

A Guitar Overdrive/Distortion Effect of Digital Signal Processing

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1. Problem Description

Urban people usually live in apartments and are not allowed to use a full-stacked guitar amplifier for practicing or recording. This is because the sound pressure level produced by an all-valve guitar amplifier could easily over the legal noise limitation to their neighbor. Therefore, a personal computer-based digital overdrive/distortion effect is one of the most important digital effects for all guitarists today. The problem is how we should do to we change the habit of guitarist to using effects in their laptop instead of a real guitar amplifier.

The secret to achieve the new trend is, to make the effect in their laptop sounds just like their real all valve amplifier.

Here comes the problem. Modeling an all valve electric guitar amplifier needs the understanding of the subjective preferences of guitarists. Instead of simulating the electric circuit which may take all the CPU resource and memory availability, a practical way is to figure out what are the most importance parameters to guitarists.

A perceptual investigation has been implementing to get the two most significant dimensions of overdrive/distortion effect which tells us the two parameters are wildness and sharpness (Marui and Martens, 2002). These two parameters can be mapping to what called 'Drive' and 'Tone' respectively. Besides, the specific clipping of wave in the pre-amp stage of an all valve-amplifier is also a significant parameter to create authentic feeling toward the audience.

This project develops and demonstrates a digital non-linear overdrive effect which contents the same parameters just like the drive-pedals guitarists are familiar with. The three parameters called 'Boost', 'Drive', and 'Tone' is intuitive for guitarist to adjust 'the gain of the input signal', 'the distortion level', and 'the low-pass filter threshold of the distorted signal' respectively.

2. Specification

The input file should be in mono *.wav format, 16 bits, and 44.1 kHz sample rates.

In this project, we simplified knobs on a stacked amplifier into three most important parameters.

i. Boost

The 'Boost' parameter in this project is a pre-amp liked function in an all-valve amplifier which allows user to decide the gain of the input signal being enlarged before sending to the drive processing stage.

This function allows user to enlarge the input signal up to 100 times.

ii. Drive

The 'Drive' parameter in this project allows users to decide their distorted wave shape should be more like a sine-wave or more like a square wave.

Here, the less the 'Drive' value is, the more the output wave sounds like the original input, which means the processed output has not much high-order harmonic distortion. In contrast, when the 'Drive' value has been set to the maximum, the increasing high-order harmonic distortion added makes the waveform sounds more like a square wave.

i. Tone

The 'Tone' parameter here is a low-pass filter threshold controller. It has been set in the last stage of the processor. In the real situation, the large scale guitar amplifier driver can hardly reproduce the high frequency among 12k Hz. Therefore, in the digital world, we have to manually filtering out the unwanted high frequency which is the not natural or typical guitar driven sound to the audience.

Here the minimum threshold is from 1k Hz, and up to 20k Hz.

3. Implementation

A non-linear overdrive/distortion signal processing engine has been developed. In addition, a tone color parameter is added which can provide a more natural sound for helping the musician to get the sound they want.

The programming of this model as a whole has been developed in Matlab environment. Although this program may not be real-time signal processing software, it can still be very useful in post-production for home studio producer.

The source code of the 'Drive' function is created by Steve McGovern, and its algorithm is sourced from a DSP resource exchange forum [2], called 'WaveShaper'. There are three parameters in the digital effect which can be adjusted by users, including 'Boost', 'Drive', and 'Tone'. These three parameters have been widely used on most of overdrive/distortion pedals. A guitarist can use adjust

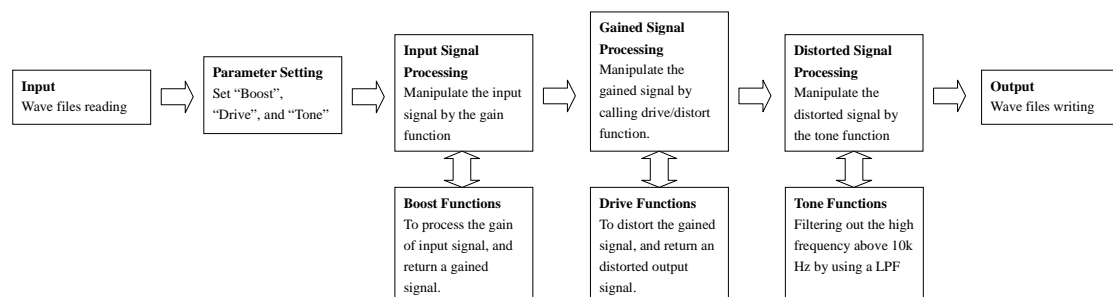


Figure 01 - The Signal Flow of Overdrive/Distortion Implementation

The main function is a signal processing flow which has been shown in Figure 01, First, users need to set the three key parameters, 'Boost', 'Drive', and 'Tone'. Then the signal would be sent into three

stage sequentially.

● **Boost**

$$\text{gain} = ((\text{boost}/100)*100)+1 \quad (\text{Equation 01})$$

Equation 01 is used to rescaling input signal by adjusting the 'Boost' value.

After we get the gain, we can multiply gain to the input signal to get the boosted signal.

● **Drive**

$$x = (1+k)*(x)/(1+k*abs(x)) \quad (\text{Equation 02})$$

$$\text{Where } k = 2*a/(1-a) \quad (\text{Equation 03})$$

$$\text{Where } a = \sin(((\text{drive}+1)/101)*(pi/2)) \quad (\text{Equation 04})$$

Note that the range of the drive parameter 'Drive' is $0 < \text{drive} < 100$, just like the 'Boost' function. This is because user may not get used to the tone it produced if 'a' in the range of -1 to 0. Here we use a re-scaling technique to provide a better mapping for users to the pedal they are using. By adjusting this value from 0, a user can get almost the same signal as the input signal. You may now notice that we just want to use the second half part of the original wave shaping function which allows the signal to be altered from a sine wave to a square wave. In short, 0% 'Drive' value lead to a copied output while 100% produce a square-liked output.

● **Tone**

The 'Tone' is basically a low-pass filter, which controls the cutoff frequency of a 2nd order Butterworth filter. The cutoff frequency can be set from 1 kHz to around 20 kHz. The default setting is 50, which result in a LPF with cutoff around 10 kHz.

```
function [filteredwave] = distfftfilter (wave, tone, fs)
```

```
filterfrequency = ((fs-2000)/2)*sin((tone/101)*(pi/2))+1000; % rescaling the tone into filter frequency,
```

```
fNorm = filterfrequency / (fs/2); % Set the norm value
```

```
[b,a] = butter(2, fNorm, 'low'); % Butterworth Low-Pass Filter
```

```
filteredwave = filtfilt(b, a, wave); % Return toned signal
```

4. Evaluation (to demonstrate that the solution meets engineering specs)

Through the demonstration of a self-recorded input signal, we can assess the process of signal being altering in different stages of this digital overdrive/distortion.

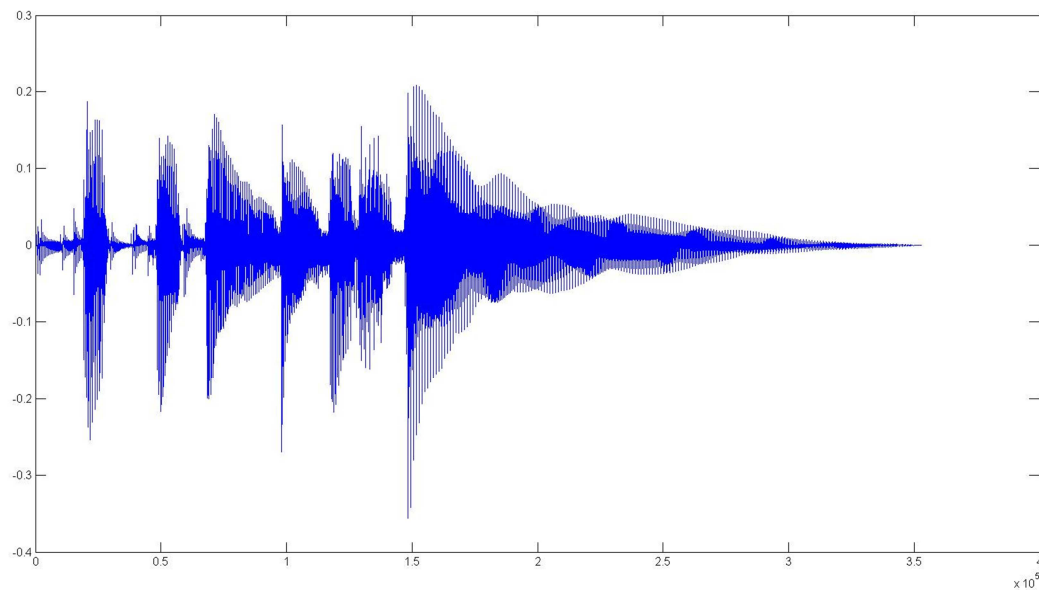


Figure - Input Signal

The input signal demonstrated here is recorded by a 1980's Gibson Les Paul Custom. The pickup position is bridge. The recording is direct input from the guitar jack output straight to the sound device of the laptop.

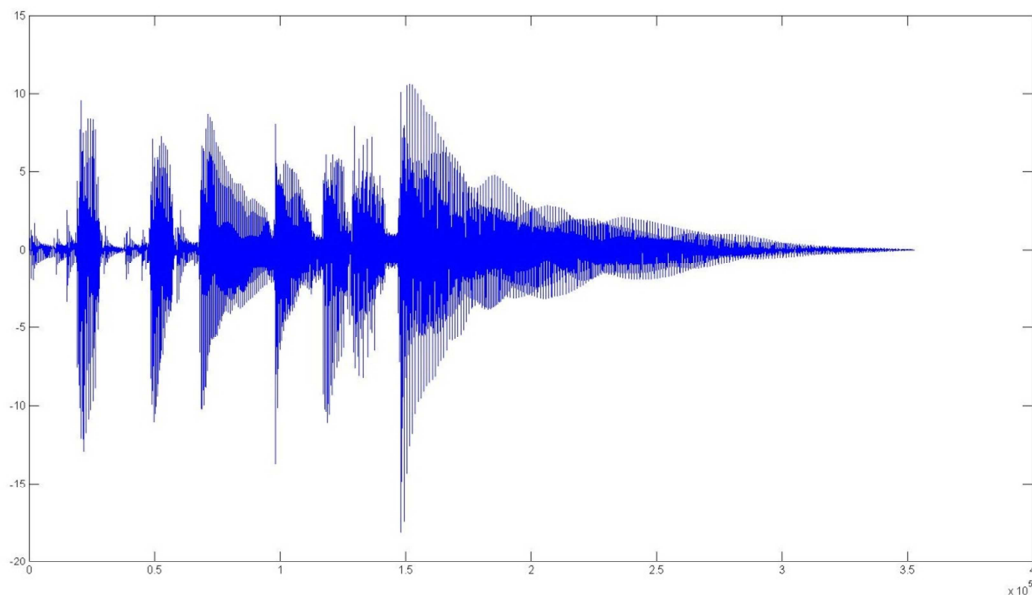


Figure - Boosted Signal

The pre-set of the 'Boost' value here is 50. As we can observe from Figure, the input signal has been amplified for nearly 50 times.

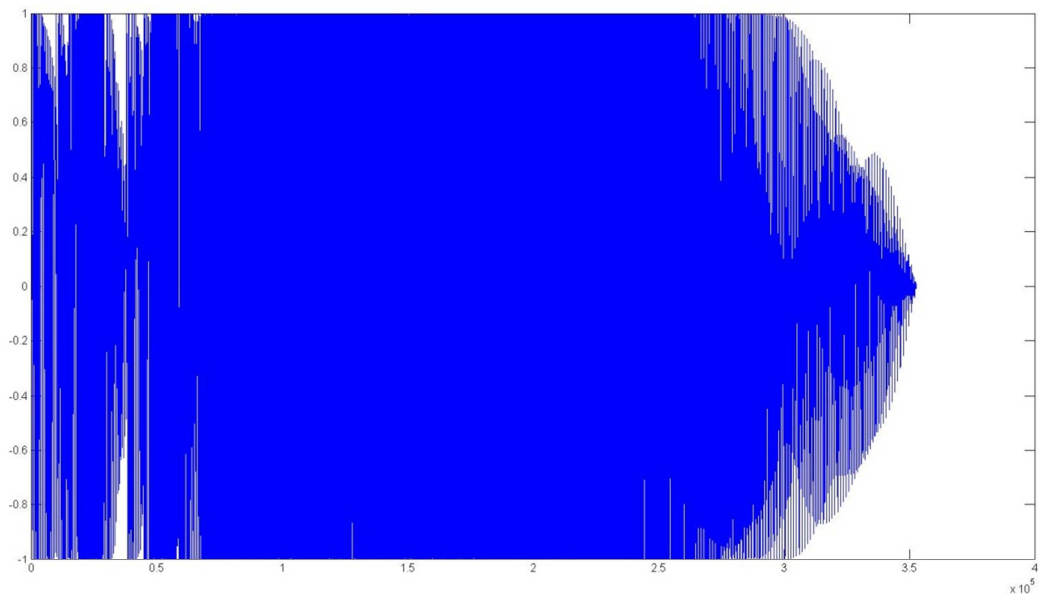


Figure Distorted Signal

Here the 'Drive' has been set to 50, from Figure, a hard clipping like distortion can be observed. At this stage, the high-order harmonic distortion may not sound naturally to the audience, yet.

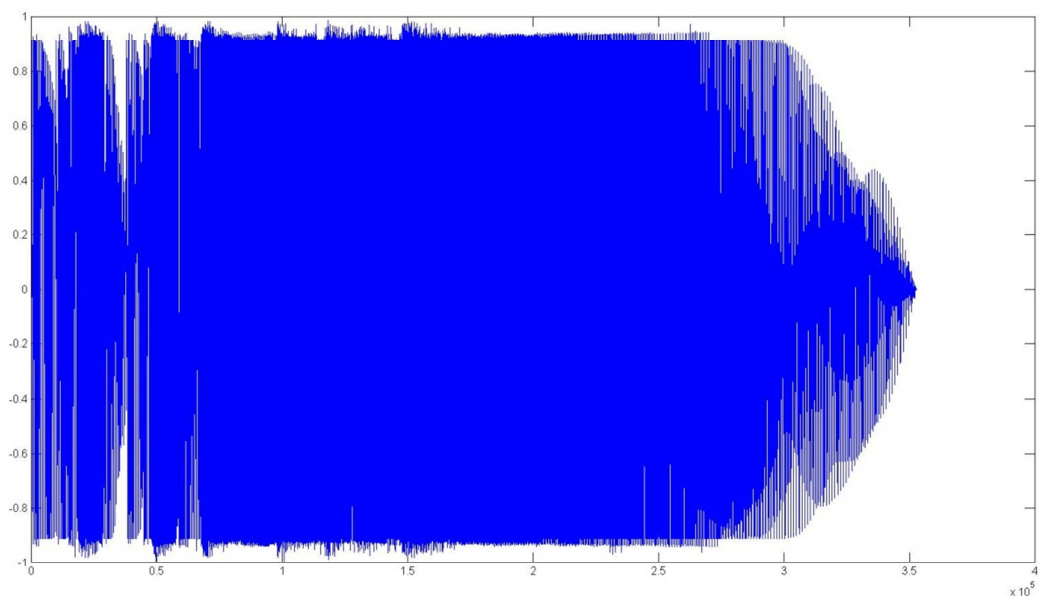


Figure – Filtered Final Output Signal

After filtering by 50% of 'Tone', the output signal sounds warmer and more pleased. From Figure, we can observe that the high frequency of some punching points have been filtered out and more

punchy.

The full demonstration can be access by using the eScholar repository system on the University of Sydney website or you can e-mail me to get the sound tracks.

V. References

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