The Candle Extinguisher

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Introduction

- Safely extinguish any candle
- Helps prevent fires
- Allows lifetime of candle to be preserved

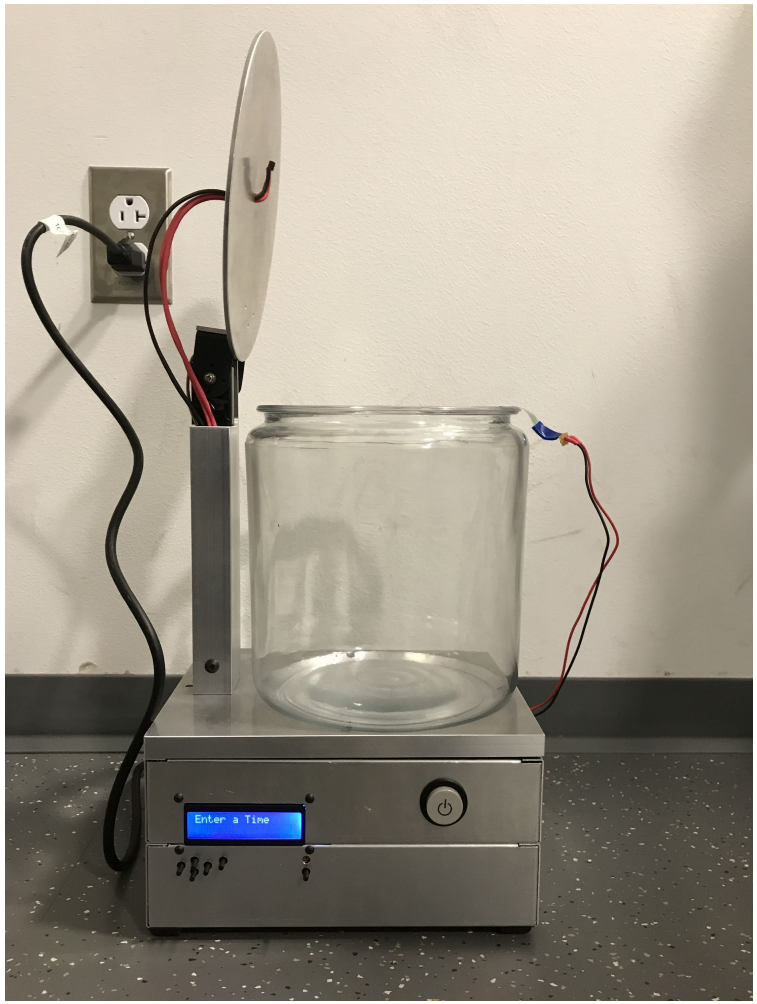
Objectives

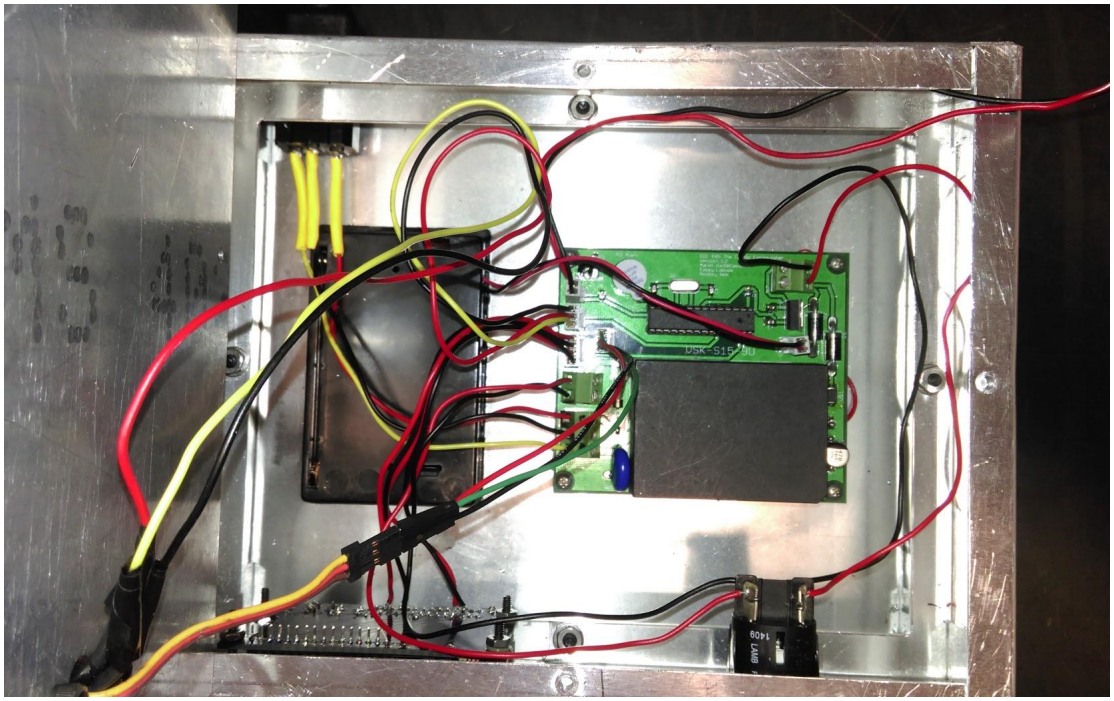
- Extinguish in five minutes
- Limit user from burning the candle for more than four hours
- Extinguish candle during a power outage

Features

- Ability to use candles of varying sizes
- Customer able to enter desired time
- Backup Alarm
- Wall power or backup batteries
- Safe

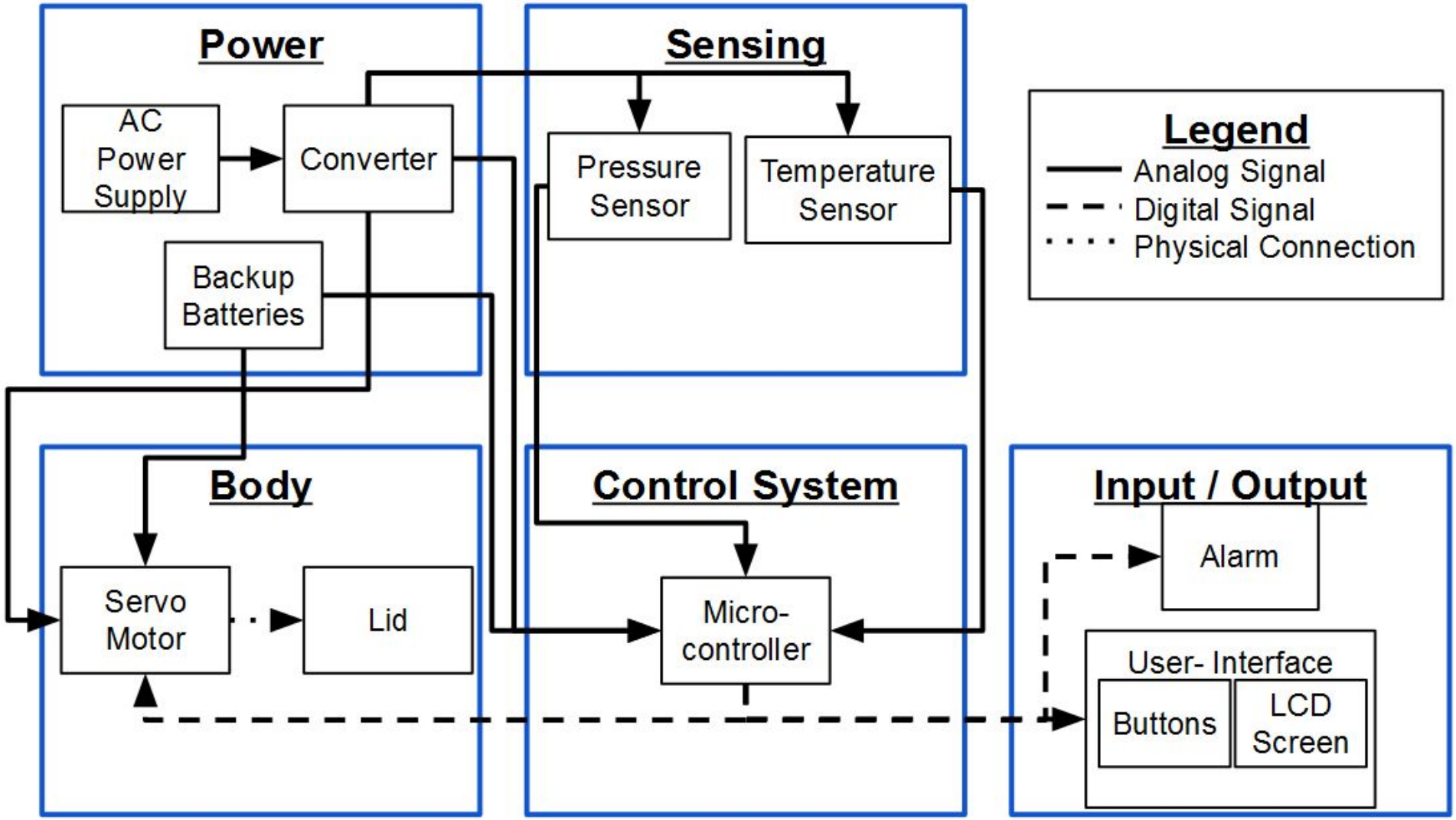
The Candle Extinguisher



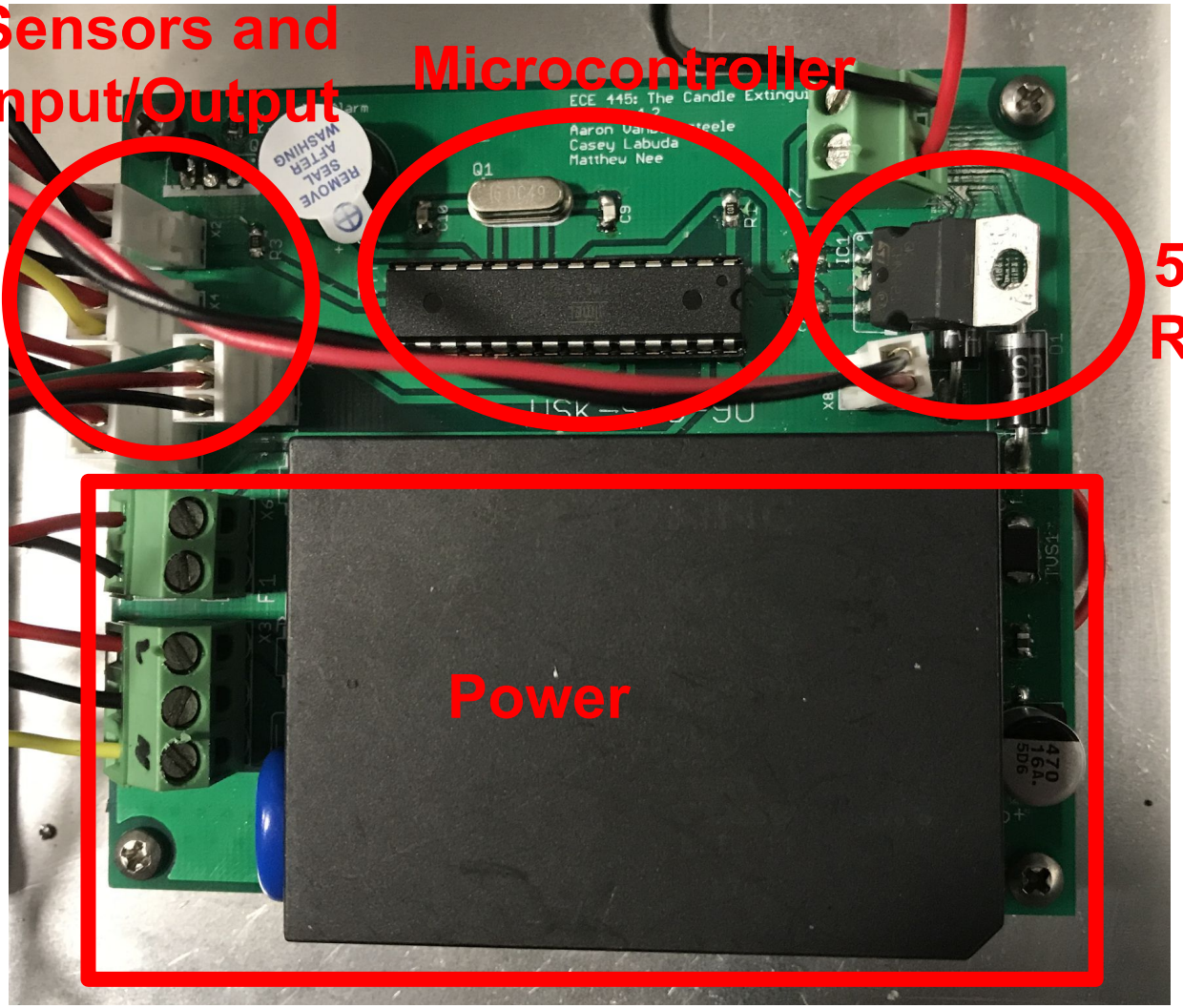


Top Down View

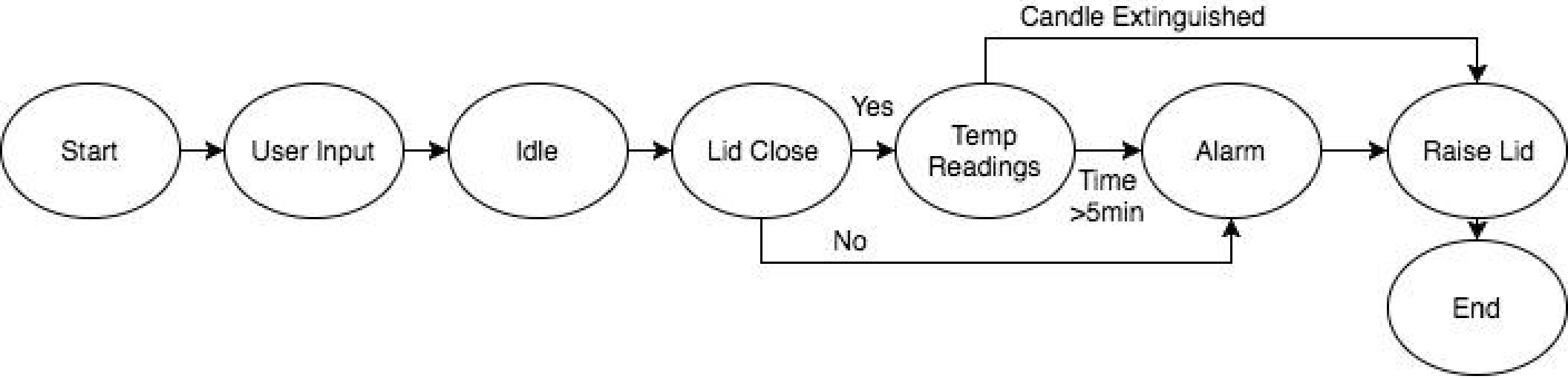
Block Diagram



Hardware Internals

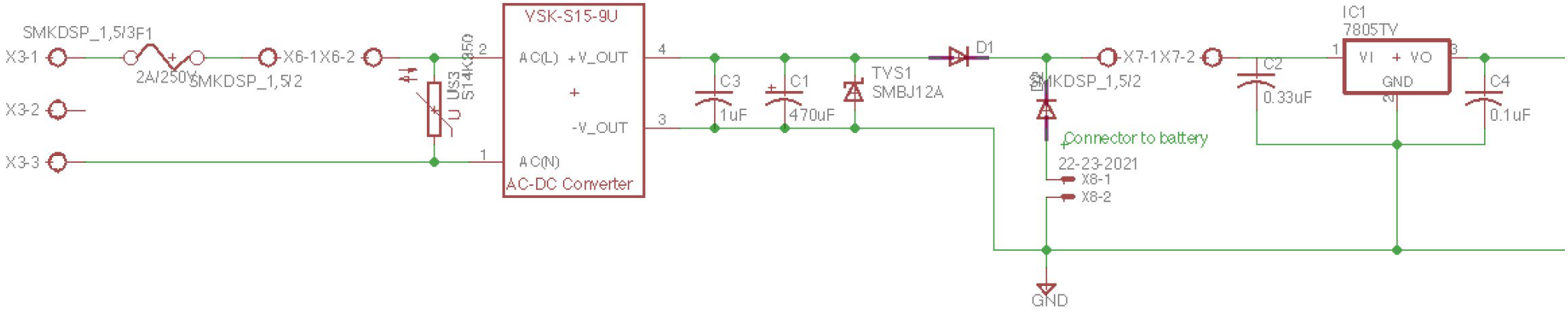


Software State Diagram



Power

Circuit Schematic



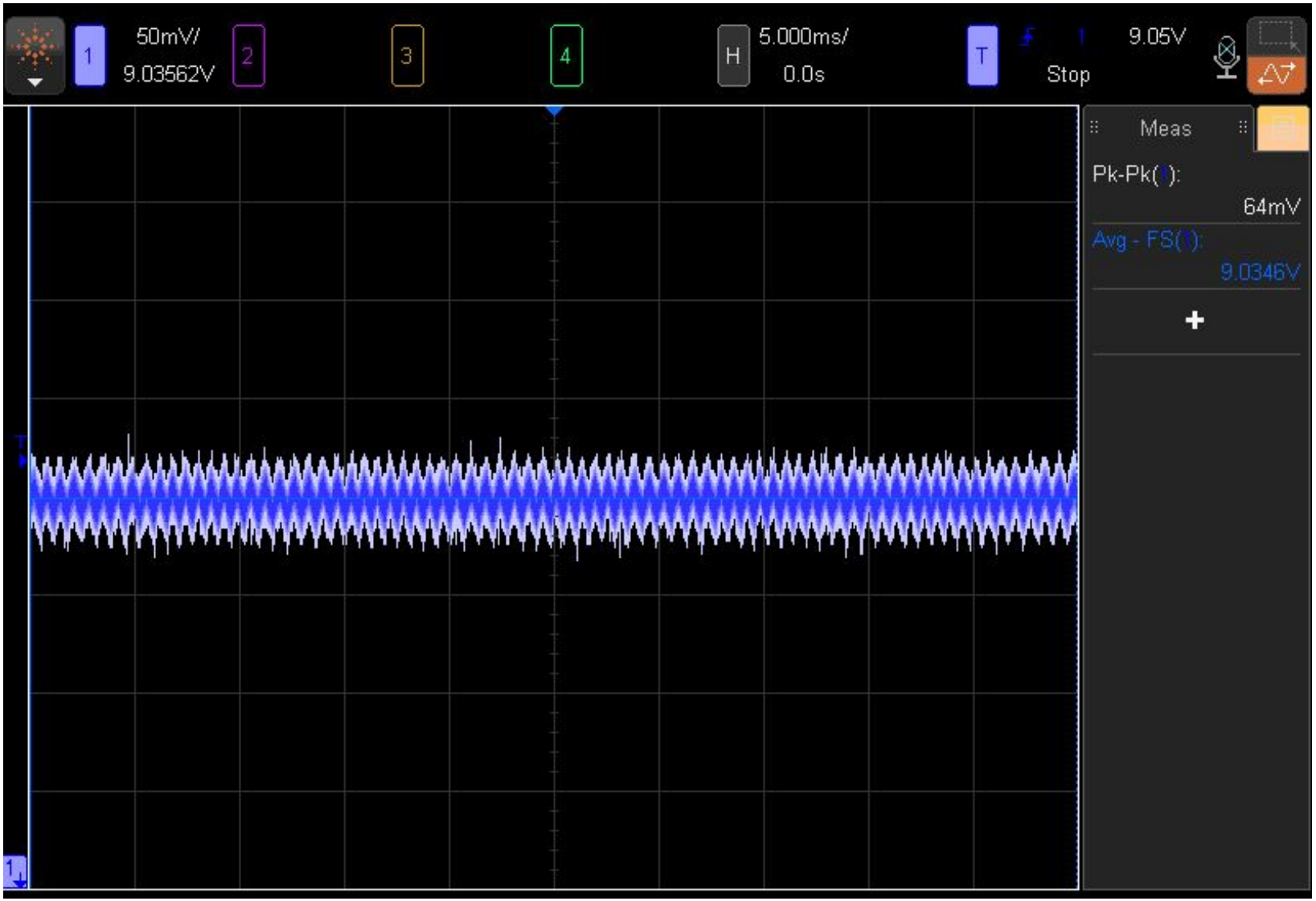
Power - Converter

- Requirements
  - Converter
    - Withstand heat
    - Input 120 Volts AC
    - Output 9 Volts DC
    - Output at least 1.5 Amps
- Verification
  - VSK-S15-9U [1]
    - Output Voltage: 9 Volts DC
    - Max Output Current: 1.6 Amps
    - Input Voltage: 80 - 264 Volts AC
    - Input Frequency: 47 - 63 Hz

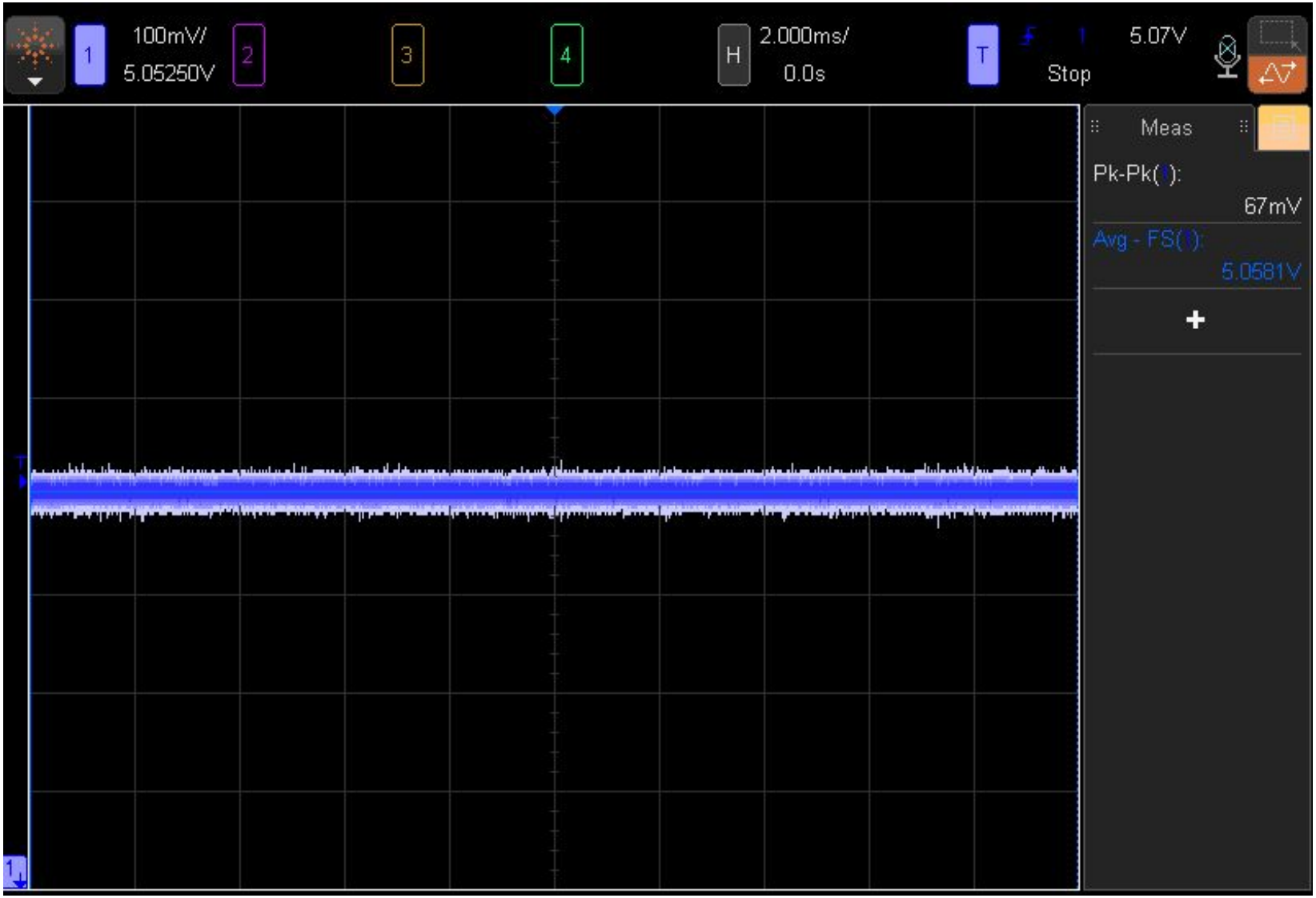
Power - Backup Batteries

- Requirements
  - Withstand heat
  - Power 4 hours
  - Not fire hazard
- Verifications
  - Powered fixture for 4 hours
  - Withstood heat
  - Any type of AA usable
  - No warning on battery to avoid using near a fire.

Power - Converter Verifications



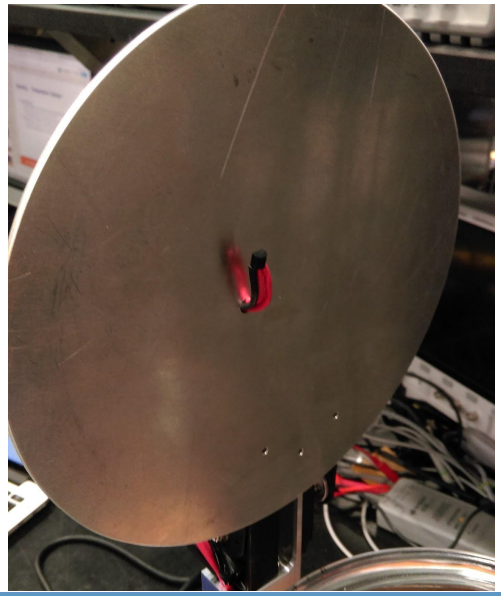
Power - Linear Regulator Verification



Wall Power to Backup-Battery

Sensing - Temperature Sensor

- Requirements
  - Detect difference between an unlit and lit candle
  - Read high temperatures up to 250℉
  - Consistently read temperatures from different height candles
- Analog Devices TMP36 Temperature Sensor [2]
  - Can read temperatures from -40℃ to 125℃ (-40℉ to 257℉)
  - Sends analog signal to microcontroller



Sensing - Temperature Sensor

- Verification
  - Sensor can read up to 257℉ according to datasheet.
    - Highest recorded temperature was 242℉
  - Temperature readings from different candle heights can confirm that the candle is extinguished.
  - Sensor can differentiate between an unlit and lit candle using our tolerance.
    - if (abs(maxRead - currentRead) >= 18 || abs(currentRead - roomTemp) < 3)

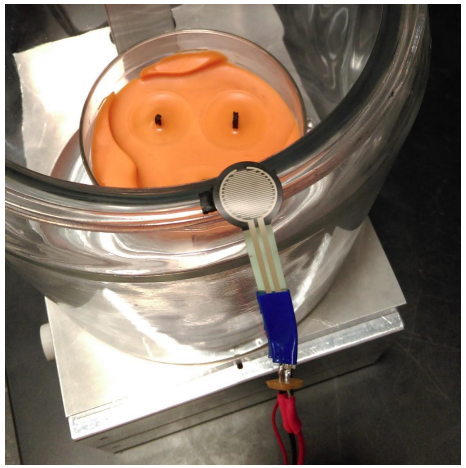
      state = 5;

      if ((millis() - extinguishTime)/60000 > 5)

      state = 6;

Sensing - Pressure Sensor

- Used to determine the position of the lid
  - If no pressure is read, the lid is in the upright position, and if any pressure readings are present, then the lid is in the down position.
- Requirements
  - Needs to detect a force of at least 0.2N
- Interlink Electronics Force Sensing Resistor [3]
  - **Verified**, according to datasheet, it can read pressure from 0.04lbs to 4.5lbs (.18N to 20.02N)



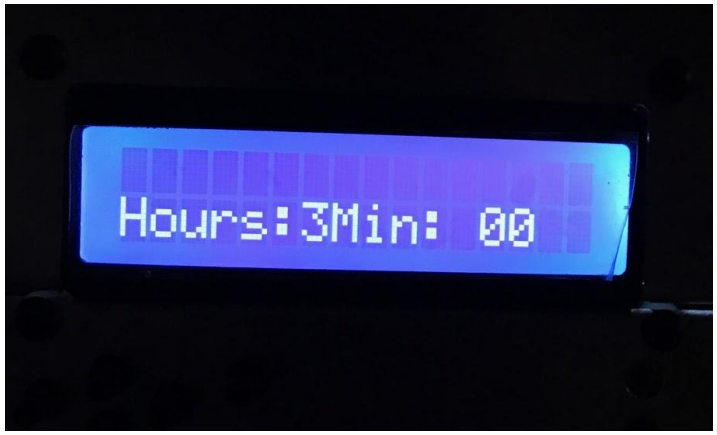
Input/Output - Alarm

- Acts as a fail-safe
- Will alert the user if the lid was unsuccessfully lowered, or if a flame is still present five minutes after the lid has been lowered.
- Requirements
  - Must be heard 20m away
  - LCD screen must flash within two seconds of alarm sound
  - Must always sound if signal is sent from microcontroller
- PUI Audio magnetic piezo buzzer

Input/Output - Alarm Video

Input/Output - User Interface

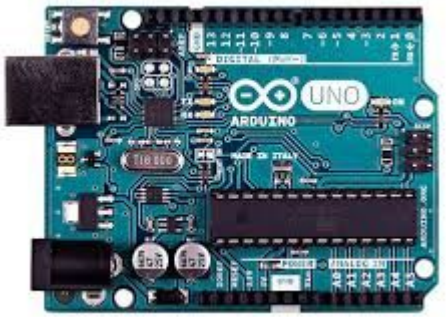
- Allows the user to input a time until the device extinguishes a candle
  - Consists of an LCD screen and five useable buttons
- Requirements
  - Ability to turn on and off the LCD backlight
  - Increase time up to four hours / 240 minutes
  - Display remaining time on LCD screen
- Adafruit LCD shield kit
- Verifications



Input/Output - User Interface Time

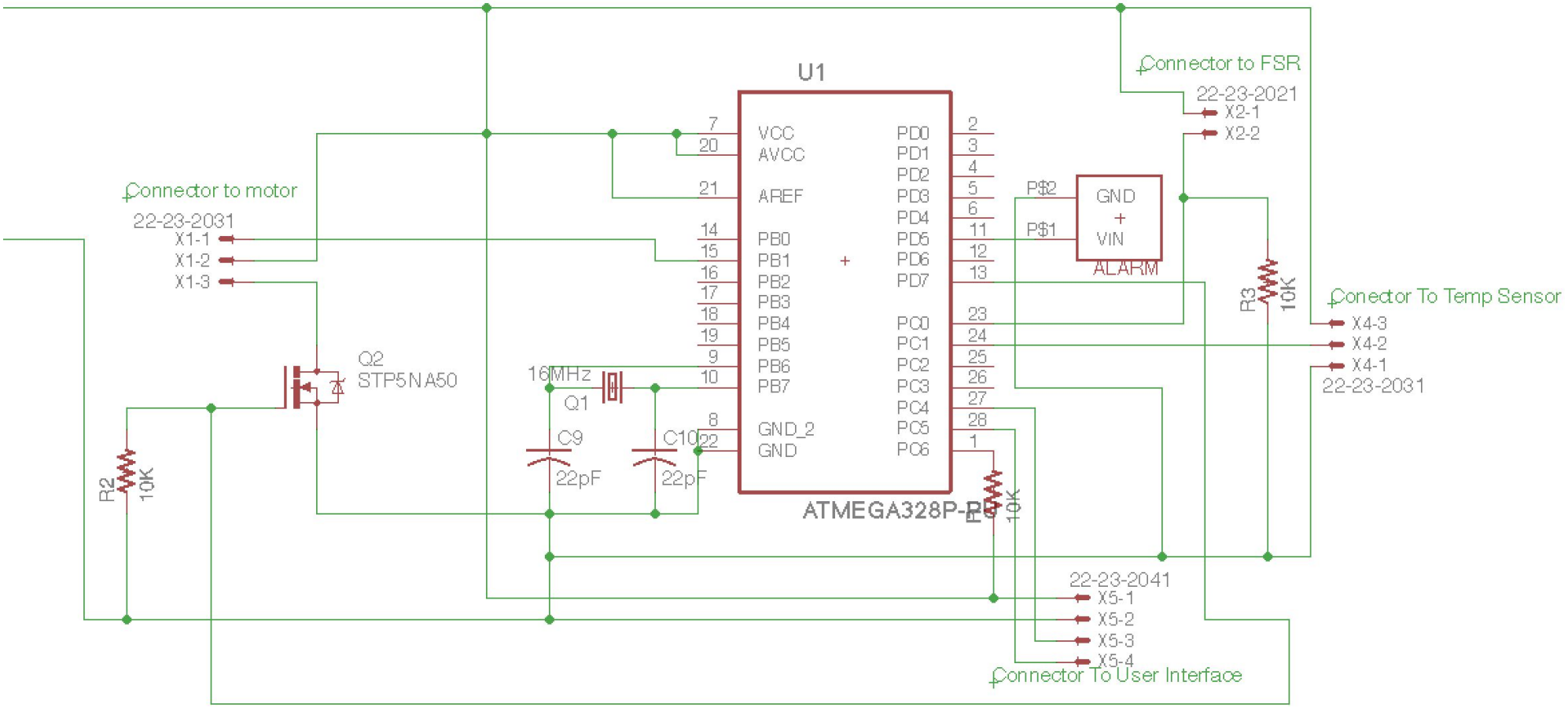
Control System - Microcontroller

- The brains behind our device.
- Connects and communicates with each component
- Requirements
  - Supplied by 5V
  - Turn on alarm if flame is still present at five minutes
  - Take in temperature sensor readings before and after the candle has been extinguished
- ATMega 328P-PU
  - The chosen microcontroller; can be found on the Arduino Uno.
  - Arduino Uno was used to program chip



Control System - Microcontroller

Circuit Schematic



Body - Servo Motor

- Servo is used to raise and lower the lid on top of the glass jar
- Minimum torque was calculated.
- Calculation

$$I = \frac{3}{2} * M * R^2$$
$$\tau = I * \alpha$$

$$I = \frac{3}{2} * 2 * .165 = 0.817 kgm^2$$
$$\tau = .0817 * .5 = \mathbf{.0408 Nm}$$

- Requirements
  - Needs to operate on battery power
  - Needs to operate on 5V from linear regulator
  - Must output at least 0.048Nm

Body - Servo Motor

- Tower Pro SG-5010 [4]
  - Chosen to meet our requirements
- Verification
  - Servo runs on 5V
  - Servo operates on battery power
  - Servo outputs 76 oz-in at 5V (0.5366Nm)

Body - Lid

- Glass lid that came with our glass jar is too heavy
- Needed a lightweight lid that would still create a good seal
- Machine shop fabricated an aluminum lid and bracket
- Requirements
  - Needs to rotate 90°
  - Must create a good enough seal to suffocate the candle flame within five minutes
- Verification
  - All requirements verified through normal use

Body - Other Components

- One Gallon Glass Jar
  - Allows the user to use many different commonly sized candles
- Aluminum Bracket
  - Created from machine shop.
  - Connects the lid to the servo motor
- Aluminum Box/Enclosure
  - Contains our PCB
  - Hides most of the wiring
  - Used to mount our user interface

Body - Bracket

Challenges

- We encountered a couple of different challenges/issues throughout the semester
  - ATMega 328P-PU issues
    - Did not implement timing crystal on initial PCB design
    - Burned numerous chips
      - Due to a flyback voltage from the servo motor
        - Resolved by using a flyback diode
    - Random resets
      - Extra capacitors were placed between the microcontroller
  - Backup Batteries
    - Initial plan of four AA batteries did not provide enough voltage for our chosen linear regulator

Conclusion - Success

- In the end, The Candle Extinguisher was able to perform as expected.
- For each candle that was tested, the device successfully extinguished the flame within five minutes.
- Each requirement was also verified

Conclusion - Future Improvements

- Implement rechargeable batteries.
- Attach force sensor not on jar.
- Lower cost of fixture.
- Make fixture smaller and more visually appealing.
- App to control multiple devices
- Height Adjustable Motor

Credit

- We would like to thank all of the TA's that gave us recommendations and advice.

- Also we would especially like to thank our TA Dan Frei for continual help throughout the semester.

- Lastly, we thank the machine shop for the manufacturing of our mechanical parts. These people consist of Scott A. McDonald, Glen W. Hedin, and Greggory Len Bennett.

Thank You!

Any Questions?

Project Build - Areas of Focus

Casey Labuda

- Machine Shop Coordinator
- Research/Order Parts
- Schematic Circuit Design
  - Microcontroller /Sensing
- Soldering
- Wiring

Matthew Nee

- Research Parts
- Schematic Circuit Design
  - Power and Backup Batteries
- Breadboarding
- PCB Design
- Hardware Debugging

Aaron VanDeCasteele

- Software Implementation
- Software Flowchart
- Coding and Debugging
- Schedule
- Experiments

References

[1] CUI Inc., 10-Jun-2015. [Online]. Available: http://www.cui.com/product/resource/vsk-s15-series.pdf. [Accessed: 01-May-2017].

[2] Analog Devices, 2015. [Online]. Available: http://www.analog.com/media/en/technical-documentation/data-sheets/TMP35_36_37.pdf. [Accessed: 01-May-2017].

[3] Interlink Electronics, [Online]. Available: http://www.interlinkelectronics.com/datasheets/Datasheet_FSR.pdf. [Accessed: 01-May-2017].

[4] Tower Pro, 10-Dec-2015. [Online]. Available: http://www.datasheetcafe.com/sg-5010-datasheet-servo-motor/. [Accessed: 01-May-2017].