Acoustic Levitation Device

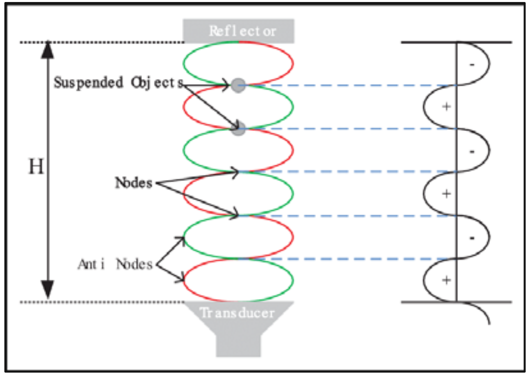
TJ Tigley - PHYS475

Overview

- Introduction to Acoustic Levitation
- Project Overview
- Requirements
- Design Considerations
- Schematic Analysis
- Analysis of Results

Introduction

- Method for suspending matter using acoustic radiation pressure
- Sound Pressure: ~150dB
  - (In reference to 20uPa of sound pressure)
- Utilizes ultrasonic standing waves (USW)
  - Nodes = minimum pressure
  - Antinodes = maximum pressure
- Two methods for USW
  - Opposing transducers
  - Transducer and reflector



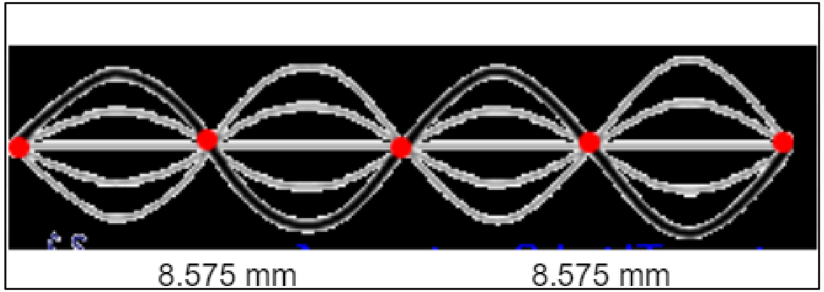
Project Overview

Two Primary Goals

1. Create an acoustic levitation device using analog components
   a. Success in digital approach
   b. Reducing cost with analog approach
2. Reduce the size of the overall design
   a. Arduino: up to 3 separate modules
   b. Minimize to one board
   c. Handheld device

Requirements

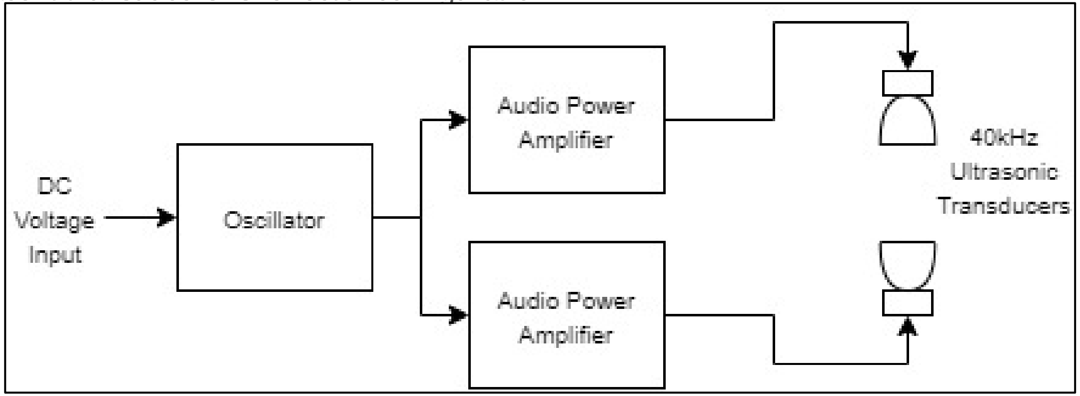
1. Ultrasonic frequency input to transducers
    a. 40kHz frequency
2. High current/voltage driving circuit
    a. </= 20V driving voltage
    b. </= 2A driving current
3. Consistent apparatus for adjacent transducers
    a. ~34.3mm separation
4. Reduced and Portable setup
    a. Untethered from static power source
    b. Single board circuit



Design Considerations

3 segment setup

1. Oscillator
    a. 40kHz driving frequency
2. Amplifier
    a. Individual amplifier inputs
    b. Maximum transducer operation
3. Ultrasonic Transducers
    a. Nominal 40kHz range
    b. Adjacent transducers vs reflector configuration

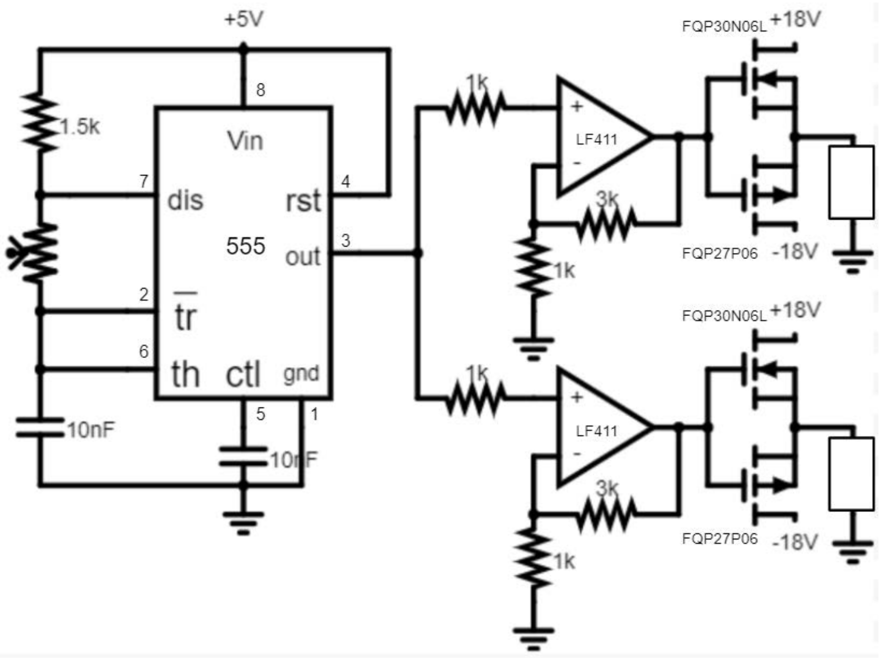


Schematic Analysis

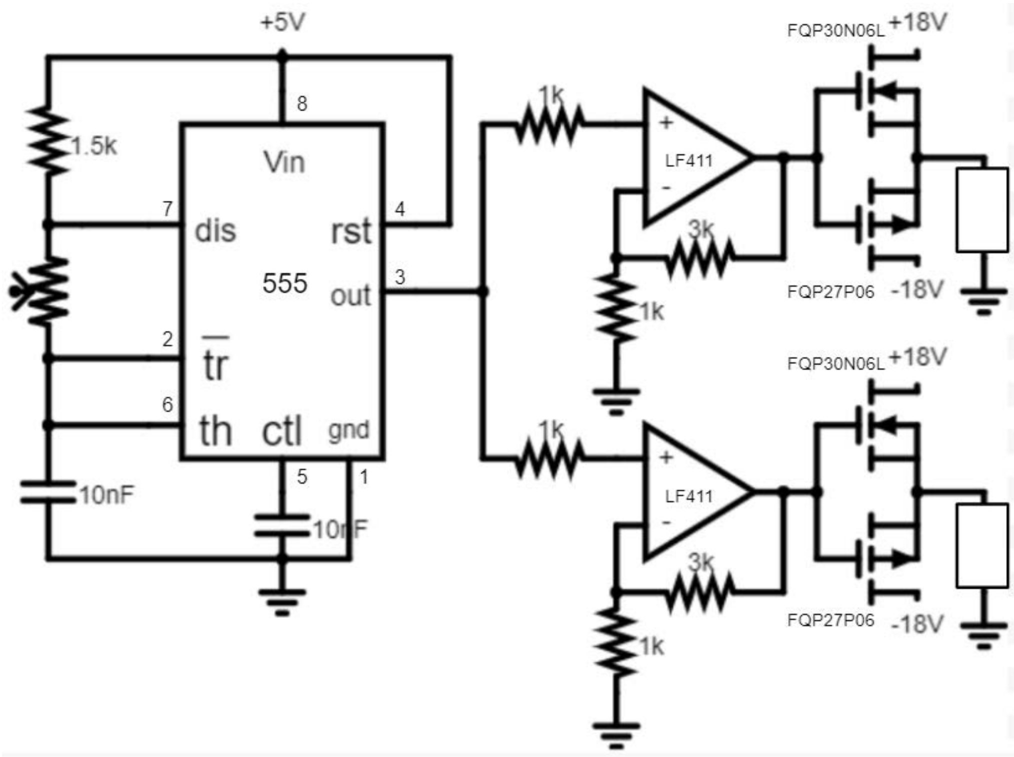
Component	Parameter	MIN	TYP	MAX	Desired	UNIT
LM555 Timer (Astable)	Supply Voltage	4.5	5	16	5	V
LF411	Supply Voltage	3.5		18	18	V
	Slew Rate	8	13		4.52	V/us
	Output Current		0.025		~ 1	A
FQP30N06L FQP27P06	Drain-Source Breakdown Voltage			60 -60	18 -18	V
TR40-16 (Transducer)	Maximum Input Voltage			20	18	V
	Center Frequency			40.0 +/- 1.0	40	kHz
	Sound Pressure Level (@40kHz)	120			120+	dB
	Bandwidth (@120dB, 40kHz)	5				kHz

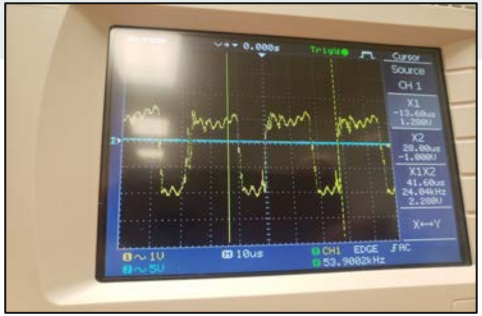
<u>Slew Rate</u>

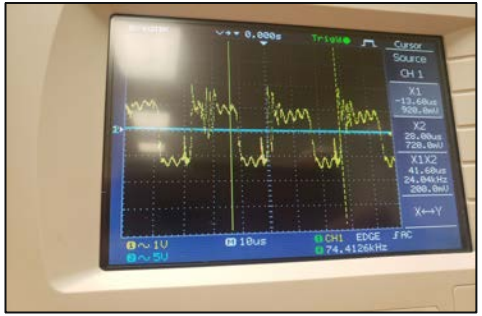
$$2\pi(40kHz)(18V) = 4.52\ \frac{V}{us}$$

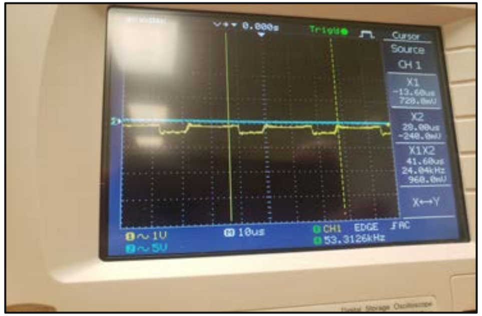


Analysis of Results









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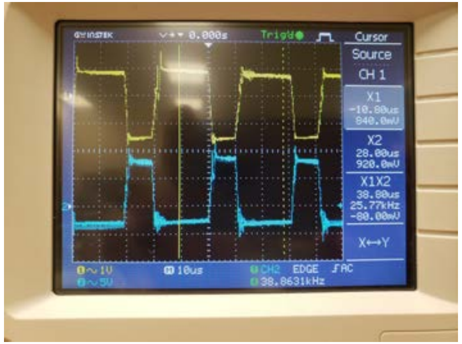
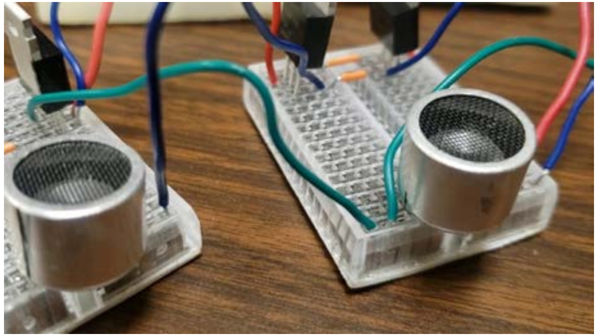
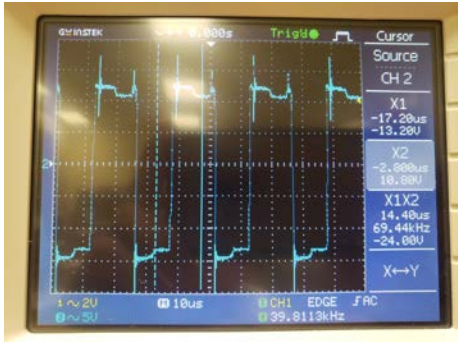


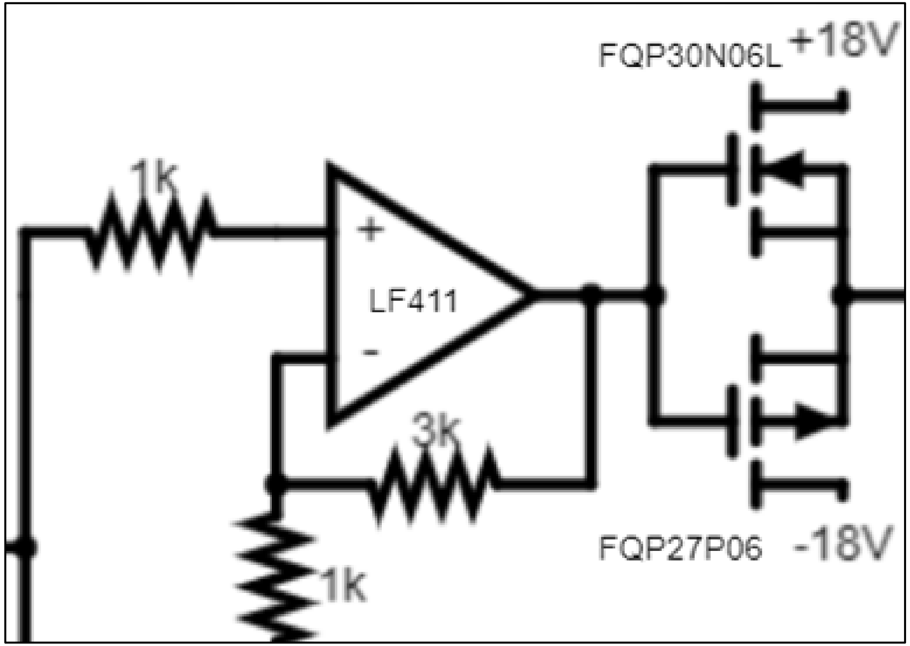


Output of the driving circuit *without* transducers

Output of the driving circuit *with* transducers



Analysis of Results



Lessons Learned

- PHYS475 concepts
- Design and lab troubleshooting process
- Understanding of audio drivers and oscillators

Summary

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Sources

[1] https://science.howstuffworks.com/acoustic-levitation.htm#:~:text=Acoustic%20levitation%20uses%20sound%20traveling,don't%20move%20or%20drift.

[2] https://www.ti.com/lit/ds/symlink/lm555.pdf

[3] https://www.ti.com/lit/ds/slos011c/slos011c.pdf?ts=1606235008590

[4] http://cdn.sparkfun.com/datasheets/Components/General/FQP30N06L.pdf

[5] https://www.sparkfun.com/datasheets/Components/General/FQP27P06.pdf

[6] https://www.estudioelectronica.com/wp-content/uploads/2018/09/SHT-USW-1.pdf

Questions?