Investigation into Fire Extinction with Sound Waves

The Sound Blasters

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Overview

- Project Premise
- Project Importance
- Theory
- Project Timeline
- Demo Time
- Experiments
- Future Experimentation

Project Premise

Requirements to burn:

- Oxygen, Fuel, Heat

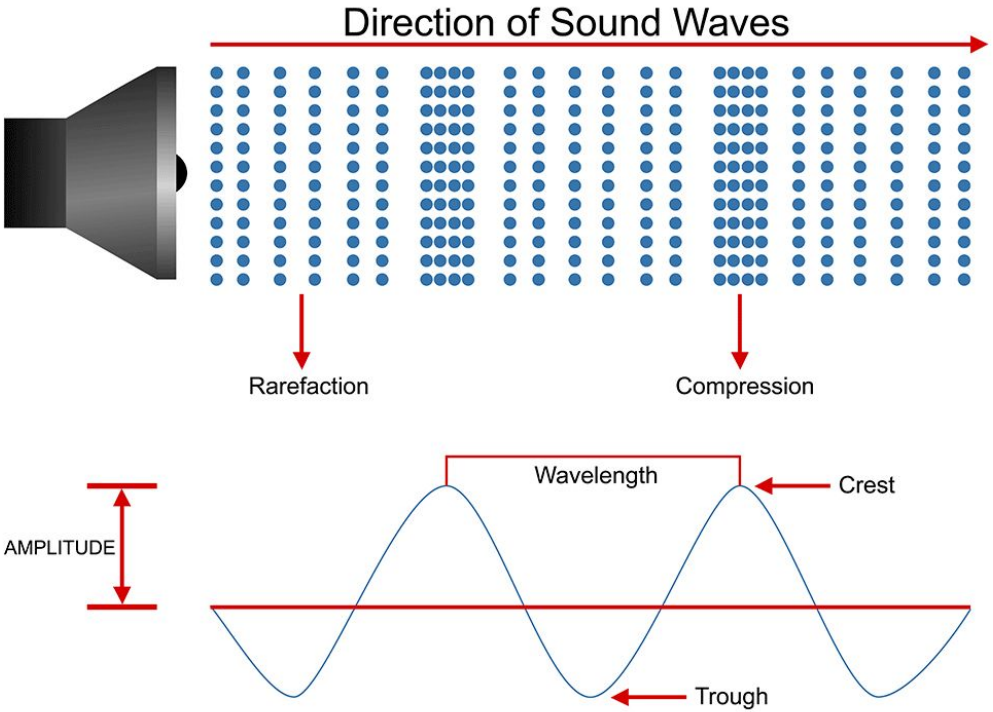
Goal: Use sound wave to deprive a flame of oxygen

Importance

Potential Situations

- Kitchen Fires
  - Grease Fire: DON’T use water
  - Chemical extinguishers damage expensive equipment
- Space Shuttle
  - Alternative method to putting out fire (other than smothering)
- Aircraft Chemical Drop
  - Uses chemicals (potential to save on this)

Theory



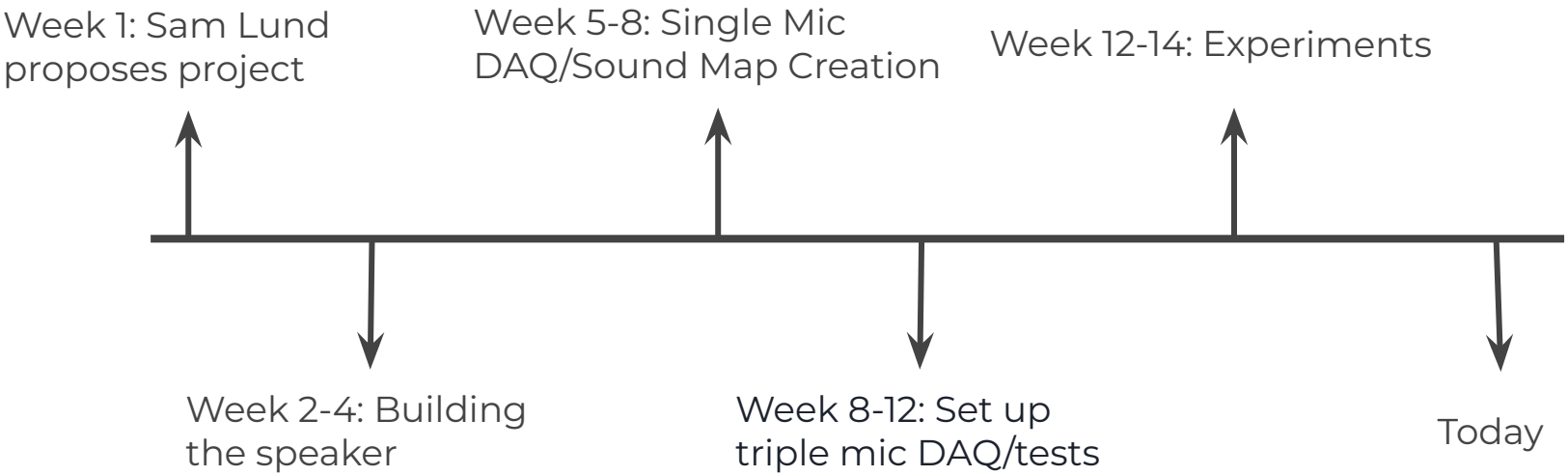
- ➔ Low frequency
- ➔ High amplitude

$$A^2 \propto I$$

$$I = \frac{P}{a}$$

$$P = \frac{V^2}{R}$$

Project Timeline



Project Timeline: Building the Device

Winston Cone:

- Typically used to focus and magnify optical waves on a certain position in space

Figure 1: Interior of Winston Cone

Wiring Diagram:

- Oscilloscope: Monitor of the function generator
- Function Generator: Voltage Source
- Amplifier: Beef up function
- Power Source: Amp Juice
- Speaker: Boom

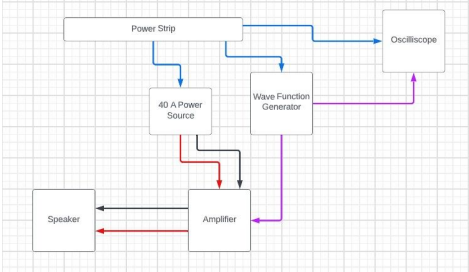
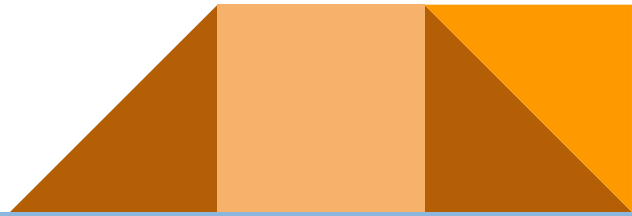


Figure 2: Wiring Diagram

Project Timeline: Building the Device

Hardware:

- Power supply
  - 12 Volt, 40 Amp
- Waveform Generator
  - 0.3 Hz - 3.0 MHz
- Oscilloscope
- Amplifier
  - Rockville dB11, 880 Watt peak, 440 Watt RMS, 4-Ohm, RCA input
- Speaker
  - Alpine W10S4 10” subwoofer, 750 Watt peak, 250 Watt RMS, 4-Ohm
  - Frequency response: 24-200Hz



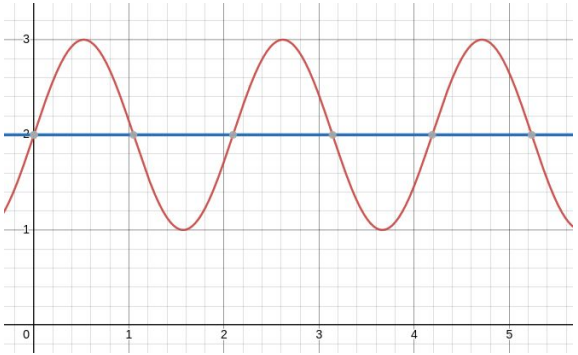
Project Timeline: Single Mic DAQ/Sound Map Creation

- Sourced Code

  Step 1: Read out the ADC values (Easy!)

  Step 2: Baseline calculation based on the first 1000 measurements

  Purpose: prevent overflow



Project Timeline: Single Mic DAQ/Sound Map Creation (Continue…)

Step 3: Loop for RMS calculation

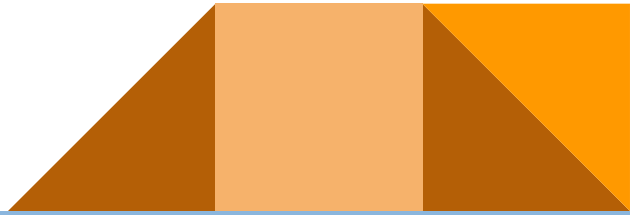
Take fixed amount of samples:

-Sum up all the amplitudes squared

-Average then take the square root

Step 4: write into SD card

We are done!



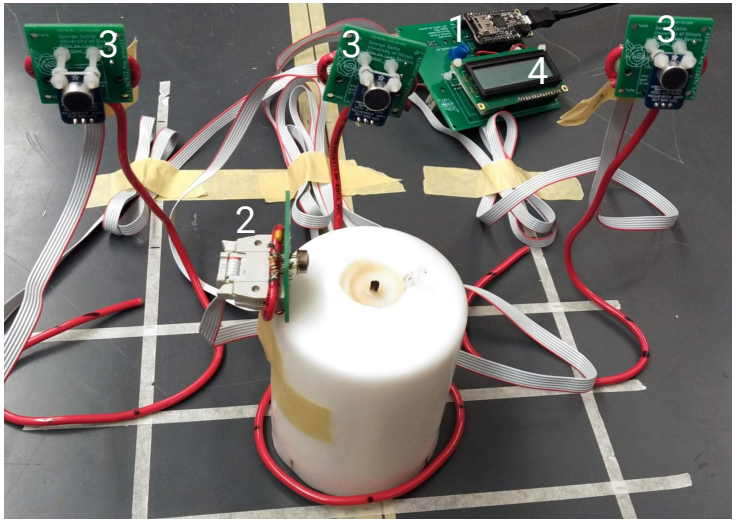
Project Timeline: Single Mic DAQ/Sound Map Creation (Continue…)

Difficulties in coding:

Getting NANs

:)

Project Timeline: Set up triple mic DAQ/tests



Adalogger

- Adalogger Feather M0 (1)
- IR sensor MLX90614 (2)
- Electret microphones (3)
- LCD (4)

Triple Mic Tests Setup

- Measures RMS at 3 locations simultaneously
- Utilizes IR sensor to detect flame out

Project Timeline: Set up triple mic DAQ/tests (continue…)

DAQ for Triple Mic w/ Difficulties

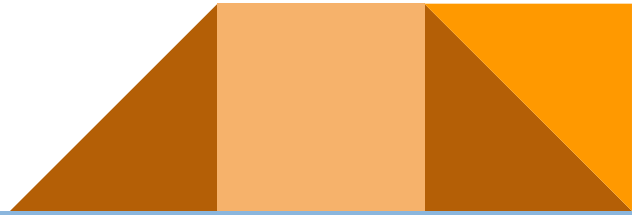
Step 1: Copy and paste the code for one mic*3 (Easy)

Step 2: Measure temperature

Step 3: Determine a algorithm for timing (time from the sound is on to the fire is out)

-a threshold value for RMS (sound on)

-a threshold value for temperature (fire out)



Project Timeline: Set up triple mic DAQ/tests (continue…)

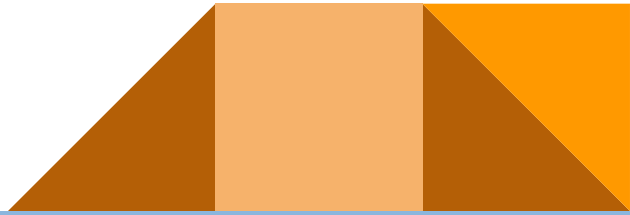
Step 4: Loop for average RMS calculation

Add up all the RMS values (speaker is on to fire is out)

Average over all the counts when the program stops timing.

Step 5: Write the time, average RMS for each mic into the SD card.

Done



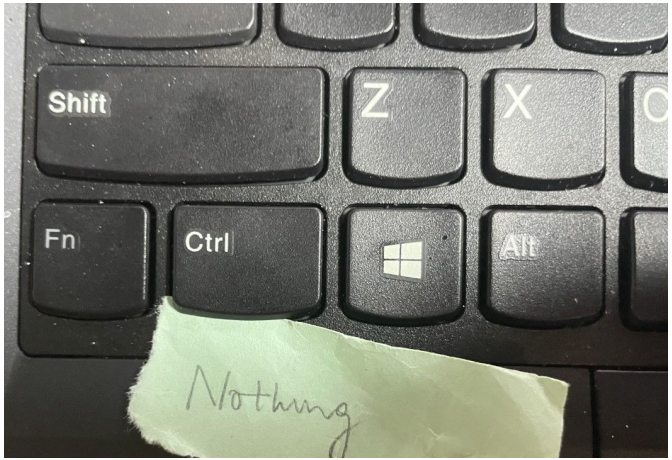
Project Timeline: Set up triple mic DAQ/tests (continue…)

Difficulties:

-Limit of arduino: 658 ms

-exit the loop (don’t use exit(0)! Use while(1){})

-mess up with the loops



Nothing is under control

Project Timeline: Experiments

Experiments List:

- Experiment 1: Waveform vs. Time at Different Distances:
  - Determine how long each waveform takes to extinguish a candle-fire at different distances
- Experiment 2: Frequency vs. Time :
  - Determine how long a sinusoid takes to extinguish a candle-fire at different frequencies
- Experiment 3: Amplitude vs. Time and RMS:
  - Determine how long a sinusoid takes to extinguish a candle-fire at different amplitudes
- Experiment 4: Voltage vs. RMS:
  - Determine RMS of a waveform for a given voltage

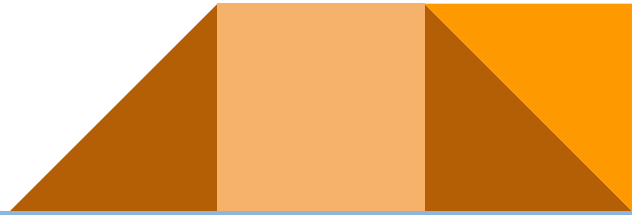


Figure 1: Super Important meme

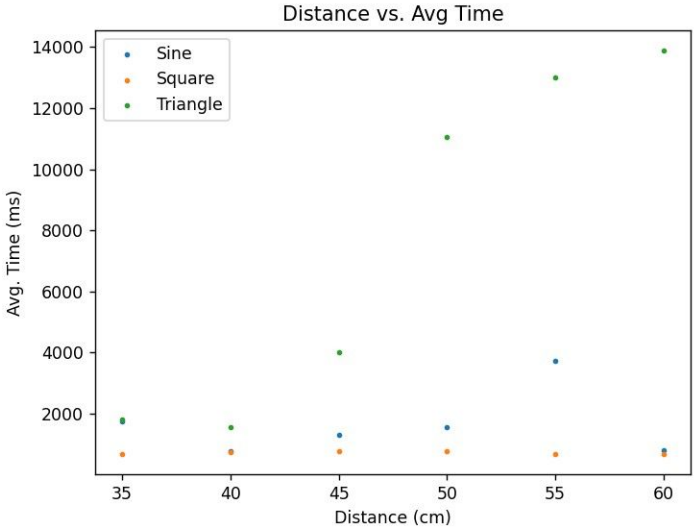
Experiment 1: Waveform vs. Time at Different Distances

Methods:

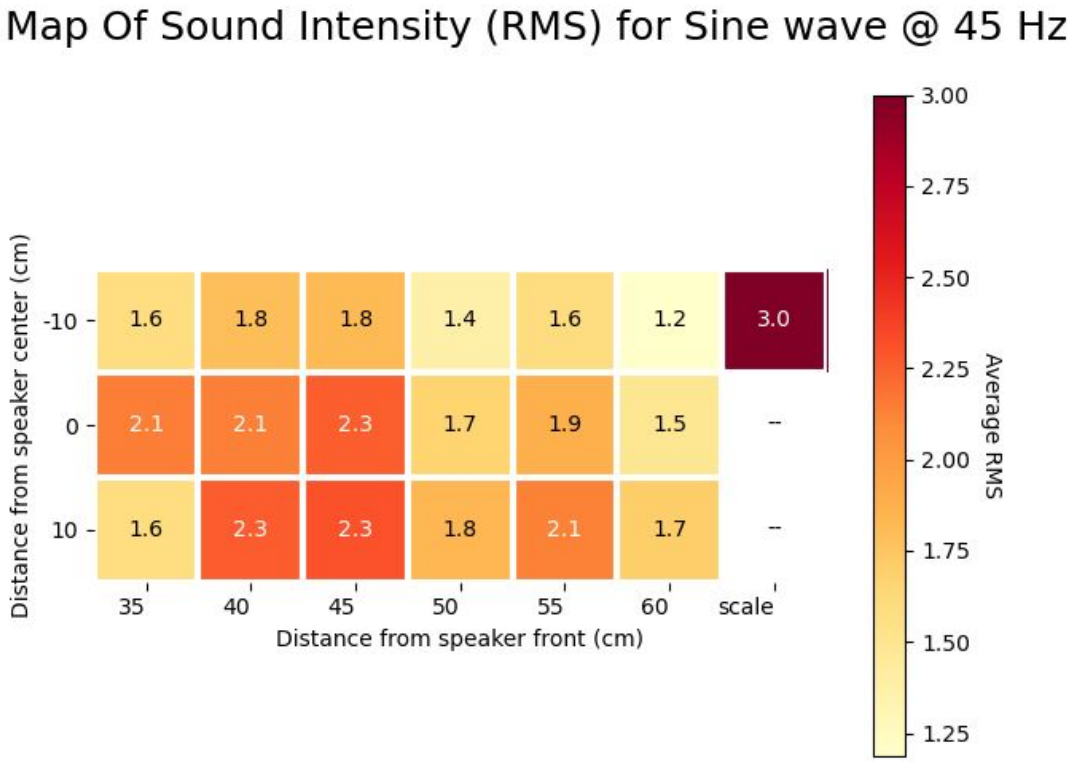
1) Positioned mics at desired distance
2) Set frequency = 45 Hz, V = 3V
3) Blast sound at fire for 5 trials, DAQ recorded the time
4) Move mics, candle to another dist. and repeat

Analysis:

- Triangle Waves are unreliable
- Square Waves are the most consistent
- Though voltage is the same, RMS values differ between the three waveforms



Experiment 1: RMS maps



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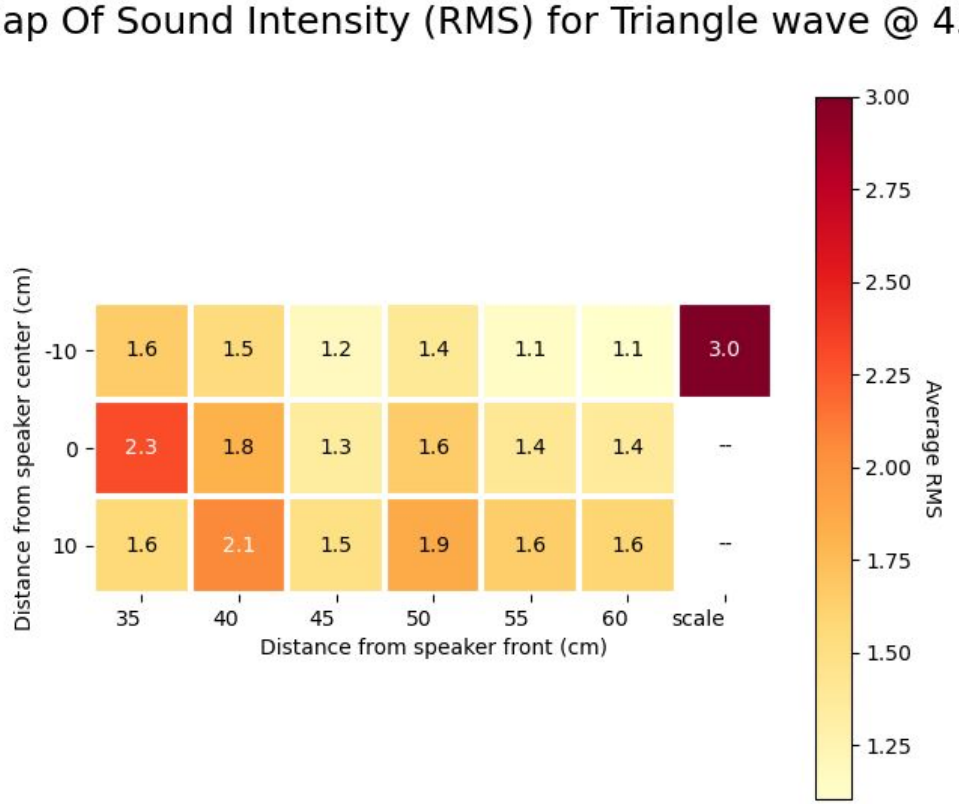

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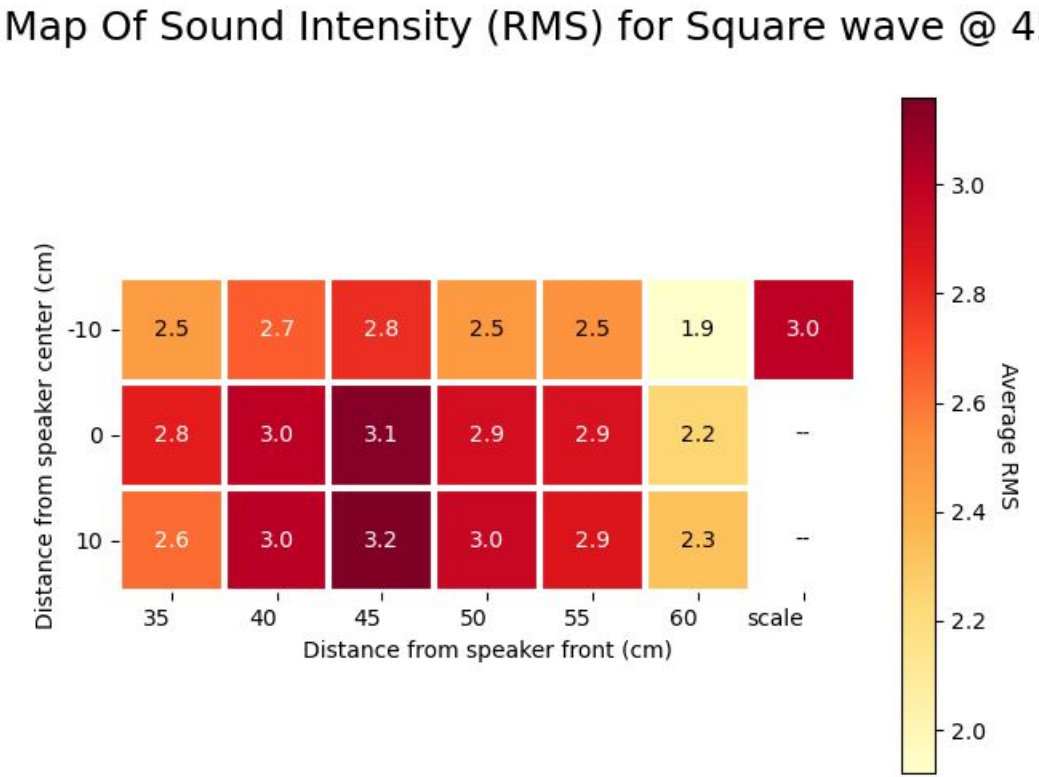


Experiment 2: Frequency vs. Time

Methods:

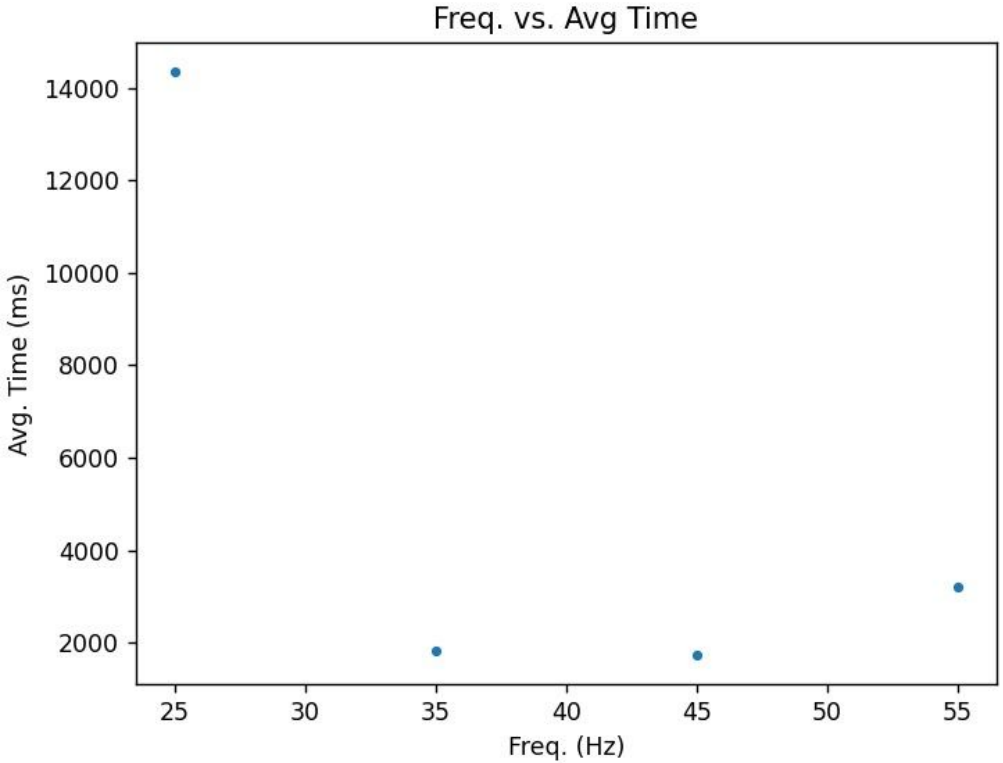
1) Positioned mics at a set distance
2) Set voltage to 3 V
3) Emitted sound of a specific frequency for 5 trials, DAQ recorded the time
4) Changed the frequency, and then repeated with mics at another distance

Time to Extinction v. Distance (cm)					
	Frequency				
Distance	21hz	25hz	35hz	45hz	55hz
35cm	-	14355.00	1813.80	1733.60	3198.80
45cm	-	-	4647.20	4007.40	5235.60

Analysis:

- 45 Hz was the most effective frequency

Experiment 2: Frequency vs. Time



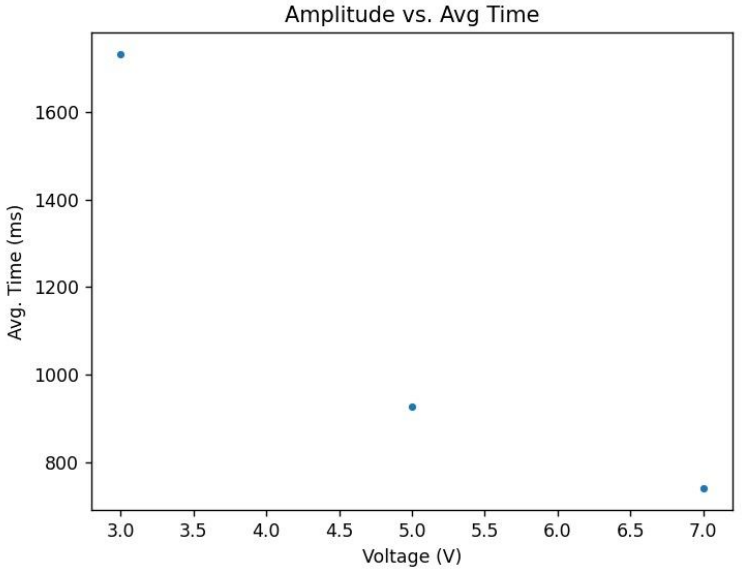
Experiment 3: Amplitude vs. Time and RMS

Methods:

1) Set mic distance to 35 cm
2) Set frequency to 45 Hz, waveform to sine
3) Emitted waves of a specific voltage for 5 trials, DAQ recorded the time
4) Repeated with different voltages

Analysis:

- Higher voltage waves are more effective
- Higher voltages led to more consistent measurements



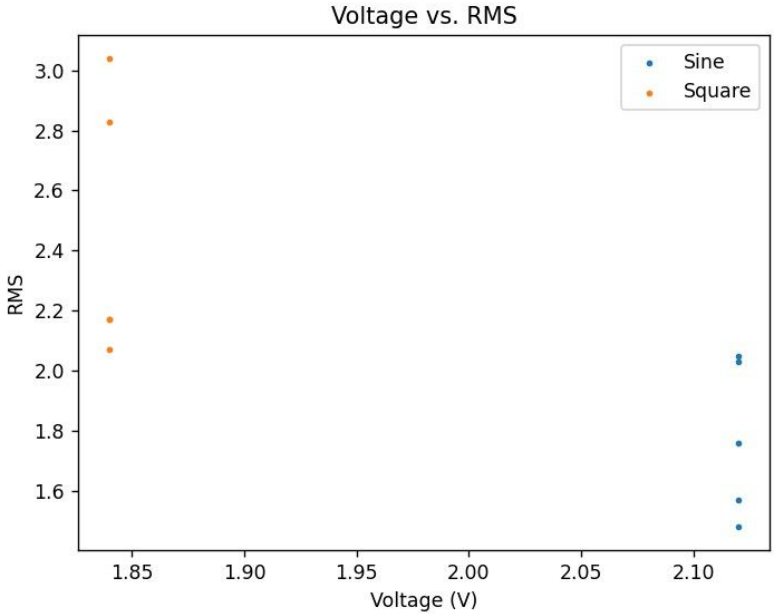
Experiment 4: Voltage vs. RMS

Methods:

1) Set f = 45 Hz and the candle to 45 cm.
2) Increase the voltage gently from V=0V until flame goes out
3) Record RMS reading and cut off voltage
4) Change waveform and repeat

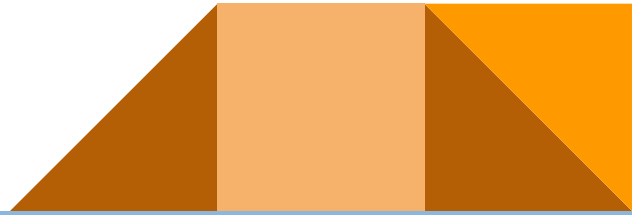
Analysis

- Square Waves produce higher RMS with a lower driving voltage than sine waves

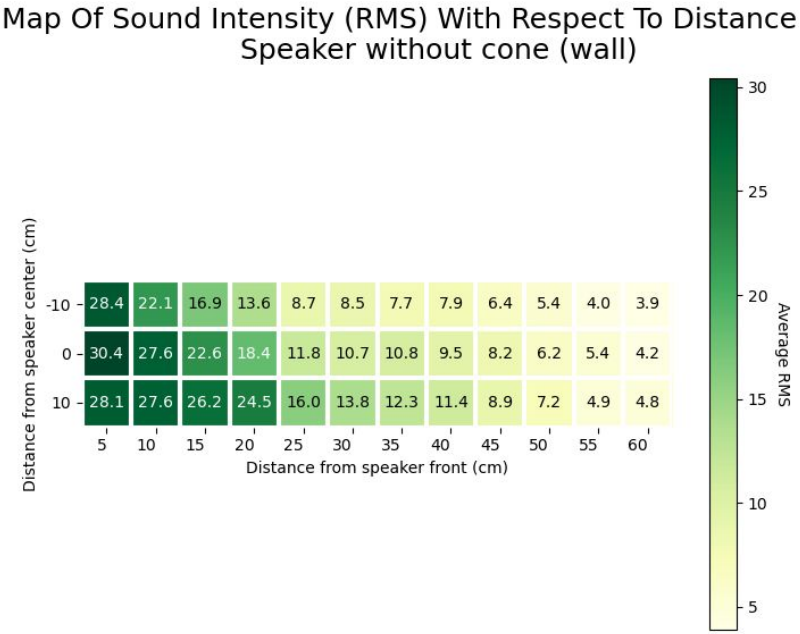


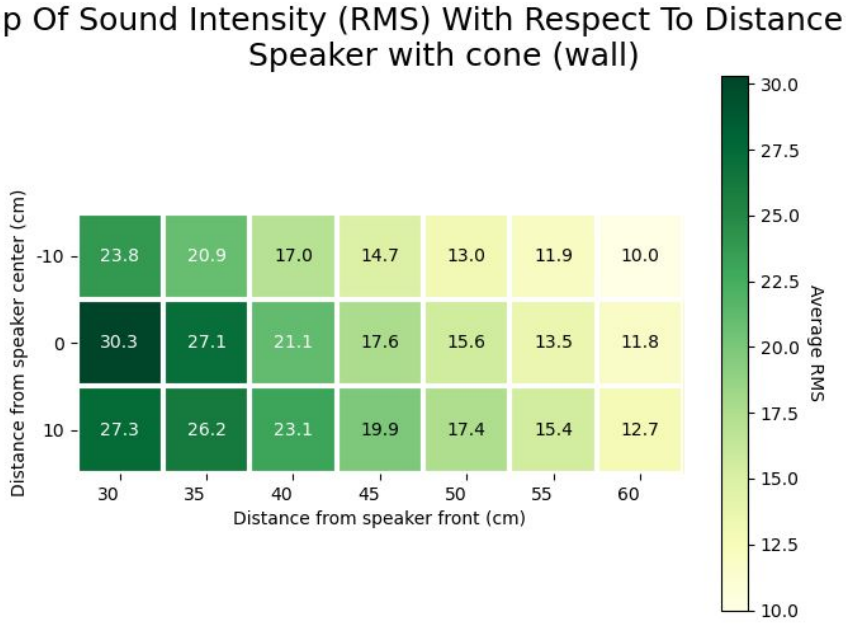
Error analysis

- The nature of fire
- Sensor sensitivity
- Inconsistent RMS (code & timing)*
- Flaws in our experimental set up
  - Wall*
  - Candle burning down*
  - Accurate only to +/- 1 cm



Future Experiments - Collimation investigation





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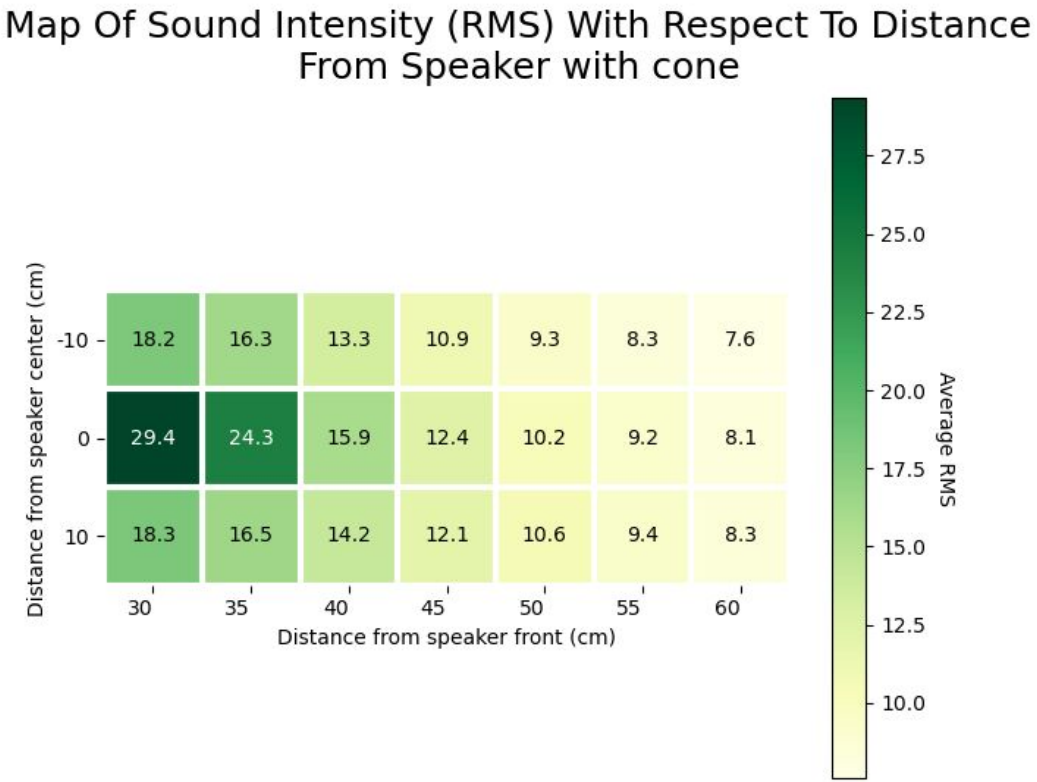
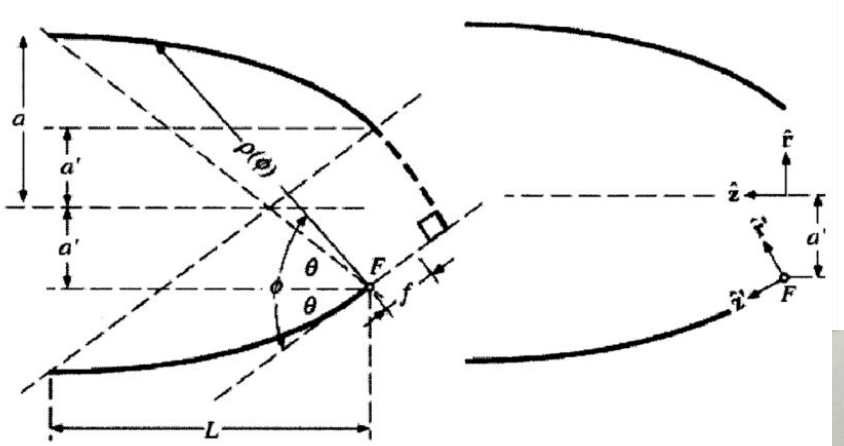
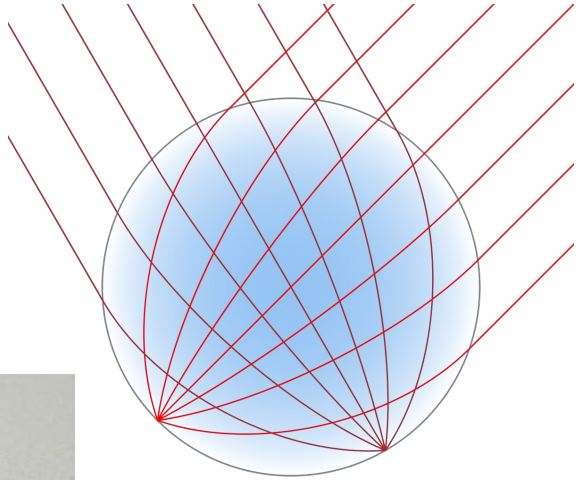
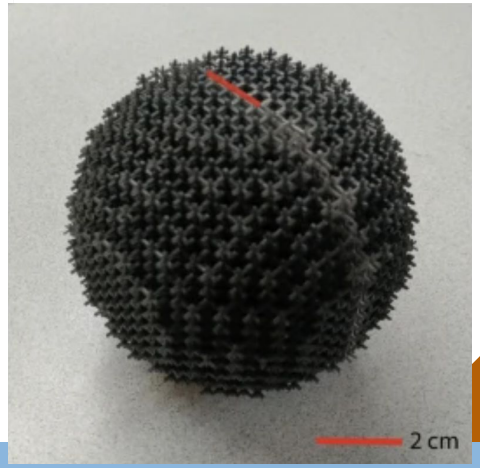


Collimation investigation - Winston Cones and Luneberg lenses







Future Experiments - Quantitative investigation of skewed waves

<- Skewed left square wave ->

Observed flame moving to high pressure areas – not successfully repeated.

Summary

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- Theory
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Questions?