TERM-PROJECT REPORT ON TEMPERATURE CONTROLLER FOR SPLIT-CELL

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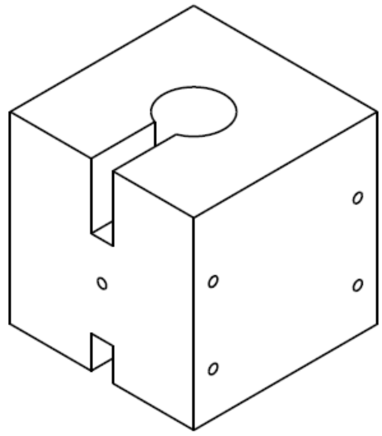
Abstract

Temperature regulation is critical for evaluating battery performance, longevity, and safety under diverse operating conditions. This report presents the design and fabrication of a thermoelectrically controlled enclosure capable of maintaining battery test cells within a 21–80°C range. The system utilises Peltier modules for cooling and a heater for heating, paired with an 85 × 85 × 85 mm aluminium block machined with precision-drilled holes, safety slots, and integrated sensors. A 12V, 20A AC to DC power supply drives the thermoelectric system, while a manual switchboard enables operators to toggle between heating and cooling modes, adjust power input, and activate a backup resistive heater. Key innovations include the use of aluminium's high thermal conductivity for rapid heat transfer, slots to isolate test cell terminals, and sensors for temperature monitoring. Testing validated the system's ability to achieve the target temperature range, though manual control introduces operational variability. This project highlights the feasibility of compact, low-cost thermoelectric solutions for battery testing, with recommendations for future automation and thermal efficiency improvements.

Introduction

This report details the design, fabrication, and operation of an aluminium enclosure integrated with thermoelectric (Peltier) and heater modules to control the temperature of battery test cells within a range of 21–80°C. The system combines manual control via a switchboard, safety features to prevent electrical contact, and sensors for temperature monitoring.



Isometric view of the block

Design Specifications

Base Material:

Aluminium Block: 85 × 85 × 85 mm (L × W × H).

Rationale:

High thermal conductivity (237 W/m·K), machinability, and lightweight properties.

Critical Features

Central Holes:

Top Hole: 28 mm diameter, 30 mm depth (test cell insertion).
Bottom Hole: 42.03 mm diameter, 55 mm depth (alignment with top hole).

Safety Slots: 15 mm deep slots on top and bottom faces to isolate test cell screws from the metal enclosure.

Thermoelectric System

1. **Peltier Modules:**
   Principle: Thermoelectric effect—direct current (DC) creates a temperature gradient (one side heats, the other cools).
   Specifications: A Peltier with a module number TECI-12706 has been used in this project.
   Placement: Mounted on the left and right faces of the block.
2. **Heat Sink & Fan:** Aluminium fins with axial fans (12V) to dissipate heat from the Peltier's hot side.

3. **Heater:**

   Type: Cartridge heater (stainless steel/NiCr wire).

   Power: 50–100W @ 12V DC (shared with Peltier system).

   Inserted 20 mm into the rear face of the aluminium block.

   Secured with thermal epoxy; wired to manual switchboard.

4. **Power Supply:** 12V, 20A DC (240W total), with automatic power adjustment.

5. **Temperature Sensor:** PT100 RTD or thermistor at the front face (accuracy ±0.5°C).

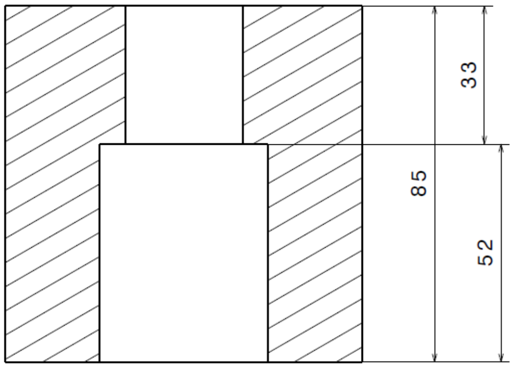
Control System

Manual Switchboard: This toggles Peltier polarity (heating/cooling modes) and activates the backup heater. Using the switchboard, all the electrical devices can be opened/closed.

Fabrication Steps

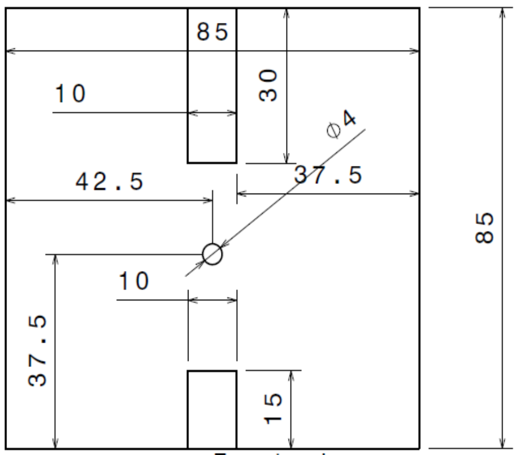
1. **Machining the Aluminium Block**

CNC drilling for central holes (ensure alignment between 28 mm top and 42.03 mm bottom holes).



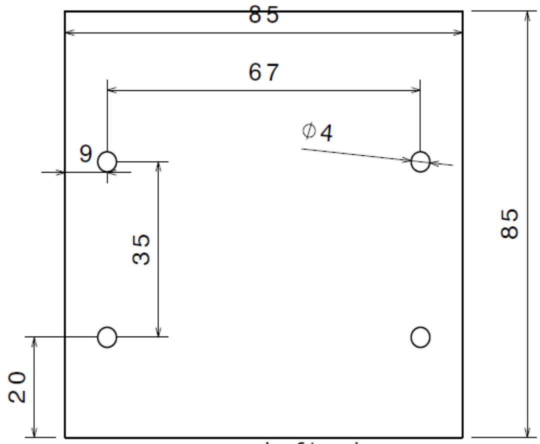
Sectional view of the aluminium block

Slot milling (15 mm depth) on top/bottom faces to prevent an electrical short circuit.



Front view

Engraving screw holes and holes for heater and temperature sensor.



Left view

Surface polishing to enhance thermal contact with Peltier modules.

2. **Peltier Installation**

   Apply thermal paste (HM501) between Peltier modules (e.g., TEC1-12706) and aluminium faces. Secure heat sinks/fans using screws and thermal adhesive.

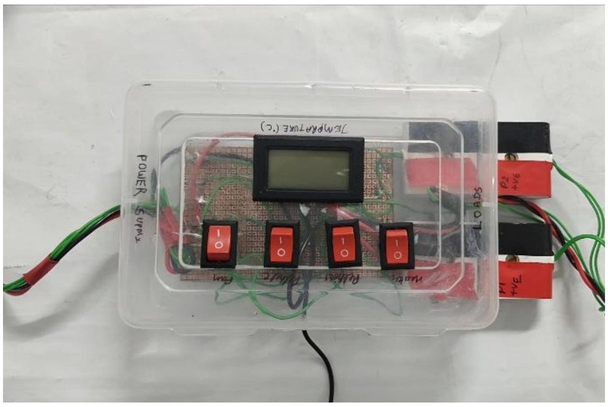
3. **Sensor Integration**

   Drill a 20 mm hole at the rear for the heating sensor (ensure a tight fit).

   Embed front temperature sensor using epoxy (avoid air gaps).

4. **Electrical Assembly**

   Wire the Peltier and heater modules to the switchboard. And connect it to the power supply as shown in the figure.



5. **Digital Display**
   Digital display on the switchboard shows the temperature of the aluminium block (±0.5°C) during heating and cooling.

Thermoelectric System Operating Principle

Heating Mode: In heating mode, the polarity of the Peltier modules is reversed, as the cold side is positioned inward. Direct current flows through both the Peltier modules and the support heater, warming the aluminium block. The heat is then transferred to the split cell via conduction.

Cooling Mode: During cooling, the Peltier modules operate with standard polarity, and the fans are activated to rapidly extract heat from the aluminium block and dissipate it externally. To prevent thermal saturation, the Peltier modules alternate operation—when one reaches its thermal limit, it is deactivated to cool down, while the other takes over. This cycle continues until the desired temperature is reached. The Peltier modules typically run for approximately 35 minutes before being switched off.

Temperature Range: Achieved 21°C (min cooling) to 80°C (max heating) by adjusting voltage and using the heater.

Limitations: Condensation risk during cooling below ambient temperature.

Cost of items and model manufacturing

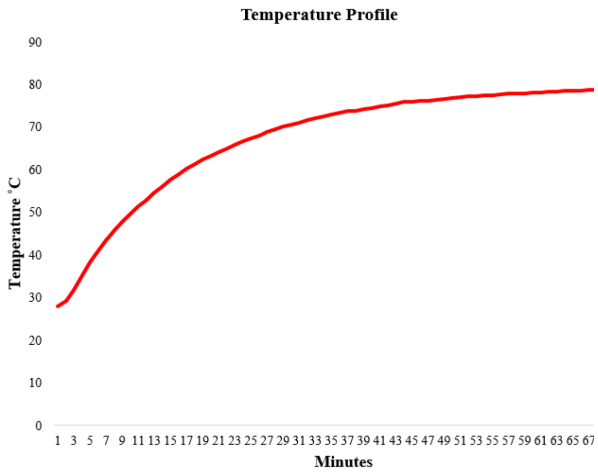
Material	Quantity	Price
Aluminium Block	3.5Kg	3097
Peltier	5 pieces	1000
Heaters	2 pieces	160
Thermal paste	2 pieces	140
12V, 10A Power Supply	1	1020
Temperature Sensor	1	120
Power Cord	1	40
Heat Sink with fans	2 pieces	300
Male/Female Connectors	2	60
Switches	4	40
Total Wires	1	50
	Total = 6027	

Result Analysis

Heating:

Case 1: Using 1 Peltier and 1 Heater

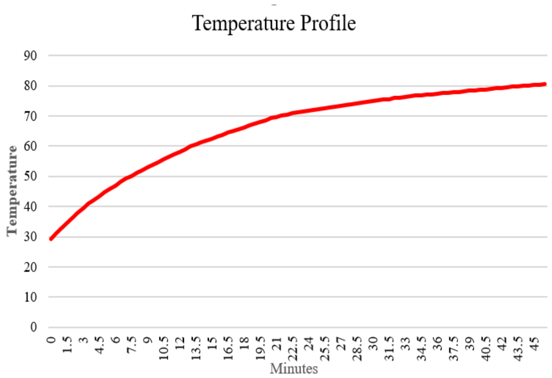
During Case 1 testing, the initial temperature of the block was nearly 26.4 ˚C that is nearly the room temperature. The Peltier module, along with heaters, was run for approximately **1 hour and 11 minutes**, and the temperature of the block ultimately reached to **79.1˚C.**



Graph showing the temperature of the block over time.

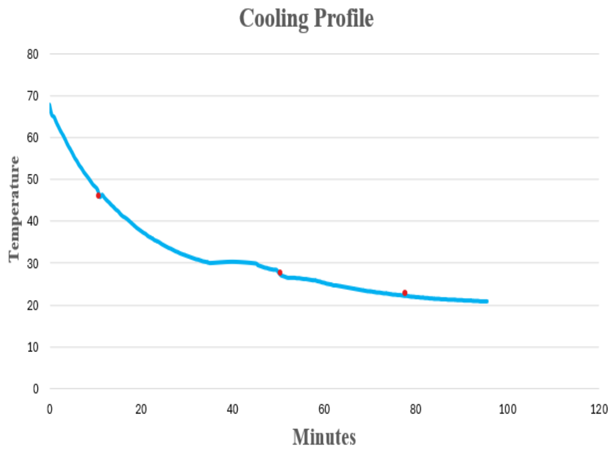
Case 2: Using 2 Peltier and 1 Heater

During Case 2 testing, the initial temperature of the block was nearly 26.4˚C. The Peltier modules, along with heaters, were run for only **46 minutes**, and the temperature of the block ultimately reached to **80.5˚C.**



Cooling

During cooling testing, the initial temperature of the block was nearly 67˚C. The Peltier modules, along with heaters, were run for, and the temperature of the block ultimately reached to 21˚C. The below graph shows the temperature profile, also the red dots show the time period where a 10-minute break was taken to give Peltier a good time to reset and come back to its fullest efficiency.



Contributions

While most teams consisted of four members, our team operated with only two. This presented unique challenges, but it also strengthened our collaboration, as we shared every responsibility equally. From research and design to implementation and troubleshooting, we worked closely together on all aspects of the project. Each decision was made jointly, and every task was a combined effort, ensuring that both of us contributed fully to the project's success. Our close partnership allowed for seamless communication, efficient problem-solving, and a unified approach to achieving our goals.

Conclusion

This project successfully designed and fabricated a thermoelectrically controlled enclosure capable of precisely regulating battery test cell temperatures within an extended range of **21°C to 80°C**, surpassing the initial objective of 60°C. The system leveraged Peltier modules for cooling, a resistive heater for heating, and an aluminium block with optimised thermal conductivity to achieve rapid and stable temperature control. Key accomplishments include:

- **Exceeding Targets**: While the project brief specified heating up to **60°C**, our design modifications (e.g., dual Peltier modules, high-power heater, and efficient thermal transfer) enabled reaching **80°C**, demonstrating enhanced performance.
- **Precision Cooling**: The alternating Peltier operation and active heat dissipation achieved a minimum temperature of **21°C**, addressing both sub-ambient and high-temperature testing needs.
- **Innovative Design**: Safety slots for terminal isolation, manual switchboard control, and sensor-integrated monitoring ensured reliability and repeatability.
- **Cost-Effectiveness**: The total expenditure (**₹6,027**) remained low despite outperforming expectations, proving the feasibility of compact, economical solutions.