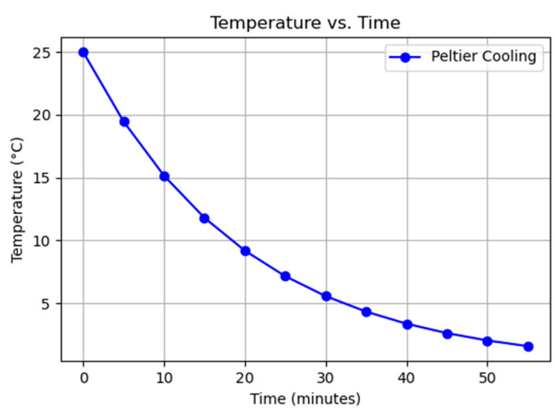


**Fig 8: Coefficient of Performance (COP)**

Fig. 8 visually represents the COP trend, showing efficiency peaks at 150W and drops at higher power levels. The decline indicates the impact of thermal limitations. Maintaining balanced power input is crucial for optimal performance.

## Conclusion:

The Peltier -based air conditioning system successfully demonstrates an alternative of energy efficiency and refrigerant free to conventional AC, which offers a sustainable cooling solution. Although the system effectively reduces the temperature, its cooling speed is slower due to thermal saturation to higher power levels, highlighting the need for optimized heat dissipation. Future improvements can focus on improving cooling efficiency through advanced heat dissipator, liquid cooling techniques and dynamic energy management techniques to regulate energy consumption effectively. In addition, the integration of hybrid cooling approaches, such as phase change materials or thermoelectric-photovoltaic systems, can further improve performance. The incorporation of renewable energy sources such as solar energy will improve sustainability, while IoT -based intelligent automation can allow real -time monitoring, adaptive control and easy to use operation. With these advances, the Peltier -based cooling system can become a viable, scalable and ecological alternative for residential, commercial and out of the network.

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