

High Current Pulse Generator

Design Document

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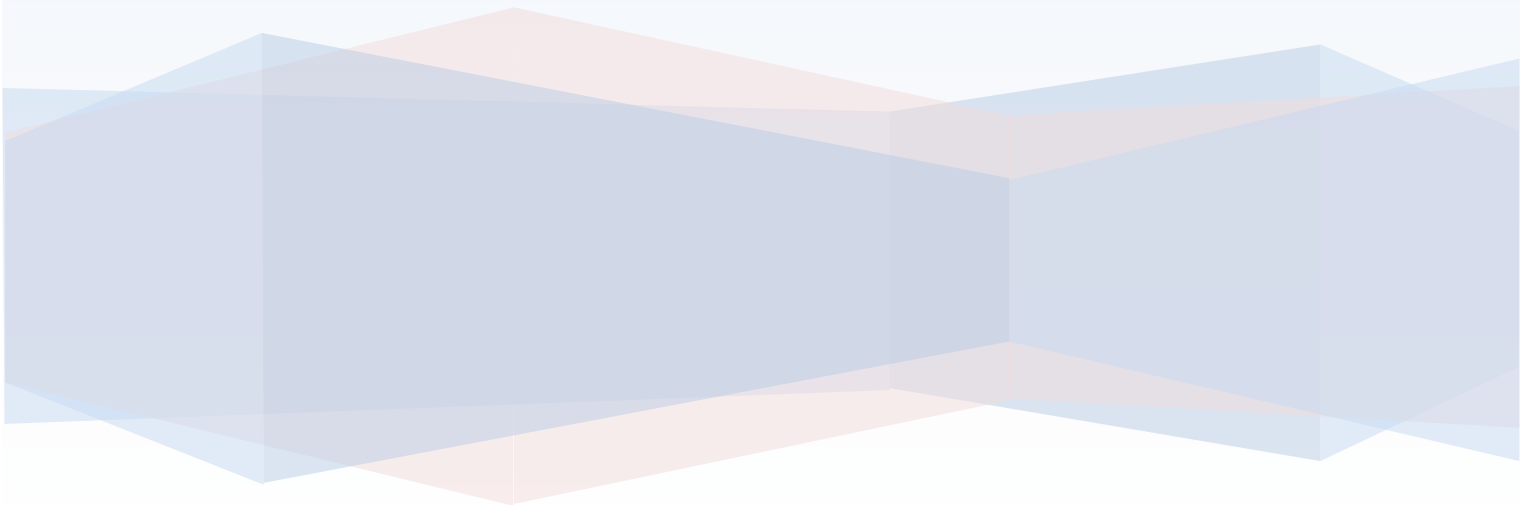


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Summary of Device

Our goal of this project is to create a high current pulse generator for the application of Transcranial magnetic stimulation (TMS). Currently, extensive researched is being done in the area of TMS for many conditions that affect the brain. For instance, TMS is being used to treat depression, migraine headaches, as well as back and neck pains. Future research is exploring the possible uses in other applications like Alzheimer's disease, posttraumatic stress disorder, Parkinson's disease, etc. Researchers are looking for a device that can produce the current needed to power the TMS coil and support deep brain stimulation.

The magnetic fields used in TMS applications are pulsed at very short time intervals. A high current pulse is sent through an electromagnetic coil to create these fields. The goal of this Senior Design team is to create a device that can deliver such a pulse. This device will have controllable parameters (such as pulse width and amplitude) and will be able to manage our inductive load. This document will cover the overall design of our amplifier circuit. We have decomposed the circuit design into its basic parts; the power supply, power storage, switching device, and switching device control. For each of these parts we have laid out our design choices and considerations.

System Requirements

Functional requirements for the system shall:

- Control of pulse width and amplitude
- Create both monophasic and biphasic pulse waveforms
- Produce 50 to 400 microsecond pulse time
- Output of 1000 Amps
- Provide control through computer or mechanical switching

Nonfunctional requirements for the system shall:

- Cost under \$500 dollars
- Have a graphical user interface in MATLAB
- Safe and Easy to use

System Analysis

Our team plans to take the wall outlet voltage and current and convert it with a transformer. We will basically draw a maximum amperage from the wall and use a voltage doubler to increase the voltage. The reason for amplifying the voltage is that it will increase the amount of charge that can be stored in our capacitors. After the

voltage is amplified, it is then stored inside of a capacitor bank to then be quickly discharged to create our required current for our circuit. To control the discharging of the capacitors we will be using a high current IGBT. In order to allow safe switching from a microcontroller a MOSFET driver and Arduino chip will provide control of the pulse width and amplitude that we need to generate at any given time. To finish off the circuit, we will have an inductive load that will act as the TMS coil to absorb all the current generated and produce the desired magnetic field.

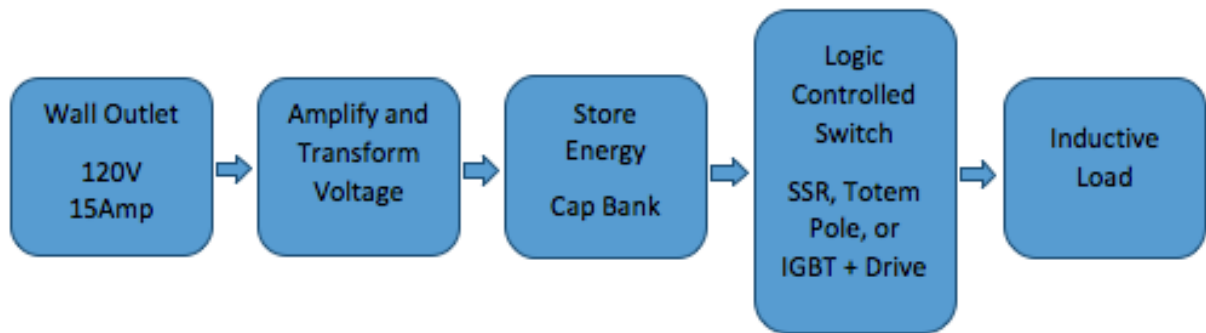


Figure 1: Block Diagram of TMS Amplifier

Power Conversion and Voltage Storage

The device is powered from a standard 120 V_{rms} wall outlet. To store the power necessary we need to convert the AC input voltage to a DC voltage. In the device we have used a transformer to increase the AC voltage followed by a voltage doubler to increase farther and rectify the input. We will keep the voltage high because when voltage is stored into our capacitors, more charge is present due to the relation $Q=CV$, where Q is charge, C is capacitance, and V is voltage. When we discharge the capacitors with our switch a rapid change in Q will result, thus high current is generated.

Switching Device

In our design our switching device must be able to handle the full 1000A current flowing through the load. The device will be an insulated-gate bipolar transistor (IGBT), a type of BJT that can handle very large currents. This device has been proven to provide the specifications that we need in order to control such a high magnitude and short period pulse. We will be using a secondary MOSFET driver in order to control this device. The reason for this is that the MOSFET driver can handle high current leakage current or current spikes that may occur from the

inductive load. In addition, a MOSFET driver allows for easy control with a microprocessor and will be able to protect it from the high IGBT currents.

User Control

The microprocessor we choose for this project is the Arduino Uno. We favored this device because it is very easy to use and will provide all the control we need for this device. Using this microprocessor we can connect to a graphical user interface (GUI) using MATLAB. This provides explicit control of the pulse waveform. The user will be able to choose monophasic or biphasic wave types. They can also set the amplitude, pulse width, period, and number of pulses. This GUI will create a user friendly environment that will allow anyone to effectively control the output of this device.

Simulation and Testing

The procedure for testing and simulation is as follows:

- Create Circuit in Multisim
- Create small scale circuit and measure error
- Build large scale circuit and troubleshoot

Multisim allows us to create any circuit design and thoroughly test it. We will measure all voltage and current input and outputs. When the desired output is achieved, we will create small scale circuits using breadboards to verify that the simulation results hold true. If this is not the case, we will make the necessary changes either in multisim or on the small scale level before moving on to a full scale design.

Prototype Testing

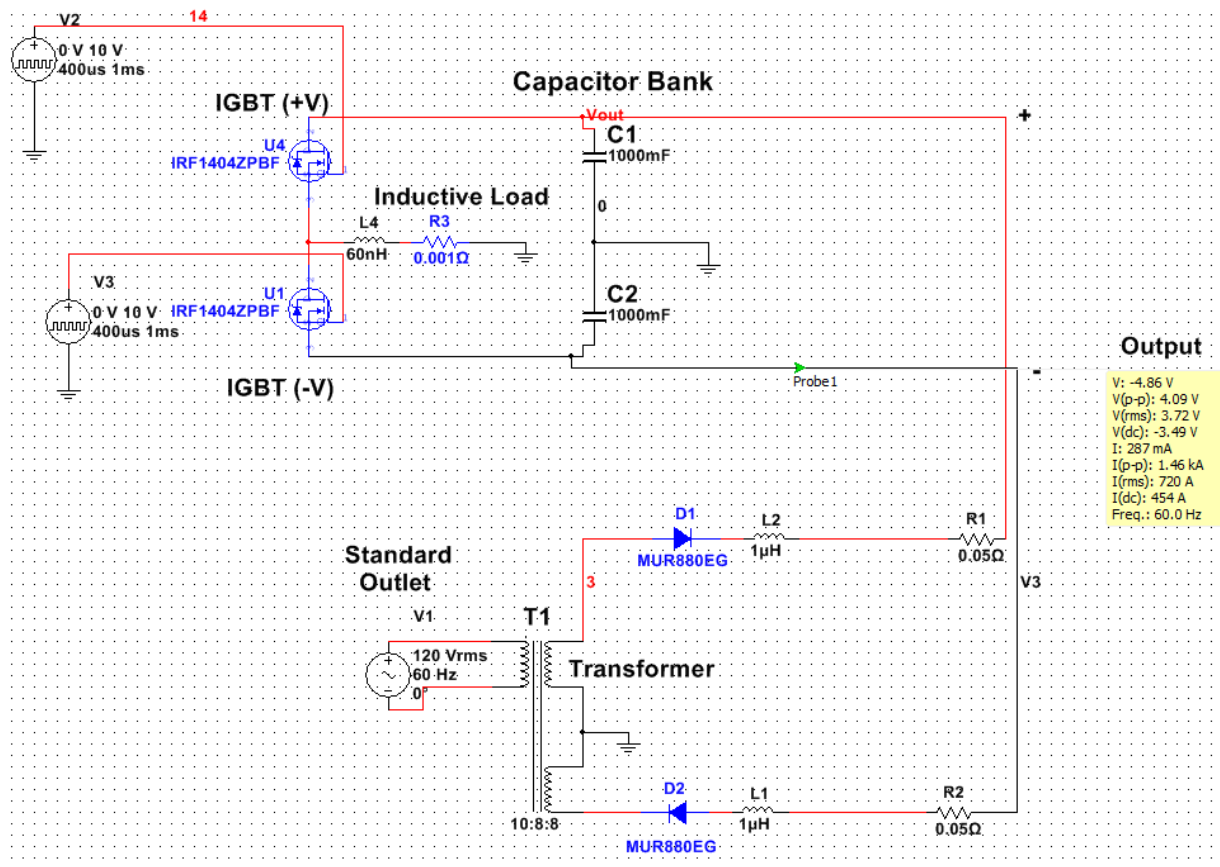


Figure 2: Prototype Circuit Schematic

This prototype schematic shows the proof of concept for our design. This circuit was made in Multisim. It can be seen that the output is pushing the desired 1000A range.

Our prototype circuit starts out in the standard outlet which then goes into our transformer. The transformer ramps down the voltage from the wall to 96 Vrms. The voltage then goes through diodes to half wave rectify the input signal. From the diodes the voltage then travels into our resistor that then takes the voltage and begins charging in our capacitor bank. The capacitor bank can be discharged by using the IGBT switches to determine when the discharging occurs. The IGBT switches receive their input pulses from the mosfet drivers and the Arduino. These two control the pulse width and amplitude for the specified range that was shown in Figure 2. When the pulse are sent and the capacitor is discharged, the resulting current then travels into our inductive load and theoretically creates a magnetic field for TMS. .

The switching circuit was simulated using an arduino chip and MATLAB. Figure 3

shows the MATLAB interface created for an LED controller. This shows that we can interface our microchip to a computer and control it through a GUI. This allowed us to successfully pulse an LED, turn it on and off, and read data from the digital pins of the Arduino.

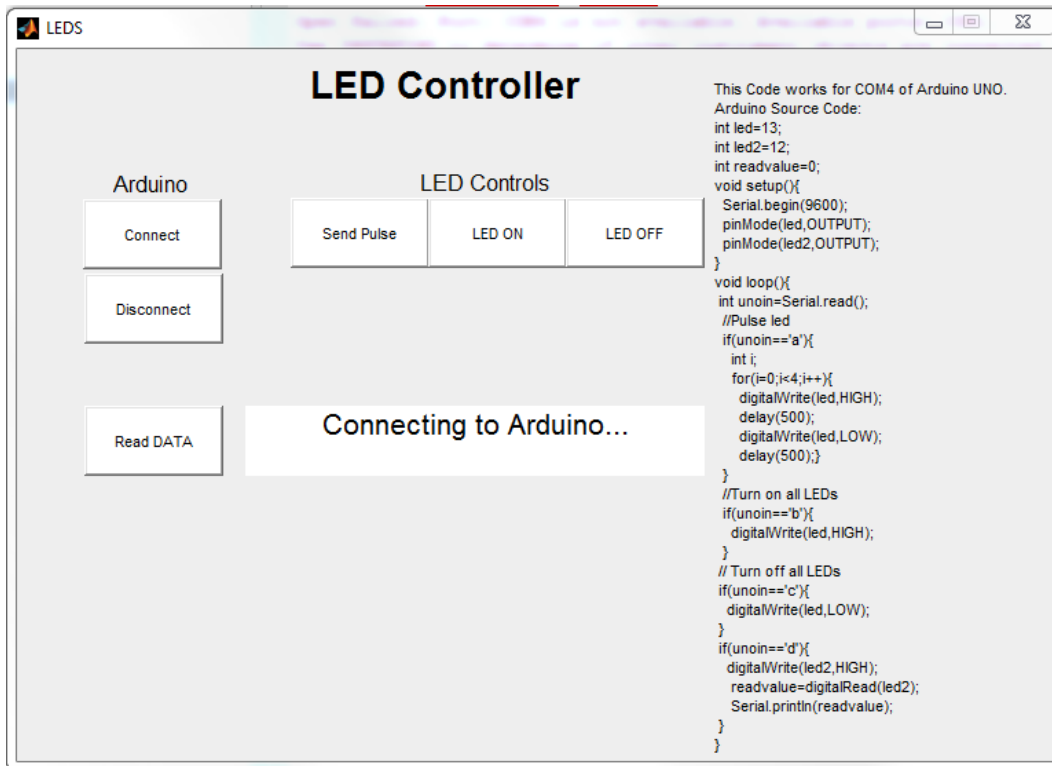


Figure 3: Arduino-MATLAB Interface

Design Review

Overall the design concepts for this device are complete and tested. The design for the actual circuit is still needed. The prototype is lacking the voltage doubler, optimized components, and safety features. Once these are implemented and tested in Multisim we will simulate them small scale to verify functionality. Lastly we will build and troubleshoot the circuit to satisfy all the specifications laid out in this document. We will also create the actual Matlab GUI to perform per the user control requirements.