

This is a great dissertation on how to modify and change guitar amp preamp circuits to your liking. I don't remember where I found this on the internet; I've had it for several years. If you know who wrote it let me know and I'll give credit where credit is due. – Attila

Modifying Preamp Circuitry

Like most of the circuits presently offered on this page, this article is geared toward high gain preamp circuitry designed to produce harmonic distortion. Most of the descriptions will be quite simple, overlooking a great deal of the real complexity of how parts in a circuit interact. But after reading this, you'll have enough understanding to go into a tube preamp to change parts, and have a rough idea of how the changes you make will sound.

This assumes that you know how to SAFELY work on such gear (power turned off, amp unplugged from A.C. socket, filter capacitors safely discharged, wearing sneakers and standing on a non-conductive surface, observing component polarities, working in a well-ventilated area, etc.) If you don't know how to work on such equipment, work with someone who does know how, having them implement the changes you want to try. Bring a notebook and a pen, watch what your friend does (maybe even bring a video camera), ask lots of questions, and take notes. Yes, you're in school, and the lessons you learn will not only help you to eventually do the work yourself, they could save several hundred volts from being discharged through your heart. Meaning saving your life.

It's safer working on standalone preamps than on the preamp section of a whole amp, as heads and combos need much higher (and thus, more dangerous) B+ voltages and currents for the power tubes to run on. But unfortunately, there aren't a lot of guitar preamps whose construction makes them easy to modify. See if you can work with someone knowledgeable about electronics and build your own. Do you have any uncles or grandparents who used to (or still do) work on televisions, radios, and old hi-fi amps? Show them some schematics, along with how many 12AX7's you're using, the specification sheets for them-like those found in Aspen Pittman's "The Tube Amp Book, Volume IV"- and they'll know what transformers, filter capacitors, and other parts to get. They might just have some old P.A. or juke box amp from the 1950's that'd serve as a decent platform for experimentation. You may even just rip out the transformers and start with a whole new chassis.

(Make a diagram of what each wire on the transformer is for before removing the transformers, though.) I suggest using high quality Mallory filter capacitors in the power supply.

Given the renewed interest in tube amplifiers, it's likely we're going to start seeing more books and kits expressly designed for experimentation. Kevin O'Connor, author of "The Ultimate Tone", is coming out with a book of such projects in the very near future. The audio world is way ahead of us guitarists, as they already have a great many kits for both valve preamps and entire amps.

While we're focusing on distortion producing circuitry, nearly all of the general principles apply to lower gain amps, like Fender Twins, and the clean channels of modern guitar amps. A Mesa-Boogie is really just a Fender amp with a couple of extra gain stages.

I'm gonna deal primarily with increasing gain, though reading this, you'll get some knowledge of altering tonal response through capacitor changes.

Increasing gain

- a. existing circuit tweaks
 - 1. gain stages
 - 2. coupling circuits
 - 3. EQ networks
- b. adding new tube gain stages

A. INCREASING GAIN THRU EXISTING CIRCUIT TWEAKS

Think of a guitar preamp as a series of pumps (gain stages) and pipes (coupling circuits) that link these pumps. There are two general ways, then, I'll talk about increasing the water (signal) flowing through.

One: Make the pumps work harder

Two: Reduce the uphill struggles and leaks in the connecting pipes.

OR

One: Increase the gain of the gain stages

Two: Reduce the "drag" of the coupling circuits.

Look at this diagram:

IN--->>GAIN---->Coupling--->GAIN---->Coupling---->GAIN--->> OUT
 STAGE Circuit STAGE Circuit STAGE

Modifying Preamp Circuitry

1. INCREASING OUTPUT OF GAIN STAGES:

Look at Gain Stage 1:

You can increase gain one of three ways:

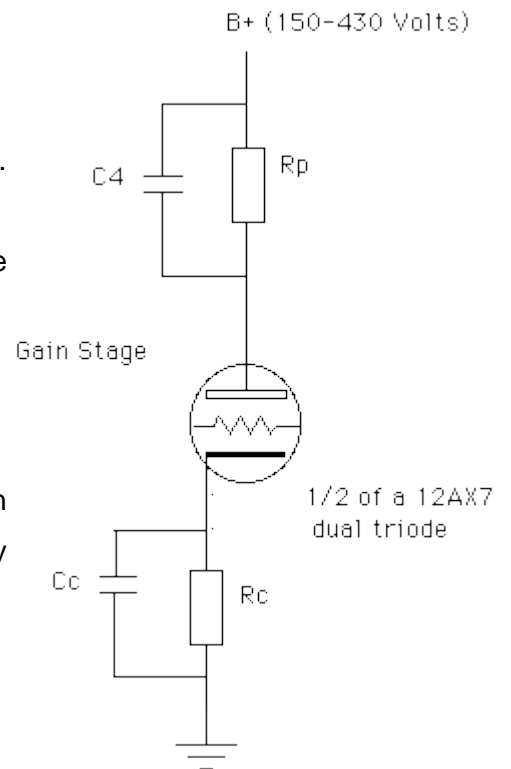
- A. Increase the value of the plate resistor (R_p). and/or
- B. Decrease the value of the cathode resistor (R_c). and/or
- C. Add a bypass capacitor (C_c) around the cathode resistor (R_c).

R_p : 47K to 470K. Usually 100K

R_c : 10K to .82K (820 Ohms). Often 1.5K to 3.3K

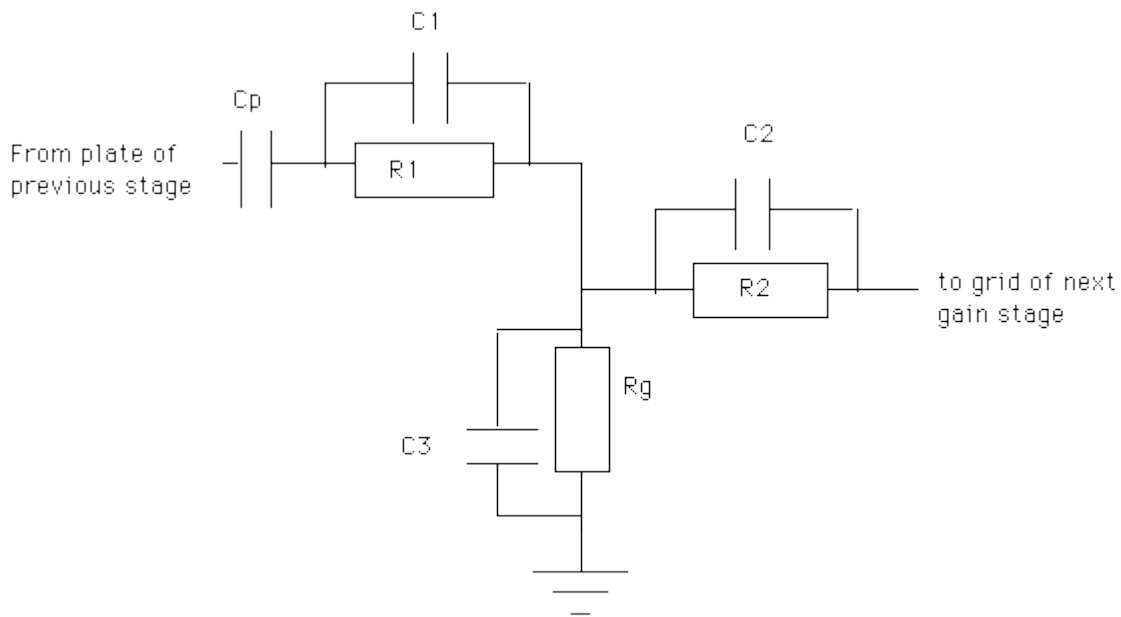
C_c : .01uf to 250 uf. .68 uf for lead preamps, 25 uf for clean preamps larger values give more gain, and deeper frequency boosts.

To reduce gain, just do the opposite.



TWO: REDUCING THE "DRAG" OF COUPLING CIRCUITS

Look at coupling circuit AA1:



To increase gain, you want to

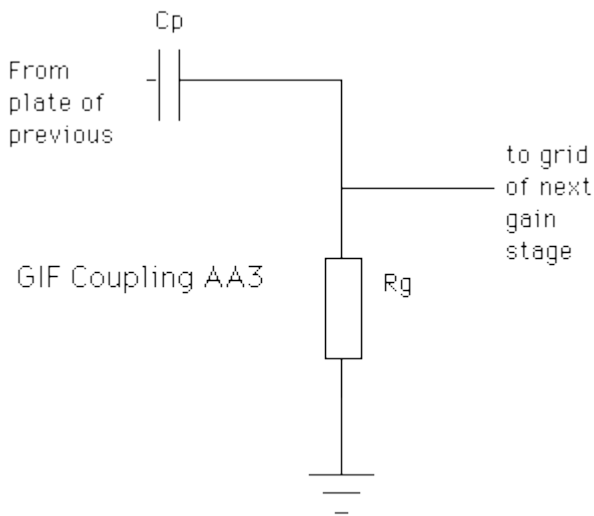
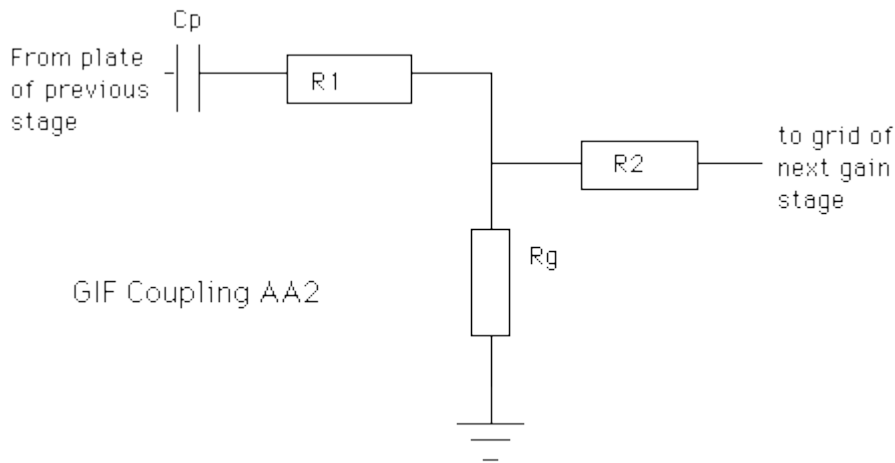
1. reduce the "uphill struggles" (R_1 and R_2), and
2. plug up the "leaks" (R_g).

In our preamp, do one or more of the following:

- A. Reduce value of R_1
- B. Reduce value of R_2
- C. Increase value of R_g (plug up the leak).
- D. Add bypass cap (C_1) around R_1 for treble gain boost
- E. Add bypass cap (C_2) around R_1 for treble gain boost
- F. Eliminate any low pass filters, such as C_3 . This will increase the amount of treble in the circuit.

Again, to reduce gain just do the opposite. To see this coupling circuit stripped down to its essential components (C_p and R_g), look at figure AA2, then AA3.

Modifying Preamp Circuitry



Here's a more detailed explanation of each resistor and capacitor:

Gain Stages

Rp: Plate Resistor. Not optional for gain stages.

Typical values range from 82K to 330K, with 100K being the most common, and 220K frequently used in lead channels. Higher values increase gain, and reduce headroom, which means the stage will distort more easily. The two highest values I've seen are 1 MegOhm, and a 4.7 MegOhm on a Music Man RD-50.

Modifying Preamp Circuitry

Rc: Cathode Resistor. Not optional.

Typical values: 820 Ohm (.82 K) to 10K (10,000 Ohms). The lower the value, the greater the gain. The higher the value, the less the gain. In a few super high gain preamps, I've seen stages with Rc values up to 39K, which significantly lowers the gain of this particular stage. Not always such a bad thing, trust me.

Cc: Cathode Resistor Bypass Capacitor. Optional, but often used.

Values range from .01uf to 250 uf. These caps function as a frequency dependent gain boost. Small values, such as .01uf or .047 uf allow for a gain boost in just the highs. Values such as .68uf and 1uf make for an increase in both mids and highs. 25uf caps boost all of the highs, and mids, and most of the bass. The exact frequencies affected depend in part on the value of the cathode resistor used. Think of capacitors as "tone windows"-the larger the window (value) the "bigger" (really, lower) the frequencies allowed through. Notice that it's not like a graphic EQ where boosting the bass boosts ONLY the bass. If you use a big cap to let bass through, any higher frequencies get through, too.

Since the voltages on the cathodes of most gain stages are pretty low, you can get away with capacitors rated for 25 or 50 volts. If you use electrolytics, make sure the positive side is facing the cathode, and the negative side is facing ground.

C4: optional

This capacitor is usually only found on one of the stages in a 3 to 6 stage preamp designed to produce distortion. It helps stop "squealing" or "oscillating" by letting very high frequencies pass around the plate resistor and out of the signal path. The loss of high end may mean you lose some of the "edge" or "bite" in your tone. Don't assume that you have to add this capacitor, unless you really have a problem with squealing. Start with 50 pf, then, move up to 330 pf, 500 pf, and 1,000 pf.

Coupling Circuits

I'm going to assume we're using the most common style of coupling network found in tube guitar preamps, consisting of a coupling capacitor (Cp) just after the plate, followed by an interstage

attenuator (Resistor R1), a resistor to ground (Rg), and finally, another interstage attenuating resistor (R2), just before the grid of the next gain stage. Look at figure AA1 and AA2.

Cp: Coupling Capacitor Not Optional

This capacitor couples the output of a gain stage to the input of a following gain stage. It blocks the high DC voltage present at the plate from getting to the grid of the next stage. Amps with bad coupling capacitors will not work properly, can damage tubes, and will sound very bad. So always make sure you've got a good coupling capacitor between any two gain stages. And make sure it's rated for the voltages it may encounter. Start with 400 volt ratings and go up from there.

The second function of this capacitor is as a tone filter, or "Tone Window". It determines what frequencies pass on to the rest of the circuit. The most common value for this cap is .022 uf, though .0022 uf (which lets less bass through) is also common.

In Fenders and Mesa-Boogie amps, you'll often find larger coupling capacitors which let more bass through-.047 uf and .05 uf caps. Mesa distortion does sound thicker (some would say "muddier") than Marshall distortion, and in part this is based on Mesa's use of larger coupling caps (.047 uf vs. .022 and .0022 uf in most Marshalls.) In bass amps, you may even see .1 uf capacitors. At the other extreme, in the Top Boost section of Vox AC30's there are 500pf (.0005uf) coupling caps. Very trebly, as nearly all of the bass and most of the mids have been blocked by this tiny capacitor. So, I guess that's your typical range: .05 uf to .0005 uf, but if you like lots of bass or ultra piercing treble, you can go outside of these parameters.

You'll notice that the values for cathode resistor bypass caps are much larger than for capacitors in the coupling circuit. What's super treble for a cathode resistor bypass cap (.02uf), is quite normal sounding for a coupling cap. Just try to keep the range of values for Cc and Cp separate in your mind.

R1: Optional

This resistor is called an "inter-stage attenuator" by some. It reduces (or attenuates) the strength of the signal. I've seen values up to 4.7 Meg Ohms (4,700 Kilo Ohms), and values as low as "zero Ohms" (i.e. a straight wire, no resistor). Common values: 1 Meg, 750K, 680K, 500K, 470K, 330K, 250K, and 100K. The higher the value, the greater the "obstacle course" or "mountain range" your

signal faces, and thus, the less the "gain". Said another way, the lower the value of R1, the more signal that gets thru.

R2: Optional

Like R1, this is an "interstage attenuator" that also reduces the strength of the signal. In conjunction with Rg, it also helps "bias" the grid of the next gain stage, but we'll tackle that later. Typical range: 680K to 0K, often 500K to 68K. You could use larger values if you wished. For more gain, reduce the value; for less gain, increase the value. Just like for R1.

Rg: Not optional (generally speaking) Sometimes called a "grid leak" or "grid load" resistor. It serves an important function in that it helps bias the grid of the following stage. All you have to know for now, is that the grid of any gain stage needs a DC path to ground through a resistor, WITHOUT a capacitor to block the DC. If you add a capacitor in series with Rg, it will block this DC path, and the next gain stage won't work right.....unless you add a new resistor to ground from the grid.

Another, very important function of Rg is that it lets signal bleed to ground, and thus, OUT of the signal path. If Rg is removed from the circuit and replaced with just a straight wire (a zero Ohm "resistor"), then all of the signal from the first gain stage will bleed to ground, and the next stage won't have anything to amplify. This is, in fact, basically what happens when you set your gain or volume control to zero. You could think of it as a pipe valve leaking water out of a pipe before it gets to a new pump (the next gain stage). So, higher values of Rg "block" this leak, keeping more signal in the signal path, where it gets to the rest of the circuit to be amplified. Lower values make the leak bigger, and you lose more signal, thus leaving less to be amplified. Want more "gain": increase Rg. Want less "gain": decrease Rg.

These grid resistors are very useful in taming the gain in multi stage circuits. A tube stage can easily become over saturated by too strong an input signal, and one way to keep it from being oversaturated, is to weaken the input signal by letting it bleed to ground through a lower value of Rg. It's certainly not the only way to solve this problem, but I think if you experiment with preamp circuits, you'll quickly find how dramatic the changes are when you substitute in different values for Rg.

These grid leak resistors can be anywhere from 2 Megs to 10K. Experiment with values like these: 1 Meg, 750K, 500K, 330K, 220K, 100K, 68K, and 10K.

C1: Optional.

Modifying Preamp Circuitry

This bypass capacitor for R1 lets some frequencies sail by R1, as though R1 didn't exist, as if it were only a wire. Small values of C1 (50pf to 500 pf) let mostly treble frequencies go by, leaving most of the midrange and all of the bass (that's gotten by Cp) to struggle through the "mountain range" of R1. So, these lower frequencies are attenuated, and the tone becomes "brighter". It's like a treble gain boost.

You could add more mids to the brew, by using larger values of C1, such as .001 to .01 uf. More of a mid and treble gain boost.

C2: Optional

Pretty much the same deal as C1, though C2 bypasses R2, not R1. The exact frequencies affected depends on a number of variables, including the resistance in the coupling circuit. I find it best just to play around with different values, and let your ears be the judge. Later, you can get the Radiotron Designer's Handbook and work out all the math as to what Hertz you're letting by.

C3: Optional.

Just like Rg works differently than R1 and R2, C3 works differently from C1 and C2. Whereas C1 and C2 increase treble, C3 reduces it. C3 works as a "low pass" filter. A small value of C3, say 500pf, lets only highs bleed off to ground (and out of the signal path). Lower frequencies are blocked by C3, and are forced to travel to the rest of the circuit-on to the grid of the next stage to be amplified. Thus, lows "pass" by this filter. A "low pass" filter.

Experiment values ranging from 20pf to .001uf. For fun, I guess you could try a .1 uf cap, but you'd basically be bleeding all of your signal to ground. Another common trick is to put a resistor in series (not parallel) with C3, in part to attenuate the loss of highs to bleeding to ground. Start off with values like 50K, 100K, 250K, and 470K.

The R1-Rg voltage divider network and volume (gain) controls. Remember I talked about how effective Rg was at affecting the volume of the signal? Well, R1 and Rg form a "voltage divider" network, where the value of both R1 and Rg affect the strength of the signal sent off to the next gain stage. A volume control is basically a substitute for the fixed R1-Rg voltage divider network.

Think of a 1 Meg Ohm volume control (a "pot" or "potentiometer") with a linear taper, so the mid way point gives you 500K on one side (for R1) and 500K on the other (for Rg). At "zero" the R1 side is 1 Meg Ohm, and the Rg side is zero Ohms. Remember, high values of R1 reduce gain, as do

INCREASING GAIN THROUGH ADDING NEW GAIN STAGES: This being the 1990's, I think by now most guitarists know that adding a gain stage to an amp increases its ability to generate distortion. This is definitely NOT always a good thing, even if you love distortion. One reason why Plexi Marshalls command such high prices, is that they have a perfect blend and balance of preamp and power amp distortion. Adding a gain stage can ruin the balance, and thus, the tone. It'll likely get much noisier, you may have problems with "squealing", it may get too mushy, and you may lose the articulation of the notes. Adding a pedal may be both cheaper and sound better. But if you do want to get into this kind of thing, read on.

A tame little two stage preamp like this: **IN----Stage1----Volume-----Stage2-----out**

Can be turned into a three stage crunch monster like this: **IN----Stage1----Volume----Stage2----Stage3-----M.V--out**

Or a searing, super high gain MOFO like this: **IN----Stage1----Volume-----Stage2----Stage3----Stage4---M.V.---out**

Adding a tube stage is a lot trickier than just modifying the existing circuit. You've got to find a place on the chassis to add the new tube and related components. You've got to make sure the existing power transformer can safely supply the extra B+ voltage and current to heat the tube. You'll probably need additional filtering of the B+ to reduce the amount of "ripple" (AC not quite fully filtered out of the DC voltage supply by the existing filter caps and choke.) You've got figure out just where in the circuit you want to add that new gain stage, and how to couple it to what's before and after it. To combat noise, shielding of wires carrying the signal may be required. There are other things to think about, like do you really want to devalue your amp if it's a vintage Fender or Marshall? Think seriously about this. Besides, if a Blues Nazi finds out you added a gain stage to your 1959 Fender Bassman, you may be in for a fight....or at least a lecture. I'm not sure which is worse.

Then there are hours of circuit experimentation to get it to sound the way you like. Yeah, this can be both fun and frustrating. And as far as connecting the new stage to the others, you could just start off with the generic coupling circuits in this article, or from the schematics in any of the new tube guitar amp books. While this article focuses on stages linked in series, you could add them in parallel, like in the input sections of Marshall's made in the 1960's, and the active EQ networks in Sound City amps. Or use circuits not normally associated with guitar amps, like cascade circuits often used in audio amps.

Modifying Preamp Circuitry

Stealing Existing Stages:

If you've got an amp with multiple channels, like an old tube P.A. amp, or with tube driven effects you don't need (maybe tremolo, or reverb), you can steal a tube from these circuits, and use them for a gain boost. Or add cathode followers to your circuit, which don't add any gain, but which do reduce the impedance of the signal. Nice before a tone stack (EQ controls). You'll still have plenty to deal with, but at least not drilling holes in your chassis.

Externally Modding Your Amp: What? Yeah, why screw around with dangerous amp innards when you can add the gain you crave with a pedal? Think of a pedal as an instantly removable amp mod. To keep the tube mystique going, add tube gain from a Mesa V-Twin or a Matchless Hot Box. You can use these boxes for a relatively clean gain boost, adding little or no distortion of their own. Just use them to slam the preamp section of your amp harder, making IT distort more. For a hybrid tube/transistor gain boost/overdrive pedal, try the Ibanez TK-999 Tube King.

For easy mods after the input of your amp, consider Soldano's "Hot Mod". It's a device that plugs into a Marshall's 12AX7/ECC83 socket, replacing the dual triode (two gain stage) 12AX7 with a triple triode (three gain stage) 6K11! No internal modification necessary. You may want to buy a couple of extra 6K11's (tested for low microphonics) as spares. Preamp tubes may last a lot longer than power tubes, but they can wear out after several years.

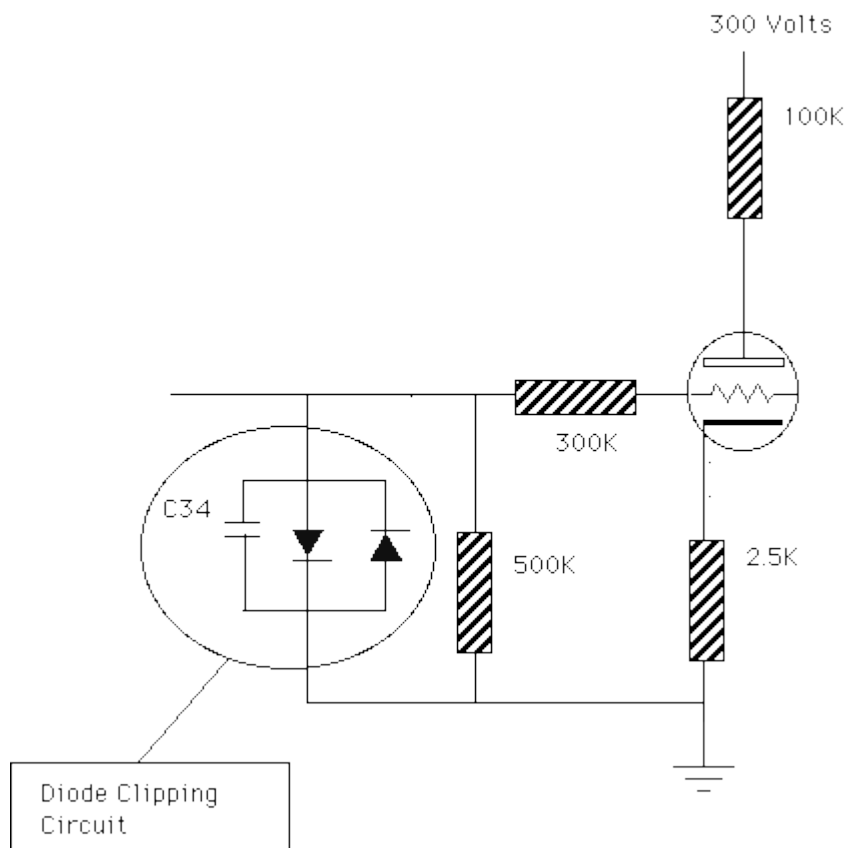
In Gerald Weber's "A Desktop Reference to Hip Guitar Amps" you'll find some easy changes for adding gain, and using your Fender's reverb circuit as an overdrive.

Adding Distortion Without Adding Gain: Yep, it most certainly can be done, most often using solid state devices. Heresy? Marshall's been doing it for years in their amps, and not just the Valvestates. Check out the new JCM Slash reissue of their Jubilee amps. I don't claim that this method sounds as good as an all tube signal path, but it's not all that bad for some rock sounds. Hell, even tube gurus often use transistor based pedals to help overdrive their tube amps.

Adding two diodes in parallel, in a path to ground from a point in one of the coupling circuits (post coupling capacitor) will do the trick.

See figure GIF diode clip circuit. It makes a clipping circuit, where each diode clips off the top of one half of the signal's waveform. You end up with a square wave, which is a highly distorted signal.

Modifying Preamp Circuitry



You may want to add a small capacitor in parallel with it to reduce some of the high end harshness. It "rounds off" some of the sharp edges of the square wave. LED's are sometimes used instead of typical diodes. Zeners, in a series circuit with each facing the opposite direction, can be used as well. Since there are tube diodes, I suppose one could figure out a circuit for tube diode clipping. Maybe run a 12AX7 as a pair of diodes.

To check out some examples of these kinds of clipping circuits, get "The History of Marshall" and look at the schematics in the back. Look at some of the JCM-800 amps, the Jubilee amps, the JCM-900's, and the Marshall Valvestates. Or get on the web and go to "DMZ" or "Leper's Musical Circuit Archive". Look at the Tube Screamer circuits. The diode clipping takes place in the negative feedback loop of an opamp.

This should be enough to get you started. Double and triple check all of this with your local amp technician. Remember you want sensible facts, not tube religion from these guys. Yes, some are worse than others. The opinions do get downright stinky with some, but the majority of amp techs are very helpful.

Especially if you pay them for their knowledge. The whole deal is a LOT more complex than I've let on, though after reading this, you'll be well on your way. Have fun, but play it SAFE. Thanks.