Self-Tuning Violin

Electrical & Computer Engineering

Team 9:
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04/29/24

Agenda

Overview

Design Components

Results

Lessons Learned

What’s Next

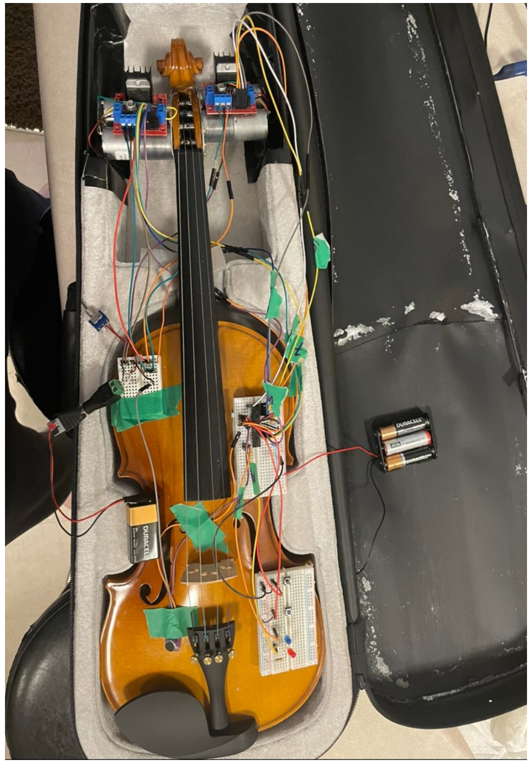
Introduction

We've created a self tuning violin.

With only plucking the strings the instrument can tune itself without the technical skills required to tune by hand.

Before:

After:



Music Terms used in the Presentation

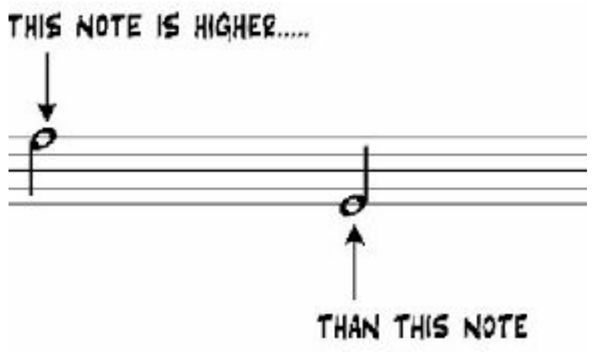
Pitch - a certain fundamental frequency measured in Hertz

Flat - the pitch has a *lower* frequency than desired

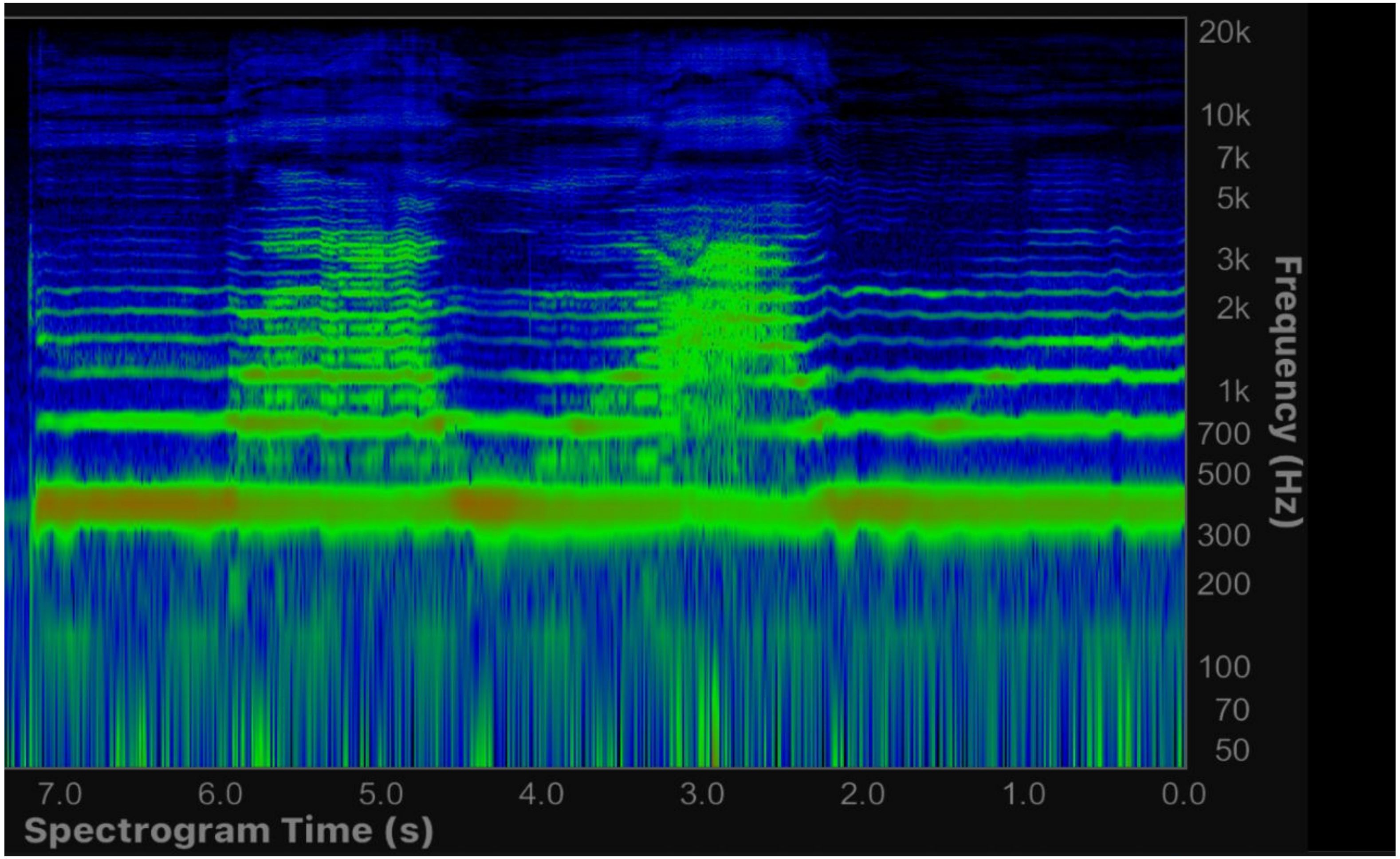
Sharp - the pitch has a *higher* pitch than desired

Tuning pegs - wooden pegs at the head of the violin used for large changes in pitch

Fine Tuners - small metal knobs at the bottom of the instrument; easy to use and for fine adjustments



Fundamental Frequency and Timbre



This is an image of a spectrogram of Kevin singing

High Level Requirements

- The system must be able to accurately turn the tuning peg to within 2.5% of the correct frequency

  (i.e, G_3 = 196.0 Hz, D_4 = 293.7 Hz, A_4 = 440.0 Hz, E_5 = 659.3 Hz)

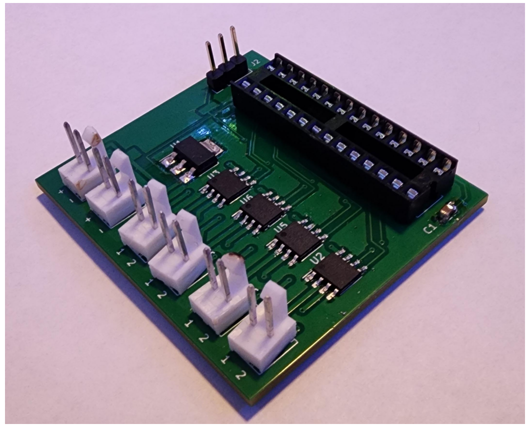
- The system must be able to complete this tuning within 30 seconds.
- The system must be able to slowly bring strings taught in the case a new string is put on in under 90 seconds.

Objective

- The **issue** is the difficulty and danger of tuning a violin for beginner students.
  - The instrument or strings can easily break when handled without care
  - The force required to tune an instrument by hand is demanding
  - The ear to tune correctly is a skill that has to be developed over time
  - Having a teacher or adult tune an instrument takes away practice time

Objective

- Our **solution** is to tune the instrument without the need for the player to touch the tuning pegs
  - A microprocessor acts as a tuner on the violin that can detect the instrument's pitch range
  - The processor can determine if the given note is flat or sharp to the desired pitch
  - This information is sent to the motors to tighten or loosen the strings correctly



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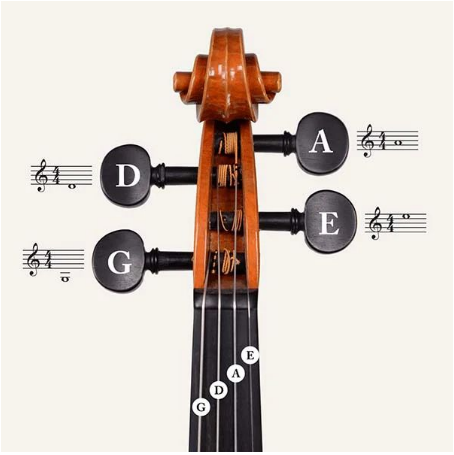
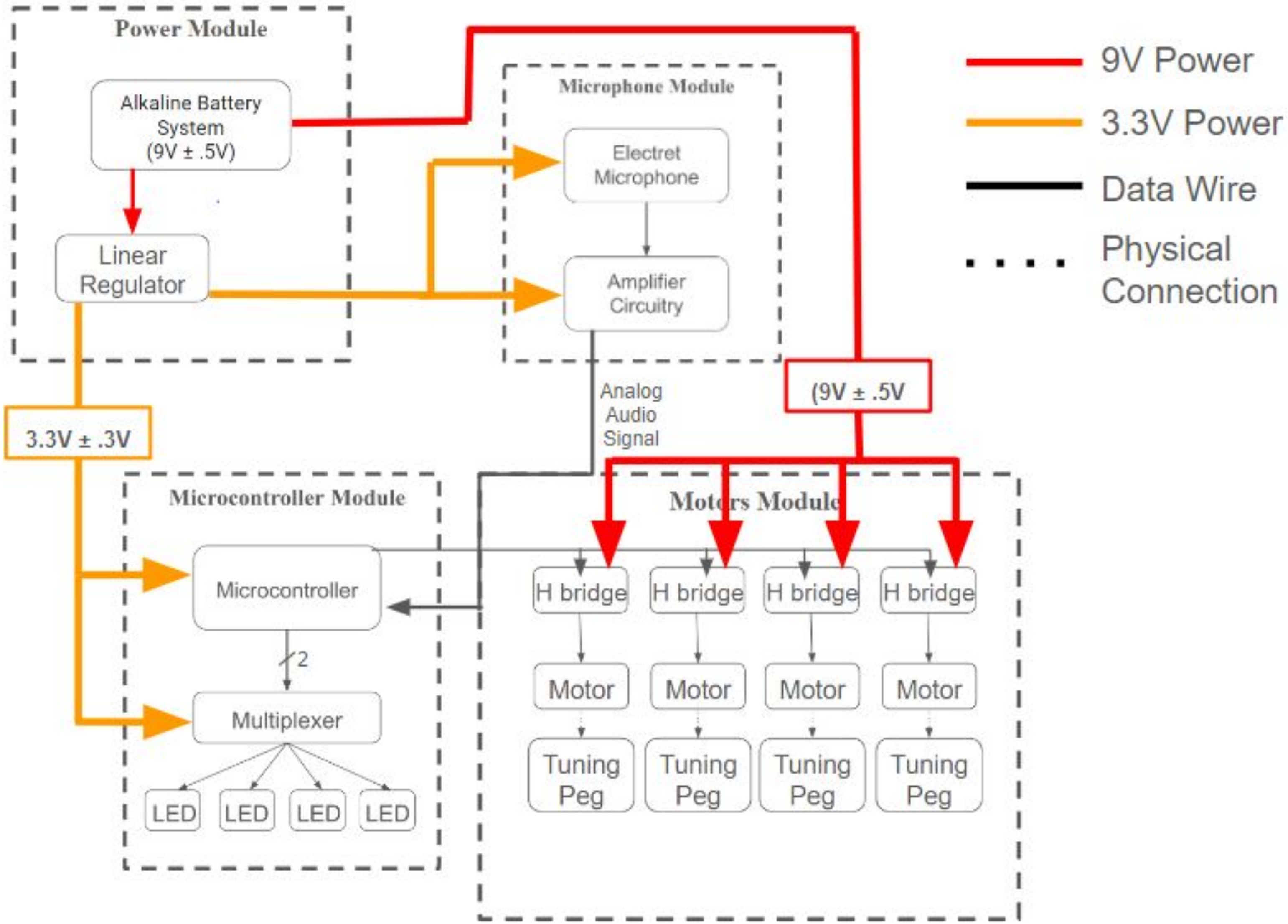
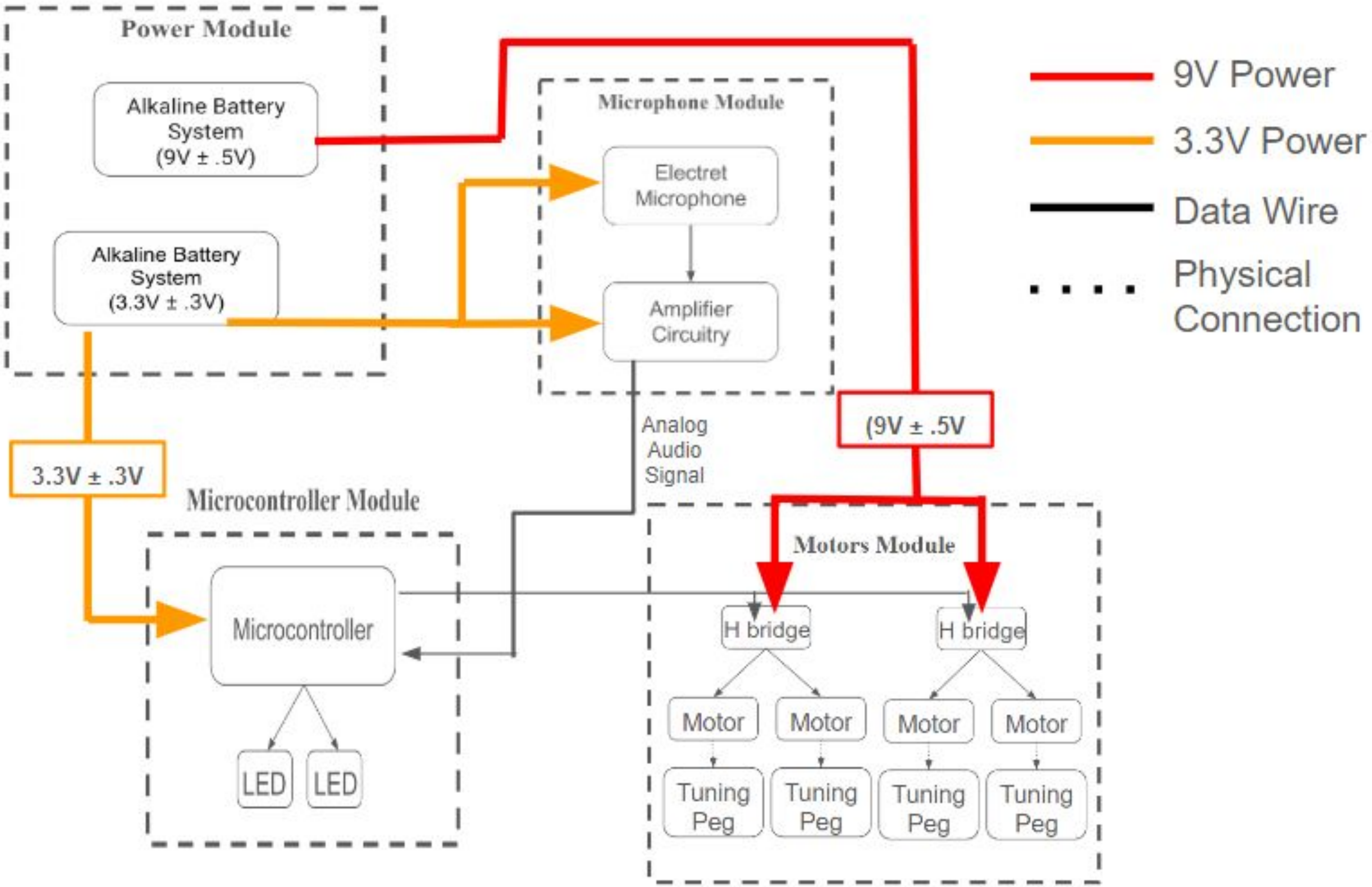


Design - Initial Block Diagram



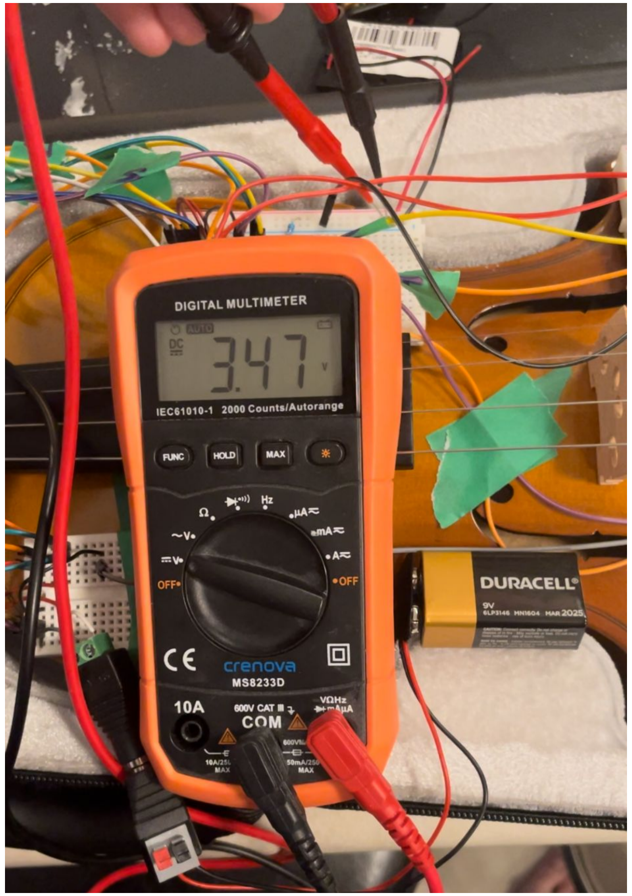
Design - Revised Block Diagram



Design - Power Module - R&V1

Provide consistent and accurate voltage to the other components, primarily a 9V ± 0.5V line to turn the motors and a 3.3V ± 0.3V line for most other items.	1. Connect all subsystems to power, either directly to the 9V line or to the 3.3V line from the batteries or voltage regulator respectively 2. Use a multimeter to verify that the 9V line is within the tolerance range, as well as verify the 3.3V line is within its own tolerance range

Design - Power Module - R&V1



Voltage of 3.3V output

Input voltage going into the ATMEGA

Voltage of 9.0V output

Voltage going into the H-bridge

Design - Power Module - R&V2

Able to keep the motors running under 5 rpm to avoid damage to the violin	1. Connect power to the motors 2. Check if motor speeds are under 5 rpm by marking one side of the motor shaft and calculating the speed of a rotation to make sure the violin will not be damaged

Design - Power Module - R&V2

Time of one rotation	RPM calculation
11.90 s	5.042 rpm
12.02 s	4.992 rpm
11.82 s	5.076 rpm
11.84 s	5.068 rpm
11.90 s	5.042 rpm
12.10 s	4.959 rpm
11.93 s	5.030 rpm

Excerpt of time per rotation to RPM measurements

Design - Microphone Module

Accurately transceive sounds ranging from a minimum span of 100 Hz to 1000 Hz	1. Set up the microphone to receive sound and send the signal to an oscilloscope 2. Play sounds with verified frequencies 3. Check that the correct frequency is displayed on the oscilloscope from the microphone input

Design - Microphone Module

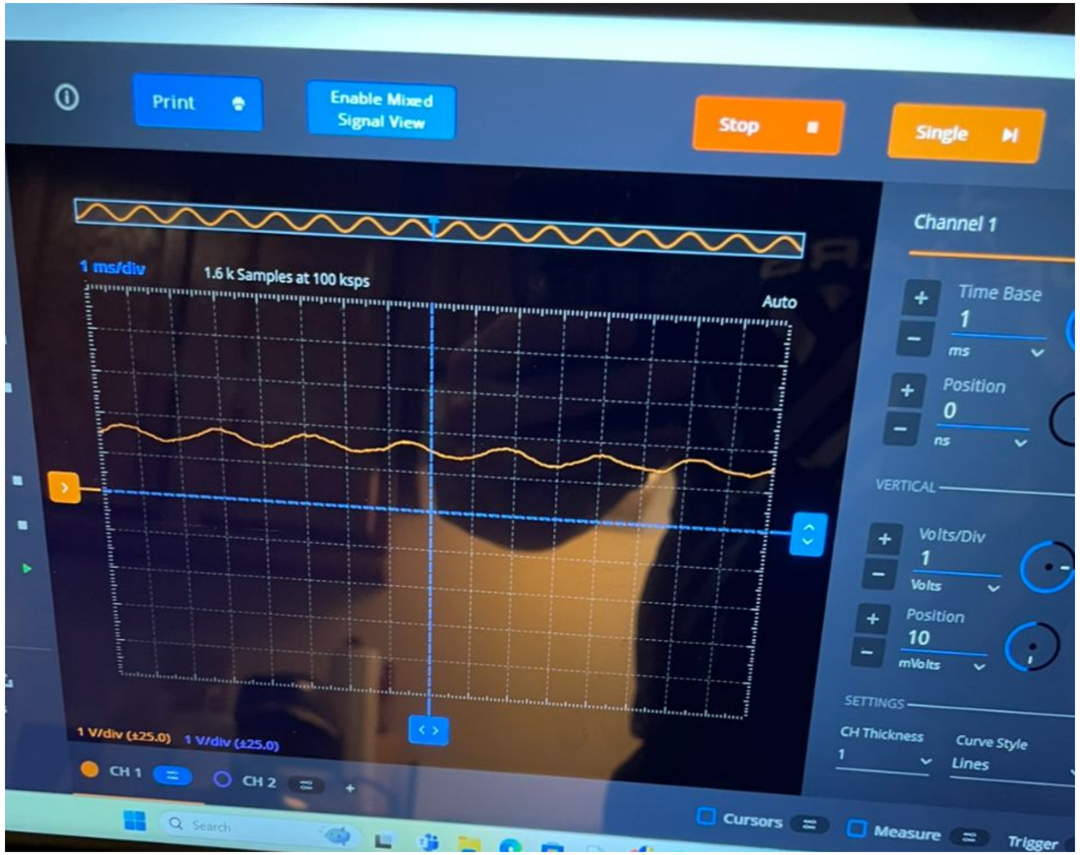


Image from oscilloscope measuring microphone receiving pure sine wave

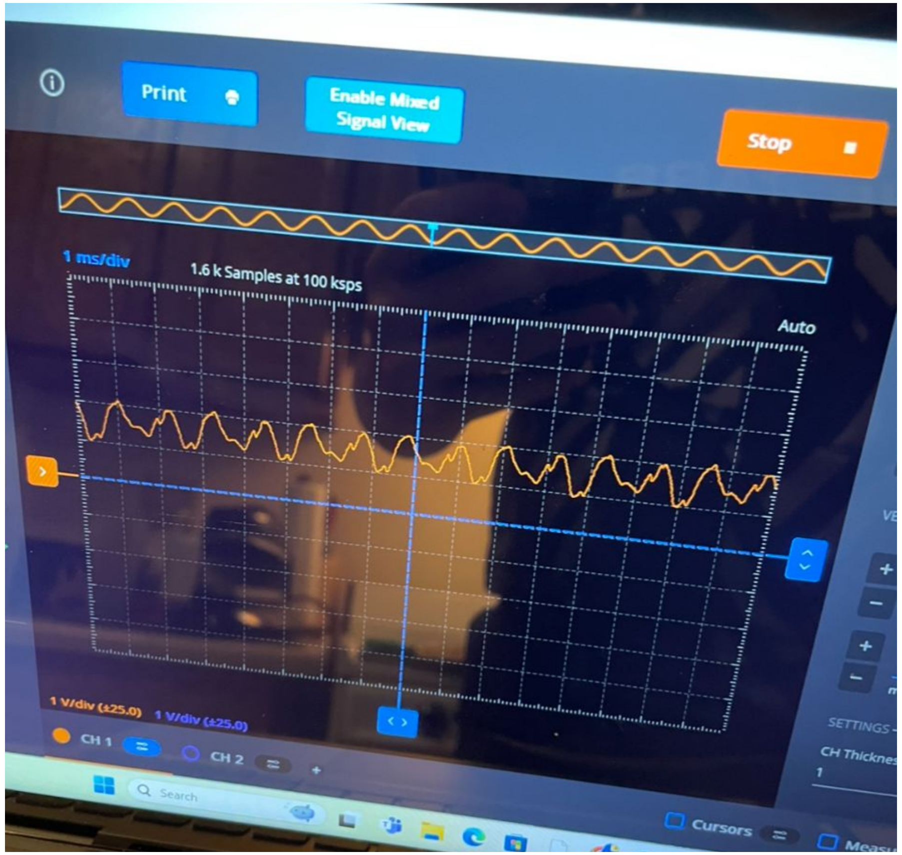


Image from oscilloscope measuring microphone receiving pure sawtooth wave

Design - Motor Module

Accurately turn the tuning peg to within 5 degrees as directed forwards and backwards through the use of H-bridges.	1. Connect the motors to the H-bridges 2. Mark the tuning peg to see where you began 3. Input a command to turn the peg a specific number of degrees 4. Check the difference between the mark and where it began and compare this to the inputted command and make sure it is within 5 degrees * $5^{o} = 166ms$

Design - Motor Module

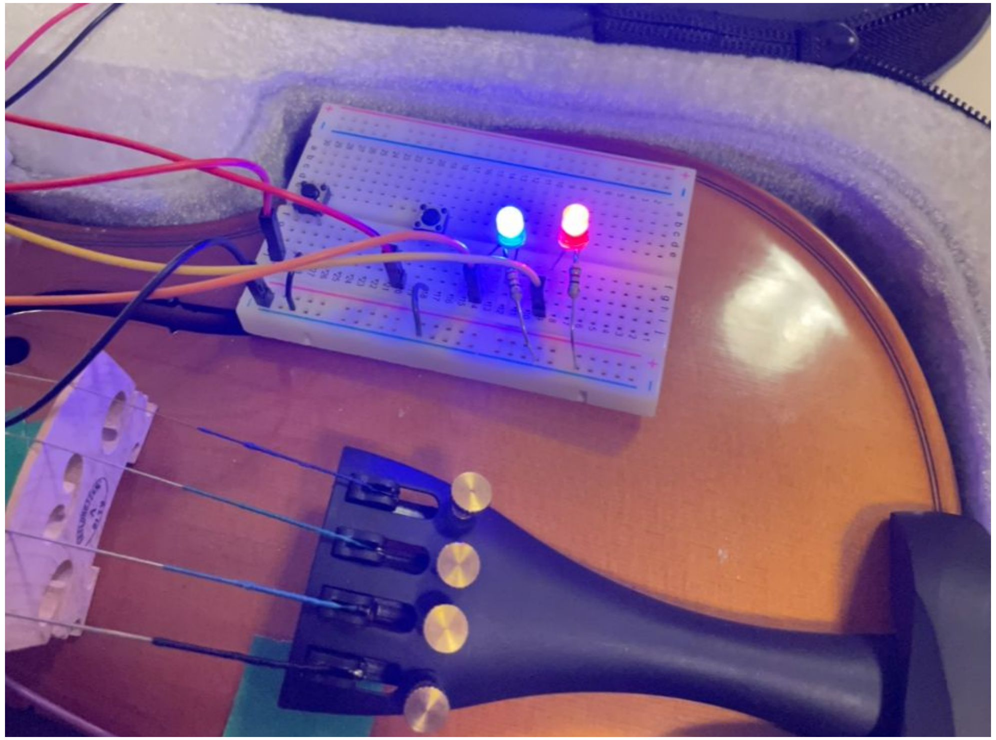
Input		Output		State
IN1	IN2	OUT1	OUT2	
L	L	OPEN	OPEN	STOP
H	L	H	L	FORWARD
L	H	L	H	REVERSE
H	H	L	L	BRAKE

H-bridge Truth Table

Design - Microcontroller Module - R&V1

Be able to control the 2 LEDs to show the current string being worked on and do this without skipping to another string or turning off completely	1. Once the power switch is turned on, the first LED should turn on for the first string to begin being tuned 2. Once the string is played, the string should be tuned by the rest of the system 3. Once this is completed the first LED will turn off, and the second will turn on to continue tuning the next string

Design - Microcontroller Module - R&V1



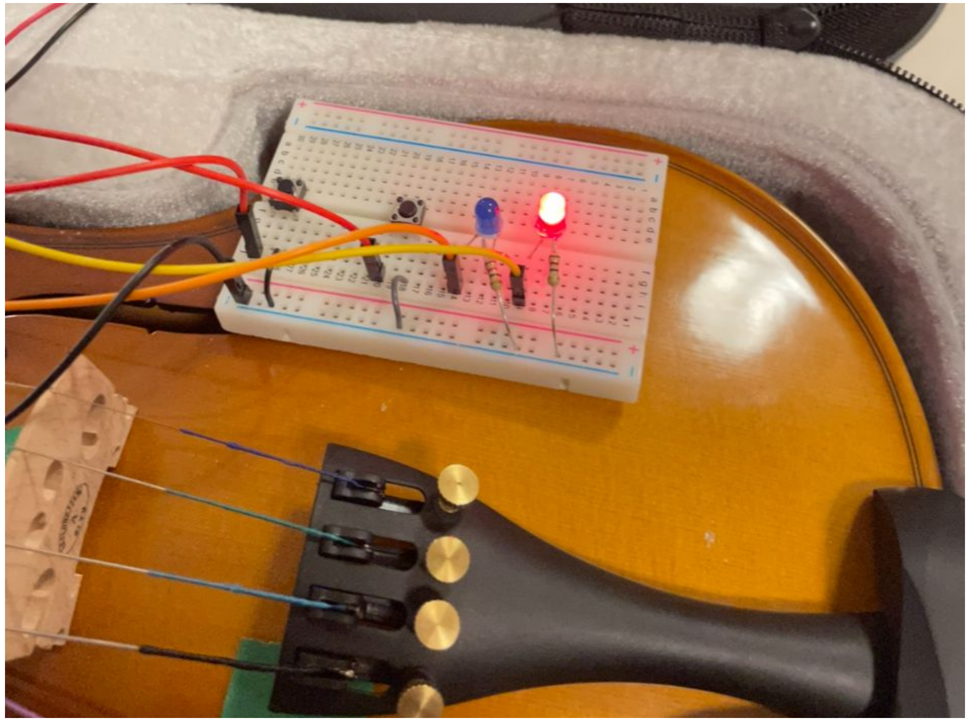


Image of LEDs functioning properly

Design - Microcontroller Module - R&V2

Accurately determine the loudest pitch in the given analog signal using a FFT with more than 95% accuracy	1. Set up the microphone to receive sound and send the signal to the microcontroller 2. Play sounds with verified frequencies 3. Run the signal through the FFT 4. Check that the frequency is within the given range of frequencies

Design - Microcontroller Module - R&V2

Actual Frequency	Perceived Frequency	Relative Error
440.0 Hz	445 Hz	%1.13
196.0 Hz	200 Hz	%2.04
293.7 Hz	295 Hz	%0.443
659.3 Hz	665 Hz	%0.865

Excerpt from microcontroller calculation of pitch given a pure sine wave

$$percent\ error = 100 * \left| \frac{(Estimated\ Value - Actual\ Value)}{Actual\ Value} \right|$$

Design - Microcontroller Module - R&V3

Send consistent signals to the motor module so the motor spins within 5 degrees of the correct location	1. Connect the microcontroller to the motors and to the power system 2. Send a command from the microcontroller to the motors to spin a certain amount of degrees 3. Check that the motor spins within 5 degrees of the correct amount * $5^{o} = 166ms$

Design - Microcontroller Module - R&V3

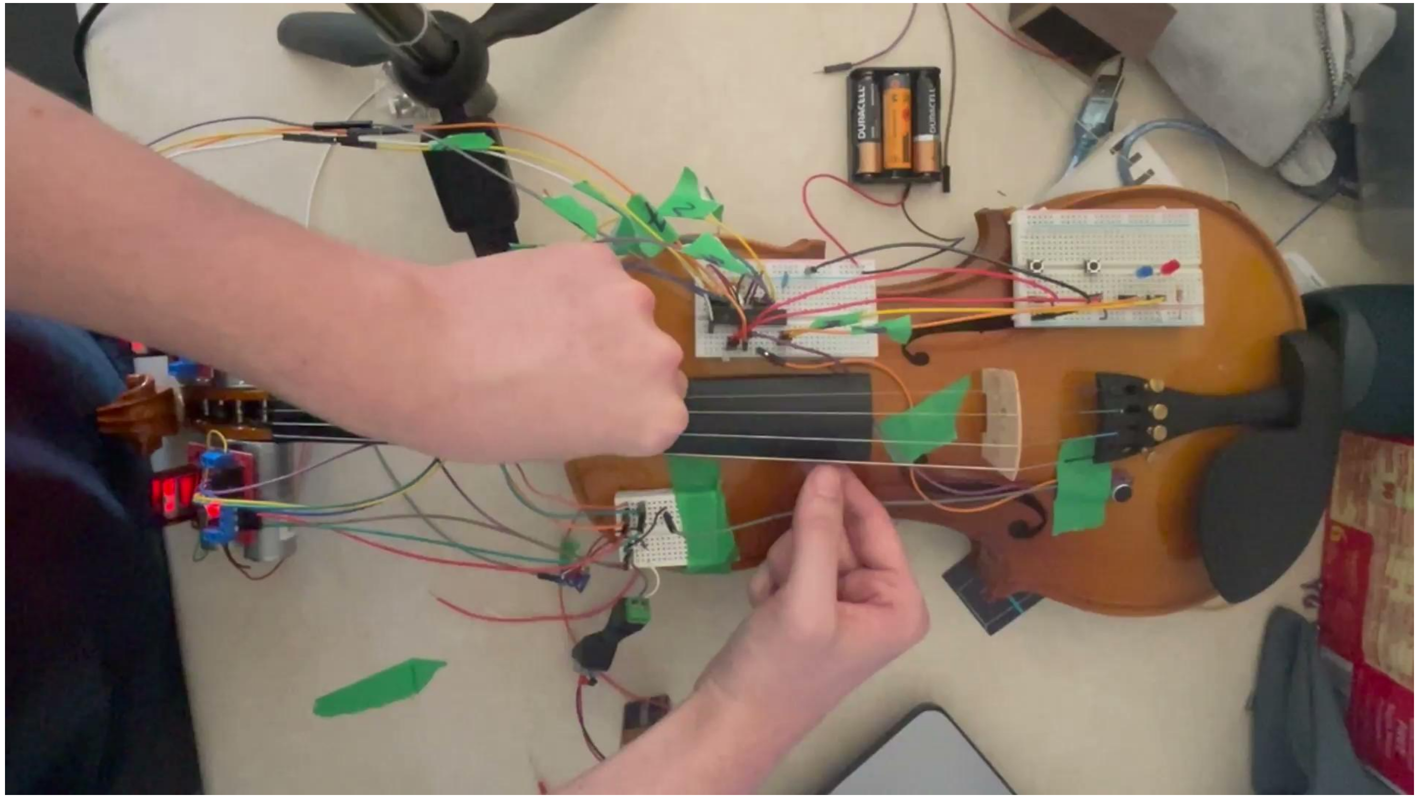
Clicks per minute	Tme Threshold calculation
181 clicks	165.746 ms
182 clicks	164.835 ms
181 clicks	165.746 ms
184 clicks	165.746 ms
180 clicks	163.043 ms

Excerpt from motor precision experiment

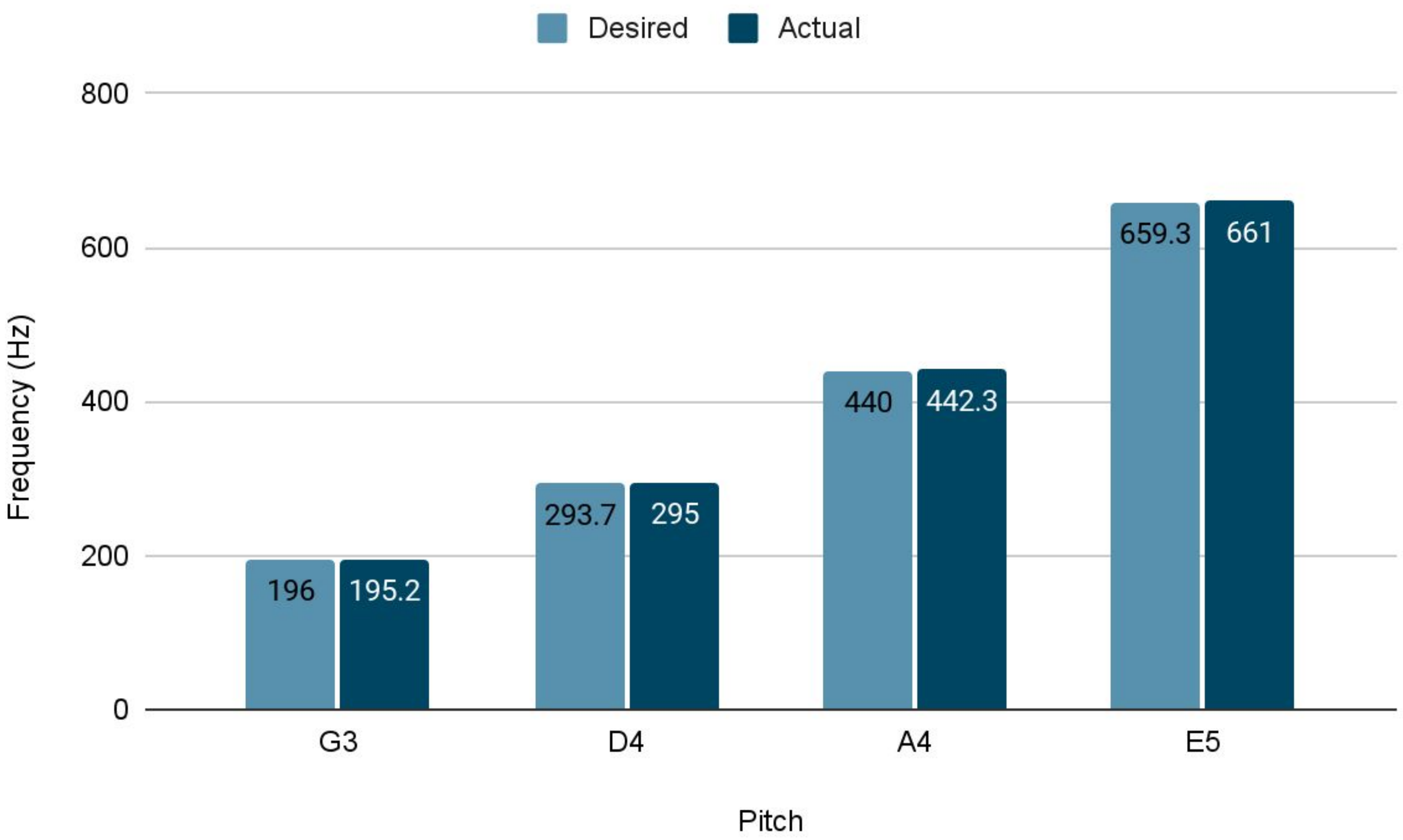
```
while (1){
    turnMotorClockwise();
    sleep(166); /// ms
    stopMotor();
    sleep(166);

    turnMotorAnitclockwise();
    sleep(166); /// ms
    stopMotor();
    sleep(166);
}
```

$$Time\ precision = 60{,}000/(BPM * 2)$$

Project Results

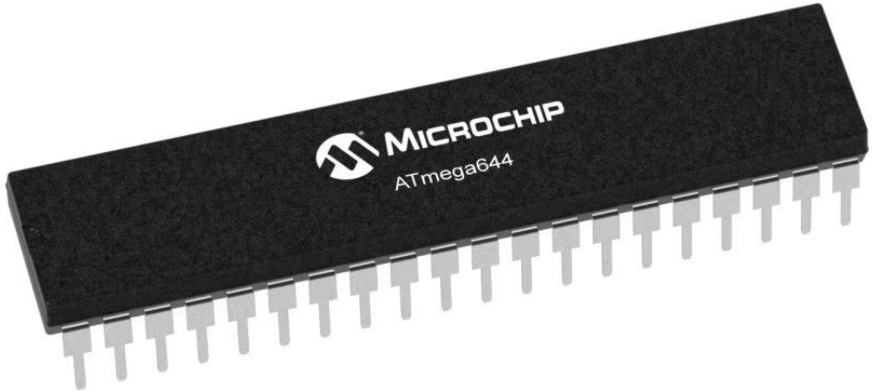


Project Results - Graphically



Successes and Challenges

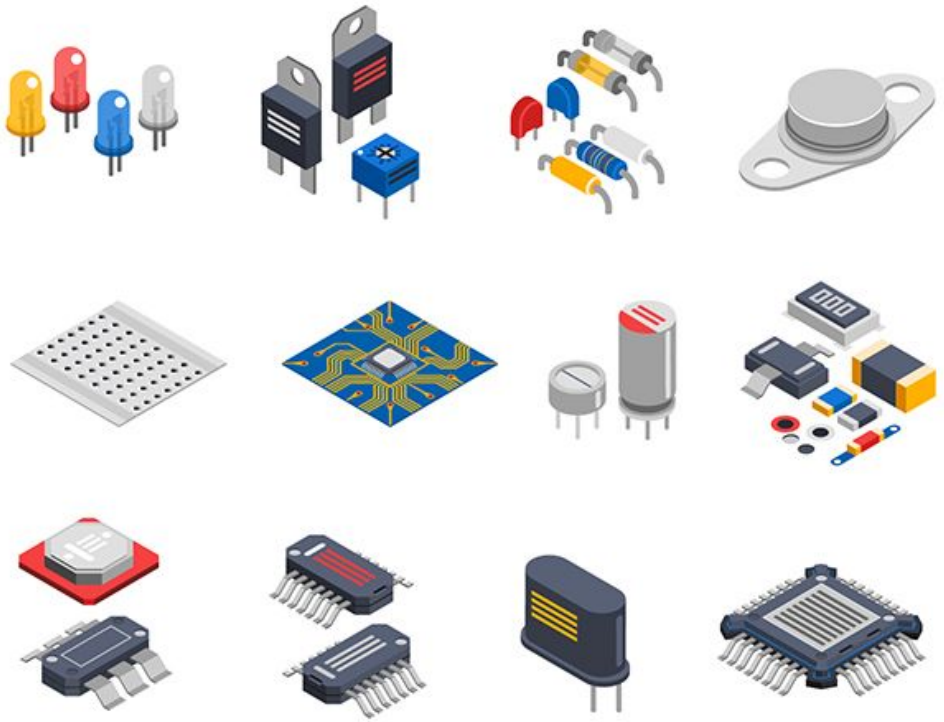
- **PCB Implementation:**
  - **Designing**
    - Misidentifying Microphone components
    - Attaching non-solderable items
  - **Soldering**
    - Excessive grounding



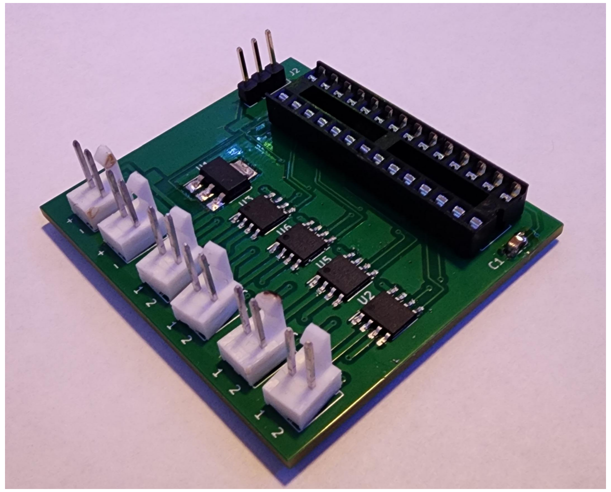
- **Underpowered Microprocessor**
  - **Computation**
    - Need more memory for higher fidelity DSP
    - Faster processor would allow for more error checks
    - Lo-fi filter implement in software
  - **I/O Pins**
    - Almost ran out of I/O pins
    - Could be circumvented using MUX

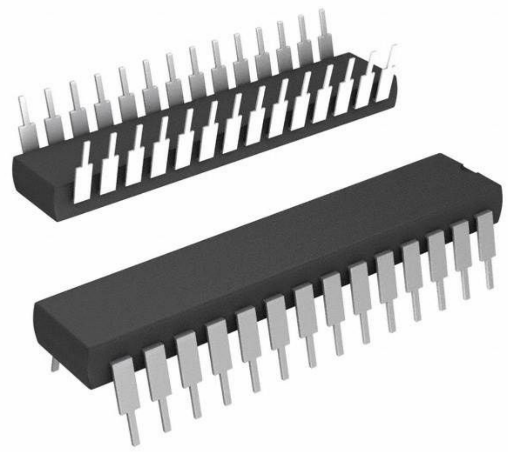
Conclusions

- **Lessons Learned:**
  - Datasheets Information
  - Part selection
  - Stay organized with materials
- **Looking back:**
  - Document with pictures and videos
  - Tested more
  - Get work done earlier



Future Endeavours





Design:

- Smaller, more compact design
- Hide exposed electrical components

Efficient Circuitry:

- A single on/off switch
- A microcontroller with more memory for more precision
- Better user interface

Thank You for Listening!

Any Questions?

The Grainger College of Engineering

UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

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Slide Title

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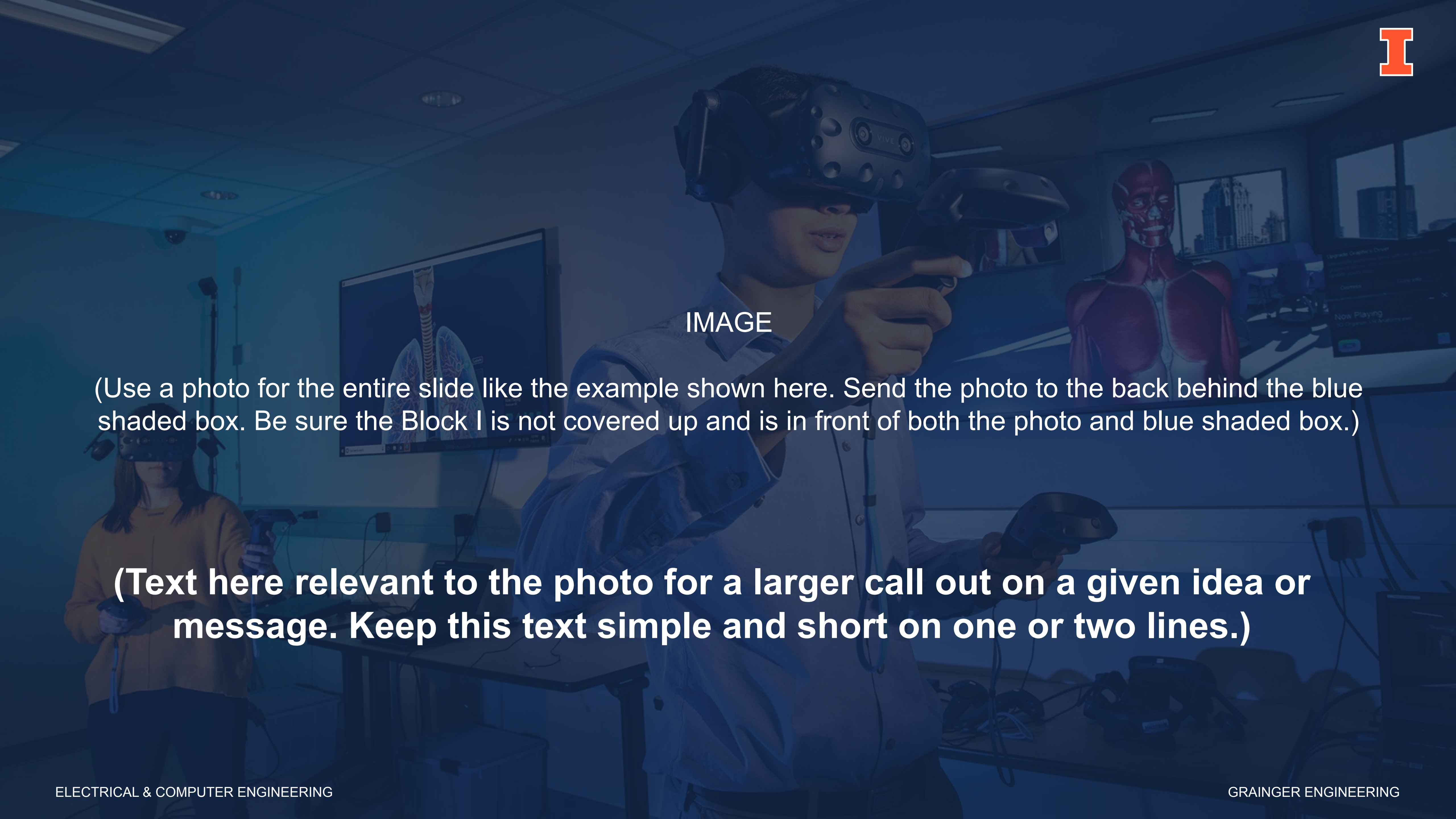

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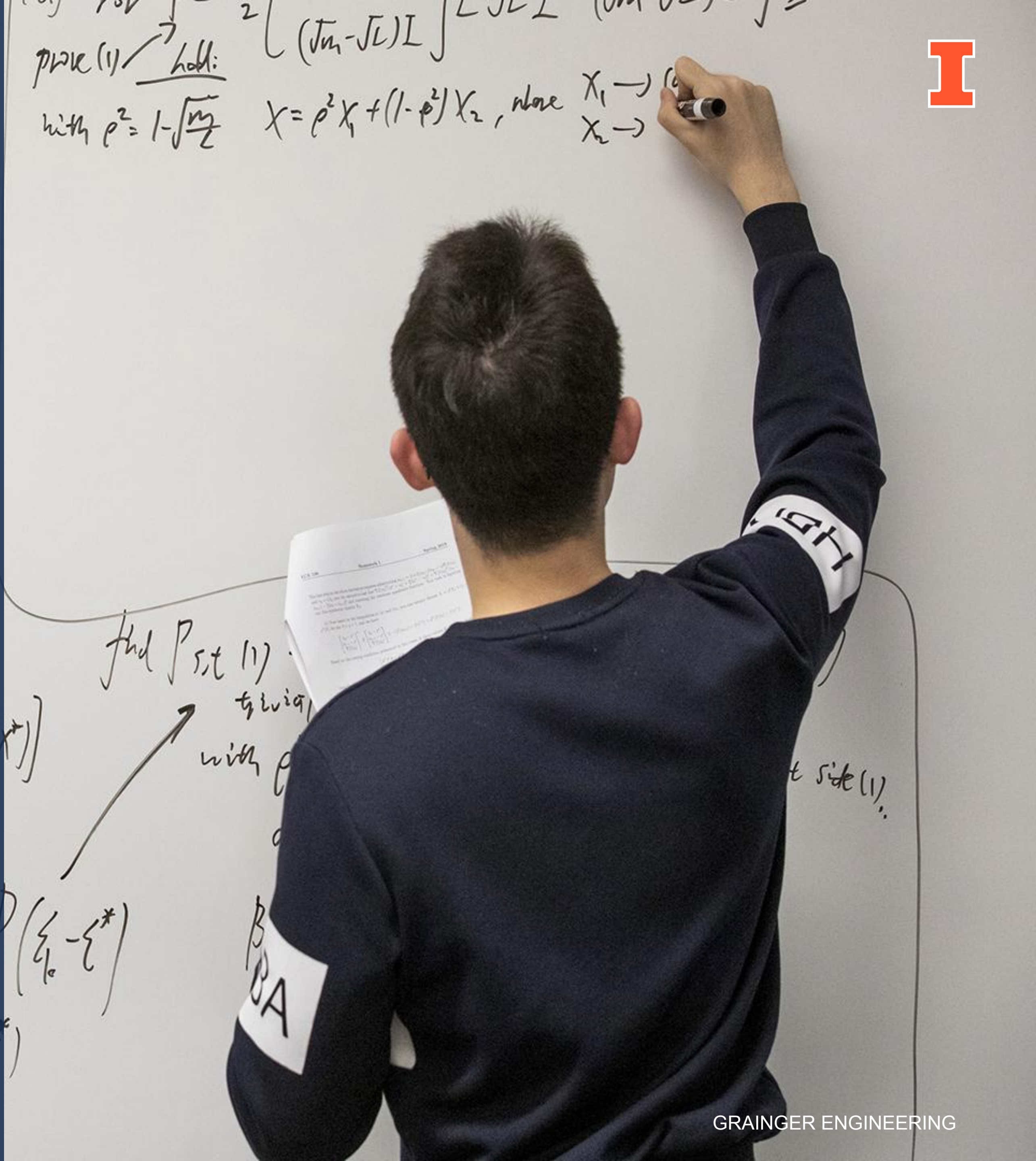

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Summary
Thank You
Questions
Contact Information

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