The Fuzz Factor:
ELEN 1201 Final Project

Jordany Acosta Capellan[1], Farhan Tanvir[2], Rosnel Leyva-Cortes [3], and Hannah Chen[4]

[1]ja3568
[2]ft2563
[3]ral2219
[4]hc3224

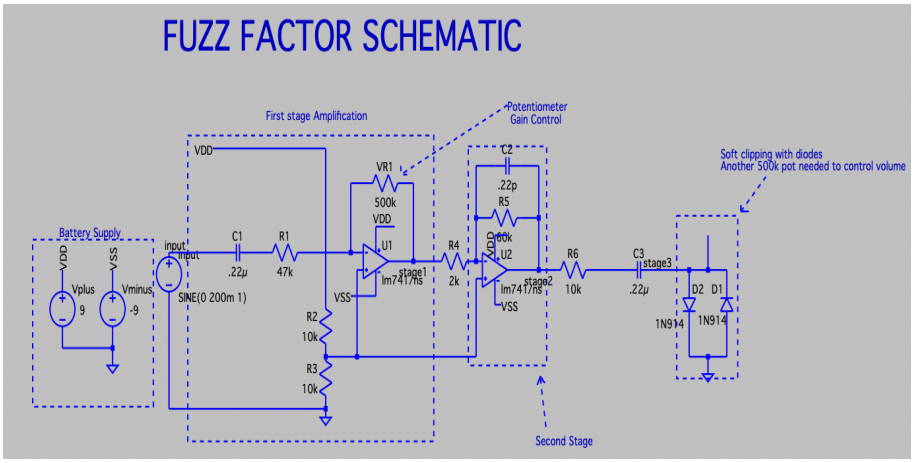
December 15, 2022

Abstract

The purpose of this circuit is to apply a "fuzz" effect on a guitar signal. It achieves this by first amplifying the signal to an audible level. Afterwards the signal is softened by clipping the peaks in a way to give the signal softer peaks and troughs. This circuit utilizes op-amps rather than transistors, which other pedals tend to use, for a couple of reasons. 1: The application of a gain factor is a concept our team understood using operational amplifiers., and 2: The LM741 amplifiers, which exhibit the behavior necessary for the schematic, were already present in the lab. There are additional considerations included for possible fabrication on a PCB.

1 Schematic

The original schematic for this project came from *Music Works* magazine volume 109. In their schematic they utilized a TL072 operational amplifier. This chip is slightly better than the LM741 because it packages two amplifiers onto one chip, which is good for keeping the circuit compact. Our design utilizes two LM741 amplifiers and implements volume control for the auditory output, which previously weren't in the original schematic.



A reference point of 4.5V for the non-inverting input of the amplifiers is also included.

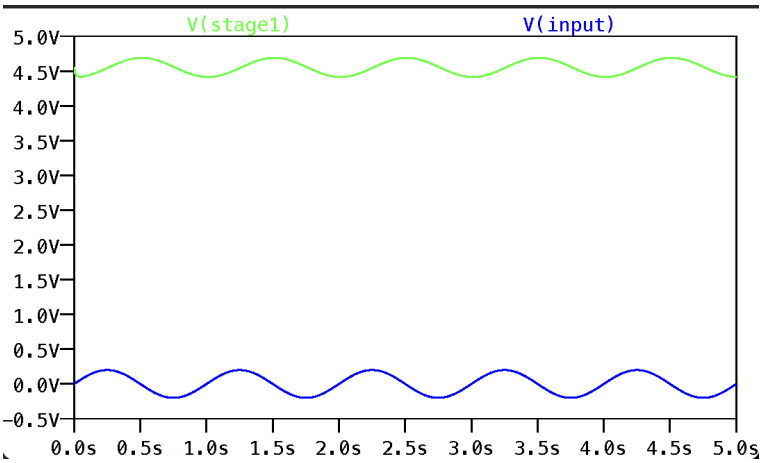
1.1 First Stage Amplification

In our circuit, the signal passes through C1, which blocks the direct current from going back to the source, and into R1, which sets the input impedance and helps determine the gain of the first stage. Both stages are configured as inverting amplifiers which have the following relationship between their input and output:

$$V_{out} = -(\frac{R_f}{R_i}) \cdot V_{in} \tag{1}$$

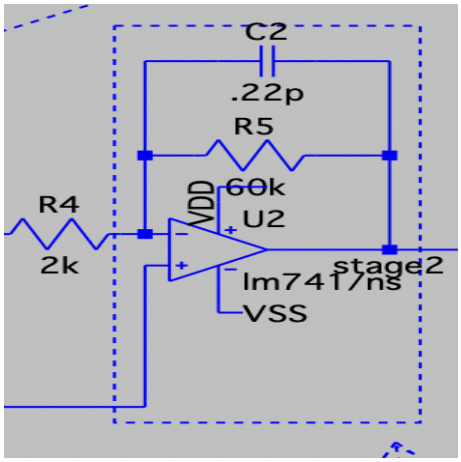
When testing with a 200mV sine wave input, we determined that a maximum gain of about 10 would be needed for the first stage. This is because from previous testing the speaker would be audible when a voltage of about 3.5Vrms from our function generator was passed into it.
We determined this gain to be appropriate from measurements taken from a real guitar signal. Using a portable oscilloscope we measured the fluctuating voltage signal from a mono audio jack connected to a guitar.

This confirmed our test inputs of using peak-to-peak 200mV (in the loudest of strums) signals to be a fair assessment of a guitar signal in our simulation.
A comparison of the input signal to the first stage amplification is shown below:

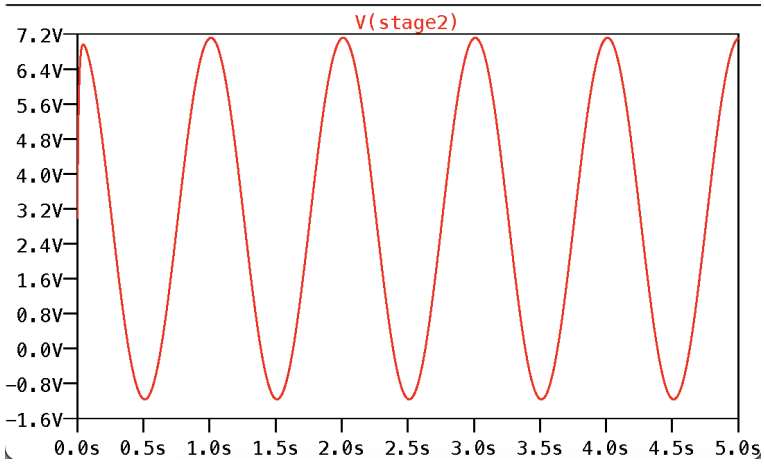


Also note that the gain in this stage can be variable by using a variable resistor was the feedback resistor, which is what we did in our implementation.

1.2 Second Stage Amplification

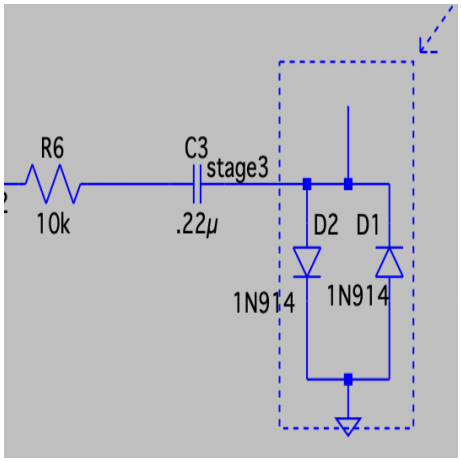


The second stage is just meant to increase the gain to a higher point than the first stage. In the first stage we got to about 4V peak-to-peak which, while still audible, can only be heard very faintly from the speaker. This stage has a gain of approximately 30.
The capacitor in parallel is meant to smooth the resulting waveform, though we saw similar results by omitting it. At this point, the capacitor is included more for personal taste than anything else.

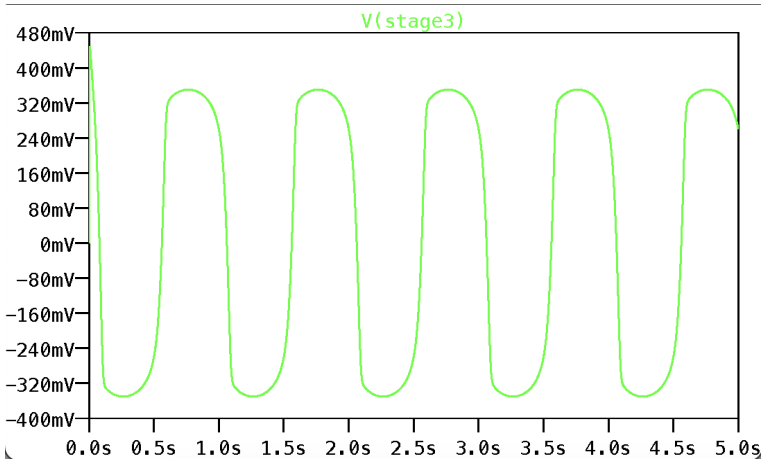


This graph shows the simulated waveform of the second stage amplified signal. At this point, this makes the total gain of the circuit around 300.

1.3 Soft Clipping



R6 and C3 couple the output to the two diodes, which provide the soft-clipping action that defines guitar "fuzz." Not shown in the schematic is the 500k potentiometer used to control the volume of the resulting waveform.
The simulated waveform is shown.



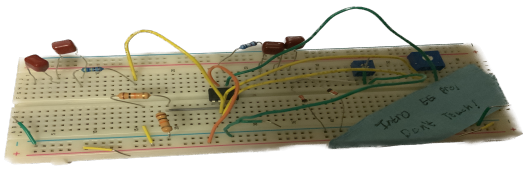
This was a bit concerning though because it appears that the signal was being dampened, i.e. the higher voltage signal from the previous signal had dropped to a few hundred milli-Volts. The current configuration of the diodes should've only clipped the top and bottom peaks of the signal by shorting them to ground, but clearly it wasn't behaving as expected. We address this in the implementation section.

2 Implementation

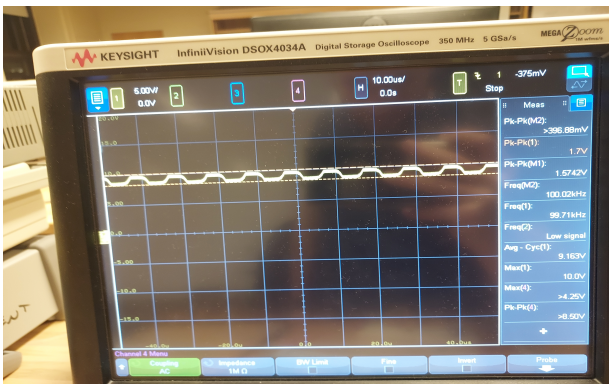
Our Physical implementation is shown below. When physically building the circuit we weren't able to get the second stage amplification to produce an oscillating signal. We tried numerous strategies to get the second op-amp to work in conjunction with the first stage but there was no audible output from the speakers, nor an oscillating output from the oscilloscope.
To account for this, we adjusted the gain on the first stage as much as we could to make the effect somewhat audible. We dropped the input resistor's value in increments and upgraded to a 1 MEG potentiometer and found a sweet-spot with a 33k resistor that made the output audible (maintaining the clipping effect with the diodes). We wanted to avoid using lower value resistors since

$$P = \frac{V^2}{R} \tag{2}$$

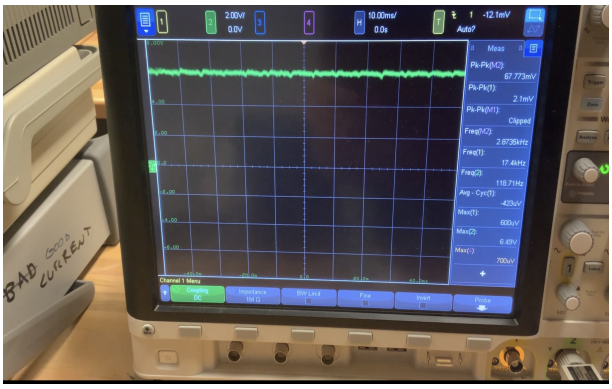
Meaning that anything lower would have significant power consumption once the voltage starts climbing from the input.



The image above is a picture of our physical implementation of the circuit, excluding wires from the input signals, power supplies, and measurement tools. When testing on a 3.5Vrms sine wave from the function generator a pretty nice, fuzzy wave is shown on the scope, and a similarly fuzzy wave is heard from the speaker with a max of 10V.



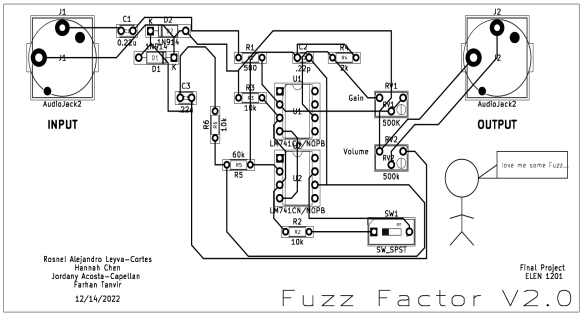
However, our pitfall was not testing with a signal similar to what the output of a guitar signal would be. When we connected the guitar to the input of the circuit we saw a smaller, yet still audible fuzzy wave with a maximum of 6.8V.



What we concluded then, was that the signal with just one stage of amplification was able to make the signal barely audible and functional, though not practical.

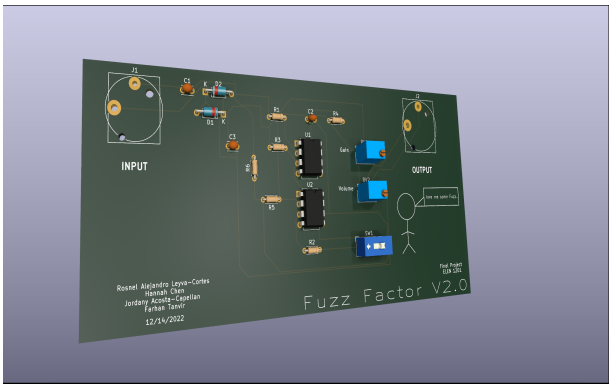
3 PCB Design

We experimented with some PCB design software to see what the circuit would look like on a PCB if sent for fabrication. Using KiCAD, we designed the schematic below.

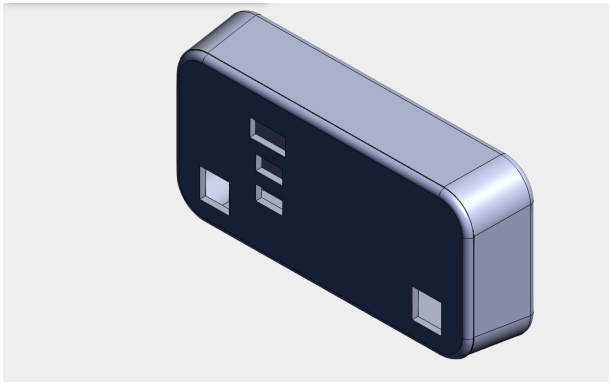


dim: 124.46mm x 58.42mm

In a full render, the PCB would look like the following.



An accompanying physical case was made for housing it in the future.



4 Next Steps

In order to continue the progress on this circuit, it is necessary for us get the second stage to be functional. We're still not completely sure why the physical circuit diverged from what we had simulated, and what conditions made it so. We also took out some polarized capacitors that were present in the reference design which we found to be unnecessary for the function of the circuit, however, it could be that these were the point of failure for the second stage amplifier. Ideally for future designs, we'd need a gain that could increase the output voltage signal to a maximum of at least 9V to drive the speaker in a more audible way.