HIGH SPEED MAGNETIC FIELD GENERATOR

Project Plan

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INTRODUCTION

PROBLEM STATEMENT

Magnetic field pulse generators have been used for various applications across many different electrical engineering disciplines. Technical requirements of generator systems vary based on the specific application. One of these applications is magneto-optical (MO) switching within fiber optic networks. These networks currently use optical switches and routers to direct signals to desired paths defined by electrical energy. During this process, the conversion from optical energy to electrical energy causes problems. Due to the different bandwidths between optical systems and electrical systems, the signal is not directed to its desired path as quick as needed. However, by utilizing the magneto-optic effect (Faraday effect), the router switching can be achieved without optical-electrical conversion and, consequently, without the high switching latency. One way of inducing the MO effect on the switching system is by applying a strong and quick magnetic field pulse. Past circuit designs have shown that it is possible to create pulse generators with relatively high power and speed. However, there is room for improvement in pulse strength, rise time, and power efficiency.

PURPOSE OF PROJECT

The purpose of our project is to design and implement a circuit that generates a quicker, stronger pulse while also improving power efficiency. This would provide a more practical way to use magnetic pulse generators in optical switching and higher-scale applications such as transcranial magnetic stimulation (TMS).

PROJECT GOALS

The goals of this project are fourfold:

1. Gain a deep, applicable, and robust understanding of magnetic pulse generator concepts and circuit theory that will help us in our future careers and education.
2. Build a circuit that can generate a 500 Gauss magnetic field pulse with a rise time of at most, 0.15 microseconds.
3. Design and build a low-power version of the pulse generator
4. Identify a more effective method of directly measuring the current through the circuit coil

DELIVERABLES

The deliverables for our project will be divided between first semester (EE491) and second semester (EE492). Completing these according to our semester timeline will keep us on track to achieve our goals by the end of the year (Spring 2017).

FALL 2016 – EE491

Our final review presentation will cover learning circuit theory and fundamentals, developing PCB fabrication skills, and new circuit modifications/improvements. We will also have two functional circuit boards with us at the final review:

1. A board identical to Dec1622 group circuit
2. A board with testing points for different current sense resistors

SPRING 2017 – EE492

In April, we will give a presentation on our progress throughout the Spring semester. This will primarily consist of how we built upon the foundation that was established in EE491. We plan on outlining the implementation of our circuit modifications and presenting our solutions to specific problems such as power consumption and measurement techniques. We hope to demo our low-power solution and show how our circuit modifications make test and measurement more accurate and consistent.

DESIGN

PAST WORKS

Over the past few years, multiple senior design groups have worked on this project. This man-power has lead to greater optimization and tailoring of specifications with a trajectory towards real-world implementation. In order to achieve the goals of our project, we needed to gain a thorough understanding of the concepts behind the application of magneto-optic switching. This research included articles, journals, online tutorials, and personal teaching from advisers. Once we had a robust understanding of the application and problem, we began looking into past solutions. Throughout the semester, our team has been working closely with the Dec1622 group in order to learn the fundamentals of their pulse generator circuit, summarized in *figure 1* below. They provided us with key resources such as design documents, project plans, circuit schematics, coil parameters, and personal advice along the way.

SYSTEM BLOCK DIAGRAM

Figure 1: System Block Diagram

PROJECT REQUIREMENTS

FUNCTIONAL

Since our project has multiple different goals, we are setting specific requirements for each goal. First and foremost, our final prototype of last year's circuit must produce a stable and predictable magnetic field pulse peaking at 500 Gauss with a rise time less than 0.15 microseconds (identical to Dec1622). In regards to our low power design, the circuit must use less than 50 Amperes of current through the inductor to achieve the same 500 Gauss magnitude. This may cause the pulse to have slightly longer latency. We will set a benchmark for the acceptable latency as we get further into testing. Lastly, our new current-sensing method needs to provide a better way of directly measuring the current through the inductor rather than through the MOSFET (current method). Meeting each of these requirements for project will help us achieve our defined goals and will give us a great foundation to build on for EE492.

NON-FUNCTIONAL

In order to complete every one of our goals, we must decide on what software we are going to use for circuit modeling and simulating, as well as layout design and PCB fabrication. Landing on a common software platform will enable us to work more efficiently throughout the different stages of our project. As a group, we have more experience using National Instruments Multisim software for circuit modeling and simulation. In terms of layout design and fabrication, our team has the most experience with NI Ultiboard. This is ideal because Multisim and Ultiboard work seamlessly together. Our use of a common software platform will prove to help a lot when we get to rapid PCB fabrication next semester. Another non-functional requirement of our project is the overall knowledge and skill we acquire during the course of the semester. By final review time, it is crucial that we have a clear and deep understanding of what our circuit is doing, how it is doing it, and all the fundamental concepts behind it. As a team, we will need to explain our reasoning behind pursuing the solutions that we chose (low-power design and change in current-sensing method). To do this, a surface-level understanding will not suffice.

CHALLENGES

The majority of our challenges have come from the non-functional areas of our project. Right from the start, it was clear that understanding the deep concepts of the past works and research was going to be difficult. It took our team much longer than expected to get past this section of the project and onto the technical design. Because of this, we have had to divide and conquer the technical portions rather than complete them as a coherent team. This has led to a lesser extent of understanding than we would have liked to have by this point. However, we believe that specialization in our own areas of the project has presented its own strengths. Another challenge we found when beginning the simulation and design of our circuit was difficulty with importing desired MOSFETs into NI Multisim 14. We found that in Multisim there is not a direct way to import SPICE files (.lib or .olb formats) like there is in OrCAD PSPICE. We eventually found the roundabout way to import our FET part and have documented that process in our

design document. Lastly, we experienced some trouble and confusion in establishing our project goals and expectations in the beginning stages of our project. Overall, we should have addressed our challenges in a timelier manner, but we believe we have done well to adapt and move on to improve for the future of our project.

WORK PLAN

PROJECT TIMELINE

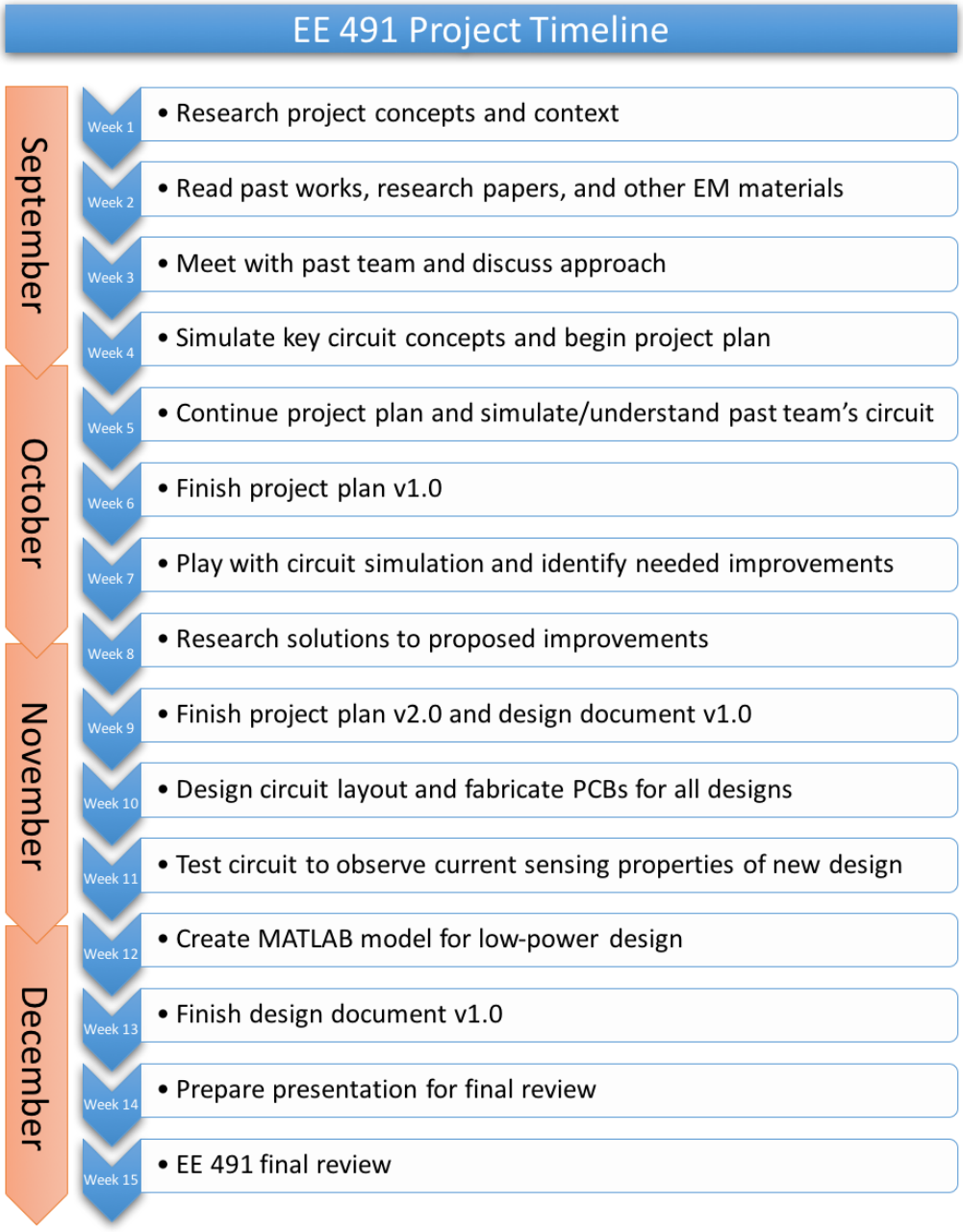

Figure 2: EE 491 Project Timeline

TEAM BREAKDOWN

In order to complete our goals on time, we needed to divide the project workload between our four group members. Below is a breakdown of our work distribution:

Jack Lamar – Jack was responsible for the general direction of the group. He made large contributions to the majority of the documentation and focused on the technical work behind the low-power solution alongside help from Jayaprakash. Jack also scheduled, organized, and led team meetings and created the final review presentation.

Qibai Zheng – Qibai was responsible for the majority of our projects board fabrication process. This included layout design, machine training and operation, and part selection. Qibai also helped Pengchao with board testing and measurement.

Ran Ma – Ran was responsible for the design and construction of our team website. With little experience to begin with, he had to learn web design on the go. Ran also made contributions to testing and measurement as well as PCB fabrication.

Pengchao Lian – Pengchao was responsible for the majority of the test and measurement of the circuit. This was done using the Dec1622 board in order to get familiar with the testing methods and to observe the differences between ideal simulations and real-world measurements. Pengchao also helped with circuit modification and fabrication.

REQUIRED RESOURCES

- ***Software***
  1. NI Multisim 14
  2. NI Ultiboard
  3. MATLAB
  4. Microsoft Office Suite
- ***Hardware***
  1. Oscilloscope
  2. DC power source (15 V)
  3. Soldering iron
  4. Circuit board drill (ECpE)
  5. ECpE parts shop

CONCLUSION

After a semester of work, we feel confident that we have a solid foundation of project improvements to build on for EE492. We faced a variety of challenges this semester, many of which were self-induced. However, a large part of this project has been learning how to overcome difficulties as a team. That is experience that will prove useful in our future career and education endeavors. Moving on from here, we will continue to work closely with our advisers to not only complete our project on time, but also gain real-world knowledge and skill through problem solving and critical thinking. We have already learned about our project material through this semester's experience. More importantly, however, we have learned about ourselves as individuals and teammates. We are eager to move into a new semester with our established background of teamwork and accomplishments.

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