Auto-Tuner with LCD Display

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1. Objectives and Background

1.1 Problem

Stringed instruments like guitars are a very important cultural tool. Found in almost every country in the world, music from stringed instruments has united groups and communities for thousands of years. This level of connection is only possible if the instrument's sound is good, and the first step to achieving this is to make sure the instrument is in tune. Tuning a guitar properly can be a bit of a challenge, either by someone with a good enough ear to determine whether a string is at the correct pitch or by using a tuner that displays the string's current pitch. Using either method, the person tuning the guitar must tune each peg and repluck the strings until each string is at the correct pitch. This process can be extremely time-consuming, tedious, and often inaccurate as pegs are turned too far. Additionally, this process is almost impossible for individuals with limited hand strength or missing extremities. To make these important cultural items as accessible as possible, it is necessary to have a device that allows easy tuning for all individuals, regardless of their circumstances, while also being more efficient than traditional tuning methods.

1.2 Solution

Our proposed solution to this problem is a motorized guitar tuner. This tuner would remove all inaccuracy and physical exertion from the tuning process, allowing for a perfectly tuned guitar with a fraction of the effort. The tuner has 3 main pieces: 1)a sensor which captures the vibrations produced by a string being plucked, 2)a microcontroller which interprets the sensor's values, converts them to a pitch value, and sends adjustment values to the peg turners, and 3) peg turners which adjust the position of the pegs to bring the string into tune. All of these components would be held in a plastic case, which would be clipped onto the guitar headstock. Once all pegs are connected to their designated turners, the device will no longer need to be removed until tuning is complete. This allows all strings to be tuned at once to reduce strenuity and possible damage to the instrument.

The top of the tuner will include two main features: 1)an LCD display to convey information about the string and what adjustments need to be made, and 2)a series of buttons that allow adjustments to the tuning procedures in case a different standard is desired for each string. This tuner, powered by an internal battery, would allow for the quick and efficient tuning of a guitar as easily as possible.

1.3 Goals and Benefits

- Allow the user to see in real time what note is being played
- Useful for novice guitar players who do not have tuning experience
- Tuning will be very precise with little error

- Helpful for musicians with limited hand strength
- Allows for quicker and more efficient tuning

1.4 High-Level Requirements

- The tuner's motor must have a certain threshold to prevent snapping a string
- We must be able to accurately detect and display the note being played in real time
- The project as a whole must be space and time-efficient for practical use

1.5 Visual Aid:

Motorized Tuner is clipped over head of guitar and is not removed until tuning is complete
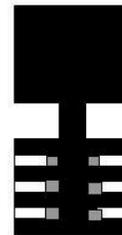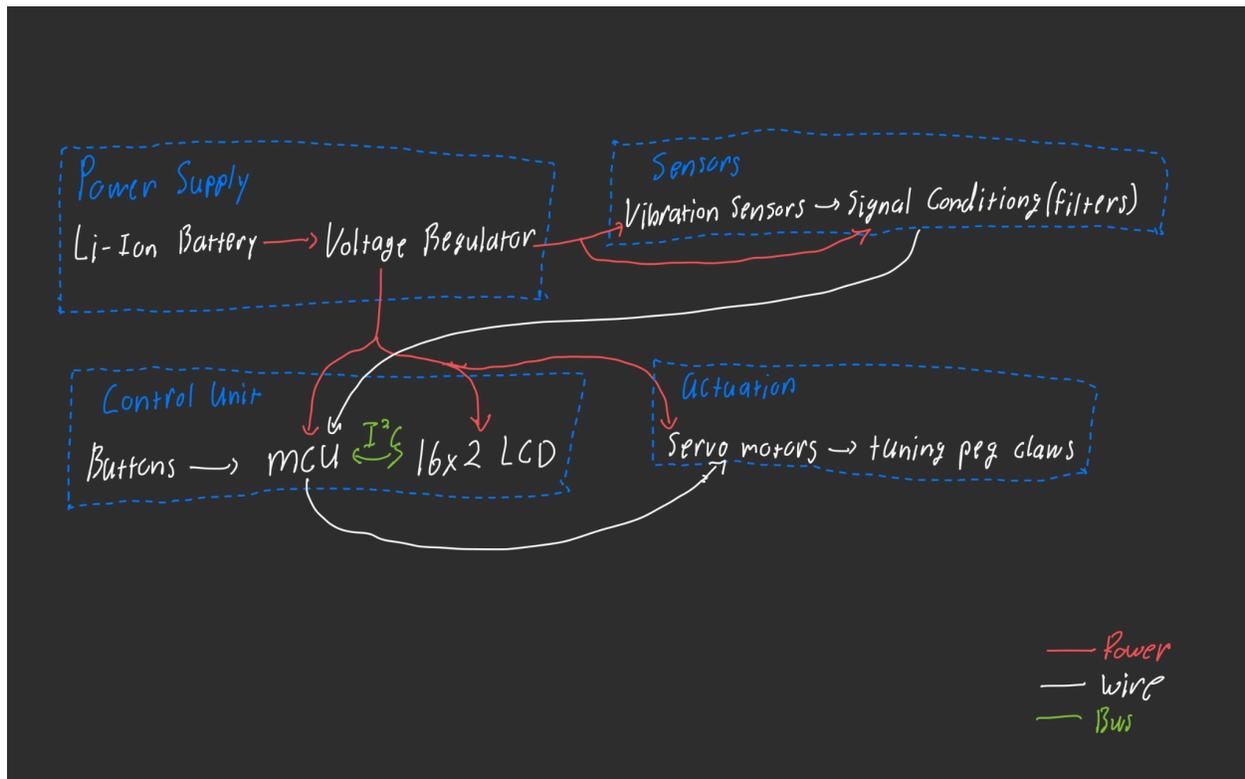
Each peg is clipped into its designated holder which is attached to a servo motor. This allows the microcontroller to turn each peg so the strings are properly tuned

Current String : G
Modifiers:None
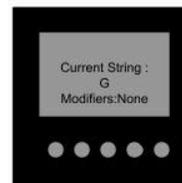
LCD on front of tuner to state any relevant information and buttons to allow tuning customization

2 Design

2.1 Block Diagram

2.1.1 Subsystem Overview

Control Unit:

The control unit contains the microcontroller, user buttons, and a 16x2 LCD interface. It serves as the system's central processing block. The microcontroller samples the vibration signal, computes the string's frequency, determines the tuning error, and generates control outputs for the LCD display and the actuation subsystem. It also interprets button inputs. This subsystem is responsible for overall system coordination and decision-making.

Power Supply:

The power supply subsystem provides power to all other subsystems in the Auto-Tuner. A Lithium-Ion battery serves as the primary energy source, and a voltage regulator converts the battery output to stable voltage rails required by the control unit, sensors, and motor actuation

circuitry. Power lines are routed from this subsystem to the blocks, enabling all subsystems to operate.

Sensing Subsystem:

The sensing subsystem captures vibration from the guitar string and converts it into an electrical signal for digital processing. The subsystem consists of vibration sensors followed by analog signal circuitry, including filtering and amplification. The signal is routed to the microcontroller in the control unit, which allows it to identify the played musical note.

Actuation Subsystem:

This subsystem is responsible for turning the guitar pegs to tune them. It uses servo motors connected to tuning-peg claws that physically rotate the guitar's tuning pegs. Mechanical torque limits and a controlled rotation speed will be implemented to prevent the tuner from breaking the strings or damaging the instrument.

2.1.2 Subsystem Requirements

Power Supply Subsystem:

- Provide a regulated 5.0V +- 0.1V for digital and motor circuitry
- Supply at least 500 mA current during motor startup and display operation
- Support at least 1 hour of continuous operation on full battery

Sensing Subsystem:

- Detect frequencies in the 80 Hx to 1 kHz range
- Provide signal amplitude
- Include filtering

Control Unit Subsystem:

- Sample the analog signal
- Drive the LCD using a standard digital interface

Actuation Subsystem:

- Deliver torque to rotate tuning pegs
- Enforce max torque limits to prevent snapping the string
- Support bidirectional rotation with variable speed control
- Respond to control signals
- Operate safely within the provided voltage and current limits

2.1.3 Tolerance Analysis

One risk in the Auto-Tuner design is whether the motors can make fine enough rotational adjustments of the guitar tuning pegs to tune the string accurately.

We are using an HS-318 servo motor that can rotate 120 degrees. It has a deadband width of 5 us, so this is the smallest step the servo can notice. The HS-318 PWM control range is approximately 1200 us, so, doing the math, 1200/120 = 10; 1 degree of rotation requires a 10 us change.

This means the servo can respond to half a degree or more of rotation. This is a very small rotation, to the point where humans would not notice the difference in tone, meaning that the Auto-Tuner can, in fact, tune the guitar to the point where it sounds perfectly fine.

3. Ethics and Safety

3.1 Ethics

For our handheld automatic guitar tuner, ethical considerations include ensuring the device operates safely and reliably without harming users or damaging the instrument. We will communicate the device's limitations as we progress on this project, including tuning accuracy and compatibility constraints across different guitars. Our implementation will include safeguards/thresholds to prevent over-tightening strings or applying excessive torque, which can cause the string to snap and potentially harm someone. Our project does not involve human or animal research, the collection of personal data, or the handling of sensitive information, so IRB and IACUC approval are not required. Overall, our design will prioritize user safety and responsible engineering practice.

3.2 Safety

Although our device will operate at low voltage, several electrical and mechanical safety concerns must still be addressed. Some electrical risks can include short circuits, battery overheating, and improper wiring. These risks will be mitigated through regulated power supplies and current limiting. Some mechanical risks include string breakage or excessive motor torque, which will be controlled through software limits and gradual tuning adjustments. During the development of this device, we will follow standard lab safety practices, such as proper soldering procedures and the safe handling of power supplies. By implementing these precautions, we will be able to minimize risks.