



Turbo Driver

Design By Erik Vincent 

Everything sounds better with more voltage, right? Tim the tool man Taylor would agree ****grunt****

The Turbo driver is a fully discrete style of overdrive / fuzz, charge pumped to 18V for extra headroom. (Note: circuit is powered on 9v). This is the pedal David Gilmore used to shape his sound in the early days of Pink Floyd.

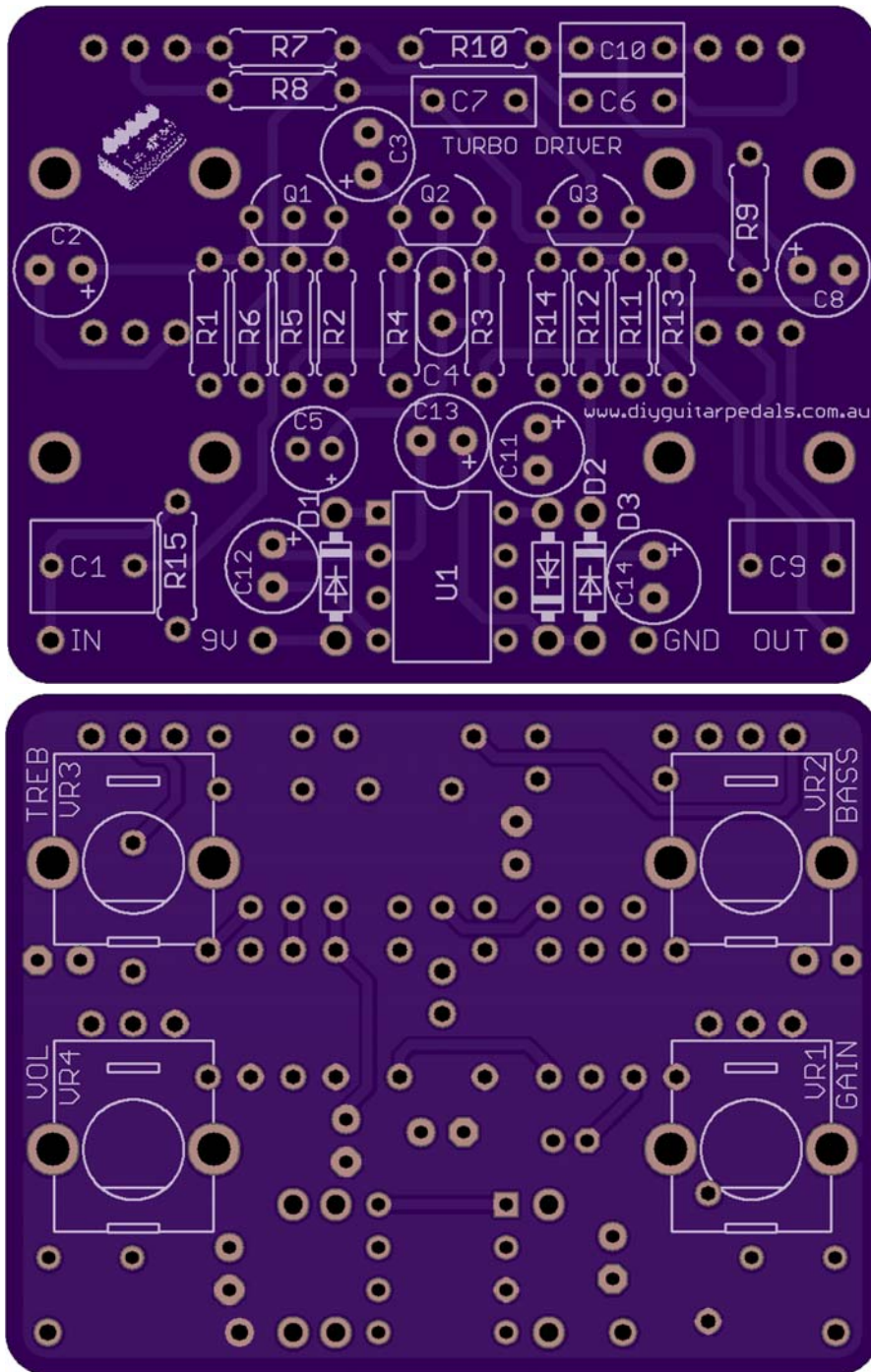
With the added benefit of a volume control to tame the output, you can crank the gain on this baby up to overdriven bliss without losing your hearing, teeth fillings or apartment lease. Suffice to say, its loud.

A beginner level project, this pedal uses 4 controls, Volume, Bass, Treble, and Gain.

The PCB will fit snug into a 1590B enclosure very easily.

Bill of Materials, Stock Turbo Driver

Capacitor		Resistor	
C1	220nF (film)	R1	6.8K
C2	22μF (Electrolytic)	R2	100K
C3	22μF (Electrolytic)	R3	1.8K
C4	470pF (ceramic)	R4	470
C5	4.7μF (Electrolytic)	R5	150K
C6	10nF (film)	R6	12K
C7	100nF (film)	R7	4.7K
C8	10μF (Electrolytic)	R8	39K
C9	220nF (film)	R9	5.6K
C10	10nF (film)	R10	4.7K
C11	22μF (Electrolytic)	R11	33K
C12	10μF (Electrolytic)	R12	150K
C13	10μF (Electrolytic)	R13	1.8K
C14	10μF (Electrolytic)	R14	470
		R15	1M
Diode			
D1	1N5817	ICs	
D2	1N5817	U1	TC1044S
D3	1N5817		
Transistor		Potentiometer	
		Gain	10kb (9mm)
Q1	2N5088	Bass	100kb (9mm)
Q2	2N5088	Treble	100kb (9mm)
Q3	2N5088	Volume	100ka (9mm)



PCB Spacing

The Turbo Driver PCB is spaced for 1590B sized enclosures

Pot Spacing

The Turbo Driver PCB mounted potentiometers are spaced for Alpha 9mm potentiometers

Assembly.

1. Soldering Order.

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

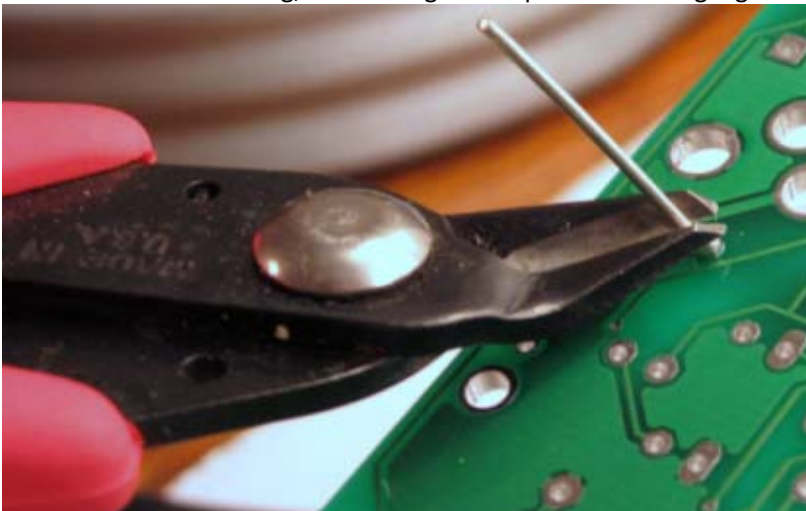
For the Turbo Driver, the best order would be: resistors, diodes, ceramic capacitors, IC sockets (if socketing), transistor/FETs, ICs (if not socketing), film capacitors, electrolytic capacitors, wiring, and then potentiometers.

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.

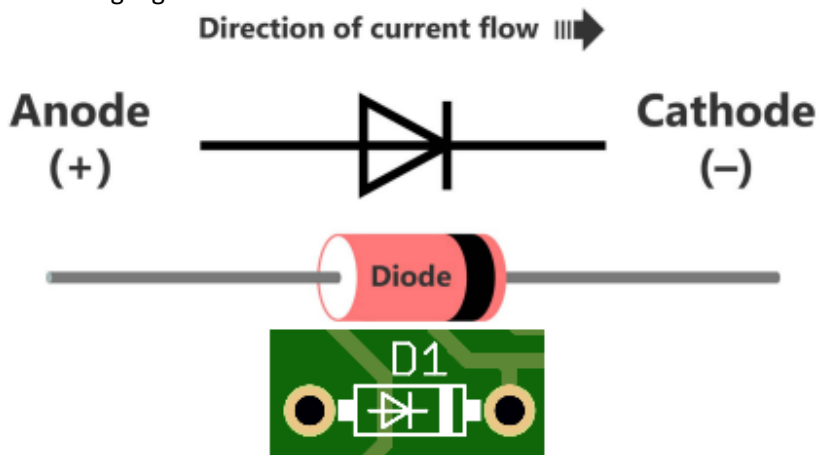


1.2 Diodes.

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 Capacitors (ceramic).

Ceramic 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.

1.4 IC Sockets.

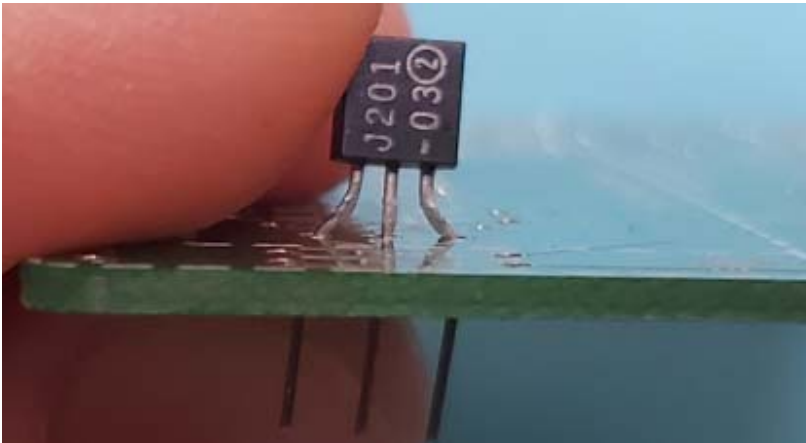
These are holders that allow easy installation and uninstallation of ICs.



These devices will have a silk screen notch to indicate an orientation with the IC or socket for the IC. Just make sure the IC notches match.

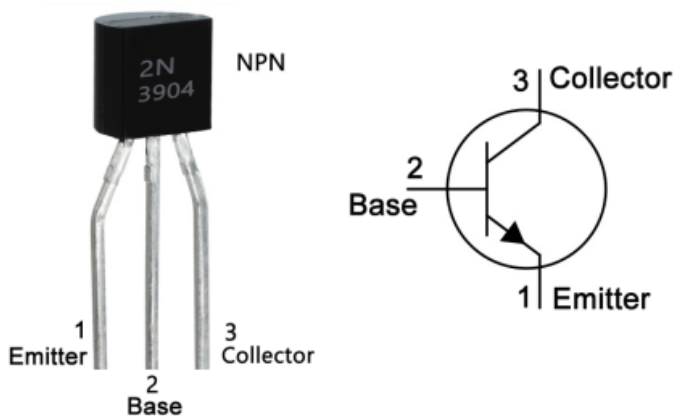
1.5 Transistors/FETs (silicon).

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.

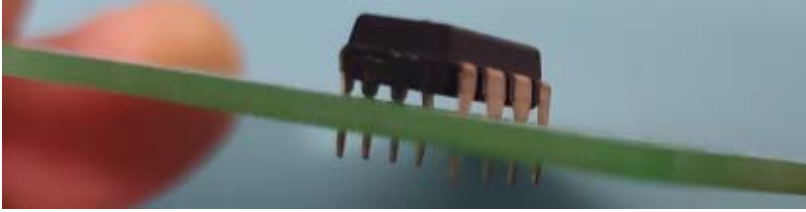
TO-92 Package



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

1.6 Integrated Circuits.

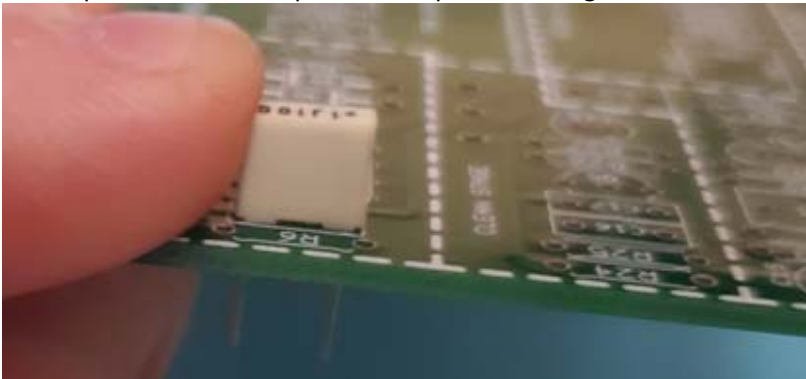
Also known as ICs, these are small analog or digital components that provide specific electrical functions.



Orientation of “which way is up” will be indicated by a notch on the silkscreen on the PCB and a dot or bar on the actual IC itself. Do make sure they match.

1.7 Capacitors (film).

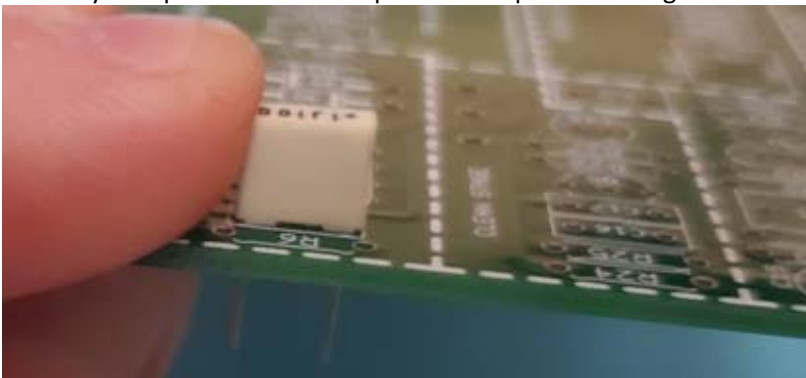
Film capacitors are small passive components designed to hold a small amount of charge in a circuit.



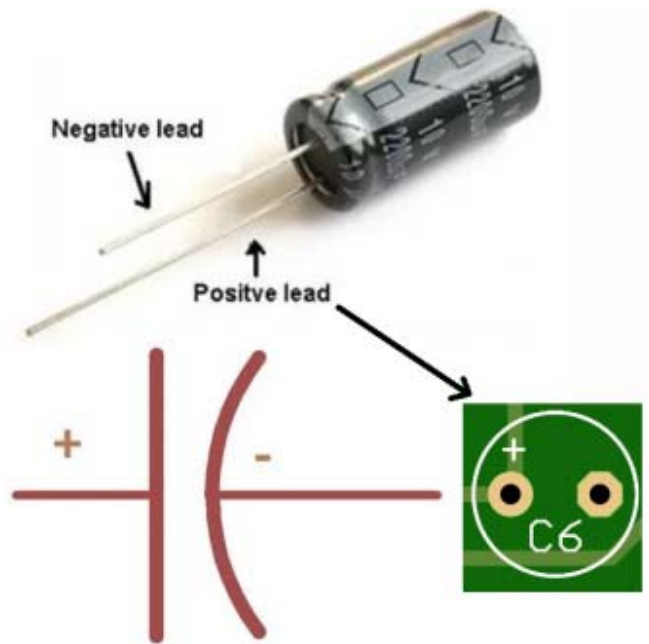
Orientation of “which way is up” doesn't matter, so you can install them either way. After installation and soldering, do not forget to clip the remaining legs from the PCB.

1.8 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.

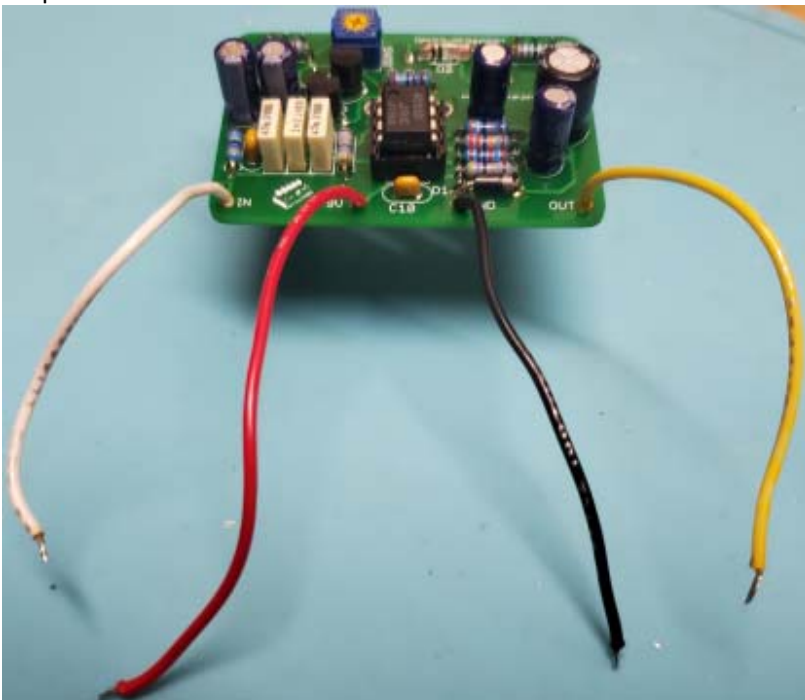


Polarized Electrolytic Capacitor and its electric Symbol

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

1.9 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.



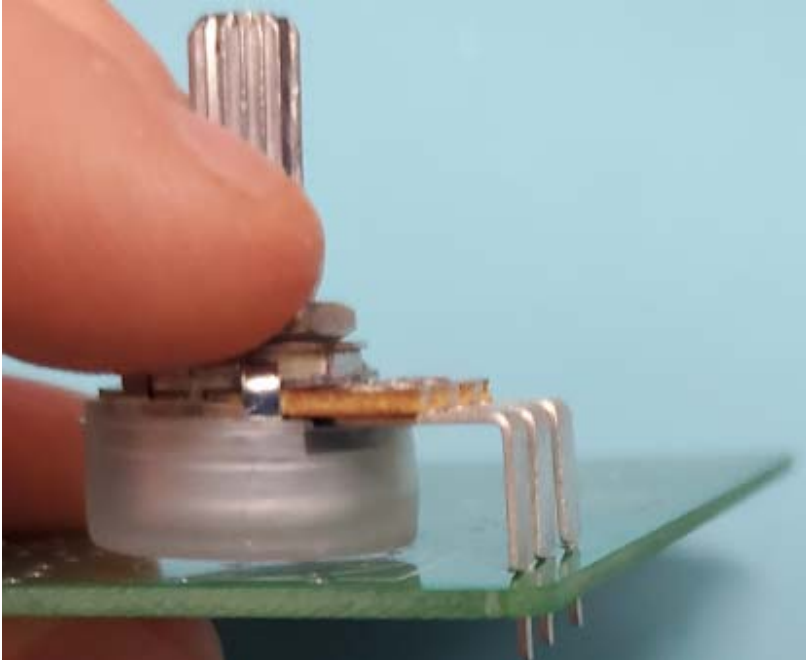
These can be installed at the very end, but in some situations, installing them before potentiometers are soldered in

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.



1.10 Potentiometers.

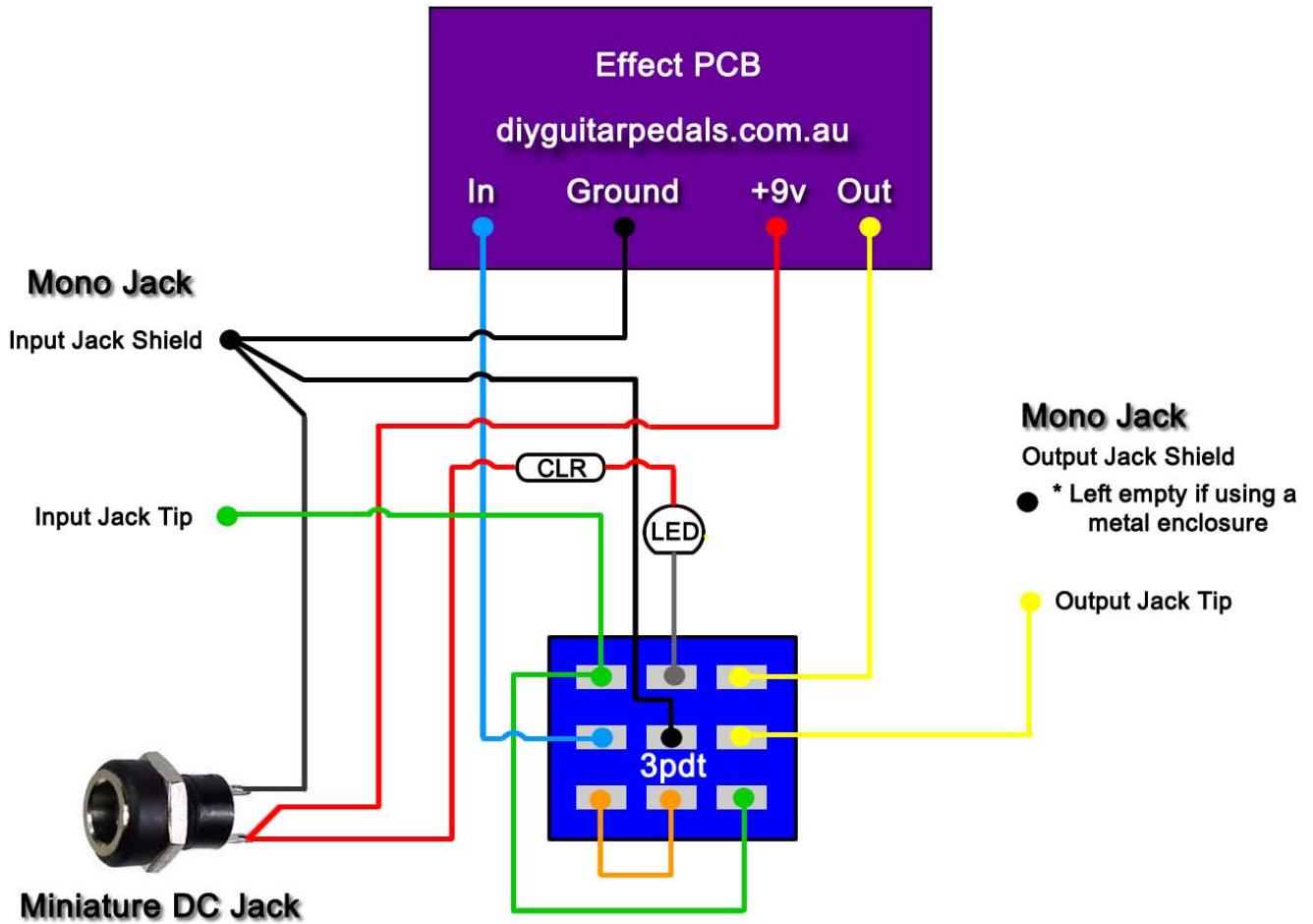
Potentiometers are variable resistors that are used for controlling aspects of the pedal.



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.

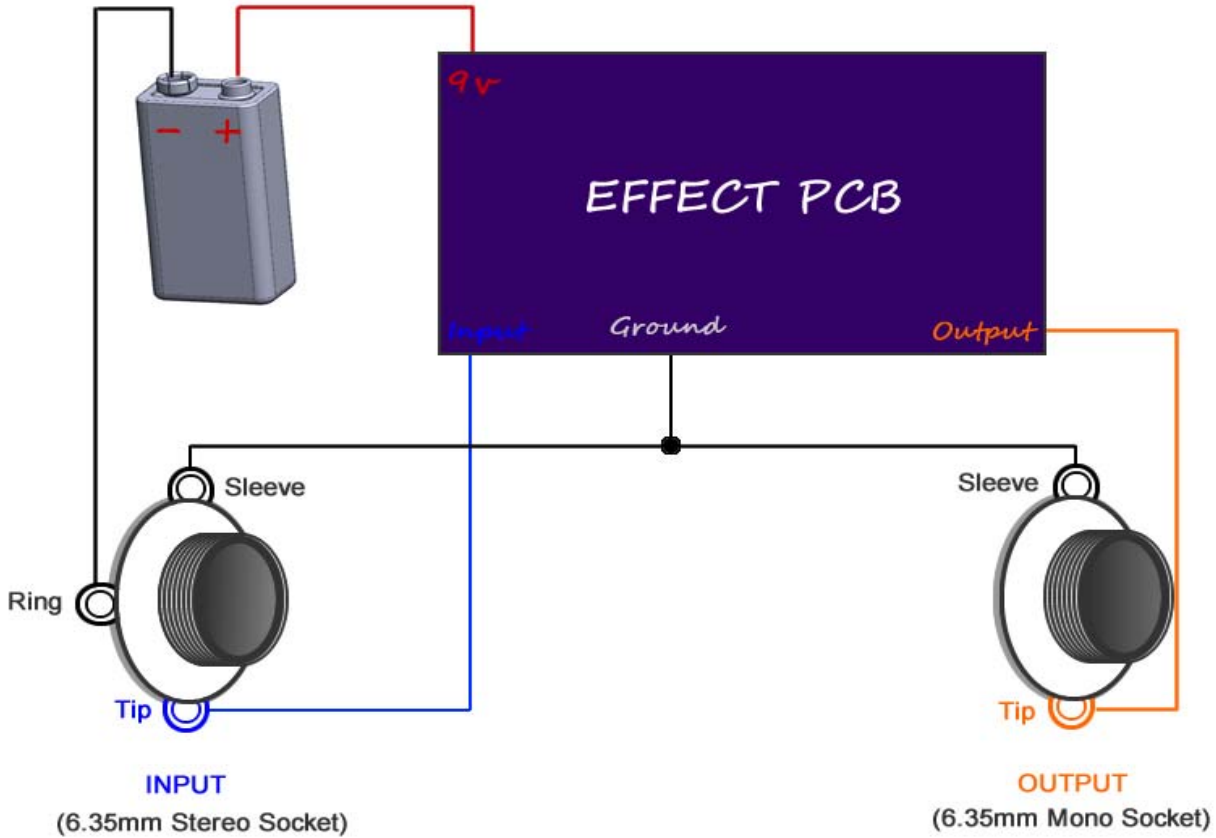
1.11 Off Board Wiring Diagram.

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



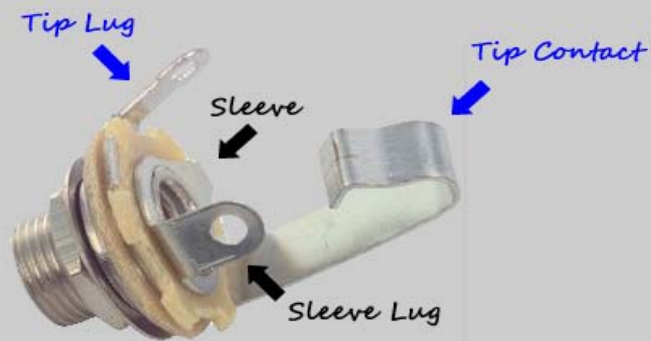
Testing Your Effect

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



Input and Output Sockets

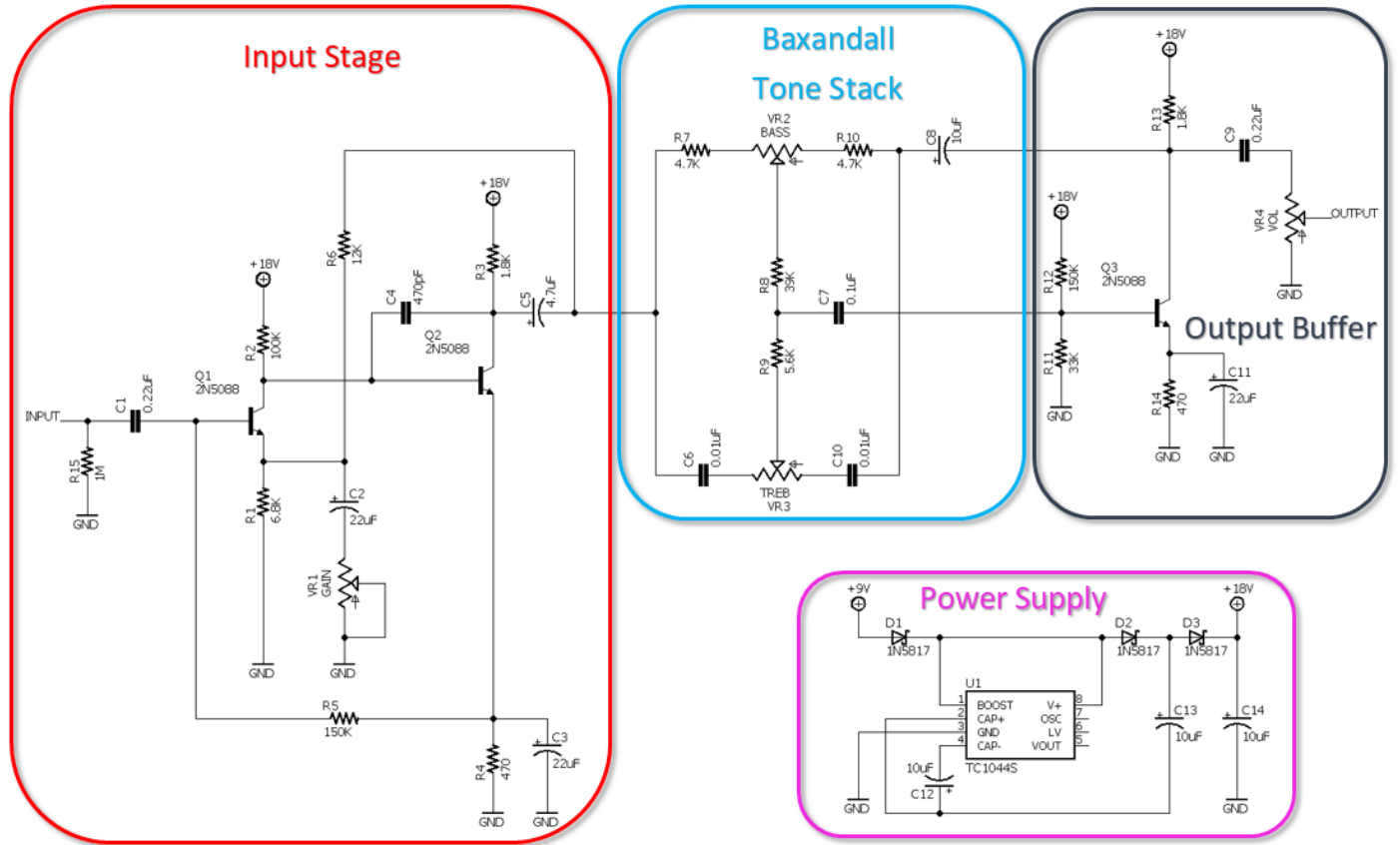
Pay close attention to the lugs of your sockets. Look at them side on so that you can distinguish the sockets individual layers. For instance the tip lug is connected to tip contact. The stereo jack looks the same as the socket below except it has an extra lug and contact for "Ring".



Turbo Driver Circuit Analysis for modifying purposes.

2. Turbo Driver Circuit.

The Turbo Driver schematic can be broken down into some simpler blocks: Power Supply, Input Stage, Baxandall Tone Stack, and Output Buffer.

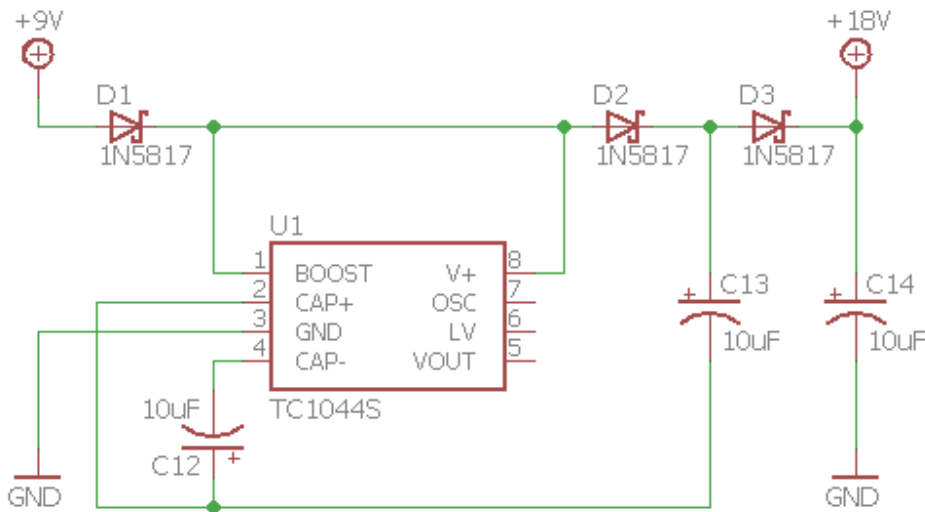


With the exception of the charge pump to boost the input voltage, this circuit is designed around a discrete transistor pair overdrive circuit with an active tone control and level control.

The input impedance on the Turbo Driver is close to 127K Ω, which is not ideal and can overload the pickups on the guitar. However, it is due to its lower impedance that it interacts well with the guitar's volume knob.

3. Power Supply.

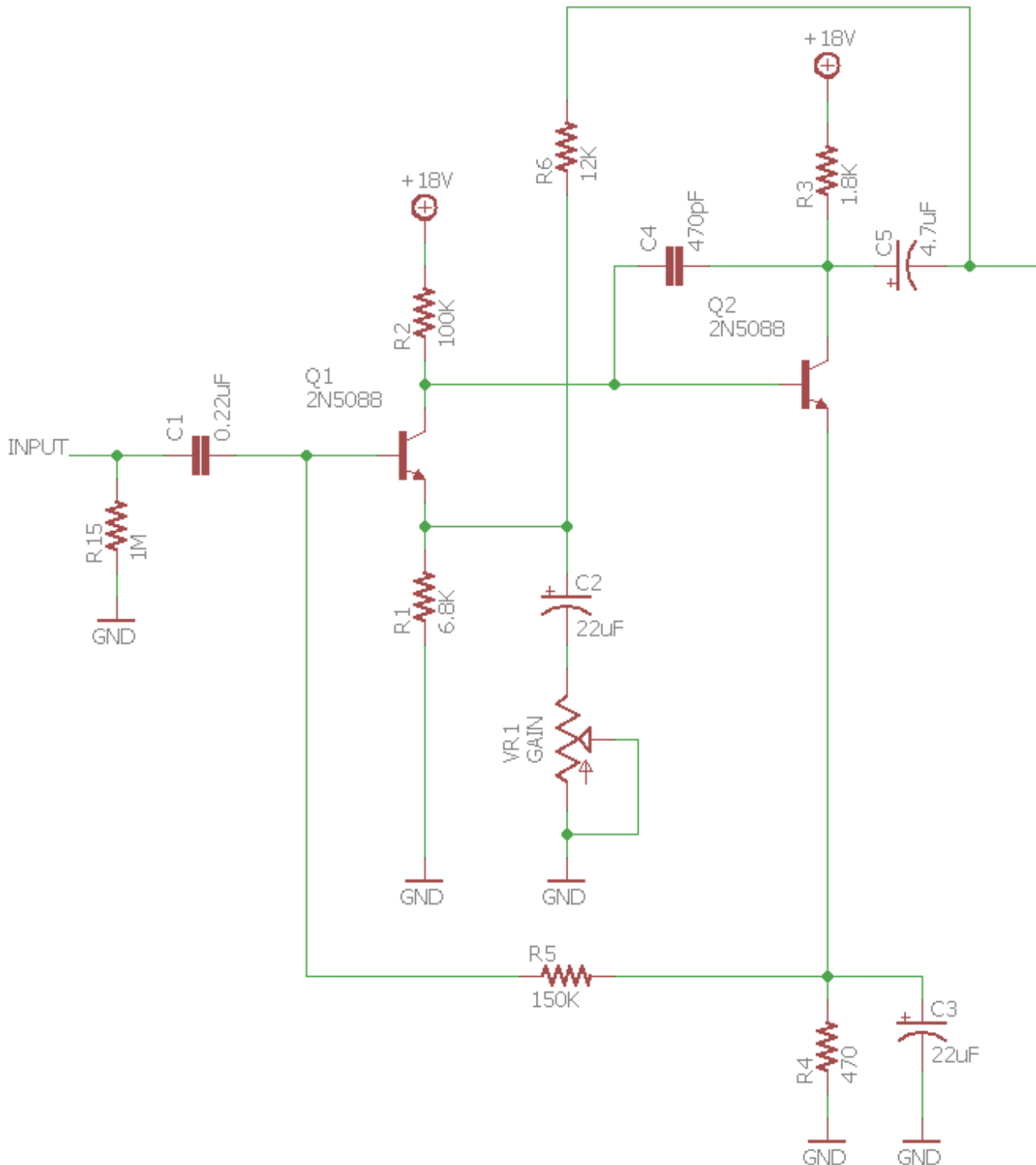
The Power Supply Stage provides the electrical power to all the circuitry, the whole power consumption is estimated around 77mA:



- The D1 Schottky diode protects the pedal against reverse polarity.
- U1 is a 1044/7660 Charge Pump IC configured as a positive voltage-doubler. In this configuration, the 9V is pushed through Schottky diodes D2 and D3 and pumped into capacitors C13 and C14 to provide 18V to the system. So long as the devices on the 18V rail do not consume more than 20mA or less, this will function properly.
- The C12 10 μ F electrolytic capacitor is used for voltage stability on the 1044 IC.
- The D2 and D3 Schottky diodes are used as “check-valves” with the charge pumps going into the C13 and C14 capacitors, but not allowing the current to flow backwards in between pumps.
- The C13 and C14 10 μ F electrolytic capacitors are used as charging reservoirs for the charge pump circuit, leaving C14 at the end of the charge pump chain to become a decoupling capacitor for the 18V rail and ground.

4. Input Stage.

The input stage is made of a pair of inverting transistor amplifiers with a negative feedback loop, which in this configuration provides better-than-average input impedance for a two transistor amplifier.



- The R15 1M Ω resistor from the input to ground is an anti-pop/bleeder resistor, it will avoid abrupt pop sounds when the effect is engaged.
- The C1 220nF film capacitor is a coupling capacitor, connecting the input jack to the rest of the circuit while rejecting DC signals from making it into the pedal. It also forms an RC filter with R4 and R5.
- The R1 6.8K Ω resistor is an emitter resistor for the Q1 amplifier.
- The R2 100K Ω resistor is a collector resistor for the Q1 amplifier.

- The R3 1.8K Ω resistor is a collector resistor for the Q2 transistor and sets its bias.
- The R4 470 Ω resistor is an emitter resistor for the Q2 amplifier.
- The R5 150K Ω resistor is a negative feedback resistor for Q1 and Q2 providing the bulk of the input impedance.
- The R6 12K Ω is a feed-forward/mixer resistor for the emitter signal coming out of Q1 being fed forward and mixed into the output collector signal of Q2.
- The C2 22 μ F electrolytic capacitor is an emitter degeneration capacitor for the Q1 amplifier, providing the AC signal a ground path.
- The C3 22 μ F electrolytic capacitor is an emitter degeneration capacitor for the Q2 amplifier, providing the AC signal a ground path.
- The C4 470pF ceramic capacitor is a miller capacitor for the Q2 amplifier.
- The C5 4.7 μ F electrolytic capacitor is a coupling capacitor connecting this section to the next section but blocking any DC signal.
- The Q1 and Q2 transistors just needs to be low-noise/high-gain ($\beta=200-700$). Using a 2N5088, or 2N3904 will work well here.

4.1 Input Impedance.

The input impedance is difficult to directly calculate due to complexity of this circuit, but a good rough approximation can be calculated as:

$$Z_{in} = R_{15} \parallel R_5 \parallel \beta$$

Assuming the β of the Q1 transistor, its collector, and base of the Q2 transistor is roughly 4.5M Ω

$$Z_{in} = 1M \parallel 150K \parallel 4.5M$$

$$Z_{in} = 1,000,000 \parallel 150,000 \parallel 4,500,000$$

$$Z_{in} = 126,760 \Omega$$

Therefore, the Turbo Driver input impedance is 127K, which isn't great, but for a discrete pedal, isn't bad either. The closer to 1M it is, the better. Increasing R15 to 2.2M would bring the input resistance up to 136K and further raising R5 to 191K, although changing R5 to increase the input impedance results in gating the pedal.

However, the lower input impedance does mean that it responds decently with the volume knob of your guitar, especially with single coil pickups.

4.2 Voltage Gain.

Without R6 there's no feedback so it's more or less a Fuzz Face and the DC feedback to stabilize the bias comes from R5. The extra stuff on the emitter of Q1 would reduce the (open loop) gain compared to a Fuzz Face. Nonetheless the overall gain of the two transistor stages is high.

The "big" cap C3 shorts out the AC signal so there's no AC feedback but it does provide DC feedback through the R5 feedback resistor.

The emitter of Q1 provides a place to provide feedback. R6 provide the feedback and the closed loop gain is approximately $1 + R6 / (R1 \text{ in parallel with } VR1)$ exactly like a non-inverting op amp. The resistor R6 is AC coupled so it doesn't affect the biasing.

However in this case the feedback is DC coupled so it stabilizes the bias and provides the feedback to set the gain.

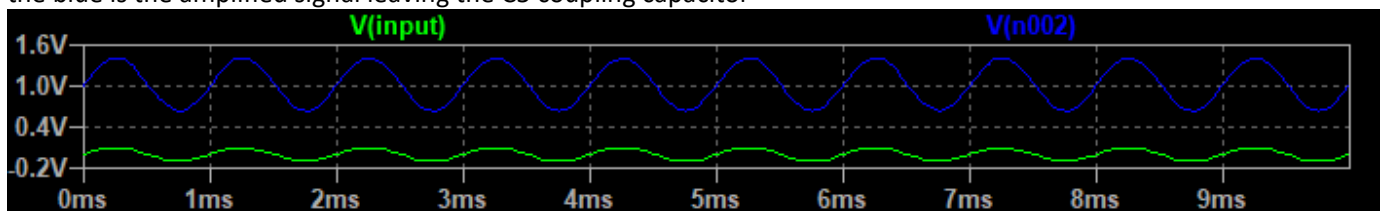
Basically you start with a high gain amp and put feedback around it just like you do with op amps. The feedback reduces or sets the gain. The difference between op amps and transistor circuits is you have to be careful about biasing and you have many options to add the feedback because you have access to all the points in the circuit.

The voltage gain for this stage varies depending on frequencies, but generally, it can be calculated as.

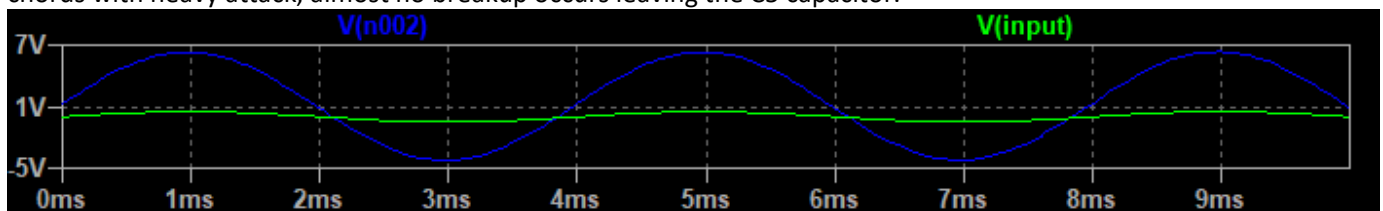
$$G_{vmin} = 1 + (R6 / (R1 \parallel VR1))$$
$$G_{vmin} = 1 + (12,000 / (6,800 \parallel 10,000))$$
$$G_{vmin} = 1 + (12,000 / 4,047.62) = 3.9647 \text{ (11.96dB)}$$

$$G_{vmax} = 1 + (R6 / (R1 \parallel VR1))$$
$$G_{vmax} = 1 + (12,000 / (6,800 \parallel 0))$$
$$G_{vmax} = 1 + 12,000 = 12,001 \text{ (81.58dB)}$$

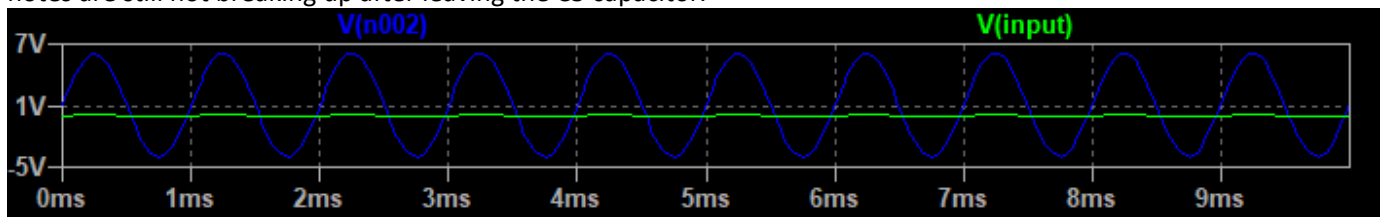
So with the gain set to minimum (resistance of 10K), the signal looks like this: The green signal is the original signal while the blue is the amplified signal leaving the C5 coupling capacitor



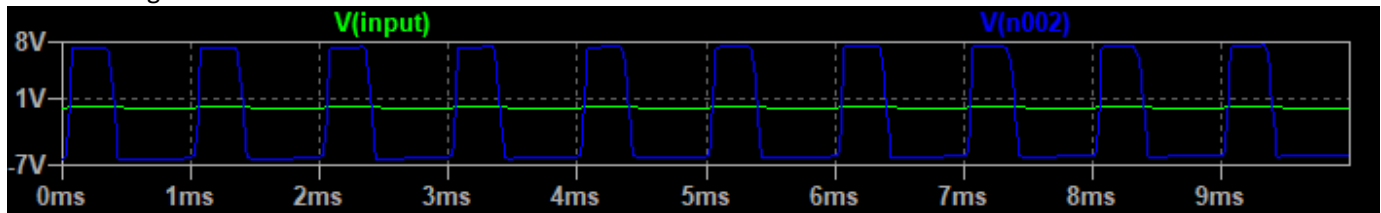
As we reduce the resistance by dialing up the gain, to around 85% (1.5K resistance), even with lower frequency power chords with heavy attack, almost no breakup occurs leaving the C5 capacitor.



If we even go further by dialing the gain almost to near maximum 97% (240 ohms resistance), moderate attacked single notes are still not breaking up after leaving the C5 capacitor.



However, at maximum gain, it is so extreme that the signal slams into the voltage rails and distorts, even with light attacked single notes.

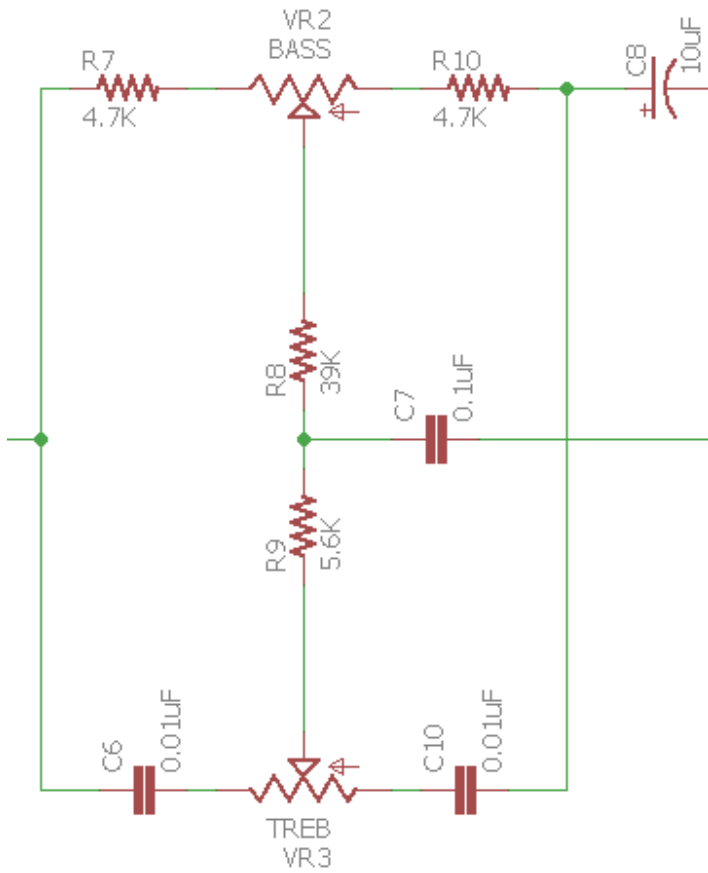


It's this characteristic of gain that drove people like David Gilmore to use it as a clean boost in the 70's as it could really push a signal out into those 70's era British tube amplifiers.

However, it's also this characteristic that some people do not like this circuit, as they are trying to get more clipping and dirt out of this pedal with the gain knob not as far up. To accomplish this, if one were to remove the U1, D2 and D3, C12 and C13, and bridge a wire from the cathode end of D1 to the cathode end of D3, this essentially removes the 18V headroom and reduces it down to 9V. Clipping occurs sooner in this scenario.

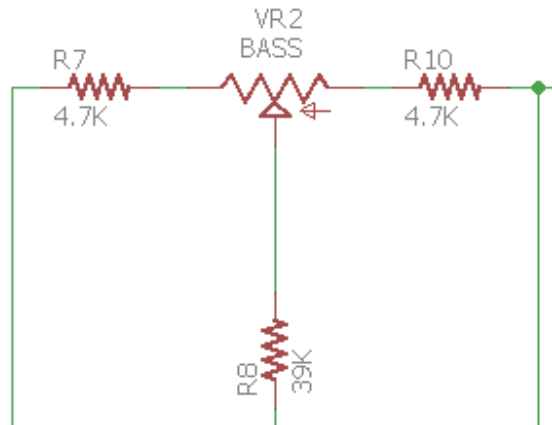
5. Baxandall Tonestack

After the general input gain stage, the tone is shaped by an active tone stack that is fed into the feedback of Q3:

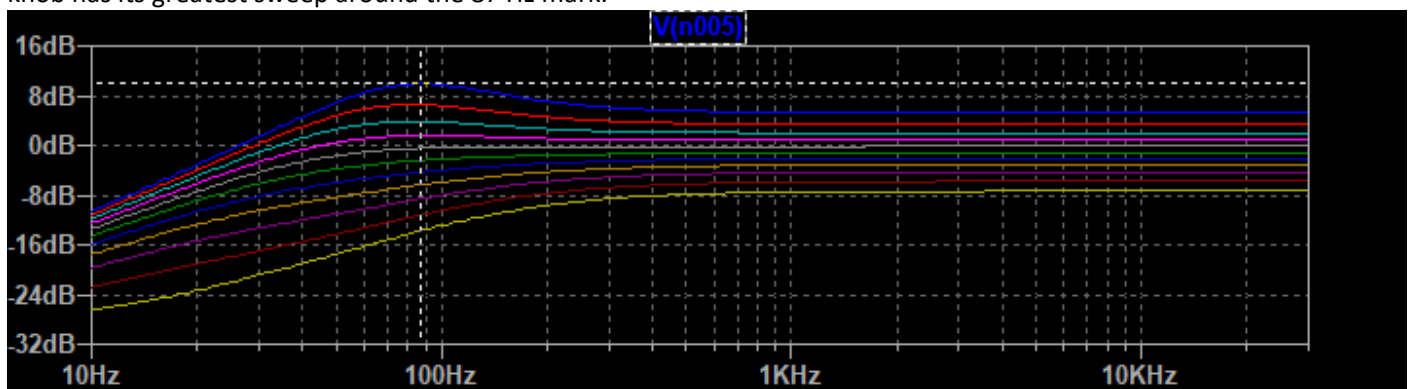


Because the tone stack feeds into both sides of the transistor Q3's negative feedback loop, this allows the two RC filters to actively cut AND boost the signal.

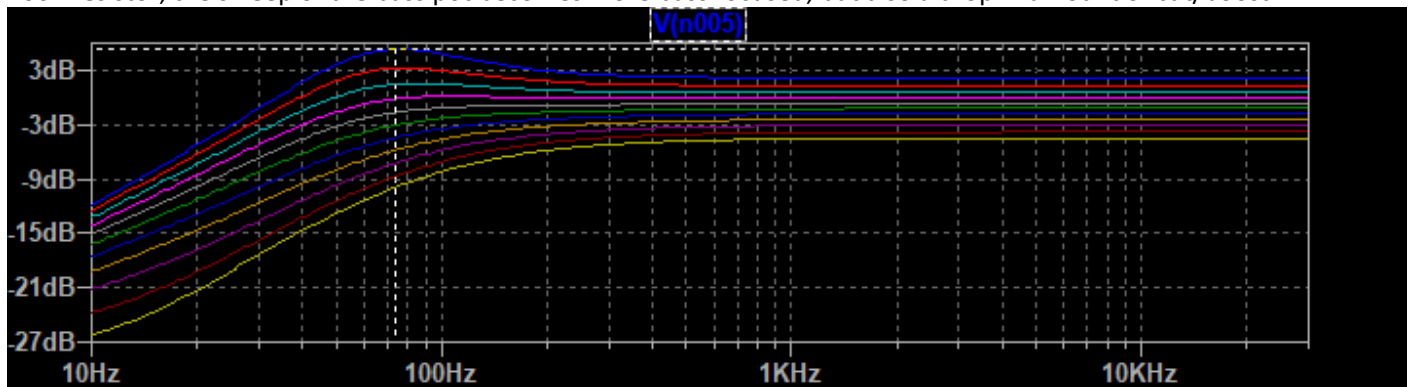
5.1 Bass Frequency Response



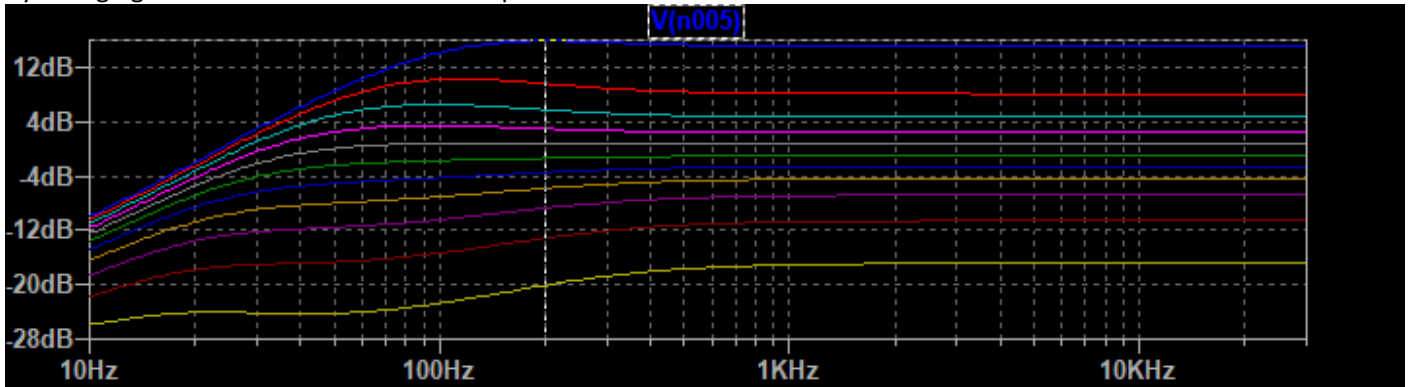
Unlike a true Baxandall, the bass side lacks capacitors which would pinch the EQ sweeps into the center. Thus the bass knob has its greatest sweep around the 87 Hz mark.



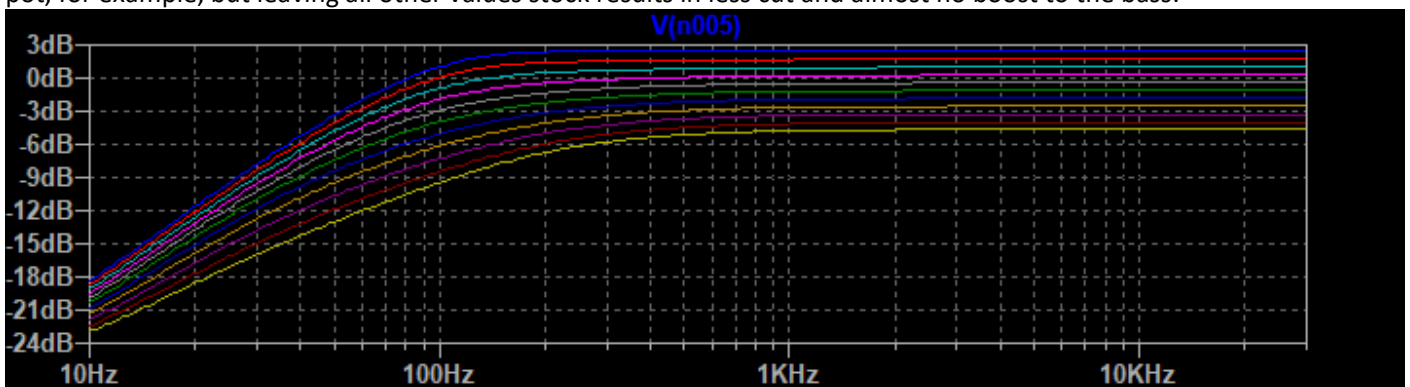
By changing the value of R8, the sweep of responses will change. For example, by changing R8 from a 39K resistor to a 100K resistor, the sweep of the bass pot becomes more bass focused, but also a drop in amount of cut/boost:



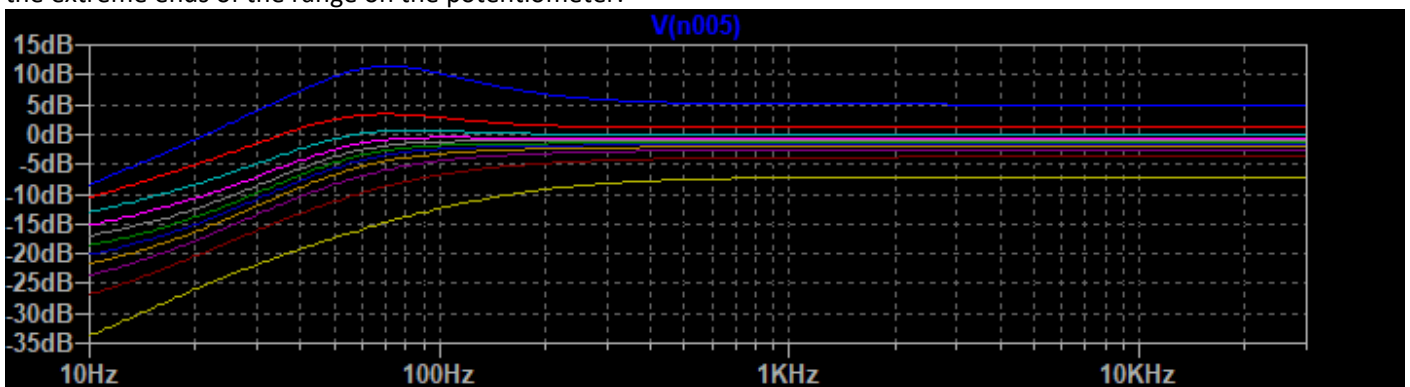
By changing R8 from a 39K resistor to a 1K pushes the focus of the bass knob closer to the 200 Hz area:



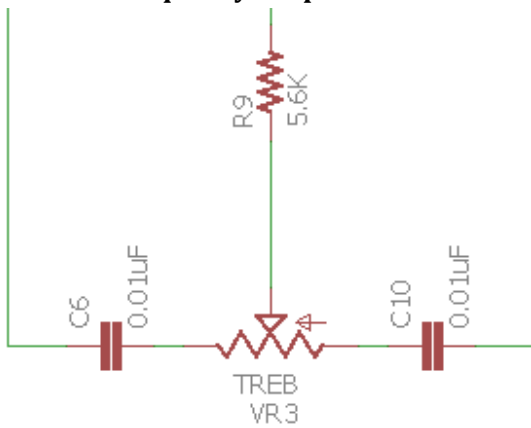
Another portion of the sweep is the potentiometer itself. If changing the value of the bass pot from a 100k pot to a 10k pot, for example, but leaving all other values stock results in less cut and almost no boost to the bass:



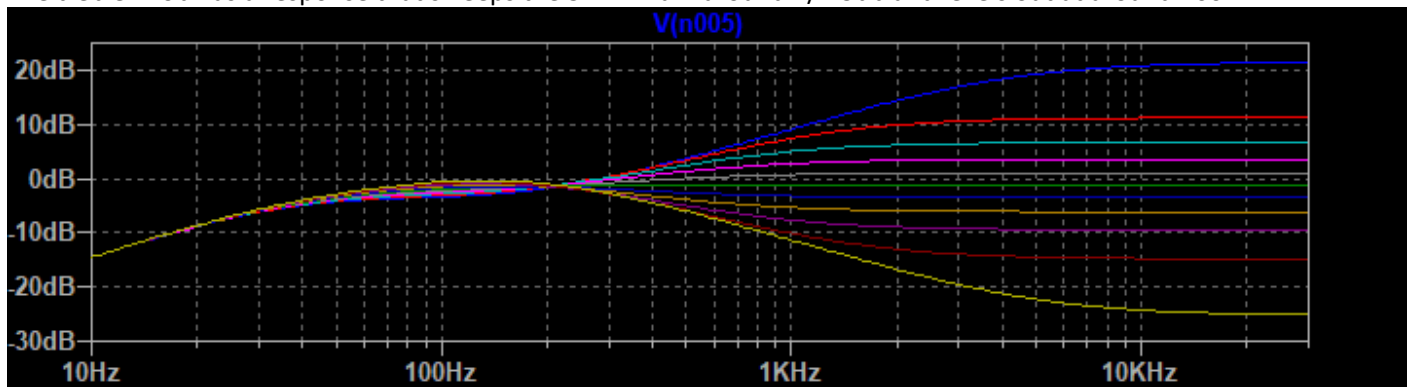
And if the potentiometer for the bass were to be increased to 1M, there will be much more boost and cut to the bass at the extreme ends of the range on the potentiometer:



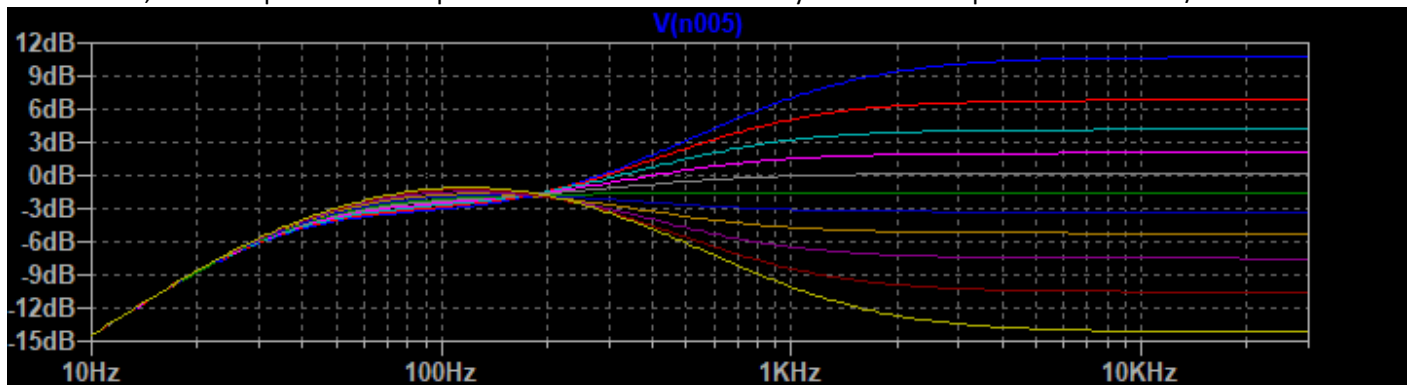
5.2 Treble Frequency Response



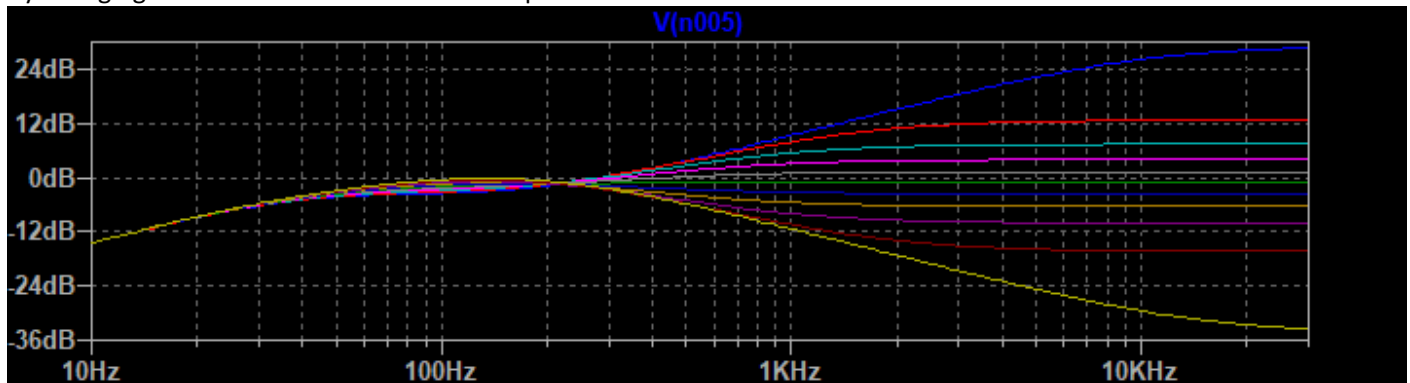
The treble knob has a response that sweeps the 5 kHz mark around +/-19db and levels out at around 200 Hz



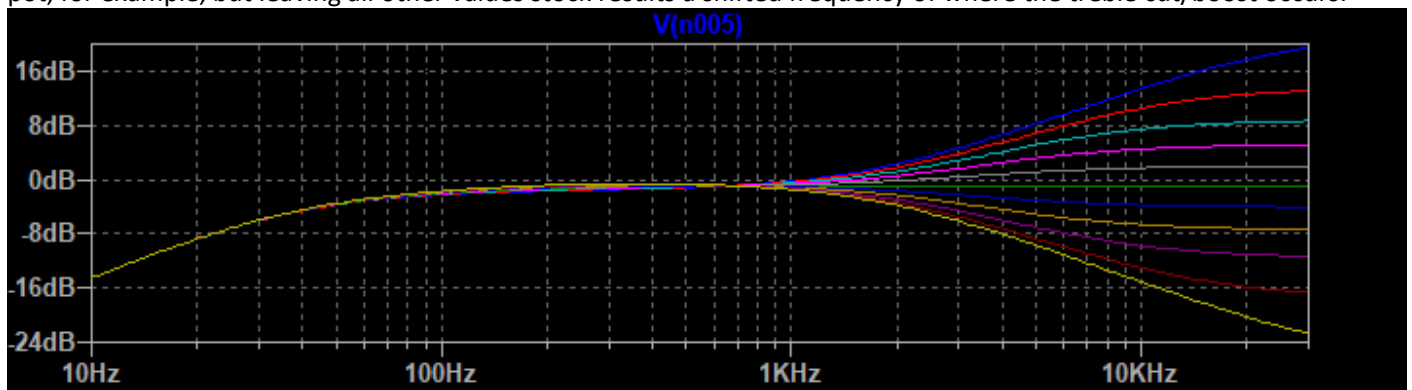
By changing the value of R9, the sweep of responses will change. For example, by changing R11 from a 5.6K resistor to a 33K resistor, the sweep of the treble pot becomes more treble heavy but also a drop in amount of cut/boost:



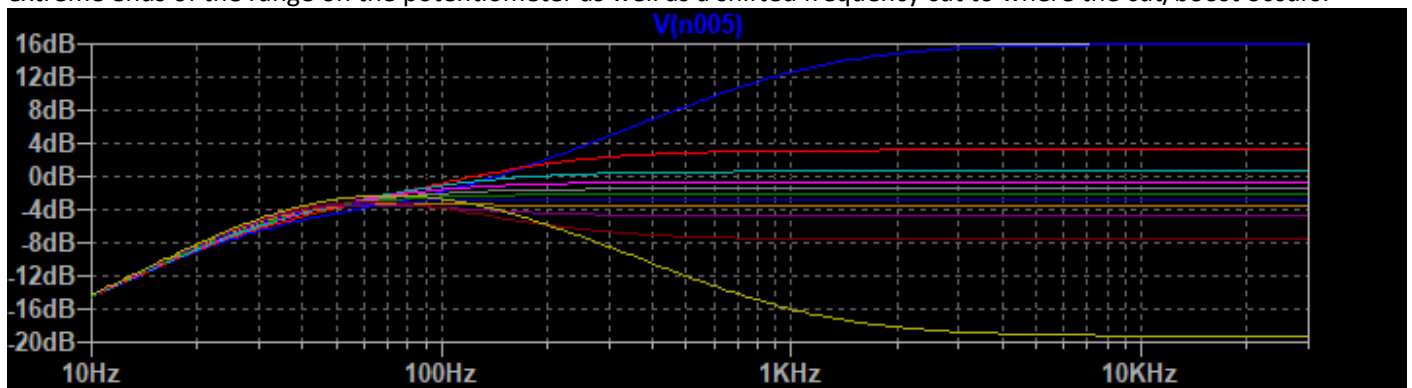
By changing R9 from a 5.6K resistor to a 330 pushes the focus of the treble knob further from the 200Hz area.



Another portion of the sweep is the potentiometer itself. If changing the value of the treble pot from a 100k pot to a 10k pot, for example, but leaving all other values stock results a shifted frequency of where the treble cut/boost occurs:

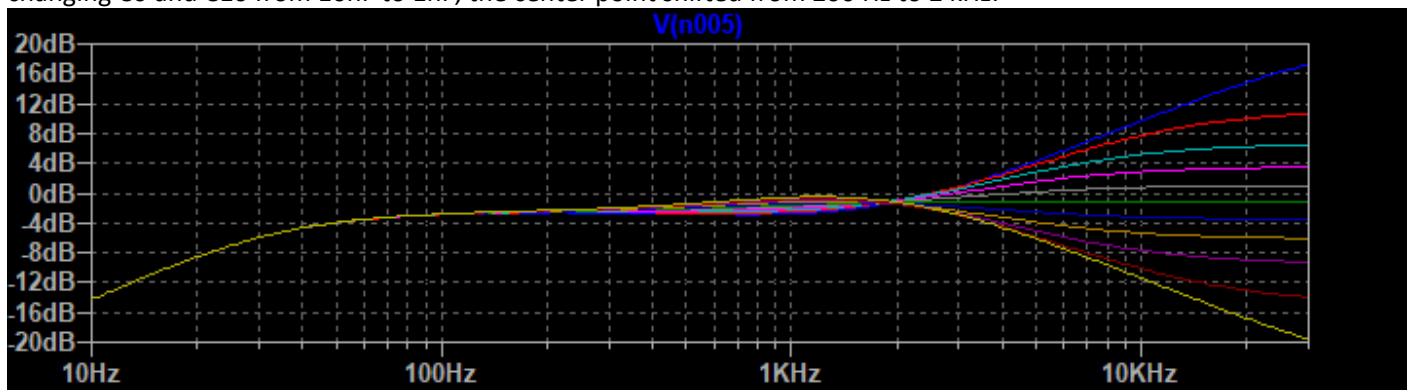


And if the potentiometer for the treble were to be increased to 1M, there will be less boost and cut to the treble at the extreme ends of the range on the potentiometer as well as a shifted frequency cut to where the cut/boost occurs:

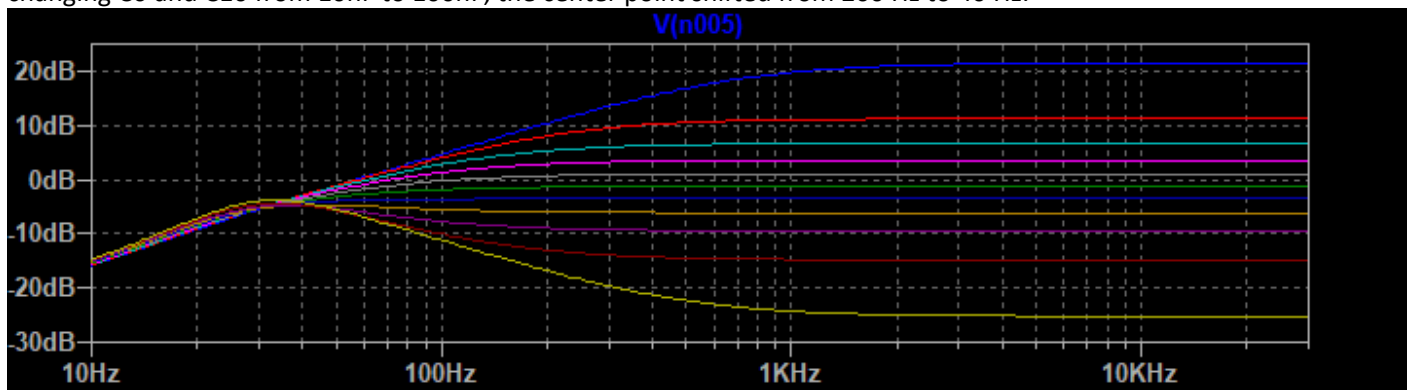


The values C6 along with the treble potentiometer effect the boost side of the treble, while C10 along with the treble potentiometer effect the cut side of the treble.

Decreasing the capacitance of C6 or C10 will effect where the frequency cut/boost point is located. For example, by just changing C6 and C10 from 10nF to 1nF, the center point shifted from 200 Hz to 2 kHz:

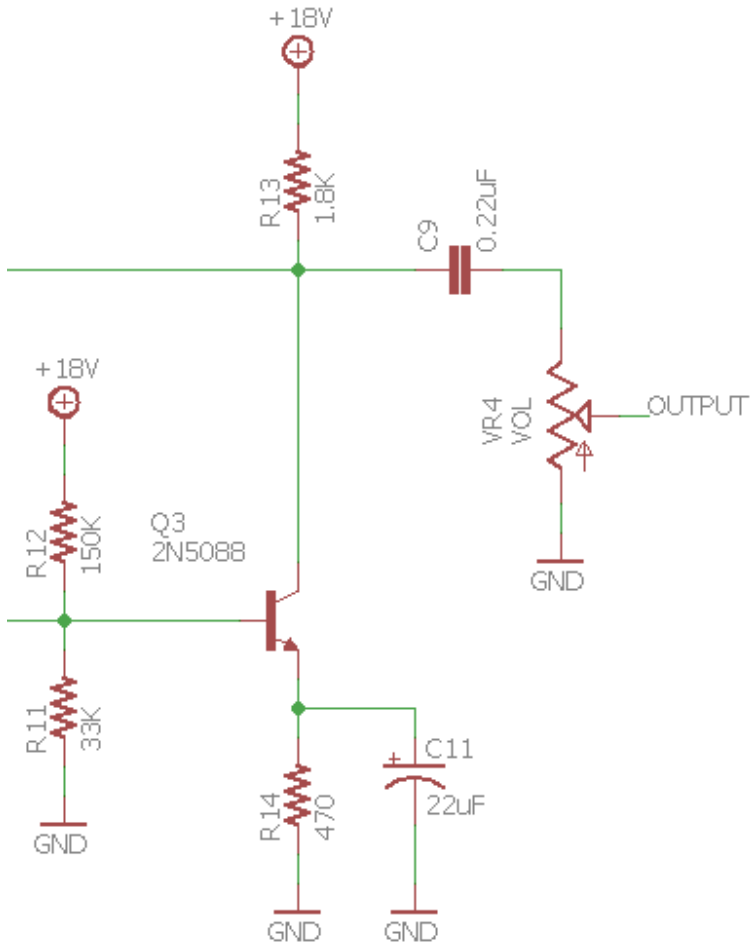


Increasing the capacitance of C6 or C10 will effect where the frequency cut/boost point is located. For example, by just changing C6 and C10 from 10nF to 100nF, the center point shifted from 200 Hz to 40 Hz:



6. Output Buffer.

The output stage is out of an inverting transistor amplifier (Common Emitter Amplifier).



The topology is very reminiscent of a Dallas Rangemaster in an NPN configuration with R11 and R12 being the bias voltage supply for Q3, R14 being the emitter resistor and C11 being the audio bypass around R14, giving it more gain.

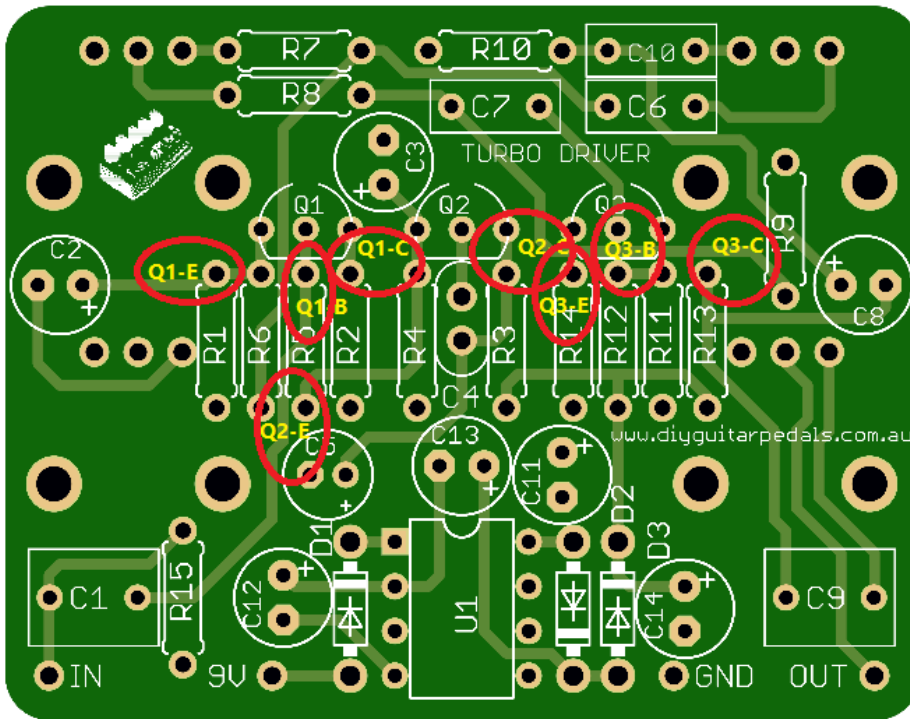
6.1 Output Impedance.

The output impedance is set by R13 in parallel with the volume knob. This said, it will never be higher than 1.77k with the volume knob maxed, which is ideal.

7. Voltage Readouts.

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

Transistor and IC read-outs



Q1-C: 2.297V

Q1-B: 1.604V

Q1-E: 1.503V

Q2-C: 9.500V

Q2-B: Same as Q1-C

Q2-E: 1.667V

Q3-C: 9.400V

Q3-B: 1.724V

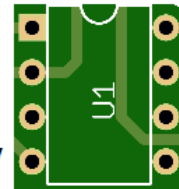
Q3-E: 1.686V

8.260V

4.233V

0.013V

-3.924V



8.260V

6.010V

3.631V

-3.758V

KNOBS

- VOL: MAX
- GAIN: MAX
- BASS: MAX
- TREBLE: MAX

8. Modifications

Following is a couple of worthwhile modifications that can be applied to the Turbo Driver.

8.1 Resistors

Changing the values of R3 and the gain potentiometer will influence the general gain of the clipping section. Increasing R3 will increase the gain while reducing the size of the gain pot will drop the general over-all gain. Reducing the value of R3 will allow more soft-clipping to occur, while increasing it will continue to soften the clipping section.

Increasing the value of R5 will cause gating to occur.

R8 changes some of the bass response while R9 changes the treble. R7 changes the bass response to boost side while R10 changes the bass response to the cut side. See section 4 as how these resistors ultimately change the tone stack.

8.2 Capacitors

C6 changes the treble response to boost side while C10 changes the treble response to the cut side. See section 4 as how these capacitors ultimately change the tone stack.

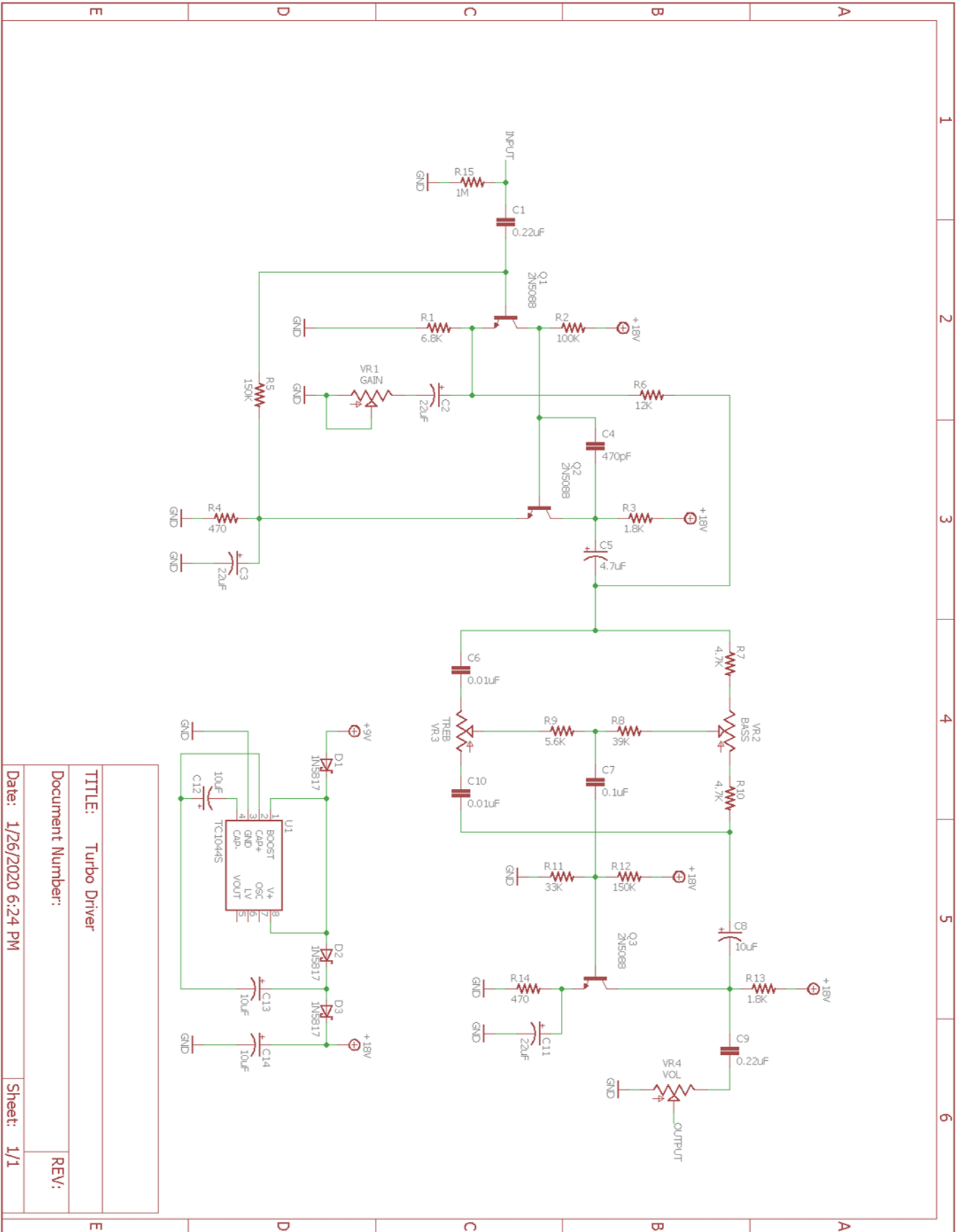
8.3 Potentiometers

Reducing the gain pot from 10k down to 1k would eliminate most of the clean boost sweep and make it more of an overdrive/distortion feel.

8.4 Transistors

Changing Q1 and Q2 transistors will have small tonality changes due to tolerances. Using lower gain 2N3904 in place of the 2N5088 will sound pretty close, but might be slightly less harsh in the higher gain settings.

9. Schematic



TITLE: Turbo Driver

Document Number:

Date: 1/26/2020 6:24 PM

REV:

Sheet: 1/1

