# Analysis And Modelling of Universal Buffer Circuit for Guitar Pedals

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**Abstract:**

This paper attempts to explain what a guitar pedal is along with its working. It also sheds light on the various pedal types and later dives into the functioning and implementation of a universal buffer circuit using discrete off-the-shelf components along with its block diagram, component description, working of each block and a proposed model. At the end, the results obtained from the study would be used to draw conclusions from the studies carried out in this paper and suggest a future scope for such do-it-yourself modular pedals.

**Keywords:** Guitar Pedal, Effect, Echo Effect, Discrete Off-The-Shelf Components, Op-Amps (Operational Amplifiers)

## 1 Introduction

In the musical industry, string-based instruments like guitars are crucial parts of any symphony. Earlier, guitars used to rely on echo chambers to produce musical notes, but since the inception of electric guitars, they no longer solely rely on resonance, but use an external amplifier to deliver the desired sound. Inclusion of electronics in a guitar opened a new dimension of music where effects can directly be added to the guitar's output. These devices are called guitar pedals & there is a wide variety of effects which these devices can impart to the sound.

Guitar effect guitar pedals have been used in music for decades, and are popular among guitarists, bassists, and other musicians. They work by capturing an incoming audio signal, adding certain effects to the received sound & mixing it back in the output.

A basic block diagram of any guitar pedal follows the below mentioned structure as seen in [1].

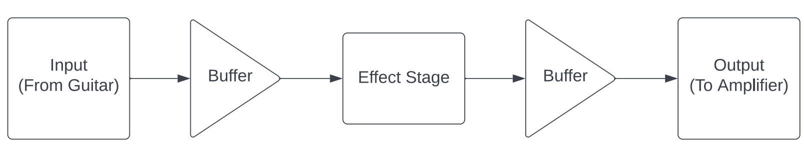


**Fig. 1 B**asic Guitar Effect Pedal Block Diagram [1].

The basic block diagram consists of five stages:

- The first stage consists of getting signal input from the guitar by using pickups.
- This is followed by a buffer stage, which may amplify the signal or define signal limits with respect to frequency or amplitude alongside providing isolation.

- Singal from the input buffer is sent to the effect block where the desired effect characteristics are imparted to the signal.
- After the effect stage, another buffer block is used to again shape the signal in terms of frequency and amplitude. This block also isolates the amplifier block from the effect circuitry.
- The shaped signal is then sent to an amplifier which amplifies it and makes the sound audible.

In terms of the distinct types of guitar pedals, they are classified into four categories [2]:

- Dynamic Effect : Shapes the volume of tones.
- Time-based Effect : Changes the playback time of tone.
- Frequency-based Effect : Alters specific frequencies of tone.
- Modulation Effect : Use LFO (Low Frequency Oscillators) to vary shape of sound.
- Modelling Effect : Use signal-processing power to digitally model the electronic, mechanical, and magnetic characteristics inherent to an instrument to create completely new sounds. It employs both time-based and frequency-based effects.

Based on the above-mentioned effect types, conventional pedals for effects like Acoustic Simulator, Chorus, Compression/Sustain, Delay/Distortion, Fuzzy can be classified into separate groups.

While studying such pedals [6-9], it was realized that guitar pedals are not manufactured in India, and the cost of purchasing a guitar pedal was quite high due to the same reason. Alongside this, each pedal only imparts a single effect, and one needs to purchase multiple pedals for individual effect. To address this issue, this paper aims to describe a model for a modular guitar pedal which can be used to impart different effects, which would use off-the-shelf components and be economic when compared to its professional counterparts and offer satisfactory performance at the same time.

This model plans to implement the power supply, buffer stage ,a true bypass switch & a dry signal cutoff switch, all of which are common components of any guitar pedal [6].
The flexible nature of this model would also allow enthusiasts to modify the specifications to tune to sound characteristics based on the individual's liking.

## 2 Proposed Methods

Based on the research carried out in this paper, it was clear that all pedals require the following components :

- Power Supply Module
- Input & Output Buffer Circuity.
- Path to bypass effect circuitry.

This model allows the user to keep the minimum required circuitry common for all effects and just vary the effect circuit to change the output effect.

A generic circuit diagram for the power & buffer block is as mentioned below based on reference from [3].

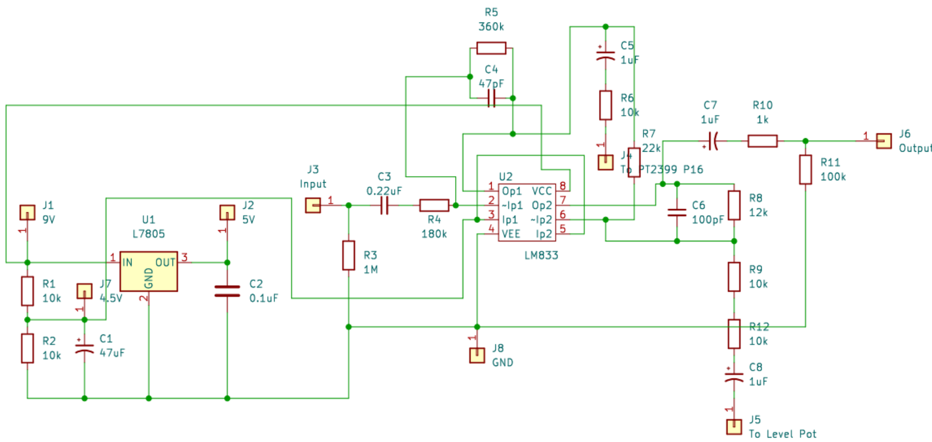


**Fig. 2 S**chematic Diagram for Basic Power Supply & Buffer Circuit.

Figure 2 depicts the schematic design which consists of a power supply module based around 7805 5V Power regulator module and the buffer block using LM833.

Any pedal requires 3 voltage levels to function namely +9V, +4.5V, and 5V. To make the design compatible with commercial pedals, a +9V 6LR61/006P battery is used to power the circuit, which inherently provides +9V. Since the circuit draws around 8mA of current, this battery can power the circuit for a significant amount of time. +4.5V can be obtained by a simple voltage divider configuration while the +5V voltage level is obtained from the regulator [13,14].

For the buffer circuit, IC LM833 is used as it has 2 high slew rate Op-Amps which can handle voltage swing of up to ±18V. A comparison table for equivalent circuits has been depicted below.

**Table 1 I**C Comparison for Buffer Circuit.

| **Parameter** | **LM833** | **NE5532** | **TL072** |
|---|---|---|---|
| IC Type | Op-Amp | Op-Amp | Op-Amp |
| $V_{CEO}$ (V) | ±18 V | ±15 V | ±30 V |
| Package | DIP/SOIC | DIP/SOIC | DIP/SOIC |
| Type | Dual | Dual | Dual |
| Slew Rate at Unity Gain | 7 V/µS | 9 V/µS | 20 V/ µS |
| Gain Bandwidth Product | 10 MHz | 100 kHz | 5.25 MHz |
| Thermal Specifications | -40 to 85°C | -40 to 85°C | 0 to 70°C |

Table 1 shows a comparative analysis of the various compatible & widely used Op-Amps. Here, LM833 offers a high enough slew rate along with the best Gain bandwidth product with the desired operational range for voltage swing. Moreover, the main reason for choosing LM833 was its cost and availability.

In Figure 2, the first Op-Amp of LM833 acts as a high pass filter having cutoff of around 8 Hz and is used in as a differential amplifier having gain factor as 2.

Cutoff frequency can be calculated by using formula 1 [6,11,13-14].

$$f_{high-pass} = \frac{1}{2\pi * R * C} = 8.841\ Hz \qquad \text{….(1)}$$

Here, by substituting value of R = R4 = 180 kΩ & C = C3 = 0.22 μF, f comes out as 4 Hz, but it was observed that the cutoff performed better when C= 100 nF, which leads to a cutoff frequency of 8.841 Hz.

Input resistance for the input stage can be calculated using the formula with reference to figure 1.

$$Z_{IN} = R3||R4 = 152{,}542\Omega \qquad \text{….(2)}$$

We have R3 = 1MΩ and R4 = 180kΩ , which give the input impedance of around 150kΩ. This results in a characteristic dark tone of the output.

For voltage gain, values R5 and R4 are considered from figure 1.

$$G_V = \frac{R5}{R4} = 2 \qquad \text{….(3)}$$

From figure 1, R5 =350kΩ and R4 = 180kΩ, which results in the voltage gain factor of $G_V$ =2.

For the output stage, cutoff frequency of low pass filter is calculated using formula 4.

$$f_{low-pass} = \frac{1}{2\pi * R * C} = 9.4\ kHz \qquad \text{….(4)}$$

This yields the cutoff frequency as around 9.4 kHz for R = R5 = 360 kΩ and C = C4 = 47pF.

For the true bypass switch, this model employs a 3-Pole Dual Throw (3PDT) latching switch to toggle between shorting the input and output and passing the signal through the effect circuitry.

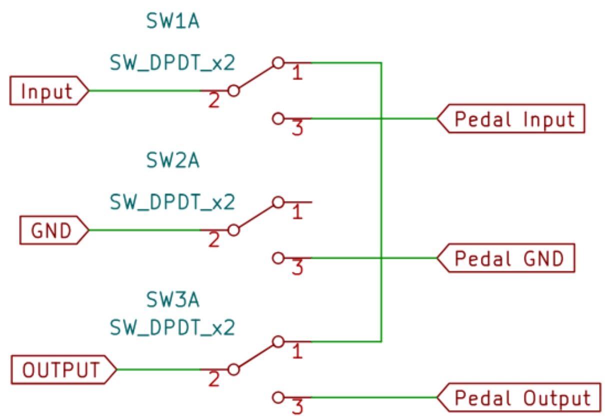


**Fig. 3 3**PDT Modelling Using DPDT

Figure 3 shows how the operation of a 3PDT can be modelled by using 3 Dual Pole Dual Throw (DPDT) switches. Here all the switching arms for the DPDT switches are linked together. This allows for switching connections between the guitar input to either the effect circuitry or directly to the output.

By combining all the above-mentioned blocks, a design for the universal pedal can be developed, by incorporating all the above-mentioned functionalities into a single circuit.

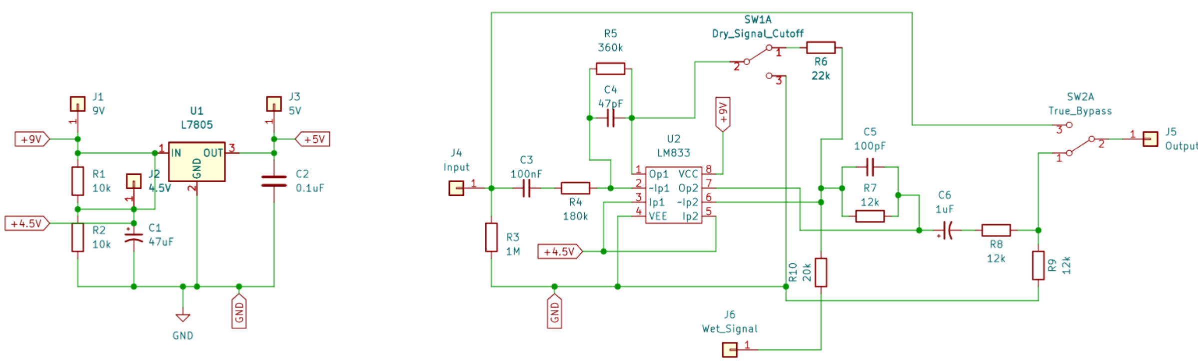


**Fig. 4 U**niversal Buffer Circuit Modelled for Echo Effect Pedal

The circuit depicted in figure 4 is a circuit diagram for a universal buffer circuit. This circuit accepts signals from guitar from the input pin and provides output on the other side and control switches for dry signal cutoff and true bypass.

This model is a basic framework which can be modified/extended based on specific use cases.

To verify functioning of the circuit devised above, it was simulated in MultiSim, to observe its Alternating Current (A.C.) response. The circuit implemented in MultiSim is depicted in figure 5.

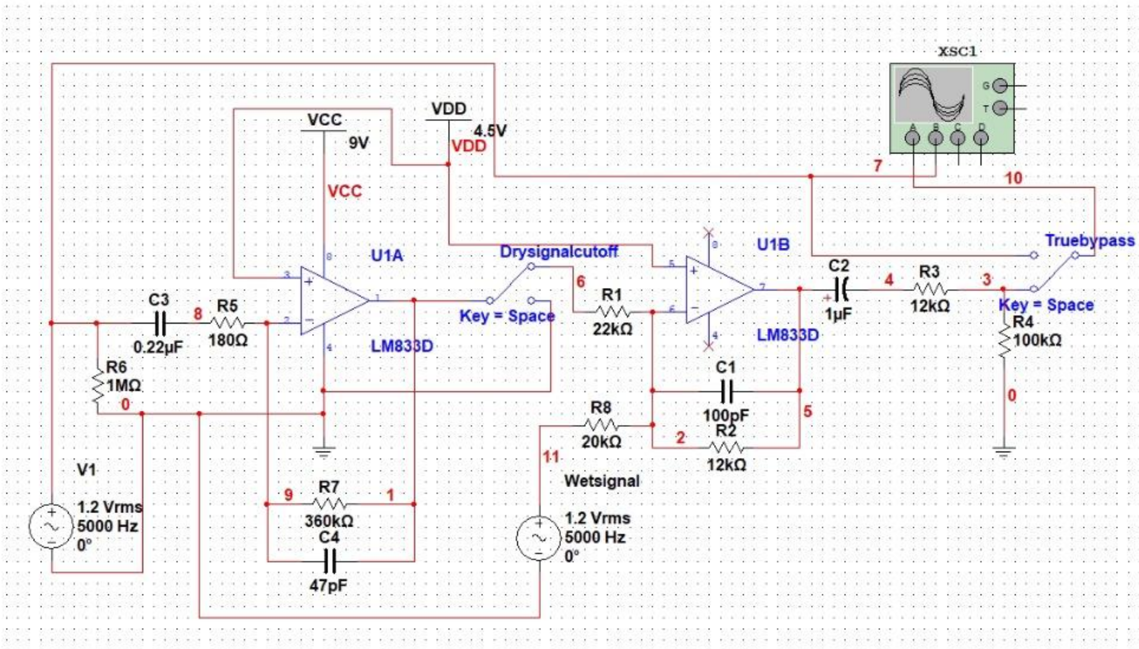


Fig 5 MultiSim Simulation Circuit for Proposed Model

## 3 Results & Discussion

The following conclusions can be drawn from the work carried out in this paper :

- Though TL072 would give a better slew rate this design employed LM833 due to its availability and large bandwidth support.
- While working on a buffer circuit, particular care needs to be taken for attenuation experienced by the dry signal on its way to the effect circuitry.
- The Op-Amps must support a slightly higher frequency than the audible frequency range to account for harmonics, which add the said "sparkle" to sound.
- While simulating, a spike was observed in the middle region of the curve, which is a slight deviation from the expected flat response of the circuit. Plot for the same has been depicted in figure 6.

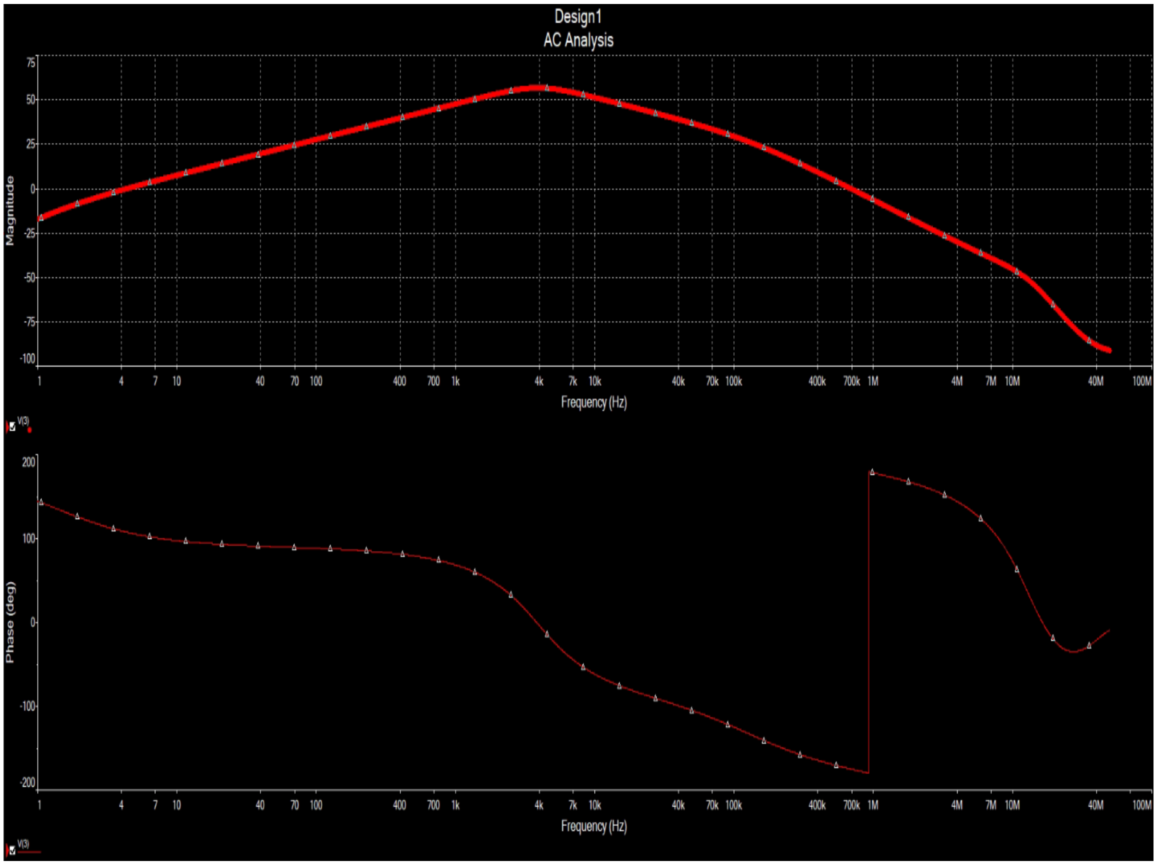


**Fig. 6 F**requency Response Curve Using A.C. Analysis

## 4 Conclusion

With this model, the aim is to have a modular framework ready to address a major problem faced by guitarists. The solution stated above also addresses issues regarding excessive cost due to import of such pedals and imparts essential features like a true bypass toggle switch, which are sold as add-ons in commercial pedals.

Modularity and flexibility of this design will also allow guitarists to tune the circuit based on their liking and it also reduces the cost of purchasing separate pedals for different effect as majority of the pedals operate within the same frequency band and contain circuitry for power and buffer blocks.

A dry signal cutoff too has been added to this model so that pedal effects such as echo, chorus, reverb can be accommodated while pedals like compressor, overdrive, distortion, fuzz effect, which do not need it can bypass this functionality without need of any separate circuitry.

This model proves that it is indeed possible to create a modular design that would fit all these various effects as well as minimize costs and add other things such as a true bypass, and a modular effect design. This will also allow daisy chaining and drive multiple pedals that may lie after the same as well as boost the signal if it passes through a long chain of pedals without distorting the output much.

There is always scope for improvement which may include but is not limited to implementing inbuilt noise gates to minimize any distortion that may be caused due to long cable, impedance mismatch or just interference from the guitar pickups themselves. From the testing carried out in this paper, it is concluded that the split coil pickups cause a drop in the mid- section of the A.C. response. Furthermore, an equalizer can be added to tune the signal outputs frequency ranges better.

Furthermore, no tests have been carried out on devices like tube amplifiers and other alternatives to the components used in this model, hence no comments can be made about their experimental results.

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