Automatic Piano Tuner - Project Proposal

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1 Introduction

1.1 Problem

Piano tuning is a time-consuming and expensive process. An average piano tuning will cost in the $100 - $200 range [1] and a piano will have to be re-tuned multiple times to maintain the correct pitch [2]. Due to the strength required to alter the piano pegs it is also something that is difficult for the less physically able to accomplish.

1.2 Solution

We hope to bring piano tuning to the masses by creating an easy to use product which will be able to automatically tune a piano by giving the key as input alongside playing the key to get the pitch differential and automatically turning the piano pegs until they reach the correct note.

1.3 Visual Aid

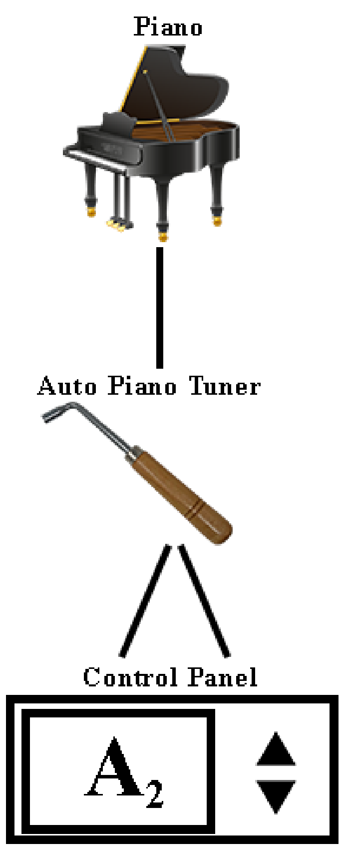

Figure 1: High level visual aid for the 'Automatic Piano Tuner'.

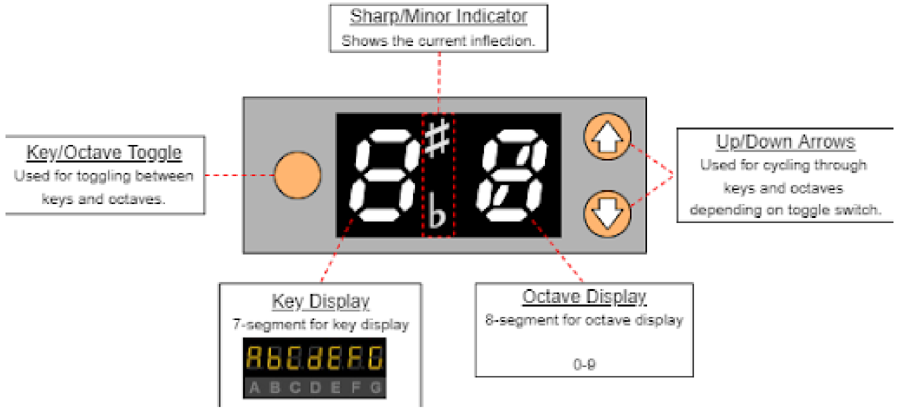

Figure 2: Close up visual aid for the 'Automatic Piano Tuner's' UI display.

Figure 3: A mock-up using a commercially available product [3] that would give the correct amount of torque ($\sim 10Nm$).

1.4 High-Level Requirements List

- The 'Automatic Piano Tuner' should be able to tune the piano to less than 1.6 Hz [4].
- The 'Automatic Piano Tuner' should be able to produce 9-14 Nm of torque [5].
- The 'Automatic Piano Tuner' should be able to control and tune to 88 [6].

2 Design

2.1 Block Diagram

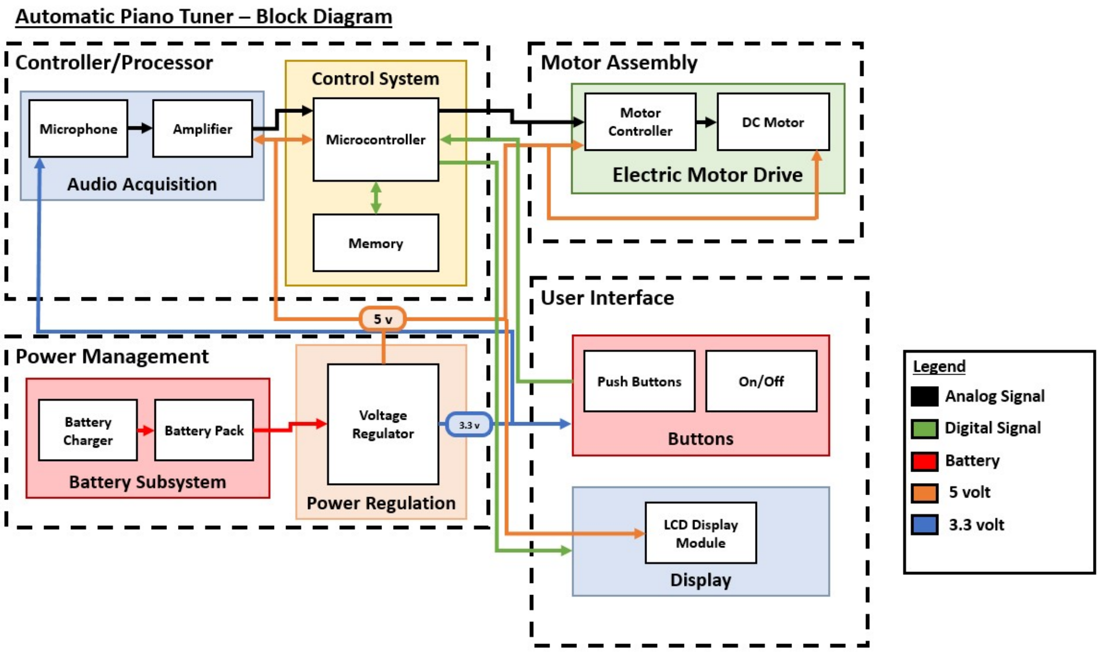

Figure 4: Block Diagram for the 'Automatic Piano Tuner'.

2.2 Subsystem Overview

2.2.1 Audio Acquisition Subsystem

The 'Automatic Piano Tuner' will use a microphone and amplifier to detect and send through the frequency of the piano's non-tuned note. This data will be sent through to the microcontroller which will compare the note given to it by the microphone with what the note should be that is saved in memory to tune the piano correctly. As the note changes from the tightening or loosening of the piano string, the microphone will continually pick up the frequency so that the microcontroller knows when to signal the motor when to stop turning.

Requirement: A piano has frequencies between 27.5Hz and 4186Hz [4], so the audio acquisition subsystem should be able to pick up on frequencies accurately within this range.

2.2.2 Control System Subsystem

The microcontroller acts as the 'command center' of the 'Automatic Piano Tuner'. It takes in frequencies from the audio acquisition subsystem and compares the frequency to what the frequency should be which is saved on memory and indexed by the note pointed to from the button subsystem. If the actual frequency is higher than the indexed frequency, it tells the motor assembly system to move left and loosen the string, while if the actual frequency is lower than the indexed frequency, it tells the motor assembly to move right and tighten the string until the frequency it receives from the audio acquisition system is within a acceptable margin of error with the indexed frequency.

Requirement: The controller must be able to successfully analyze and find the difference between frequencies that are 1.6Hz apart, as the lowest notes on a piano (A0 and A♯0) are separated by 1.6 Hz [4].

2.2.3 Battery Subsystem

The 'Automatic Piano Tuner' should be able to be used for an entire piano tuning session without having to be re-charged or plugged in. The battery system is connected to the power regulation system to deliver enough power for the rest of the 'Automatic Piano Tuner' to function.

Requirement: Battery has to last for at least 2 hours of use (a typical piano tuning lasts between 1 and 1.5 hours) [2].

2.2.4 Power Regulation Subsystem

The power regulation system is responsible for delivering numerous stable voltage levels to the various components in the system. It will transform the battery voltage into usable voltage for the microcontroller, user interface, and microphone sensor. It must provide sufficient current to the motor such that it does not saturate before reaching the desired torque output.

Requirement: The power regulation subsystem should have power lines of 5 volts and 3.3 volts and sufficient current to drive the electric motor.

2.2.5 Electric Motor Drive Subsystem

The drive system will utilize a small torque motor and a gear shaft to produce the required amount of torque. As torque motors can get large, it will be important to create a capable gear shaft that will be able to amplify the torque of a smaller motor.

Requirement: Torque on the motor system must be able to reliably produce 9-14 Newton-meters of torque. This is the typical torque required to turn a tuning peg on a piano that is under string tension [5]. This torque is also low enough to allow for the peg to be turned slowly.

2.2.6 Display Subsystem

The 'Automatic Piano Tuner' will use an LCD display to show the current note, including if the note is sharp, alongside the current octave number. There will be a 7-segment display to show the note letter: A, b, C, d, E, F, G, an 8-segment display to show the octave number: 0, 1, 2, 3, 4, 5, 6, 7, 8, and an extra display to show if the note is sharp or not. The display will get the current note and octave from the microcontroller which will get the current note from the button subsystem.

Requirement: The display should be able to accurately show all 7 note letters, the 9 possible octave numbers, and if the note is sharp or not.

2.2.7 Buttons Subsystem

There will be three buttons on the 'Automatic Piano Tuner' associated with moving up and down keys as well as changing octaves. These buttons will send a digital signal to the microcontroller which will use the button press signal to alter the frequency the tuner is tuning to in the software as well as send a signal to the LCD display to correctly show the new key/octave. The up button will move the key up one note in order: C, C♯, D, D♯, E, F, F♯, G, G♯, A, A♯, B. The down button will move the key's in the reverse direction: B, A♯, A, G♯, G, F♯, F, E, D♯, D, C♯, C. If the key is C and the octave is 8 (the last key on a standard piano), the up button will not change anything. Similarly if the key is A and the octave is 0 (the first key on a standard piano), the down button will not change anything. If the current key is B and the up button is pressed, the key will wrap around to C with the octave increasing by 1. Likewise if the current key is C and the down button is pressed, the key will wrap around to B with the octave decreasing by 1. The octave button will automatically move the octave up by 1 to quickly change keys. For keys: C♯, D, D♯, E, F, F♯, G, G♯, if the octave is 7, the octave will wrap around to 1. For keys: A, A♯, B, if the octave is 7, the octave will wrap around to 0. Finally, if the key is C and the octave is 8, the octave will wrap around to 1.

Requirement: Due to the large amount of button presses needed to tune a single piano (88 at full efficiency), the buttons should be able to withstand a large amount of presses while still functioning.

2.3 Tolerance Analysis

One concern for this project is producing enough torque to be able to tune the pins of the piano. We have already established that this tool will need to produce 9-14 Nm of torque [5]. We have identified a prime candidate for the motor we would use in this tool [7]. This motor produces less torque than required and thus to generate the required torque we will be using a motor gear shaft drive that will amplify the torque of the motor. Gear shafts amplify torque based on the 'gear ratio' which is the ratio of the gear diameters. We can calculate using the following equation and parameters:

Motor Torque: 2.962 Nm, Required Torque: 12 Nm

$$GearRatio = \frac{d2}{d1} = \frac{OutputTorque}{InputTorque} = \frac{12Nm}{2.962Nm} \approx 4 \tag{1}$$

The ratio of the gear diameters must be 4, which we believe will be doable on this gear train. The diameter of the motor shaft is 0.091" [7] which we can stick a 0.25" driver gear on. The driven gear would then have to be 1" in diameter to get the required torque. With the overall diameter of the motor being 1.2", we believe we can use a housing that would be small and ergonomic enough to fit inside the piano. With these considerations in mind we believe we can produce a tool that would have the required amount of torque.

3 Ethics and Safety

In our project we aim to firmly adhere to both the IEEE and ACM Code of Ethics. While developing 'Automatic Piano Tuner' we will be careful to cite and credit all work that we use or that influences us. Additionally we will pay close attention to and graciously use advice given to use by course TAs and professors as per IEEE Code of Ethics I.3. [8] Throughout the entire development of the 'Automatic Piano Tuner', we also seek to respect all people we work with. Due to requiring outside people to successfully accomplish our project, we will make sure throughout the process to treat everyone fairly as per IEEE Code of Ethics II [8]. Due to using a battery in our project design, we will insure we are following all safety and regulatory standards regarding preventing fires and explosive injuries from lithium powered devices including keeping the batteries at temperatures below 130° F and above 32° F, and making sure we are not dropping, crushing, or puncturing the 'Automatic Piano Tuner' [9].

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