Guitar Effects

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1 Introduction

Guitar pedals are used to modulate and amplify the amplitudes and frequencies of the original input signal that are obtained from the pickups on a guitar. These pedals can be used to produce a variety of sounds that can embellish the tonal palette of a song or recording. Pedals producing effects such as distortion, fuzz, or looping are expensive and can be financially out of reach for musicians who wish to implement these effects in the music they create. Our goal is to integrate these pedal effects into one device that provides the user with the ability to select the pedal effect they wish to use and minimize the cost required to utilize these effects.

2 Problem Statement and Proposed Solution

The problem with using guitar pedals on their own is that they are usually expensive and must be purchased separately to have access to the different effects they provide. The steep price of guitar pedals could prevent someone from being able to utilize these effects for their desired purposes. The pedals also must be activated using your foot, whereas our design aims to provide the user with an interface in which the different pedal effects can be selected without the need to manually activate them on a physical pedalboard. Digitization of the guitar pedals and its effects eliminates the need for physical pedals to be carried around and provides accessibility to those who cannot afford a physical pedal. Our design consolidates the circuit that will be used to generate guitar pedal effects such as distortion, fuzz, and looping where the input signal will be digitally processed and routed to an amplifier.

The main goal of this project is to emulate the various effects produced by guitar pedals through digital signal processing, and allow the user to be able to incorporate the same effects produced by pedals at a lower cost. We are aiming to develop a user interface which will allow the user to easily select the effect they wish to use through a switchboard that communicates with the microcontroller via Bluetooth. Enabling a switch will result in the modification of the digital audio signal to achieve a specific pedal effect.

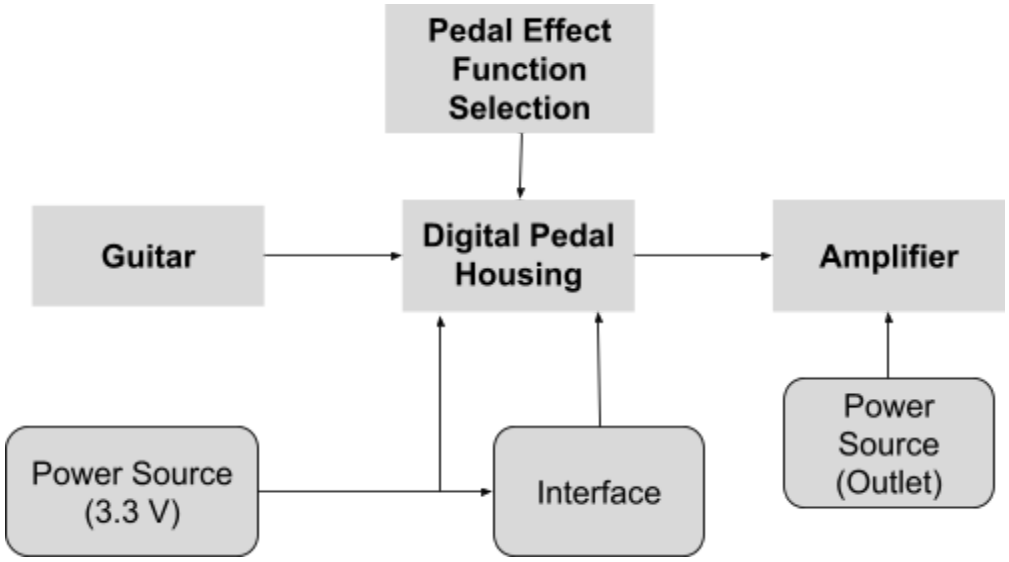
Our solution will consist of utilizing the digital signal processing capabilities of the ESP32 to emulate various guitar pedal effects such as distortion, fuzz, and looping. We aim to route the guitar signal to an analog-to-digital converter, modify the digital audio signal to achieve the desired effect, and convert the signal back to analog using a digital-to-analog converter. The resulting signal will be passed to an amplifier that will output the signal and the desired pedal effect in real time. Our goal is to consolidate the circuit components in a compact housing, and develop an interface that can be used to adjust certain parameters such as gain and volume. This will make the device more convenient for the user. The signal is then passed to an amplifier where we should hear the corresponding effect to the specific circuit chosen. Our design will include the cheapest components that fulfill all of the circuit design specifications. All of these features ensure that our device is: affordable, simple to use, and advantageous compared to using multiple pedals daisy-chained together.

3 System Requirements

- Guitar Amplifier
- Functional electric guitar
    - ¼”audio jack output
- Adjustable clip that wraps around the body of the guitar
    - Includes various switches for corresponding pedal effect
    - Bluetooth signal transmission containing the information of which switch was pressed
- Mechanical device with volume adjustment and LEDs signaling which effects are currently being executed.
    - Microcontroller
    - Device contains a receiver for the BT switches signal from the adjustable guitar clip
    - Analog to digital converter at input
    - Digital to analog converter at output
    - Memory unit for loop effect
    - Bluetooth connectivity with adjustable clip to receive the signal indicating the desired effect from the user
- Power supply to regulate and route voltage to the microcontroller, analog-to-digital converter, digital-to-analog converter,and the internal flash memory.
    - Rechargeable power source
- ESP32-C3 Digital Signal Processing
    - Manipulation of converted digital guitar input to emulate distortion, looping, fuzz, and other guitar pedal effects.
    - Utilization of native Espressif DSP (ESP-DSP) libraries to create the code that will modify the digital input signal to generate the desired guitar pedal effect.
- Code that reads in the chosen guitar effect
    - Triggers loop in code that alters the signal for the desired sound
    - Multiple desired effects will trigger multiple loops simultaneously and can be turned off by the user at any time

4 System Block Diagram

1.1 Overall System:

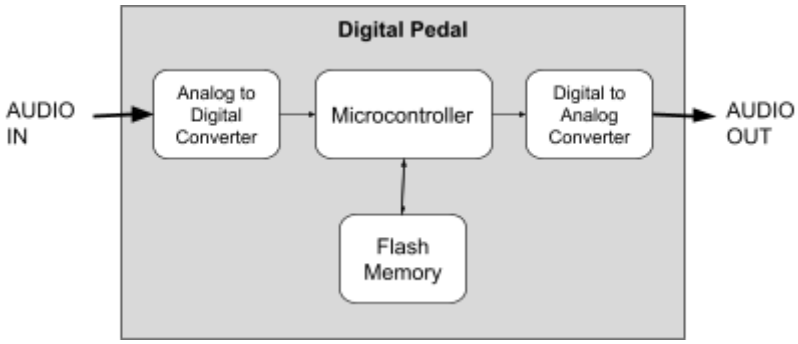


1.2 Subsystem and Interface Requirements:

1. Bluetooth Switchboard
    - ◆ Function and Installation:
        - Provides a physical interface for the user to choose the desired guitar effect(s) and their intensities via the adjustment of knobs, each one controlling a different effect
        - Attaches to the body of the guitar
        - Replaces a physical foot pedal
    - ◆ Requirements:
        - Knobs for each effect must correctly control the intensity of the selected effect and relay that information to the Digital Effects Pedal.
        - Switchboard must be able to transmit via Bluetooth information on the selected effect(s) and their intensities to the Digital Effects Pedal.
        - Bluetooth capabilities must support 2 devices – the Switchboard and the Digital Effects Pedal. Only a short range is required since

the Switchboard would be attached to the guitar, and the Digital Effects Pedal would plug into an amplifier.
- Switchboard must be compact and lightweight.
- Switchboard must attach to the guitar body via clip or other method that allows for retrofitting on different shapes and sizes without damaging the guitar.
- Switchboard will operate on 4 AA batteries.
- Switchboard must be able to operate for several hours between charges.

2. Digital Effects Pedal



◆ Function and Installation:

- Digitizes and processes the signals from the Bluetooth Switchboard and the guitar to apply the desired effect(s) to the audio signal
- Electrical components are contained within a housing device for the safety of the user to separate them from any voltage or current.
- Housing device interfaces with the guitar via cable.
- Housing device interfaces with an amplifier via cable.

◆ Requirements:

- LEDs on the housing device must indicate which effects are currently active.
- Bluetooth capabilities must support 2 devices – the Digital Effects Pedal and the Switchboard. Only a short range is required since the Switchboard would be attached to the guitar, and the Digital Effects Pedal would plug into an amplifier.
  - Digital Effects Pedal must perform Analog-to-Digital and Digital-to-Analog conversions to allow for manipulation of the audio signal.
  - Digital Effects Pedal must take the guitar's output signal as its input and convert the analog signal to digital.

- Digital Effects Pedal must perform Digital Signal Processing (DSP) on the digital signal to apply the desired guitar effect.
- Digital Effects Pedal must convert the modified digital signal to analog and send it as an output to the amplifier.
- Digital Effects Pedal must have a rechargeable battery that can be recharged via cable.
- Digital Effects Pedal must be able to operate for several hours between charges.

1.3 Future Enhancement Requirements

- Create library of effects to select from and download onto device.
- Create an interface that allows user to custom-make, save, and select presets that incorporate different levels of multiple effects.
- Add amplifier circuit and headphone audio output. Doing this would also help the goal of making guitar equipment more financially available.

5 High Level Design Decisions

System 1: Bluetooth Switchboard

➔ Replaces the need for foot pedals; Acts as a mobile control for multiple guitar effects.
- ◆ Interface will be a series of 3-4 knobs, each corresponding to a different effect.
- ◆ Powered by 4 AA batteries.
- ◆ Attached to an adjustable clip that wraps around the back of the guitar.
  - Rests the switchboard on the top of the body of the guitar.
  - Maintains the aesthetic of the guitar by wrapping around the back.
  - Adaptable to different guitar shapes without disrupting performance.
- ◆ Bluetooth signal transmitter
  - Sends signal to the device housing the microcontroller.

System 2: Digital Effects Pedal

➔ Digitizes and processes both signals: switchboard signal, and guitar signal. The output of the guitar signal will be determined by the input from the switchboard. The loops of code corresponding to the pressed switches will alter the input signal. By digitizing the signals, we can cut down on our hardware requirements allowing for a more compact and portable device compared to a strictly analog circuit.

- Analog-to-digital converter
    - Transforms the analog input signal from the guitar cable to a digital signal and sends it directly to the microcontroller.
- Bluetooth signal receiver
    - Collects incoming data from the mobile switchboard and relays the signal to the microcontroller.
- Microcontroller
    - Processes both the digitized guitar signal and digital input from the switchboard.
    - Through hardcoding the device, different loops will activate when its corresponding switch has been pressed. Each loop will execute a different function on the signal.
    - The signal is then output to a digital-to-analog converter.
- Digital-to-analog converter
    - The digitized output signal from the microcontroller is transformed back to an analog signal. This analog signal is transmitted through a cable to the amplifier.
- Rechargeable battery powered
- Memory unit
    - The loop pedal effect will require a memory unit to remember the output signal from the microcontroller. This output will be relayed to the amplifier indefinitely, or until the device dies.
    - Will not require much memory.
- LEDs
    - Each LED on the housing device will correspond to a pedal effect to show which functions are currently being performed.
- Volume knob(s)
    - Adjust individual levels of the corresponding effect as well as one for the overall signal gain.

6 Open Questions

- What will the circuitry look like for the Bluetooth Switchboard with switches and signal emitter?
- How will the independent memory system work for the microcontroller for just one guitar effect?
- How many different effects are we able to do?
    - How many effects can we use simultaneously without destroying the original signal?
    - How will the original signal sound through the amplifier without any effects being activated?
- How will we determine which switch is being pressed on the Bluetooth Switchboard?
- How will the microcontroller handle the input signal from the guitar as well as an input signal from the BT switches?
    - How will this affect our circuitry?

7 Major Component Costs

Component	Estimated Cost Per Unit ($)
Amplifier	N/A
Electric Guitar	70-100
Analog-to-Digital Converter	<5
Digital-to-Analog Converter	<5
3.3 V Regulator	<2
Guitar Cables x2	10
Housing for Pedal	10
Housing for Switchboard	
Rechargeable 9V Battery	5-10
AA Batteries	<5
Bluetooth Transceiver	10-15
LEDs	<1
3D Printed Adjustable Clip	N/A

8 Conclusions

Physical guitar pedals can be expensive and often do not provide the user with the option to apply different effects that can change and modify the guitar signal. The goal of our project is to eliminate the need for utilizing physical guitar pedals and provide the user with greater control and accessibility of guitar pedal effects. This project will allow us to learn more about digital signal processing and the implementation of various other electronic components to achieve full digitalization of guitar pedal effects. We aim to provide a cost-effective solution to the utilization of guitar pedal effects while maintaining the same audio quality and integrity provided by a physical guitar pedal.

9 References

https://digitalcommons.calpoly.edu/cgi/viewcontent.cgi?article=1451&context=eesp
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