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University Physics II

Lab Section H1

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Plasma Speaker

The intent for this project was to construct a plasma speaker. The speaker works by sustaining a plasma arc, basically a lightning bolt, and running a time varying current through it to play music. This project was inspired by a scene in Disney's "The Sorcerer's Apprentice" where the protagonist plays a song by manipulating the frequency of tesla coil discharges. Being greatly interested in both music and dangerous contraptions (you only die once, right?) it seemed like the perfect project. I wanted the project to be a bit smaller and potentially simpler, and stumbled across plans for constructing a plasma speaker.

The trouble with traditional speakers is that they rely on Lorentz forces moving an electromagnetic coil and the attached speaker cone to create pressure (sound) waves. This works okay, but moving all that mass is very inefficient and limits bass response, creating distortion at extremes in frequency and volume. Since the plasma arc is massless, it doesn't have these issues. A plasma speaker works the same way a traditional speaker does, by following a time varying current (audio signal) to move the air and create a sound wave. However, a plasma speaker accomplishes this differently, instead of moving a large assembly, it only relies on the electrical arc vibrating with the current and, in turn, the air around it. This also varies from the tesla coil discharge mentioned earlier, because with the tesla coil, one is actually hearing the discharge tuned and timed to the music which gives the music a strange sound, a plasma speaker sounds as if the song were being performed live. The plasma speaker does have its own issues such as being an exposed electrical arc and generating ozone, both of these things are known causes of death. While ozone in the upper atmosphere (stratosphere) is useful, blocking ultra-violet radiation, in the lower atmosphere ozone is considered a pollutant and can cause cardiopulmonary problems including asthma, bronchitis, and heart attacks. The exposed arc is a hazard for the obvious reason that high voltage shocks at a minimum leave burns, and can cause muscle spasms which are especially dangerous in that one that pumps blood.

The design for this speaker was obtained from from the internet, all the circuitry was assembled as depicted in Figures 1.1 and 1.2, though possibly with flaws. A few additions were made to the design, the first of which was a section cut from an automotive cabin air filter which uses activated carbon to scrub pollutants, including ozone, from the air, coupling the filter with a twelve volt fan to direct the airflow from the arc to the filter should allow for extended operation. The other key addition was a plexiglas housing to protect the circuitry and make it more presentable, and to provide a safety barrier around the otherwise exposed arc. With these design additions the speaker can be operated more safely.

Figure 1.1

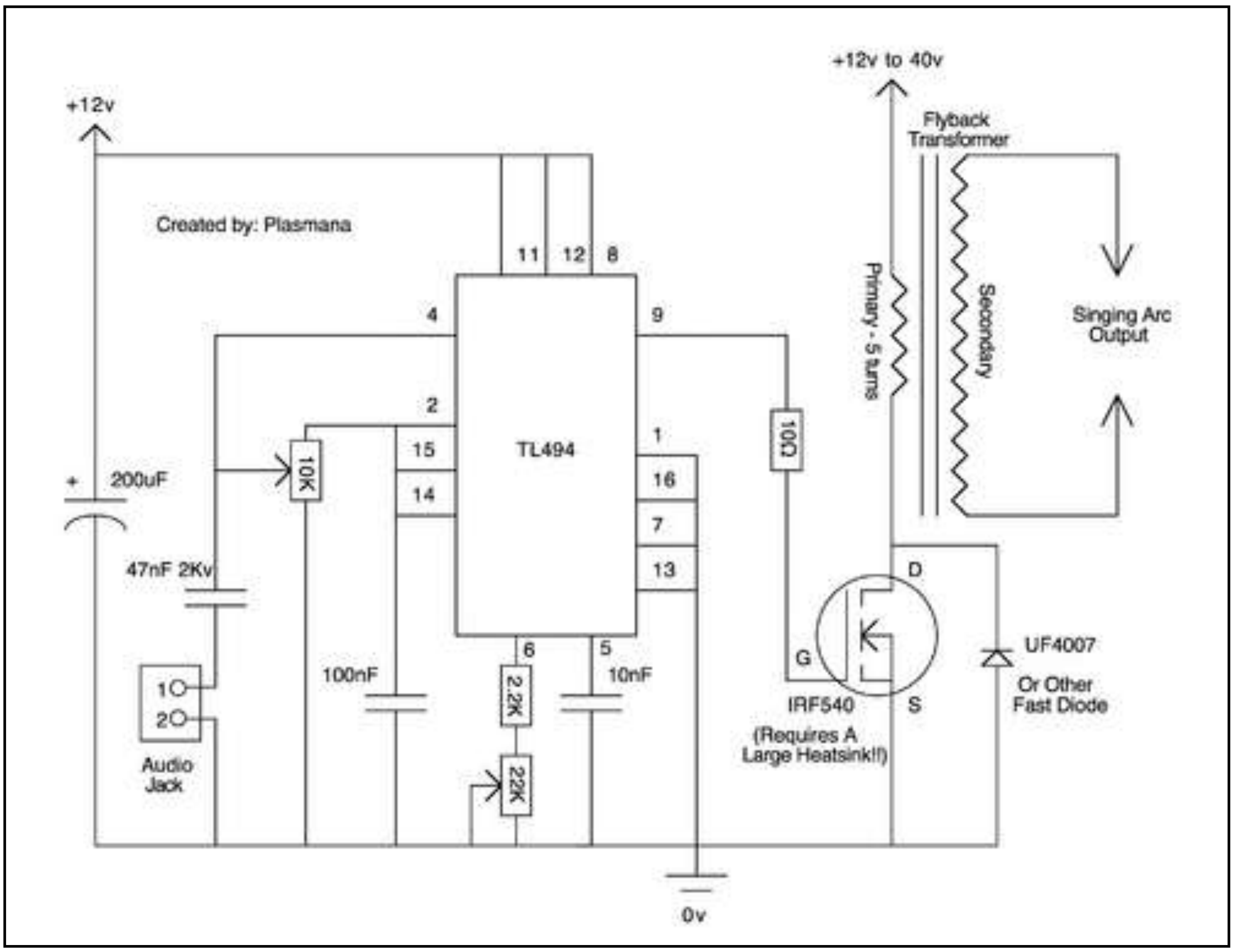
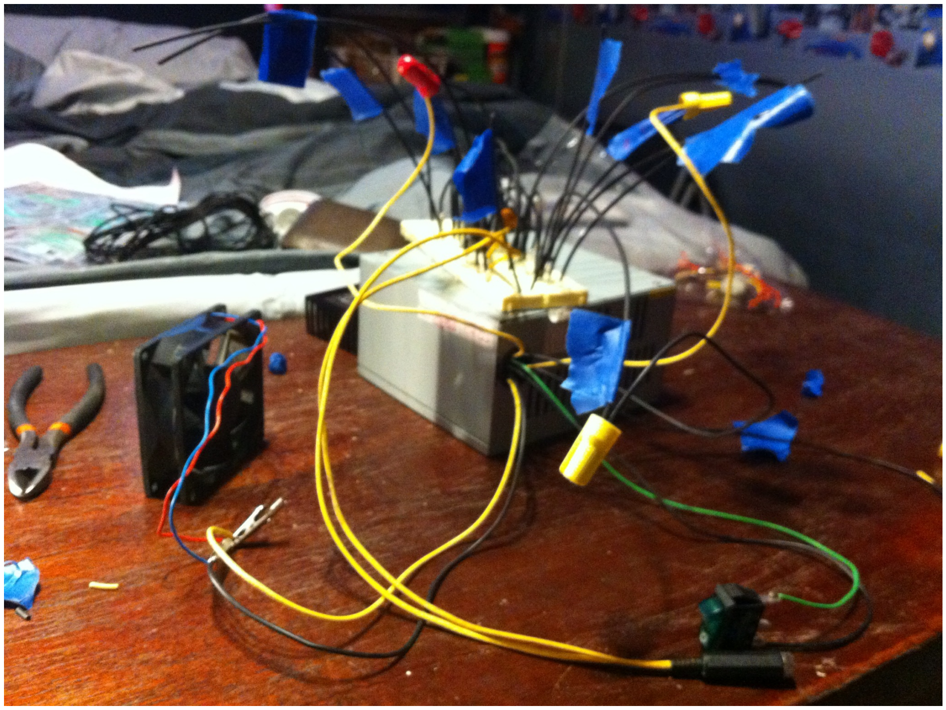


Figure 1.2



This circuit falls into the classification of a flyback driver, because it employs a flyback transformer to step up the voltage and generate the arc. A transformer operates on Faraday's Law of inductance. The construction of a transformer consists of two electrically isolated coils wrapped on a ferromagnetic core. A current through the primary coil generates magnetic flux, this flux carries through the core and creates an electromotive force, or voltage, in the secondary coil (Figure 2). Transformers can be used to change voltages depending on the ratio of turns in the primary and secondary coils, this project requires the voltage to increase so the secondary coil has more turns than the primary. A flyback transformer works just like any traditional transformer except a flyback depends on the switching on and off of current, usually by some sort of transistor. A flyback is charging the primary when the current is on, then discharges through the secondary while the current is off. The most common application of flyback transformers is to supply high voltage to cathode ray tube monitors, and the transformer for this project was scavenged from an old television. This design called for a self made primary coil as all the pins on a flyback can be quite difficult to identify, the primary coil consisted of five turns of thick (14 gauge) solid conductor wire as seen if Figure 3.

Figure 2

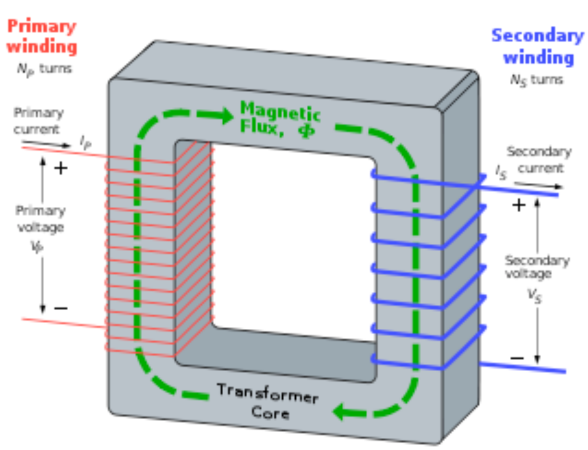
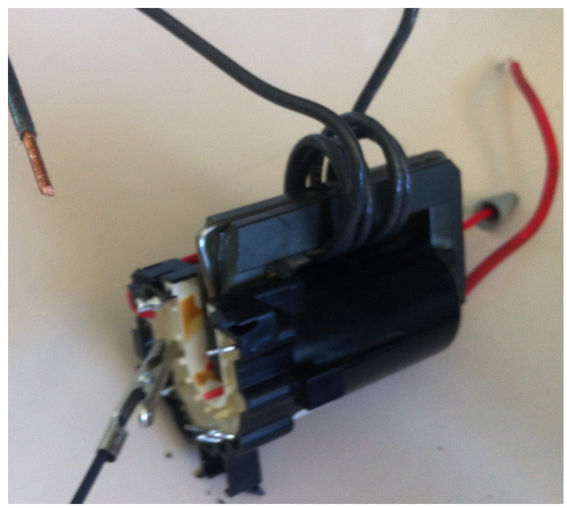


Figure 3



I believe the reason this attempt at constructing the plasma speaker doesn't work is a failure in the flyback transformer. Due to the high voltages within a flyback and compromise between insulation in the coils and a space saving design often an older flyback will fail due to a short between the turns.

Another key component to this project was the TL494 chip (Figure 4), which acts as an oscillator and a modulator. The chip feeds a high frequency to the transformer to create the high voltage arc, when an audio signal is added the chip incorporates this into the main high frequency and causes the vibrations in the arc. The 22k potentiometer tunes the high frequency, this is necessary because at lower frequencies the plasma arc buzzes and would distort the sound. What the potentiometer does is allow one to tune the frequency above above 20kHz, the upper limit of human hearing, so that the buzzing vanishes and leaves only the music. This speaker may not be pet friendly.

Figure 4

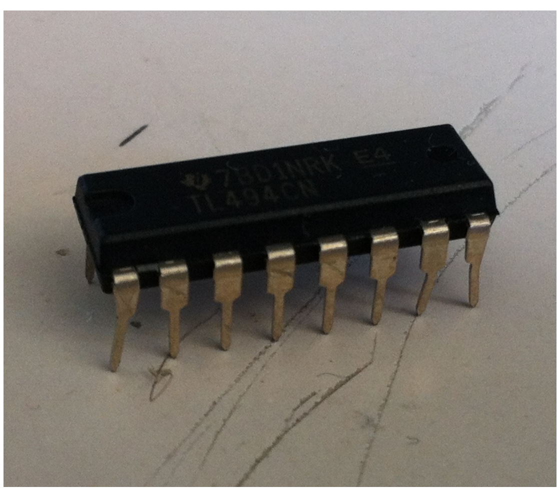
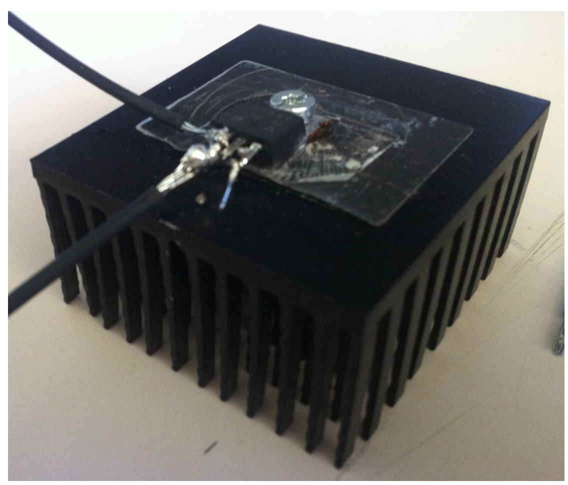


Figure 5

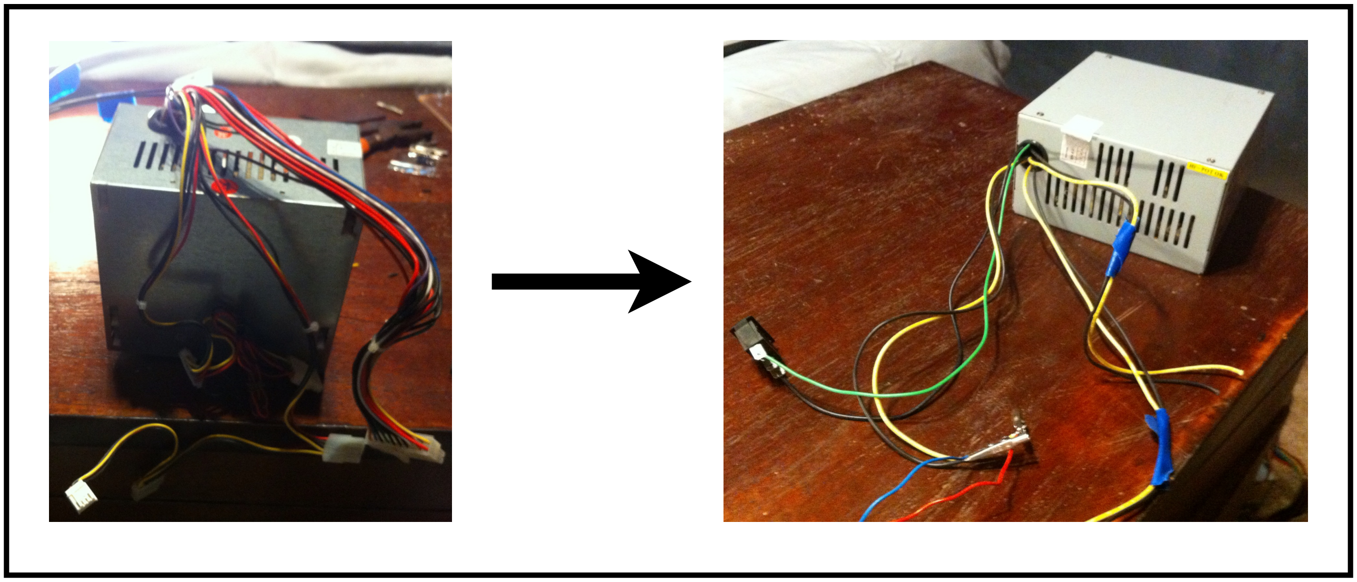


The MOSFET transistor, provides the switching current needed to run the flyback transformer. MOSFET, is an acronym for metal-oxide field effect transistor. Any change through the gate and source terminals of the transistor are reflected in the discharge terminal creating the switching effect. The MOSFET in this circuit expels large amounts of energy as heat, to prevent burning out the transistor a CPU heat sink was added to help dissipate the extra energy. The MOSFET with heat sink shown above in Figure 5.

The UF4007 diode acts as a check valve between the flyback transformer and the rest of the circuit. Semiconductor diodes, also known as rectifiers, use a p-n junction, much like those found in photovoltaic solar cells, to limit the flow of current to one direction through the element. A p-n junction consists of a bit of positively doped (electron deficient) semiconductor, in this case silicon, as the p-type; and negatively doped (excess electrons) forming the n-type. When current flows into the n-type (positive terminal) it excites the electrons and causes them to “jump” the gap to the p-type carrying the current out of the negative terminal. Because of this current can only flow one direction through the diode, because the diode is the last circuit element before the flyback transformer it protects the rest of the circuit from high voltage spikes bleeding back off of the flyback. The fact that diodes (including the light emitting ones) are polarized, was not fully realized until the circuit was deemed a temporary failure and deconstructed. Therefore the lack of functionality in this construction attempt could’ve been due to the diode being installed backwards. Even with this safety feature, high voltage spikes all the way back up the circuit are still a concern so a walkman cd player (circa 1997) was dug out of a closet to bite the high voltage bullet as opposed to the spare iPhone.

The schematic calls for a twelve volt power source for both the TL494 chip and the primary coil, power would also be needed for the fan; the example that was followed implemented batteries for both of these sources. Calling on experience as computer technician I knew that an Advanced Technology eXtended (ATX) power supply has multiple twelve volt sources in a convenient package that won't run flat: there were also at least a dozen readily available. After identifying the power on line (green) and connecting it to a switch, making the power supply ready for use was as simple as cutting and capping the excess three volt, five volt, and ground wires, and removing the computer specific plugs. The process for modifying the power supply is shown below in Figure 6.

Figure 6



Things required for this project included the aforementioned TL494 chip, MOSFET transistor (with heat sink), flyback transformer, twelve volt power supply, UF4007 (fast) diode, and 22k potentiometer. Also needed were various capacitors (200 uF, 47nF, 100nF, 10nf), a few resistors (2.2kohm, 10ohm), and a 10k potentiometer to control the intensity of the audio signal. This project required fair soldering skills, which when learned using an ancient and possibly malfunctioning soldering iron are somewhat lacking. There were no solder bridges though the joints were kinda ugly. The heat from the soldering does have a slight potential to burn out the MOSFET and could've been another failure point in this project.

The conclusion is that this project may have been a bit above of my skill level, especially working in such a tight timeframe. I will come back to this someday with more time and a better knowledge of all the components, both to claim victory over this build and to have the very interesting end product.

References

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