Handmade Guitar Effect Pedal

Abstract: Guitar effect pedal plays an important role in creating a symbolic tone for the electric guitar. In most of the early effect pedals, analog circuits are used to process the audio signal. In this project, we propose a guitar boost pedal based on the transistor common emitter amplifier. The circuit is successfully simulated on the NI Multisim and implemented on a stripboard, thereby realizing the function of enhancing (boost) the input guitar signal.

1. Introduction

The principle of generating sound for the electric guitar is based on electromagnetic theory. The pickup under the steel strings, which is composed of magnets and coils, produces a magnetic field around itself and induce the strings. When the strings vibrate, the relative motion between the strings and the pickup changes the flux of the magnetic field. According to Faraday's law of induction, the changing magnetic flux will produce an electric field, then induce a current in the coil. In this way, the physical motion of the strings is converted into an electrical signal, which will eventually enter an amplifier and become the sound we hear.

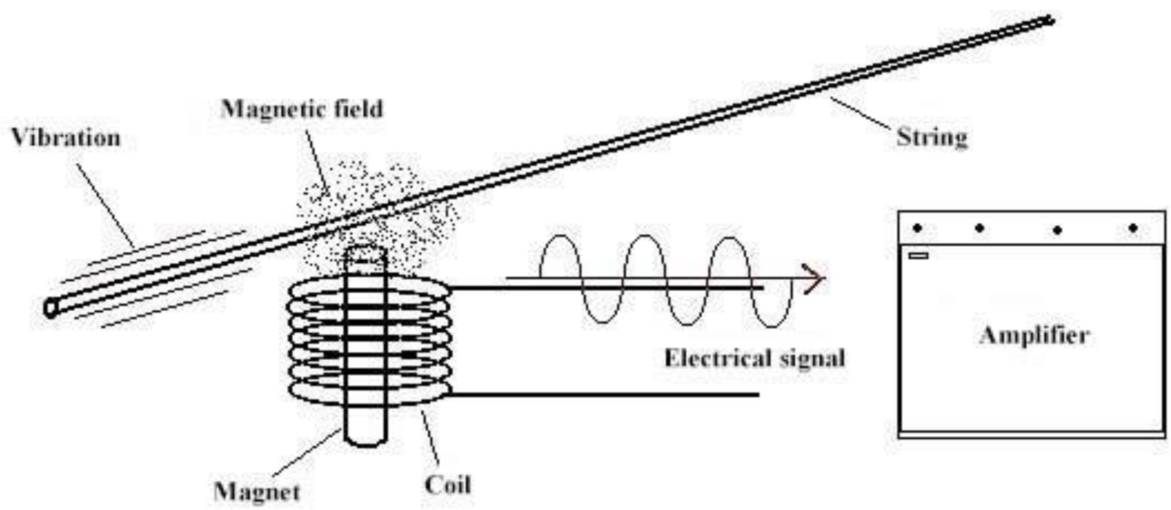


Fig. 1: The principle of the guitar pickup

The earliest pickups were attached on the acoustic guitars. Because of the feedback in the hollow of the guitar body, the electrical sound became distorted and fuzzy. Inspired by this phenomenon, musicians attempted to alter the sound in their favor and thus invented guitar effect pedals. Before the advent of DSP technology, people usually adopted analog electronic methods to process guitar audio signals. For example, the overdrive pedal, which can distort the sound, is a series of the operational amplifier integrators. In this project, we develop a transistor common emitter amplifier circuit to enhance the input signal. Such a circuit is a boost pedal, generally called "booster".

2. Circuit Analysis

We select the 2N2222 NPN bipolar junction transistor, one of the most available transistors on the market, as the core of the amplifier circuit. It is a common transistor used for general purpose low-power amplifying.

The audio signal frequencies of an electric guitar are mainly distributed within the hearing range (20 to 20,000 Hz). In this frequency band, the common emitter amplifier circuit is suitable. Hence we choose the typical RC coupling common emitter amplifier as the basic topology of this booster.

A boost pedal usually only boosts volume without fuzzing the sound. In other words, we don't expect too much distortion. Therefore, when setting the quiescent point of the transistor, we tend to choose the active region. On the other hand, we will use a Fender Stratocaster guitar, whose tone is thin and bright, to test the pedal. Thus we expect the pedal to be a treble booster, which mainly boosts the upper-mid frequencies. Similarly, in the following simulations, we mainly concern those frequencies over 659.26 Hz (notes higher than the E5 on a guitar).

Based on the factors above, we modify the components and analyze the simulation results on the NI Multisim. After many attempts, we obtain the desired circuit, as shown in Fig. 2.

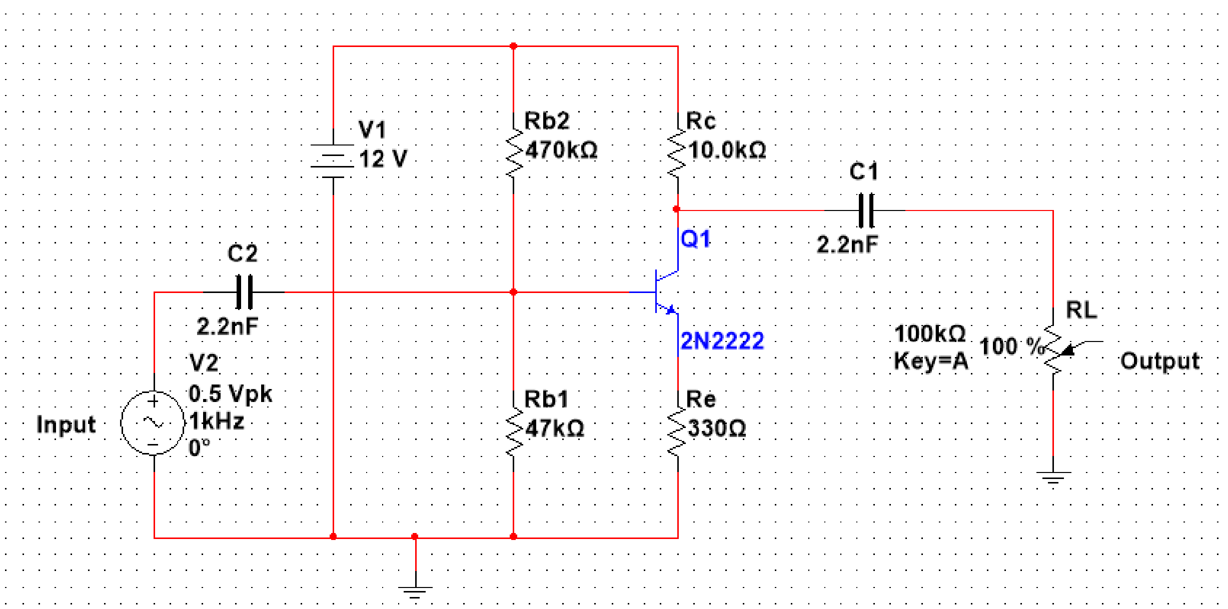


Fig. 2: The circuit diagram of the boost pedal

According to the frequency response of RC coupling single stage common emitter amplifier, the lower cutoff frequency f_L of this circuit is given by:

$$f_L = \frac{1}{2\pi(R_c + R_L)C}$$

where R_c is the collector resistance, R_L is the load resistance, and C is the coupling capacitance. We can estimate that f_L is 657.67 Hz, which satisfies the requirement for the frequency band. In addition, we obtain a Bode plot through the AC Analysis function on the NI Multisim. The treble notes are all within the passband, as shown in Fig. 3.

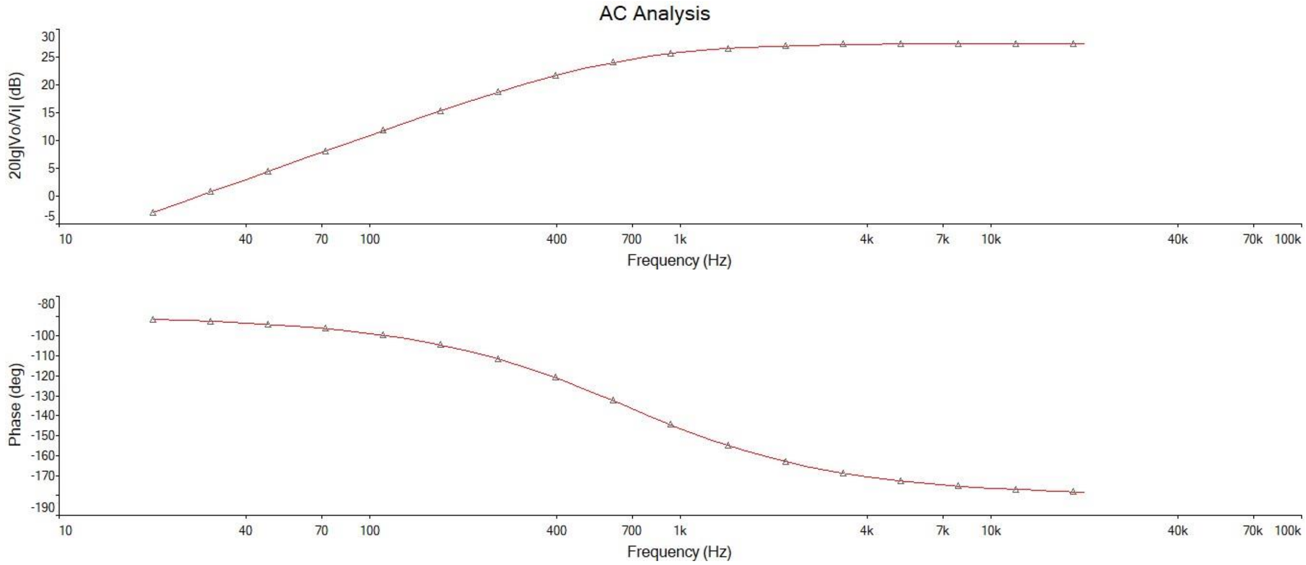
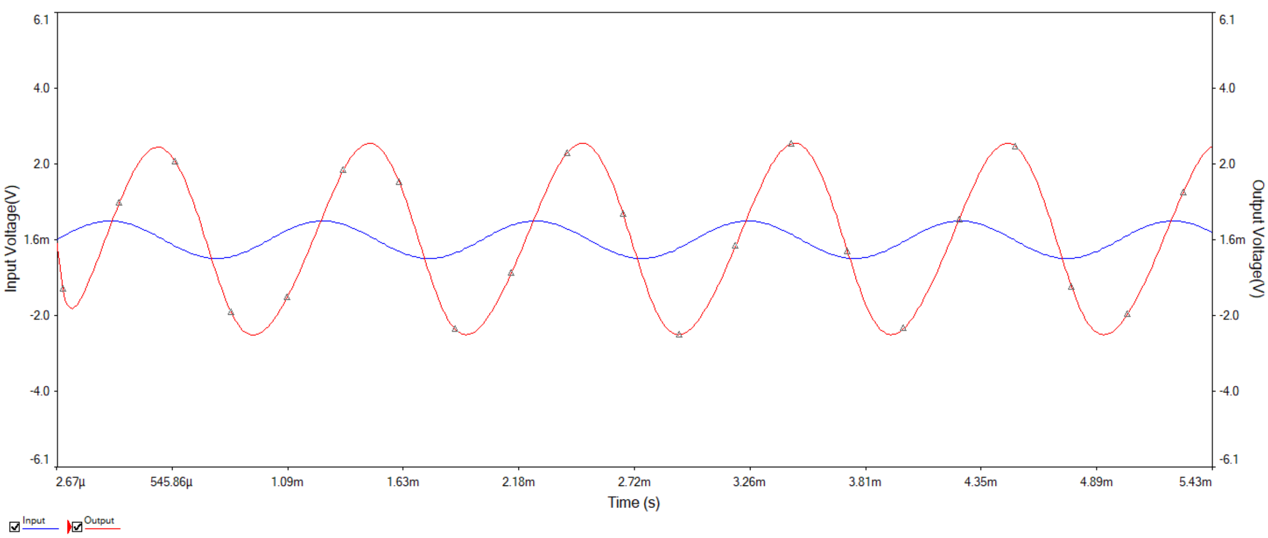


Fig. 3: The Bode plot of the booster circuit

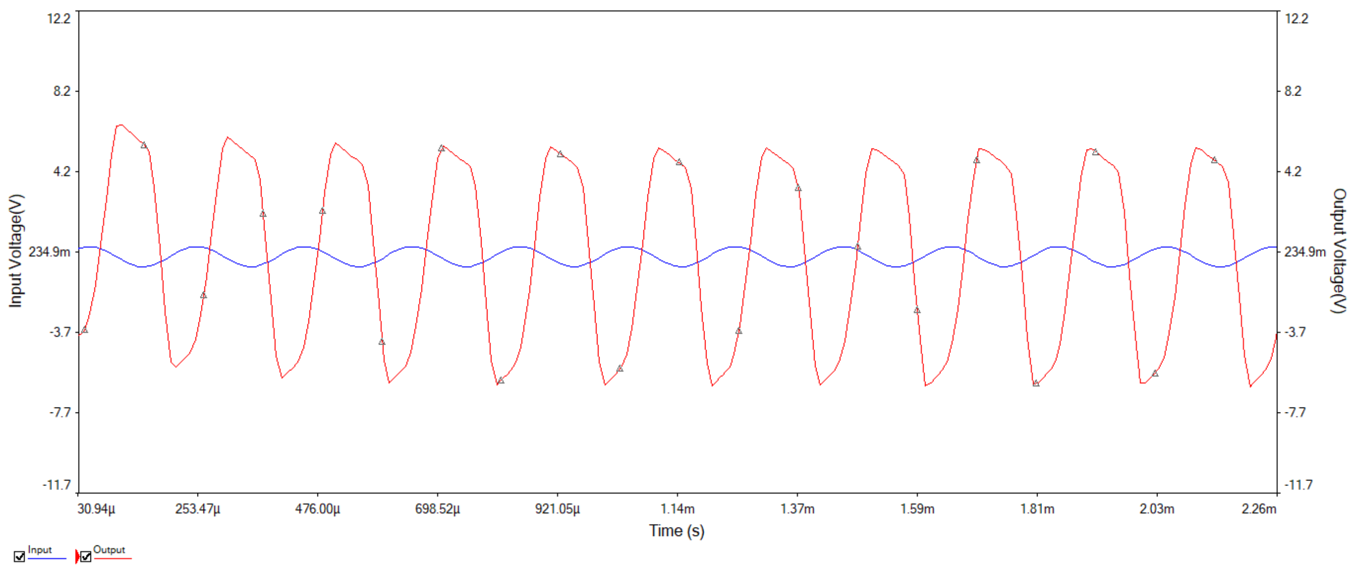
3. Simulation Results

During the simulation, we input AC voltage signals of different frequencies (mostly over 1 kHz) and observe waveforms' amplification as well as distortion. Among these results, the signals of lower frequency (under 2 kHz) are significantly amplified. However, signals of higher frequencies (e.g., 5 kHz) output distorted waveforms. This phenomenon is acceptable since the highest note on an electric guitar is D6 (1174.7 Hz) or E6 (1318.5 Hz).

Admittedly, every note is composed of a fundamental frequency and many higher harmonics, which will distort when passing through the booster. But in practical application, one effect of a booster is to make the sound start to break up, which originates from the slight distortion of these harmonics.



(a) Input frequency: 1 kHz

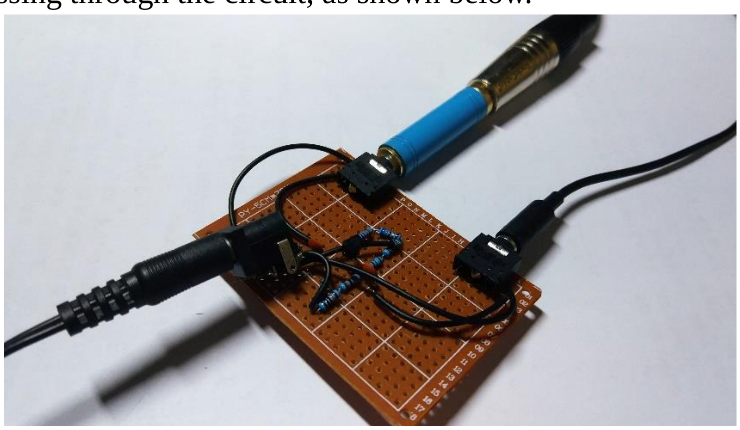


(b) Input frequency: 5 kHz

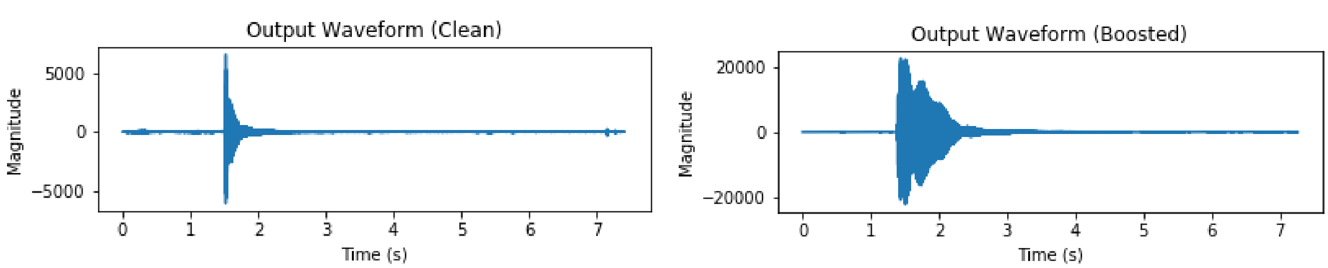
Fig. 4: Input and output waveforms of simulation (input: blue; output: red)

4. Implementation Results

We make a demo of this boost pedal with the devices in hand. Primitive as it is, guitar audio signals are indeed boosted after passing through the circuit, as shown below.



(a) Demo of the boost pedal



(b) Output guitar audio waveforms: clean and boosted

Fig. 5: Hardware demo and practical output waveforms

During the practical test, we play the note E5 on the guitar. Fig 5b compares the original clean signal and the boosted signal. We can see a notable increase in the amplitude of the boosted signal as expected. Aurally, on the other hand, the boosted note sounds louder and thicker, which is the desired effect.

5. Conclusion

Our work has successfully implemented a guitar boost pedal, which amplifies the input audio signal and alters the original sound effect. However, with limited components, our effect pedal is a still a primitive demo that soldered manually on a stripboard, lacking reliability and beauty. Thus, we will consider building the circuit on PCB and containing it within a box for further improvements, which will pave the way for some more complicated effect pedal circuits, such as overdrive, delay, reverb, etc.

Furthermore, with the development of the DSP technology, a digital effect pedal highly integrated in a reliable microchip, has become increasingly popular, which may be covered in our next research.