The Vanilla Shake

Design By Erik Vincent

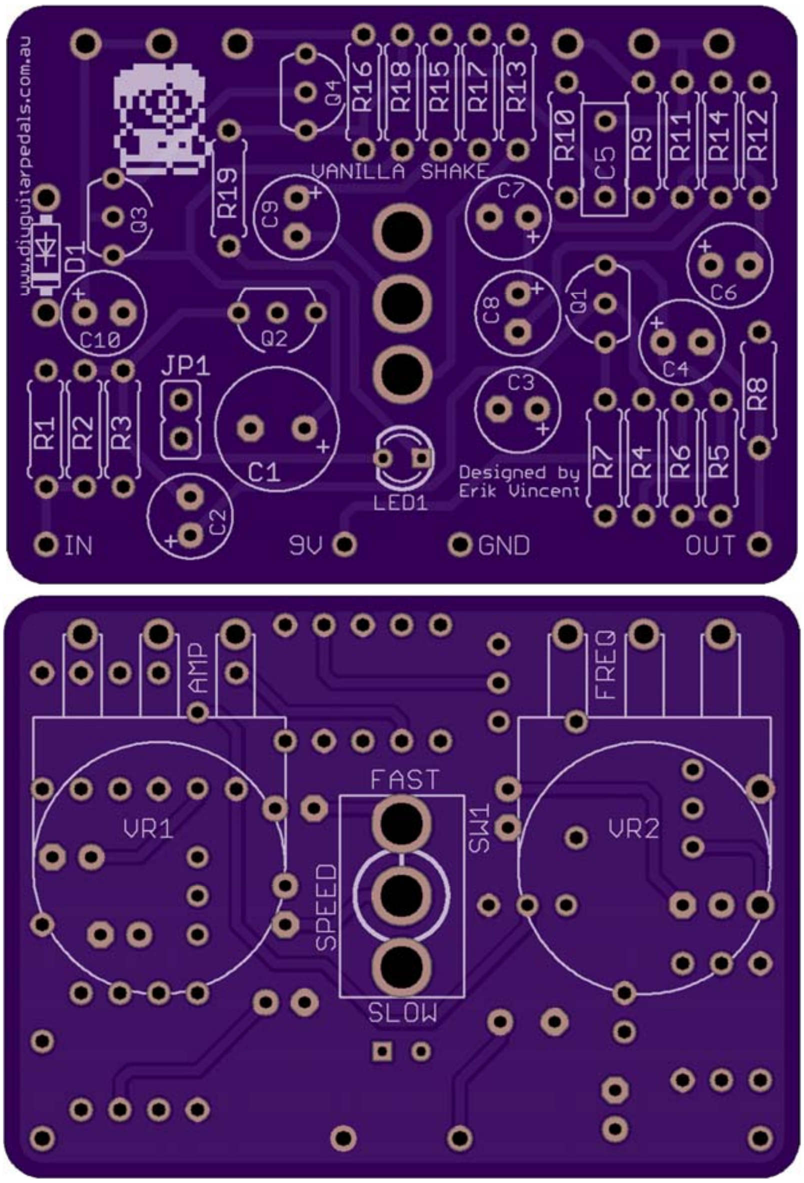
Based off the TR-68, The Vanilla Shake is a simple to build, beginner friendly, tremolo with only low levels of distortion. (Any small amount of distortion can be mitigated with a roll back on the guitar volume) The Vanilla Shake has an old vintage tone and features two simple controls: amplitude and frequency. The effect also gives a speed control option to hold the sounds' shape.

This pedal also works as a good example of sound wave manipulation.

PCB Sizing: The project is spaced to fit into a 1590B enclosure

Bill of Materials, Stock Vanilla Shake

Capacitor		Resistor	
C1	100µF (Electrolytic)	**R1**	1M
C2	4.7µF (Electrolytic)	**R2**	47K
C3	22µF (Electrolytic)	**R3**	47K
C4	4.7µF (Electrolytic)	**R4**	470K
C5	47nF (film)	**R5**	6.8K
C6	10µF (Electrolytic)	**R6**	2.2K
C7	4.7µF (Electrolytic)	**R7**	2.2K
C8	22µF (Electrolytic)	**R8**	1M
C9	10µF (Electrolytic)	**R9**	15K
C10	22µF (Electrolytic)	**R10**	330K
		R11	47K
Diode		**R12**	2.2K
D1	1N4001	**R13**	220
		R14	2.2K
Transistor/JFET		**R15**	2.2K
Q1	2N5088	**R16**	27K
Q2	2N5088	**R17**	6.8K
Q3	2N5088	**R18**	2.2K
Q4	2N5088	**R19**	2.2K
LED		**Potentiometer**	
LED1	T1-3mm LED (Any Color)	**Amplitude**	25kb (16mm)
		Frequency	1mb (16mm)
Switch			
SPEED	SPDT ON-ON		

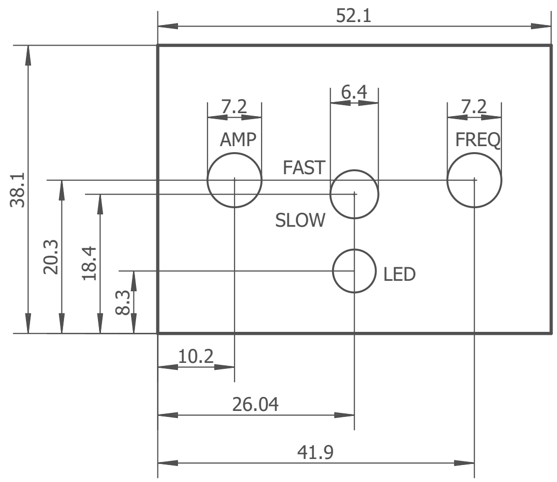


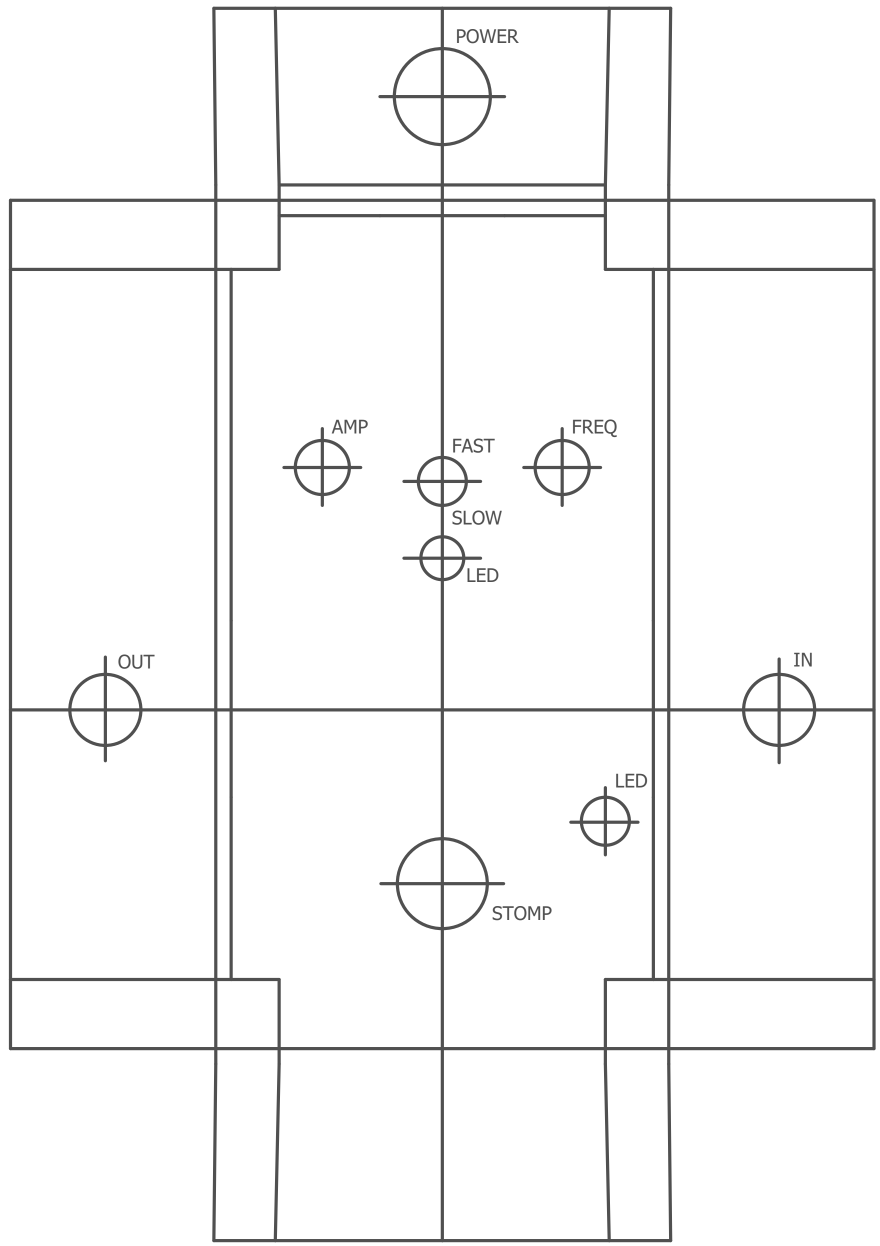
PCB Spacing

The Vanilla Shake PCB is spaced for 1590B sized enclosures or larger

Pot Spacing

The Vanilla Shake PCB mounted potentiometers are spaced for Alpha 16mm potentiometers with dust covers


52.1
6.4
7.2
7.2
AMP
FREQ
FAST
SLOW
LED
38.1
20.3
18.4
8.3
10.2
26.04
41.9


POWER
AMP
FAST
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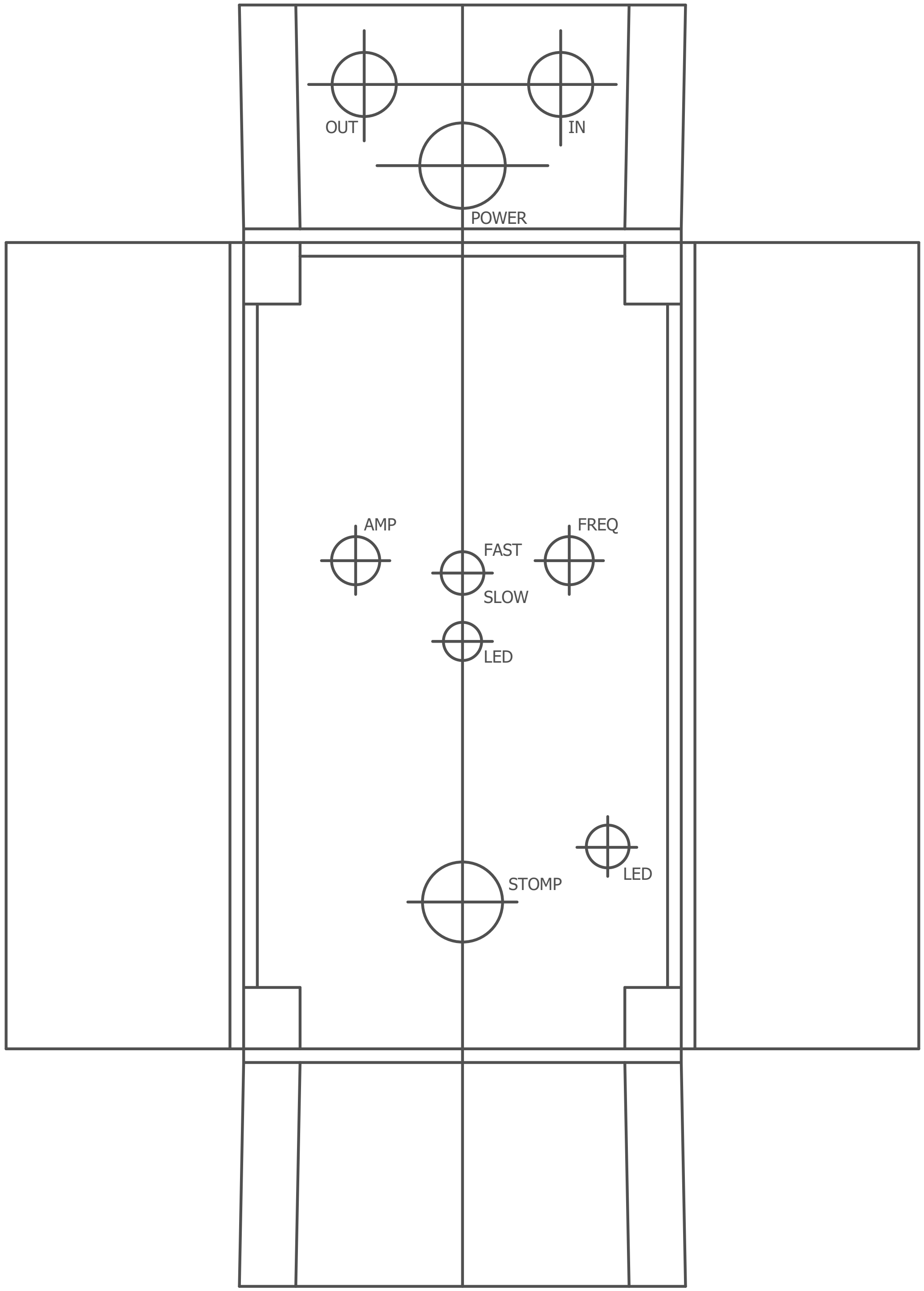
OUT
IN
LED
STOMP


OUT
IN
POWER
AMP
FAST
FREQ
SLOW
LED
STOMP
LED

Assembly.

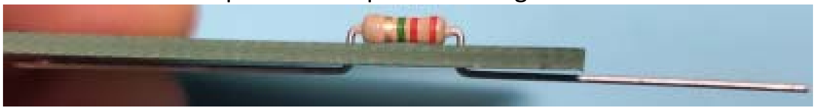
1. Soldering Order.

When soldering things to the PCB, the idea is to solder things on from lowest profile to tallest.

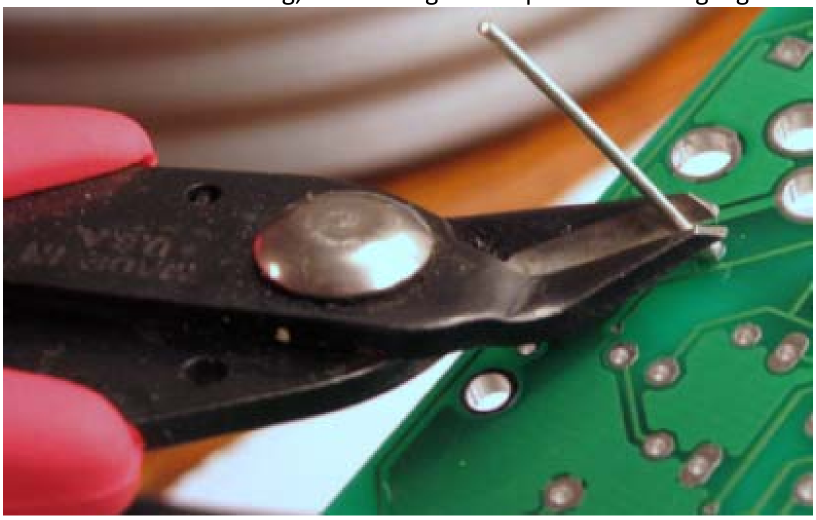
For the Vanilla Shake, the best order would be: resistors, diodes, LEDs, transistor/FETs, film capacitors, electrolytic capacitors, wiring, potentiometers, and then switches.

1.1 Resistors.

Resistors are small passive components designed to create a resistance of passage of an electric current.

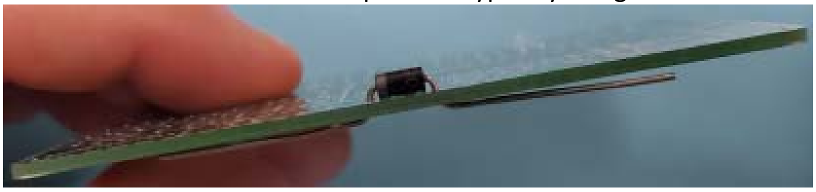


For this pedal we will be using 1/4 Watt resistors. These can either be 5% tolerance carbon resistors, or 1% tolerance metal film resistors. Orientation of “which way is up” doesn’t matter, so you can install them either way. After installation and soldering, do not forget to clip the remaining legs from the PCB.

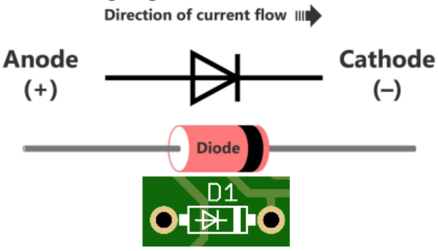


1.2 Diodes.

Diodes are semiconductor components typically designed to allow the flow electric current to go in one direction only.

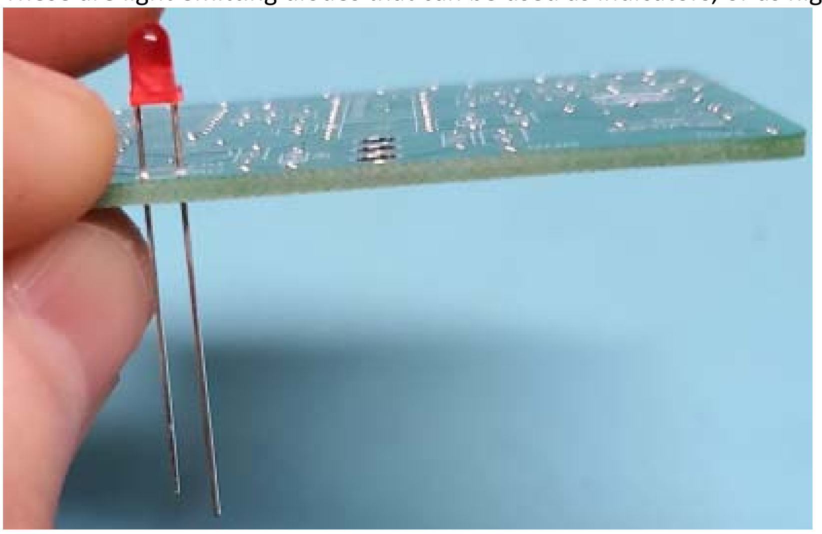


The orientation of a diode does matter based on the cathode and anode of the diode in the circuit. Make sure the stripe on the diode lines up with the stripe on the PCB's silkscreen. After installation and soldering, do not forget to clip the remaining legs from the PCB.

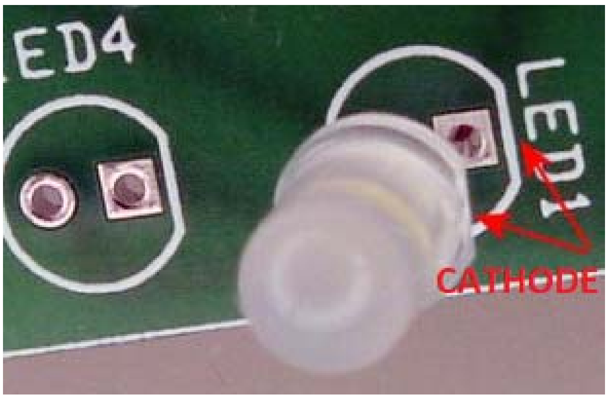


1.3 LEDs.

These are light emitting diodes that can be used as indicators, or as high-forward voltage, low signal diodes.

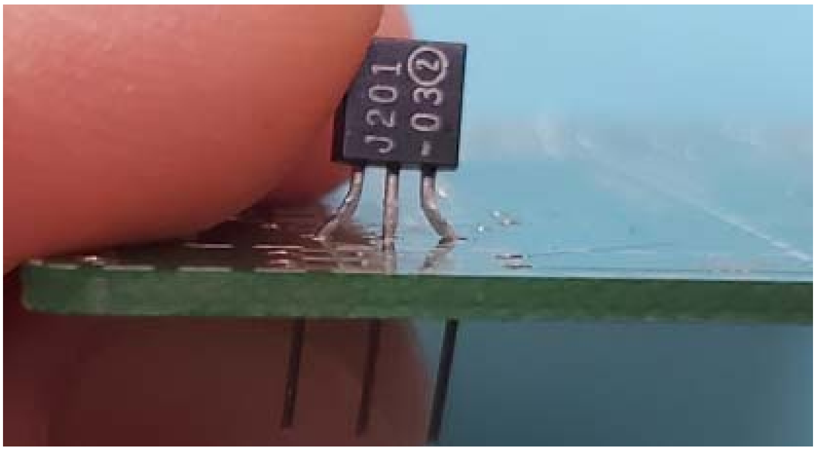


These devices will have a silk screen notch to indicate an orientation. Make sure the flat side on the PCB matches the LED's flat cathode when placing on the PCB.

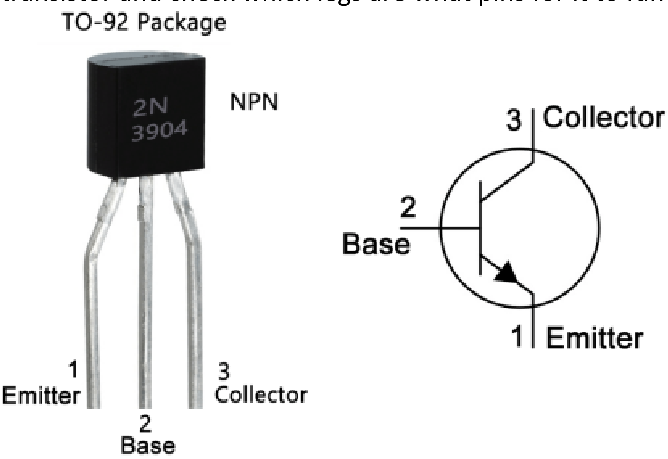


1.4 Transistors/FETs (silicon).

These semiconductor devices come in a few categories, such as BJT, JFET, MOSFET, and IGBT and are used for a variety of functions



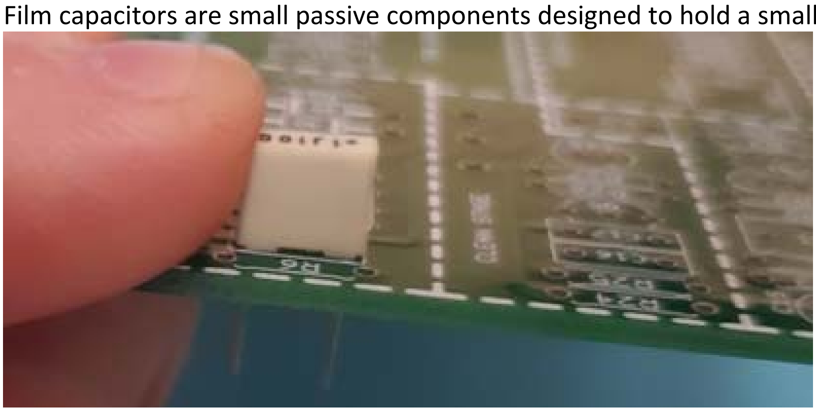
These devices typically only install one way, but pinouts can differ from different part numbers, so if using a different part number transistor than the one called out in the bill of materials will require that you check the datasheet of the transistor and check which legs are what pins for it to function properly.



After installation and soldering, do not forget to clip the remaining legs from the PCB.

1.5 Capacitors (film).

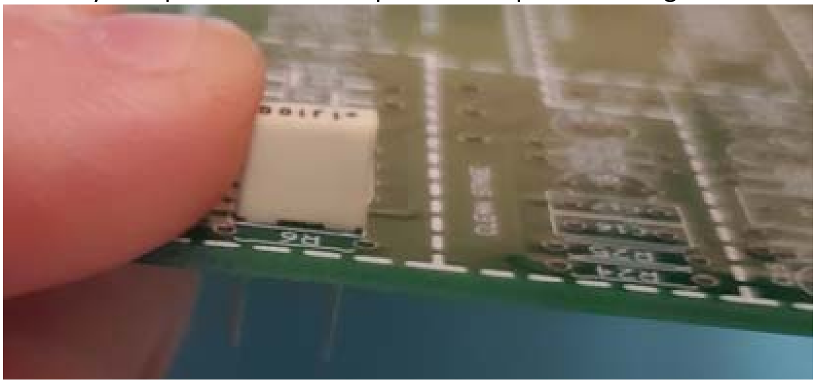
Film capacitors are small passive components designed to hold a small amount of charge in a circuit.



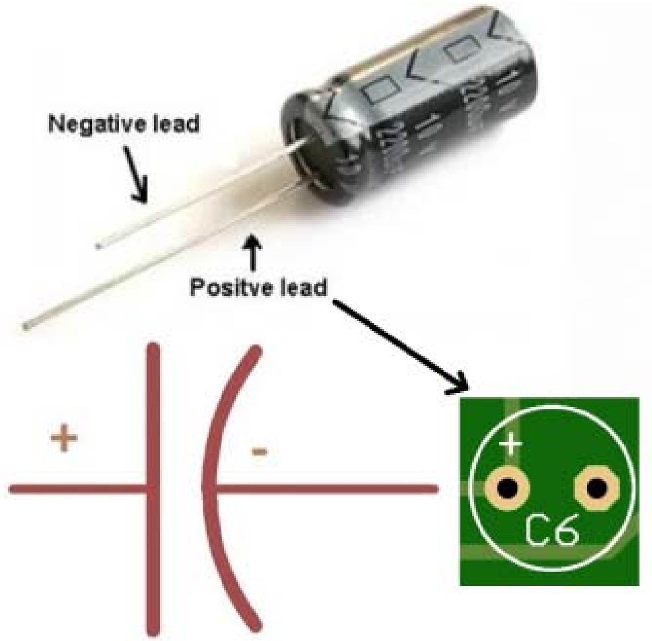
Orientation of "which way is up" doesn't matter, so you can install them either way. After installation and soldering, do not forget to clip the remaining legs from the PCB.

1.6 Capacitors (electrolytic).

Electrolytic capacitors are small passive components designed to hold a small amount of charge in a circuit.



Electrolytic capacitors are typically polarized, so orientation will matter.

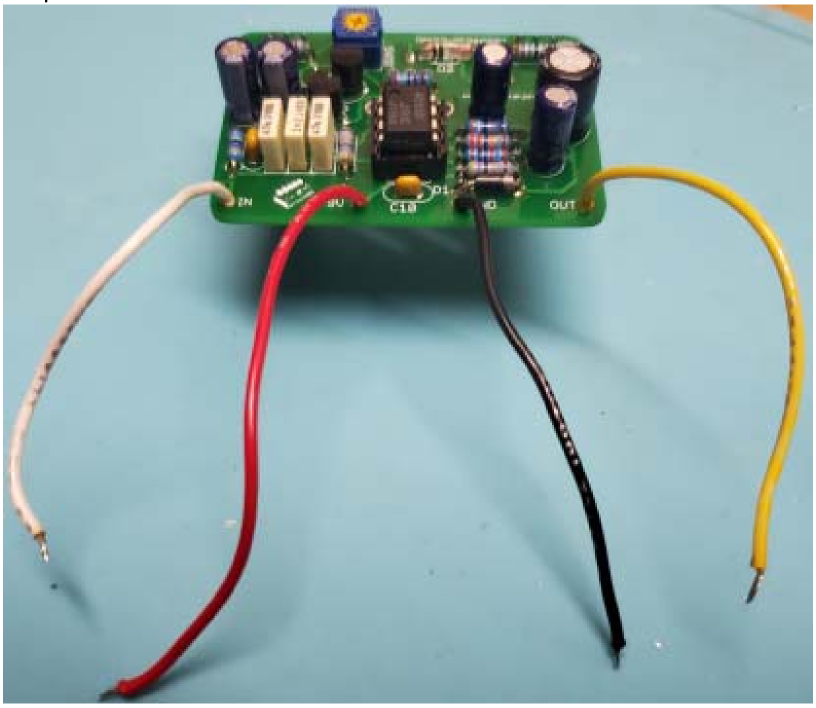


Polarized Electrolytic Capacitor and its electric Symbol

After installation and soldering, do not forget to clip the remaining legs from the PCB.

1.7 Wiring.

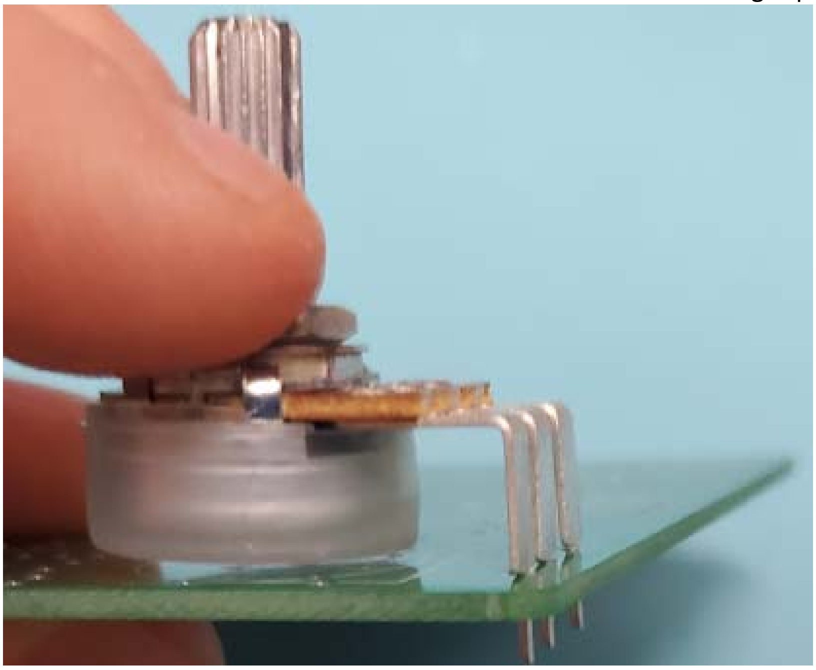
Wires used for the pedal are for delivering power over the hot and ground wires as well as signal for the input and output.



These can be installed at the very end, but in some situations, installing them before potentiometers are soldered in place can be advantageous. Colored wire doesn't change the properties, but using color codes for hot and ground wires, like red being hot, and black being ground, are common place. Typically, stranded hook-up wire, AWG 24 or 22 is used for this task. Using wire strippers, strip away about 1/8" (3mm) of the wire from either end and then using a soldering iron, tin the exposed tips with solder before installing into the PCB.

1.8 Potentiometers.

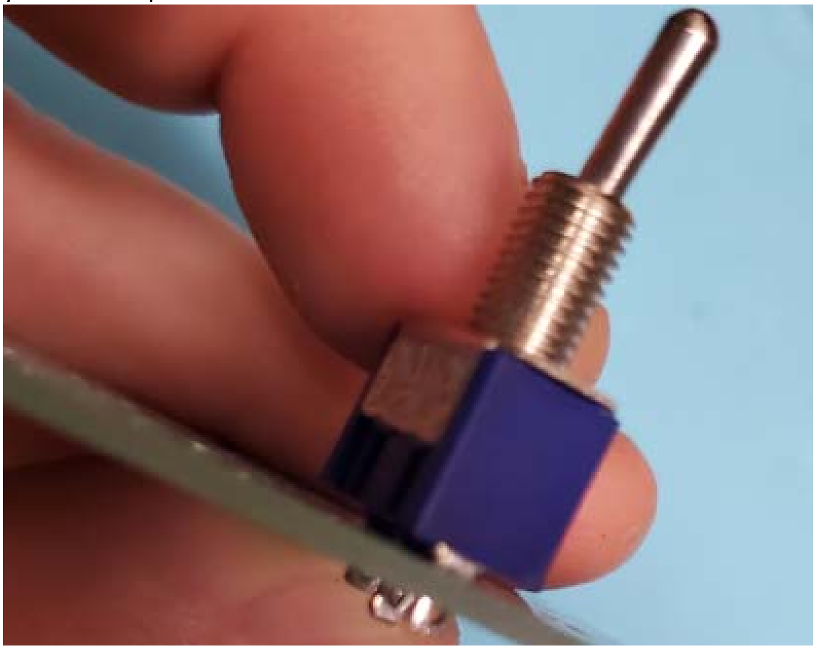
Potentiometers are variable resistors that are used for controlling aspects of the pedal.



This pedal can utilize 16mm pots. These are typically installed on the backside of the PCB and uses the included washer and jam-nut to mechanically secure the PCB to the enclosure via a strategically drilled hole on the enclosure. Orientation of potentiometer is preferred to line up the knob on the silk screen with the knob of the potentiometer.

1.9 Switches.

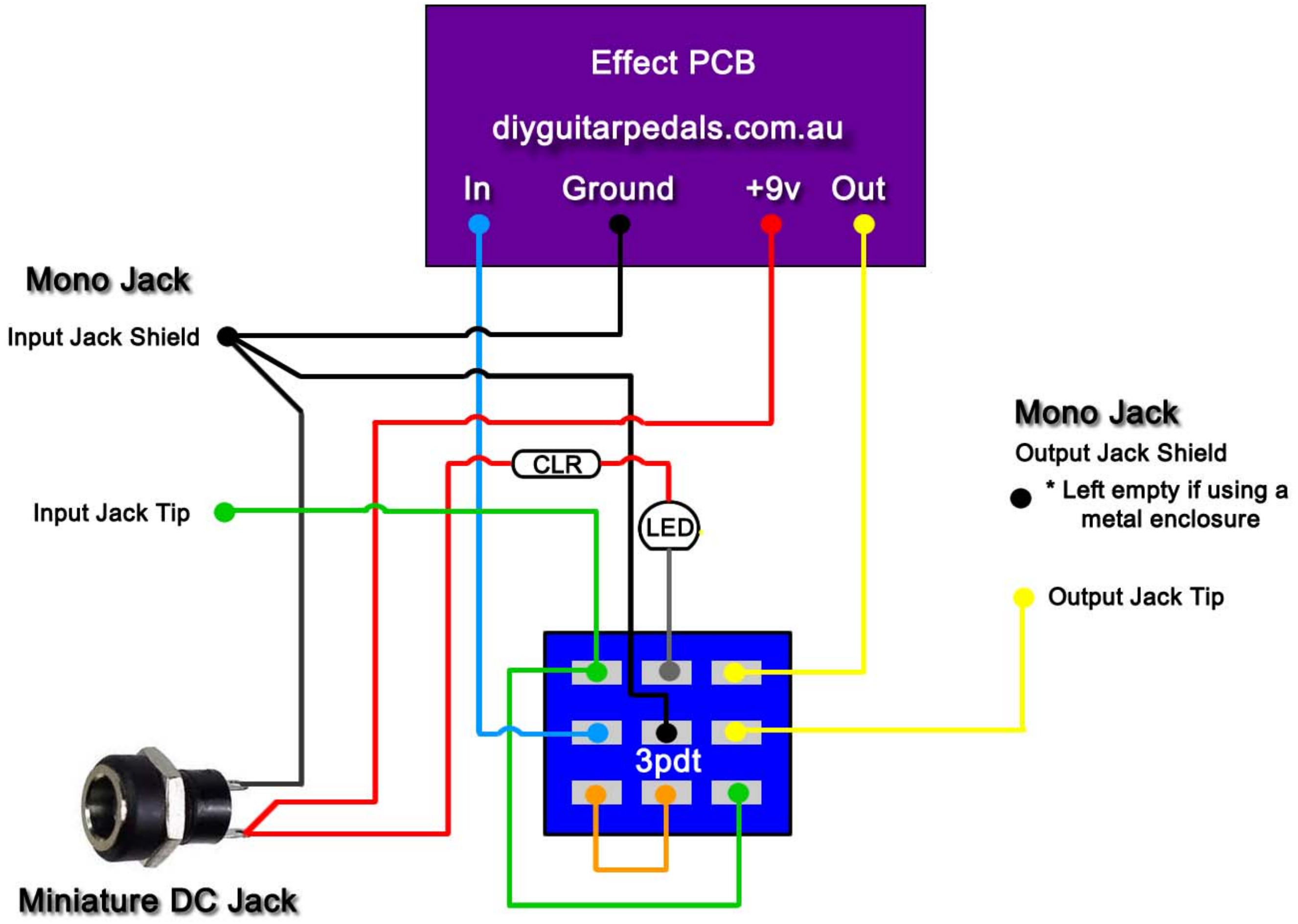
Switches are mechanical devices that change the flow of electricity on a circuit, usually to provide different options to your effects pedal.



These are typically installed on the backside of the PCB and uses jam-nuts to set the "height" of the actuator and to mechanically secure the PCB to the enclosure via a strategically drilled hole on the enclosure. Orientation should not matter with most switches.

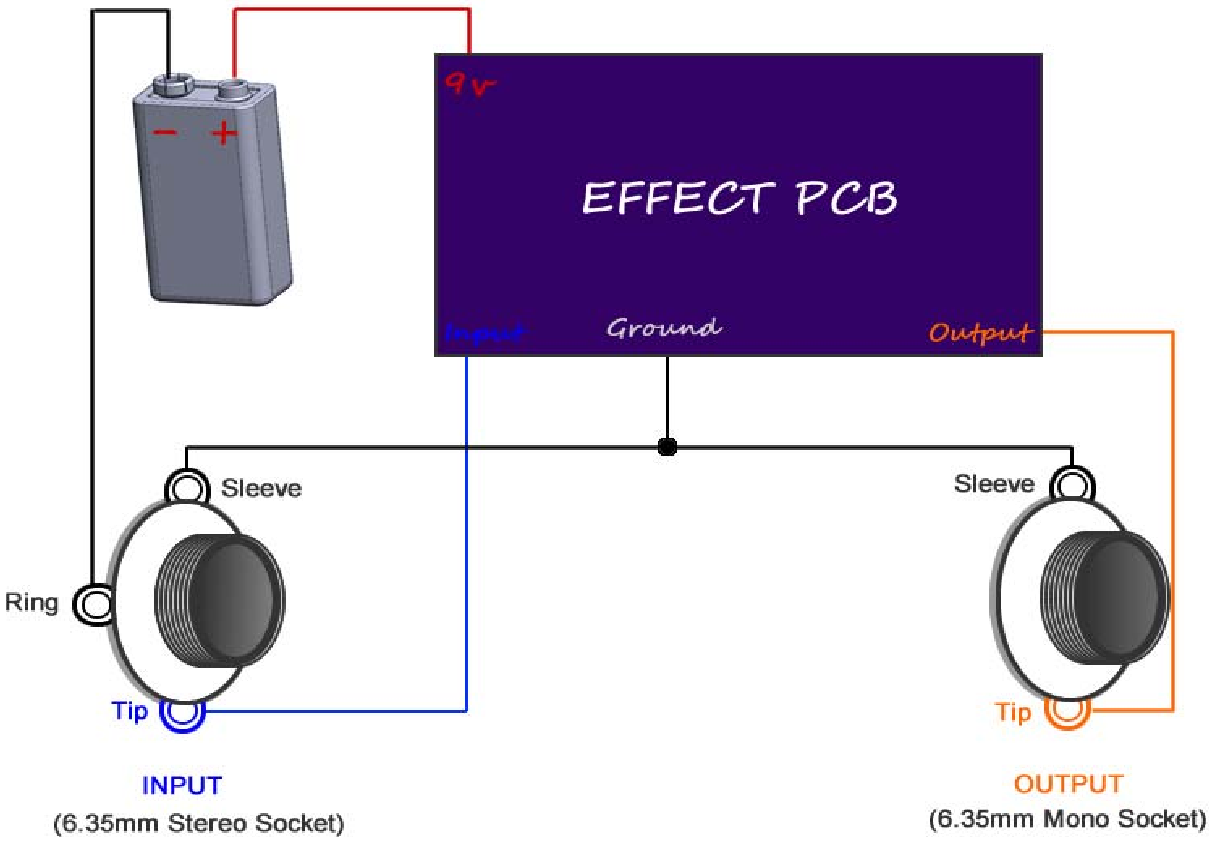
1.10 Off Board Wiring Diagram.

Potentiometers are variable resistors that are used for controlling aspects of the pedal. Using a non-switched miniature DC Jack and 2 Mono Jacks



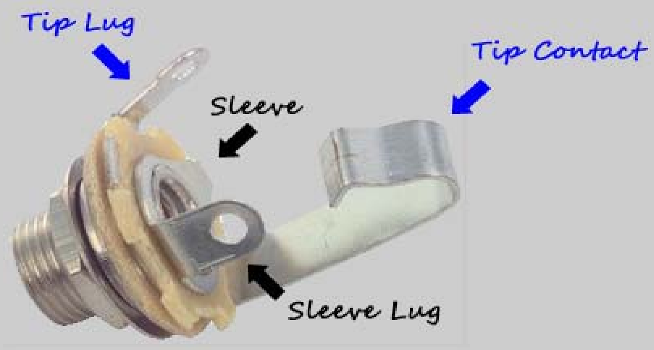
Testing Your Effect

Using aligator clips or soldering directly, wire your effect as in the following...



Input and Output Sockets

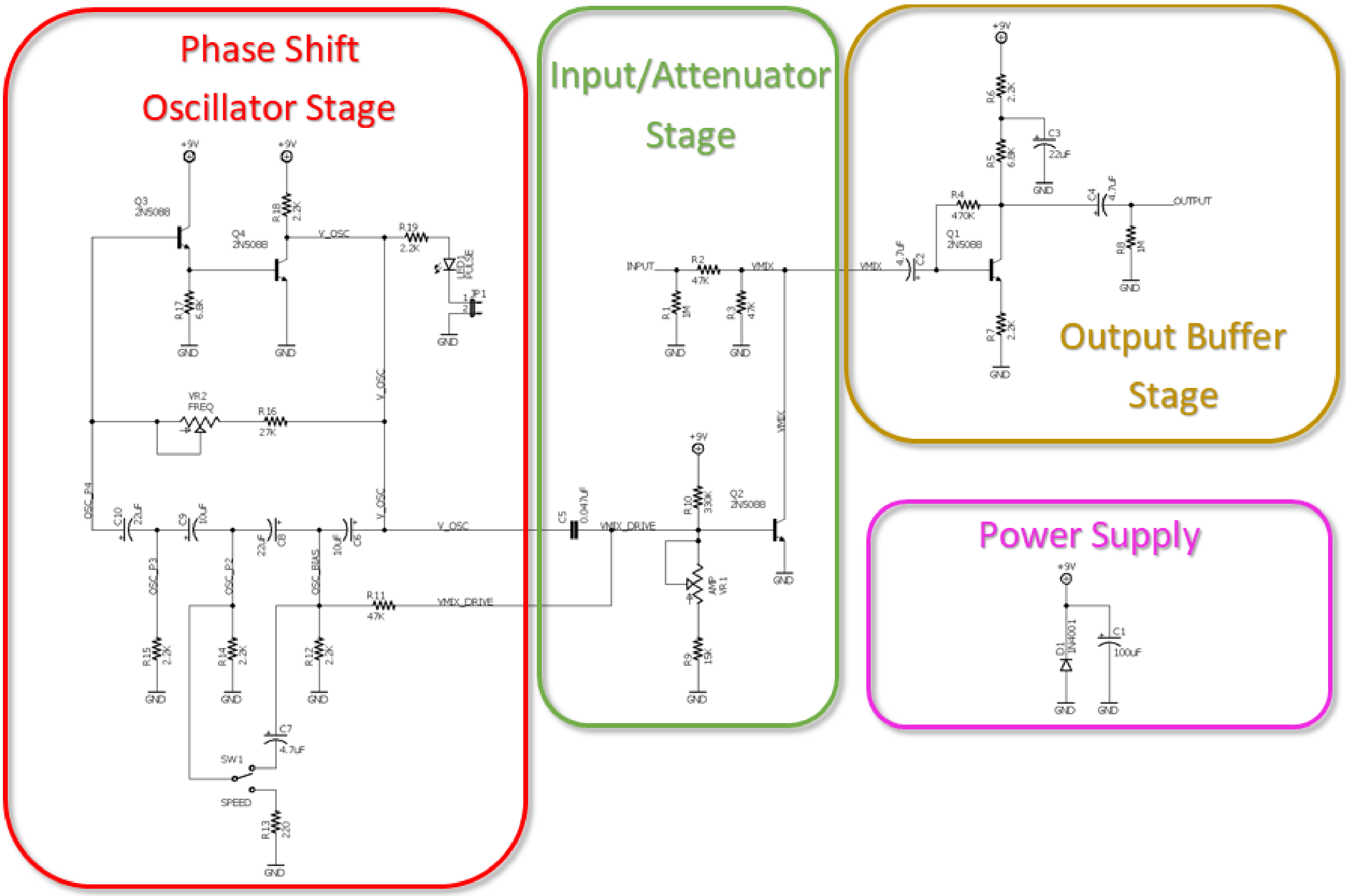
Pay close attention to the lugs of your sockets. Look at them side on so that you can distinguish the sockets individual layers. For instance the tip lug is connected to tip contact. The stereo jack looks the same as the socket below except it has an extra lug and contact for "Ring".



Vanilla Shake Circuit Analysis for modifying purposes.

2. Vanilla Shake Circuit.

The Vanilla Shake schematic can be broken down into some simpler blocks: Power Supply, Input Attenuator Stage, Phase Shift Oscillator Stage, and an Output Buffer Stage.

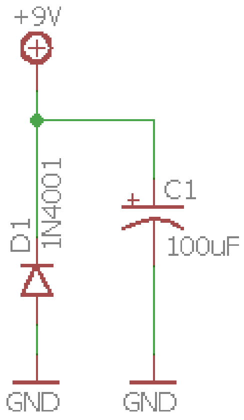


The design is based around a simple common emitter amplifier that is gets its input signal grounded via a phase shift oscillator. How hard the oscillator’s sine wave grounds out the input signal is determined by the Mixer stage.

The base input impedance on the Vanilla Shake is close to 64K – 74K Ω, depending on the amplitude potentiometer, which would potentially overload the pickups and cause tone-sucking to occur. However, when the signal from the oscillator amplifier stage is running, the impedance fluctuates drastically, as this is part of what makes the Vanilla Shake make the tremolo effect.

3. Power Supply.

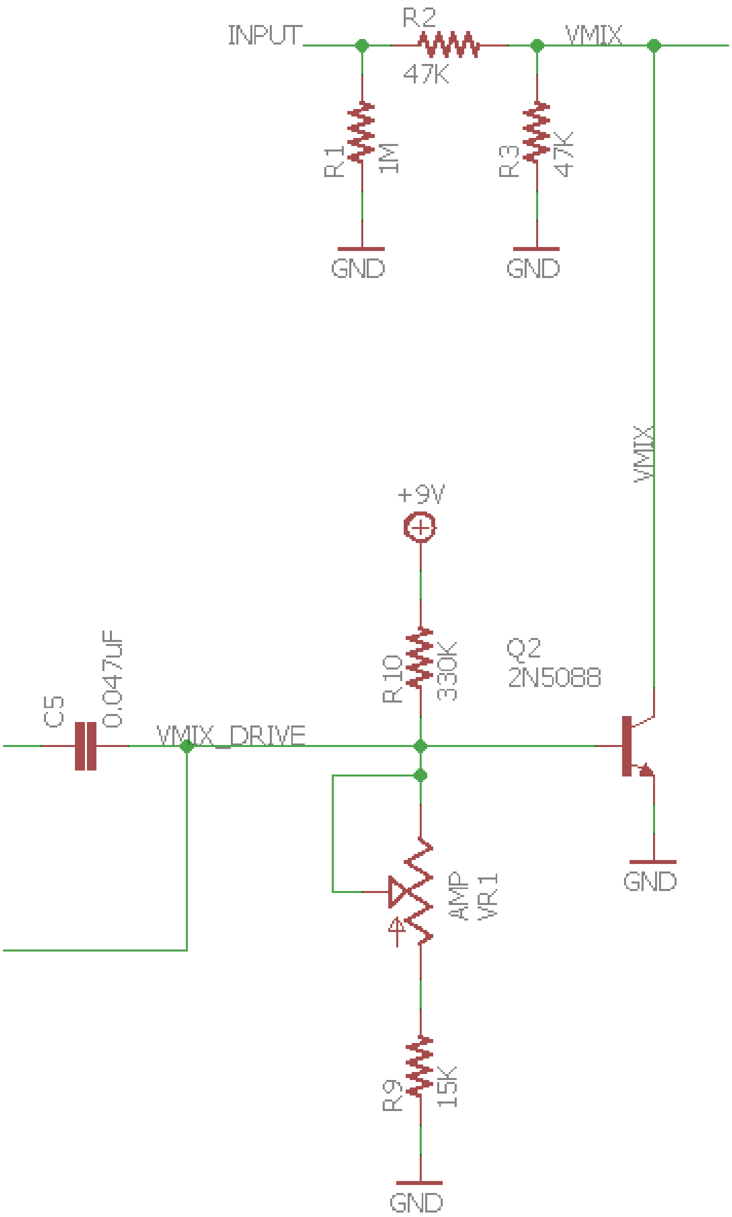
The Power Supply Stage provides the electrical power and bias voltage to all the circuitry, the whole power consumption is low and estimated around 4mA:



- The D1 rectifier diode protects the pedal against adapter reverse polarity connections.
- The C1, 100µF electrolytic capacitor, decouples power to ground to provide power stability to the circuit.

4. Input/Attenuator Stage.

This is where the guitar signal comes in and is attenuated by the Q2 transistor, acting as a "variable resistor" to ground. This is what chops the signal.



This stage sets how hard the input signal gets chopped by varying degrees of being pulled to ground. Firstly, the input signal is cut down by a minimum of 6dB with the 47k dividers or R2 and R3. R2 is serving as a simple isolator between the input and the "Vmix" node. That's because Q2 serves as a variable impedance in parallel to R3. It can either be dominated by R3 as Q2 presents a high impedance, or pulling to GND.

The Amplitude Pot is a variable resistor that sets the bias point of Q2. When amplitude pot's resistance is 0, it's basically preventing Q2 from barely turning on at all. In fact, if R9 was replaced with a 0 ohm resistor, and the amplitude pot was also at a 0 resistance, the Q2 transistor wouldn't turn on. This means the input signal remains unaltered. When the amplitude pot is maxed at 25K, along with the series resistor R9, adding an additional 15K (40K total), it is biasing Q2 such that it is effectively shorting Vmix to GND. This leads to the input signal being turned off, or muted. This, in and of itself, seems useless, but begins to get more interesting once you start looking at what's driving Q2.

4.1 Input Impedance.

The Vanilla Shake input impedance is generally determined by (R1 || R3) + R2:

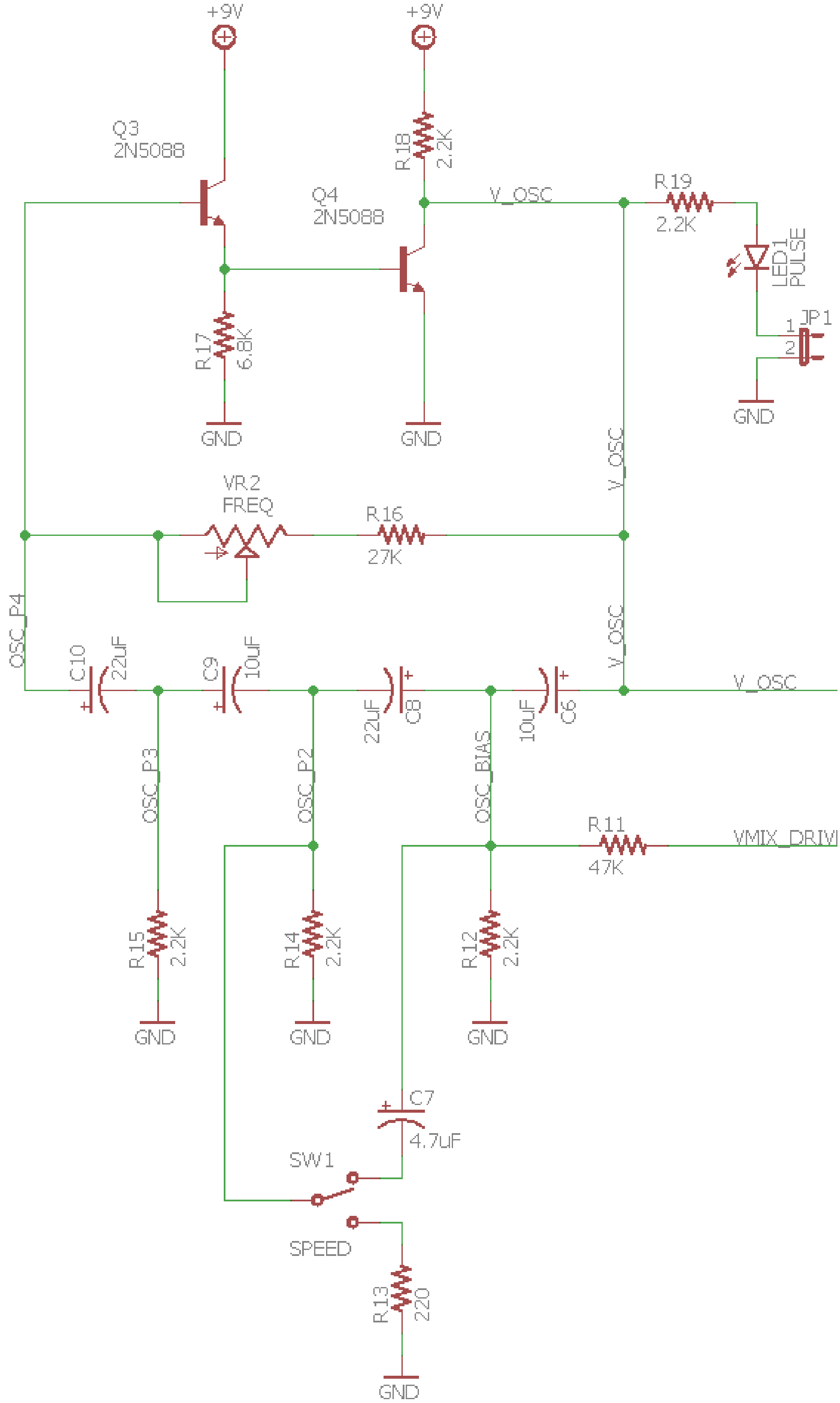
$$Zin = (R_1 \| R_3) + R_2$$
$$Zin = (1{,}000{,}000 \| 47{,}000) + 47{,}000$$
$$Zin = 44{,}890 + 47{,}000 = 91{,}890$$

However, as the Oscillator Amplifier Stage tugs on the Common Emitter Amplifier stage to chop up the audio signal, the input impedance varies, which is how the effect generally works.

When the amplitude potentiometer is at its smallest resistance (practically zero) and the amplitude is at its highest/loudest, the input impedance is reduced down to about 74K Ω. When the amplitude potentiometer is at max resistance (25K) and the amplitude is at its lowest/quietest, the input impedance is reduced down to about 64K Ω.

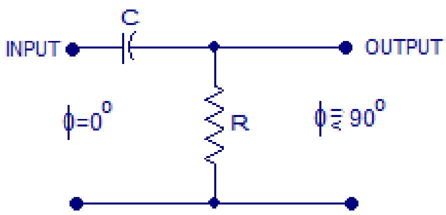
5. Phase Shift Oscillator Stage.

The Vanilla Shake's Q2 has a variable impedance because it's base node and Vmix drive is modulated by a really simple low frequency oscillator: An RC Phase Shift Oscillator



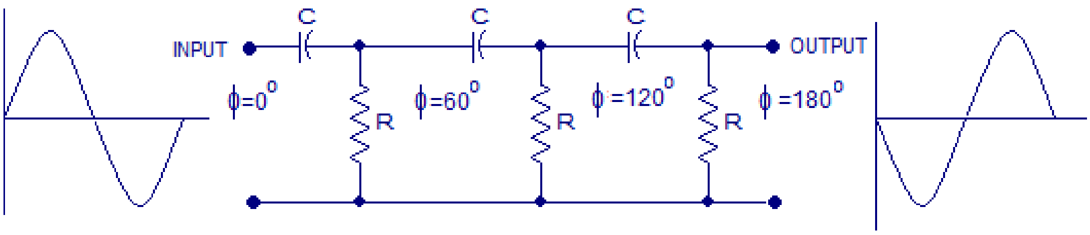
RC phase shift oscillator or simply RC oscillator is a type of oscillator where a simple RC network (resistor-capacitor) network is used for giving the required phase shift to the feedback signal. The main feature of an RC phase shift oscillator is the excellent frequency stability. The RC oscillator can output a pure sine wave on a wide range of loads.

RC phase shift network is a simple resistor capacitor network that can be used to give a desired phase shift to a signal. The circuit diagram of a simple single stage RC network is shown in the figure below.



Single stage RC phase shift network

Theoretically in a simple RC circuit, the output voltage will lead the input voltage by a phase angle Φ =90°. Anyway in practical case the phase angle will be something below 90° just because it is impossible to get a purely ideal capacitor. Phase shift of a practical RC network depends on the value of the capacitor, resistor and the operating frequency.
Let **F** be the operating frequency, **R** be the resistance and **C** be the capacitance. Then the capacitive reactance **Xc** to the frequency **F** can be given by the equation $Xc = 1 / (2\pi FC)$
The effective impedance of the circuit can be given by the equation $Z = \sqrt{R^2 + Xc^2}$
The phase angle of the RC network can be derived as $\Phi = \tan^{-1}(Xc / R)$
Just by making an RC network with phase shift equal to 60° and cascading three of them together the desired phase shift of 180° can be attained. This 180° phase shift by the RC network plus the 180° phase shift made by the transistor gives a total phase shift of 360° between the input and output which is the necessary condition for maintaining sustained oscillations. The circuit diagram of a three stage RC network producing a phase shift of 180° is shown in the figure below.

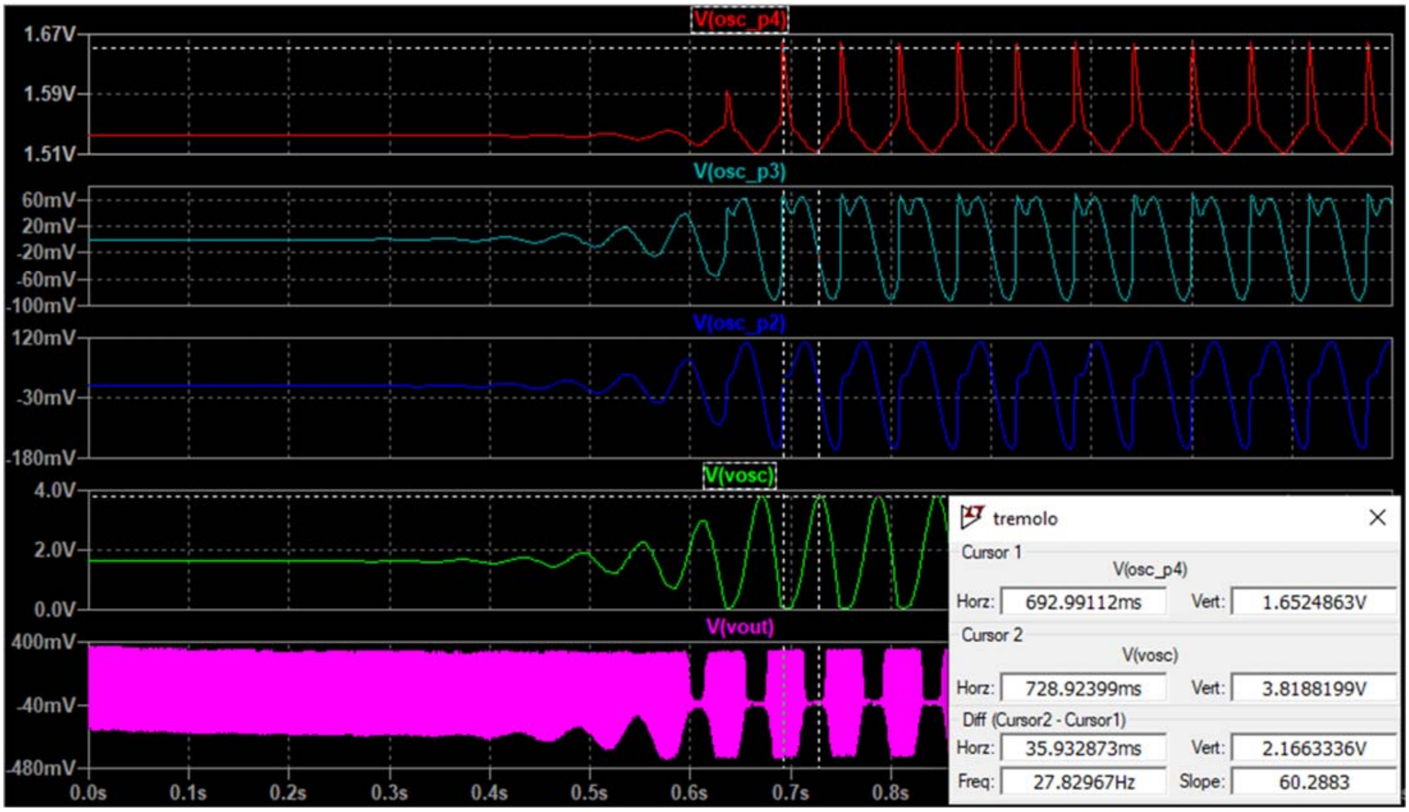


Three stage RC phase shift network

Connecting such a three stage RC phase shift network between the input and output of a common emitter transistor amplifier will result in a transistor based RC phase shift oscillator. However, if impedance matching is required, a second transistor should be added as an emitter-follower to isolate the common emitter transistor amplifier.

On the Vanilla Shake, Vmix drive is capacitively coupled to Vosc, the output of a low frequency oscillator. Q3/Q4, along with their RC feedback network and the R16 + Frequency Pot (1M) branch, form a phase shift oscillator. Phase shift oscillators are, conceptually, very, very simple. They depend on a charging network of RC circuits to offset the turn on/turn off of a switching element.

When power is applied, Q4 is off, which allows R18 to pull Vosc up to 9V. This also weakly biases the base of Q3 through R16 and the Frequency Pot. As caps C6, C8, C9, and C10 charge up, Q3 begins to conduct just a bit more strongly. This eventually causes Q4 to turn on, which creates a discharge path for C6, C8, C9, and C10. Those caps discharge until the bias on Q3 is gone, and Q4 shuts off, and the whole process starts over again. Thus: oscillation!

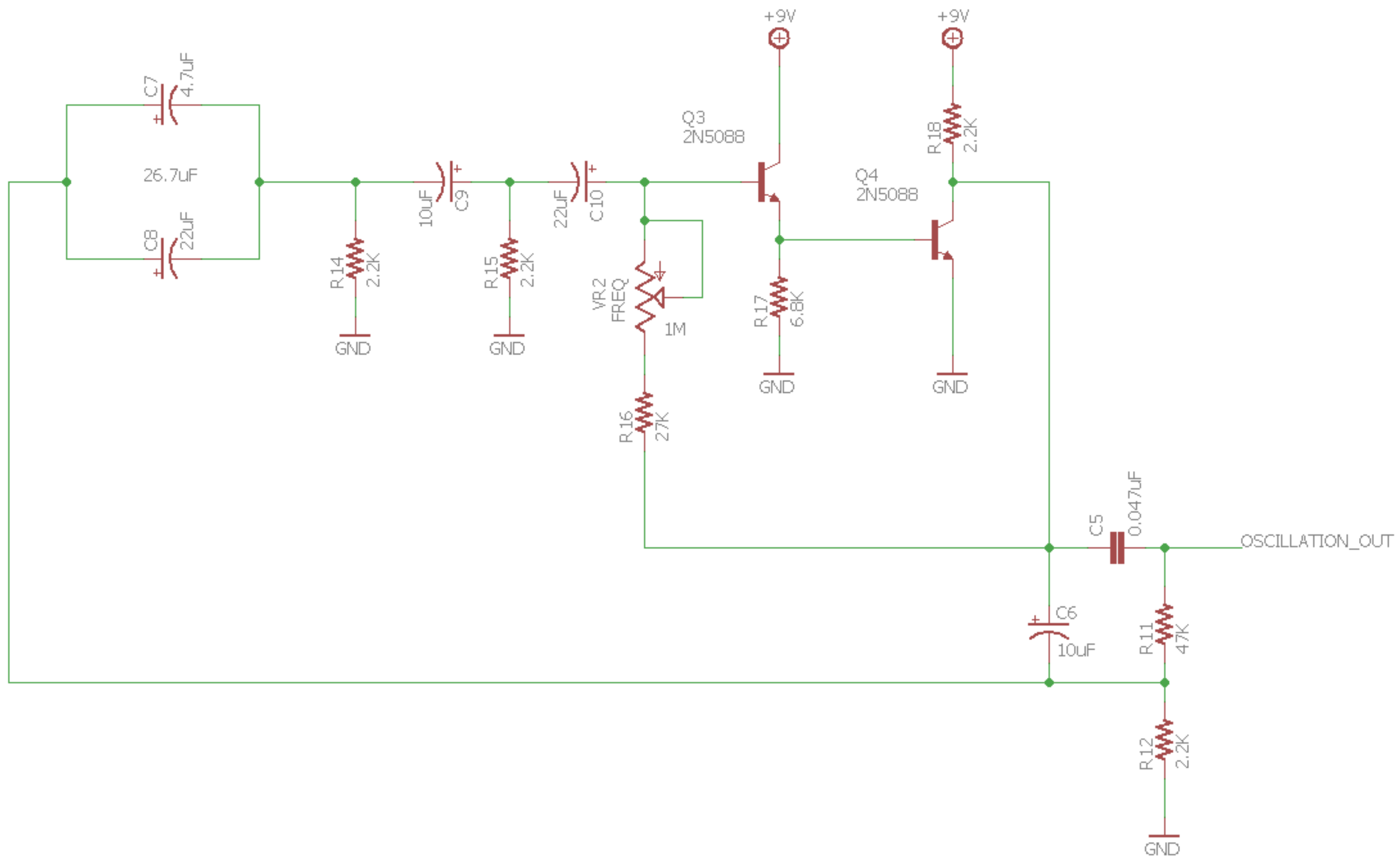


This is a pretty miniscule process when power is first applied. The oscillation depends on noise to get started, and takes a few seconds of sim to start switching with any appreciable amplitude. It takes about 2 seconds of sim time to see meaningful switching (greater than half a volt or so) out of the oscillator. You can get a better view of startup if you use multiple panes - allows for different DC offsets to view each switching startup up close.

The Frequency Pot sets the bias point of Q3, and as a result, governs the oscillation cycle time of the LFO. A higher resistance between Vosc and osc_p4 means that the oscillator is more dependent on RC charging to toggle the oscillator state. Lower resistance, conversely, means faster oscillations.

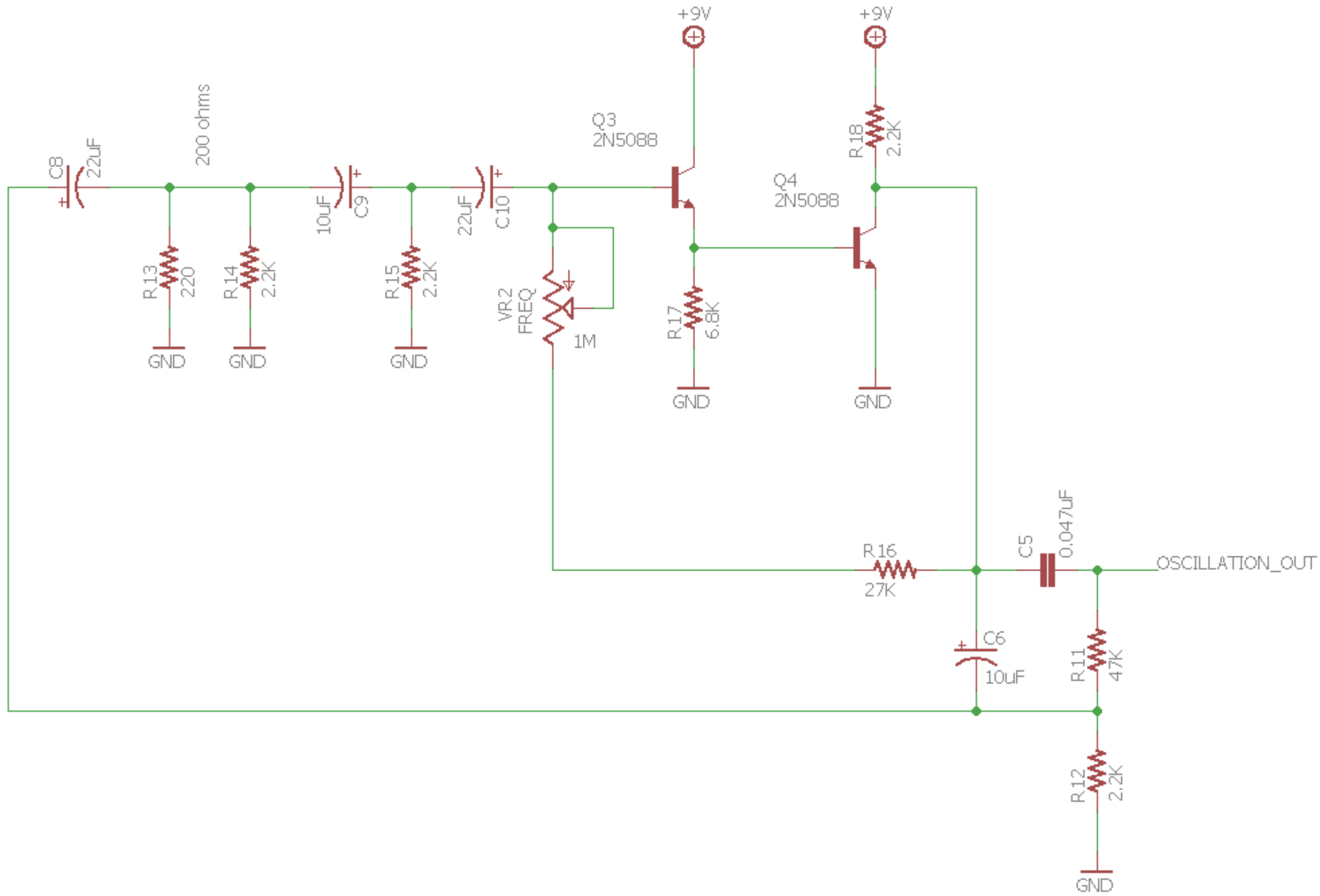
There are two ways this circuit can be viewed due to the speed switch.

5.1 Slow Mode.



With the switch in the slow position, it brings capacitors C7 and C8 in parallel with each other and removes R13 from the circuit. This adds capacitance to the first portion of the phase shift oscillator (26.7uF instead of 22uF) and increases the resistance at this portion of the phase shift oscillator (2.2K instead of 200 ohms), which drops the overall frequency range of the oscillator immensely. Somewhere around 2.8Hz to 7.8Hz

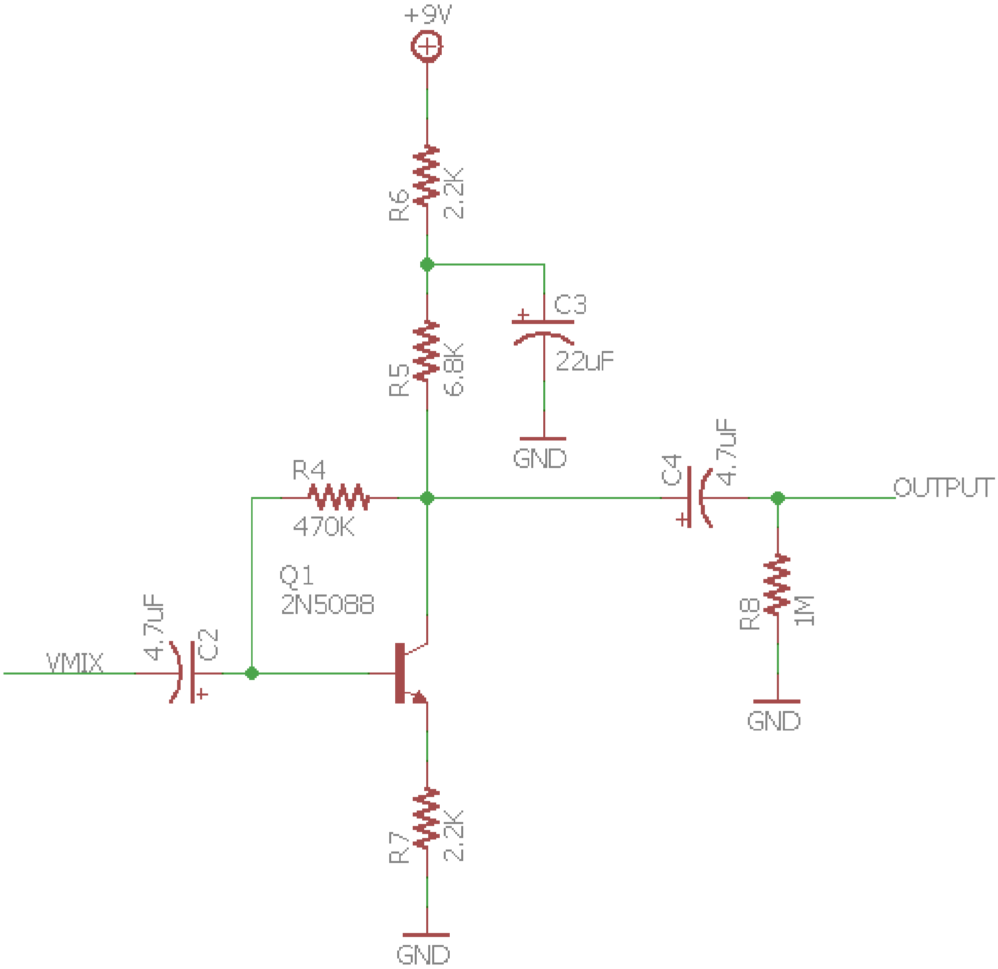
5.2 Fast Mode.



With the switch in the fast position, it brings resistors R13 and R14 in parallel with each other and removes C7 from the circuit. This reduces capacitance to the first portion of the phase shift oscillator (22uF instead of 26.7uF) and decreases the resistance at this portion of the phase shift oscillator (200 ohms instead of 2.2K), which raises the overall frequency range of the oscillator immensely. Somewhere around 6.5Hz to 22.6Hz.

6. Output Buffer Stage.

This clean boost stage is based on a Common Emitter amplifier with Shunt Feedback and some arrangements to enhance the performance.



This stage sets a low output impedance and isolates transistor Q2 from the downstream signal, ultimately creating amplitude modulation.

6.1 Shunt Feedback Common Emitter Stage.

In common emitter amps, the approximate voltage gain is collector resistance divided by the emitter resistance (R_C/R_E), but the effect of the feedback resistor has to be taken into consideration:
The resistor R4 from collector to base also called Shunt Feedback resistor or R_F is a method to apply negative feedback to the amplifier. While it results in a reduced overall voltage gain and input impedance, a number of improvements are obtained:

- Better stabilized voltage gain.
- Improved frequency response.
- Reduced Noise.
- More Linear operation.
- More immune against variations in temperature and transistors Beta.

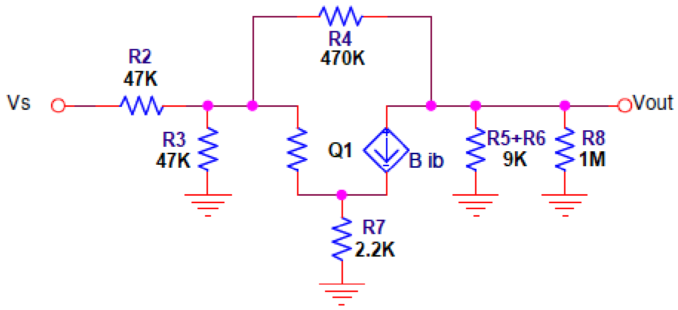
How this works is if the emitter current were to increase, the voltage drop across Rc increases, decreasing Vc, reducing Ib feedback to the base. This, in turn, decreases the emitter current, correcting the original increase. The value of R4 should be selected so that the collector voltage is half of the supply voltage.

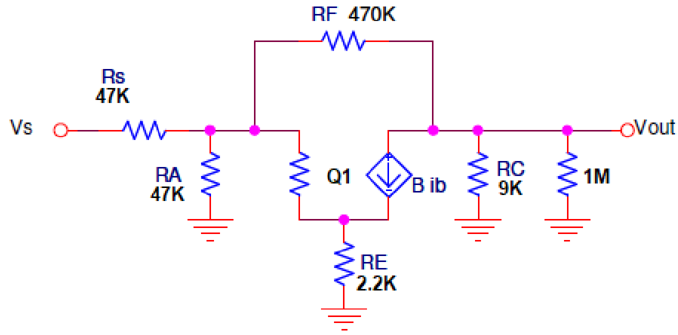
6.2 Input Booster Voltage Gain Calculation.

A simplified analysis method must be used to calculate the voltage gain of the amplifier, otherwise, it turns into an arithmetic nightmare. It consists of 3 steps:

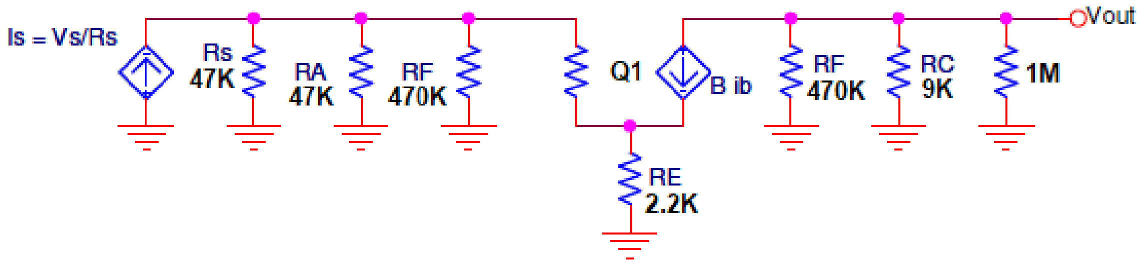
a) Identify the Amplifier Topology:
The topology is known as *Voltage-Shunt Feedback*: voltage refers to connecting the output voltage as the input to the feedback network and Shunt refers to connecting the feedback signal in parallel/shunt with the input current source.

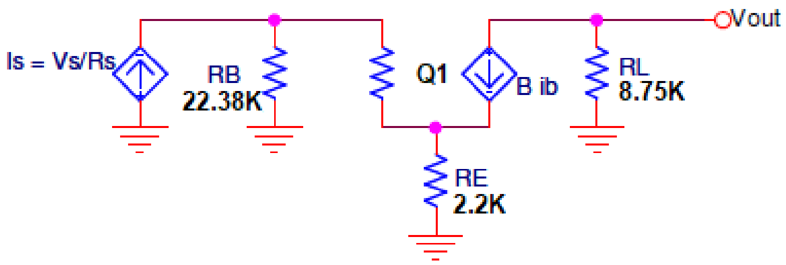
b) Draw the equivalent circuit without the feedback network: The idea is to draw an equivalent amplifier without feedback but taking the loading of it into consideration. In the image below, the resistor values are substituted by generic labels, in order to make the formulas more intuitive:





The equivalent circuit uses Norton's current source since the feedback signal is current. In the image below, the feedback resistor is grounded in the input and output sections and the resistors grouped:





Where:

$R_B = R_S \,||\, R_A \,||\, R_F = 47{,}000 \,||\, 47{,}000 \,||\, 470{,}000 = 22.38K$

$R_L = R_8 \,||\, R_C \,||\, R_F = 1{,}000{,}000 \,||\, 9{,}000 \,||\, 470{,}000 = 8.75K$

c) The voltage gain can be calculated following the simplified analysis of these equations:
AZ: Voltage-Shunt Gain without feedback formula:

$$with \quad (\frac{R_E(\beta+1)i_b}{R_B}) >> i_b + (\frac{r\pi \cdot i_b}{R_B})$$

$$A_z = \frac{V_{out}}{I_s} = \frac{R_B \cdot R_L}{R_E}$$

BG: Feedback Voltage-Shunt formula:

$$B_G = \frac{I_F}{V_{out}} = \frac{1}{R_F}$$

AZF: Voltage-Shunt Gain with Feedback

$$A_{ZF} = \frac{A_Z}{1 + A_Z B_G} = \frac{\frac{R_B \cdot R_L}{R_E}}{1 + \frac{R_B \cdot R_L}{R_E} \cdot \frac{1}{R_F}}$$

GV: Voltage Gain:

$$G_V = \frac{V_{out}}{V_S} = \frac{V_{out}}{I_S \cdot R_S} = \frac{A_{ZF}}{R_S}$$

Replacing the Q1 circuit values RB = 22.38K, RL = 8.75K, RE = 2.2K, RS = 47K and RF = 470K the results obtained are: AZ = 89K, BG = 1/470K, AZF = 75K and the voltage value is GV = 1.6 (4dB).

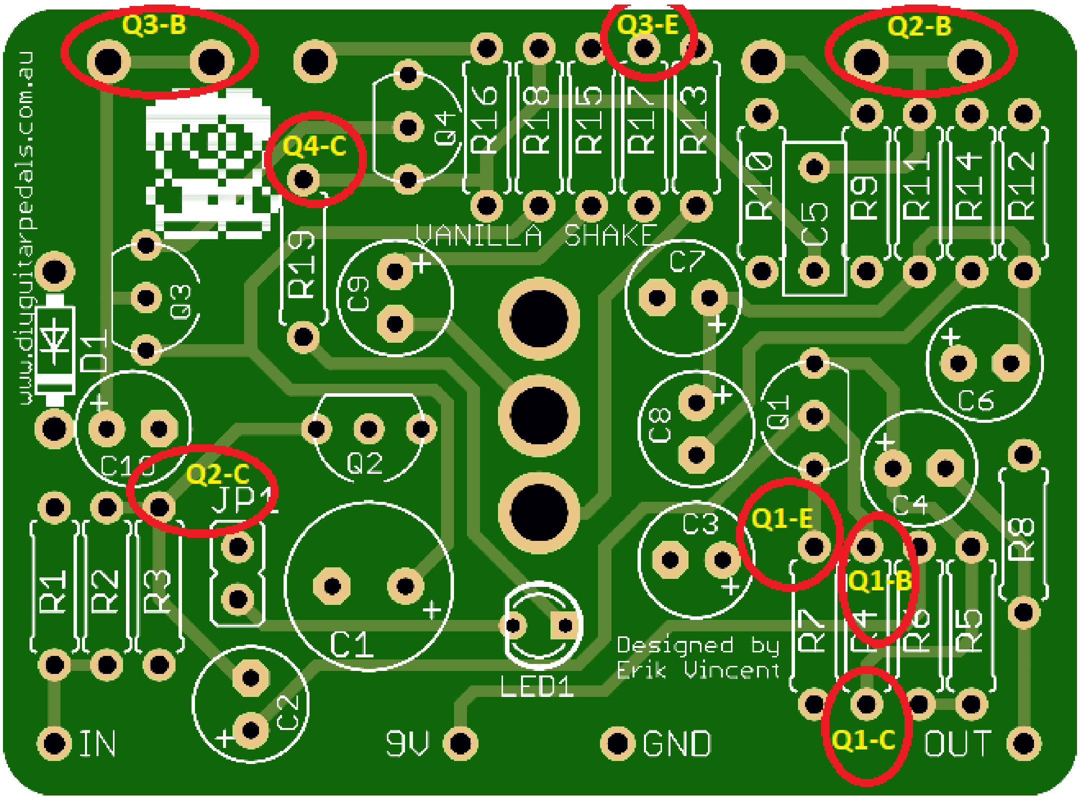
6.3 Output Impedance.

The pedal output impedance is rather hard to calculate due to the oscillation stage but varies between 5.8K with the amplitude resistance maxed and 5.3K when the amplitude resistance is at near 0. So long as the output impedance is below 10K, this is very ideal.

7. Voltage Readouts.

Below are the voltage readouts of the transistors onboard, assuming 9V Power Supply.

Transistor and IC read-outs (following the DS-1 Classic)



Q1-C: 2.717V - 2.727V
Q1-B: 2.115V - 2.117V
Q1-E: 1.522V - 1.525V

Q2-C: 0.004V - 0.006V
Q2-B: 0.407V - 0.529V
Q2-E: 0.000V

Q3-C: 8.96V
Q3-B: 1.200V - 1.237V
Q3-E: 0.644V - 0.667V

Q4-C: 0.401V - 2.061V
Q4-B: Same as Q3-E
Q4-E: 0.000V

KNOBS

- AMPLITUDE: MAX
- FREQUENCY: MAX
- SPEED: SLOW

8. Modifications

Following is a couple of worthwhile modifications that can be applied to the Vanilla Shake.

8.1 Resistors

To add a broad range of amplitude, shunt R9, replace VR1 with a 50K pot, and change R10 to 470K. This variant makes the chops have even more subtle tones when close to off.

Increasing the resistance of R13 will make the “fast” mode slower than the stock build. Reducing the resistance would make it go faster, but with the stock build it will go into self-oscillation, so this is not recommended.

If the output amplification isn’t enough, changing R7 down to 1K will add a bit more of a clean boost to the circuit. If the pickups on your guitar are hot and cause a bit of breakup, increase R7 up to 2.7K or even 3.3K.

8.2 Capacitors

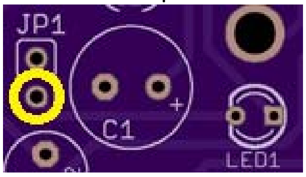
Changing the value of C7 to a higher capacitance than 4.7µF will make the “slow” mode range even slower, however it isn’t recommended going much higher than 15µF. Decreasing the capacitance will make the “slow” mode faster than the stock build.

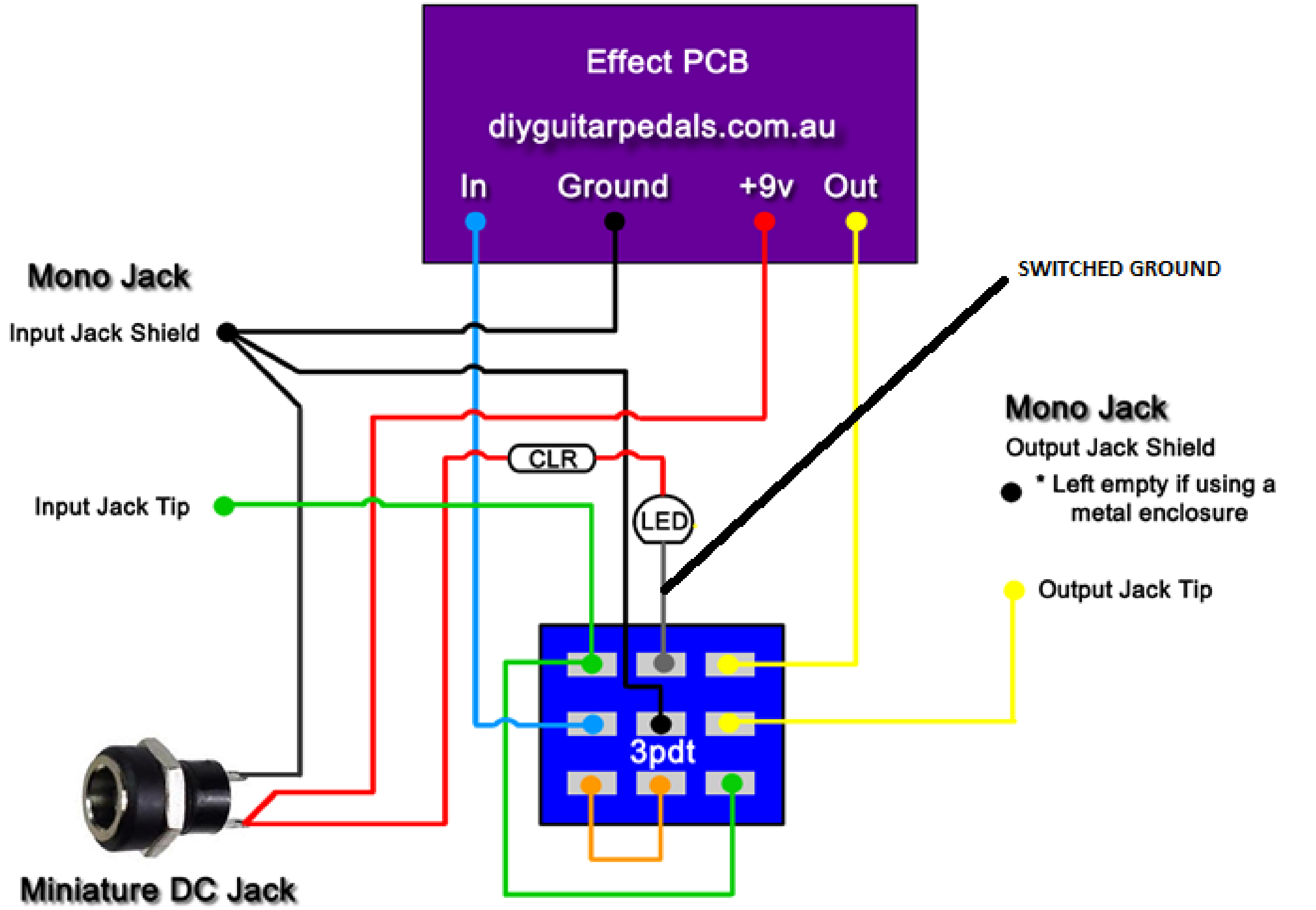
8.3 Potentiometers

Increasing the Frequency potentiometer from a 1M Ω to a 2M Ω will grant a larger sweep of slow to fast between each mode.

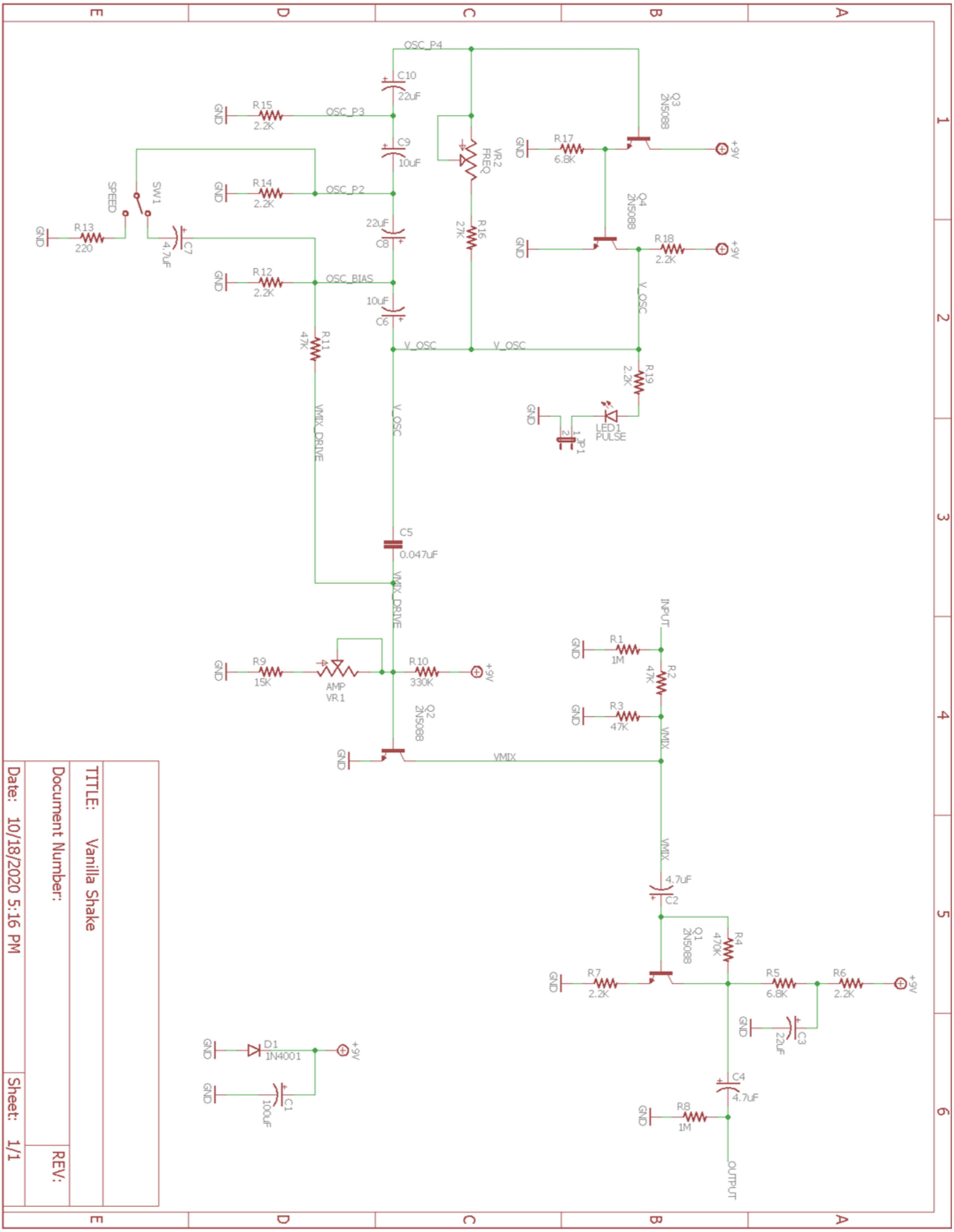
8.4 Pulsing LED1

If the jumper JP1 is shunted, LED1 will have power going to it at all times, regardless if the pedal is engaged or not. However, if there is a switched ground (such as what can be found on 3PDT PCBs), that wire from switched ground can be ran to the pad on JP1 that connects to LED1





9. Schematic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Date: 10/18/2020 5:16 PM
Sheet: 1/1
A
B
C
D
E
1
2
3
4
5
6
OSC_P4
C10
22uF
R15
2.2K
OSC_P3
C9
10uF
VR2
FREQ
R17
6.8K
Q3
2N5088
+9V
SPEED
SW1
R14
2.2K
OSC_P2
Q4
2N5088
R13
220
C7
4.7uF
22uF
C8
R16
27K
R18
2.2K
R12
2.2K
OSC_BIAS
10uF
C6
V_OSC
R11
47K
R19
2.2K
LED1
PULSE
JP1
VMIX_DRIVE
C5
0.047uF
INPUT
R1
1M
R2
47K
R9
15K
AMP
VR1
R10
330K
R3
47K
Q2
2N5088
VMIX
C2
4.7uF
Q1
2N5088
R4
470K
R7
2.2K
R5
6.8K
R6
2.2K
C3
22uF
D1
1N4001
C1
100uF
C4
4.7uF
R8
1M
OUTPUT
GND