ECE 445 - Senior Design Project Laboratory

Project Proposal

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Self Tuning Violin

Team No. 9

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1. Introduction

Problem

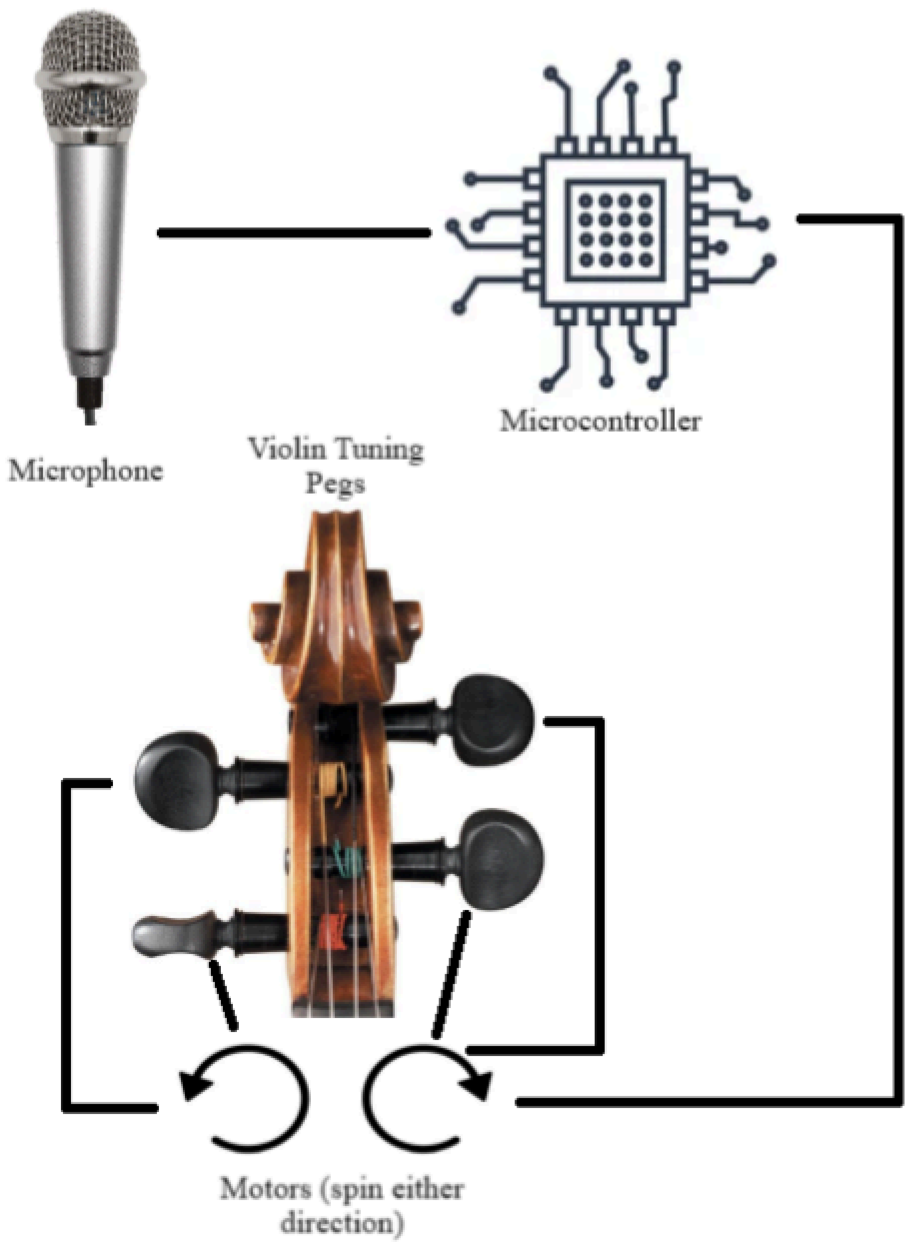
Musicians beginning to play string instruments are often discouraged to tune their own instrument due to the fragility of the pegs – four knobs that tighten and loosen the strings to create a specific pitch – and how easily it can fall back out of tune. Specifically, violins, violas, and cellos are far more sensitive as they use a friction based tuning system. Consequently, many novice students are learning how to play a string instrument without proper intonation or simply waste lesson time as their teacher tunes their instrument during the lesson.

Solution

However, our proposal is to create an automatic tuner. While we have seen similar devices implemented, friction-based instruments require more skill and tact to tune. Our idea is to play a note, and an electromechanical module can adjust the strings to produce a well-tuned note through audio signal processing and mechanical components to automatically turn the instrument's pegs.

Essentially, once a note is played, a small microphone will pick up the sound and create a signal to be sent through an amplifier circuit. Amplifying the signal allows the microprocessor to use it as an input and pick out what note the string needs to be tuned to. This is handled through programming the chip to accurately access what string needs tuning and to what pitch by running a Fourier Transform on the signal. Once the fourier transform is performed, it's much easier to identify a peak frequency and compare it with a standardized set of frequencies for each note for proper tuning. When the signal closely resembles a specific frequency, the microprocessor sends the signal to the appropriate motor – attached to a peg through clamps – so that the motor spins the tuning peg to the proper frequency.

Visual Aid



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.

2. Design and Requirement

Block Diagram

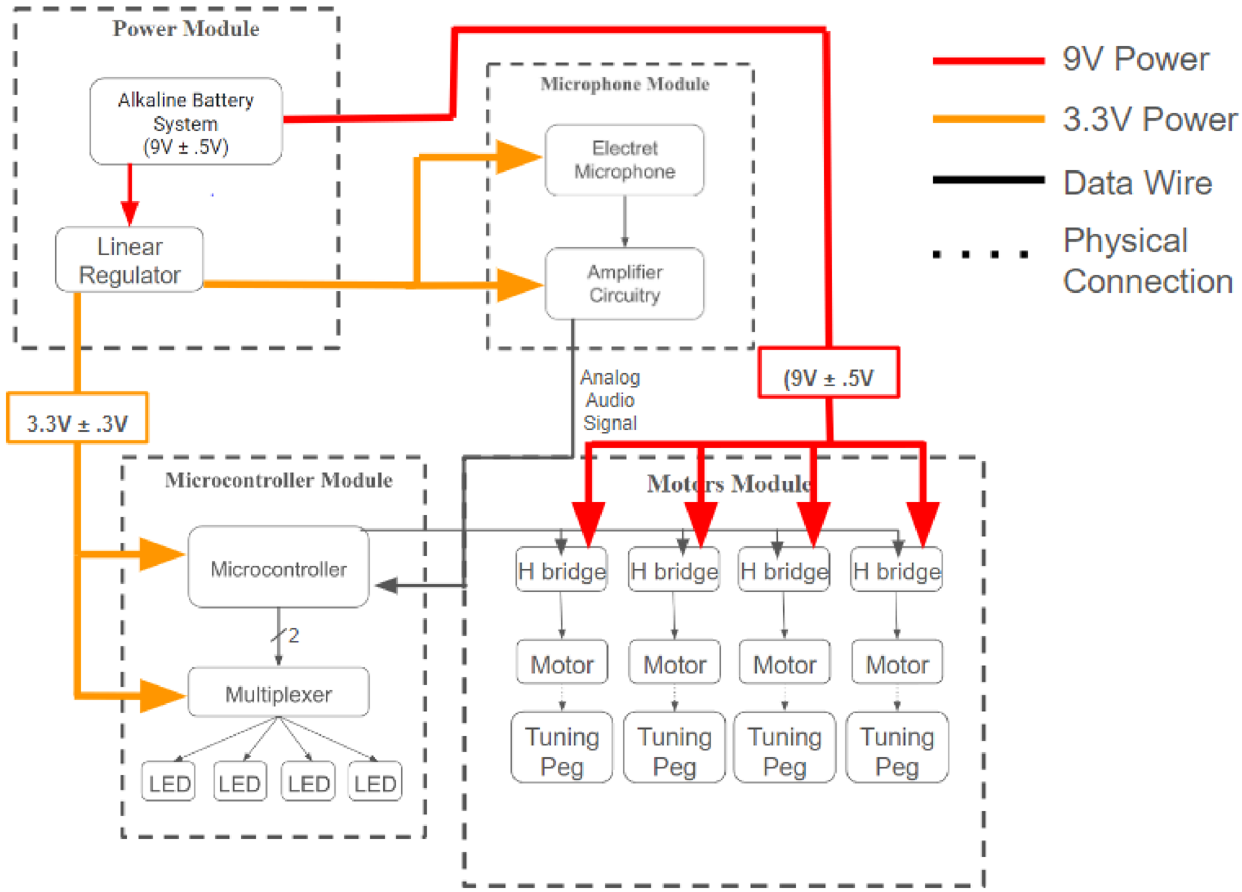


Figure 1: Block Diagram of proposed system

Power Module

The power module would use an alkaline battery system, with an output voltage of about 9 Volts(± .5V). The power module would then distribute this power to the other subsystems through the use of a linear regulator to about 3.3 Volts, or directly to the H bridges for the motors as they have an operating voltage of 5 Volts to 12 Volts, and at 9 Volts we would be able to keep the motor running at lower speeds to avoid damage to the instrument.

Requirement	Verification
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
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

Microphone Module

The microphone module would take in audio input from the electret microphone and then send this audio through the amplifier circuit and into the microcontroller to analyze the incoming sound from the violin that is played. The amplifier may or may not be necessary depending on the exact microphone we get. The amplifier would assist in a strong signal for the Microcontroller to analyze if the particular microphone provides a small signal. The microphone should be able to record frequencies ranging from 100hz - 1000hz to cover the effective range of the violin.

Requirement	Verification
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

Microcontroller Module

The microcontroller module would process all inputs and send all outputs. It would do this by first taking the audio from the microphone module and analyzing it to determine what the current frequency of the violin string is when played, and how the string would need to be changed using the motors. It would then send an output to the motors to adjust the tuning pegs accordingly. The analysis would be achieved with a Fast-Fourier Transform and depending on if the pitch is higher or lower than wanted, it will send the appropriate voltage to the Motor Module to adjust the tuning pegs.. The microcontroller will also control 4 LEDs that will tell the user which string to play and is currently being worked on.

Requirement	Verification
Be able to control the 4 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.
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
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

Motors Module

The motors module would take a signal from the microcontroller module and turn the tuning pegs to what they need to be. This would consist of 4 small motors, one for each of the tuning pegs, and 4 H-bridges leading to the motors to power them, with the ability to reverse the motors direction using the H-bridge.

Requirement	Verification
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.

Tolerance Analysis

One of our main worries is making sure our voltage regulator can output 3.3 V reliably as most of our parts are functional with a 3.3V input. According to the LM1117 datasheet this can be achieved by a general equation such as:

$$V_{OUT} = 1.25\left(1 + \frac{R2}{R1}\right)$$

From the equation, we have a value of 1.25 as a voltage reference that is dropped across the resistor 1 (R1). While reference voltage could be a range of different values, we'll take a simple example.

$$V_{OUT} = 3.3V$$
$$3.3 = 1.25\ (1 + (R2\ /\ R1))$$
$$2.64 = 1 + (R2\ /\ R1)$$
$$1.64 = R2\ /\ R1$$

The ratio of the R2 and R1 (in series) should equal 1.64. This allows us some freedom to pick resistors that can satisfy the equation and maintain a 3.3V output.

3. Ethics And Safety

As far as our device goes there are few strong ethical or safety concerns. The device does little more than fine adjustments to a fragile part of an instrument. We will adhere to the IEEE code of ethics. According to the IEEE code of ethics, we will treat all people fairly as well as attempting to avoid any injuries with our project [1]. The safety concern of the high tension strings should be noted. Violin strings are under high tension when correctly tuned and inevitably strings pop under the tension. This is not necessarily an error; occasionally a string can pop with little cause or mishandling. Although, we can mitigate the chances of popping by designing the product to tune slowly and prevent significant overshooting of the target pitch. Both of these precautions will put less sudden stress on the strings, and help to limit the possibility. In the case a string does break, it is no more dangerous than playing a normal instrument. No extra care or worry needs to be placed than when normally playing a string instrument. Both are safe within reasonable limits, but it's our onus to do what we can for the safety of the instrument and players.

4. Citations and References

[1] IEEE. “IEEE Code of Ethics.” IEEE Code of Policies, Section 7 - Professional Activities (Part A - IEEE Policies). June 2020. https://www.ieee.org/about/corporate/governance/p7-8.html. (accessed Feb. 8, 2024).