ECE 445 Design Document – Spring 2018

Automatic Trumpet Tuner

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2-22-2018

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1. Introduction

1.1 Objective

A large problem in any musician's life is tuning. The tuning of an instrument changes constantly based on the temperature of the room and the instrument, the changing embouchure (placement of the lips on the instrument) the musician uses, and on every note played. While an experienced musician can account for this most of the time, a beginner or intermediate player will still have trouble consistently staying in tune. This can be detrimental at times, especially on longer notes where you can tell whether one member of a band is out of tune or not. The trumpet section is often the largest section of any band, and because of this each trumpet player needs to pay close attention to tuning with all the other players.

Our proposed solution is to create an automatic tuner (auto-tuner) that can be placed on the trumpet and will adjust the tuning. The auto-tuner will be battery powered so that the musician may move around freely, but also have a DC source that will allow for longer sessions of playing with the auto-tuner. The auto-tuner will listen to the player's trumpet, and perform frequency prediction to show the player whether they are sharp, flat, or in-tune. At this point, the player has to do nothing but play normally, as the auto-tuner moves the tuning slide in or out depending on the frequency prediction done. We predict this solution to be a low to medium cost solution, while still striving for a quality product that will accurately tune the trumpet.

1.2 Background

A trumpet's intonation, how in-tune a note is, consistently changes during a practice session. The intonation is so prone to changing due to many factors like temperature, experience, tendencies of certain notes to be flat or sharp because of the physics of the instrument, among others [1]. In group settings, like a band, multiple instruments are playing that all experience these intonation effects. The result of even one instrument being out of tune is the creation of a beat frequency. This beat frequency is equal to the difference of the tuning between the two instruments, and sounds like a fading and approaching tone at a certain speed, which is undesirable. For more experienced players, they can adjust their embouchure before the beat frequency becomes noticeable to the audience which makes the music more pleasant. The question is how do musicians typically practice to get to this point?

The most common way to learn these tendencies of the trumpet is by sitting down with a chromatic tuner, playing each note slowly, and recognizing when the instrument isn't in tune so that you can adjust your embouchure for the next time you play. This relies on spending a lot of time practicing, and being able to hear the tone accurately and recalling it, called tonal memory or pitch memory [2]. While the use of an auto-tuner will be beneficial for practicing the music itself, because the player will hear correct pitches while playing music at a normal speed, and in group settings because musicians can focus on blending with other players, it likely won't completely negate the practice necessary to develop pitch memory. An auto-tuner will enhance a musician's experience while practicing pitch memory though, because instead of worrying about adjusting the slide or embouchure for every note, which is the only method currently available to adjust tuning, they can continuously play while the auto-tuner provides the necessary adjustments.

1.3 High-level requirements

- The tuner shall automatically adjust the trumpet's main tuning slide according to any chromatic scale note within the trumpet's range
- The tuner shall adjust the tuning of the trumpet to within 2 Hz of the desired note
- The tuner shall be able to run on battery power
- The tuner shall be able to run on a DC power source

1.4 Frequency to Cents: A Crossover between Music and Electrical Engineering

In Electrical Engineering, frequency analysis is almost always done in hertz, while in Music, frequency analysis is always done in terms of cents and note number, which corresponds to the note in the chromatic scale used in all western music. Why this is the case is beyond the scope of this paper, however it is important to realize the mathematical relationship between the two, and how this is applicable to an auto-tuner.

The first thing to note is that a linear change in note number does not correspond to a linear change in hertz, but an exponential change. The formula [3] for this is given as:

$$Frequency = 2^{\frac{note\,number}{12}} * 440\;Hz \quad (1)$$

Where a B4 (middle B) on trumpet corresponds to 440 Hz. Because of this, an octave above a note is double its frequency, while an octave below is half its frequency.

Beyond this, there is a measurement that musicians use called "cents" to tell how above, sharp, or below, flat, a note is relative to the calculated frequency. This is called being "out-of-tune," and what this auto-tuner aims to fix. The formula [3] for cents to frequencies is given by:

$$Cents = 1200 * log_2\left(\frac{f_{heard}}{f_{actual}}\right) \quad (2)$$

From this, it can be seen that at the lowest frequencies of trumpet, a 1 Hz difference will cause about a 10 cents difference. Although this is relatively high, if we were in the middle range of the trumpet, our ability to distinguish this as out of tune in the low range is diminished [4], especially when mixed with the fact that playing at this low of a frequency on a trumpet, the ability of the player to hold a steady pitch using their lips affects the tuning much more than the slide will. A generalization can be made for the whole range of trumpet then, that 2 Hz is more than satisfactory to consider a trumpet in-tune.

2. Design

2.1 Block Diagram

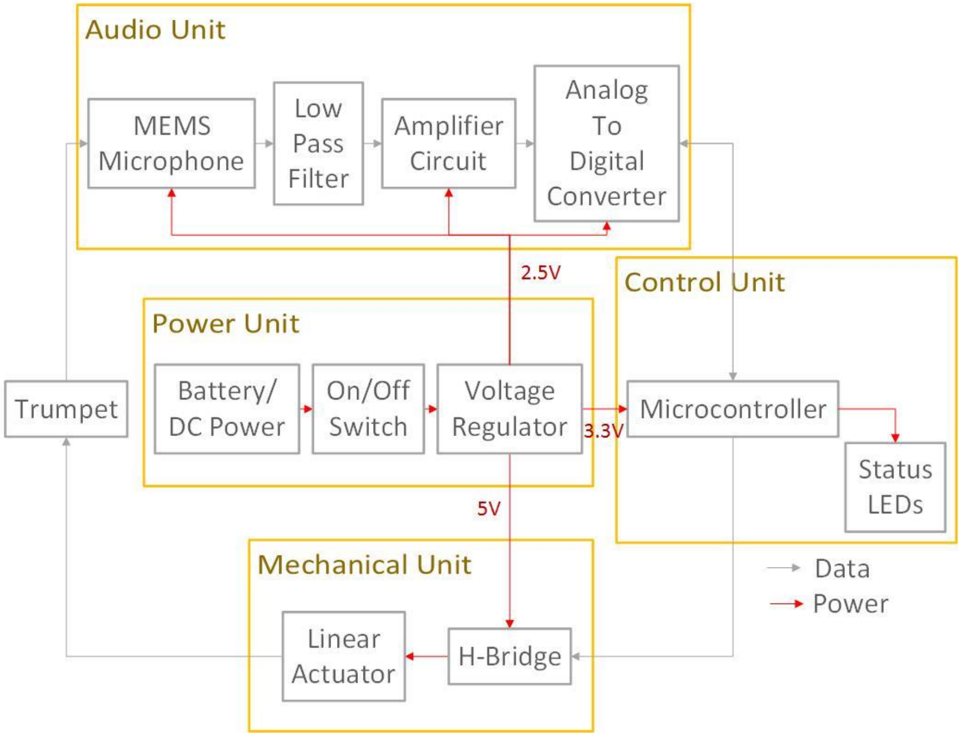

Figure 1. Block Diagram of the Auto-Tuner

2.2 Physical Design

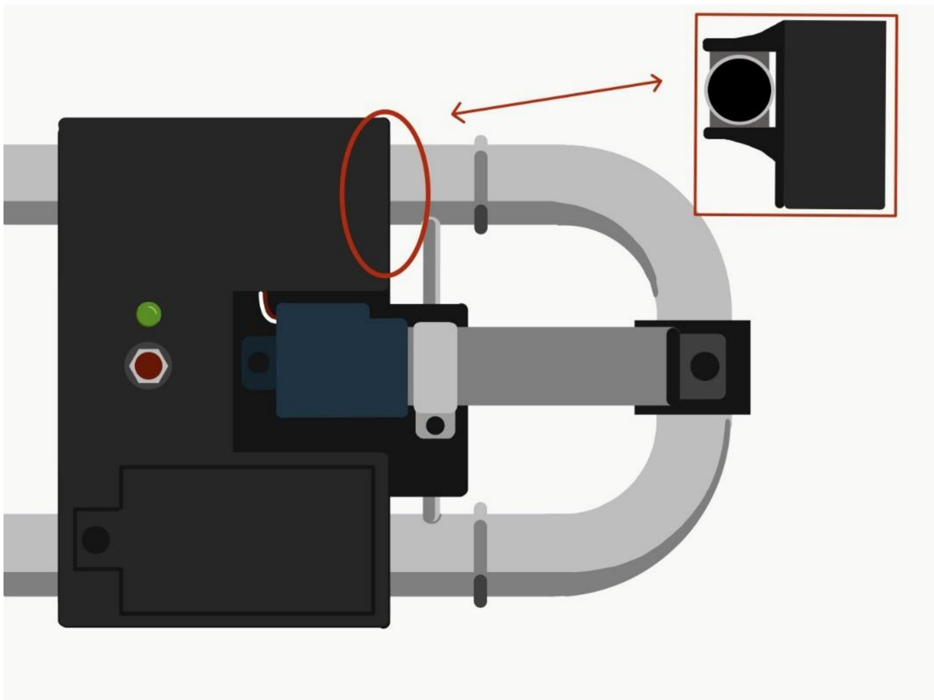

Figure 2. Physical Model Concept

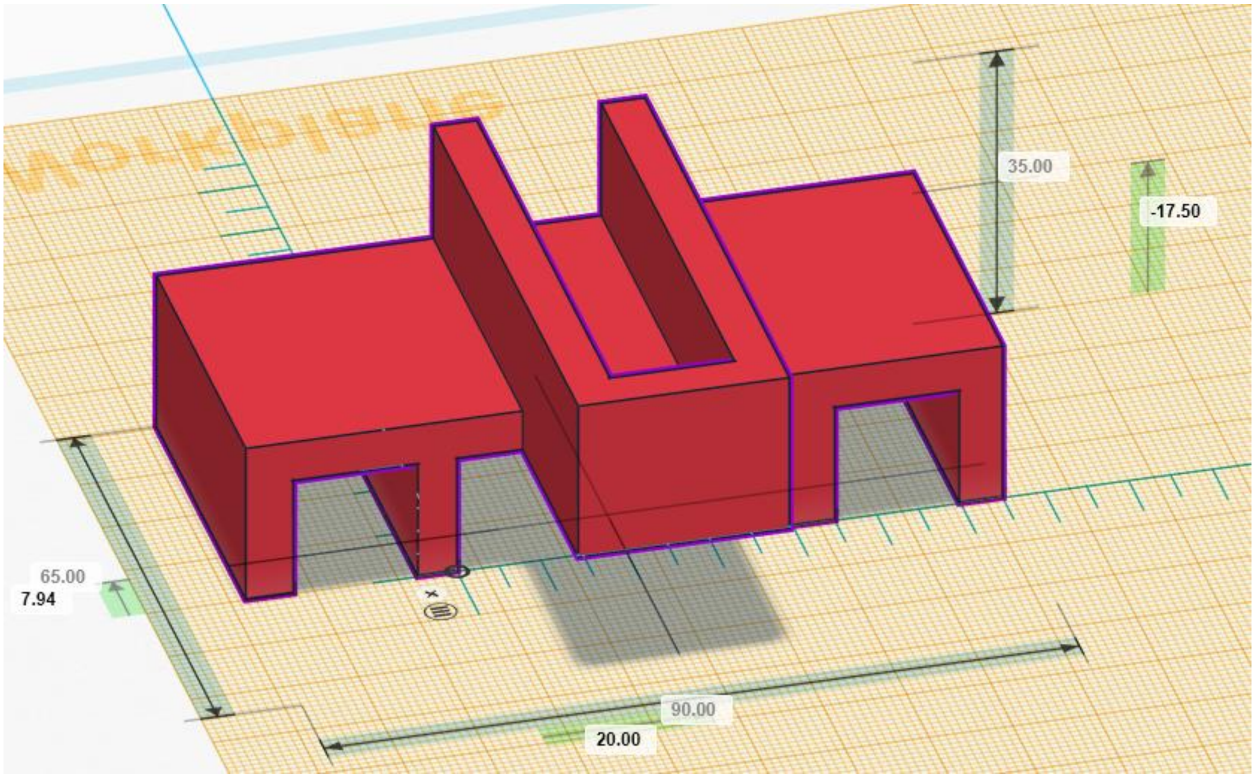

Figure 3. 3D Rendered Casing Draft

2.3 Functional Overview

The first block, in Figure 1, of importance in the device's function is the audio unit. This is where the audio signal is captured and changed into a digital format for the processing unit. The processing unit will take this signal, perform frequency analysis on it, and based on that control the LEDs to show whether the pitch was high or low, and control the mechanical unit. The mechanical unit will receive a digital signal from the processing unit to control whether the motor needs to move the slide out or in. The power unit is the block that supplies each other block with power at the appropriate level for the devices in that block.

2.4 Audio Unit

The audio unit will be used to capture audio using a microphone and turn it into a digital number format using an analog to digital converter for the control unit to process. The range of trumpet frequencies are from 165 Hz to 988 Hz [5]. Because of this, creating a filter to lower the effects of harmonics and interference is required to ensure no aliasing occurs. The low pass filter was placed before the amplifier because less filtering is needed than if it was placed after, where the harmonics would be at much higher levels.

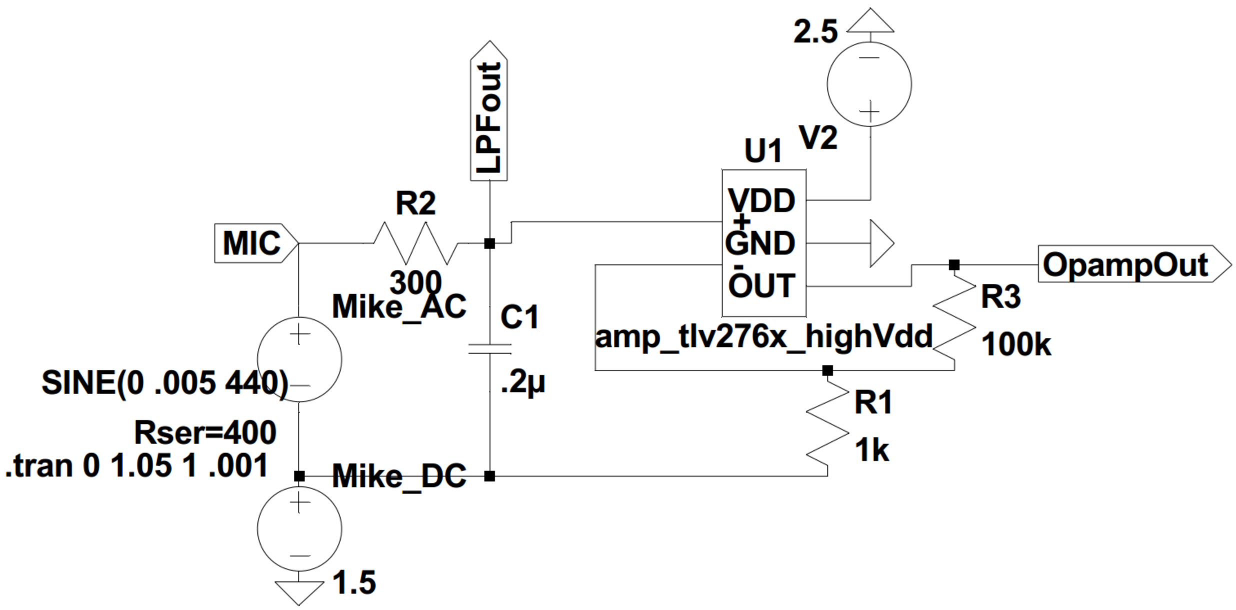

Figure 4. Circuit Diagram for Simulation of Low Pass Filter and Amplifier Output with MEMS Microphone

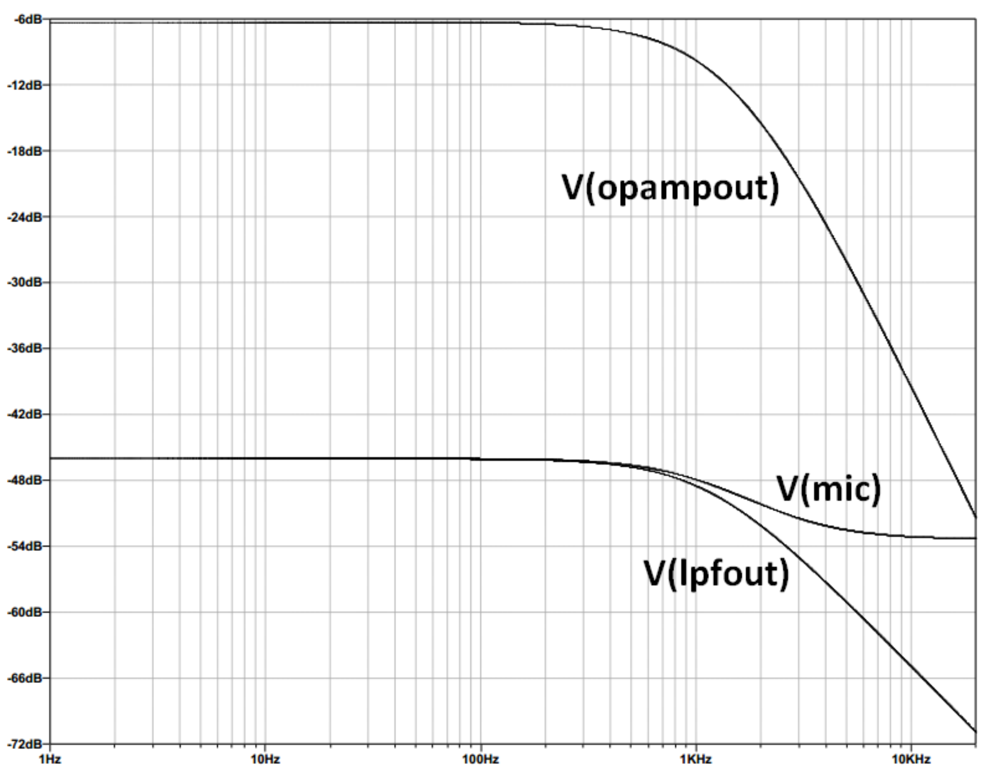

Figure 5. Frequency Magnitude Response Simulation of Low Pass Filter and Amplifier given a 5 mV Sine Wave offset at 1.5 V

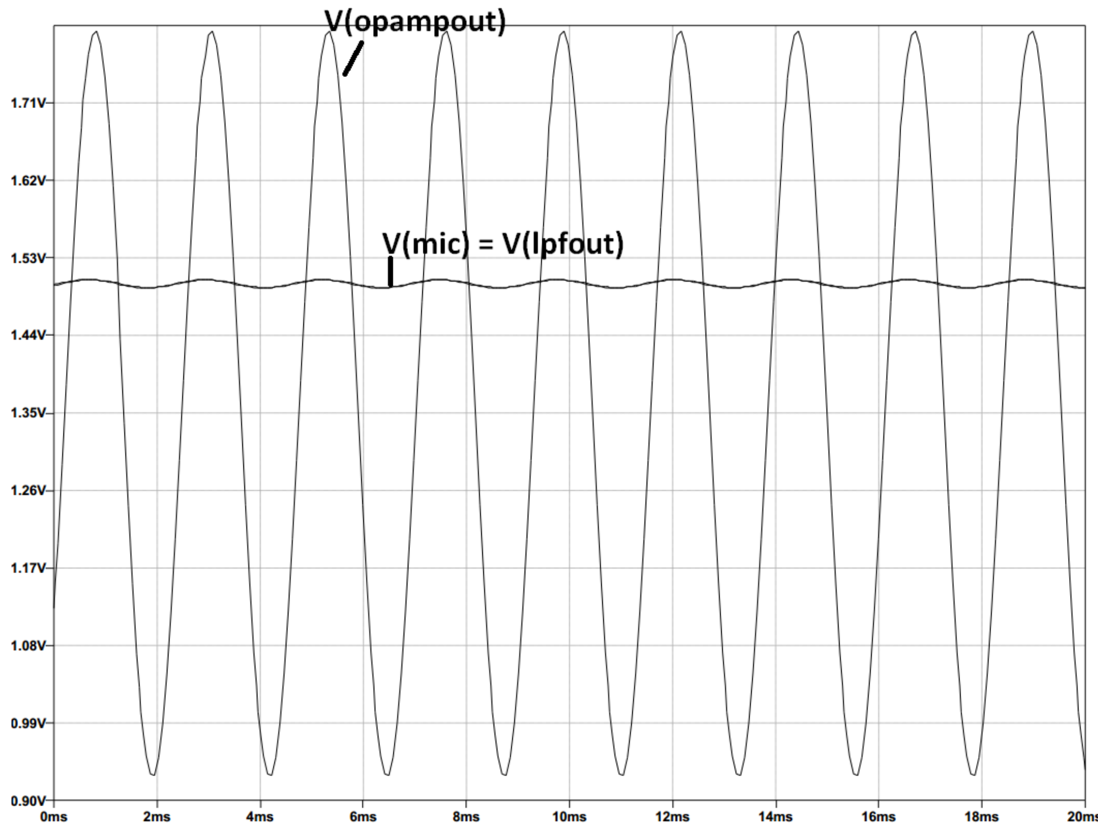

Figure 6. Time Domain Simulation of Low Pass Filter and Amplifier Output Given 440 Hz Sine Wave with 5 mV Amplitude offset at 1.5 V

2.4.1 MEMS Microphone

The MEMS microphone will be used to capture sound from the trumpet and environment. A MEMS microphone was chosen for its low power, and better sensitivity than an electret microphone. The amplitude of this microphone is 5 mV offset by 1.5 V. The STMicroelectronics analog MEMS microphone that was chosen has a series resistance of 400 Ohms, which is important for matching the impedance of the low pass filter for minimal loss.

2.4.2 Low Pass Filter

The low pass filter, in Figure 4, helps lower noise above the bandwidth we are interested in for better fundamental frequency estimating, and to reduce harmonics to prevent anti-aliasing. A single pole RC filter was chosen because of its simple design and effectiveness at dampening frequencies above the cutoff, where a sharp edge is not required since our sampling frequency was chosen to be much higher (~10x) our highest frequency of interest. The formula for determining our cutoff frequency is:

$$F_{-3dB} = \frac{1}{2\pi RC} \quad (3)$$

From this, easy values that would be guaranteed to allow off-the-shelf components, and would give a close match to the MEMS microphone were chosen: 400 Ohm resistor with a .3 micro-farad capacitor. Experimentally with the simulation software, the values were slowly adjusted in 50 Ohm and .1 uF increments to still give a cutoff frequency around 1.2 kHz while giving the lowest loss as shown in Figure

5. The results were that a 300 Ohm resistor and .2 uF capacitor had relatively low loss, while still being reasonable choices for components.

Although a higher order low pass filter could have been used, it would be unneeded in this case. The main purpose it serves is to reduce any effects of atmospheric noise or harmonics, which will have much lower amplitude than the sound of a trumpet. Without the low pass filter, certain circumstances where the atmospheric noise adds with a harmonic because of aliasing could overpower the fundamental frequency, causing the microcontroller to send a wrong control signal.

Requirement	**Verification**
The low pass filter shall have an attenuation of 3 dBV, decibels relative to 1 V, relative to the passband at the cutoff frequency of 1.2 kHz ± 100 Hz.	1. Connect a waveform generator at the input of the low pass filter with a sine wave of 5 mV at 800 Hz 2. Slowly increase the frequency of the sine wave and note the frequency which is exactly 3 dBV down from the initial measurement using an oscilliscope

2.4.3 Amplifier Circuit

The amplifier will take the small voltage signal that the microphone produces and amplify it to be used for the full range of input voltages for the analog to digital converter. For this, a TLV2761 op-amp was chosen because of its low power applications, and flat response across our band of interest. The gain for this amplifier is determined by the formula:

$$A_v = \frac{Vo}{Vi} = \left(1 + \frac{R_F}{R_G}\right) * \left(\frac{1}{1+2\pi f * R_{LPF} C_{LPF}}\right) \text{(4)}$$

From here, the amplifier circuit was determined to need a gain of 100 to amplify the small AC signal, while not causing clipping on the analog to digital converter. The low pass filter and amplifier circuits were created using modeling software, Figure 4, and the frequency and time domain results of the circuit were simulated, Figure 5 and Figure 6, to view the waveform input of a 440 Hz sine wave to the amplifier circuit and the output of the amplifier circuit into the analog to digital converter.

Requirement	**Verification**
The amplifier shall amplify the max value of the small signal input, 5 mV, by 35 dBV ± 6 dBV.	1. Connect a waveform generator with a sine wave of 5 mV at 500 Hz to the input of the amplifier circuit 2. Connect the output of the amplifier circuit to an oscilloscope and verify voltage is within specification

2.4.4 Analog to Digital Converter

The analog to digital converter is the key component that will allow an analog voltage to be converted into a digital number in order to do processing on the signal. The sampling frequency chosen for the ADC will be 9.6 kHz, since frequencies above 1 kHz are not of interest, and by 5 kHz they are reduced by 21 dBV, which is around 1/10th the voltage compared to our band of interest. An observation while simulating the audio unit using MatLAB was that 8 bits of resolution caused a much noisier frequency spectrum than higher resolutions. 12 bits of resolution was found to be the best option as it requires no extra software configuration, yet reduces the noise in the sampled signal drastically.

Requirement	Verification
The analog to digital converter shall send a digital signal with at least 12 bits of resolution at 9600 Hz sampling rate or better to the microcontroller.	1. Assemble the MSP432 IC on the PCB as specified in the datasheet as the basic configuration 2. Configure the driver for the MSP432 ADC using direct memory access 3. Connect through a socket interface built into MSP432 to receive captured data and verify accuracy

2.5 Processing Unit

The processing unit will be used for controlling the mechanical unit and the status LEDs based on the data received from the analog to digital converter.

2.5.1 Microcontroller

The microcontroller will take care of time to frequency domain conversion, frequency analysis, control of the interface, and control of the mechanical unit. A MSP432P401R was chosen for this because it has a built-in high-precision ADC that can be taken advantage of, if needed and is a very low power microcontroller. Another benefit is the wide variety of debugging tools that Texas Instruments makes for this microcontroller which will be very helpful when working with the signal processing aspects of this project, done in software.

A model of the algorithm, Figure 6, which will be implemented on the microcontroller is shown below, as well as the frequency plots, Figure 7 and 8, created with this algorithm using MatLab. As is shown by the graphs, a trumpet's harmonics could still be present in the range of interest, but they are at a much lower magnitude, and can be ignored completely. An alternative to doing this algorithm in software is to use a hardware frequency counter, however, this would require stricter hardware filtering, and the harmonics of the trumpet would be likely to interfere.

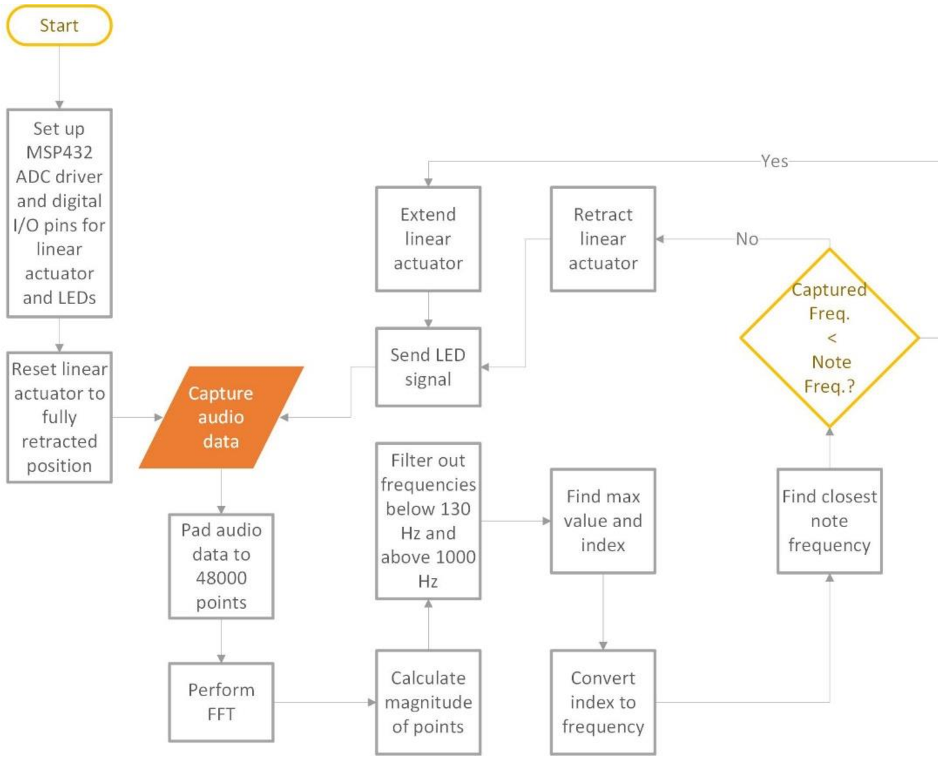

Figure 7. Software Flow Diagram for Microcontroller

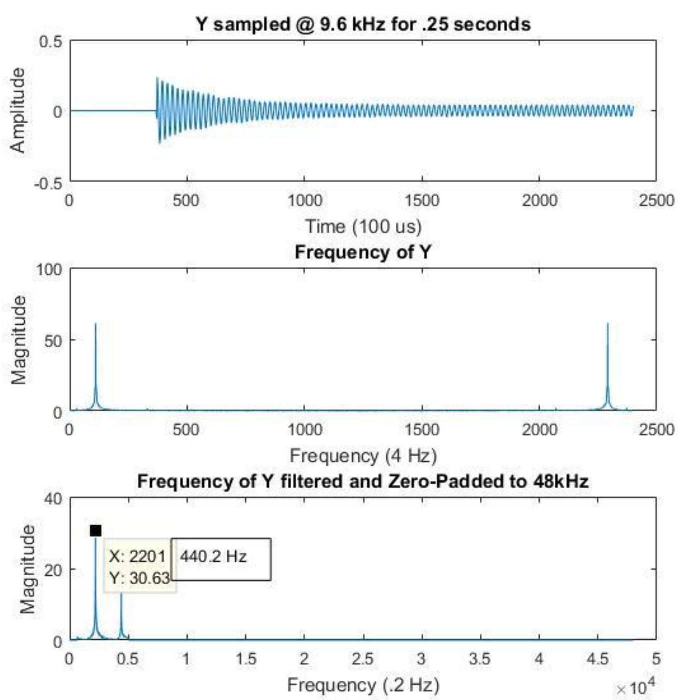

Figure 8. Pure 440 Hz Sine Wave Captured from Computer Microphone with Time and Frequency Domain Analysis

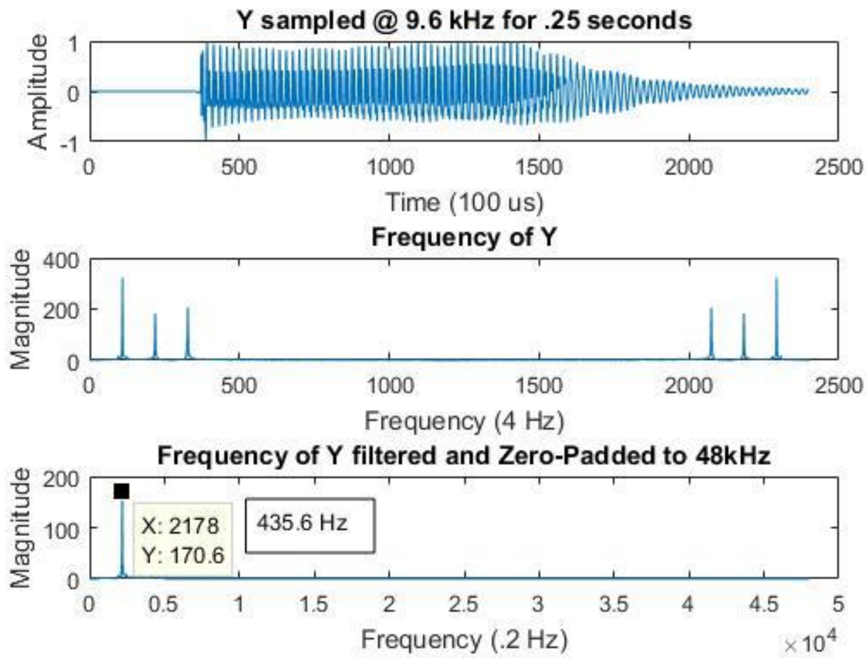

Figure 9. Out-of-tune Trumpet Played at B (440 Hz) Captured from Computer Microphone with Time and Frequency Domain Analysis

Requirement	Verification
The microcontroller shall attenuate frequencies below 130 Hz and above 1000 Hz by at least -6 dBV	1. A socket connection will be established from a computer to the microcontroller to verify that data captured has been filtered properly
The microcontroller shall complete one cycle of capturing audio and computation on that audio within 500 ms.	1. One digital I/O pin will be connected to an oscilloscope and a debug signal will be sent at the beginning of every cycle for the time to be determined

2.5.2 Status LEDs

The status LEDs will show whether the player is sharp or flat and will be powered by the microcontroller.

Requirement	Verification
The Status LEDs shall be clearly visible and be made up of 2 red and 1 green to show the current status of the tuner.	1. When assembled, 3 sine wave tones should be played from a tone generator: a 430 Hz tone, a 440 Hz tone, and a 450 Hz tone. A different LED will light up for each of these different tones.

2.6 Power Unit

The power unit will source its power from a 9V battery, regulate the voltage to 5V, 3.3V, and 2.5V, and distribute the power to various electronic and mechanical components of the tuner. The battery will be removable and replaceable. When no battery is present, the tuner will have the option to operate off of an external DC power supply.

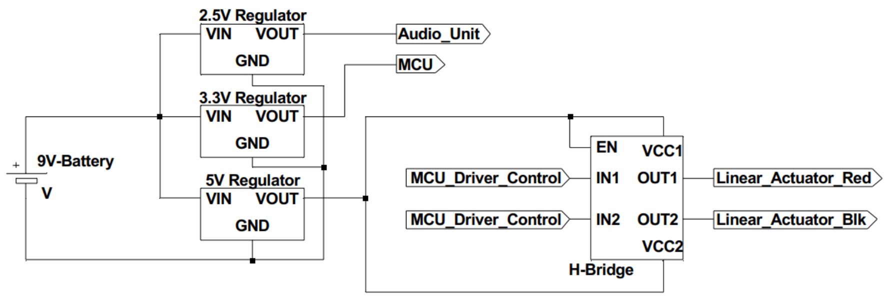

Figure 10. Circuit Schematic for Power Unit (Shown with 9V battery power source)

2.6.1 Battery/DC Power

The first design consideration regarding the battery is its output voltage. The 9V battery has a usable operating voltage between 9V and 5V. To get the most out of our battery, our tuner must operate across this wide input voltage range. For this reason, we have chosen our three voltage regulators such that the maximum input voltage we can supply is 13V, as limited by the 5V DC-DC converter, and the minimum input voltage we can supply is 5.3V, as limited by the 3.3V linear voltage regulator.

The second design consideration is the output current. The battery must be able to output the peak current draw of the linear actuator as well as the operating current for all of the electrical components in our tuner. The peak current draw can be found by referencing the peak force required to move the tuning slide, as found in Table 1, and determining the corresponding current draw from Figure 12. Thus, for our peak force of about 40N, we can determine that the actuator will draw about 150mA of current. Estimating the current draw for the rest of our electrical components as 5mA, the total peak current draw will be about 155mA. This current draw is well within the 9V Duracell's limits.

The third design consideration for the battery is its operating time. Assuming an average current draw of about 100mA and using a Duracell MN1604 9V battery as reference, the battery will maintain our desired voltage range of 9V to 5.3V for nearly 3 hours. This estimate is obtained by referencing our average current with the graph in Figure 11. Then, if we assume that each tuning session takes about 5 minutes, we will be able to complete at about 36 tunings before the battery voltage drops below a useable level. The performance of the battery depends on many factors, including some of we cannot control such as manufacturing variability and temperature. To take these intro consideration, we will set our goal for the number of tunings each battery should complete at 28.

When the battery is not installed, the tuner will be able to operate off of a DC power supply through a barrel connecter. This power supply is allowed to operate between 5.3V and 13V according to the specifications of our voltage regulators. For our purposes we will be using an external 9V DC power supply connected through this barrel connecter.

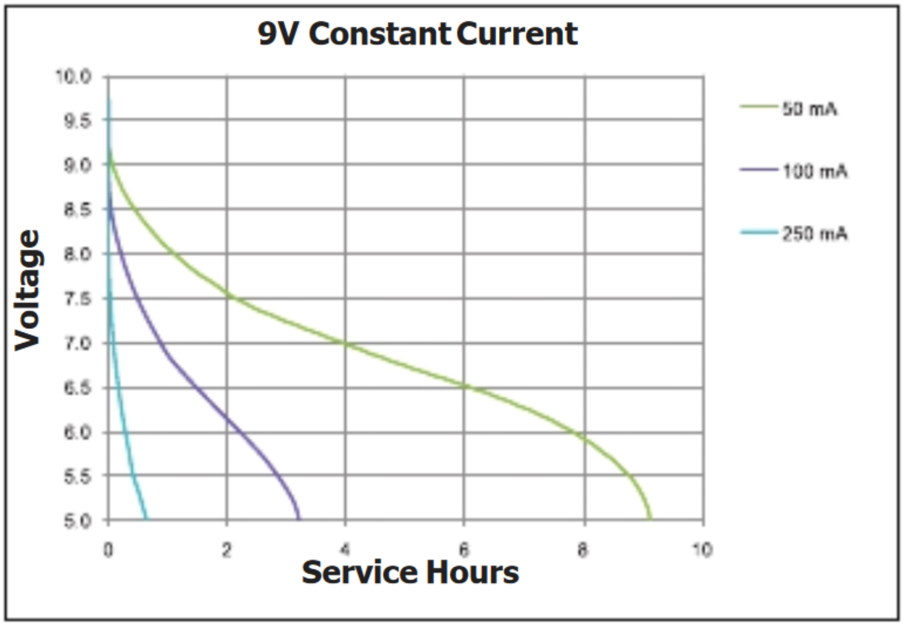

Figure 11. Graph of Current and Voltage vs. Service Hours for 9V battery [6]. Our linear actuator should draw about 100mA of current on average, thus allowing us to approximate a battery life of 3 hours.

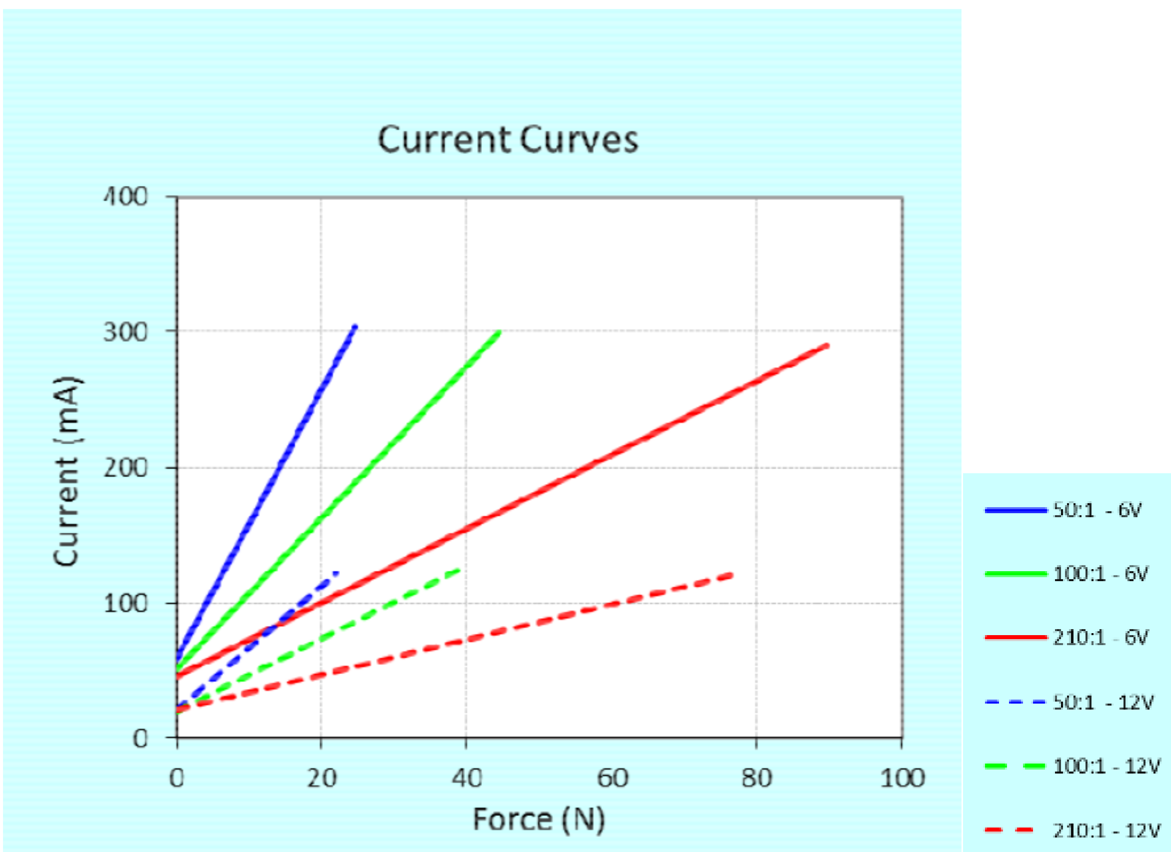

Figure 12. Force vs. Current of Linear Actuator [7]. Our Actuator is the 210:1 – 6V configuration and is denoted by the solid red line. It is seen here that a force of 40N will result in a current draw of about 150mA.

Requirement	Verification
The battery pack shall be able to provide the peak current of 155mA over the range of 9V to 5.3V for about 28 tuning sessions.	1. Operate the tuner in 5 minute increments while monitoring the battery voltage on a multimeter. 2. Record the number of tunings completed before the voltage drops below 5.3V

2.6.2 On-Off Switch

The on-off switch is responsible for disconnecting the battery from the rest of the electronic components while the tuner is not in use.

2.6.3 Voltage Regulator

The voltage regulator circuit is responsible for converting the variable battery voltage to 3 constant specified output voltages. These voltages will be used to power the audio unit, control unit, and mechanical unit. To obtain our 3 output voltages, one DC-DC converter will output 5V for the H-Bridge and linear actuator, a linear regulator will output 3.3V for the microcontroller, and another regulator will output 2.5V for the MEMS microphone, amplifier, and ADC. A 5V DC-DC converter was chosen to power our linear actuator to increase our battery life. A 6V converter that can handle the 9V to 5V operating range of the battery was not available, so we chose a 5V converter that could. The drawback to this is that the characterization of our linear actuator given by Figure 12 is less accurate.

Requirement	Verification
The regulator shall output 5V ± 1% to the mechanical unit. Must be able to supply 150mA [8].	1. Bias the regulator with voltages between 9V and 5.3V using a DC power supply and record the output voltage with a multimeter to ensure it is within the desired range
The regulator shall output 3.3V ± 24% to control unit. Must be able to supply 4.8mA [9].	1. Bias the regulator with voltages between 9V and 5.3V using a DC power supply and record the output voltage with a multimeter to ensure it is within the desired range
The regulator shall output 2.5V ± 8% to the audio unit. Must be able to supply .5mA [10].	1. Bias the regulator with voltages between 9V and 5.3V using a DC power supply and record the output voltage with a multimeter to ensure it is within the desired range

2.7 Mechanical Unit

This unit will be responsible for taking a signal from the control unit and appropriately moving the trumpet tuning slide.

2.7.1 H-Bridge

The H-Bridge will be responsible for taking 5V from the DC-DC converter and applying the correct voltage polarity to the linear actuator in accordance with the control signal from the microcontroller.

Requirement	Verification
The H-Bridge shall toggle power to the linear actuator as well as invert the 5V bias across the actuator to reverse actuator motion. Must be able to supply 150 mA.	1. Bias the H-Bridge using a 5V DC power supply and apply 3V control signals from the microcontroller to toggle each of the driver outputs. 2. Measure output voltage of each driver output with a multimeter to ensure the output changes between 5V and 0V when toggled by the microcontroller

2.7.2 Linear Actuator

This component will be required to move the trumpet tuning slide in or out and will be powered directly from the H-Bridge. The linear actuator must supply up to 9.6lbs of peak force to move an ungreased tuning slide according to our recorded data. Our recorded data for the peak force required to move a greased and ungreased turning slide is provided in Tables 1 and 2. Following the tables is Figure 12 which provides a graph of the current draw from the actuator across a range of force applied. Finally, we have determined the 50mm range of the linear actuator to be enough to adequately tune a trumpet while avoiding the risk of completely removing the tuning slide from the trumpet at 61mm.

Table 1. Force Required to Move Ungreased Tuning Slide

Direction	Force (lbs)/(N)
Out	9.6/42.7
In	9.6/42.7
Out	9.5/42.3
In	8.0/35.6
Out	9.2/40.1
In	8.5/37.8

Table 2. Force Required to Move Greased Tuning Slide

Direction	Force (lbs)/(N)
Out	7.2/32.0
In	3.6/16.0
Out	6.0/26.7
In	4.4/19.6
Out	6.9/30.7
In	4.1/18.2

Out	5.3/23.6
In	4.4/19.6

Requirement	**Verification**
Linear actuator shall apply up to 9.6lbs of force to move the tuning slide over a distance of 50mm.	1. Connect the end of the actuator to a force gauge and apply a 5V bias with the current limited to 150mA from a DC power supply. 2. Record the peak force and compare to our maximum required force.

2.8 Tolerance Analysis

In order for our tuner to function properly, there is one tolerance we must take into consideration with nearly every electrical component we pick in our power circuit. The linear actuator must be able to physically move the trumpet tuning slide in or out for our system to be able to tune the trumpet. Depending on the condition of the tuning slide, whether it has been greased or not, the linear actuator will be required to exert a wide range of force. What we must take into consideration then is the current requirement of the linear actuator across this range of forces it must apply. In order for us to build a circuit that can supply the actuator with its required current draw, we will need to analyze the relationship between force and current draw. For that reason, the actuator power consumption will be the focus of our tolerance analysis.

To determine how much force our linear actuator will need to apply, we connected a force gauge onto the ungreased tuning slide of a trumpet and slowly pulled it either in or out. We recorded the peak force applied for it to start moving in Table 1. Next, we greased the tuning slide and performed the test again, recording the new data in Table 2. From these two data sets we could see that the peak amount of force the actuator would have to apply to move an ungreased tuning slide is about 9.6lbs. We can also see that when moving a freshly greased tuning slide, the tuner would be able to operate with as little as 3.6lbs of force.

Before we start our analysis on the power consumption of the linear actuator, it is important to note why we chose the linear actuator we did. Our actuator features a low required voltage bias (6V), has the largest gear ratio available in its class (210:1), operates at a slow pace (5mm/s), and contains limit switches to prevent the system from overextending the actuator. The benefit of these design choices are that the actuator is easy to control and requires the least amount of power to operate. The slow actuation time is usually a tradeoff for the high gear ratio, but for our purposes it works in our favor since it gives our feedback loop time to react to the trumpet's tuning. In addition, the slow actuation time makes the transition time of our H-Bridge insignificant since at 5mm/s, the 800ns delay will result in an undesired movement of about .04 nm.

After choosing our linear actuator, we estimate the amount of current draw it will require at the range of forces we expect it to exert. Knowing that the peak force we recorded was 9.6lbs (42.7N for easy reference to the graph) and our minimum force was 3.6lbs (16N), we can reference these values to

Figure 12 which was provided to us by the actuator's datasheet. From this, we determine that the actuator will draw between 90mA and 150mA of current with nominal use.

Finally, we have our nominal current range. With this information we can ensure that each electrical component involved in powering the linear actuator will be able to handle this range of current with plenty of headroom. Our device with the lowest current rating, our H-Bridge, can handle up to 600mA of continuous current which is 300% above our highest nominal current value. Knowing this, we can say with near certainty that our device will be able to function as intended.

3. Costs and Schedule

3.1 Bill of Materials and Labor

Table 3. Bill of Materials and Labor		
Part	**Distributor**	**Price**
MSP432P401RIRGCT Microprocessor	DigiKey	$7.03
MP23AB01DHTR Analog MEMS Microphone	DigiKey	$3.96
TLV2761IDBVR IC Op-amp	DigiKey	$1.95
L12 Linear Actuator 50mm 210:1 6V Limit Switch	RobotShop	$70.00
2.1mm Barrel Jack Adapter	RobotShop	$0.95
Switching Power Supply 9V 1A	RobotShop	$6.95
9V to 2.1mm Barrel Jack Adapter V2	RobotShop	$1.70
PCBs	PCBWay	$45.00
3D Printed Casing	3DHubs	$20.00
Screws	Home Depot	$1.00
Assorted Resistors, Capacitors, LEDs (Est.)	DigiKey	$10.00
LD1117S25TR 2.5V Regulator	Mouser	$0.41
UA78M33 3.3V Regulator	Mouser	$0.68
TRN 3-0511 5V Voltage Regulator	Mouser	$18.39
L293D H-Bridge	Mouser	$3.91
Total Price:		$191.93
Laborer	**Hours**	
James Lithgow	35	
Tyler Baldassone	30	
Lowie Rodriguez	28	
Multiplier	2.5	
Price/Hour	$33.65	
Total Cost of Labor:	$7,823.63	
Total Cost of Project:	$8,015.56	

3.2 Schedule

Table 4. Schedule			
Task Name	Start	Finish	Resource Names
Auto-Tuner Project	Mon 1/15/18	Thu 5/3/18	James Lithgow Lowie Rodriguez Tyler Baldassone
Week 1 Design	**Tue 2/13/18**	**Mon 2/19/18**	
Audio unit circuit diagram and simulation			James Lithgow
Power unit circuit diagram and simulation			Tyler Baldassone
Microcontroller algorithm drafting			Lowie Rodriguez
Week 2	**Tue 2/20/18**	**Mon 2/26/18**	
Breadboard Audio Unit for validation of simulation			James Lithgow
Circuit schematic of power and mechanical unit completed			Tyler Baldassone
Circuit schematic of audio unit completed			Lowie Rodriguez
Week 3	**Tue 2/27/18**	**Mon 3/5/18**	
Circuit schematic of processing unit completed			James Lithgow
Order parts for power, mechanical, audio, and processing unit			Tyler Baldassone
Design software to control linear actuator and status LEDs			Lowie Rodriguez
Week 4	**Tue 3/6/18**	**Mon 3/12/18**	
Combine and order PCB design			James Lithgow
Test software for controlling linear actuator using H-Bridge			Tyler Baldassone
Order 3D printed casing for auto-tuner			Lowie Rodriguez
Week 5	**Tue 3/13/18**	**Mon 3/19/18**	
Design software for audio processing			James Lithgow
Assemble power, audio, and mechanical circuits on PCB			Tyler Baldassone
Assemble processing circuit on PCB			Lowie Rodriguez
Week 6	**Tue 3/20/18**	**Mon 3/26/18**	

Design socket connection software for testing audio processing			James Lithgow
Perform initial power consumption test			Tyler Baldassone
Mount circuits on casing and casing on trumpet			Lowie Rodriguez
Week 7	**Tue 3/27/18**	**Mon 4/2/18**	
Test audio processing with completed microcontroller			James Lithgow
Test linear actuator for force of pushing trumpet slide			Tyler Baldassone
Integrate audio processing code with mechanical control code			Lowie Rodriguez
Week 8	**Tue 4/3/18**	**Mon 4/9/18**	
Validate all conditions of audio unit are met			James Lithgow
Validate all conditions of power unit are met			Tyler Baldassone
Validate all conditions of processing unit are met			Lowie Rodriguez
Week 9	**Tue 4/10/18**	**Mon 4/16/18**	
Prepare project for demo			James Lithgow
Begin final presentation			Tyler Baldassone
Begin final report			Lowie Rodriguez
Demo Due	Tue 4/17/18	Tue 4/17/18	

4. Ethics and Safety

4.1 Ethics

Our project does not involve human and animal testing, so we will be concerning ourselves mostly with the IEEE Code of Ethics. Referencing this code:

Our project will not endanger the safety, health, and welfare of the public and the environment. We do not know of any conflicts of interest, but we will resolve them properly if they come up. Our claims are realistic, and we will maintain a consistent record of data throughout the design process. With our combined experience and knowledge, we deem ourselves qualified for the technological tasks that this project will require, and we will seek out honest criticism and review when needed. We will reject bribery, and we will not utilize our project to injure others or harm their property. We will treat our colleagues and our teammates with the respect all men and women deserve, and we will hold ourselves to following this code of ethics. [11]

4.2 Safety

Soldering will be necessary for this project, so we must conduct ourselves carefully when using soldering tools and ensure that all tools are properly shut off when finished. Other than soldering, we do not expect to need to utilize any hazardous chemicals for this project.

Our project will contain moving mechanical parts. While we don't anticipate sudden, forceful movements from our design we will nonetheless conduct ourselves carefully around these mechanical parts. We will ensure that the mechanical parts are consistently safe to be around before testing the trumpet tuner, as testing requires our face to be rather close to the apparatus. These same risks will apply to our end user as well, so ensuring these parts pose no risk to the user will be important.

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