Diode-based Analog Guitar Distortion Effect

Designing and Observing various clipped waveform based on analog circuit parameter variation.

Goraksh Bendale: 23110118, Goral Mashru: 23110119, Gosike Raviteja: 23110120

***Abstract*—The aim was to design and study an analog circuit that produces signal distortion effects from scratch. Widely used in the music industry in conjunction with guitars, these play an integral role in music production. We utilised diode clipper circuits in conjunction with various high pass and low pass filters to (1) Clip the signal waveform and (2) Filter out unwanted noise, AC or DC. The circuit, void of any micro-controllers, is able to achieve soft and hard distortion with the help of diodes, op-amps, resistors, and capacitors. The output waveforms are an inherent property of the circuit and variation in the resistance and distortion parameters influence the circuit and directly the waveforms. We observe this through simulations as well as through a physical circuit.**

***Index Terms*—distortion, diode based, analog, etc.**

I. Aim

Our aim is to design an analog circuit using Op-amps and diodes, to study the signal distortion effects produced by it and to use it as a guitar amplifier circuit.

II. Theory

Diodes are semiconductor devices that allow current to pass through when connected in forward bias and offer high resistance when connected in reverse bias. In forward bias, diodes have a cutoff voltage (0.7 V for silicon diodes), which is the maximum voltage across the diode. Thus, once the current starts flowing, the potential drop across diode remains constant. This property of diodes makes it very useful in clipper circuits, used especially in distortion pedal circuits.

We can provide two types of clipping using different arrangement of diodes in a circuit.
a) Soft Clipping: This type of clipping is obtained when two diodes are connected in parallel in opposite directions in the feedback loop of the Op-amp. Soft clipping refers to the softening of the edges of the clipped signal. It produces a smoother, tube-like tone.
b) Hard Clipping: This type of clipping is obtained when two diodes are connected in parallel in opposite directions and this configuration is connected to the ground on one side. Hard clipping produces a chopped off signal with flat peaks, similar to a square wave.

In this project, we have made a circuit that contains both the soft clipping and hard clipping configurations.

III. Materials Required

A. Op-Amp 741

An operational amplifier is an integrated circuit used to perform several functions on signals, like amplification, inversion, sum, difference, multiplication, etc. It typically has two input terminals, inverting and non-inverting, and one output terminal.

B. Diodes 1N4148, LEDs

Diodes are semiconductor electronic devices that conduct electricity in one direction and offer high resistance if connected in the reverse direction. In this project, we have used diodes for the clipping function of the circuit.

C. Resistors

Resistors are electrical components that offer resistance to the flow of current. They are generally used to control voltage across two points in a circuit. In this project, we have used fixed and variable resistors to control the gain factor, tone and volume of the circuit.

D. Capacitors

Capacitors are two-terminal electrical devices that can store electrical energy in the form of charge. It consists of two conductors placed very close to each other. In this circuit, we have used capacitors to control the Op-amp gain and to make integrator/ differentiator circuits.

E. Breadboard

A Breadboard is a prototyping board with inbuilt connections which can be used as a base to build semi-permanent circuits. It has holes arranged in a grid pattern in which electrical components can be connected.

F. Switch

An electrical switch is a simple device used to connect two parts of a circuit such that the connection could be broken off or changed at any point of time. It typically contains two positions which lead to two different circuit formations.

G. Connecting Wires

Connecting wires are typically made of conductors like copper. They are used to connect two components of a circuit while providing little to no resistance.

IV. Procedure

a) Connect the input to the non-inverting terminal of an Op-amp through a 1 k-ohm resistor and a 22 nF capacitor in series.

b) Connect the variable resistor (for gain control) across the Op-amp feedback loop.

c) Connect the output of this Op-amp in series with a 100 nF capacitor and 10 k-ohm resistor to the inverting terminal of the second Op-amp.

d) Connect the soft clipping diode configuration along with a 1 M-ohm resistor and 100 pF capacitor in parallel across the op-amp feedback loop.

e) Across the output of the second op-amp, connect a 1 micro Farad capacitor, a 1 k-ohm resistor and the hard clipping diode configuration.

The output of this circuit will provide a clipped signal. The various capacitors and resistors used in the circuit help to filter out the unwanted noise.

Fig. 1. Circuit designed in the laboratory

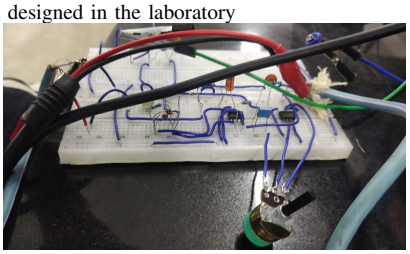
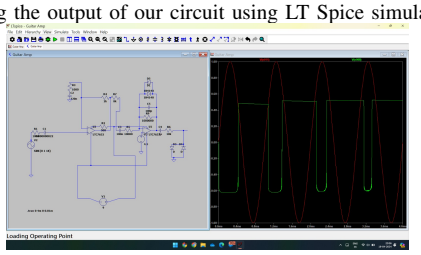


Fig. 2. Testing the output of our circuit using LT Spice simulator



V. Results

A. Taking input from a signal generator and obtaining output on a DSO

We took a 200 Hz, 1 Vpp sinusoidal wave as the input signal. The output we observed on the DSO was a sinusoid that was clipped at the peaks, which looked somewhat like a square wave. The Amplitude of the output signal was about 0.7 V, which is the cutoff voltage of a silicon diode.

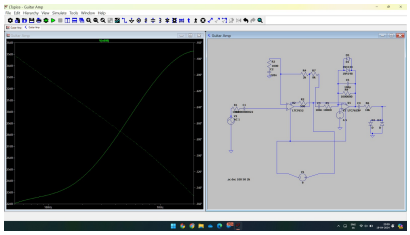
On increasing the amplitude of the input signal, the output showed more and more sharp clipping.

Fig. 3. Taking input from a signal generator and obtaining the clipped signal output on a DSO

B. Taking input from an Electric Guitar and obtaining output on a speaker

We took the signals obtained from an electric guitar as an input and connected the output to a speaker in an attempt to reproduce the distortion pedal circuits on our simple analog circuit without using a microcontroller. We observed that the sounds plaayed from the guitar seemed to be distorted.
Additionaly, by varying the resistance connected to the feedback loop of our first op-amp, we were able to regulate the gain of the output signal, which was noticeable from the speaker output. We also demonstrated the effect of variable resistance on the LT spice simulator by creating Bode plots at different values of the variable resistance. We observed that as the resistance increased, we obtained a higher gain at higher frequencies.

Fig. 4. Bode PLot showing Gain vs Frequency at a Variable resistance value of 2 k-ohms



VI. Discussion

Through this project, we obtained some valuable insights about the working of clipping circuits and the practical implementation of op-amps and diodes.
The results we observed fairly resonated with the theoretical outcomes. We had also tried to include some more controls into our circuit which are involved in actual distortion pedals, like tone control and volume control. However, they did not produce satisfactory results. We believe there is scope for us to try and incorporate them into our circuit to improve its functionality.
Apart from this, there is also scope for variation and experimentation with the diodes we used in our circuit. For example, we could replace the silicon diodes with LEDs and study the effects it has on the output. Such analysis would allow us to choose the best diode for our circuit.