Swedish Chainsaw

Design By Erik Vincent

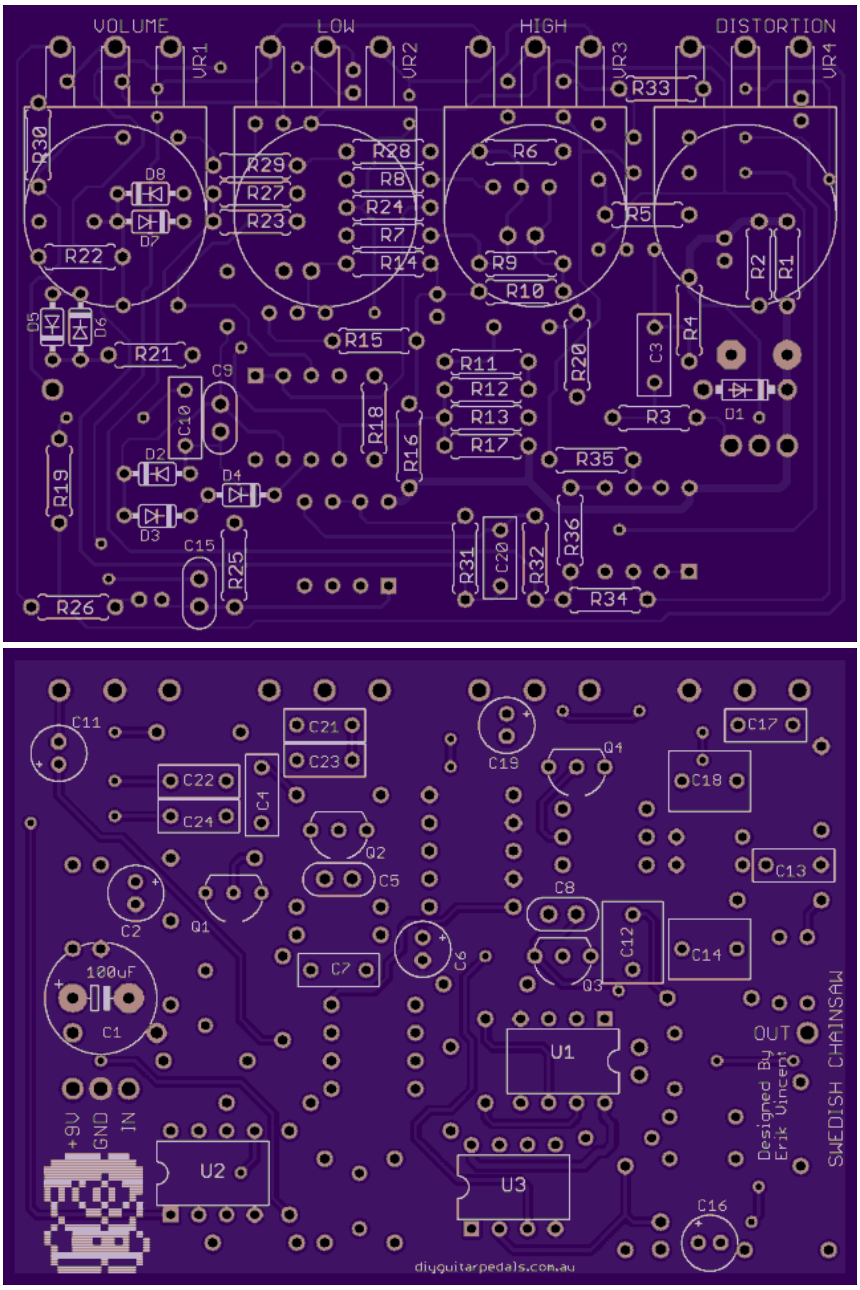
90's death metal tone in a box. A faithful HM2 inspired distortion, the Swedish chainsaw is a straight up remake of this classic, coveted effect. Check out the sound demo for an example of just how good this nasty distortion can sound with a common place IC like the TL072. Although there are many components for this project, assembly is not overly complicated and is basically just a matter of soldering. Lots of soldering. But let's be honest, we pedal builders love the sweet smell of solder right??

The Rev A layout is compact enough to fit in a 1590bb, however Rev B will fit in a 125B enclosure

Bill of Materials, Stock Swedish Chainsaw

Capacitor		**Resistor**	
C1	100µF (Electrolytic)	**R1**	10K
C2	47µF (Electrolytic)	**R2**	10K
C3	47nF (film)	**R3**	10K
C4	47nF (film)	**R4**	1M
C5	100pF (ceramic)	**R5**	10K
C6	47µF (Electrolytic)	**R6**	22K
C7	47nF (film)	**R7**	100K
C8	100pF (ceramic)	**R8**	22
C9	100pF (ceramic)	**R9**	470K
C10	47nF (film)	**R10**	10K
C11	10µF (Electrolytic)	**R11**	22K
C12	1µF (film)	**R12**	470K
C13	1nF (film)	**R13**	10K
C14	1µF (film)	**R14**	100K
C15	470pF (ceramic)	**R15**	120
C16	10µF (Electrolytic)	**R16**	1K
C17	47nF (film)	**R17**	68K
C18	1µF (film)	**R18**	220K
C19	1.5µF (Electrolytic)	**R19**	47K
C20	68nF (film)	**R20**	150
C21	150nF (film)	**R21**	10K
C22	6.8nF (film)	**R22**	10K
C23	100nF (film)	**R23**	68K
C24	4.7nF (film)	**R24**	3.3K
		R25	3.3K
Diode		**R26**	10K
D1	1N4001	**R27**	470K
D2	1N4148	**R28**	10K
D3	1N4148	**R29**	1K
D4	1N4148	**R30**	100K
D5	1N34A	**R31**	330
D6	1N34A	**R32**	100K
D7	1N4148	**R33**	330
D8	1N4148	**R34**	82K
		R35	330
Transistor/JFET		**R36**	100K
Q1	2N5457	**R37**	2.2M
Q2	2N3904		
Q3	2N3906	**Potentiometer**	
Q4	2N3904	**Volume**	10kb (16mm)
		Low EQ	10kb (16mm)
ICs		**High EQ**	10kb (16mm)
U1	M5218A or JRC4558 or TL072	**Distortion**	250kb (16mm)
U2	M5218A or JRC4558 or TL072		
U3	M5218A or JRC4558 or TL072		

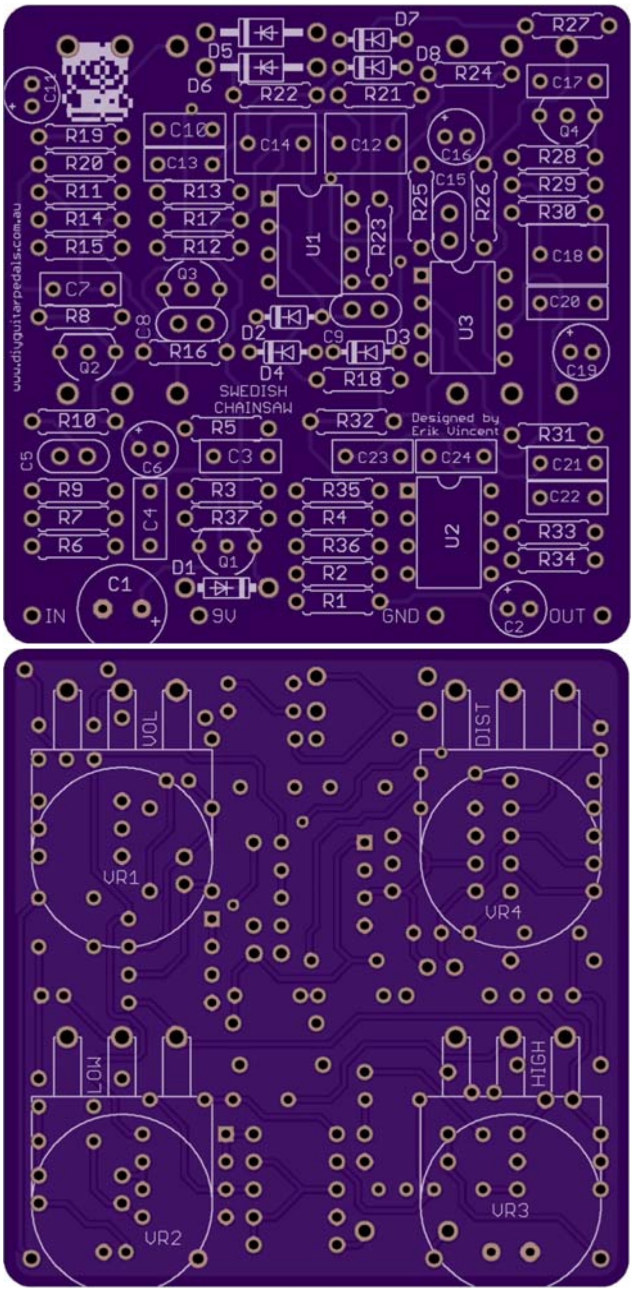
REV A



PCB Spacing
The Swedish Chainsaw PCB is spaced for 1590BB sized enclosures

Pot Spacing
The Swedish Chainsaw PCB mounted potentiometers are spaced for Alpha 16mm potentiometers.

REV B



PCB Spacing
The Swedish Chainsaw PCB is spaced for 125B sized enclosures

Pot Spacing
The Swedish Chainsaw PCB mounted potentiometers are spaced for Alpha 16mm potentiometers.

Assembly.

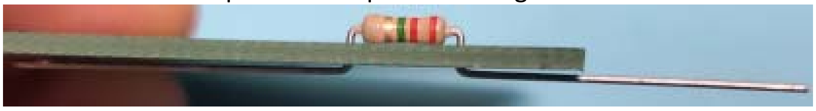
1. Soldering Order.

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

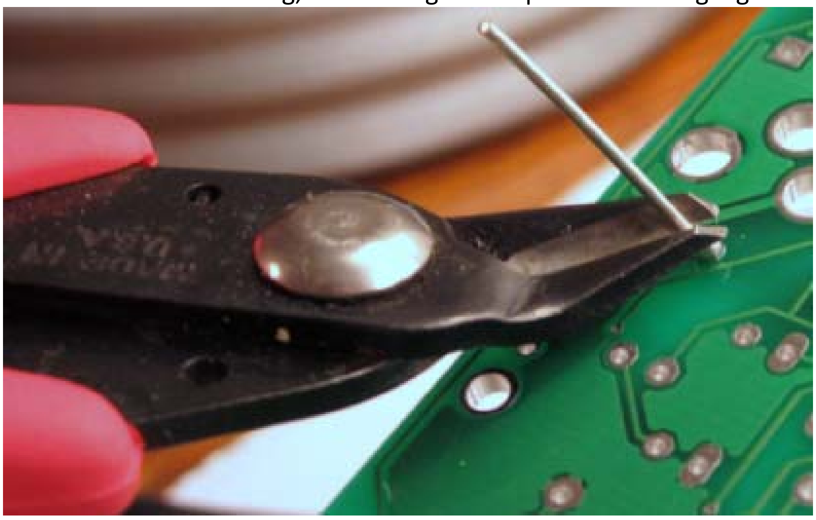
For the Swedish Chainsaw, the best order would be: resistors, diodes, ceramic capacitors, IC sockets (if socketing), transistor/FETs, ICs (if not socketing), film capacitors, electrolytic capacitors, wiring, and then potentiometers.

1.1 Resistors.

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

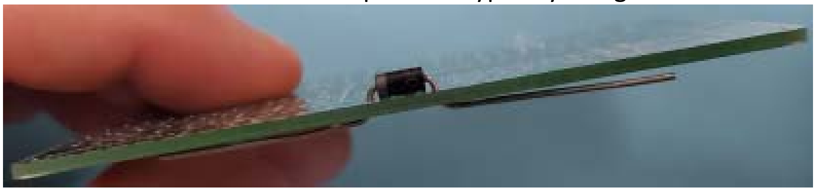


For this pedal we will be using 1/4 Watt resistors. These can either be 5% tolerance carbon resistors, or 1% tolerance metal film resistors. Orientation of “which way is up” doesn’t matter, so you can install them either way. After installation and soldering, do not forget to clip the remaining legs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

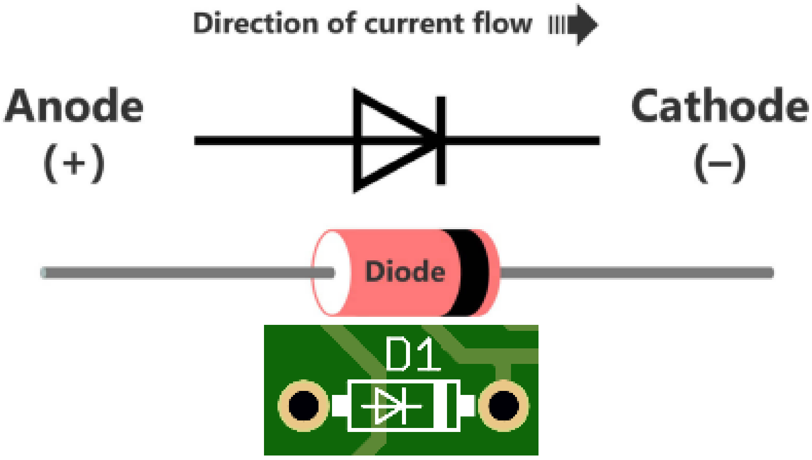


1.2 Diodes.

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

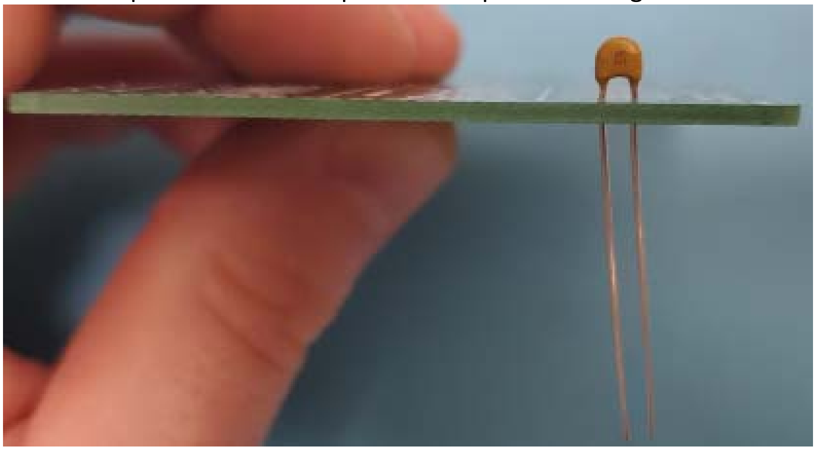


The orientation of a diode does matter based on the cathode and anode of the diode in the circuit. Make sure the stripe on the diode lines up with the stripe on the PCB's silkscreen. After installation and soldering, do not forget to clip the remaining legs from the PCB.



1.3 Capacitors (ceramic).

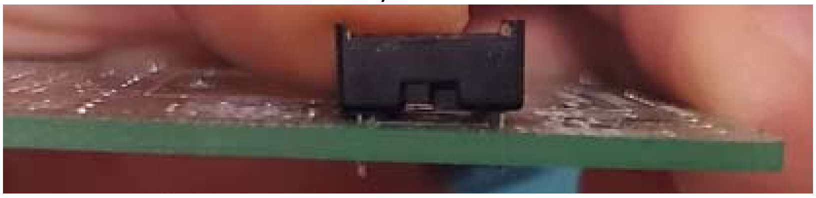
Ceramic capacitors are small passive components designed to hold a small amount of charge in a circuit.



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.

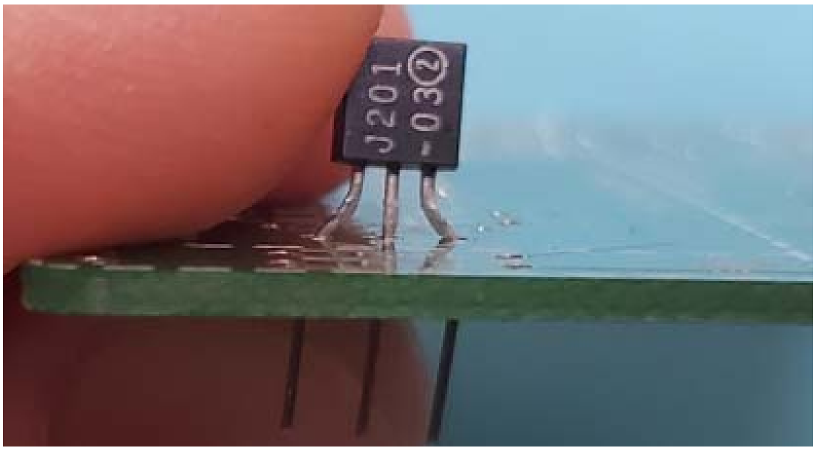
These are holders that allow easy installation and uninstallation of ICs.



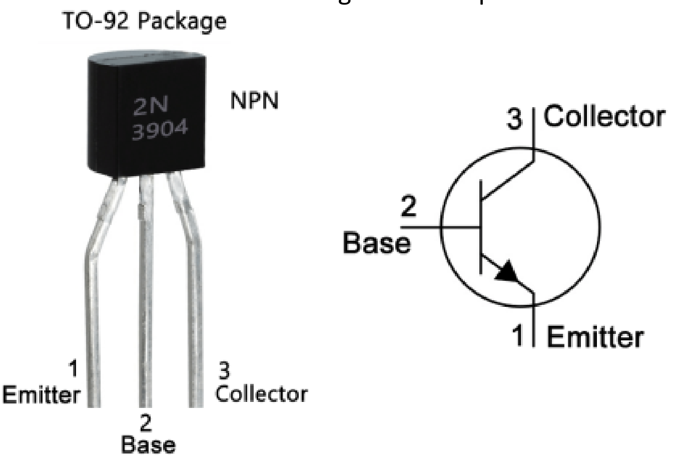
These devices will have a silk screen notch to indicate an orientation with the IC or socket for the IC. Just make sure the IC notches match.

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



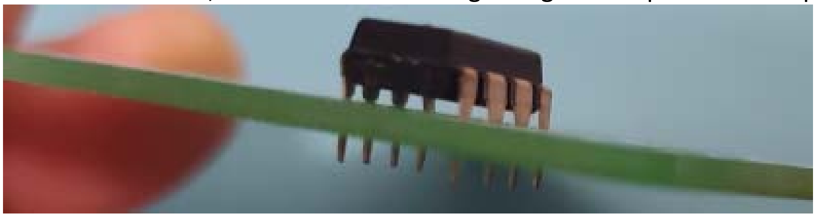
These devices typically only install one way, but pinouts can differ from different part numbers, so if using a different part number transistor than the one called out in the bill of materials will require that you check the datasheet of the transistor and check which legs are what pins for it to function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



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

1.6 Integrated Circuits.

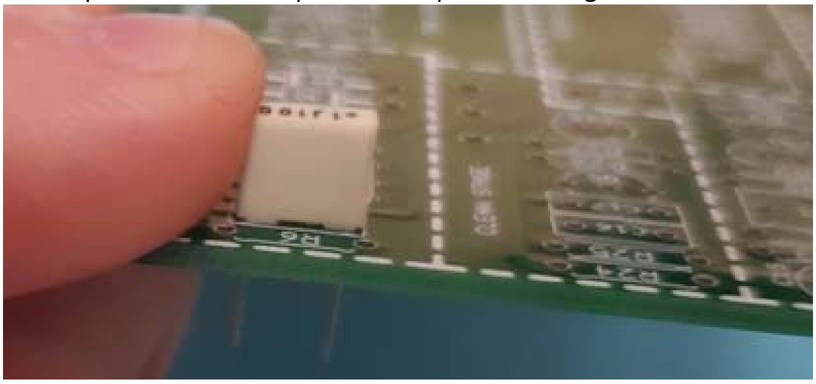
Also known as ICs, these are small analog or digital components that provide specific electrical functions.



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).

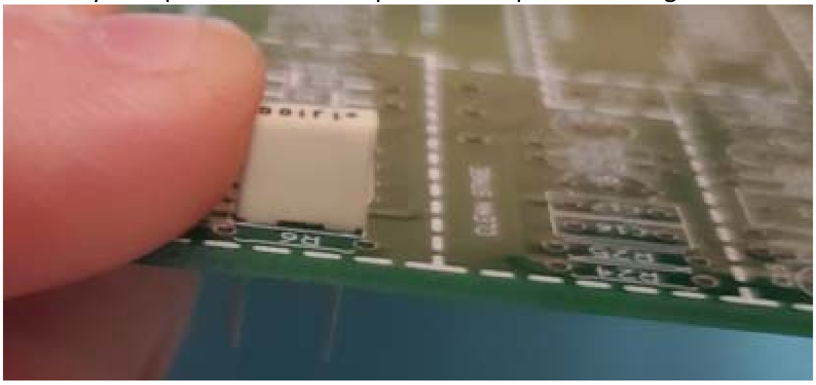
Film capacitors are small passive components designed to hold a small amount of charge in a circuit.



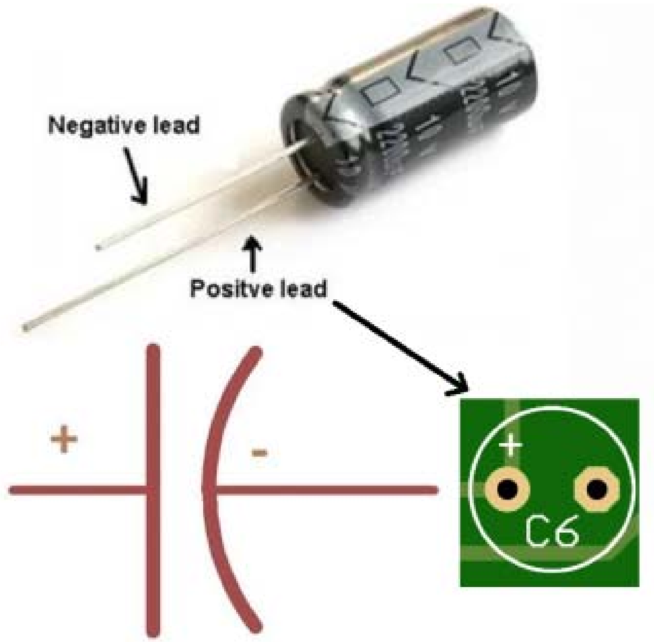
Orientation of “which way is up” doesn’t matter, so you can install them either way. After installation and soldering, do not forget to clip the remaining legs from the PCB.

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.

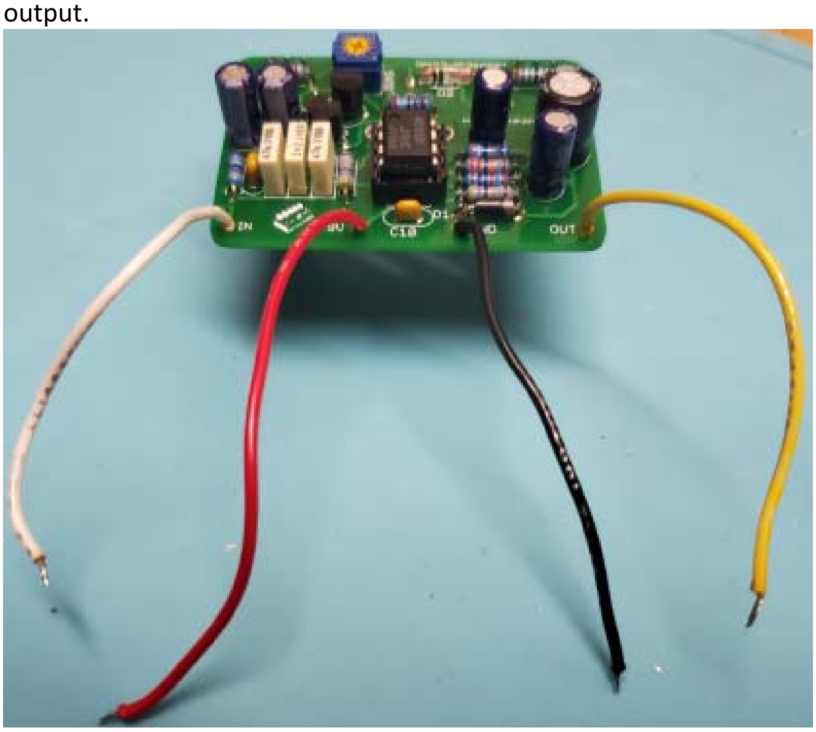


Polarized Electrolytic Capacitor and its electric Symbol

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

1.9 Wiring.

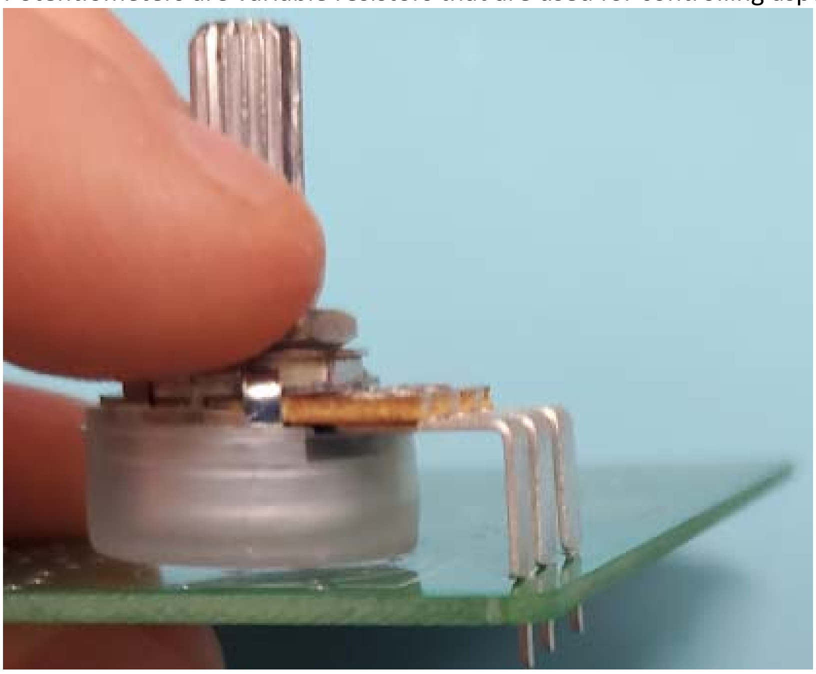
Wires used for the pedal are for delivering power over the hot and ground wires as well as signal for the input and output.



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.

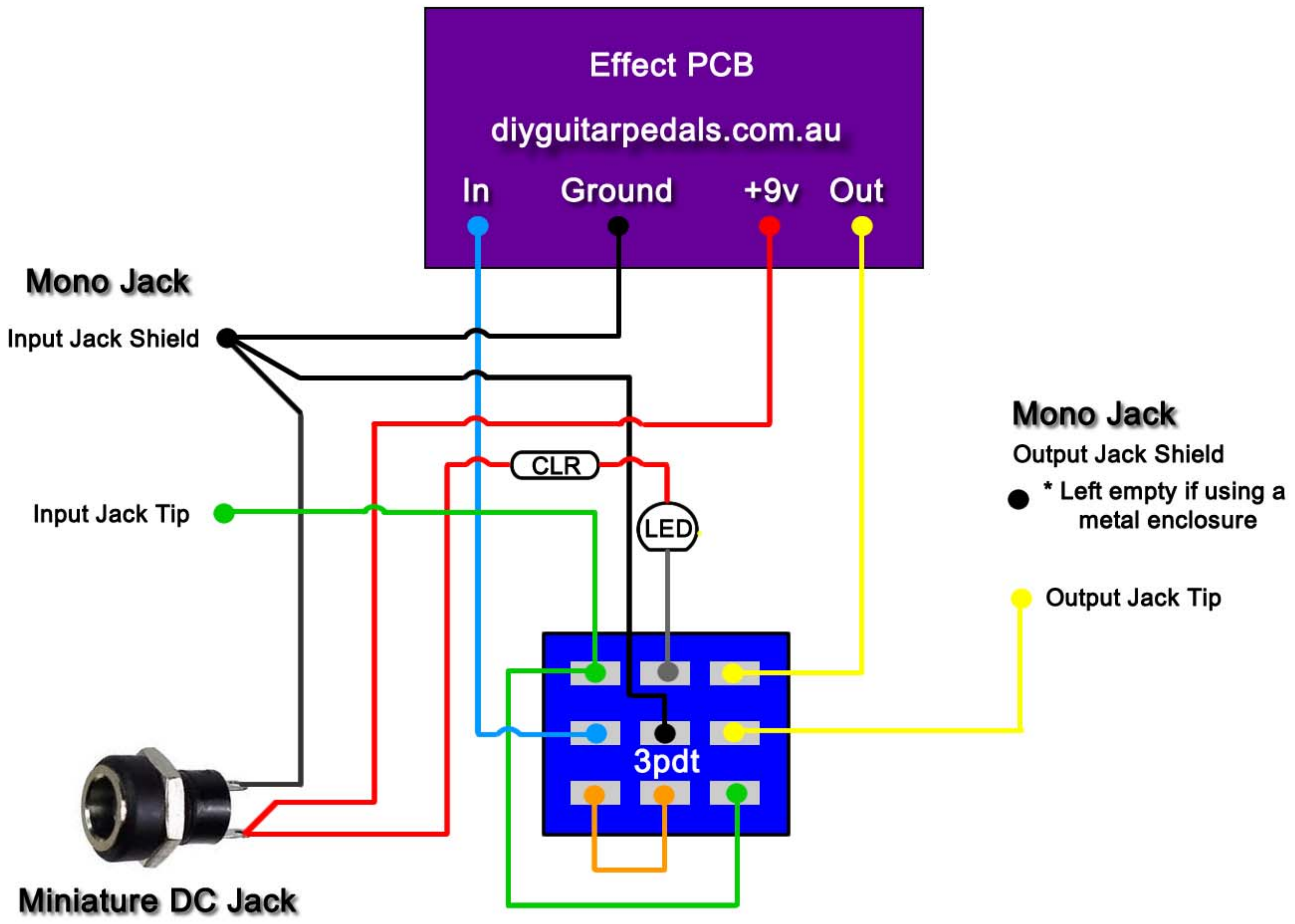
Potentiometers are variable resistors that are used for controlling aspects of the pedal.



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.

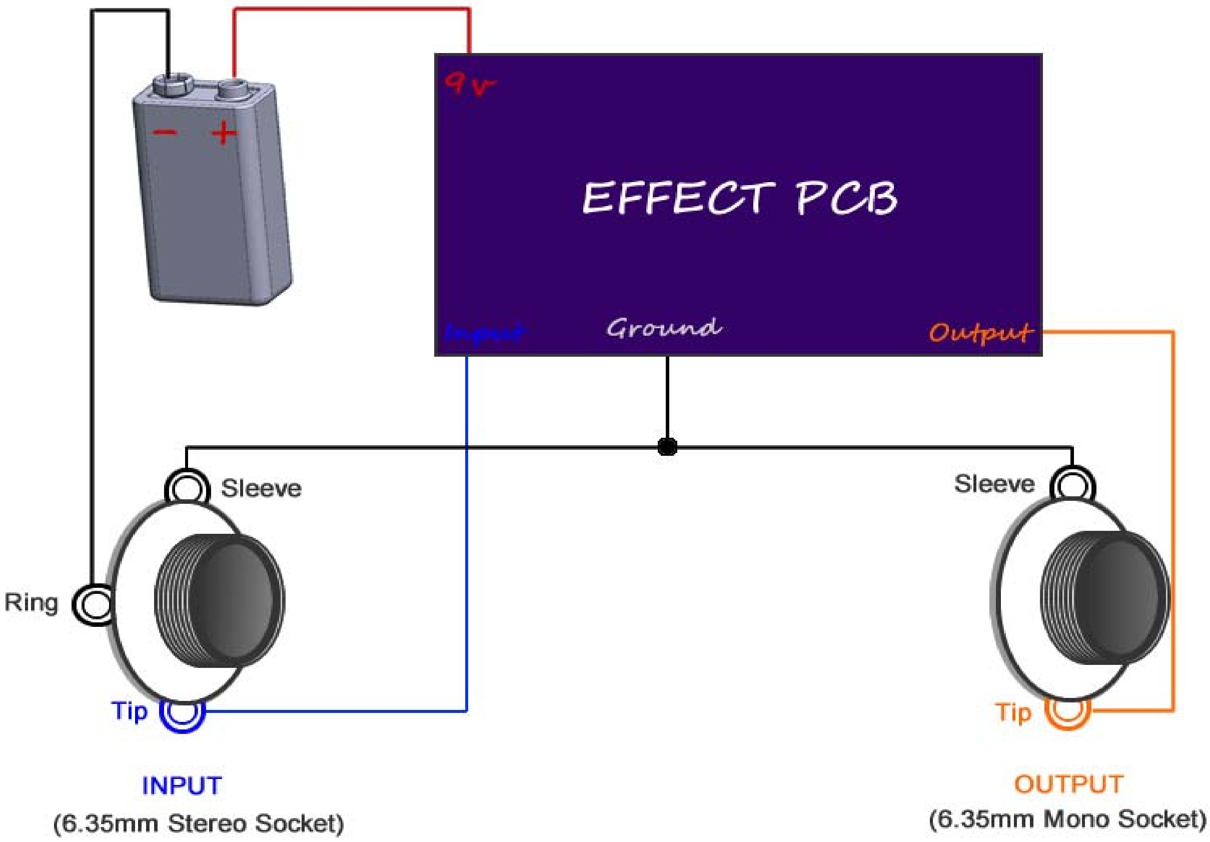
1.11 Off Board Wiring Diagram.

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



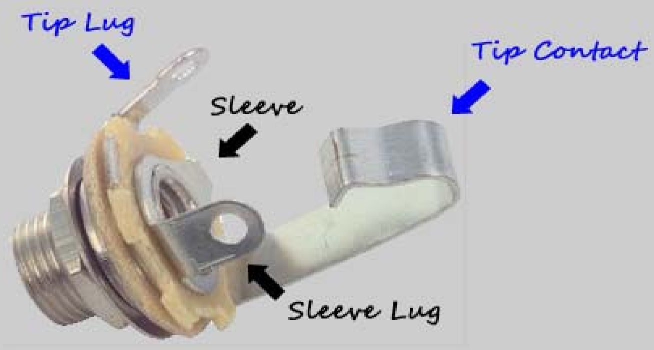
Testing Your Effect

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



Input and Output Sockets

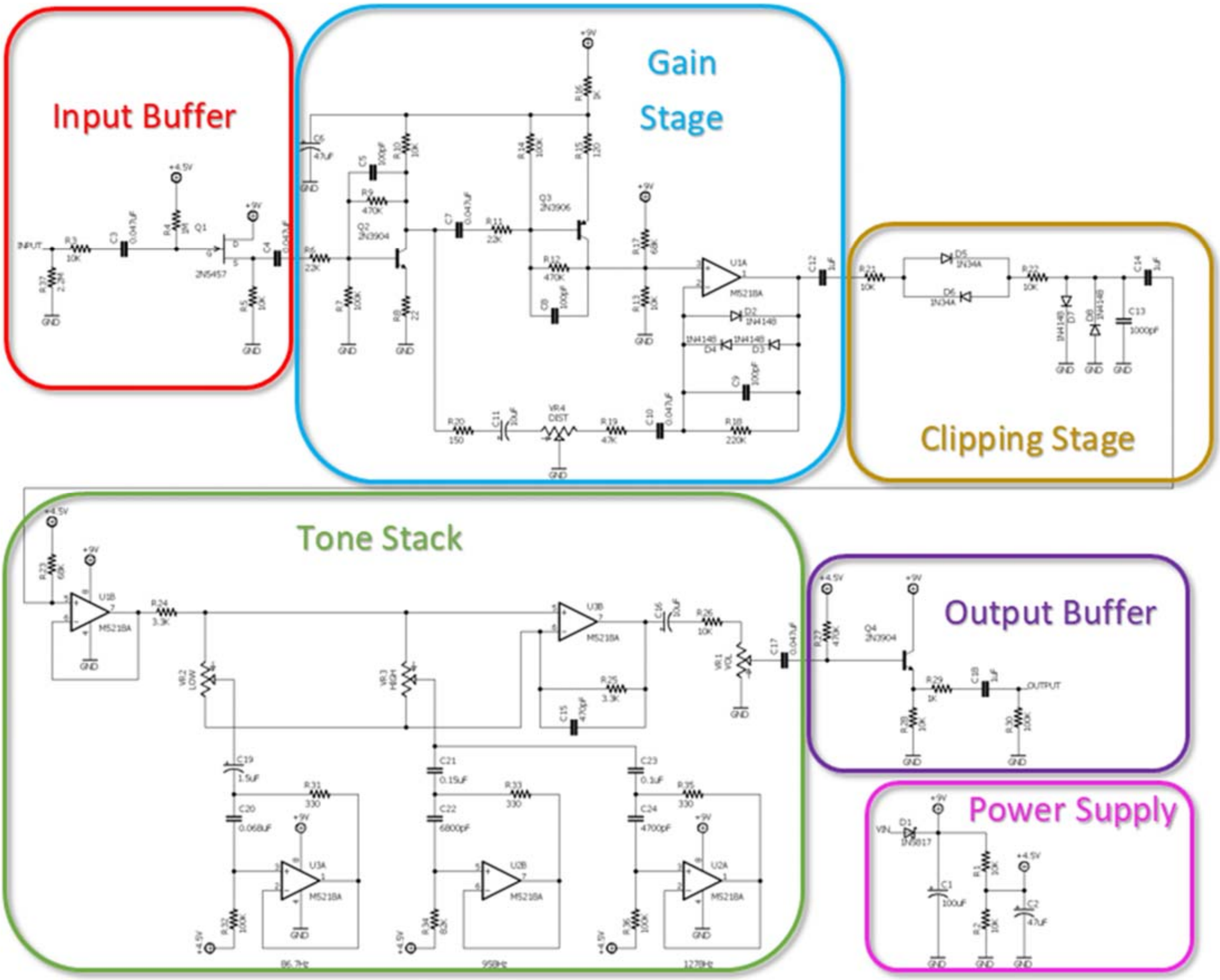
Pay close attention to the lugs of your sockets. Look at them side on so that you can distinguish the sockets individual layers. For instance the tip lug is connected to tip contact. The stereo jack looks the same as the socket below except it has an extra lug and contact for "Ring".



Swedish Chainsaw Circuit Analysis for modifying purposes.

2. Swedish Chainsaw Circuit.

The Swedish Chainsaw schematic can be broken down into some simpler blocks: Power Supply, Input Buffer, Gain Stage, Clipping Stage, Tone Stack, and Output Buffer.

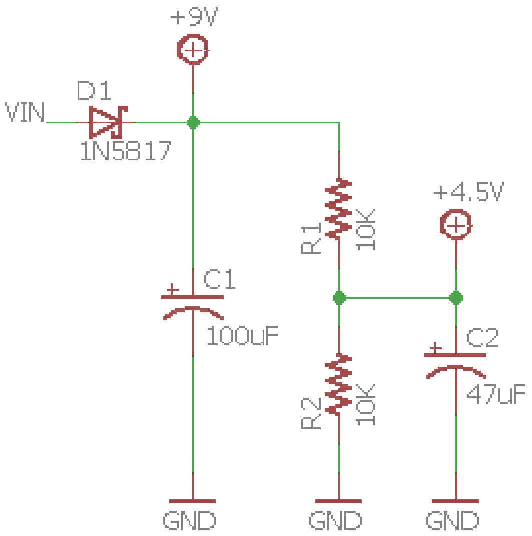


The circuit is designed around a single op-amp gain and hard clipping while using transistors to handle buffering and boosting the input signal and buffering a recovery stage at the end.

The input impedance on the Swedish Chainsaw is close to 692K Ω, 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.

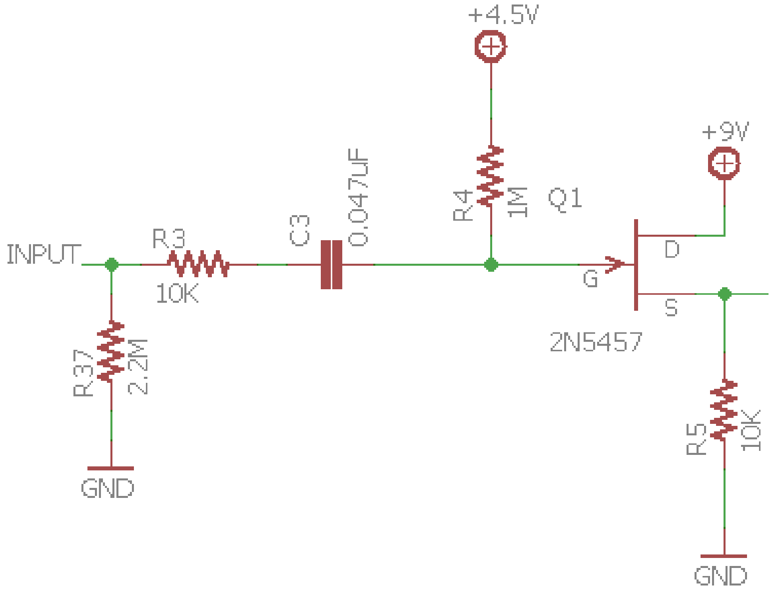
The Power Supply Stage provides the electrical power and bias voltage to all the circuitry, the whole power consumption is low and estimated around 10mA:



- The Schottky diode D1 protects the pedal against adapter reverse polarity connections. As the diode is in series with the positive power rail, there will be a slight voltage drop of around 180mV, dropping the total voltage of 9V down to 8.82V.
- The resistor voltage divider composed by R1 and R2 generates 4.5V to be used as a bias voltage/virtual ground. The resistors junction (+4.5V) is decoupled to ground with a large value electrolytic capacitor C2 47uF.
- C1 is a large electrolytic capacitor of 100uF used to stabilize the power supply lines.

4. Input Buffer.

The input buffer is a JFET voltage follower (aka Common Drain Amplifier, aka Source Follower) with unity gain and high input impedance that preserves signal quality eliminating tone sucking (high-frequency loss):



The 2.2MΩ R37 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 HM-2, this resistor was not present as it effected the Input Impedances on their original design, though this has been corrected for on the Swedish Chainsaw.

The 47nF C3 input capacitor blocks DC and provides simple high pass filtering. C3 and R4 create a high pass filter.

$$fc = 1 / (2\pi RC)$$
$$fc = 1 / (2\pi \cdot R_4 \cdot C_3)$$
$$fc = 1 / (2\pi \cdot 1{,}000{,}000 \cdot 0.000000047)$$
$$fc = 3.4Hz$$

With a cut of 3.4Hz it will block DC and any low-frequency parasitic oscillation.

R3 input series resistor will protect the gate of the JFET from surge currents from electrostatic discharges from the guitar jack tip.

R4 is a bias resistor used to help control the input impedance of the buffer, as well as to set the bias voltage to the gate of the JFET that it is going to.

R5 is a source resistor to ground for the source pin of the JFET. The value here is not too critical and can be any value from 3.3K to 10K without much change in the sound. Going lower than 3.3K starts to negatively affect the input impedance while going higher than 10K provides less drive on the negative portion of the audio cycle if this was the only pull-down resistor, or is the lowest resistance on the line.

The Q1 is a JFET that is being used as a unity-gain buffer. Any JFET would likely work here with little change in sound.

4.1 Input Impedance.

JFETs have the advantage over bipolar transistors by having an extremely high input impedance along with a low noise output making them ideal for buffers that have very small input signals. The input impedance is defined by the formula:

$$Zin = Q_1 \,||\, R_{37} \,||\, R_4 + R_3$$

$$Zin = \infty \,||\, 2{,}200{,}000 \,||\, 1{,}000{,}000 + 10{,}000$$

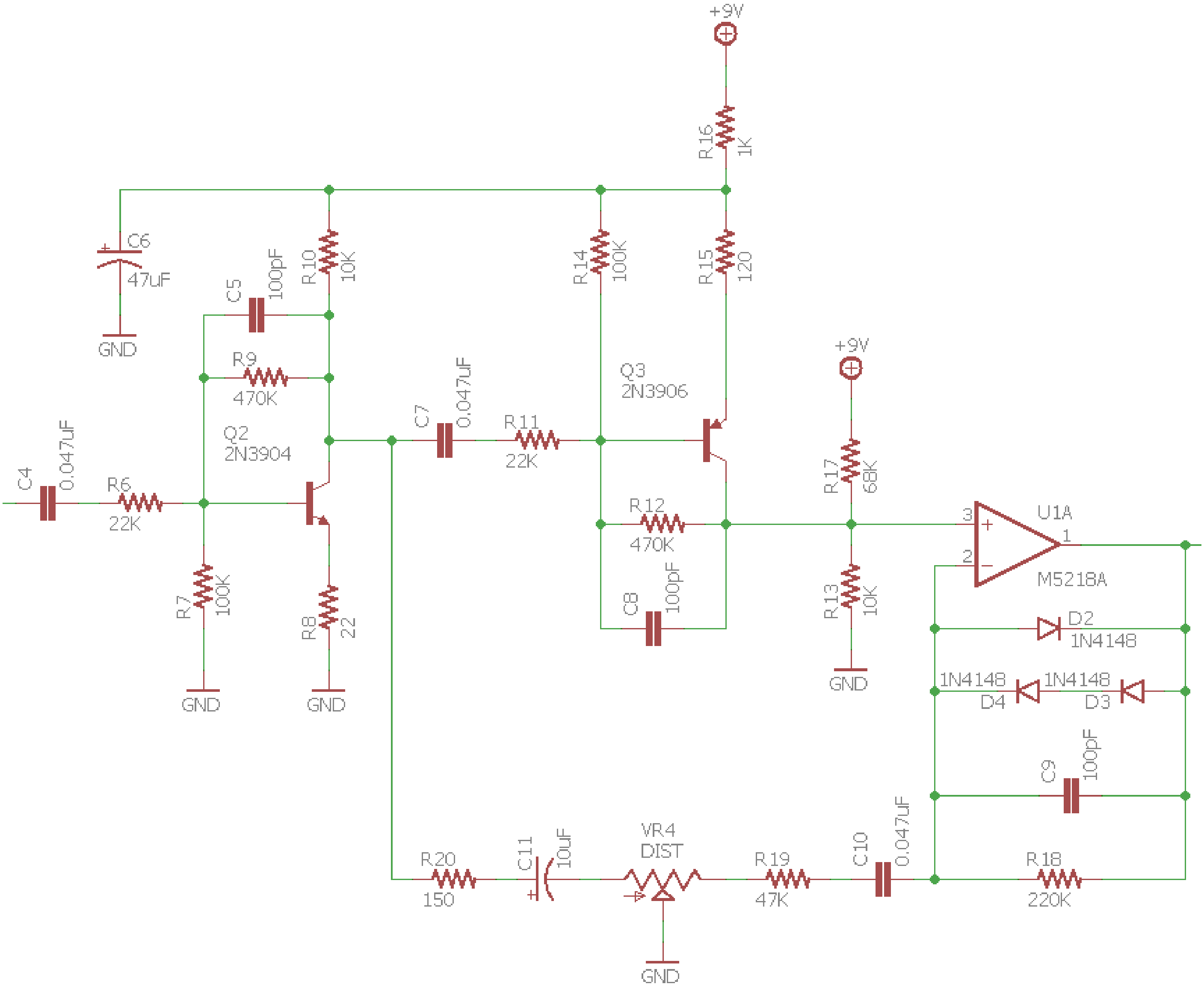
$$Zin = 687{,}500 + 10{,}000$$

$$Zin = 697{,}500\Omega$$

Therefore, the Swedish Chainsaw input resistance is 697.5K, which isn't bad, but the closer to 1M it is, the better. Increasing R4 to 2.2M would bring the input resistance up to 1.11M, although that would also effect the input high pass filter.

5. Gain Stage.

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.



C4 is a coupling capacitor blocking DC, but allowing the AC guitar signal to flow from the Input Buffer into this gain stage. C4, along with R6+R7 form a high-pass filter of around 27 Hz.

R6, R7, R8, R9, R10, and R16 with C5, and Q2 form an inverting, NPN Voltage-Shunt Feedback amplifier whose output sustain/distortion pot is pulled into the negative feedback loop of U1A. This boost topology is similar to that of the first stage of a Big Muff Pi. This stage has a gain of 12, or around 21dB. As the bias is unevenly set, it will most likely start soft-clipping the bottom of the guitar signal.

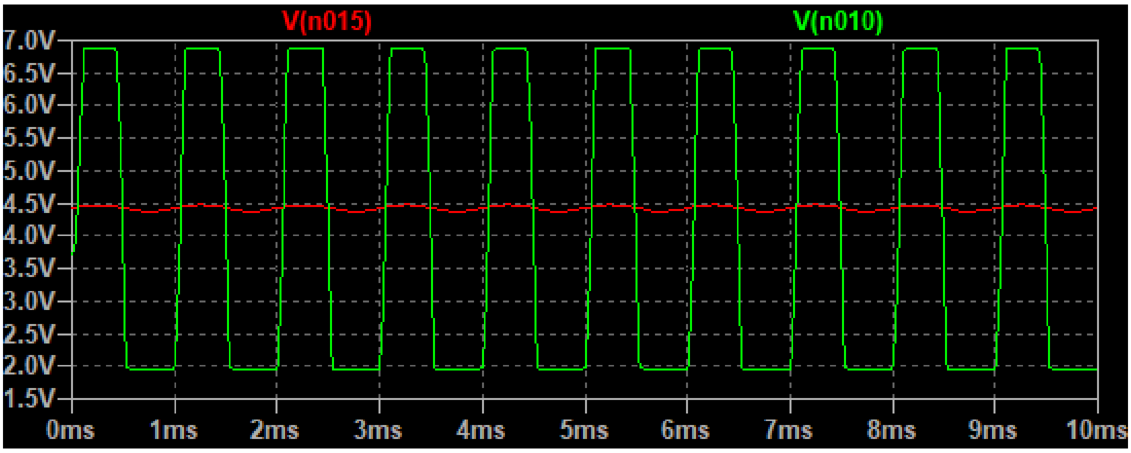
R11, R12, R14, R15, and R16, with C8, and Q3 form an inverting, PNP Voltage-Shunt Feedback amplifier whose sustain value is hard set by R17 going to 9V, and ultimately goes into U1A's non-inverting pin. This boost topology is similar to the NPN one that comes before it and with the two combine, form a crude, discrete op-amp. The gain from this amplifier adds an additional gain of 118, or around 41dB.

U1A takes in the two voltage-shunt feedback amplifier stages, which because they were inverted twice, are back to non-inverted, and amplifies them further via a non-inverting op-amp, controlled by the resistance of the distortion potentiometer. R18 and C9 form a low pass filter that helps trim some of the highs in the soft clipping section of this op-amp, in the whereabouts of 7,234 Hz and above.

C10 and R19, along with the distortion potentiometer form a high-pass filter. With the distortion pot all of the way at 0, we further trim 11 Hz and under of signal, but as we turn the distortion knob to max, we start trimming 72 Hz and under.

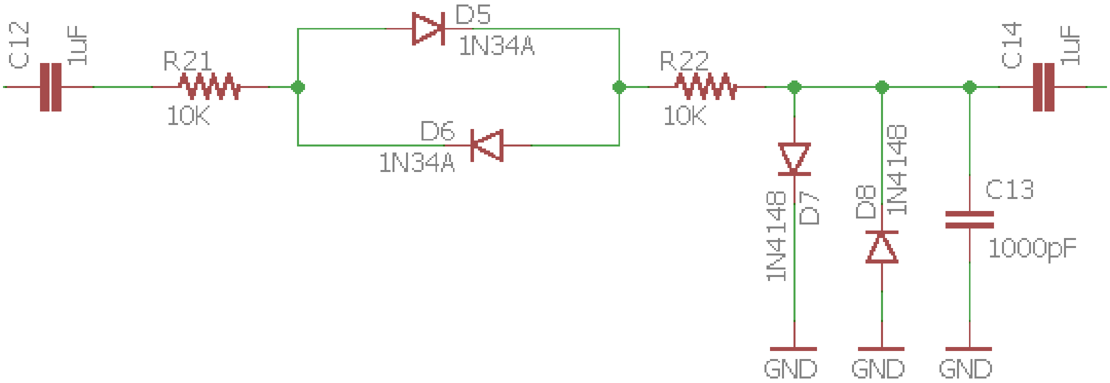
Diodes D2, D3, and D4 are silicon diodes used to asymmetrically soft-clip the amplified signal. Because the bottom of the wave-form was rail clipped on the bottom due to uneven bias in the voltage-shunt feedback amplifier stages, the asymmetry of the soft-clipping diodes clips more on the top of the wave-form, almost balancing the soft-clipping of both sides.

Below is a comparison between the input signal and the output signal leaving the output pin of U1A



6. Clipping Stage.

After the amplification that causes rail clipping goes into the first op-amp and performs soft-clipping with diodes, the signal leaves the op-amp to go into another set of distortion topologies. First, a cross-over distortion diode section going into a hard-clipping diode section.



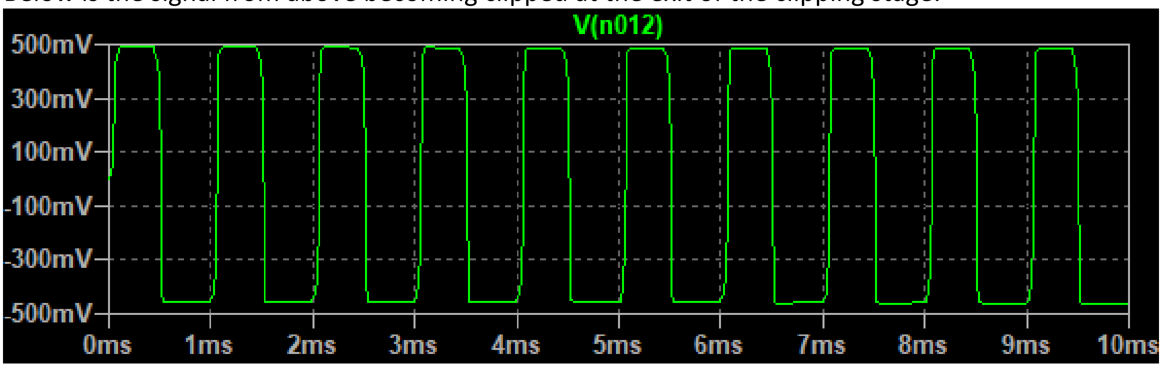
C12 and C14 are coupling capacitors keeping the DC away from the incoming and outgoing signals.

D5 and D6 are germanium diodes because of their lower turn-on threshold. Silicon diodes with high turn-on threshold will likely result in a gating effect. In a way, it creates a crude noise gate by muting signals below the diode's forward voltage, reducing noise floor, but creating crossover distortion in the process. If it likely the intent was for cross-over distortion, with the perk of crude noise-gate and not the other way around.

D7 and D8 are traditional hard clipping diodes used to directly chop off the tops and bottoms of the waveform by the forward voltages of the diodes, ultimately compressing the signal.

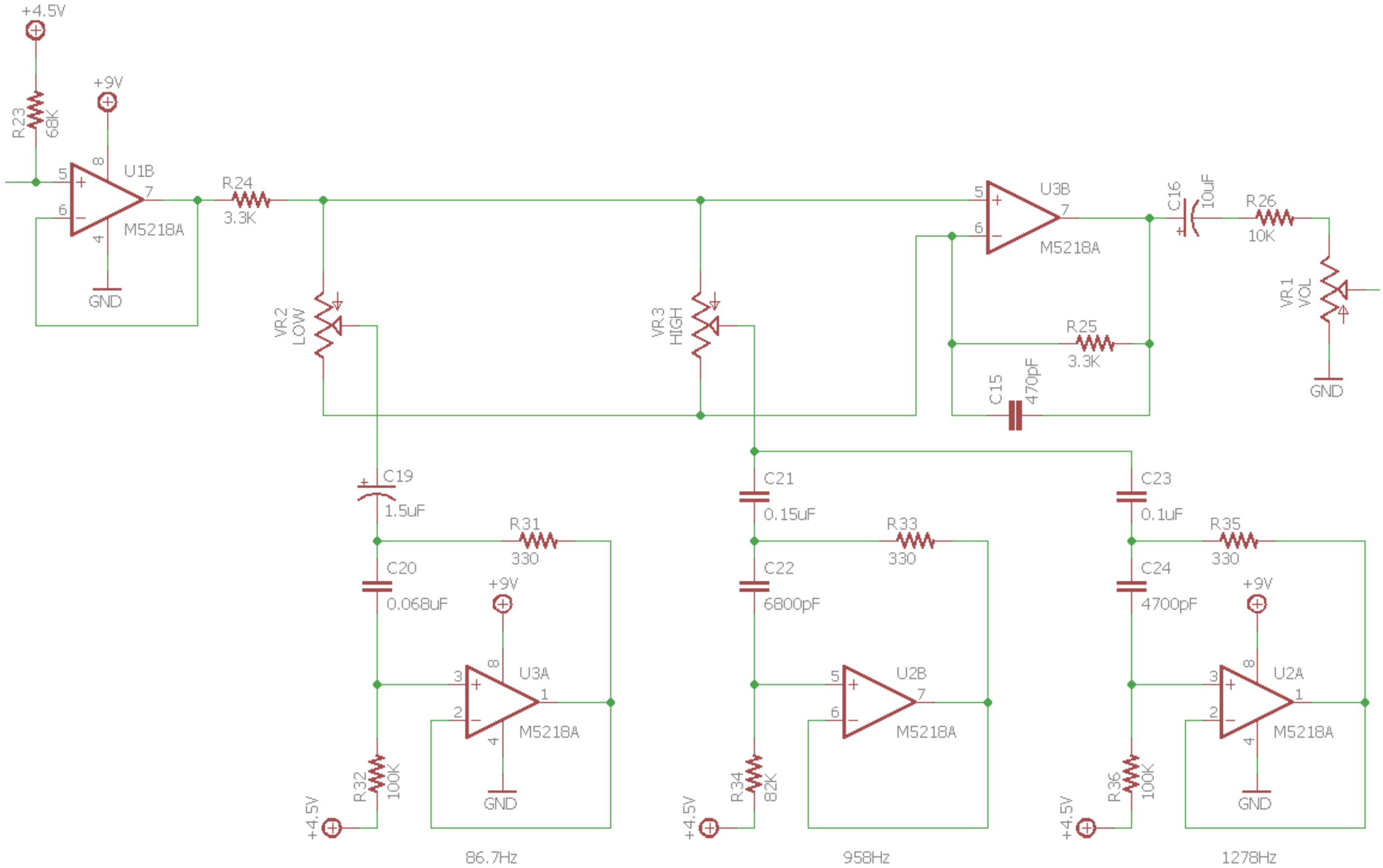
C5, along with R22 form a low-pass filter that will remove some of the harsh harmonics from the hard-clipping diodes: D7 and D8. Frequencies above 15.9 KHz will be trimmed.

Below is the signal from above becoming clipped at the exit of the clipping stage:



7. Tone Stack.

The Swedish Chainsaw uses an active tone stack designed to cut or boost frequencies. Utilizing two EQ controls, it shapes the tone by setting the three op-amp gyrators.



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 Cut and Boost Amounts.

On the Swedish Chainsaw, note that R24 and R25 are the same value? This is deliberate for calculation of the boost/cut ratio. It makes the formula smaller if they are the same, when calculating gain. So, all 3 gyrators on the Swedish Chainsaw have the same boost and cut ceilings because R31 = R33 = R35. And the calculation would be:

$$\textit{Maximum Cut/Boost} = 20 \cdot \log [(R_E + R_X) / R_X]$$
$$\textit{Maximum Cut/Boost} = 20 \cdot \log [(R_{24} + R_{31}) / R_{31}]$$
$$\textit{Maximum Cut/Boost} = 20 \cdot \log [(3{,}300 + 330) / 330]$$
$$\textit{Maximum Cut/Boost} = 20 \cdot \log [11]$$
$$\textit{Maximum Cut/Boost} = 20.83 dB\ \textit{cut/boost}$$

However, this is typical when each potentiometer is tied to only one gyrator. In the case of the Swedish Chainsaw, two gyrators are tied to one potentiometer. Those in turn get an extra bump and cut at around 22.47dB

7.2 Selected Frequencies.

On the Swedish Chainsaw, there are 3 gyrators to look at: the low frequency gyrator, tied to the bass knob, the hi-mids frequency gyrator, and hi frequency gyrator, both tied to the treble knob.

The low frequency gyrator frequency point can be calculated as:

$f = 1 / (2 \cdot \pi \cdot \sqrt{(C_{19} \cdot C_{20} \cdot R_{31} \cdot R_{32})})$

$f = 1 / (2 \cdot \pi \cdot \sqrt{(0.0000015 \cdot 0.000000068 \cdot 330 \cdot 100{,}000)})$

$f = 1 / (2 \cdot \pi \cdot \sqrt{(0.000003366)})$

$f = 1 / (2 \cdot \pi \cdot 0.00183466618217047866312361586648))$

$f = 1 / (0.01152754759939281814128526856019))$

$f = 86.75\ Hz$

The hi-mids frequency gyrator frequency point can be calculated as:

$f = 1 / (2 \cdot \pi \cdot \sqrt{(C_{21} \cdot C_{22} \cdot R_{33} \cdot R_{34})})$

$f = 1 / (2 \cdot \pi \cdot \sqrt{(0.00000015 \cdot 0.0000000068 \cdot 330 \cdot 82{,}000)})$

$f = 1 / (2 \cdot \pi \cdot \sqrt{(0.0000000276012)})$

$f = 1 / (2 \cdot \pi \cdot 0.00016613608879469866706038614733))$

$f = 1 / (0.00104386383210713379924308966816))$

$f = 957.98\ Hz$

The hi frequency gyrator frequency point can be calculated as:

$f = 1 / (2 \cdot \pi \cdot \sqrt{(C_{23} \cdot C_{24} \cdot R_{35} \cdot R_{36})})$

$f = 1 / (2 \cdot \pi \cdot \sqrt{(0.0000001 \cdot 0.0000000047 \cdot 330 \cdot 100{,}000)})$

$f = 1 / (2 \cdot \pi \cdot \sqrt{(0.00000001551)})$

$f = 1 / (2 \cdot \pi \cdot 0.000124539150470845913828318747728))$

$f = 1 / (0.00078250256040704672489940785967))$

$f = 1{,}277.95\ Hz$

7.3 Selected Q Values.

On the Swedish Chainsaw, there are 3 gyrators to look at: the low frequency gyrator, tied to the bass knob, the hi-mids frequency gyrator, and hi frequency gyrator, both tied to the treble knob. Q values approaching 4 and above are narrow and precise, but can result in ringing and phase shifting if not too careful. Q values approaching 1.2 and below are wide and risk interacting with adjacent frequency bands next to it, if any are present. Per National Semiconductor, 1.7 is the ideal Q factor.

The low frequency gyrator Q value can be calculated as:

$$Q = \sqrt{(C_{20} \cdot R_{32} / (C_{19} \cdot R_{31}))}$$
$$Q = \sqrt{(0.000000068 \cdot 100{,}000 / (0.0000015 \cdot 330))}$$
$$Q = \sqrt{(0.0068 / 0.000495)}$$
$$Q = \sqrt{(13.737)}$$
$$Q = 3.7$$

The hi-mids frequency gyrator Q value can be calculated as:

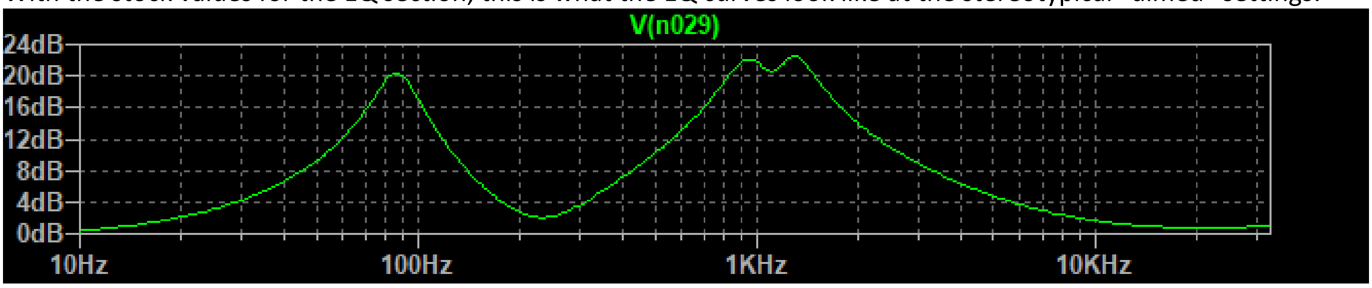
$$Q = \sqrt{(C_{22} \cdot R_{34} / (C_{21} \cdot R_{33}))}$$
$$Q = \sqrt{(0.0000000068 \cdot 82{,}000 / (0.00000015 \cdot 330))}$$
$$Q = \sqrt{(0.0005576 / 0.0000495)}$$
$$Q = \sqrt{(11.265)}$$
$$Q = 3.6$$

The hi frequency gyrator Q value can be calculated as:

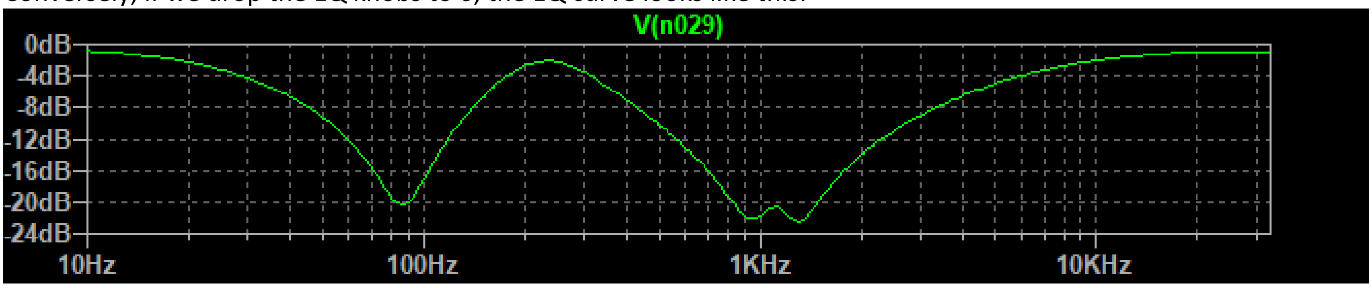
$$Q = \sqrt{(C_{24} \cdot R_{36} / (C_{23} \cdot R_{35}))}$$
$$Q = \sqrt{(0.0000000047 \cdot 100{,}000 / (0.0000001 \cdot 330))}$$
$$Q = \sqrt{(0.00047 / 0.000033)}$$
$$Q = \sqrt{(14.2)}$$
$$Q = 3.8$$

7.4 Frequency Curves.

With the stock values for the EQ section, this is what the EQ curves look like at the stereotypical “dimed” settings:

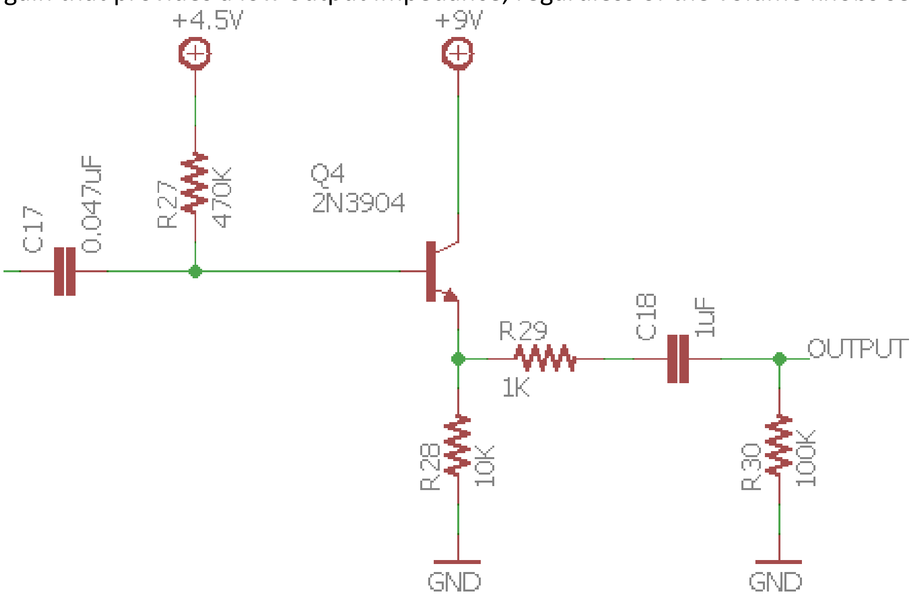


Conversely, if we drop the EQ knobs to 0, the EQ curve looks like this:



8. Output Buffer.

The output buffer Is a common collector amplifier (Emitter Follower) which acts as a non-inverting amplifier with a unity gain that provides a low output impedance, regardless of the volume knobs settings.



C17 is a coupling capacitor separating the DC between the output buffer stage and the previous tone stack stage.
R27 is a bias resistor, setting the signal that is about to leave the buffer at a bias of 4.5V.
C17 and R27 form a high-pass filter at about 7.2 Hz. The idea is just to remove the DC levels so the transistor can be correctly biased.
R28 is an emitter resistor for the Q4 buffer.
R29 is a series resistor designed to absorb static discharge coming from the output jack, protecting the Q4 transistor.
C18 is an output capacitor, designed to couple the output jack to the buffer.
R23, along with C18 provide another high-pass filter, but this time at 1.6 Hz. Again, just trying to remove DC levels from the final output of the pedal.
Q4 is just a regular Bipolar Junction Transistor used for unity gain and for a low output impedance signal.

8.1 Output Impedance.

BJT Transistors, though their input impedance isn't terribly great, their output impedances are usually ideal. To calculate the output impedance of this pedal, we assume the beta of the 2N3904 to be around a 200 gain:

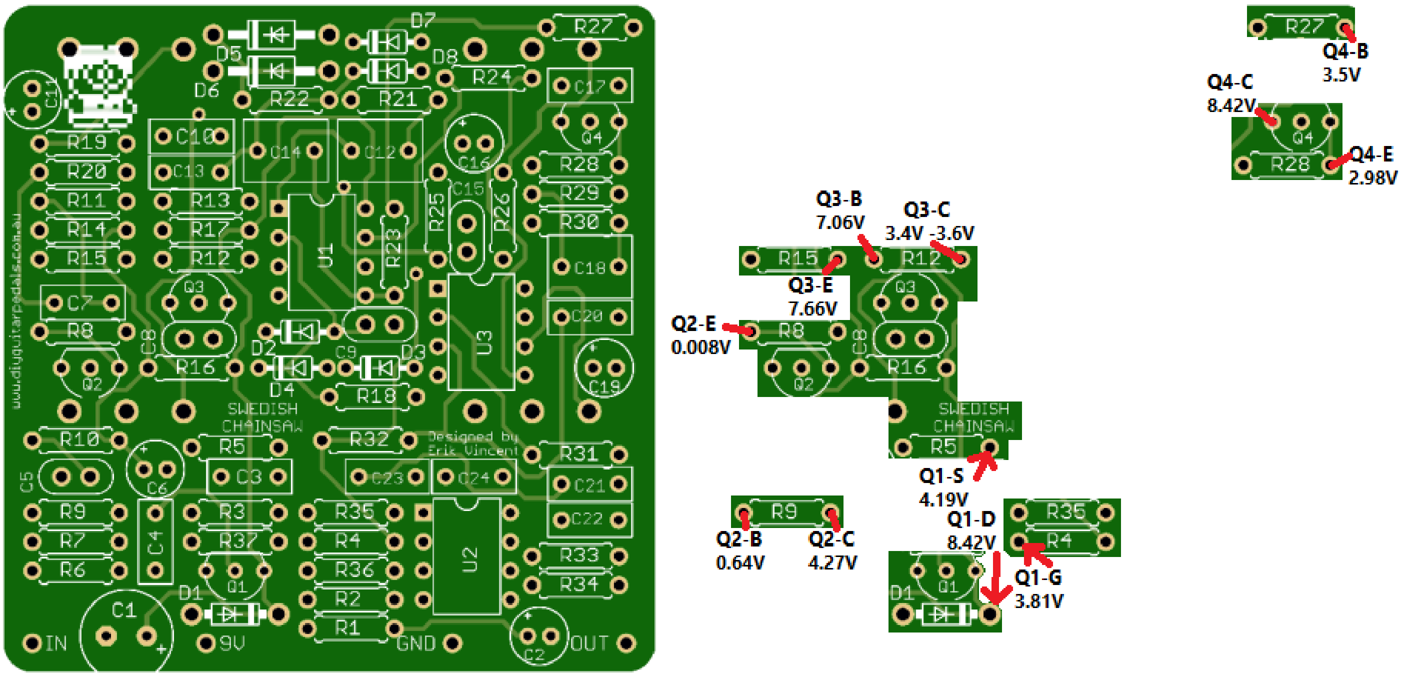
$$Zout = R30 \,||\, (R29 + (R28 \,||\, (R27 / (\beta + 1))))$$
$$Zout = 100{,}000 \,||\, (1{,}000 + (10{,}000 \,||\, (470{,}000 / (200 + 1))))$$
$$Zout = 100{,}000 \,||\, (1{,}000 + (10{,}000 \,||\, (470{,}000 / (201))))$$
$$Zout = 100{,}000 \,||\, (1{,}000 + (10{,}000 \,||\, (470{,}000 / 201)))$$
$$Zout = 100{,}000 \,||\, (1{,}000 + (10{,}000 \,||\, 2{,}338))$$
$$Zout = 100{,}000 \,||\, (1{,}000 + 1{,}895)$$
$$Zout = 100{,}000 \,||\, 2{,}895$$
$$Zout = 2{,}895\Omega$$

Therefore, the Swedish Chainsaw out resistance is around 2.9K, a low value needed to keep the guitar signal uncorrupted.

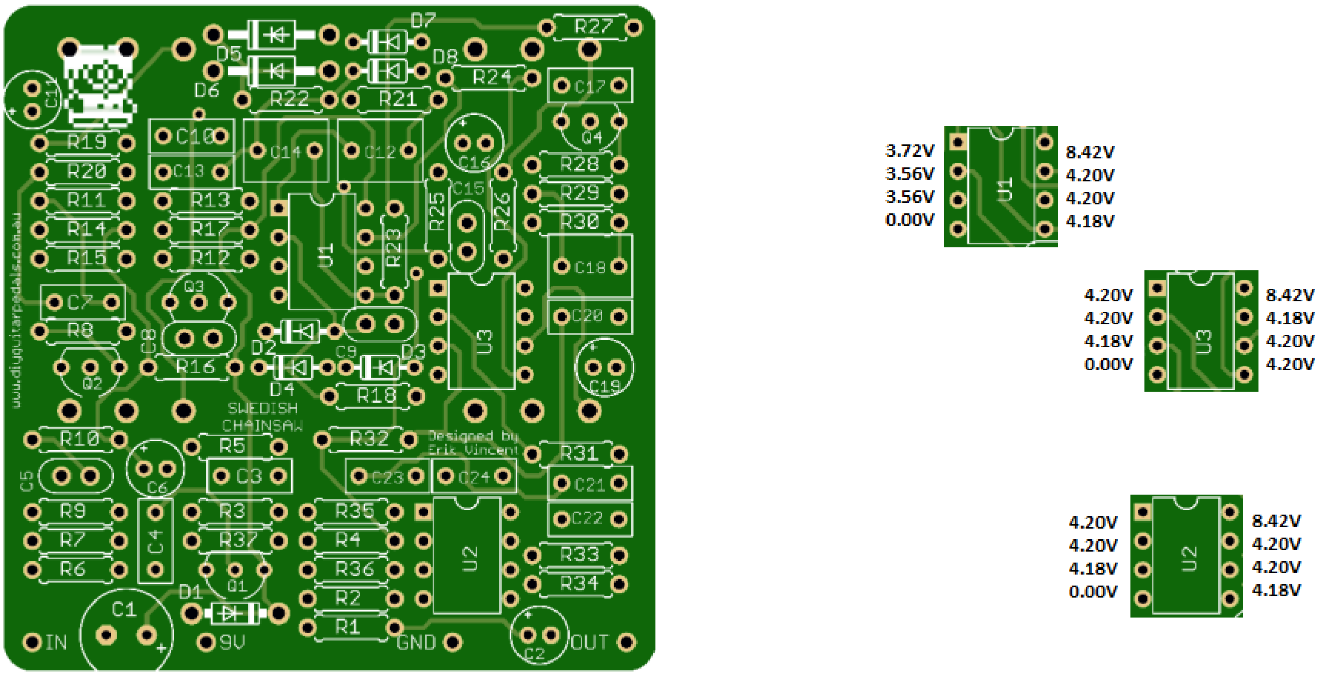
9. Voltage Readouts.

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

Transistor and FET read-outs



IC read-outs



KNOBS

- VOL: NOON
- DIST: MAX
- LOW EQ: MAX
- HIGH EQ: MAX

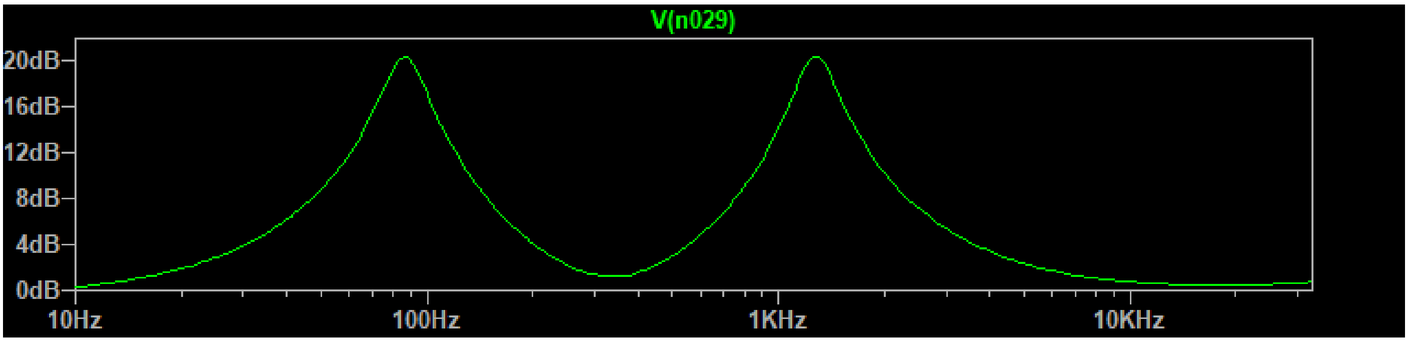
10. Modifications

Following is a couple of worthwhile modifications that can be applied to the Swedish Chainsaw.

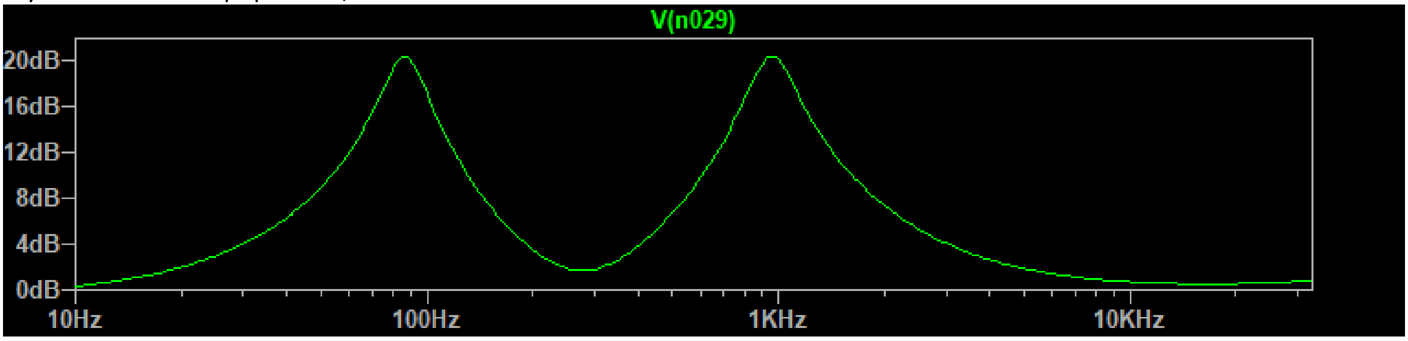
10.1 Capacitors

Wait. The sound of this pedal is iconic. Why change anything?

Well, some people like to separate the mid-hi and hi gyrators out to its own individual controls. Some people remove one of the two gyrators all together and create a more scooped sound. If you leave C21 unpopulated, the “dimed” EQ curve looks like this:



If you leave C23 unpopulated, the “dimed” EQ curve looks like this:



To get further bass response, changing C3 and C4 to a 1uF electrolytic.

10.2 Diodes

D5 and D6 can be swapped out for germanium diodes to get a different, older style of distortion clipping.
Removing all diodes but D2 and D3 and shunting D5 and D6 would make this pedal more of an overdrive on steroids
Removing all diodes but D7 and D8 and shunting D5 and D6 would make this pedal similar to a Boss DS-* distortion.

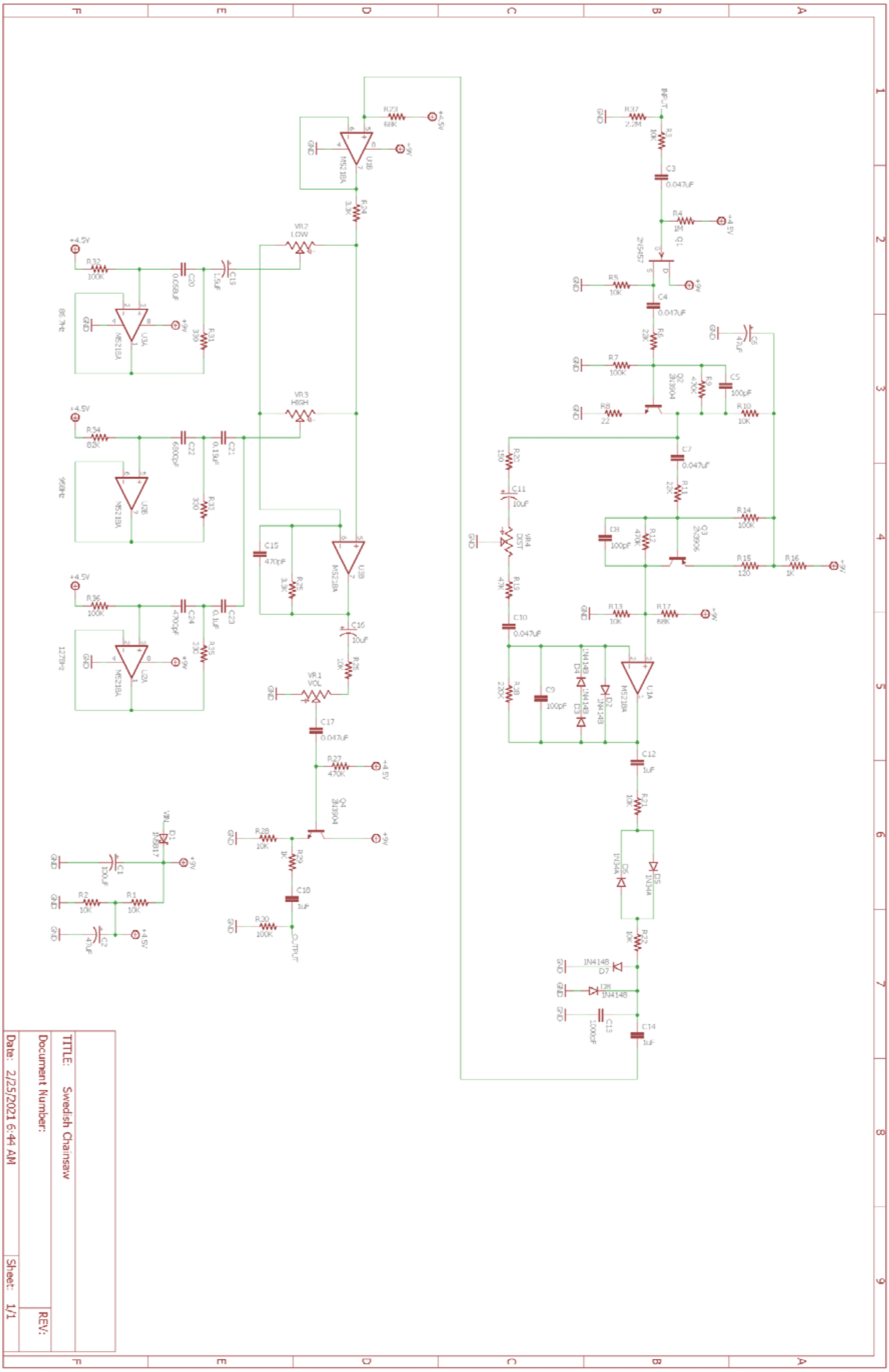
10.3 Op-Amps

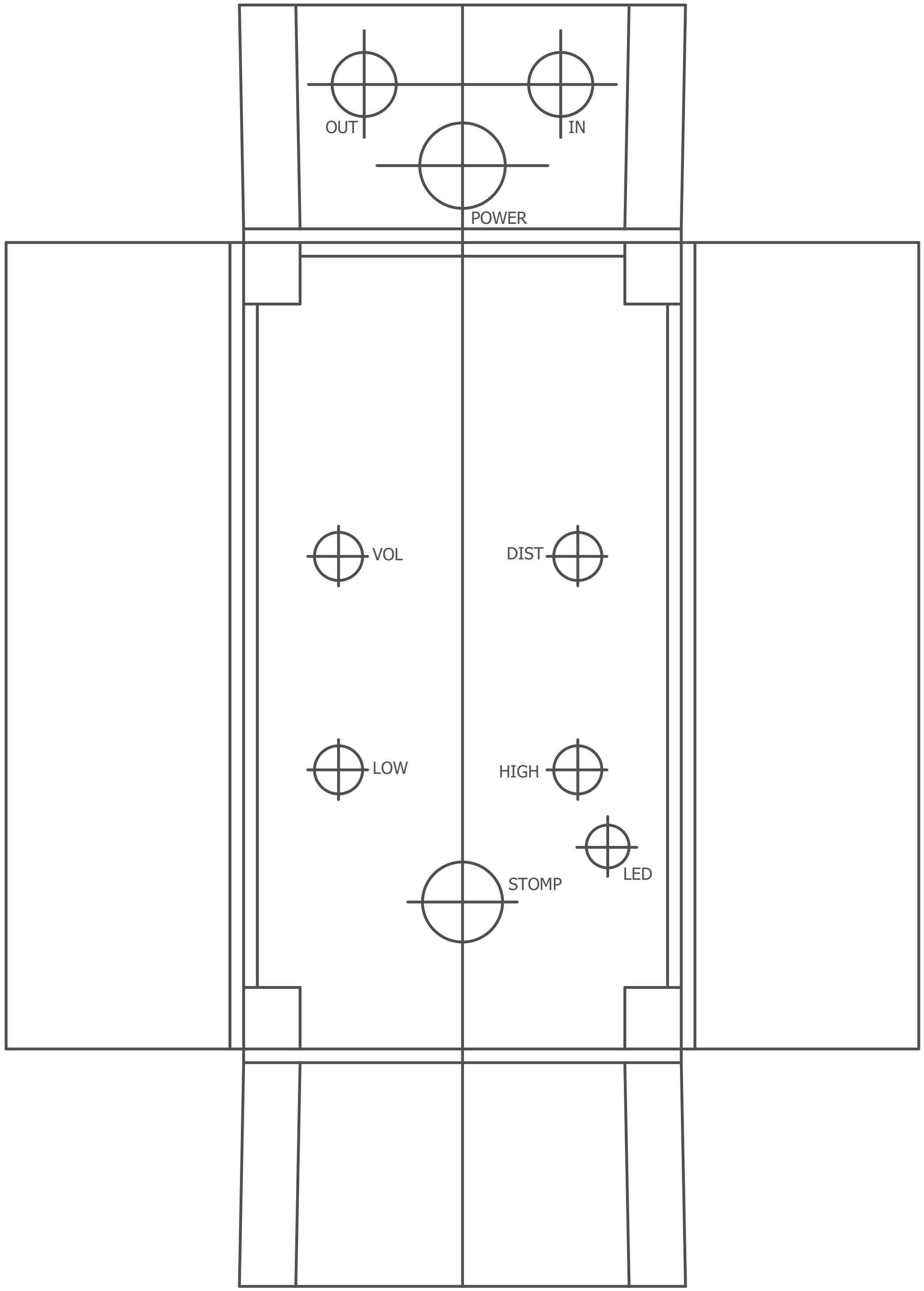
The Mitsubishi M5218 is a key ingredient to the Swedish Chainsaw’s sound. However, this op-amp is long since out of print and therefore hard to come by. The characteristics of the M5218 are similar to the 4558, 4559, or 1458 (similar to a dual 741). These alternatives don’t typically have the Gain Bandwidth Product of the M5218, but they can come close and they are more plentiful.

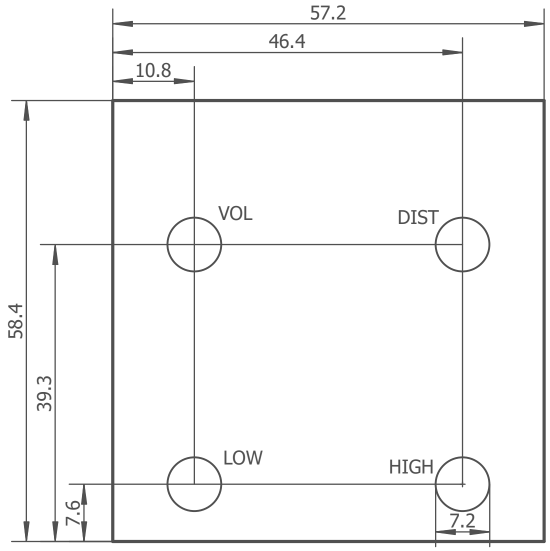
10.4 EQ Section

Three aspects of the EQ section can be set to customized values: The amount of cut/boost, the frequency points targeted, and their Q factor. Please look at section 6 to see how these can be modified.

11. Schematic




OUT
IN
POWER
VOL
DIST
LOW
HIGH
LED
STOMP


57.2
46.4
10.8
VOL
DIST
58.4
39.3
LOW
HIGH
7.6
7.2