Athletic Recovery Device

ECE-499

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Problem Statement

- Sports cause acute injury

https://www.macleans.ca/society/the-end-of-the-ice-age/

- Cold therapy treatment
  - RICE Method: Rest, **Ice**, Compression, Elevate
  - Application of cold surface to injured area

- At Union College
  - Plastic Ice Bags
    - ➕ Pros: Easy to use, cheap, sanitary
    - ➖ Cons: Unsustainable, lack of temp. regulation

https://unionathletics.com/images/2020/5/25/union_logo_teaser_new.jpg?width=1920&quality=80&format=jpg

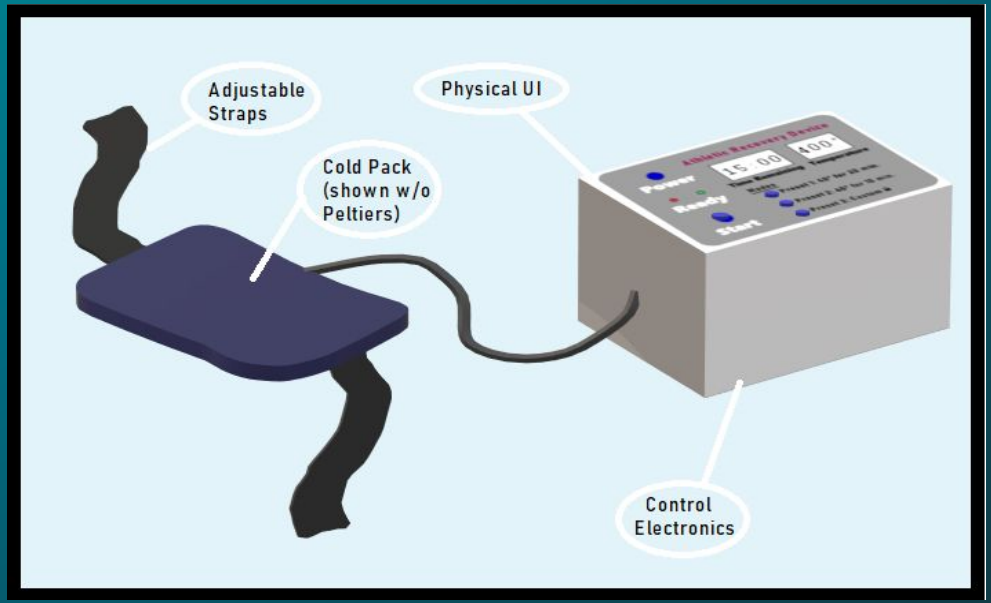
Existing Products

- Chemical Packs
  - ⊕ Easy to use
  - ⊖ Must be refrozen
  - ⊖ Too cold/not cold enough
- Liquid Circulation Systems
  - ⊕ Consecutive Use
  - ⊕ Temperature control
  - ⊖ Expensive, Inconvenient
- Electrically Powered Devices
  - ⊕ Temperature Control
  - ⊖ Expensive
  - ⊖ Limited Market

https://capitalosteopathy.ca/ice-packs-pain-sprained-ankles/

https://cdn11.bigcommerce.com/s-gpuq0v2/images/stencil/1280x1280/products/639/2890/Kodiak-cold-therapy-withpad__62594.1579814446.png?c=2

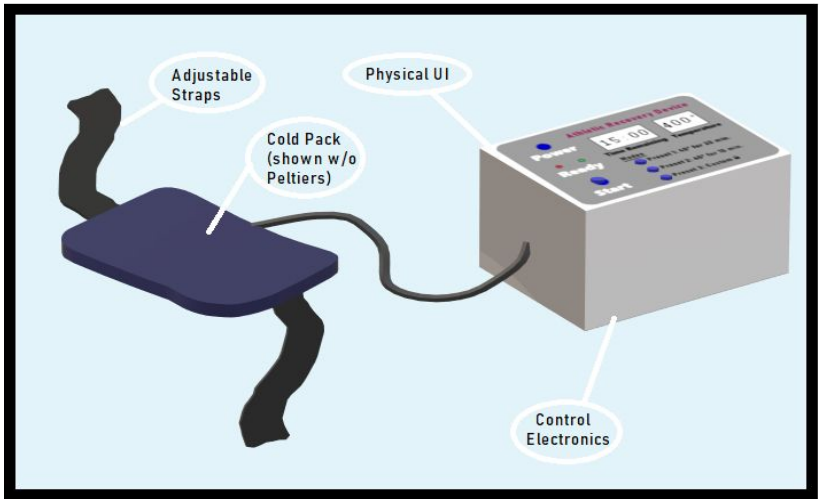
https://www.greatnesscollective.com/recoverx



Project Goal

To create an electronically powered ice pack with the ability to control the temperature and duration of the treatment for consecutive uses. We believe this would be a valuable and sustainable asset to the Union College training room.

User Requirements



Software and Signals

- User-Friendly Interface
- Treatment Modes

Temperature Control

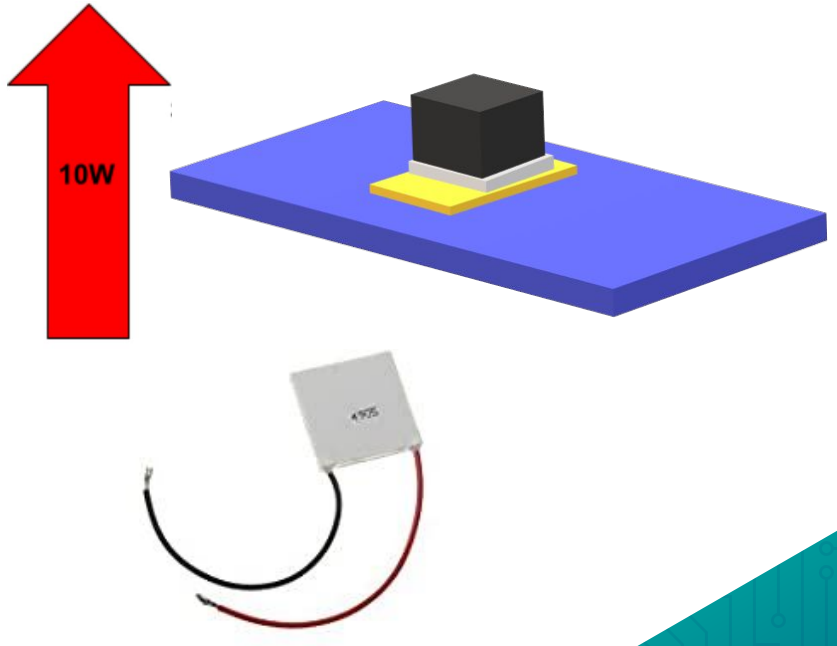
- Reaches 40-50^{o}F in <5 min.
- Hold temp. for duration of treatments (3+hrs)
- Uniform cooling

Construction & Safety

- Fit in 2 cubic foot area
- Ensuring user isolation and sanitation
- 180-360^{o} coverage

Temperature Control Overview

- Why use Peltier Coolers?
- Module Requirements
  - 10W thermal transfer
  - 100cm^2 cooling area
- Two Modules (one shown)

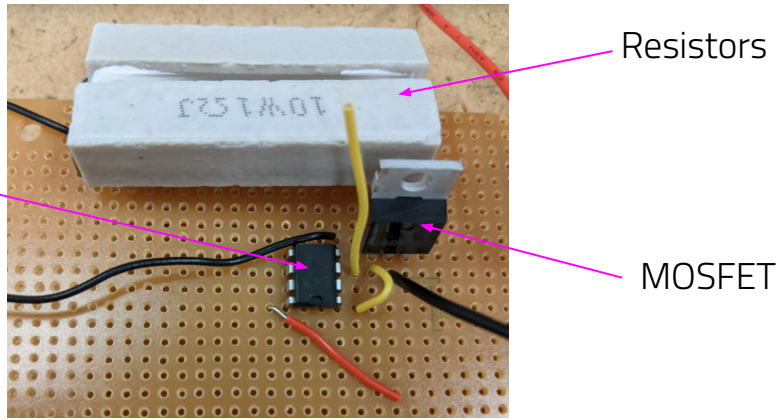


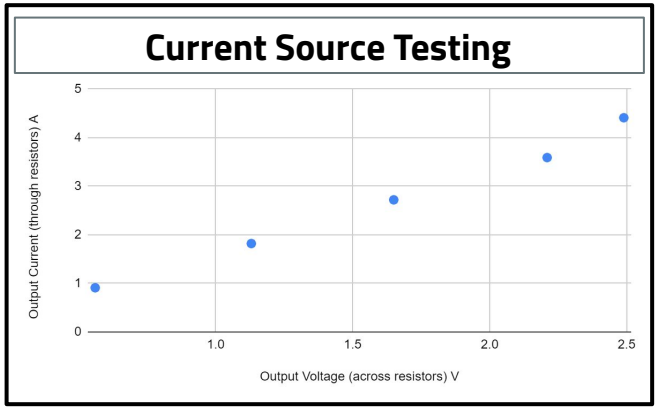
https://images-na.ssl-images-amazon.com/images/I/21YbBk21-qL.jpg

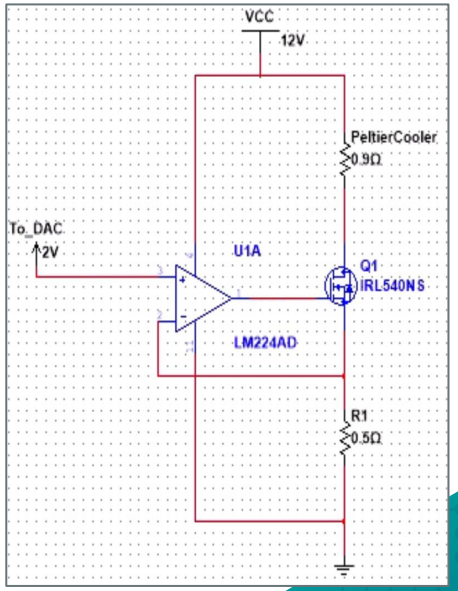
Peltier Control

Variable Current Source

- 8V 8A Peltier as load
- 10A Power MOSFET
- Op amp control

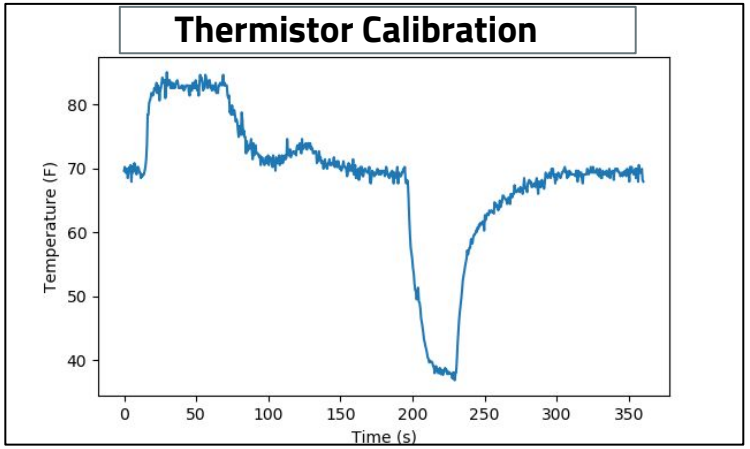


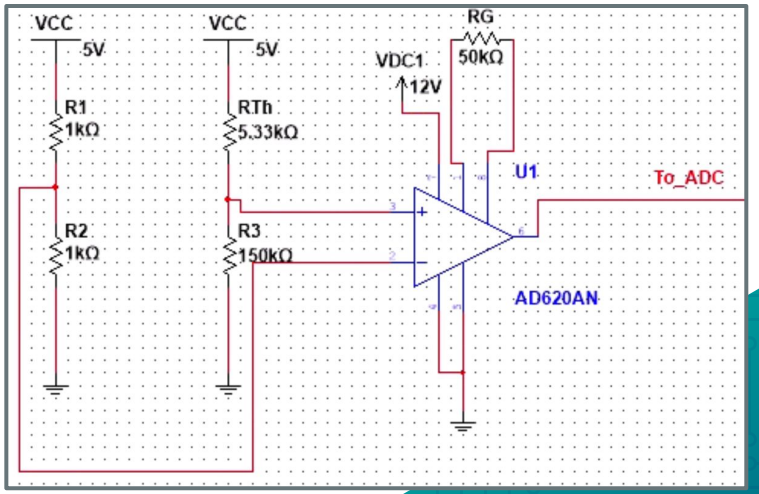




Temperature Measurement

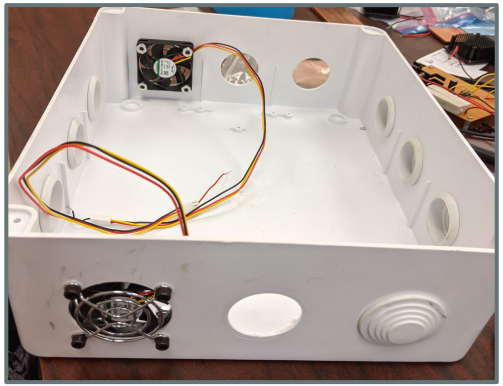
- Use 10k Thermistor (1/module)
- Instrumentation amp (AD620)
- ADC value 1-5V
  - Headroom requirements
- Capacitor needed

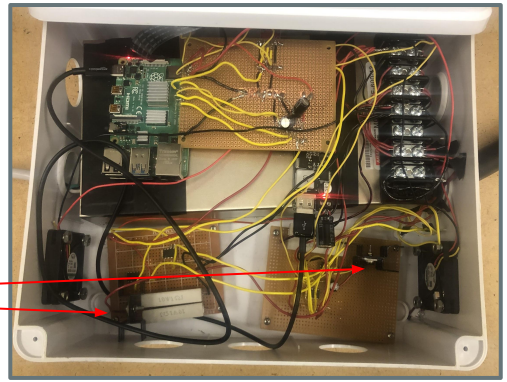




Layout and Wiring: Case

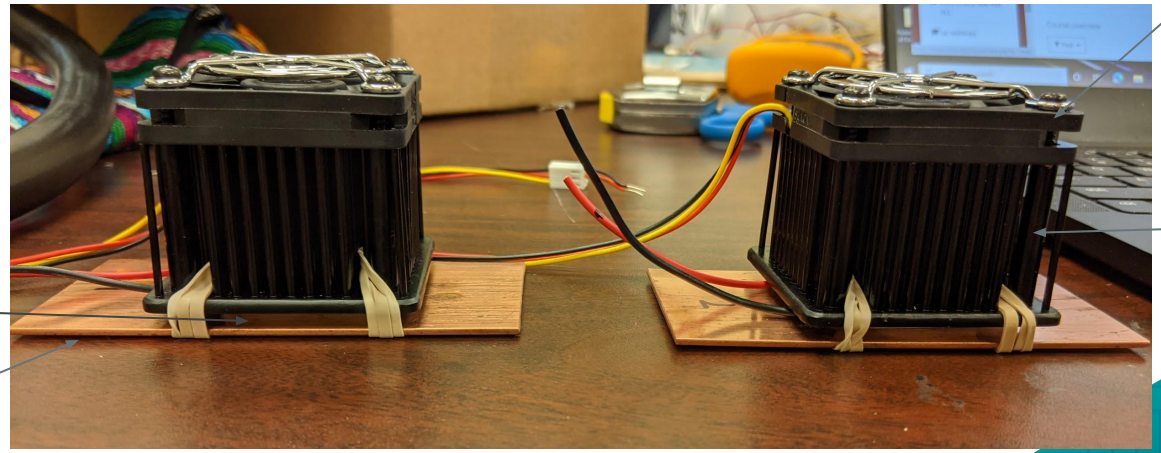
- Power supply SE-600-12: 12V and 50A
  - Takes up more space than expected
- Raspberry Pi and buck converter on power supply
  - Isolation
- Fan Orientation and placement
  - Blow Inwards, 3 exits
  - Heat sinks close to fan





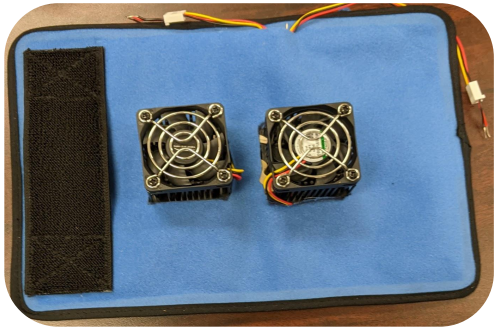
Sleeve electronics

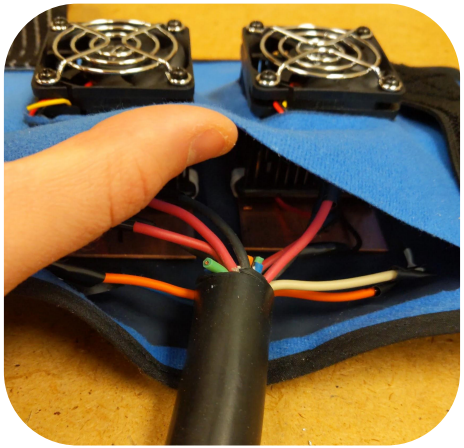
- Holding fans, bar, and peltier together
  - Thermal tape: not strong enough thermal connection
- Alternate solution: rubber bands!!
  - Thread rubber bands through heat sink
- Electric tape: isolate all connections



Sleeve

- Emptying gel pack
- Openings for electronics
  - Inserting electronics
  - Fan Openings
- Velcro strap
- Table of cable connections
- 2 subsystems
  - Trim cable wires





System wire
Peltier 1 +
Peltier 1 -
Fan 1 +
Fan 1 -
Thermistor 1 +
Thermistor 1 -
Pelter 2 +
Peltier 2-
Fan 2 +
Fan 2 -
Thermistor 2 +
Thermistor 2 -

Software and Signals

Control Device:

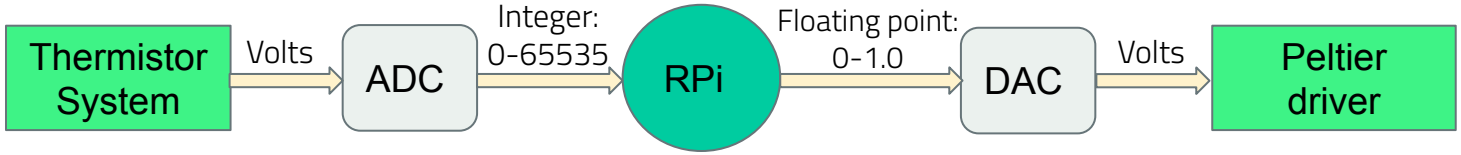
- Raspberry Pi 4 Model B (RPi)

Graphical User Interface (GUI):

- Tkinter Program using Python

Signals Processing

- Input from 16-bit Analog-to-Digital Converter (MCP3008 ADC)
- Output to 12-bit Digital-to-Analog Converter (MCP4725 DAC)

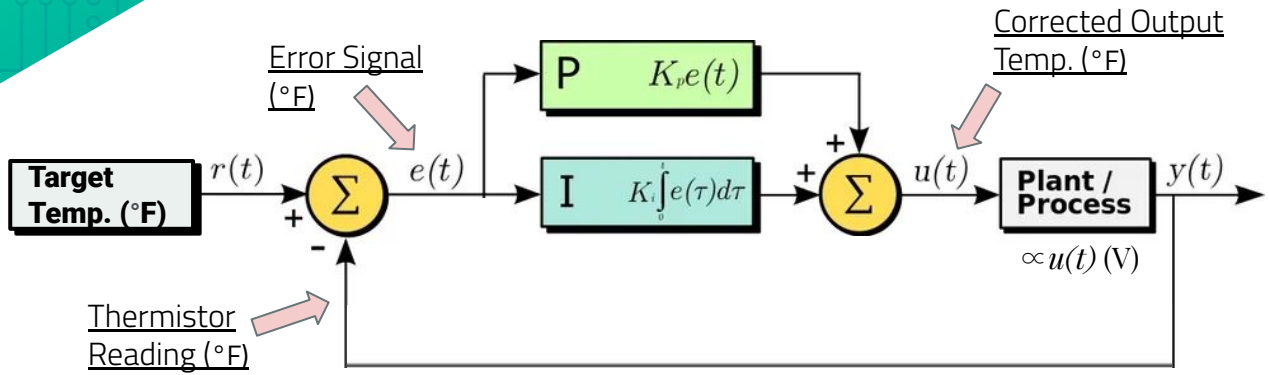


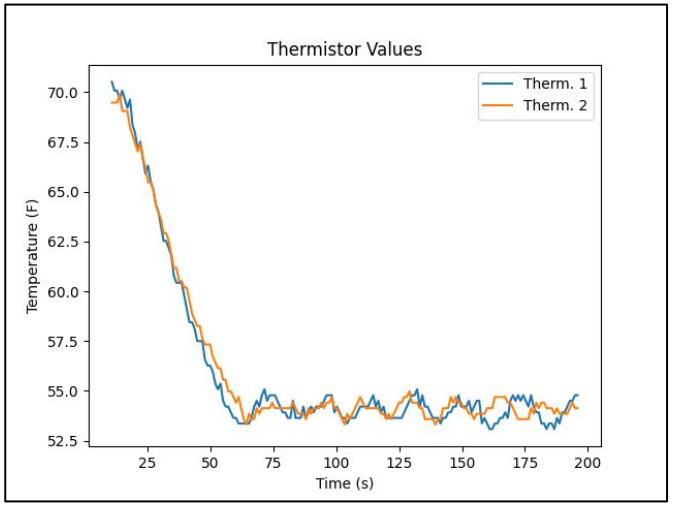
User Interface

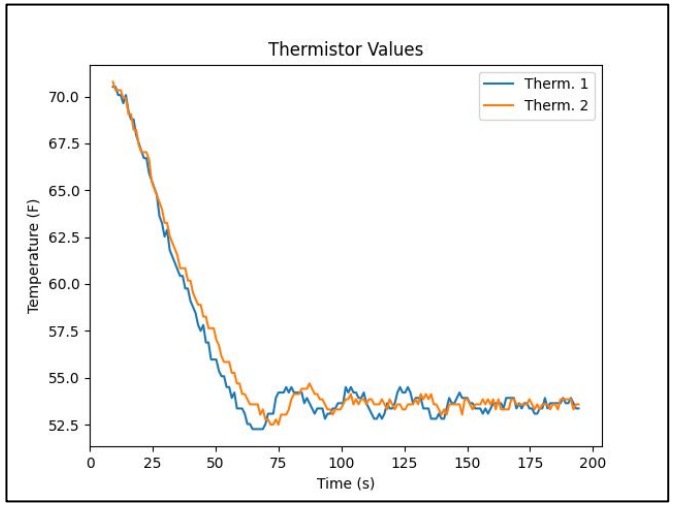
Tkinter:

- **Frames:** Layers of the interface
- **Widgets:** Button, Label, Entry
- **StringVar():** Dynamically updates variables

ntrol System







Ultimate Gain: $K_U = 63$

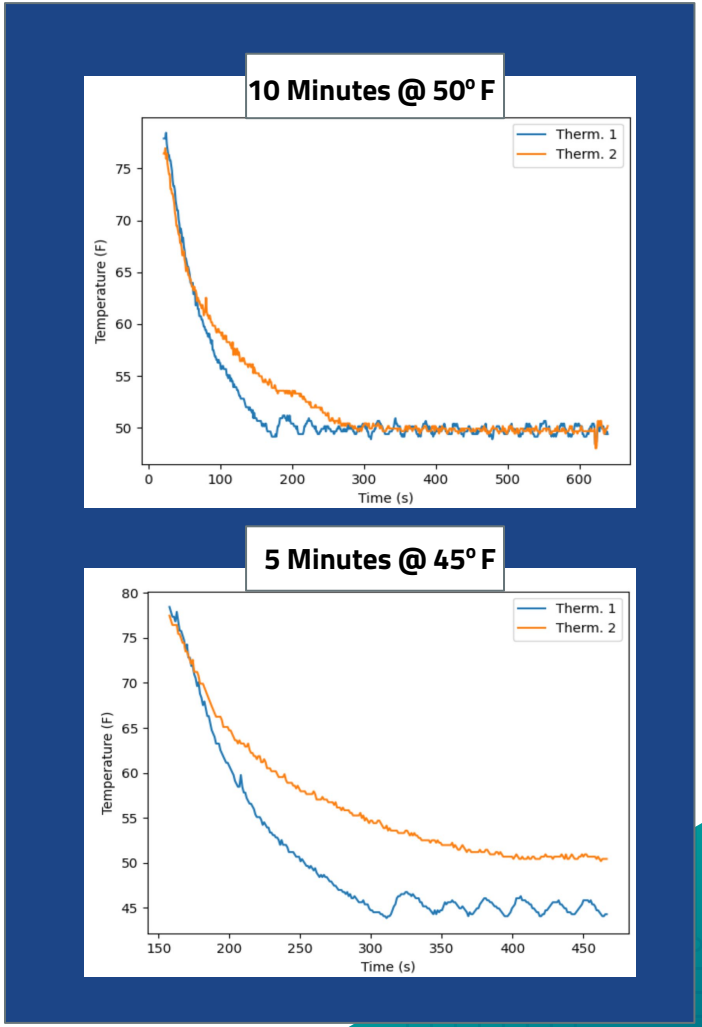
Oscillation Period: $T_U = 23s$

Proportional Gain: $K_P = 28.35$

Integral Gain: $K_I = 1.48$

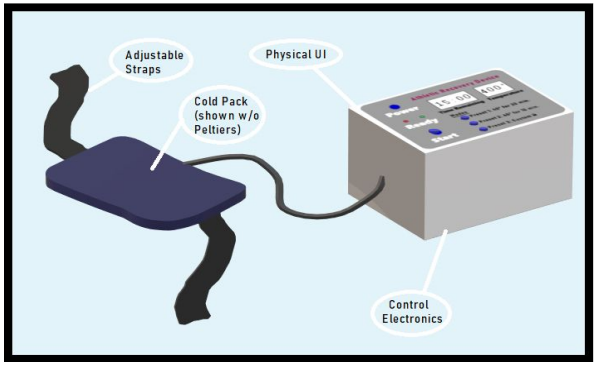
Testing Results

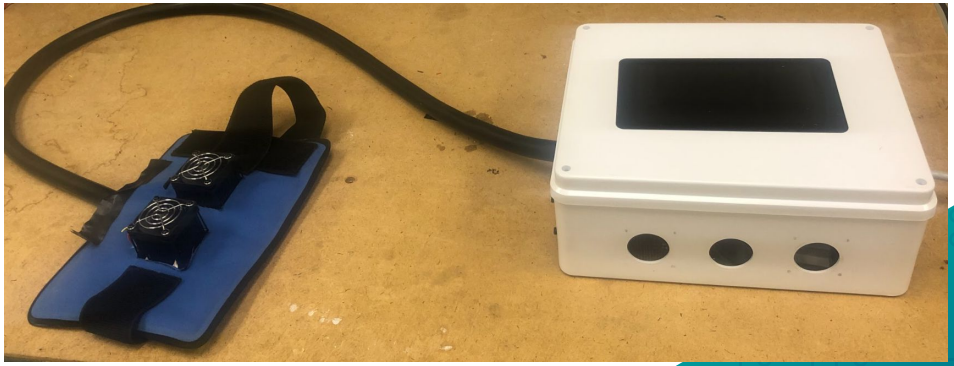
- 50° F works great!
- 45° F test half successful
  - One module bad connection
  - Flaws in construction
  - No time to fix
- Oscillations



Design Requirements Met?

- 40-50^{0} F on skin
- <5 min cool down
- 3 hour near-continuous use
- <2 ft^{3}
- 180-360^{0} coverage
- Uniform cooling
- Treatment modes





Cost Analysis & Market Requirements

- Material Costs: $485.68
- Labor costs: $700 (35 hrs @ $20/hr)
- Total costs: $1185.68
- Likely class 2 device
  - Requires FDA classification
- Likely De Novo 510(k) Clearance
- Use existing relevant standards
  - Eg. ISO 59752, 9241

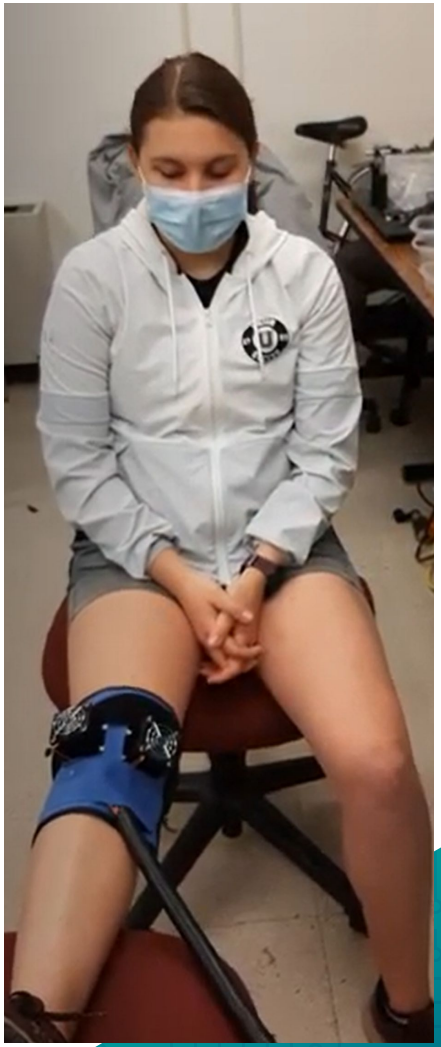
https://www.freepngimg.com/thumb/dollar/64032-united-money-symbol-dollar-sign-states-currency.png

https://www.wallseals.com/misc%20seals/DHHS_FDA.jpg

https://cliparts.zone/paperwork-cliparts

Trainer feedback

- Approval:
  - Reached temperature values
  - Size: portable if needed
  - Interface: easy to use
  - Good area of coverage
- Concerns:
  - Robustness and durability: protruding heatsinks
  - Cable: both size and securedness
- Other thoughts:
  - Useful during travel
  - Contrast therapy



Future work

- Software:
  - Tuning of PID System
  - Modularization of code
- Temperature Control:
  - Potential to use higher currents
  - Contrast therapy
- Construction and safety:
  - Neater wiring
  - Improved isolation
  - More reliable connections

Acknowledgements

Professor Buma: *Project Advisor*

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Questions?