AUDIO CLIPPING PREAMP FOR ELECTRIC GUITAR

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Introduction

In the modern sound/audio industry the term "tone" is frequently used to describe the sound quality that an audio device can produce. "Exceptional Tone", when referring to a device used in sound modification and amplification, illustrates the ability to replicate or improve upon the audio appeal of a source that is fed to it. This concept of sound quality enhancement has been applied to the instrument of the guitar in the form of pre-amplification units ("stump pedals"), intended to give the player the ability to alter the guitar's "tone" with the push of a button. One such product is known as *The Tube Screamer*, created by Ibanez Co.. This analog device is designed to produce "clipped tones" (distortion) that emulate the warmth of an overdriven vacuum tube power amplifier. The industry trend is to depict multiple analog devices like *The Tube Screamer* and implement their various sound clipping functions into one package using digital technology for the aim of diversifying the control of sound pre-amplification.

Research Project Objectives

Unfortunately, this procedure fails to effectively capture the tone quality of the individual analog devices being emulated. In order to correct the shortcomings found within digital preamps, an analog device is proposed here that allows diversity of functional controls, as well as excellent tone quality. Three objectives have been accomplished for achieving these goals. The first objective is to replace the '*Tube Screamer"* configuration of the operational amplifier, to a summation gain set up. This allows the device to produce more gain, resulting in a larger range of clipping distortion. The second objective alters the frequency response of the device, allowing lower "bass" frequencies to be amplified. This objective is implemented by adding a switch that allows the user to change the reactance within the summation circuitry, thereby altering the low-end frequency response of the entire system. Thirdly, a clipping network has been developed that allows the shape of the clipped signal produced by the summing amplifier to be adjusted. This is accomplished by placing two silicone-controlled rectifiers and a variable RC network within the summation gain feedback loop.

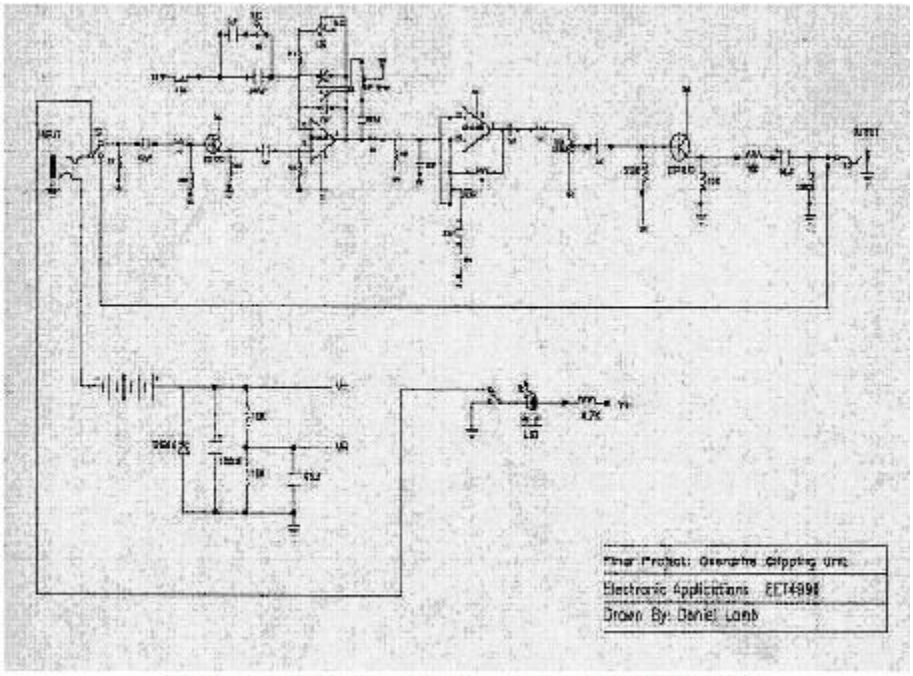

Fig. 1. Schematic Diagram of the proposed design set up

Theoretical Analysis and Implementation Details

In the first process the summation gain of the preamplifier has been modified. The findings referring to clipping and gain reveal three points within the pre amp's functionality that could be improved upon. Firstly, the gain of the non-inverting, negative feedback amplifier using the pre-existing configuration was noted to be $A_V = 1010$ (+60dB). Since the output of the amplifier distorts further as gain increases, an increased level of gain from the op amp would increase the range of clipping that the pre amp could achieve. In order to achieve this increased gain, a summation amplifier setup is proposed which is twice the gain of the pre existing configuration. Summation gain approximately doubles the A_V level, allowing a larger range of clipping. If a larger level of gain where needed, more input summation leads could be summed together.

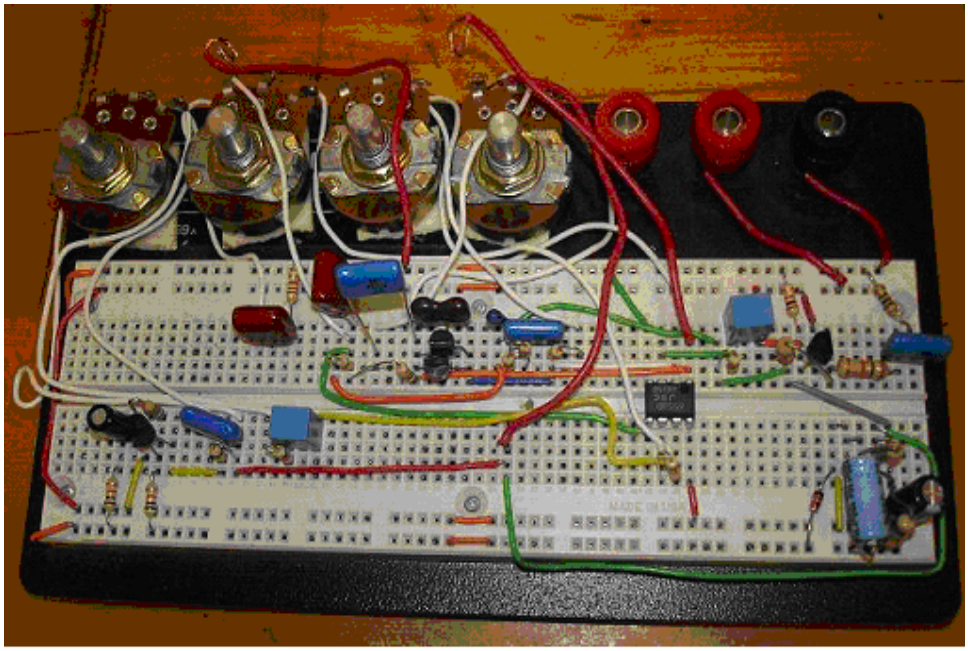

Fig. 2. Bread board set up of the complete system

It has been identified that substantial amount of work can be done to improve the frequency response of the operational amplifier gain. The frequency range for the gain of the op amp is dependent on the impedance of two capacitors. By changing the values of one of these capacitors, the level of frequencies which the op amps gain will respond to can be increased. This proposed alteration is to be implemented

Fig. 3. Internal Details of the final product

by connecting a capacitor in parallel using a SPST switch to the capacitor that is in series with R_I. When the switch is closed, the parallel capacitance combination alters Z_I, thereby extending the op amps gain response range to lower frequencies.

The third and important aspect that needs to be improved is the capability of this circuit for clipping. This is an area in which many boutique pre amp builders have attempted to alter by implementing a variable clipping system to replace the stock 1N914 diodes within the *Tube Screamer*. Due to the deviation found in various diodes voltage conduction ranges, a multi-position selector switch connecting various types of diodes in parallel R_F produces a crude variable clipping system. The problem with this system is that it is limited to the number of types of diodes that are implemented, and the range of clipping is not continuous but rather stepped. In order to correct this, a continuous variable clipping system using a silicone controlled rectifier (SCR) and RC network is proposed. The SCR is a three terminal device composed of an anode, cathode, and gate. It conducts from the anode to the cathode when there is an adequate signal levels of parameters V_{GT} and I_{GT} (gate trigger voltage and current) are present on the gate terminal. By replacing the 1N914 with the SCR, and feeding the output from the op amp through a variable RC phase shifting network and connecting it to the trigger, the SCR can be turned on and of at various points of the signal waveform. This causes the SCR to be used as a vertical clipping device by shorting R_F gain element at various levels depending on the phase of the trigger signal.

Discussion and Results of Proposed Circuit Implementation

Upon completing the inquiries that can be made into the functionality of the pre amp's circuitry and proposed modifications have been designed, it is necessary to test these modifications in a laboratory setting. The pre amp schematic was breaded in a laboratory environment, and a function generator signal was fed to the input to simulate a signal from a guitar. A guitar signal was not used for tests concerning oscilloscope snap shots due to the unstable nature of the produced waveform. The signal used was $1V_{AC}$, 1,109Hz, which is equivalent to an open D note on the guitar.

Fig. 4. Final product packaged and fully funcational

The exact levels of gain achieved by the original *Tube Screamer* and the proposed summation amplifier were unable to be measured to the fact that the JRC4558D clips before the extent of the gain can be produced. One measurement that was taken that was helpful in determining the increase of gain for the summation amplifier was to take a reading of the R_F rheostat when the exact moment of clipping in the op amp occurred. These readings are as follows:

Summation: op amp clips at $R_F = 11.4K\Omega$; *Tube Screamer:* op amp clips at $R_F = 14.4K\Omega$

These readings show that the summation amplifier setup clips at a lower value of R_F. If the same value of rheostat is connected in the summation as the pre existing set up, a larger range will then be able to be achieved. The proposed variable clipping modification was tested by first choosing an SCR with appropriate current and voltage trigger levels. The proposed gain frequency response modification was tested by placing 1uF tantalum capacitor in parallel with the pre existing .047uF capacitor in the Z_I leg of the op amp.

Conclusions

The project produced interesting and unique results. After testing the proposed circuit in the lab environment with a function generator, an electric guitar was attached as an input signal. The pre amp was connected to a power amplifier/speaker to make conclusions on the functionality of the finished pre amp in producing pleasing distortion tones that mimics an overdriven vacuum tube amplifier. The results were pleasing as the output signal from the pre amp could be manipulated within a wide range in the areas of clipping, gain, and frequency response. Although the vertical clipping produced by the SCR was not identical to the horizontal clipping levels found in boutique pre amps, its unique sound was agreeable. The clipping of the SCR was also enhanced by the extended range of gain available from the summation amplifier configuration. The low-end frequency response, when activated using the 1uF capacitor, brought out bass frequencies in the guitar that were previously unnoticeable. The proposed schematic is constructed on a PCB circuit board and placed within an aluminum enclosure to decrease chances of external noise interfering with the pre amp's operation. The pre-amp is activated using a DPDT stomp actuating switch to allow the pre amp circuitry to be fully bypassed when not in operation. The frequency gain range selector switch is also stomp actuated in order to allow the guitar player the ability to activate its function with his foot, leaving his hands free for guitar operation.

Daniel Lamb has been working relentlessly for the last six month's on these designs. Final results are extremely valuable which can achieve a diverse range of tonal control than any other design techniques implemented to date. Various implementation stages can be seen from the figures 2-4 that are close to the final product which Dan plans to sell in the market.