Dr. dB

The Digital Guitar Amplifier

EGR 423 - Digital Signal Processing Systems Final Project

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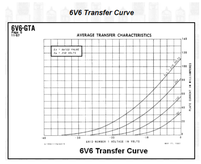
What is Distortion?

Distortion is the addition of new harmonic content to a signal. Harmonics are integer multiples of a signal's frequency. Guitar amplifiers and effects pedals intentionally introduce varying amounts of distortion, depending on the topology of the circuit. This can be accomplished with a variety of components, such as diodes, transistors, or vacuum tubes.

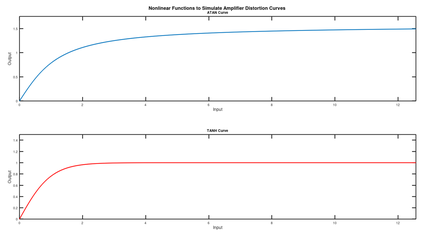
Below is an example of vacuum tube transfer curve, which shows the tube's current as a function of its voltage. Note that these curves are nonlinear.



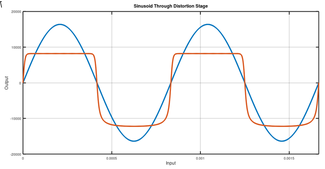
https://mdoidomarte.com/Tube_Guitar_Amp_Overdrive.html#:~:text=Tube%20amplifiers%20transfer%20curves%20are,harmonic%20and%20intermodulation%20distortion%20too.

Modeling Distortion

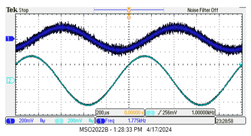
From Ohm's Law, we can model this output current through a resistance as a voltage, which will reflect this curve over y=x. These curves are similar to selected trigonometric functions, namely arctangent and hyperbolic tangent.



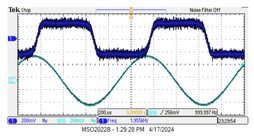
Many circuit introduce asymmetrical distortion, where the positive half of the signal is distorted differently from the negative half. Dr. dB models this by processing the positive inputs with a hyperbolic tangent lookup table, while the negative inputs are processed with an arctangent lookup table. This varies the amount of harmonic content in the different signal regions. A simple example of this is shown belo



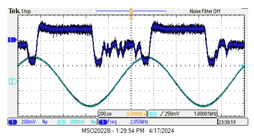
The following images are oscilloscope measurements taken of the output signal from Dr. dB given a 1.5kHz input signal.



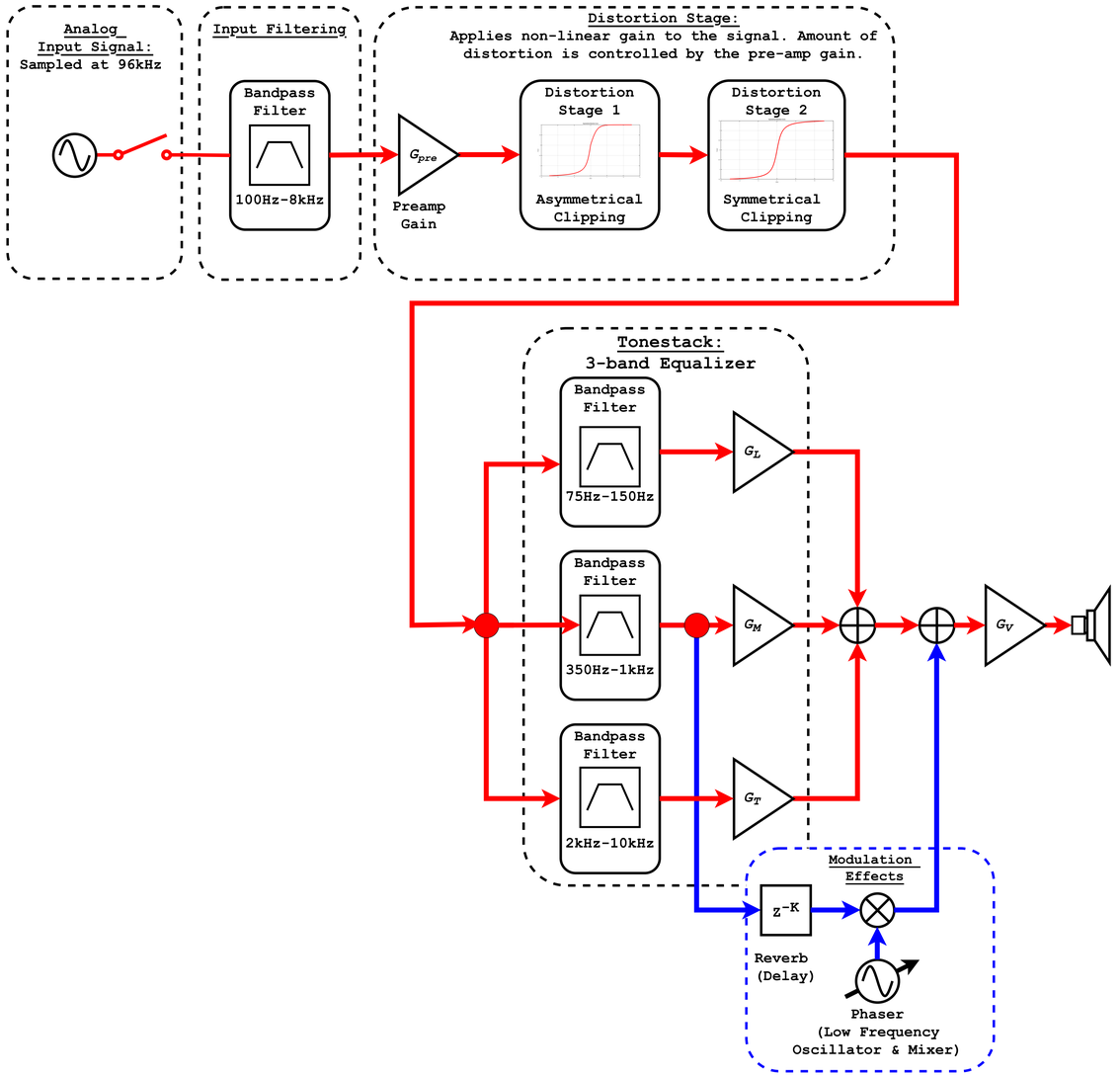
Distortion Off



Distortion At Minimum



Distortion At Maximum



Guitar Amplifier Signal Flow

The guitar amplifier uses the linear response of various digital filters to stack the filters. The first filter is the a bandpass filter, filtering noise near DC and high frequency noise.

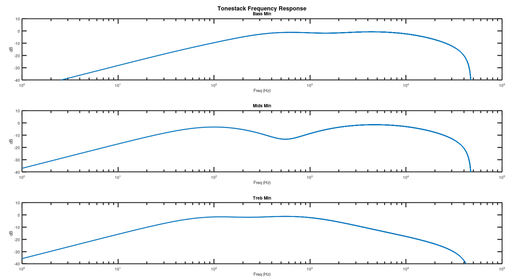
Next, a gain is applied to the input, allowing the user to control the amount of distortion. After distortion is the tonestack, allowing the user to decide how much of each band they want in their signal.

The final stage implements a set of modulation effects-a phaser and reverb. These are both linear and can be applied in parallel without major concern.

The last stage before outputting to the audio jack is the volume control, or gain.

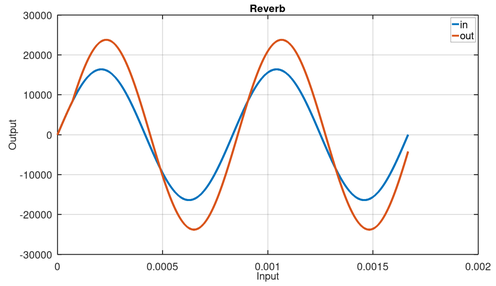
Tonestack Response

Below are three graphs, each with one of the tone ranges at minimum, and the others at maximum. Most guitar amplifiers use a 3 band tonestack: bass or low, mid, and treble or high. This tonestack concept was implemented with three independent band pass IIR filters, one for each band. These each have their own gain, independent from each other. Additionally, when each of the bands are set to the same value they produce minimal ripple in the overall passband.



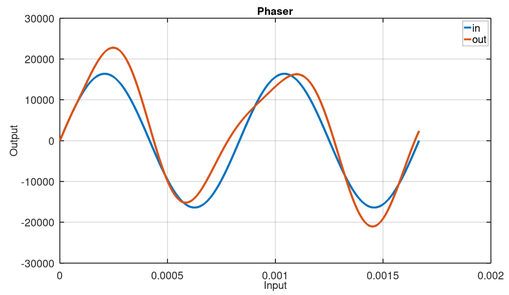
Reverb

The reverb effect is implemented by re-adding the attenuated signal into the original. This delays the peaks, and the transient at the beginning is the process of filling the buffer.



Phaser

The phaser effect is achieved by taking a low frequency oscillator and multiplying it by the input signal. The phaser oscillator is allowed to vary between 5 ad 10 Hz, user selecteable.



Acknowledgements

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