Funktastic

Modded DOD FX25 Inspired Envelope Filter

Design By Erik Vincent

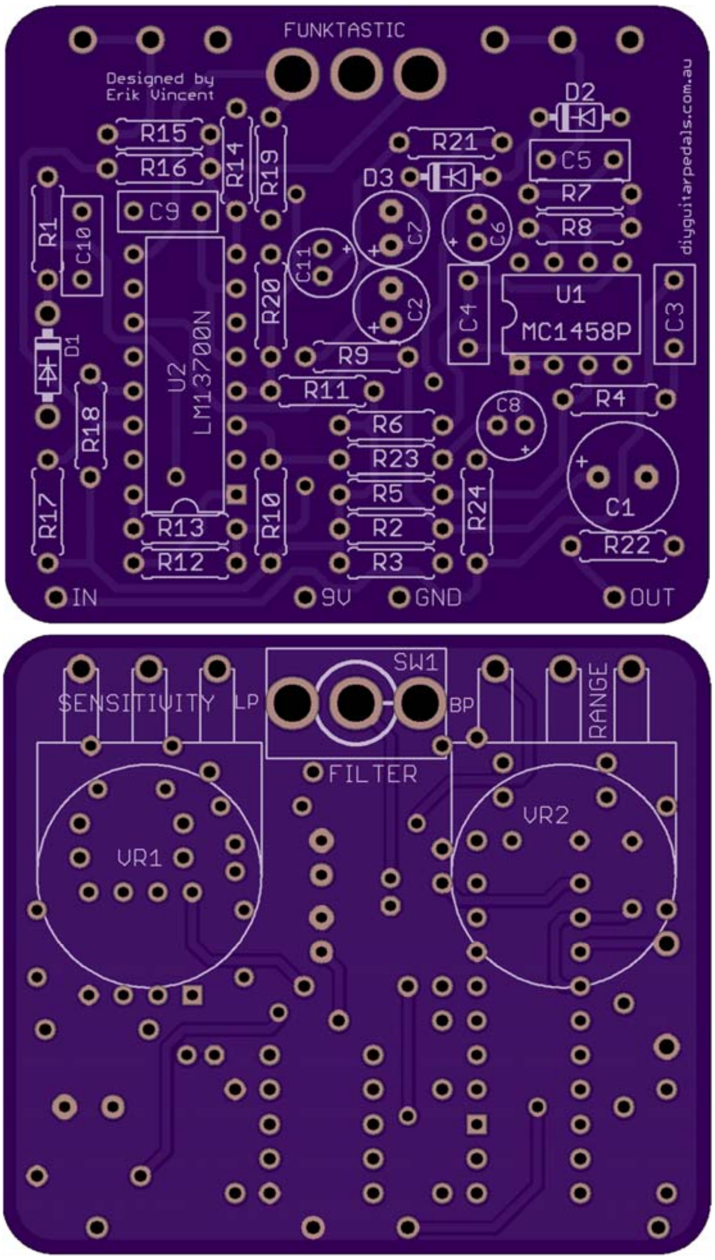
Funk up your guitar or bass!
Funk up
FUNK…

Based around the DOD FX25 Envelope Filter, this effect also adds a low pass filter circuit to give the bottom end a bunch of response. This effect uses 2 standard pot control: Range, and Sensitivity, and includes a switch modification to flip between band-pass filtering or low pass filtering. We have done away with the hard to find CA3080 and replaced it with a common, in production LM13700.

Enclosure Size: 125B enclosure or Larger.

Bill of Materials, Stock Funktastic

Capacitor		Resistor	
C1	100µF (Electrolytic)	**R1**	51
C2	10µF (Electrolytic)	**R2**	22K
C3	10nF (film)	**R3**	22K
C4	2.2nF (film)	**R4**	10K
C5	100nF (film)	**R5**	470K
C6	4.7µF (Electrolytic)	**R6**	150K
C7	22µF (Electrolytic)	**R7**	4.7K
C8	1µF (Electrolytic)	**R8**	1M
C9	10nF (film)	**R9**	1M
C10	10nF (film)	**R10**	1K
C11	1µF (Electrolytic)	**R11**	1K
		R12	10K
Diode		**R13**	10K
D1	1N4001	**R14**	22K
D2	1N4148	**R15**	22K
D3	1N4148	**R16**	22K
		R17	1K
ICs		**R18**	1K
U1	MC1458P	**R19**	22K
U2	LM13700N	**R20**	22K
		R21	1K
Switch		**R22**	100K
Filter	SPDT (ON ON) Micro-switch	**R23**	10K
		R24	1M
		Potentiometer	
		Sensitivity	100kb (16mm)
		Range	100kb (16mm)



PCB Spacing
The Funktastic PCB is spaced for 125B sized enclosures

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

Assembly.

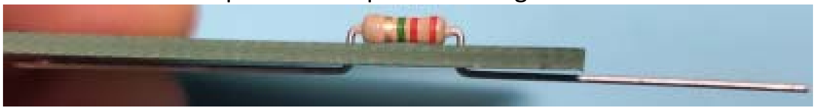
1. Soldering Order.

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

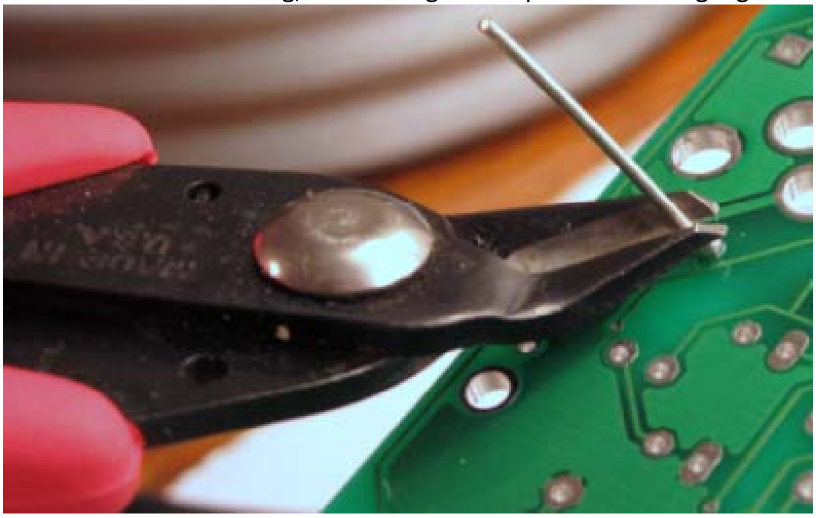
For the Funktastic, the best order would be: resistors, diodes, IC sockets (if socketing), ICs (if not socketing), film capacitors, electrolytic capacitors, wiring, potentiometers, and then switches.

1.1 Resistors.

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

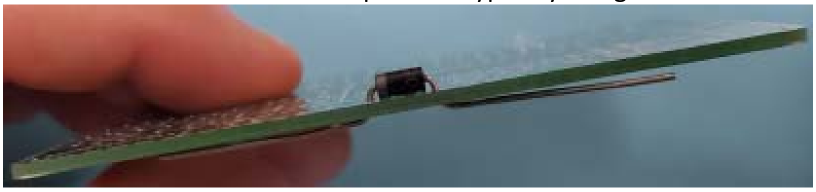


For this pedal we will be using 1/4 Watt resistors. These can either be 5% tolerance carbon resistors, or 1% tolerance metal film resistors. Orientation of “which way is up” doesn’t matter, so you can install them either way. After installation and soldering, do not forget to clip the remaining legs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

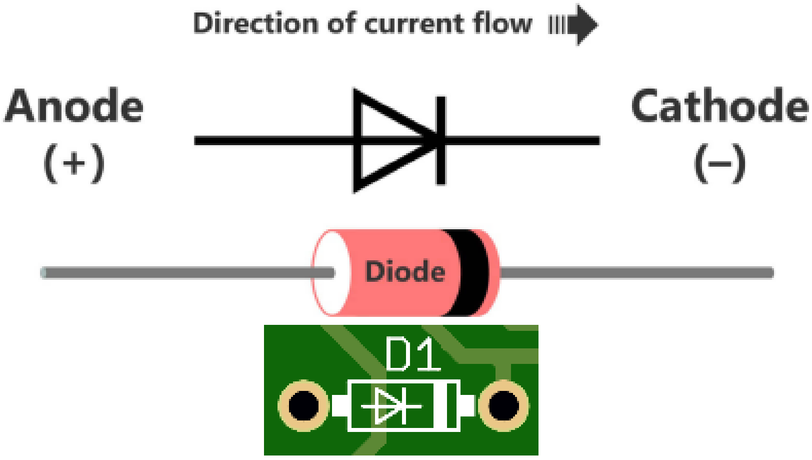


1.2 Diodes.

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



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



1.3 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.

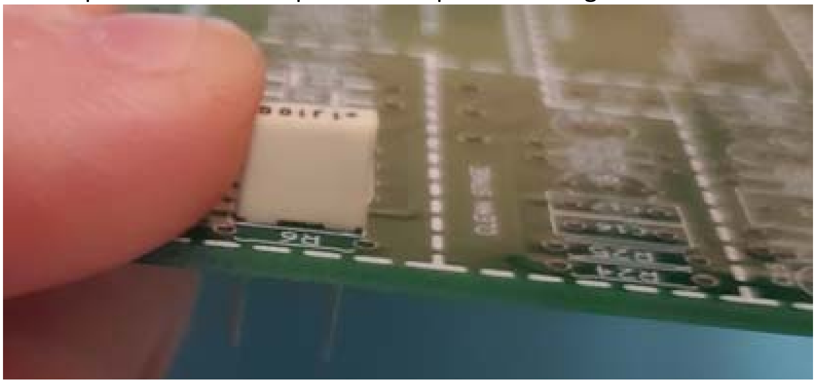
1.4 Integrated Circuits.

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.

1.5 Capacitors (film).

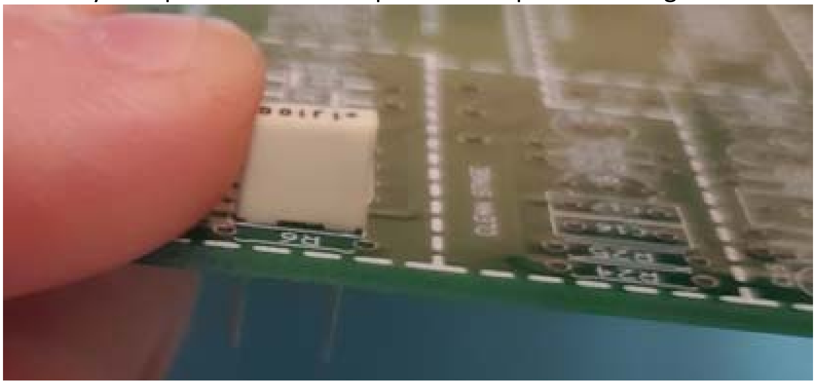
Film capacitors are small passive components designed to hold a small amount of charge in a circuit.



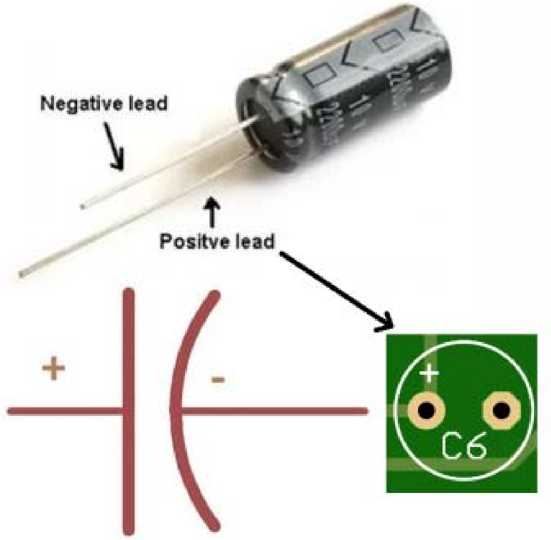
Orientation of “which way is up” doesn’t matter, so you can install them either way. After installation and soldering, do not forget to clip the remaining legs from the PCB.

1.6 Capacitors (electrolytic).

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



Electrolytic capacitors are typically polarized, so orientation will matter.

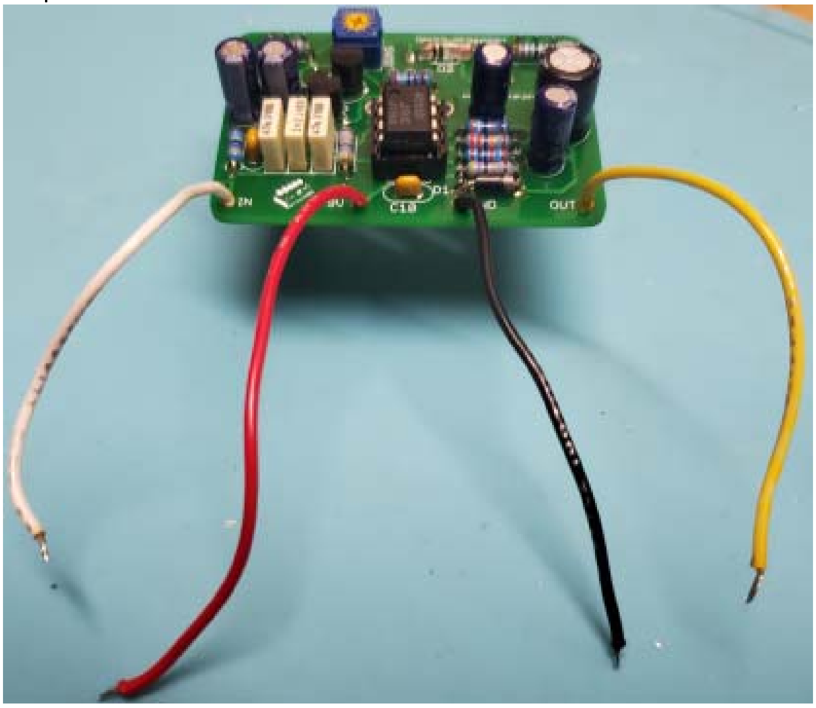


Polarized Electrolytic Capacitor and its electric Symbol

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

1.7 Wiring.

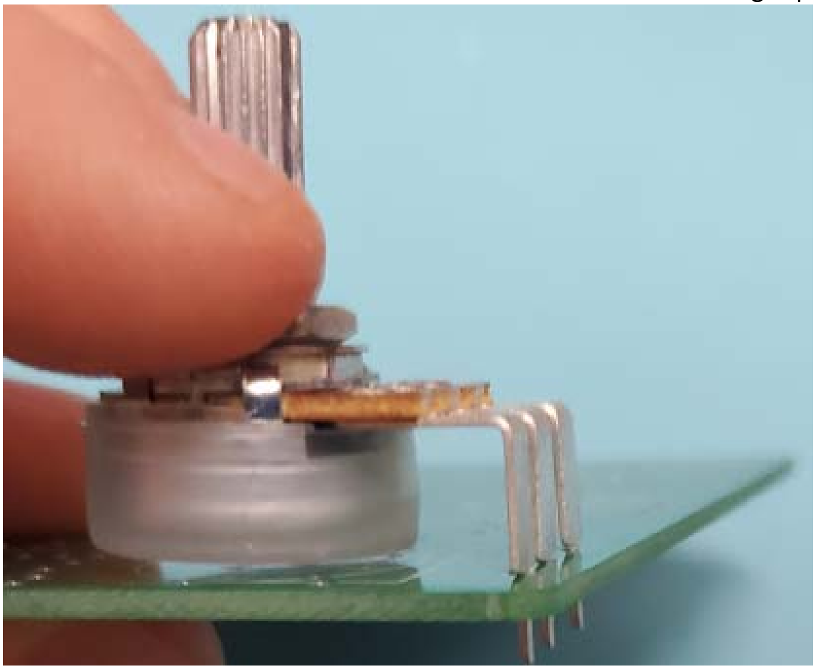
Wires used for the pedal are for delivering power over the hot and ground wires as well as signal for the input and output.



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

1.8 Potentiometers.

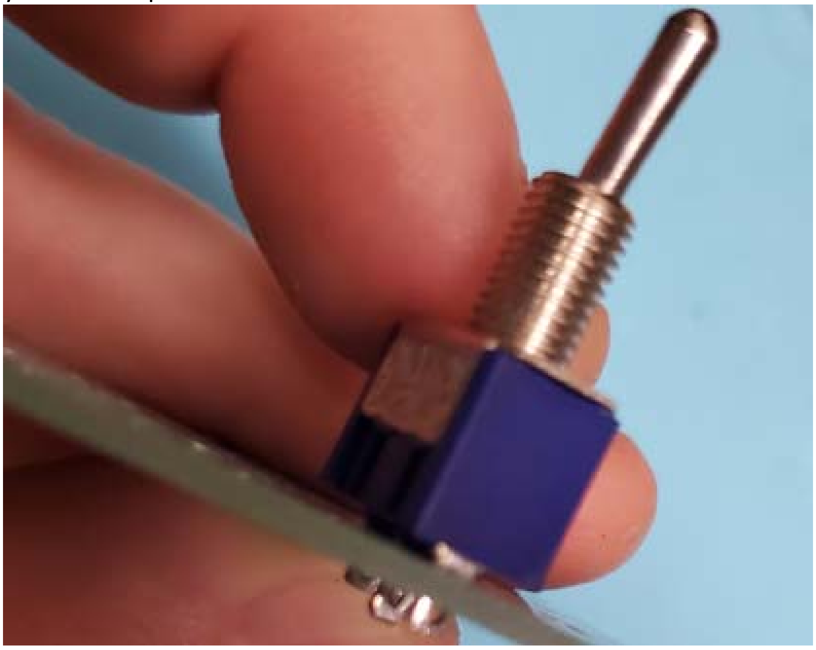
Potentiometers are variable resistors that are used for controlling aspects of the pedal.



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

1.9 Switches.

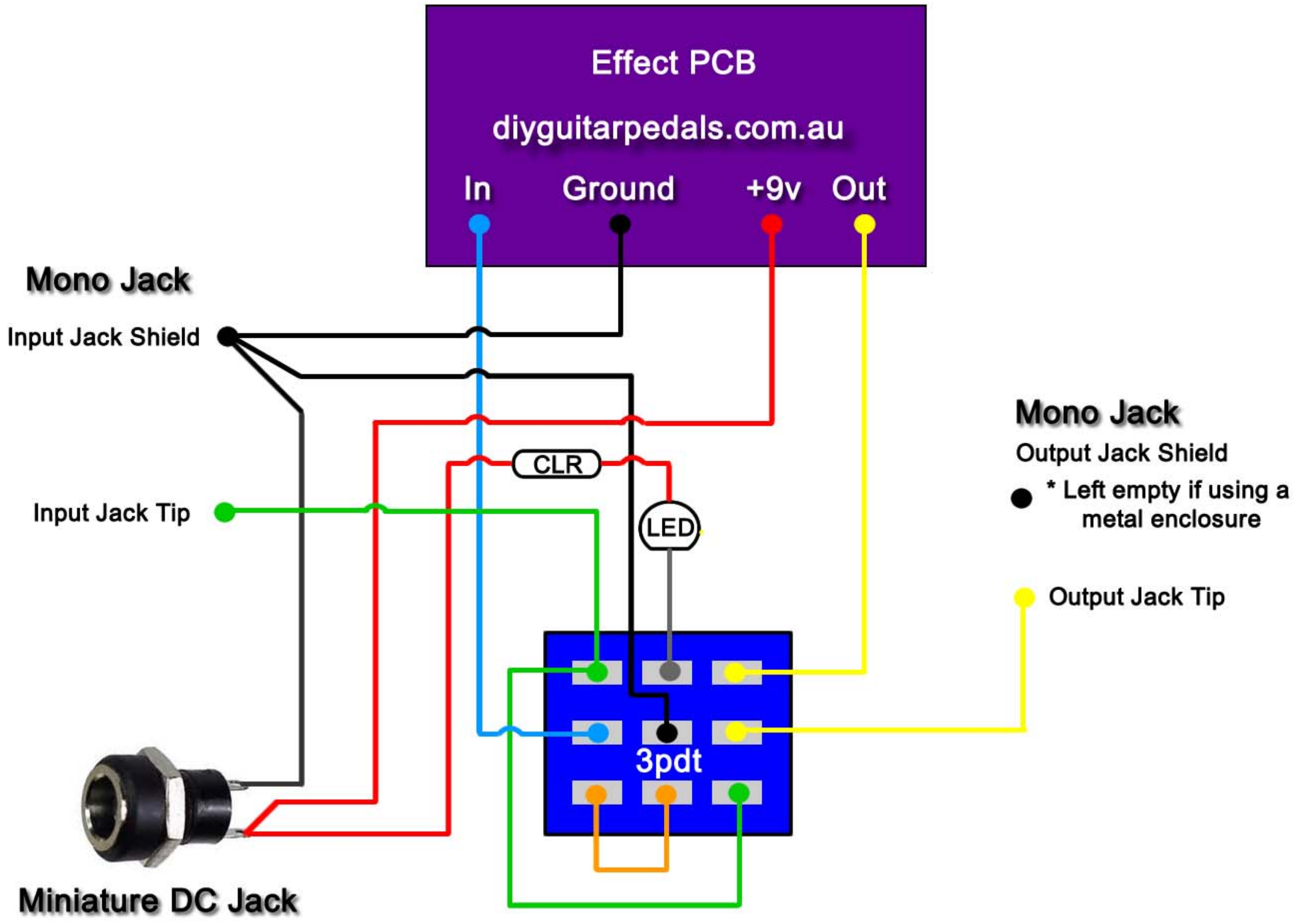
Switches are mechanical devices that change the flow of electricity on a circuit, usually to provide different options to your effects pedal.



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

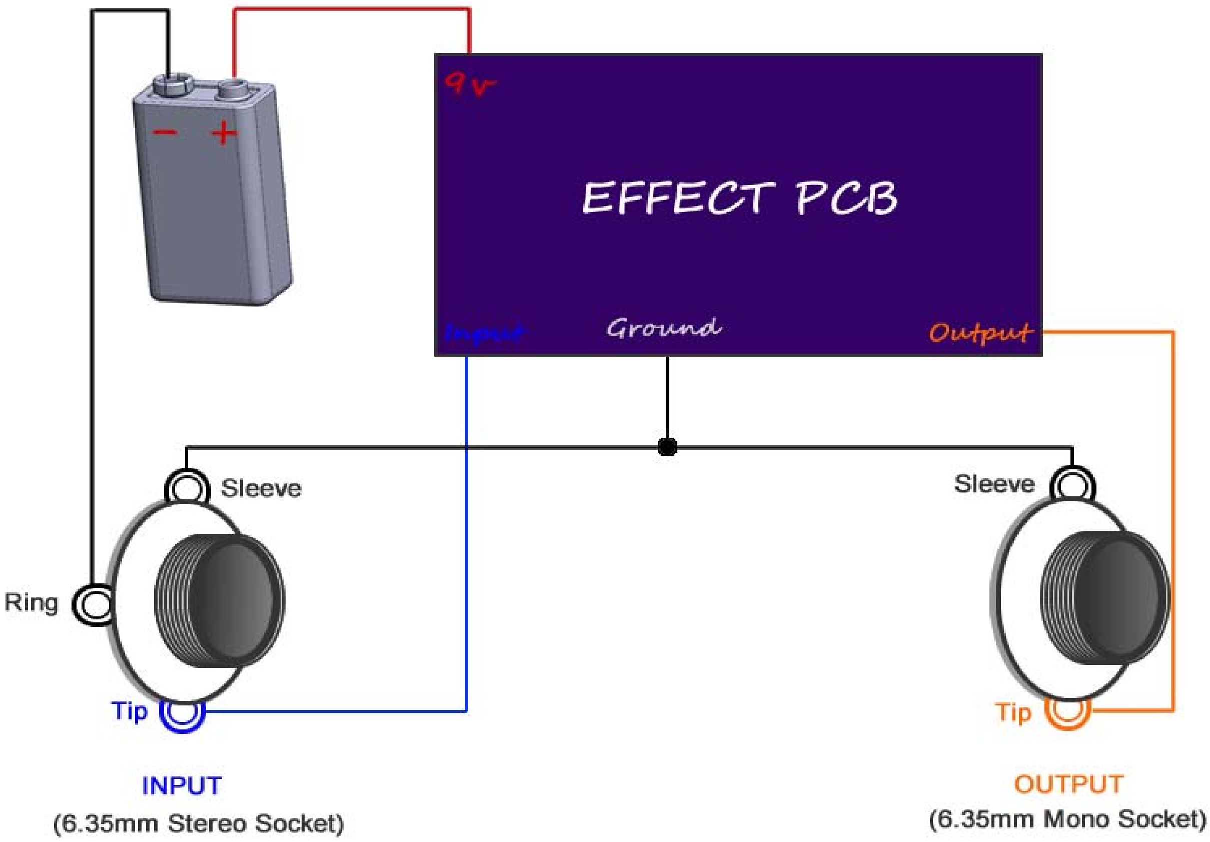
1.10 Off Board Wiring Diagram.

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



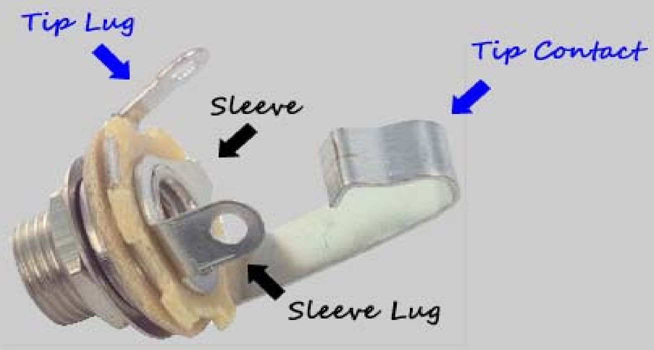
Testing Your Effect

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



Input and Output Sockets

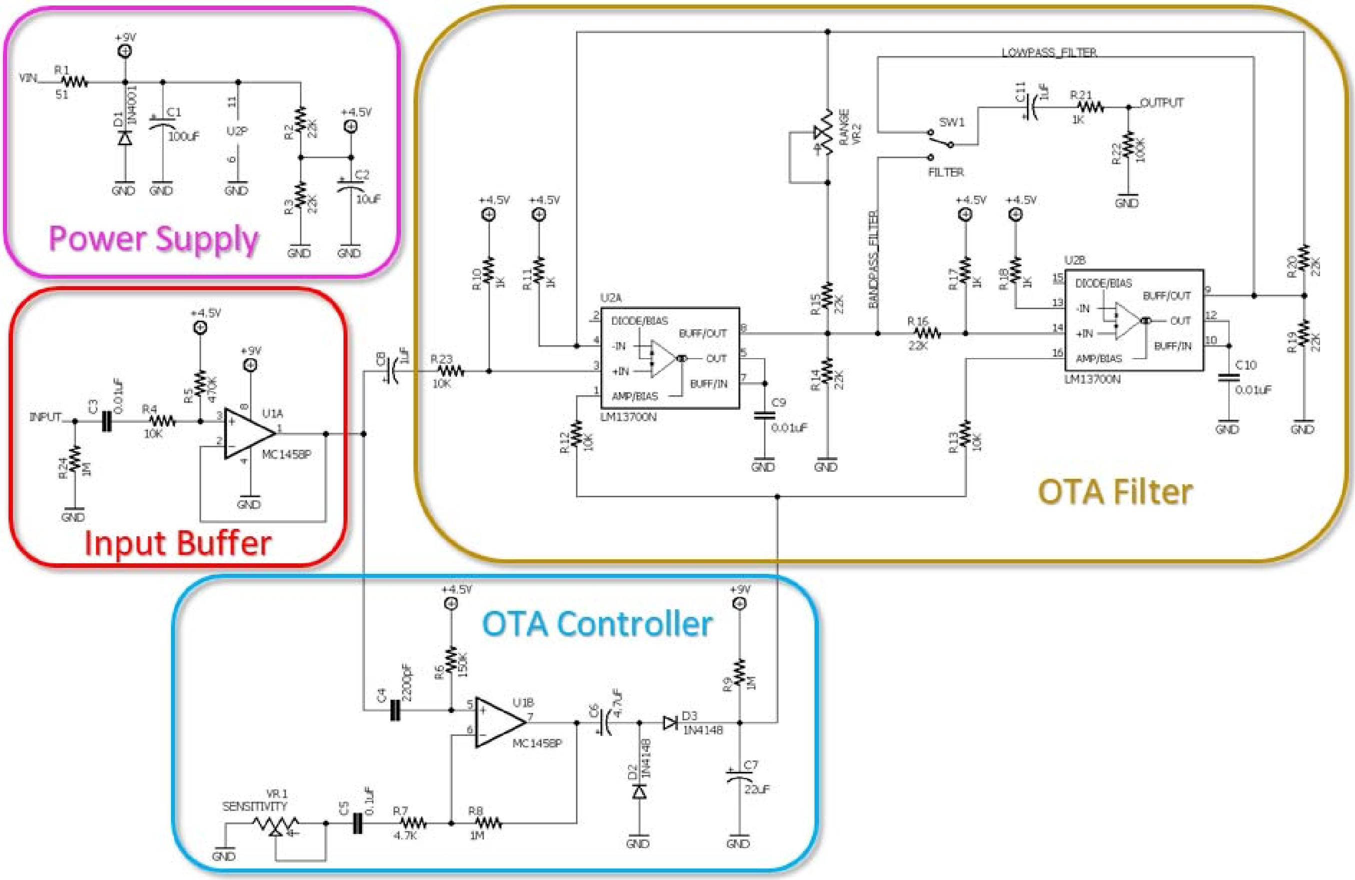
Pay close attention to the lugs of your sockets. Look at them side on so that you can distinguish the sockets individual layers. For instance the tip lug is connected to tip contact. The stereo jack looks the same as the socket below except it has an extra lug and contact for "Ring".



Funktastic Circuit Analysis for modifying purposes.

2. Funktastic Circuit.

The Funktastic schematic can be broken down into some simpler blocks: Power Supply, Input Buffer, OTA Controller, and OTA Filter.

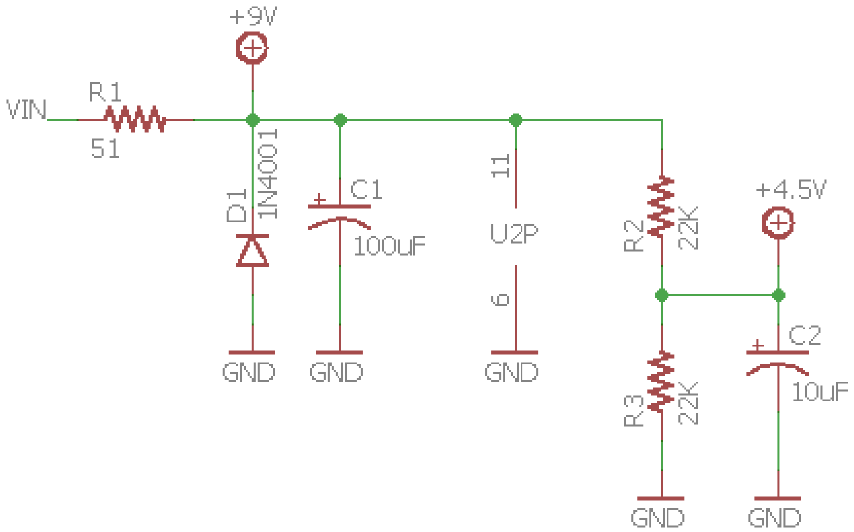


The circuit is designed around a State Variable Filter that is controlled by a Dual Operational Transconductance Amplifier, or OTA. The filter is made up of a band pass and low pass filter.

The input impedance on the Funktastic is close to 329K 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.

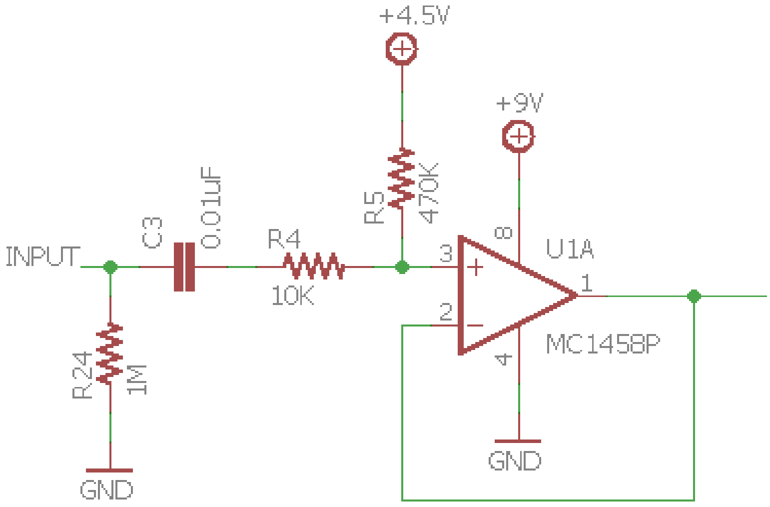
The Power Supply Stage provides the electrical power and bias voltage to all the circuitry, the whole power consumption is low and estimated around 3mA:



- The diode D1 protects the pedal against adapter reverse polarity connections.
- The R1 51 Ω resistor creates a small voltage drop from the input 9V power rail of around 120mV. It also creates a small RC filter with C1 removing high frequency noises above the 31 Hz range.
- The C1 100µF electrolytic capacitor is a bulk capacitor but also forms an RC filter with R1.
- The R2 and R3 22K Ω resistors form a voltage divider to provide a bias voltage (virtual ground) for the circuit
- The C2 10µF electrolytic capacitor is a decoupling capacitor between bias voltage and ground.

4. Input Buffer.

The first gain stage is made of a non-inverting op-amp amplifier used as a unity gain buffer.



- The 1MΩ R24 resistor from the input to ground is an anti-pop/bleeder resistor, it will avoid abrupt pop sounds when the effect is engaged.
- The 10nF film capacitor, C3, is an input coupling capacitor to block DC signal. It also forms an RC filter with R4 and R5.
- The 10KΩ R4 resistor is a current limiting resistor protecting the non-inverting pin on the op-amp.
- The 470KΩ R5 resistor is a bias resistor for U1A op-amp.
- The MC1458P op-amp is a dual op-amp known for being a "dual 741" op-amp. Any general op-amp could really be used here.

4.1 High Pass Filter.

The input buffer provides a bit of high pass filtering:

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

$fc = 1 / (2\pi \cdot (R_4 + R_5) \cdot C_3)$

$fc = 1 / (2\pi \cdot 480{,}000 \cdot 0.00000001)$

$fc = 33\ Hz$

4.2 Input Impedance.

The input impedance is defined by the formula:

$Zin = ((R_{24} \,||\, R_5) + R_4) \,||\, Z_{inMC1458}$

If you look up the datasheet for the MC1458, under the electrical characteristics, the input resistance is 200M

$Zin = ((1M \,||\, 470K) + 10K) \,||\, 200{,}000{,}000$

$Zin = (319{,}728 + 10K) \,||\, 200{,}000{,}000$

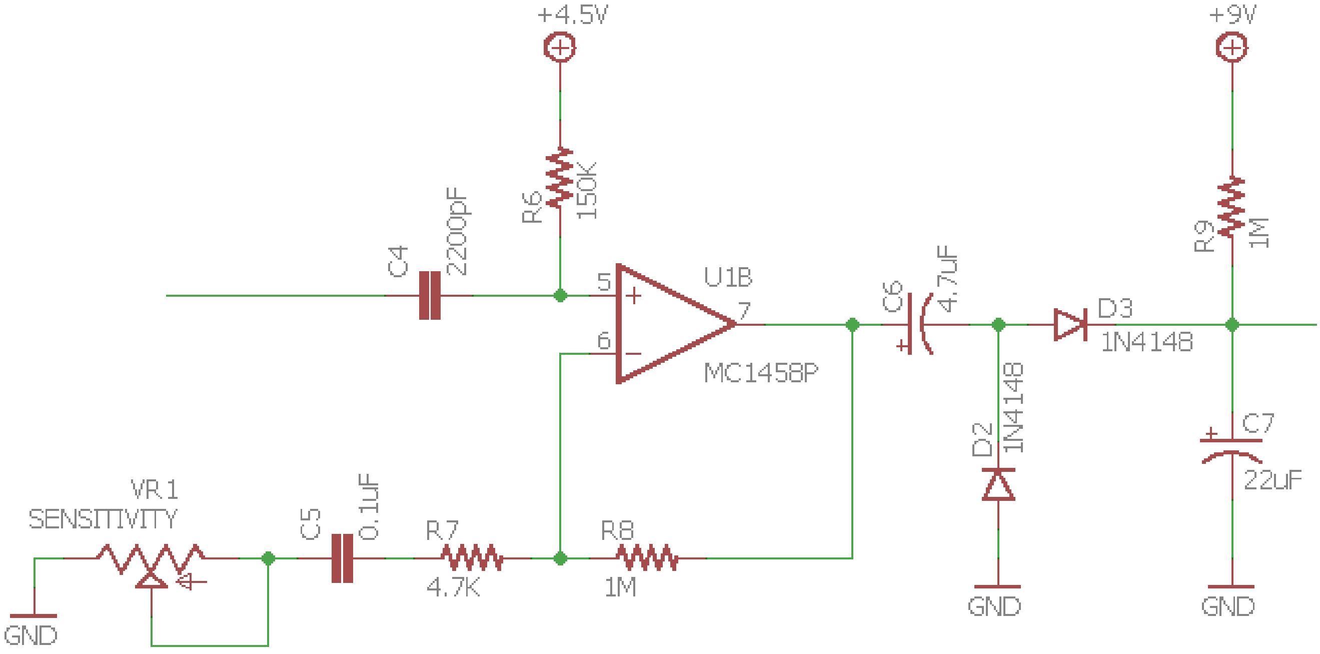
$Zin = 329{,}728 \,||\, 200{,}000{,}000$

$Zin = 329{,}185\Omega$

Therefore, the Funktastic input resistance is 329K, which isn't bad, but the closer to 1M it is, the better. Increasing R24 and R5 to 2.2M would bring the input resistance up to 1M, although that would also effect the input high pass filter (reduce C3 to a 2.2nF capacitor to resolve this).

5. OTA Controller.

The OTA Controller is setup as a gain stage, but not to effect the "sound" of the circuit, but rather to generate large enough current to control the OTA.



- The 2.2nF film capacitor, C4, is an input coupling capacitor to block DC signal. It also forms an RC filter with R6.
- The 150KΩ R6 resistor is a bias resistor for U1A op-amp.
- The MC1458P op-amp is a dual op-amp known for being a "dual 741" op-amp. Because this op-amp is "slow" it doesn't go into oscillation easily, which is desired here.
- The 1MΩ R8 resistor along with the 4.7KΩ R7 resistor and 100KΩ Sensitivity potentiometer, in the negative feedback loop of the op-amp, set the variable gain of this stage.
- The 100nF film capacitor, C5, is a filtering capacitor used to create a low pass filter with the amplified signal.
- The 4.7µF electrolytic capacitor, C6, is a coupling capacitor leaving the op-amp and going into a rectifier section.
- The D2 and D3 fast-switching diodes form a half bridge rectifier to generate a more "DC" signal out of the AC guitar signal.
- The 1M R9 resistor biases the rectified signal.
- The 22µF electrolytic capacitor, C7, is a decoupling capacitor for the rectified signal as well as a reservoir for the current driving the upcoming OTA Filters.

5.1 High Pass Incoming Filter

The input of this stage has a small high-pass filter blocking out a lot of the low frequencies before entering this stage:

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

$fc = 1 / (2\pi \cdot R_6 \cdot C_4)$

$fc = 1 / (2\pi \cdot 150{,}000 \cdot 0.0000000022)$

$fc = 482\ Hz$

5.2 Voltage Gain.

The voltage gain for this stage is calculated like a typical non-inverting op-amp, but is also frequency dependent based on the filtering.

$G_{vmin} = (R_8 / (R_7 + VR_{SENSITIVITY}))$

$G_{vmin} = (1{,}000{,}000 / (4{,}700 + 100{,}000))$

$G_{vmin} = (1{,}000{,}000 / 104{,}700) = 9.55\ (19.6dB)$

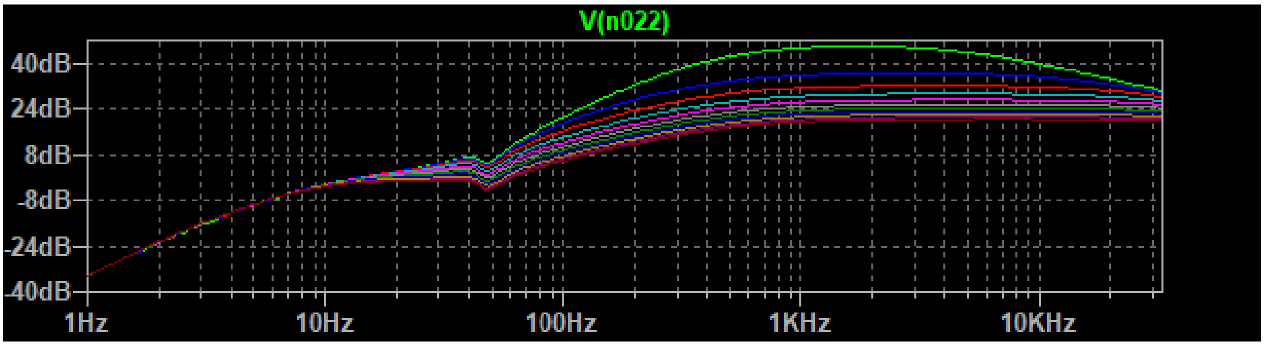
$G_{vmax} = (R_8 / (R_7 + VR_{SENSITIVITY}))$

$G_{vmax} = (1{,}000{,}000 / (4{,}700 + 0))$

$G_{vmax} = (1{,}000{,}000 / 104{,}700) = 212.77\ (46.6dB)$

5.3 Low Pass Feedback Filter

Due to the position of the variable resistor, the Sensitivity potentiometer, it is easier to demonstrate the RC filter curve via a simulation.

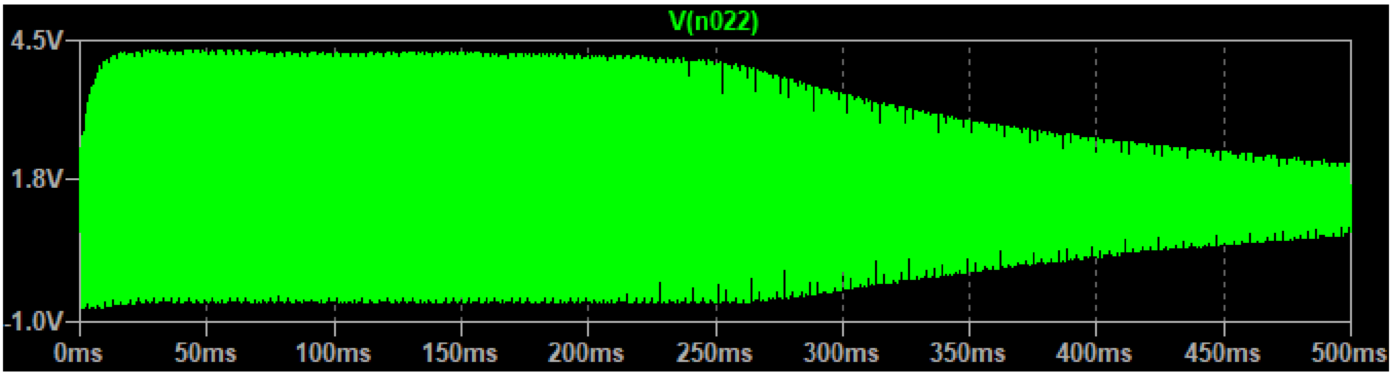


The green line is when the sensitivity pot is set to a near 0 ohm resistance, providing the highest gain at around the 2 KHz mark, but then filtering out the higher frequencies. As the sensitivity pot resistance increases, the gain at around 2 KHz begins to diminish and becomes more flat with the rest of the high frequencies. This is also due to the low pass filter moving higher up into the inaudible frequencies.

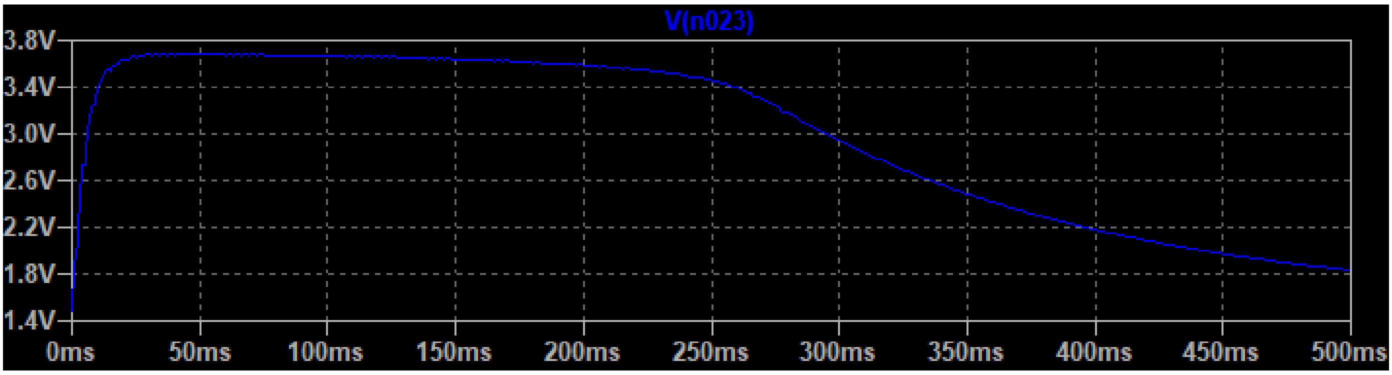
5.4 Half Bridge Rectifier.

Once the desired signal is created, we will take the high-side of the AC guitar signal and make a DC signal out of it.

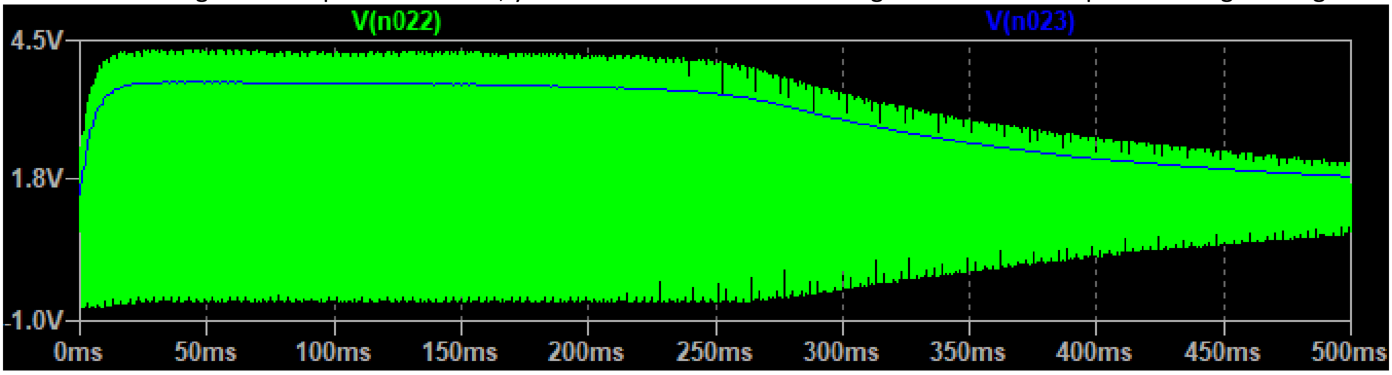
Right after the coupling capacitor C6, our signal looks like this:



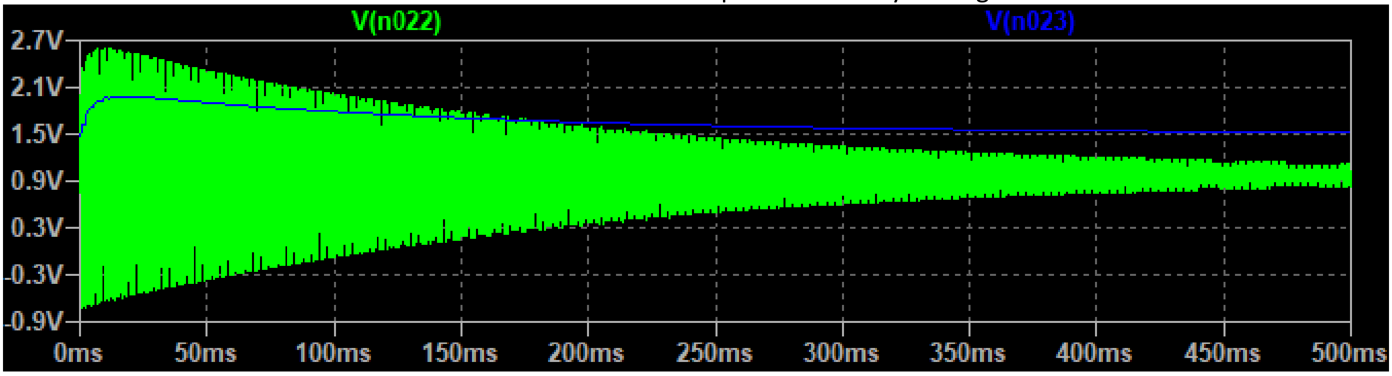
But after our signal passes beyond D2 and through D3, the bottom half of the wave is rectified out and is further smoothed out by the large C7 capacitor to look like this:



If we stack the signals on top of each other, you see how the DC rectified signal follows the top of the AC guitar signal.

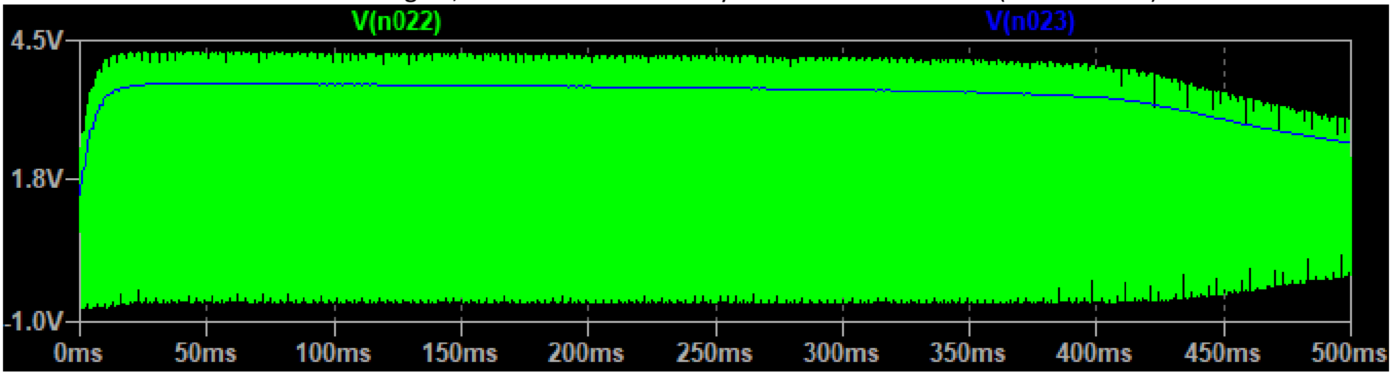


The previous wave form is a relatively loud chord with a bit of attack and the sensitivity knob is at noon, but how about the same chord that is less loud due to a lesser attack and keep the sensitivity settings?



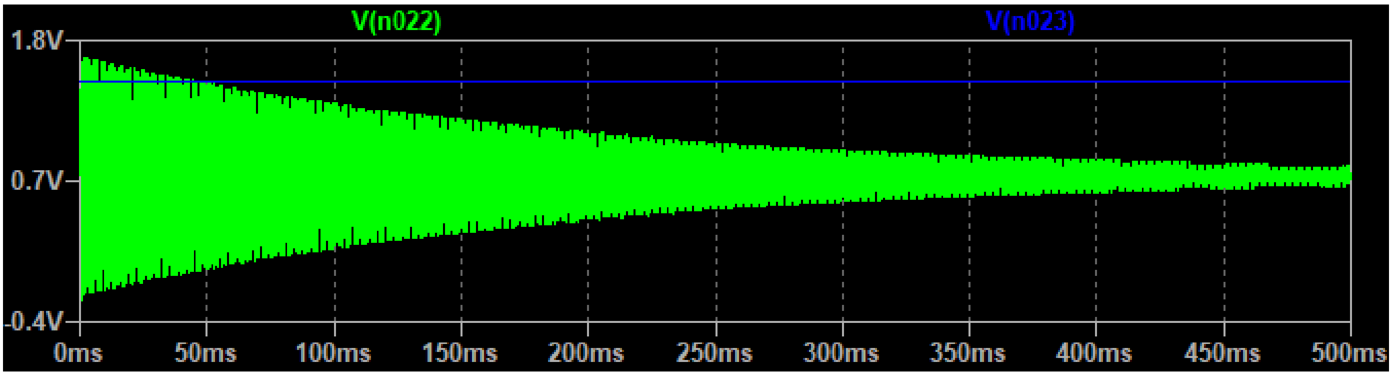
Notice how the DC signal is beginning to react differently once a lesser attack signal has a chance to ring out?

Now with the same lesser attack signal, but with the sensitivity knob set to maximum (near 0 ohms):



Now the once weaker attacked signal is amplified back up enough that the rectified signal keeps up for the duration of the note ringing out past 500ms.

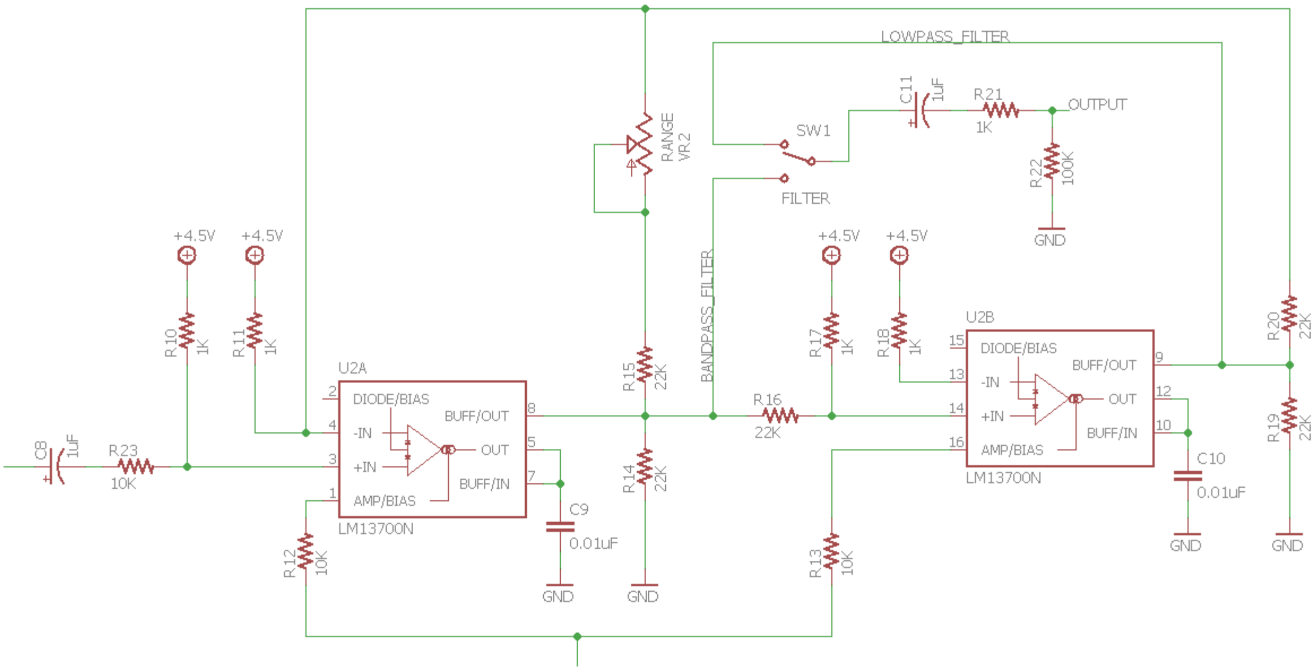
However, if we take that same weakly attacked signal and reduce the sensitivity knob (near 100K), our signal now looks like this:



Now the DC signal barely reacts at all with the signal ringing out.

6. OTA Filter.

The Funktastic, at the end of the day, is a state-variable filter, but achieves the variances with the filter by use of Operational Transconductance Amplifiers, or OTAs.



- The 1µF electrolytic capacitor, C8, is an input coupling capacitor to block DC signal. It also forms an RC filter with R23 and R10.
- The 10KΩ R23 resistor is a current limiting resistor which also forms a voltage divider with R10 into the non-inverting pin 3 of the OTA.
- The 1KΩ R10 resistor is a bias resistor which also forms a voltage divider with R23 into the non-inverting pin 3 of the OTA.
- The 1KΩ R11 resistor is a bias resistor which also forms a voltage divider with R20, R15 and Range pot, into the inverting pin 4 of the OTA.
- The 10K R12 resistor is the bias to the amp pin 1 of the OTA.
- The 22KΩ R16 resistor is a current limiting resistor which also forms a voltage divider with R17 into the non-inverting pin 14 of the OTA.
- The 1KΩ R17 resistor is a bias resistor which also forms a voltage divider with R16 into the non-inverting pin 3 of the OTA.
- The 1KΩ R18 resistor is a bias resistor going into the inverting pin 13 of the OTA.
- The 10K R13 resistor is the bias to the amp pin 16 of the OTA.
- The 22K resistors R14 and R19 are to evenly bias outputs of the OTA with resistors R15 and R20 respectively.
- The 10nF film capacitors C9 and C10 form RC filters with the OTA's varying resistances.
- The Filter switch determines if we get our output out of the band-pass OTA or low-pass OTA.
- The 1µF electrolytic capacitor, C11, is an output coupling capacitor to reject DC signal. It also forms an RC filter with R21 and R22.
- The 1K R21 forms an RC filter with C11.
- The 100K R22 resistor acts as a bleeder resistor for ground on the output of the pedal.
- The LM13700 is a dual operational transconductance amplifier.

6.1 High Pass Filter.

The input buffer provides a bit of high pass filtering:

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

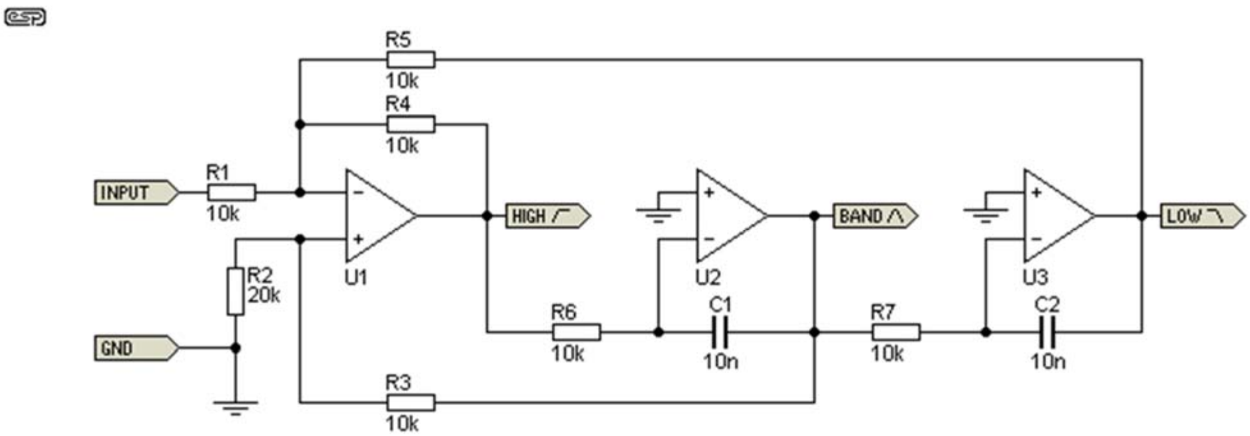
$fc = 1 / (2\pi \cdot (R_{23} + R_{10}) \cdot C_3)$

$fc = 1 / (2\pi \cdot 11{,}000 \cdot 0.000001)$

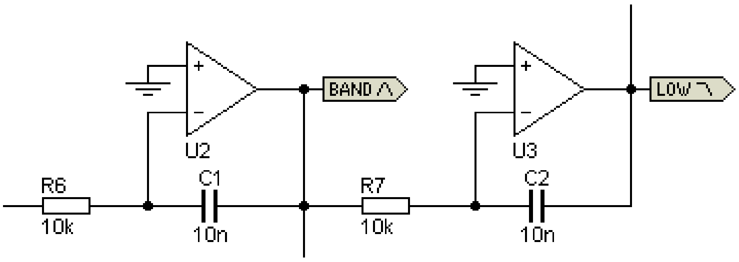
$fc = 14\ Hz$

6.2 State-Variable Filter

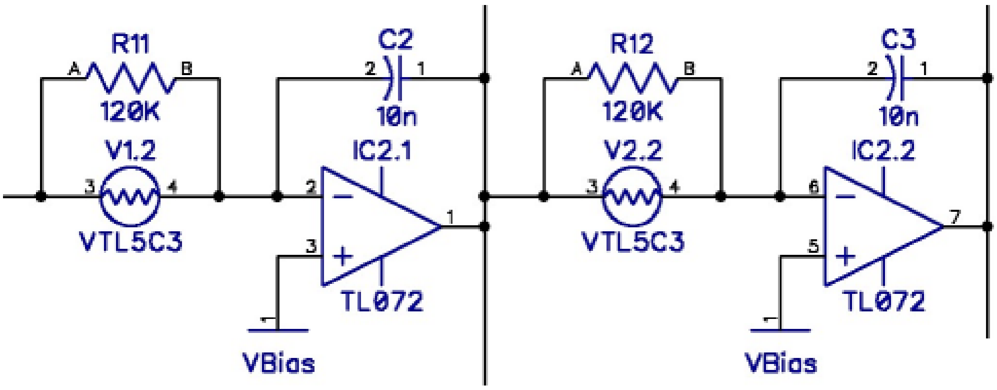
The basic building block for a state-variable filter is shown in the below figure. The first stage is the adder/ subtractor, which sums the outputs from the two integrators that follow. By varying resistor values, we can change the Q (bandwidth), gain and frequency.



The Funktastic lacks the mixer portion which would provide the high-pass piece. However, it utilizes the band-pass filter and low pass filters:



A simple way to vary the RC filtering is to make the resistors into vactrols, or Light Dependent Resistors that change resistance based on the current going through an LED, like below from Electric Druid's FilterFX:

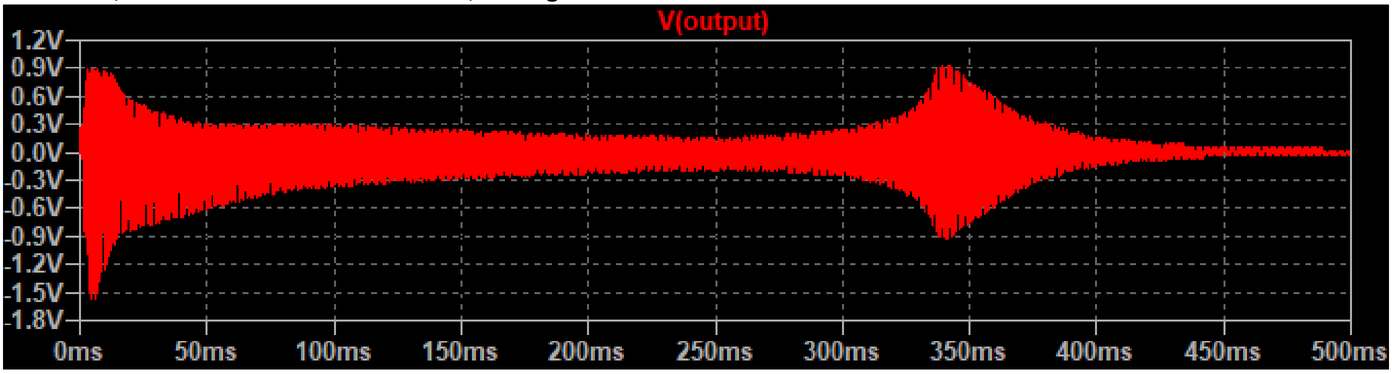


However, vactrols, though simpler, have wide tolerances, and usually require a builder to make their own, as factory made ones are almost no-longer made. So instead, we use an OTA to act as our "vactrol". We send the signal in, properly buffered from the input buffer, and "control the current of the vactrol" with the OTA controller section. This varies the resistance in the filters over time, based on the attack of the signal.

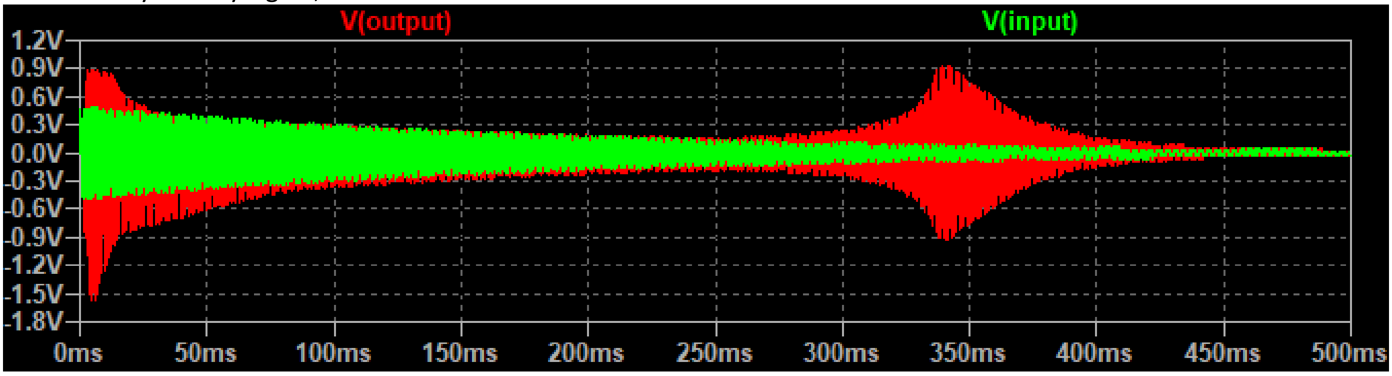
6.3 Range Control - Bandpass.

On the original DOD FX-25, the Range knob controlled the size of the Q, or the bulge on the signal

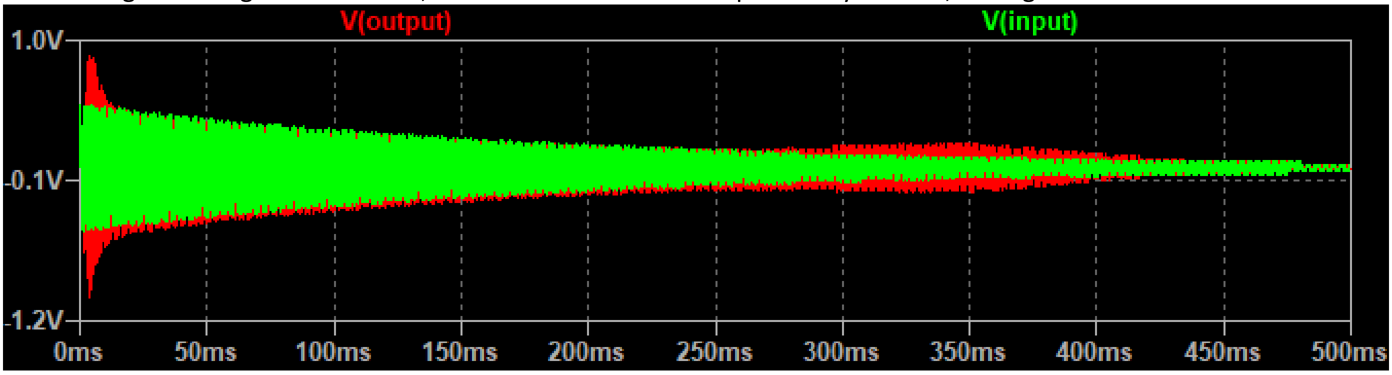
With the sensitivity at noon, and a well attacked, loud chord higher up on the neck (1 KHz), with the range set to minimum, for the full resistance of 100K, the signal looks like this:



If we overlay the dry signal, it looks like this:

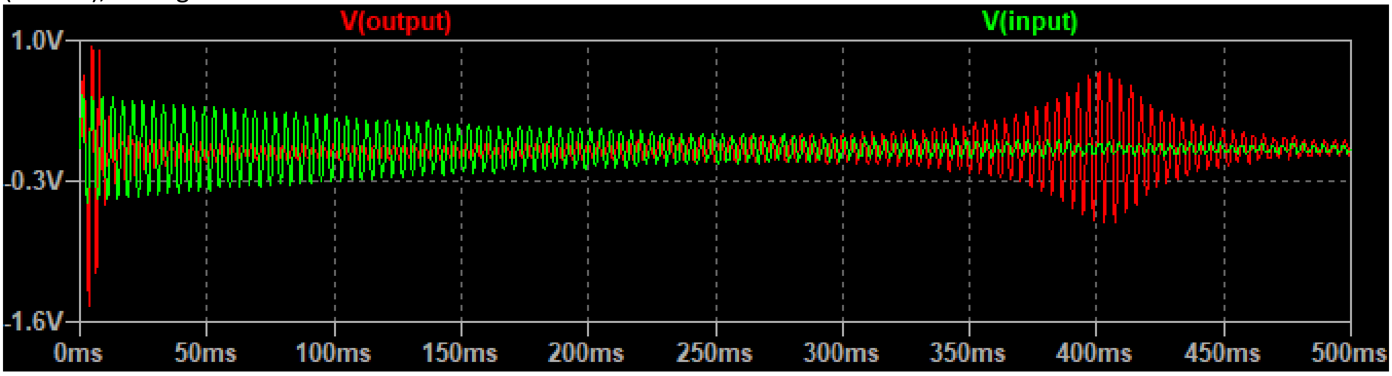


If we change the range to maximum, for the least resistance of practically 0 ohms, the signal looks like this:



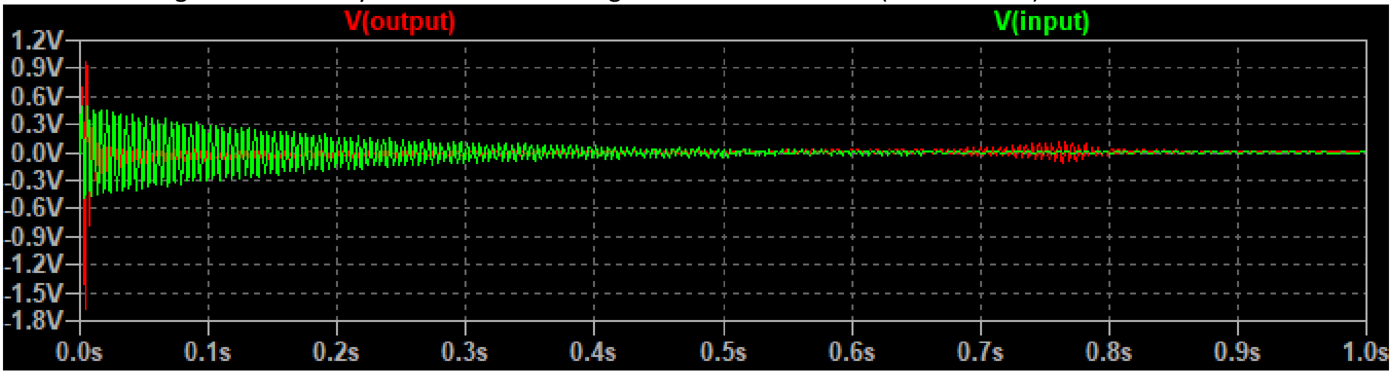
Note that the bulge still starts at around 275ms and ends at around 425ms, but is much flatter.

If we set the range back to minimum (100K), and keep everything else the same, but play a loud chord lower on the neck (250 Hz), the signal looks like this:



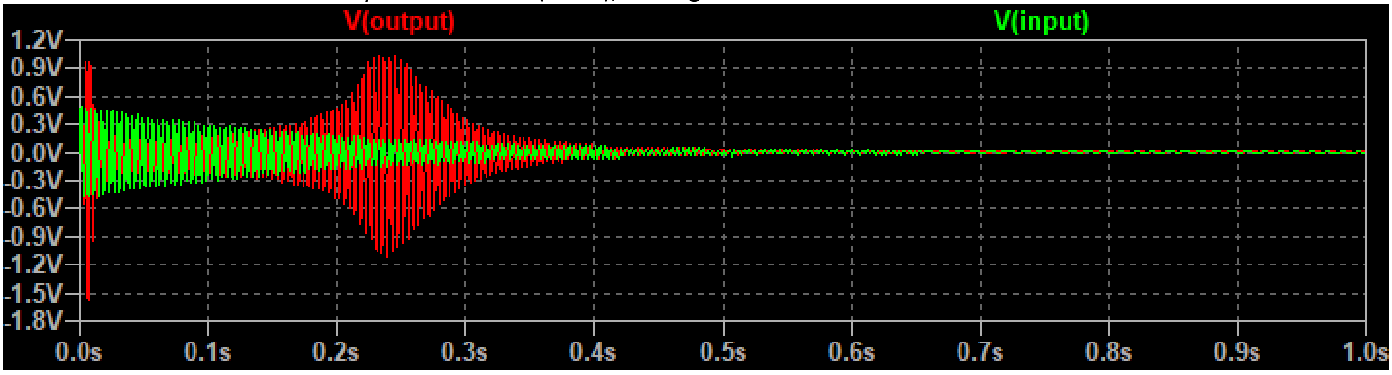
Note how the bulge of sound occurred later in its duration, at around 300ms to 450ms?

Now let's change the sensitivity knob on the same signal from noon to max (near 0 ohms)



Now the bulge is less pronounced and occurs much later in the duration of the signal between 700ms and 800ms.

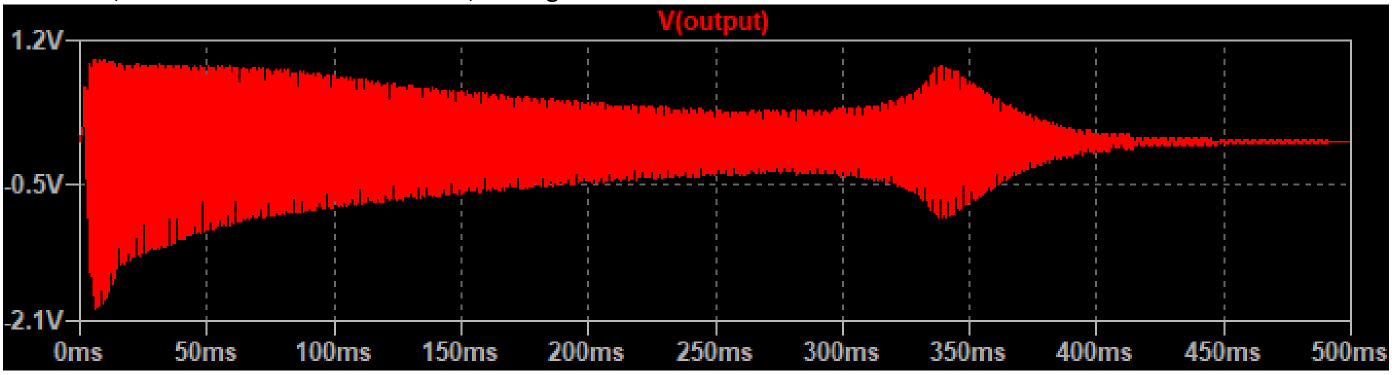
If we then reduce the sensitivity to almost off (100K), the signal looks like this:



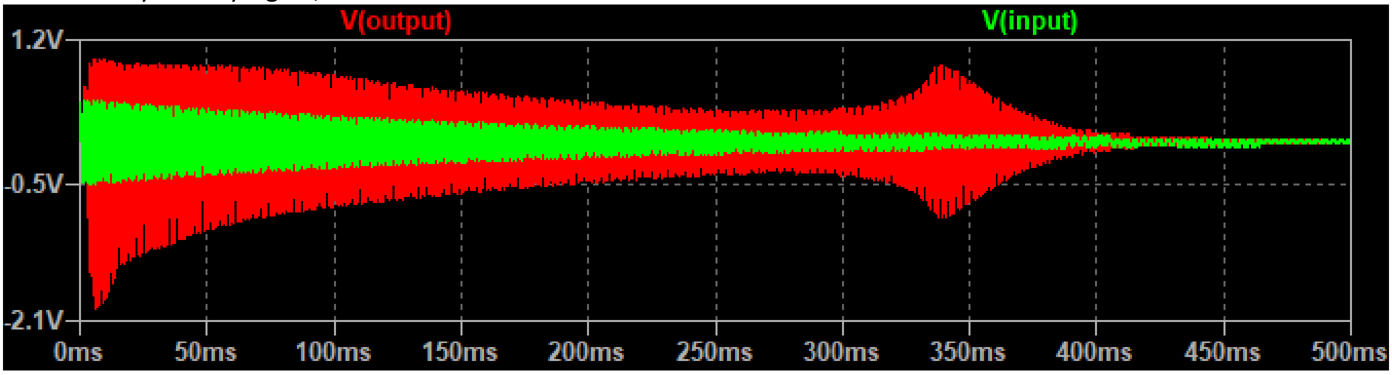
6.3 Range Control – Low Pass.

On the original DOD FX-25 did not include a low-pass output option, but by adding it, the signal becomes more bass heavy, which is desired for bass players and baritone guitarists.

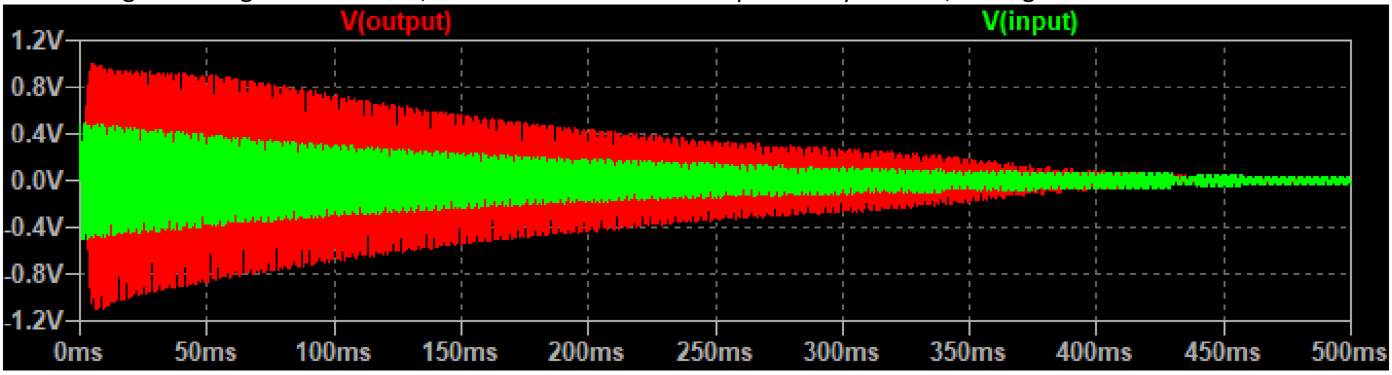
With the sensitivity at noon, and a well attacked, loud chord higher up on the neck (1 KHz), with the range set to minimum, for the full resistance of 100K, the signal looks like this:



If we overlay the dry signal, it looks like this:

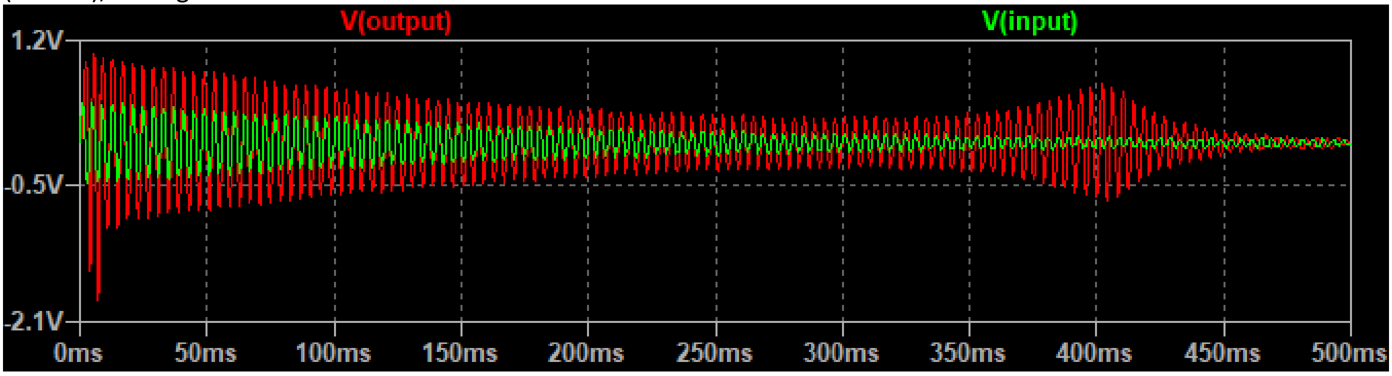


If we change the range to maximum, for the least resistance of practically 0 ohms, the signal looks like this:



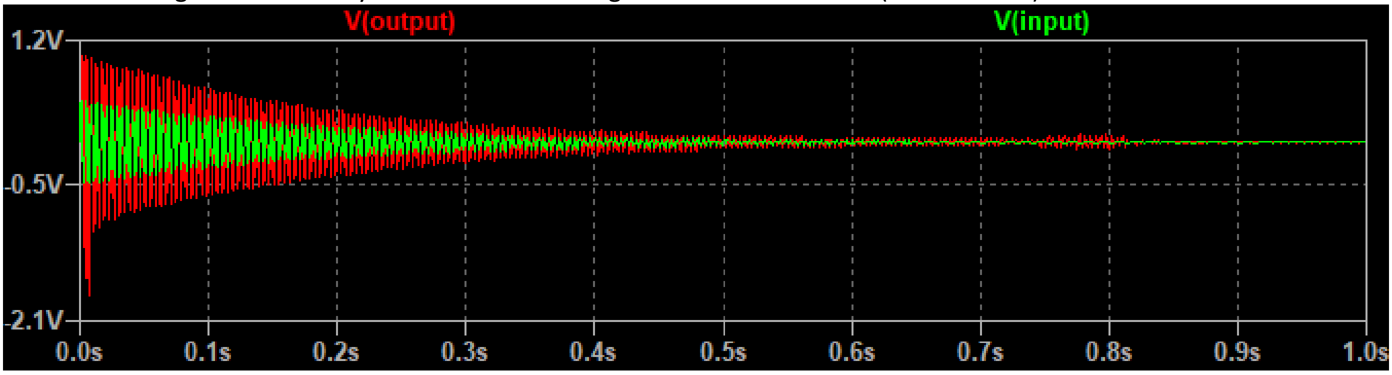
Note that the bulge has become tapered, creating a sloping response of an amplified low pass filter that decays over time.

If we set the range back to minimum (100K), and keep everything else the same, but play a loud chord lower on the neck (250 Hz), the signal looks like this:



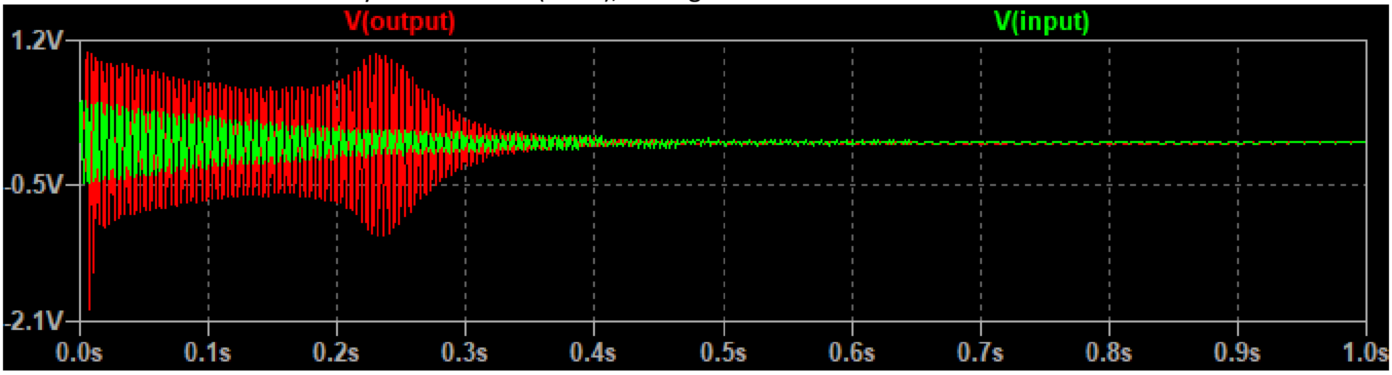
Note how the bulge of sound occurred later in its duration?

Now let's change the sensitivity knob on the same signal from noon to max (near 0 ohms)



Now the bulge is less pronounced and occurs much later in the duration of the signal between 700ms and 800ms.

If we then reduce the sensitivity to almost off (100K), the signal looks like this:

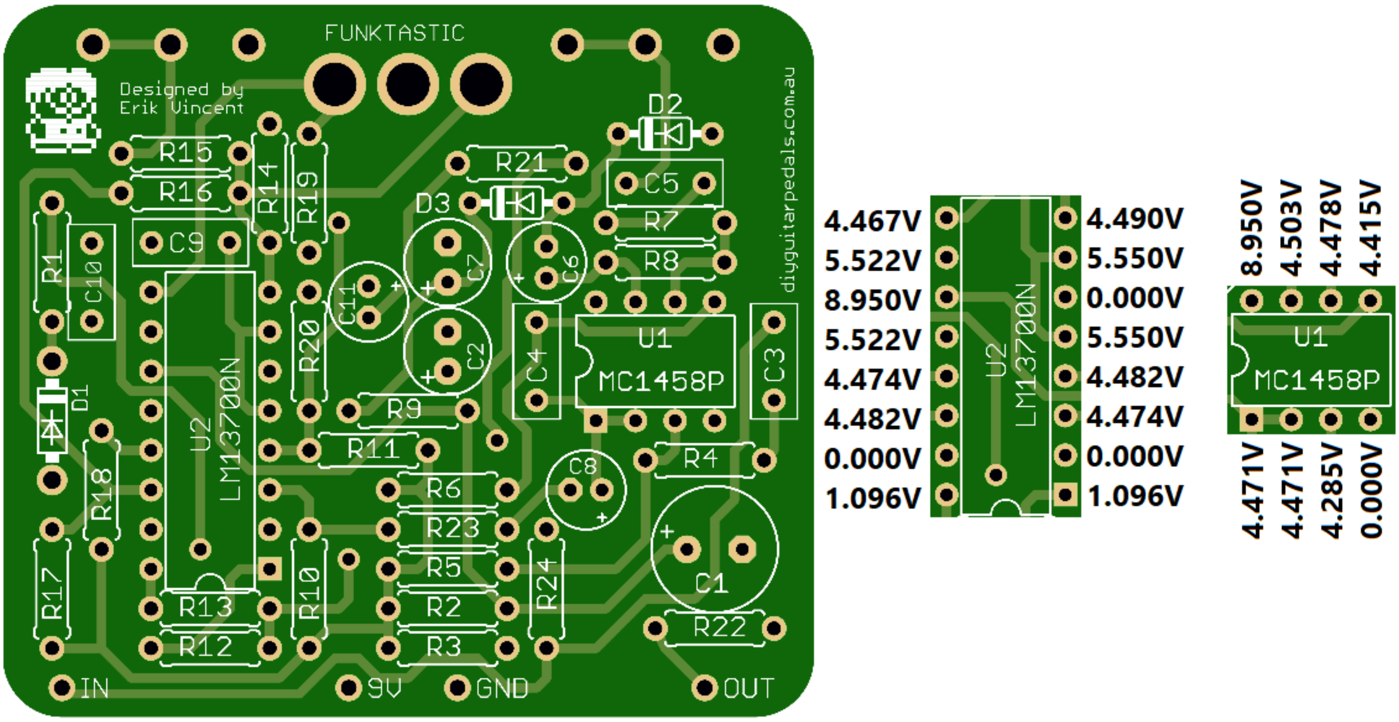


Basically, the Low Pass retains all of the bass content while the band pass removes the bass and treble content, keeping the mids intact.

7. Voltage Readouts.

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

IC read-outs



KNOBS

- SENSITIVITY: MAX
- RANGE: MAX
- SWITCH: LOW PASS

8. Modifications

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

8.1 Capacitors

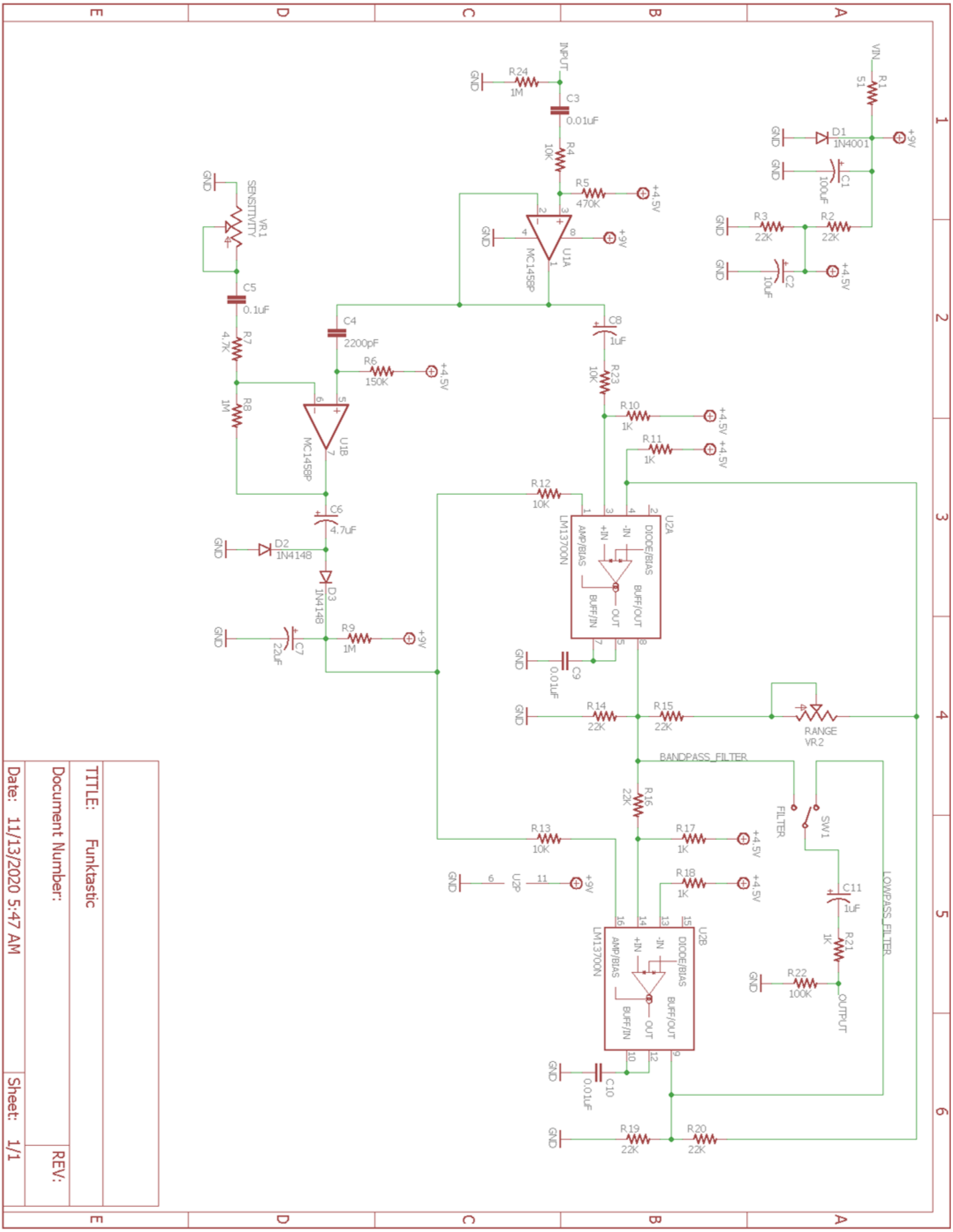
Decreasing C4 from 2.2nF to 1nF will increase the tightness of the sensitivity of the filter, meaning you will have to hit the strings harder to get the filter to engage, which may be desirable for guitarists, but not some much for bassists. Bassists may even wish to increase this up to 3.3nF for decreased sensitivity.

Increasing C9 and C10 from 10nF to 15nF will allow more bass to be filtered, while reducing C9 and C10 will increase the brightness.

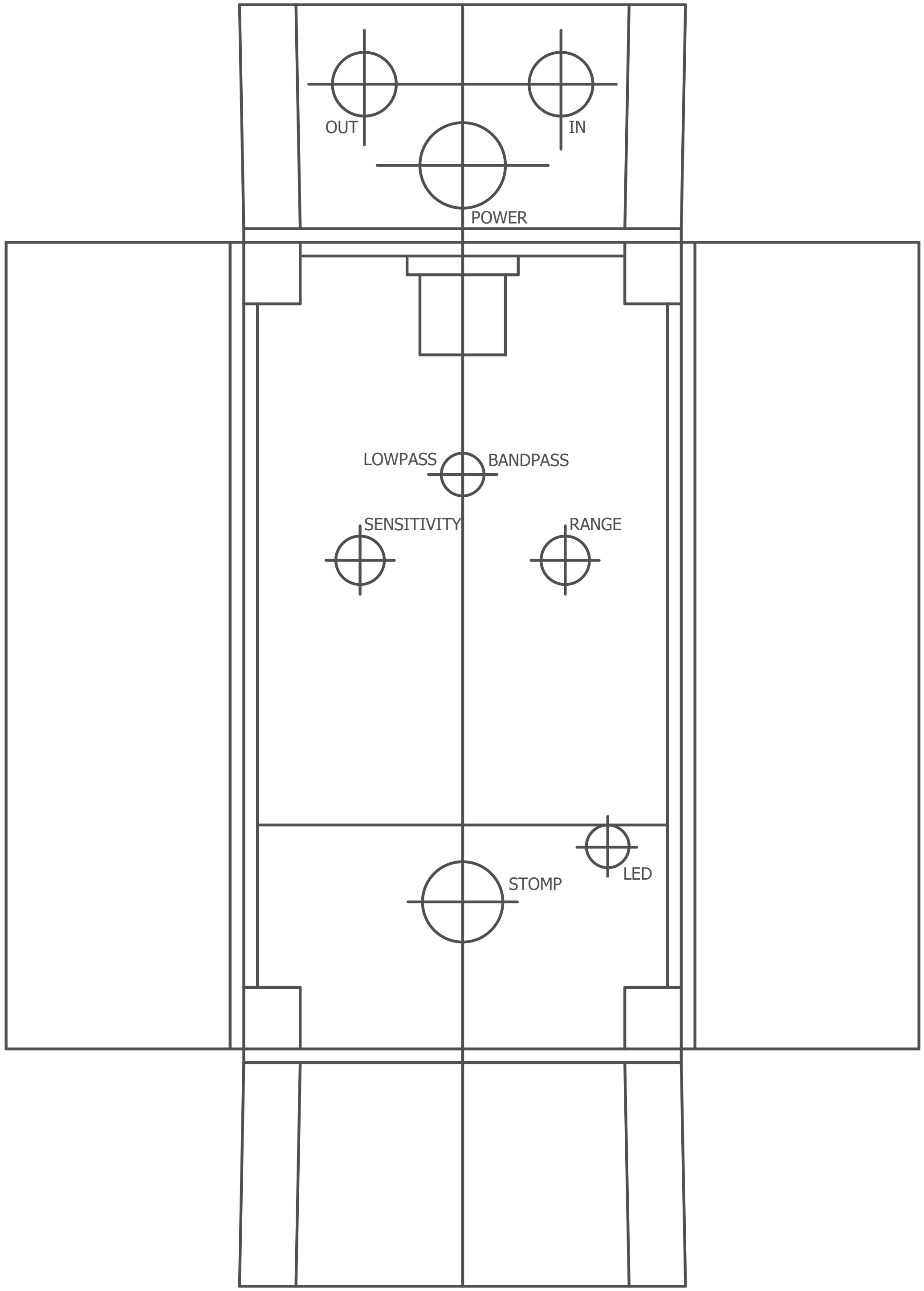
8.2 Op-Amps

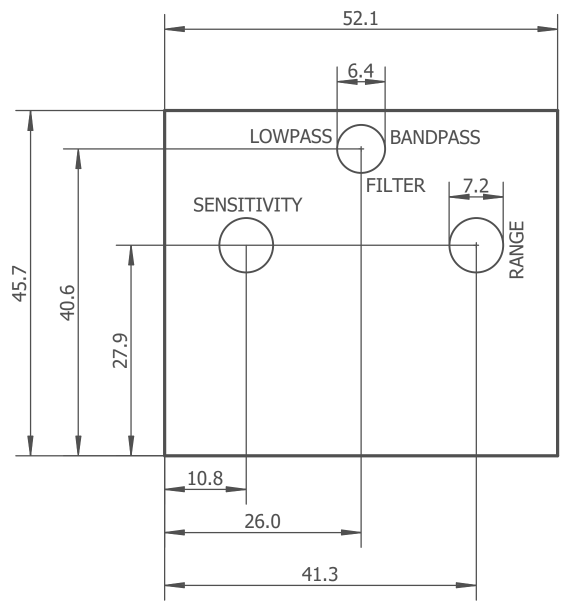
Changing the dual OpAmp will affect the buffering that occurs in the circuit. Using 4558's may improve treble response slightly in the sound.

9. Schematic



TITLE: Funktastic
Document Number:
REV:
Date: 11/13/2020 5:47 AM
Sheet: 1/1
INPUT
VIN
+9V
+4.5V
GND
R1 51
D1 1N4001
C1 100uF
R2 22K
R3 22K
C2 10uF
R24 1M
C3 0.01uF
R4 10K
R5 470K
U1A MC1458P
C4 2200pF
R6 150K
U1B MC1458P
VR1 SENSITIVITY
C5 0.1uF
R7 4.7K
R8 1M
C6 4.7uF
D2 1N4148
D3 1N4148
C7 22uF
R9 1M
C8 1uF
R23 10K
R10 1K
R11 1K
R12 10K
U2A LM13700N
C9 0.01uF
R14 22K
R15 22K
RANGE VR2
BANDPASS_FILTER
LOWPASS_FILTER
R16 22K
FILTER SW1
R13 10K
R17 1K
R18 1K
U2P
C11 1uF
R21 1K
R22 100K
OUTPUT
U2B LM13700N
C10 0.01uF
R19 22K
R20 22K


OUT
IN
POWER
LOWPASS
BANDPASS
SENSITIVITY
RANGE
LED
STOMP


52.1
6.4
LOWPASS
BANDPASS
FILTER
7.2
SENSITIVITY
RANGE
45.7
40.6
27.9
10.8
26.0
41.3