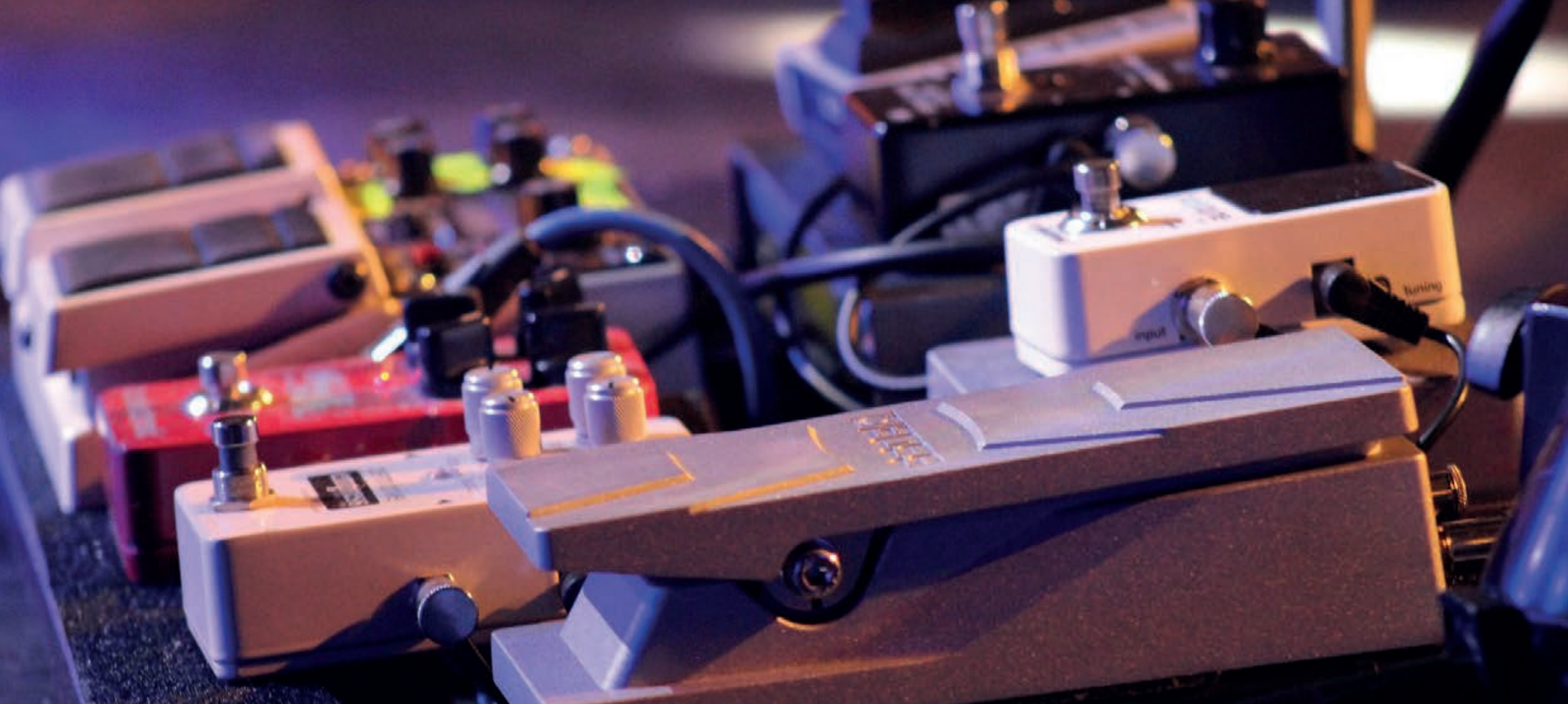

Battery-powered overdrive pedal for guitar effects

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Amplified guitars appeared in the early 1930s. In those days, however, early recording artists strove for clean, orchestral sounds. In the '40s, DeArmond manufactured the world's first standalone effect. At that time, amplifiers were valve-based and bulky.

The '40s to the '50s saw competitive individuals and bands frequently turning up their amps to overdrive levels, and distorted sound became increasingly popular. In the '60s, transistor amplifiers became available, with the Vox T-60 appearing in 1964, to further achieve the distorted sound, which by then was very sought after. This is when the first standalone distortion effect was born!

Analogue and digital processing of music signals can provide new sounds, and active overdrive effects now recreate the overdriven clipping of those early valve amps.

While distortion is usually unwanted, and to be minimised in an amplifier, the opposite is true in terms of this effect. Clipping produces frequencies not present in the original sound, partially the reason for its appeal in the early days. Strong and almost square-wave-related clipping produces very harsh sounds that are inharmonic to their parent tone, while soft clipping produces harmonic overtones and, so, generally, the generated sound depends on the amount of clipping and depletion with frequency. It's our strong belief that the quality of an overdrive pedal (Figures 1 and 2) depends on the proportion of harmonic to inharmonic tones throughout and the ability to preserve the harmonic tones at higher amplifications.

Preserving existing signals

Here, we present an overview of a circuit for preserving existing signals and producing those overdrive sounds. Using Dialog Semiconductor's SLG88104V – a 375nA quad-channel CMOS input operational amplifier – we achieved a low-power overdrive pedal that is less bulky and using only two AA batteries, which are widely available and less expensive than 9V PP3 batteries. If desired, AAA batteries can be used instead, although the extra capacity of the AA make it the better choice. Further, the circuit will optionally work on 4.5V (1.5V centre line +3V) or 6V (3V centre line +3V) if desired.

We used the non-inverting topology of the amplifier as a base for the gain stages due to its high input impedance and easy adaptation for frequency selection:

$$A_{Gain} = 1 + \frac{R2}{R1}$$

As we've seen, the gain in this setup is solely dependent on the feedback. If we convert this as a high-pass topology, gain will be dependent on feedback and input frequencies as per some overdrive arrangements. Further, if the filter feedback circuitry is doubled, then the topology will apply one range of responsive gains to the input and then a second different set of responsive gains. This setup can both, clarify the design and allow a more frequency directional/ selective amplification; see Equations 1 and 2 and Figure 4.

This topology is an important crux relied upon by the final overdrive circuitry which will incorporate it as a main core several times to maintain a working model.

If we look at things more simply, then for a certain frequency f:

$$A_{Gain} = 1 + \frac{2\pi fC1R2}{2\pi fC1R1+1} \qquad (1)$$

and

$$A_{Gain} = 1 + \frac{2\pi fC1R2}{2\pi fC2R3+1} \qquad (2)$$

The actual equation for A_{Gain} at a particular frequency f is thus:

$$A_{Gain} = 1 + \frac{R1R2+R3R2+\left(\frac{R2}{2\pi fC1}\right)+\left(\frac{R2}{2\pi fC2}\right)}{\left(R1+\frac{1}{2\pi fC1}\right)\left(R3+\left(\frac{1}{2\pi fC2}\right)\right)} \qquad (3)$$

which breaks down further to produce a final formula:

$$A_{Gain} = 1 + \frac{2\pi fC1R1}{2\pi fC1R1+1} + \frac{2\pi fC2R2}{2\pi fC2R3+1} \qquad (4)$$

As evident, this is analogous to the addition of the simplified Equations 3 and 4, except for the inherently constant unity gain of the amplifier. In summary the frequency response gain of each high-pass feedback topology leg is compounded. The aim of such arrangements is to obtain a more uniform amplification of the input signal over the frequency range so that at higher frequencies, where the op-amp's gain is reduced, we can introduce more gain. At low voltages the sound can be preserved through those low frequencies, even though the headroom is not very high.

The circuit

SLG88103/4V has built-in input protection to protect against overvoltage at its inputs. Extra protection diodes have also been added at the initial overdrive stage for extra robustness.

The first stage, with its high input impedance, serves as a preamplifier for the overdrive stage. Its gain is about two, although varying with frequency. At this stage, care needs to be taken to minimise the amplification, since any amplification at this stage is multiplied into the overdrive amplification.

Continuing on to the overdrive stage, where the signal will undergo large gains, frequency-selective amplification again ensures that the higher frequencies get a boost for more consistent amplification, and consecutively we induce clipping using two diodes in forward-conductive mode. A simple low-pass filter forms the tone, leading to a simple volume potentiometer and a buffer to drive the output.

Only three of the on-board operational amplifiers are used, and the last remaining one is wired appropriately as per "proper setup for unused op-amps". If desired, 2 x SLG88103V devices can be used instead of a single one.

A low-power light-emitting diode indicates the on-state. The importance of using a low-power version can't be understated, due to the low quiescent currents and running power of the SLG88104V. Indeed, the power indicator LED will be the circuit's main consumer of power. In fact, due to the extremely low 375nA quiescent current, the power usage for the GreenPAK SLG88104V is very small.

Most of the power loss is through the decoupling low-pass capacitors and the emitter-follower resistor. If we measure the complete circuit's quiescent current, it turns out to be only about 20µA, increasing to around 90µA when the guitar is in action. This is very small compared to the 2mA consumed by the LED and is the reason using a low-power LED is imperative.

Figures 1 and 2: Guitar overdrive pedal

On average, a single AA alkaline battery contains around 2000mAh. A decent new pair of batteries producing 3V should then be able to source over 4000mAh.

With the LED in place, our circuit draws 1.75mA, from which we can expect over 2285 hours or 95 days of continuous usage. Because overdrives are active circuits, ours can produce a hell of a kick at minimal current usage. As a side note, the AAA batteries should half as long as the AAs.

As with any pedal, the user needs to adjust the settings to find the sound just right for them. Turning the amp's mid and bass higher than treble seem to give really cool overdrive sounds for us (as treble was harsher). It then resembled the warmer old-fashioned type of sound. EW