Department of Computer and Electrical Engineering

Tesla Coil Arc Generator
Final Project

Created for

EE 330 Electromagnetics

Summer Term Two and Three

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By

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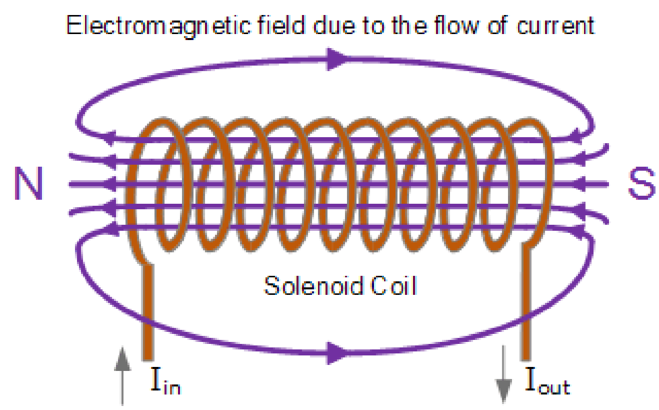
Abstract

Electromagnetics class has covered important topics concerning vector analysis, electrostatics and magnetostatics. The class has gone in detail about these topics and has given students the opportunity to learn and solve engineering problems within the scope of the class. One of the class requirements is to complete a final project. The final project required the students to design, construct, and demonstrate some type of arc generator driven by electrostatics, magnetostatics, and/or electromagnetics. The team composed of Daniel Senda and Mohamad Jundi chose to create a tesla coil arc generator for the final project. The tesla coil has the capability of generating electrical arcs through electromagnetics means. The diagram above helps depict the electromagnetic filed that the tesla coil creates. The project does not only fulfill the electrostatics, magnetostatics, and/or electromagnetics requirement, but also has helped the students solidify some key concepts in electromagnetics.

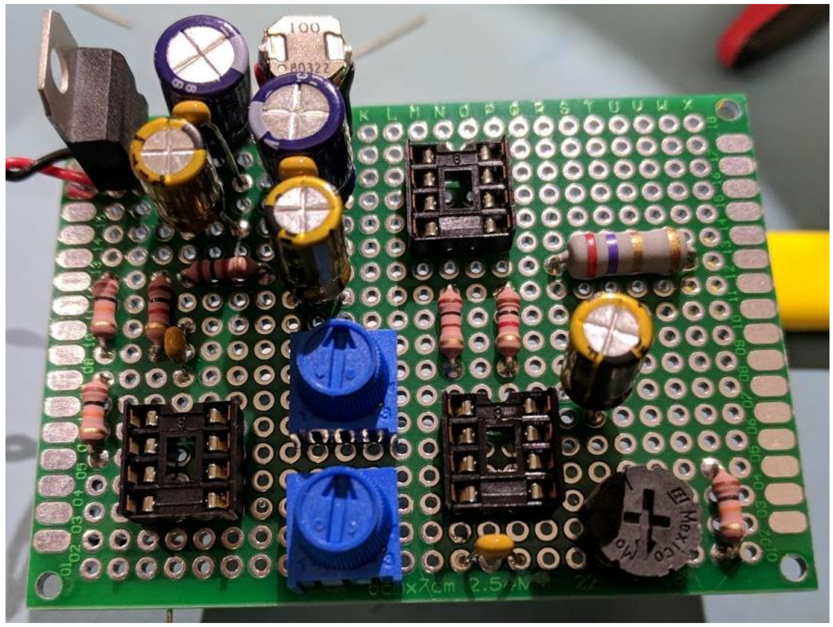


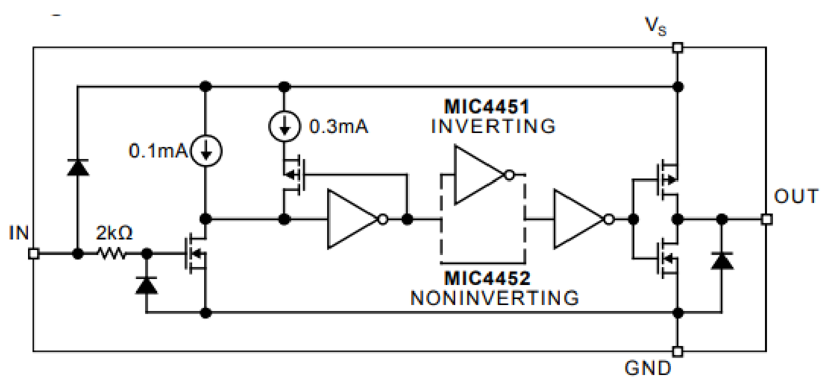
Theory

In electrical engineering, there are plenty of ways to generate power and transform power using different methods. Wireless power can be generated using countless means. For the tesla coil, the process used to generate power is called electromagnetic induction which is the creation of electromotive force on an electrical conductor due to a changing magnetic field. The electric potential created by the magnetic field causes current to flow through the electrical conductor. The tesla coil in other words can be seen as a variation of a transformer that is capable of generating high voltage. The tesla coil has two coils that are not physically connected but rather are wirelessly connected when the circuit is on. The circuit is made up of basic electrical components and also some integrated chips. When operating, the area around the tesla coil becomes filled with a magnetic field that can be disruptive to other electronics, but also provides wireless power.

The circuit consists of two coils, a primary coil of about 10 turns and a secondary coil of about more than 700 turns. The main process that drives the entire circuit is the ability of the circuit to oscillate the primary coil at the resonant frequency of the secondary coil. In the design of this circuit, there is a toroid on the top of the secondary coil which increases capacitance. This capacitance, along with the secondary coil inductance, will create a sharp resonance frequency. Once both coils start oscillating at the same frequency, it allows for the primary coil to transfer the maximum power to the secondary coil and radiate it to the air. There will be a large voltage value at the secondary coil that can create electrical arcs if other variables agree. The voltage value this occurrence happens at depends on the environment, so it is difficult to give an exact value. The correct operation of this process creates the wireless power that turns on fluorescent light bulbs, and similar bulbs, that are placed near the secondary coil. This sums up the operation of oscillating part of the circuit.

Most of the integrated chips and components of the circuit are powered by 5 volts. \The 5 volts are generated by a voltage regulator, which is powered by an external voltage source of 12 volts. The operational amplifier ICs, low power comparator, and most basic components are fed by the output of the voltage regulator. The MOSFT gate driver of the circuit is an exception; it is powered by the external 12-volt source. This is needed because the gate driver demands large spikes of current to drive the MOSFET gate capacitors. The part of the circuit utilizing the dual comparators (MCP6542) is connected to potentiometers. These potentiometers can tune the generated square wave anywhere between 500kHz to 1.5MHz. The tuned signal, in theory, should be at the resonant frequency of the secondary coil creating a successful solid-state tesla coil.





Calculations

The resonant frequency of the secondary coil was found using the oscilloscope. The resonant frequency was found to be around 1MHz. The inductance of the coil was found by hooking it up to an LRC meter, which was 3.22mH. From these known variables, the capacitance was found.

$$f = \frac{1}{2\pi} * \sqrt{\frac{1}{L * C}} \quad => \quad C = \frac{\left(\frac{1}{2 * \pi * f}\right)^2}{L} = \frac{\left(\frac{1}{2 * \pi * (1 * 10^6)}\right)^2}{3.22 * 10^{-3}} = 7.87pF$$

The following work demonstrates how to find the output voltage of the secondary coil. Another piece of information that is needed is the inductance of the primary coil which is around 3 μH.

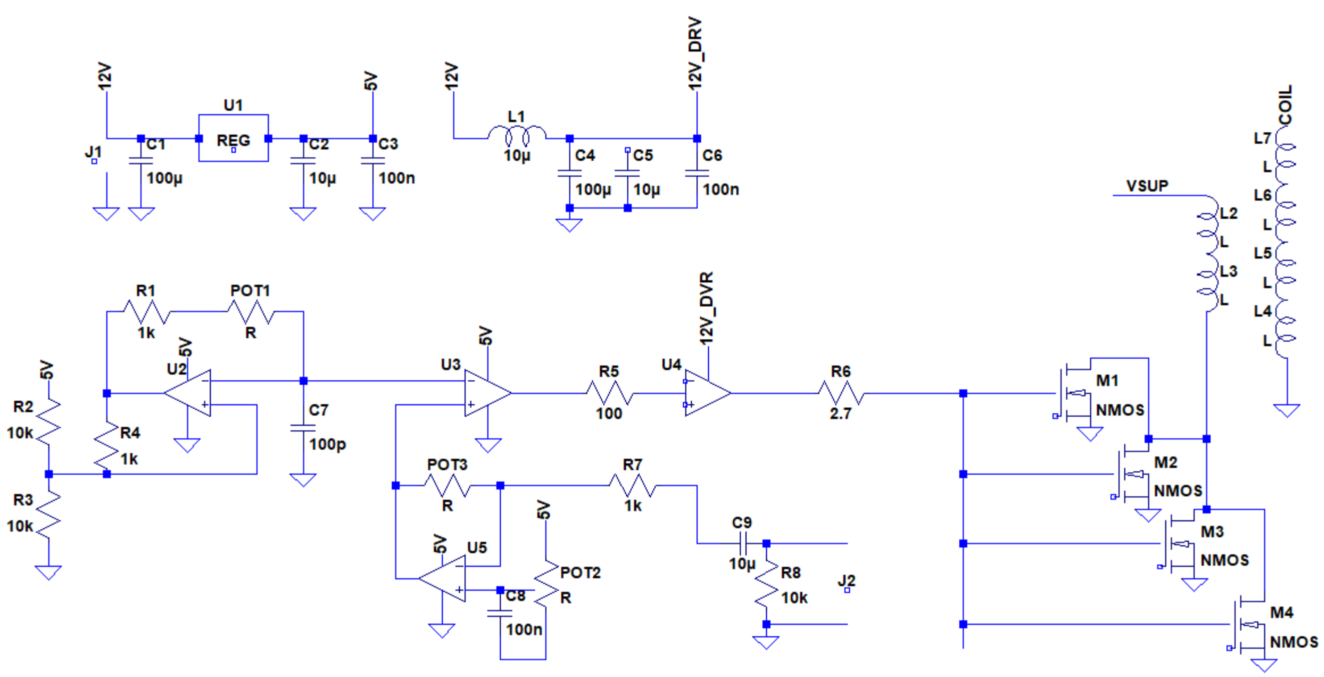
$$W_1 = \frac{1}{2} * C_1 * V_1^2 \quad => \quad W_2 = \frac{1}{2} * C_2 * V_2^2 \quad => \quad W_1 = W_2$$

$$V_2 = V_1 * \sqrt{\frac{C_1}{C_2}} = V_1 * \sqrt{\frac{L_2}{L_1}} \quad => \quad V_2 = V_1 * \sqrt{\frac{L_2}{L_1}} = 20 * \sqrt{\frac{3.22 * 10^{-6}}{3 * 10^{-3}}} = 655.2\ V$$

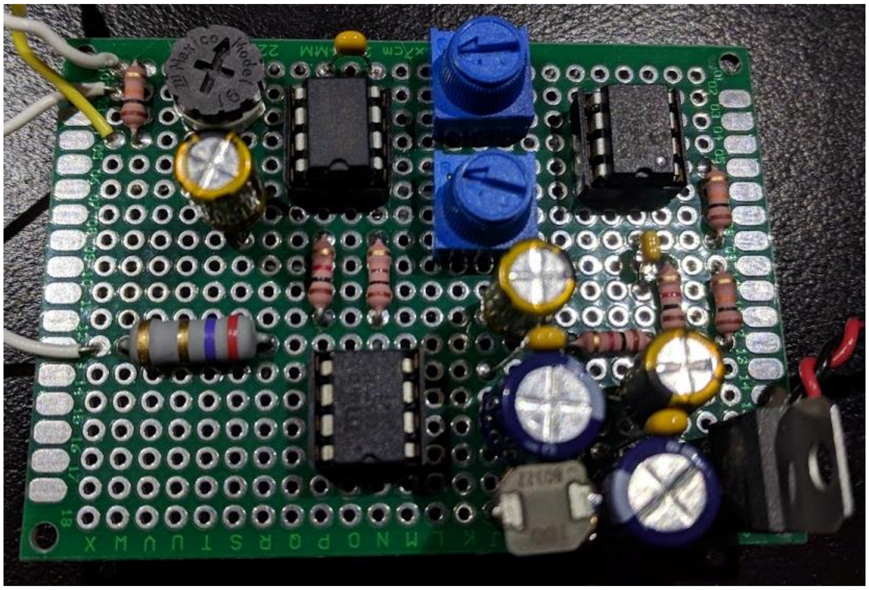
According to the calculations, the output voltage of the secondary coil should be around 655.2 volts.

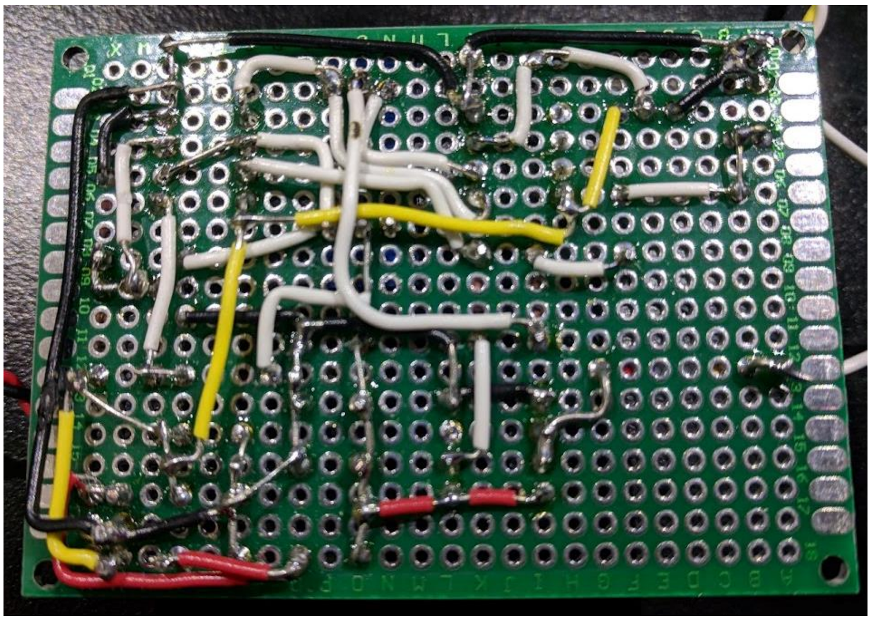
Design Structure

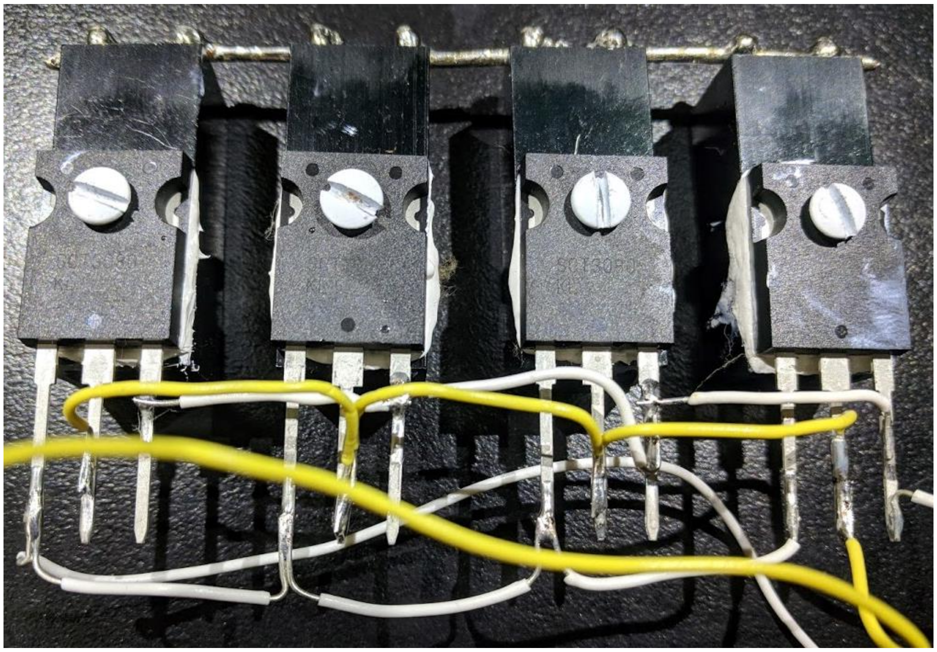
The following is the schematic diagram, created in LTSpice, of the circuit that was built.



The following are more pictures of the top of the prototype board and bottom on the prototype board where the circuit was assembled on. It was a time consuming task that took many hours to complete as attention to detail is vital for proper operation. Also included is a picture of the MOSFETS setup and wiring.







Conclusion

The Tesla coil is a very unique device that can turn a low voltage into a high voltage and is done through electromagnetic means. It is also a very fun circuit to watch as the electrical arcs leave the secondary coil into the area surrounding it when the appropriate voltage levels are reached. The project took many man hours and was frustrating at times, but at the end of the day was completed successfully. We learned a lot from this project and will carry these experiences with us into our engineering careers.