Metal to the Pedal:
Digital Signal Processing Methods for Guitar Effects

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Introduction

Digital signal processing (DSP) is generally defined as modifying an incoming signal by way of using computer code or specialized digital processors. Research into the use of DSP is ongoing in many applications like RADAR [1], LIDAR [2], face recognition [3], image processing [4], and seismology [5] to name a few. For this project, DSP is utilized in the creation of guitar effects through an adapted, open-source guitar pedal design. Elements of computer science and both electrical and mechanical engineering are used throughout making it a unique, multidisciplinary project.

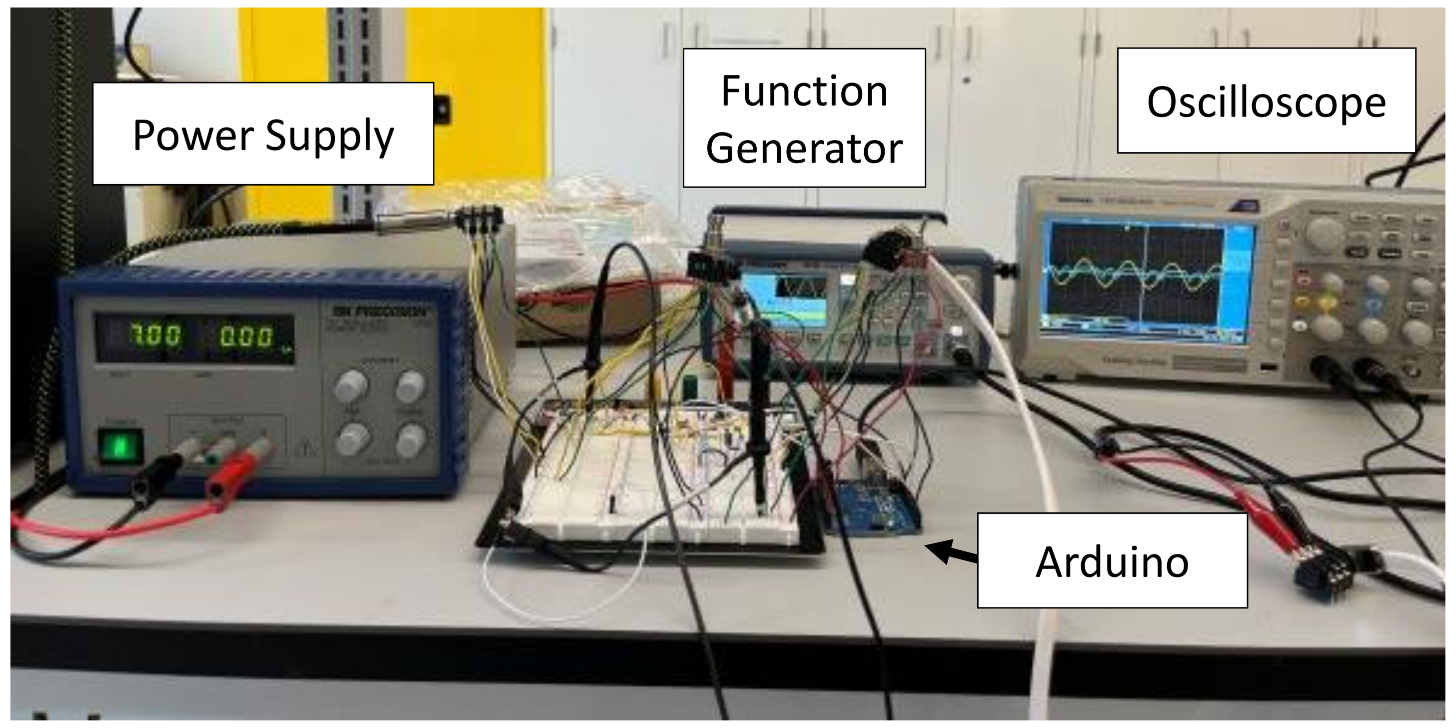
Prototype Development

Early prototype (v 0.99) with enclosure

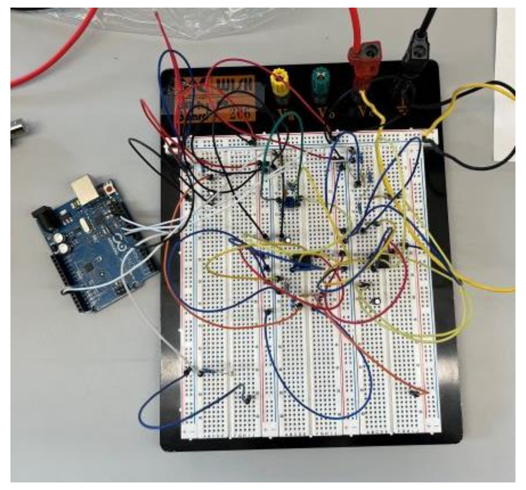
SFA Axe Grinder Pedal

Specifications:

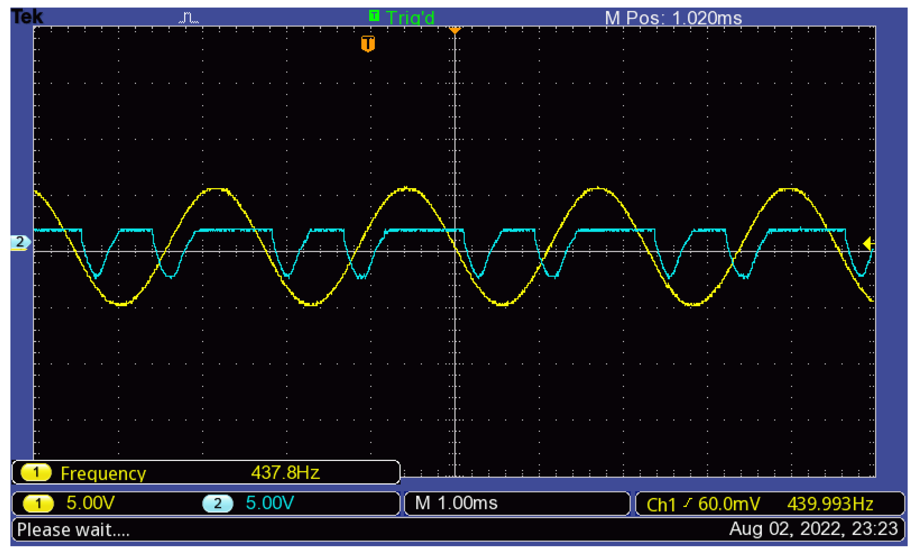
- Input and output jacks (1/4" Mono)
- Two press buttons
- Toggle Switch (2 place)
- Footswitch
- USB (Arduino)
- Power Supply (9V 1A)



A testbed for the effects pedal wired on an electrical breadboard



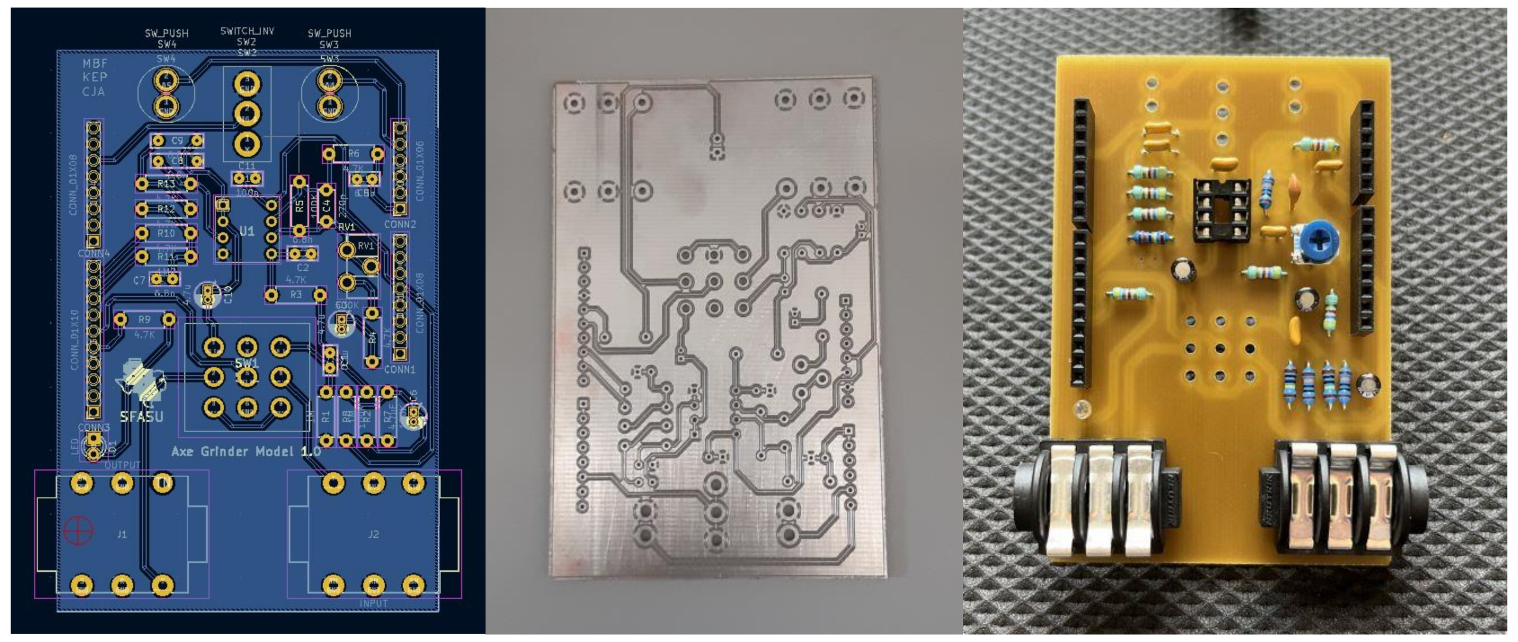
Prototype on breadboard



Oscilloscope display with yellow wave as guitar input and blue wave as pedal output

Printed Circuit Board (PCB)

A Printed Circuit Board (PCB) was designed using an open-source, Computer Aided Design (CAD) software called Kicad 6.0. Shown left to right is an evolution from CAD model to the final PCB with components.



Signal Processing Code

The pedal relies on an Arduino Uno SMD R3 single-board microcontroller. Diagram below illustrates a basic signal modification. Multiple codes were adapted for the pedal and can be loaded onto the board via USB. Some of the coded effects include clean, booster, tremolo, and distortion.

- Define Hardware
- PWM parameters
- Initialize other variables

setup(){
- Configure pins
- Set up ADC
- Set up PWM

}

Loop(){
- Light up LED when toggle is ON
- Turn off LED when toggle is OFF

}

ISR(){ // Interrupt Service Routine
- Read in ADC
- Read hardware (pushbuttons/toggle/switch)
- Make volume adjustments
- Write PWM

}

Guitar Signal

SFA Axe Grinder Pedal

Analog Filtered Input

Arduino w/ DSP

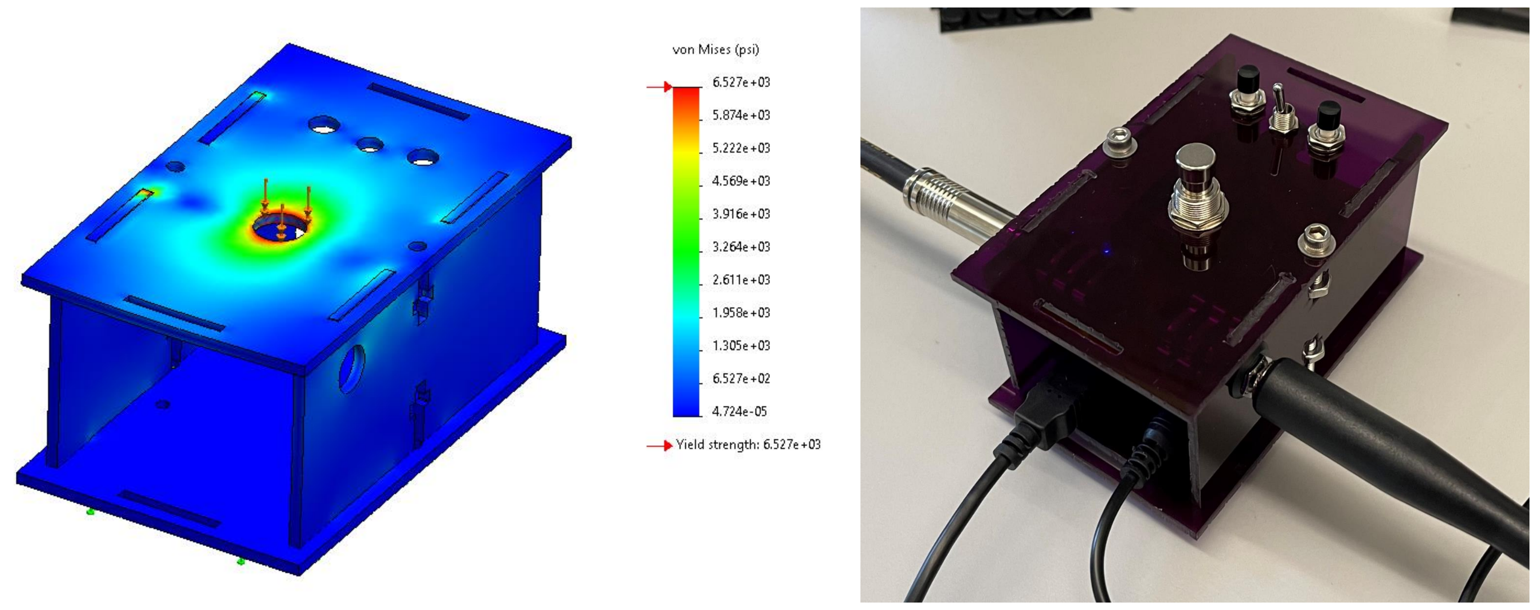
PWM to Analog Output

Output Signal

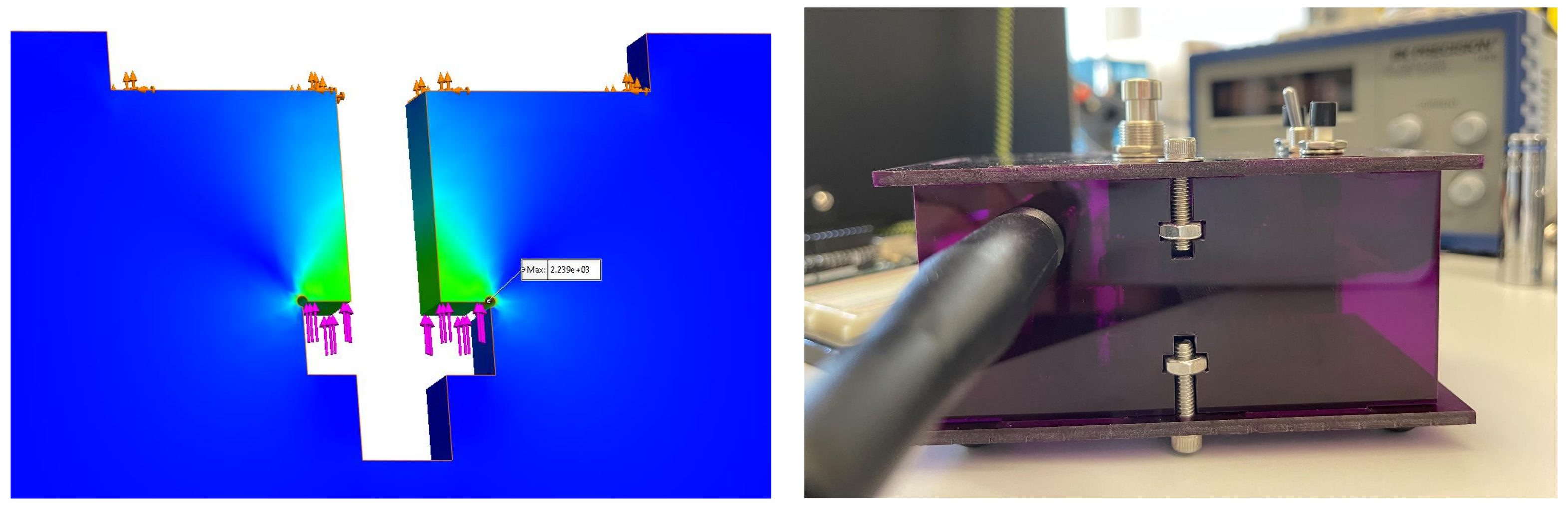
Amplifier

Design of Enclosure

A Finite Element Analysis (FEA) was preformed on the enclosure designed to house the pedal components using SOLIDWORKS CAD software. A maximum loading of 40 lbs is applied at the location of the footswitch. The largest stresses are shown in red near the application of the force.



Enclosure design of version 1.0 of the guitar effects pedal



Analysis of high-stress points in acrylic joint under compression

Future Work

- Continue development of code to improve efficiency and functionality.
- Transition to a more robust microcontroller to eliminate need for Arduino.
- Add new components such as potentiometers for extended control.
- Adapt new codes for various effects like delay, chorus, reverb, etc.
- Create modules for keyboard and/or synthesizers.

Conclusions

- An Arduino-based guitar effects pedal was designed and fabricated.
- A prototype platform for future use was developed.
- Deeper knowledge of DSP and microcontroller systems was gained.
- A custom enclosure was tested and built using in-house manufacturing.

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