# Bass Rockman Distortion Analysis

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Aaron Geldert
Christian George

Introduction

The following is an analysis of several sub-circuits contained in a patent by Donald T. Scholz, founder of Scholz Research and Development. The device designed is the Bass Rockman, an bass guitar amplifier unit that generates distortion characteristic to Scholz's design. The entire system is best described in the patent, which states that it is, "an electronic audio signal processor… suited for electrical instruments such an electric bass guitar for providing controlled distortion and tone alteration." Key components of the original circuitry, as well as several possible modifications to the original Rockman design, are analyzed and simulated.

Original Distortion Circuit Theory of Operation

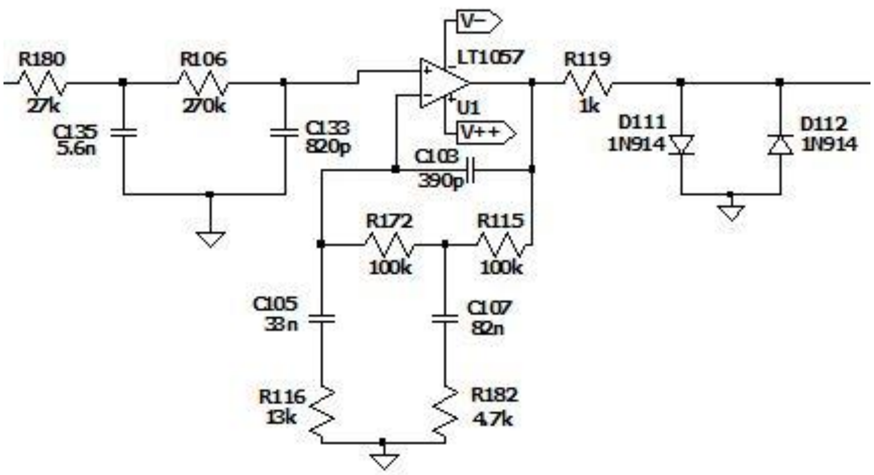



*Figure 1:* Schematic of Scholz' original bass rockman distortion circuit.

Entering into the LT1057 op amp, which substitutes for the IC102A op amp used in the original patent, are two passive, first order RC low-pass filters in series. Placed together, these effectively form a 2nd order low-pass filter, with a characteristic roll-off of -12 dB/octave. This pre-distortion low pass filtering was a signature component of Scholz's signal flow, and high frequency amplification is provided in a later stage for tone equalization. The transfer characteristics of each individual filter can be described with the following transfer function:

$$H(s) \ = \frac{1}{1 + j\omega CR}$$

The cutoff frequencies of both individual filters can be found with the following equation:

$$fc = \frac{1}{2\pi RC}$$

However, the placement of the filters in series alters the transfer characteristics. The cutoff frequency of the overall 2nd order filter can be found with the equation below. *N* is the order number of the filter; in this case, it is 2.

$$fc = \frac{1}{2\pi\sqrt{R1C1R2C2}} \times \sqrt{2^{(1/n)} - 1} = \frac{1}{2\pi\sqrt{27k\Omega \times 5.6nF \times 270k\Omega \times 820pF}} \times \sqrt{2^{(1/2)} - 1}$$
$$= 540\ Hz$$

As described on page 6 of the Scholz patent, these filters have, “the effect of reducing the high frequency signals coupled to the input of the distortion amplifier.” Below is the frequency response for this initial filtering stage:

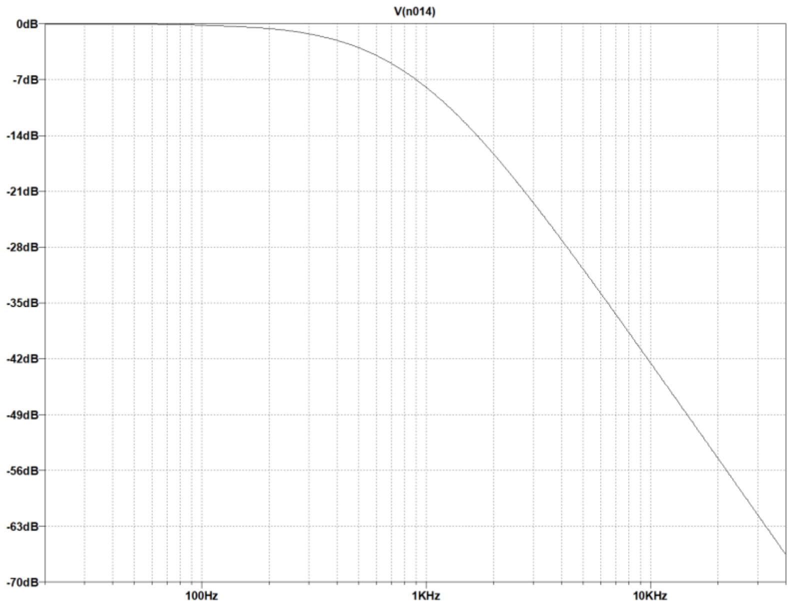



*Figure 2.* Frequency response of the active 2nd order low pass filter with a cutoff at 500 Hz.

Following the input filter, the RC network in the feedback path of the LT1057 op amp serves as another filter. As stated in the patent, the network is “primarily a band pass filter centered at around 300 Hz” (6). The frequency response for the entire circuit, including both low pass and band pass networks, is shown below:

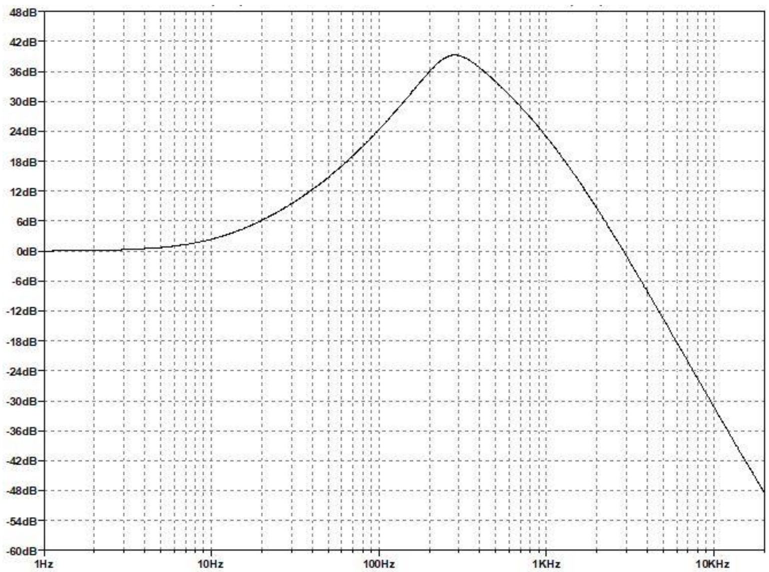



*Figure 3.* Frequency response of the peaking band pass filter centered around 300 Hz.

This network also performs voltage amplification. As visible in the frequency plot, the maximum gain lies at 38 dB at the peak frequency (300Hz) of the band pass filter. This maximum dB equates to a voltage gain factor:

$$Av = 10^{(38/20)} = 79.4$$

Following resistor R119,  the signal distortion of this distortion amplifier occurs. As the signal output of the LT1057 op amp swings either above or below 0.7V, one side of the IN914 diodes becomes forward biased. This couples the audio signal to ground, effectively clipping it at 0.7V.

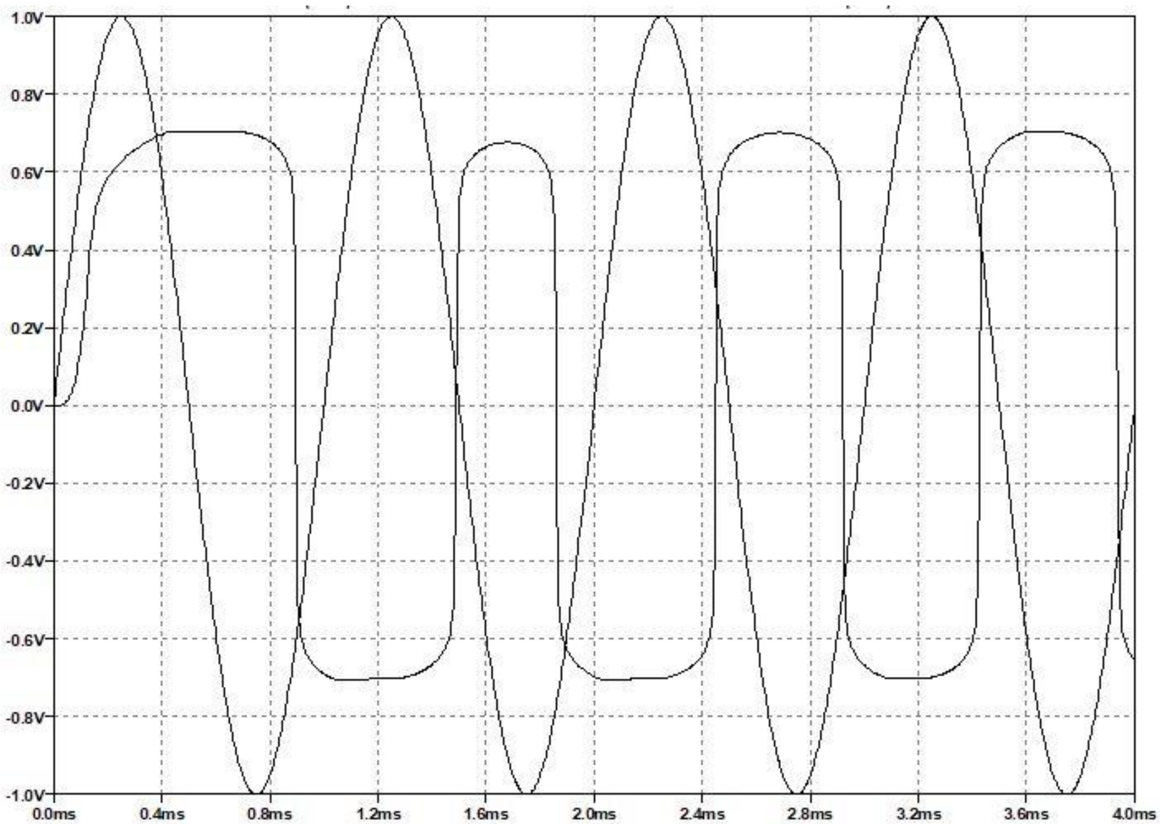



*Figure 4.* Transient response depicting the distortion of the input 1 kHz signal.

The input 1V, 1 kHz sine wave is inverted and distorted to form a rounded wave that does not exceed $\pm$0.7V.

High Frequency Clipper Theory of Operation

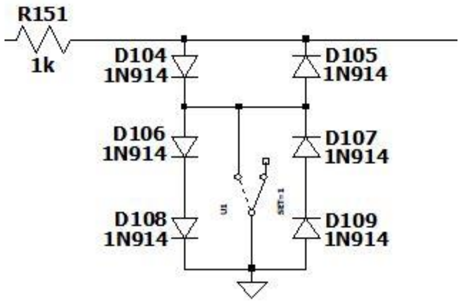



*Figure 5.* Switchable diode clipping circuit

The clipper circuit above is attached to the high frequency equalizer of the Rockman amplifier. Its function mirrors the diode clipper featured in the distortion amplifier discussed above. However, this diode network features a controllable switch that will alter the clipping voltage of the input.

In the current switch position, the input signal will only clip when it exceeds approximately 2.1V, the voltage necessary to forward bias 3 diodes in series. Upon reaching 2.1V, the signal is coupled to ground and clipped. In the alternate position, the high frequency clipper acts exactly as the diode network in the distortion amplifier. The signal will be clipped at 0.7V, as the bottom four diodes are effectively coupled to ground by the switch.

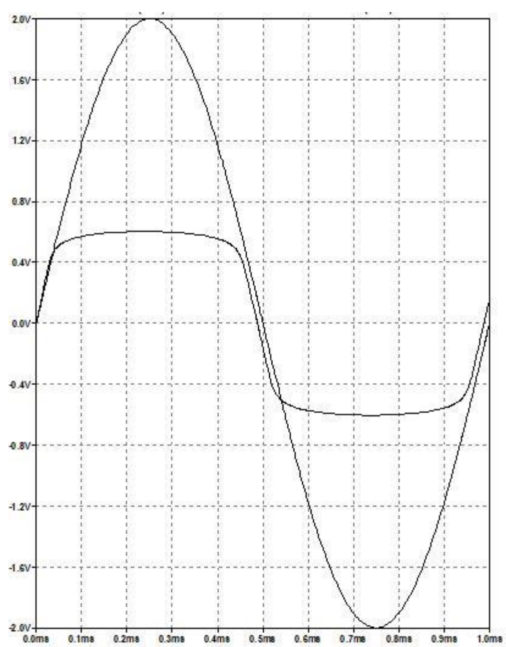



*Figure 6.* 0.7V diode clipping from a 2V input

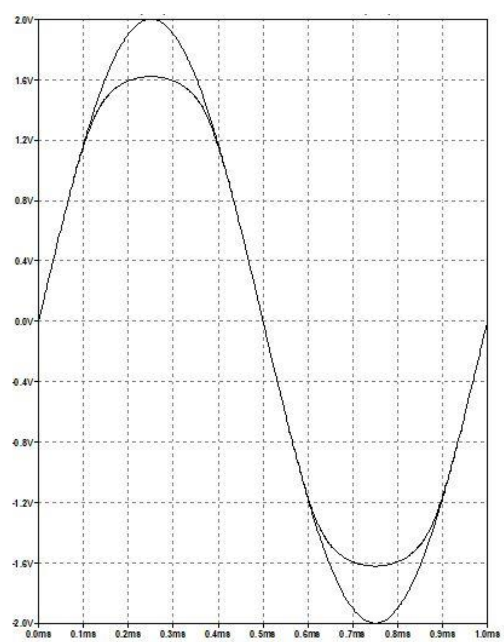



*Figure 7.* Approximately 1.8V clipping voltage, less than the ideal 2.1V.

Modifications to Original Design

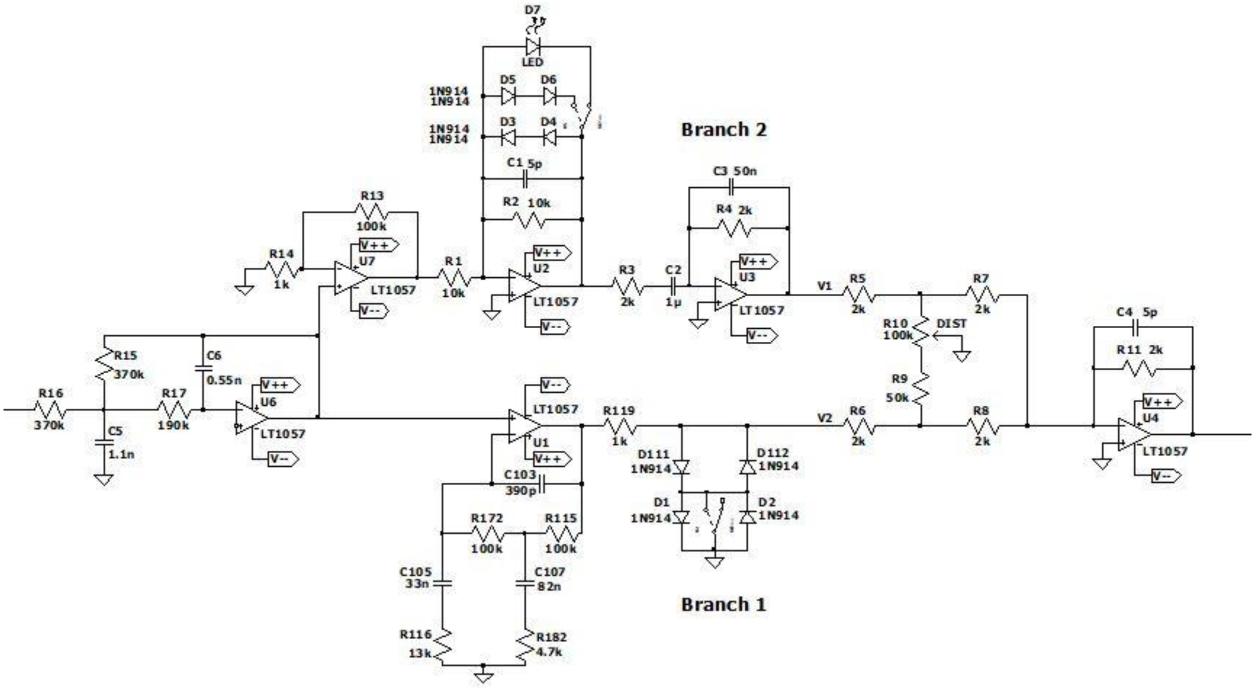



*Figure 8.* The schematic of the modified version of the Rockman.

Below are four significant modifications that this Bass Rockman design contains that differ from Scholz's original distortion circuitry. They include:

1. Converting a passive 2nd order LPF to an active equivalent circuit
2. Creating 2 parallel distortion branches, "DIST" blend control to mix the two
3. Implementing asymmetrical, LED, Germanium diode, and silicon diode distortions
4. Post-distortion filtering vs. pre-distortion filtering on the two distortion paths

These modifications are all contained within the same distortion circuit, so their individual explanations will somewhat overlap. The overall goal of these modifications is to give the user more variety in the sound of distortion achieved, as well as preserve signal strength.

1. Active 2nd order LPF

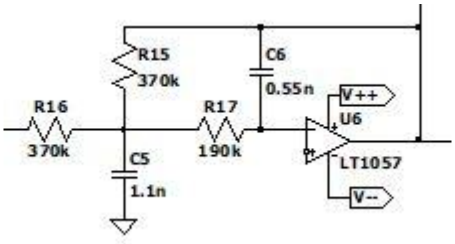



*Figure 9.* Active 2nd order low pass filter circuit, with a cutoff at 500 Hz

Reconfiguring the passive 2nd order low pass filter into an active version will help preserve a stronger signal. Capacitor and resistor values were designed in order the maintain a cutoff frequency of 500 Hz, identical to Scholz's passive circuit.

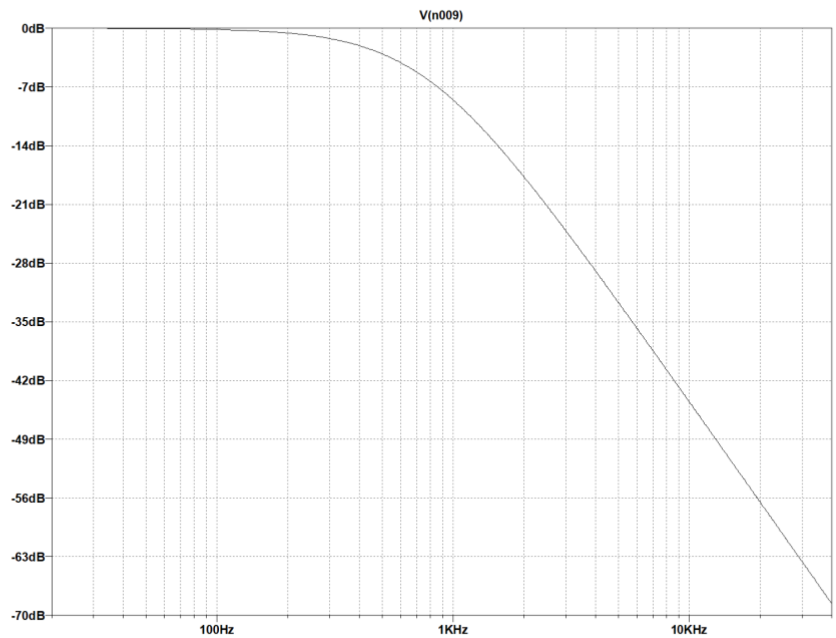



*Figure 10.* Frequency response of the active 2nd order low pass filter with a cutoff at 500 Hz.

2a. Parallel Distortion Branches

Following the active 2nd order LPF, the signal is split into two separate distortion pathways. Branch 1 of the improved Rockman circuit inherits the majority of its components from the original in an unaltered fashion. This is done with the intention of maintaining the original Rockman sound that made the amplifier so popular to begin with.

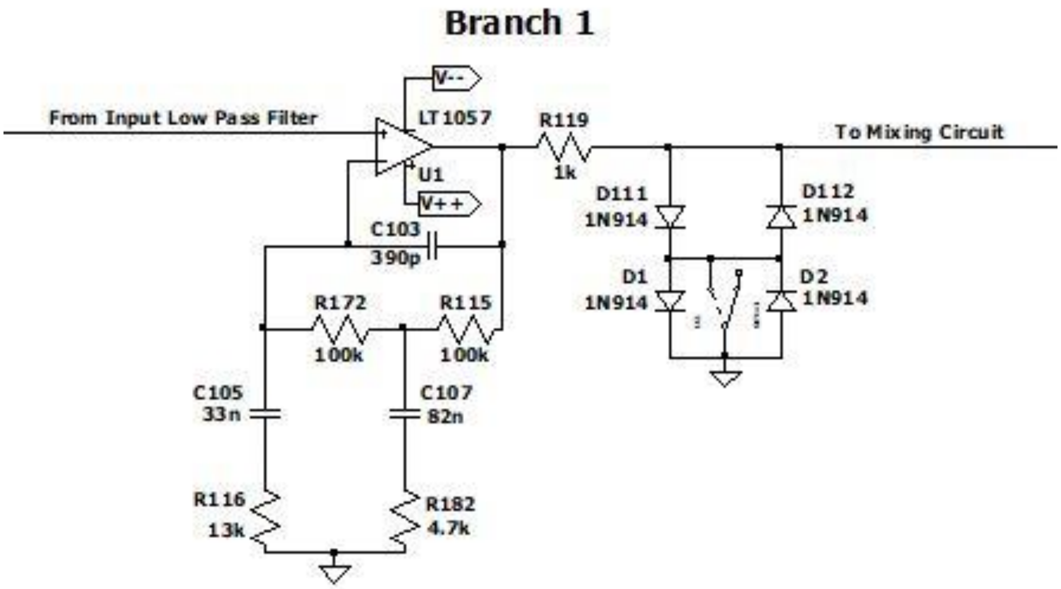



*Figure 11.* Schematic of Branch 1's gain, filtering, and distortion.

The band pass filter formed by the network is an exact duplicate of the original. Its frequency characteristics are shown in Figure 10.

The diode network in this version contains a network of four IN914 diodes, instead of the original two. A switch is implemented to give the user the option to switch between a clipping voltage of 0.7V and 1.4V. This circuit mirrors the functionality of the high frequency clipper circuit contained in the original Rockman circuit.

Regardless of the switch position, the gain characteristics of the amplifier are the same as its original Rockman counterpart.

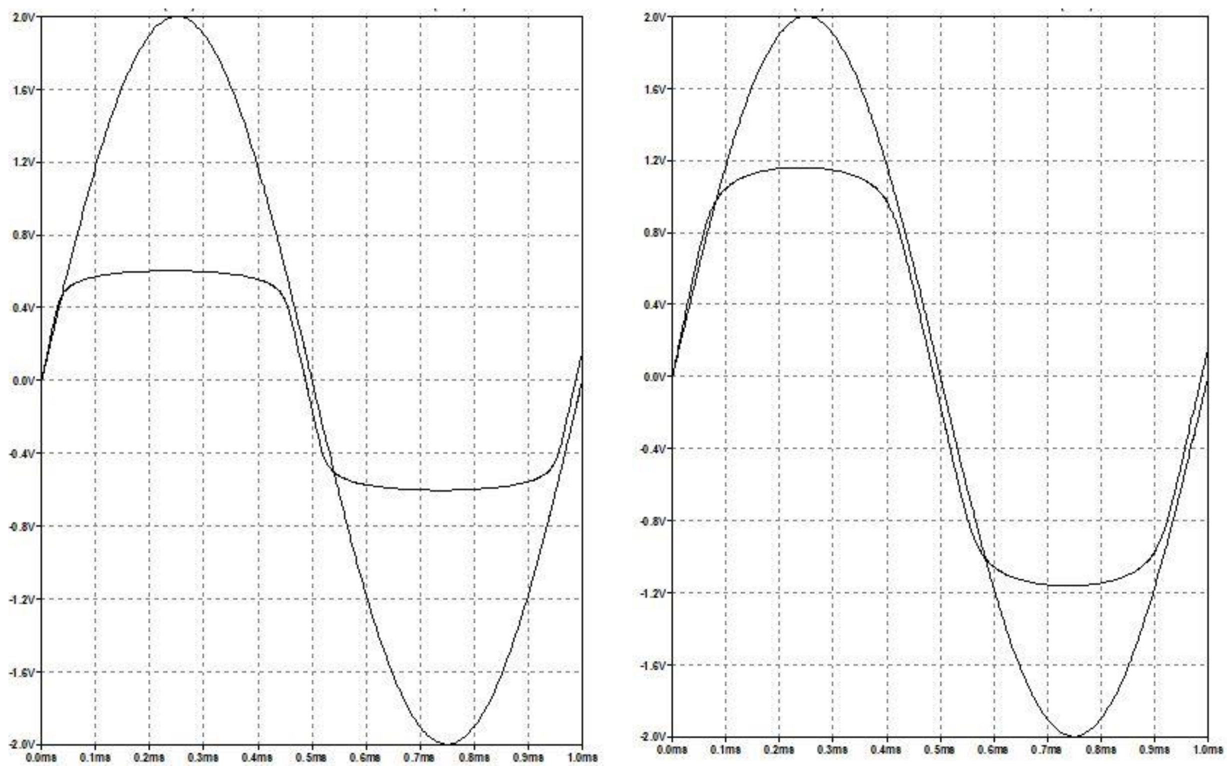



*Figure 12.* Transient response showing clipping via a single diode vs. a pair of diodes in series.

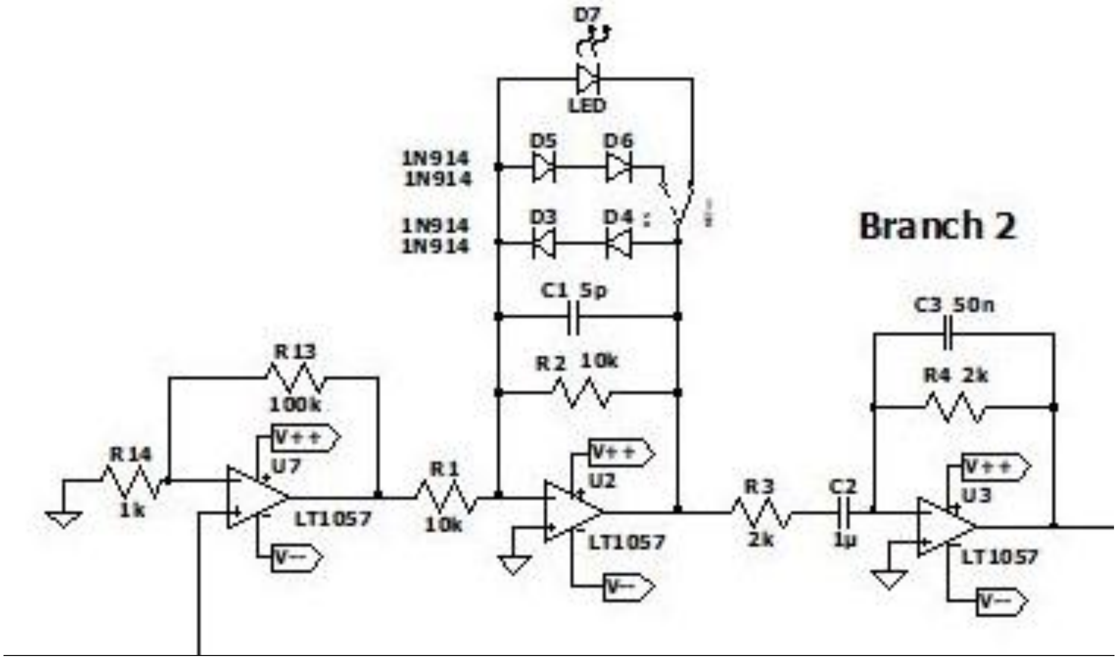



*Figure 13.* Schematic of branch 2, with a gain, distortion, and filtering stages.

Branch 2 implements a different concept of distortion and filtering than branch 1, giving the user the options to control their tone both through each branches' switches and the mix between the branches. Branch 2 first amplifies the signal at the non-inverting op-amp U7 by 40 dB in order to match the gain of the active filter in Branch 1 (per Scholz's original Rockman). This is followed by an op-amp with diodes in the feedback path (much like the popular Tube Screamer pedal circuit), followed by a band pass filter with no amplification. Branch 2 also includes a switch for changing which diodes are distorting the sound, offering either asymmetrical symmetrical options. A more detailed explanation of the second branch's distortion circuit is in section 3.

2b. Parallel Distortion Branches Summing

Coming out of each branch is a resistor divider circuit, where the added "DIST" 100k potentiometer mixes the two distortion sounds achieved in each path. At one extreme of the potentiometer, branch 2 will be completely shunted to ground, outputting a 100% mix of branch 1 . At the other extreme, a mix of 67% branch 2 and 33% branch 1 is observed. The signals are mixed at the summing/inverting op-amp U4, whose output is equal to:

$$V_{out} = -\left(V_1 \frac{R11}{R7} + V_2 \frac{R11}{R8}\right)$$

Since R5 = R6 = R7 = 2k, the summing op-amp is applying unity gain is applied to both branches when the "DIST" potentiometer is in the center. Note that the summing op-amp inverts the signal, though each branch's filters already inverted the signal. Also note the addition of C2, a high frequency compensation capacitor to prevent parasitic capacitances at the op-amp from generating a high frequency "squeal" at the output.

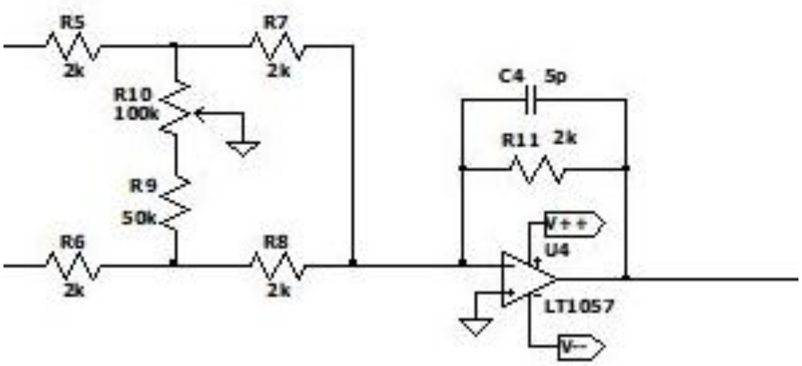



*Figure 14.* The mix control and summing op-amp

3. LED and Asymmetrical Distortion options

Branch 2 begins with a distortion op-amp that has diodes in the feedback path in addition to a feedback resistor and high frequency compensation capacitor. These diodes can either be symmetrically clipping the signal at +/- 1 V, through the use of two 1N914 silicon diodes in series. A switch can also replace the negative side of the distortion with a single LED, so clipping will occur at a lower voltage of -1.6 V.

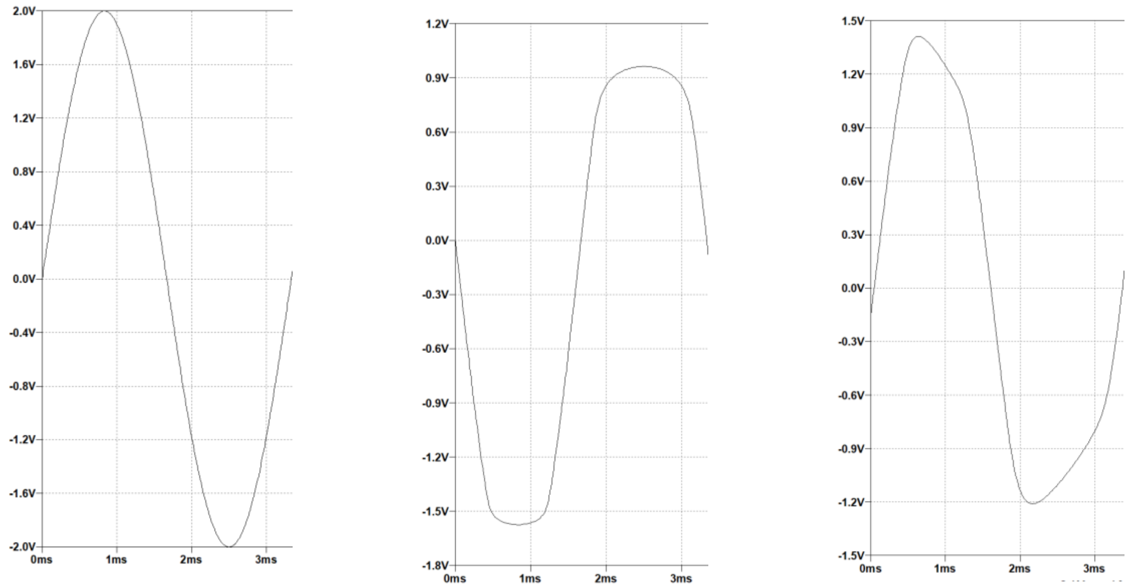



*Figure 15.* The input signal (300 Hz, 4 $V_{pp}$), asymmetrically distorted signal, and band pass filtered signal.

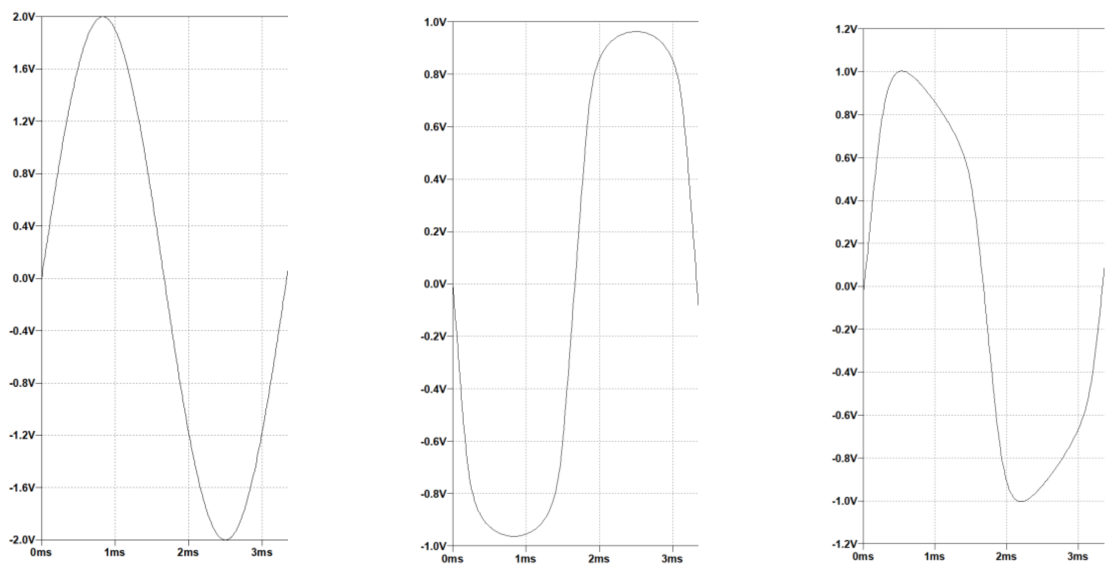



*Figure 16.* The input signal (300 Hz, 4 $V_{pp}$), symmetrically distorted signal, and band pass filtered signal.

4. Post-distortion filtering

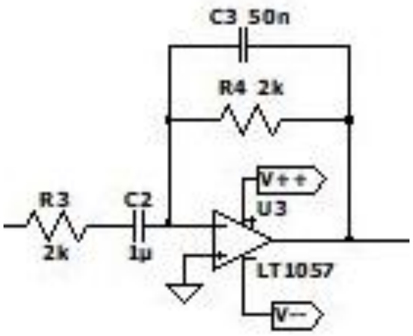



*Figure 17.* The band pass filter stage of the second branch.

The final part of the second branch is an inverting band pass filtering op-amp. The BPF has a lower edge cutoff frequency at 80 Hz and an upper cutoff at 1.6 kHz, and -6 dB/octave slopes on both sides. This differs from both Scholz's patented distortion circuit and the first branch in several ways. First, the band pass is of a simpler design here, and the bode plot shows a quite different response without the amplification of the mid-range frequencies. Secondly, this filter occurs after the distortion stage, and thus is able to attenuate the harmonics generated in distortion - whereas branch 1 band pass filters before distorting the signal.

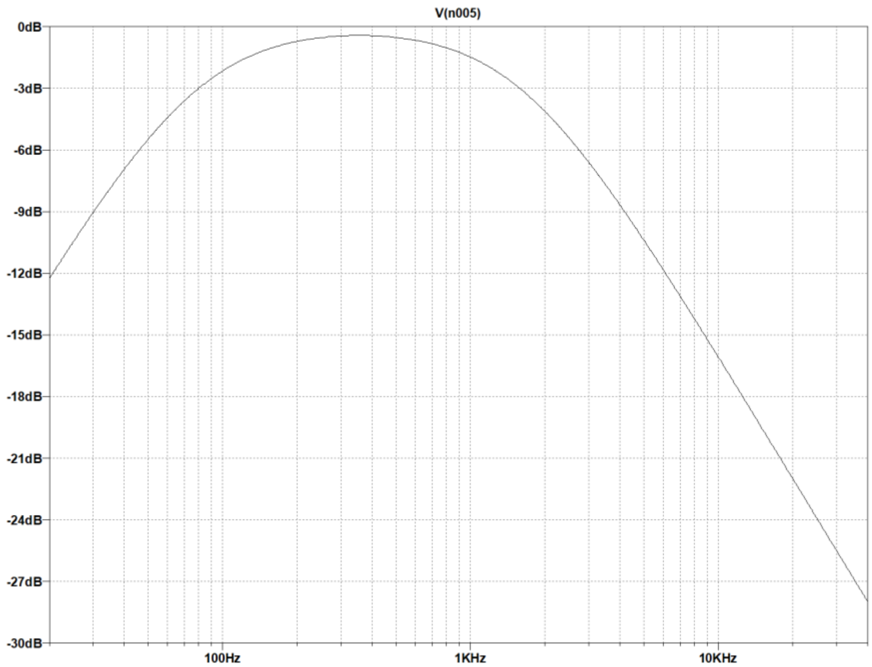
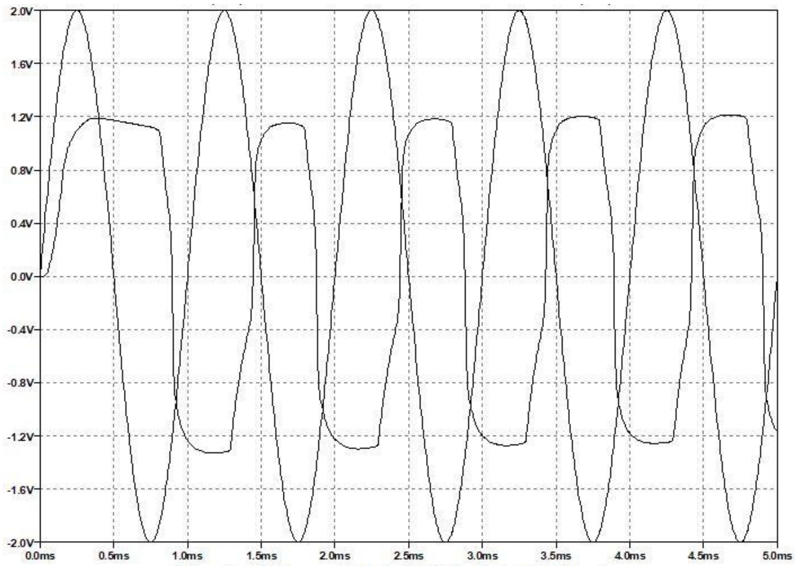


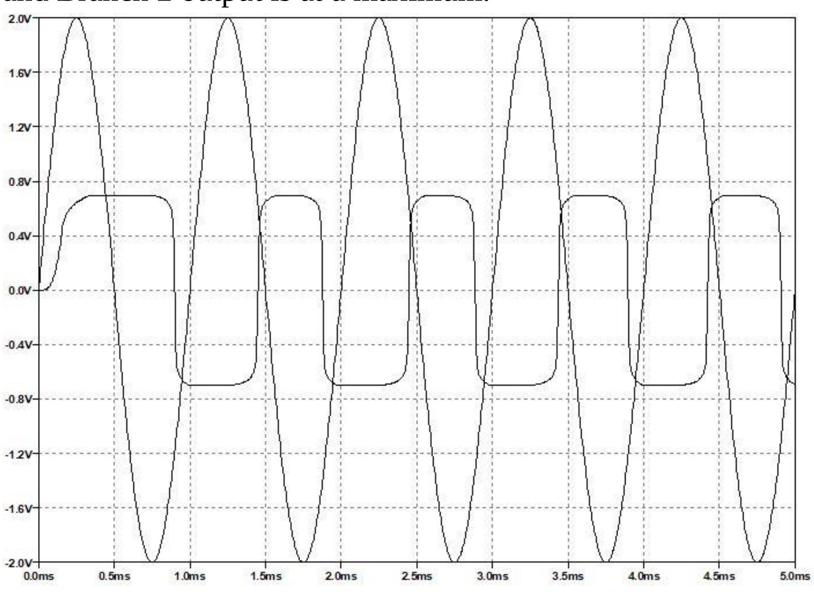

*Figure 18.* Frequency response of the band pass filter in branch 2, with edge frequencies at 80 Hz and 1.6 kHz, and 6 dB/octave slopes.

Output of Modified Amplifier
Due to the many user modifications possible to the final output of the modified amplifier, only two instance is displayed below. For both instances, asymmetrical distortion on Branch 2 is disabled; the LED in the distortion path is disconnected. Branch 1 clip voltage is set at 1.4V; all diodes in the distortion amplifier network are connected.

Below, the DIST potentiometer is set to its maximum value; Branch 1 output is at a minimum and Branch 2 output is at a maximum.




Below, the DIST potentiometer is set to its maximum value; Branch 1 output is at a minimum and Branch 2 output is at a maximum.




Below is the overall frequency response for the modified circuit:

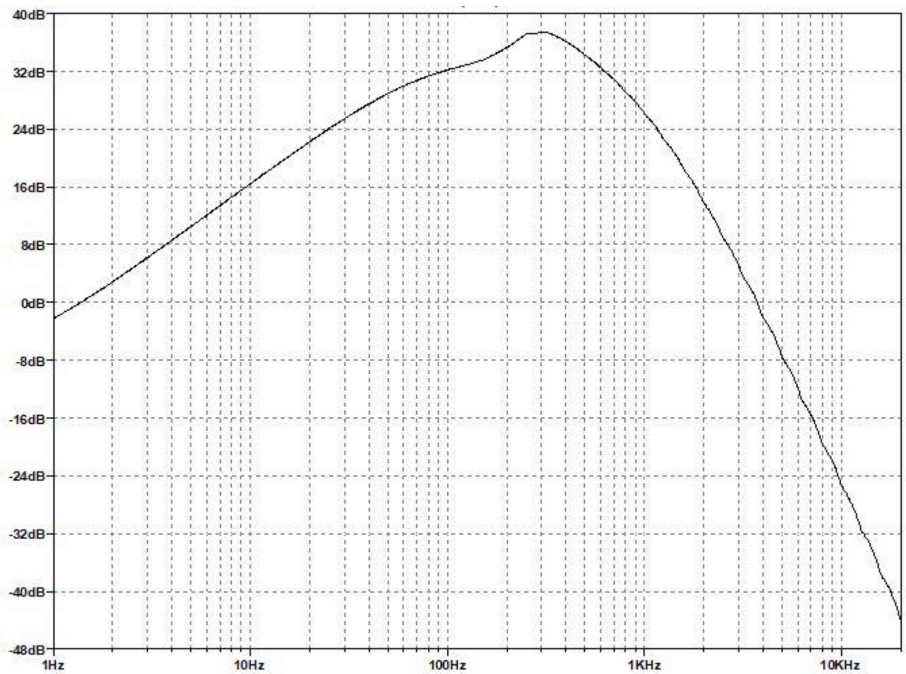


*Figure 19.* Frequency response of the overall output of the distortion DIST = Maximum