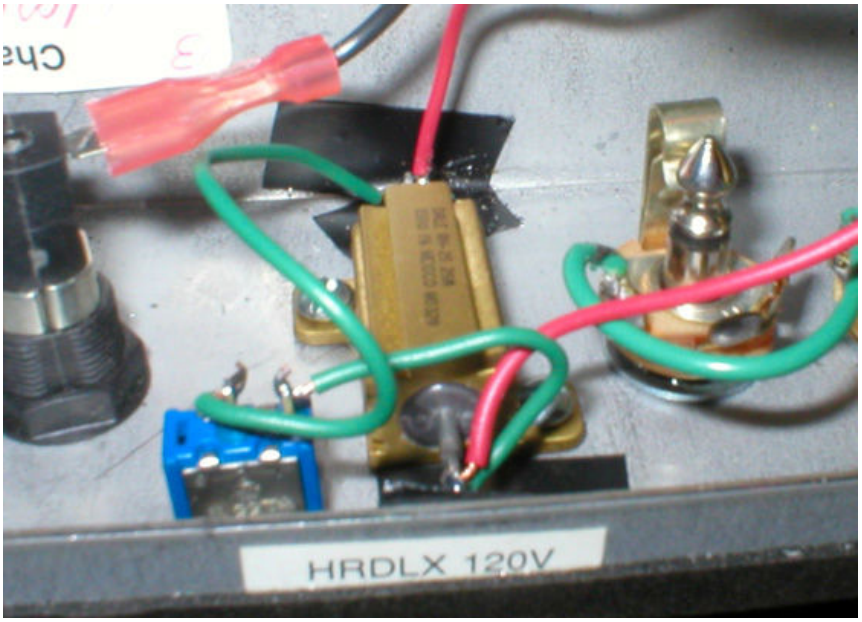
How to Get Tube Rectifier "Sag"

Warning! This mod is extremely dangerous if done incorrectly, and will void your warranty! Experience will high voltage power supplies is necessary. Proceed at your own risk!



Tubey or not Tubey, THAT is the Question!
Installation of a tube rectifier is really unnecessary. At one point I wanted to put one in so bad I shopped around for a 5V filament transformer and started making plans. **The fact is: You don't need a tube rectifier to get a tube rectifier type sound—believe it or not.** The sound, or effect, that a tube rectifier often contributes is described as "sag."

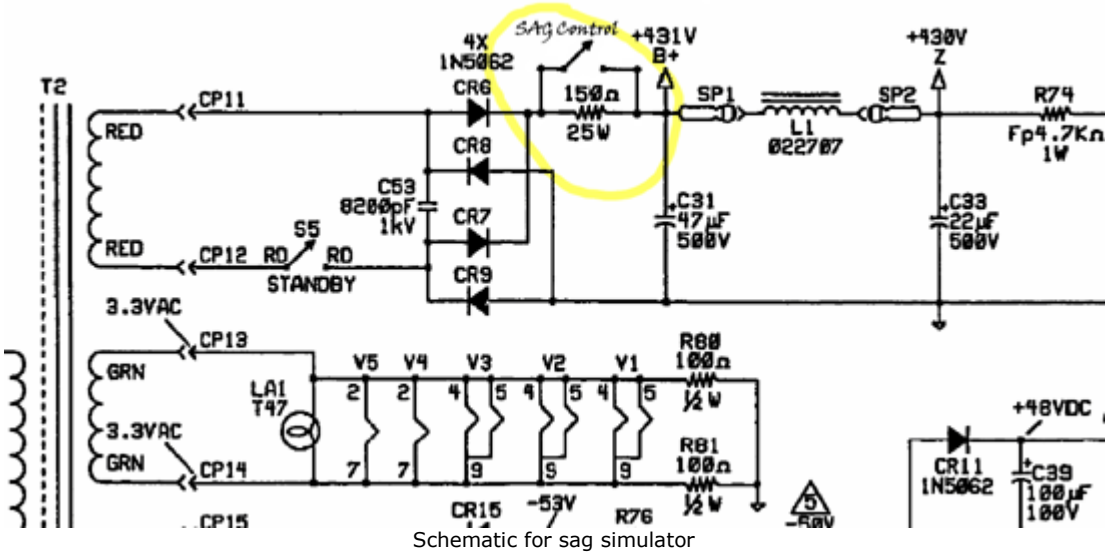
What is sag? It's the compressed, spongy feel that vintage amplifiers have. With sag our amp will be more "touch sensitive" at loud volumes, and notes will seem to blossom as they're picked. There will also be a decrease in clean headroom and bass response. Note that sag isn't the same as having a compressor. Having sag after distorted preamp tubes smoothes out "raspiness," which should help out our Hot Rod's tone. A compressor can not do this. It also lowers clean headroom, and takes "punch" away from the sound. Sag is great for the blues, but not so hot for styles where a more "in your face" sound is needed. Most harmonica players prefer tube amps with lots of sag.

How it Works
The voltage drop across the rectifier is what gives us the sagging effect. Remember, a voltage drop is resistance times current (Vd=R*I) where R is the value of the resistor and I the measured current through the resistor. (*I* is used instead of *C* because *C* is reserved for "capacitance.") When we compare a tube rectifier to a solid state rectifier we'll see a major difference in the resistance between the two. Solid state rectifiers use silicon diodes. These have an extremely low resistance, and once the "knee voltage" (usually

0.7V) is reached they're basically like a short circuit. The voltage drop across a silicon diode is fixed, which is the same or really close to the knee voltage.

It must be realized that the effect produced by a resistor will never be *exactly* the same as an actual tube. The voltage drop across a resistor proceeds in a linear fashion, or like a straight line, while the voltage drop across a tube is logarithmic, or a slope shaped line. As to exactly how the lines compare under similar conditions is unknown by me, as I do not have the proper equipment to perform the necessary tests. We do know, on the other hand, that we can make the voltage drop across the resistor less "perfect" by introducing a series inductance after the resistor. This will make our sag mod feel more like the "slow turn on" of tube rectifiers. We'd use an inductor because its resistance to current will increase as the tubes try to draw more current. Kevin O'Connor, author of The Ultimate Tone series of books, recommends using an inductance from 1mH to 100mH—a 10mH inductor would be a good place to start with a 100 ohm resistor. There is a type of resistor that naturally has some inductance already—wire-wound resistors—which are what we'll order later on.

A vacuum tube, on the other hand, has a lot more internal resistance. Since our Hot Rod is a Class AB amplifier, the current drawn by the plates is going to be much greater when we're playing than when we're not. This swing in current is going to cause a constantly changing voltage drop across the tube rectifier. This prevents our power tubes from drawing more current, especially at loud volumes. Say we crank our amp and play a chord. Instead of a large increase in volume we'll hear a compressed effect—thanks to the tube rectifier denying the power tubes current. Silicon diodes have a fixed voltage drop and are not effected by large changes in current. Hence, they don't "sag."



Schematic for sag simulator

To get a sagging effect we'll need a power resistor in series with the positive end of the DC power supply—more commonly called the "B+." Originally type B batteries were used for the DC power supply in tube circuits, the positive (+) side was connected to the plate of the tube. The name "B+" stuck even after batteries were no longer ideal for

higher voltage DC power supplies. Similarly, the bias supply is sometimes called "C-" because a type C battery was originally used. Our power resistor needs to go between the rectifier's output (CR6) and the first filter cap (C31). [Circled in the schematic above.] This will simulate the voltage drop of a tube rectifier, though it will not feel exact as resistors lack the capacitance and inductance of a tube. The greater the resistance of the resistor the more sag we'll get, and the more pronounced the effect will be at lower volumes. We can also install a SPST switch across the resistor to bypass the sagging effect, though toggling back and forth will through the bias off. How so?

The larger the resistance used, the colder the tubes will be biased. The cathode current, which is measured at the *bias test point*, will lower because the DC voltage at the plate was lowered. Remember Ohm's Law? (V/Ω = I) If we lower the plate voltage the plate and cathode current will also decrease. This can be easily remedied by tweaking the bias supply. If you own a Deluxe, and you'd like to transpose the biasing range higher, try soldering a 100K resistor in parallel with R77, or solder the 100K in the empty slot labeled R83. Increasing the resistance of R76 will also decrease the negative voltage sent to the control grids, and therefore increase the current flowing through both power tubes at idle.

Simulating a Specific Tube Rectifier

It's possible to simulate a specific tube rectifier type. WeberVST and THD Electronics have known about this for years, and have products that accordingly do so. Below is a chart that specifies the average working conditions of different types of tube rectifiers, and gives an approximation of the voltage drops under those conditions.

Tube Type	DC mA	PIV	FIL AMPS	Max ACV	DCV	DCV DROP	Slow warm up
Diode Rectifier					412		No
5AR4 / GZ-34	250	1700	1.9	450	402	10	Yes
5V4-GA	175	1400	2	375	387	25	Yes
5V4-G	175	1400	2	375	386	26	Yes
5U4-GA	250	1550	3	450	379	33	No
5U4-GB	275	1550	3	450	377	35	No
5U4-G	225	1550	3	450	377	35	No
CV378 / GZ37	250	1500	2.8	450	375	37	Yes
5R4G/GY/GYA	250	2800	2	750	367	45	No
5R4GYB	250	3100	2	900	362	50	No
5Y3-G/GT	125	1400	2	350	352	60	No

Before installation I biased my stock Hot Rod to 68mV and measured 422VDC plate voltage. I then installed a 100 ohm power resistor—the most typical value used for this mod. My power tubes were instantly rebiased to 54mV at the *bias test point*. After rebiasing to 68mV I found that my 100 ohm resistor dropped the plate voltage to 397V, or by 25V—approximately the same amount of sag as a 5V4-GA tube rectifier. Power is equal to V^2/R. So 25*25/100 = 6.25W at idle. Our resistor is dissipating 6.25W of heat even when we're not playing! Since we're using a 25W resistor, it should continue operating within spec and last as long as the amp itself. (Remember, the voltage drop across the power resistor at full power is going to be greater than at idle.)

I then installed a 220Ω 25W power resistor, but the highest I could rebias was 58mV! I'll either have to tweak the bias supply for more range, or use a smaller power resistor if I want to bias warmer! The highest resistance we should use for sag, assuming we plan on tweaking the bias supply, would be 500 ohms. If we go too high we'll get "ghost notes," or an inharmonic note that rides on top of our played note. In my opinion, 500Ω would be *far* too much sag for my taste. I'd expect practically no clean headroom at all.

I ended up settling on a 150 ohm power resistor. With the bias pot maxed out I can get to about 70mV, which is fine. I also installed a bypass switch that I bought for a few dollars from Radioshack, which is capable of handling the high voltage and current. (I had to search through their drawers for a while and only found one.) The only problem with the switch, and adjusting the bias range, is that the power tubes may exceed their rated plate dissipation if our power resistor is bypassed. With a high voltage DPDT switch, and a little ingenuity, we could also incorporate bias range switching so that the tubes will always remain properly biased. The values needed will vary according to the amp's B+, power resistor resistance, and taste in biasing so I'll leave that up to you. Just unsolder R76 and run a wire from the C43/CR15 side to one side of the DPDT switch's common. From there you'd solder the approprate resistors on each end of the switch and run a wire to the other side of where R76 used to be. Double check that you didn't hook up the resistors and wires wrong. The other side of the DPDT switch would be used to bypass the power resistor.

Lets Do It!

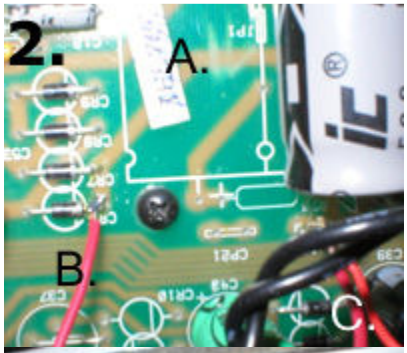
I asked the opinions of a few highly-respected tube amp techs, whom do this type of stuff for a living. They recommended I use a wire-wound resistor in an aluminum casing for a non-vintage amp. (The reason a wire-wound resistor is preferred is because it already has some inductance.) This power resistor needs to be mounted to the chassis for heat sinking purposes. Many may be reluctant to modify the chassis, so you could also use two 10W wire-wound resistors in parallel. I chose Vishay/Dale 25W 1% Aluminum Housed Wire-Wound Power Resistors for quality and reliability. Be sure you get the type that has "RH25" in the part number, and not the "NH25," which are non-inductive. We want ours to be inductive for a more tube like response! These cost approximately US$3.25 each at Mouser.

Also, I was using a smaller guage wire in these pictures, but it ended up causing problems. Whenever I'd dig into the guitar the increase in current draw would cause the amp to choke out. The wire simply couldn't supply enough current. I ended up going to

the local hardware store and buying larger wire available in the electrical section. It's recommended that you use no wire physically smaller than 18 guage, and none larger than 16 guage—preferably stranded because it's a lot easier to work with. (Remember, 16 guage wire is physically larger than 18 guage.)

1. Always drain the filter caps! Keep yourself safe. By now you should know how to do this.

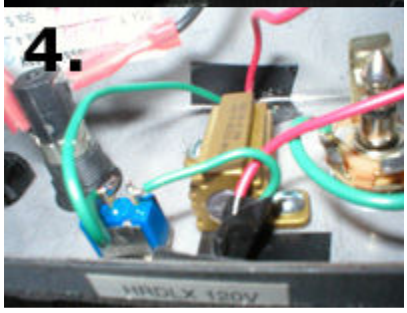
2. **A.** Break the connection from CR6/CR7 to C31 by scratching off a section of the trace under the PCB. This will force the high voltage B+ to go through our power resistor.
B. Hook one side of the resistor to CR6/CR7 with a wire.
C. Hook the other side of the resistor to the positive side of C31.



3. Assuming you've ordered the part from mouser, drill two holes in the chassis for the resistor. If you want you can install a SPST switch, which will bypass the resistor and put our Hot Rod back in stock configuration. This requires an extra hole and is the blue thing in the picture at the top of the page. I had to go to the hardware store to find some screws and nuts that were small enough to use with the resistor.



4. **DANGER! If either end of the power resistor shorts to the chassis you will have a deadly amount of voltage on the chassis. I recommend using heat shrink tubing or electrical tape to protect yourself from such a hazard, and be sure to tightly mount the resistor to the chassis.**



5. Enjoy your cool new mod!

By Justin Holton