Advanced DIY Effect Pedals
How to Design, Customize, and Build Effect Pedals
Intermediate - Advanced Level

7-06
Reference # 7061a

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Disclaimers

Warning Disclaimer: These modifications and projects are recommended for persons over the age of 18. If you are under 18, you should have adult supervision before attempting modifications. Please use safety precautions when doing any of these types of projects, painting, using tools and soldering. We are not to be held responsible if you get hurt in any way, hurt someone else or destroy property. By reading this book beyond this page you hereby agree and you comply with the above statement and fully realize any risks that may be involved with performing any of the modifications listed. Always wear safety protection and follow safety guidelines and directions on products. Solder can pop in your eyes, burn skin, etc. Some materials used in guitar pedals can be harmful if inhaled. Paint fumes can kill you, and/or damage your lungs and cause other health problems. Batteries can explode acid on your skin and clothing. Never use any sort of drug while doing this type of work, including alcohol and/or prescription drugs which may inhibit your ability to do any of this type of projects**. USE PRECAUTIONS, READ DIRECTIONS AND ALWAYS WEAR SAFETY PROTECTION.**

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Huge thanks go to my family for putting up with me ;) , and everyone who helped contribute including but not limited to: Aron Nelson, Mark Hammer, RG Keen, Jack Orman, Andy Carroll of Dragonfly FX, JD Sleep, Steve at smallbearelec.com, Dirk Hendrik of www.dirk-hendrik.com , everyone at www.diypedals.com , www.diystompboxes.com , www.muzique.com, www.tonepad.com , www.geofex.com , www.smallbearelec.com , and www.generalguitargadgets.com

Who is Indyguitarist?

I've been playing guitar since I was 7. I'm 31 now. I distinctly remember how it happened...my brother was in a high school rock band, and they were practicing at our house one day. I was enamored by the guitarist...He had a Gibson Flying V, and they kept practicing the same song over and over..."don't tell me you love me" my Night Ranger. Sad but true! That is the point that started it all! My Grandparents were even in a band in their youth, and even received quite a bit of radio play in their day. So I guess in one way or another, I was bitten by the music bug genetically.

I always have been kind of a 'gear geek'...always trying different guitars/amps/effects to achieve certain sounds. It wasn't until 2001 or so when Paul Weller (FiremanFx) modified a pedal for me, and I was amazed at how much better it sounded. I immediately opened it up, wondering what he had done to make it sound so much better...

That is what sparked my interest in the Effects modification world...I had always been good with my hands and a quick learner, so I dove in head first and read, and read, and read some more. Then I bought several different effects and tested other's ideas, as well as my own. I was astonished at how one capacitor or resistor could make a pedal have much more bass/mids/treble/distortion/etc.

I actually holed myself up in my garage for about a month, replacing components in key areas, one at a time, and recorded the results on the first 'mod sheets'. These were just notes for myself to remember what I did, and what the change effected.

I did this one at a time, for every pedal I could get my hands on...each time recording the results, and recording the before and after tones from the pedal through the same setup.

I modified a few for the folks at Harmony-central effects forum, and the response was crazy...almost immediately I saw there was a demand for a service modifying pedals, even though a few were already doing it. Word of mouth grew quickly, and I started my website **"www.indyguitarist.com"**

Within about a year I was literally working 18 hour days, modifying pedals like crazy...even famous musicians were calling me asking me if it would 'be alright' for them to send me their pedals...some even invited me to come with them into the recording studio, so they could get the exact sound they were wanting...sort of an audio consultant...what an exciting time!!

The good thing is it hasn't slowed down -- in fact, its picked up quite a bit!! Nowadays I can turn on many radio stations and hear my pedals -- in fact my pedals are being played on most of the country songs you hear on country radio nowadays!

During the course of this time, I had so many emails pouring in asking how I did this or that, so I decided to sell my secrets... this was the beginning of my website **"http://www.guitartone.net/"**

Many many updates, new pedal modifications, and several years later, we now have several books on modifying pedals, videos on playing guitar better, videos on modifying and building pedals, and we are ALWAYS striving to be THE best at what we do. I feel the best way to do this is to provide the best possible products for the lowest possible price, and treat everyone, customer or not, famous or not, with the same respect I treat my family.

As of the middle of 2004, this is my full-time 'job'. I can't say 'job' really -- I love it, and its a huge passion! It's sort of like a paid vacation every day!!

I have a wife, one 5 year old boy (adopted as an infant from Russia), and another on the way (adopting an infant from Guatemala).

I play in a Southern Rock/Blues/Country band here in Indiana, as well as a Sunday Worship rock band at **Greenwood Christian Life Church** (www.gclife.com an ultra-hip, laid back, and very contemporary church) in Greenwood, Indiana.

Our view on the effect pedal world...

There is a disturbing trend that has been going on the past couple of years...I've noticed there are many 'builders' on the web who can build you an overdrive, distortion, or fuzz pedal that isn't much different from the next. I'll admit, many of them look very nice! Having played many of them, I don't understand just what they are offering that is different from the other thousands of builders trying to push their pedals on the web. Seriously -- aren't you tired of buying the 'latest and greatest' and then selling it months later when it just doesn't inspire you to play? Shouldn't EVERY pedal make you want to play more, create more, and do it with passion?

OF COURSE IT SHOULD!!!

That is my personal goal – It is my sincere intention to give you the knowledge necessary to modify and build your own effects in such a way that you are more inspired to play.

Enjoy the book! :)

Brian

between sets at a gig

Introduction

Thank you for your continued interest in my books – I appreciate it! While this book is shorter than some of my previous DIY books, it definitely isn't skimpy on tons of information explaining how to start designing and building your own effects. While my previous books were oriented towards someone with absolutely NO electronics experience, this book assumes you know how to solder, read schematics, and have already built a pedal or two from the previous book, “How to build effect pedals...for beginners”.

All these designs are for your use any way you see fit – commercial use or just for your own personal enjoyment. We have 'ready to go' circuit boards and parts kits available for most of these projects as well – simply email me to learn more: brian@indyguitarist.com OR visit www.IndyGuitarist.com/purchase.htm

It is my personal desire that you enjoy building these circuits as much as I have – I've built each and every one and they all sound wonderful!

Enjoy,
Brian

Circuit Breakdowns

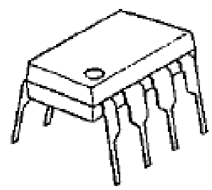
Effect pedals in general are using circuits that have been around forever, they are just using them in ways that cater to use for instruments. In overdrive/distortion/fuzz pedals, they are basically made from IC chips (audio amps and opamps), Bi-polar transistors, Fets, and sometimes tubes. Let's look at each a bit closer:

IC chips

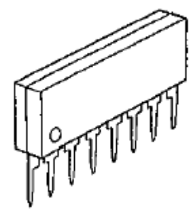
IC chips have many different uses. The ones we mainly use for gain/dirt type pedals are opamp or audio amps. Basically, the boost the signal and can clip (distort) when hooked up to form certain circuits.

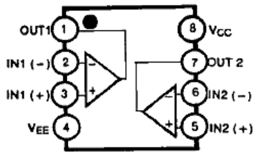
Shown here are two different types of housings that you will find them-DIP (on left) and SIP (inline chip on right)

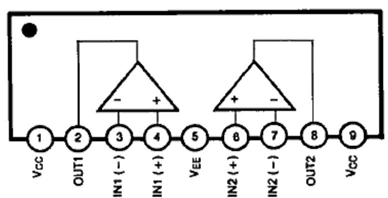
DIP



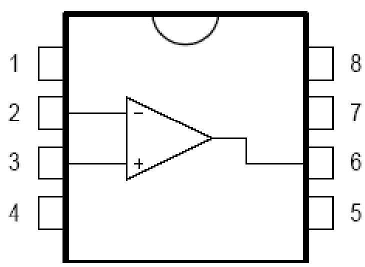
SIP







Looking at the top of the opamp, the pins are numbered as shown here.

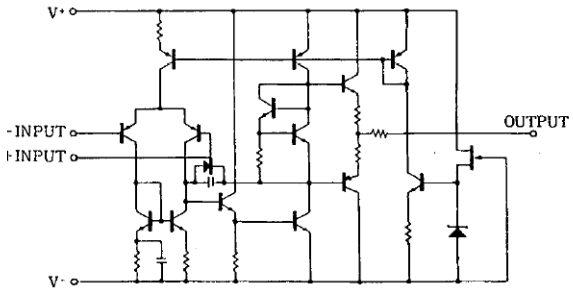


1 - Offset null 1
2 - Inverting input
3 - Non-inverting input
4 - V_{CC}^{-}
5 - Offset null 2
6 - Output
7 - V_{CC}^{+}
8 - N.C.

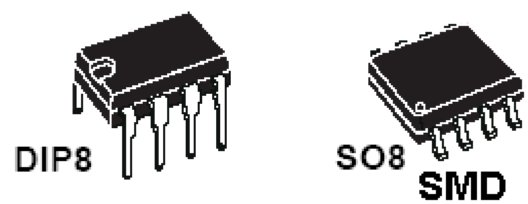
Single opamps look the same, but only contain one opamp circuit instead of two (more about this later).

The internal circuit looks similar to this:

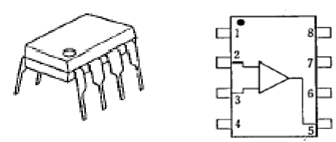
In a dual opamp, there are TWO of these circuits in it. In a single opamp, there are only one of these circuits in it.



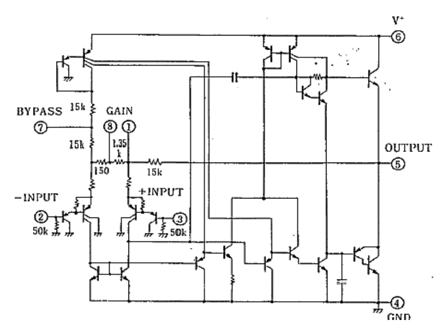
In addition, many of the newer pedals coming out by Boss, Danelectro, Digitech, and many other large companies are using 'SMD' components, or 'surface mount components'. This is because you can get a more intricate circuit in a tighter place (and inside a smaller housing) and it is less expensive to mass manufacture them this way. They look similar, but are smaller.



Audio amplifiers, such as the 386 type IC chip, look the same physically but the circuit inside is different. Also, these small IC's can be made into a small practice amp. In fact, many “boutique” builders are starting to build small amps using this chip. It CAN, in fact, be used in distortion, overdrive, and fuzz pedals though with excellent results.



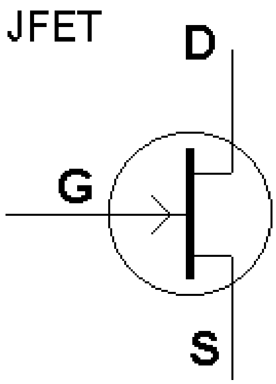
The 386-type chips have a circuit internally that looks like this:

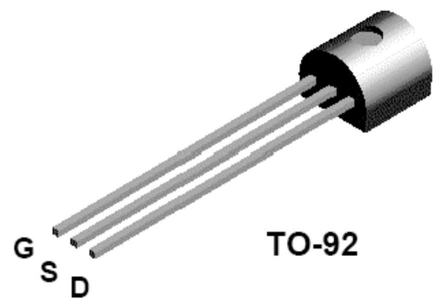


FETS and “Bi-polar” transistors

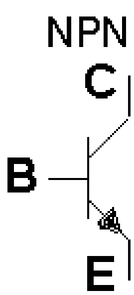
What is the difference between Fet's and transistors anyway?
A FET stands for Field Effect Transistor, and work different internally than bipolar transistors do. There are also two types of bipolar transistors, PNP AND NPN. The type of transistor noted in each schematic will dictate what type of FET or transistor is to be used.

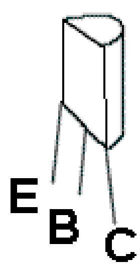
JFETs have three connections – the 'gate', 'drain', and 'source' – to form the “pinout”. Connection diagrams later in this book will show you about connecting them in a circuit. Also, you'll need to check with the supplier of your parts – sometimes different manufacturers will have different pinouts for the same part. This is true of each different transistor or FET.



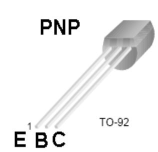


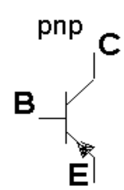
NPN Transistors





PNP Transistors

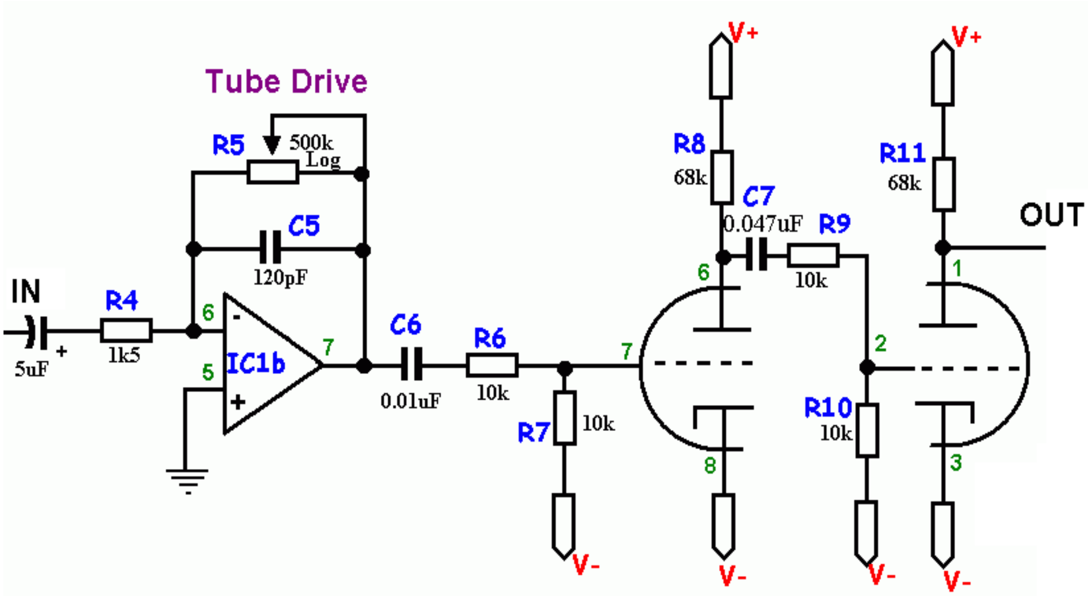




Lastly, let's take a quick look at tubes.

I am generally not in favor of tubes in pedals simply because instead of pumping high voltage through them like an amp does, most circuits involving tubes will either pump just a little bit of voltage making the tube “starve” and therefore clip in a very fuzzy fashion, use the tube as a clipping diode, or do all the distorting in a traditional circuit and then put a tube on the end as a buffer which then acts as a low pass filter.

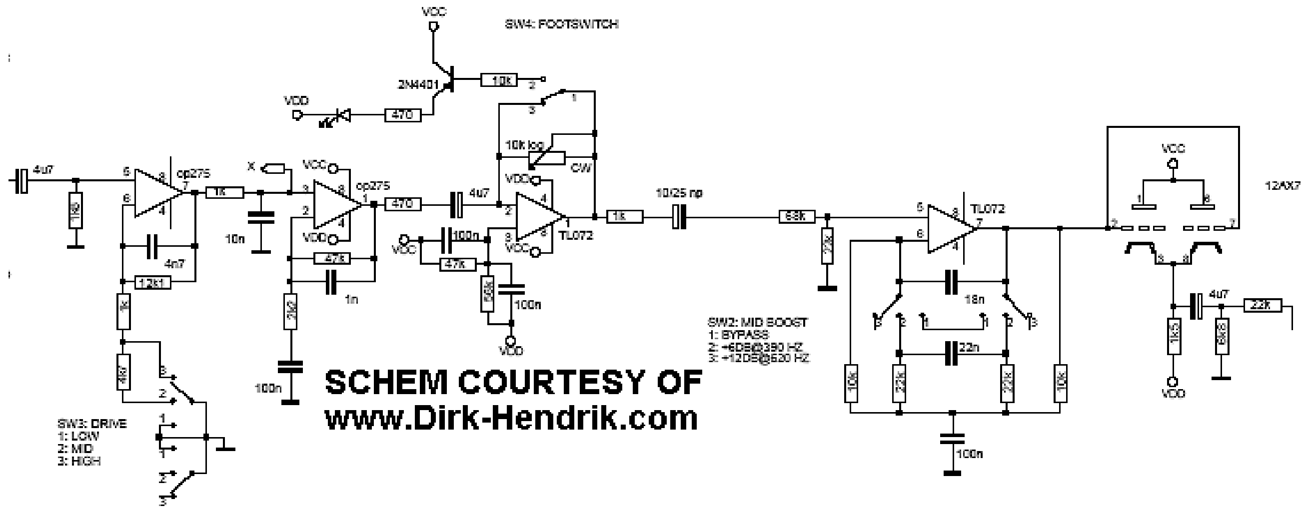
An amp circuit that is using tubes in a high voltage fashion actually looks more similar to a JFET circuit (we'll discuss this later in this book). Each stage is boosted and clipped via the tubes. Then, the preamp signal is sent through the Phase Invertor and Power amp stage which clips further and boosts the signal to the transformer, which then drives a speaker. So, in reality a tube amp design is COMPLETELY different than what you'll find with a tube based distortion pedal.



SCHEM COURTESY OF GeneralGuitarGadgets.com

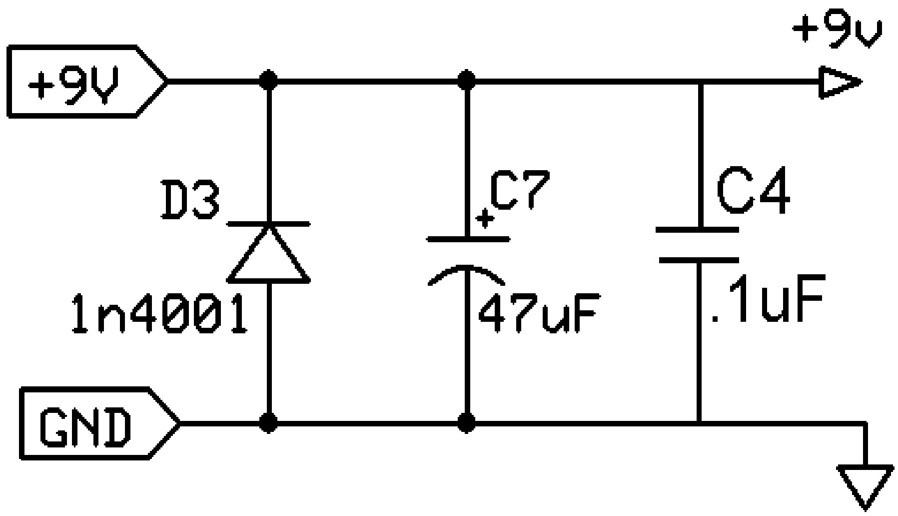
This is part of the “tube driver” schematic. The gain is set in C5 via a traditional opamp. The signal then goes through the tubes which are being voltage-starved, creating fuzzy distortion.

Another popular tube based pedal, the ToneBone Classic, uses the tubes as a buffer which simply colors the signal a bit. That circuit looks like this:



As you can see, there are plenty of opamps providing clipping as well as EQ tailoring. The 12ax7 is on the right with a 22k leading to the next EQ stage (other stages not shown).

Power Supply Filtering



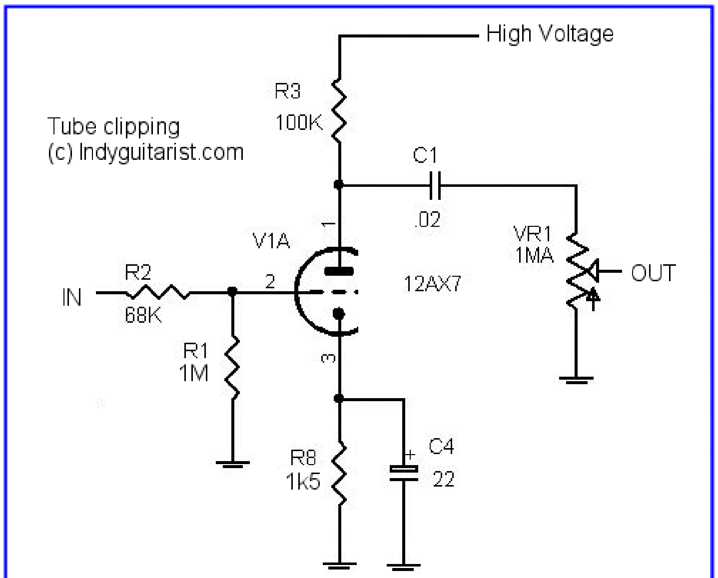
On all circuits there is a small portion dedicated to power supply filtering. Power can actually contribute a bit of noise depending on the power supply used to power one's pedals. To counteract this, we insert the circuit shown above into the power section. Notice that the horizontal line at the top represents 9vdc + and the horizontal line on the bottom represents 0 volts, or 'ground'.

D3 protects against connecting the wrong type of power supply, C7 and C4 filter out noise. Pretty simple actually. Not all schematics show this, but in the electronics world it is assumed that you already know this...unfortunately these type of assumptions exist too often in the electronics world and it is my goal to help bring you to the point where you understand these little intricacies.

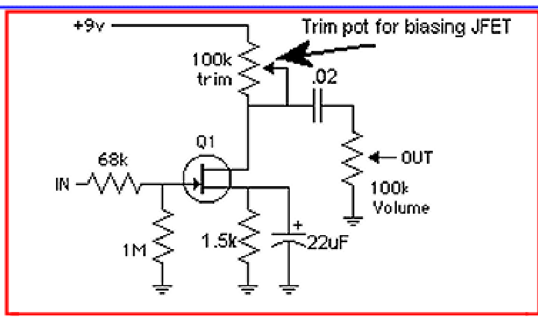
JFET

A website called “Run Off Groove” (www.runoffgroove.com) made popular the idea that a person can emulate a tube amp circuit by copying the schematic of a given tube circuit and simply replacing the tubes with JFETs. This is very cool because you can get reasonably close to the sounds of expensive amps simply by building an inexpensive pedal.

For example, a basic tube clipping circuit like the ones used by various manufacturers might look like the image below. Notice that the same circuit that has the JFET’s already substituted is directly below. Notice the similarities. The voltage requirements are different, the sound isn’t identical, but fairly close. Even more, the JFET circuits sound different than opamp based circuits. Not better, just different.



Tube Clipping circuit compared to JFET clipping circuit. For more gain, add another clipping circuit after the .022uF cap.



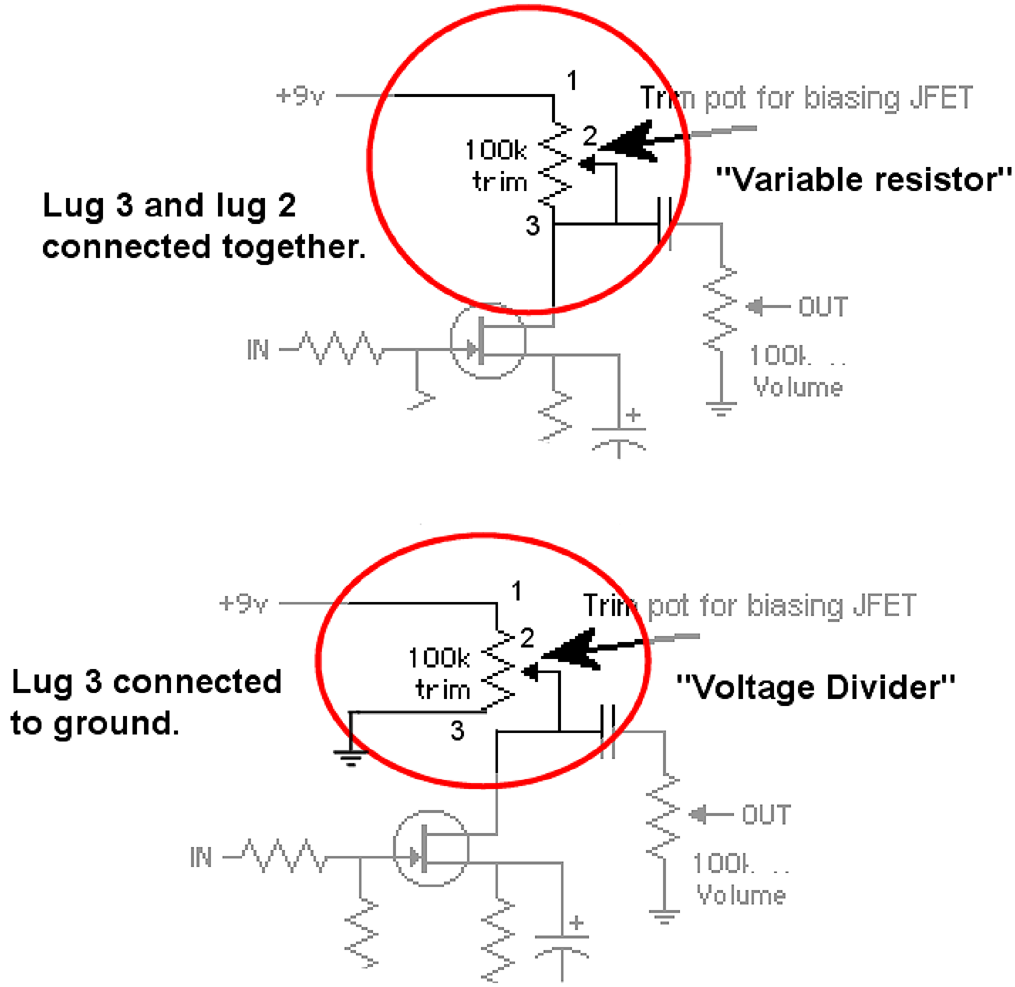
JFET clipping circuit, emulating a tube clipping circuit

HOWEVER, the more elaborate the JFET circuit, the harder it can be to bias everything just right. If it is unbiased, it will tend to sound very compressed, mushy, and ‘splatty’ until it is tweaked just right.

When we speak of “bias” on a JFET we are speaking of the amount of voltage going to the “drain “ pin of the JFET. A misbiased transistor sounds splatty, sputtery, compressed, and usually just plain bad. A properly biased transistor is working and sounding like it is intended to.

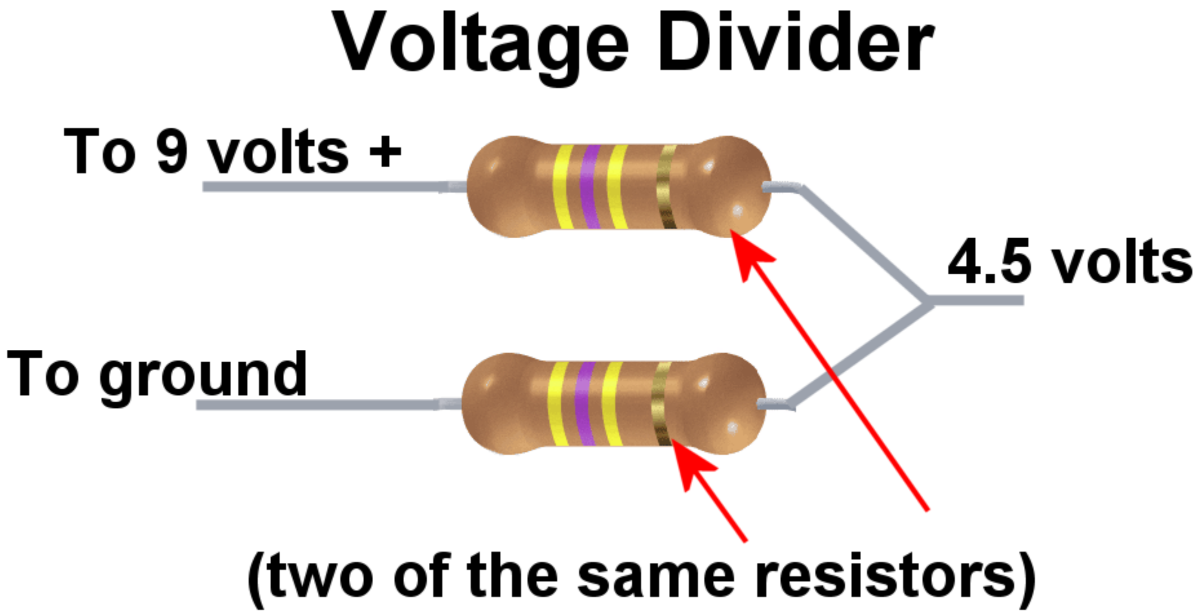
Like tubes, JFETs are depletion devices. They conduct heavily with no bias on the gate/grid, and you have to pull the gate/grid negative to turn them off. However, they do not have the exact same characteristics though many folks believe that they sound, feel and *react* very similarly.

Two methods for connecting power to Transistor



Notice that the top image is using a variable resistor method of reducing power to the transistor. The bottom image is how I like to do it. It is using the “voltage divider” method. No difference as far we are concerned here, they both will divide the power down to your required voltage as long as there is a resistor from the “source” pin to ground (we’ll get more into that in just a minute).

This may help you a bit. Let's say you have a 9 volt supply and you only need 4.5 volts. Using a Voltage divider, you could use two like resistors, one from the positive side, One from the negative side, and make the other ends of the resistors 'meet'. Here is a diagram that may help to show what I mean:

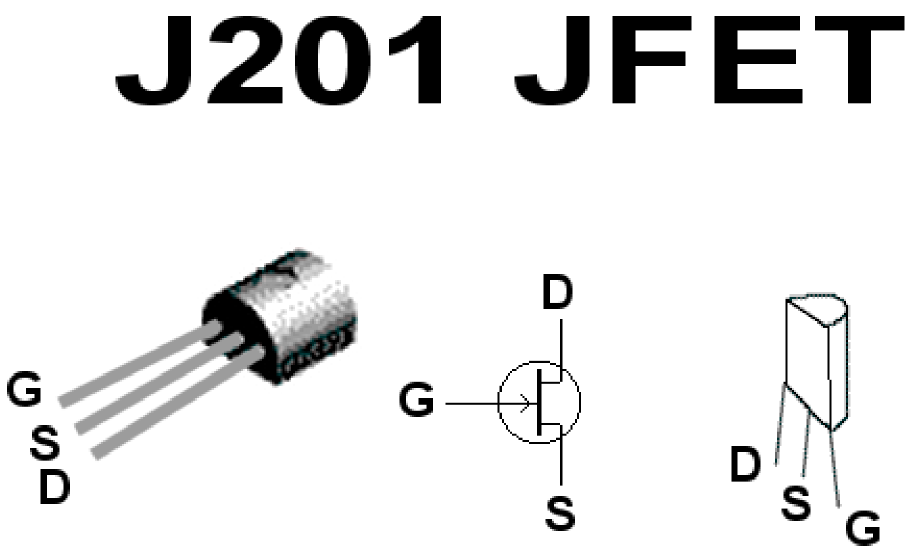


Likewise, if you have a "hot" signal, you can use this method to divide the signal in half, which is extremely useful so you don't make a following clipping stage clip **too** much, as well as making a pedal more usable if it is too loud.

This diagram is the exact same as having a linear taper pot which is set in the middle and which has lug 1 going to 9 volts positive, lug 3 going to ground, and the middle lug will measure 4.5 volts.

There are three legs on a JFET: Drain, Gate, and Source. If you want detailed explanations of how they work and why they work, there are excellent online documents that will teach you all the gruesome boring details. However, these details won’t help you sound better, play better, build a better pedal, or even win friends and influence people so I’m not going into the details on that.

For the J201 JFET, here is the pinout:

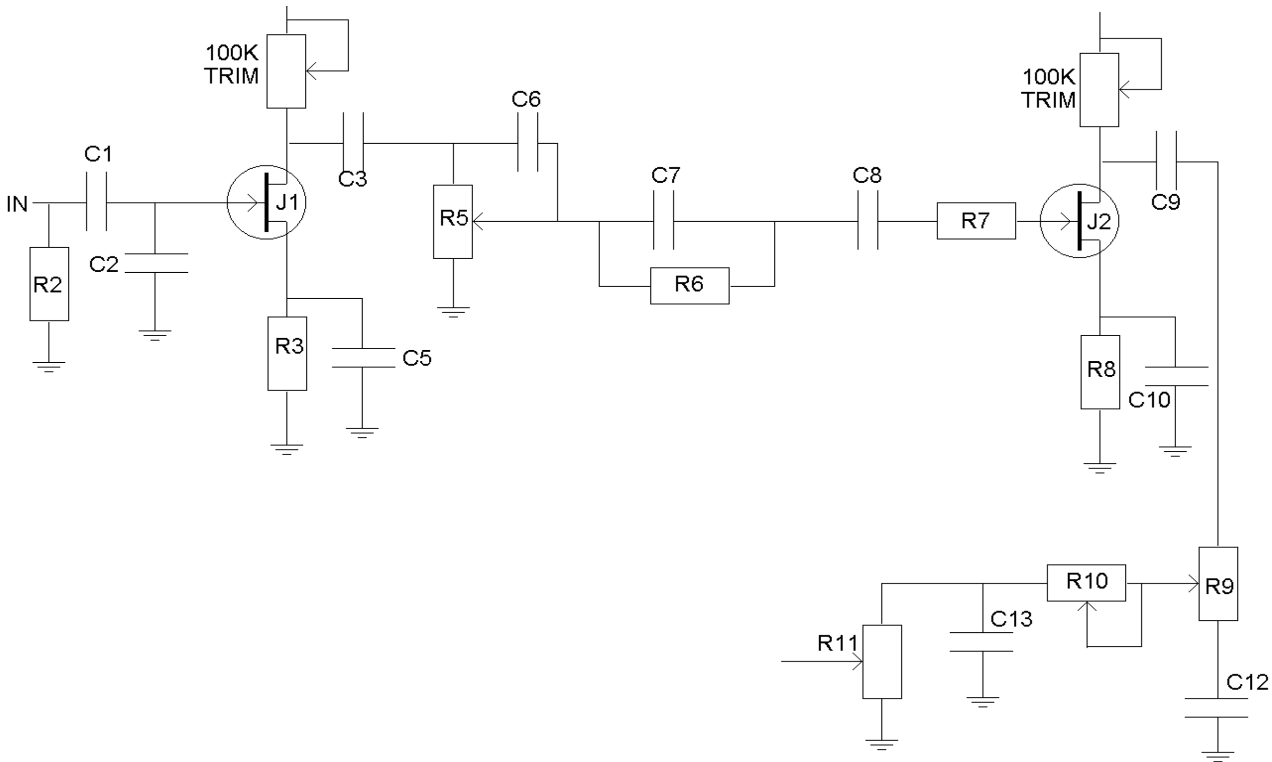


The middle image is what it looks like on a schematic. The other two images simply show what the transistor looks like in relation to it’s legs and their respective pinout.

One would think that every JFET, mosfet, and other transistors would all have the same pinout, wouldn’t they? Ah, but that would be too easy. For some reason, brilliant minds at some point in time decided that even the same part from the same manufacturer should have the freedom to choose whatever pinout it would like to follow, so you will need to find the datasheet for your brand of JFET. Usually the J201 is as pictured above though. If you buy the part from Mouser (for example), go to their website, type in the part number and you will see the link for the datasheet right there. You can sometimes google for ‘transistor datasheet’, j201 (or substitution) datasheet or something like that.

See the following circuit for a great overdrive circuit using JFETs.

Smooth Overdrive with JFETS



This is a great sounding circuit using JFETS (J201s) to emulate a tube-like feel and sound. C1 is the input cap. C2 is a low pass filter, filtering RF (Radio Frequency) as well as a bit of pre-clipping EQ. R2 is the resistor that stops the switching from popping when clicked on and off (you'll see this throughout – if a drawing doesn't show a resistor here in the 1m-4.7m range then just assume one should be there). J1 is the first clipping stage.

R3 and C5 set the gain. The 100k trim pots are for bias reasons of course. C3 is the output cap for this stage before it heads into a voltage divider – basically a volume pot between stages. This will act just as a gain pot will on an amp, so we'll label this a 'gain' control. C6 allows the pedal to clean up without getting muddy when you turn the gain control down. C7 and R6 are connected in parallel to form a high pass filter which sets the frequencies that will get clipped in the next clipping stage, J2. C8 and R7 can be omitted if you desire – I have them here for possible mods later, such as a low pass filter if one desires, or even a bass control. In fact, if you wanted a bass control, simply make C7 a 400-600pf, R6 would be a potentiometer (wired like you see on R10) with the value of 500k or so. This will have a lot of sweep on one end, so you may want to connect a 100k pot in series with a 400k ohm (or so) resistor which will have the same effect but be more tweakable. This resistor/pot combination would go in PLACE of R6.

If you wanted a low pass filter before J2, simply connect a capacitor from in between R7 and J2, and connect the other end to ground.

For J2, R8 and C10 set the gain once again, C9 is the output cap before going to the tone control, R9. C12 is the cap that controls the frequencies of the tonestack. R10 can be a trim pot if desired – this will tailor the eq of the pedal and is in effect another low pass filter. R11 is the volume pot.

C1: .001uF
C2: 100pf - .001uF
C3: .047uF
C5: 10uF to 47uF
C6: 200pf
C7: 470pf
C8: .022
C9: 1uF
C10: 22uF – 47uF
C12: .022uF
C13: .01 - .1uF

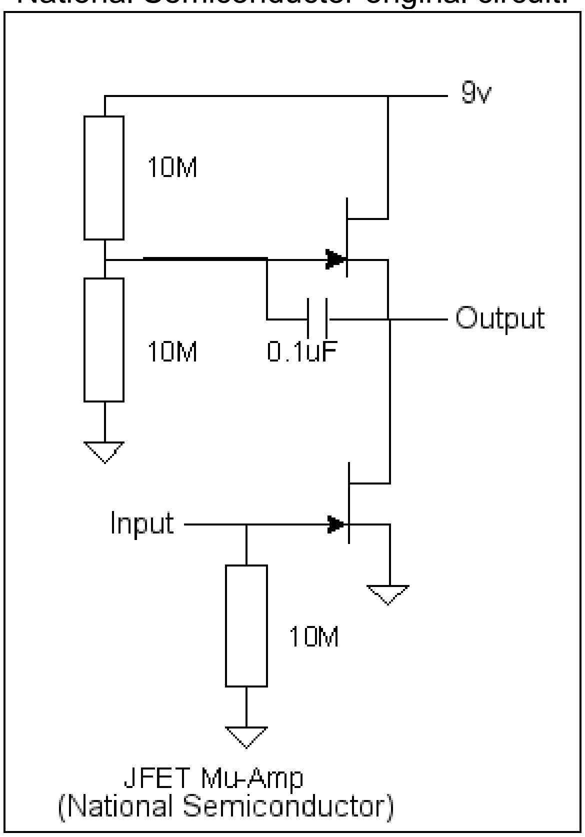
R2: 2.2m
R3: 1k
R5: 100k audio taper
R6: 470k
R7: 47k
R8: 4.7k
R9: 50k
R10: 20k
R11: 100k Audio taper

Mu-amps

Another popular way of using JFETs for pedals is in a small amplification circuit called a "mu-amp" and popularized by Jack Orman with his design of the "miniboost".

> ***SIDE NOTE:*** The mu-amp actually is a very old circuit. It was fairly common during the vacuum tube era, where it offered the opportunity to get a lot of gain and signal output out of common triodes. National Semiconductor published a JFET adaptation of the mu-amp in their JFET applications notes in a collection of JFET cookbook circuits. In about 1980 effects designer/builder/guru Jack Orman used the mu-amp for a guitar gain circuit, renaming the circuit the "minibooster". The use of the mu-amp has been adapted into several DIY effects circuits from there including Aron Nelson's "booster 2.5", The ever popular "brown sound in a box" pedal, and Doug Hammond's "Sweet Thing" just among a few. You can see the original circuit on National Semi's web page at http://www.national.com/an/AN/AN-32.pdf

National Semiconductor original circuit:



Connecting two of these mu-amps circuits together will make a very nice heavy distortion or overdrive as well.

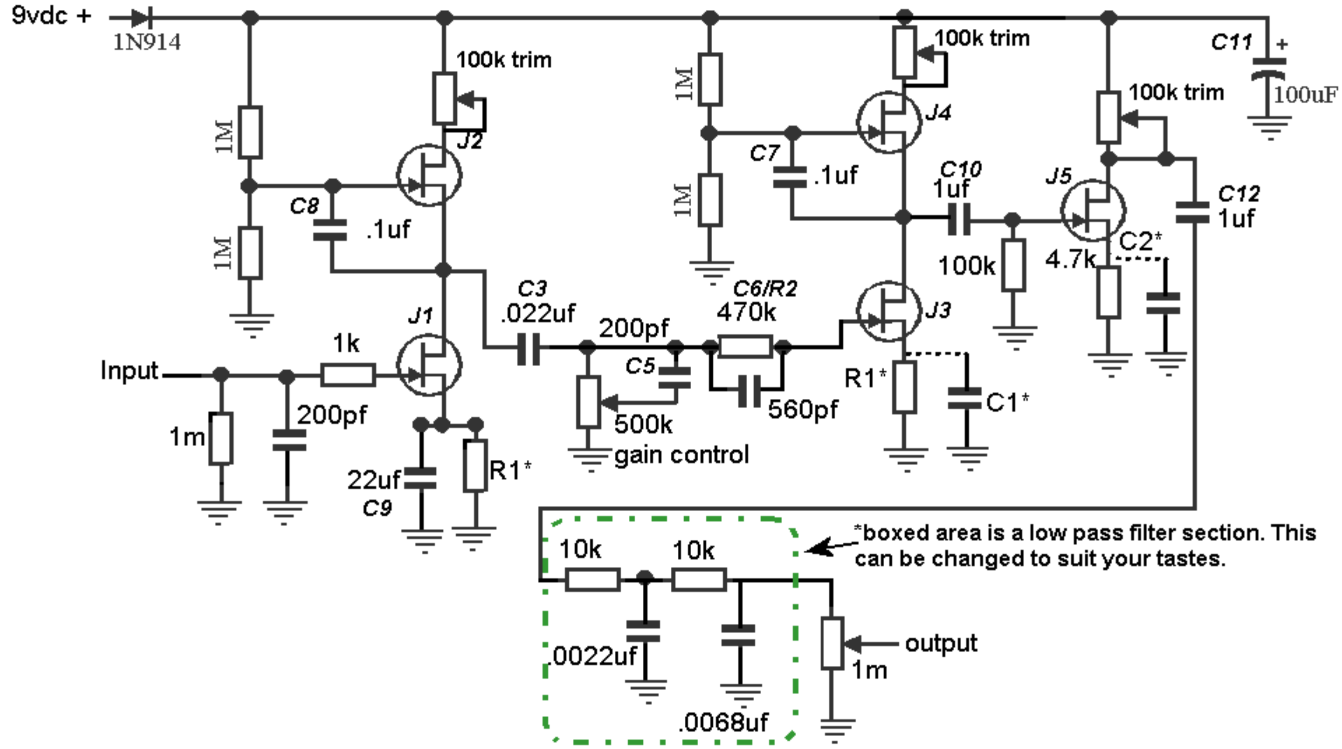
Tons of pedal builders have since used this type of circuit in many of their designs. You can see the original circuit from National Semiconductor here:
You can read in detail how this circuit works online here: www.indyguitarist.com/diy/muamp.htm

Use of the mu-amp circuit brought about several pedals in the DIY world that are quite well known: Aron Nelson's “booster/booster 2/booster 2.5, Doug Hammond's “sweet thing”, and Ed Guidry's “Brown Sound In A Box”, or “bsiab2” as it is known.
See the following page for a similar circuit which will sound wonderful for a smooth overdrive or distortion tone.

On the next page is an example I have came up with that is derived from similar circuits of this type (Aron Nelson’s ‘booster 2.5’, Jack’s Minibooster and Ed Guidry’s “Brown sound in a box”.

Mu-amp overdrive/distortion

A smooth distortion circuit.



Let's break this circuit down a little bit. The signal comes in at the input, the 1m resistor prevents popping from switching, the 200pf blocks radio frequencies from coming through. The 1k resistor limits the signal just a little before it reaches the JFET. After the signal is boosted and clipped a bit through the first two JFETs (J1 and J2), it goes through the .022uf capacitor (C3). Also, changing C8 will control the bass content before the signal is clipped more thoroughly. C9 boosts the gain of the clipping circuit, smaller caps will yield less gain in conjunction with R1. If you want a lot of distortion, make R1 a 1k or so. If you want more of an overdrive, make R1 a 4.7k – 22k (in both locations shown).

After C3 we have the gain control – basically a pot that controls the amount of signal that gets clipped through the next stages. C5 should be a 200-400pf or so – this will give a cleaner tone when the gain knob is turned down.

C6/R2 is a high-pass filter that sets the frequency for the next clipping stages. In this case, everything below 600 hz or so is filtered out. (See www.muzique.com/schem/filter.htm for a calculator to tailor this to your needs).

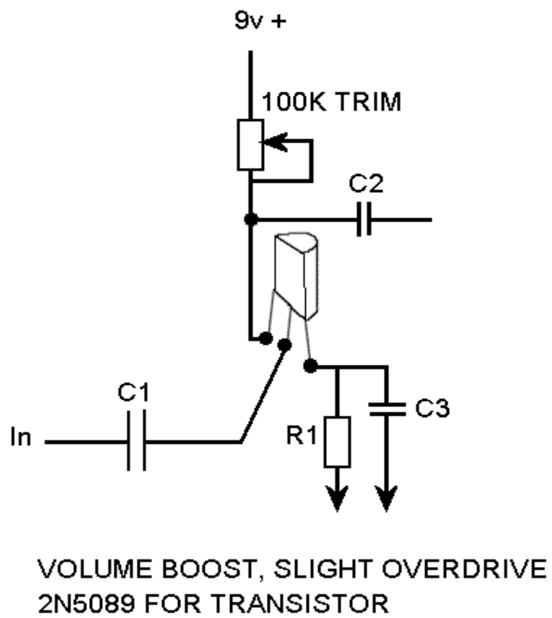
After C6/R2 the signal goes into the next mu-amp stage, J3 and J4. Again, C7 will control some bass content. The signal travels through C10 before getting quite a bit of the signal sent to ground via the 100k resistor. This is so it doesn't overload J5 which provides an additional gain/volume boost. The signal exits through C12 which then goes into a low pass filter section. This can be omitted and or changed to suit your needs. In the one shown above, the 10k resistor and .022uf cap allow all frequencies over 7200 hz or so to be filtered out. Then, all frequencies over 2300 hz are filtered out additionally. You could insert a number any style of tonestack here, even a traditional low-pass filter style knob to further tailor the highs to your liking. A 3 band tonestack (like a marshall style tonestack) sounds wonderful here. After this, it exits via the volume pot.

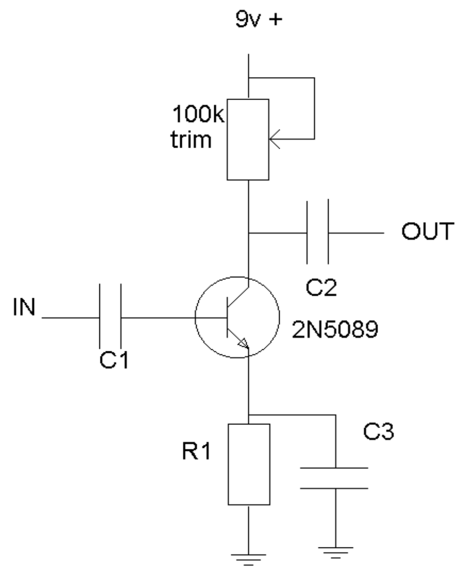
Notes:
C9, C1, and C2 all boost the gain of the clipping circuit, smaller caps will yield less gain in conjunction with R1. If you want a lot of distortion, make R1 a 1k or so. If you want more of an overdrive, make R1 a 4.7k – 22k (in both locations shown). Alternatively, you can remove C9, C1, AND C2 and have a smooth overdrive, especially ifyou make R1 a 10k or larger resistor.

The trim pots on the board will need to be tweaked by ear – this is where it gets interesting. General voltages going to the drain (on the individual JFETs) should be around 4.5 volts. Set this with a multimeter and then tweak by ear from there. You'll notice that as you tweak it, it will get louder and smoother, or softer and grittier. Tweak this to your tastes.

*We have printed circuit boards and parts kits available for this pedal, see www.indyguitarist.com/purchase.htm for info.

Transistor Overdrive/Boost circuit



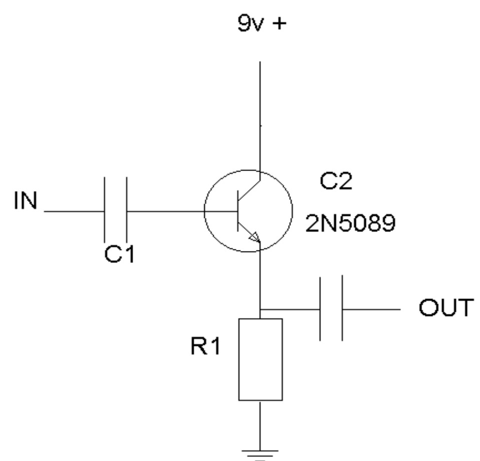


Transistors, JFETS, etc. all sound a little different from each other. Here is a smooth overdrive circuit using 2n5089 transistor instead of JFET. Notice that the connections are similar but the pinout may be different. Also, you'll have to adjust the bias from one transistor to another, as they vary quite a bit from one to the next.

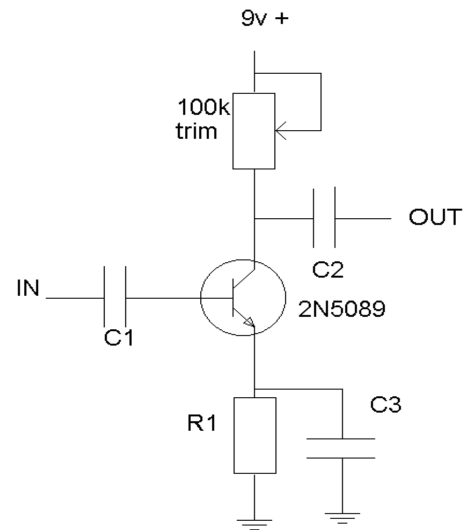
This one has a light overdrive, very good for adding warm smoothness to a clean tone. You can connect these in series to get more gain.

Suggested values:
C1: 1uF
C2: 1uF
R1: 1K – 10K
C3: 22uF – 47uF capacitor

Transistor used as a buffer



Transistor used as a buffer



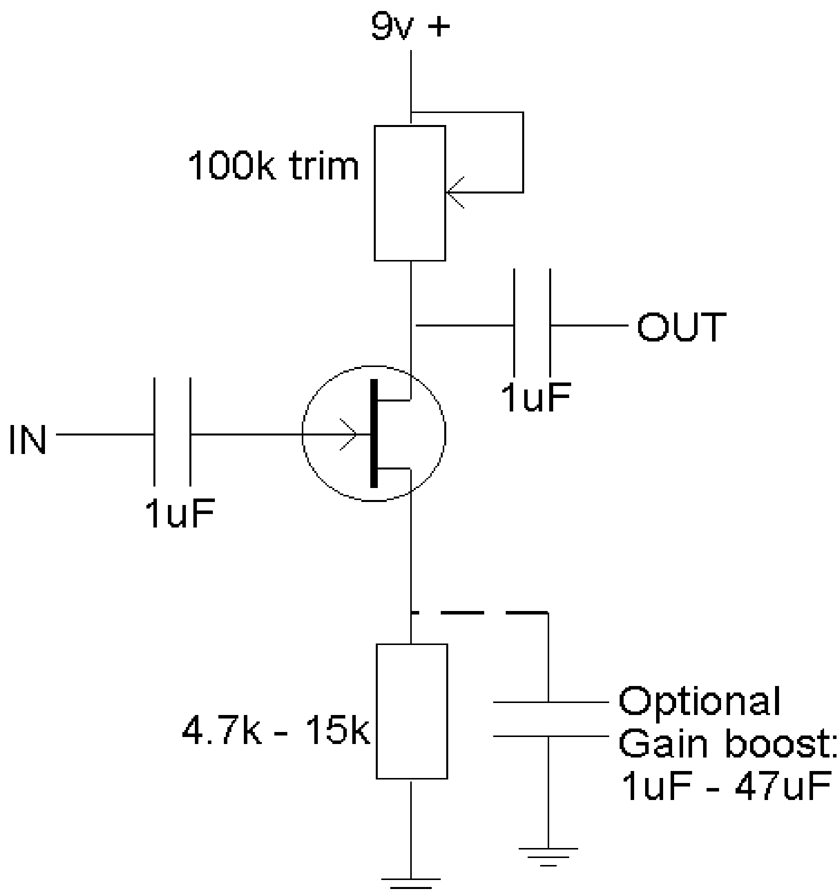
Transistor used as a gain boost (signal boost)

Even though the circuits look similar, there is a distinct difference....in the image on the left, the gain is unity...or no gain boost or loss. However, the impedance is converted to a low impedance in order to not “load” the next stage.

What is loading? “Loading” is what happens when there is a reduction of signal in the ratio of the output impedance of the guitar and the input impedance of the effect. The output impedance of the guitar is frequency sensitive because the pickups are inductive and their impedance rises with frequency at 20db/decade.

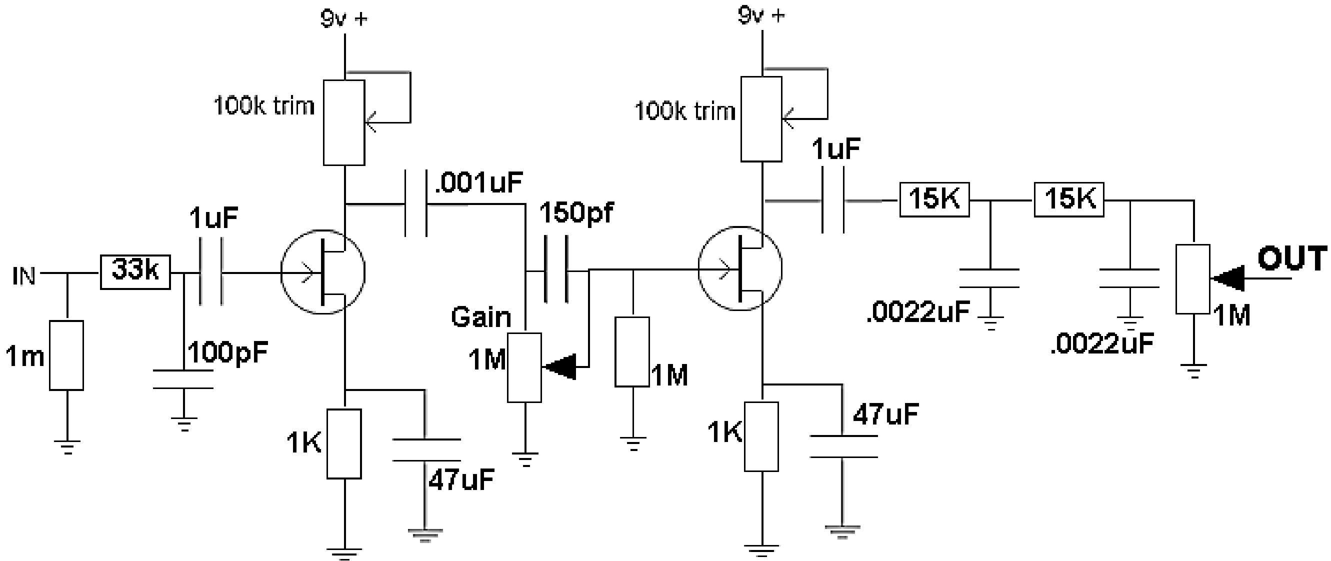
Loading is actually easier to demonstrate than it is to explain in layman's terms. For example, connect your guitar to 40 feet of guitar cable direct into your guitar amp. Then, take a buffered pedal (boss/ibanez/etc) and insert it direct from your guitar with the effect “off”. The difference is that the cable and it's capacitance was “loading” your signal. The pedal has a buffer in it which converts the signal to low impedance and therefore solves many 'loading' problems. The buffer circuit has a gain of '1'...no signal boost or cut. The circuit on the right boosts the signal and can provide some help with loading, but not as much as when it is used as a buffer like the image on the left.

JFET clean boost



This small circuit is a wonderful signal boost. It has a very tube-like feel and response, and is slightly colored tonality somewhat like a tube. Experiment with putting this little circuit at the beginning or the end of a circuit for a warm and smooth tonality and very dynamic feel. For a gain boost, connect the 1uf-47uf capacitor in parallel with the resistor as shown, but this is optional. If you are getting too much clipping, insert a voltage divider between the input and the input cap. JFET choice can be J201 or similar.

JFET AC-30 emulation



***Sounds similar to AC-30**

JFET's do a great job of emulating tube amp circuits. RunOffGroove.com has done a great job in pioneering a method of emulating classic amps using JFETs. One such circuit is this Vox AC-30 sound-alike.

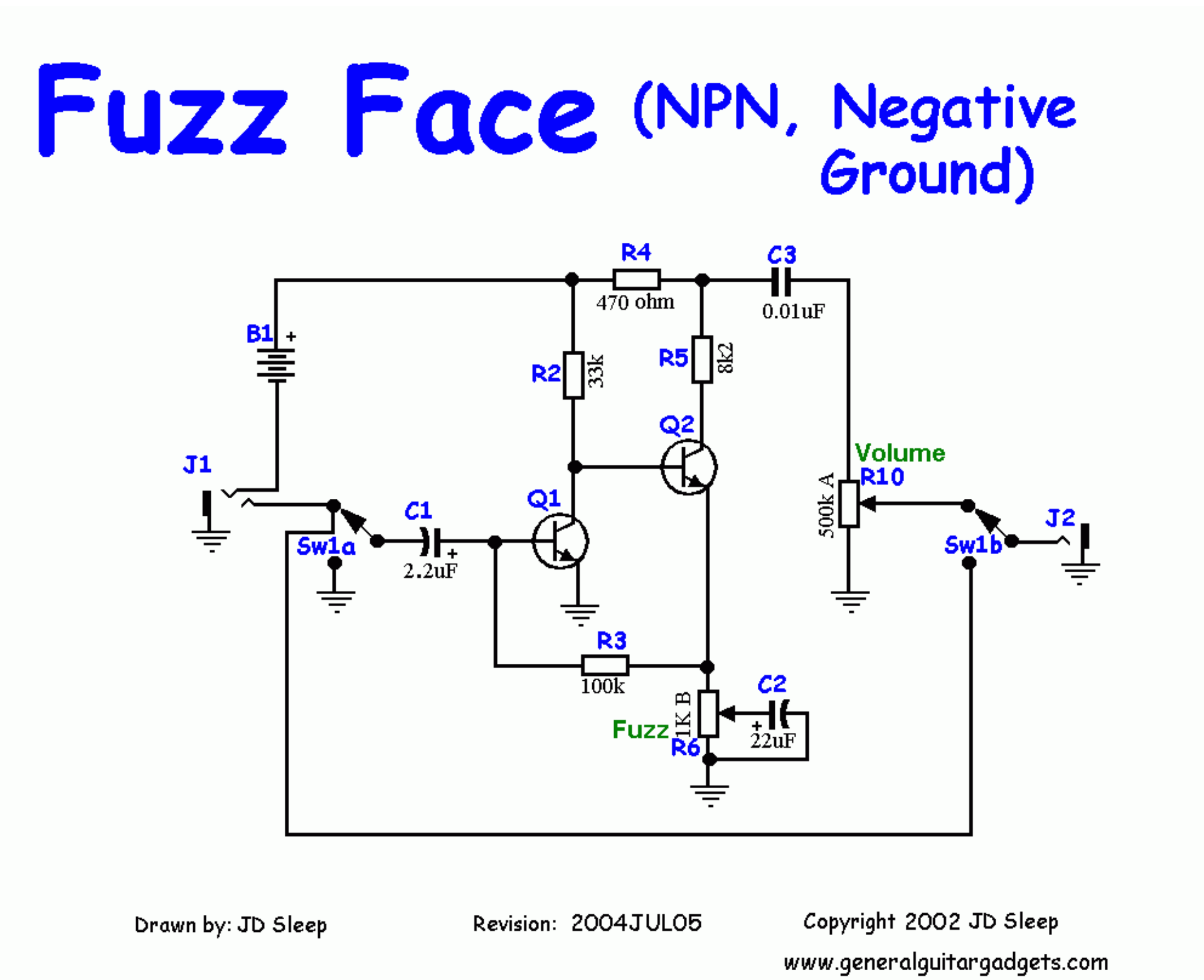
For JFETs, use either J201's or 2n5457's. Bias the 100k trims to 4-6 volts, tune it by ear to it's loudest point. As you turn it, you'll hear the signal get weaker and stronger. It is easiest to have someone playing a guitar into this circuit while you are tweaking the trimpots.

The 15k/.0022uF low pass filters on the end are power amp and speaker emulations. If the circuit is too 'dull' sounding, simply eliminate one 15k/.0022uF section.

You can also add a tone control on the end if desired.

The 150pf on the gain control is to make sure the tone doesn't lose any highs when the control is turned down. This is essentially a high pass filter when the control is turned down.

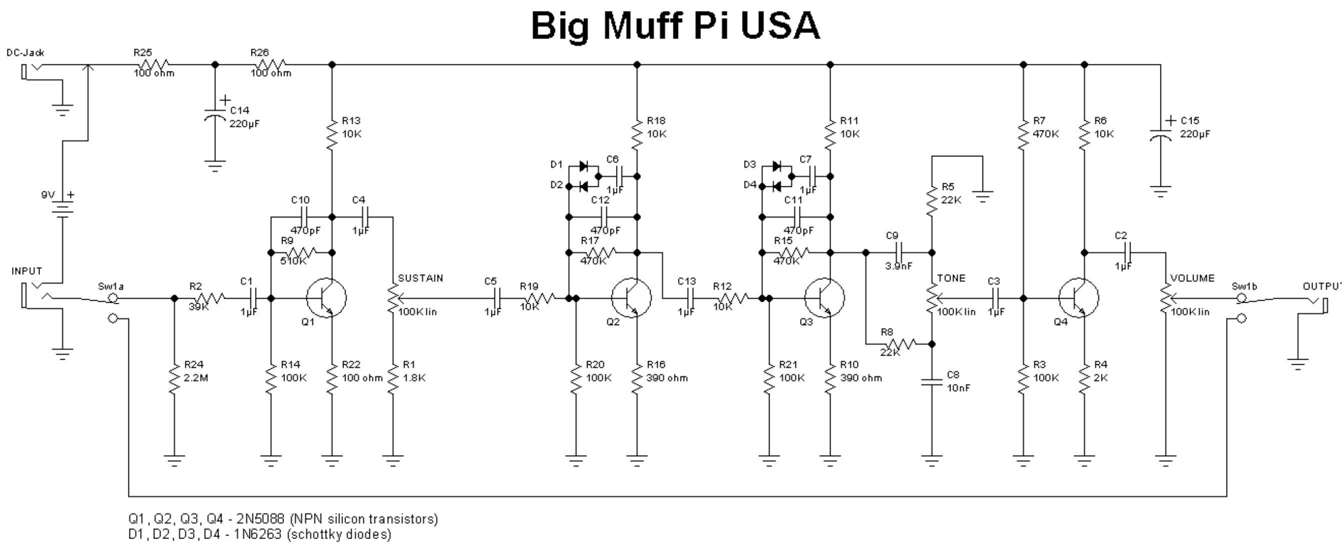
Fuzz Face Transistor Fuzz



The Fuzz Face circuit is one that's been used over and over in countless overdrives, distortions and fuzz pedals. RG Keen of Geofex.com has written an article that details the fuzz face quite well – see http://www.indyguitarist.com/fuzzface.htm to read the article (no cost).
Areas of modification interest would be R3 (increase for more gain), R5 (control clipping texture), C1 and C3 (input and output caps). Of course, you could add tone controls, low and high pass filters at the input or output of the circuit to tailor the tonality and response of the pedal.

*Circuit boards for this project available at www.generalguitargadgets.com

“Big Muff Pi” type fuzz

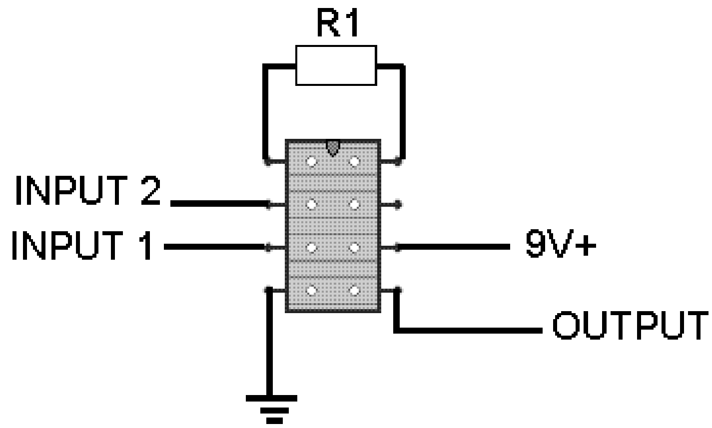


The Big Muff Pi is another often-duplicated circuit that finds it's way into many boutique pedals. The circuit shown above is very similar to the “Big Muff Pi” fuzz circuit. What you have here is multiple clipping stages cascading to provide creamy fuzz. The tone control (what is actually called a “big muff” style tonestack) starts at C9/R8 and ends at the C3 location. You could modify C9, R8, C8, or R5 to tailor the tone control to your needs. Alternatively you could remove this tonestack and insert any other type.

R9, R17, and R15 are controlling the amount of gain for each stage. Increase these for more gain. You could also connect a 1uF to 47uF capacitor in parallel with R22, R16, or R10 to get more gain and/or a different clipping texture.

D1, D2, D3 and D4 can be changed as well for different clipping textures.

A basic circuit with a 386 IC chip



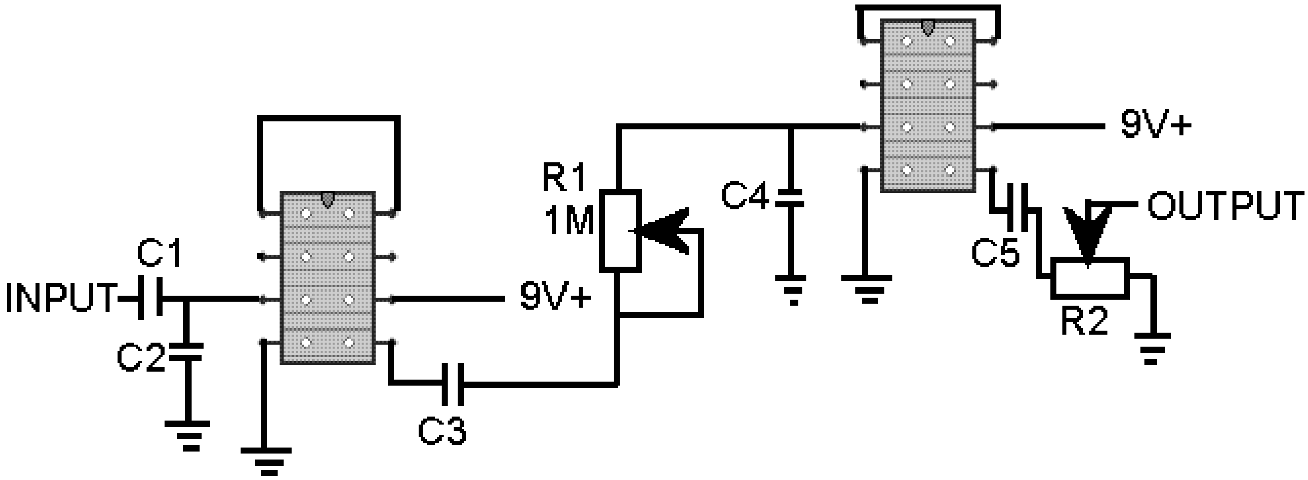
"386" TYPE AUDIO AMPLIFIER (IC CHIP)

In the previous “How to build effects...for beginners” book we discussed mainly simple circuits using a 386 type IC chip, or more accurately, 'audio amplifier'. Though it is technically a small audio amplifier, it can be used for signal clipping/boosting as well.

Looking at the diagram above, you'll see there are two inputs. You can use either one though input 1 is generally considered a little 'hotter' and therefore used most often. If you get a lot of noise and or undesired clipping you may want to use input 2 instead. Pin 4 connects to ground, pin 6 connects to 9vdc positive. Pin 7 is unused. Gain is controlled by R1. You'll still have some gain with no connection between pins 1 and 8, but for more gain you can insert a jumper connection or even a 10k or so potentiometer. Also, connecting a 100uf or so electrolytic capacitor will give you a nice thick distortion as well.

The 386 is somewhat limiting when used for overdrive or distortion but does have it's own unique sound. Later, we'll discuss a circuit that uses the 386 into a dual opamp which will make a great “metal” distortion. Also of interest is connecting two of these basic 386 circuits in series to get a nasty, raspy fuzz. An example of this is in the following circuit.

386 FUZZ

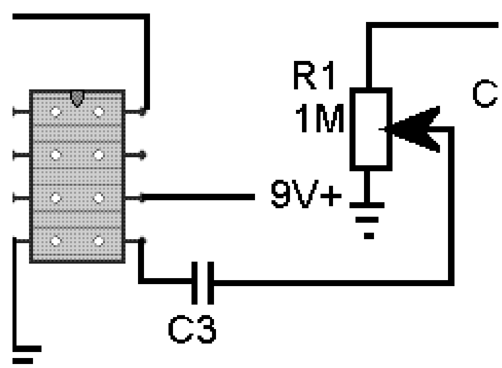


386 BASED FUZZ

This would be a great easy fuzz circuit. R1 is the gain control, R2 is the volume control. You can add the tone control of your choice.

C1: .047uF	C4: 470pF
C2: 470pF	C5: 1uF
C3: 1uF	R2: 100K.

If you still have too much gain with the gain control down low, you may want to use a voltage divider (what the volume control is) to shunt the signal to ground. That would look like this:



Lug 1 would going to the input of the 2nd 386 chip, Lug 2 would be coming from the output of the first chip. Lug 3 would connect to ground.

About opamps

As you research pedals and their schematics you'll start to notice a lot of similarities. Many overdrives look similar to a tubescreamer. Many distortions have clipping diodes going to ground. Many fuzzes are using transistors. These aren't the rule, but for some reason a trend I've noticed. We don't have to stick to that though – a tubescreamer can be a distortion, fuzz, OR overdrive, depending on the tones you want.

As we look at different circuits, you want to notice the 'building blocks', or segment of circuits that are similar in pedal after pedal. You can string these 'building blocks' to form an entire new pedal. Brian Marshall of SubDecay (www.subdecay.com) said this once:

“When i first designed the stupid box a couple years ago, i took just the clipping section of a tubescreamer, and followed it with a passive tone control... I then changed a bunch of stuff, and messed around with the tone control a little, and found something that i really liked.”

So just what are opamps? Op-amps usually consist of many BJTs (bi-polar junction transistors), resistors, diodes and other necessary components. They often use JFETs or CMOS devices at the inputs to increase input impedance. Op-amps essentially arrange many transistors to achieve low noise, high input impedance, high bandwidth and high gain potential. Gain is controlled by using negative feedback.

JFETs use electrical fields to vary the resistance of a channel of semiconductor material. They also provide slightly non-linear amplification that is slightly analogous to triode vacuum tubes. The typical gain from one JFET is much less than an opamp though, and their characteristics very from piece to piece, even within the same part type.

Opamps can do many things that FETS cannot (by themselves at least) do. FETs are very high input impedance so they do not load down circuits much. They are modest gain, and modestly accurate as a transparent buffer. They have a high variability from one unit to the next. Opamps have high impedance, but not as high as FETS. They are capable of achieving high gain which is basically entirely controlled by feedback components, so the variation from unit to unit almost does not matter.

Technical stuff

This article illustrates some typical applications of solid-state integrated circuit operational amplifiers. A simplified schematic notation is used, and the reader is reminded that many details such as device selection and power supply connections are not shown.

The resistors used in these configurations are typically in the kΩ range. <1 kΩ range resistors cause excessive current flow and possible damage to the device. >1 MΩ range resistors cause excessive thermal noise and bias currents.

Note: It is important to realize that the equations shown below, pertaining to each type of circuit, assume that it is an ideal op amp.

Operational amplifier applications

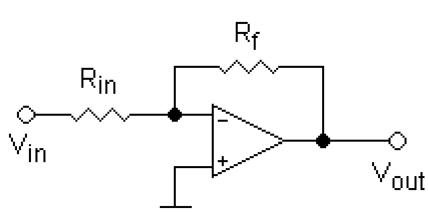
From Wikipedia, the free encyclopedia

This article from wikipedia illustrates some typical applications of solid-state integrated circuit operational amplifiers. A simplified schematic notation is used, and the reader is reminded that many details such as device selection and power supply connections are not shown.

The resistors used in these configurations are typically in the kΩ (Ω means ohm) range. Less than 1 kΩ range resistors cause excessive current flow and possible damage to the device. Greater than 1 MΩ range resistors cause excessive thermal noise and bias currents.

You may or may not have heard of inverting/non-inverting amplifiers. Though you will see the formula's behind it, what you need to know is that they sound and react a little differently from each other…nothing dramatic but different nonetheless. For examples of inverting and non-inverting, study the boss od-1 and sd-1 circuits, the second amplification stage of each circuit. The od-1 is an inverting amplifer, and the sd-1 is using a non-inverting amplifer.

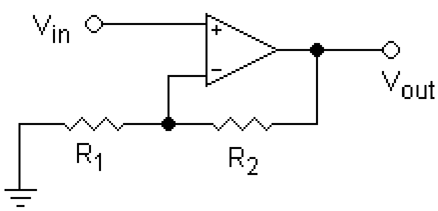
Inverting amplifier - Inverts and amplifies a voltage (multiplies by a negative constant)



$$V_{\mathrm{out}} = -V_{\mathrm{in}}(R_{\mathrm{f}}/R_{\mathrm{in}})$$

$Z_{in} = R_{in}$ (because V_- is a virtual ground)

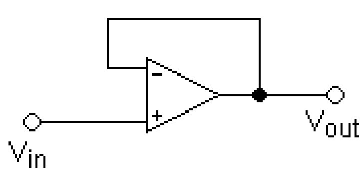
Non-inverting amplifier - Amplifies a voltage (multiplies by a constant greater than 1)



$$V_{\mathrm{out}} = V_{\mathrm{in}}\left(1 + \frac{R_2}{R_1}\right)$$

$Z_{\mathrm{in}} = \infty$ (realistically, the input impedance of the op-amp itself, 1 MΩ to 10 TΩ)

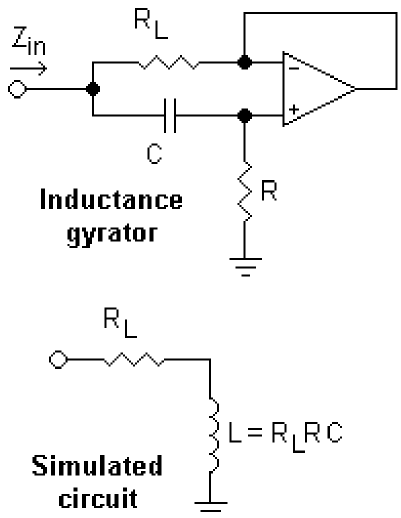
Voltage follower - Used as a buffer amplifier, to eliminate loading effects or to interface impedances (connecting a device with a high source impedance to a device with a low input impedance)



$$V_{\mathrm{out}} = V_{\mathrm{in}}$$

$Z_{\mathrm{in}} = \infty$ (realistically, the differential input impedance of the op-amp itself, 1 MΩ to 1 TΩ)

Inductance gyrator - Simulates an inductor

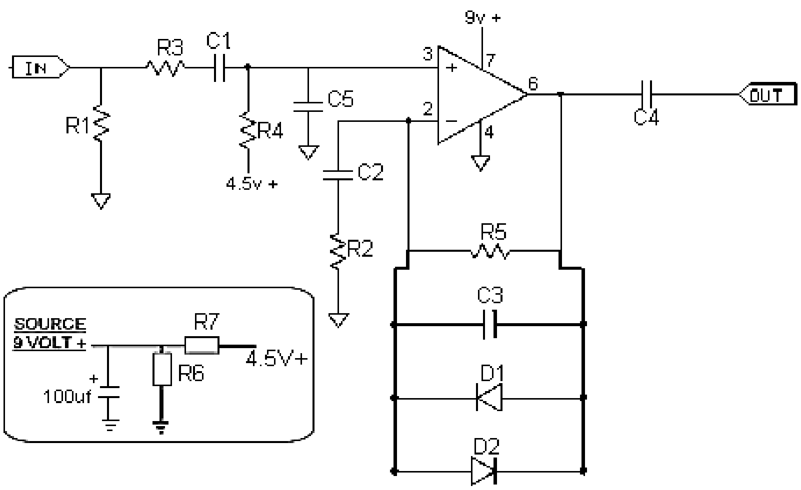


This is used in guitar eq pedals – for example, a 7 band Boss eq has 7 gyrator circuits. Wah pedals use inductors to adjust the frequencies to get the 'wah' sound. A gyrator is a circuit that emulates the inductors in order to boost or cut a specific frequency. More about this in the “EQ” section.

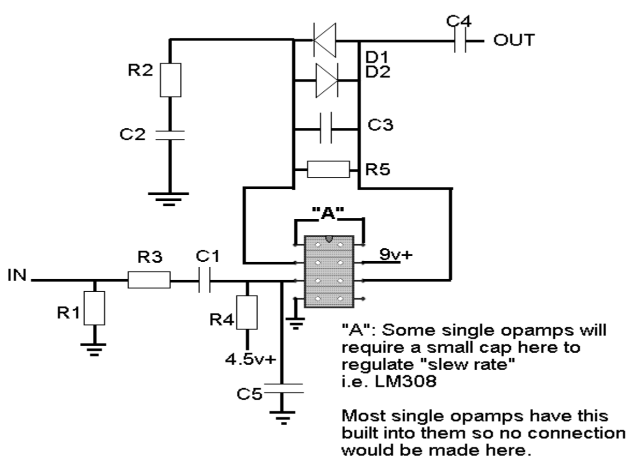
Opamps in laymen's terms

Single opamps

Single opamps look the same but only have one opamp in them. Some examples are LM308, TL071, TL081, LM741, etc.
Below is a schematic of how a clipping circuit for a single opamp might look:



The connections for a single opamp would look like this:



Many overdrive, distortion, and fuzz pedals are designed with opamps. Let's look at what the necessary parts are for these type of circuits. Looking at the diagrams on the previous page we see that the input meets R1 which eliminates much of the popping from true bypass switching, C1 which filters out DC from the opamp (in other words, eliminates noise from the electric functions going on inside the opamp). C5 filters out radio frequencies and is in fact a low pass filter with R3. You can tailor this filter to determine what frequencies you want the first stage to clip. For example, a Proco Rat Distortion pedal uses this method of pre-clipping eq adjustment to get it's unique clipping sound and texture.

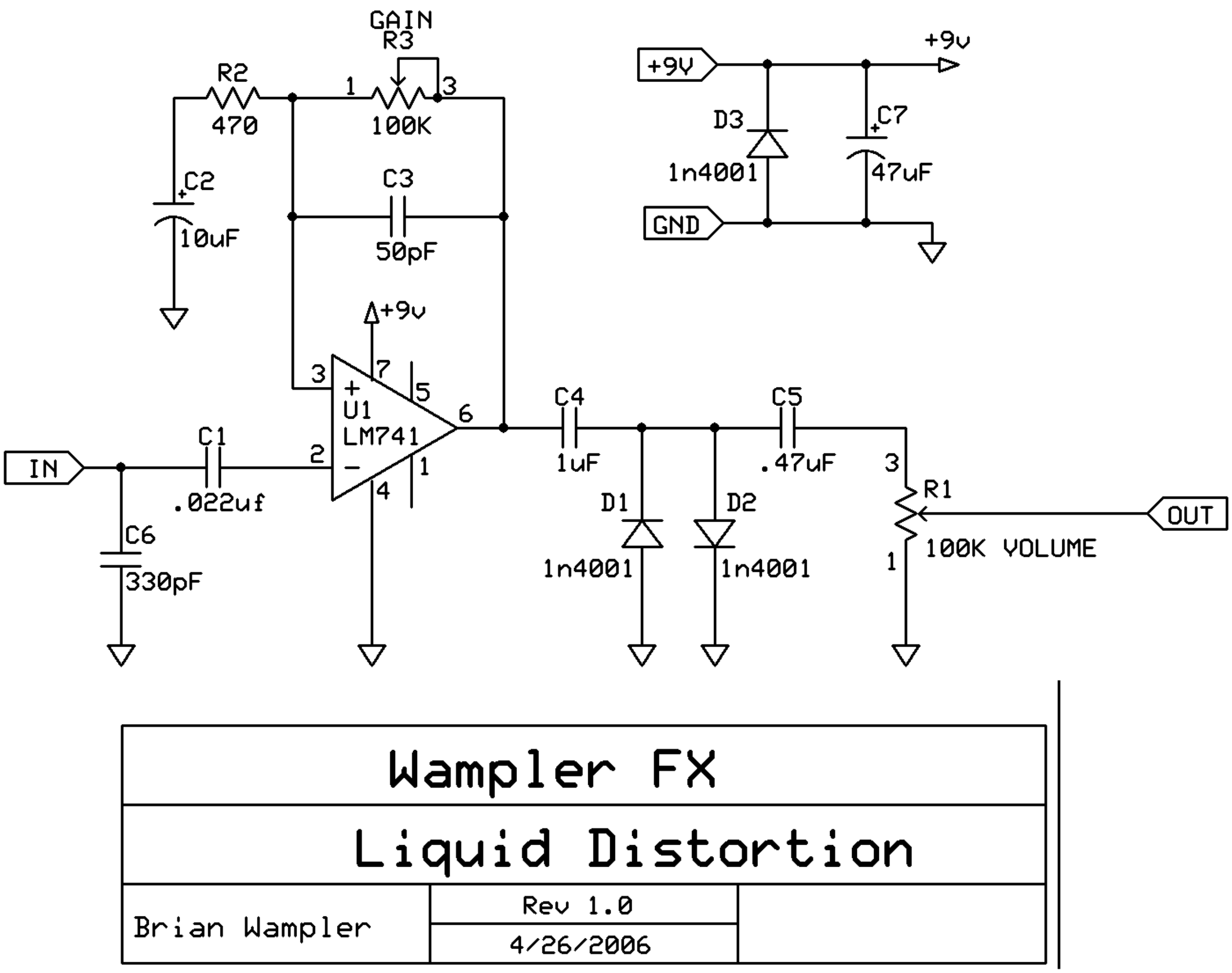
On a single opamp like we are discussing, the input will be pin 3. To set 'bias' for this part of the circuit you will generally have a resistor, R4, coming from 4.5v+ connecting to pin 3 as well (and coming AFTER the input cap which is C1). A general value is 470k or so but you'll notice changing this value doesn't affect much tonally.

Pins 2 and 6 are connected via a resistor OR a pot, R5. In a pedal such as the Rat pedal this resistor is a pot. In a pedal such as the MXR Distortion Plus this is a set resistor. C2 and R2 connect to form the 'negative feedback' portion of the clipping circuit. Notice that it wouldn't matter which one connected to ground – the sum of both parts is what is what is important here.

For op-amps, the gain is also determined by how much 'negative feedback' from the output you DON'T provide back to the input. The absolute highest gain will occur under what is called "open loop" conditions, namely no feedback whatsoever between output pin and input pin. This usually results in tons of oscillation. So, looking at our circuit, not only does R2 and C2 form a negative feedback circuit, it also controls the **frequency** of the signal that get's clipped and passed on. For example, in a tubescreamer, the stock values are .047uf and 4.7k respectively which gives you a frequency center of about 720 hz. Nothing below this frequency is allowed past the clipping stage, which is why the tubescreamer has such a pronounced mid-hump. Make the capacitor bigger to increase bass, make the resistor smaller to increase gain. Refer back to http://www.muzique.com/schem/filter.htm to see the effect this will have. Notice that changing the resistor to a 2.2k and the cap to a .1uf (basically, halving the resistor, doubling the cap) will yield th same frequency, but you'll have more gain available.

In the distortion plus, R2 is connected in series with another variable resistor, or potentiometer, to control gain. This, however, changes the eq of the pedal as you change the gain knob's setting. In other pedals R5 is a potentiometer and is used to control gain, similar to what the tubescreamer uses.

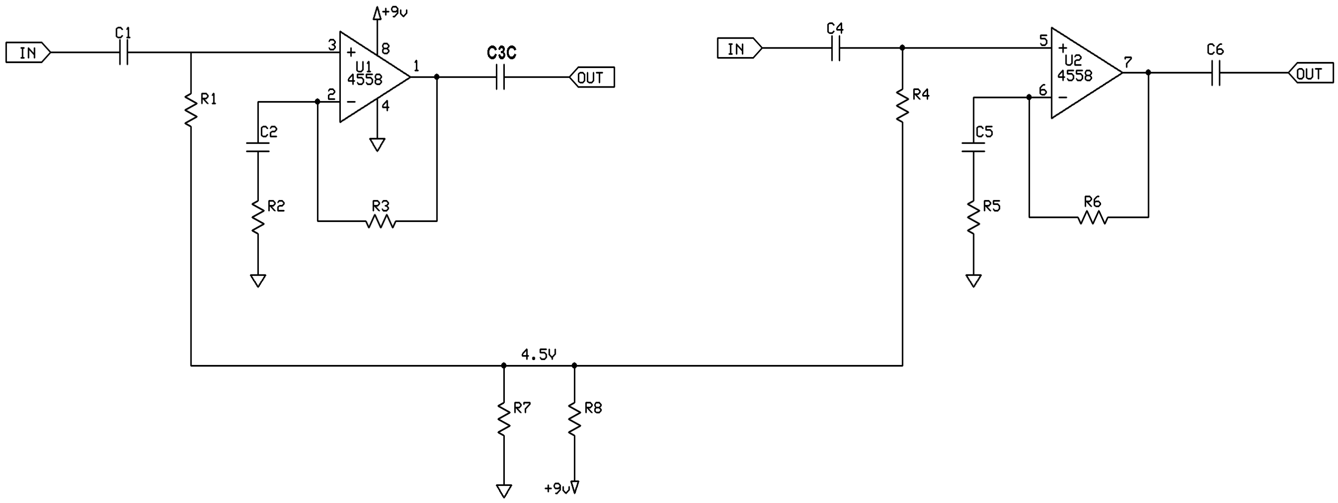
Single opamp circuit examples



*Keep in mind the modifications as already discussed as you are looking at these circuits. Many variables can be changed...R2/C2, D1, D2, C6, C1, as well as adding tone stacks (tone controls) and low or high pass filters. A tone control is not shown here but you could add one very easy by inserting it on the output.

Changing the opamp to something such as the TL071 will sound totally different and you may or may not like it. Definitely something to mess around with though.

Dual Opamps



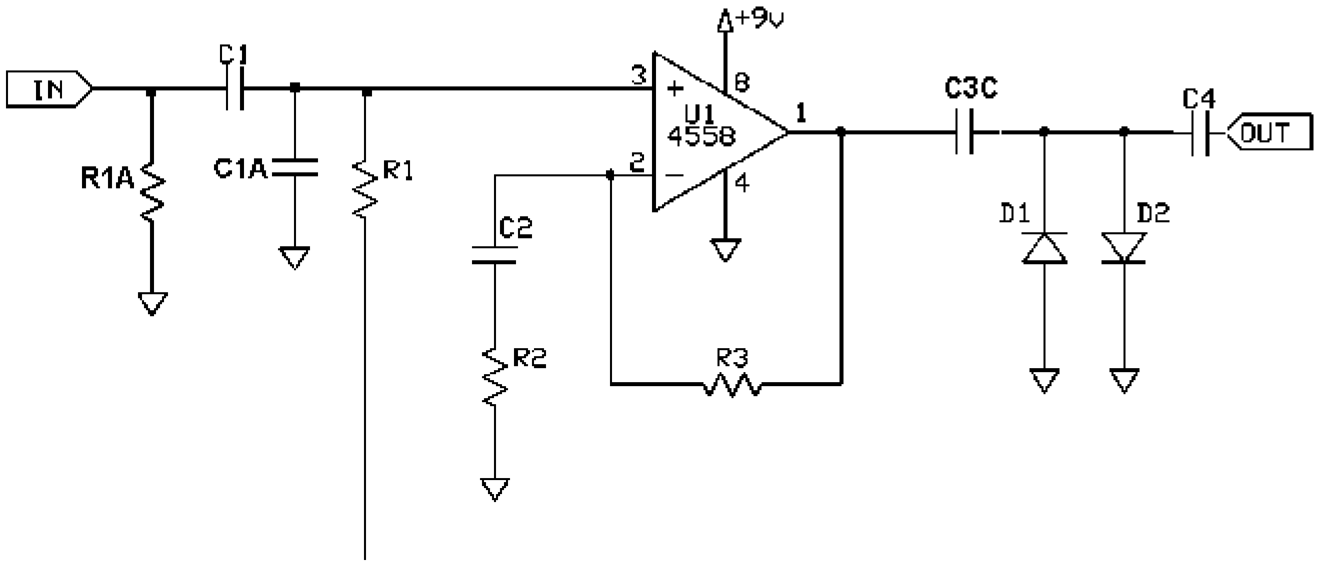
Sometimes it is easier to use a dual opamp (as shown above) instead of two single opamps,. For this purpose we generally use a dual opamp such as the 4558, TL072, TLO82, etc. types.

Looking at the diagram on the next page we see that the input meets R1A which eliminates much of the popping from true bypass switching, C1 which filters out DC from the opamp (in other words, eliminates noise from the electric functions going on inside the opamp), while C1A filters out radio frequencies and is in fact a low pass filter. Insert a resistor in series with C1 and you can decide what frequencies you want the first stage to clip.

On a dual opamp such as the 4558 types, the input will be pin 3. To set 'bias' for this part of the circuit you will generally have a resistor, R1, coming from 4.5v+ connecting to pin 3 as well (and coming AFTER the input cap which is C1). A general value is 470k or so but you'll notice changing this value doesn't affect much tonally.

Pins 1 and 2 are connected via a resistor OR a pot, R3. Again, in looking at our circuit, not only does R2 and C2 form a negative feedback circuit, it also controls the **frequency** of the signal that get's clipped and passed on. For example, in a tubescreamer, the stock values are .047uf and 4.7k respectively which gives you a frequency center of about 720 hz. Nothing below this frequency is allowed past the clipping stage, which is why the tubescreamer has such a pronounced mid-hump. Make the capacitor bigger to increase bass, make the resistor smaller to increase gain. Refer back to http://www.muzique.com/schem/filter.htm to see the effect this will have. Notice that changing the resistor to a 2.2k and the cap to a .1uf (basically, halving the resistor, doubling the cap) will yield th same frequency, but you'll have more gain available.

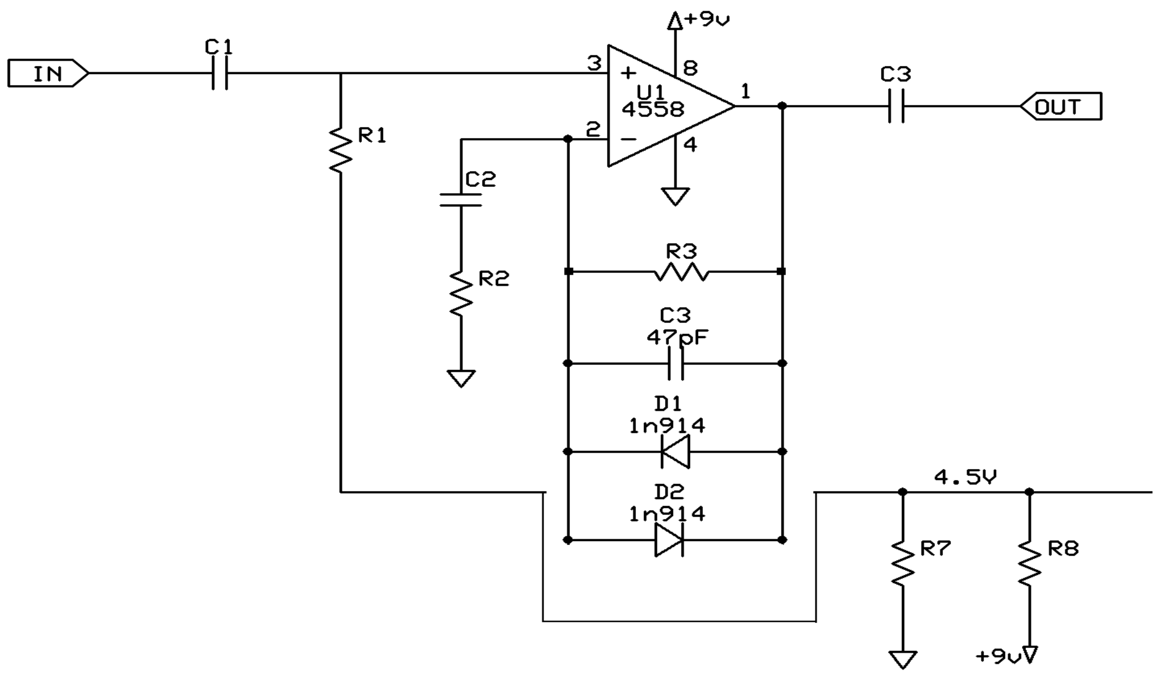
In the schematic we are looking at you'll see C3C coming from pin 1. Pin 1 is obviously the output of this clipping circuit...remember that the 4558 (dual opamp types) have TWO opamps in one, or for our purposes, the possibility of two stages of clipping out of one opamp. As such, C3C can have a clipping diode to ground portion such as what you see on the next diagram:



OR, you can tailor the eq by inserting a high-pass AND/OR a low-pass filter after C3C. C4 is shown here if you were going to the output instead of to another clipping stage. If you did this, you could eliminate C3C.

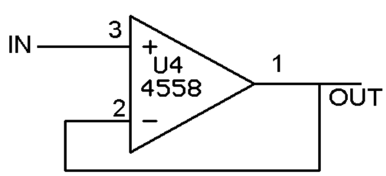
For softer clipping or what most call “more tube-like” you can add diodes facing opposing directions in PARALLEL with R3. Many times you'll see a small cap here as well to help get rid of any stray noise from the opamp.

Soft clipping explained



Some pedals such as the Nobels ODR-1 Overdrive adds clipping diodes to ground such as in the previous diagram ALONG with the soft clipping (as shown above) the the feedback loop.

So to get to the core of it, change C2 and R2 for more gain (along with the value of R3 – make R3 a larger value if you need more gain), and also to tailor the eq "pre-clipping". More pre-clipping eq can be added prior to entering the opamp, POST-clipping eq can be changed by adding filters AFTER C3C. For gain control, make either R3 OR R2 a pot, depending on what you are wanting. Some people like for their distortion to have less bottom end when the gain is turned up which is why R2 would be a good choice of pot placement for these folks.

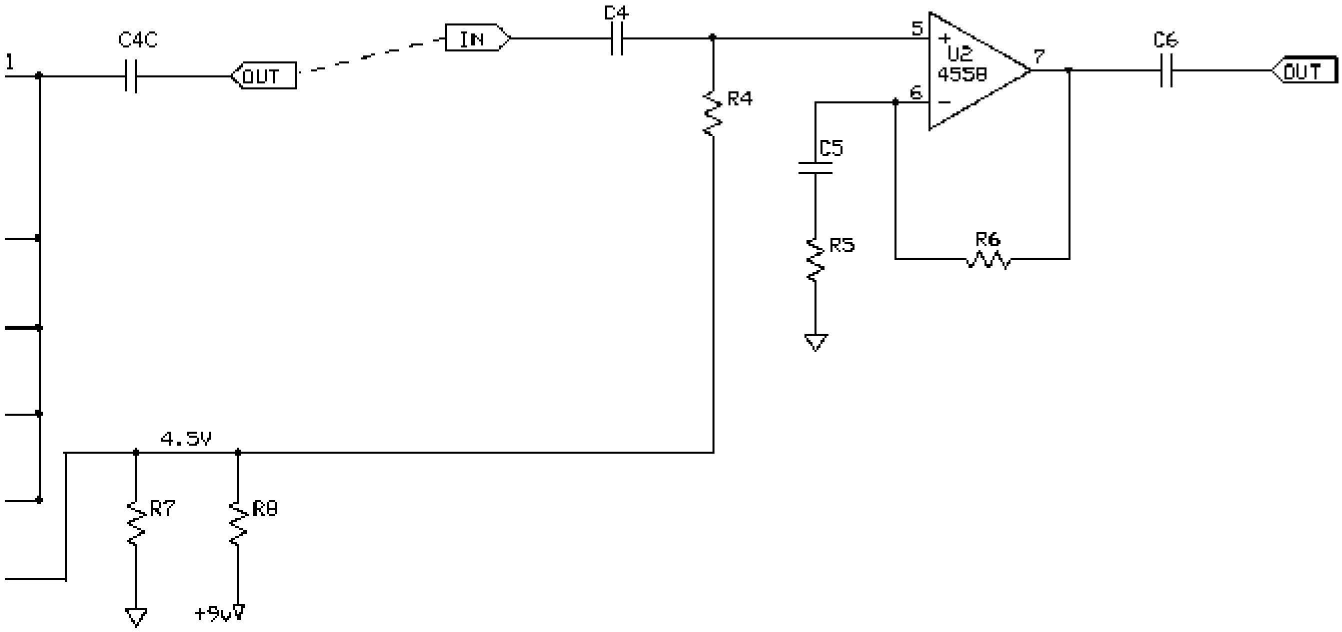


Dual Opamp, buffer

If you were going to use this opamp for a buffer you would simply connect pins 1 and 2, (leave out R3, R2, C2, C3, D1, and D2). Just a straight connection between the two pins. On the single opamp this would be pins 2 and 6 that are connected. Easy, huh? :)

At this point, you could add a tone control (a low pass filter or other method) as well as a volume knob and be done. OR, you could add another clipping circuit.

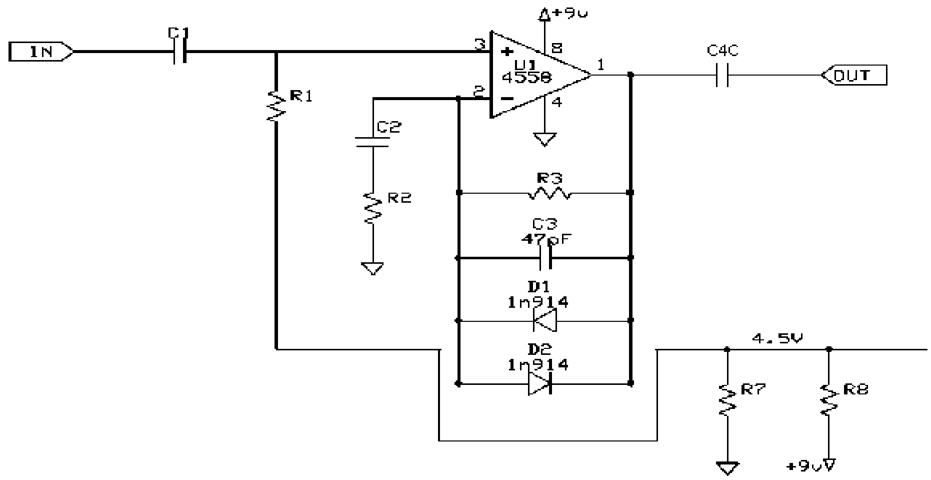
Let's look at the second half of the dual opamp.

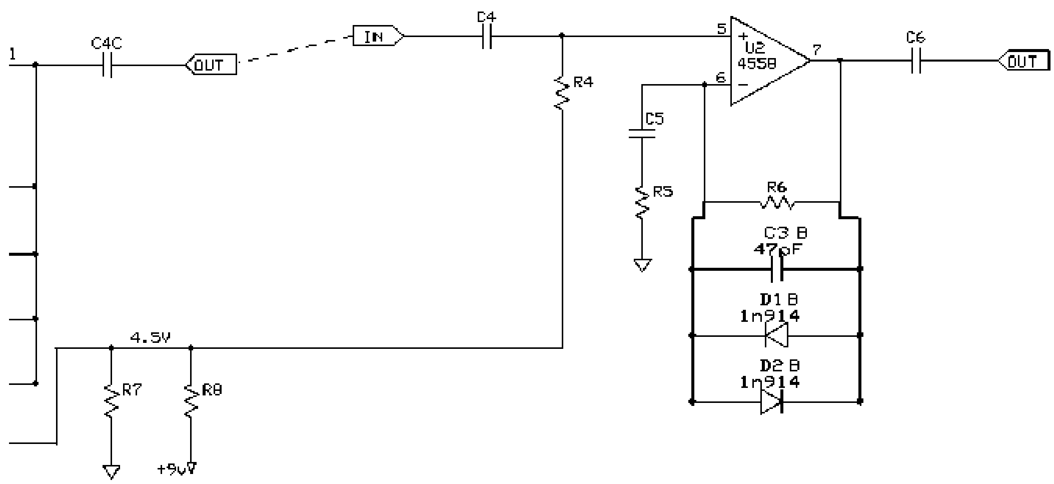


Basically, you have an identical circuit – another opamp circuit that can be used for clipping, boosting, eq tailoring, buffering, etc. Pin 5 is analogous to Pin 3, Pin 6 and 7 are analogous to pins 1 and 2 respectively. R4 is setting the bias, C4 is the input cap, C6 is the output cap. R7 and R8 is just a voltage divider to get 4.5 volts from the 9 volt source.

Other connections for dual opamps are pins 4 and 8. Pin 4 will connect to ground, while pin 8 goes to 9 volts. These connections MUST be made in order for the opamp to work, regardless of whether you are using one half of the IC or both halves.

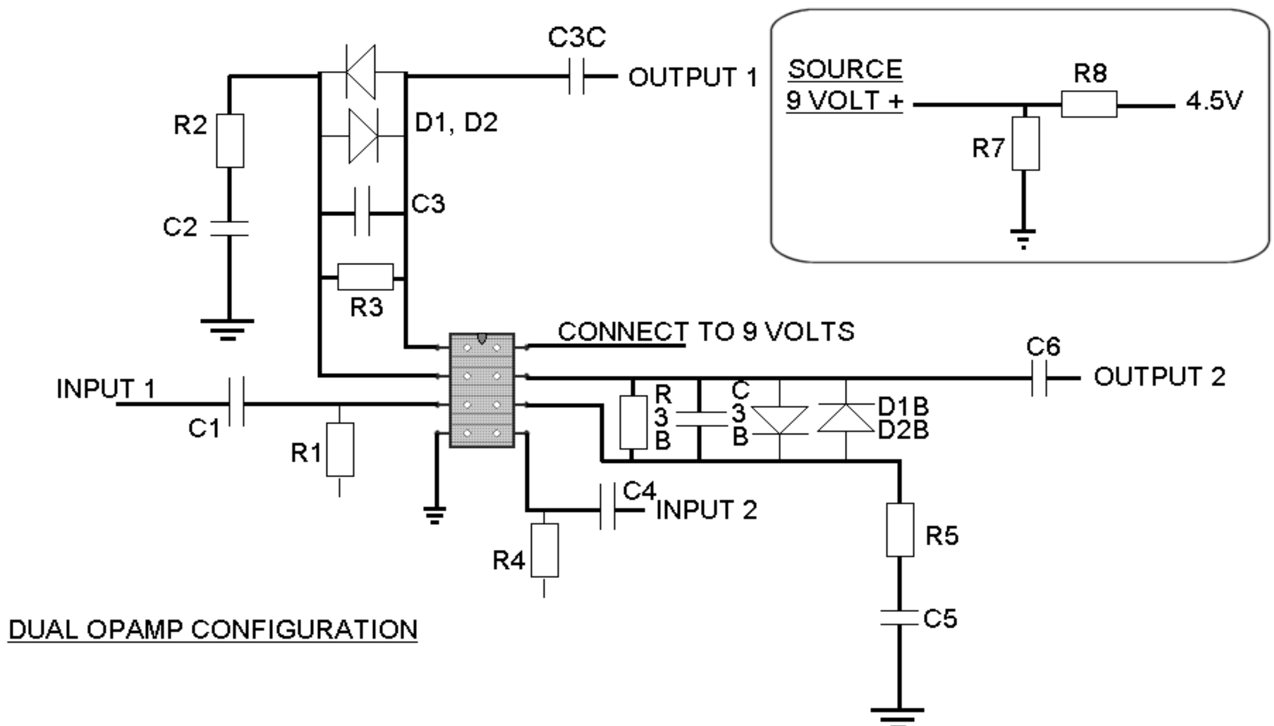
On the next pages, I'll display a generic schematic using a dual opamp and then a diagram showing how the connections would be made to the opamp.





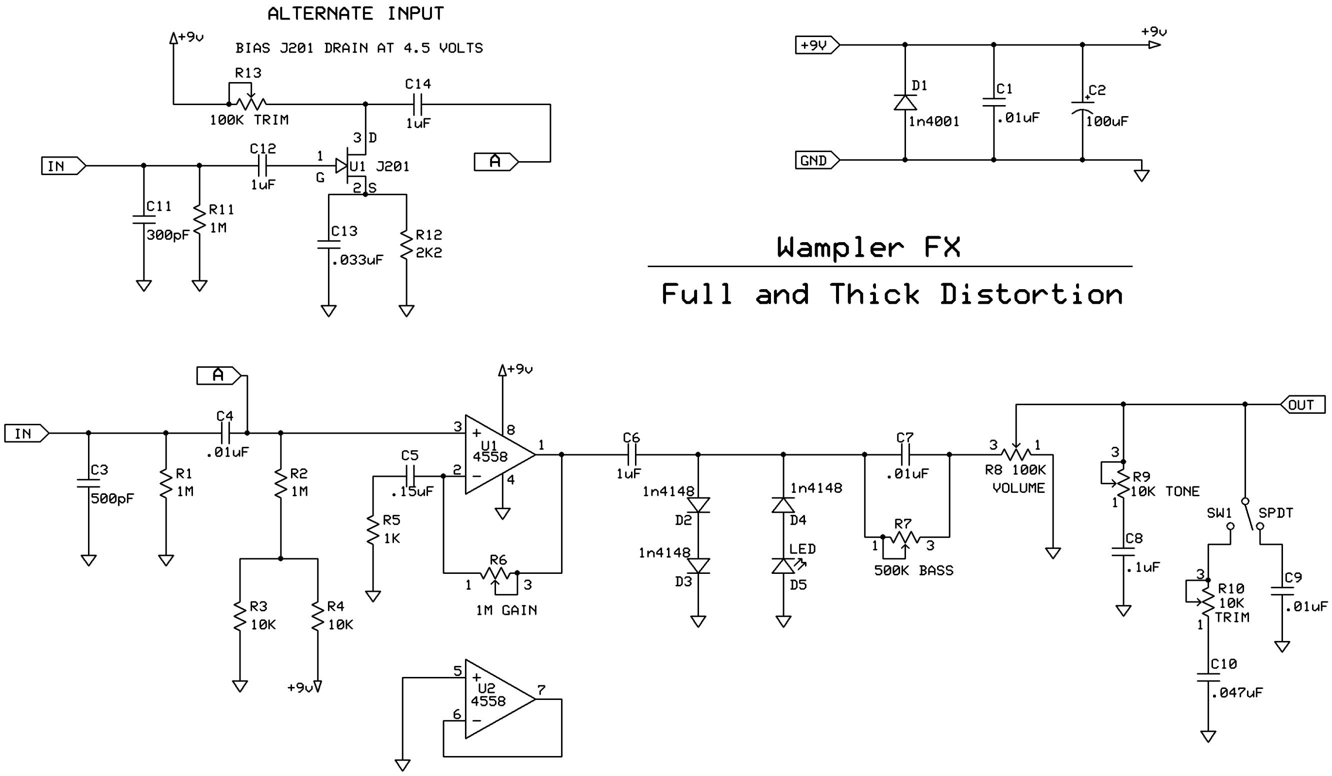
Schematics of a dual opamp. This is basically two clipping circuits all in one chip. Notice that C4C and C4 would be two caps in series if we connected these two clipping circuits together without any other circuitry between them. Since this would not be needed, we could simply eliminate one or the other.

See the next page for image of how the connections are made using the above schematic for reference.



Note that both R1 and R4 connect to the 4.5v source.
This circuit is just an example – you could add low pass or high pass filters or even another diode section (connecting to ground) after C3C as we discussed earlier.

Full and Thick Distortion circuit

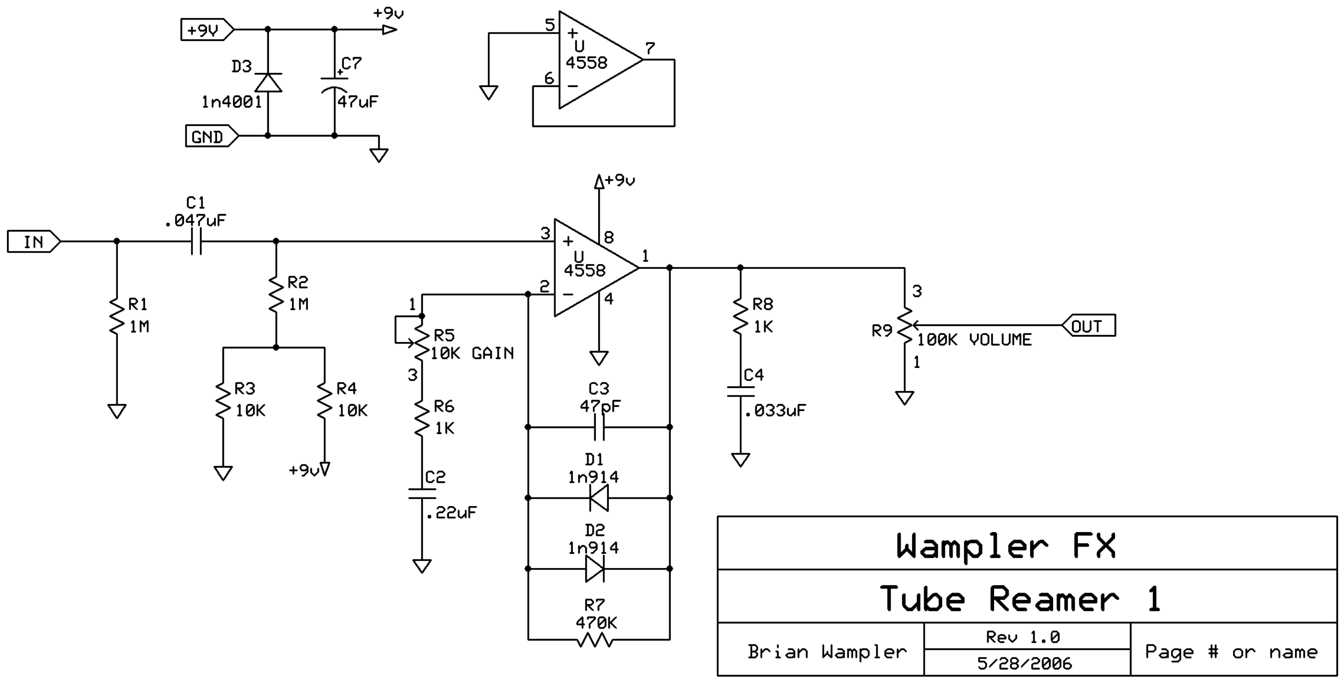


There are two possibilities shown here. One is going directly into the opamp, the other is being boosted through a JFET first and then inserted directly after “C4”. Note that using the JFET first will eliminate the need for C3, R1, or C4.

After the volume pot (R8) you will see a tone control (R9 + C8), as well as two different low pass filters which are connected to a spdt switch. This will give you a flatter response or more midrange controlled by the switch. R10 can be adjusted to provide the exact response desired.

Of course, D2, D3, D4, and D5 can be changed as well as moved so they are parallel with R6 (the gain control) instead of hard clipping to ground. This type of modification can be applied to nearly any overdrive or distortion pedal and is something to keep in mind as we discuss these different circuits.

Advanced Modification for “Tube Reamer” pedal



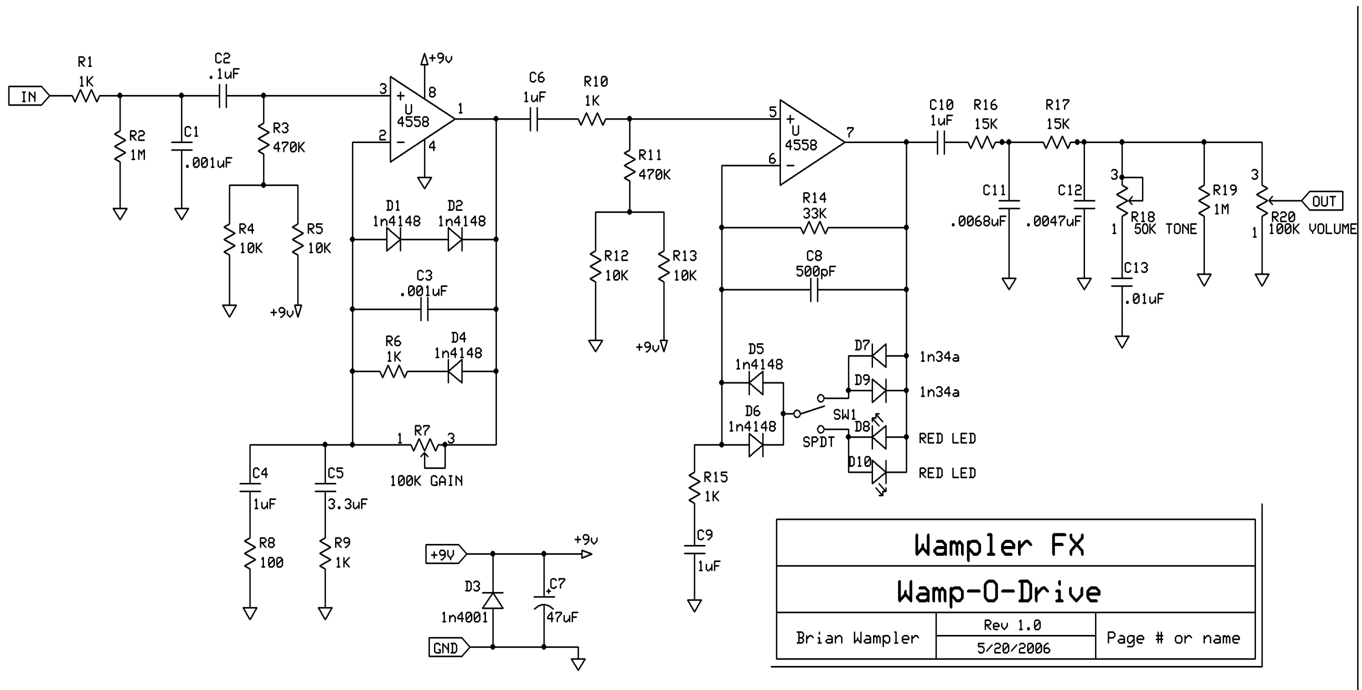
Original circuit from www.runoffgroove.com

The first incarnation of the Tube Reamer was developed as a stripped-down, yet edgier version of the classic Ibanez Tube Screamer. ROG (the staff at RunOffGroove.com) removed the input and output buffers as well as the tone control stage, plus implemented a different gain control. Many builders enjoyed the circuit, but many of us modified that circuit to suit our own needs. Shown above is the stock version. On the next page you will see one of the ways I like to modify the pedal. It actually has a bit of the MXR Distortion feel along with smoother clipping more similar to the tubescreamer.

On the modified version I'v changed the gain control so there is more variance. R8 and C4 is now a tone control, followed by a buffer which allows the tone control to not interact as much with the volume. Let me clarify that a bit...

Sometimes when a tone control is tied directly to the volume you will notice that when the volume is up all the way the tone control doesn't have as much affect on the tonality. The buffer helps to solve that. Of course, changing the diodes is standard, I liked to use a 1n4148 and germanium 1n34a, connected in series, in place of each diode as shown on the schematic.

The “Wamp-o-drive” circuit

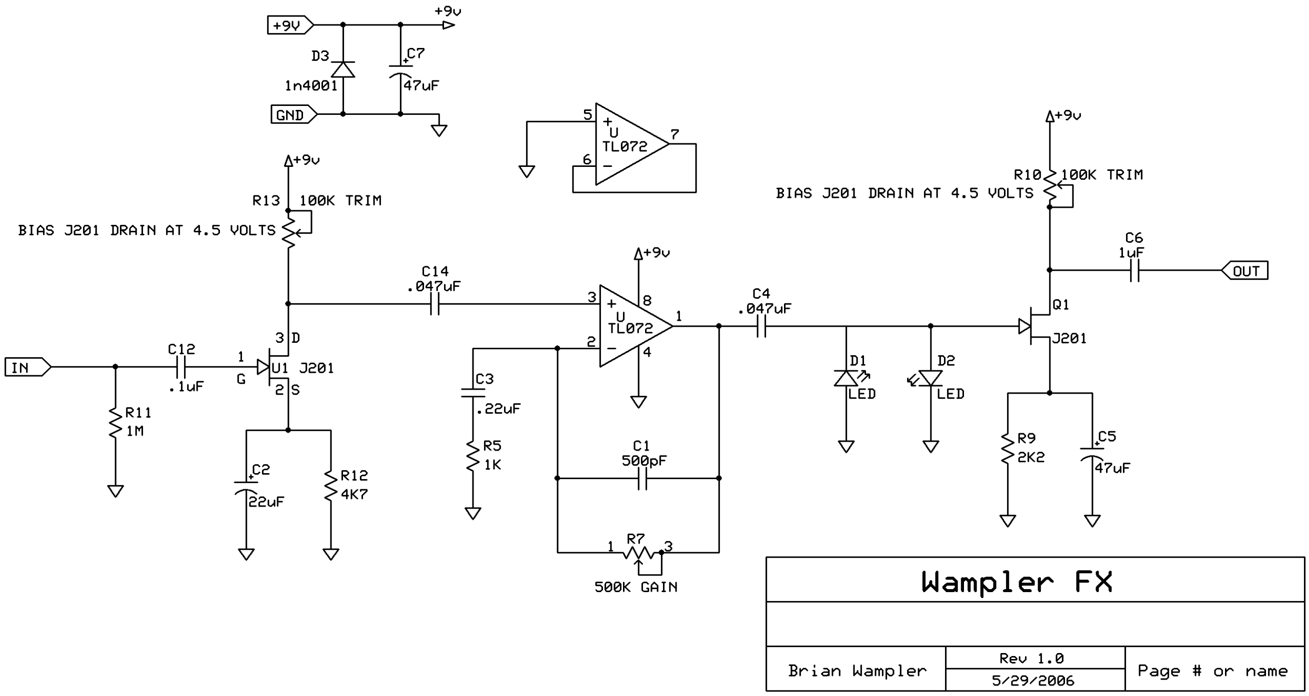


The 'Wamp-o-drive' is a big, full, fat and thick overdrive or distortion pedal. Notice that C4/R8, and C5/R9 are in parallel. The reason for that is that it affects both frequency centers.

R6 is connected in series with D4. That helps make the first clipping stage a little less asymmetrical than D4 by itself. The next clipping stage has a spdt switch to go from germanium diodes and LED's for clipping textures. The R15/C9 network will make the circuit's tonality fairly transparent, especially after dropping some highs with the low pass network at R16/C11 and R17/C12.

The tone stack shown can be implemented with any other tone stack of course, but this is the one I had used (R18/C13). R19 can be removed unless you are adding a JFET on the end (more about that on the next page).

Using JFETs on the input and output



Here is an idea worth experimenting with...JFETs going in AND out of an opamp circuit. This will give you a more dynamic feel and response as well as making the tone warmer. You may need to insert another capacitor and a voltage divider after D2 to control the amount of signal going to the opamp. Inserting a potentiometer here (acting as a voltage divider) would allow tweaking as well.

You could also omit D1 and D2 as shown in the schematic and insert them in parallel with C1 for a different clipping texture.

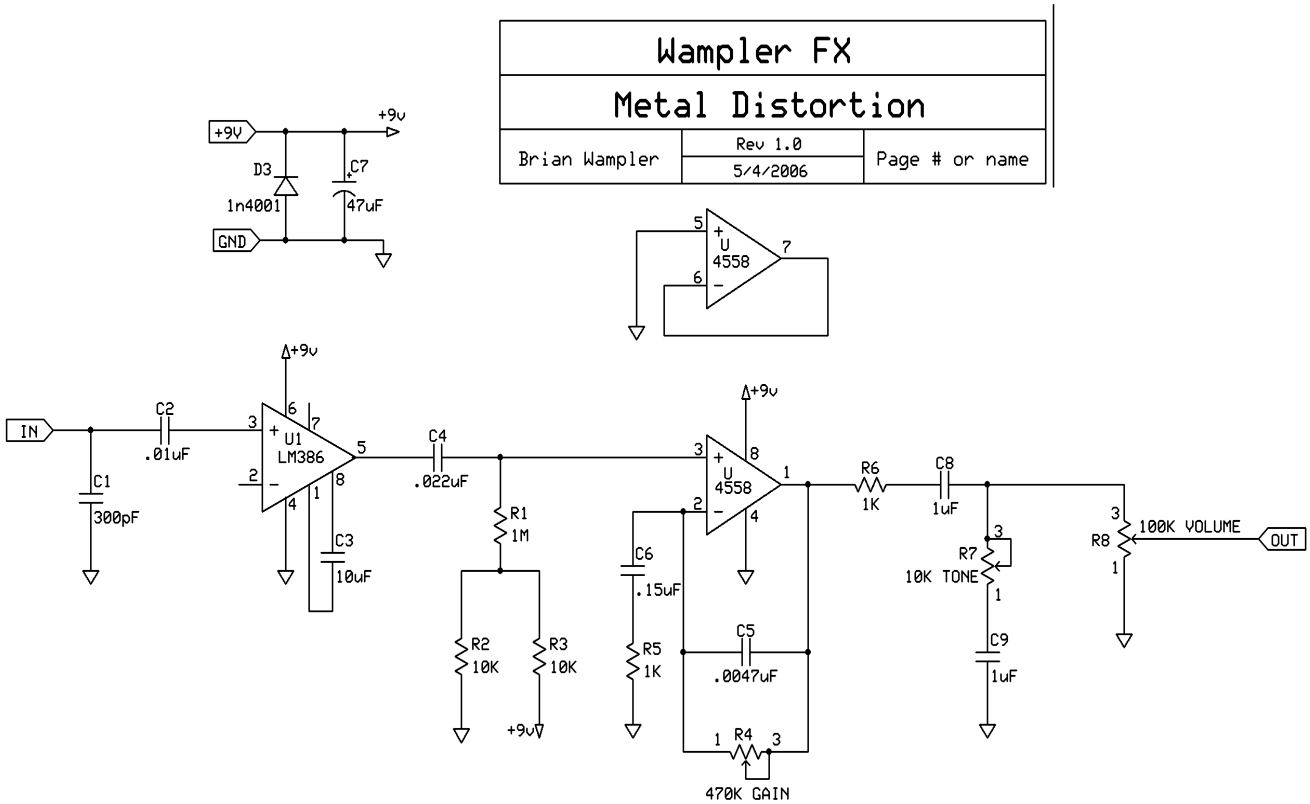
Changing R5 and C3 would tailor the frequencies that are clipping, which then could be tailored further by installing a low or high pass filter after D1 and D2.

Also, being that only a portion of the dual opamp is being used, you could change the connections to work with a single opamp such as the LM741 or even the LM308 and get a warmer darker tonality.

LED's aren't essential for the diodes, you'll want to experiment of course in all areas that are applicable as discussed earlier in the opamp basic section.

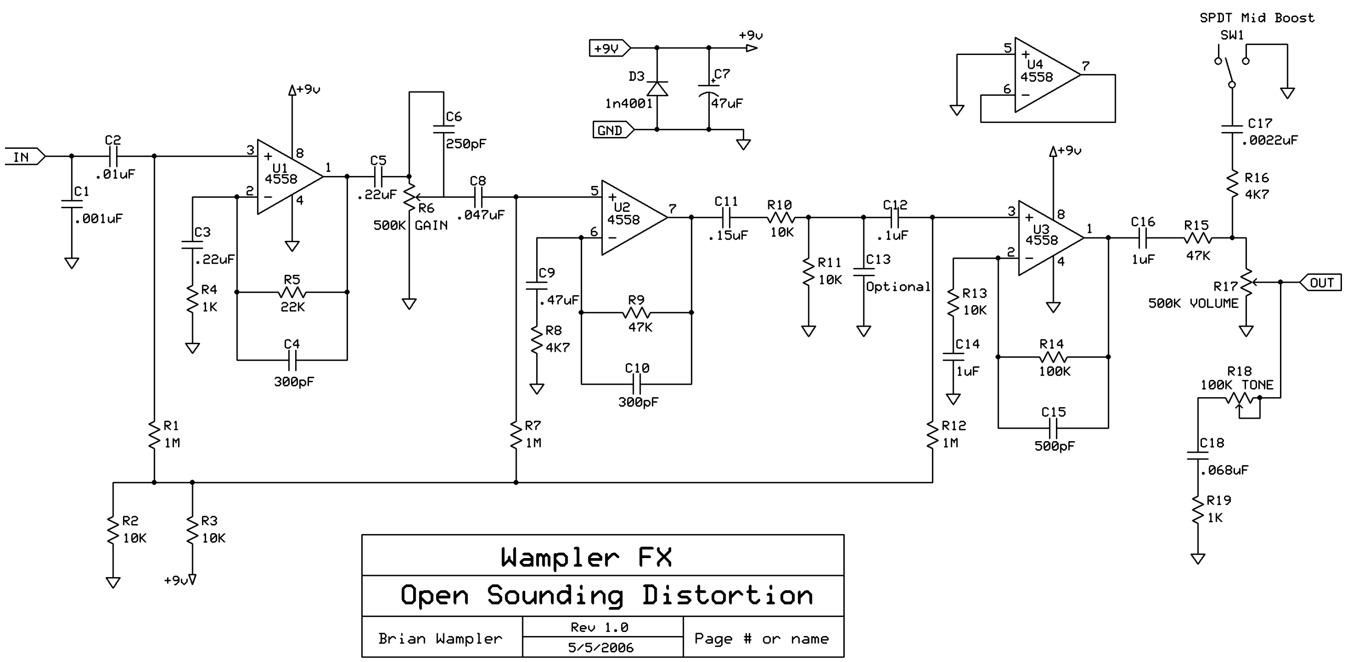
Note that a volume control is not shown but you've most likely learned that it is just a simple voltage divider on the end, as shown on all previous circuits. Most common value is a 100k and it would go immediately after C6.

Metal Distortion circuit



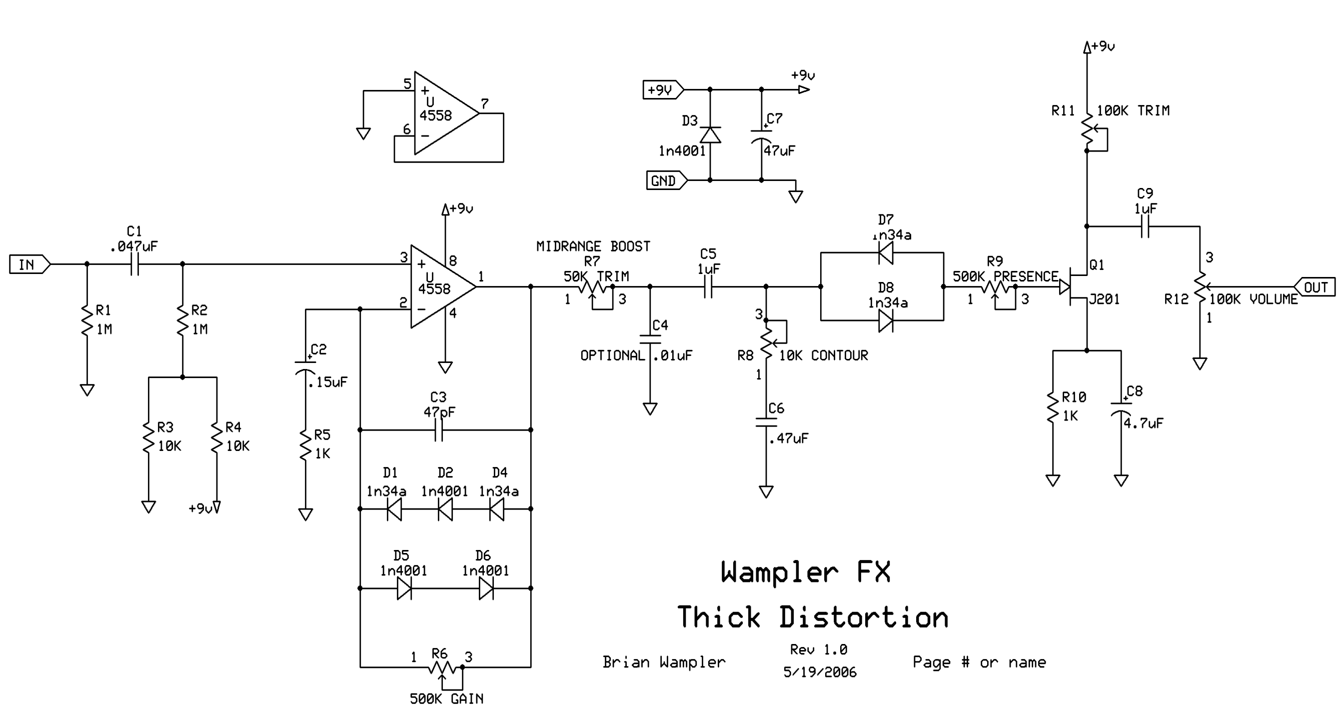
Shown here is a 386 type circuit going into an opamp clipping circuit to provide a great metal tone. Possible mods include adding diodes either in parallel with C5 or after R6. Change C6/R5 and/or C9 for EQ changes. Distortion is still present even WITHOUT diodes of course, as the opamp is clipping as well. Adding diodes will just change the texture of clipping.

Very 'open' sounding distortion



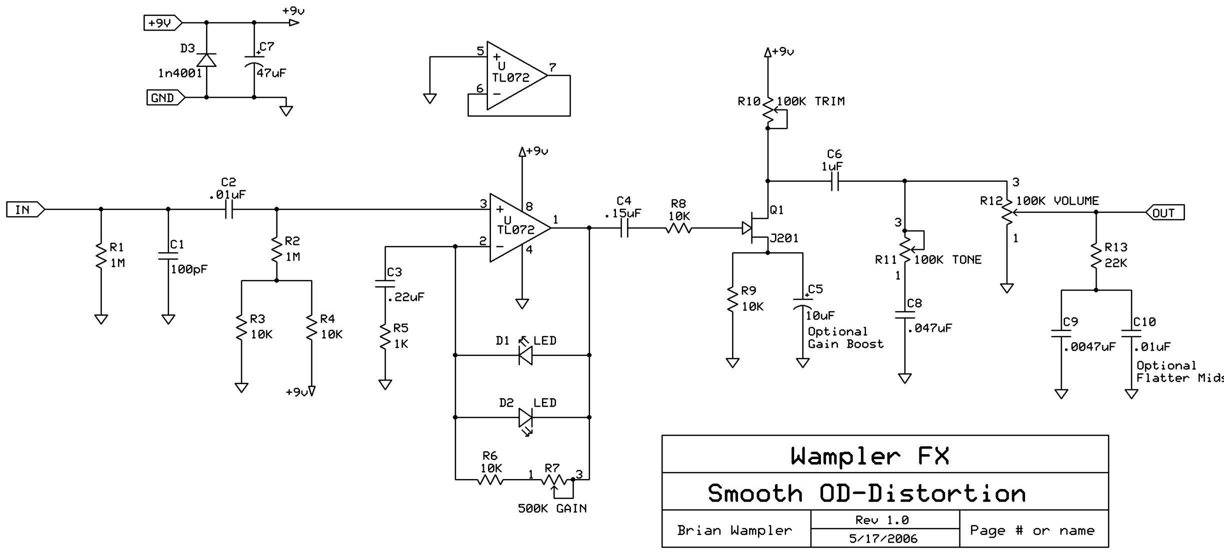
Here's another huge sounding distortion circuit with multiple gain stages. You'll notice that R6 is controlling the amount of signal going into the next opamp stages...effectively creating a gain control similar to what you would find in a guitar amp circuit. Also, notice R10 and R11 which forms a voltage divider so the next clipping stage doesn't get too mushy. Alternatively, connect germanium diodes to ground after C11 for a different clipping texture (and possibly eliminate R10/R11. R16/R17 is simply a low pass filter which when connected will filter out some mid frequencies. This can be tailor as well or even eliminated.

Thick distortion circuit



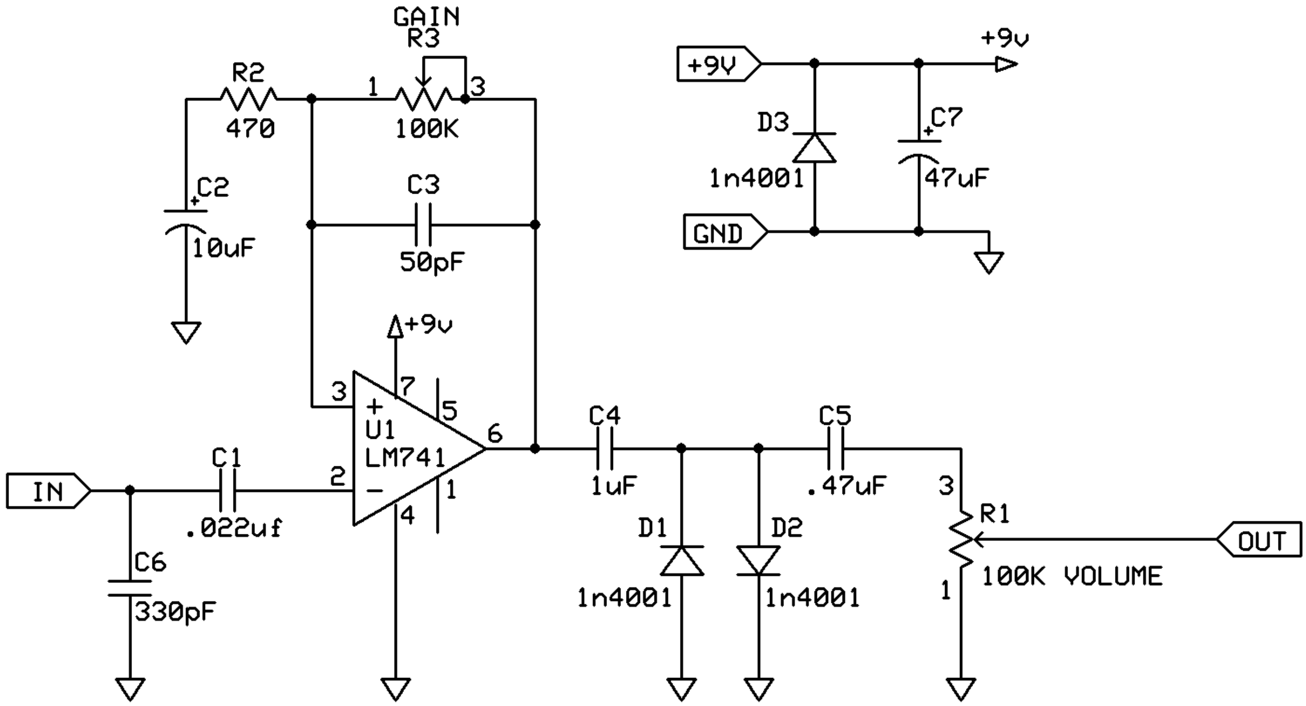
There are a few tricks in this circuit...a low pass filter at R7/C4 which will act as a midrange boost as well as R8/C6 which acts as an EQ control. D7 and D7 are germanium diodes that the signal passes through...this will give a different tonality than it would connecting them to ground like you generally see with distortion circuits. You'll notice a little more compression like this. R9 acts as a presence control in this circuit. It is actually controlling the amount of signal getting passed on through Q1 which then boosts the signal into the output.

Smooth Overdrive and/or Distortion circuit



Here is a great smooth sounding overdrive or distortion. D1 and D2 are LED's. The magic in this circuit is that there is SO much signal present going into Q1 that Q1 clips the signal smoothly and really give the tone a tube-like flavor. R10 is adjusting the bias for Q1 of course, R11/C8 is a tone control. R13/C9/C10 is a low pass filter.. C9 and C10 would be connected to a spdt switch so you can select a 'flatter mids' setting.

“Liquid” distortion circuit



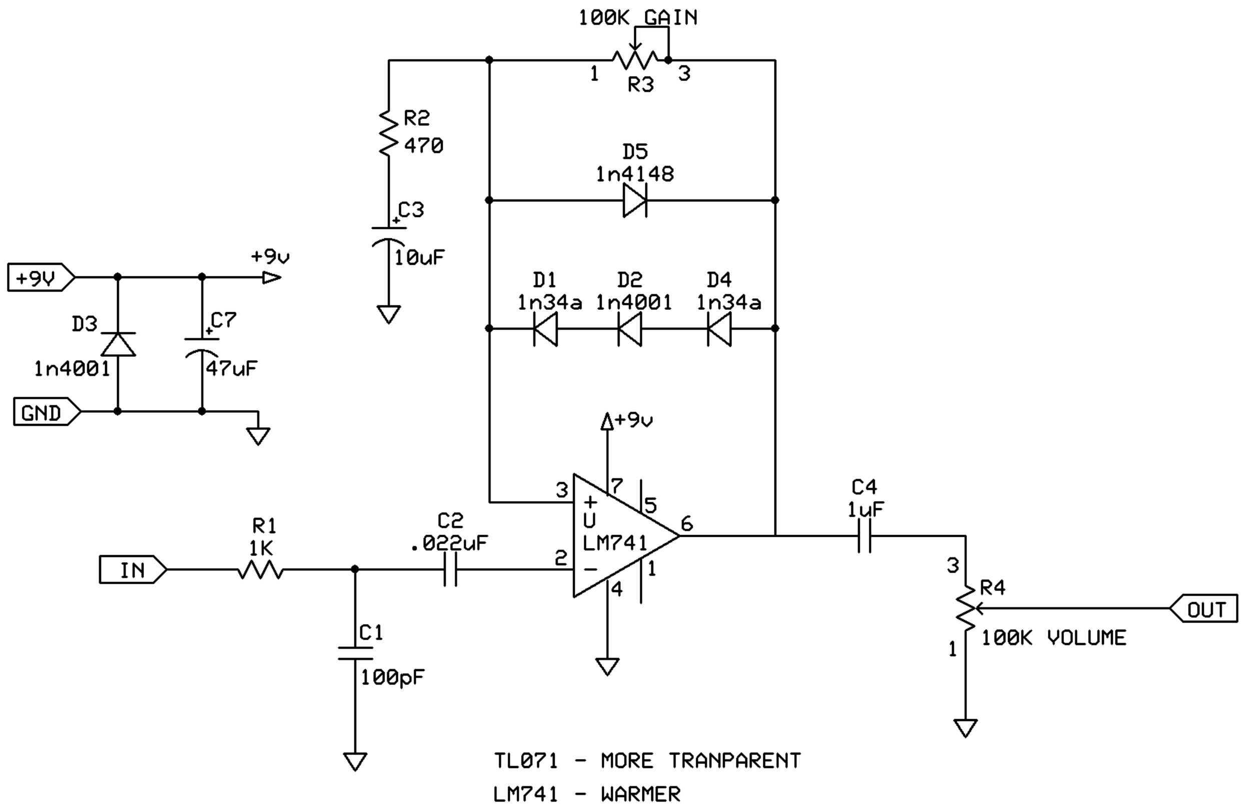
This overdrive/distortion circuit provides a very smooth almost “liquid”-like tone. It is also a quick and easy build. Various tone controls could be implemented. Add a 47k resistor BEFORE C1 and in series with C1 to provide a bit more smoothing and compression if desired.

Change C6 to a .001 to .0047uF for a frequency shift in the tonality of the clipping. A .001uF will be similar in tonality to a Rat type distortion.

Also notice that this circuit is very similar to a MXR distortion +, or a DOD OD250 (which are both nearly identical to each other), just with a different gain and tonality due to R2, C2, and the C6 modification if desired.

Additionally, try adding a 10k mini-trim pot after C4 (in series) to adjust the amount of compression/clipping saturation the diodes produce. These type of mods can be interchanged with just about ANY opamp shown throughout this book.

Warm 741 Overdrive

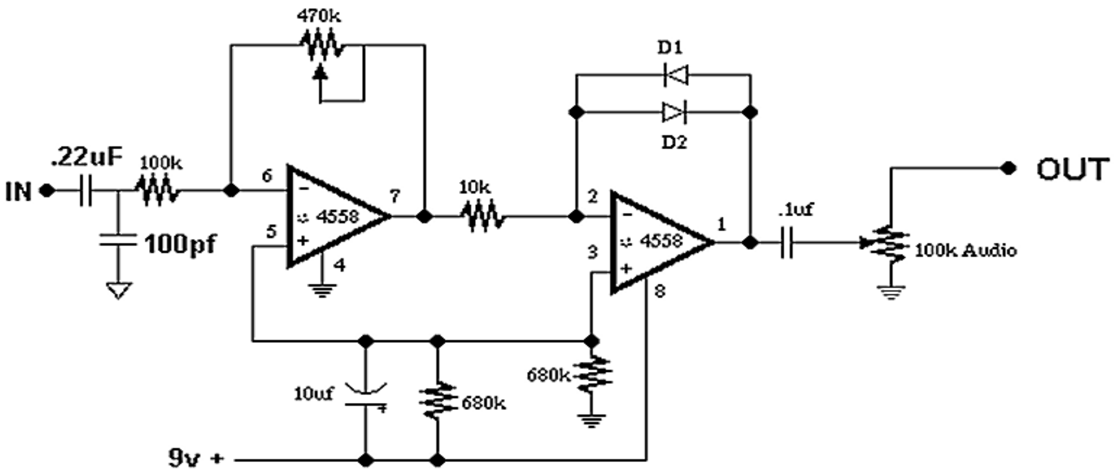


Alternatively, put the clipping diodes in the feedback loop instead of going to ground (as in the previous circuit, the liquid drive) and you'll get a softer clipping, and less fuzzy type of overdrive.

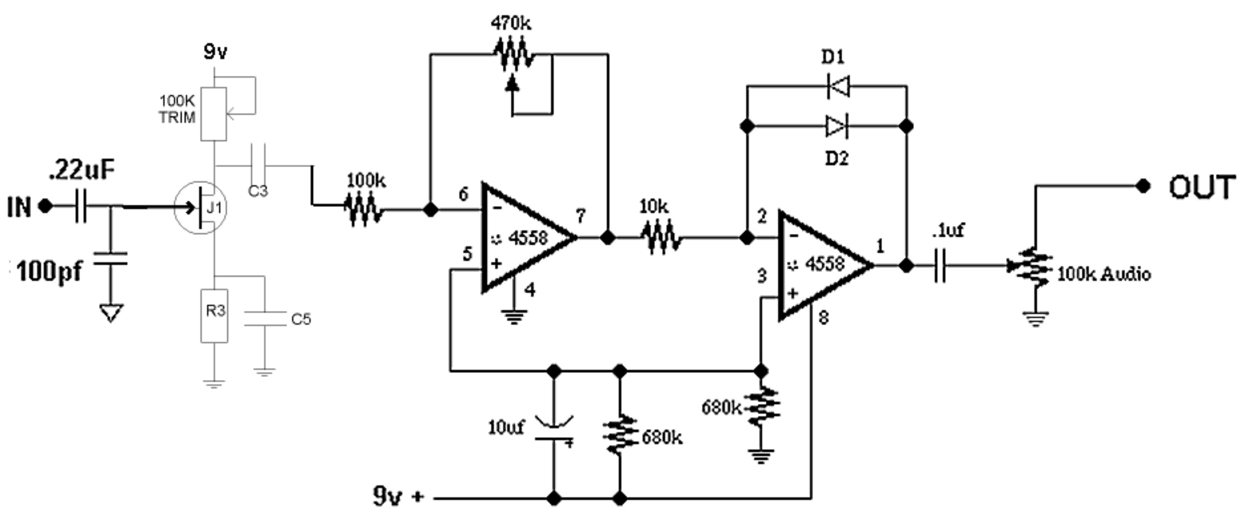
A 741 type opamp will be a bit warmer, and a TL071 will be louder, yet cleaner sounding.

Muff Fuzz using opamps

Muff Fuzz type Fuzz

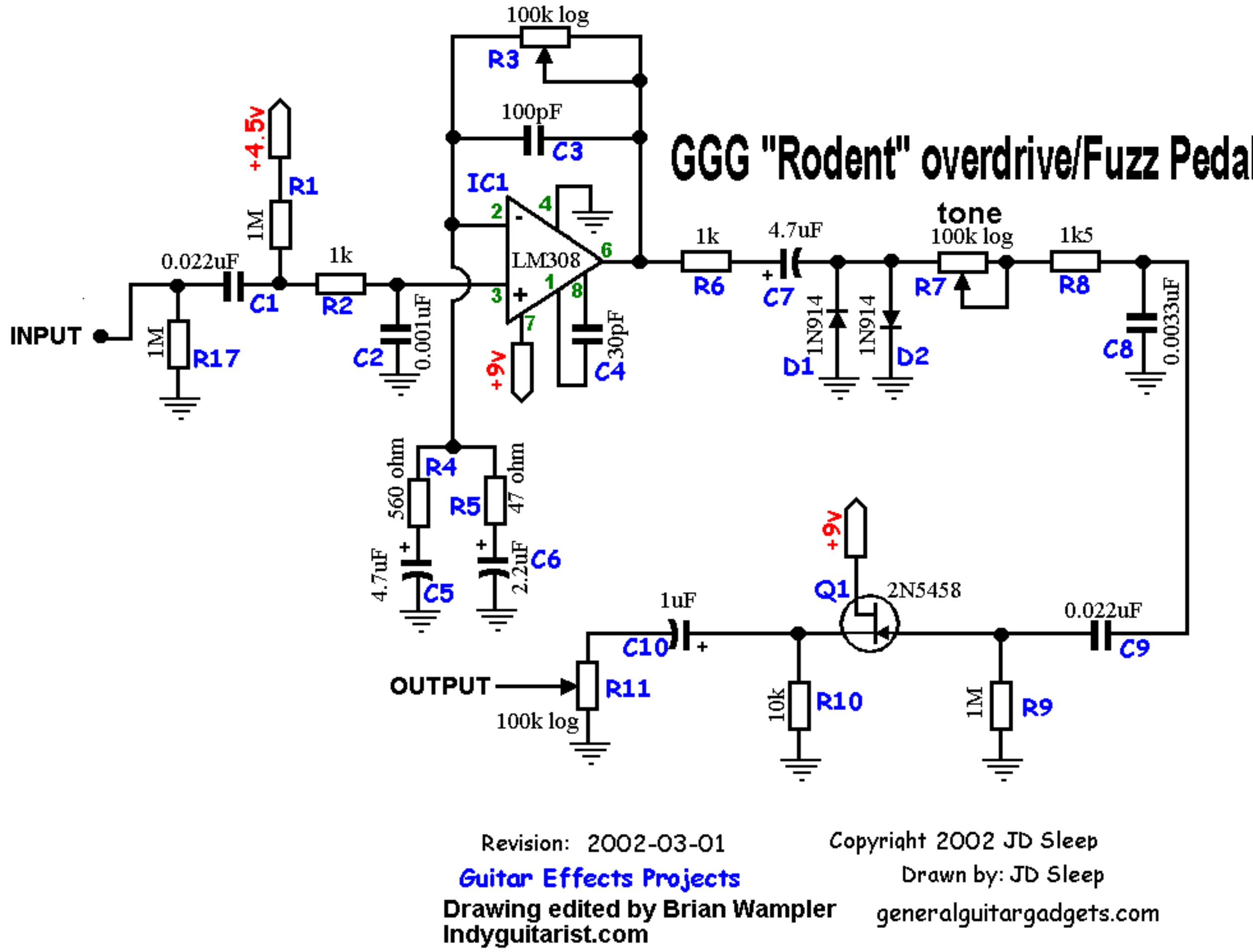


Electro Harmonix came out with a fuzz pedal called a “Muff Fuzz” that used a dual opamp. This is different in that many of their fuzzes were based around transistors. The schematic above is based off of their circuit. No tone control is shown but as always, insert the tone control of your choice. For even more fuzz, insert a transistor or JFET stage before the 100k resistor on the input. This will give you even more gain and will allow you to get a nastier fuzz. It would look like this:



R3: 1k, C5: 47uf, C3: 1uF D1/D2: 1n34a germanium or 1n4148 silicon diodes

Distortion/Fuzz similar to Proco Rat

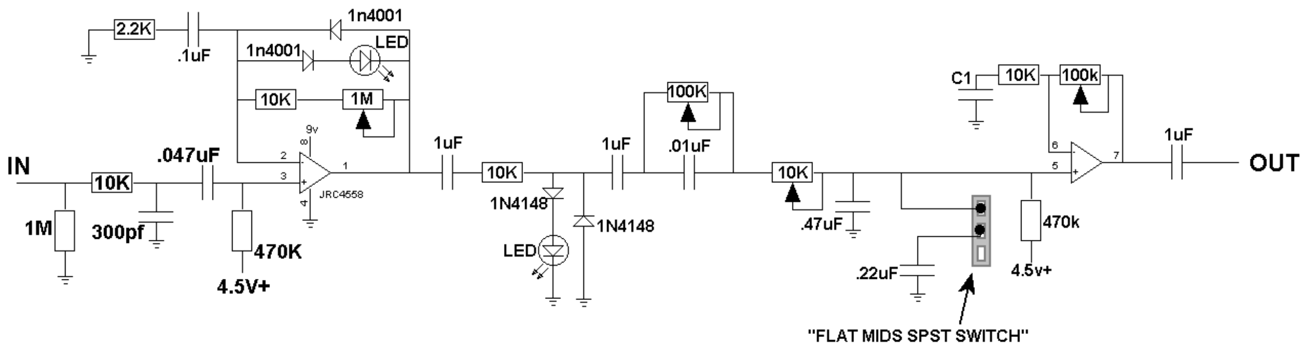


Many people seem to like the tonality of the Proco Rat Distortion pedal. JD Sleep of www.GeneralGuitarGadgets.com and Scott Swartz designed a similar circuit which some feel has a similar tonality. Mods that I like to do is to insert an additional low pass filter after R6, change C9 to a 1uF and add a JFET boost circuit on the end AFTER C10. Changing C5/R4 and C6/R5 will change the tonality of the pedal also.

Also, adding a JFET boost circuit similar to what we did with the Muff Fuzz type circuit (previous page) will allow you to get a fuzzier tone as well.

You can get printed circuit boards for this circuit directly from JD at www.generalguitargadgets.com

Overdrive/Distortion similar to Boss OD-3



The Boss OD-3 has been known to be one of the best kept secrets in the overdrive world for a while now. Many guitarists find that an OD-3 does just as well as many of the 'boutique' overdrives available today, especially since 95% of overdrives that are sold by these 'boutique' builders are nearly identical copies of a tubescreamer anyway.

While the Boss OD-3 is actually using a 'discrete' opamp, this version is using standard (integrated) opamps.

A 'discrete' opamp is slang for the circuit you would build if you used transistors, resistors, and other individual components to build an opamp circuit. A integrated (standard) opamp is what we have been discussing in this book.

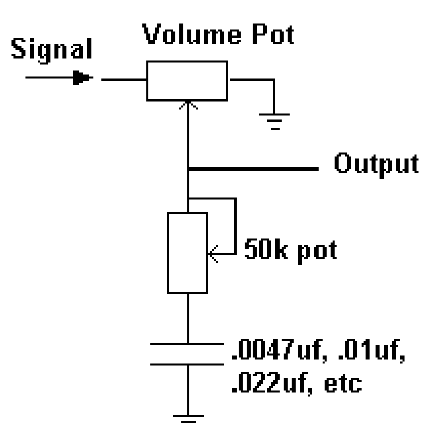
C1 (on the second opamp close to the output) can be tailored and used as a frequency boost. Try anywhere from .01uF to .22uF.

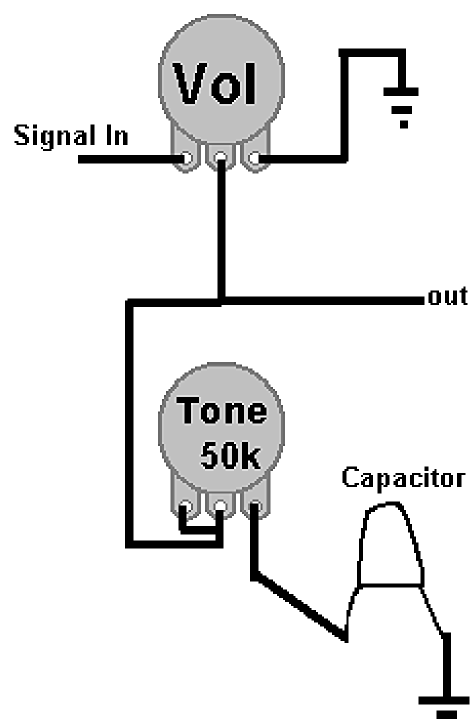
Tone stacks and tone controls

Most distortion, fuzz, or overdrive pedals have a tone stack to tailor the tone of the pedal. A tonestack is basically a small circuit that adjusts frequencies and can be a high or low pass filter (as in a traditional tone control), series of these, an inductor-emulation like most dedicated EQ pedals use, midnotch filters, and a combination of any of these. Some pedals use a 3 band passive eq circuit that is nearly identical to what most instrument amplifiers use.

Low and high pass filters are probably the most common and the easiest to implement.

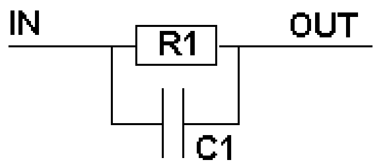
The image below shows a traditional low pass filter that is most often used as a tone control. The signal goes into lug 3 of the volume pot, lug 1 of the volume pot connects to ground, lug 2 goes both to the tone control AND to the output, which is where the volume should still be connected to. What you are doing is simply adding a wire from lug 2 of the volume pot into lugs 2 and 3 (or just lug 2, it doesn’t make a difference here), lug 1 of the tone control pot connects to a capacitor, which then connects to ground. You can also use a mini-trim pot and keep this control inside the pedal. I prefer linear taper pots for this type of tone control.



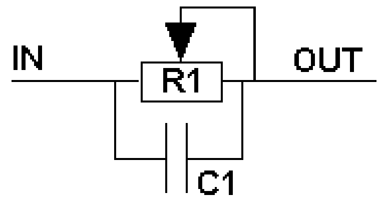


High Pass filter to control low frequencies

Bass control:



high pass filter

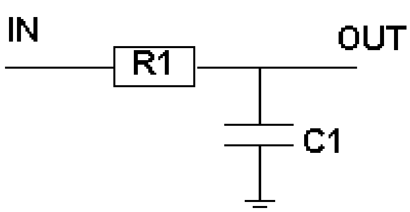


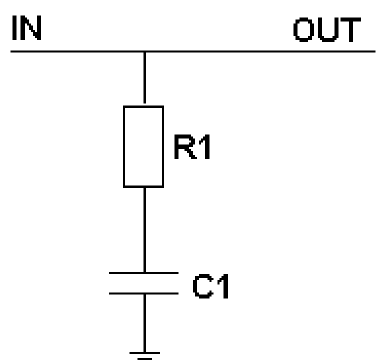
variable high pass filter

If you want to control the lows with a pot, make R1 a 470k potentiometer (linear taper) and change the capacitor to match the frequency you are wanting to control.

Alternatively, you can install the high pass filter before clipping to control the clipping frequencies.

A low pass filter to control mid and high frequencies





Both of these low pass filter circuits do the same thing – allow low frequencies to pass dependent on the value of R1 AND C1. On the next page there is a table that will show what the cutoff frequency is.

Frequency table for low and high pass filters

R1 (ohms)	C1 (uF)	FREQUENCY
10k	.22	72hz
10k	.15	106hz
10k	.1	159hz
10k	.08	199hz
10k	.068	234hz
10k	.056	284hz
10k	.047	338hz
10k	.033	482hz
10k	.022	723hz
10k	.01	1.5khz
10k	.0047	3.3khz
10k	.0022	7.2khz
10k	.001	15.9k
470k	.0047	72hz
470k	.0022	154hz
470k	.001	338hz
470k	500pf (.0005uF)	667hz

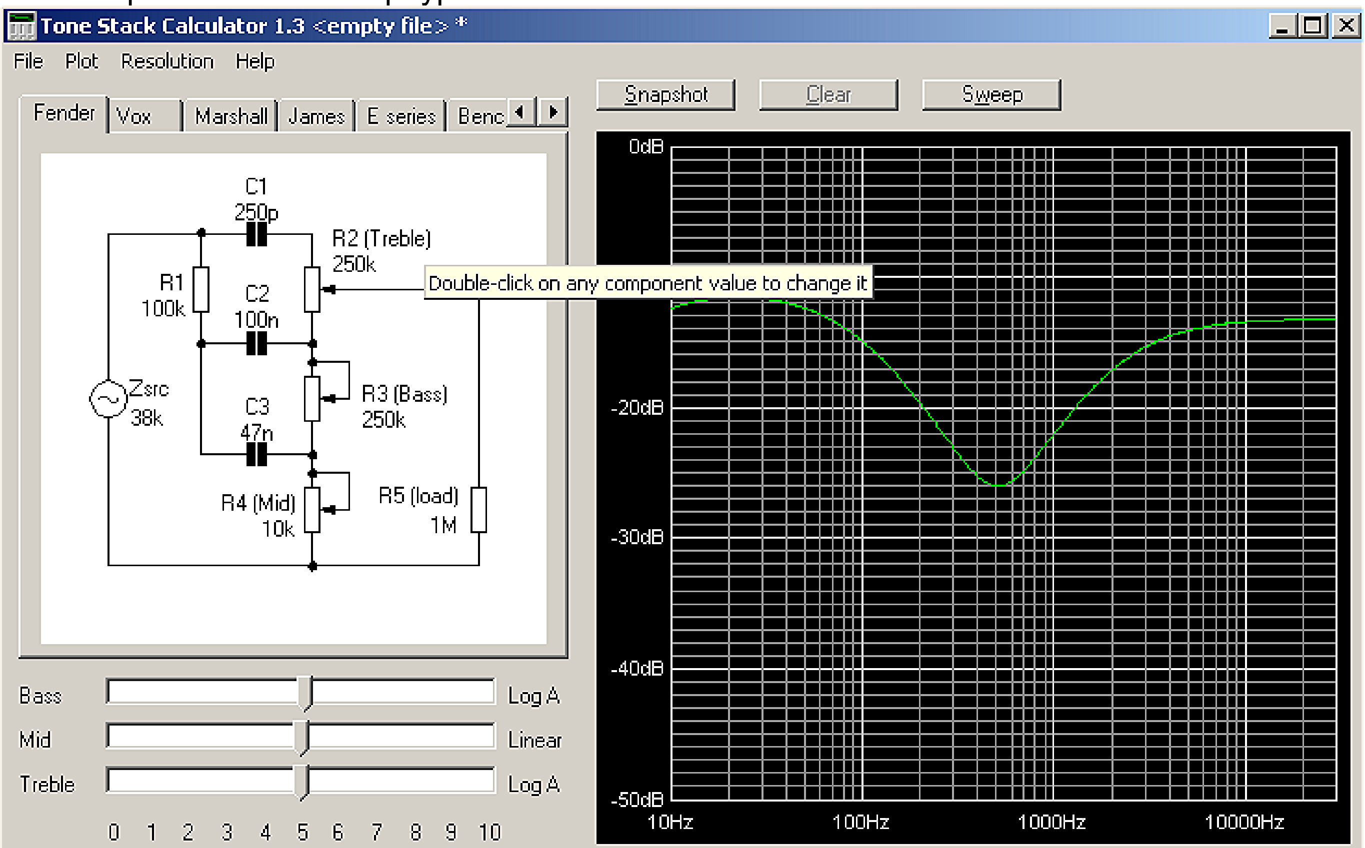
*Free online calculator at http://www.muzique.com/schem/filter.htm

Keep in mind that R1 and C1 affect the same frequencies in high AND low pass filters. The difference is that they affect them differently. For example, if your high pass filter has the values 10k for R1 and .047uF for C1 then most of the frequencies BELOW 338hz are limited, or not passed through (actually, not ALL frequencies are limited, but 6db per octave pertaining to the cutoff frequency). In a low pass filter with the same values the frequencies ABOVE 338hz are limited.

Free software for designing tonestacks

Duncan amps has created a handy piece of software free for download which allows you to change the components on different EQ circuits and see the response to the frequencies. Here is the download link:
www.duncanamps.com/tsc/

An example of a fender amp type tonestack looks like this with the software:

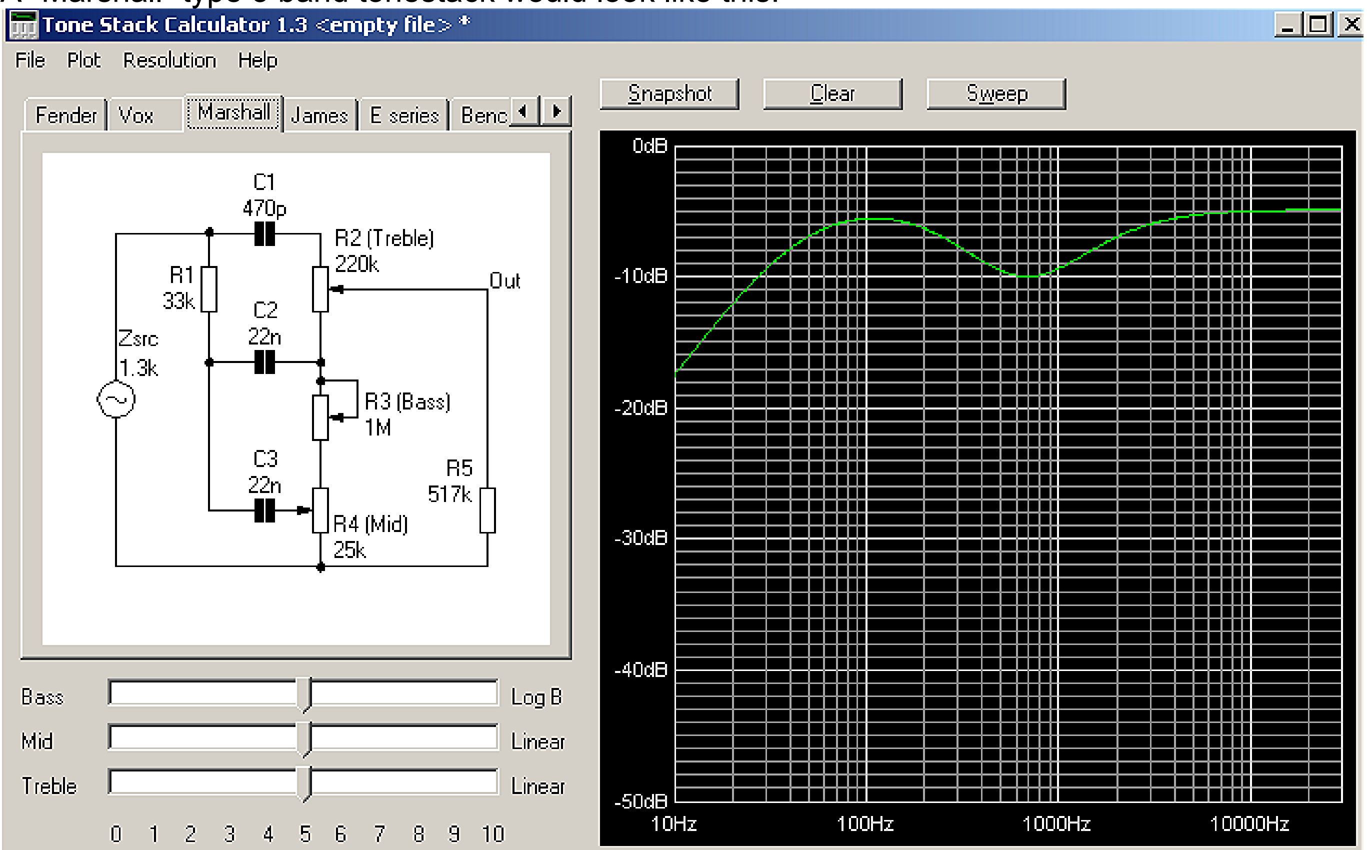


Notice that the capacitors in this software are measured in 'nanofarads' (nf). You may want to convert them to microfarads (uf or mf) to avoid confusion. For example, 100nf is the same thing as .1uf.

Some cool things about the software: Values can be altered simply by double-clicking on the component. With potentiometers, the taper can also be altered. The generator source impedance can be altered to give realistic simulation results for both cathode followers and common cathode drivers.
Bass/Mid/Treble controls: Slide the controls along and see the changes to the tone stack frequency response in real time.

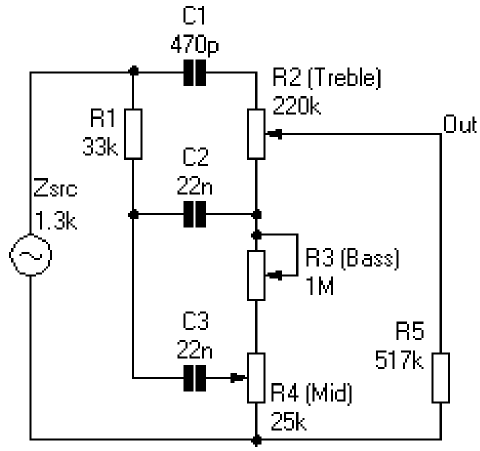
This also allows you to see what effect the circuit will have on the circuit with all controls at '5', or set flat. For example, using the 3 band circuit on the previous page would give the circuit a bit of a 'scooped' sound when all controls are set flat.

A “Marshall” type 3 band tonestack would look like this:

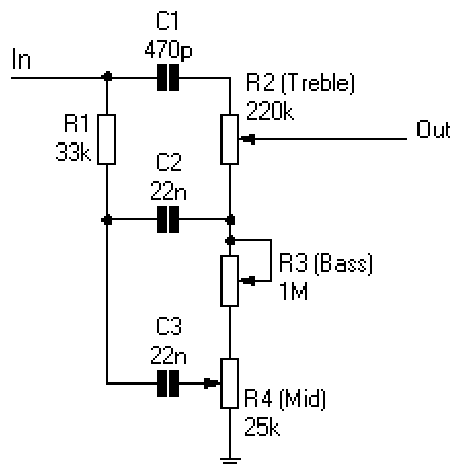


Notice that there is a bit of a mid hump than the fender type of tonestack.

Also, when working with this software, it may be confusing as to where the input and output is. “Zsrc” is the input signal. Looking at this same Marshall tonestack schematic, here is what it looks like in the “Tone Stack Calculator”:

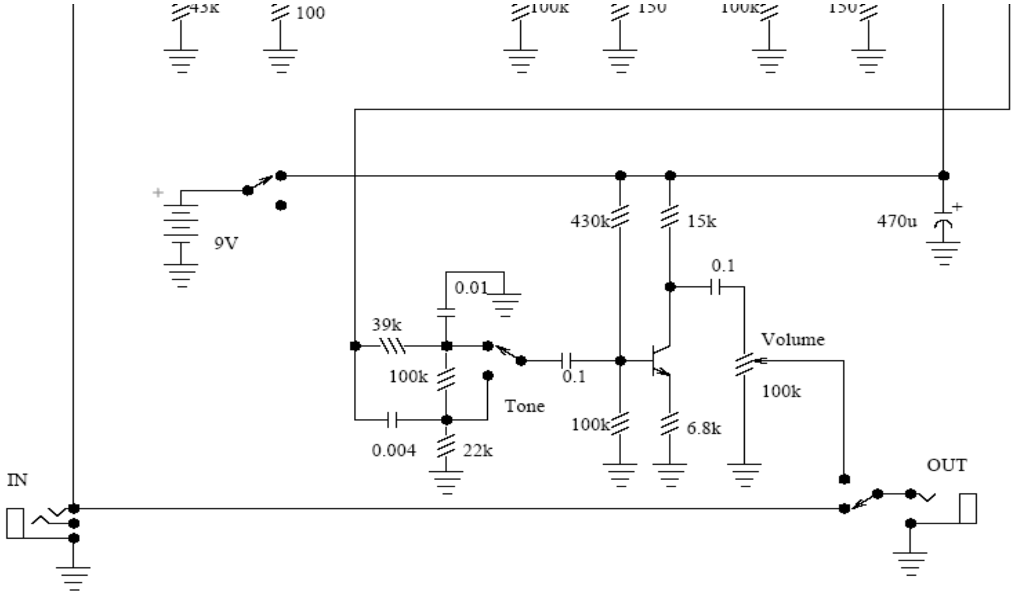


To connect it to a circuit, here are the parts you will connect:

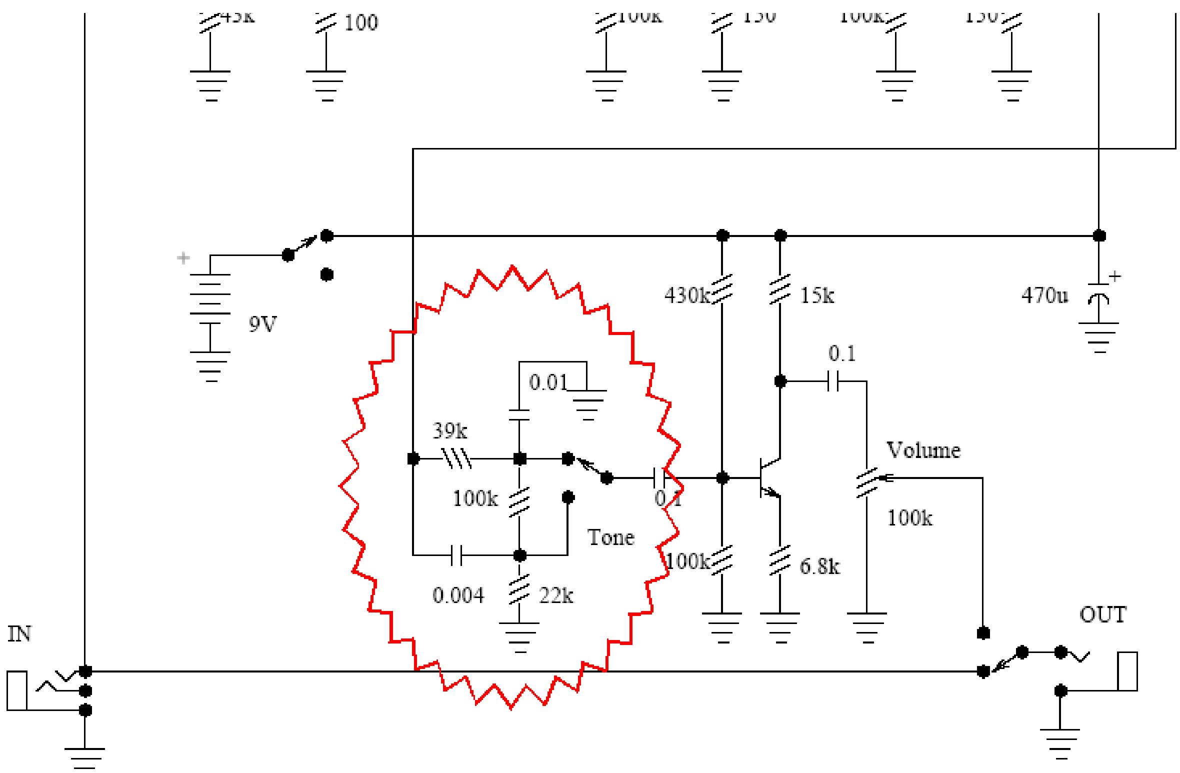


You can also download schematics of other pedals and see what type of tone control they are using, and simply use this type of circuit in your design. Go to http://www.indyguitarist.com/schematics or http://www.freeinfosociety.com/electronics/schempage.php?cat=1 to download various schematics.

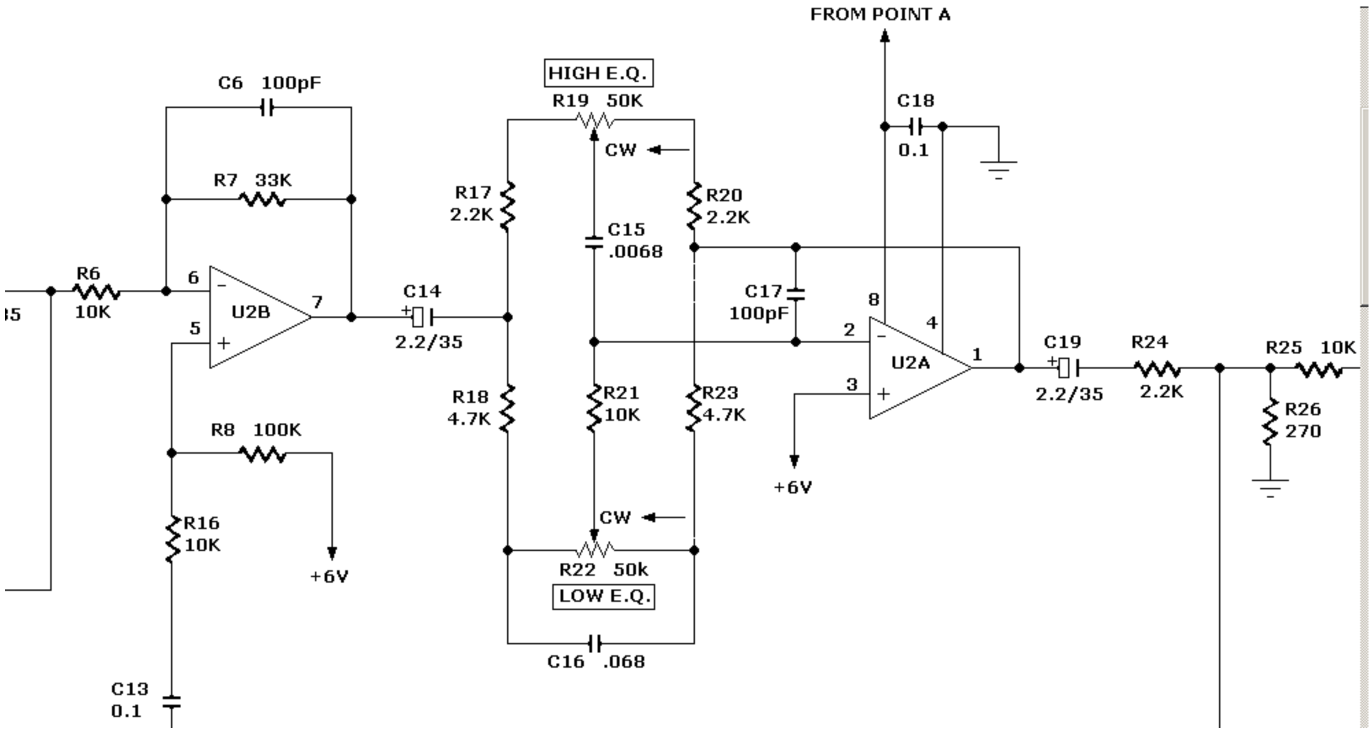
For example, let's look at part of a fuzz circuit. We'll simply find the location that is labeled as the tone control (after a while, you'll be able to spot them easily), and we'll copy this into our circuit.



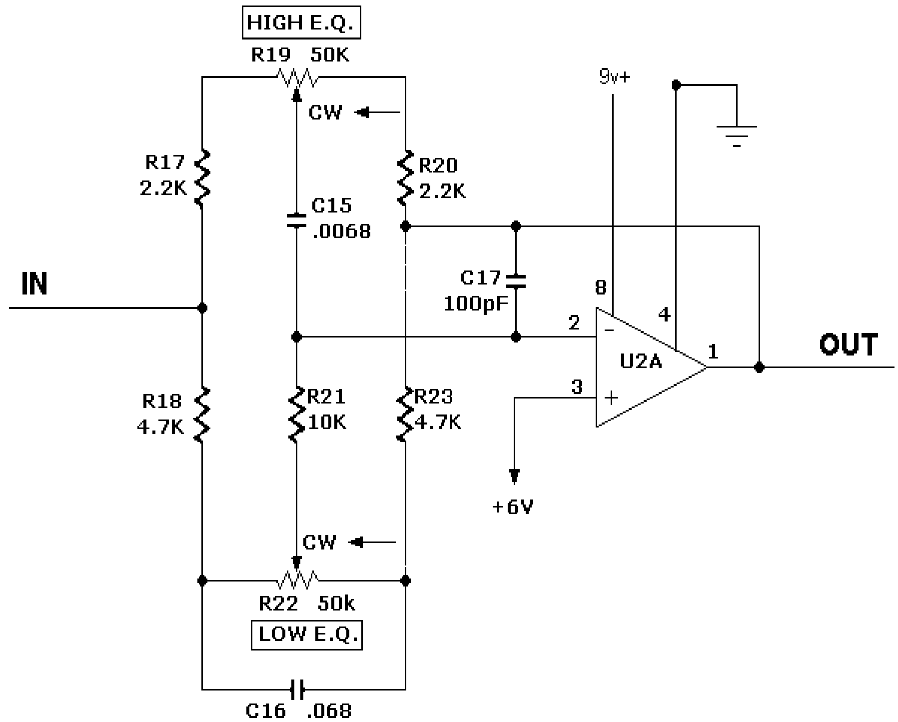
Above is a portion of a basic fuzz circuit, I'll circuit the tone stack below:



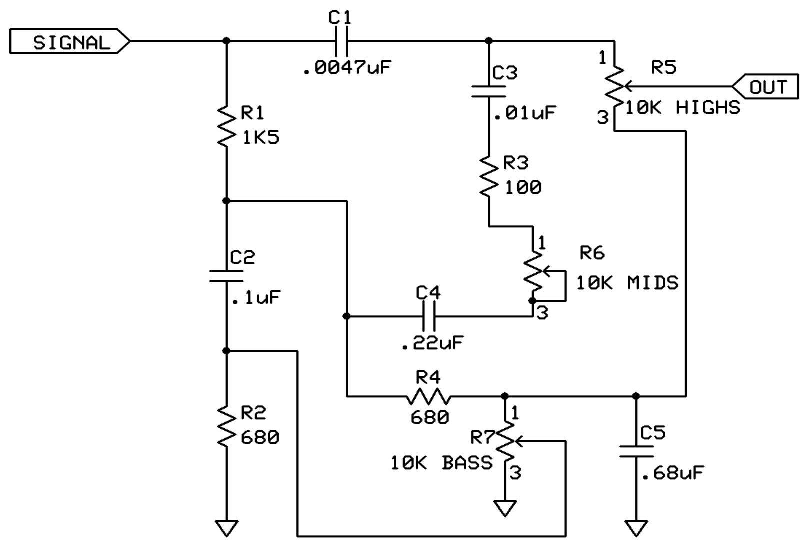
So the input comes in and meets the 39k resistor as well as the .004uf capacitor. This control shown is simply a spdt switch selecting between two different filters. Let's look at one from an amp.



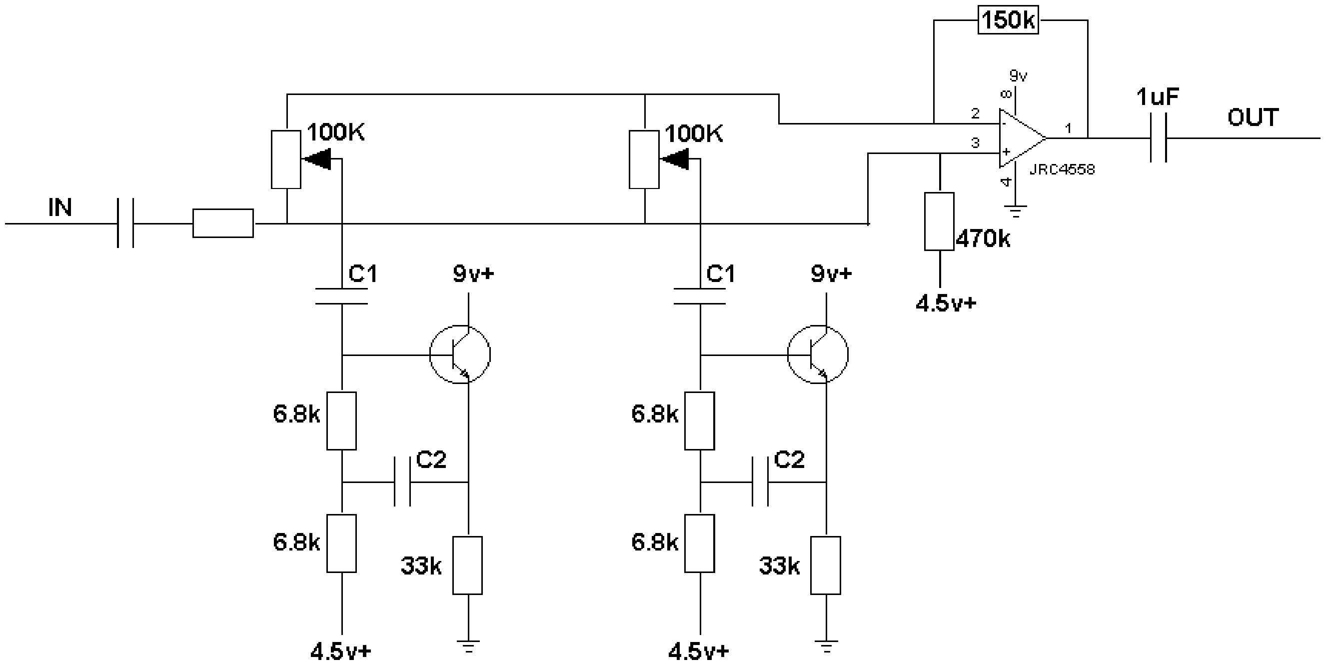
Shown above is part of a schematic of a Peavey amp. The tone stack is marked as “low EQ” and “high EQ”. The input comes in from C14 and the output comes in at pin 1 on the dual opamp. C18 can be eliminated here if desired, as it is just some filtering on the power supply of the amplifier. Here is the finished schematic:


HIGH E.Q.
R19 50K
CW
R17
2.2K
R20
2.2K
C15
.0068
9v+
IN
C17
100pF
8
4
2
-
U2A
1
OUT
3
+
R18
4.7K
R21
10K
R23
4.7K
+6V
CW
R22 50k
LOW E.Q.
C16 .068

Typical 3 band EQ tonestack, similar to “Marshall” type tonestack



Graphic EQ tonestack using NPN transistors



You may want to add an active EQ section in your pedal. In low and high pass filters you are filtering all frequencies above or below your desired frequency, this is what is referred to as a “passive” eq section. In the image above, you can select an exact frequency to boost/cut and dial in the amount of boost/cut, exactly like a graphic eq pedal. You can read more details about this type of circuit at www.geofex.com.

You can actually keep adding additional bands as desired by inserting additional 'gyrator' circuits as shown on the next page.

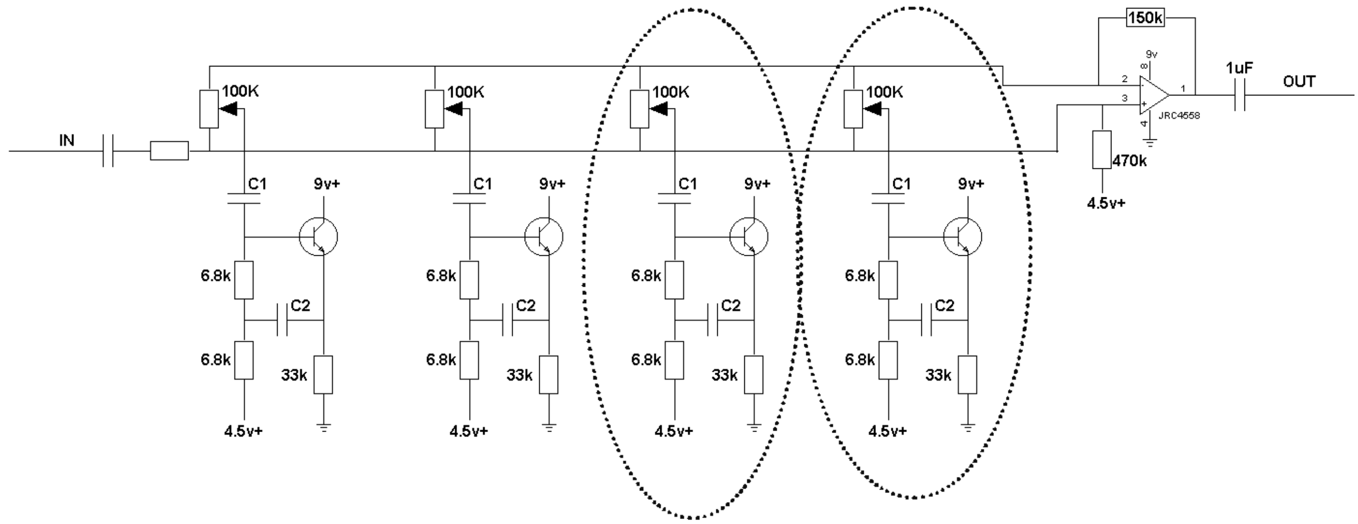
Note that you should put a buffer at the input for best results.

To control what frequency is affected, use the following table:

Frequency	*C1*	*C2*
60hz	.1uF	1uF
150hz	.047uF	.47uF
400hz	.022uF	.22uF
1khz	.0068uF	.068uF
2.5khz	.0033uF	.033uF
6khz	.001uF	.01uF

15khz	470pf	.0047uF

Adding additional bands to an Active EQ circuit



You can add as many additional bands as you desire, just change C1 and C2 to match your desired frequency.

In Closing...

The past couple of years have gone by quick...about 5 years ago I was figuring out how to design my own circuits to make them stand out among the others. I hope that I've helped you do just that in a much shorter time!

In fact, you may want to build several of these pedals for profit. That is totally fine, you are free to do so as long as you don't copy this book in any form without written approval from me.

I truly hope you get years of use out of this book, if I can be of any help please do not hesitate to contact me: brian@indyguitarist.com

Take care,
Brian Wampler
Owner IndyGuitarist.com