

# Modifying a Fender Blues Jr. Guitar Amplifier

*Making a good amp great*



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Final Project

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## **Motivation:**

Vacuum tube guitar amplifiers produce incredible tones and creamy overdrive that have yet to be fully matched by solid state electronics. An overwhelming majority of professional musicians choose tube amplifiers over solid state for their tonal qualities in spite of the increased purchase price and maintenance cost of tube electronics. Ever since I started playing the guitar, I have wanted a nice tube amp.

Before graduate school I played guitar in a few bands, and I used a Fender “Stage 160,” which is a 160 Watt, solid-state 2 × 12” amplifier. It was a practical amp for gigging, because it could get loud and its tone quality was sufficient for the stage. But, I always thought I would eventually trade up for a 2 × 12” tube amp such as the Fender Twin. However, after graduating from college and moving on to graduate school, I realized that my gigging days were over for the foreseeable future. So, I started looking at less expensive, lower power tube amps more suitable for bedroom guitar playing. I ultimately purchased the Fender Blues Junior.

The Blues Jr. was first introduced by Fender in 1995 and since then it has developed a reputation for its good quality at an affordable price (\$699.99 MSRP, according to <http://www.fender.com>). It is a 15 Watt combo amp with a single 12” driver. It has three 12AX7 tubes in the preamp and two EL84 tubes in the power amp. It has volume, treble, mid, bass, master volume, and reverb controls, as well as a “FAT” switch which slightly boosts the mids and increases the gain in the preamp stage.

I purchased my Blues Jr. in the summer of 2010, and soon thereafter stumbled across a website (<http://www.billmaudio.com>) devoted to the Blues Jr. and various modifications that can drastically improve its already decent stock tone. At that time, I

thought it best to leave my amp in its stock state at least until Fender's five-year repair warranty ran out. But, as the months went by, my curiosity got the best of me and I decided that I couldn't wait for five years. I had to see how great my amp could sound.

My top priority in modifying my amp was to improve its bass response. A common complaint among Blues Junior owners is that the amp sounds small and boxy. This is due in part to some of the capacitor values used in the amp that serve to selectively attenuate lower frequencies. It is also due to the small, low-quality output transformer. I replaced several capacitors in the circuit with better and sometimes different-valued caps, and I also purchased a new output transformer. These components will be discussed in more detail later in this paper.

My second priority in modifying this amp was to adjust the bias on the power tubes. This is one modification that Bill Machrone (maintainer of <http://www.billmaudio.com>) highly recommends because the stock Blues Jr. has a fixed bias on the EL84s that is too 'hot'; this has little or no tonal advantage, and it shortens the lifetime of the power tubes.

Additionally, Professor Errede suggested inserting a cathode follower into the signal path between the preamp and the tone stack. This takes the input signal from the preamp and outputs a signal with the same voltage but amplifies the available current so that the tone stack can't easily load down the voltage provided from the preamp, which could cause frequency-dependent distortion. An interesting and baffling thing about the stock Blues Jr. is that it uses three 12AX7 preamp tubes, but one of these tubes has half of its pins grounded. In other words, half of that tube is not used at all in the stock design,

and it is perfectly suitable for this type of modification. The next section of this paper will describe in detail all the modifications I made to my Blues Junior.

## The Modifications:

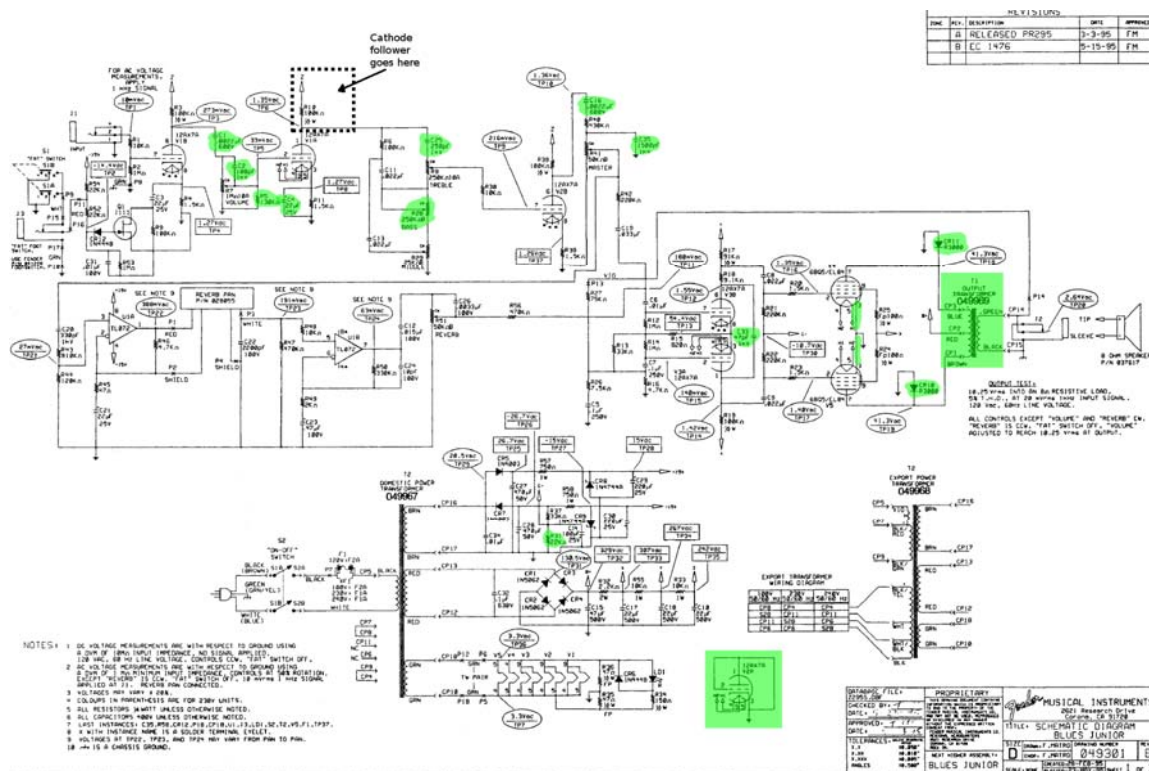


Figure 1: The Blues Jr. schematic. Highlighted parts have been modified in some way for this project.

Figure 1 is an annotated schematic of the Fender Blues Junior. Components that were modified are highlighted. The input jack is at the top left of this schematic, and from there the signal traverses the preamp stage which accounts for the portion to the left of the dotted box labeled “Cathode follower goes here”. The top-middle section of the schematic represents the tone stack, which is where controls for treble, middle, and bass are placed in the circuit. The section of the schematic directly below the preamp and tone stack is the reverb section which was modified only slightly in this project. The part of

the schematic at the bottom of the page outlines the connections between the wall plug and the power amp section through the power transformer. To the right of that, the unused half tube mentioned above is highlighted in green. The portion of the schematic above that unused half-tube and to the right of the tone stack is the power amp section of the Blues Jr., which includes the power tubes and the output transformer. I will now outline the modifications in further detail, beginning with those in the preamp. Figure 2 provides a closer look at the preamp stage and the highlighted parts therein.

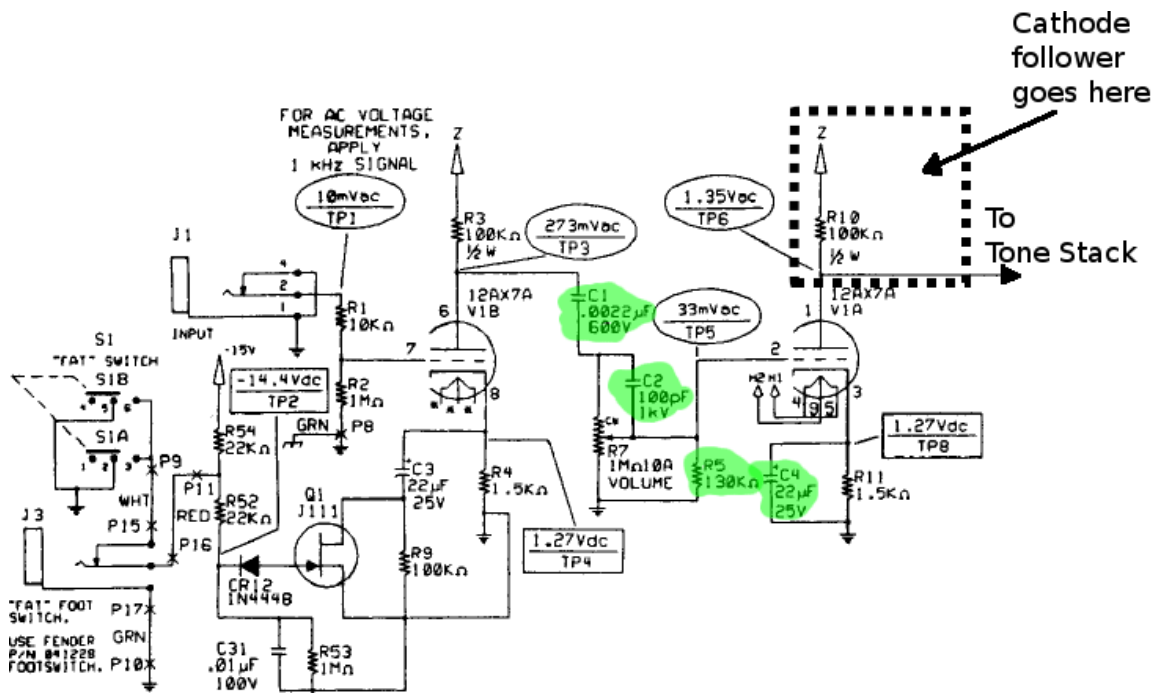


Figure 2: Blues Jr. preamp circuit.

In the preamp stage, I replaced C1 with a 0.022  $\mu$ F orange drop capacitor, which increased the RC time constant of the effective high-pass filter made up of C1 and the volume pot by an order of magnitude, which therefore decreased the cutoff frequency by an order of magnitude. I also removed C2 and replaced C4 with a 250  $\mu$ F electrolytic capacitor. These mods collectively improved the bass response of the preamp. Also, the

replacement components were of higher quality than the stock components. R5 was removed, which effectively increases the gain in the first preamp tube, denoted 12AX7A in the schematic. Because this resistor was removed, the first tube had to be replaced with a 12AY7 preamp tube, which is schematically identical to the 12AX7 but has a smaller amplification factor. The 12AY7 also is capable of sourcing more current than the 12AX7. Because of these traits, the 12AY7 gives the amp a bit more clean headroom than the 12AX7.

Figure 3 shows a schematic view of the cathode follower. This was inserted in the boxed area of Figure 2. The 100 k $\Omega$  resistor labeled R8 in Figure 3 is the same resistor as that labeled R10 in Figure 2. Node A in Figure 3 is between R10 and pin 1 of 12AX7A in Figure 2. Pin 1 of the 12AX7 in Figure 3 is attached to Z in Figure 2. Node B in Figure 3 goes to the tone stack.

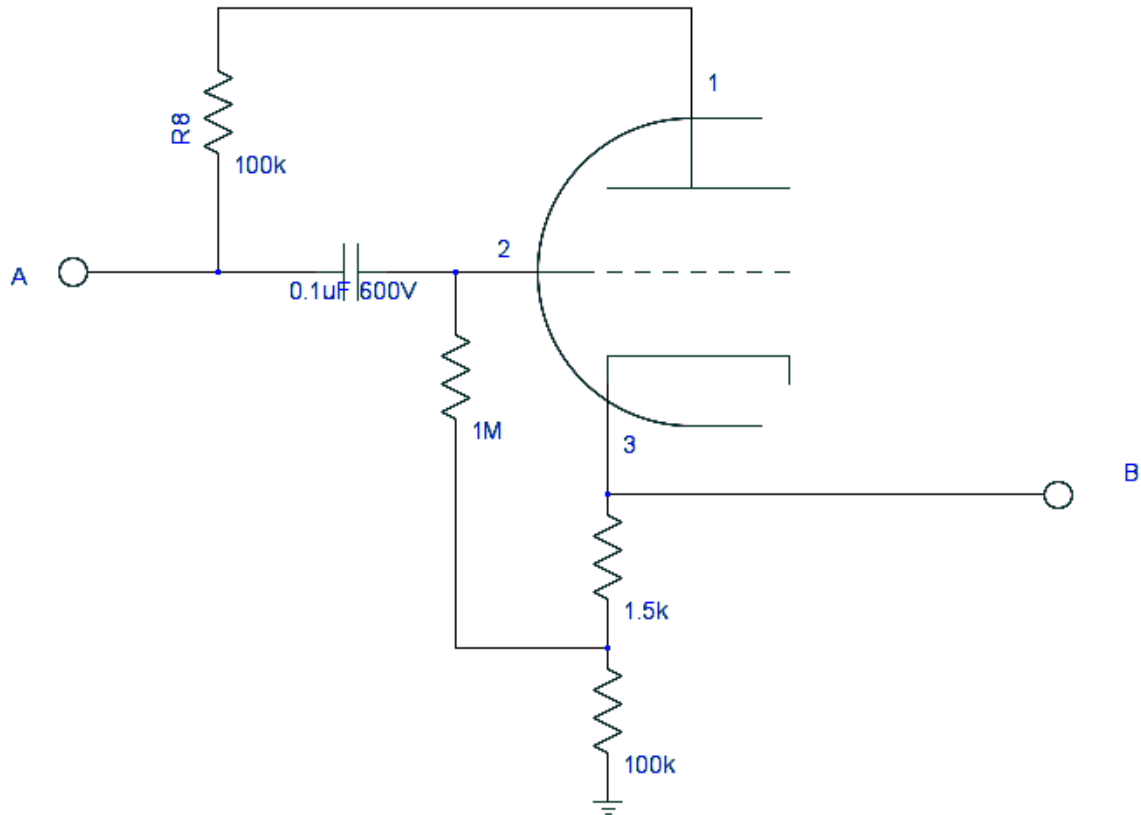


Figure 3: Cathode follower schematic.

The parts of the tone stack that I modified are shown schematically in Figure 4. I replaced the stock 250 k $\Omega$  bass control potentiometer with a 1 M $\Omega$  audio pot. This gives the bass knob a greater range of control. The 0.0022 $\mu$ F capacitor at C16 was replaced with a 0.022  $\mu$ F orange drop capacitor. This decreased the cutoff frequency of the effective high-pass filter made up of C16 and the master volume potentiometer by an order of magnitude thereby improving bass response of the circuit. C35 was removed because it was unnecessarily filtering the output. I replaced the ceramic disc capacitor at C25 with a silver mica capacitor of the same value.

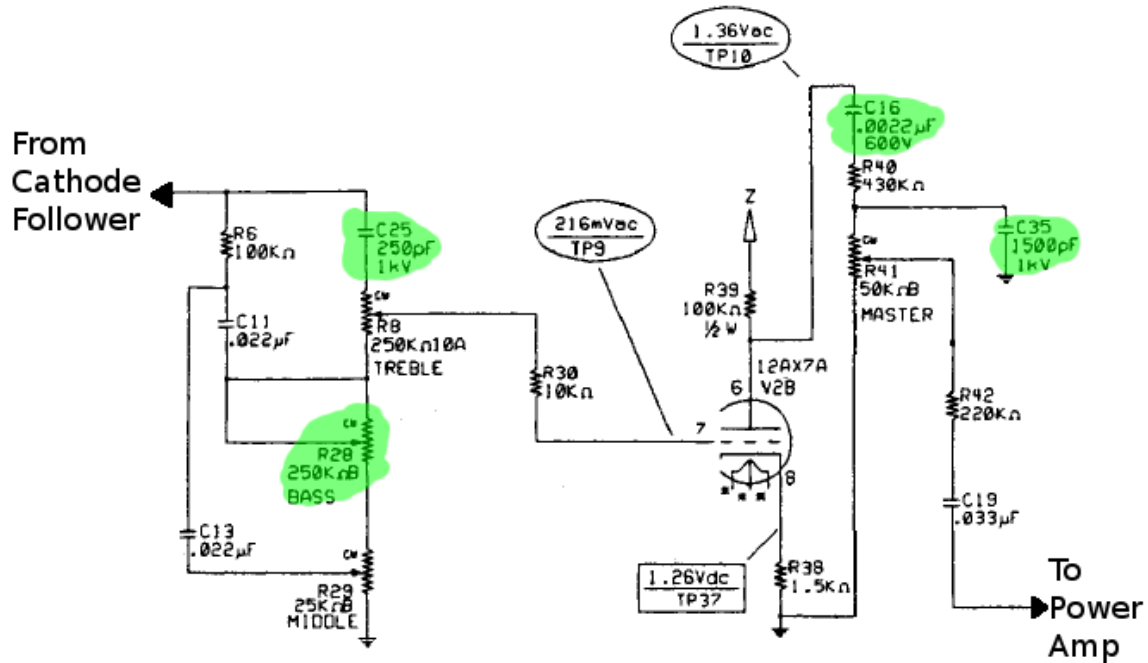


Figure 4: Tone stack schematic. Modified components highlighted.

Figure 5 shows the power amp and power transformer sections of the schematic. The most expensive part I installed in my amp was a replacement output transformer. The stock output transformer is small and cheap. The replacement transformer I purchased, a Heyboer TO20, was specifically designed with the Blues Jr. in mind. It is much beefier than the stock output transformer, but it is small enough to fit the stock holes. This was great, because I did not have to modify the amp chassis in any way to make the new OT fit. CR10 and CR11 are two diodes that provide protection from unlikely, potentially damaging spikes in the voltage across the terminals of the output transformer.



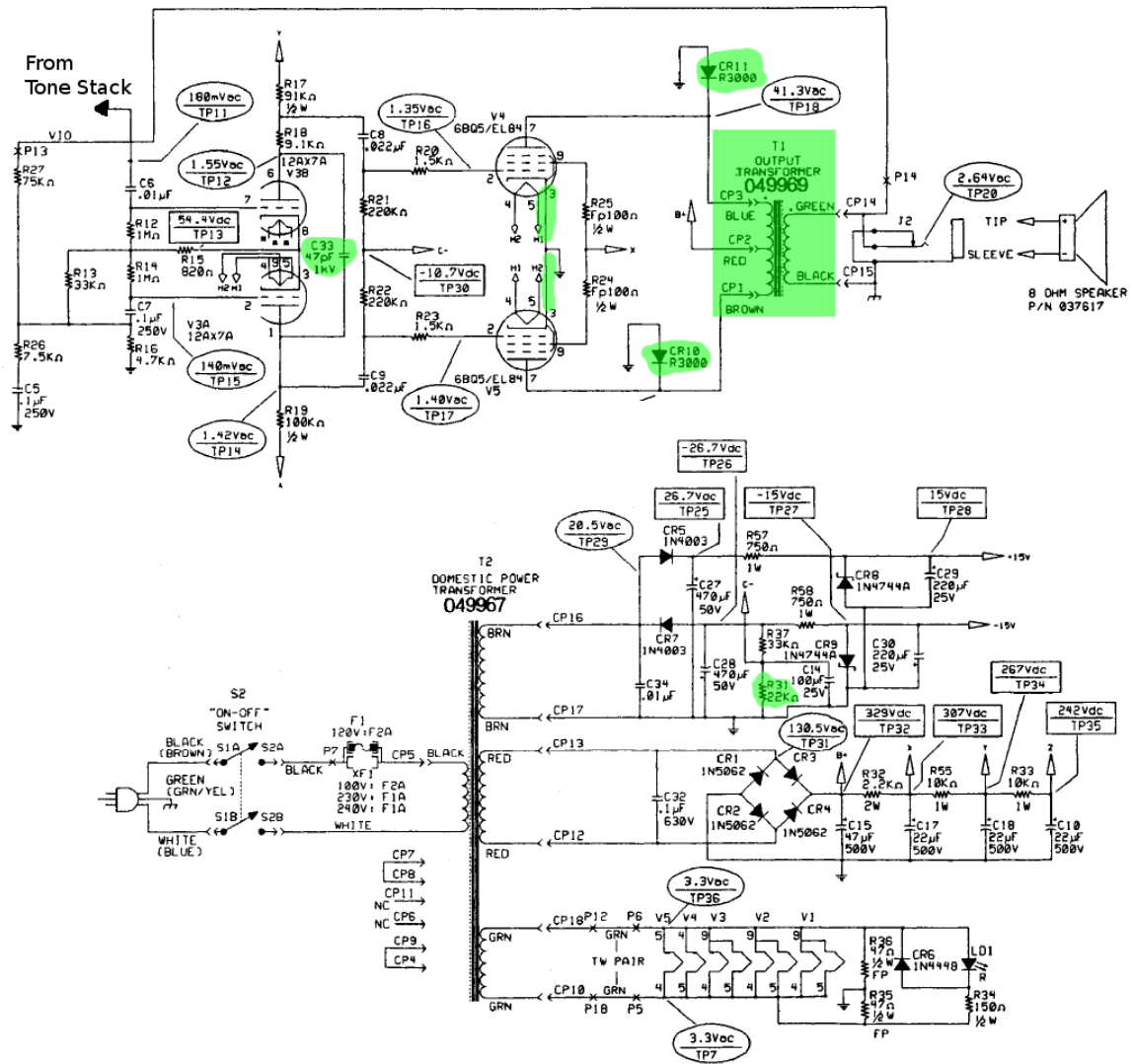


Figure 5: Power amp and power transformer portions of the schematic. Modified components highlighted.

Professor Errede suggested that they might have a subtle, negative effect on the tone of the amp. Per his advice, I removed these. I replace C33 with a better quality silver mica capacitor of the same capacitance. R31 and the two highlighted leads coming from the plates of the EL84s indicate areas that were modified in order to make the bias adjustable. I inserted 1 Ω, 2 W, flame-proof resistors between the EL84 plates and ground to provide a place to check the current flowing there; Ohm's law states that  $V=iR$ , where  $i$  is current,

$R$  is resistance, and  $V$  is voltage. So, with  $1\Omega$  resistors,  $V=i*1\Omega$ . Therefore, measuring the voltage across these  $1\Omega$  resistors gives a one-to-one measure of the current flowing through them in Amps. I placed a  $20\text{ k}\Omega$  trimpot between R31 and ground which allows the adjustment of the voltage on the grid of the EL84s.

### **Measurements:**

Before I opened up my Blues Jr., we measured its stock frequency response with the controls at a few different settings. To do this, we put a white noise test signal into the input jack and measured the output from the speaker using a microphone. We measured the amp with all tone and volume knobs at “6” (their middle position), reverb at “0”, and with the “FAT” switch both on and off. These curves are shown in Figure 6, along with the noise floor for the measurements. Note that the noise floor accounts for all ambient HVAC, equipment fan, and computer noise in the lab that could be detected by the pressure mic.

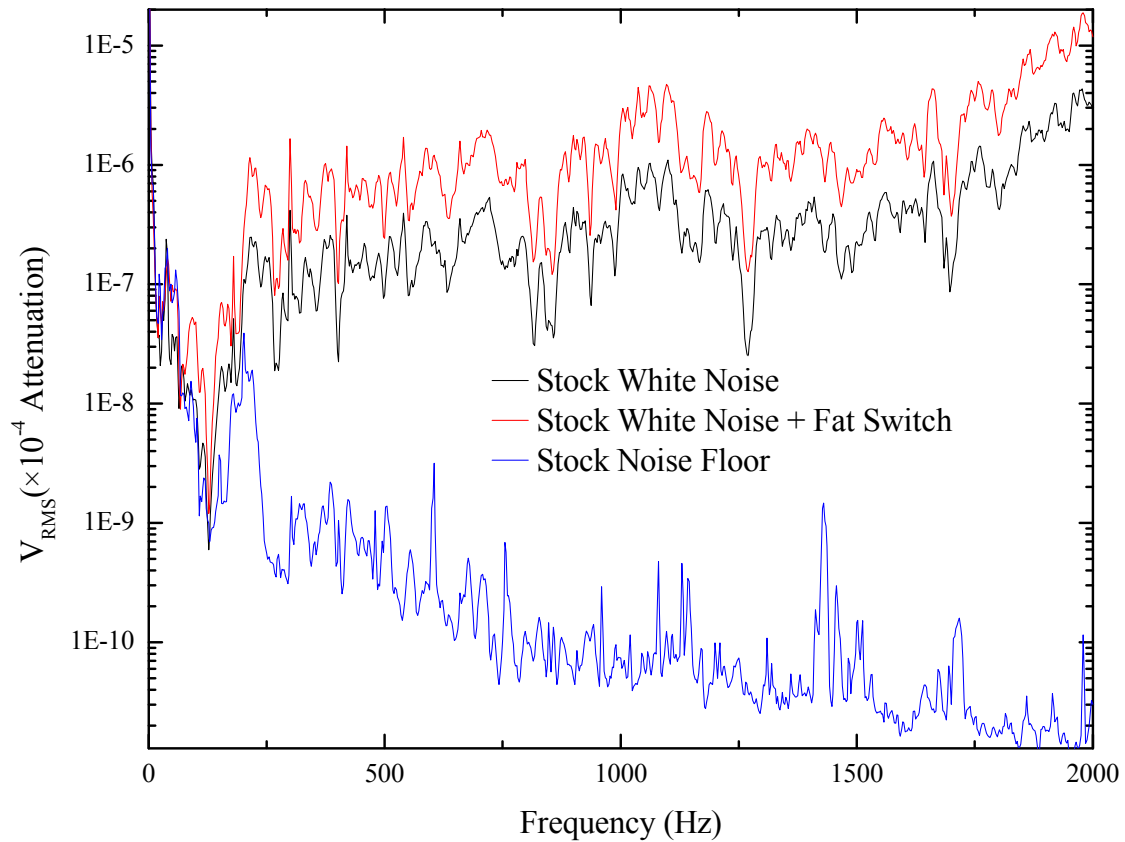


Figure 6: Frequency response of stock Blues Junior. Tone/volume controls set to “6”; reverb set to “0”.

Note the diminished output in the lower frequencies relative to the higher frequencies. Especially note the fact that the output at higher frequencies is orders of magnitude greater than the noise floor, while at frequencies below 250 Hz the output follows the noise floor very closely. Figure 7 shows the log of the ratio of the output signal to the noise floor. This plot again shows a dramatic cutoff in output for frequencies at and below 250 Hz, further illustrating that the bass response of the Blues Junior is lacking.

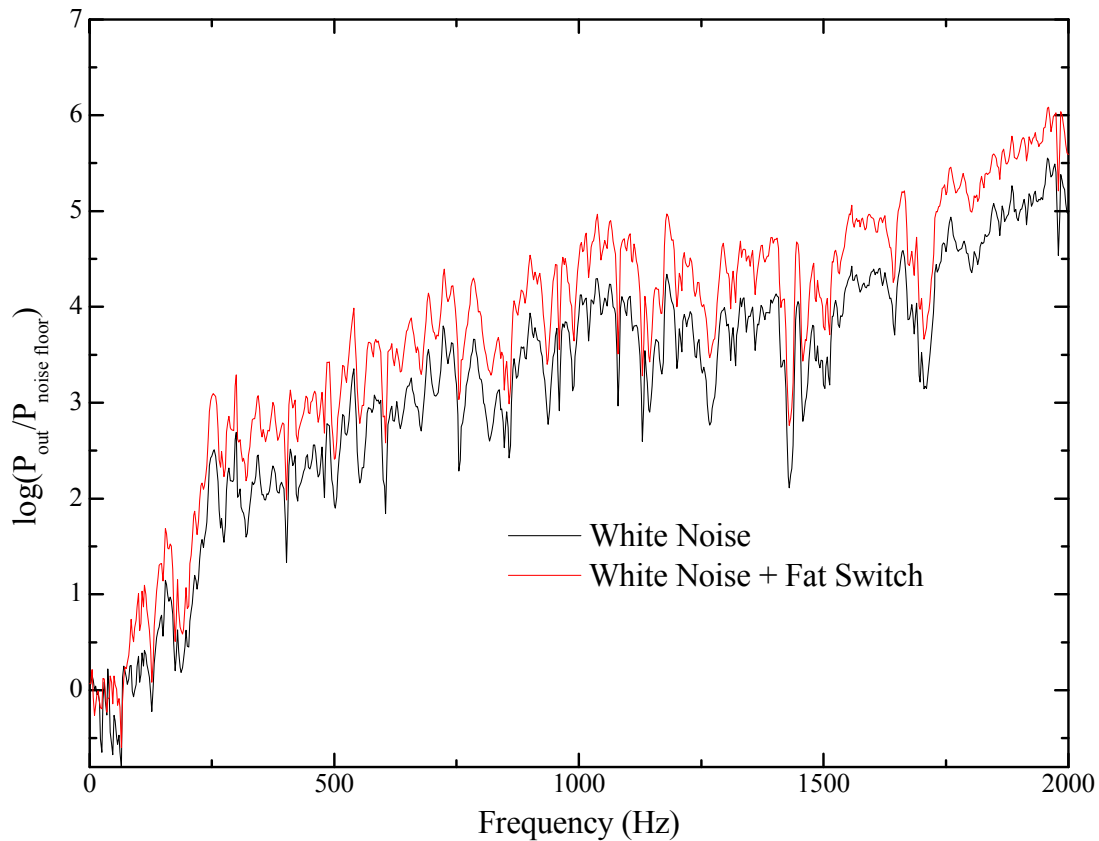


Figure 7: Frequency response of stock Blues Junior. Tone/volume controls set to “6”; reverb set to “0”.

We also measured the output from the amp with each one of the tone controls independently turned to both its maximum and minimum, leaving the other controls at their middle positions. From this data, I was able to extract curves that represent the frequency range that each of the tone controls can attenuate or accentuate and the relative magnitude of that effect. Figure 8 shows these curves. The bass control has a notably smaller magnitude than both the mid and treble controls.

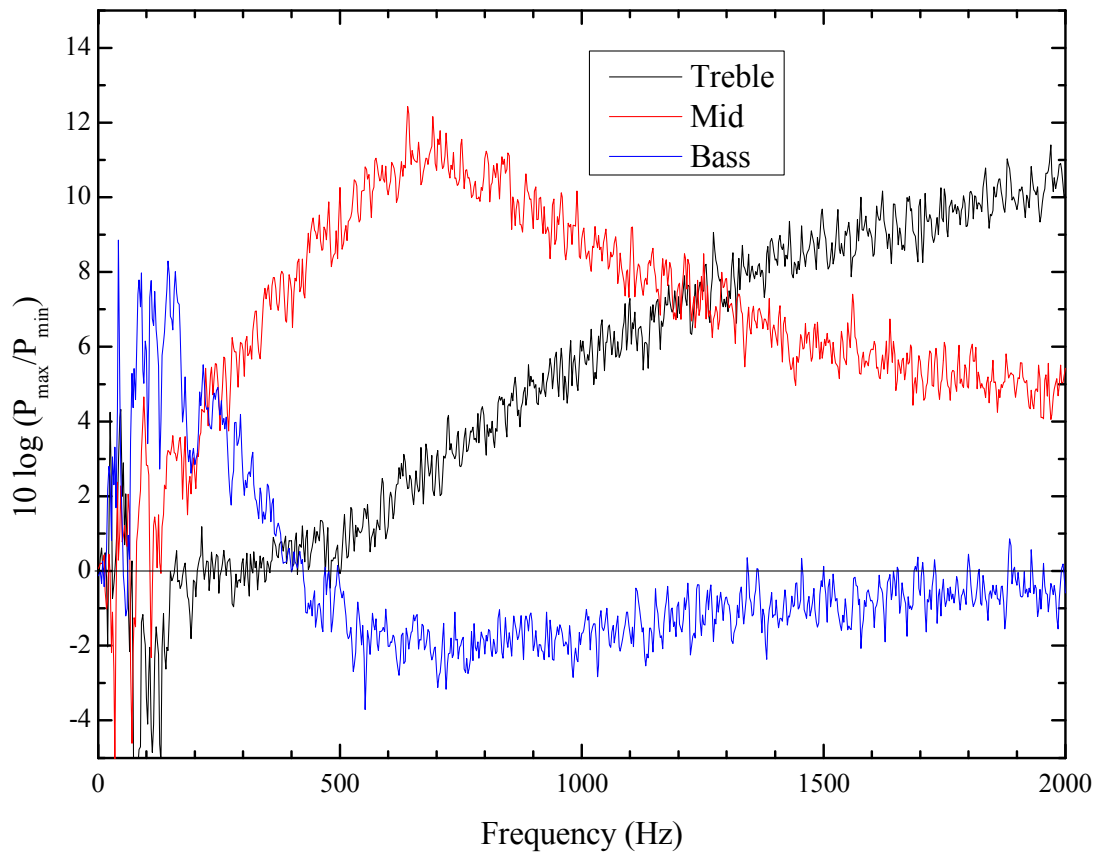


Figure 8: Treble/Middle/Bass tone control frequency ranges and their relative amplitudes.

After the modifications were implemented, I repeated the measurements outlined above. Figure 9 shows the log of the ratio of the white noise measurement to the noise floor measurement after the modifications. By comparing this figure with Figure 7, we can see that the modified amp has more output than the stock amp for frequencies below 250 Hz. Figure 10 shows a before and after comparison of the measured output from white noise.

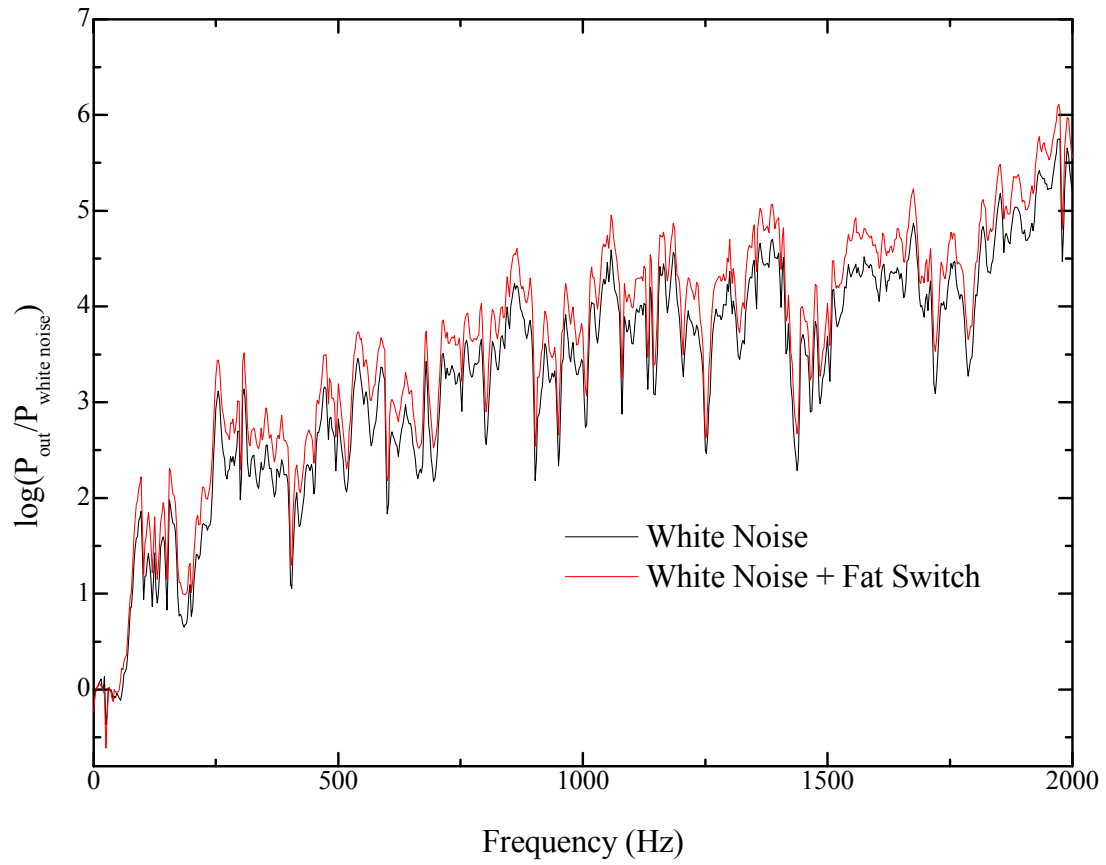


Figure 9: Frequency response of modified Blues Junior. Tone/volume controls set to “6”; reverb set to “0”.

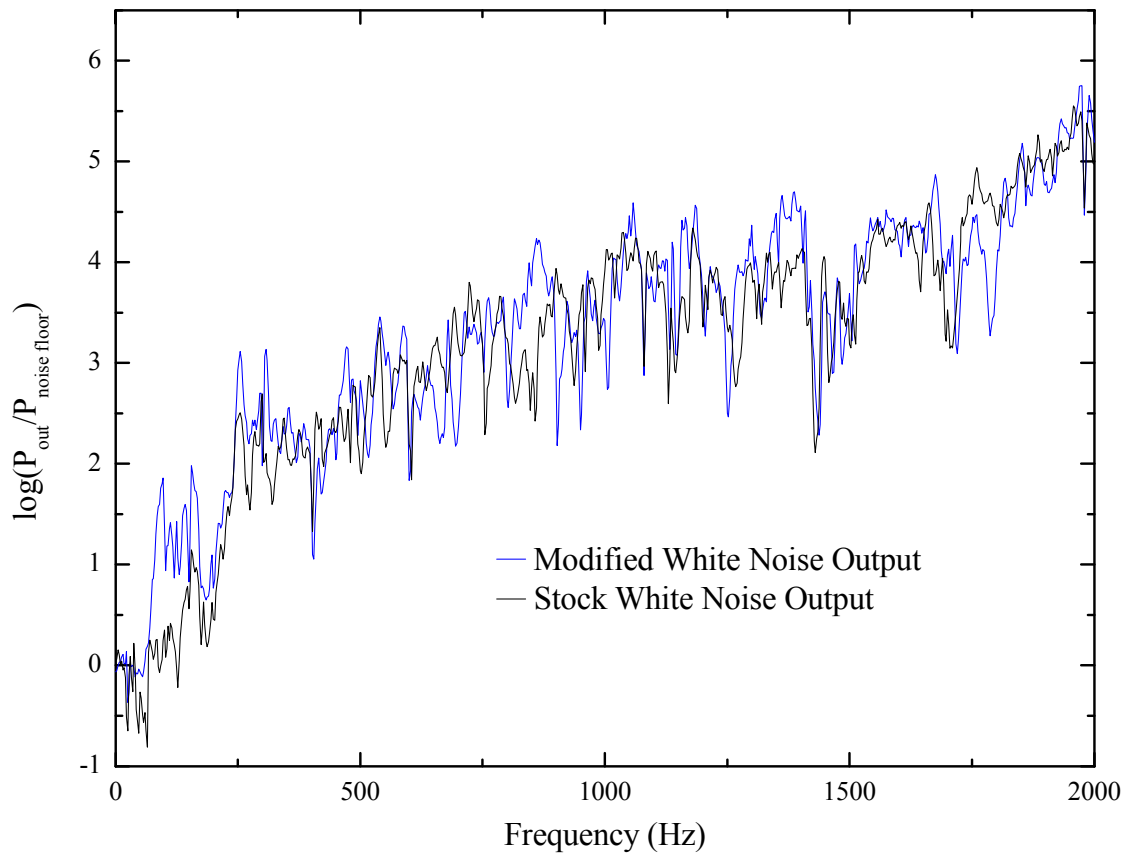


Figure 10: A before and after comparison of the frequency response of my Blues Junior.

Figure 11 shows a before and after comparison of the tone stack control ranges. Note the increased magnitude of the bass knob control range in the modified amp, as well as the narrowed middle control frequency range. These changes in the tone stack are sufficient to make the amp sound drastically different than before.

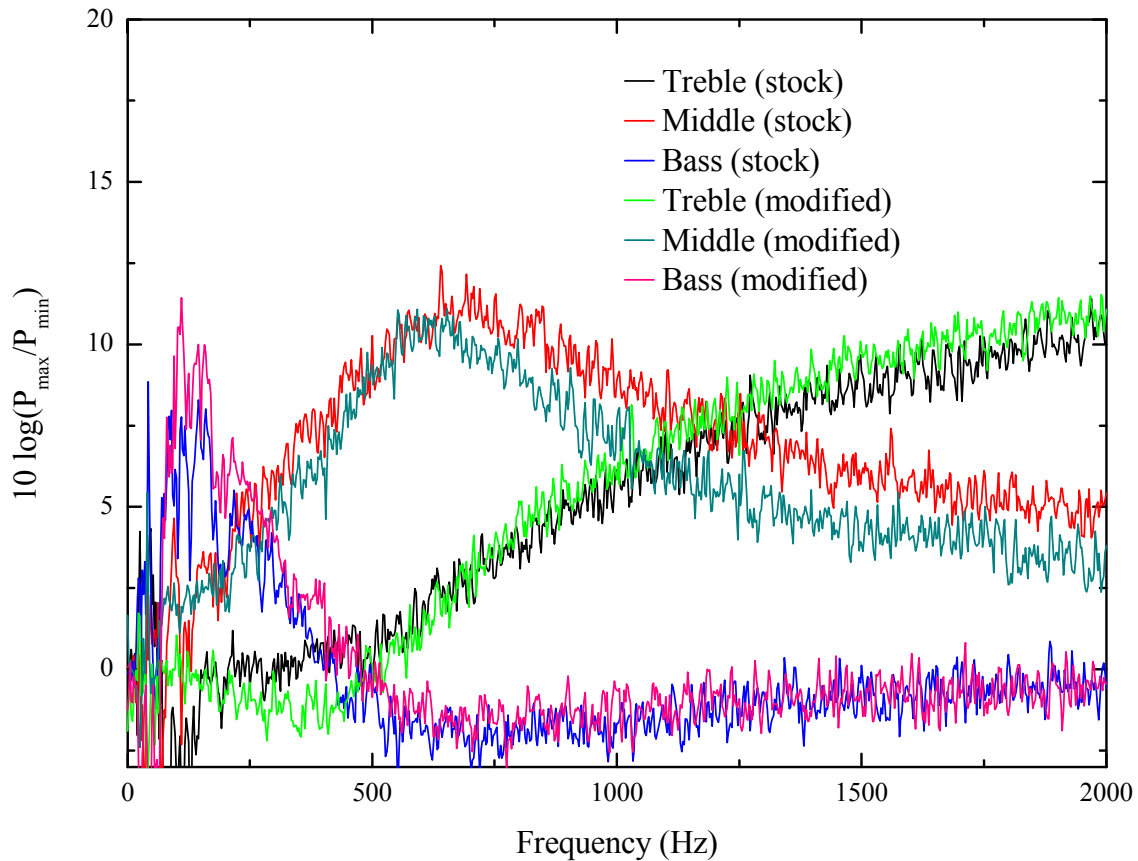


Figure 11: A before and after comparison of the tone stack controls of my Blues Junior.

The measurements and data described in this section have shown that the amp is now capable of outputting more bass than before, but the magnitude of this effect is hard to discern from data alone. So, I include the following qualitative assessment to give the reader an idea of how much the behavior of the amp has changed. Before the modifications to this amp, I would typically keep the bass control knob at its maximum value, and I would dial back the middle and treble controls to get a sound I was happy with. After the modifications, for me the bass is too intense for general playing past about 7 (out of 12).



## **Conclusions:**

At the beginning of this project I was really excited about the prospect of making a relatively inexpensive amp sound better. But in the process of implementing these modifications, I also learned a lot about tube amps. This task was intimidating because I had never modified electronics so expensive and potentially dangerous. Fortunately for me, Professor Errede had modified a Blues Junior himself before and was able to offer advice and suggestions throughout the process. Ultimately, the risk to my amp was worth it; I really like the improvement in tone, and I also learned a lot about my amp. Thanks to Prof. Errede for suggesting these modifications and for guidance in this project. I now have a sweet tube amp that didn't break the bank!