Vacuum Tube Amplification

Alex Martin

Honors University Physics II

Dr. John Stewart

April 25th, 2011

Tube amplification is the technique of using electron tubes to amplify an input source to a desired higher level. These tubes have been around for about a century and have been used in multiple items such as musical instrument amplifiers, professional audio gear, and different radio types (Barbour para. 13-17). Electron tubes all still quite popular today in the audio world, with most people preferring them over their transistor counterpart. The construction of a tube amplifier was relatively easy with a kit, with only a few minor problems.

The basis for the electron tube made it's first appearance around 1904, when a scientist named John Ambrose Fleming unveiled his new “Fleming Diode” (Barbour para. 1). This diode consisted of a filament of a light bulb, along with an electrode not far from in the a vacuum (Barbour para. 1). When the light bulb filament was heated to extremely high temperatures, electrons would begin to be emitted off of it into the vacuum. The electrode, which was positively charged, would then attract the electrons, and create a flow of current between itself and the filament (Barbour para. 1). The flow of the electrons would only go one way, and therefor would convert AC into DC (Barbour para. 1). Around 3 years later, a scientist named Lee de Forest improved upon the “Fleming Diode” by adding in a third electrode, this one being bent and placed in between the filament and first electrode (Barbour para. 1). When he applied the current through the center electrode, he found that it had a better signal, and actually modulated the applied current (Barbour para. 1). This device was called “The Audion”, and is the first real amplification tube (Barbour para. 1).

The basic components of a electron tube are a cathode, an anode, and a “grid” in between them, which is negatively charged (Harper para. 1). Electrons begin to flow from the filament (cathode) to the plate (anode) by thermionic emission, with the grid in the middle acting as a control upon how much current gets from the cathode to the anode (Douglas-Young 200). The grid is able to do this because it is negatively charged, and will repel the like charged electrons. The electrons are able to escape the filament or cathode because of its metal properties. For metals, the electrons inside of them are in a sea like arrangement. They flow all across the metal and are never paired with a certain proton. Because they flow so easily, they can be removed from the metal with relative ease. In able to escape the surface though, the electron must have enough energy, which is measured by,

$$E=\frac{1}{2}mV^2 \quad ,$$

the basic kinetic energy formula. When looking at the mass of an electron, 9.02 x 10^{-31} kg, it can be seen that this will be a very small number (Harper para. 2). To make it a more manageable number, the energy can be converted from joules to electron volts, where 10^{-19} joules is about 1 eV (Harper para. 2). With the eV known, the current flow between the cathode and anode can be found by Dushmann's Equation

$$I_0=AT^2e^{\frac{11600w}{T}}$$

where A is the constant 120.4 A/cm^2, T is temperature in kelvin, and w is the eV of the cathode (Harper para. 2).

Amplification comes into play because of the many changes in voltages with the corresponding current flow. The amplification factor can be found by the equation

$$\mu=\frac{\Delta V_p}{\Delta V_g}$$

where ΔV_p is the change in voltage of the anode and ΔV_g is the change in voltage of the grid (Douglas-Young 204). As a current is applied to the grid, the flow of electrons between the cathode and anode increases dramatically (Pittman para. 3). The grid bias control then regulates the voltage across the tube, by applying a negative voltage to the grid, and creating an “idle” current for the tube to take in (Barbour para. 18). When this bias is set correctly, a large output signal will appear because of a large voltage increase on the anode plate (Pittman para. 3).

The construction of the tube amp wasn't very difficult. I purchased a mono channel tube amp kit, which came with all the components (resistors, capacitors, etc.) needed, and a corresponding circuit board. The kit came with 5 tubes, all relatively small compared to standard sized amplification tubes (30-75 W). The final product is a 16 Watt amplifier, which I connected to an 8 ohm speaker. The only problem I really had with the amplifier was the potentiometer that the manufacturers sent with the kit. The potentiometers purpose was to control the voltage output through the circuit, and thus control the volume for the amplifier itself. The potentiometer I received was set up for a 2 channel circuit, and only worked in a very small voltage range. I found out after testing the pegs for voltage that the channel that the kit used was a bad channel that the potentiometer had. Because the amplifier technically still worked, I decided that replacing the potentiometer at this point in time would be quite risky, since I have low experience with soldering in general.

Over all, the project was a success. The construction of a basic vacuum tube amp was nearly painless (aside from the fact that I grabbed the soldering iron at one point), and the product works pretty well. Vacuum tubes have been around for quite awhile, and have really shaped the technology that we have today. Even though transistors and semiconductors are replacing vacuum tubes in audio technology, tubes are still widely considered to produce a greater tone, and are preferred in higher quality audio systems and amplifiers. With their rich tone, vibrant reverb, and crunching distortion, the vacuum tube will definitely be around for a long time.

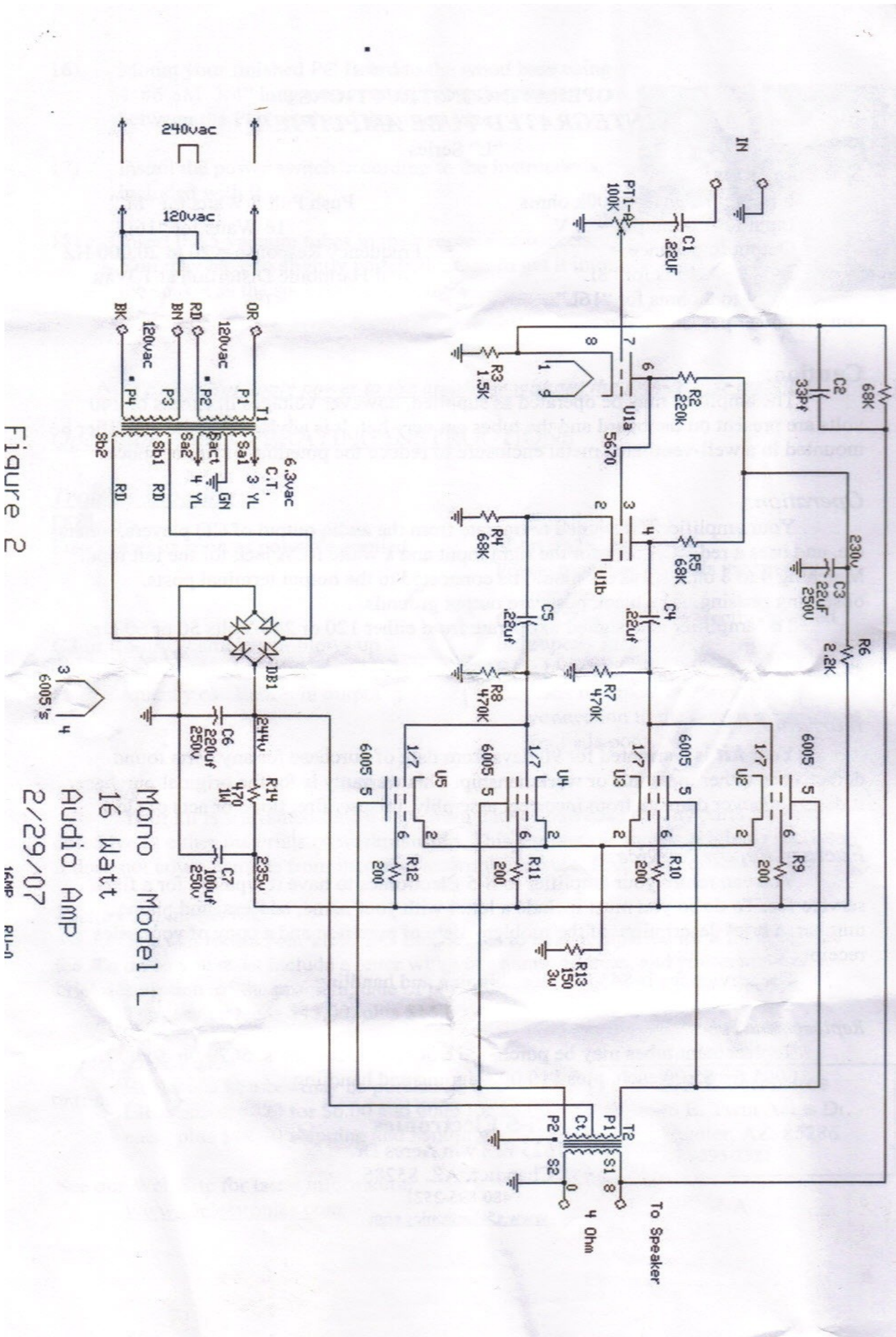

Figure 1: Diagram (*Monointegrated Tube Amplifier Kit 16 Watt*, 11th October 2007.)

Bibliography

Barbour, Eric. "How Vacuum Tubes Work", *vacuumtubes.net*, 3th April 2011, http://www.vacuumtubes.net/How_Vacuum_Tubes_Work.htm

Douglas-Young, John. *Illustrated Encyclopedic Dictionary of Electronics.* West Nyack, NY: Parker Publishing Company, inc, 1981.

Harper, John. "Tubes 201, How Vacuum Tubes Really Work", *john-a-harper.com*, 2003, http://www.john-a-harper.com/tubes201/

Pittman, R. Aspen, "Tubes: Mechanics & Mystique", *kpabbs.com*, June 1983, http://www.kbapps.com/tubes.html.

Monointegrated Tube Amplifier Kit 16 Watt, 11th October 2007.