

Design and Fabrication of a Smart Compressor-Less Refrigerator Using Peltier Module and IOT

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Abstract— This project presents the design and fabrication of a smart compressor-less refrigerator using thermoelectric Peltier cooling integrated with Arduino-based control and Internet of Things (IoT) monitoring. Unlike conventional refrigerators, the proposed system does not use a mechanical compressor or refrigerant, thereby providing silent operation, compact construction, and reduced maintenance. Two thermoelectric modules are installed with aluminium heat sinks and exhaust fans to transfer heat from the cooling chamber and improve thermal performance. Two high-speed BLDC fans are provided inside the chamber for uniform circulation of cooled air. The system is powered by a 12 V, 10 A SMPS as the external supply and a 12 V, 7 Ah battery for backup operation. An Arduino controller receives temperature and humidity measurements from sensors and manages the cooling and auxiliary devices. An IoT module connected to a cloud server enables real-time remote monitoring of temperature, humidity, and system status. LED lighting and control switches improve usability. The developed refrigerator is intended as an energy-conscious, eco-friendly, and portable cooling solution for small-scale food storage, medicines, laboratory samples, and other temperature-sensitive applications. The combination of dual-module cooling, forced heat dissipation, controlled air circulation, and continuous sensing is expected to improve practical cooling reliability.

Keywords—*Thermoelectric Cooling, Peltier Module, Compressor-less Refrigerator, Arduino, IoT.*

I. INTRODUCTION

Refrigeration is an important technology for preserving food, medicines, beverages, laboratory samples, and other temperature-sensitive materials. Conventional refrigeration systems generally employ mechanical compressors and refrigerants to remove heat from an enclosed chamber.

Although compressor-based refrigerators provide effective cooling, they involve moving components, produce operational noise, require maintenance, and depend on refrigerant-based vapor-compression cycles. These limitations create a need for compact and reliable alternatives for small-scale cooling applications [1][2].

Thermoelectric refrigeration provides an alternative approach based on the Peltier effect. When direct current is supplied to a thermoelectric module, heat is transferred from one surface to the other, producing a cold side and a hot side. Because the cooling mechanism is solid-state, it does not require a compressor or circulating refrigerant. This makes Peltier cooling attractive for portable refrigerators and applications where simplicity, low maintenance, silent operation, and compact construction are important. However, effective heat removal from the hot side is essential because poor heat dissipation can reduce the temperature difference and overall cooling performance [3][4].

The proposed project focuses on the design and fabrication of a smart compressor-less refrigerator using two thermoelectric modules. Each module is coupled with an aluminium heat sink and an exhaust fan to remove heat from the hot side. Two high-speed BLDC fans are installed inside the cooling chamber to circulate cooled air and improve temperature uniformity. An aluminium frame and insulated chamber provide the structural enclosure and reduce unwanted heat transfer between the interior and surrounding environment [5].

The electrical system uses a 12 V, 10 A SMPS as the main external power source and a 12 V, 7 Ah rechargeable battery for backup operation. An Arduino controller acts as the central control unit. Temperature and humidity sensors continuously

measure the internal chamber conditions and provide feedback to the controller. Based on the measured conditions, the controller can manage the cooling system and associated loads through suitable control switches [6].

IoT technology is incorporated to make the refrigerator more intelligent and accessible. An IoT module communicates the measured temperature, humidity, and relevant operating information to a cloud server. This enables real-time monitoring and provides the possibility of observing refrigerator conditions remotely through an internet-connected device. LED lighting is also incorporated to improve visibility inside the chamber during operation [7].

The developed system is therefore intended to combine thermoelectric cooling, electronic control, battery backup, and IoT monitoring in a compact refrigerator. The proposed design aims to provide a practical compressor-less cooling solution for small-scale applications such as food preservation, medicine storage, laboratory samples, and portable refrigeration. Its compressor-free construction, silent operation, reduced mechanical complexity, and smart monitoring capability make it a useful platform for demonstrating thermoelectric and IoT based refrigeration technology. The system also provides a foundation for future improvements such as automated set-point control, energy monitoring, predictive maintenance, improved insulation, and advanced cloud-based analytics. By integrating these functions, the project demonstrates how thermoelectric refrigeration can be developed beyond a basic cooling unit into a connected smart appliance. The approach emphasizes practical fabrication, controllability, monitoring, and reliable operation for localized cooling applications [8][9][10].

II. PROBLEM IDENTIFICATION

- **High Power Consumption:** Conventional refrigerators use compressor-based refrigeration systems that can consume considerable electrical power, making them less suitable for small-scale and portable cooling applications.
- **Use of Refrigerants:** Conventional systems require refrigerants and mechanical compression cycles, which increase system complexity and may create environmental concerns.
- **Mechanical Complexity:** Compressors contain moving components that can generate noise, require maintenance, and increase the overall size and weight of refrigeration systems.
- **Limited Smart Monitoring:** Basic thermoelectric refrigerators generally do not provide continuous monitoring of internal temperature and humidity or remote access to operating conditions.
- **Poor Heat Dissipation:** Peltier-based systems can experience reduced cooling performance when heat generated on the hot side is not effectively removed using suitable heat sinks and exhaust fans.
- **Non-uniform Cooling:** Insufficient air circulation inside the cooling chamber can produce temperature variations and reduce effective cooling of stored materials.
- **Power Interruption:** Dependence on a continuous external power supply can interrupt refrigeration during electrical failures. Therefore, battery backup, Arduino-based control, and IoT monitoring are required to develop a reliable smart compressor-less refrigerator.

A. Existing System

The existing refrigeration system mainly uses a conventional vapor-compression cycle consisting of a compressor, condenser, expansion device, and evaporator. The compressor circulates refrigerant through the system to remove heat from the refrigerated space and maintain the required temperature. Such refrigerators are widely used for domestic, commercial, medical, and food-storage applications because they provide effective and continuous cooling. Conventional systems generally operate directly from the electrical grid and use mechanical components for refrigeration. Some existing portable thermoelectric refrigerators use Peltier modules, heat sinks, and fans instead of compressors. However, the uploaded project material mainly describes a solar-powered thermoelectric system, whereas the proposed system eliminates solar integration and focuses on dual-Peltier cooling with Arduino and IoT monitoring.

B. Drawbacks

The existing refrigeration approaches have several limitations. Conventional compressor-based refrigerators contain moving mechanical components, resulting in noise, maintenance requirements, and greater system complexity. They also depend on refrigerants and comparatively larger refrigeration assemblies. Basic thermoelectric refrigerators can overcome compressor-related limitations but may suffer from low cooling efficiency because Peltier modules generate considerable heat on their hot side. Inadequate heat dissipation can further reduce cooling performance. Non-uniform air circulation may also produce temperature differences inside the chamber. Existing systems may lack integrated IoT monitoring, automatic control, and battery backup. The uploaded material also identifies insufficient heat dissipation, limited smart control, and the need for compact and reliable thermoelectric refrigeration as important limitations.

III. LITERATURE REVIEWS

A) Literature Survey:

Zhang et al. 2023, investigated the geometric optimization of thermoelectric coolers using finite-element simulations. The study examined important structural parameters such as thermoelectric leg dimensions, spacing between P/N legs, copper thickness, and the distance between the leg edges and copper edges. Their influence on maximum temperature difference, coefficient of performance, and thermal stress was evaluated. The research demonstrated that appropriate geometric optimization can significantly improve thermoelectric performance while reducing undesirable thermal stresses. The study is particularly relevant to the proposed refrigerator because it confirms that Peltier-module construction and thermal design strongly influence cooling performance.

Chen et al. 2023, studied the performance of a thermoelectric refrigerator operating under natural convection conditions. A three-dimensional numerical model was developed and experimentally validated to investigate cooling behavior. The researchers examined the influence of thermoelectric cooler configuration and heat-transfer

conditions on refrigerator performance. Results indicated that increasing the number of cooling modules can improve thermoelectric cooling performance, while increasing fin height reduces internal air temperature. However, changes in fin height had relatively limited influence on cooling capacity and COP. The study demonstrates the importance of module arrangement and heat-dissipation design for achieving effective cooling in compact thermoelectric refrigeration systems.

Rudresha N. et al. 2023, This study investigated the performance of thermoelectric refrigeration systems using computational fluid dynamics. Different refrigerator configurations and insulation arrangements were analyzed using ANSYS. The researchers examined the influence of insulation materials and airflow characteristics on the thermal performance of the cooling chamber. Aluminium foil and polyurethane foam were considered for improving insulation and controlling heat transfer. The research highlighted that thermoelectric refrigerators generally have lower COP than conventional vapor-compression systems, making thermal management particularly important. The study emphasized that system-level improvements, especially heat dissipation, insulation, and airflow management, can significantly improve the practical performance of Peltier-based refrigeration systems.

Yang et al. 2023, proposed a new thermal-management approach for thermoelectric coolers by combining radiative sky cooling with conventional air cooling. The objective was to increase cooling capacity while reducing power consumption. The investigation demonstrated that suitable thermal-management conditions can improve the performance of thermoelectric cooling systems compared with standalone air cooling. The study also identified an appropriate relationship between cooling intensity and thermal-management area. Although the proposed system differs from the exhaust-fan arrangement used in the present project, its findings strongly support the importance of efficient hot-side heat removal. This principle is directly applicable to the proposed dual-Peltier refrigerator using aluminium heat sinks and exhaust fans.

Chen and Zhang 2023, investigated the use of phase-change materials to improve the cooling performance and energy efficiency of thermoelectric cooling systems. A simulation model of a two-stage thermoelectric cooler was developed and coupled with a heat-storage structure. The phase-change material absorbs heat during its phase transition, helping control the temperature of the heat sink and improve the temperature difference across the thermoelectric module. The research demonstrated that advanced thermal management can enhance cooling performance under high-current conditions. The findings are relevant to the proposed project because they emphasize that effective removal and management of Peltier hot-side heat is essential for maintaining stable and efficient refrigeration.

Okorie et al. 2024, designed and fabricated a compact mini refrigerator using a Peltier thermoelectric module. The Peltier device was positioned between an internal cooling radiator and an external heat sink to transfer heat from the refrigeration chamber to the surrounding environment. The research focused on portability, compact size, and cost effectiveness. Heat generated at the hot side was removed

using a heat-sink and fan assembly. The study demonstrated the practical feasibility of Peltier technology for small refrigeration applications. Its architecture closely relates to the proposed refrigerator because the present design also uses thermoelectric modules, aluminium heat sinks, and forced-air cooling without requiring a conventional compressor or refrigerant.

Elnaggar et al. 2024, investigated methods for improving the coefficient of performance of mini refrigerators using Peltier thermoelectric units. The research examined the relationship between operating voltage, temperature difference, and thermoelectric refrigerator performance. Improving the thermal and electrical operating conditions of Peltier modules was considered important for increasing cooling effectiveness and reducing unnecessary energy consumption. The study is significant for compact refrigerator development because thermoelectric systems generally have lower COP than conventional refrigeration. Its findings support the need for optimized operating conditions, adequate heat dissipation, and suitable module selection. These considerations are incorporated into the proposed system through dual Peltier modules, heat sinks, exhaust fans, and controlled 12 V electrical operation.

Sankar et al. 2024, experimentally investigated a Peltier-based thermoelectric refrigerator and examined the effect of using different numbers of Peltier modules. Three thermoelectric modules were employed, and experiments were conducted using one, two, and three modules. The modules absorbed heat from the cold side and rejected it through the hot side using heat sinks and fans. The study demonstrated the influence of module quantity on refrigeration performance and explored waste-heat utilization. This work is particularly relevant to the proposed refrigerator because it experimentally supports multi-module Peltier cooling. The present system similarly uses two thermoelectric modules to increase cooling capacity while maintaining a compact refrigerator configuration.

Amri et al. 2025, developed an IoT-enabled thermoelectric coolbox for mango storage using a TEC1-12706 Peltier module and an additional ice-pack arrangement. The system was designed to maintain suitable storage conditions while enabling remote monitoring through IoT technology. Temperature and environmental information could be observed remotely, demonstrating the usefulness of connected monitoring for thermoelectric cooling applications. The study is highly relevant to the proposed smart refrigerator because both systems combine Peltier cooling with IoT-based supervision. However, the proposed project extends this concept by using two Peltier modules, Arduino control, humidity monitoring, BLDC circulation fans, battery backup, and cloud-based monitoring for a more integrated smart refrigerator.

Said et al. 2025, designed, fabricated, and experimentally evaluated a compact 4.7-liter thermoelectric cold-storage system intended for low-power and decentralized refrigeration. The prototype incorporated a TEC1-12706 Peltier module, aluminium finned heat sinks, black-foam insulation, and a variable DC power supply. Experimental testing produced a cooling load of 43.1 W with a 77 W electrical input at 6.4 A. The research confirms that proper insulation, heat-sink design, and appropriate electrical

operation are important for achieving useful cooling from compact Peltier systems. These findings directly support the proposed project, which uses dual Peltier modules, aluminium heat sinks, insulation, and controlled 12 V power for improved refrigerator performance.

Alghanima et al. 2022, investigated different cold-side heat-sink configurations and fan operating conditions in a thermoelectric compartment integrated into a household refrigerator. The study showed that heat-sink geometry and airflow strongly influence temperature uniformity and cooling performance. Operating the fan at 2000 rpm produced approximately 20% higher COP than operation at 500 rpm. Vertical slots in the heat sink improved air distribution compared with a simple plate-fin arrangement. The findings directly support the proposed refrigerator because it uses heat sinks and high-speed BLDC fans for improved cold-side air circulation. The study demonstrates that appropriate fan speed and heat-sink geometry are important for achieving uniform cooling and improved thermoelectric refrigerator performance.

Joemax Agu et al. 2023, developed a portable thermoelectric refrigeration system based on the Peltier effect. The system was designed to maintain storage temperatures between 10°C and 20°C under ambient conditions approaching 30°C. Heat generated at the hot side was removed using heat sinks and fans. Experimental observations showed that the refrigerator could maintain the required temperature with approximately 65 W power consumption. The research confirms the feasibility of Peltier modules for compact refrigeration applications where portability, silent operation, and reduced mechanical complexity are important. These findings are relevant to the proposed system because it similarly uses Peltier modules, aluminium heat sinks, forced-air cooling, and a 12 V electrical supply.

Thapa et al. 2023, studied and fabricated a thermoelectric refrigerator using the Peltier effect and experimentally evaluated different thermal-management configurations. The investigation compared hot-side cooling using fan-enhanced heat pipes and conventional air cooling. Different cold-side heat-sink shapes, air-circulation arrangements, and numbers of thermoelectric modules were also examined. The work emphasized that thermoelectric refrigeration offers compactness, portability, reliability, low noise, and zero direct refrigerant emissions. Experimental comparison of module quantity and airflow provided useful information for improving cooling performance. The research is closely related to the proposed project because the present refrigerator also requires optimized heat dissipation, cold-air circulation, and suitable selection of multiple Peltier modules.

Adutwum et al. 2022, developed a low-power thermoelectric refrigeration system by retrofitting an existing refrigerator with Peltier modules and electronic control circuits. The thermoelectric module was positioned between two heat sinks, with the cold-side heat sink installed inside the cabinet and the hot-side heat sink exposed externally. Experimental testing demonstrated measurable cooling while eliminating the requirement for environmentally harmful refrigerants. The study reported cold-side and hot-side temperatures of approximately -2.1°C and 39.4°C under one operating condition. However, its performance remained below conventional refrigeration. The work highlights the

importance of hot-side heat rejection and demonstrates the practical feasibility of converting conventional cabinets into compressor-less thermoelectric refrigeration systems.

Jayanth et al. 2023, fabricated a portable refrigerator using a thermoelectric Peltier module. The cold side of the module was positioned inside the refrigerator cabinet, while the hot side was connected to a heat sink and fan for heat rejection. Temperature measurements were obtained using thermocouples and a data-logging arrangement. The researchers also evaluated heat rejection and coefficient of performance. The study demonstrated that Peltier technology can provide a compact and portable refrigeration solution without moving compressors or circulating refrigerants. Its design approach is particularly relevant to the proposed project because the present system also uses Peltier modules, heat sinks, exhaust fans, an aluminium chamber, and electronic temperature monitoring.

Faraz Afshari et al. 2023, This study developed and experimentally evaluated a thermoelectric refrigeration system using a boosted heat exchanger without conventional fans or pumps. Numerical CFD analysis was combined with experimental testing to investigate thermal behavior and heat transfer. The research highlighted that thermoelectric refrigeration can be compact, portable, and simple compared with vapor-compression systems. The fanless architecture was investigated specifically to reduce noise and vibration caused by auxiliary mechanical components. Although the proposed system uses exhaust fans and BLDC fans rather than a fanless configuration, the research emphasizes the importance of optimizing heat exchangers and thermal paths. Such findings are useful for improving the aluminium heat-sink arrangement of the proposed refrigerator.

Alam et al. 2023, developed a thermoelectric refrigerator using two Peltier modules, two heat sinks, cooling fans, and an internal circulation fan. The experimental refrigerator was evaluated under different environmental conditions to determine its cooling response and coefficient of performance. The dual-module configuration demonstrated significant cooling improvement, with the cabin temperature decreasing substantially during testing. The study achieved a COP of approximately 0.61 under the investigated operating condition. Although the system was powered using solar energy, its dual-Peltier arrangement is highly relevant to the proposed project. The research confirms that combining multiple thermoelectric modules with effective heat sinks and internal air circulation can improve practical refrigeration performance.

Abu Raihan Mohammad Siddique et al. 2023, The researchers proposed a phase-change-material-enhanced thermoelectric cooling system for food refrigeration and storage. An organic phase change material was integrated with a Peltier-based cooling system to provide additional passive thermal storage and temperature regulation. The prototype was designed to maintain low storage temperatures while reducing dependence on continuous electrical cooling. Experimental results demonstrated that the system could achieve temperatures below 5°C with low power input under the investigated conditions. The research also considered environmental impacts through life-cycle assessment. The study demonstrates an advanced method for improving thermoelectric refrigeration performance and provides a

possible future direction for the proposed refrigerator through additional thermal storage.

R. N., V. K. M., M. M. Math et al, 2023, The researchers performed a CFD-based investigation of thermoelectric refrigeration using ANSYS to study internal airflow, insulation, and refrigerator geometry. Different insulation configurations and internal designs were evaluated to determine their influence on temperature distribution and cooling performance. The investigation reported temperature differences in the approximate range of 7.5–9.4°C for the studied configurations. The optimized sharp-edge configuration showed better thermal performance than partially rounded and filleted designs. The authors also suggested future integration of multistage Peltier modules and smart temperature control. This recommendation is directly aligned with the proposed project, which combines multiple Peltier modules with Arduino-based control and IoT monitoring.

Hichem Ykrelef, et al. 2025, designed and experimentally evaluated a thermoelectric refrigerator operating near room temperature and investigated thermal behavior using artificial neural-network-based modelling. The prototype used thermoelectric modules with a maximum cooling capacity of approximately 46 W. The research focused on predicting and improving refrigerator thermal performance under different operating conditions. Application of ANN methods provided a means of estimating thermal behavior and supporting design optimization. The study demonstrates the potential of intelligent control and computational prediction for improving thermoelectric refrigeration. Its findings provide a foundation for future enhancement of the proposed Arduino-IoT refrigerator through data-driven temperature prediction, adaptive cooling control, and cloud-based performance analysis.

B) Literature Summary

- Recent studies demonstrate that Peltier-based refrigeration provides compact, silent, compressor-less cooling without conventional refrigerants, making it suitable for portable and small-scale applications.
- Research shows that heat-sink design and forced-air cooling significantly influence Peltier performance by effectively removing heat from the hot side.
- Studies using multiple thermoelectric modules report improved cooling capacity compared with single-module configurations when thermal management is properly designed.
- Insulation and internal air circulation improve temperature uniformity and reduce unwanted heat gain inside the chamber.
- Recent research increasingly integrates IoT and intelligent monitoring, enabling remote temperature observation and data management.
- Overall, literature supports combining dual Peltier modules, efficient heat dissipation, Arduino control, sensors, IoT monitoring, and battery backup for practical smart refrigeration.

C) Research Gap

- Many existing Peltier refrigerator studies focus mainly on cooling performance and thermal analysis, while integrated smart monitoring remains comparatively limited.

- Several prototypes use single Peltier modules, restricting cooling capacity and making them less suitable for larger or more practical cooling chambers.
- Inadequate hot-side heat dissipation remains a major limitation, particularly when compact heat sinks and insufficient airflow are used.
- Existing systems often lack simultaneous temperature and humidity monitoring with automatic controller-based operation.
- Remote IoT/cloud monitoring is not consistently incorporated into thermoelectric refrigeration prototypes.
- Battery-backed operation is also insufficiently addressed for uninterrupted cooling.
- Therefore, the proposed system combines dual Peltier modules, aluminium heat sinks, exhaust fans, BLDC air circulation, Arduino control, temperature-humidity sensing, IoT cloud monitoring, and 12V battery backup in one integrated compressor-less refrigerator.

IV. RESEARCH METHODOLOGY

A) Proposed System

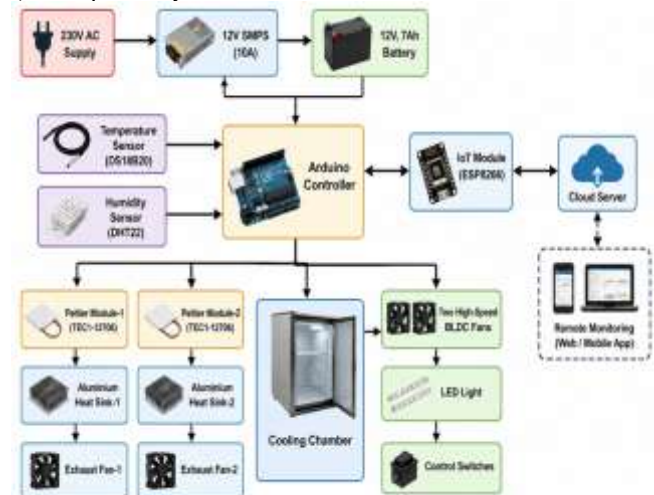


Figure 1. Block Diagram

- Power Supply:** The system receives 230 V AC input, which is converted into regulated 12 V DC using a 12 V, 10 A SMPS. A 12 V, 7 Ah battery provides backup power during mains interruption.
- Controller Operation:** The Arduino controller acts as the central control unit. It receives sensor information and controls the Peltier modules, fans, LED light, and other connected devices according to programmed conditions.
- Temperature and Humidity Monitoring:** A temperature sensor and humidity sensor continuously measure the internal conditions of the cooling chamber. The measured values are processed by Arduino for monitoring and cooling control.
- Thermoelectric Cooling:** Two 12 V Peltier modules are installed between the cooling chamber and external heat-dissipation arrangement. When DC power is applied, heat is transferred from the cold side toward the hot side, producing cooling inside the chamber.
- Heat Dissipation:** Aluminium heat sinks are attached to the hot sides of the Peltier modules. Exhaust fans remove accumulated heat from the heat sinks, helping maintain effective heat rejection and improve cooling performance.
- Air Circulation and Illumination:** Two high-speed BLDC fans circulate cooled air throughout the chamber to reduce temperature variation. LED lights provide internal

illumination, while control switches allow convenient system operation.

- IoT Monitoring: The IoT module receives operating information through the Arduino and transmits temperature, humidity, and system status to a cloud server. This enables real-time remote monitoring and supports intelligent operation of the refrigerator.

B) Hardware Used

- Thermoelectric Peltier Modules: Two 12 V Peltier modules are used to produce cooling through the thermoelectric effect. They transfer heat from the cooling chamber toward the hot side.
- Aluminium Cooling Chamber: An aluminium-framed insulated chamber forms the refrigerator enclosure and provides a lightweight structure for storing temperature-sensitive materials.
- Aluminium Heat Sinks: Heat sinks are mounted on the hot sides of the Peltier modules to absorb and dissipate generated heat effectively.
- Exhaust Fans: Two 12 V exhaust fans remove heat from the heat sinks and improve hot-side thermal management.
- High-Speed BLDC Fans: Two BLDC fans circulate cooled air inside the chamber, helping maintain more uniform temperature distribution.
- Arduino UNO: The Arduino acts as the main controller, processing sensor readings and controlling cooling and auxiliary operations.
- Temperature and Humidity Sensors: These sensors continuously measure chamber temperature and humidity and provide feedback to the Arduino.
- ESP8266 IoT Module: The Wi-Fi module transfers monitored parameters to the cloud server for remote observation.
- 12 V, 10 A SMPS: Provides the primary regulated DC power required by the refrigerator components.
- 12 V, 7 Ah Battery: Provides backup power during external supply interruptions.
- LED Lights and Control Switches: LED lights illuminate the chamber, while switches provide convenient manual control of system functions.

V. CALCULATION

1. Peltier Module Power

For one TEC1-12706 module:

$$P=V \times I$$

$$P=12 \times 6=72W$$

For two modules:

$$P_{Peltier} = 2 \times 72 = 144W$$

Total Peltier power = 144 W

2. Exhaust Fan Power

Assuming each 12 V exhaust fan consumes approximately 0.25 A:

$$P=12 \times 0.25=3W$$

For two fans:

$$P_{exhaust} = 2 \times 3 = 6W$$

Exhaust-fan power = 6 W

3. Internal BLDC Fan Power

Assuming each 12 V BLDC fan consumes approximately 0.20 A:

$$P=12 \times 0.20=2.4W$$

For two fans:

$$P_{BLDC} = 2 \times 2.4 = 4.8W$$

BLDC fan power = 4.8 W

4. Control and IoT Power

Approximate power consumption:

Arduino = 0.3 W

ESP8266 = 0.6 W

Temperature/humidity sensors = 0.2 W

LED lighting = 2 W

$$P_{control} = 0.3 + 0.6 + 0.2 + 2$$

$$P_{control} = 3.1W$$

5. Total Electrical Power

$$P_{total} = P_{Peltier} + P_{exhaust} + P_{BLDC} + P_{control}$$

$$P_{total} = 144 + 6 + 4.8 + 3.1$$

$$= 157.9 \text{ w}$$

VI. ADVANTAGES AND APPLICATIONS

A) Advantages

- Compressor-less operation: No mechanical compressor is required, reducing noise, vibration, and maintenance.
- Eco-friendly: Peltier cooling operates without conventional refrigerants.
- Compact design: Aluminium construction provides a lightweight and portable refrigerator.
- Smart monitoring: IoT enables real-time temperature and humidity monitoring through the cloud.
- Reliable cooling: Dual Peltier modules and BLDC fans provide effective air circulation.
- Battery backup: 12V, 7Ah battery supports operation during power interruptions.
- Low maintenance: Solid-state thermoelectric modules have fewer moving components.

B) Applications

- Food preservation: Suitable for storing fruits, vegetables, dairy products, and beverages.
- Medicine storage: Can be used for temperature-sensitive medicines and small medical supplies.
- Laboratory applications: Suitable for temporary storage of laboratory samples.
- Portable refrigeration: Useful for outdoor, transportation, and remote cooling requirements.
- Agricultural applications: Supports short-term preservation of agricultural products.
- Educational projects: Demonstrates Peltier cooling, Arduino control, and IoT technology.
- Small commercial use: Suitable for compact cooling requirements in shops, offices, and laboratories.

VII. CONCLUSION

The proposed project successfully presents the design and fabrication concept of a smart compressor-less refrigerator using thermoelectric Peltier technology and IoT. The system replaces the conventional compressor-based refrigeration mechanism with two Peltier modules, providing a compact, silent, and low-maintenance cooling solution. Aluminium heat sinks and exhaust fans are incorporated to remove heat effectively from the hot sides of the thermoelectric modules, while two high-speed BLDC fans circulate cooled air throughout the chamber for improved temperature uniformity.

The refrigerator is operated using a 12 V, 10 A SMPS, with a 12 V, 7 Ah battery provided as backup during power interruptions. An Arduino controller continuously processes temperature and humidity sensor data and manages the connected cooling and auxiliary components. The integration of an IoT module and cloud server enables real-time remote monitoring of chamber conditions and system status.

The proposed system eliminates the requirement for conventional refrigerants and mechanical compressor components, making it environmentally friendly and easier to maintain. The combination of dual-Peltier cooling, effective thermal management, controlled air circulation, battery backup, and IoT monitoring provides a practical smart refrigeration platform. The developed concept is suitable for food preservation, medicine storage, laboratory samples, portable refrigeration, and small-scale cooling applications.

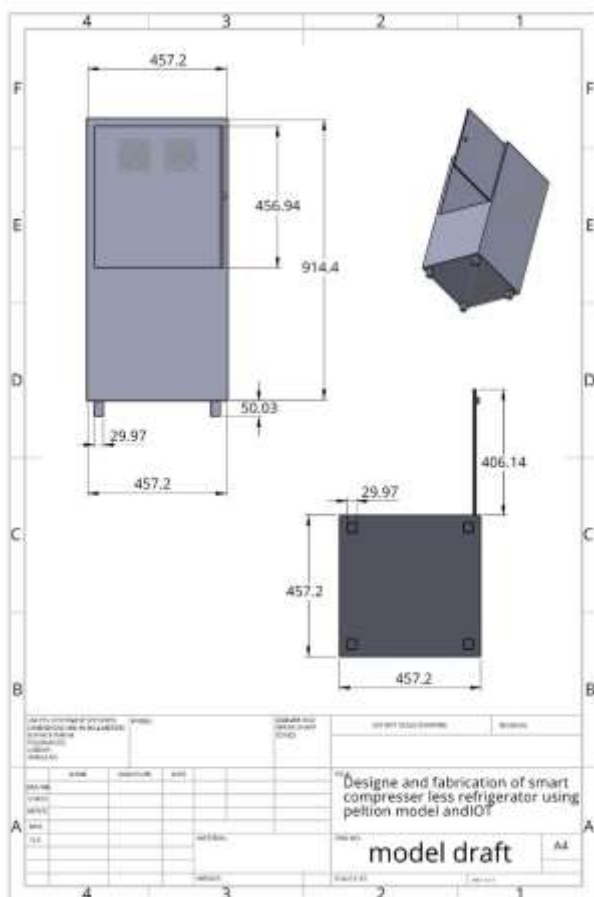
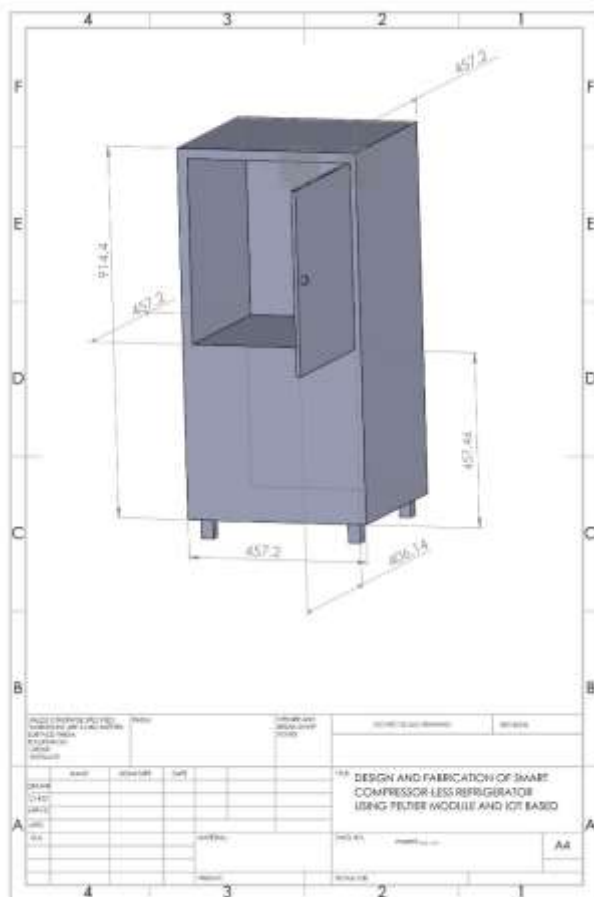


Figure 2. 3D model

VIII. FUTURE SCOPE

- AI-Based Control: Future systems can use AI algorithms to predict cooling requirements and automatically optimize Peltier operation, fan speed, and energy consumption.
- Advanced IoT: Mobile applications, cloud analytics, alerts, and historical data logging can provide improved remote monitoring and predictive maintenance.
- Improved Thermal Management: Advanced heat sinks, phase-change materials, better insulation, and optimized Peltier arrangements can improve cooling capacity, COP, and battery backup duration.

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