TMS: Transcranial Magnetic Simulation

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Project Plan V2

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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 process 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.

Goal:

Our goal for this project is to create a high current amplifier that will support deep brain stimulation for TMS. We will improve on a previous semesters design while keeping the budget set at around $500. This means that our device needs to have higher current output, roughly 1000 Amps, and accurate control of the pulse while having the parts needed for a cost effective system. To reach these goals, thorough understanding of high current amplifiers and how to control pulse parameters is needed.

Operating Environment:

Our team will be working with our advisor Robert Bouda and the bioengineering team to create this high pulse generator. The bioengineering team is responsible for creating the inductive load that will be given to us to use in the final design. The environment that we will be working in will be the TLA to use the computers to design the circuit using multisim and to conduct research for anything that might leave us with questions. Other environments may include the high-speed engineering lab in Durham to create our PCB board and out adviser's lab in order to fabricate the device. One other lab we might utilize is the senior design lab which has the necessary tools for creating the circuit as well.

System Requirements/Specifications:

Functional requirements for the system shall:

- Control pulse width and amplitude
- Create both mono-phasic and bi-phasic pulse waveforms
- Produce 50 to 400 micro-second pulse width
- Output 1000 Amps
- Provide control through computer or mechanical switching

Nonfunctional requirements for the system shall:

- Cost under $500 dollars.
- Have a graphical user interface (GUI) utilizing MATLAB.
- Safe and easy to use.

System Description:

Since the TMS coil will need a current pulse to generate the magnetic field, our goal is to create a mono-phasic and bi-phasic pulse for a TMS device. Both mono-phasic and bi-phasic systems will consist of three main sections: power supply, energy storage, switching mechanism. A button will be used to trigger the pulse, sending out the pulse through the load. For the power supply we intend to take a standard wall outlet and split the voltage using the transformer. When then use a voltage doubler and rectify it into positive and negative DC voltages of +/- 200V. That voltage is then filtered using our inductor so we get an even DC voltage as an output. The filtered voltage is then stored into our capacitor bank for both positive and negative sides of the circuit to create mono/bi-phasic waves. The banks will produce approximately 1000 Amps when they are discharged into the inductor via IGBT control. The IGBT's allow us to control this high current to produce either mono-phasic or bi-phasic. Our Arduino unit utilizes an IGBT driver for protection and is able to manage how long the IGBTs are conducting.

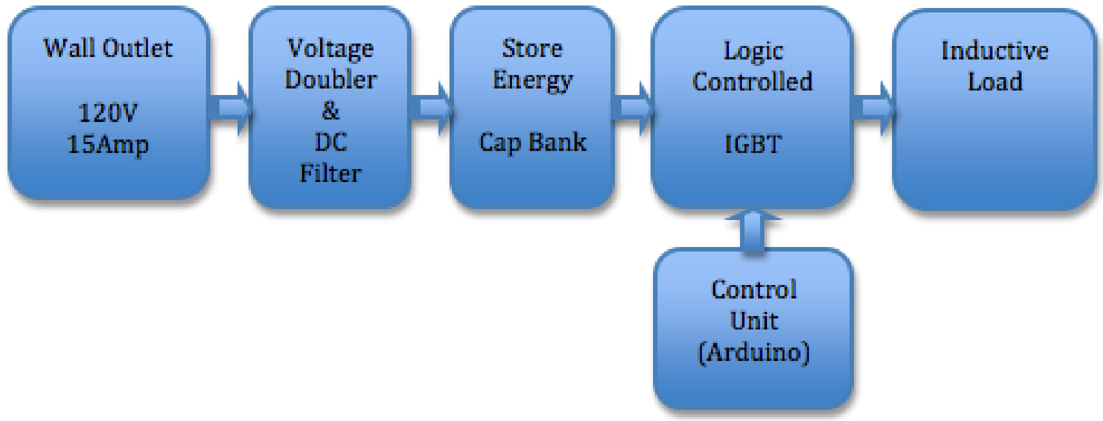

Figure 1: TMS Amplifier Block Diagram

From our block diagram you can see that our key components that will be a major part of this circuit will be our transformer that will help us power the device and help shield the wall from the current surges. In order to limit the current drawn from the wall outlet we are using a current limiter built with the transformer. Our voltage doubler is our second major build that will include the use of diodes to rectify the circuit into DC voltage, and capacitors and inductors to help filter and amplify the signal. Our capacitor bank is most likely our most important part of this circuit since it will allow us to produce the 1000 Amps of current that we need to complete the specifications of the device. The two final important components that will be needed to complete the circuit will be our IGBTs that will control the mono/bi-phasic properties; these IGBTs will be connected to our Arduino so the Arduino will be in control of the IGBTs. The final component will be our inductive load of 60 micro-henrys with a resistance of 50 mili-ohms.

User Interface:

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 mono-phasic or bi-phasic 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. Other than the GUI we will provide switches connected to the outside of the casing and will label what each switch can do. Some of the switches we will have will be a power switch to turn on the circuit, discharge switches for the capacitors that will be one the GUI and will also be hardwired just in case of GUI failure.

Since the GUI will be written in MATLAB, the code will be written using a procedural program design. This means that the code will represent data in variables and use them as arguments. The code will call a sequence of functions in order to implement code. This way out Senior Design Team can delegate tasks into individual functions. Each function will mainly control a feature that the GUI will handle. This process is favored in MATLAB code and will allow for easy addition of functions and code manipulation in the future.

Possible Complications and Risks

While researching for this design we came across some complications and risks that can be associated with this design. One major risk is the amount of current that needs to be generated from the capacitors is dangerously high and therefore safety measures have to be implemented into the design. A major complication is the fact that high current amplifiers on the market are usually over $1000. Having the ability to create such a high-powered amplifier with the $500 dollar budget could be an issue. The components in this design could be a complication as well since we are dealing with such high current. High current implies a lot of heat, and heat implies damage over time. Having the ability to create a robust circuit that will be able to operate under these conditions will be a challenging task. In addition, given the scope of this project, the time constraint could prove to be difficult to meet. This is attributed to the fact that group members are all taking other classes with other projects which in effect limits our time to work together. Having nearly a year to create a fully functioning design that will meet all the required specifications will be a challenging task.

Solution Statement:

The problem with the high current from the capacitor can be solved by having a discharge switch that will connect the capacitor to a high rated resistor that can drain out the potential charge inside the capacitor. A way to fix the cost of the circuit is to research and find components that can be within our budget given to us and can be implemented easily in the circuit. The major component that will break the budget will be the IGBTs since they need to be highly rated due to the amount of strain that will be put onto them. The time constraint issue will be our biggest complication to this project due to having to deal with other classes that will assign homework, tests, projects, etc. Due to having other classes while working on this design project will limit everybody on this project. Since this limits all the team members sometimes when we meet as a group not all of us will be there due to studying for tests or dealing with other projects since their due date will be sooner than this projects.

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
- Order parts for fabrication and create circuit and test for any problems

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. We have only worked on the multisim version of the circuit since we have not yet received our components to start the fabrication process. Our group plans to test the circuit once we fabricate the components together on PCB boards and get everything connected. Once it is all connected our major testing phase will begin and we will start to optimize our circuit to better fulfill our project specifications. To do this we will be using high current probes, DMMs, and oscilloscopes to measure and record data. The data will be documented and analyzed in order to keep track of circuit modifications and performance.

Deliverables:

The final product created by this senior design team will include a fully working mono/bi-phasic device. Our Arduino GUI will control the parameters of the pulse. A standard wall outlet that is 120 Vrms and 15 amps will power the device. This device will produce 1000 Amps of current that was needed to improve on last years design.

Project Schedule:

Below is an approximate timeline with a more brief one attached to the bottom along with a Gantt chart.

Part 1 January through February 2014:

January:

- Pick project and meet group, advisor, and client.
- Become familiar with group and set up times for future meetings.
- Brainstorm and research about TMS.

February:

- Start up web design for the HQ of our project.
- Research totem pole drivers, high current amplifiers, transformers, large capacitors, inductors, and power supplies.
- Refamiliarize with Multisim.
- Start working on Matlab to Arduino GUI.

Part 2 March 2014:

March:

- Start implementing ideas into a final design on Multisim with mono/bi-phasic properties.
- Finalize Matlab GUI that will control the pulses and mono/bi-phasic properties.
- Run tests and simulations of the circuit to make sure it meets the specifications listed.

Part 3 Late March to mid April 2014:

April:

- Identify any problems or errors and fix design.
- Redesign.
- Find optimal parts that will be needed for the circuit and create a bill of material that will be under budget.
- Using the parts found create an Ultiboard of the circuit with the dimensions from the parts listed.
- Order parts and Ultiboard system/PCB board that will implement components.
- Find the dimensions of the circuit and create casing

Part 4 Mid April to end of spring semester 2014:

May:

- Receive components and construct a prototype circuit within the casing and begin a testing phase with built circuit.
- Fix any problems with prototype.

- Start implementing our Arduino and other possible components needed after redesign process is finished.
- Prepare Reports and presentations for dead week.

Part 5 Beginning of term to mid September 2014:

August:

- Our group will need to reacquaint ourselves with our circuit to be able to continue with project.
- After our group reacquaints itself with the project being another testing phase to make sure the circuit can still work.
- Redesign if necessary.

September:

- Gather feedback from client on possible adjustments.
- Continue testing the circuit and replace any burnt out components with more optimal components.

Part 6 Mid September to Mid November 2014:

October:

- Continue with the fabrication of the circuit and finish the casing with implementing push buttons and a fan to make sure the circuit does not overheat.
- Continue testing the physical circuit and replace any burnt out components.

Part 7 Mid November to Final presentation 2014:

November:

- Work out any remaining problems with design.
- Add any new devices needed for design.
- Upgrade design.

December:

- Finish fabricating design to client specifications.
- Prepare final documents and Presentations.
- Present our design.

Task Name	Start Date	End Date	Duration
Spring Semester	**01/14/14**	**05/09/14**	**84**
Part 1	**01/14/14**	**02/28/14**	**34**
Decide project, meet team, familiarize with TMS	01/14/14	01/24/14	9
Start setting up website	01/24/14	02/03/14	7
Familiarize with Mutltisim and research	02/04/14	02/28/14	19
Part 2	**02/28/14**	**03/20/14**	**15**
Begin MATLAB Gui	02/28/14	03/07/14	6
Create final design	02/28/14	03/20/14	15
Part 3	**03/21/14**	**04/17/14**	**20**
Identify problems and redesign	03/21/14	03/27/14	5
Create bill of materials	03/27/14	04/03/14	6
PCB board	04/03/14	04/17/14	11
Part 4	**04/18/14**	**05/09/14**	**16**
Construct prototype circuit and test	04/18/14	05/09/14	16
Fully integrate Arduino	04/18/14	04/23/14	4
Final Presentation	04/28/14	05/09/14	10
Summer Vacation	**05/09/14**	**08/25/14**	**77**
Vacation	05/09/14	08/25/14	77
Fall Semester	**08/25/14**	**12/16/14**	**82**
Part 5	**08/25/14**	**09/15/14**	**16**
Reacquaint with project	08/25/14	09/01/14	6
Testing Phase	09/01/14	09/15/14	11
Part 6	**09/15/14**	**11/20/14**	**49**
Continue fabrication and casing improvement	09/15/14	11/20/14	49
Test circuit and replace any burnt components	09/15/14	11/20/14	49
Part 7	**11/20/14**	**12/16/14**	**19**
Workout any bugs	11/20/14	11/27/14	6
Finish design fabrication	11/20/14	12/12/14	17
Prepare final documentation and presentation	12/01/14	12/16/14	12

Table 1: Design Process Plan

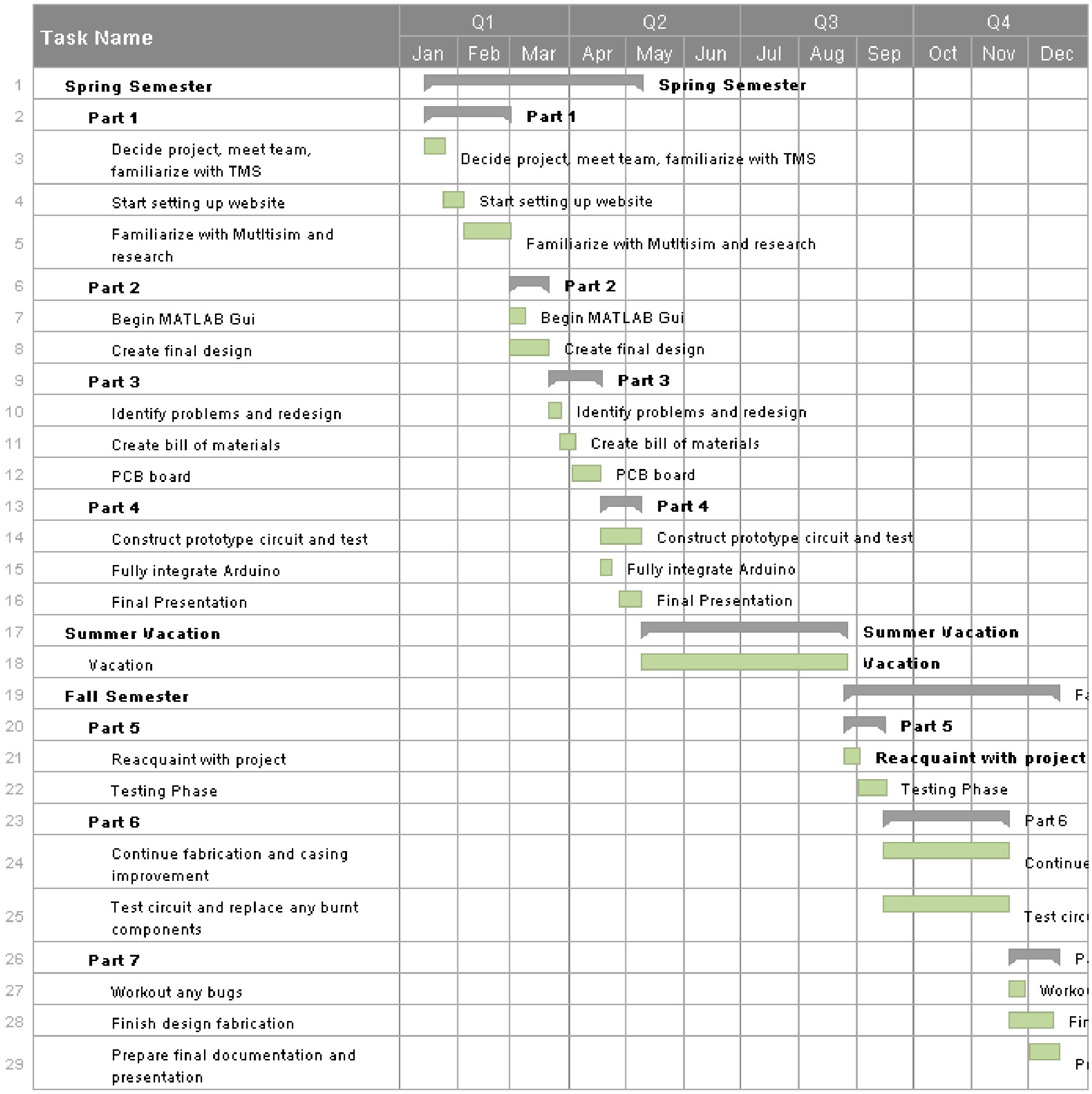

Figure 2: Design Schedule

Appendix:

To accomplish the goals of this project we had to use resources from our advisor and to other resources that we found ourselves. A comprehensive list is shown below:

Resources from Iowa State University:

- Iowa State University will provide a budget for the design, testing, and implementation of the design.
- Will fulfill all purchase orders.
- Will provide any tools needed for fabrication.

Resources from the group:
As a group we had to do a lot of research into this circuit that we put links onto our google drive as a group. We also researched more into inductors and capactiors using past books and got some help from our advisor. Some of the links are below:

http://www.ph.utexas.edu/~espg/paper/118.pdf

http://www.bigel-labs.de/3.Physik/CB-Discharges/Discharge behavior of capacitor banks.htm