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A new Design for Audio Clipping Pre-amplifiers based on Silicon Control Rectifiers

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Abstract

This paper presents a new engineering approach to audio clipping preamplifier that can be used for the tone modification and volume control of electronic devices. The approach consists of a unique design based on a summation amplifier, Silicon Controlled Rectifiers (SCR) and RC networks that enables signal gain, improved frequency response, tone modification and signal shape clipping. The proposed summation amplifier based design produces more gain resulting in larger range of clipping effect as compared to existing methods. The response is altered to produce low bass frequencies that have been amplified based on a new configuration allowing the user to change the reactance within the summation circuitry. Also, a new technique of Silicon Controlled Rectifiers (SCR) with a variable RC network accomplishes a clipping network that adjusts the shape of clipping signal. The main advantage of the proposed amplifier is that it can generate a wide range of tonal control that to date the industry has yet to produce. The proposed method being an analog approach also addresses current drawbacks found within the digital preamplifier which fails to effectively capture the tone quality of the individual analog devices. The paper explains the design details, simulation set up including analysis, real-time testing/trouble shooting on an electric guitar and constructional details.

Introduction

The notion that distortion produced by an amplifier could be beneficial to tone, dates back to the early days of guitar amplification. Before solid-state devices, all guitar amplifier systems were powered by vacuum tubes. When these amplifiers were operated at high audio levels, their power tubes would operate in saturation, thereby producing a pleasing clipped distortion and of the guitar signal. This distortion produced by vintage amplifiers is a greatly sought after sound in modern guitar amplification. Modern tube amplifiers are able to achieve vintage distortion, but tube power amplifiers as a whole have several disadvantages such as they can be costly to maintain, as tubes need frequent replacement. Also the higher power tube amplifiers are notably heavier and more cumbersome than modern solid-state amplifiers.

Many solutions to the tube/solid-state amplifier dilemma have been explored, the most popular of one being the use of analog pre-amps as a supplement or replacement of vacuum tube units. One such pre-amp is the *Tube Screamer* [1] developed by the *Ibanez Co.* in the late 1970's. This product utilized distortion produced from an operational amplifier to replicate the overdriven sound of vintage vacuum tube amplifiers. The *Tube Screamer* was set apart from other devices like it, in that it produced a warmer and more accurate depiction of tube distortion. This was largely due to two 1N914 clipping diodes that were implemented across the feedback loop of the operational amplifier. These diodes effectively developed a smooth clipped waveform, thereby causing a warmer sound to be produced [2].

Several versions of the *Ibanez Tube screamer* have been released since 1970 as it has become popular due to the unique tones produced by its diode clipping circuit. In 1985, the Master or L-series were introduced and subsequently a Power series version was developed. Further in 2000 a Tone Lok series were introduced which included a switch for added gain [3]. One of the main reason for Tube Screamer's success was it subtlety in producing the clipping circuit. *Ibanez's Tube Screamer* product has inspired many other independent "boutique" builders [4], [5] to create replica devices based around its circuitry. Generally, these boutique pre-amps are able to fetch large sums of money due to the fact that many are hand wired, and can be built to individual customer specifications. Such specifications usually include packaging appearance and feature modifications as well.

One such variation now in production is the Maxon OD808 [6]. The OD808 design is virtually identical to the original TS808 circuit and features a dual operational amplifier IC chip (JRC4558D) which is a reissue of the original chip (JRC4558) containing dual operational amplifier that is internally compensated. Functionally they have excellent channel separation allowing the use of a dual device in a single amp application. The unit guarantees 2MHz unity gain with short-circuit protection. It does not require any frequency compensation and provides low power consumption, large common-mode and differential voltage ranges. The packaging on the OD808 is reminiscent of vintage pre-amps with its thin (wide) metal box and large foot switch. In another effort, Aramat [7] offers a Super 808 mod to a modern Tube Screamer (TS9, TS9DX, TS10, TS5 or TS7). These original "vintage" chips claim to have a much warmer and transparent sound. The necessary resistors are changed and a Germanium diode is added to the drive stage, which adds gain, clarity, and expressiveness.

This research effort delivers an entirely different and unique approach for audio clipping preamplifier. The important areas of development include gain amplification with summation amplifier and improved clipping circuit with Silicon Control Rectifier (SCR) and an RC network.

The paper describes

- the basic technology in tone modifying pre amp;
- the important design changes that are incorporated in the proposed method;
- gain amplification for maximum clipping range;

- improvement in clipping based on an RC network developed using SCR's;
- improvements in the frequency response of the op amp gain;
- discussions and merits of the proposed circuits; and
- Conclusions.

Technology in the Tone Modifying Pre Amp

An overview of the technology in tone modifying preamp is necessary before a detailed investigation into its functionality as a clipping pre-amplifier can be made. This section will demonstrate the basic building blocks of a tone modifying and audio clipping pre-amplifier. The block diagram of the proposed circuit is as shown in figure 1 and each block are discussed and analyzed as follows.

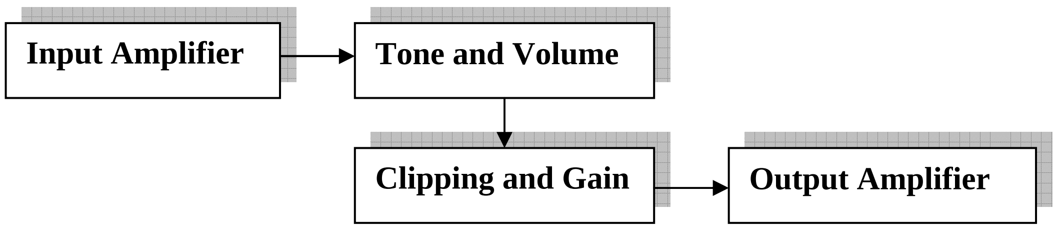

Figure 1: Block diagram of a tone modifying and audio clipping pre-amplifier

<u>Input and Output Amplifiers</u>

The input and output amplifiers are both 2N3904 transistors and are biased in an identical emitter follower configuration. Their purpose is to provide high input impedance and low output impedance buffer to prevent electrical loading. This buffer is essential in guitar pre-amplification due to the high impedance of guitar pickups that produce the input signal. The high input impedance and the impedance of the pickups, function as a voltage divider. Also, higher buffer input impedance corresponds to a larger signal voltage being present across the load. Both input and output buffers provide a unity voltage gain, but a significant current gain. Appropriate derivations and results for 'Z_{IN}', 'A_V' and 'A_I' are as follows:

$$A_v = \frac{[(1+\beta)R'_L]}{[R_\pi + (1+\beta)R'_L]} \quad (1)$$

$$Z_{IN} = Z_{INT} \parallel R_B \quad (2)$$

$$A_I = \left[A_V \left(\frac{Z_{IN}}{R'_L} \right) \right] \quad (3)$$

Where: 'A_V' represents voltage gain, 'Z_{IN}' the input impedance and 'A_I' the current gain.

It is worth noting that the design for lowest noise at this stage is not important as the clipping and tone modification stages enables for noise clipping, gain amplification and tonal modification. The only requirement at this stage will be to ensure input and output impedance matching that has been accomplished by the amplifier design.

Clipping and Gain

After the signal is buffered from the pickups of the electric guitar to the pre amp, it enters the clipping/gain section. This section utilizes one of the operational amplifiers that are contained within the implemented dual operational amplifier package. This operational amplifier is a widely used one in audio amplification due to its excellent slew rate and the manner in which it distorts when operated beyond its limitations. The pre amp configures its gain op amp as a non-inverting amplifier with negative feedback. The theoretical expression for circuit is given by:

$$A_V = V_{IN-DC}\left[1+\left(\frac{R_F}{R_I}\right)\right] \qquad (4)$$

This large amount of gain causes the op-amp to distort the guitar signal in a fashion similar to the distortion of the vacuum tube amplifier. The gain also determines the frequency response of the pre amp. Within the negative feedback configuration there are two capacitors. The first capacitor is located in parallel with R_F, which decreases the effective 'Z_F' value. As frequency increases, the impedance of the capacitor $\left(Xc = \frac{1}{2\pi fc}\right)$ decreases, thereby decreasing the value of 'Z_F' and the resulting gain (A_V). The second capacitor is located in series with 'R_I', which increases the effective value of 'Z_I'. As frequency decreases, the impedance of the capacitor increases, consequently increasing the value of 'Z_I' and decreasing the gain. Due to the relationship between theses two capacitors and the gain, a frequency bandwidth is created. Each capacitor's sets the high and low frequency limits for this bandwidth.

The clipping is a function of the negative feedback configuration. Two 1N914 signal-clipping diodes are located in apposite directions parallel to 'R_F'. These diodes have a threshold voltage at which they are forward biased and act like a short circuit. The effect of this threshold voltage is that as the amplified sinusoidal signal from the guitar ramps up to the 0.5V - 0.7V limit, it receives the full gain determined by 'A_V'. When the signal passes into the threshold range, the diodes begin to conduct causing 'A_V' to drop of towards one, gradually clipping the peaks of the positive and negative alterations of the signal. Since the signal is already harshly clipped due to the distortion from high gain op amp, the diode's gradual conduction smoothen corners of the clipped output.

Tone and Volume Controls

The output from clipping/gain stage is fed to an active tone filter, which utilizes the second op amp within the dual op-amp package (JRC4558D). Its role is to cut out any harsh high frequencies produced as a result of the distortion introduced by the clipping and gain. The cut-off frequency for this low pass active filter can be adjusted by a potentiometer strung across the negative and positive inputs of the op amp. The adjustment of cut-off frequency is warranted when the proposed pre-amplifier is used with various electric guitar devices. The tuning will be accomplished during the initial stages of device set up.

The volume control is another potentiometer device with the output from the tone control connected to one terminal, V_{IN-DC} connected to the other, and the signal out connected to the wiper. As the potentiometer is adjusted, various levels of signal are fed to the output buffer due to the voltage divider between V_{IN-DC} and the wiper output. The adjustment to deliver substantial changes in the volume level together with smooth audible tone due to high frequency cut off has been considered as notable feature of this pre-amplifier.

Proposed architecture and developments

A complete basic schematic of the *audio clipping preamplifier based on the Silicon Control Rectifier* evolved from the previous discussion is as shown in figure 2.

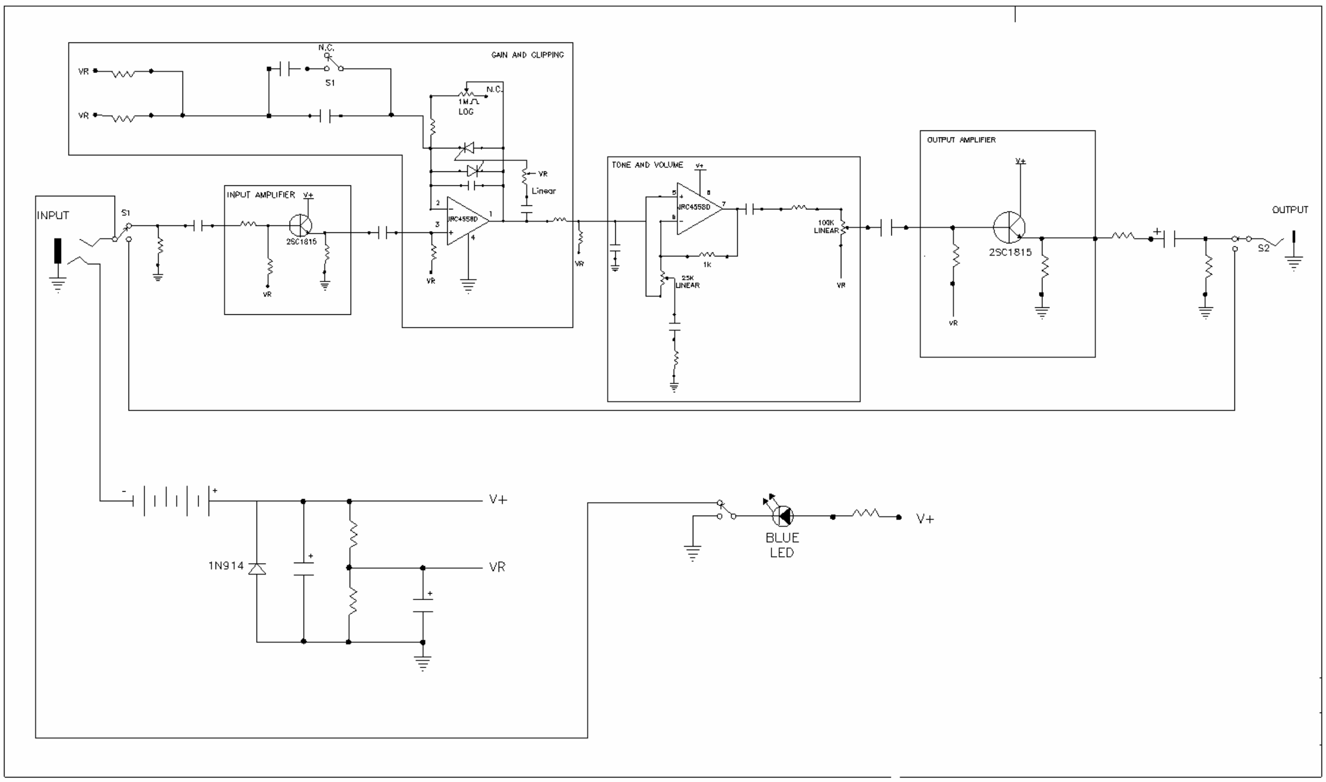

Figure 2: Proposed Audio Clipping Pre-amplifier based on Silicon Controller Rectifier

The relevant improvements and the technical details of this circuit are as follows.

<u>Input and Output Amplifiers</u>

As previously stated, the buffer amplifiers provide high input impedance, low output impedance, a unity voltage gain, and an adequate current gain to the rest of the circuit. Following derivations explains how 'Z_I' and subsequently 'A_I' can be improved by changing 'R_B'.

Derivations of 'A_V' can be developed as follows [8]:

$$V_B = R_B I_B + V_{BE} + [R_E(1+\beta)] \tag{5}$$

$$I_C \cong \beta I_B \tag{6}$$

$$V_{CE} = V_{CC} - I_C R_C \tag{7}$$

$$R'_L = R_1 \parallel R_C \tag{8}$$

$$R_\pi = \left(\frac{V_T \beta}{I_C}\right) \tag{9}$$

and $$A_V = \frac{(1+\beta)R'_L}{R_\pi + (1+\beta)R'_L} \tag{10}$$

Based on this and with proposed values, 'A_V' (= 0.98) was found close enough to unity for the purpose in which the amplifier is used. 'Z_I' can be calculated as follows:

$$Z_{IT} = V_{IN} / I_B = [R\pi + (\beta + 1)R'_L] \tag{11}$$

$$Z_{IN} = Z_{IT} \parallel R_B \tag{12}$$

Where: 'Z_{IT}' represents the base impedance.

When appropriate values are applied, a high level 'Z_{IN}' can be obtained. This high level of 'Z_{IN}' is adequate to overcome any signal loss due to the high impedance of the guitar pickups. Increasing the value of 'R_B' would subsequently increase the value of 'Z_{IN}'. For example, a case with a value of 1MΩ for R_B yielded a Z_{IN} = 605KΩ.

Based on the calculations for 'A_V' and 'Z_{IN}', the current gain 'A_I' can be obtained as follows:

$$A_I = A_V (Z_{IN} / R_L) \tag{13}$$

An increased 'A_I' can be achieved by increasing the value of 'R_B'. For the case of R_B = 1MΩ, 'A_I' was found to be 118.58.

Clipping and Gain

The discussions outlined in the previous section reveals three important aspects within the pre amp's functionality that could be improved upon. These improvements greatly enhance the ability of pre-amp and are the main contribution of this research effort. The design details of these changes and how that enhances the capability of the amplifier is discussed next.

Gain Improvement: Firstly, the gain of the non-inverting, negative feedback amplifier using the pre-existing configuration was increased. This would extend the range of clipping produced by the output of op amp. In order to achieve this increased gain, a summation amplifier setup is proposed which will double the gain of the previous setup. Functionality of this proposal can be derived as follows:

$$A_V = [(R_F + R) / R_A] V_{INA} + [(R_F + R) / R_B] V_{INB} \tag{14}$$

It has been observed that the summation gain approximately doubles the 'A_V' level, allowing a larger range of clipping. If a larger level of gain was needed, more 'V_{IN}' legs could be summed together. The details of this modification and design can be seen from figure 3.

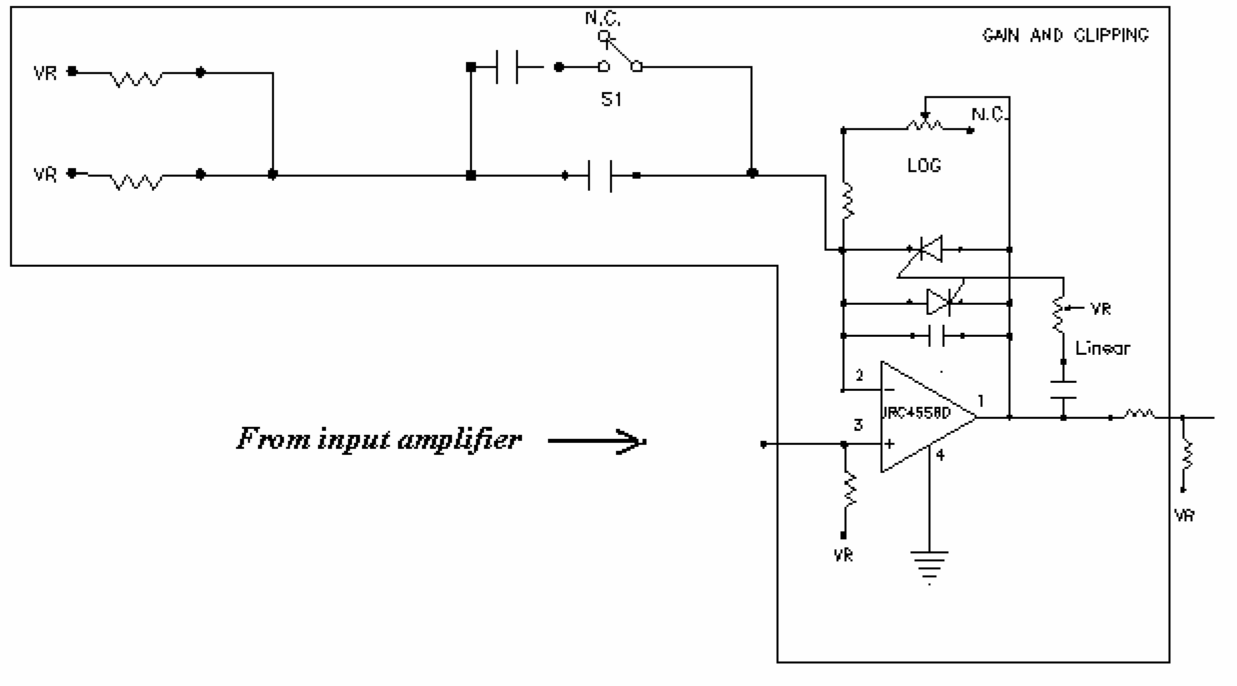

Figure 3: Proposed clipping and gain circuit

Improvements in 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 diodes (1N914) within the *audio clipping pre-amplifier*. 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 Silicon 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 gate signal level ('I_{GT}' and 'V_{GT}'). Figure 4 shows the forward and reverse characteristics of an SCR. By replacing diode with the SCR, and by feeding the gate from the output of the op amp through a variable RC phase shifting, 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. The trigger phase is adjustable using a 25KΩ potentiometer and a 0.1uF capacitor.

The theoretical details on this new treatment of using SCR for clipping can be explained as follows. One of the important considerations is to clip the output waveform of the signal such that the audio effect can be improved. This is till now done using two diodes back to back acting on the feedback path of the operational amplifier. In the proposed design two SCR's have been introduced in the feedback path of the operational amplifier as shown in figure 3. The idea behind such an approach is to allow clipping as needed as opposed to a continuous value. The gate control of the SCR triggers ON/OFF states such that the vertical clipping is achieved as required. The important concept is to design a gate trigger circuit to achieve this objective and to turn on and operate the SCR in the forward mode.

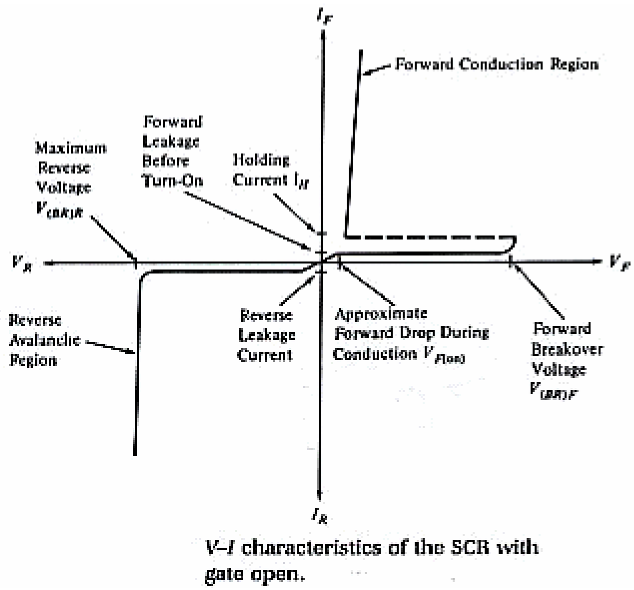

Figure 4: Typical SCR Characteristics [9]

The gate is triggered by using a variable resistor capacitor combination which has a voltage potential derived from the amplifier output. When higher clipping occurs, the modulation and distortion has a negative impact on the output. This means, fixed clipping produced by the diodes even though desirable has never been an optimal method for clipping. However, as it can be noticed from the previous discussions that variable clipping can worsen the output signal if not done effectively. As known, the RC series circuit provides the impedance as follows.

$$Z = R - j\left[\frac{1}{2\pi fC}\right] \qquad (15)$$

$$\tan\theta = Xc / R \qquad (16)$$

This impedance design is a critical factor in providing optimal clipping. The development of harmonics in the output for smooth clipping clearly shows that an optimal value of frequency is required for perfection at various input values. Based on the proposed design, the gate triggering circuit is adjusted in such a way that when the waveform central frequency falls below a predefined value (calculated based on the offline studies and testing), the impedance increases which makes the gate current to fall below the threshold. As it can be seen in figure 3 and 4, the triggering angle is in fact adjusted by this arrangement. On the other hand, if the frequency of the output changes, the impedance angle will change accordingly (16). As shown in figure 5, this will in turn change the firing angle and the average voltage requires triggering the gate. Thus when frequency is high the firing angle is low making the average voltage and gate trigger current higher.

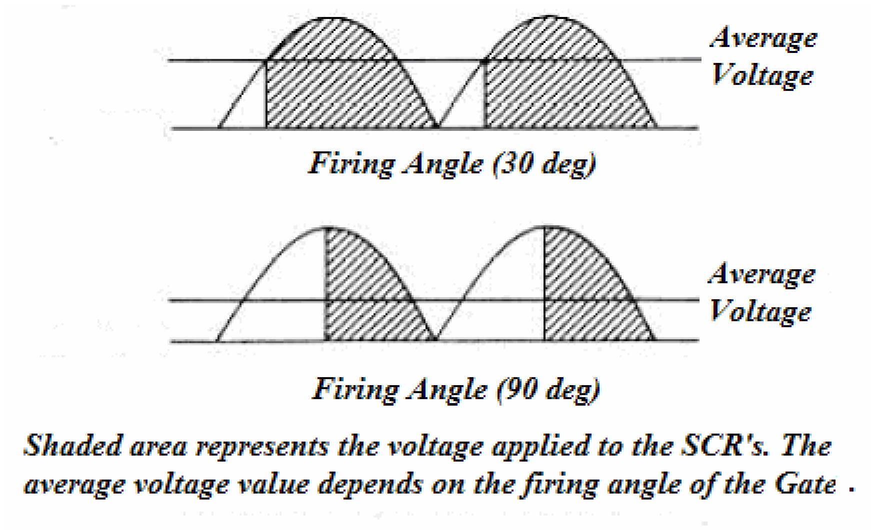

Figure 5: SCR firing and average voltage for various angles

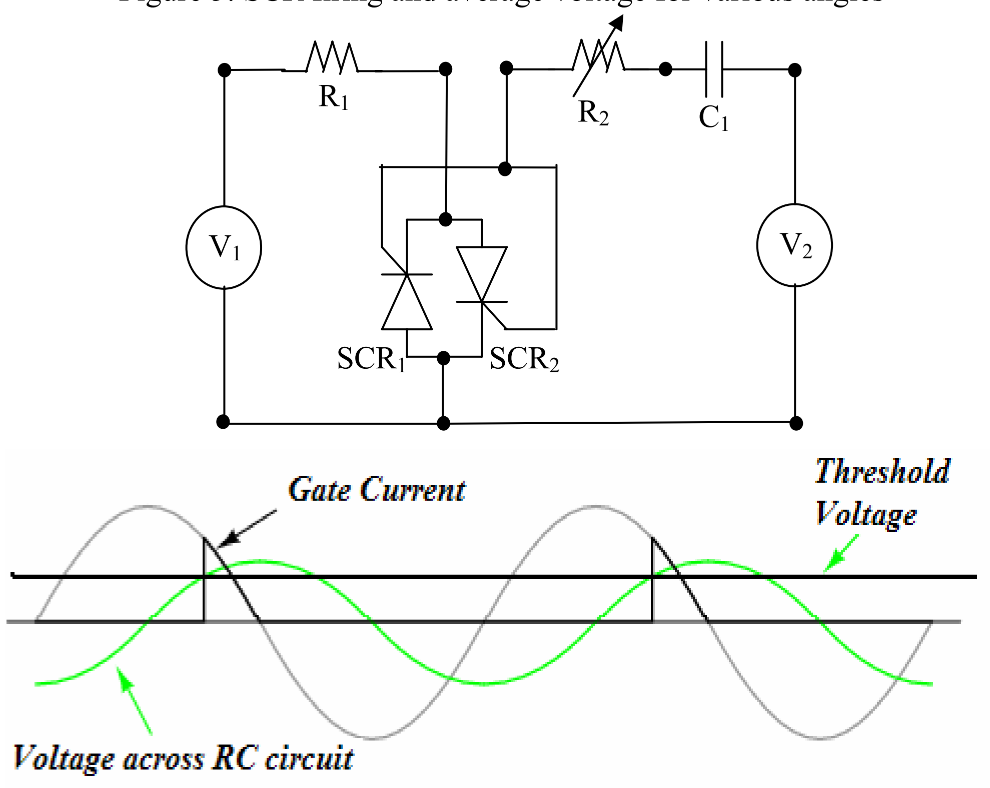

Figure 6: SCR clipping circuit model and waveforms

Figure 6 shows the circuit model, the voltage across the RC circuit and the current used to trigger the SCR's. When the voltage value reaches it peak, the RC voltage is still rising. This gives the advantage of current triggering the SCR (which is obviously the current through the RC network), on a certain point of time other than the voltage peak. As explained in (15) and (16), the angle of capacitor RC voltage can be changed by using the variable resistance and there by changing the gate trigger value. One of the main concerns in such a design is that when the SCR latches itself onto the ON position, the voltage across RC circuit distorts by itself. However this is during the OFF to ON state which is a very small duration.

In the event of forward voltage (voltage across the clipping circuit) falling below a pre-defined value the anode current falls below the holding current thus turning off the SCR's. This is an extremely important characteristic of the proposed circuit that has been achieved since the anode current is directly proportional to the output of the amplifier. Thus, if the input signal varies, anode current changes which in turn affect the clipping. As it can be seen from the diode design, till now there is no way that the clipping can be controlled. Thus, the proposed scheme can be used to a) turn OFF and ON the clipping circuit and to effectively control the clipping level.

Various configurations of clipping circuits were looked into to obtain the proper level of 'I_{GT}' to turn the SCR on and off. These configurations as discussed below were constructed and tested.

- Signal from op amp ⇒ capacitor ⇒ potentiometer with wiper to ground ⇒ SCR trigger
- Signal from op amp ⇒ capacitor ⇒ potentiometer with wiper to $4.5V_{DC}$ ⇒ SCR trigger
- Signal from op amp ⇒ emitter follower current amplifier ⇒ capacitor ⇒ rheostat ⇒ SCR trigger.

It was identified that the voltage 'V_2' is required for efficient clipping which consists of $4.5V_{DC}$.

<u>Modifications in frequency response:</u> The third area that needs improvement deals with the frequency response of op amp gain. As outlined earlier, the frequency range for the gain of the op amp is dependent on the impedance of two capacitors. Previous research external to this paper has proposed widening this frequency bandwidth by changing the values of these capacitors. This proposed design is to be implemented by connecting a capacitor in parallel using a SPST switch to another 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 following cases for a low frequency signal of 30Hz will explain this concept further.

Case with open switch: C = 0.047uF

$$X_C = 1/2\pi(30 * 0.047\mu F) = 112.88K\Omega \tag{17}$$

For specific values of components mentioned in figure 2 and 3,

$$A_{VMAX} = [(1M + 4.7K)/4.7K + 112.88K)]*9 = 76.9(37.7dB) \tag{18}$$

Case with closed switch: C = 1.047uF

$$X_C = 1/2\pi(30 * 1.047\mu F) = 5.07K\Omega \tag{19}$$

Similarly using the designed component values,

$$A_{VMAX} = [(1M + 4.7K)/4.7K + 5.07K)]*9 = 925.8(59.3dB) \tag{20}$$

*Note for low frequencies, reactance from C_F can be disregarded and Z_F approximated as 1MΩ.

It is apparent that when the switch is closed, larger gain levels can be reached at lower frequency levels.

Discussion and Results

In this section the test results based on the proposed modifications are illustrated. 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 since the time varying measurements cannot be produced due to the dynamic nature of the guitar signal. Instead, the signal level of $1V_{AC}$ has been used with 1.109Hz (figure 7), which is equivalent to the 'D' string on a guitar.

Summation Gain

The exact levels of gain achieved by the proposed summation amplifier were unable to be measured due to the fact that the dual op-amp package clips before the extent of the gain can be produced. Instead, measurement was taken (value of potentiometer 'R_F' at the instant of clipping) for cases with and without summation gain amplifier. These readings are as follows:

With summation: op amp clips at R_F = 11.4KΩ
Original Circuit (with out modification): op amp clips at R_F = 14.4KΩ

These readings show that the summation amplifier setup clips at a lower value of the 'R_F' potentiometer. Thus for a fixed value of 'R_F', the summation amplifier will produce a larger gain output than the original audio clipping preamplifier. A snap shot of the summation gain can be seen in figure 8**.**

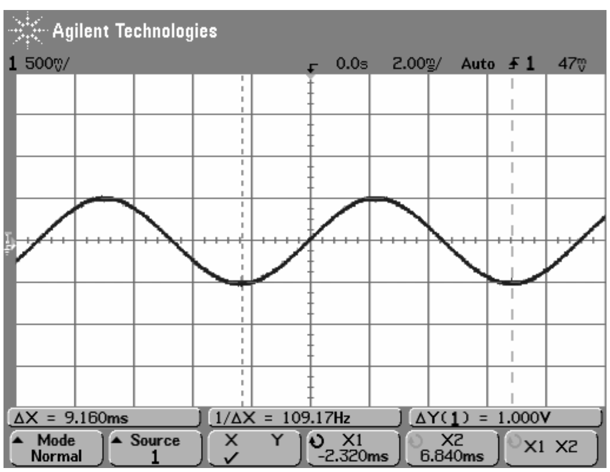

Figure 7: Input from function generator.

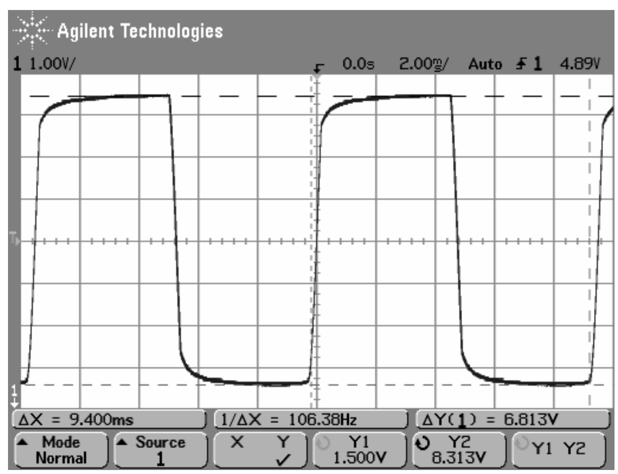

Figure 8: Summation gain clipping @ R_F

SCR Variable Clipping

Initially the details of the clipping with and without the diode have been studied. The details are as illustrated in figures 9 & 10, respectively. As it can be seen from these figures the diode clipping provides a positive effect and is one of the important concepts in the tuning which strengthen the earlier thoughts.

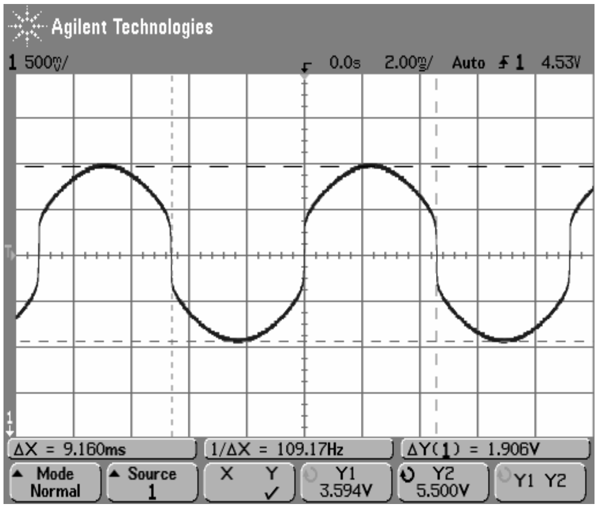

Figure 9: 1N914 Diode "smoothed clipping"

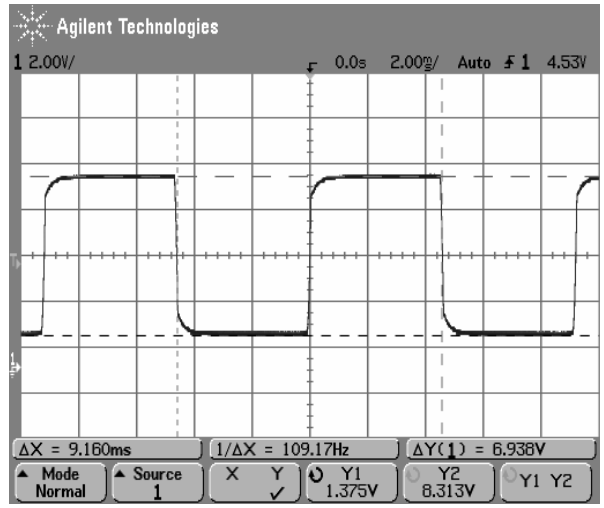

Figure 10: Op amp distortion without diodes

- Wiper to $4.5V_{DC}$: (Figure 11, 12): Range of clipping satisfactory with limits of no vertical clipping reminiscent of the 1N914 diode, to extreme vertical clipping.

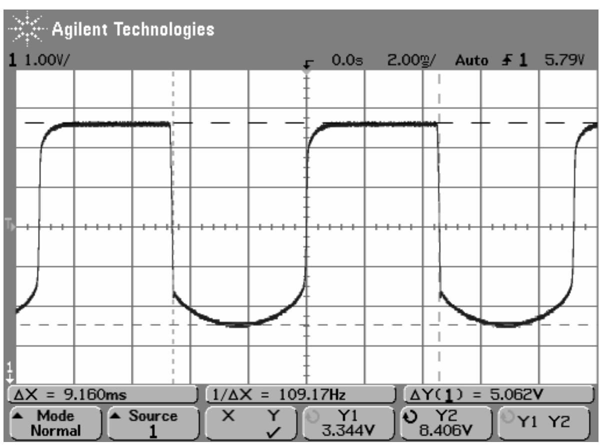

Figure 11: SCR with wiper to 4.5V @ 100% of potentiometer

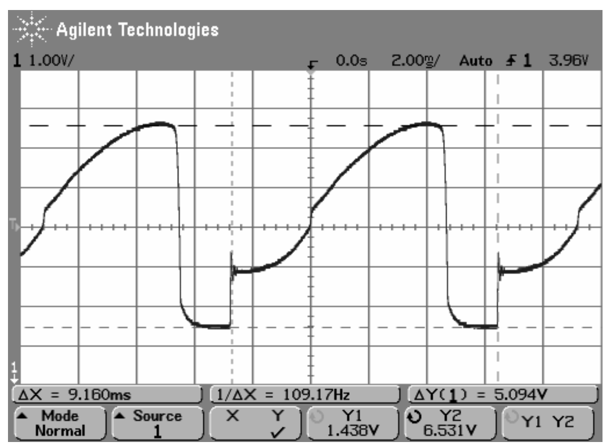

Figure 12. SCR with wiper to 4.5V @ 0% of potentiometer

Before testing the proposed variable clipping modification, an SCR with appropriate current and voltage trigger levels was chosen. After looking into various SCR data sheets, the NTE5400 was selected due to adequate trigger parameters of I_{GT} = 0.8A, and V_{GT} = 0.8V. The NTE5400 was then placed appropriately on the breadboard, and snap shots were taken of the clipped output with two of the RC network configurations outlined in the previous section. Two configurations arise as a result of these improvements. These results are demonstrated in the following figures. From these results it is clear that the SCR clipping provides a variable clipping arrangement that is extremely useful for tone control. The fact that this is being accomplished using the input signal to the amplifier itself is another advantage. This online variable clipping approach is new and provides a way to control the tone depending on user interaction.

- Wiper to ground: (Figure 13, 14): Range of clipping produced was not satisfactory due to insufficient 'I_{GT}' from RC network.

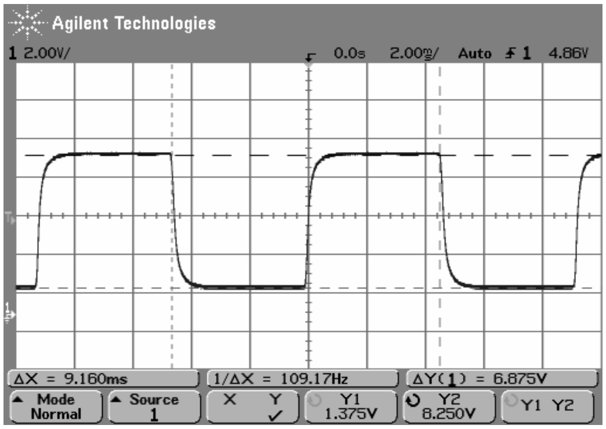

Figure 13: SCR with wiper to ground @ 100% of potentiometer

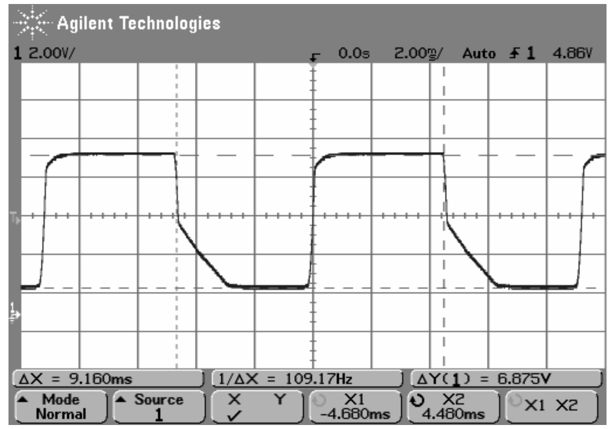

Figure 14. SCR with wiper to ground @ 0% of potentiometer

It should be worth noting that the RC configuration 3 outlined in previous sections was not tested due to the fact that the current gain it produced was unnecessary.

Low End Frequency Response

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. Snap shots were then taken of a low 30Hz input signal at C_I = .047uF, 1.047uF (figure 15 and 16).

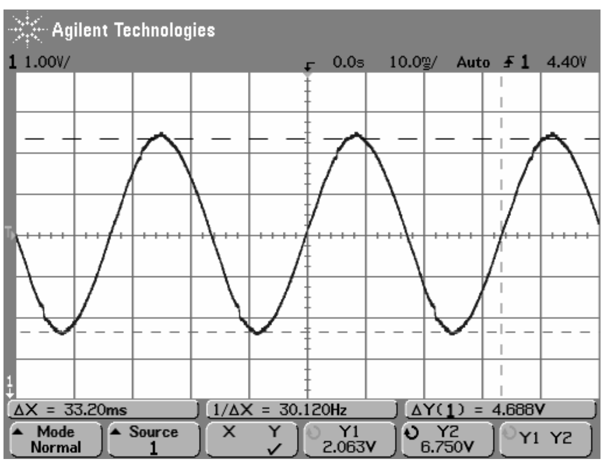

Figure 15: Op amp gain with C_I = .047uF

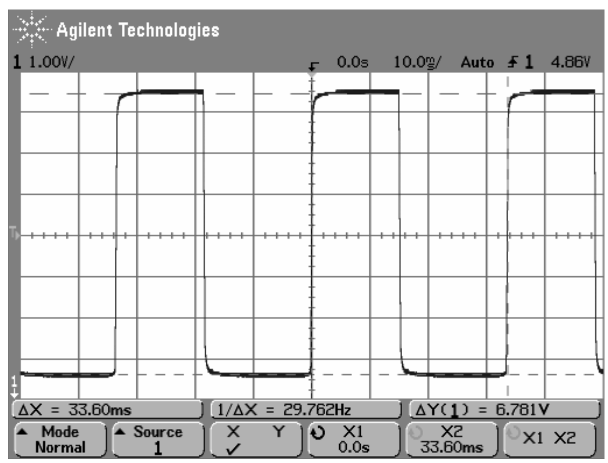

Figure 16: Op amp gain with C_I = 1.047uF

From figure 15 it is noticeable that when C_I = 0.047uF then, 'V_{OUT}' is at 4.69V. Similarly from figure 16 it can be seen that when C_I = 1.047uF then 'V_{OUT}' is clipped at 6.78V. For the 1.047uF capacitor, the 30Hz signal receives enough gain to clip the signal, where as the 0.047uF capacitor does not. The audible implication of this data is that when C_I = 1.047uF, lower frequency notes will receive clipping similar to those at higher frequencies.

Tone Control

Though a proposed modification of the tone control circuitry was not warranted, tests were conducted to observe its ability to filter out high frequencies.

Potentiometer @ 0%
At cut-off: F_{GEN} = 100 KHz ⇒ V_{OUT} = 390mV (Figure 17a)
Below cut-off: F_{GEN} = 4 KHZ ⇒ V_{OUT} = 1.56 V (Figure 17b)

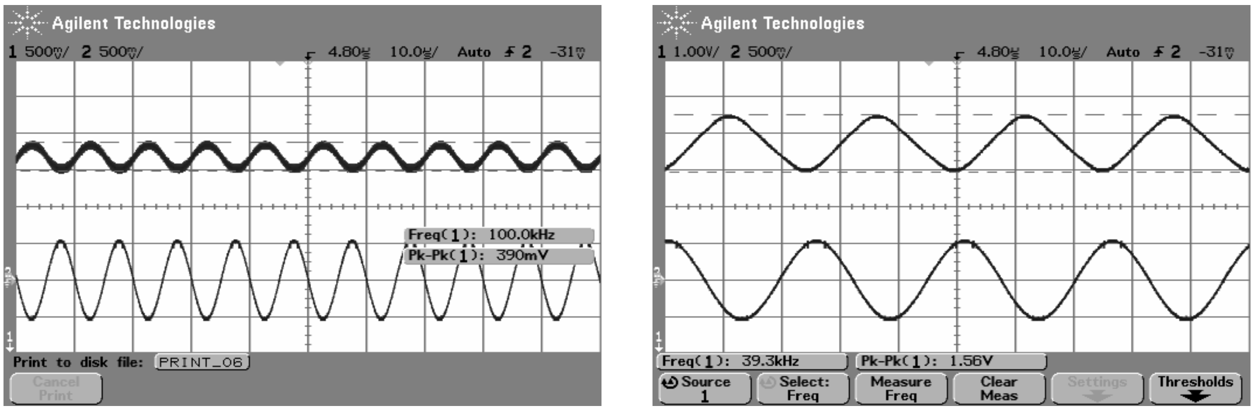

Figure 17: Tone Control @ 0%
a) Top: Minimal filtered output from tone control
Bottom: Cut-off frequency input to filter
b) Top: Filtered output from tone control
Bottom: Below Cut-off input to filter

Potentiometer @ 100%
At cut-off: F_{GEN} = 37 KHz ⇒ V_{OUT} = 360mV (Figure 18a)
Below cut-off: F_{GEN} = 4 KHZ ⇒ V_{OUT} = 2.16 V (Figure 18b)

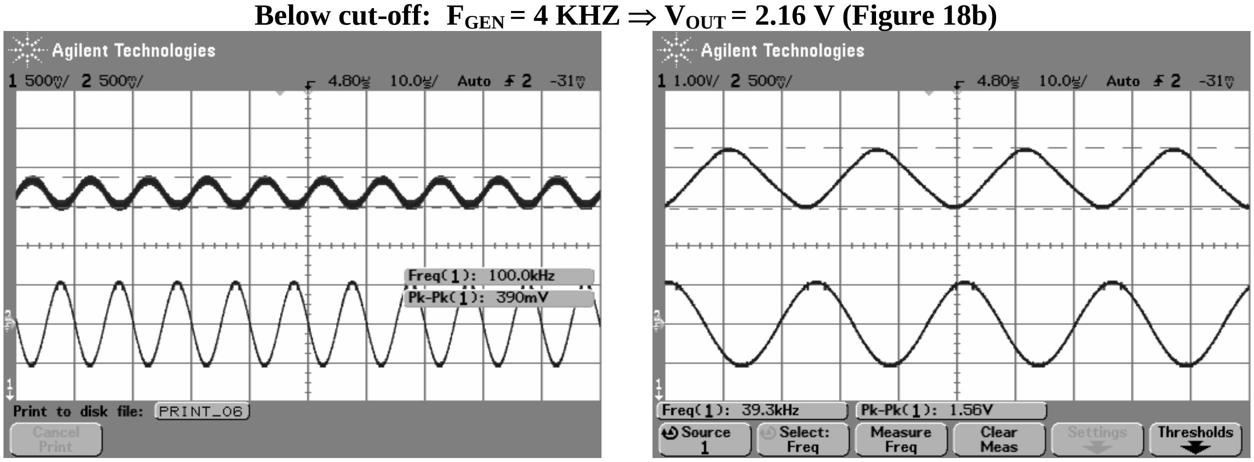

Figure 18: Tone Control @ 100%
A) Top: Minimal Filtered output from tone control
Bottom: Cut-off frequency input to filter
B) Top: Filtered output from tone control
Bottom: Below Cut-off input to filter

In order to find the cut-off frequencies for the filter at the two extremes of 0% and 100%, the frequency of the function generator was gradually turned up and observations were taken from the filter's output. When the filtered output appeared to be a minimal value compared to the input, the frequency level on the generator was recorded as the 'f_C'.

Figures 17 and figure 18 shows the selected readings with a 1Vac input signal. These readings show that the active filter is correctly filtering signals for frequencies over a set cut off frequency determined by the potentiometer. As the potentiometer value increases, the cut off frequency lowers, cutting more of the high frequency harmonics within the signal. The ability in operating the filter to cut-off harmonics is notable from the above measurements. It is worth noting that this mix of minimizing the harmonics and at the same time deriving the clipping effect is extremely useful and most wanted.

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 and speaker to make conclusions on the audible functionality of the finished circuit in producing distortion tones that mimic 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 clipping range was agreeable and preferred. 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.

It is recommended that the proposed schematic needs to be constructed on a Printed Circuit Board (PCB) and placed within an aluminum enclosure to decrease chances of external noise interfering with the pre amp's operation. The pre-amp should be activated using a DPDT stomp actuating switch to allow the circuitry to be fully bypassed when not in operation. The frequency range selector switch should also be stomp actuated to allow the guitar player with an ability to activate the low frequency range function with the foot, leaving hands free for guitar operation. Figure 19, shows the final product developed that are ready to be used on any electric guitar and has the potential capabilities and advantages. The product has been tested and is currently being used in the industrial electronics market under the guidance of the first author.

Figure 19: Final Product and package contents

Conclusions

This paper presents a new approach for an audio clipping preamplifier that can be used for responsive tone modification and volume control. The main design aspect of the proposed approach is due to the introduction of Silicon Controlled Rectifiers, summation amplifiers and RC networks in order to generate high frequency gain, improved frequency response, tone modifications and signal wave clipping. The design details of the amplifier set up and the implementation results both with simulated test signals and on an actual electric guitar has been illustrated. The main advantages of the proposed design are the wide range of tonal control, improved online changes due to the SCR clipping and subsequent changes to the firing angle of the gate. It was found that all the proposed effects were adequately produced by this new design within a simulated environment as well as in the real-time. Also the clipping of SCR was enhanced by the extended range of gain available from the summation amplifier configuration. The ability to clip the tone was considerable such that the use of the SCR and the proposed modifications should prove beneficial to the field of audio pre-amp clipping and tone control.

Bibliography

[1] Ibanez Co. *Tube Screamer TS808* schematic http://www.generalguitargadgets.com.
[2] Keen, R.G. "The Technology of the Tube Screamer". R.G. Keen, 1998.
[3] Huges, T. " Analog Man's Guide to Vintage Effects, For Musicians only Publishing, 2004.
[4] http://www.robertkeeley.com/
[5] http://www.badcatamps.com/.
[6] http://www.grailtone.com/guitar-reviews/tubescreamer-review.html.
[7] http://www.aramateffects.com/mods/.
[8] Buchla, David, Floyd, Thomas L. Fundamentals of Analog Circuits. Columbus: Prentice Hall, 2002.
[9] http://www.americanmicrosemi.com/tutorials/scr.htm

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