Building Blocks and Sub-Circuits with Magnetic Field Generators

Team sdmay23-29
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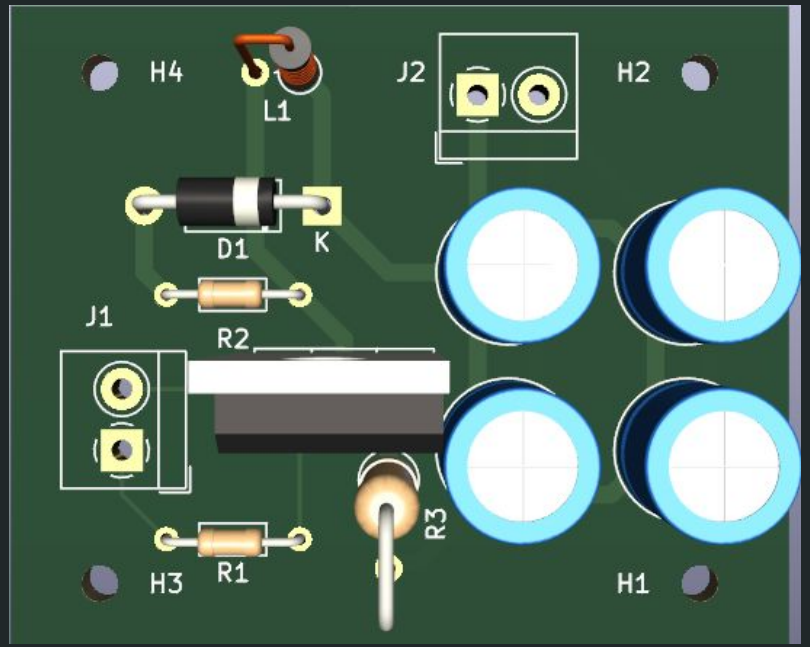
Client: Wei Shen Theh
Advisors: Mani Mina, Robert Bouda
Date: 5/3/23



3D Model of PCB

Project Introduction

Context

Our project consists of designing a magnetic field generator (MFG) with a focus on optical design/simulation.

Problem Statement

Our goal is to enhance the MFG circuits of past senior design projects and create our own optical simulation with various softwares.

Implementation

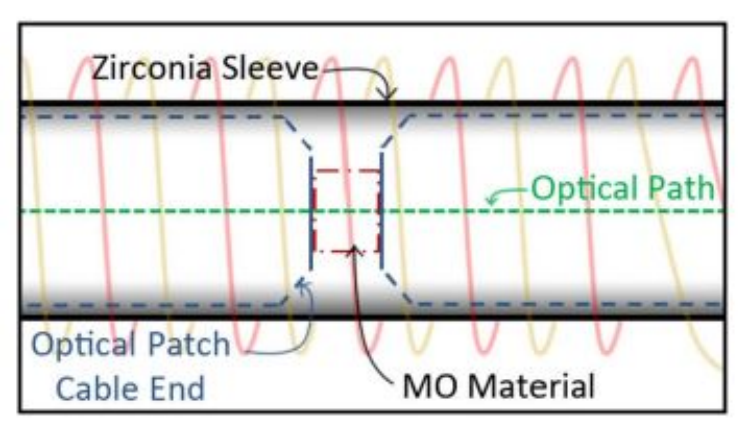
Circuit Design Tools

- MultiSim (Circuit Simulation)
- KiCad (PCB Design)

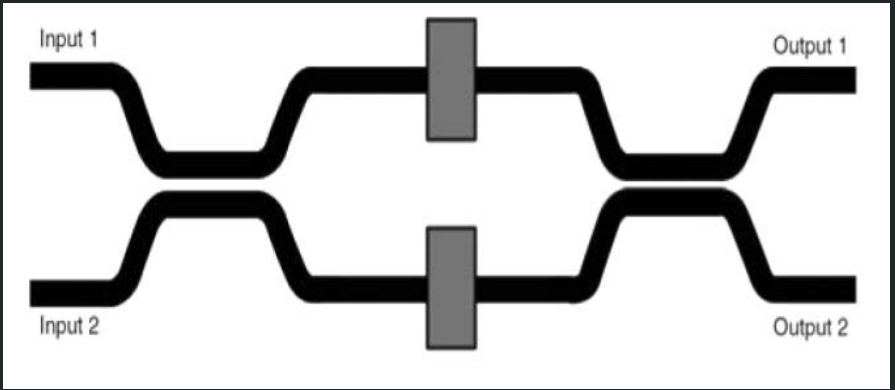
Optical Simulation Tools

- MATLAB
- COMSOL
- CST

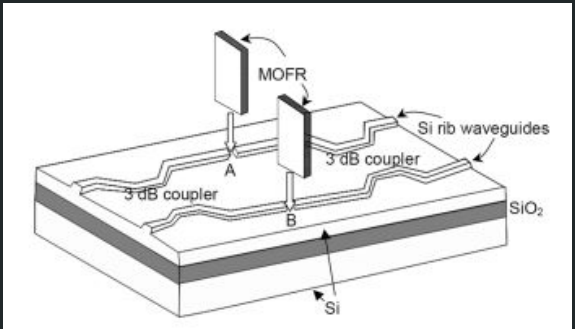
Optical Simulation



[1] MO material between two optical patch cable ends, fitted within the mating sleeve.



[2] Structure of Magneto-Optic (MO) Switch based on Mach-Zehnder interferometer Configuration.

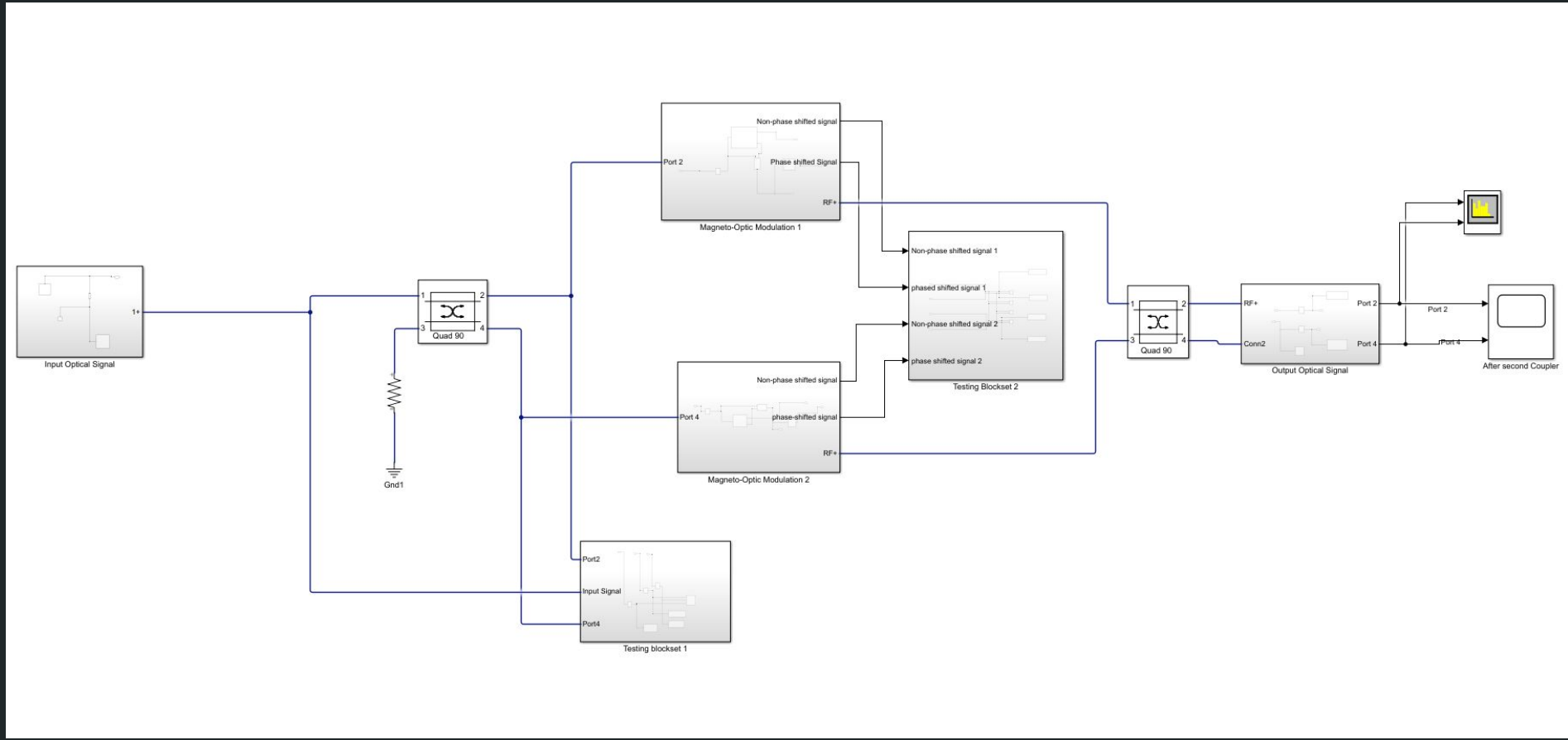


[2] Purposed Silicon-On-Insulator integrated Magneto-Optic Switch

[1] J. W. Pritchard, M. Mina and R. J. Weber, "Improved Switching for Magneto-Optic Fiber-Based Technologies," in *IEEE Transactions on Magnetics*, vol. 48, no. 11, pp. 3772-3775, Nov. 2012, doi: 10.1109/TMAG.2012.2202275.

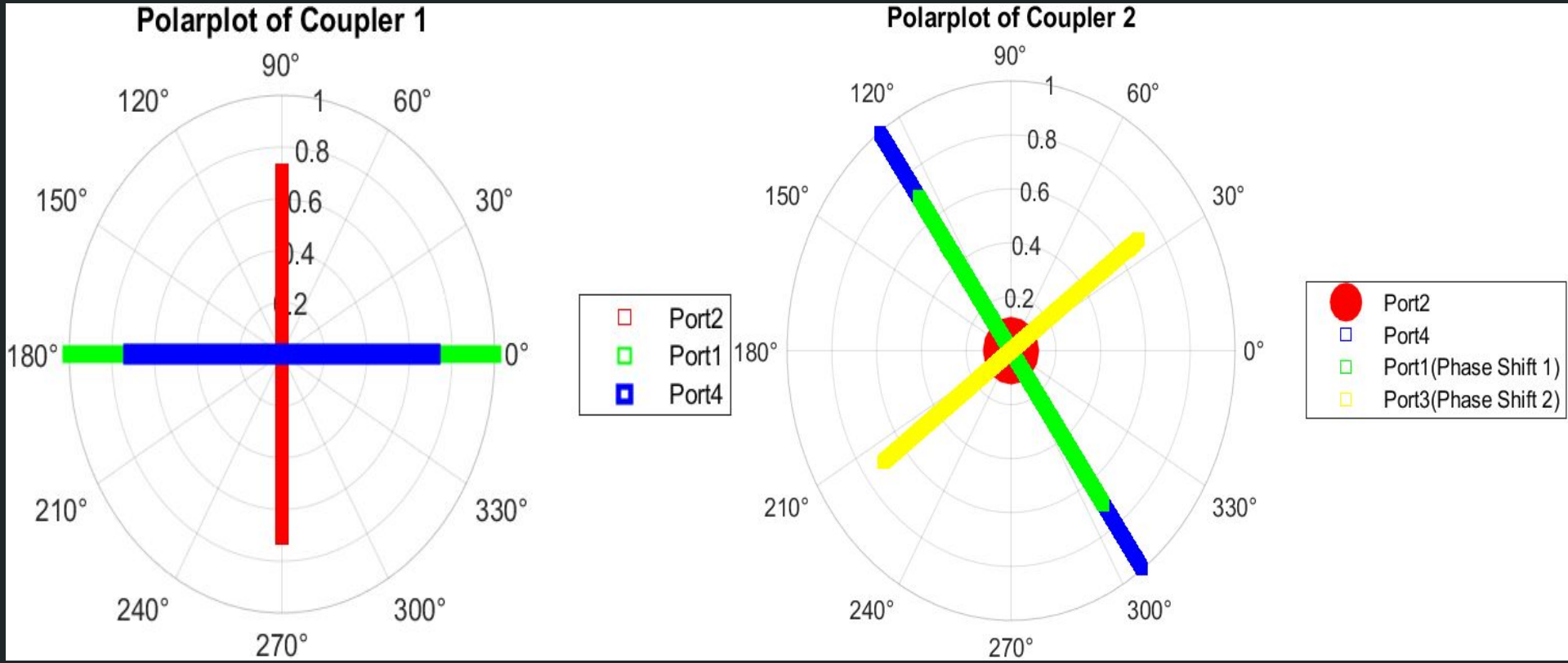
[2] J. -W. Tioh, M. Mina and R. J. Weber, "All-Optical Integrated Switch Utilizing Faraday Rotation," in *IEEE Transactions on Magnetics*, vol. 46, no. 6, pp. 2474-2477, June 2010, doi: 10.1109/TMAG.2010.2042433.

Optical Simulation In MATLAB

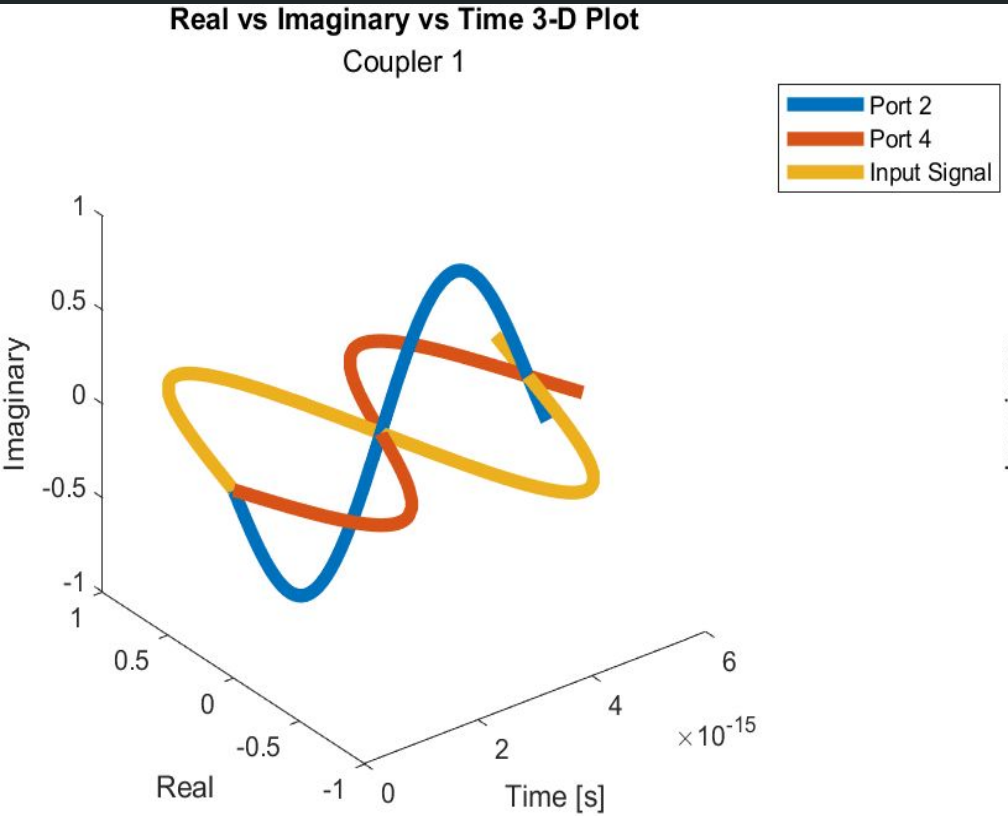


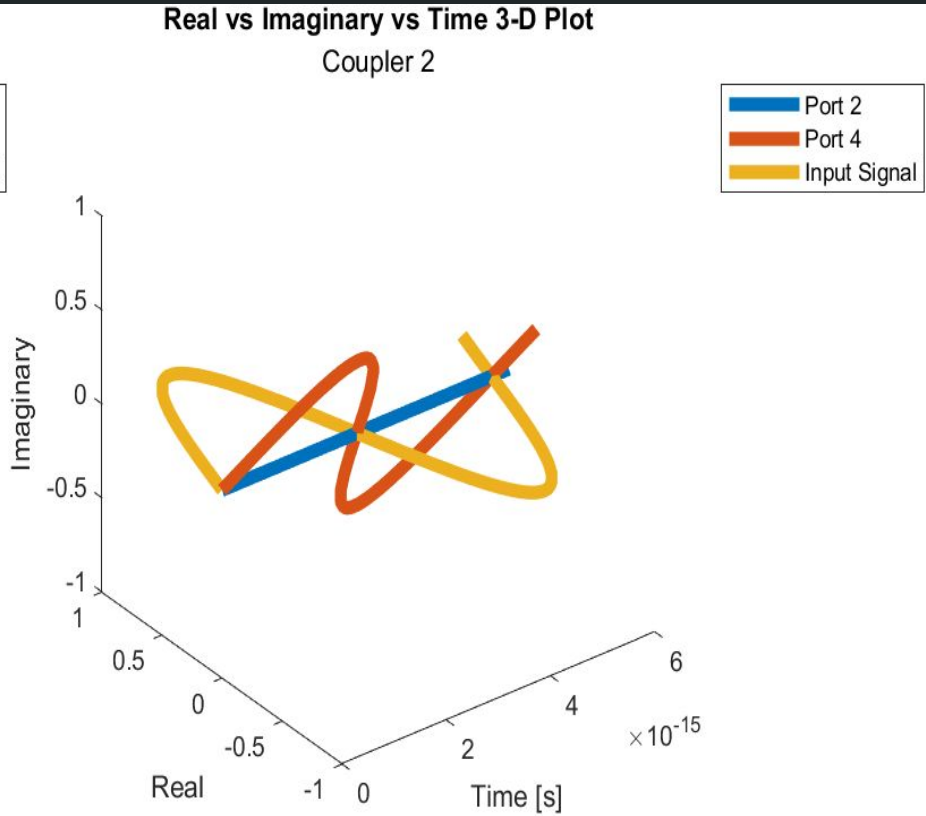
Current MZM Model in MATLAB

Polar Plots of the Couplers



3-D Plots of the Couplers





Inductor Design

$$B = \frac{\mu_0 N I}{\sqrt{l^2 + 4r^2}}$$

$$L = \frac{\mu_0 N^2 \pi r^2}{\sqrt{l^2 + 4r^2}}$$

$N = 4\ turns$

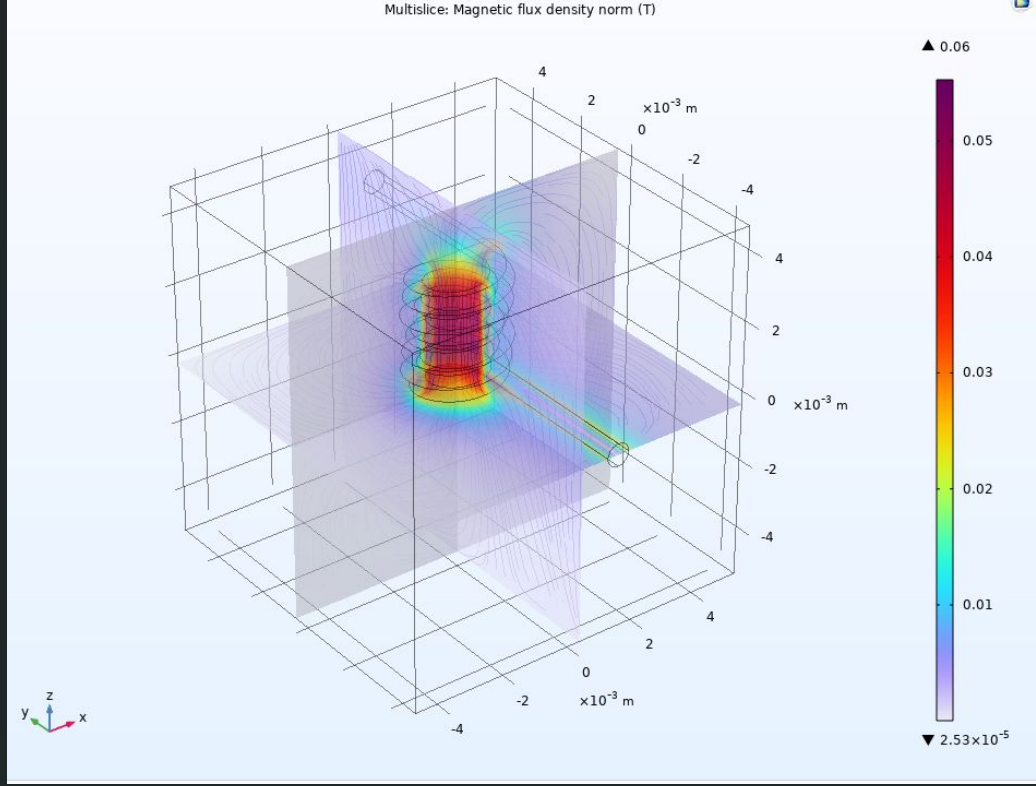
$r = 1.1\ mm$

$l = 3.5\ mm$

$\mu_0 = 4\pi * 10^{-7} H/m$

Calculated Inductance = 20.2 nH

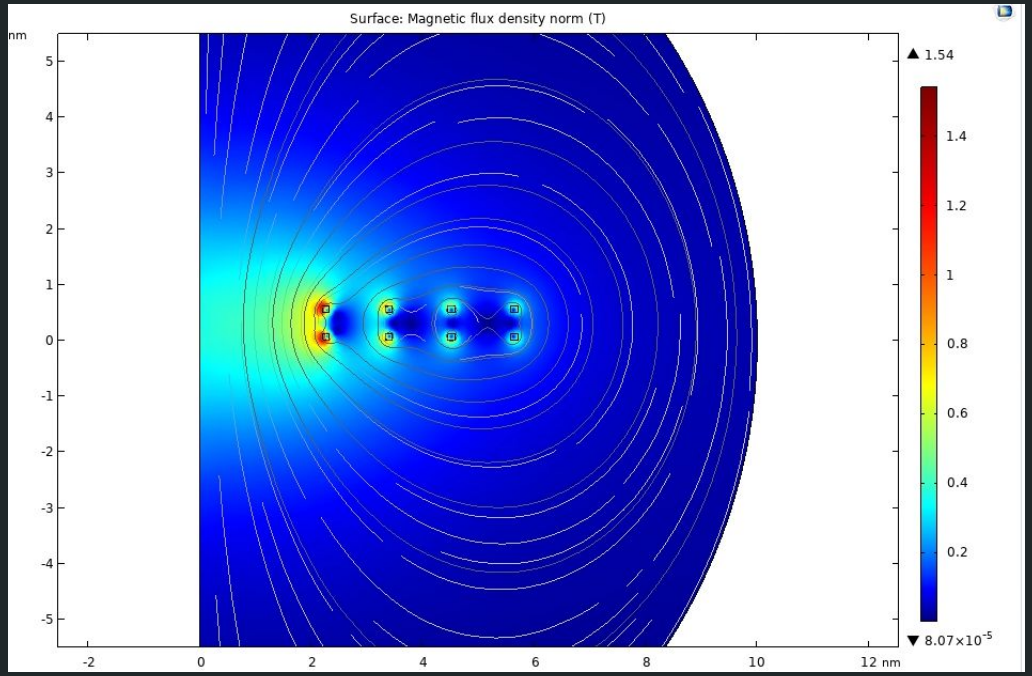
Inductance Calculated in COMSOL = 21.73 nH



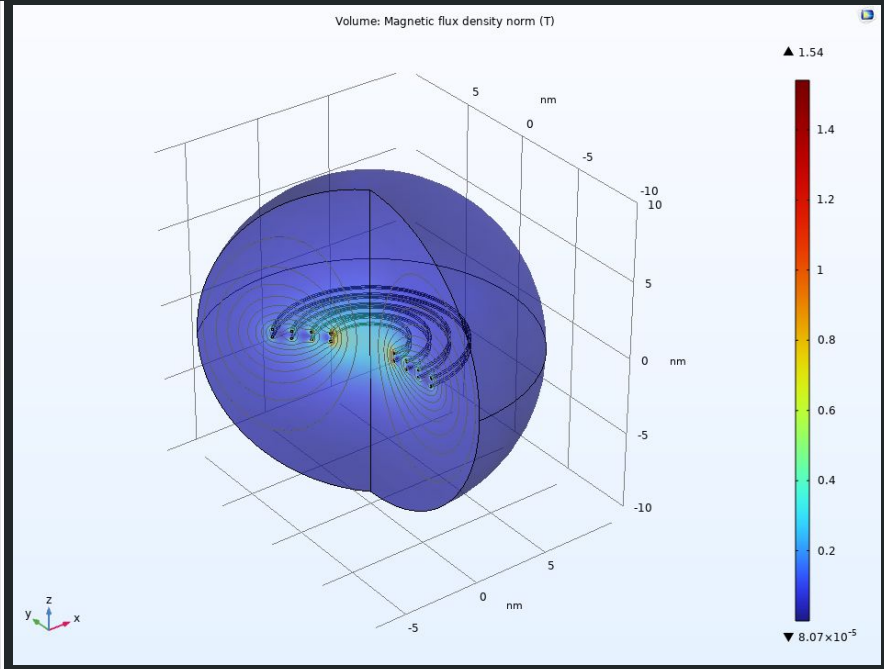
Magnetic Flux Density of Inductor in COMSOL

"39 • fast, compact, High Strength Magnetic Pulse Generator," *sdmay22*. [Online]. Available: http://sdmay22-39.sd.ece.iastate.edu/. [Accessed: 05-Dec-2022].

Planar Spiral Coil

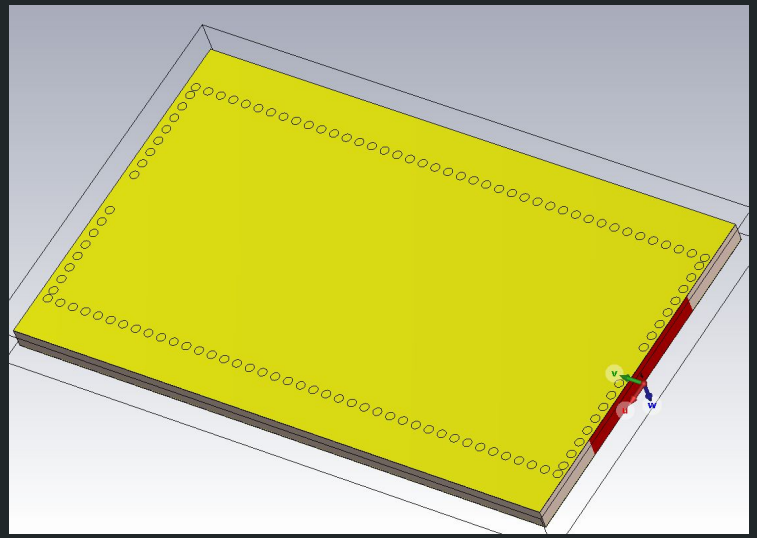


2D View of Coils

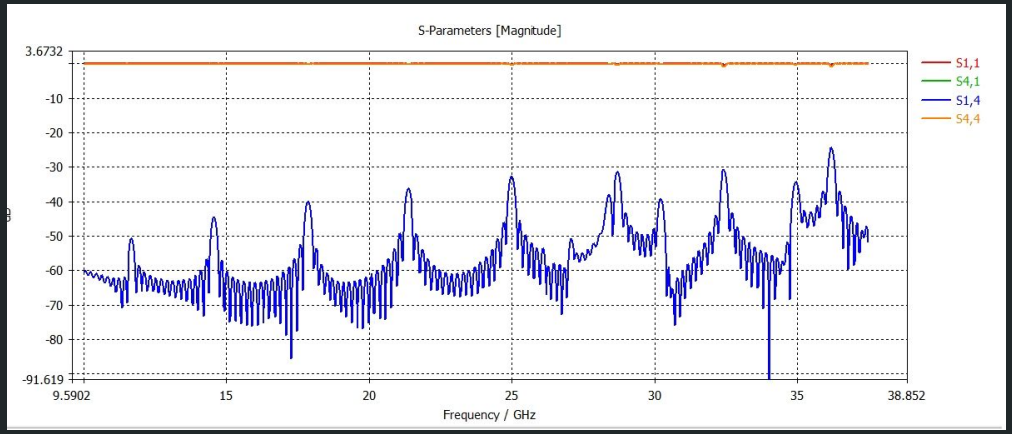


Magnetic Flux Density of two spiral coils in COMSOL

Optical Simulation In CST Studios (Work In Progress)



Substrate-integrated Waveguide(SIW) in CST



S-parameters for SIW

Magnetic Field Generator Circuit Design

Circuit Specs:

VDC: <= 15V

Flux Density:> 500 G

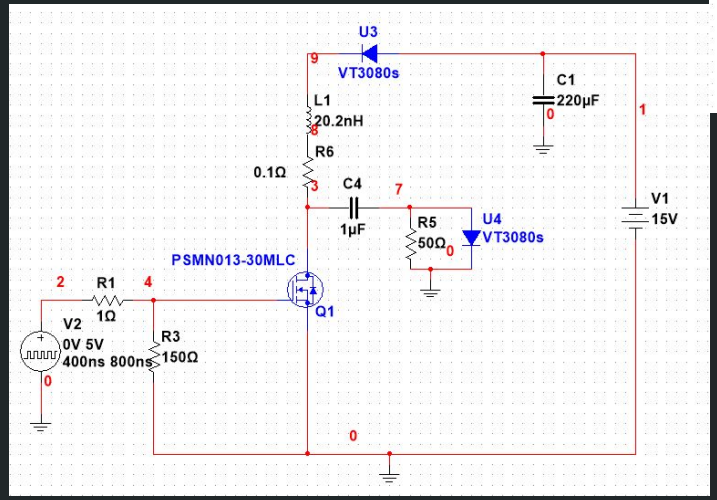
Rise Time: < 100 ns

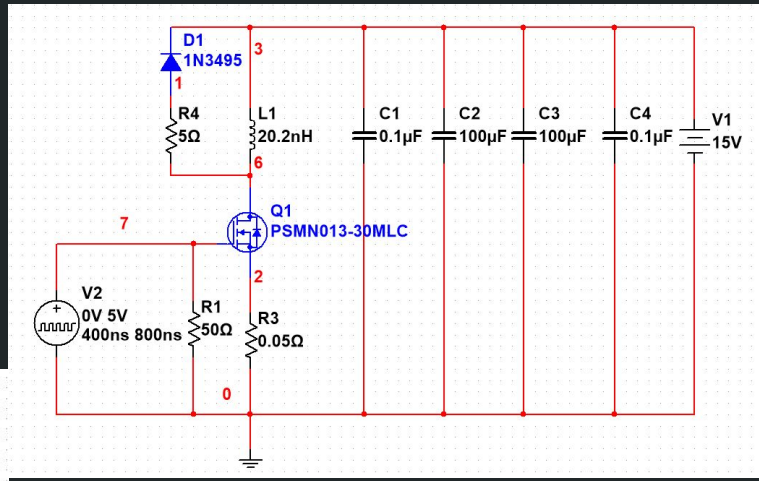
PCB Size: 3.5” x 2”

ZVS Benefits:

- Decreased switching losses

Schematic of ZVS Circuit





Schematic of MFG Circuit

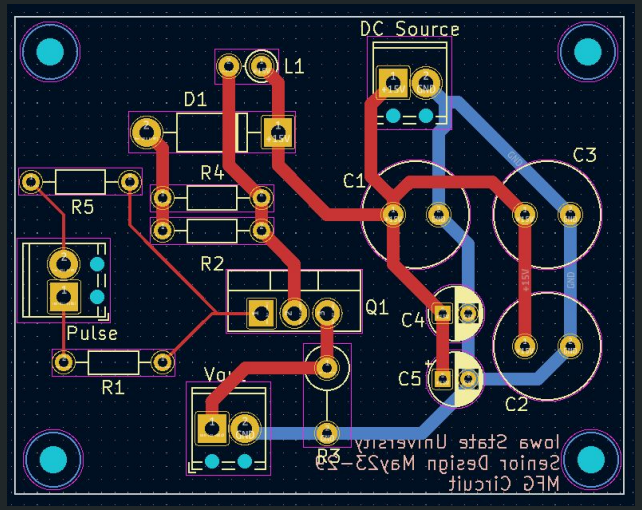
MFG Circuit

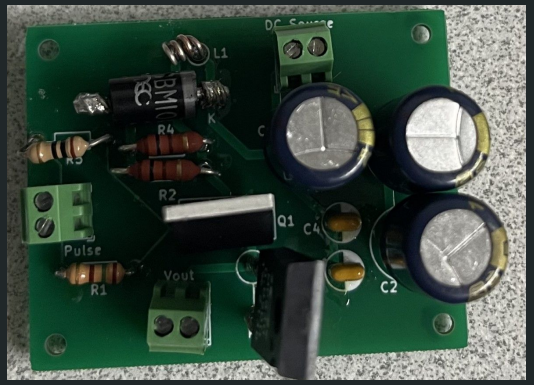
Inductor Current: 42.2 A

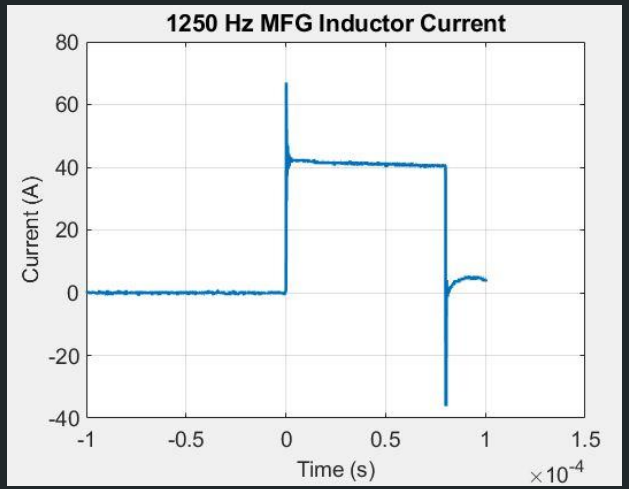
Flux Density: 569 G

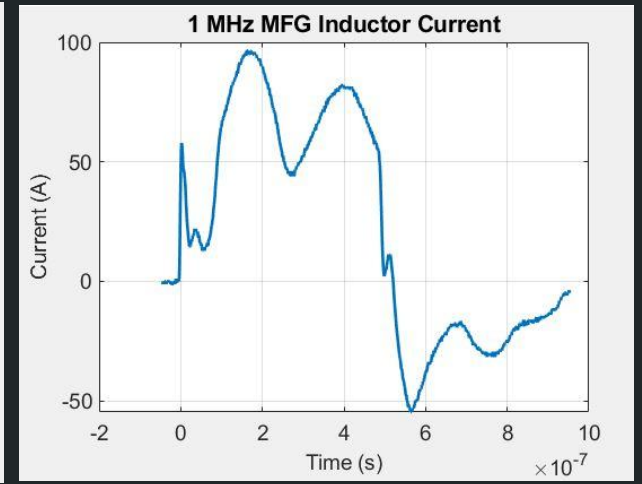
Rise Time: 96 ns

High frequency: 1 MHz









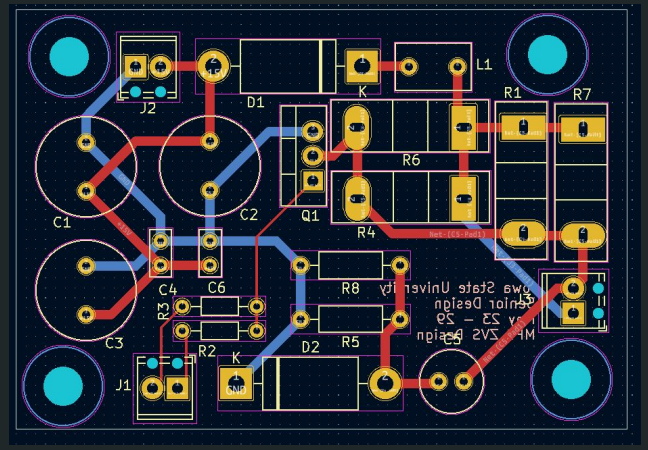
ZVS Circuit

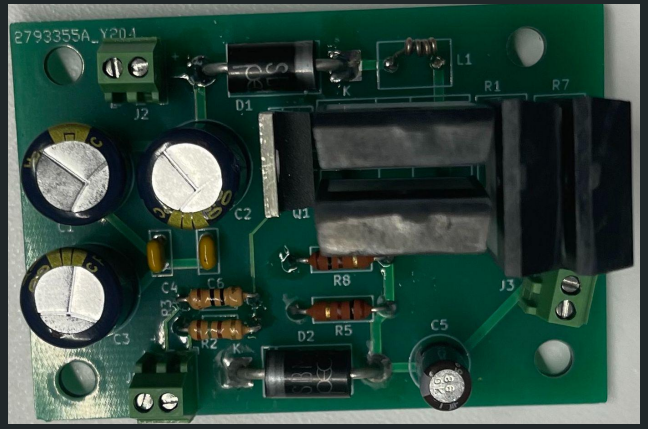
Inductor Current: 52.3 A

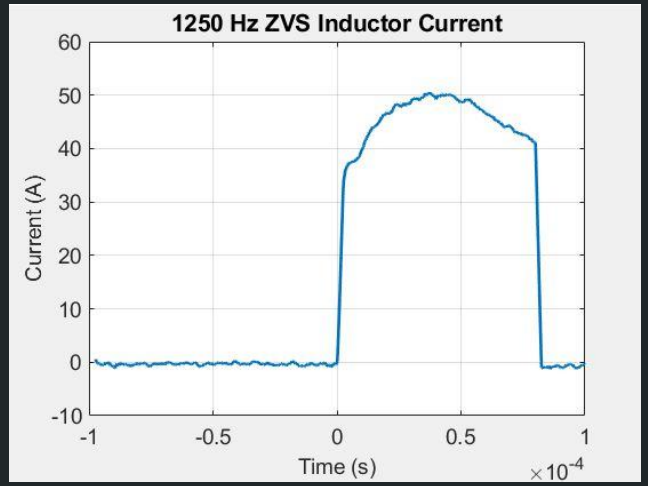
Flux Density: 630 G

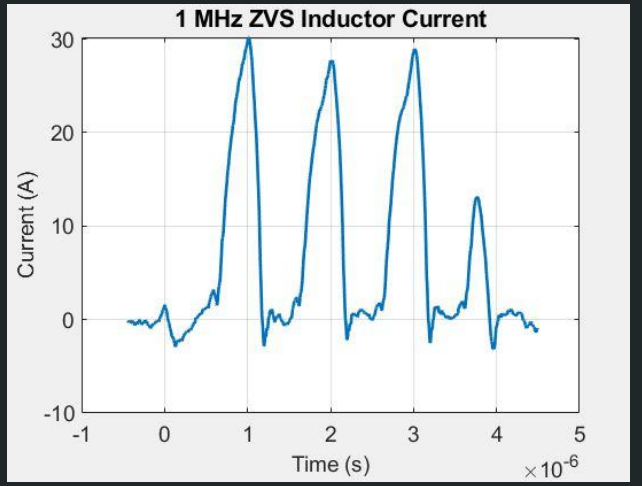
Rise Time: 1.0 µs

High frequency: 1 MHz









Individual Contributions

- Umair Sarwar
  - Created Inductor Coil in Comsol and Helped with CST setup
- William Nichols
  - Started simulation of our Mach-Zehnder loop in CST
- Michael Lopez
  - Created Matlab/Simulink Model of Mach-Zehnder Loop
- Andrew Murphy
  - Circuit Design, Simulation and Testing
- Steven Huynh
  - Circuit Design, Simulation and Testing

Challenges and Solutions

CST

Challenge

- Implementing waveguide and Coupler

Solution

- Research into SIW waveguides

COMSOL

Challenge

- Understanding 2D Modeling and Spiral Coils

Solution

- Reading multiple different research articles of 2D Modeling

MATLAB

Challenge

- Configuring the RF Blocks

Solution

- Watched videos with experimentation

Circuit Design

Challenge

- Implementing SM MOSFET into ZVS Circuit

Solution

- Due to time constraints we used a TH device

Future Improvements

Improvements

- Increased knowledge in CST
- Improve accomplished Mach-Zehnder loop simulation
- Addition of Sagnac and Resonators in MATLAB Simulation
- Understanding 2D Modeling and Spiral Coils in COMSOL
- Creating a fully surface mount design
- Full implementation of ZVS design
- MFG circuit reaching as low as 36ns

Conclusion

- Designed a MFG circuit meeting our clients specifications
- Created Mach-Zehnder simulation in MATLAB
- Learned new programs to create more accurate simulations
- Produced base simulations for future groups to build off of

Questions?