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PHYS 406

Big Muff Pi Kit

Introduction

For my Physics of Music semester project, I choose to build an effects pedal. I bought a kit from General Guitar Gadgets [4]. This kit was to model the black Russian version of the Big Muff Pi made by Electro Harmonics. After building this kit, I modeled the circuit in Multisim and later compared the measurements that I took to the output of the simulation. I took measurements in both the time domain using an oscilloscope and the frequency domain using a spectrum analyzer.

About this effects pedal

This pedal produces what is known as a fuzz distortion effect. The reason behind choosing this pedal was that I wanted a distortion effect to use for both electric guitar and bass guitar, as I play both of these instruments. The Big Muff Pi is a popular choice for both guitarist and bassists and the Black Russian version is particularly known for use with a bass guitar. Also, it is a discontinued product so the only way to get one is to buy it used, or to build it form a kit like the one that I purchased. [2]

The way that distortion effects work is by introducing higher harmonics into the signal from the guitar or bass through a circuit that has a non-linear response. These higher harmonics alter the tone of the instrument creating a sound that can be harsher or warmer sounding depending on the circuit and its specific response. Fuzz distortion effects are a very old type of guitar effect and create a dirty, buzzy sound. There are many different ways that a non-linear response can be introduced into a circuit but here as with many other fuzz distortion pedals clipping diodes are used. These limit the amplitude of a signal. [3]

There are three different controls on this pedal, volume, tone, and sustain. The volume is fairly self-explanatory, this controls the amplitude of the final output and therefore the volume. The tone works by filtering out low/high frequencies depending on its position. Sustain controls how much the signal is distorted and controls the “harshness” of the final sound.

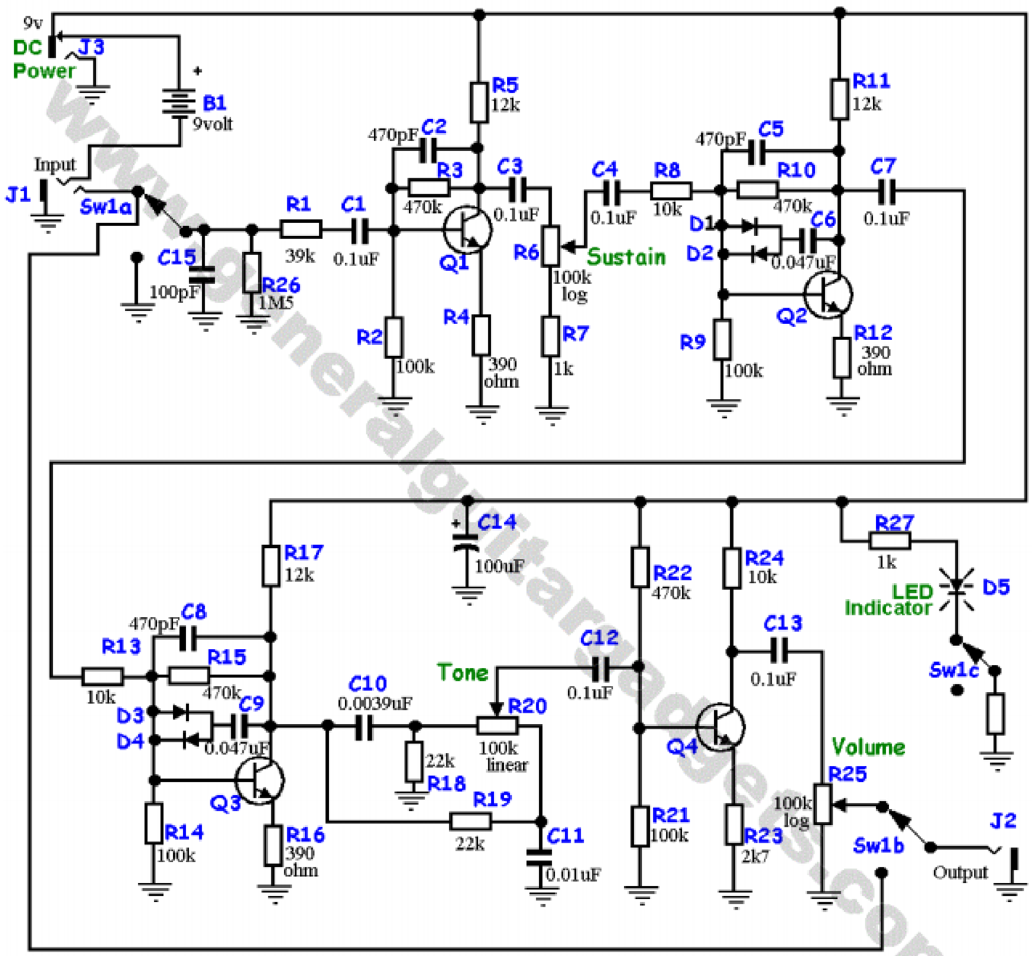


Figure 1. Circuit Diagram

Above is the circuit that is in the effects pedal. In the circuit there are four transistor stages. The first has its output controlled by the sustain potentiometer and acts as an amplifier. The next two contain the clipping diodes, which are labeled D1, D2, D3 and D4. The more the first stage amplifies the input signal the more the diodes clip the signal, creating the harsher and more distorted sound. After these stages there is a band pass filter which is controlled by the tone potentiometer. Lastly there is the final transistor stage which acts as a simple amplifier with the amount that it amplifies the signal controlled by the volume potentiometer. [1]

Construction

The first step in constructing the kit was to sort and solder all the resistors, diodes, capacitors and transistors to the printed circuit board (pcb). After the complete pcb was constructed, I mounted the three potentiometers, LED, and foot switch. Then the input/output. Finally I wired the whole thing together and also put in a 9V battery to power everything.

Above are some pictures of the final construction of the pedal. The masking tape is covering the 9 volt battery which powers the pedal. I chose not to paint or label the exterior with anything other than a sharpie, but to make it look nicer I may do this later.

Measurements

To make all of these measurements, the input used was a sine wave signal at 1000 Hz with 100 mV peak amplitude. This is the default on the function generator that I used but is also within the range of frequencies produced by a guitar and also approximately the same as the output amplitude of an average guitar. I measured the pedal with the tone and sustain set at a minimum, middle, and maximum positions, which corresponds to the pots being rolled all the way to the left, in the middle, and all the way to the right. This resulted in nine different measurements total (3 x 3).

Scope and Simulation Comparison

The first measurements I took were with the oscilloscope to compare to the measurements I obtained with the MultiSim virtual model. In MultiSim I chose the exact same input as I had as the function generator for the pedal. Unfortunately, in MultiSim there are not logarithmic sliders to control the virtual potentiometers, so I was not able to accurately have a middle position like on my actual pedal measurements. So I could only make an exact comparison at the four min and max combinations.

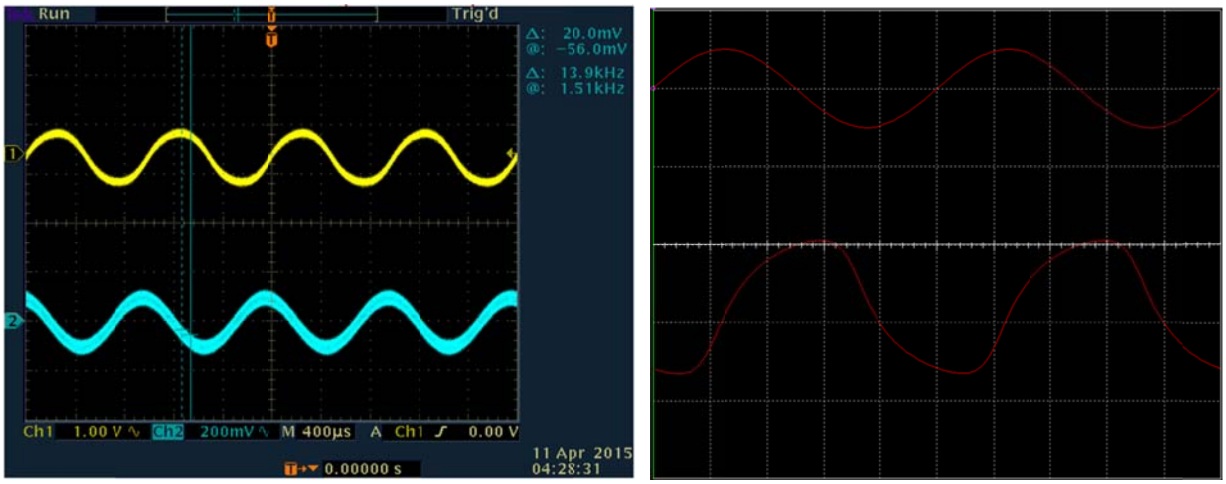


Figure 4 BMP vs simulation: min tone, min sustain

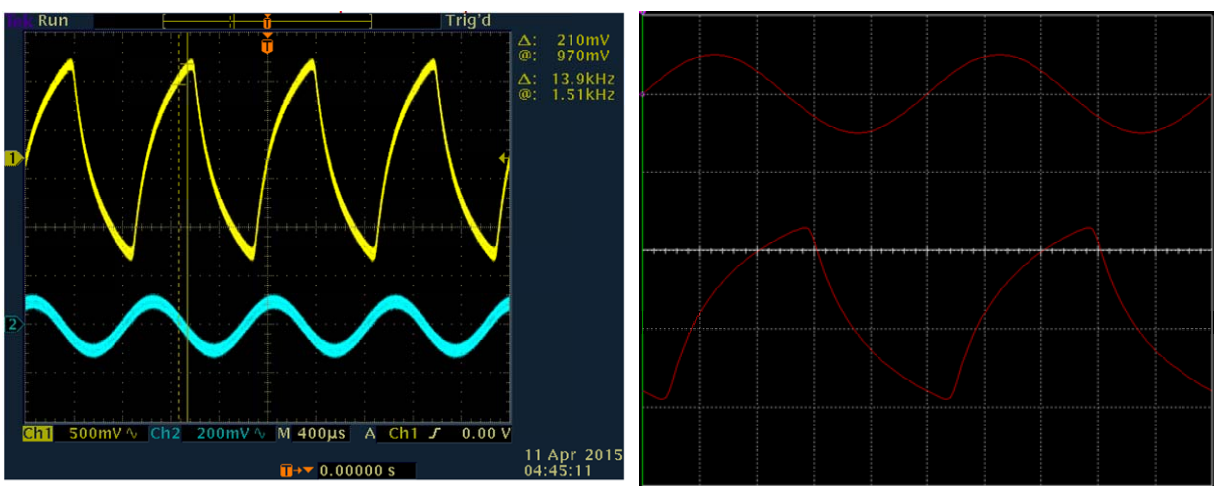


Figure 5 min tone, max sustain

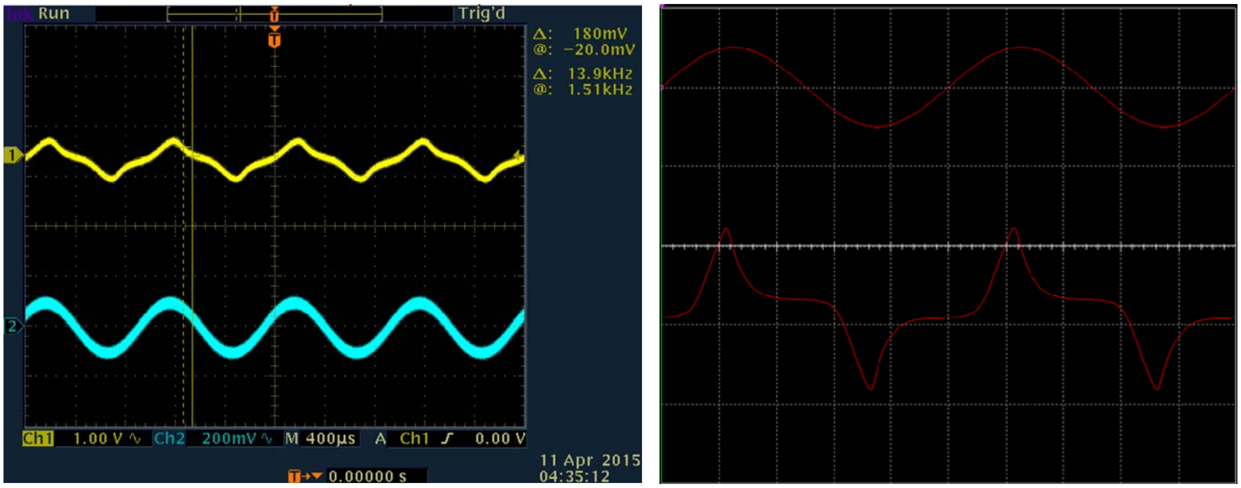


Figure 6 max tone, min sustain

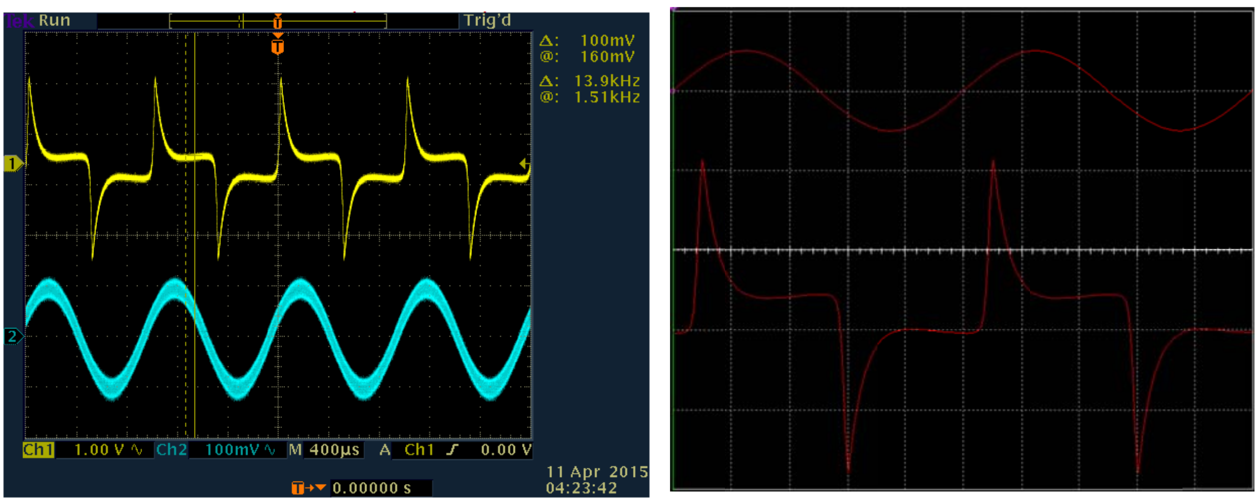
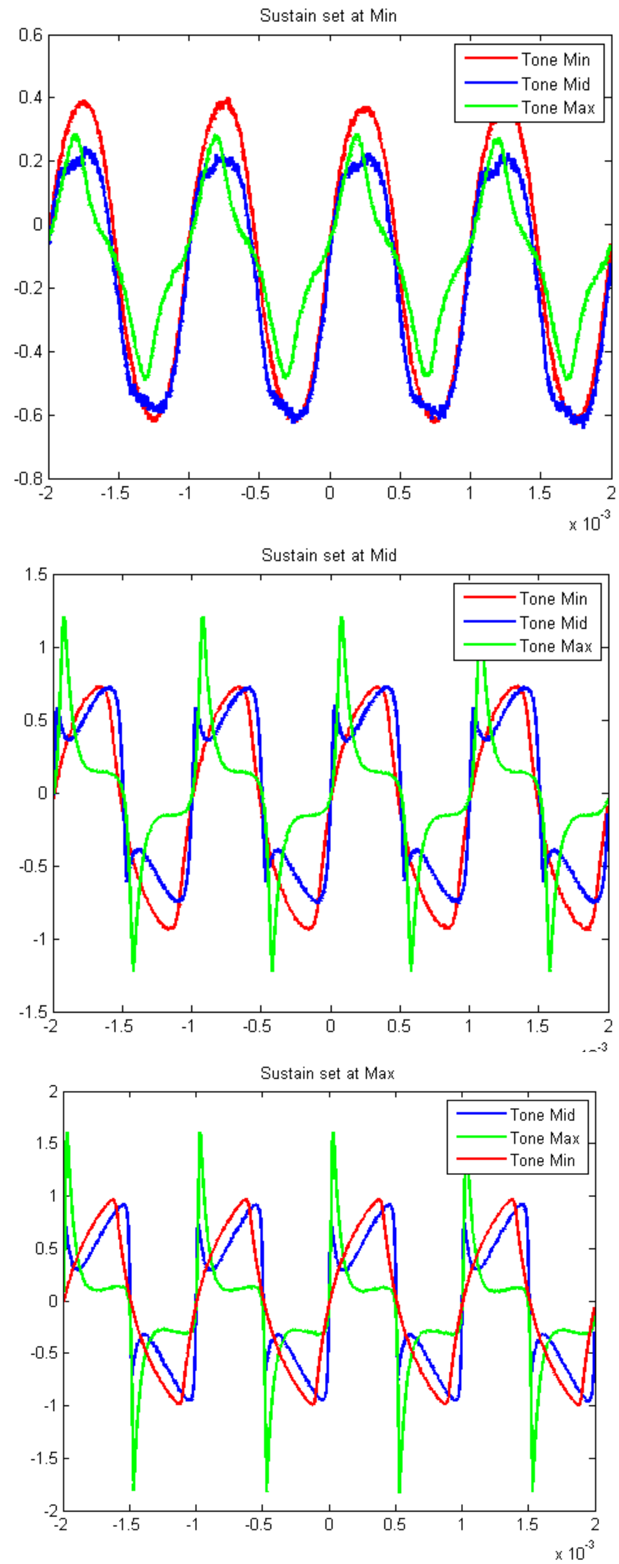


Figure 7 max tone, max sustain

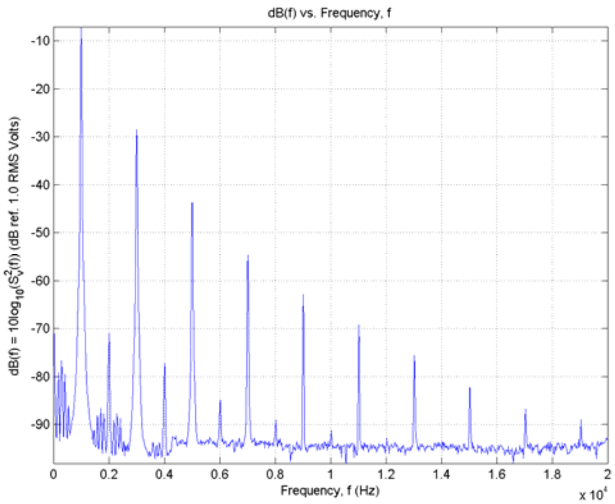
In these screen shots, the oscilloscope measurements are on the left and the simulation on the right. Somewhat confusingly the output on the oscilloscope measurements is the yellow top signal, and on the simulation images the output is the bottom signal. Both the pedal and the model have similar waveforms and phase relative to the input signal one exception being the tone and sustain minimum setting. The simulation shows a slight “shark fin” shape while the pedal was outputting what appears to simply be a sine wave. The phase of the outputs at this setting still seems to agree though. Overall there is agreement between the simulation and the real measurements.



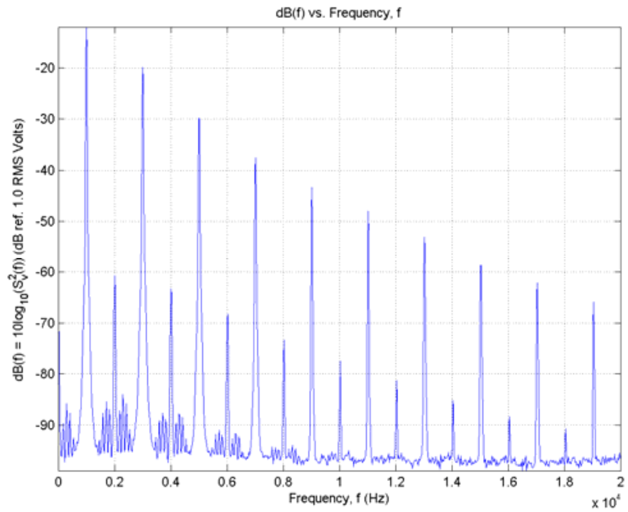
Time Domain Measurements

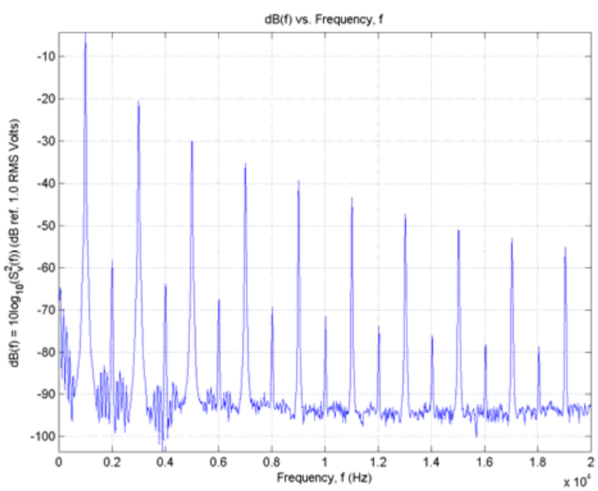
These figures were produced by taking the output of the oscilloscope and importing that data into MatLab. In these figures we can see the changes in the waveform at each sustain setting, and each tone setting. First, the waveform that this pedal produces is not simply a clipped sine wave. Which is to be expected because although that is the principle that fuzz pedals are built on the circuit of this pedal is much more complicated. We see that as the sustain gets higher the distortion of the waveform becomes more pronounced. Also, the filtering effect can be seen here. The waveform has sharper peaks as the tone is increased, suggesting that it is working as a filter. It allows more high frequencies, which is seen in the sharper peaks, when it is set to maximum and allows more low frequencies, seen as a smoother waveform, when set at a minimum.

Frequency domain

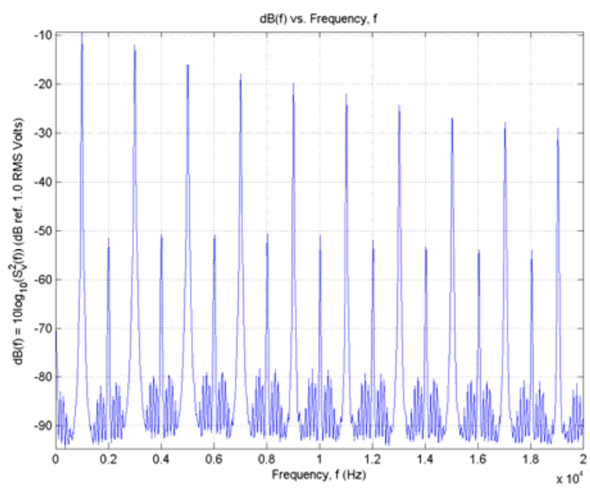


min sustain, min tone





max sustain, min tone

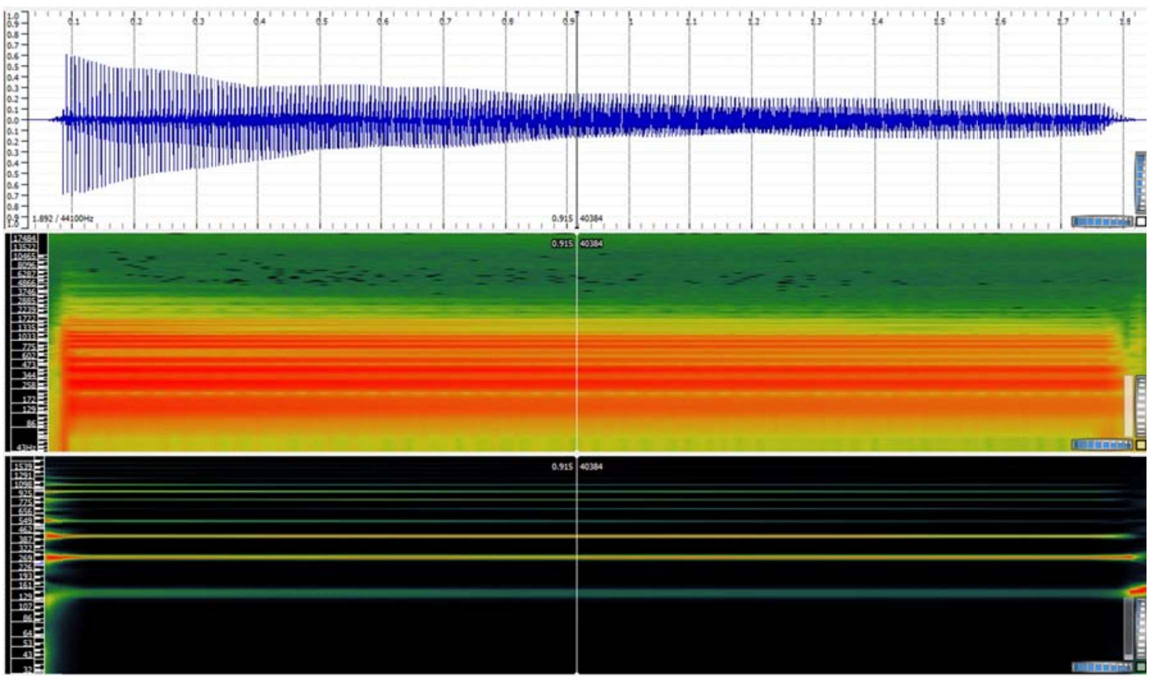


max sustain, max tone

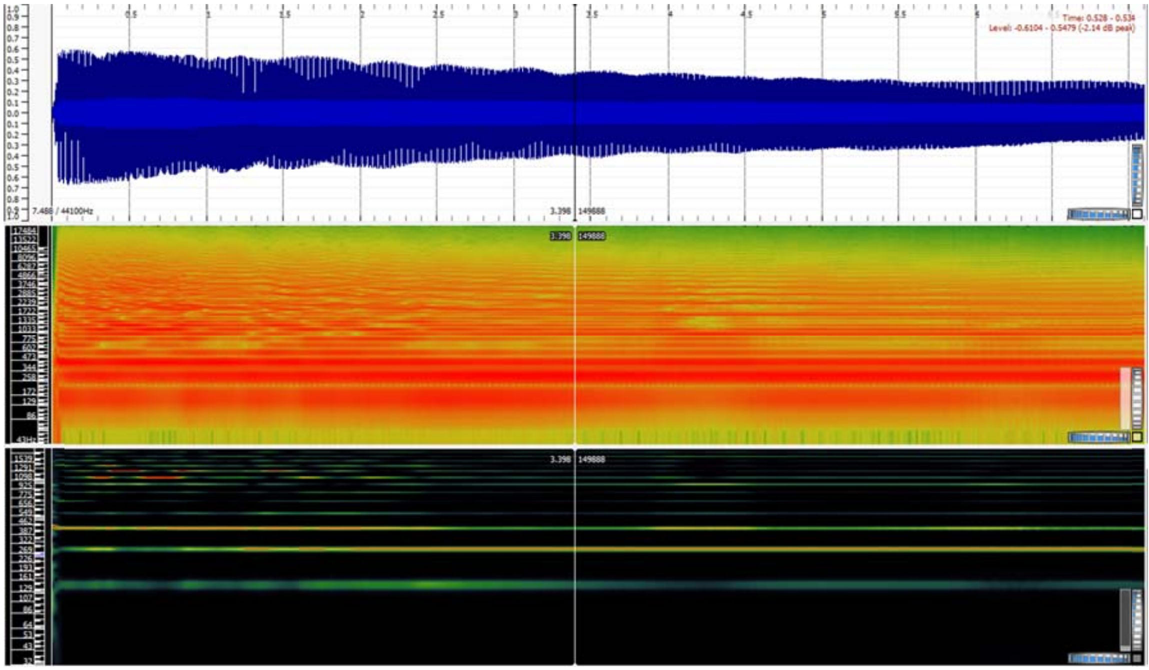
These figures were made by plotting the output from a spectrum analyzer in MatLab. In these graphs of the spectrum of the output waveform we can see several things. First, that at all settings the Big Muff Pi mostly introduces odd harmonics. Comparing the graphs on the left to the ones on the right shows that as the tone setting is increased, the power of the higher frequencies increases and the power of the lower frequencies decreases. This illustrates how the tone control works as a band pass filter, allowing more low frequencies when set at a minimum and higher frequencies at a maximum. This corresponds to the tone from the final amplifier being muddier when the tone setting is at a minimum, and brighter or harsher when the tone is at a maximum.

Comparing the top graphs to the bottom graphs shows the difference between minimum and maximum sustain settings. When sustain is set to maximum all frequencies have higher power, but setting the sustain knob this way introduces more power into the higher harmonics. The even harmonics especially so. This corresponds to the harsher dirtier sound associated with this setting.

Guitar Signal Measurements



Open D string, effect off



Open D string, effect on, max sustain, max tone

I recorded my Epiphone SG throught a USB interface and used the free program Sonic Visualizer to create these spectrograms. The top graphs are from a recording of playing the open D string. Below is the same note with the fuzz pedal effect turned on with the tone and sustain set to a maximum. In the lower graph we can see how there are much higher frequency harmonics present. This further illustrates how the pedal adding these through its non-linear response creates the fuzz effect sound.

Conclusion

I'm glad that I chose this project. I think that it was successful, and now I have a new effects pedal that I'll be able to use. After taking many measurements I was able to see how the pedal effects an input and how it introduces harmonics into a signal to produce a fuzz distortion effect. I was also able to compare my pedal to a simulated circuit and found that it was working just as the simulation predicted. I really enjoyed this project and the class in general and would highly recommend it to anyone who is thinking about taking this class.

Sources

1 Rae, Kit. "Big Muff Guts." N.p., n.d. Web. 14 May 2015. <http://www.kitrae.net/music/big_muff_guts.html>.

2 "Big Muff Pi (Russian) - DISCONTINUED | Electro-Harmonix." EHX.com. Electro-Harmonix, n.d. Web. 14 May 2015. <http://www.ehx.com/products/big-muff-pi-russian>.

3 Dailey, Denton J. "Electronics for Guitarists." Google Books. Springer, n.d. Web. 14 May 2015. <http://books.google.com/books/about/Electronics_for_Guitarists.html?id=PPg5_lPQJyMC>

4 http://www.generalguitargadgets.com/effects-projects/distortion/big-muff-pi/