

Modification of a Tube Amplifier

Michael Schubert

Physics 406 – Spring 2013

5/10/2013

Introduction

The tube amplifier has been a mainstay of rock and roll music since its beginning. Even now, despite being “outdated” technology, tube amplifiers are the tool of choice for most serious musicians. They provide a tone that to this point has not been duplicated by modern amplifier circuits that typically use silicon transistors in an attempt to emulate their sound.

I entered this class knowing that I wanted my project to somehow involve tube amps, as I have been interested in their origins and operation since shortly after I began playing guitar. My first plan was to build an amplifier from scratch. After looking up various schematics and build lists online, it became apparent that this would be prohibitively expensive, costing around five hundred dollars minimum. Next, I looked in to gutting an amp that I already had and reusing the cabinet and certain components, such as the transformers, to save money. After looking at the amp with professor Errede, we decided that it would be too much work to salvage the amplifier, so that plan was also abandoned. I began to look for vintage amplifiers online in hopes of finding a good price on an amp that could be restored. In my search, I found a good deal on a VHT Special 6 head and cabinet. While not the vintage amp I was looking for, it turns out that the hand wired, point to point layout of the circuit was specifically made to allow easy modification. I ordered the amp and set about finding the schematics online in order to get a sense of what I was working with.

Background

A tube amplifier works by using vacuum tubes to amplify the input signal to audible levels, which it then outputs through a speaker. Typically there are two transformers, a regular input transformer and an output transformer that serves to match the load out of the tubes to the speaker. The circuits vary in complexity from amp to amp, but they all have a set of resistors known as a tone stack, either fixed values or variable potentiometers, that are used to shape the bass, mid and treble frequency response. An amp will also have at least one preamp tube and one power (output) tube. A vacuum tube consists of a cathode and an anode in a vacuum environment enclosed inside of a glass tube. When the filament inside the cathode is heated, electrons shoot off of it and are attracted to the anode due to a difference in voltage. Vacuum tubes also contain a grid – a metal wire or set of wires carrying some voltage that is used to control the flow of electrons between the cathode and the anode. The beauty of the characteristic tube tone comes from the device's imperfection. When a vacuum tube amplifies a signal, it introduces some degree of distortion. While the amount varies from tube to tube, at low voltages the distortion is not very noticeable, providing clean tones. As the voltage gets higher, the distortion becomes increasingly obvious. The distortion of a signal by a vacuum tube is less abrupt than that of a solid state transistor. The signal clipping is softer, which in turn provides a warm, organic tone when compared to the harsh, sterile sound of solid state distortion.

The amplifier that I purchased, a VHT Special 6, utilizes a relatively simple circuit. There is one preamp tube, a 12AX7, and one power tube, a 6V6. Both of these tubes are widely used in amplifiers. It has six volt high setting and a three volt low setting, making it good for use in apartment buildings where noise levels need to be controlled. The tone stack originally consisted of four fixed value resistors, limiting the sonic options.

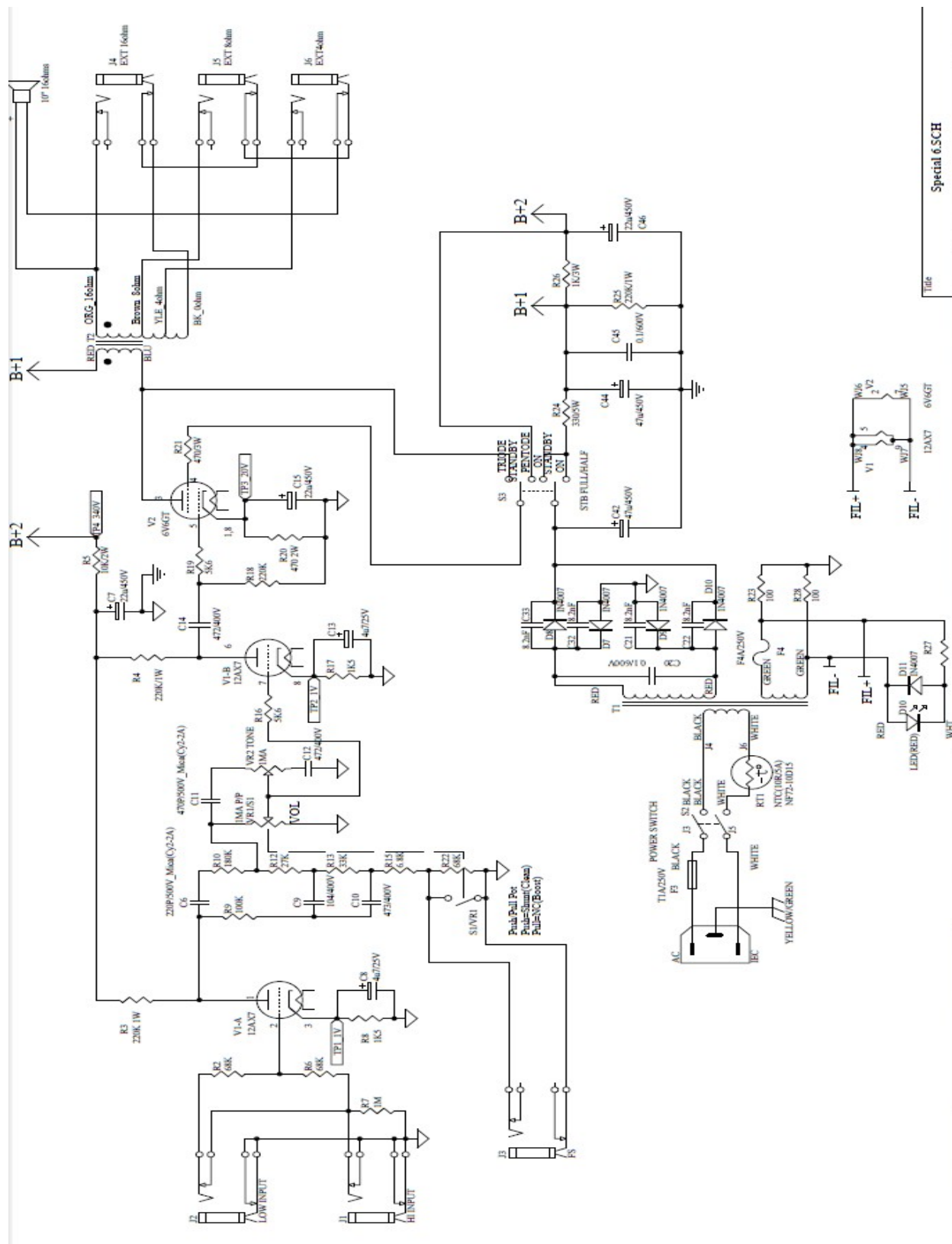


Figure 1: VHT Special 6 Schematic

Analysis

Once the amplifier arrived, the first order of business was measuring its frequency response using the HP-3562A Dynamic Signal Analyzer. We created an eight ohm dummy load to use in place of a speaker cabinet to ensure that loading the amplifier did not cause the circuit to blow out. We used 100 mV of white noise from the analyzer in order to obtain a frequency response that ranged from 0 to 20,000 Hz. Measurements were taken with each knob set in increments of 25 out of a possible 100. The resulting data was then plotted on a log-log graph and a semi-log graph.



Figure 2: Experimental Setup – analyzer left, amp right

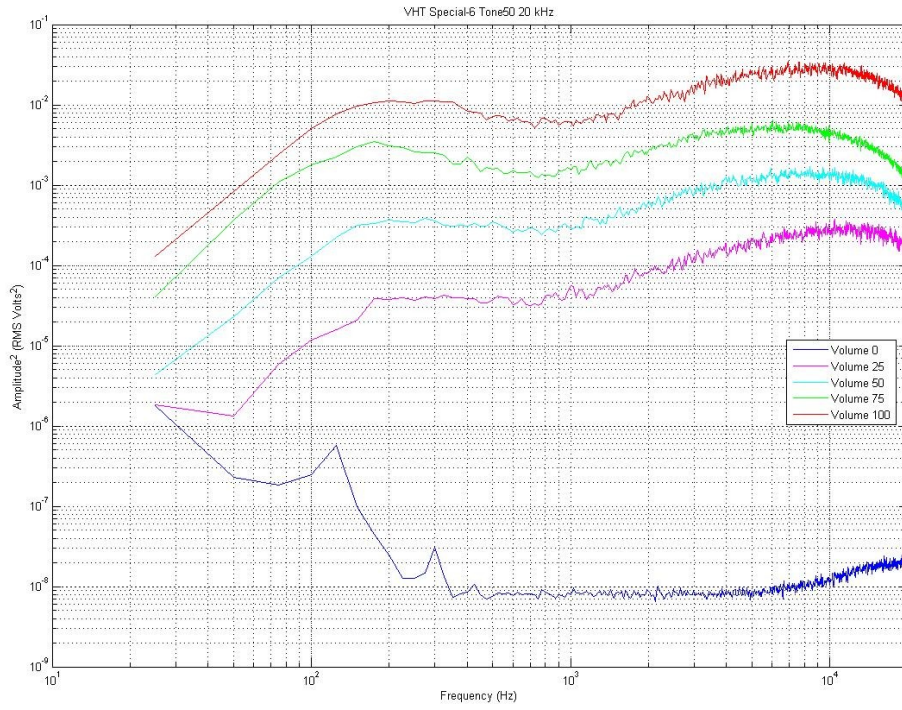


Figure 3: Tone50 LogLog Plot

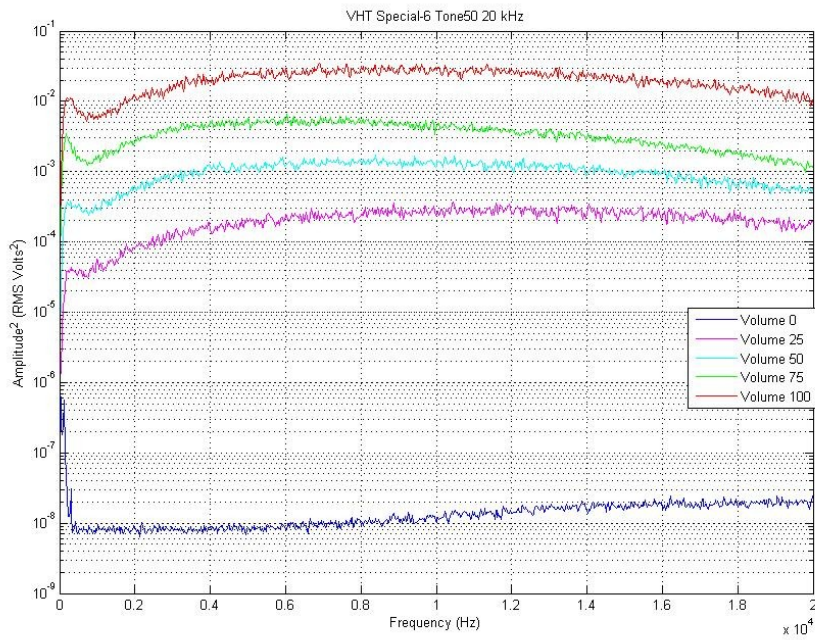


Figure 4: Tone50semilog

Modification

After reviewing the shortcomings of the amplifier, I decided that the most useful modification would be to change the fixed valued resistors in the tone stack to variable potentiometers. Originally, the amplifier had a single tone knob that controlled all three channels – bass, mid, and treble. The user could roll off the treble for a deeper tone with the bass emphasized, or roll off the bass for a more jangly, tinny tone. By changing the resistors to potentiometers, the user would be able to control each channel independently, enabling access to a much wider range of tones. Doing this presented a challenge, however, as each potentiometer, of which there would be three, required its own knob. The control panel for the amplifier was not designed for this and as such had no room for that number of knobs.



Figure 5: Original Control Panel Layout

The solution to this problem was to use a concentric potentiometer. A concentric potentiometer is a pair of stacked potentiometers with two nested shafts. Each shaft independently controls one of the potentiometers. This allows two potentiometers controlled by two stacked knobs to take up the same amount of space as a normal potentiometer. In order to make room for the concentric pot, we moved the led from its original spot and placed it below the power switch. We then placed the concentric pot in the hole originally drilled for the led. In order to control the third channel, we took out the tone potentiometer and replaced it with one of the necessary value. At the recommendation of professor Errede, I decided to model the tone stack after the one found in the classic Fender Twin Reverb. This meant that

the concentric potentiometer had to be 250k/250k and would control the bass and the treble, and that the mid would be controlled by a 25k linear potentiometer. The potentiometers were then wired back to the main circuit using coaxial cable in order to prevent electromagnetic interference.

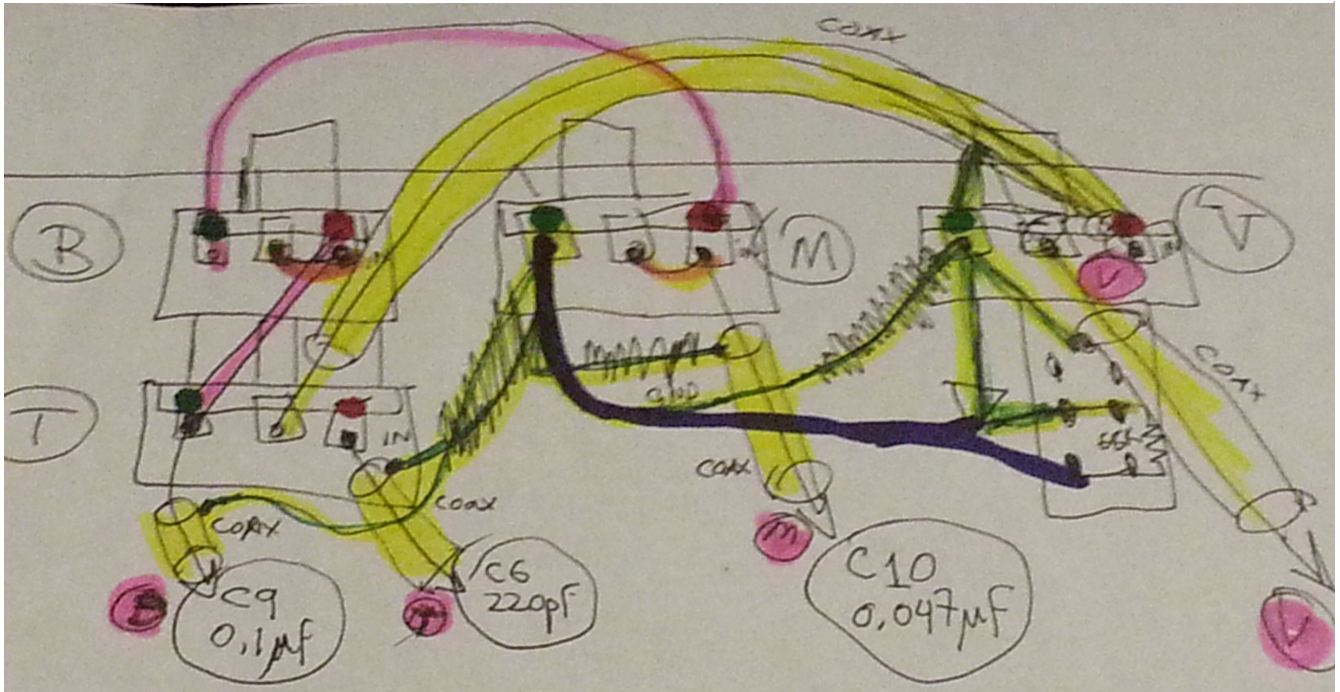


Figure 6: Potentiometer Connection Schematic

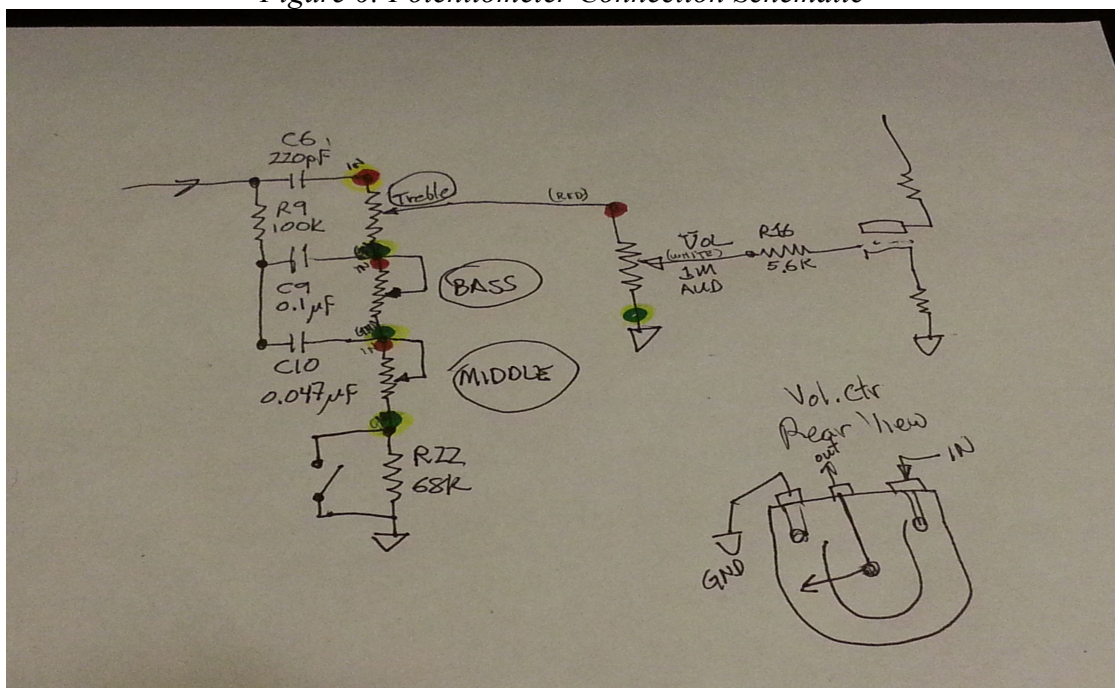


Figure 7: Potentiometer/Circuit Interface Schematic

After a brief lesson in cable management, the amplifier was theoretically finished. Everything was soldered in place and looked good. Once reassembled, we hooked up the amplifier to a speaker cabinet and tried to play through it. A garbled signal came out, with the knobs controlling the wrong channels. We opened up the amplifier and began to check the integrity of the circuit. It turns out that one of the wires had melted, shorting out the rest of the circuit. After fixing this, we reassembled the amplifier and tried again. This time, everything worked as it should.

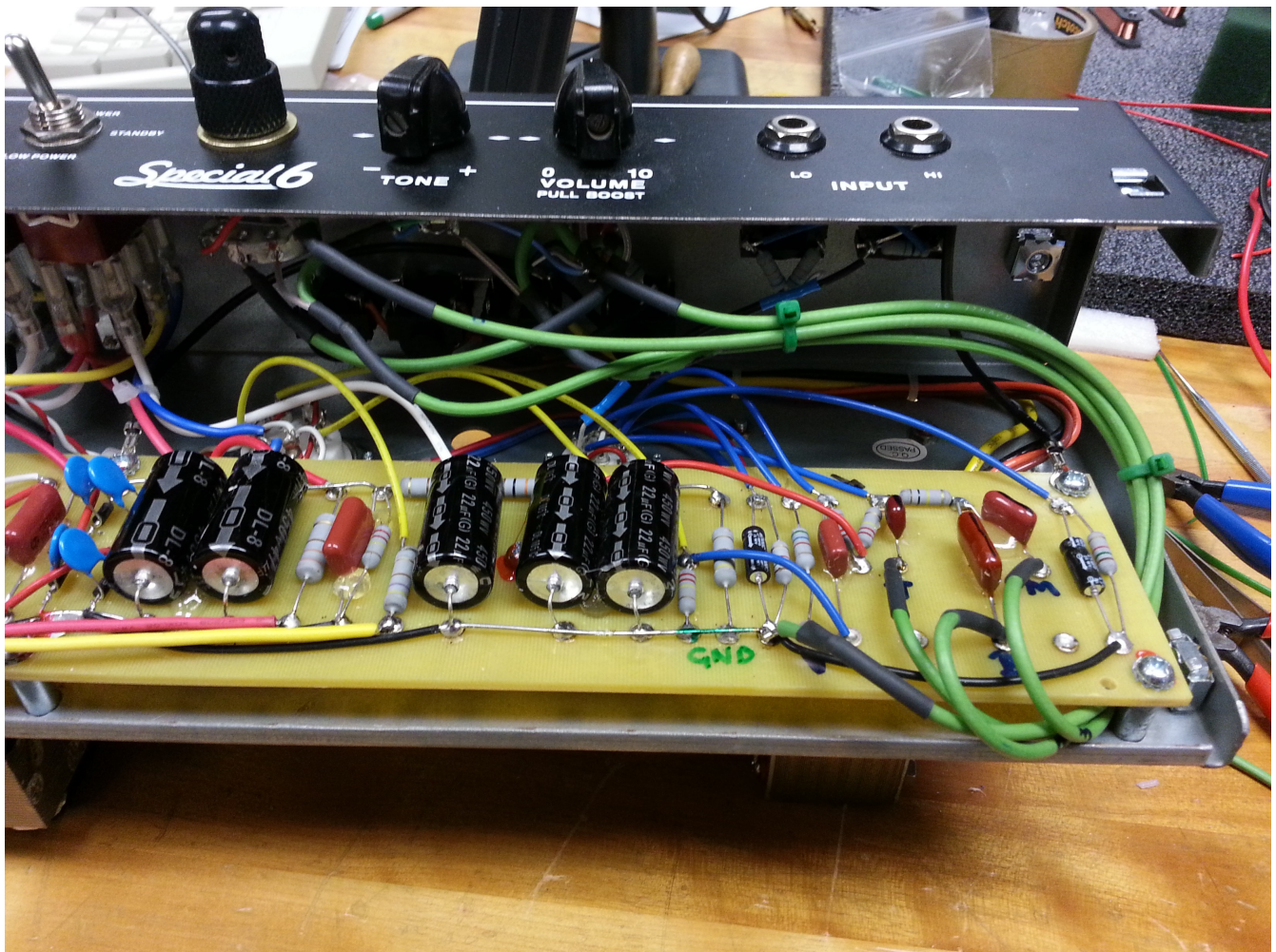


Figure 8: Final Internal Layout

Conclusion

After modifying the amplifier, it was immediately clear that many more tones were accessible than had been previously. The only issue that quickly became evident is that one of the potentiometers is a bit scratchy. Surprisingly, it seems that it is the Bourns 25k linear potentiometer making the noise, not the lower quality alpha concentric potentiometer.

Setting out to alter this amplifier, I had no real experience in working with electrical systems. Over the course of the project, I learned how to analyze circuits, solder, troubleshoot circuits and analyze frequency response data. I also learned how vacuum tubes amplify a signal, which was what originally interested me. I came away from the project with a functioning amplifier that provided more interesting tones than it did originally, as well as with the knowledge to further modify the amplifier or other electronics if I so choose.

Acknowledgments

Professor Errede – Without his unparalleled knowledge of all things guitar and his guidance this project would have never come to fruition. He came up with the necessary changes and provided me with easy to read schematics. He also saved the day when the assembled amp did not work.

Sources

http://www.webphix.com/schematic%20heaven/www.schematichaven.com/index_HTML.html

http://www.premierguitar.com/Magazine/Issue/2009/Jan/Everything_You_Ever_Wanted_to_Know_About_Preamp_Tubes.aspx

http://www.vhtamp.com/pdf/VHT_Special_6_Schematic_5-17-10.pdf