ECE 445 Senior Design Laboratory

Project Proposal

Self-Adjusting Volume Pedal

Team 34

Norbert Lazarz (nlazarz2)

Noah DuVal (nbduval2)

Chris Jurczewski (cmj7)

Spring 2024

TA: Nithin Balaji Shanthini Praveena Purushothaman

1. Introduction

1.1 Problem

Electric guitars are one of the most versatile instruments you could play and give you a tremendous amount of options for what tone you would like to have. Generally there are two ways to majorly affect your guitar's tone, those being the EQ (Treble, Mids, and Bass) on the amplifier, and having pedals that have their own specialized effects built in. Pedals give an almost infinite set of combinations for sound alteration like delay, distortion, phasors, reverb, etc. Finding a tone that matches your playing style and what you want to define as "your sound" can be very difficult and time consuming. Therefore, when you find that perfect tone, you want to be able to recreate it at any volume level at any time. This is where you encounter a problem with only having two options of volume adjustment on a typical guitar/amp setup. When changing the volume, using a volume knob (Can choose to set 1-10) on the guitar, there is often a very noticeable change in tone especially in the lower range (1-3). A similar problem arises when adjusting the volume knob of the amplifier however the effect is even more noticeable. On the amp, when going from 1-10 the increase in volume is not linear and behaves similarly to a population curve where growth is exponential in the beginning, but between 6-10 there isn't a huge difference in gain. This on top of fluctuation in tone makes these options imprecise and not practical if you want to maintain "your sound." This is also a problem during performances where you don't necessarily want to change your tone, but make slight adjustments to how loud the guitar is compared to the rest of the performers.

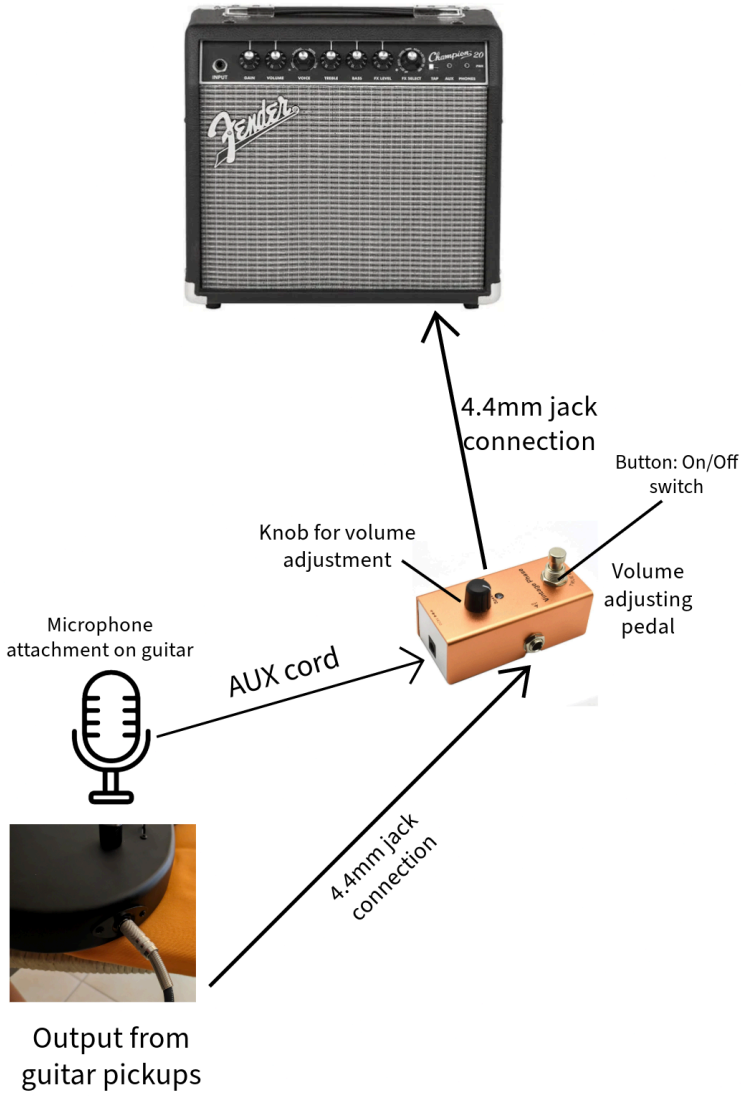
1.2 Solution

To allow for a more precise and consistent way to adjust your guitar's volume without needing to also adjust the tone of the guitar, this project will have two main components. There will be an attachment that will go on the bottom of the guitar's body that will collect audio data from the amplifier and send that sampled data to the microcontroller. This data will be collected by two microphones (Powered by 9V battery) that will be placed on the front and back of the guitar so that the player can choose to face away from the amplifier without losing data due to the microphone's limited FOV. This data will then go to a comparator which will see which signal has a greater amplitude and send that through an AUX cord to the microprocessor.

1.3 Visual Aid

Microphone Diagram:

Pedal Diagram:



The second component of this project will be the pedal itself which will include the user interface, microprocessor, inverting, and amplification system. The user interface will be a knob potentiometer that will allow the user to choose between a range of 30-90 dB which will determine the magnitude the pedal will try to achieve at the microphones. There will also be a button for turning the pedal on and off as well as an LED to indicate. The microprocessor itself

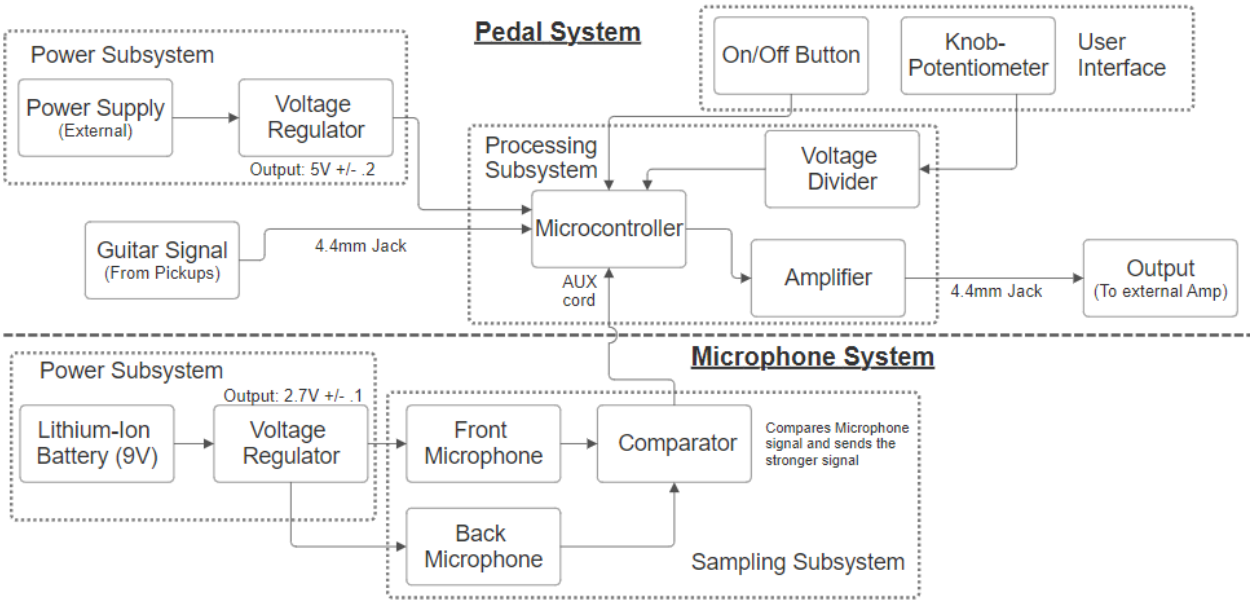
will be responsible for determining how much amplification is needed to get the desired volume depending on the signal received from the microphone guitar attachment. For example if the user set the pedal's knob to 60dB the goal of the pedal system is to make the amplitude of the signal at the microphone 60dB. If the microphone picks up a weaker signal the pedal will amplify the guitar's signal (Output from guitar pickups) to bring it up to 60dB and vice versa for signals stronger than 60dB. If the player were to step away the volume at the microphone would understandably get weaker and the guitar signal would need to be amplified.

1.4 High-level requirements list:

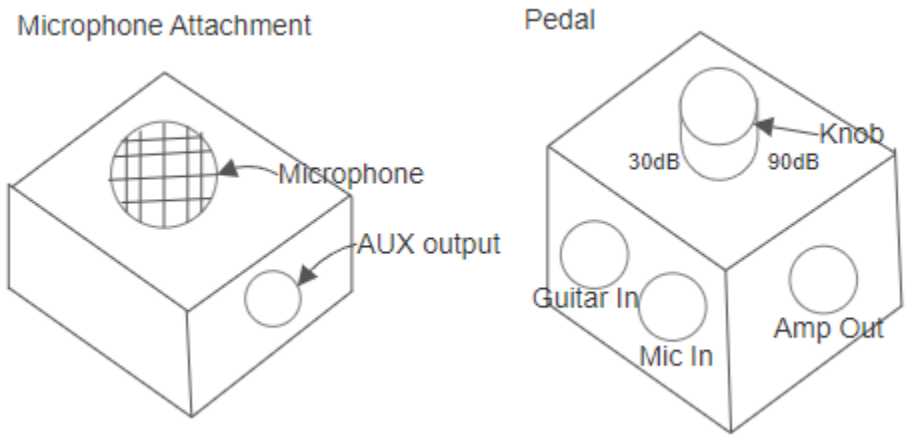
- ➔ Audio stays consistent for the player without large jumps or stutters and volume at microphones stays within 5% of the decibel volume selected by the pedal.
- ➔ The preset tone (highs, mids, lows) and effects (distortion, wah, flange, or other pedal effects) should remain the same no matter what setting is changed on the pedal. Volume should be the only variable changing. Change in any tones and effects will be audible.
- ➔ Any frequencies picked up by the microphones not within the range of 80-1500 Hz will be filtered out and should not change the volume of the guitar.

2. Design

2.1 Block Diagram



2.2 Physical Design



2.3 Subsystem Overview

2.3.1 Processing Subsystem (Pedal)

This system is the heart of the guitar pedal, it will be responsible for filtering, processing, and amplifying the signal. It will consist of a microcontroller with ADC capabilities to receive and modify audio signals, and cascading op-amps for necessary gain. Two filters will be implemented through code from software and burned onto the chip memory. The noise filter will be a moving average filter to smooth data and the bandpass filter will attenuate frequencies outside our desired range. The data from the filters will then be amplified accordingly based on data from the guitar device. The amplified signals will be sent through a jack to the speaker system.

2.3.2 User Interface Subsystem

Adjustable knob connected to a potentiometer to change the decibel setting. There will be a visual aid on the physical pedal to detail the decibel level to the user. This system will interface with the control unit to decide on amplification settings. There will also be a push-button to turn the pedal on/off as well as an LED indicator

2.3.3 Power Subsystem (Pedal)

There will be a personal power bank for the pedal. For power delivery, our team will use a lithium ion battery to supply ample power to the chips. There will need to be two voltage regulators, to change the input voltage to the specific components.

2.3.4 Sampling Subsystem (Guitar)

The sampling subsystem is the main component of the guitar attachment. It will be responsible for receiving signals from the surrounding air and delivering it to the microchip onboard. We will likely implement two microphones on either side of the guitar to receive sound from the amp and deliver to a comparator. Whichever sound is louder will be sent through bluetooth to the pedal for filtering.

2.3.5 Power Subsystem (Guitar)

There will be a personal power bank for the guitar attachment. This subsystem will be very similar to how we will power the pedal.

2.4 Subsystem Requirements

2.4.1 Processing Subsystem (Pedal)

The Processing subsystem will be responsible for filtering the received signals in real time, while modifying them properly for amplification. Without the proper filters applied with precise coefficients, the amplifier will receive improper frequencies and possibly result in stutters/jumps in volume.

Requirement	**Verification**
The processing unit must attenuate frequencies in the signal outside of accepted range.	● A tone generator will be played at frequencies below 80 Hz and above 1500 Hz near the microphones. If our attenuation filter works properly, these signals will not be detected through the speaker.
Amplification of signal to the preset volume is within 5% and should not stutter while the user is moving.	● The guitar will be played stationary. ● Using a decibel meter, we will record the decibels at the user's position and compare it to the set value. ● The player will move around, as will

	the decibel meter. ● There should be no stutters detected, and the volume read from the decibel meter will be within 5% of the preset.

2.4.2 User Interface Subsystem

The user interface system is the only component of our project where the user has an ability to change the base decibel volume of the amp. Thus, it is vital that this system will accurately set the volume.

Requirement	**Verification**
Knob appropriately sets volume at the user's location to volume within 5% of selected dB.	● User interface will be turned to a maximum value in dB and the guitar will be played stationary. ● Using a decibel meter, we will record the decibels at the user's position and compare it to the set value. ● We will test the lower bounds of the system next. ● Finally we can use a middle position to solidify the accuracy of our device.
On/Off Button works properly	● Switching this button will accurately turn on and off an LED.

2.4.3 Power Subsystem (Pedal)

The power subsystem for the pedal is vital to keeping the microcontroller and op-amps in rated voltage after going through a voltage regulator.

Requirement	**Verification**
Must be able to supply rated voltage for each component within a +/- 0.2V tolerance after going through voltage regulators.	● Open up the pedal to expose components. ● After each component, verify what voltages are read before the Vcc pins and compare to rated voltage values.

On/Off Button works properly	• Switching this button will accurately turn on and off the voltage in the whole circuit.

2.4.4 Sampling Subsystem (Guitar)

The sampling system is important in gathering the signal and sending out data in real time to the pedal. Without proper sampling, we would receive stutters and jumps in data.

Requirement	**Verification**
Must be able to record channels for each microphone and the comparator must select the louder signal 95% of the time.	• A microphone can be removed and left in a stationary position. • The user can move the guitar's positions while playing. • The amplification of the signal should remain constant if the user gets further away, since the stationary mic should be chosen from the comparator. • Vice-versa for when the user is moving closer to the speaker.
Able to relay data to the pedal in real time.	• While playing the guitar, there are no stutters, jumps, or delays in the audio. Volume should ramp up or down accordingly as the guitar's position is changed.
Decibel volume detected should not change if the user is in a stationary position.	• If the guitar does not move and the volume from the speaker becomes quieter or louder, then this requirement is failed.

2.4.5 Power Subsystem (Guitar)

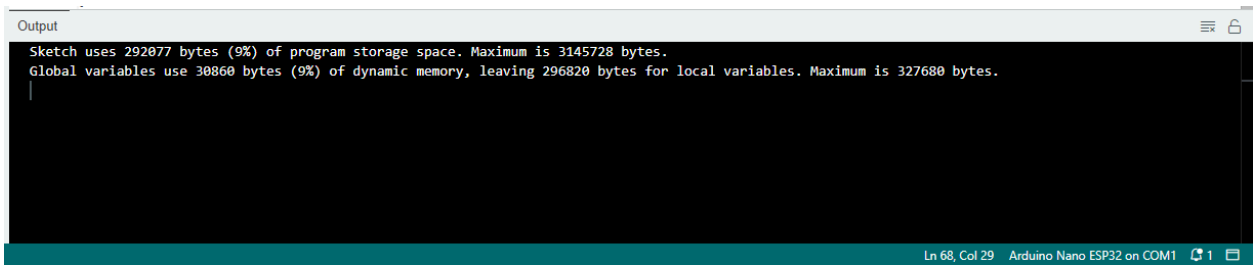
The power subsystem for the guitar is vital to keeping the microphones in rated voltage after going through a voltage regulator.

Requirement	Verification
Must be able to supply rated voltage for each component within a +/- 0.2V tolerance after going through voltage regulators.	• Verify that the battery is supplying 9V using a multimeter. • After each component, verify what voltages are read before the Vcc pins and compare to rated voltage values.
The battery must be able to power the microphones for every demo.	• The same battery should be used throughout the semester to ensure our components are working properly.

2.5 Tolerance Analysis

One tolerance risk we face when implementing this project is properly allocating memory space for our microcontroller with the most efficient filters possible. A heavy portion of our project is focused on coding very effective filters to make data transfer and modification seamless and simultaneous.

A filter designed to attenuate frequencies outside of our bounds, 80-1500 Hz, was designed in the Arduino IDE. After doing so, compiling on an ESP32 chip (previously chosen microcontroller but in the future will be switched for audio capabilities of STM32) allocated 9% of the flash memory, which was 300kB. If we plan on using the STM32, that would correlate to 18%, since the STM32 has half of the flash memory that the ESP32 MCU has.



The STM32 microcontroller has 2MB of flash memory, which should be enough space but could cause risk when we plan on implementing more filters to refine our design. Overall, it will be necessary to design efficient, precise filters and not settle for simple due to memory concerns.

3. Ethics and Safety

The goal of this project is to provide a quality of life product that does not replace or make obsolete other products attempting to solve similar issues. In section I.3 it states, “to avoid real or perceived conflicts of interest whenever possible, and to disclose them to affected parties”[1]. To ensure this doesn’t happen we intend to make this product to solve unique use cases and to be used alongside existing products that also deal with volume alteration. Also to comply with section I.5 of the IEEE code of ethics we intend to credit all preconstructed systems that use or take inspiration from. We also intend to be fully transparent with any shortcomings of this project and won’t attempt to cover up or omit information regarding any faults.

On the topic of safety this system will be using a Lithium Ion Battery contained in the guitar attachment. We intend to make this system as safe as possible mainly by not having the recharging system contained in the attachment. Recharging will be done externally using the proper equipment. The attachment will also allow adequate airflow as to not allow for the battery to overheat while contained within the system. Other concerns are, “Thermal runaway may be triggered if a battery has certain defects that can lead to short-circuiting, is overheated, is subject to high pulse power usage, or is punctured” [2]. To solve this the placement of the battery will also not facilitate any high heat environments and will not be in danger of suffering water damage or puncture.