Lava Lamp

Faster. Brighter. Safer. Decoupled.

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TA: James Norton

Outline

- Introduction to Lava Lamps
- Client Requirements
- Design
- Integration
- Comparative Results
- Future Work
- Acknowledgements

What is a lava lamp?

Client Requirements

Clients: James Norton & Sung Soo Shin

Faster

Problem: Heats rather slowly

Solution: Provide more power to the lamp / Improve heat transfer

Brighter

Problem: Light is dim and can only be one color

Solution: Use high power multicolor LEDs

Safer

Problem: Heats past optimal operating temperature

Solution: Implement a temperature controller

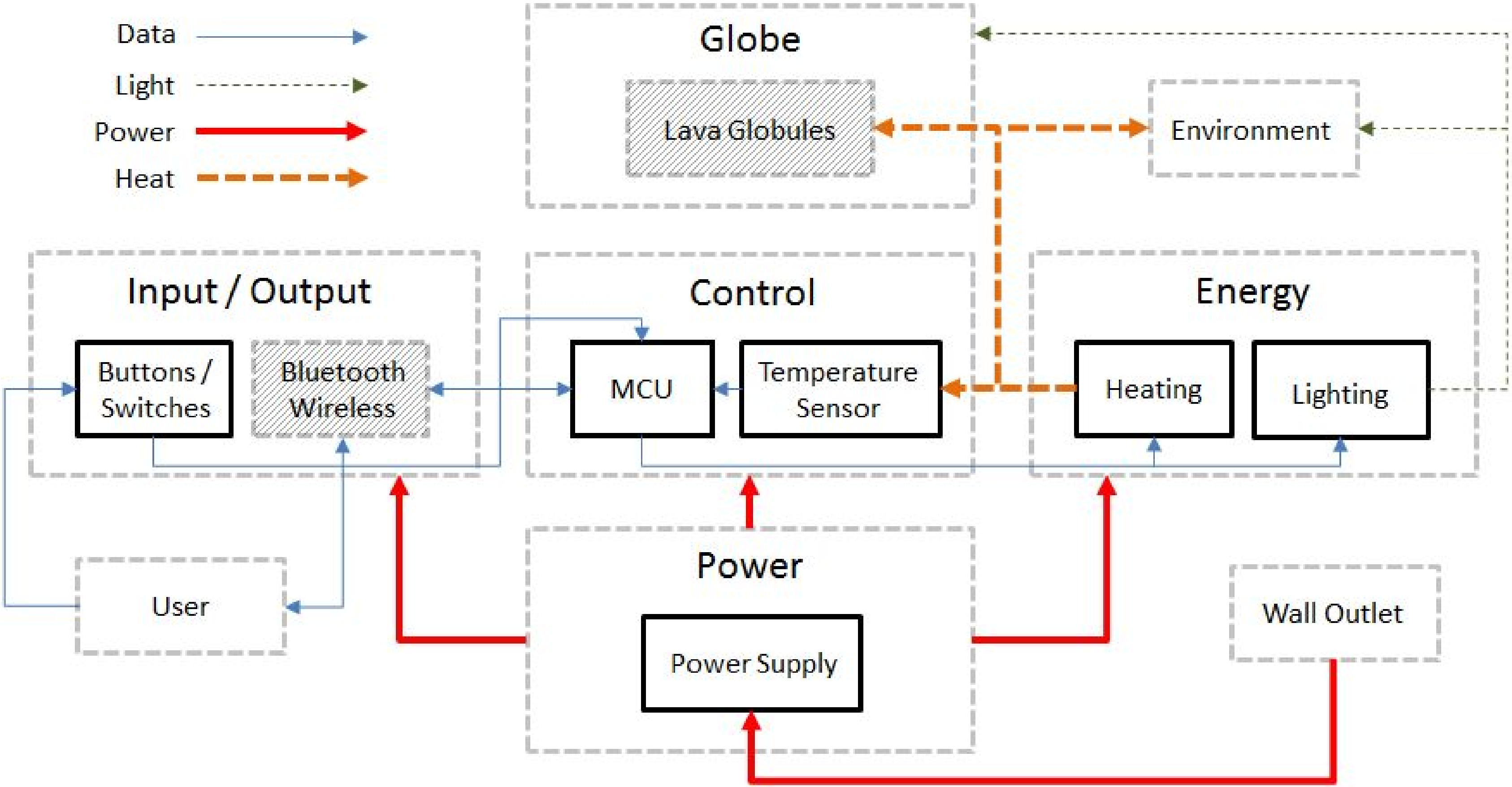
De-coupled

Problem: We can’t adjust heating and lighting independently

Solution: Use a separate heat source and light source

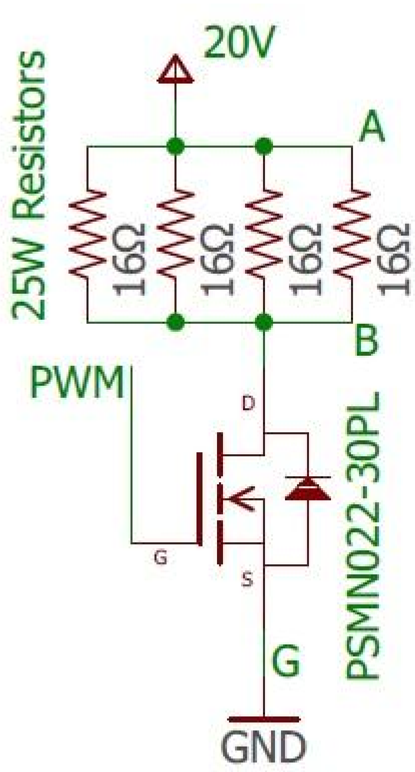
Possible explosion hazard

Initial lab safety measures



Data
Light
Power
Heat
Globe
Lava Globules
Environment
Input / Output
Buttons / Switches
Bluetooth Wireless
Control
MCU
Temperature Sensor
Energy
Heating
Lighting
User
Power
Power Supply
Wall Outlet

Design



Heat Source - ***Faster.***

Requirements

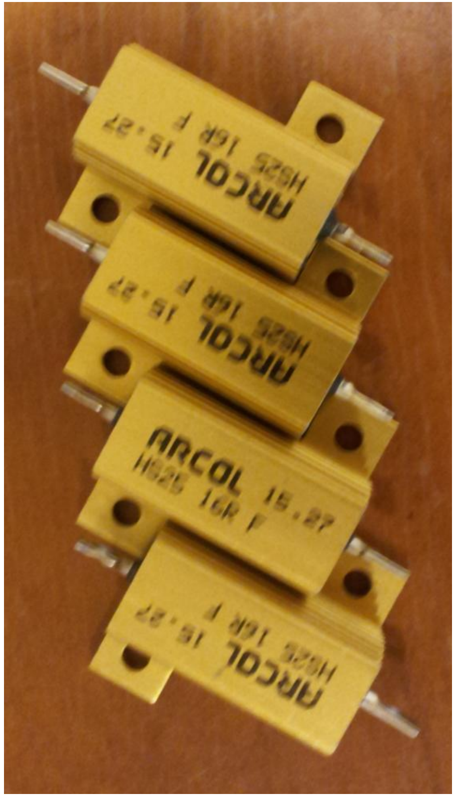
- High wattage (> 50 W)
- High Max Temperature (> 90 °C)
- Adjustable (~1 W)

HS25 16R F Power Resistors

- Max Power: 100 W
- Max Temperature: 110 °C [1]

PSMN022-30PL nMOS [2]

- Drain-Source Voltage: 30 V
- Drain Current: 30 A



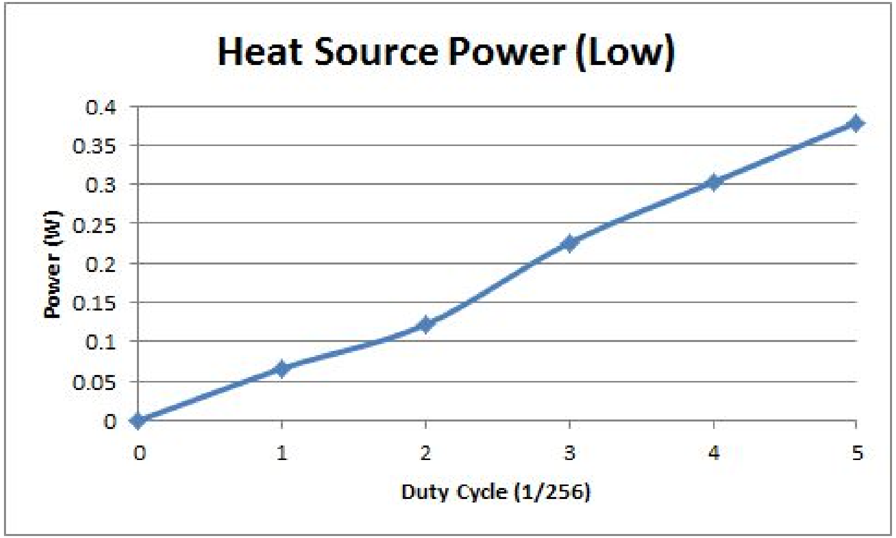
25 W Resistors

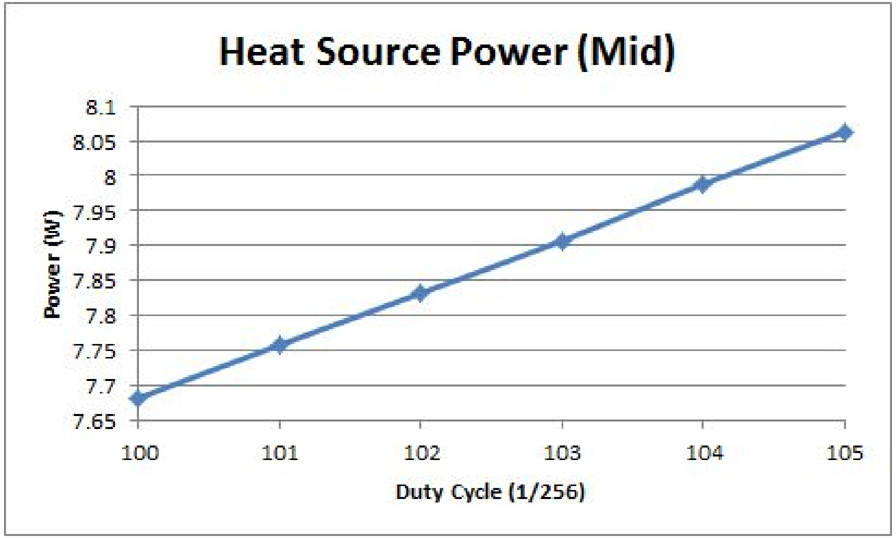
Traditional: ~36 min. Our's: ~11 min.

Heat Source Requirements

Must be able to have power adjusted in increments as small as 1W.

Resistance = 4.121Ω $$P = \frac{V^2}{R}$$ Smallest Increment: ~0.01W





Faster… ✓ **Decoupled from light…** ✓

Light Source - ***Brighter***

<u>Requirements</u>

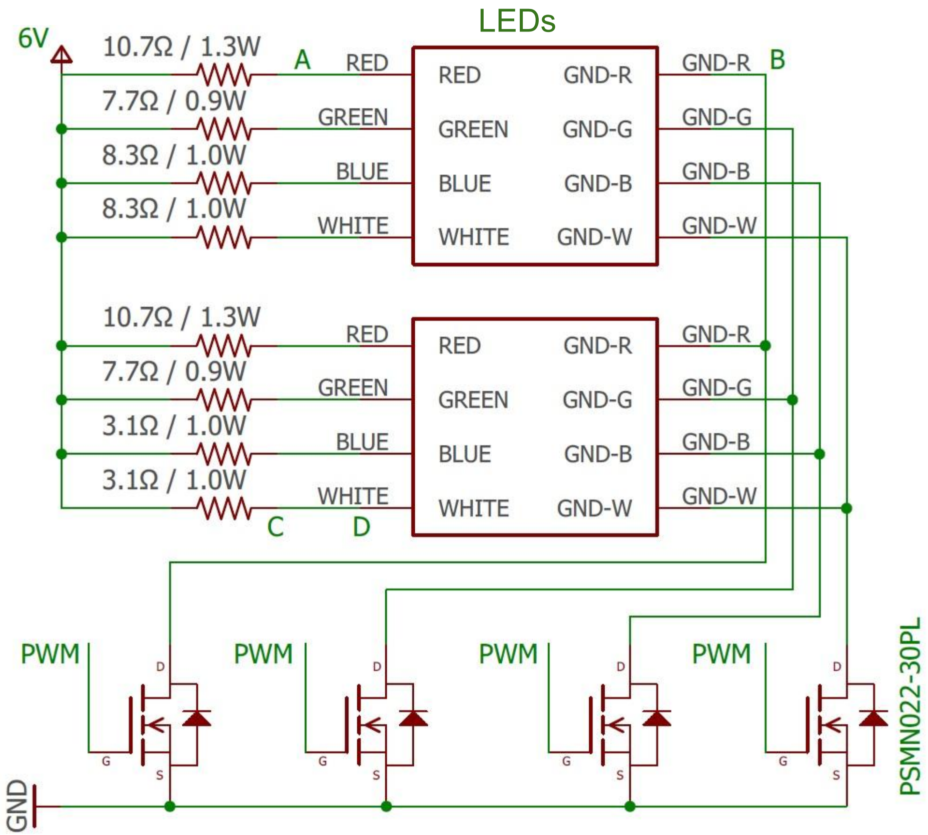
- Bright (10 lux at glass)
- Multicolored
- Adjustable (Step ~0.05 lux)

CREE XLamp XM-L Color LEDs [3]

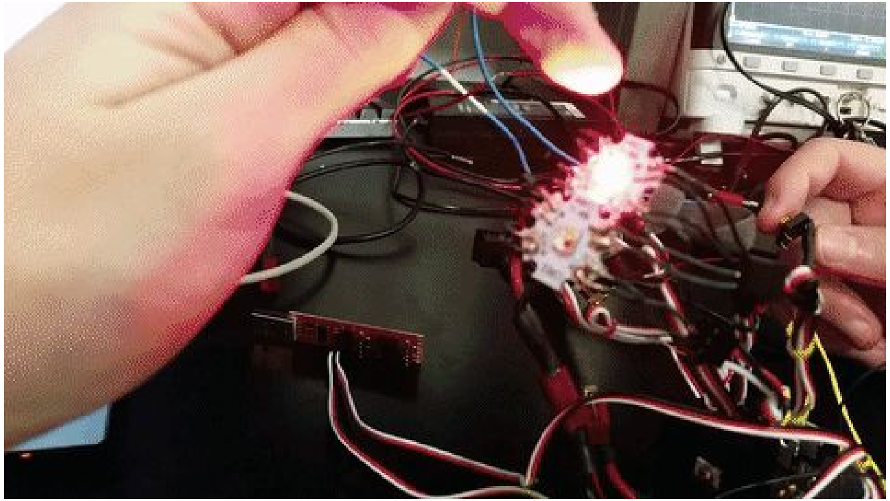
- Current: 350 mA
- Light output: 13.9-100 lumens/channel

PSMN022-30PL nMOS

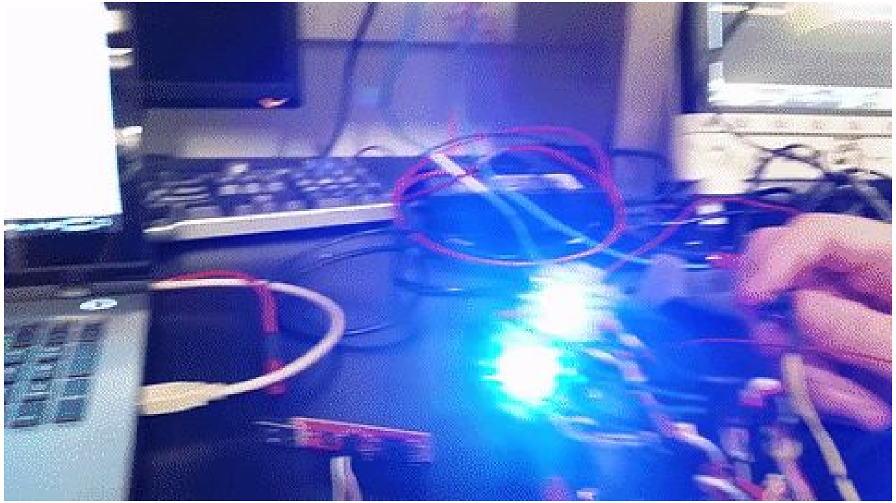
- Same as heat (simplify design)



Light Source Verifications



Color changes



Brightness adjusted

Provide red, green, blue, purple, and aqua lighting.

Traditional	12.54 lux	Required Step	0.05 lux
Our lamp	7.21 lux ✗	Our Increment	0.04 lux ✓

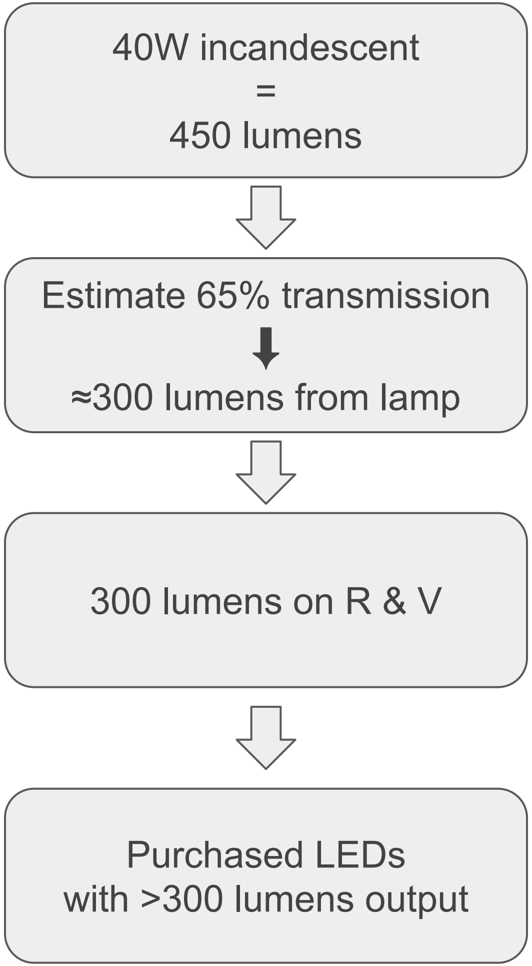
Decoupled from heat… ✓

Brighter… Not quite...

Brighter?

We purchased parts according to R&V, but didn't meet client requirements. Why?

- R&V was written in complex manner
- Confusing R&V interpreted incorrectly



Power Supply

Requirements

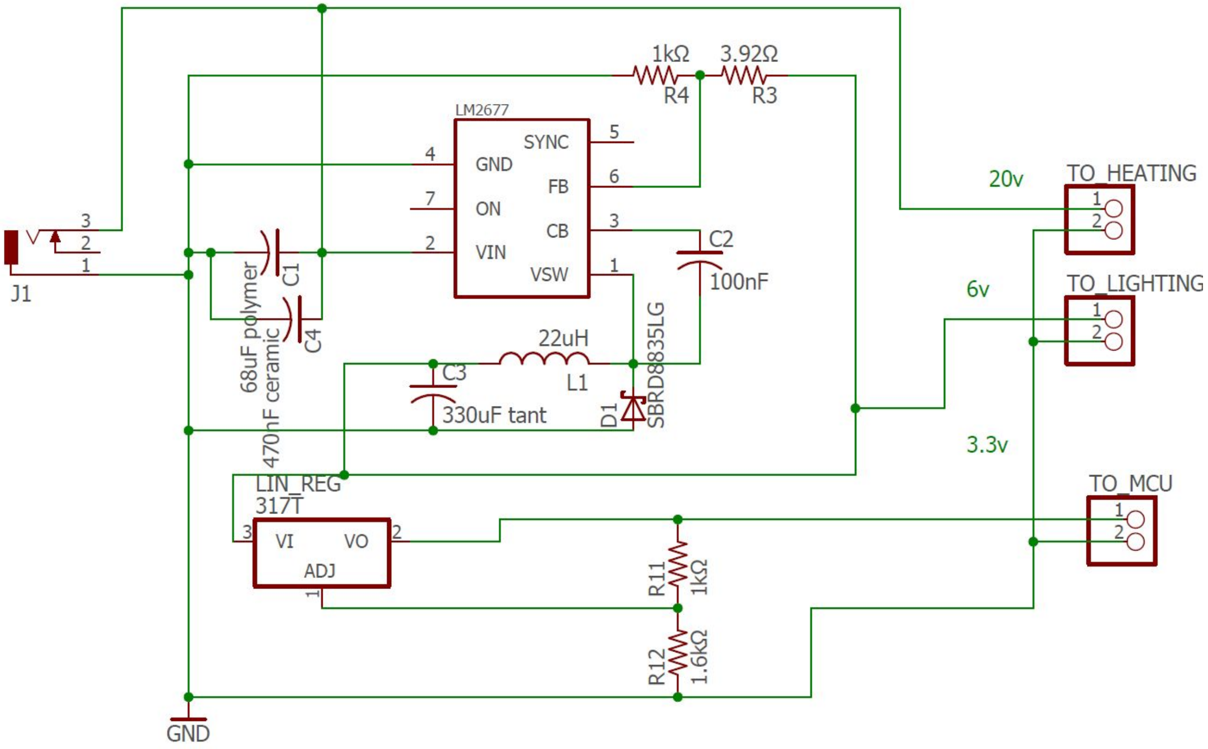
- Supply 2.8V - 3.4V at 500mA
- Supply 5.5-6.2V at 3A

LM2677

- Buck regulator capable of up to 5A
- 6V for lighting

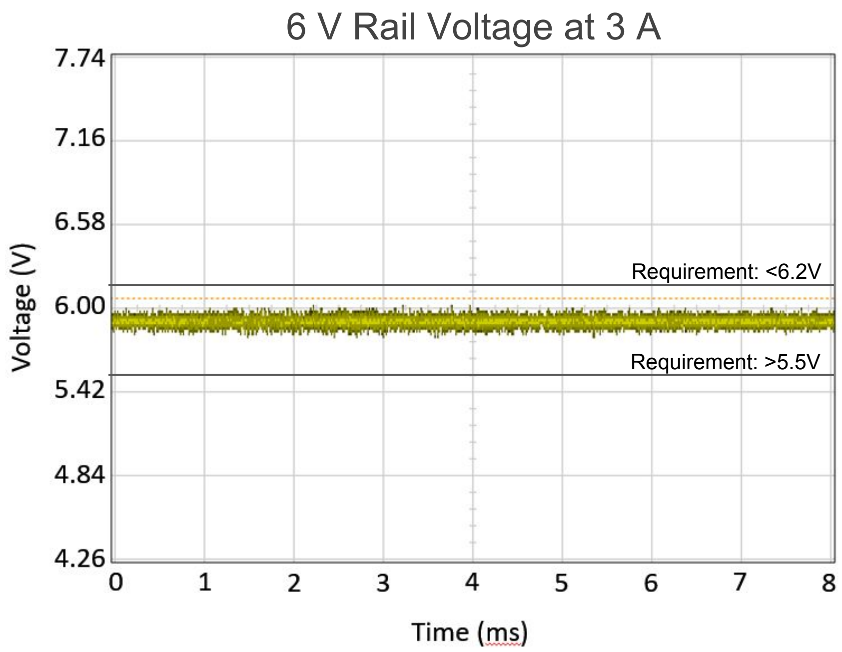
LM317T

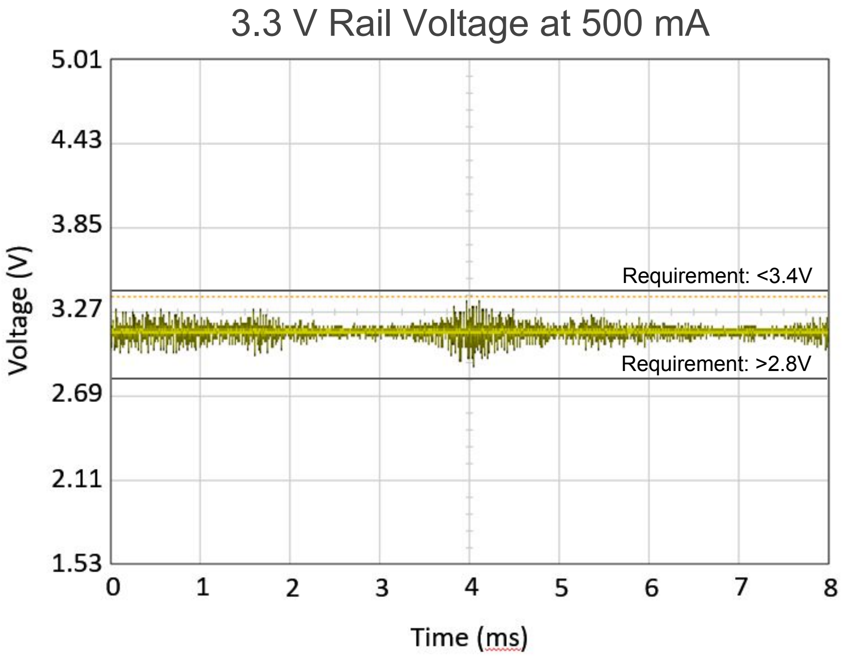
- Linear regulator
- 3.3V for microcontroller



Schematic of power supply, including linear regulator and buck converter.

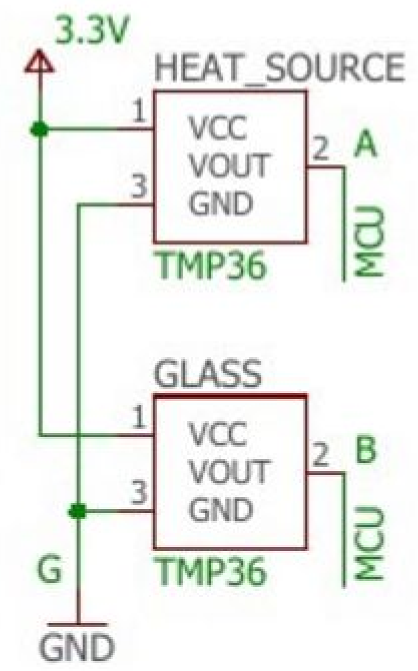
Power Supply: Verification





Notice noise from switching regulator

Temperature Sensors



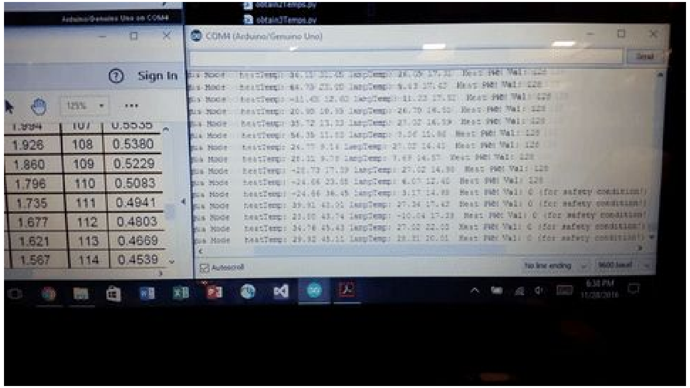
Requirements
- Fast (>= 1 Hz)
- Accurate (±2℃)
- Operate from 25 ℃ to 100 ℃

TMP36 Temp. Sensor [5]
- Analog Sensor
- Calibration-free with a ±2℃ Temperature Accuracy
- Operates from −40°C to +125°C

(Temp in ℃) = (V_{OUT} - 500mV) * 100

Temperature Sensors Verification

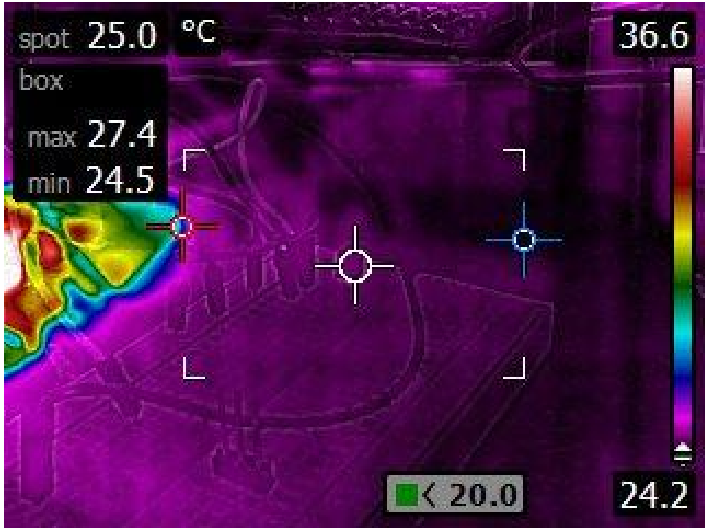
Able to read temperature at least once every second.



Serial data from MCU

Accurate to ±2℃

Reading	IR (℃)	Sensor (℃)
1	25.4	25.6
2	25.0	24.1
3	24.3	23.0



IR gun image

Temperature Sensor Issues and Solutions

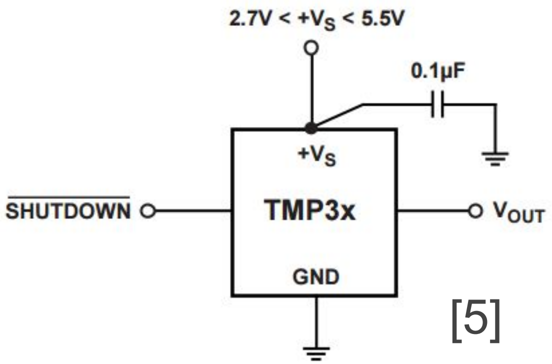
Problem: A large amount of noise in the readings.

Hardware solutions:

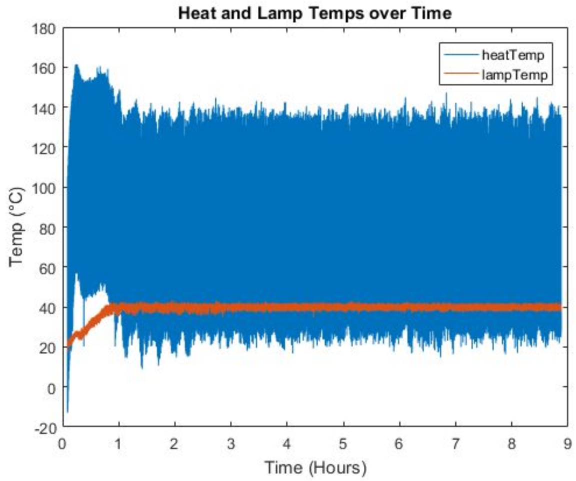
- Strategically placed 0.1 uF capacitors according to data sheet [5].
- Lower noise from power supply (future)
- Digital sensors or thermistors (future)

Software solutions:

- Averaging filter

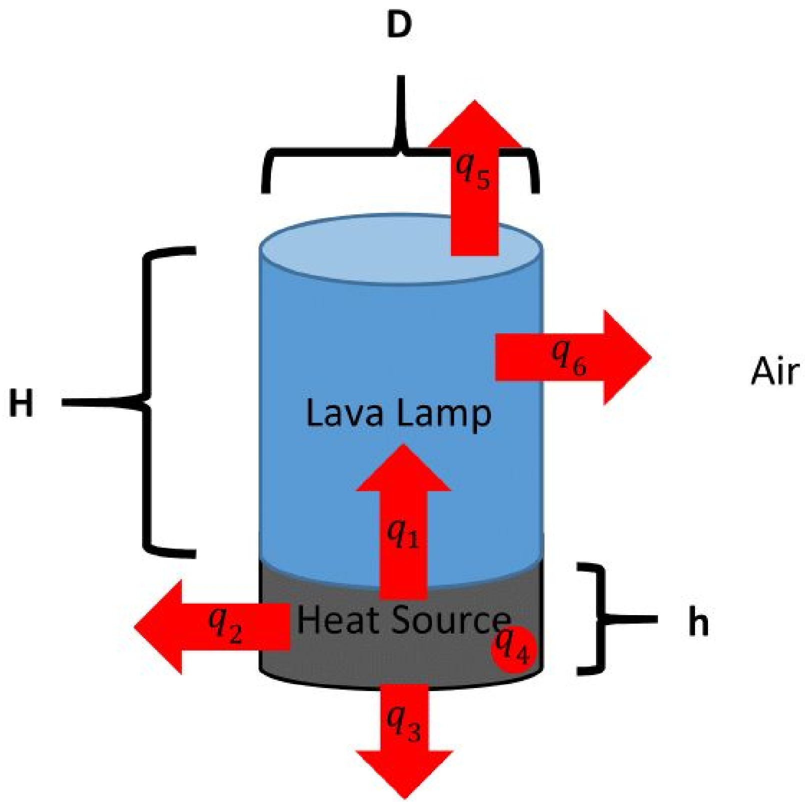


[5]



Raw Sensor Data

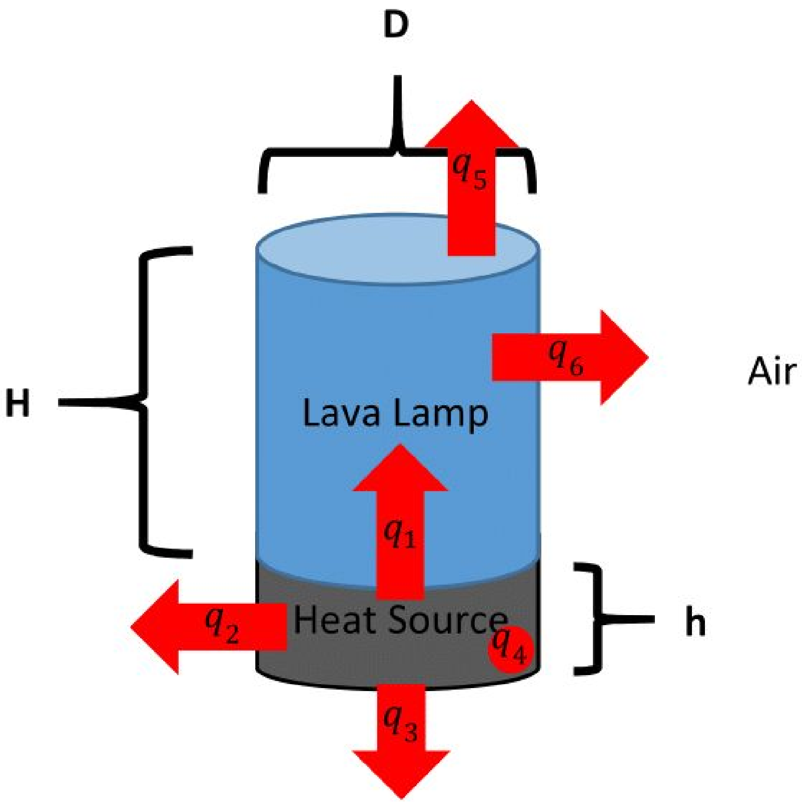
Control



<u>Requirements</u>

- ***Faster***
  - Rise Time of 40 minutes or less (of Lava Lamp Temperature to first movement)
- ***Safer***
  - Overshoot of 10 °C or less (of Lava Lamp Temperature)
- Accurate
  - Steady-State Error of 1.0 °C or less (of Lava Lamp Temperature)

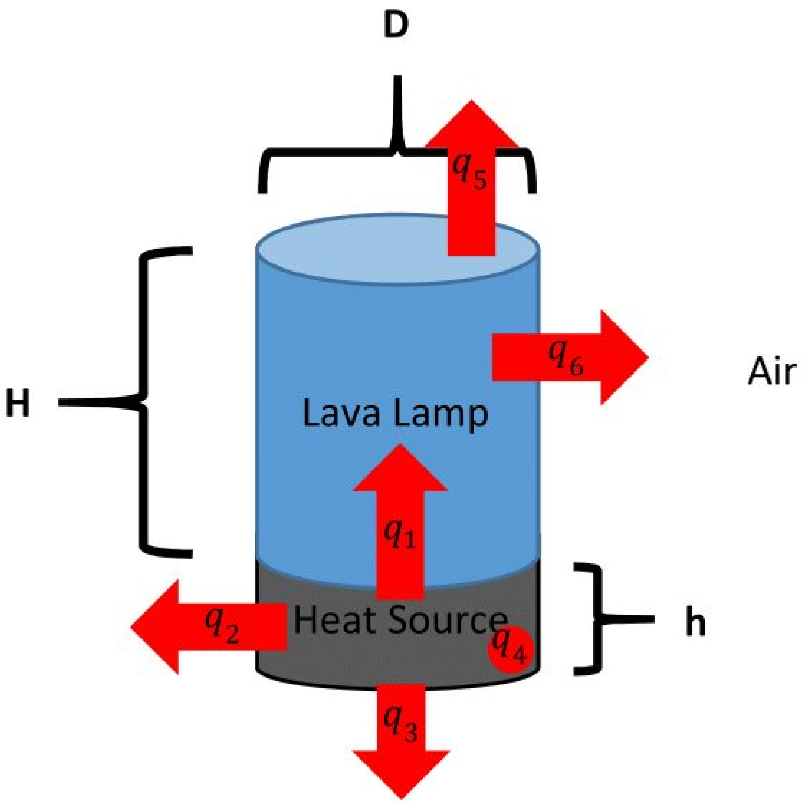
Control - Model



$$q = \frac{1}{R}(T_1 - T_2)$$

$$\dot{T} = \frac{1}{C} q$$

Control - Model



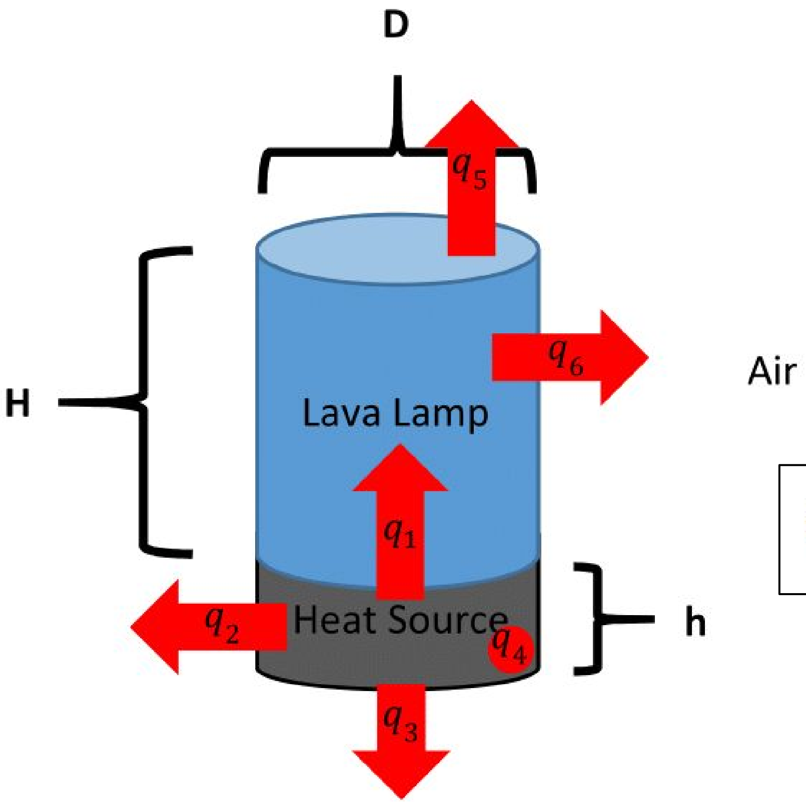
$$q = \frac{1}{R}(T_1 - T_2)$$

$$\dot{T} = \frac{1}{C}q$$

$$q_{Heat} = q_4 - q_1 - q_2 - q_3$$

$$q_{Lava} = q_1 - q_5 - q_6$$

Control - Model



$$q = \frac{1}{R}(T_1 - T_2)$$

$$\dot{T} = \frac{1}{C} q$$

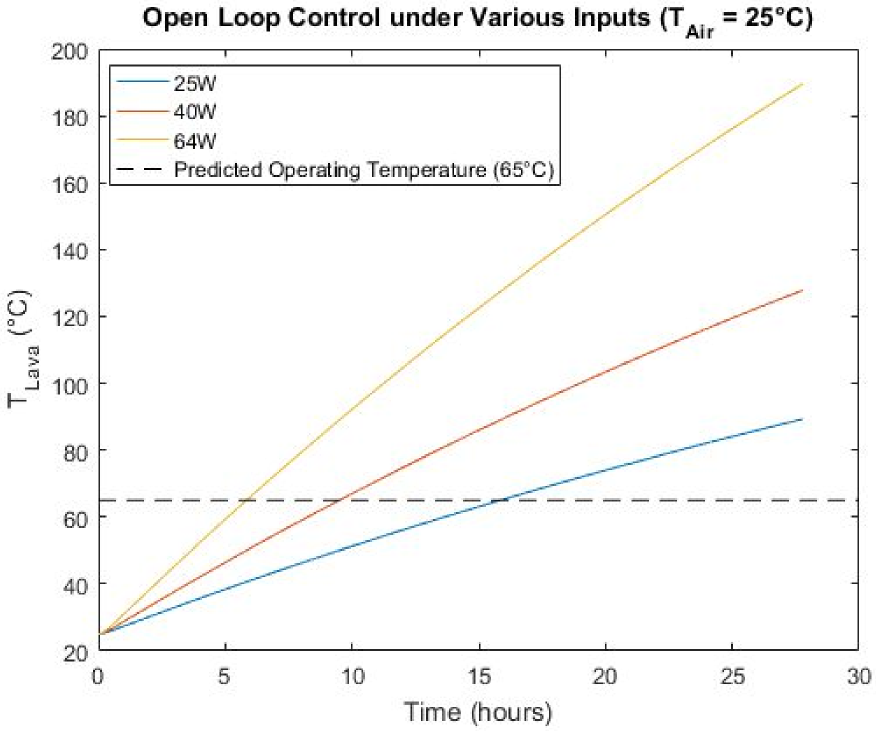
$$q_{Heat} = q_4 - q_1 - q_2 - q_3$$

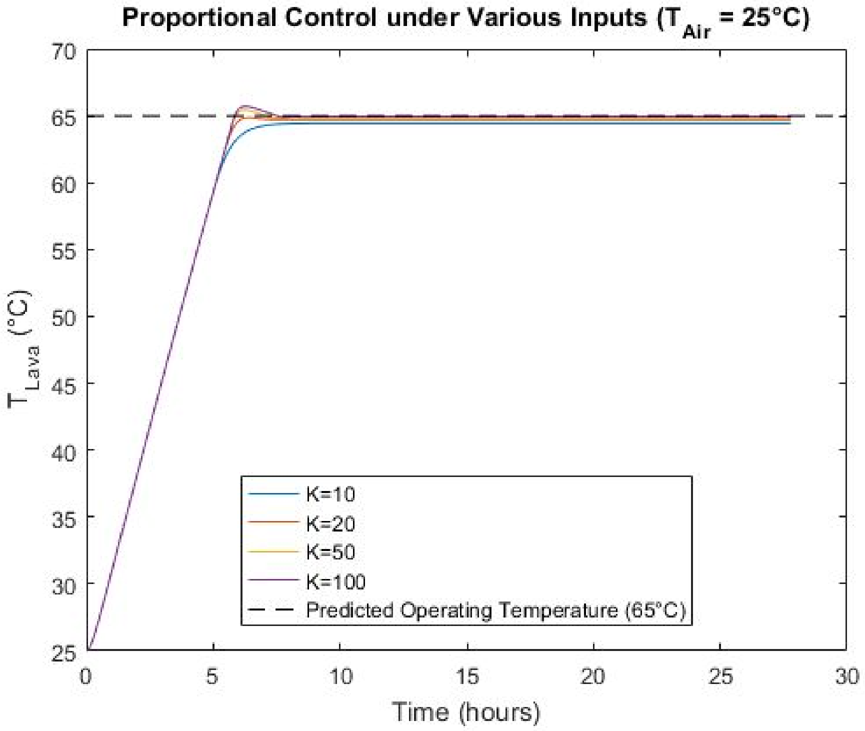
$$q_{Lava} = q_1 - q_5 - q_6$$

$$\dot{\tilde{T}}_{Heat} = \left(\frac{-1}{R_{1,2,3}C_{Heat}}\right)\tilde{T}_{Heat} + \left(\frac{1}{R_1 C_{Heat}}\right)\tilde{T}_{Lava} + \left(\frac{1}{C_{Heat}}\right)q$$

$$\dot{\tilde{T}}_{Lava} = \left(\frac{1}{R_1 C_{Lava}}\right)\tilde{T}_{Heat} + \left(\frac{-1}{R_{1,5,6}C_{Lava}}\right)\tilde{T}_{Lava}$$

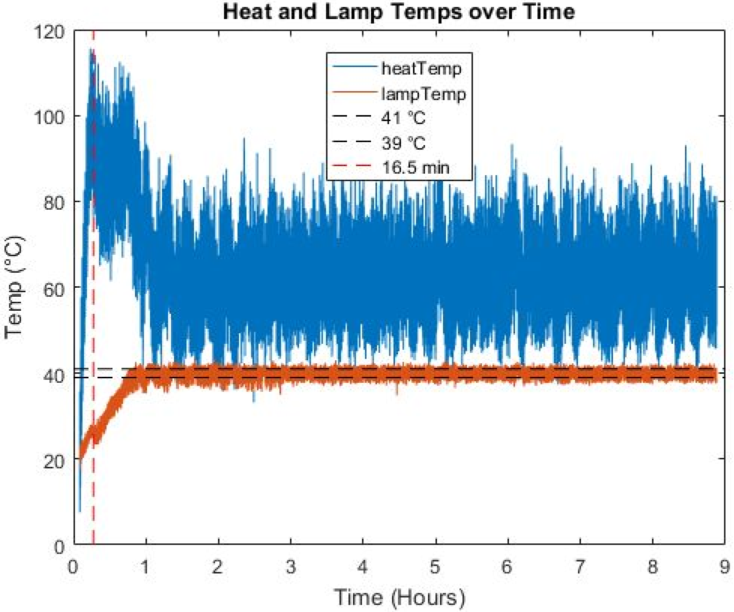
Simulations





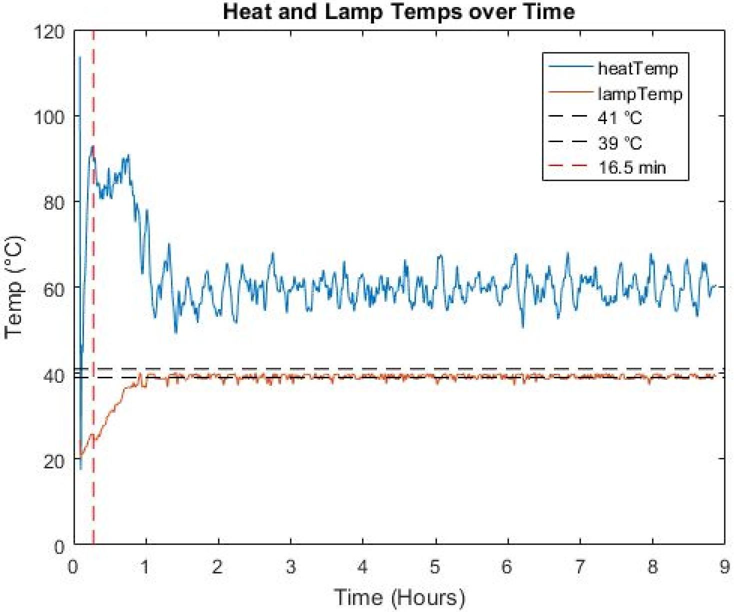
Experimental Data

Smoothed (implemented)



Faster… Safer… ✓

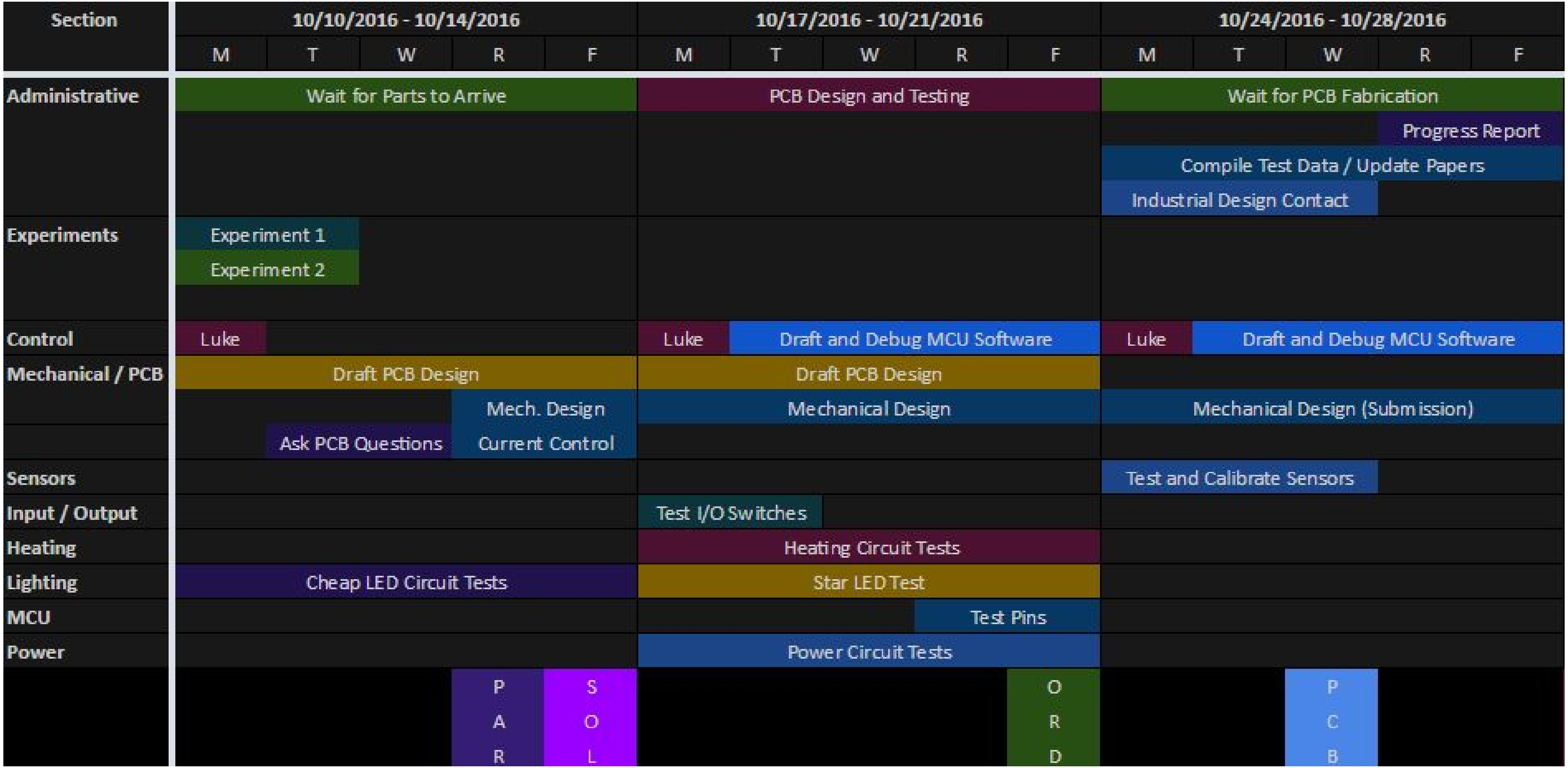
Butterworth Filter (future)



Credit: Jamie for helping us with MATLAB

Traditional: ~36 min. Our's: ~11 min.

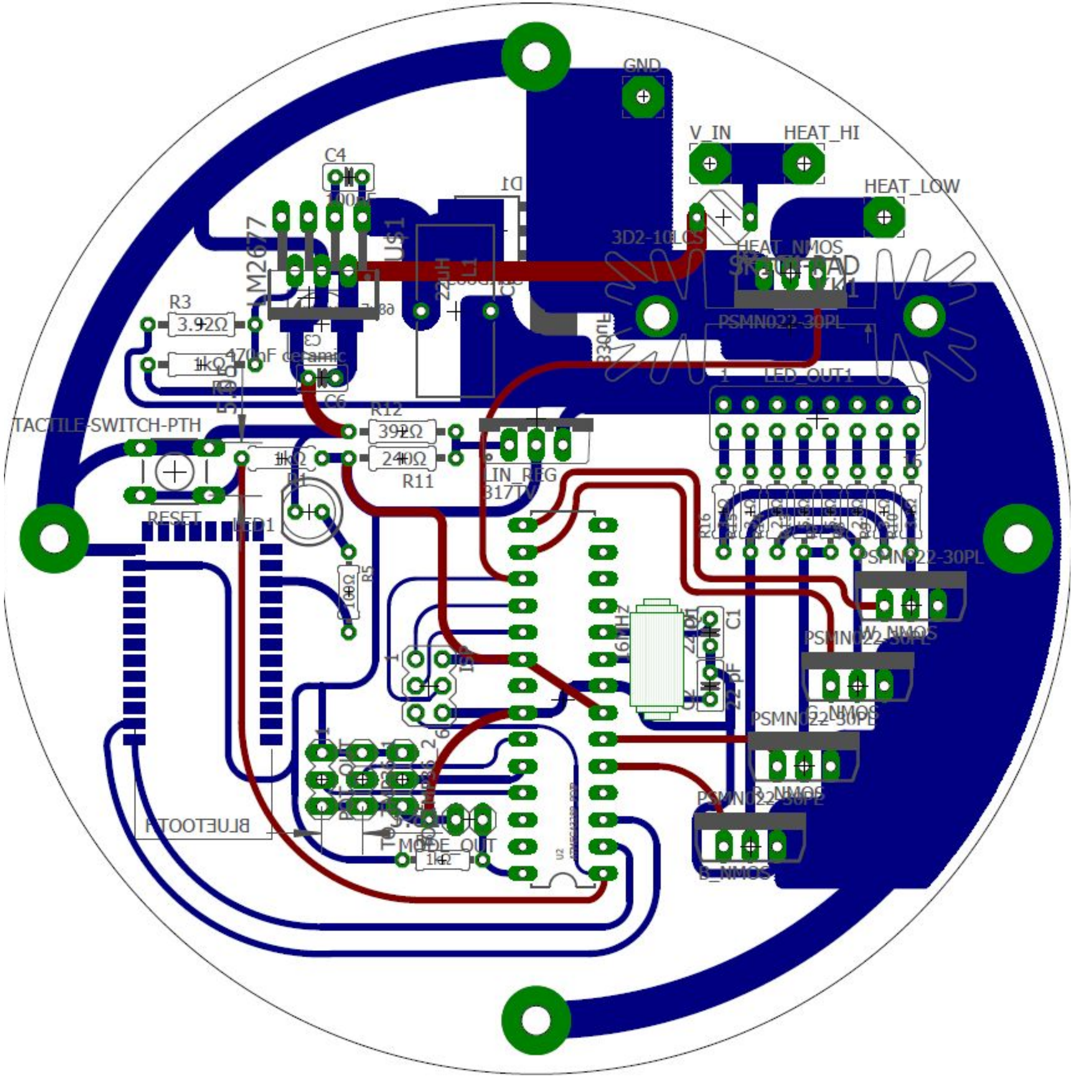
Integration



Sample of our Gantt chart schedule on Google Sheets

10/10/2016	Assigned	Due	Description
Wait for Parts to Arrive	Everyone	None	Get as much preliminary work done as possible while we wait for parts to arrive.
Soldering Assignment	Everyone	10/14/16	
Experiment 1	Matthew	10/14/16	PURPOSE: Obtain temperature constants for control problem (light bulb). EXPERIMENT: Use an IR gun to test how hot the light bulb gets after XX amount of time. MATERIALS: Lava lamp base, IR gun from Bird (the TA). DESIRED RESULTS: 1. Light bulb temperature vs. time graph 2. Data chart 3. Temperature constant 4. Picture of experimental setup
Experiment 2	Matthew	10/14/16	PURPOSE: Obtain temperature constants for control problem (lamp external). EXPERIMENT: Use an IR gun to measure how hot the glass gets after XX amount of time. MATERIALS: Lava lamp, IR gun from Bird (the TA). DESIRED RESULTS: 1. Glass temperature vs. time graph 2. Data chart 3. Temperature constant 4. Picture of experimental setup
Experiment 3	Matthew	10/14/16	PURPOSE: Obtain temperature constants for control problem (lamp internal). EXPERIMENT: Use a liquid compatible temperature sensor to see how hot the internal liquid gets after XX amount of time. MATERIALS: Lava lamp, liquid compatible temperature sensor. DESIRED RESULTS: 1. Liquid temperature vs. time 2. Data chart 3. Temperature constant 4. Time to get to operational temperature (and what that temperature is) 5. Time to overheat (and what that temperature is) 6. Picture of experimental setup

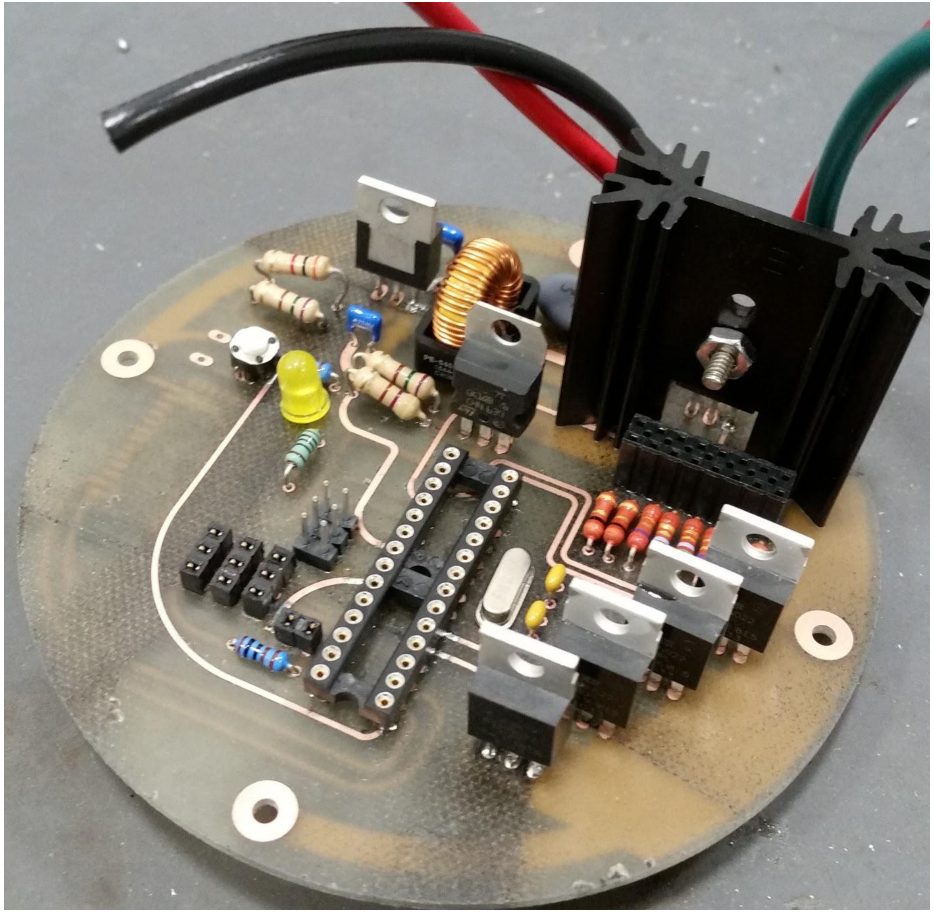
Sample of our detailed schedule on Google Sheets



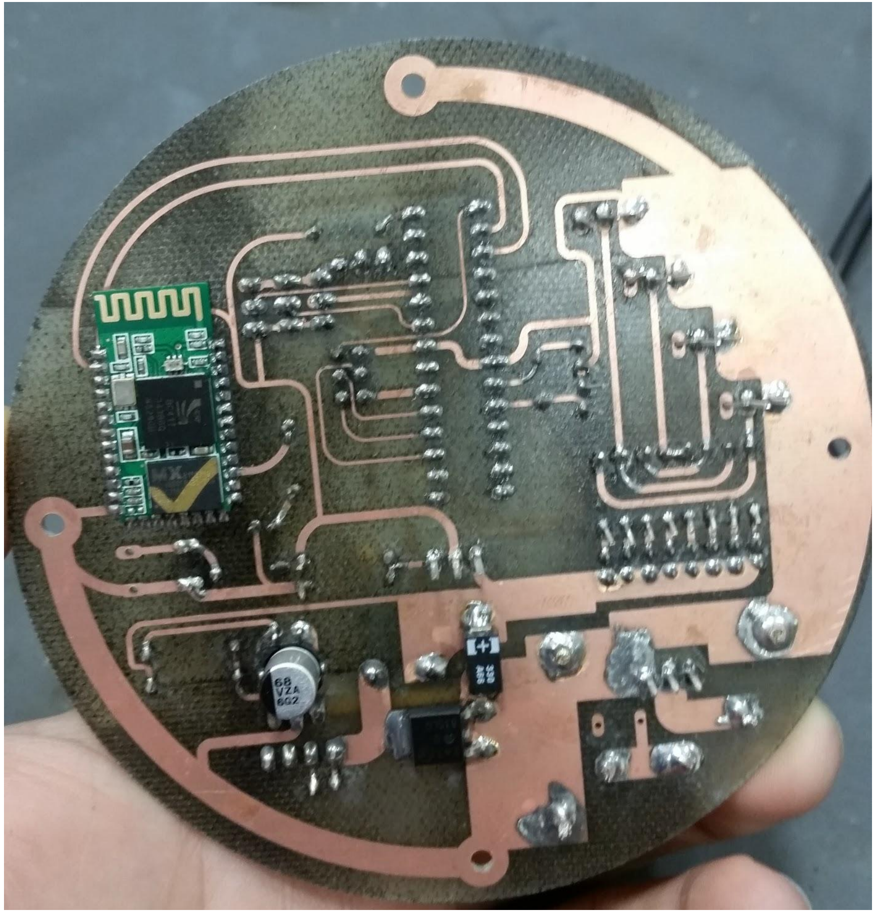
PCB

Design Considerations

- Circular
- Mounting holes
- Minimize vias and top routed traces to pins
- Through hole where possible



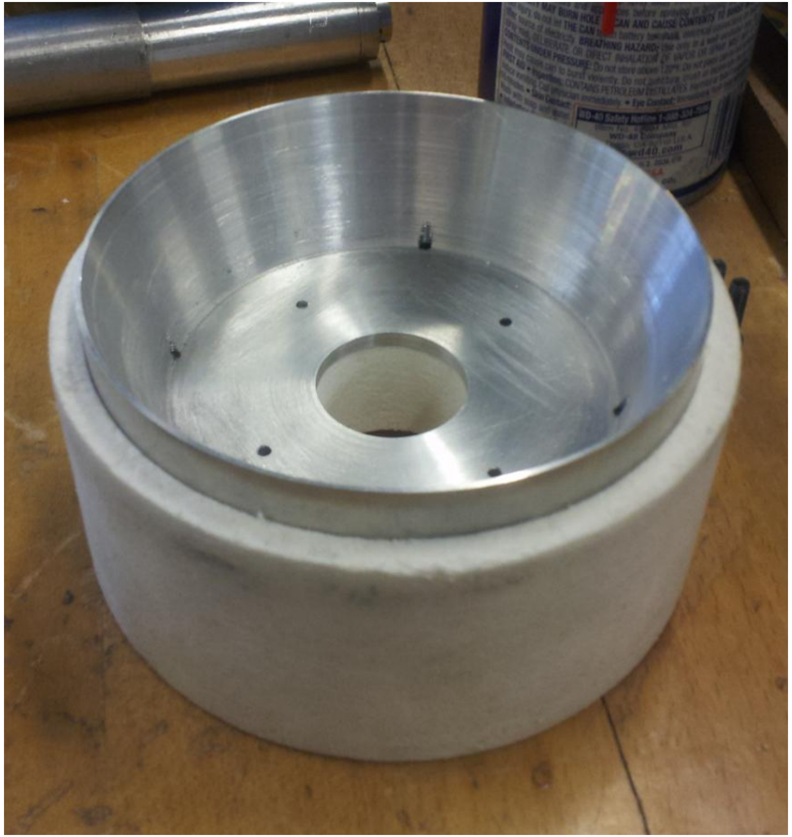
PCB (top)



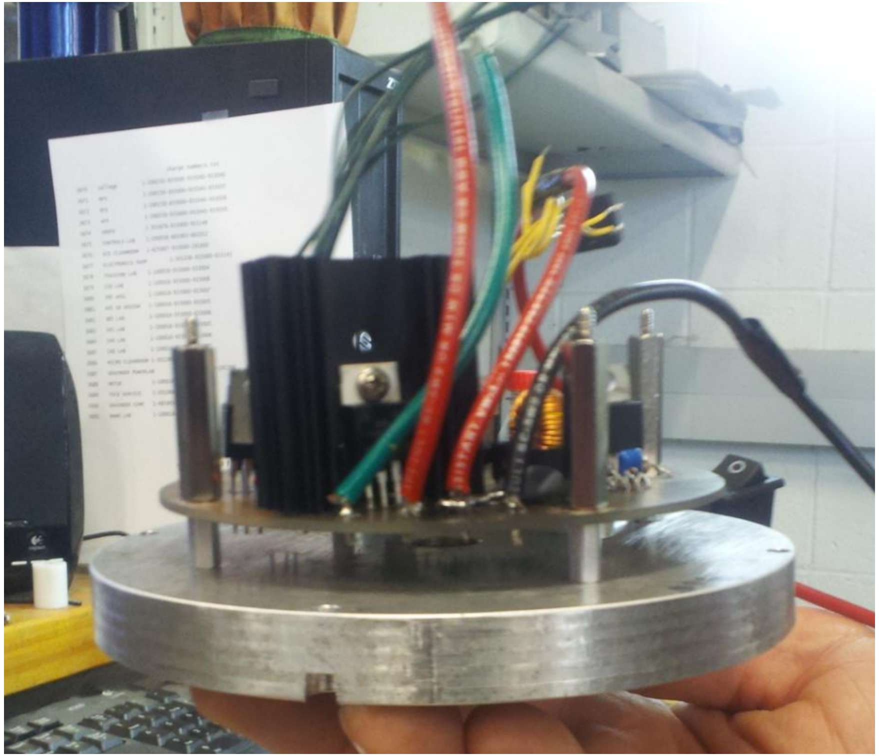
PCB (bottom)

Mechanical Design

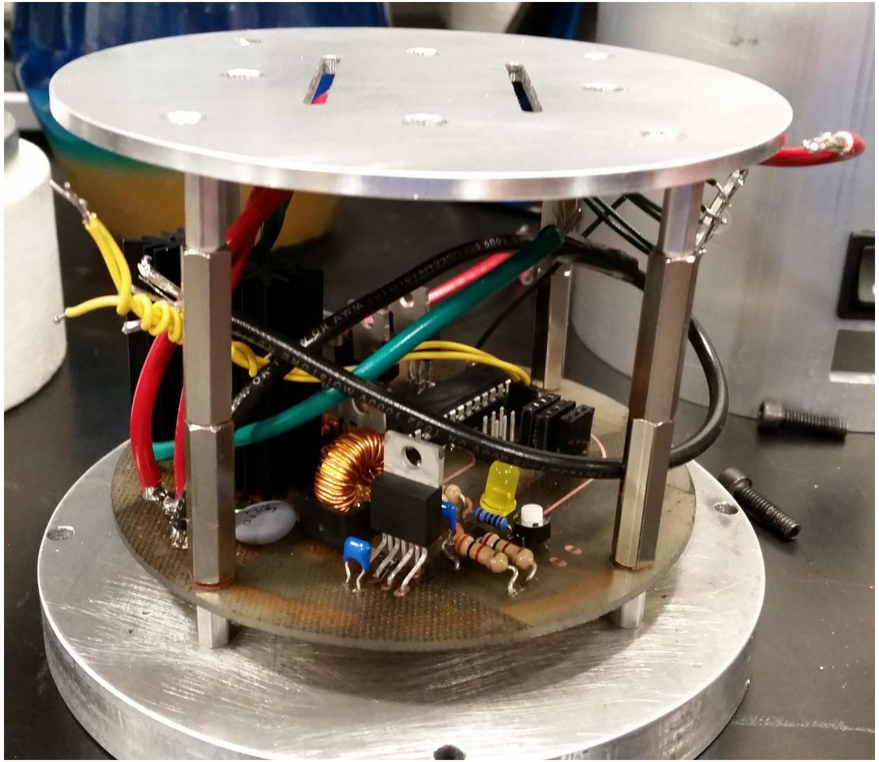
Heat spreader (bottom) thermal isolator (top)



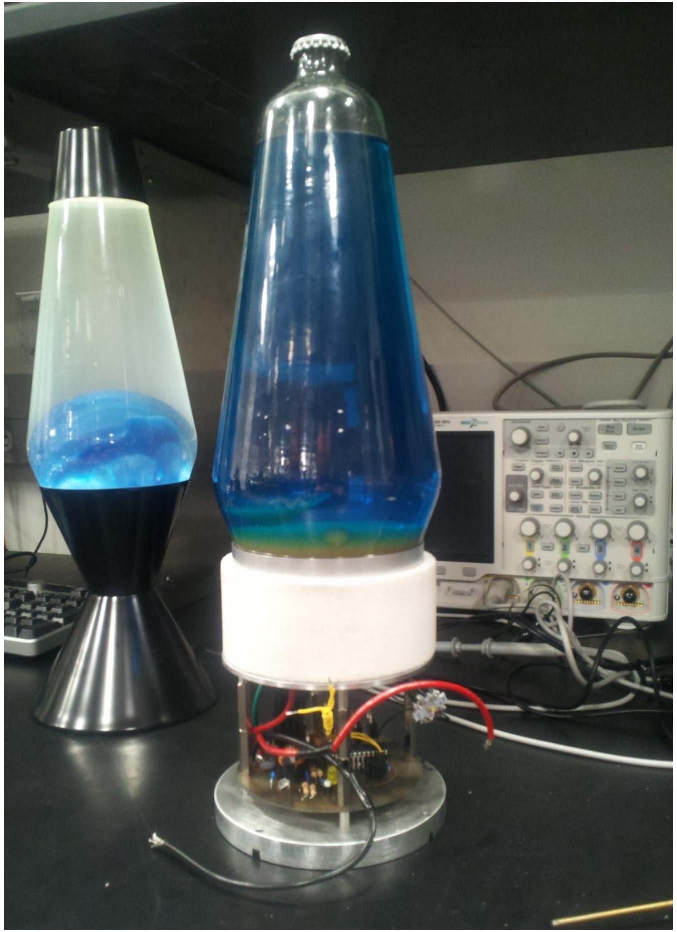
Heat spreader inside thermal isolator



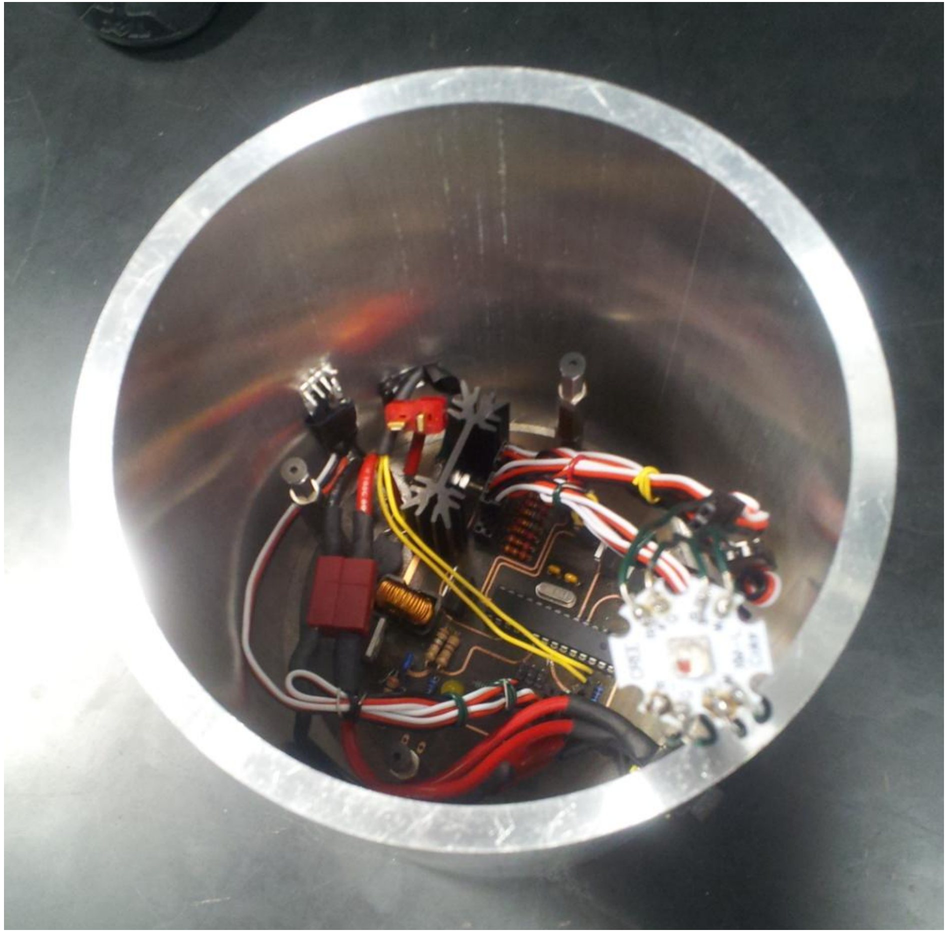
PCB mounted to bottom base plate



PCB mounted between base and LED plates



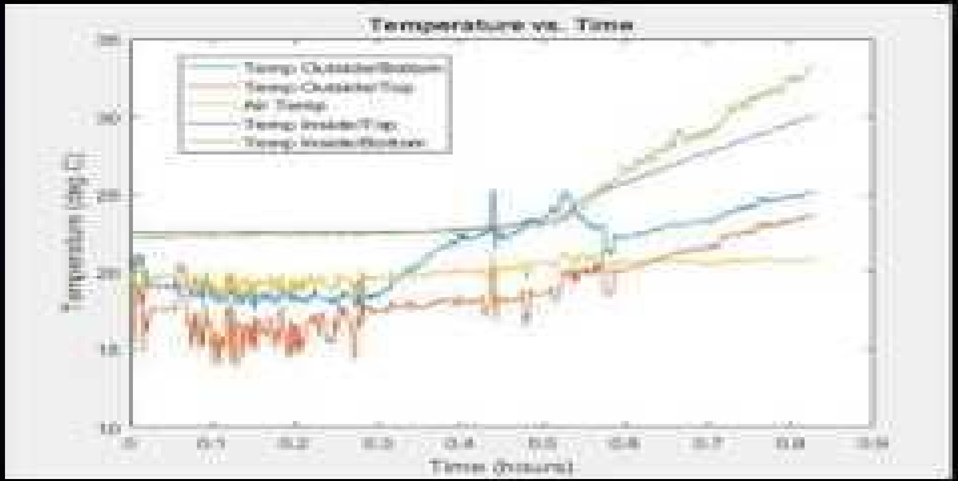
Base assembly without shell



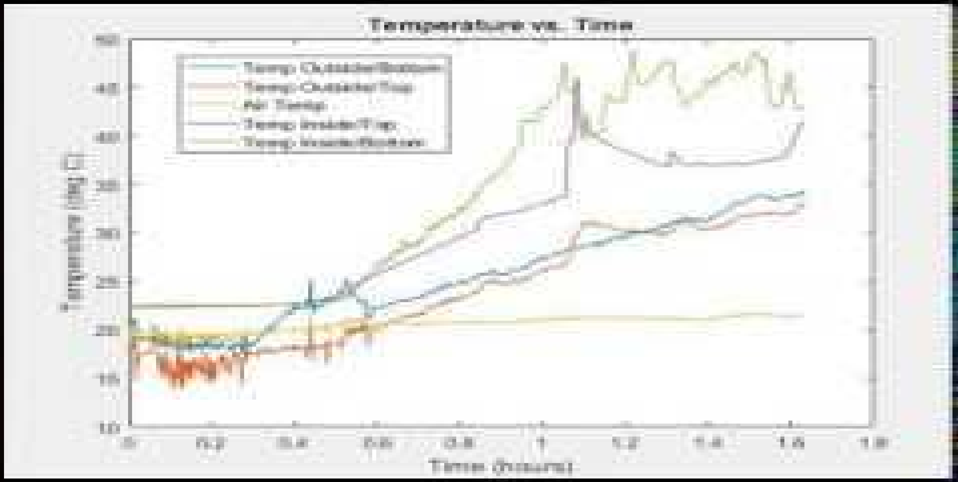
PCB et. al. mounted inside of the shell

Comparative Results

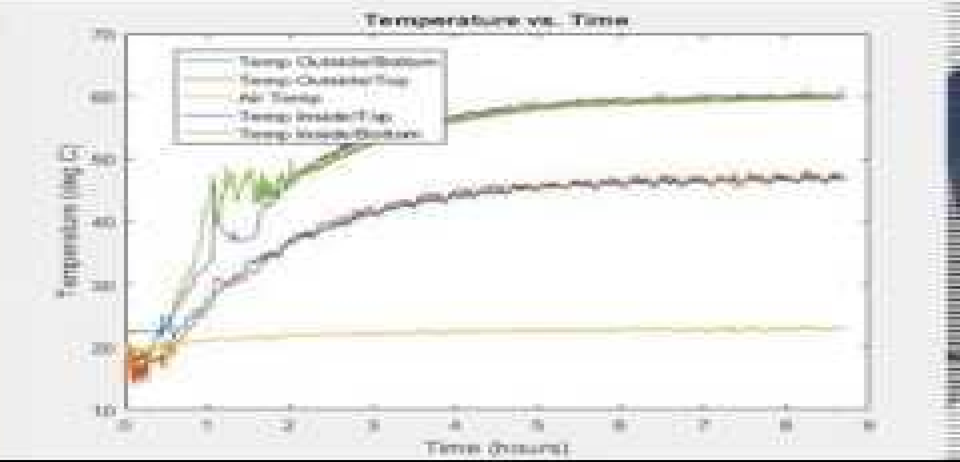
Results - Traditional Lava Lamp



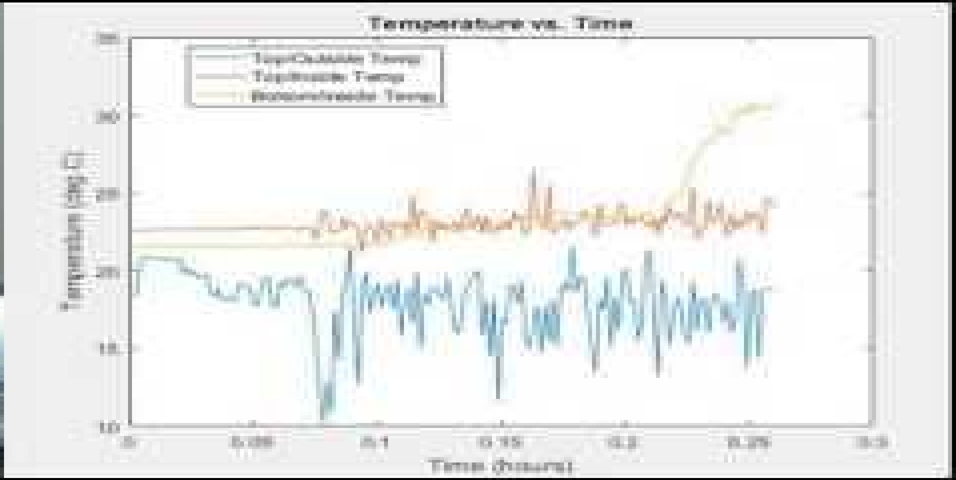
Results - Traditional Lava Lamp



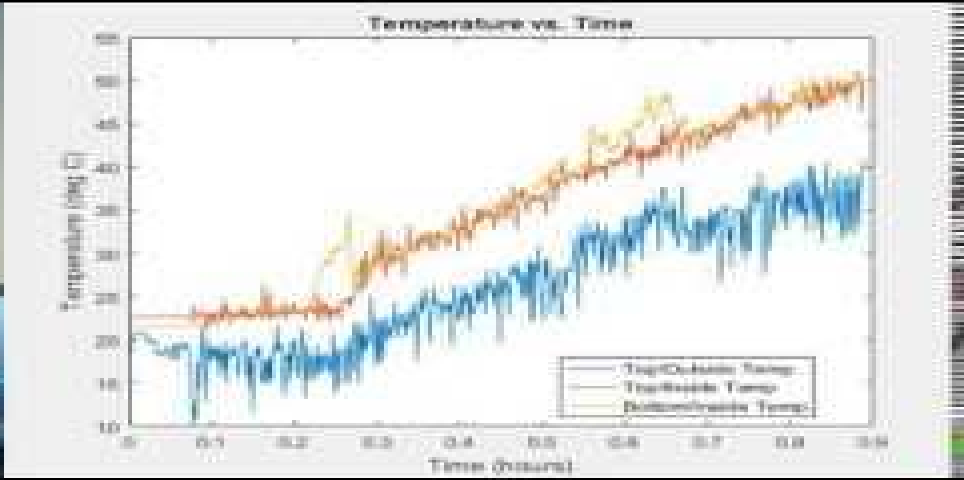
Results - Traditional Lava Lamp



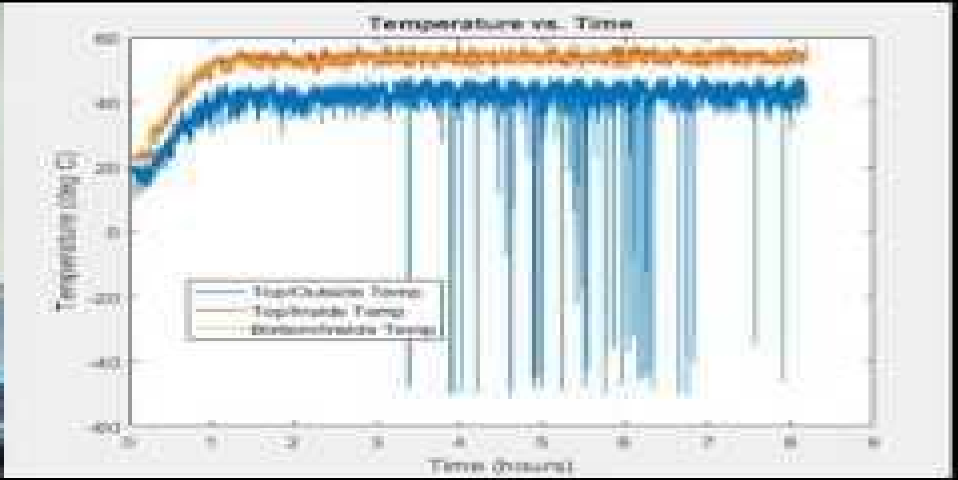
Results - Improved Lava Lamp



Results - Improved Lava Lamp



Results - Improved Lava Lamp

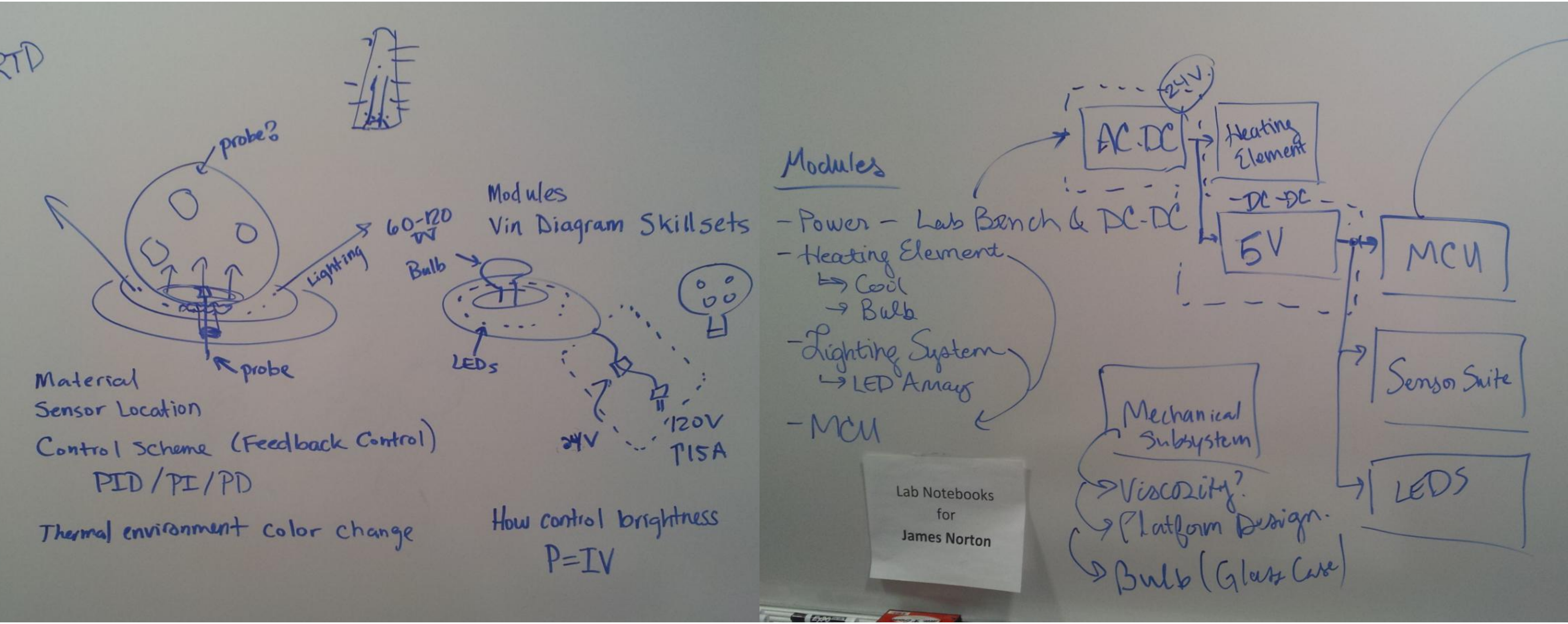


Future Directions

- Continue pursuing an industrial design model
- Inductive heating
- LEDs in a ring around base for better lighting
- Wireless capability with companion application
- Improved PCB layout
- More accurate/less noisy temperature sensors
- Auto-calibration to determine system parameters and air temperature for more accurate and advanced control schemes

Acknowledgements

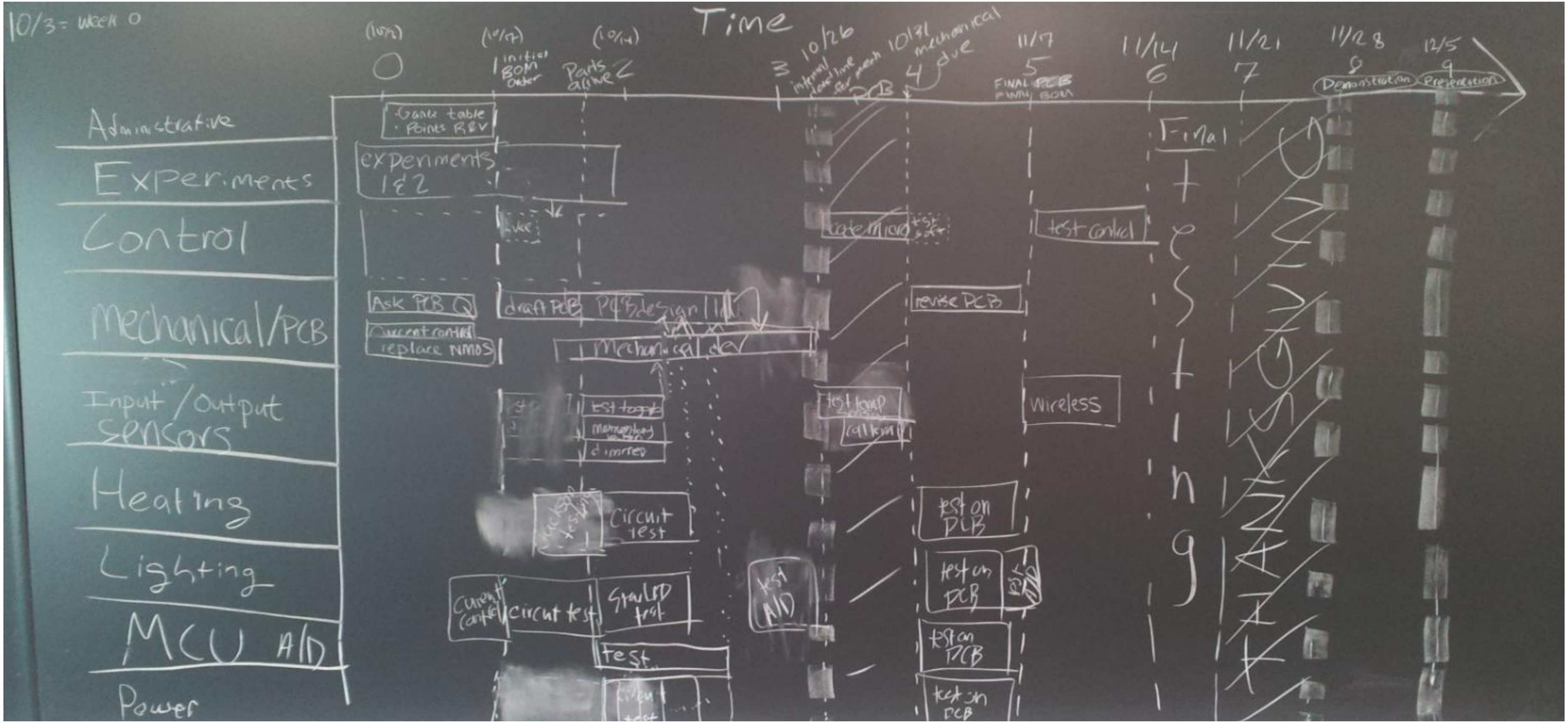
Teaching Assistants: Jackson Lenz & Katherine O’Kane



Little Baby Lava Lamp

Jackson also helped us not kill ourselves on the high power supply in the lab.

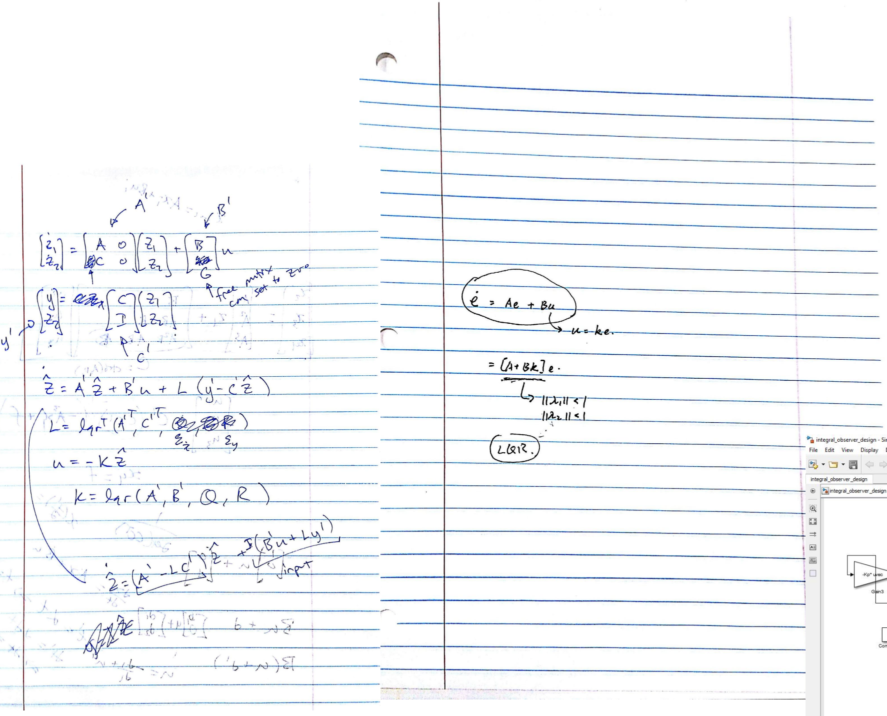
Teaching Assistant: James Norton

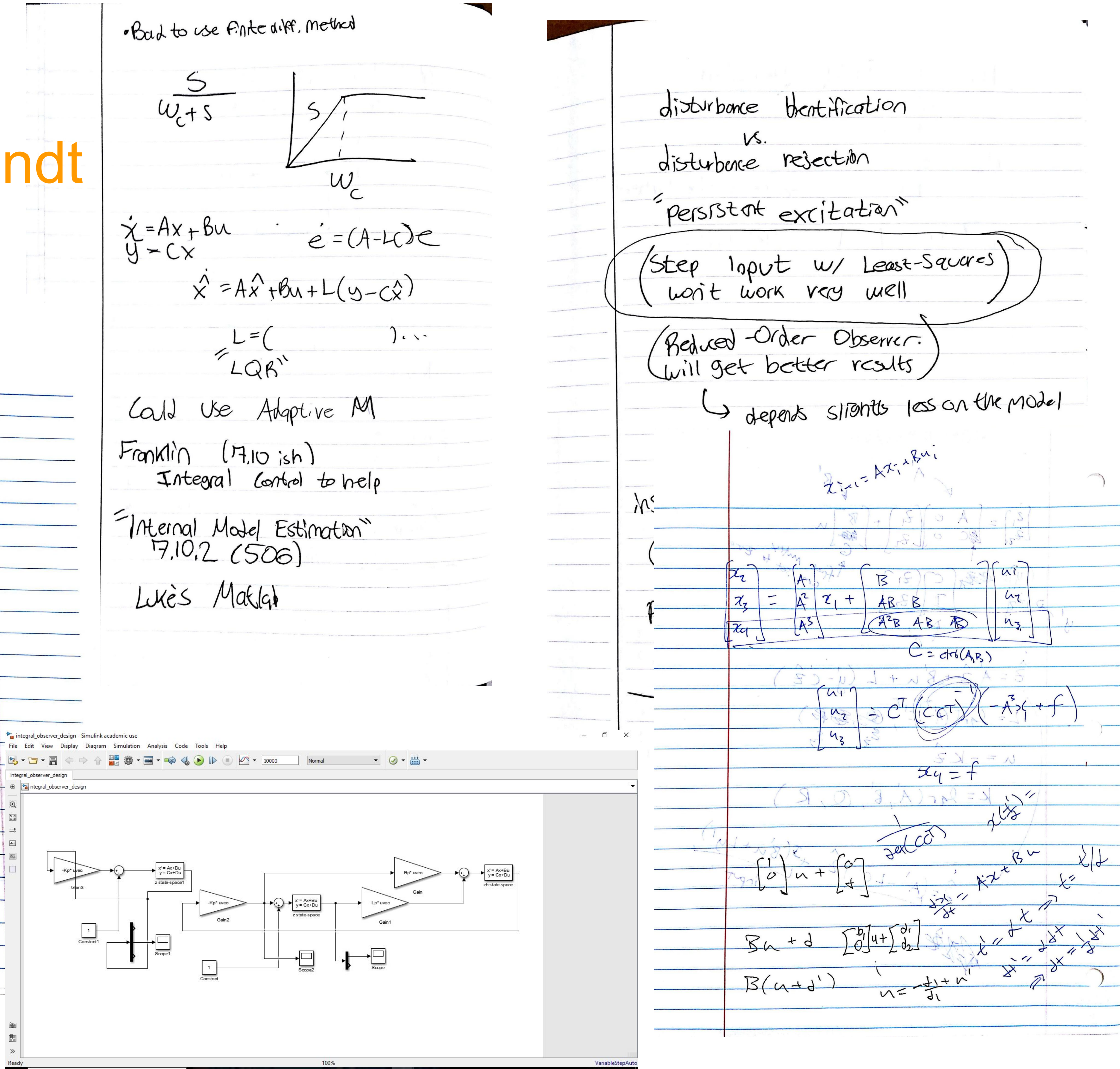


The conception of the Gantt chart schedule

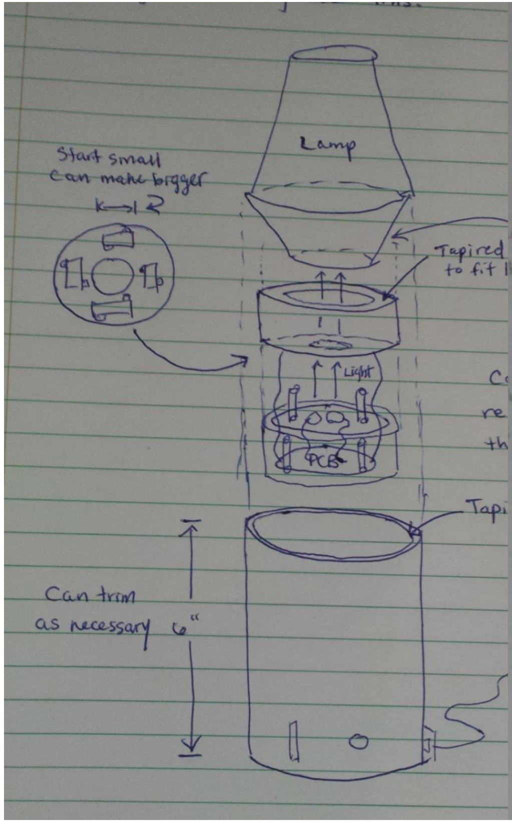
Teaching Assistant: Luke Wendt

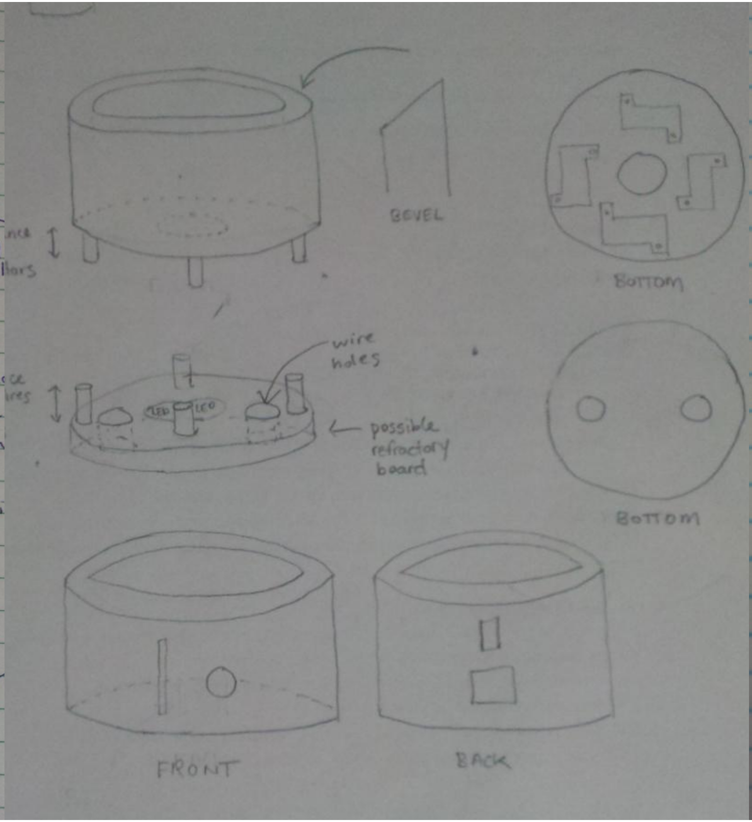
Control problem guruship

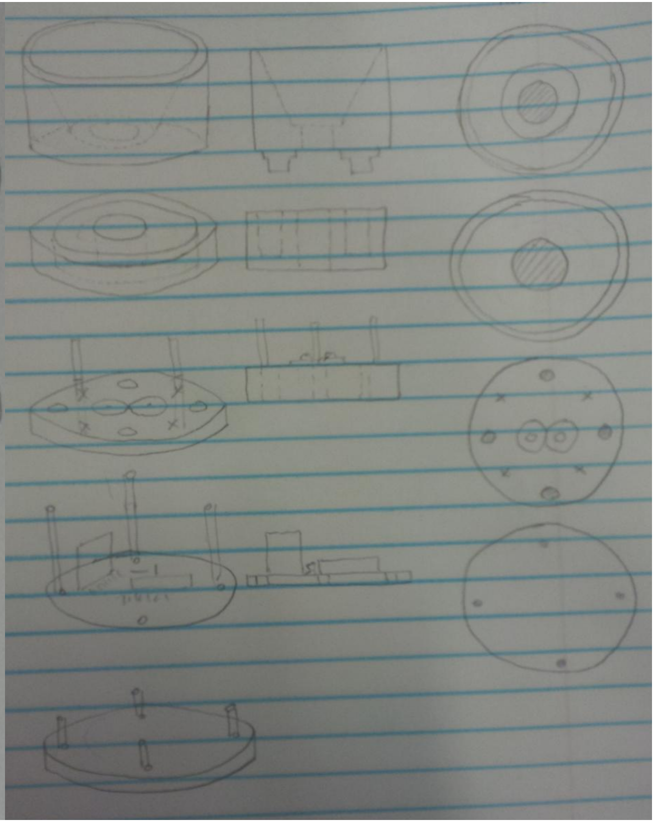




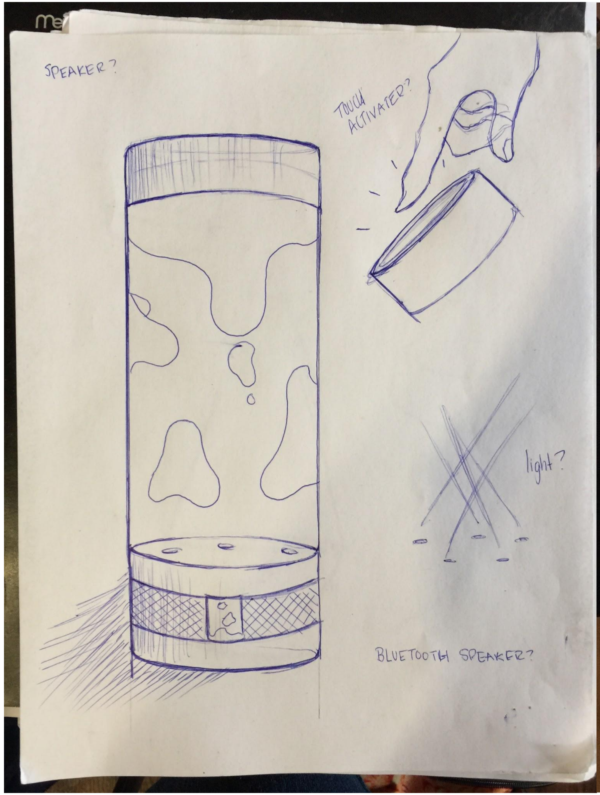
ECE Machine Shop: Skee G. Aldrich & Scott A. McDonald

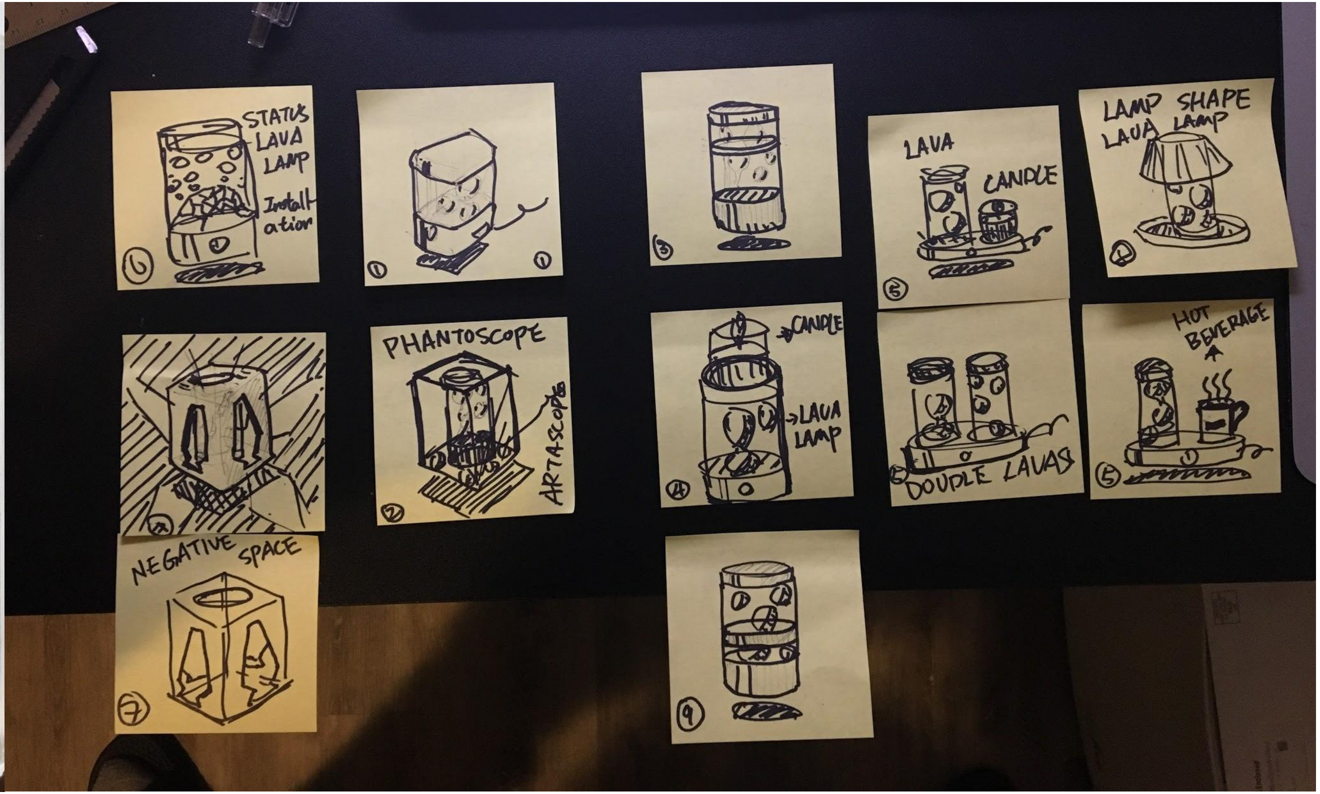


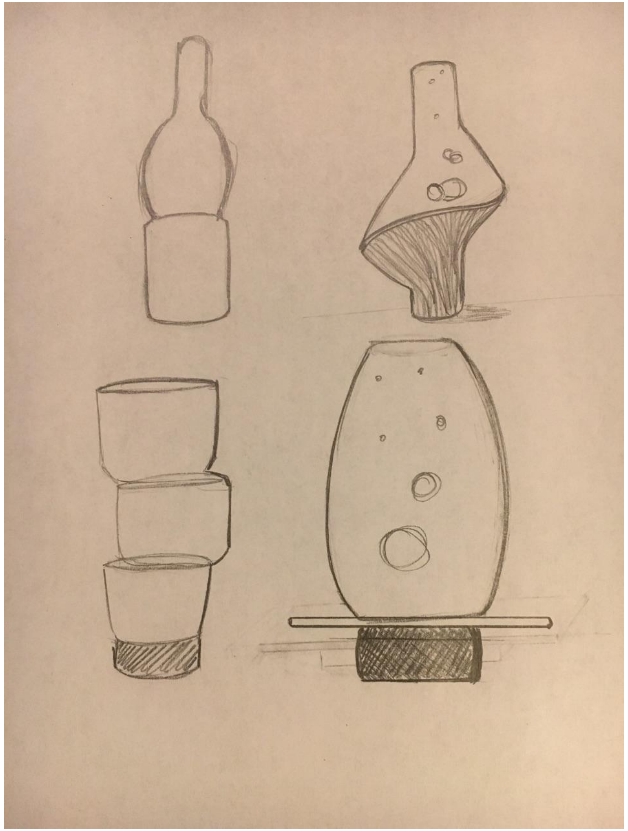


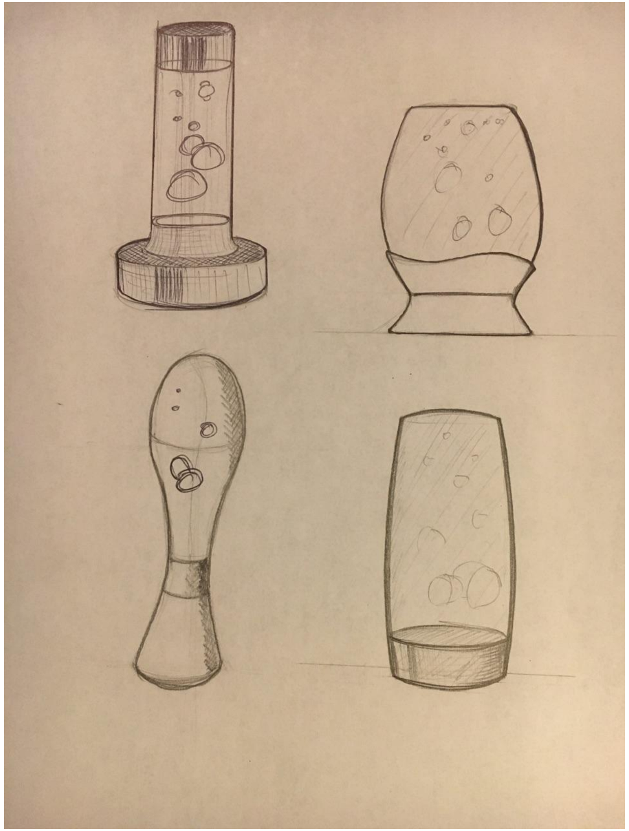


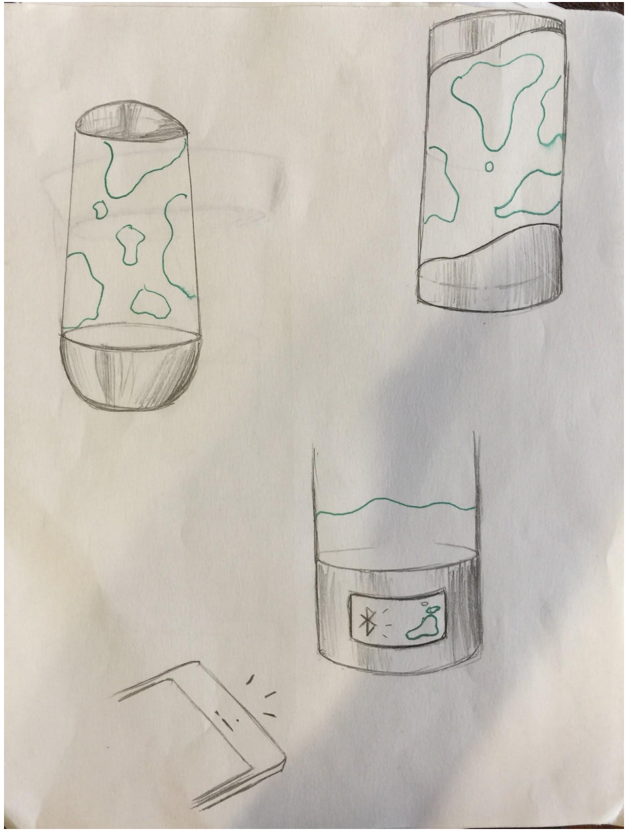
Industrial Design Team: Sarah Spalding, Jarek Diaz, Jill Moore, and Lucas Mai

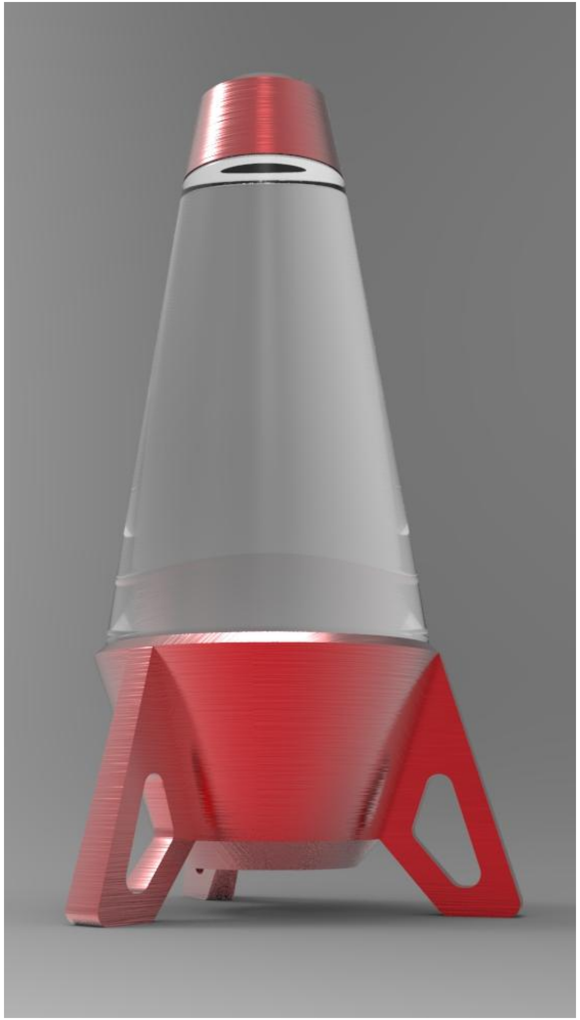






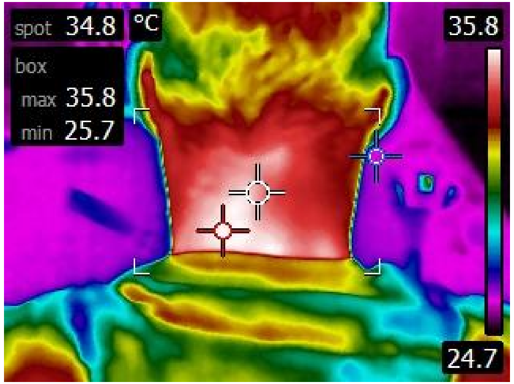


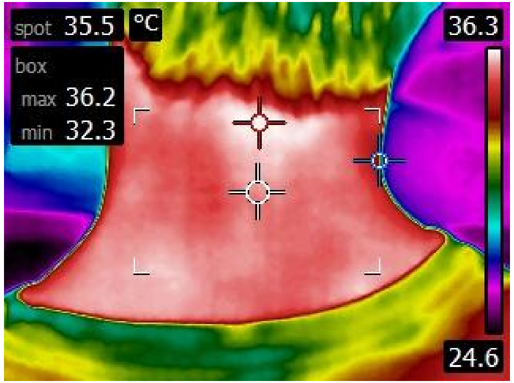


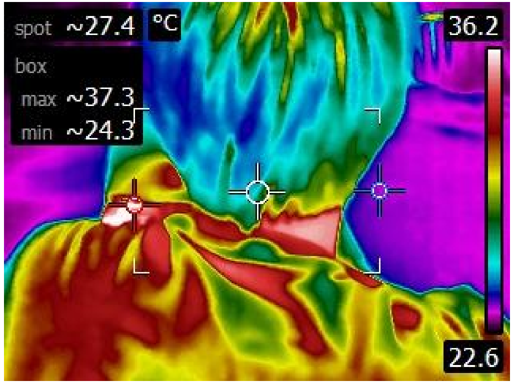



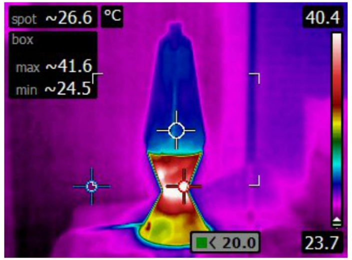

Teaching Assistant: Bird

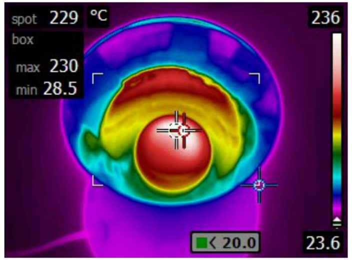
IR Gun

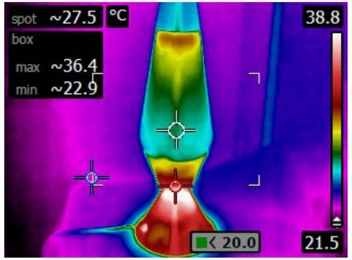


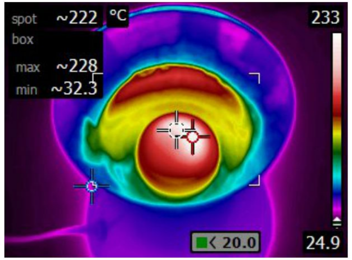


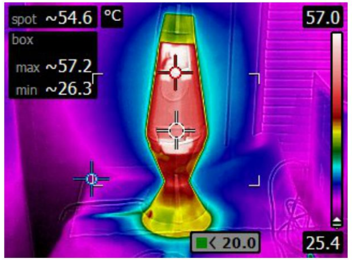


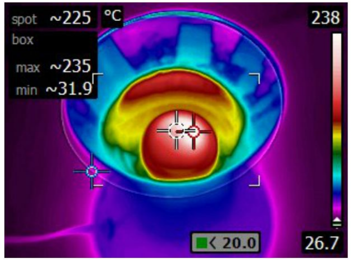


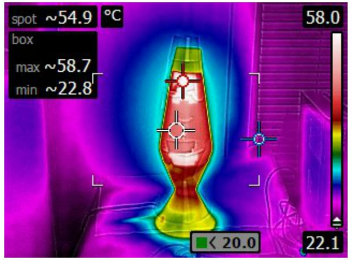


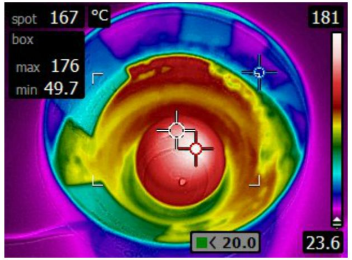






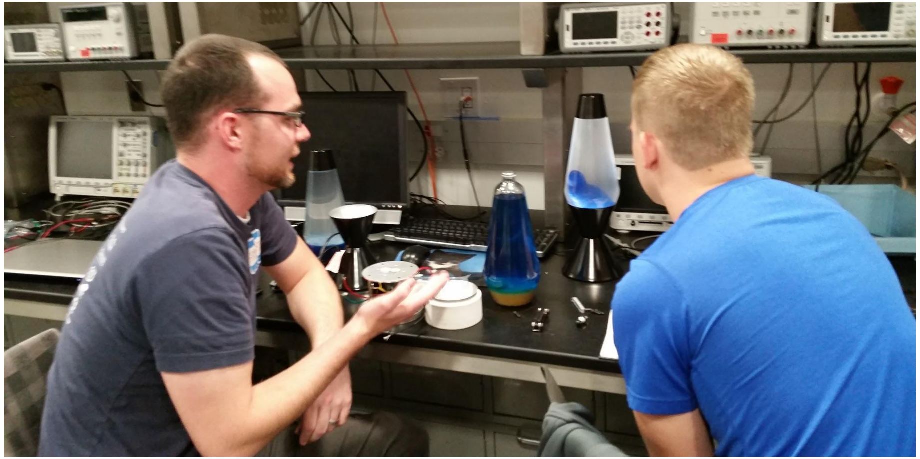


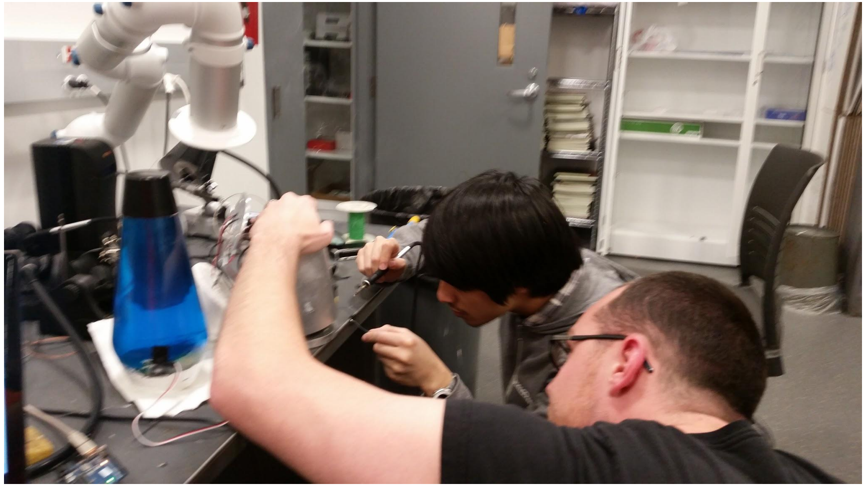


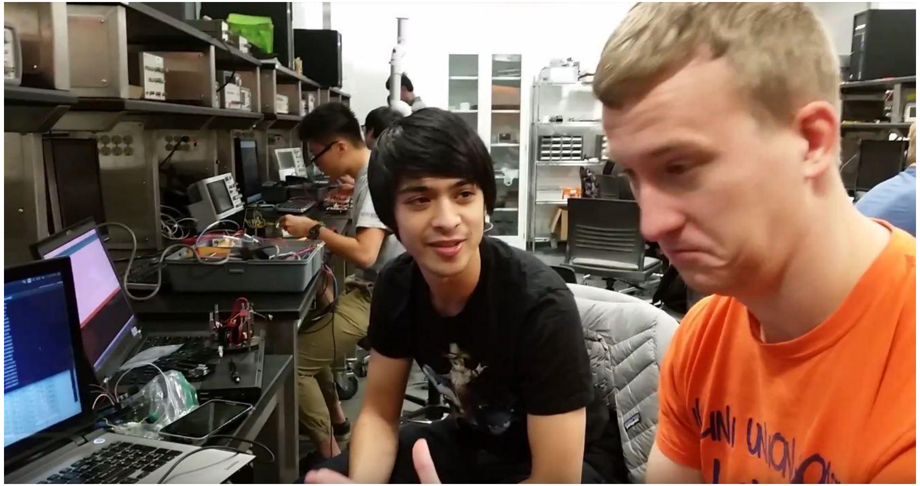


Team Lava Lamp

Awesome semester







Conclusions

Faster - About twice as fast!

Safer - Temperature controller!

Decoupled - Independent and adjustable light and heat!

Questions?

Devin Bryant

- Schedule
- LED and Heating Circuit
- Mechanical Design
- Organization
- Co-pilot

Matthew Romano

- Control
- Data Collection
- Videos
- Experiments
- Pilot

Daniel Frei

- Power Supply
- PCB Design
- Soldering
- Industrial Design Contact
- Knowledge Shinobi

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