



## Angry Orange

*Design By Erik Vincent* 

The DBE spin on the DS1 - an accurate retake of this classic 90s distortion pedal.

A problem encountered with many online DS1 schematics floating around is less than unity output with the volume cranked. This is not true of the original DS1 and has been fixed in the Angry Orange from references of the correct original DS1 schematic.

Using easy-to-find components, including silicon transistors, this design embodies the classic Boss DS-1 tone-control and some very cool mods (optional). Check out the 3 unique bill of materials! (70's, Ultra and Angriest)

PCB Sizing: 1590B enclosure (with some planning) otherwise 125b

## Bill of Materials, Stock Angry Orange (To get the angriest sound)

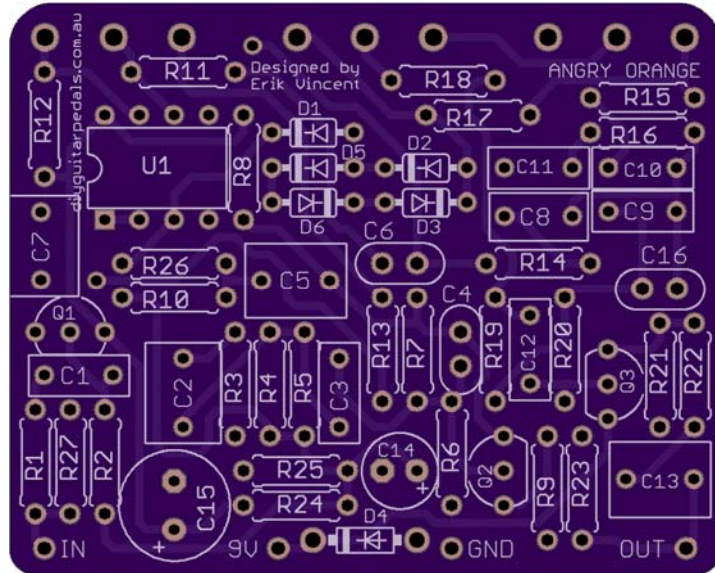
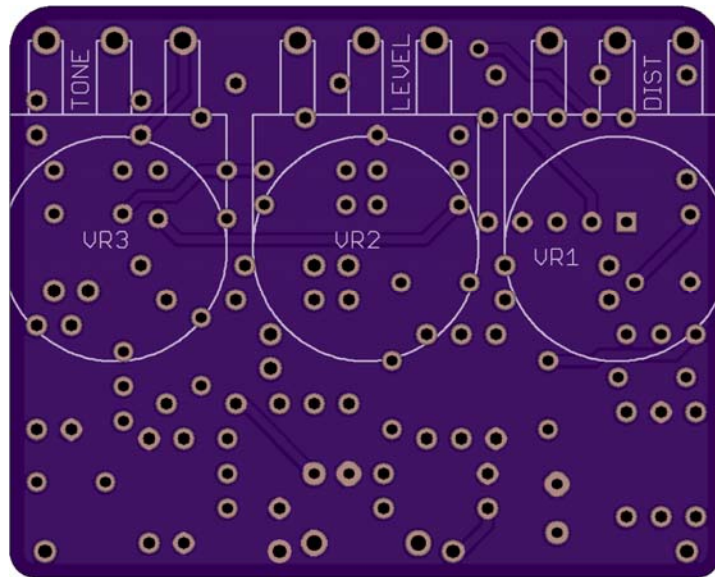
<b>Capacitor</b>		<b>Resistor</b>	
<b>C1</b>	47nF (film)	<b>R1</b>	1K
<b>C2</b>	470nF (film)	<b>R2</b>	470K
<b>C3</b>	47nF (film)	<b>R3</b>	10K
<b>C4</b>	220pF (ceramic)	<b>R4</b>	100K
<b>C5</b>	470nF (film)	<b>R5</b>	1M
<b>C6</b>	100pF (ceramic)	<b>R6</b>	100K
<b>C7</b>	1μF (film)	<b>R7</b>	470K
<b>C8</b>	470nF (film)	<b>R8</b>	10K
<b>C9</b>	10nF (film)	<b>R9</b>	22
<b>C10</b>	22nF (film)	<b>R10</b>	100K
<b>C11</b>	100nF (film)	<b>R11</b>	100K
<b>C12</b>	47nF (film)	<b>R12</b>	1K
<b>C13</b>	1μF (film)	<b>R13</b>	4.7K
<b>C14</b>	47μF (Electrolytic)	<b>R14</b>	2.2K
<b>C15</b>	100μF (Electrolytic)	<b>R15</b>	2.2K
<b>C16</b>	<b>DO NOT POPULATE</b>	<b>R16</b>	6.8K
		<b>R17</b>	6.8K
		<b>R18</b>	10K
<b>Diode</b>			
<b>D1</b>	1N4148	<b>R19</b>	1M
<b>D2</b>	1N4148	<b>R20</b>	1M
<b>D3</b>	1N4148	<b>R21</b>	100K
<b>D4</b>	1N4001	<b>R22</b>	1K
<b>D5</b>	1N4148	<b>R23</b>	100K
<b>D6</b>	1N4148	<b>R24</b>	10K
		<b>R25</b>	10K
<b>Transistor</b>		<b>R26</b>	22K
<b>Q1</b>	2N5088	<b>R27</b>	2.2M
<b>Q2</b>	2N5088		
<b>Q3</b>	2N5088		
		<b>Potentiometer</b>	
		<b>Distortion</b>	100kb (16mm)
		<b>Level</b>	100kb (16mm)
<b>ICs</b>		<b>Tone</b>	25kb (16mm)
<b>U1</b>	MC1458P		

### Bill of Materials, DS-1 Classic (To get the classic '78 sound)

Capacitor		Resistor	
<b>C1</b>	47nF (film)	<b>R1</b>	1K
<b>C2</b>	470nF (film)	<b>R2</b>	470K
<b>C3</b>	47nF (film)	<b>R3</b>	10K
<b>C4</b>	220pF (ceramic)	<b>R4</b>	100K
<b>C5</b>	470nF (film)	<b>R5</b>	1M
<b>C6</b>	100pF (ceramic)	<b>R6</b>	100K
<b>C7</b>	1μF (film)	<b>R7</b>	470K
<b>C8</b>	470nF (film)	<b>R8</b>	10K
<b>C9</b>	10nF (film)	<b>R9</b>	22
<b>C10</b>	22nF (film)	<b>R10</b>	100K
<b>C11</b>	100nF (film)	<b>R11</b>	100K
<b>C12</b>	47nF (film)	<b>R12</b>	<b>DO NOT POPULATE</b>
<b>C13</b>	1μF (film)	<b>R13</b>	4.7K
<b>C14</b>	47μF (Electrolytic)	<b>R14</b>	2.2K
<b>C15</b>	100μF (Electrolytic)	<b>R15</b>	2.2K
<b>C16</b>	<b>DO NOT POPULATE</b>	<b>R16</b>	6.8K
		<b>R17</b>	6.8K
		<b>R18</b>	10K
Diode			
<b>D1</b>	1N4148	<b>R19</b>	1M
<b>D2</b>	1N4148	<b>R20</b>	1M
<b>D3</b>	1N4148	<b>R21</b>	100K
<b>D4</b>	1N4001	<b>R22</b>	1K
<b>D5</b>	<b>SHUNT</b>	<b>R23</b>	100K
<b>D6</b>	<b>SHUNT</b>	<b>R24</b>	10K
		<b>R25</b>	10K
Transistor		<b>R26</b>	22K
<b>Q1</b>	2N5088	<b>R27</b>	2.2M
<b>Q2</b>	2N5088		
<b>Q3</b>	2N5088		
		Potentiometer	
		<b>Distortion</b>	100kb (16mm)
		<b>Level</b>	100kb (16mm)
ICs		<b>Tone</b>	25kb (16mm)
<b>U1</b>	TL072		

### Bill of Materials, Keeley "Ultra" DS-1 (To get tweaked up sound)

<b>Capacitor</b>		<b>Resistor</b>	
<b>C1</b>	100nF (film)	<b>R1</b>	1K
<b>C2</b>	1μF (film)	<b>R2</b>	470K
<b>C3</b>	100nF (film)	<b>R3</b>	10K
<b>C4</b>	220pF (ceramic)	<b>R4</b>	100K
<b>C5</b>	100nF (film)	<b>R5</b>	1M
<b>C6</b>	220pF (ceramic)	<b>R6</b>	100K
<b>C7</b>	1μF (film)	<b>R7</b>	470K
<b>C8</b>	1μF (film)	<b>R8</b>	10K
<b>C9</b>	10nF (film)	<b>R9</b>	22
<b>C10</b>	47nF (film)	<b>R10</b>	100K
<b>C11</b>	100nF (film)	<b>R11</b>	100K
<b>C12</b>	1μF (film)	<b>R12</b>	1K
<b>C13</b>	1μF (film)	<b>R13</b>	2.4K
<b>C14</b>	47μF (Electrolytic)	<b>R14</b>	1.5K
<b>C15</b>	100μF (Electrolytic)	<b>R15</b>	2.2K
<b>C16</b>	47pF (ceramic)	<b>R16</b>	6.8K
		<b>R17</b>	6.8K
		<b>R18</b>	10K
<b>Diode</b>			
<b>D1</b>	1N4148	<b>R19</b>	1M
<b>D2</b>	1N4148	<b>R20</b>	1M
<b>D3</b>	Red LED	<b>R21</b>	100K
<b>D4</b>	1N4001	<b>R22</b>	1K
<b>D5</b>	Red LED	<b>R23</b>	100K
<b>D6</b>	<b>SHUNT</b>	<b>R24</b>	10K
		<b>R25</b>	10K
<b>Transistor</b>		<b>R26</b>	20K
<b>Q1</b>	2N5088	<b>R27</b>	2.2M
<b>Q2</b>	2N5088		
<b>Q3</b>	2N5088		
		<b>Potentiometer</b>	
		<b>Distortion</b>	100kb (16mm)
		<b>Level</b>	100kb (16mm)
<b>ICs</b>		<b>Tone</b>	25kb (16mm)
<b>U1</b>	MC1458P		



**PCB Spacing**

The Angry Orange PCB is spaced for 1590B sized enclosures or larger

**Pot Spacing**

The Angry Orange PCB mounted potentiometers are spaced for Alpha 16mm potentiometers without dust covers

## Assembly.

### 1. Soldering Order.

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

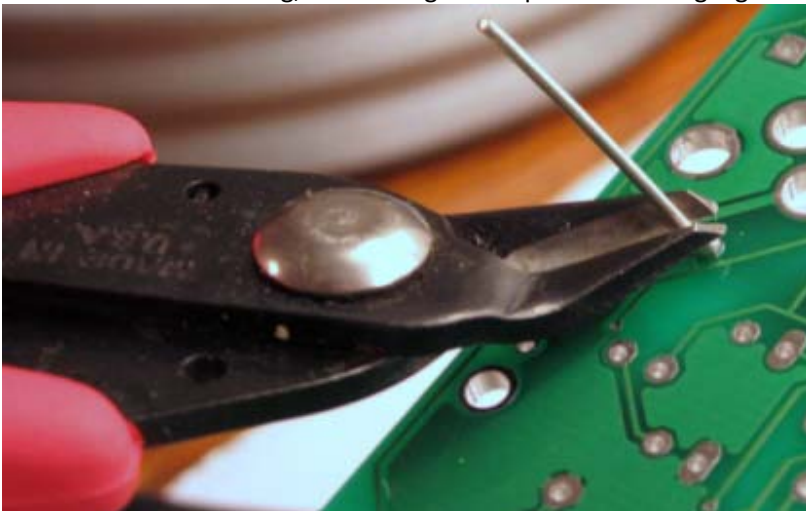
For the Angry Orange, the best order would be: resistors, diodes, ceramic capacitors, IC sockets (if socketing), transistor/FETs, ICs (if not socketing), film capacitors, electrolytic capacitors, wiring, and then potentiometers.

#### 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.

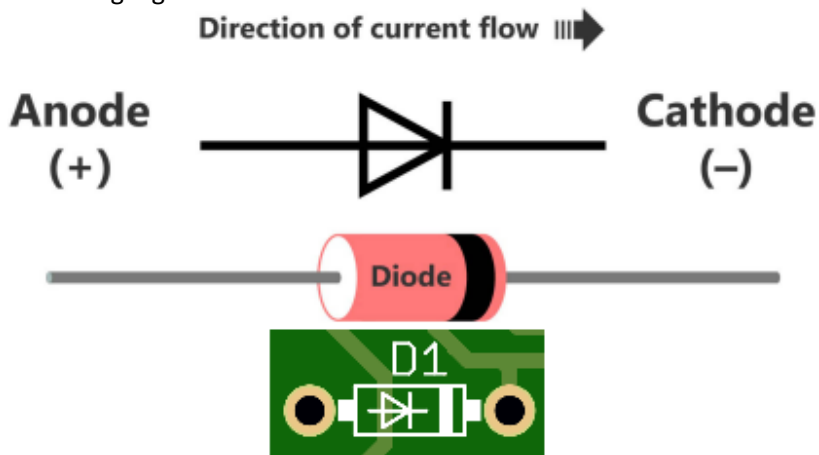


## 1.2 Diodes.

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).

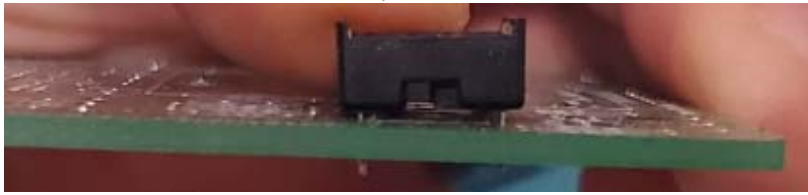
Ceramic capacitors are small passive components designed to hold a small amount of charge in a circuit.



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.

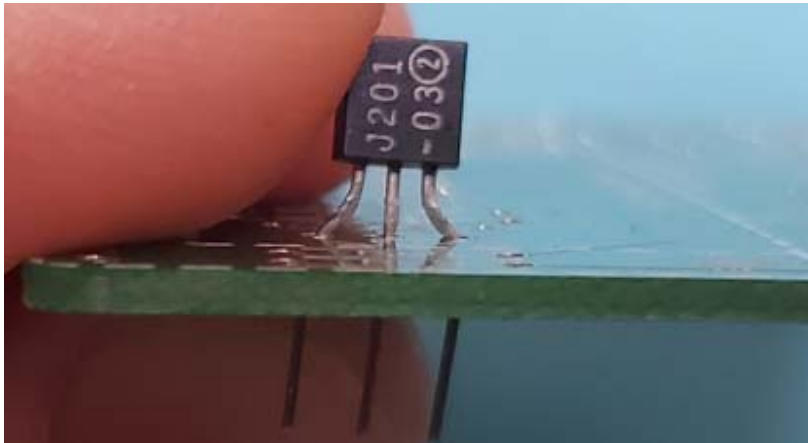
These are holders that allow easy installation and uninstallation of ICs.



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.

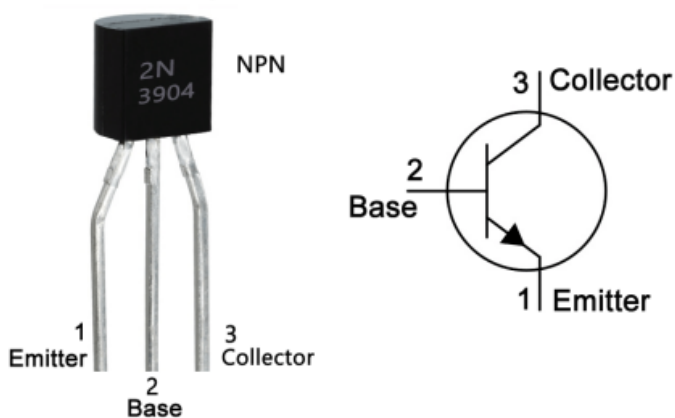
### 1.5 Transistors/FETs (silicon).

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

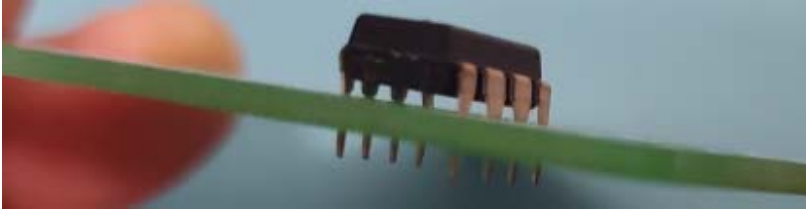


After installation and soldering, do not forget to clip the remaining legs from the PCB.



## 1.6 Integrated Circuits.

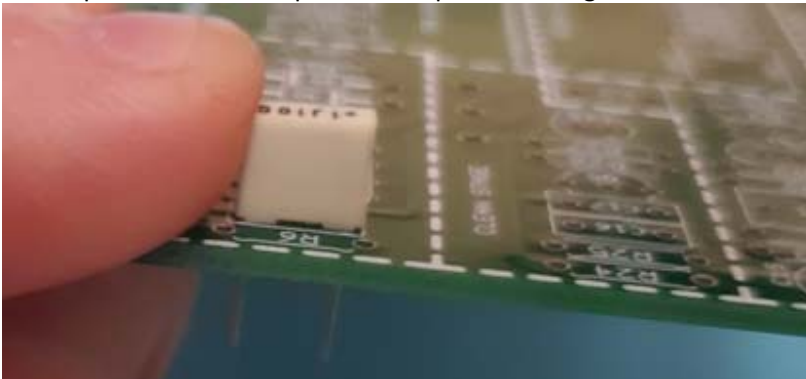
Also known as ICs, these are small analog or digital components that provide specific electrical functions.



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).

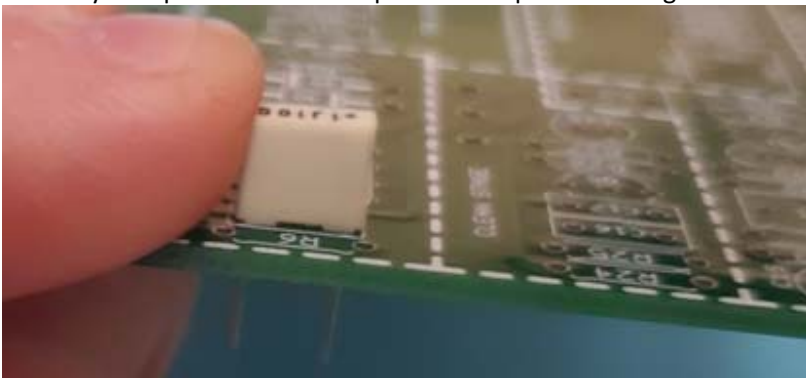
Film capacitors are small passive components designed to hold a small amount of charge in a circuit.



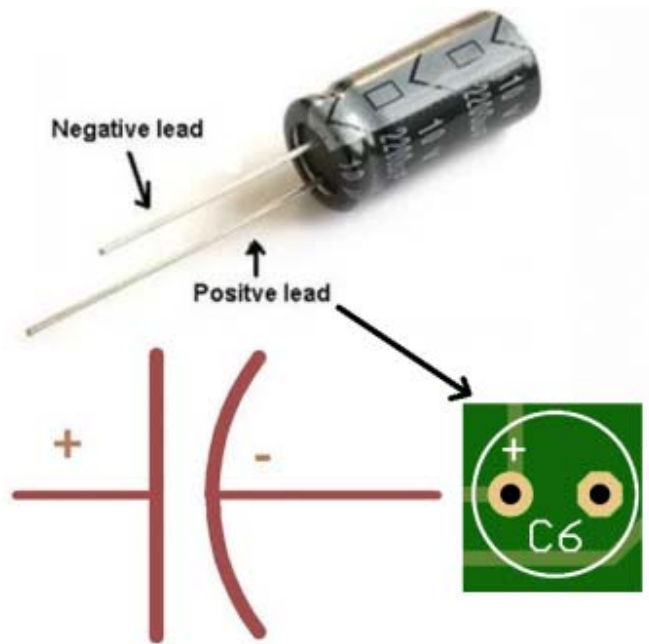
Orientation of “which way is up” doesn’t matter, so you can install them either way. After installation and soldering, do not forget to clip the remaining legs from the PCB.

## 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.

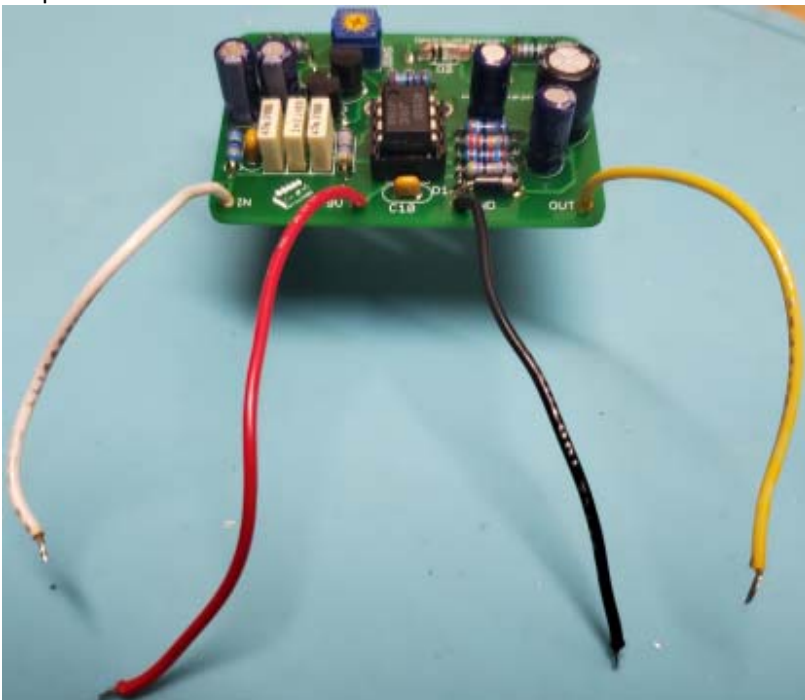


**Polarized Electrolytic Capacitor and its electric Symbol**

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.



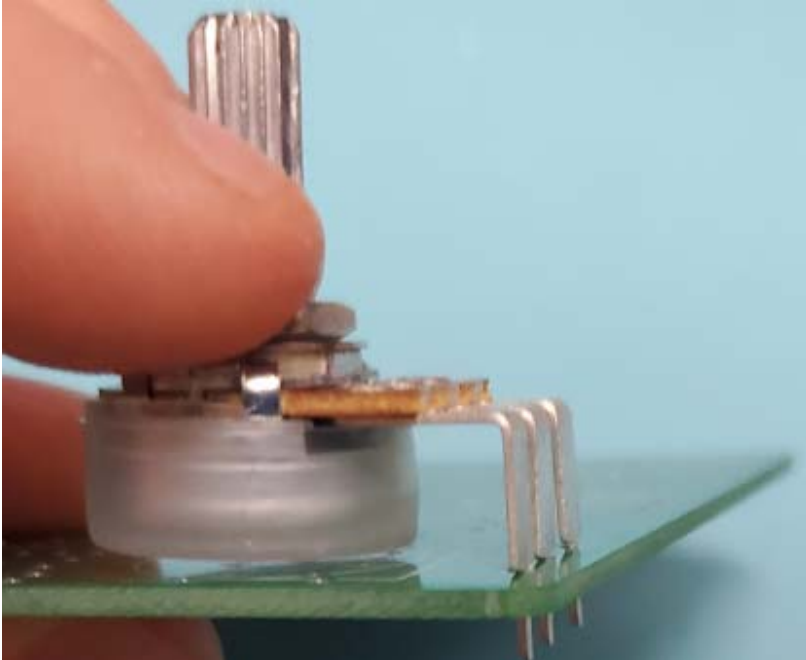
These can be installed at the very end, but in some situations, installing them before potentiometers are soldered in

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.

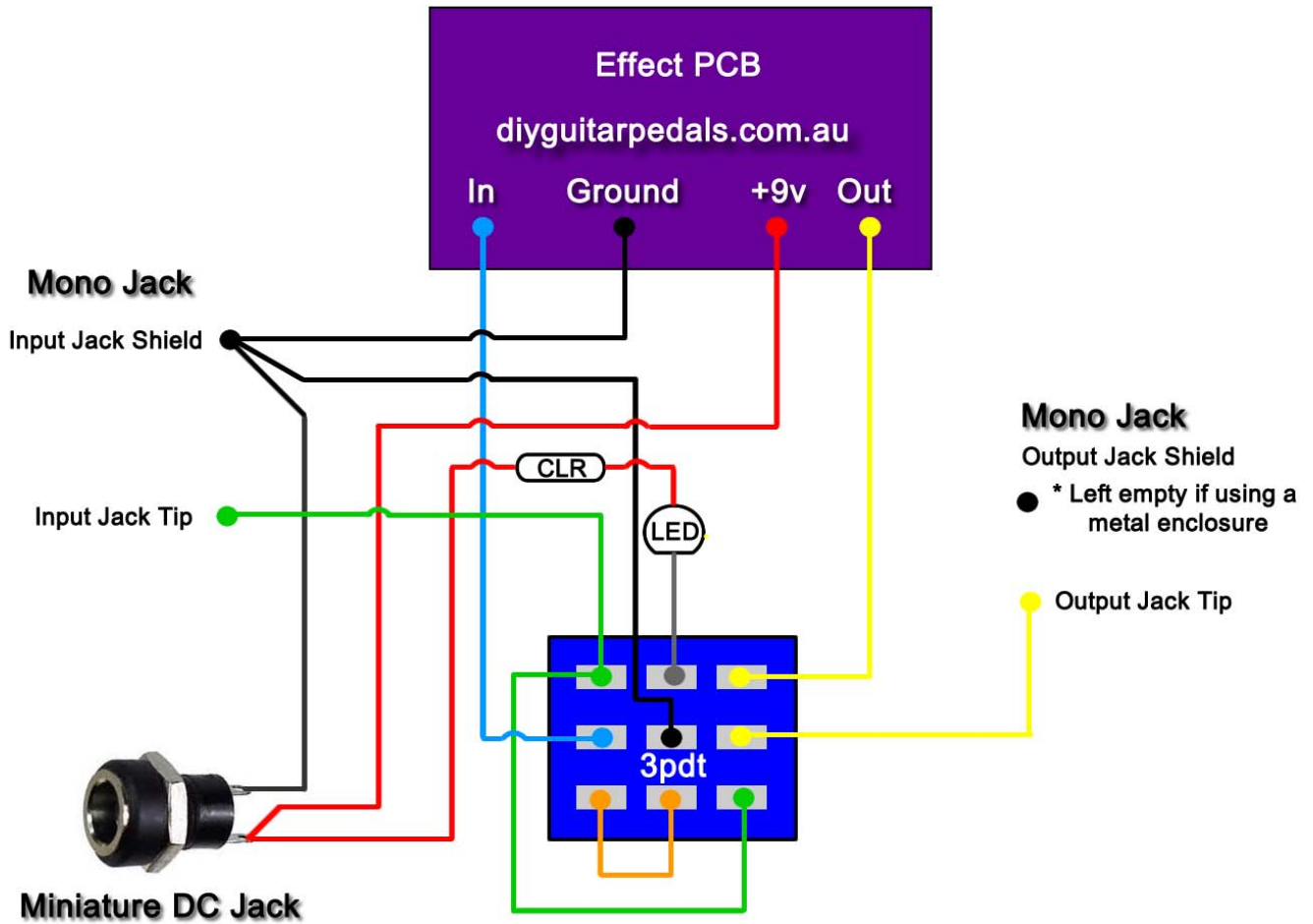
Potentiometers are variable resistors that are used for controlling aspects of the pedal.



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.

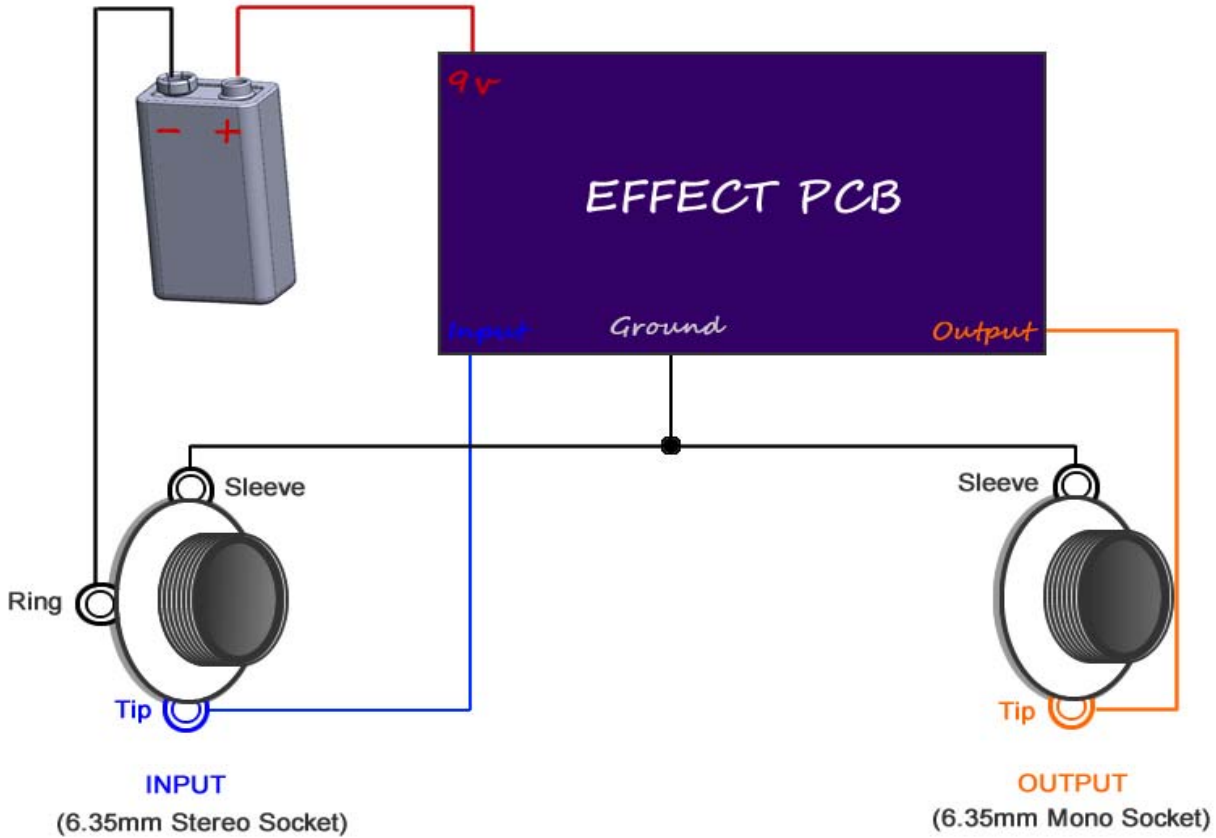
### 1.11 Off Board Wiring Diagram.

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



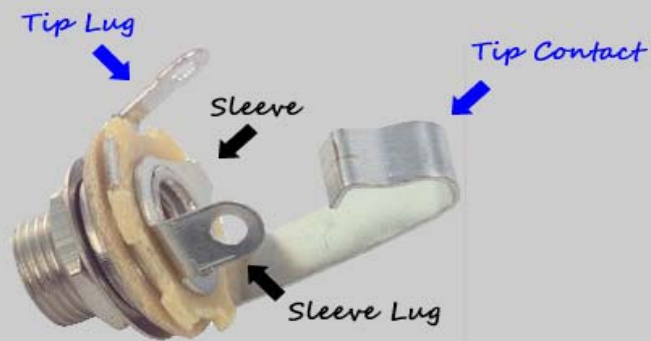
# Testing Your Effect

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



## Input and Output Sockets

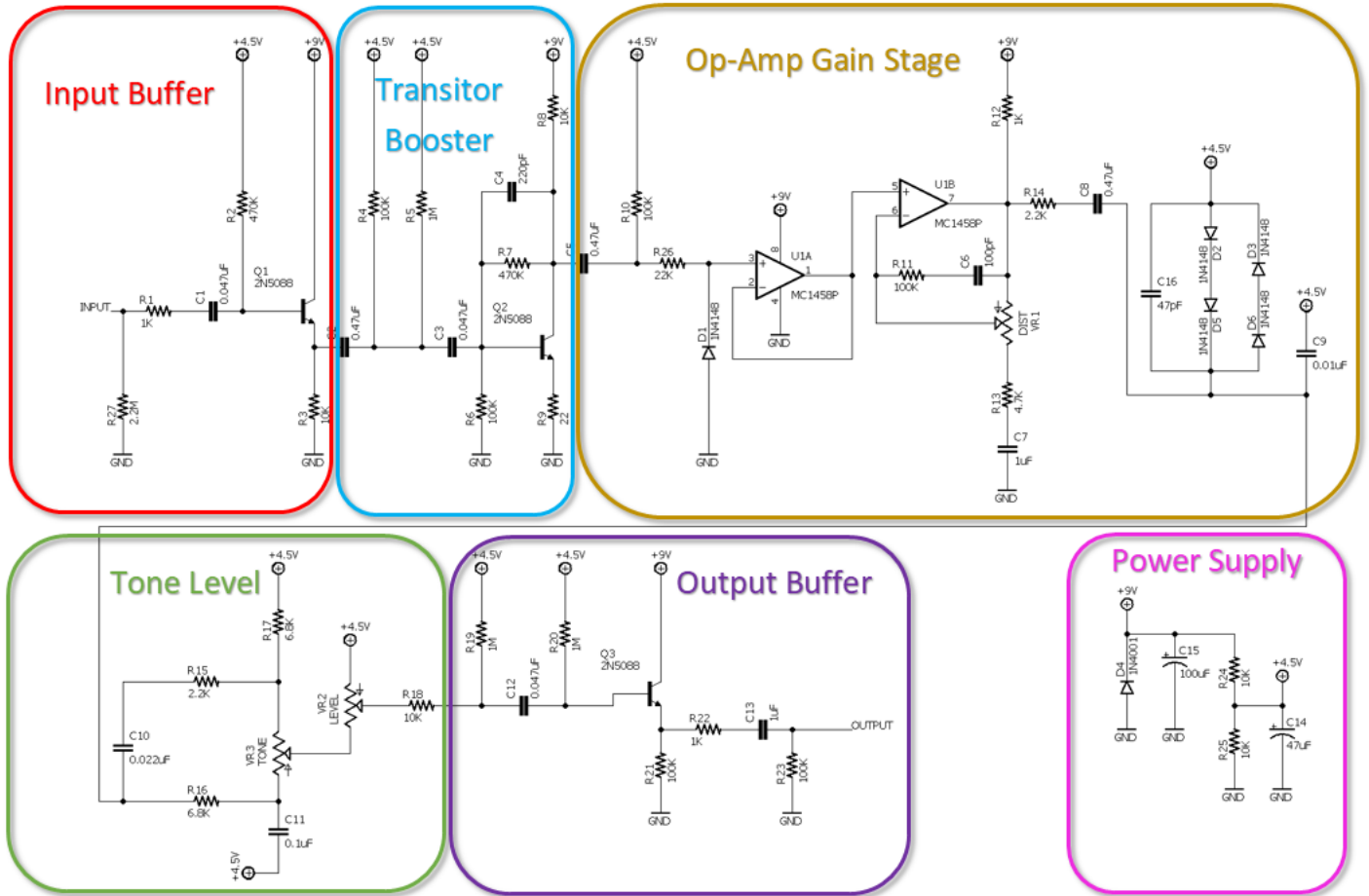
Pay close attention to the lugs of your sockets. Look at them side on so that you can distinguish the sockets individual layers. For instance the tip lug is connected to tip contact. The stereo jack looks the same as the socket below except it has an extra lug and contact for "Ring".



# Angry Orange Circuit Analysis for modifying purposes.

## 2. Angry Orange Circuit.

The Angry Orange schematic can be broken down into some simpler blocks: Power Supply, Input Buffer, Transistor Booster, Op-Amp Gain Stage, Tone Level, and Output Buffer.

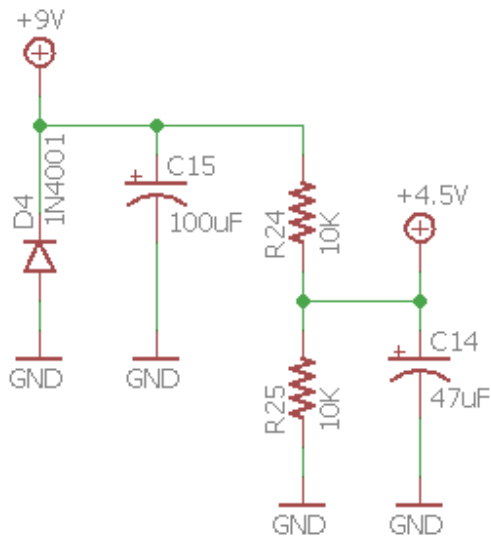


The circuit is designed around a single op-amp gain and hard clipping while using transistors to handle buffering and boosting the input signal and buffering a recovery stage at the end.

The input impedance on the Angry Orange is close to 239k  $\Omega$ , allowing the pedal to not overload the pickups on the guitar or to tone suck, but as a rule of thumb, increasing to 1M would be ideal.

### 3. Power Supply.

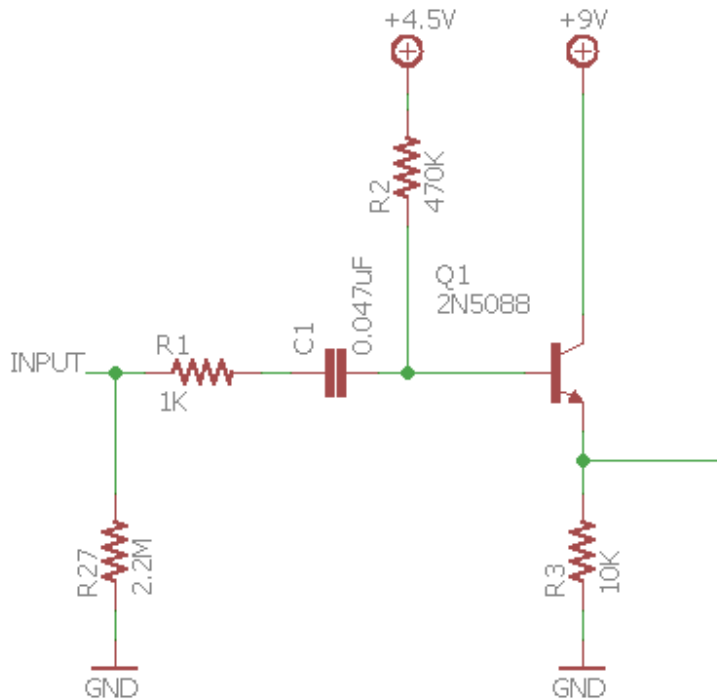
The Power Supply Stage provides the electrical power and bias voltage to all the circuitry, the whole power consumption is low and estimated around 6mA:



- The D4 rectifier diode protects the pedal against adapter reverse polarity connections.
- The C15 100µF electrolytic capacitor is a bulk capacitor used to stabilize the power supply lines.
- The R24 and R25 10K Ω resistors form a voltage divider, creating a 4.5V reference signal used for bias voltage, also known as virtual ground.
- The C14 47µF electrolytic capacitor is a decoupling capacitor for the bias voltage.

#### 4. Input Buffer.

The input buffer is a plain, non-inverting, Emitter Follower (aka Common Collector) with unity gain and high input impedance that preserves signal quality eliminating tone sucking (high-frequency loss):



- The R27 2.2M  $\Omega$  resistor from the input to ground is an anti-pop/bleeder resistor, it will avoid abrupt pop sounds when the effect is engaged. On the original Boss DS-1, this resistor was not present as it effected the Input Impedances on their original design, though this has been corrected for on the Angry Orange.
- The R1 1K  $\Omega$  resistor is a current limiting resistor designed to protect the upcoming transistor from static discharges at the input jack side, as well as provide some extra input impedance to the transistor.
- The C1 47nF 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 R2.
- The R2 470K  $\Omega$  resistor is a bias resistor used to bias the base pin of the Q1 transistor. It also forms an RC filter with C1.
- The R3 10K  $\Omega$  resistor is an emitter resistor for the Q1 transistor. Any values between 3.3K and 10K will work here.
- The Q1 transistor 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 defined by the formula:

$$Z_{in} = R_1 + (R_{27} \parallel R_2 \parallel \beta \cdot R_3)$$

Assuming the  $\beta$  of the Q1 transistor is 62 in this circuit.

$$Z_{in} = 1K + (2.2M \parallel 470K \parallel (62 \cdot 10K))$$

$$Z_{in} = 1,000 + (2,200,000 \parallel 470,000 \parallel 620,000)$$

$$Z_{in} = 239,372\Omega$$

Therefore, the Angry Orange input resistance is 239K, which isn't bad, but the closer to 1M it is, the better. Increasing R2 to 2.2M would bring the input resistance up to 660K, although that would also effect the input high pass filter.

#### 4.2 High Pass Filter

The 47nF C1 input capacitor blocks DC and provides simple high pass filtering. C1 and R2 create a high pass filter.

$$f_c = 1 / (2\pi RC)$$

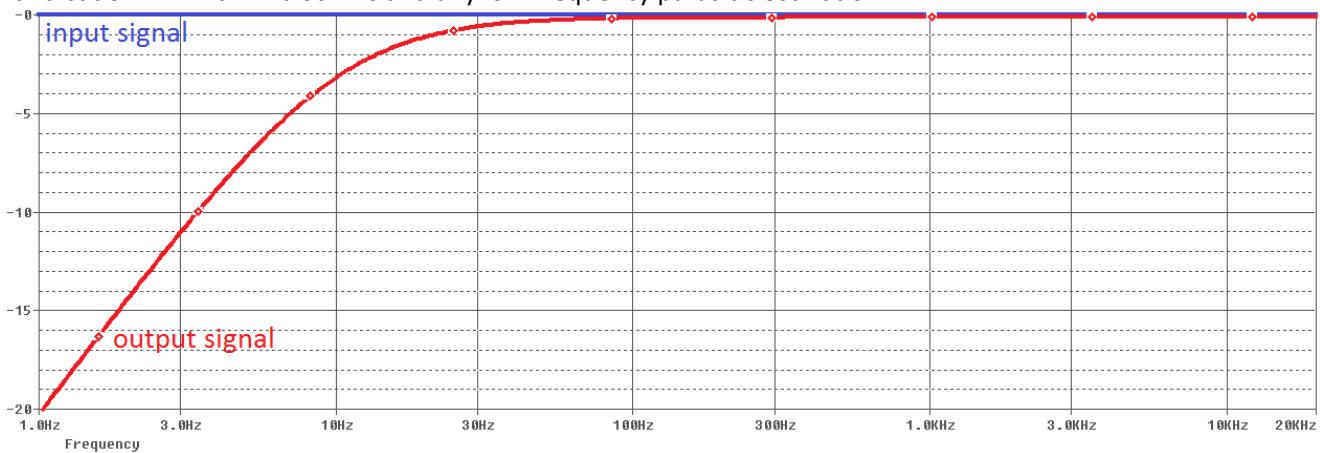
$$f_c = 1 / (2\pi \cdot R_2 \cdot C_1)$$

$$f_c = 1 / (2\pi \cdot 470K \cdot 47nF)$$

$$f_c = 1 / (2\pi \cdot 470,000 \cdot 0.000000047)$$

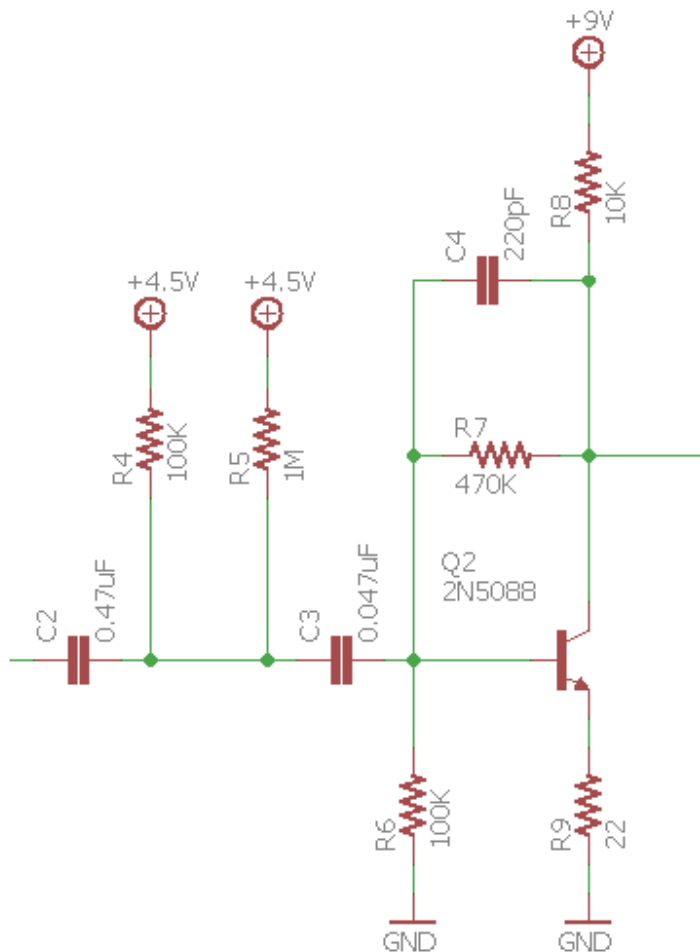
$$f_c = 7.2Hz$$

With a cut of 7.2Hz it will block DC and any low-frequency parasitic oscillation.



## 5. Transistor Booster.

This stage applies some frequency filtering and signal boosting before the op-amp stage. The idea is to raise the signal levels so the next stage can work with acceptable levels although as we can see later, the signal is maybe too boosted after this stage.



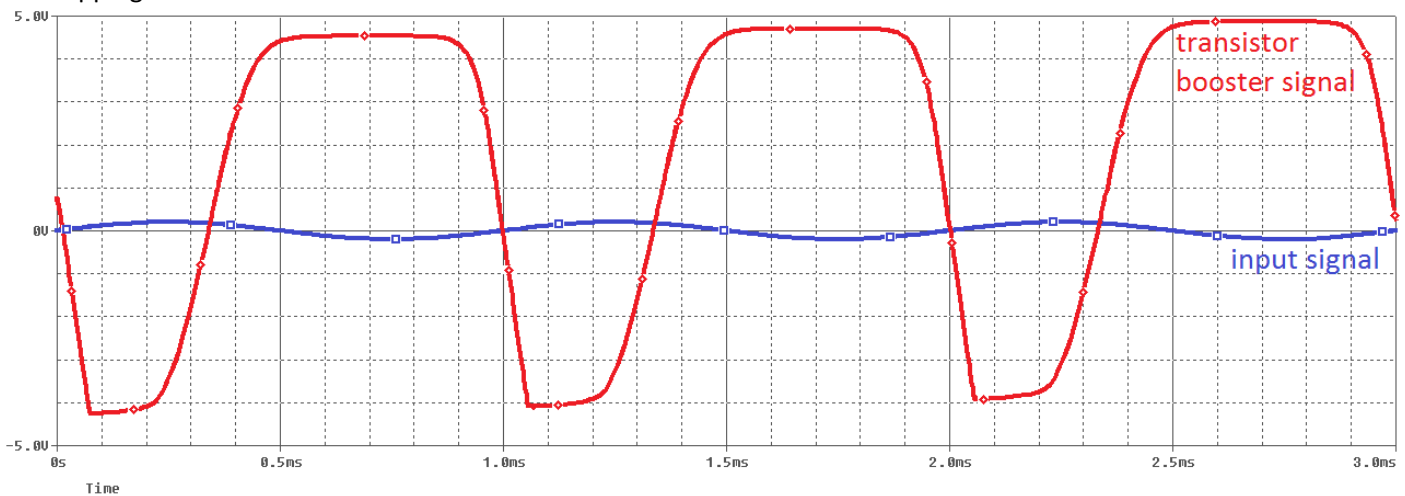
- The C2 470nF film capacitor is a coupling capacitor. It also forms an RC filter with R4 || R5.
- The R4 100K  $\Omega$  and R5 1M  $\Omega$  resistors are in parallel and become a "91K  $\Omega$ " resistor. If you have a 91K  $\Omega$  resistor, you could populate R4 with that and not populate R5. This also forms an RC filter with C2.
- The C3 47nF film capacitor is a coupling capacitor. It also forms an RC filter with R6.
- The R6 100K  $\Omega$  resistor is a bias resistor used to bias the base pin of the Q2 transistor. It also forms an RC filter with C3.
- The R7 470K  $\Omega$  resistor is a shunt-feedback resistor for the Q2 amplifier.
- The R8 10K  $\Omega$  resistor is the collector resistor for the Q2 amplifier.
- The R9 22  $\Omega$  resistor is the emitter resistor for the Q2 amplifier.
- The C4 220pF small ceramic capacitor is a Miller capacitor for the Q2 amplifier, which prevents oscillation and removes some of the high frequency noise.
- The Q1 transistor just needs to be low-noise/high-gain ( $\beta=200-700$ ). Using a 2N5088, or 2N3904 will work well here.

## 5.1 Common Emitter Amplification.

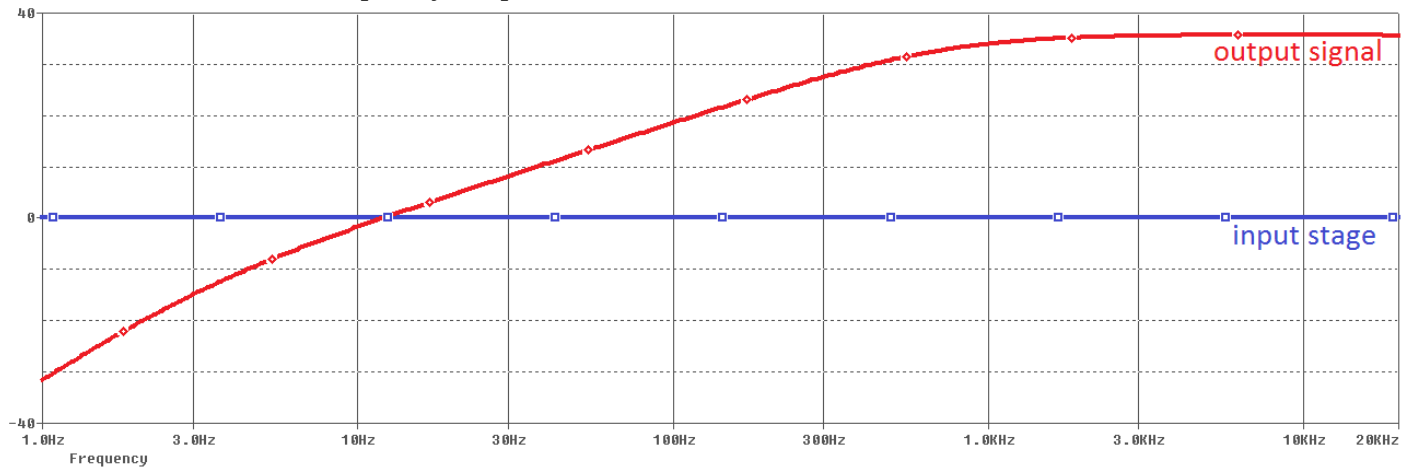
The transistor stage is a Common Emitter amplifier, the approx. voltage gain in this topology is collector resistance divided by the emitter resistance ( $R_C/R_E$  or  $R8/R9 = 10K/22 = 454 = 53dB$ ), but the effect of the feedback resistor and capacitor ( $R7$  and  $C4$ ) will lower this gain to 35dB have to be taken into consideration.

In a nutshell, the original high gain (454) is reduced to a more sensible value of 56 (35dB) with better immunity to noise/temperature and oscillation.

However, a gain of 56 times is a huge amount of it, if we have a guitar input signal of 200mVpp, after the transistor booster the signal level is 11.2Vpp, the waveform will be distorted because the pedal supply is 9V. This gain will create a clipping that looking at the image below is asymmetric (cycles have a slightly different duration) and has a soft knee or soft clipping:



## 5.2 Transistor Booster Frequency Response.



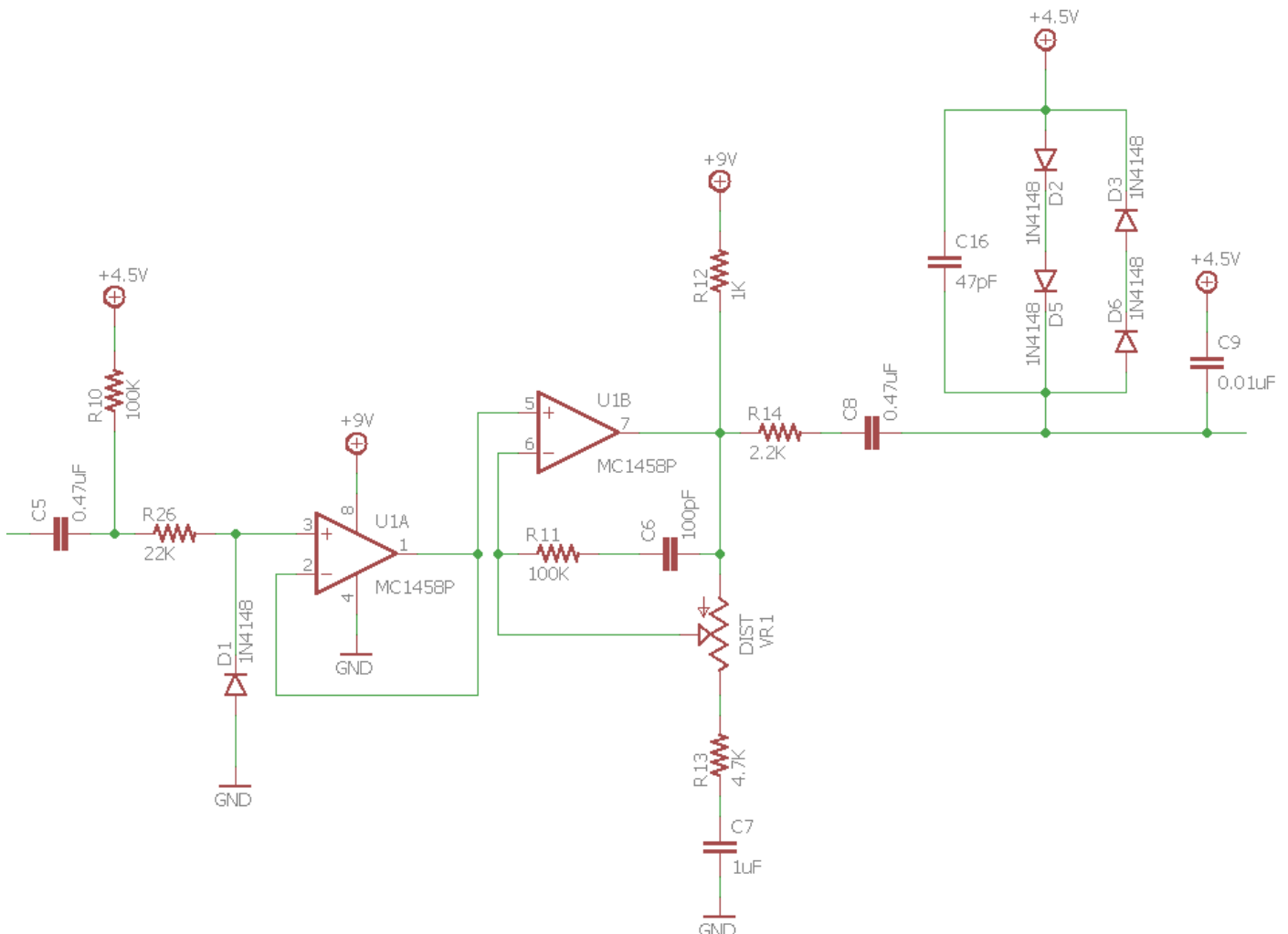
- C2 and R4 || R5 create a high pass filter with a cut frequency of 3.7Hz
- C3 and R6 create a high pass filter with a cut frequency of 33.9Hz

The response of the Transistor Booster stage has an attenuation of the low frequencies because of the 2 high pass filters discussed above, so the frequencies below 33.9Hz are attenuated (6dB/oct) and reaching the bottom of the graph at 3.7Hz the signal has a -12dB/oct roll-off

The signal has a raw gain of 35dB (56 times bigger) on frequencies above 3.7 kHz that makes this stage to boost the guitar signal to the (soft) clipping.

## 6. Op-Amp Gain Stage.

The Operational Amplifier block is the heart of the circuit, it is built using a variable non inverting op-amp amplifier with two diodes to do the clip/distortion action and some passive RC filters ( passband = low pass + high pass) to set the clipping and the frequency at which it occurs.



- The C5 470nF film capacitor is a coupling capacitor. It also forms an RC filter with R10.
- The R10 100K  $\Omega$  resistor is a bias resistor for the upcoming op amps. It also forms an RC filter with C5
- The R26 22K  $\Omega$  resistor is a current limiting resistor designed to protect the op amp from static discharge along with D1.
- The D1 fast switching diode is placed to protect the op-amp input. At the op-amp input, signals will float around 4.5V biased by R10, and in case that signal coming from the previous stage tries to drive the op-amp input below the negative rail, the diode will clip at -0.7V (-VF) not allowing dangerous voltages to be present at the + pin. Q2's collector is biased around +5.8V, and when going into saturation, without D1, U1 pin 3 would be driven to -1.3V. When an op-amp input is driven beyond the rails, bad things happen. Some op-amps are damaged, some will latch-up, but most take time for the input stage to recover from being over-driven, and that screws up the sound. It is important to mention that by the time this diode is conducting, the op-amp is already clipping. Therefore D1 has nothing to do with asymmetrical clipping or any kind of guitar signal modification.
- The R11 100K  $\Omega$  resistor and R13 4.7K  $\Omega$  resistor (along with the distortion 100K potentiometer) set the general gain of the U1B amplifier.

- The C6 100pF small ceramic capacitor creates an RC filter with R11 to remove high frequency noise.
- The C7 1 $\mu$ F film capacitor provides an AC path to ground in the negative feedback loop as well as forming an RC filter with R13.
- The R12 1K  $\Omega$  pull-up resistor is only necessary when using sensitive op amps, like the Mitsubishi M5223AL.
- The R14 2.2K  $\Omega$  forms an RC filter with C8.
- The C8 470nF film capacitor is a coupling capacitor. It also forms an RC filter with R14.
- The D2, D3, D5, and D6 fast switching diodes are the hard clipping diodes.
- The C9 10nF film capacitor and the C16 47pF small ceramic capacitor filter out high frequency harmonics from the clipping diodes.
- The U1 op amp is used as a buffer for itself, and then to become a non-inverting amplifier. The original BOSS DS1 used a Mitsubishi M5223AL. However, as these are out of print, the MC1458 will work as a substitute.

**note:** If you are using a sensitive op-amp, like the Mitsubishi M5223AL, you will need a 1K pull-up resistor from the second op-amp output to +9V. This resistor is labeled as R12 and will force the op-amp to work into class-A reducing distortion. Read the last page of the M5223A datasheet for more information, as an example of how this can prevent harmonic distortion. If used on a non-sensitive op-amp, it will simply smooth out the highs. It can be removed in this case.

The first half of the U1 dual op-amp is a simple buffer, it won't add (or remove) anything to the guitar signal. It buffers and interfaces the previous Transistor Booster stage with the second half of the op-amp that will do all the magic.

#### 4.1 RC Filters

The 47nF C5 input capacitor blocks DC and provides simple high pass filtering. C5 and R10 create a high pass filter.

$$f_c = 1 / (2\pi RC)$$

$$f_c = 1 / (2\pi \cdot R_{10} \cdot C_5)$$

$$f_c = 1 / (2\pi \cdot 100,000 \cdot 0.00000047)$$

$$f_c = 3.4 \text{ Hz}$$

At the beginning of the stage, there is an RC network (C5-R10) that creates a high pass filter with a cut frequency of 3.4Hz. This is not an intentional filter, just a cap is needed to couple the previous transistor gain stage and a moderate-high value resistor is needed to bias the + pin of the op-amp at virtual ground (+4.5V).

At the non-inverting op-amp gain stage, there are two RC filters to note. The first filter is the high-pass filter created by C7 and R13 (and part of the VR1 pot depending on its position) which will remove frequencies below 33.86Hz (or lower depending on the VR1 position)

$$f_{c_{max}} = 1 / (2\pi RC)$$

$$f_{c_{max}} = 1 / (2\pi \cdot R_{13} \cdot C_7)$$

$$f_{c_{max}} = 1 / (2\pi \cdot 4,700 \cdot 0.000001)$$

$$f_{c_{max}} = 33.86 \text{ Hz}$$

$$f_{c_{min}} = 1 / (2\pi RC)$$

$$f_{c_{min}} = 1 / (2\pi \cdot (R_{13} + VR1) \cdot C_7)$$

$$f_{c_{min}} = 1 / (2\pi \cdot 104,700 \cdot 0.000001)$$

$$f_{c_{min}} = 1.52 \text{ Hz}$$

At max distortion, harmonics over 34Hz get the full gain of the distortion stage, and everything below it gets progressively less gain and distortion. Bass notes are less clipped, so the distortion is frequency selective (similar to what happens in the Tube Screamer, but in that case, the frequency limit is 720Hz instead of 34Hz).

The frequency response of the Op-Amp Gain stage is set in the low frequencies by the high-pass filter formed by C7 & R13 (fc=34Hz).

The second filter is the low pass filter formed by C6 and R11. This is used to limit amplification of high frequencies

$$f_c = 1 / (2\pi RC)$$

$$f_c = 1 / (2\pi \cdot R_{11} \cdot C_6)$$

$$f_c = 1 / (2\pi \cdot 100,000 \cdot 0.0000000001)$$

$$f_c = 15.9 \text{ KHz}$$

#### 4.2 Op Amp Gain

The second half of the U1 is a non-inverting amplifier that will boost the signal up to 22.3 times (26.5 dBs) following the formula:

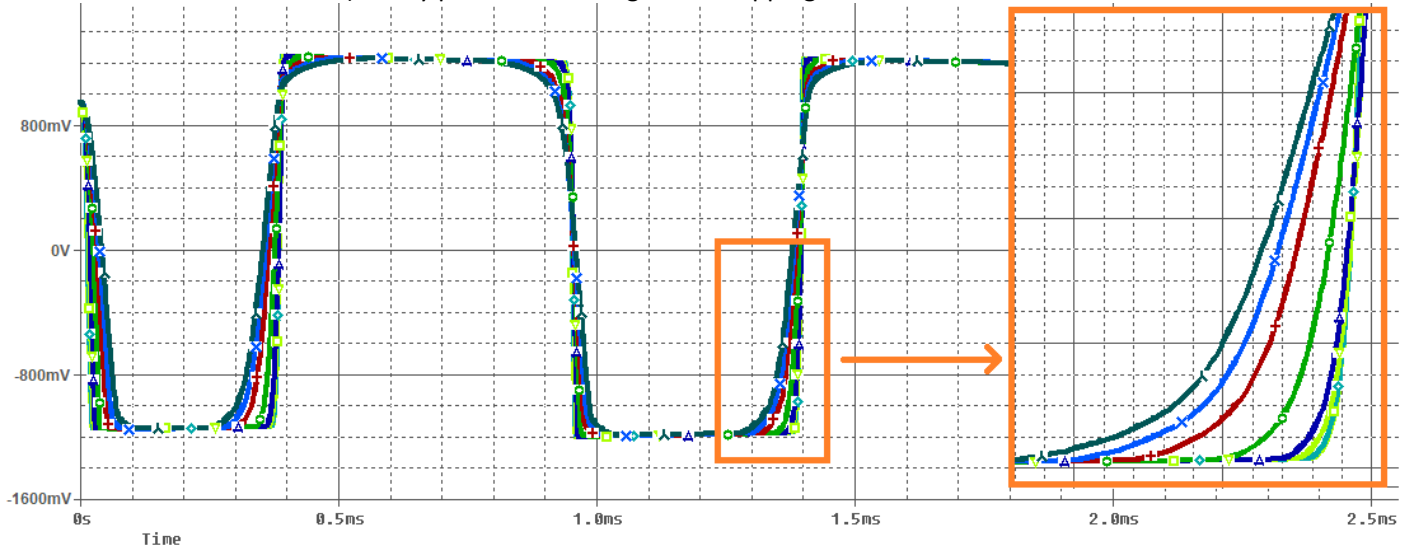
$$G_{V_{op-amp \ max}} = 1 + (VR1) / (R13) = 1 + (100K / 4.7K) = 22.3 \text{ (26.5dB)}$$

$$G_{V_{op-amp \ min}} = 1 + (0\Omega) / (R13) = 1 + (0K / 4.7K) = 1 \text{ (0dB)}$$

### 4.3 Hard Clipping Section

The clipping stage defines the distortion signature sound, it is built using 2 back to back diodes that shunt the signal to AC ground (4.5V), this kind of clipping technique gives a “hard-clipping” sound also used in the MXR Distortion+ or the RAT opposed to the “soft-clipping” style created by placing the diodes on the feedback loop of the op-amp and used in other pedals like the Tube-Screamer.

With the 26.5 dB of gain, the audio signal will be bigger than the VF of the diode 1N4148 that is around 1.4V (or only 0.7V if D5 and D6 are shunted) in any position, creating a hard clipping action:



The image above shows the waveform after the clipping diodes, it exhibits a clear squared shape limited between +1.4V and -1.4V which is the VF of the diodes. Playing with the distortion potentiometer the edge of the waveform can be softened by in any case the overall look is pretty squared and distorted.

Capacitor C6 (100pF) reduces the high harsh harmonics at the very top of the audio spectrum. It controls it by allowing highs through the feedback loop.

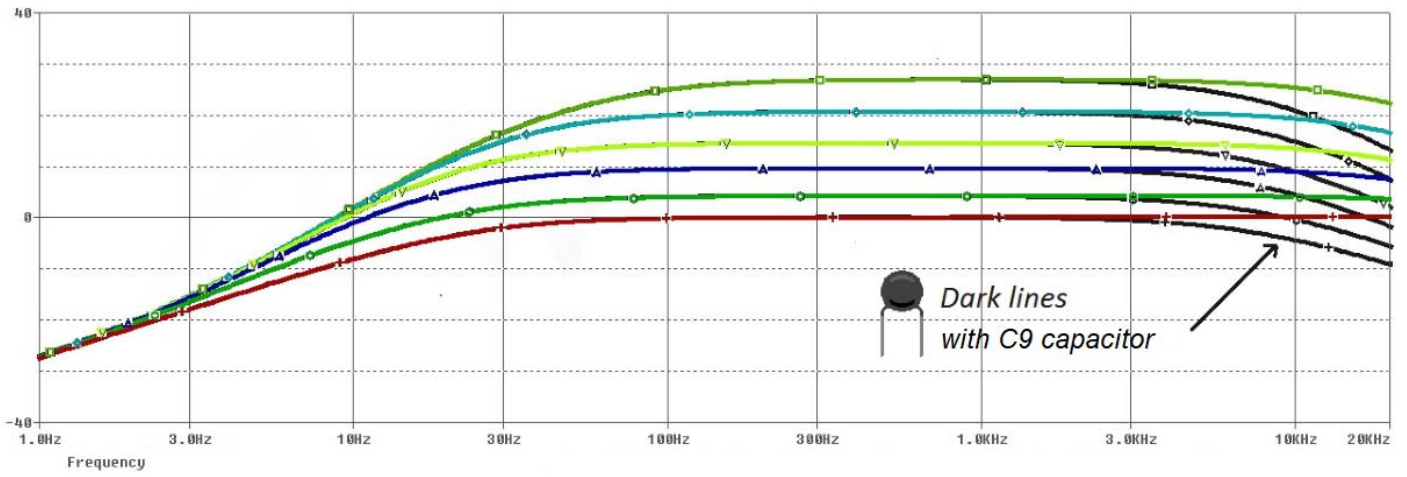
On the high frequencies by the low-pass filter formed by R14 and C9 will attenuate harmonics over 7.35 kHz, this is better explained in the section below. The cap C6 will also reduce harmonics at very high frequencies, softening a bit the distortion and reducing oscillation problems.

The minimum gain is 0dB and can go up to 26.5dB depending on the position of the distortion potentiometer, this amount of gain is not massive (the Tube Screamer has 41dB, the Proco Rat has 67dB) but the fact that the previous stage has a gain of 35dB makes that the resulting signal is completely clipped.

With C8 and C9 in series with each other, the capacitance of the two is 9.79nF, which is then added to C16 47pF capacitor totaling 9.837nF. This forms an RC network with R14, which is in parallel with D2 and D3 (and D5 and D6 in series with them) clipping devices. The D2 & D3 diodes load the R14 - C10 network and drastically alter the cutoff freq. When either D2 or D3 are conducting, the impedance at R14 – C9 junction is greatly reduced. This is a non-linear circuit, the best way to analyze the behavior is in the time-domain.

The image below is only applicable to the case where the signal is so small (below clipping) that the diodes don't conduct, where the resistor R14 and C9 form a low pass filter with  $f_c=7.35\text{kHz}$  that will mellow the signal, but most of the time D2 or D3 are conducting.

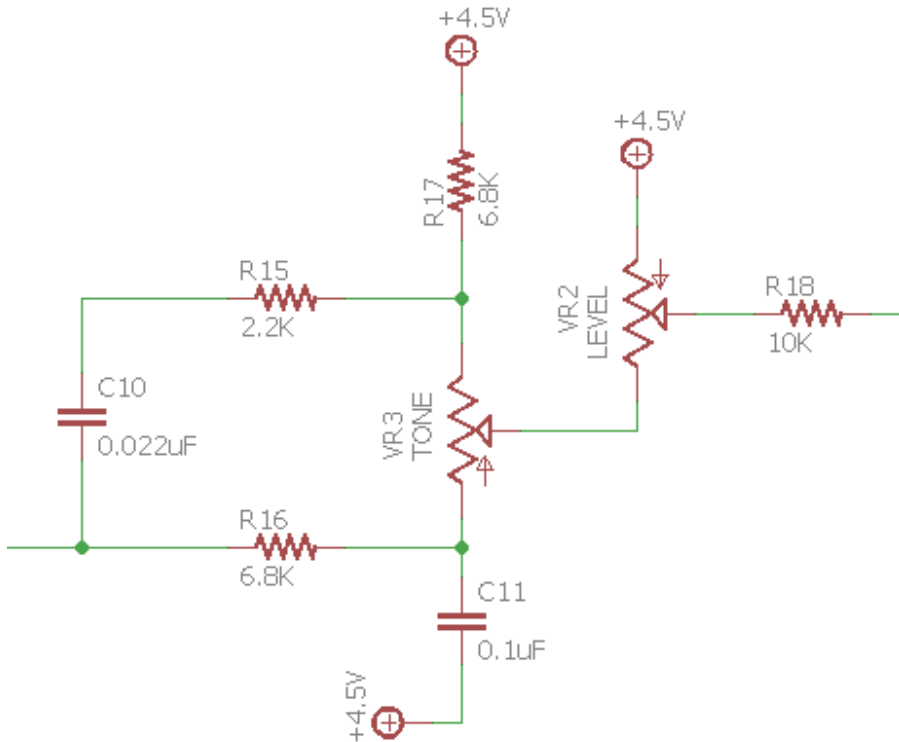




Generally speaking, the C9 cap makes the distortion less grainy, making a rounder-pleasant distortion.

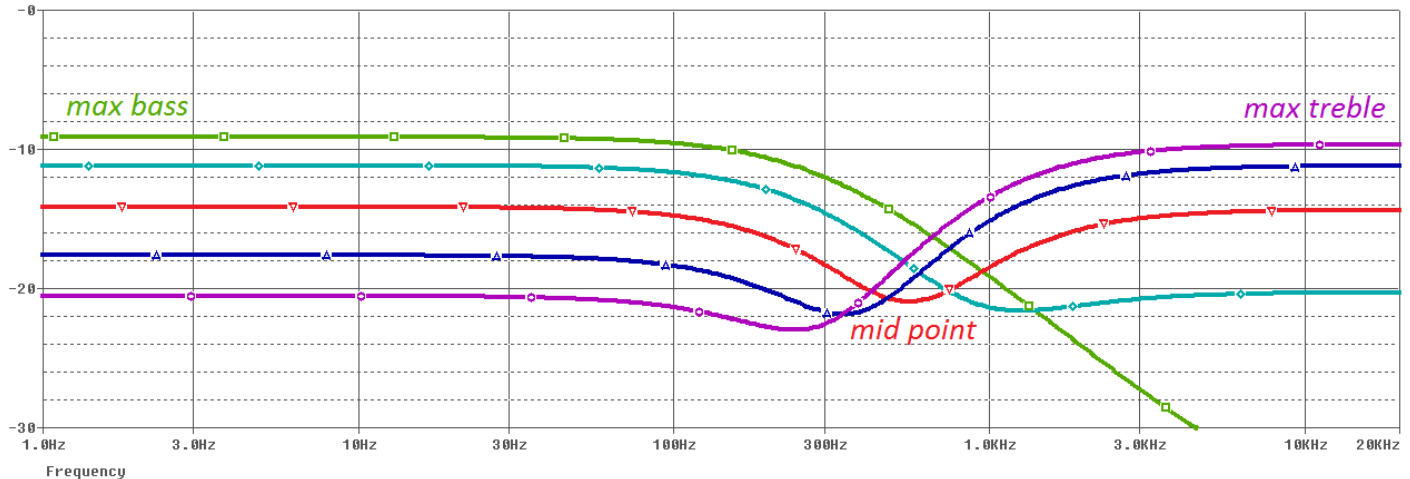
## 7. Tone Level Stage.

The Angry Orange uses a passive *Big Muff Pi* style tone control, which scoops the mids and attenuates the lows or highs, depending on which way you turn the knob. The circuit consists of a simple fixed -6dB/oct low pass filter (formed by R16 and C11 with an  $f_c=234\text{Hz}$ ) and a fixed -6dB/oct high pass filter (formed by C10 and R17 with an  $f_c=1063\text{Hz}$ ) using the VR3 pot to mix the two signals. The cut-off points of both filters are calculated so that their interweaving effect create a frequency scoop/notch around 500Hz when the tone control is set to the middle position.



After the initial tone shaping carried out by the first part of the circuit and the VR3, the VR2 pot regulates the level by bleeding part of the signal to AC ground.

## 7.1 Tone and Level Frequency Response.



The frequency response of the Tone control looks similar to the Big Muff Pi, the Angry Orange has a scoop around 500Hz. This equalization enhance the bass and treble of the signal and is used in hard rock, other pedals like the Tube Screamer have a completely different approach boosting the mids creating a mid-hump.

There is an overall -12dB (4 times) loss and at the notch the loss is about -20db (450Hz - 500Hz) but there is no problem with this because in the previous stage after the diode clipping the signal has a 1.4Vpp amplitude, with -12dB loss the resulting signal will be 350mVpp (1.4Vpp/4times) which is fine for an output level and won't distort the input stage of the next pedal on the chain or the guitar amplifier.

This works by taking two filters, a high-pass filter (allows highs to pass through, but cuts out lows) and a low-pass filter (allows lows to pass through, but cuts out highs) and allows the user to balance between the two filters via a potentiometer.

$$f_c = 1 / (2\pi RC)$$

$$\text{Low } f_c = 1 / (2\pi \cdot R_{16} \cdot C_{11})$$

$$\text{Low } f_c = 1 / (2\pi \cdot 6,800 \cdot 0.0000001)$$

$$\text{Low } f_c = 234\text{Hz}$$

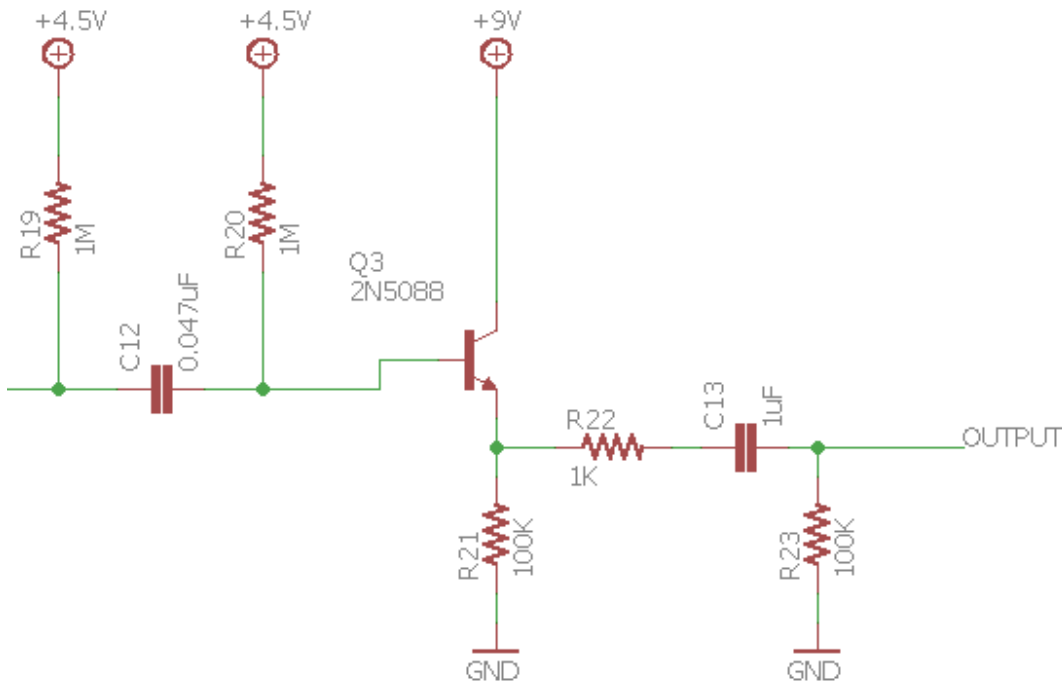
$$\text{High } f_c = 1 / (2\pi \cdot (R_{15} + R_{17}) \cdot C_{10})$$

$$\text{High } f_c = 1 / (2\pi \cdot 11,000 \cdot 0.000000022)$$

$$\text{High } f_c = 658\text{Hz}$$

## 8. Output Buffer.

The output buffer has exactly the same circuit as the input buffer, its task is to keep a low output impedance for better signal integrity in the guitar-pedals-amp chain. Like the Input Stage, this buffer is implemented with a plain Emitter Follower with a 100K emitter resistor R21, biased from the 4.5V source with R19 in parallel with R20 (1M || 1M=500K).

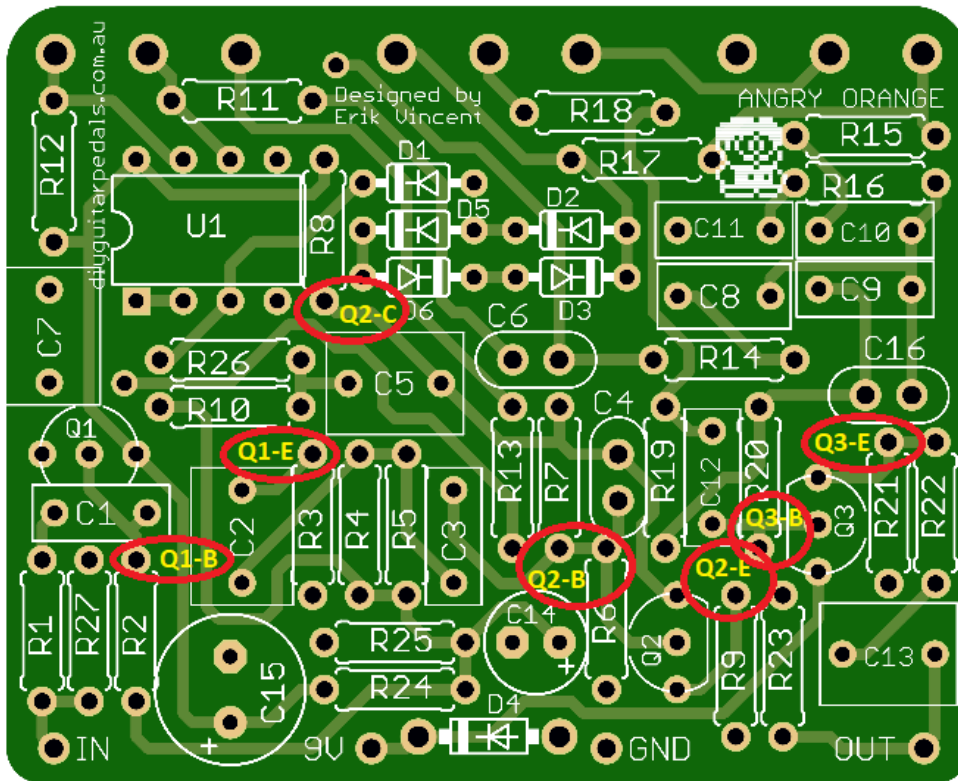


- The input capacitor C12 and R20 create a high pass filter with  $f_c=3.4\text{Hz}$  ( $f_c=1 / (2\pi RC)$ ), the idea is just to remove the DC levels so the transistor can be correctly biased.
- The 2N5088 is a cheap high-gain transistor, a simple gain buffer does not have high requirements for the transistor.
- R21 is the emitter resistance, 10K is a standard value for an Emitter Follower buffer to keep unity gain. However, due to the tone sucking that can occur from the previous stage, increasing the value to 100K amplifies the circuit a bit more.
- C13 and R23 form a high pass filter with an  $f_c=1.6\text{Hz}$  below the audio spectrum. The purpose of this filter is just to remove the DC levels from the final output signal.
- The output impedance by this circuit comes out to around 1.7K, which is an excellent amount.

## 9. Voltage Readouts.

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

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

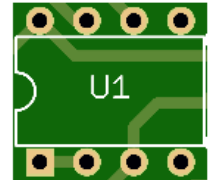


Q1-C: 9.000V  
 Q1-B: 3.992V  
 Q1-E: 3.556V

Q2-C: 3.965V  
 Q2-B: 0.612V  
 Q2-E: 0.013V

Q3-C: 9.000V  
 Q3-B: 4.068V  
 Q3-E: 3.893V

9.000V  
 4.509V  
 4.508V  
 4.508V



4.508V  
 4.508V  
 4.457V  
 0.000V

## KNOBS

- VOL: MAX
- TONE: MAX
- DIST: MAX

## 10. Modifications

Following is a couple of worthwhile modifications that can be applied to the Angry Orange.

### 10.1 Transistors

Currently this pedal uses three 2N5088 NPN Transistors, which have a rather high gain to them. Though 2 of them are merely input and output buffers, Q2 in the booster section, can have a more drastic effect on the sound. Changing out to different transistors with higher or lower gain, may be desired. For lower gain, a 2N3904 would be an alternative, whereas a 2N5089 would give it a bit higher gain. For a wide swinging transistor, a SS9014 would also be an alternative.

### 10.2 Capacitors and Resistors

C2 with R4 and R5 create a high pass filter along with C3 with R6 (cutting frequency of 34Hz). This is designed to remove excess bass to prevent the distortion stage from outputting a muddy sound. Changing these values allows frequencies desired or not desired from being amplified

C4 with R7 are creating a classic Big Muff Pi Input Booster Stage, which stabilize the gain and reduces oscillation. The math for this rather complicated to explain, but if one were to look up Big Muff Pi Input Booster Calculation, it should be more easily explained in depth there.

R9 effects how hard the transistor Q2 overdrives the signal, so raising it from 22 ohms up to 1K and create a more “vintage” or “fat” tone. This is because at 1K, the transistor boost will no longer easily clip at the op-amp stage anymore.

C6, in the Op-Amp gain stage, reduces the high harsh harmonics at the very top of the audio spectrum. It controls it by allowing highs through the feedback loop. Lowering this value cuts out more of the highs by letting them through the feedback loop. Keep to values in the 100’s of pF

C7 and R13 create a high-pass filter along with VR1 (distortion) will remove frequencies below a calculated area and lower via the VR1 potentiometer.

Frequency cut max =  $1 / (2 \times \pi \times C7 \times R13)$

Frequency cut min =  $1 / (2 \times \pi \times C7 \times (R13 + VR1))$

At max distortion, harmonics over “frequency cut max” Hz get the full gain of the distortion stage, and everything below it gets progressively less gain and distortion. Bass notes are less clipped, so the distortion is frequency selective.

C9 and R14 create a low-pass filter which stabilizes the distortion sound after the clipping diodes. Usually, people change the value of R14 and lower it from the stock value to add to the stabilization, making the distortion less harsh. Typically the values for R14 are between 1K and 3K.

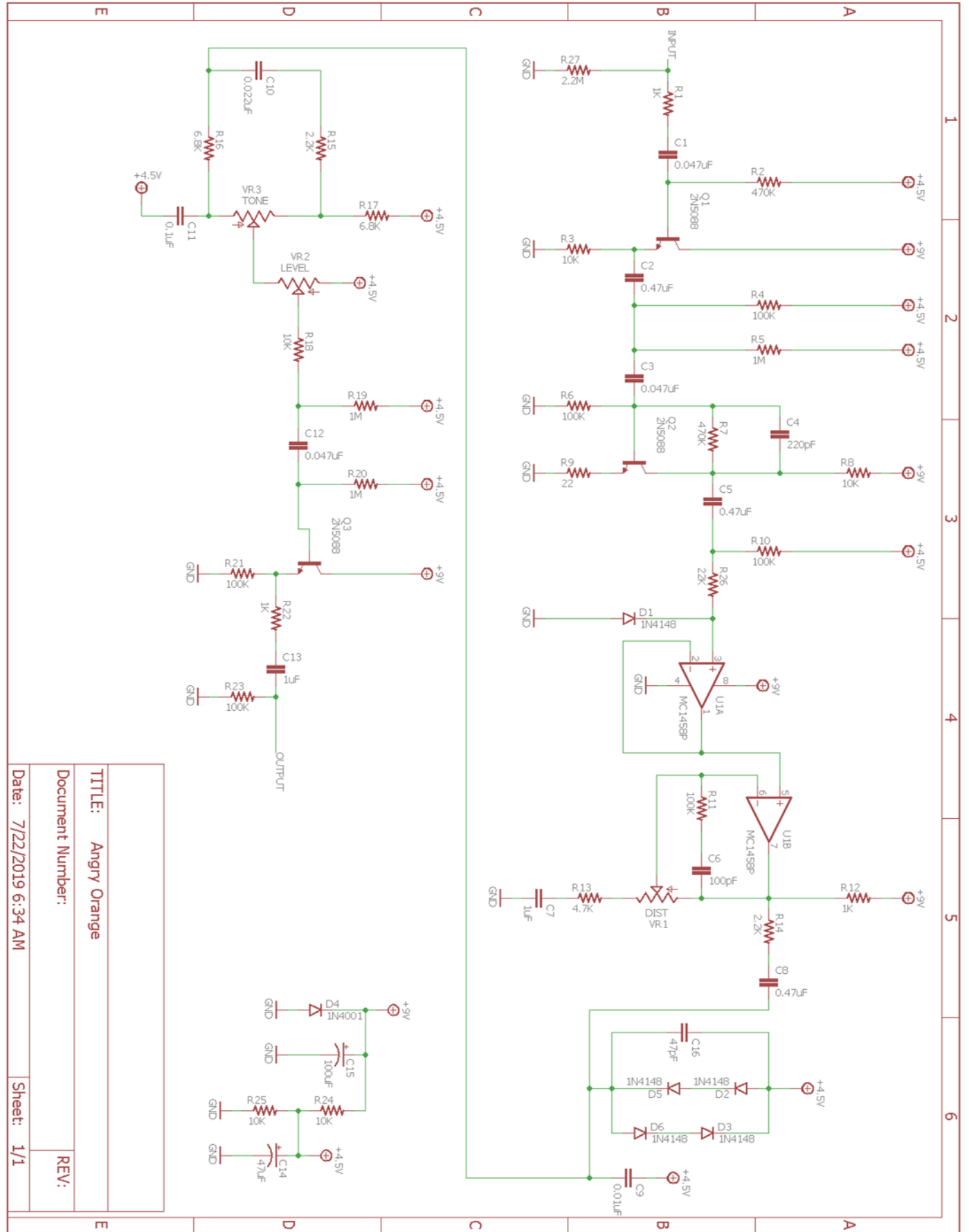
C12 and R16 create a low-pass filter while C10 and R17 create a high-pass filter, which in turn a mixed with the tone knob which mixes the two signals. This essentially scoops/notches the mids, which in a stock build is around 500Hz.

### 10.3 Diodes

D1 is meant to protect the Op-Amp and does not add or subtract from the sound.

D2 and D3 are the original hard clipping diode positions, which when populated with typical 1N4148 diodes (and D5 and D6 are shunted), they will clip the amplified signal when it goes over or below the forward voltage of the diode, which in the case of a typical 1N4148 is 0.7V. Adding inline diodes (populating D5 and D6) will change the clipping a bit, as well as changing out D2 and D3 with different style of diodes due to the effects of a changed forward voltage. The layout also allows for asymmetrical clipping where D2, D3, and D5 are populated, but D6 is not as seen in the Keeley “Ultra” mod. This is a unique sound that is desired by some.

# 10. Schematic



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