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Final Paper/Project
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Introduction

Distortion is a commonly used tool in music today. But where does it come from and how is it generated. What is it? This goal of this project was to gain a basic understanding of the effects of distortion on the waveform and to make a device that would take a guitar signal and distort it in a way that the human ear would find pleasing.

The Basic Circuit

The circuit is purposely very simple. It consists of only four op-amps, four resistors, five capacitors, 2 potentiometers (pots), and 2 diodes. It is meant to be a very simple circuit for a number of reasons, most importantly, to make the understanding of the effects easier and to make the assembly of the device easier.

The first phase of the fuzz box is a simple op-amp buffer. The second phase is a variable gain phase. Because of the orientation of the resistors around the op-amp a gain of between 1 and 11 is possible. There is a small, 22-pF capacitor in parallel with the gain pot to reduce noise.

After the gain comes the diode clipping. The diode clipping section of the fuzz box circuit is the most important as that is where the actual signal distortion takes place. When the voltage in front of a diode reaches a certain set level (the turn on voltage) the diode, here's a surprise, turns on. That excess voltage goes to ground. A similar phenomenon may be seen in the negative half of the signal. The result of this diode clipping is a wave that has a flat top and bottom but curved sides (what is left of the original sine wave"). This is where the primary distortion takes place.

The next op-amp is another buffer, which is followed with the tone control setup. The tone control is just a simple, passive, high pass RC filter. This filters out a variable amount of the higher harmonics from the signal. This allows to user to get a deeper distortion or, alternatively, a higher pitched, "screechy" distortion. The tone control is followed by another buffer.

The reason for so many buffers has more to do with the arrangement of the TL072 op-amps used in this circuit than with the betterment of the circuit. The TL072 op-amp is a chip that actually has a pair of op-amps per chip. So, in favor of letting the extra op-amps go to waste, they were used as buffers.

Finally, although not shown on the schematic, voltages for the op-amps are ±9 V, supplied by a pair of regular 9 V batteries. These are wired in series such that a voltage of positive 9 V is on the one side while a voltage of –9 V is on the other.

Distortion theory

The end result of the circuit looks like a sine wave but has flat tops and bottoms. But what does this flat topped signal sound like and why does it sound that way? This flat topped signal sounds a lot like the fuzz type distortion used by many musicians. The reasons why it sounds this way are a little more difficult to explain.

The simplified analysis presented in this paper will use a sine wave as the input to the system to represent the guitar signal. Fourier decomposition is based on the idea that any periodic function may be represented as an infinite sum of sine and cosine terms with appropriate coefficients. A sine wave (the function we have defined as our input) would simply be defined as $y = A \sin(\omega t)$. A more complex function, our signal after diode

clipping, would be represented with a much longer equation, using both sine and cosine terms with increasing frequencies and decreasing amplitudes. This is the easiest way to imagine the effect of the distortion on the tonal qualities. The signal goes from being a single sine/cosine curve to being approximately a square wave, which is represented with a large number of sine/cosine curves. The base frequency has the highest amplitude and is therefore loudest, while the higher harmonics are much quieter but still prevalent. This is what is heard.

Recommendations

One improvement that could be made to this circuit is the inclusion of a final volume control. After the gain phase, the amplitude can be anywhere from 1 to 11 times the original amplitude. This represents a much larger volume. Including a volume control in the circuit would more easily allow the use of both modes of the circuit.

Also, if the distortion is not harsh enough for the listener, simply increasing the gain in the gain phase can increase the level of distortion. This is done by changing the ratio of the two resistances. Dropping the input resistance by half or more will up the gain by a factor of two. This will result in much more noticeable, harsh distortion.

Conclusions

This simple fuzz-type distortion circuit effectively and noticeably altered a guitar signal. The distortion ranged from a vintage-type overdriven tube amp distortion to a harsher heavy metal style distortion. The circuit does have a number of shortcomings

that could be addressed in future iterations but in its current state, it succeeds in what it was charged to do.

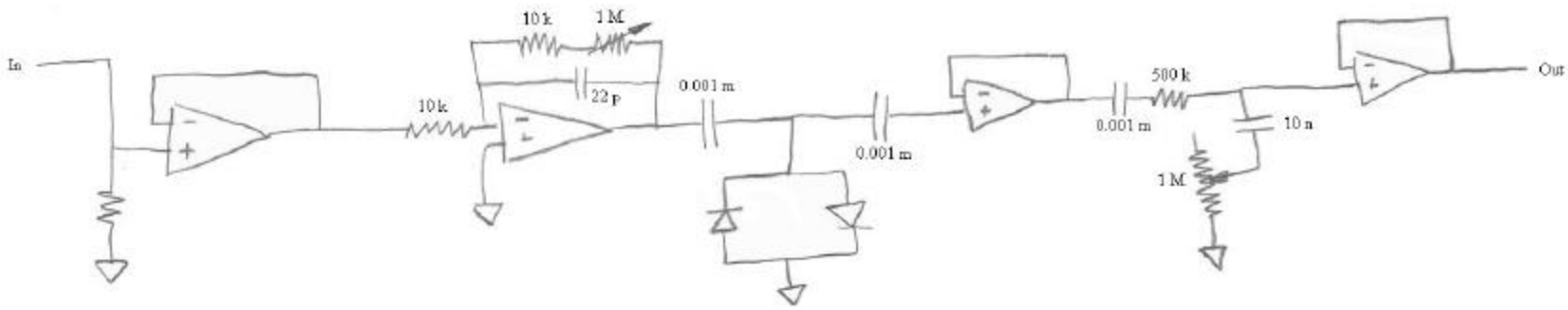

Figure 1: Schematic of Fuzz-Type Distortion Circuit