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Evercold Tech: A Proposed Portable Temperature-Control Device

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Abstract - *Portable temperature control can be useful when beverages or temperature-sensitive items need to be kept within a chosen range during everyday use. Evercold Tech is a student project proposing a compact temperature-control device that combines thermoelectric cooling with electrically controlled heating. The proposed cooling path uses a Peltier module, heat sink, and fan, while an ESP32 controller is intended to read a temperature sensor and coordinate operation. A Kapton-film heater is also being considered for the heating function. The current design notes include a power-regulation stage and battery-management components, although final ratings and some component choices still need confirmation. The project is also exploring medicine-storage integration; this remains a possible application rather than a validated medical-storage product. Hardware integration and software work are ongoing, so no measured cooling rate, temperature stability, energy use, or medicine-storage performance is claimed. This paper describes the motivation, related thermoelectric systems, proposed architecture, intended control sequence, and a practical evaluation plan. The next stage is to assemble the device, confirm safe operating limits, and collect repeatable temperature and power measurements before drawing conclusions about its performance.*

Keywords - ESP32, Kapton-film heater, medicine-storage integration, Peltier cooling, temperature monitoring, thermoelectric system

1. INTRODUCTION

Portable temperature control is useful when a person needs to keep a drink or another item near a chosen temperature while away from a fixed refrigerator or heater. A conventional insulated container can slow temperature change, but it cannot actively correct the temperature once the contents begin to warm or cool. Small thermoelectric modules offer one possible approach because they move heat when supplied with electrical power and do not require a compressor-based refrigeration cycle [1], [2]. Their practical performance, however, depends strongly on heat rejection, electrical input, insulation, and the load being cooled.

Evercold Tech is a Problem-Based Learning project exploring a compact device that combines Peltier-based cooling with a separate Kapton-film heating element. The initial idea was framed around a cooling bottle, but the project is now considering a broader device concept that may support medicine-storage integration. The immediate goal is to build and understand the temperature-control hardware first. The medicine-storage idea is not yet validated, and no particular medicine or storage-temperature range has been selected.

The main engineering problem is therefore not simply to make one side of a Peltier module cold. The system must also remove heat from its hot side, measure temperature reliably, switch high-current loads safely, and avoid unintended simultaneous heating and cooling. A portable design must account for power consumption and physical separation between electronics, hot surfaces, and any stored contents. These points guide the proposed architecture and the evaluation plan in this paper.

The present contribution is a documented design proposal and a test plan based on the project materials available at the time of writing. It does not report a completed prototype or experimental findings. The remaining sections review relevant thermoelectric cooling work, describe the proposed components and control sequence, define the measurements needed for evaluation, and discuss limitations and next steps.

2. RELATED WORK

Al-Rubaye, Al-Farhany, and Al-Chlaihawi experimentally studied a portable thermoelectric water-cooling system [1]. Their work examined applied voltage, heat-sink fan speed, and initial water temperature. The authors reported that fan speed and starting water temperature affected thermal performance, while increasing the applied voltage reduced the coefficient of performance in their test conditions. This is directly relevant to Evercold Tech: a Peltier module cannot be selected or driven independently of the heat sink, fan, and available electrical power.

Hammad and colleagues described a water-cooling arrangement based on the Peltier effect and presented it as a compact alternative for cooling water [2]. The article supports the general feasibility of using a thermoelectric module in a portable cooling concept. However, a general demonstration of Peltier cooling does not by itself establish how quickly a particular enclosure will cool, how

long it can maintain a setpoint, or how efficiently it will run. Those questions must be answered for the actual device and its thermal load.

Pourhedayat investigated an instant running-water cooler using thermoelectric modules and evaluated operating conditions such as water flow, voltage, and inlet temperature [3]. Unlike a storage container, that system cools water as it passes through a thermoelectric unit. Even though its arrangement differs from the present project, it reinforces the importance of measuring operating conditions rather than assuming that a thermoelectric module will deliver the same performance in every configuration.

Across these studies, the shared lesson is that heat rejection and operating conditions have a substantial effect on performance. Evercold Tech differs in its intended integration of an ESP32-based temperature-monitoring path, a Peltier cooling path, and a separate Kapton-film heater. The proposed medicine-storage use also creates a different validation requirement: the device would need to maintain a defined range appropriate to a specified item, not merely produce a noticeable cooling effect. The current project has not yet generated measurements that would establish such performance.

3. PROPOSED SYSTEM AND METHODOLOGY

The project is currently in the component-integration and software-development stage. The following architecture reflects the project notes and should be read as a proposed design, not as a verified circuit. Some component options and electrical ratings remain open and must be confirmed against the actual parts before the device is powered.

3.1 Functional Architecture

Fig. 1 presents the intended functional relationship between the temperature sensor, ESP32 controller, power stage, and two temperature-control outputs. The sensor provides feedback to the controller. Based on the selected operating mode and measured temperature, the controller is intended to command either the cooling drive or the heating drive. A power stage supplies the loads; it is separate from the low-voltage logic circuitry.

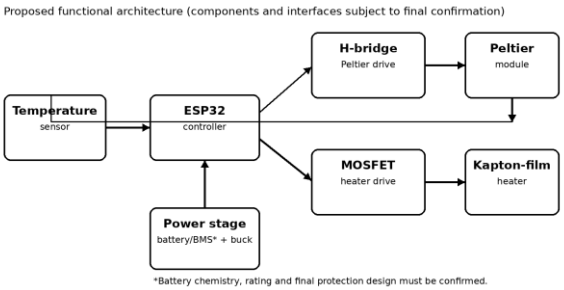


Fig. 1. Proposed functional block diagram; final wiring and component selection are still under development.

The project notes identify a TEC1-12715 Peltier module for cooling, an aluminium heat sink and DC fan for hot-side heat rejection, and an ESP32 for control. Temperature sensing is planned through either a DS18B20 sensor or an NTC thermistor; the final choice has not been confirmed. The ESP32 family provides programmable input/output and peripheral interfaces suitable for embedded control [4], but the exact pin mapping, sampling interval, and software structure for this project still need to be documented.

The Peltier module is intended to be driven through an H-bridge or the selected power-control arrangement stated in the project design. The final circuit must match the actual module current and voltage requirements. The Kapton-film heater is planned to use a MOSFET switching module. The two outputs should be interlocked in software so that cooling and heating are not commanded at the same time. A heat sink and fan are necessary on the hot side of the Peltier module; poor heat removal can reduce cooling performance and may overheat components.

The design notes also mention a battery with a battery-management system (BMS) and a buck converter. The proposed battery chemistry, capacity, current rating, charging method, fuse/protection arrangement, and converter ratings need confirmation before a portable power design can be considered safe. The diagram therefore shows the power stage at a functional level only. It is not a wiring schematic or a bill of materials ready for construction.



Peltier Chip (TEC) Temperature Sensor



ESP-32 Chip



Heat Sink And Fan

3.2 Proposed Control Sequence

The control logic is intended to follow a simple feedback loop. First, the controller reads the sensor and checks that the value is plausible. Second, it compares the measured temperature with the chosen setpoint and an allowed tolerance band. Third, it enables the cooling output when the temperature is above the upper limit, or the heating output when the temperature is below the lower limit. If the temperature is inside the tolerance band, both outputs remain off or operate according to a later-defined hold strategy. A delay or hysteresis band should be used to avoid rapid switching around the setpoint.

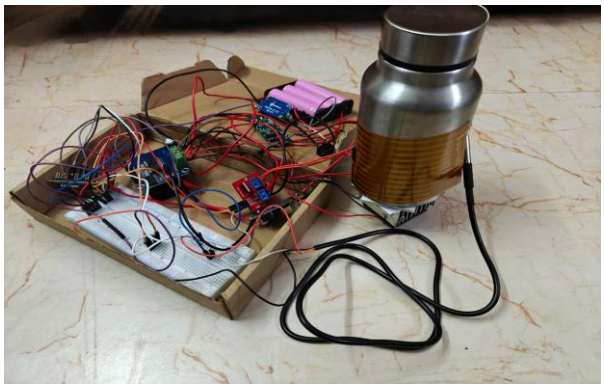
The controller should also enter a safe state if the sensor reading is missing or out of range, if the measured temperature exceeds a defined safety limit, or if a power-stage fault is detected. The actual thresholds cannot be specified until the target use, sensor, actuator ratings, and thermal arrangement are finalized. The project abstract mentions Python monitoring alongside the ESP32, but the available materials do not document a completed communication interface or software implementation. For that reason, Python monitoring is treated as an intended feature rather than a demonstrated function in this paper.

3.3 Planned Evaluation Procedure

After assembly, testing should begin with the electronics and actuators checked separately before the complete system is run. The sensor reading should first be compared with a reference thermometer over the intended operating range. The cooling and heating paths should then be tested individually with suitable current limits and with the heat sink and fan correctly installed. Only after these checks should closed-loop operation be attempted.

For each thermal test, the team should record ambient temperature, starting temperature, target temperature, elapsed time, supply voltage, and current. Tests should use the same starting conditions as far as practical and be repeated so that variation can be observed. The team should also record the location of the sensor and the position of the temperature probe, because a reading near the Peltier surface may not represent the temperature throughout the storage space. The medicine-storage concept should not be tested with actual medicines unless the relevant storage requirements and safety controls have been defined.

4. RESULTS AND PLANNED MEASUREMENTS



FINAL PROTOTYPE IMAGE

No measured performance results are available at the time of writing. The project materials state that hardware integration is in progress and that testing will follow assembly. It would therefore be misleading to report a cooling time, minimum temperature, heating rate, battery life, coefficient of performance, or temperature-stability value as though it had already been measured.

The first planned measure is temperature change over time. For a test interval, the average rate of change can be calculated as the difference between the final and initial temperatures divided by elapsed time. The sign and magnitude should be reported alongside the starting and ambient temperatures so that results from different tests are not compared without context. A second measure is temperature stability: once the target range is reached, the team should record how far the measured temperature moves above or below that range during a defined observation period.

Electrical input should be measured at the supply to the relevant load. Instantaneous electrical power can be estimated from $P = V \times I$, where V is the measured voltage and I is the measured current. Energy use over a test can then be estimated from the power readings over time. If the power varies during switching, logging several readings or integrating power over the interval will be more informative than using a single current value. The cooling results should be considered alongside power use, since a faster temperature drop may require substantially more energy.

The planned test matrix should vary one factor at a time where practical: fan speed, Peltier drive level, initial

temperature, and insulation or enclosure arrangement. The aim is to identify whether the system behaves consistently and which factors have the largest effect. The final report should present actual readings in a table or graph, include units and test conditions, and distinguish measured observations from explanations. Until these tests are complete, the results section remains a plan rather than an experimental finding.

5. DISCUSSION

The reviewed studies show that thermoelectric cooling can be applied to water-cooling systems, but they also show why a module rating alone is not enough to predict the performance of a new design [1]–[3]. Heat-sink quality, airflow, applied voltage, starting temperature, and thermal contact all influence the outcome. In Evercold Tech, the heat sink and fan must remove heat from the Peltier hot side while the cold side is coupled to the intended storage space. If heat accumulates around the module, the temperature difference available for cooling may become smaller and the system may consume power without reaching its target.

Adding a separate Kapton-film heater makes the concept more flexible, but it also adds a second power load and a new safety concern. The heater should be physically separated from sensitive contents and controlled with a temperature limit independent of the normal setpoint logic. The controller should not rely on software alone for every protection function; suitable component ratings, fusing, wiring, insulation, and thermal safeguards must be considered in the hardware design. Moisture and condensation around a cooled enclosure also need attention before the device is used repeatedly.

Medicine-storage integration should be treated cautiously. Different medicines can have different storage requirements, and the acceptable temperature range must come from the instructions for the specific product or authoritative guidance. A device that cools an empty enclosure does not automatically prove that it can hold the contents within the required range. Validation would need to measure temperatures at representative storage positions, check performance during opening and closing, and test behaviour under relevant ambient conditions. Until then, the project should be described as exploring a possible medicine-storage application, not as a medicine-safe product.

There are also limitations in the present documentation. The final sensor type, control thresholds, battery ratings, enclosure design, and details of the Python/ESP32 interface are not yet confirmed. No completed tests, calibration data, or power measurements were supplied for this paper. These gaps are normal for a design that is still being integrated, but they should be resolved systematically and reported transparently. The most useful next milestone is a safe, working bench prototype with a documented circuit and repeatable baseline measurements.

6. CONCLUSION AND FUTURE WORK

Evercold Tech proposes a portable temperature-control device that combines Peltier-based cooling, a Kapton-film heating element, temperature sensing, and ESP32-based control. The design is being considered for broader storage use, including a possible medicine-storage application. Existing thermoelectric cooling studies support the choice of technology, while also highlighting the importance of heat rejection and operating conditions. The present work documents the proposed architecture and a method for evaluating it; it does not claim a completed or validated prototype.

The next steps are to confirm the sensor and power components, complete the circuit and software integration, add appropriate electrical and thermal protection, and test each output independently before closed-loop operation. The team should then measure temperature change, temperature stability, voltage, current, and energy use under repeatable conditions. Any medicine-storage use should remain a future possibility until product-specific limits are defined and the assembled device is shown to maintain them reliably.

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