UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

Smart Defrosting Device

Electrical & Computer Engineering

Team 49

Ben Civjan, Brad Palagi, Payton Thompson

5/2/23

The Problem

Problem:

- Defrosting meat is a common task that is a long and tedious process with a lack of innovation
- Leaving on container, leaving in refrigerator, cool water, microwave, defrost plate

Solution:

- Hands-off, fast, and reliable meat defrosting device
- Defrost completion detection
- Heating system

High Level Requirements

High-level Requirements

Heat, shut off, alert

- Power a heating element and display the current internal temperature
- Shut off heat once 0°C and sound alarm

Fast

- Thaw faster than standard techniques
- At least 20% decrease compared to defrost plate alone

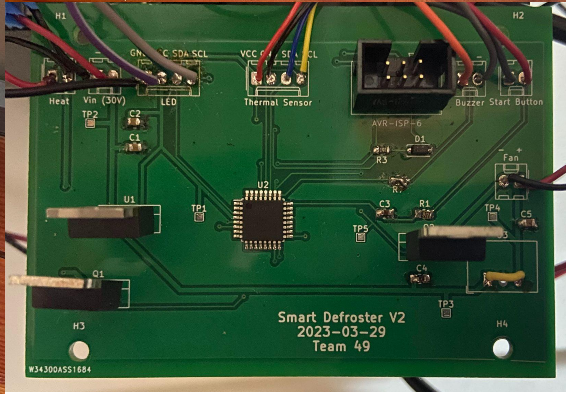
Even defrost

- Meat evenly defrosted
- Less than 10% frozen or cooked when process completed

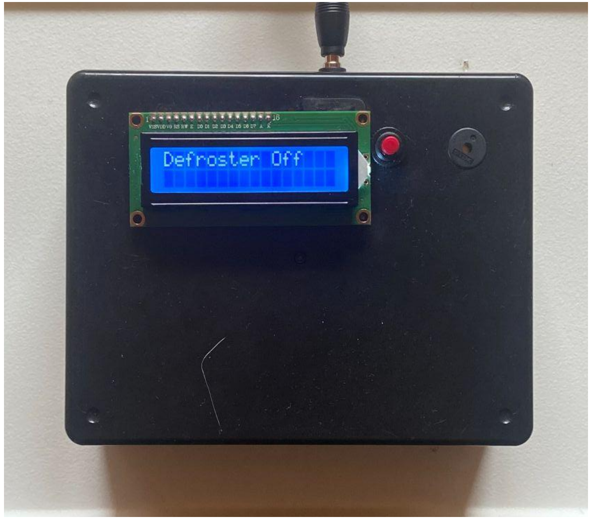
Washable

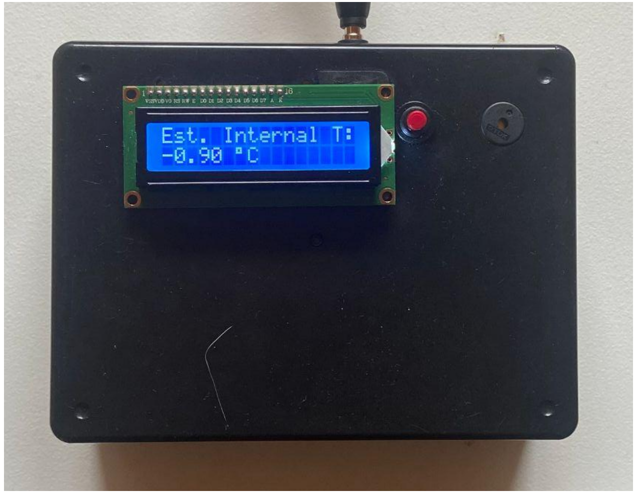
- Device washable and reusable
- Won’t damage the electronics

Final Product


H1
H2
Heat
Vin (30V)
LED
Thermal Sensor
Buzzer
Start Button
AVR-ISP-6
TP2
C2
C1
D1
R3
Fan
U2
U1
TP1
C3
R1
TP4
C5
TP5
Q1
C4
TP3
H3
H4
Smart Defroster V2
2023-03-29
Team 49
W34300ASS1684

Project Images

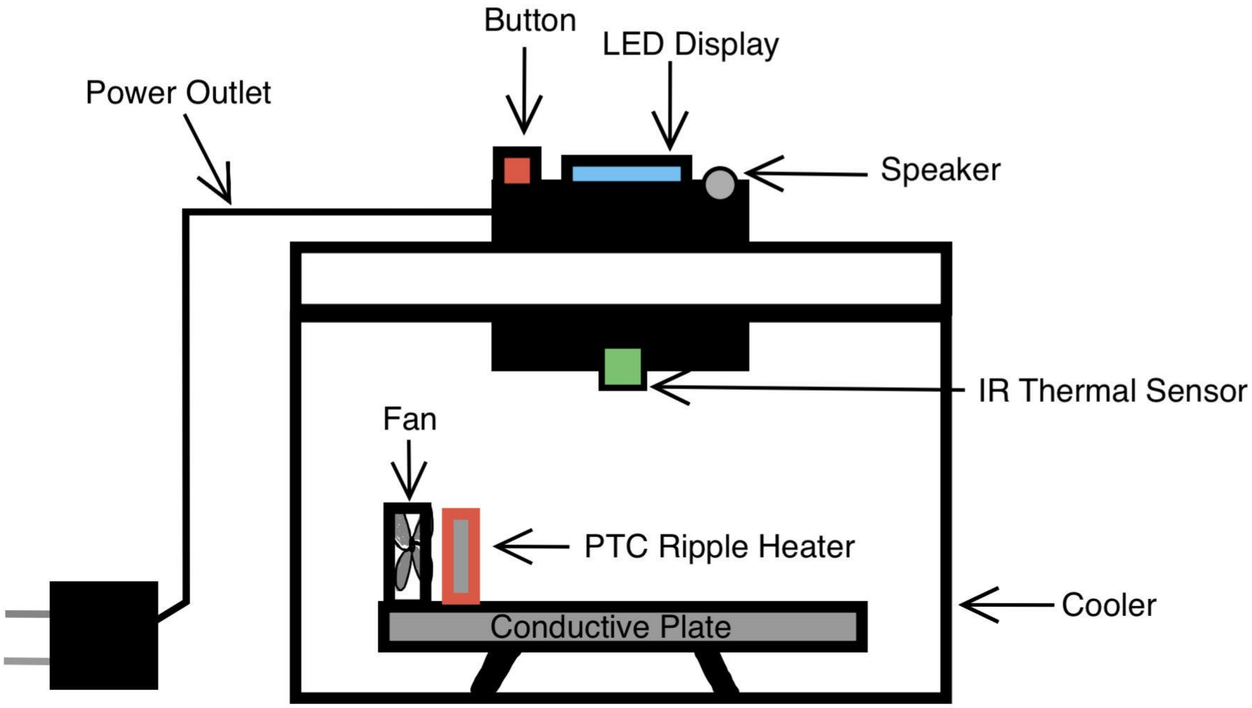




Video Demonstration

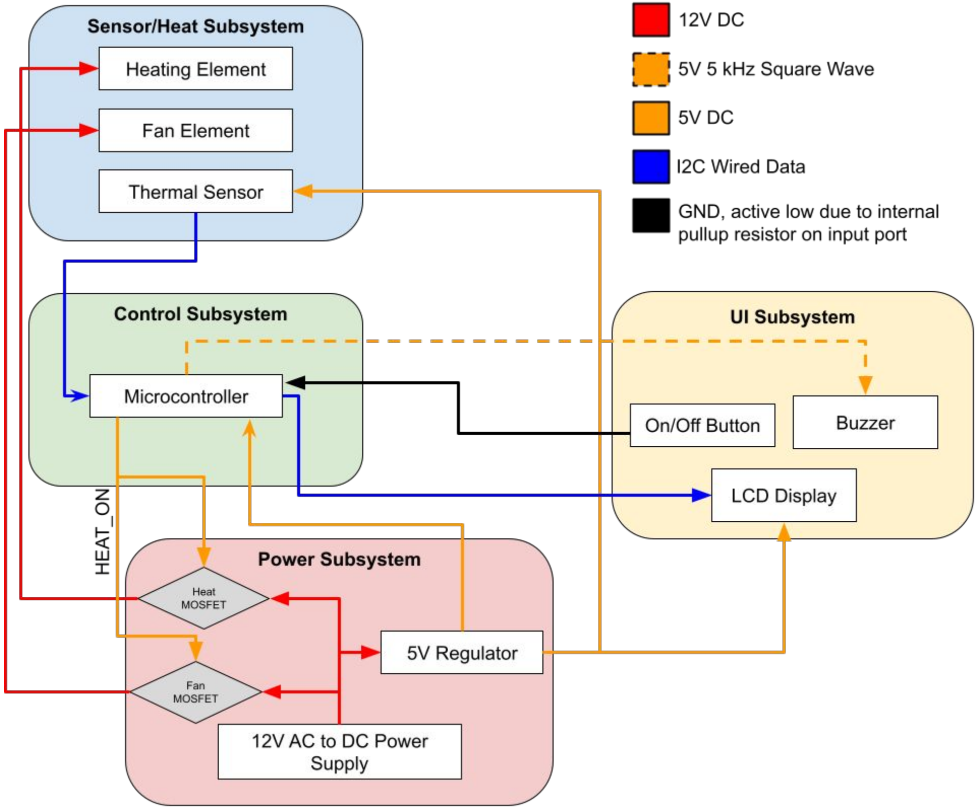
The Design

Illustrated Diagram



Side View

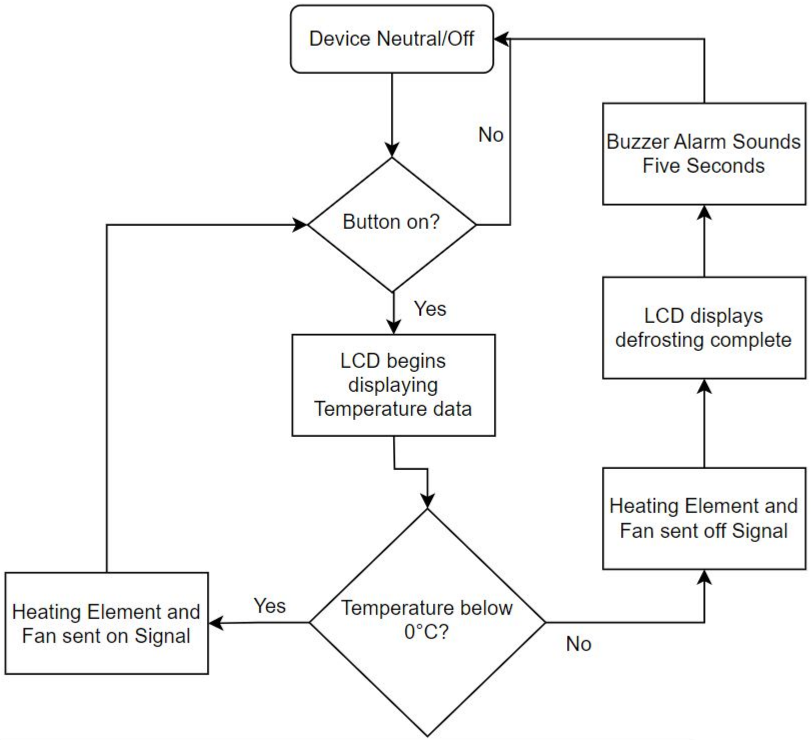
Block Diagram



Control Subsystem

ATMega328PB Microcontroller

- 5V microcontroller
- Easy integration with I2C devices using libraries in Arduino IDE
- Easily programmable, enable and disable power to heating subsystem
- Produces square wave for Piezo Buzzer



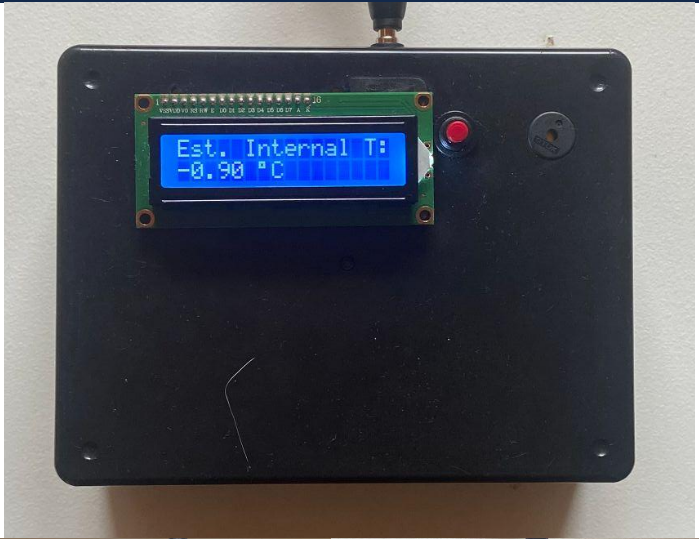
Control Subsystem

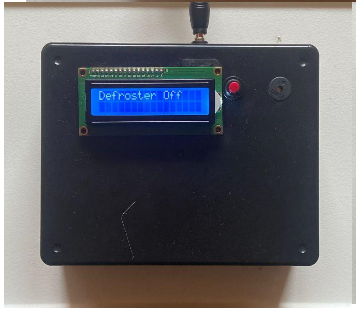
Requirement

Pass temperature data from the microcontroller to the LCD Display

Verification

- When the device is powered ensure the display receives 5V DC power
- Ensure the user can view the meats estimated current internal temperature, which is sent using the I2C protocol



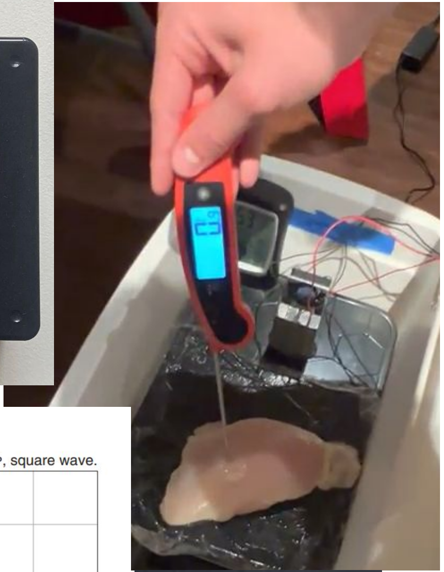


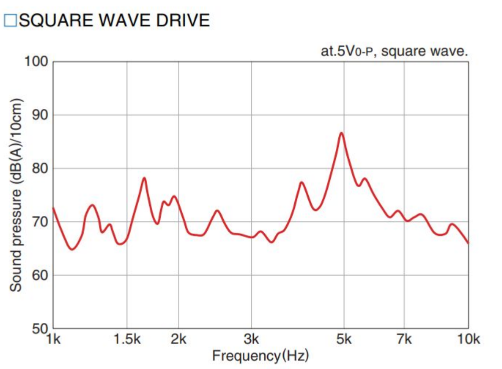
Requirement

Microcontroller completes defrosting once the estimated internal temperature reaches 0 degrees Celsius

Verification

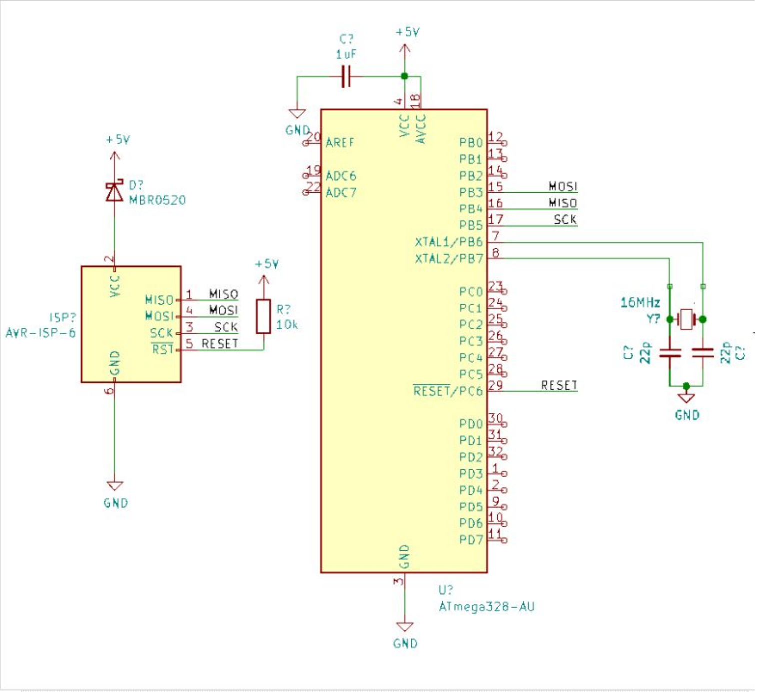
- Heat and fan are enabled from button press, and are disabled when temperature reaches 0 C
- Sound an audible buzzer and display on the LCD that defrosting has completed





Issues Encountered

- Fried first two MCU's on PCB
    - Unsafe probing
    - Incomplete soldering
- Learned about external oscillator after PCB order
- Attempted to use Microchip Studio IDE
- Lead on buzzer snapped off
- 7SEG Display I2C Backpack failed

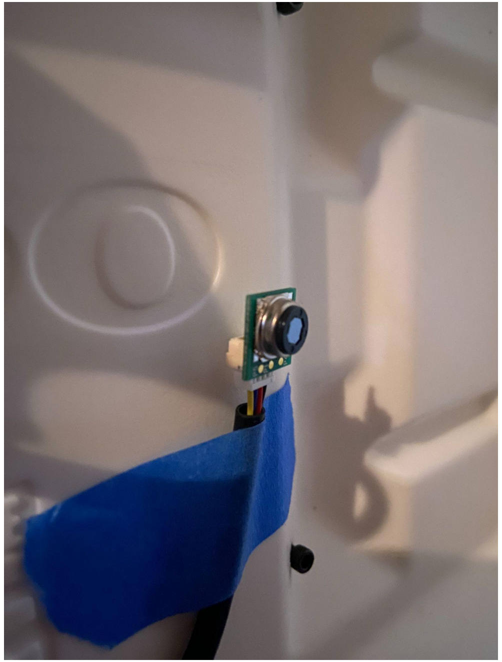


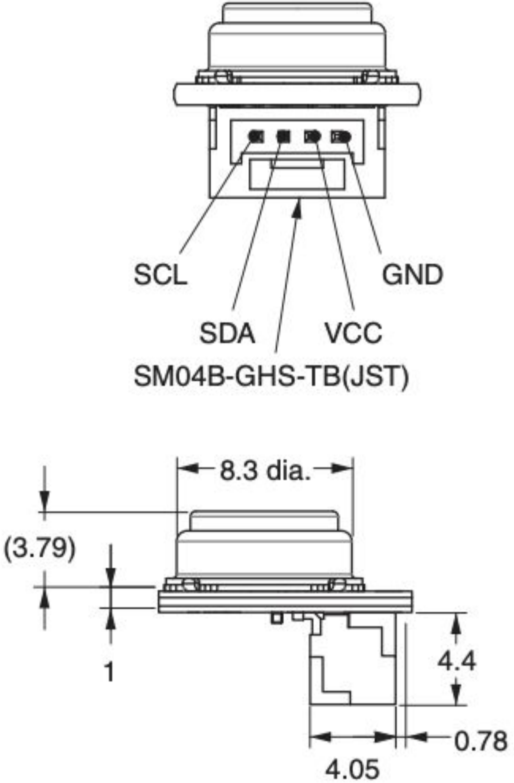
Minimal USBasp programmable ATMega328 schematic

Sensor Subsystem

Sensor Subsystem Overview

- Infrared Thermal Sensor
  - ±1.5°C maximum error
- 5 VDC power
- I^2C data connection





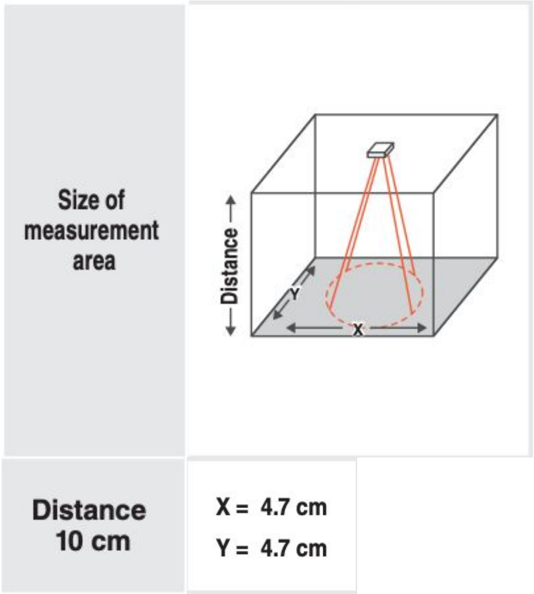
Requirement

Read external meat temperature within ±2°C

Verification

- ±1.5°C maximum error within circular detection range
  - Radius increases with distance
  - 9cm distance yields 4.5cm radius

- Raise conductive heat plate to achieve this distance from sensor location



Requirement

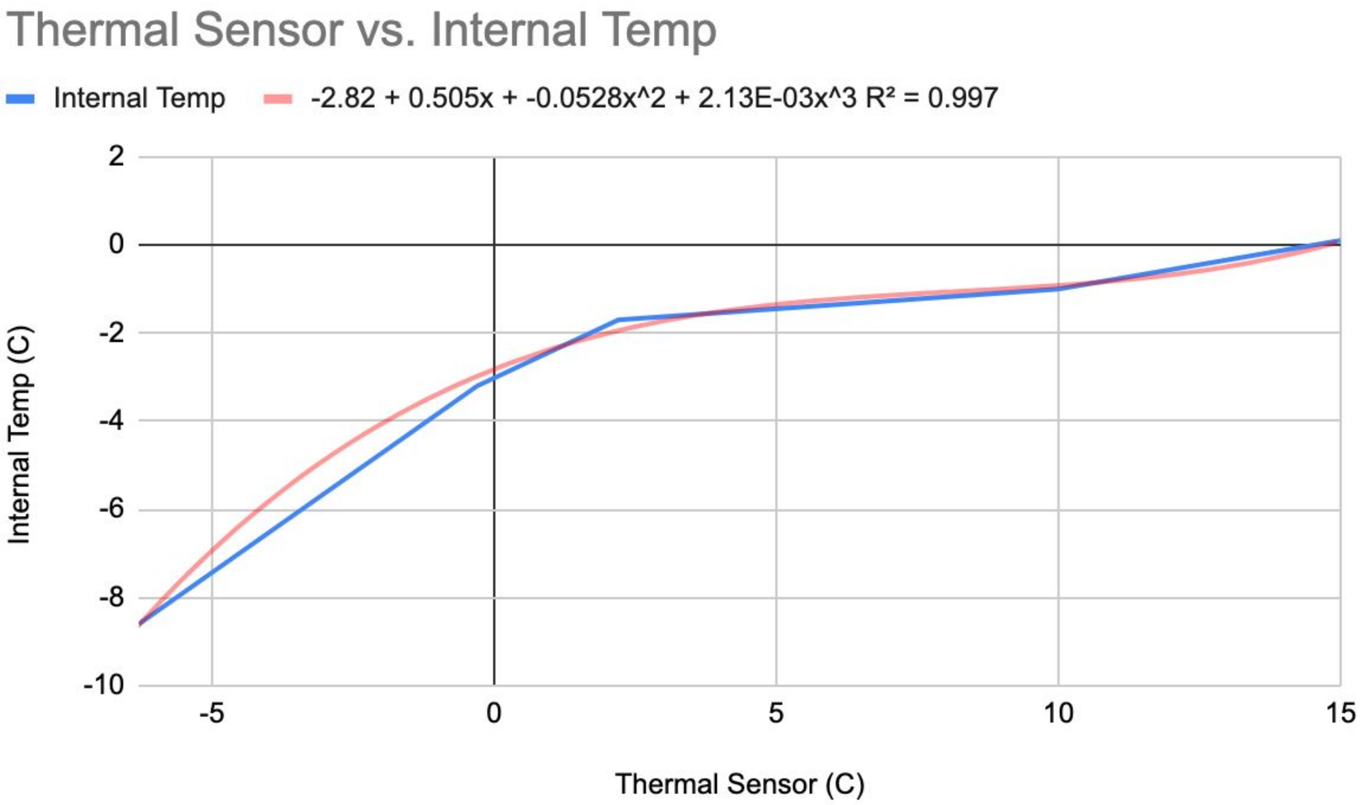
Calculate internal temperature within ±2°C

Calibration

- Test with chicken breasts of moderate size (~220g)
- Record internal temperature and thermal temp at equal intervals
- Create polynomial regression model to map thermal sensor reading to internal temperature

Javelin Pro Thermometer (accurate to 0.5°C)

Sensor Subsystem



Challenges

Thermal sensor readings were updating very fast and fluctuating noticeably on the display

Solution: Buffer 10 sensor readings and take their average before updating the LCD screen

Sensor takes 10 readings per second, we update display once per second

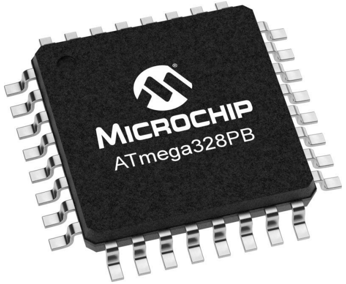
Power Subsystem

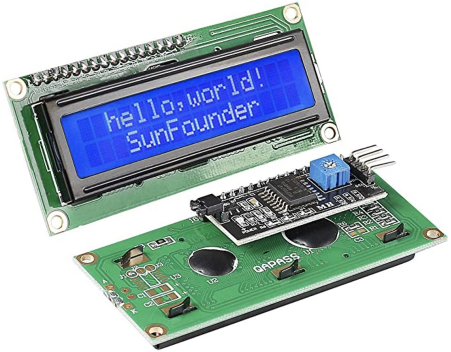
Elements to Power

- Microcontroller (5V)
- Thermal Sensor (5V)
- LCD Display (5V)
- Fan (12V)
- Heat (12V, 6A)

Components:

- 12V, 6A AC/DC Power Supply
- 5V Linear Voltage Regulator
- 2 40V, 120A MOSFETs





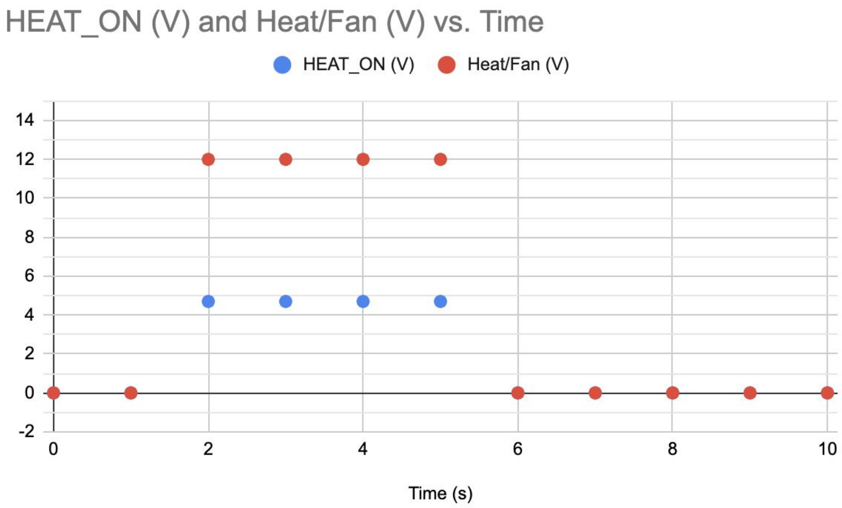
Requirements

Maintain an output voltage between 4.5 and 5.5 V (for microcontroller and thermal sensor)

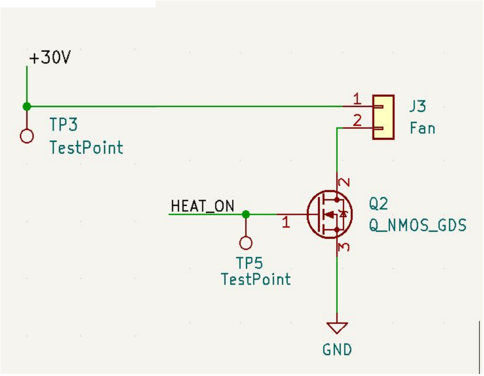
Provide an output voltage of 12 V to the fan

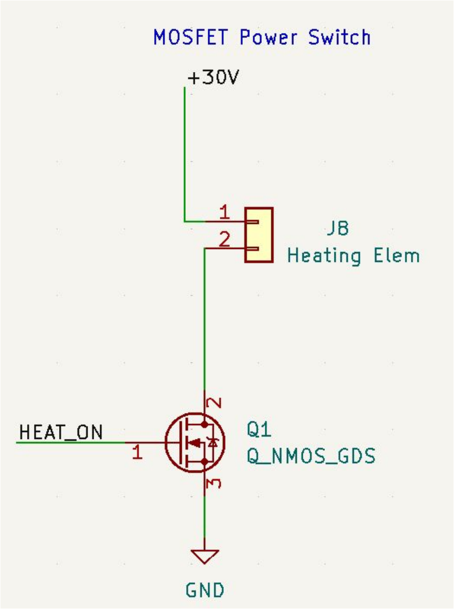
Stop supplying power to the heating system once the *HEAT_ON* signal has been set to 0

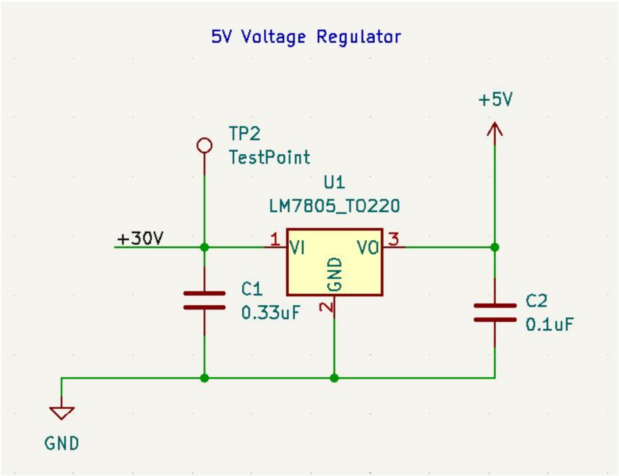
Heat Subsystem controllable with On/Off button



Power Component Design







Challenges

Power Supply Issues

- Our first supply rated for 1A shorted due to overcurrent protection
- Changed to heating element with higher current draw

MOSFET Turn on voltage

- Our microcontroller can only output ~4.7V
- The higher the voltage the more current flows to heater

Synchronous Buck Converter

- Needed when using 30V Power Supply to step down to 12V efficiently
- Limited to 1A current

Heat Subsystem

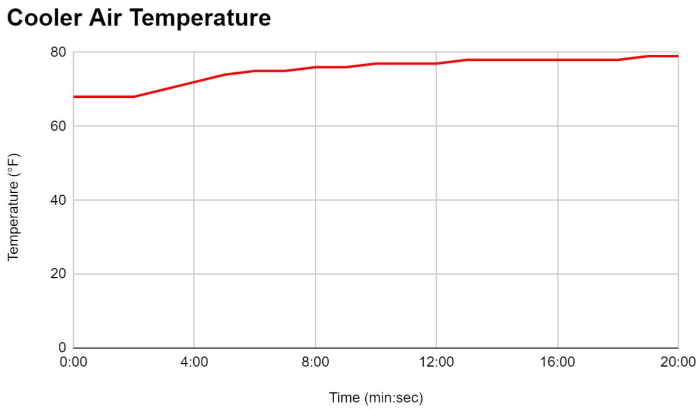
Heat Requirements & Verification

Components:

- Fan (12V)
- Ripple Heater (12V, 6A, 70W)
- Conductive Defrosting Plate

Strategy:

- Convection
- Conduction



Heat Requirements & Calculations

Requirement:

Container air temperature consistently at 32.22℃ and reaches in less than 15 min

Calculation:

Convection heating equation:

$$Q = V \times \rho \times c \times \Delta T$$

$$7579.86\,J = 0.2755 \times 1.204 \times 1870 \times 12.22$$

$$120\ sec\ to\ heat\ up: \frac{7579.86J}{120sec} \approx 70W$$

Heat energy required (Q), J

Volume space (V), m^3: $0.2755m^3$

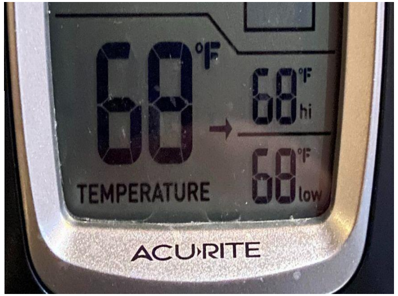
$0.2286m \times 0.38735m \times 0.31115m$

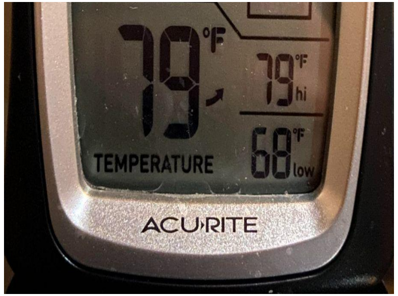
Temperature difference (ΔT), °C: $12.22\,°C$

$32.22\,°C - 20.00\,°C$

Density of air (ρ), $\frac{kg}{m^3}$: $1.204\,\frac{kg}{m^3}$

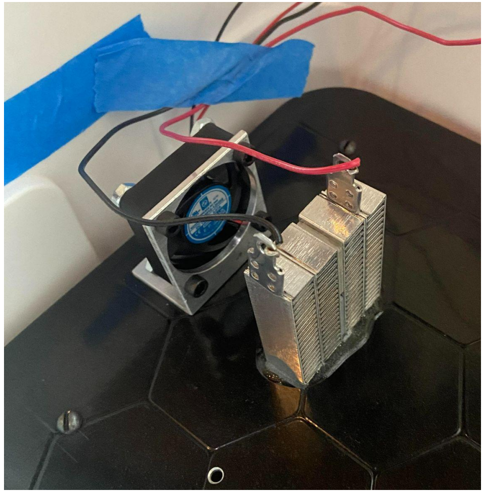
Specific heat capacity of air (c), $\frac{J \times kg}{°C}$: $1870\frac{J \times kg}{°C}$

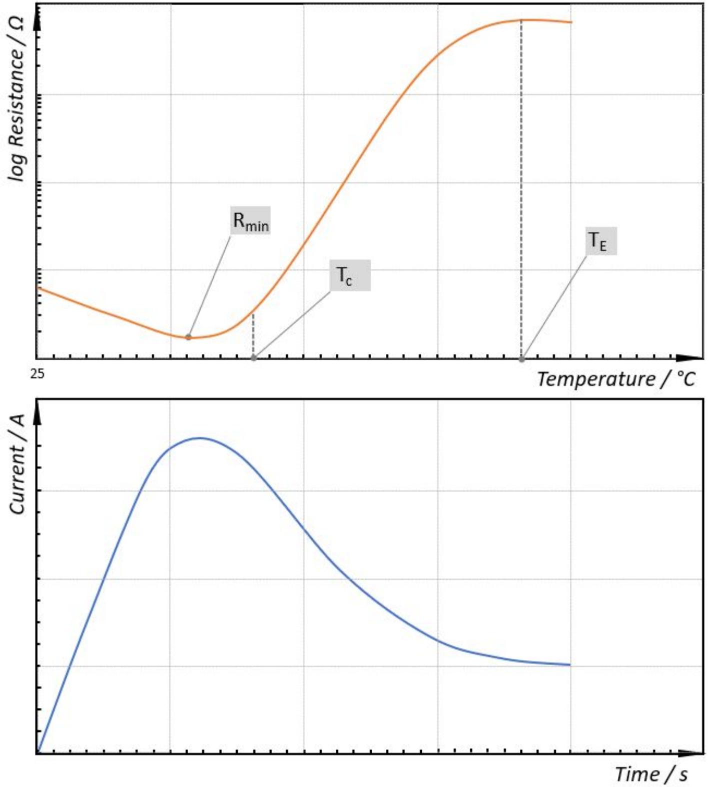




Challenges:

- Original Plate Heater (30V,1A,30W)
- Powering the Heat Supply
- Conduction > Convection





Unstable performance led to the power subsystem issues

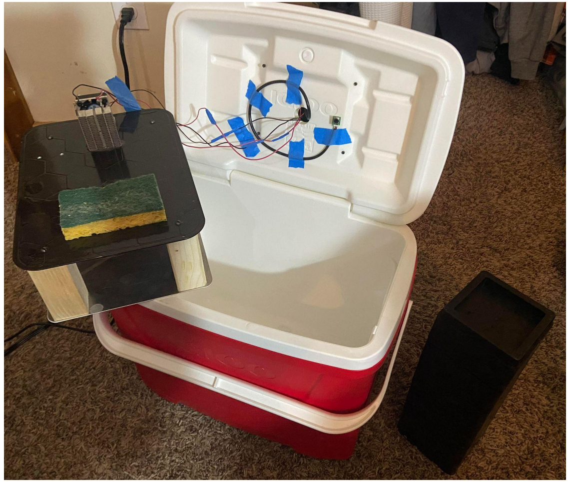
Conclusions

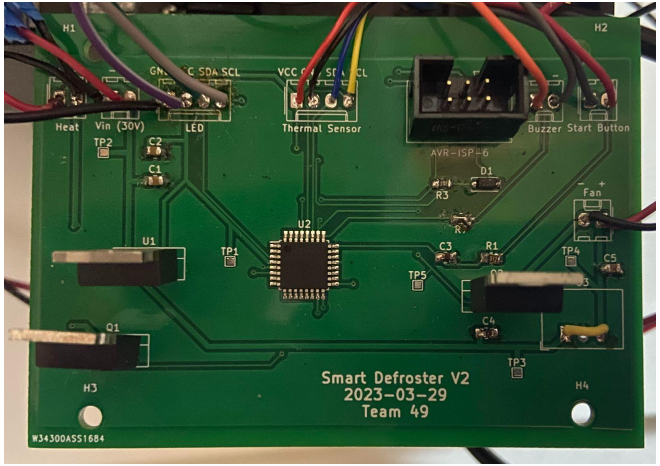
Conclusion

Smart Defroster

Ultimately our project resulted in a device with significant improvement on standard defrosting techniques.

- Defrost time reduced by 50%
- Even thawing
- Hands off
- Easily washable





Future Work

Polish and Enhance

- Cosmetic Improvement
  - Relocate wires to non visible internal locations
  - Use a more compact cooler
- Performance Improvement
  - To further decrease defrosting time
    - Add more duct work to improve airflow, especially beneath the defrost plate
  - To improve ease of cleaning
    - Relocate the fan and heater mount so the defrosting plate is fully removable
  - Multiple meat type settings
    - Only applicable with system due to internal/surface temperature ratio

Thank You For Listening

Questions?

Contacts:
bcivjan2@illinois.edu
bpalagi2@illinois.edu
pthomp22@illinois.edu

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