

How a Vacuum Tube Guitar Amplifier Operates

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An Introduction

For decades, musicians of all types have trusted the tube guitar amplifier to deliver unparalleled tone and reliability for recording and live settings. Artists, ranging from Led Zeppelin to Jimi Hendrix to Pink Floyd, have learned to master these complex devices, helping to make their music stand the test of time. But what makes the tube amplifier so unique? The following information will explain the operation of a vacuum tube guitar amplifier, and will elaborate on what is on the inside that makes them tick.

Although this packet is intended to teach someone how tube guitar amplifiers operate, please do not use it as an excuse to go poking around in an amplifier's circuitry without proper training. There are lethal voltages stored within the amplifier even when it is switched off and unplugged. Please note that this is intended for informational purposes only.

Electrons and the Vacuum Tube

Let's start broad by going over some basic electric principles. The electron is defined as a negatively charged subatomic particle, which is often referred to as the source of all electric energy. A vacuum is defined as a space that is absent of all air or matter.

Now, research has shown that an electron can be controlled within a vacuum if it is attracted by a significant positive charge. This is exactly what happens in tube amplifiers: in the center of a tube's glass casing is a cathode. The cathode carries a slightly positive charge and prepares to release millions of electrons. The anode (aka the plate) surrounds the cathode within the tube and carries a significantly positive charge. The plate pulls the electrons towards the center of the tube (due to opposites forces attracting). Now, with just these two elements alone, electrons will fly wildly towards the plate, but when adding a third element, the grid, between the anode and cathode, the electrons can be controlled. You can see, in Figure 1, the glow of the electrons within the tubes.

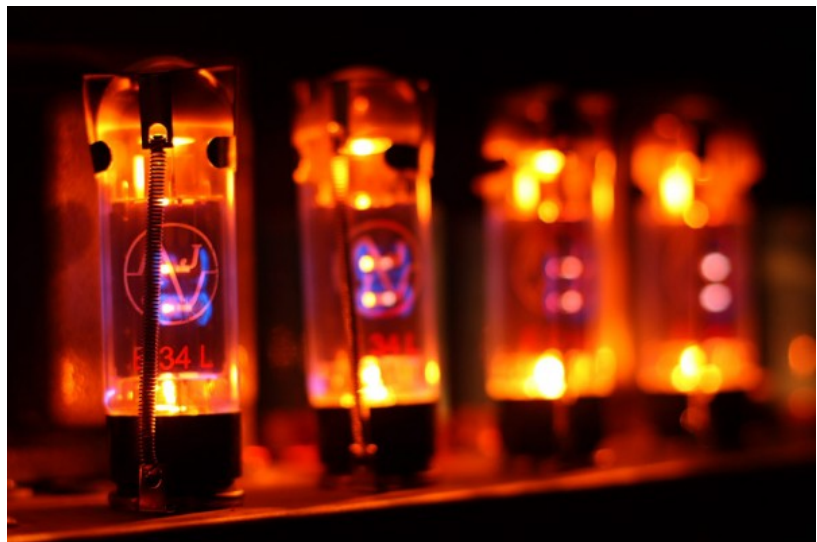


Figure 1: The flow of electrons causes an orange-yellow glow within vacuum tubes.

When the grid is positioned near the cathode and connected to the small signal coming from your guitar's pickups, that small signal unleashes a flood of electrons from the cathode to the plate. This electron flow mirrors the guitar's signal and amplifies it many times over.

Obviously, the amplification process is quite more detailed than the above description, but it serves as a solid basis of understanding. Next we will look at the parts of an amplifier much more closely and put the pieces together to finally realize how a tube amplifier truly operates.

Voltages

The main operation of the guitar amplifier runs based on voltage. For beginners, voltage is just the amount of potential energy between two points on a circuit. If one point has more charge than another, that difference is called the voltage and is expressed in volts.

The first and largest component within an amplifier is the power transformer. The power transformer converts the AC (alternating current) signal coming from the wall into AC voltages that can be used properly by the amplifier. This step is important as to not burn out the circuit from voltages that exceed the amplifier's proper working conditions. The AC signal that enters the power transformer is a sine wave of electricity (alternating positive and negative). Now, an amplifier cannot properly use a negative signal to produce a sound, so it needs to then travel into a rectifier tube (normally the first tube in the circuit), which converts AC into DC (direct current). This means that everywhere that the sine wave was negative was flipped into the positive region and can be used by the amplifier. So, as can be seen in the middle image of Figure 2 below, we are left with a positive rippled signal. These ripples can be detrimental to the rest of the circuit. Filter capacitors are able to take that voltage and smooth out the ripples to achieve a smoother signal that is then sent to the tube plates in order to prepare for electron flow.

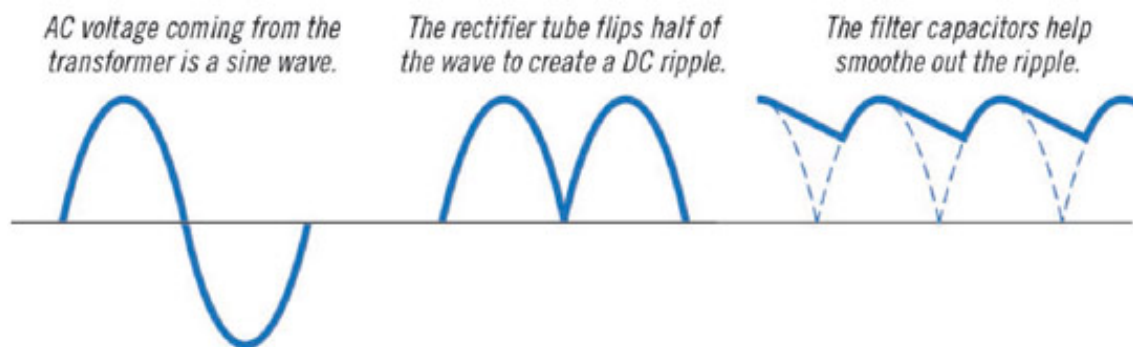


Figure 2: The process that voltages go through when entering a tube amplifier. The signal starts as an AC sine wave, rectifies to DC, and is smoothed out by Filter Capacitors before entering the power tube section.

Amplifier Components

Figure 3 shows an open back of a Vox amplifier with the components labeled by numbers. Refer back to this picture when reading about each of the different components that makes a tube amplifier unique.

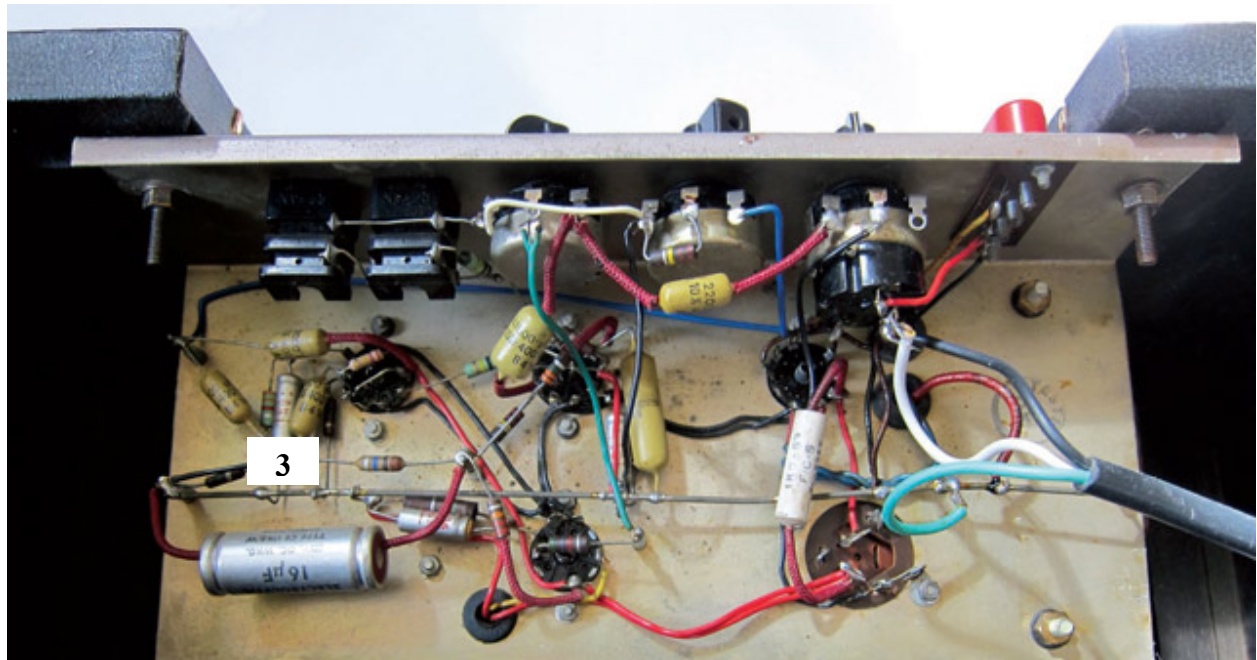
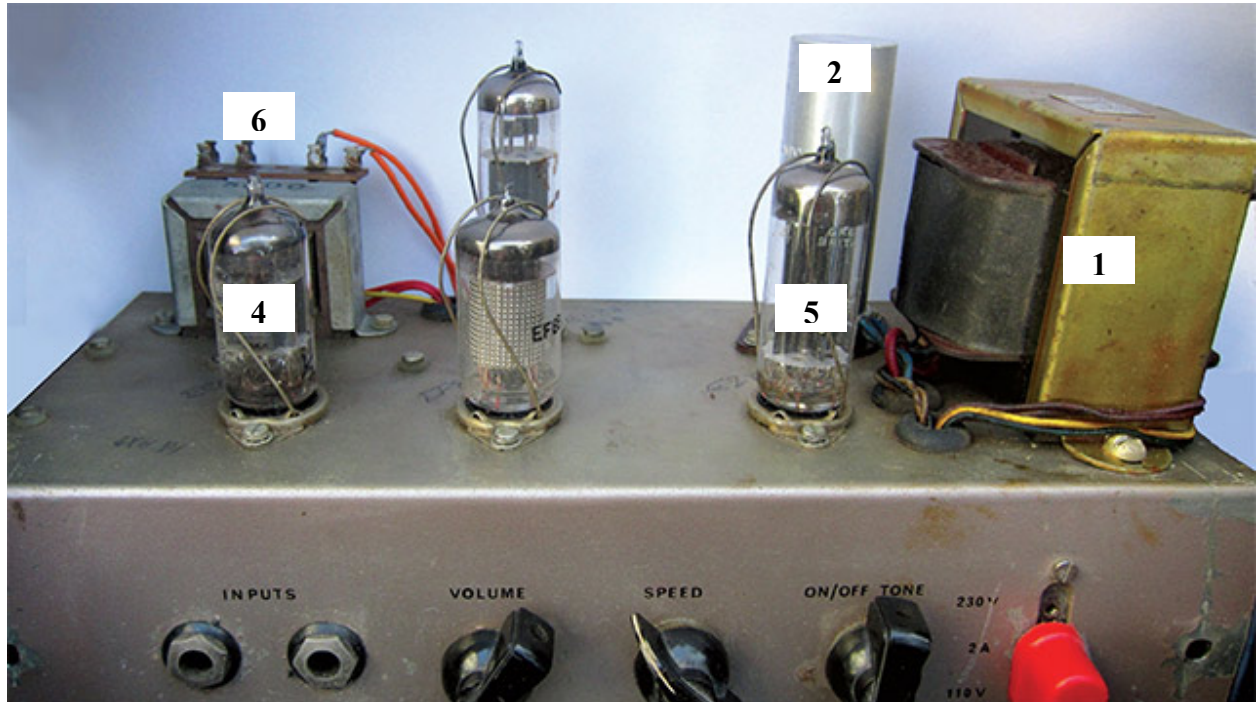


Figure 3: A Vox AC4 Amplifier. Pictured above is the tube and transformer section of the circuitry and pictured below are the connections to the control pots. Reference the numbers on the description of each component in order to visualize the specific part.

(1) *Power Transformer:* The power transformer is the largest component within the amplifier. Its job is to convert the 120V coming from the wall into a higher AC voltage entering the rectifier. The transformer also supplies voltage to the tube filaments in order to begin heating them for efficient electron flow.

(2) *Capacitors:* There are three main types of capacitors used within guitar amplifiers. They are as follows...

Filter: Filter capacitors are large metal cylinders that hold a charge. These capacitors are responsible for smoothing out the DC signal from the rectifier tube by storing and releasing high voltages. These components can be very dangerous, for they are capable of storing lethal voltages.

Bypass: Bypass capacitors are wired in parallel (side by side) to a resistor within the cathodes of the power and preamp tube sections. The resistor is useful in adding DC voltages to the cathodes but can also resist the flow of the guitar signal. So, bypass capacitors allow the electrons to bypass the resistor as to not distort the signal of the guitar.

Signal: Signal capacitors are smaller capacitors within the amplifier's circuitry. They are responsible for blocking DC voltage while allowing AC voltage to pass. They also are responsible for allowing certain frequencies to pass, which can be very important when trying to color the tone of the guitar.

(3) *Resistors:* Resistors are small cylindrically shaped components that resist the flow of current. They can come in many values with higher values resisting current more so. They are measured in ohms and their main purpose is to decrease voltage as electrons attempt to travel through them.

(4) *Preamp Tubes:* These are the first tubes that the signal of the guitar will reach and be amplified by. These tubes are considered pentode tubes. This means that they have five elements rather than a triode tube that has three (such as the ones we talked about before). The other two elements are a suppressor and a screen. These both are wire wraps within the tubes that induce electron flow in ways that colors the guitar tone. The preamp tubes are the sole contributors to why every amp has different tonal quality.

(5) *Power Tubes:* Just as the preamp tubes amplified the guitar signal, the power tubes amplify the already amplified signal from the preamp tubes. These are larger in size and also considered pentode tubes (meaning they include a screen and suppressor).

(6) *Output Transformer*: The Output Transformer converts the voltage from the power tubes into a low-voltage, high current signal that is responsible for driving the speaker. The diagram in Figure 4 shows the schematic of how a signal travels from the power tube to the output transformer.

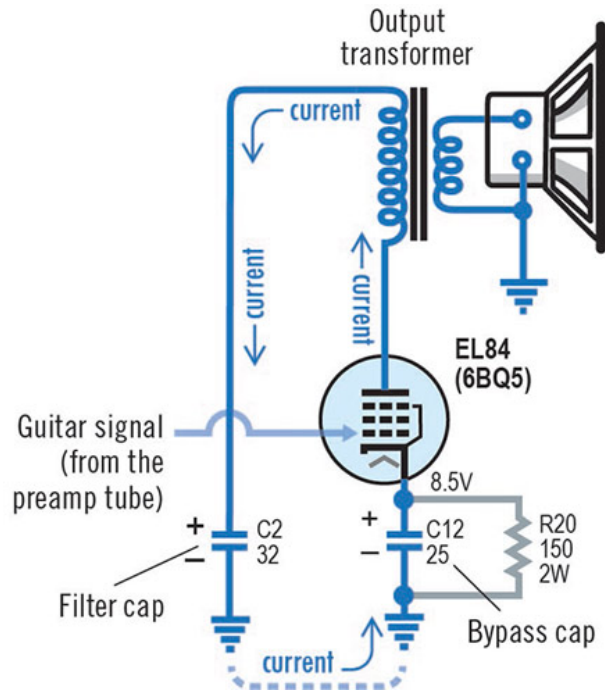


Figure 4: A schematic of the output transformer. Notice how the signal travels from the guitar, to the EL84 power tube into the transformer in order to drive the speaker.

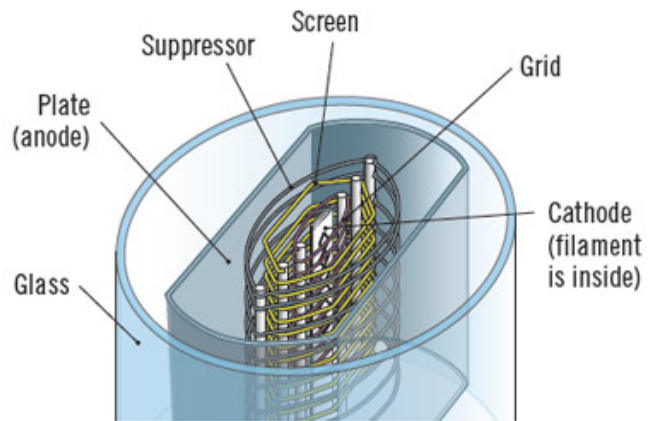
Tube Diagrams

When reading a tube diagram, one must realize that the order of the diagram is only a schematic and not the actual order of the components within the tube. Figure 5 shows a very specific tube diagram of an EL84 power tube.

Even though the schematic shows the elements as if they were towered on one another, they are actually wrapped around each other in an almost symmetrical fashion. The plate is made of bent metal that wraps all the way around the cathode, followed by the suppressor, screen and then grid, which are all bent wires allowing electrons to travel from the cathode to the plate. Finally, the filament that heats the cathode is inside of the cathode.

Conclusion

Tube guitar amplifiers are still revolutionizing the world of music, and now that the general operating procedure of one has been uncovered, feel free to explore the millions of amplifier schematics and do further reading on premierguitar.com or Marshall amplification forum to better your understanding.



Elements in a pentode



Figure 5: Diagram and schematic description of an EL84 power tube.

Works Cited

Research

Formosa, Dan. "How Tube Amps Work". *Premier Guitar*. 15 Jul. 2013. Web. 29 Jul. 2014. <<http://www.premierguitar.com/articles/17116?page=1>>.

Images

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Formosa, Dan. Figure 5: Tube Diagram. Diagram. 2013. "How Tube Amps Work". *Premier Guitar*. Web. 29 Jul. 2014. <<http://www.premierguitar.com/articles/17116-how-tube-amps-work?page=5>>.

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