Fully Automated Guitar Tuner

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1 Introduction

1.1 Objective

Tuning guitars is a hassle for guitar players of all levels. When tuning by ear, it is extremely hard to find the right pitch. There are tuners that will tell you whether you are sharp or flat, however players must still physically adjust the tuning knobs and manually pluck the guitar string each adjustment.

We envision a complete package that will require minimal user input to tune 3 strings of a guitar at a time with minimal user input. The device will be battery powered and compact, making it easily portable. The user would attach it to the head of the guitar and adjust the motor arms so they sit on the tuning pegs. The device would then strum and tune 3 strings, and the process would repeat on the other side, making tuning as automatic and convenient as possible.

1.2 Background

It's an unfortunate fact of life that guitars fall out of tune over time. Playing on pitch is hugely important, but is impossible to do if the instrument itself is out of tune. Those with perfect pitch may do it by ear, but experts estimate only 0.01% to 0.05% of the population has that ability [1]. Everybody else must rely on a tuner. Simple microphone-based pitch indicators have existed for a long time but widely commercially available automatic single-string tuning guitar tuners such as the Roadie 2 started in 2010 and only came to popular market within the last few years costing a hefty $130 [2]. Totally automated 6-string guitar tuning systems have existed in the form of embedded electronics into the head of the guitar since 2008 [3] but lack universality. Our project differentiates itself by tuning 3 strings at a time as well as automating the strumming.

1.3 Physical Design

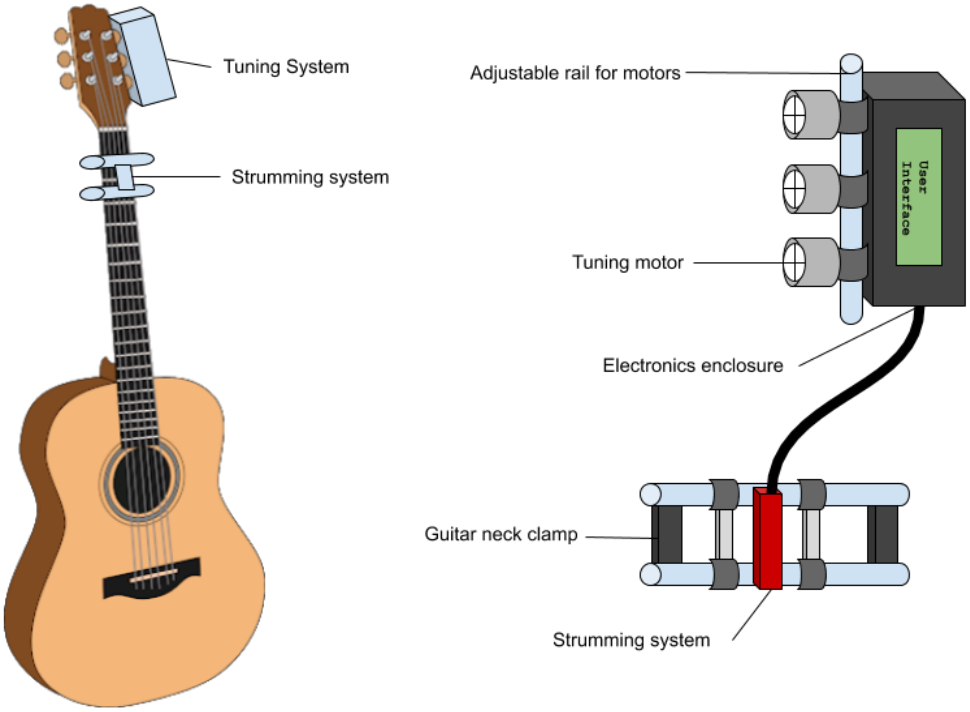

Figure 1.1 Physical Design Overview

1.4 High-Level Requirements

- Identify triple pitches to within 10 cents each
- Tune guitar within 15 cents
- Tune within within 1 minute

2 Design

2.1 Block Diagram

We have divided our fully automated guitar tuner system into five primary subsystems: the strumming attachment, which will strum the strings; the audio recording system, which will convert the analog audio into digital data; the microcontroller/DSP system, which will identify the frequency of the input and compare it to the target frequency; the tuning motor system, which tunes the guitar based on the data sent from the microcontroller/DSP system; and the power system, which will supply power to the other subsystems.

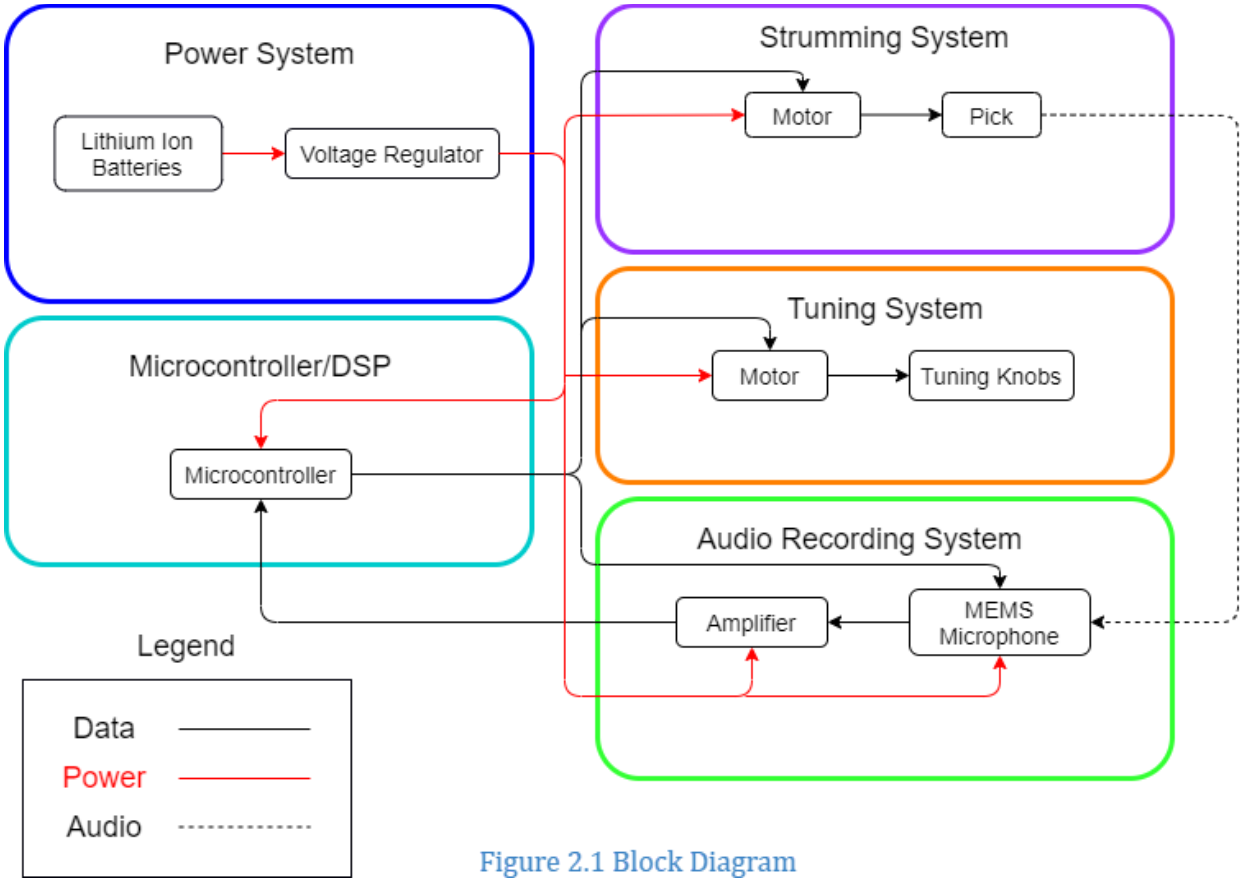

Figure 2.1 Block Diagram

2.2 Functional Overview

2.2.1 Strumming Mechanical System

This will be a rail-mounted motor equipped with a strumming pick clamped to the guitar neck that is both adjustable in clamping onto the neck of the guitar and range of motion for the strumming using mechanical stops. The width of the neck of guitars are relatively standardized and provides both a convenient mounting and strumming point for the system. By having an automated strumming system, the traditional need for user intervention is minimized and strumming will always be performed at optimal times for the signal processing algorithm.

2.2.2 Audio Recording System

The primary concern of this subsystem is size. The two kinds of microphones that are suitable for us are electret and MEMS. We have chosen to use the latter due to its smaller package size and higher digital noise tolerance [4]. We plan on using a cardioid configuration in order to attenuate background noise as much as possible. We will likely also use an amplifier to boost the signal before processing.

2.2.3 Microcontroller

A great deal of audio processing and control logic is necessitated by our design. This subsystem is responsible for controlling our device - strumming the strings, processing the audio data, and communicating how much the tuning system should turn.

The key portion of this subsystem will be the DSP algorithm. Pitch detection is a fairly simple project for many DSP classes and is used in every single commercial tuner. Its limitation is that it can only handle one input at a time. Chord detection is a field that is still being researched and most current algorithms involve machine learning and neural networks, which will be too intensive for our purposes. We plan on leveraging a 1999 paper from Fujishima [5] for our algorithm. We will first take the DFT of the audio after windowing and filtering, then we will create a spectrum bin table. By summing up the DFT values where the DFT index matches the table values, we generate a pitch class profile which will have peaks at the detected frequencies. We can further enhance the results by using a harmonic product spectrum, which removes the higher order harmonics that are present in the DFT. Those harmonic products will then be translated into adjustments for the tuning mechanical system.

2.2.4 Tuning Mechanical System

Our design will implement automatic guitar tuning by mounting three adjustably-distanced servos with custom heads to mount onto the tuning knobs. The two most prevalent tuning knob spatial configurations are three on each side of the guitar head and all six knobs on one side of the guitar head. In order to accommodate both of these popular configurations as well as create a smaller form factor, we are limiting our tuning design to only adjust three knobs at a time.

2.2.5 Power System

Due to the mechanical dependence of our design, having a robust power system with multiple voltage levels is critical to our design. This system will consist of a lithium ion battery and appropriate level converters to power the necessary components of our design. The components to be powered include the microcontroller, servos for tuning, motor for strumming, and audio recording system.

2.4 Block Requirements

2.4.1 Mechanical Systems

- Strumming system must be able to reliably only strum the desired 3 strings at time at a detectable volume without damaging the guitar
- Tuning system must have the torque and precision to adjust tuning knobs to the desired level of pitch accuracy without damaging the guitar

2.4.2 Audio Recording System

- Must amplify signal with enough resolution for processing
- Must sample at 16 bit, 44.1 kHz

2.4.3 Processing System

- Must be able to accurately create the pitch class profile
- Must be able to calculate the pitch of three different strings at once
- Must auto-calibrate servo rotation based on observed pitch differences between adjustments

2.4.3 Power System

- Must consistently step up battery voltage to 5V +/- 5% for components
- Must have less than than 5% voltage sag under load

2.5 Risk Analysis

The microcontroller/DSP subsystem would be the component that poses the biggest risk to the completion of our project. Compared to the audio input system and the tuning motor system, which only communicates with one other component, the microcontroller/DSP component interacts with two. The microcontroller/DSP subsystem needs to take in input sent from the audio input system, measure the correct difference between the plucked string's current frequency and the target frequency, and finally, accurately regulate the tuning motor system to tune the current string to the correct pitch. Additionally, the project hinges on the algorithm being able to correctly identify the pitches being played.

3 Safety and Ethics

Following the IEEE Code of Ethics, our only issue in regard to Code of Ethics #1, that our design holds the safety of the public as its first priority and informs the public of any endangering aspects [6]. Our project utilizes rechargeable lithium ion batteries, which is our main source of power for our project. Lithium ion batteries have the potential to cause fire hazards from overheating [7] or environmental hazards if disposed of incorrectly [8]. We will monitor the battery temperature using a semiconductor temperature sensor and a LED to notify users when battery temperature goes above 55 degrees Celsius. We will also make it easy to deconstruct our system so that the lithium ion battery can be disposed of properly. Although we are using a microphone to take in audio input, we are directly processing the audio data and not saving it in any way, so this does not violate the code of ethics.

4 References

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