Electronic Device Temperature Monitor

Enoch Adebayo, John Parker, Matthew Thomsen, Alexander Walter, Julian Castellanos
Dallas College, Richland Campus, Richardson, TX

Abstract

Consistent exposure to higher temperatures is detrimental to batteries, with a linear increase in temperature leading to an exponential decrease in battery life. This project is a device that measures the ambient temperature of an electronic device enclosed inside it, indicates the range of that temperature to the user via LEDs, and safely reduces it to a normal operating range via a Peltier module. After issues with the system's components were resolved, namely the MOSFET driver module, the prototype finally gained functionality. PETG filament was used over PLA filament where appropriate for the enclosure.

Introduction

Temperature is a significant factor in battery performance, shelf life, charging and voltage control; consistent exposure to higher temperatures is detrimental. Using accepted data and the law of Arrhenius, a battery with a lifespan of fifteen years at 20°C (68°F) becomes reduced to 7.5 years at 30°C (86°F) and to a little under 4 years at 40°C (104°F). (1)

$$\ln(k) = \ln(A) - EA/\mathrm{RT}$$

This means that it isn't improbable for individuals living in hotter climates (i.e. phone users in Texas, or workers in the summer) to have the expected lifespan of their electronic devices more than halved.

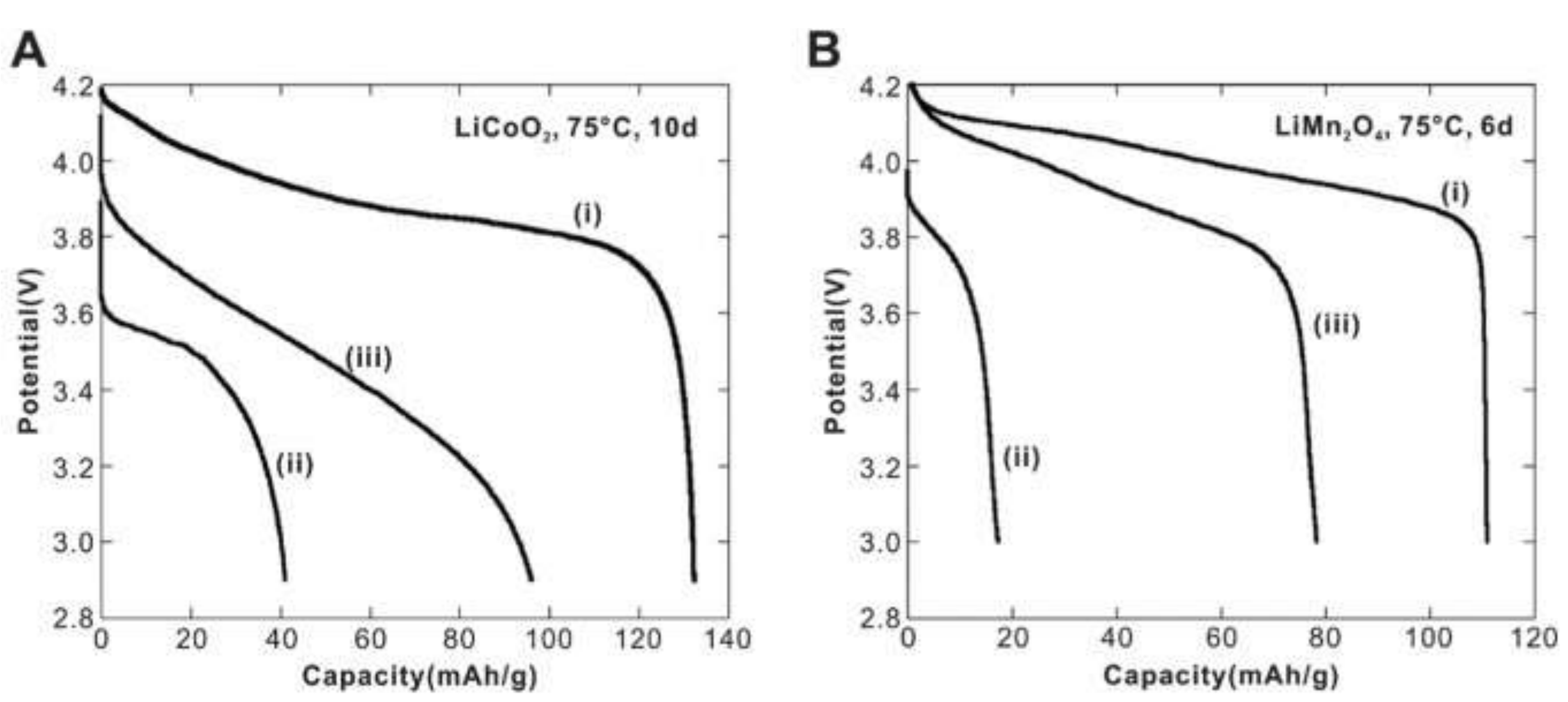

Figure 1. Discharge curves of batteries with (A)LiCoO2 and (B)LiMn2O4 cathodes before and after aging at 75 °C for 10 days and 6 days, respectively, (i) after the 5th cycle before aging, (ii) after the 1st cycle after aging, (iii) after the 5th cycle after aging. (2)

Methods and Materials

Major Components

- Peltier Module (TEC1-12706 cooling element)
- IRLZ44N MOSFET
- TMP36s
- INA219 Current Sensor
- K-type Thermocouple

Figure 2. MOSFET driver module

A Peltier module was the cooling element chosen for this proposal. The temperature of the Peltier is controlled by a MOSFET acting as a switch for current flowing through it. The TMP36 temperature sensors are intended to enable the automation of Peltier temperature. The MOSFET gate is opened depending on the ambient temperature detected by the TMP36s to ensure that the device enclosed is within its operating temperature.

Two separate components are used monitor the efficiency of the system: the thermocouple, which will detect the surface temperature of the Peltier module, and the INA219, which will measure the current flowing across the entire system.

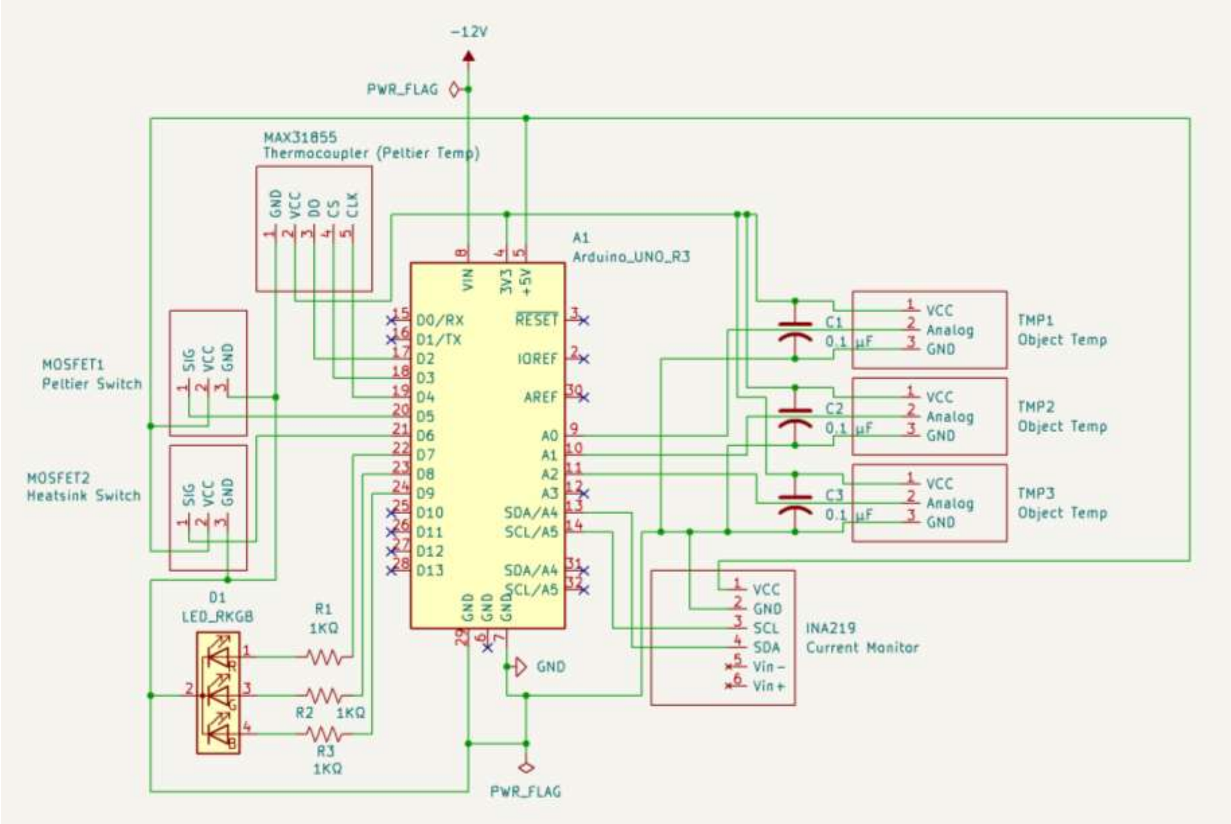

Figure 3. Schematic of electronic components. Note that this schematic does not include the systems/wiring existing outside of the PCB, like the load on the MOSFET driver modules.

Results

The MOSFET driver module effectively runs current through its gate and into the Peltier when prompted by Arduino IDE. The TMP36s also detects temperature with an acceptable amount of accuracy, but readings are given to the serial monitor relatively slowly because of the capacitors that are series. Using TMP36s without capacitors give poor readings because of noise.

Because PETG filament has a higher temperature resistance than PLA filament, the former was used for the object holder. It provided slightly better heat insulation.

The Peltier itself is relatively ineffective in cooling down the device in the enclosure due to their distance. The Peltier will likely be more effective with surface-to-surface contact.

Discussion

The MOSFET was the biggest concern throughout the assembly of this project. The module initially used the wrong MOSFET: an IRF540N, which cannot be fully powered by an Arduino. The 5V maximum that the latter provides leads to both excessive heat generation and a lack of functionality as a switch. The IRF540N had to be desoldered and replaced with an IRLZ44N, a logic-level MOSFET designed to be controlled by lower voltages.

Another thing to note is that while the initial intention was to utilize pulse-width modulation (PWM) for more precise current flow, it is generally best to avoid this with MOSFETs for the same reason as before. MOSFET gates are meant to be completely open or completely closed most of the time, so keeping it at an intermediate via PWM switching would also create excess heat, which would be counter-productive to the goal of this proposal. (3)

An inherent design flaw is the use of the INA219, which has a maximum operating current of 3.2 amps. Although the Peltier is powered by a 5A power supply, this component essentially caps the power that it can receive at 3.2 amps, reducing its potential cooling ability.

Figure 4. 3D-printed enclosure for components (left) and battery-powered device (right), along with an Arduino, the Peltier, and its heatsink for reference.

Conclusions

A Peltier module is not the best component for precise or longer distance temperature control. A revised enclosure should be designed to ensure that the Peltier and the device its cooling are as close in proximity as possible. TMP36s are also prone to noise especially when surrounded by other components; this project could have benefited from a more modernized temperature sensor. Traditional MOSFETs should not be used with microcontrollers with lower voltages like Arduinos, logic-level MOSFETs is the correct component for uses requiring them.

Acknowledgments

Thank you to Jessica Gonzalez, John Parker, Matthew Thomsen, Alexander Walter, Julian Castellanos, and Dallas College for the opportunity, resources, and mentorship.

Funded by the Title V Abriendo Caminos DOE Grant P031S210233

References

1. https://discoverbattery.com/support/learning-center/battery-101/why-does-temperature-affect-a-batterys-available-capacity
2. https://www.sciencedirect.com/science/article/pii/S1002007118307536#s0010
3. https://forum.arduino.cc/t/using-mosfet-to-control-peltier/338159