Railgun Power Supply @ Trine University

Trine University
Electrical Engineering

Brett Young, Cory Burnett, Joshua Vankainen, Logan Bowling, Joshua Dick
Advisor: Kevin Woolverton Ph.D.
Trine University
One University Avenue, Angola, Indiana 46703

Introduction:

Railguns have been marked as the United States Army's number one priority in long range weapons. Army Chief General Mark Milley confirmed this when he stated, "The service's No. 1 priority for modernization is long-range precision fires". The sky's the limit when it comes to railgun capabilities. While we have not uncovered the maximum potential of railguns, they still surpass any range and lethality compared to standard artillery or naval guns. Jon Harper, writer for the National Defence Magazine, stated that, "The technology enables the projectiles to travel at hypersonic speeds of Mach 5 (3,800 miles per hour) or faster". Additionally, railguns can save the US Navy and Army millions of dollars. Not only are they more lethal and can shoot farther, railgun shots are a fraction of the cost of traditional missile shots. Peter W. Singer, a military technology expert, stated that, "The railgun concept is also promising for air and missile defense because it could dramatically change the cost equation. Traditional missile interceptors can cost millions of dollars each, whereas railgun projectiles are expected to cost tens of thousands of dollars per shot.".
The largest problem that has been brought up for railgun implementation is power consumption and durability of the rails. The only ships that are capable of the 25 megawatts of power "are the Zumwalt-class destroyers, and only three will be produced due to budget considerations, down from the originally planned 32." Given this fact our project was to scale down this technology and familiarize ourselves with the power supply aspects of railgun technology.

Materials and Methods:

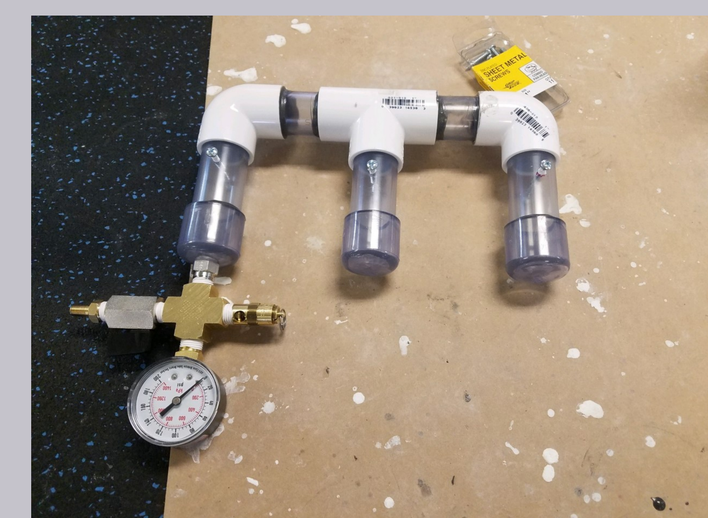
Software programs used were TINA, LT Spice, and Waveforms.
The materials used in this project were:

- Water Resistors made from tygon tubing, copper plugs, and tapped zinc plated screws.
- The custom transformer for the ZVS flyback was made of magnet wire rated at 30 gauge.
- The custom spark gaps were made from Schedule 40 PVC rated at 220 PSI. The gaps included a four way female brass valve, pressure safety valve rated at 30 PSI, PSI gauge, and ball valve for input.

The testing methods used in this project were:

- RC circuit using Waveforms to calculate the resistance value of our custom made water resistors.
- Water submersion to test for leaks in the pressure system.
- Simulations on circuit behavior modeled in TINA and LT Spice.
- Simple component testing using a Digital Multimeter.

A



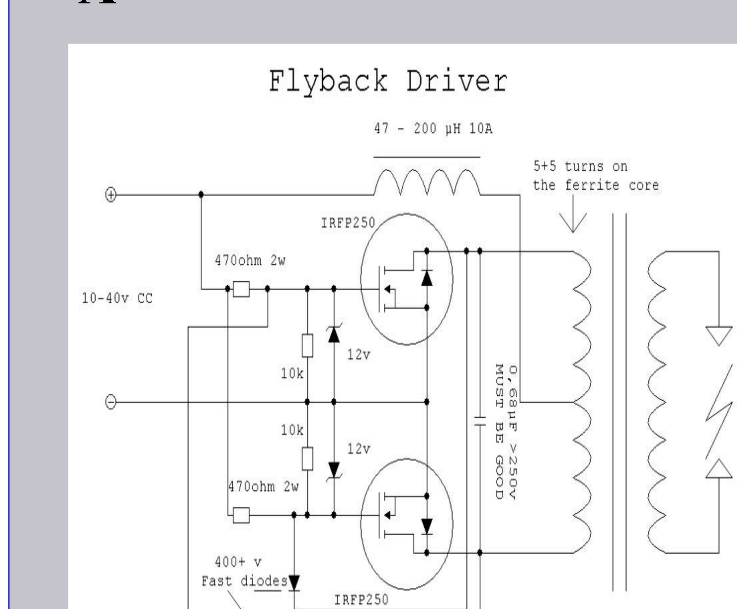
B

Figure 1: **(A)** Pressure system made from PVC. **(B)** A demonstration of our pressure system working at a value of 20 PSI.

Results and Discussion:

- The first problem that we encountered was how to supply an appropriate amount of voltage to the capacitor bank. We solved this by using a ZVS flyback transformer, which is commonly used in high power applications. This transformer is very compact and capable of giving an output in the tens of thousands of volts. We had to effectively and safely step down this voltage to give us something that we could use for our capacitor bank.
- The capacitor bank was something that took us a long time to design. Small scale railguns have been built, but generally uses a standard parallel capacitor design. We wanted to achieve very specific voltage and amperage outputs. This lead us to the Marx Bank which multiplies its stage voltage into one large output voltage. So if each stage of our Marx was charged with 500V, and we constructed three stages then this output would result in the desired 1500V output. From there we only needed to get a very low resistance rail system to ensure that the output from the bank would also achieve our 1000 amp goal.
- The only sub-system that was not yet complete when progress stopped on the project was the Ragowski coil, and going forward much more testing on this would need to be done to ensure that current readings from our circuit were accurate.

A



B

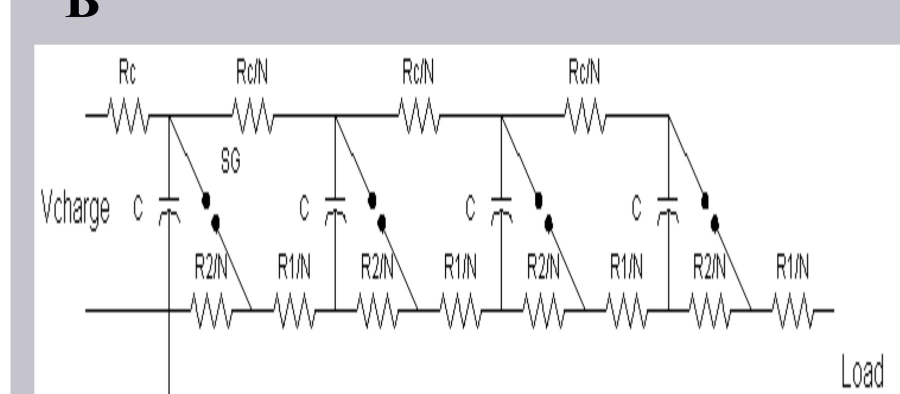


Figure 3:
(A) ZVS Circuit Diagram
(B) Marx Bank Diagram

A

B

C

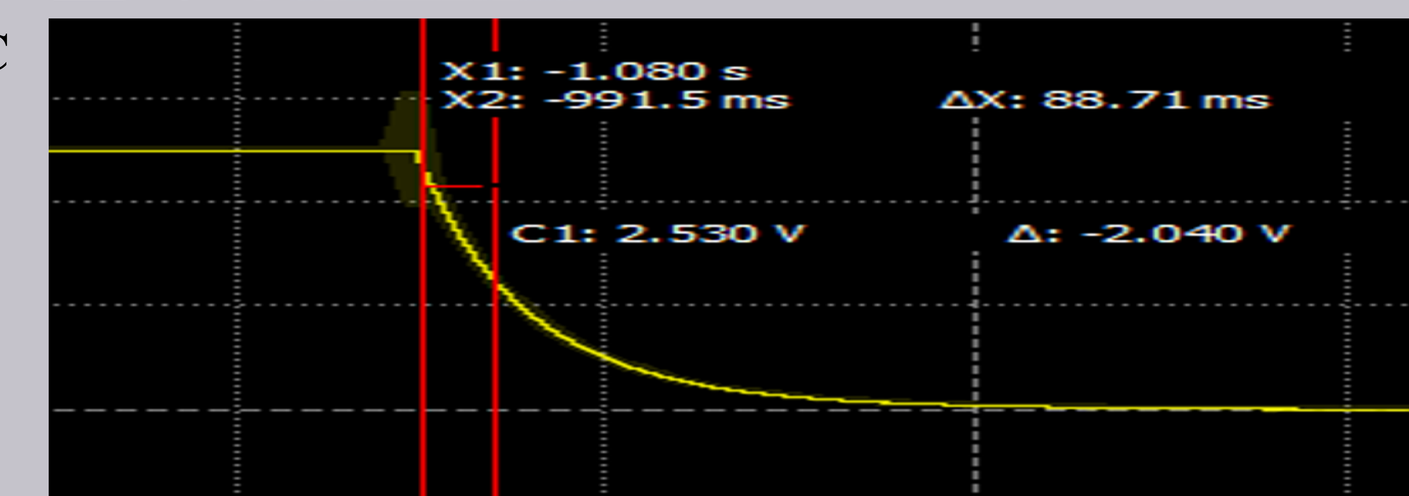


Figure 2: **(A)** Water resistor (B) Water resistor hooked up to the testing RC circuit (C) Waveforms water resistor response diagram

Conclusion:

Our team was able to do extensive research concerning railgun technology, and formulate an effective design that would give us a high output current and voltage. The subsystems of our project had all been decided upon and we had reached the integration stage. The charging circuit, capacitor bank, and dumping system were all complete. Unfortunately, due to the COVID-19 outbreak we were unable to finish the integration process. This halted all progress in testing, and we were unable to confirm if the 1000 amp output from our scope was achievable.

Future Work:

The following are ideas to further improve the Power Supply:

- Test the output voltage of the ZVS flyback with the custom built water resistors.
- Achieve a breakdown in our custom spark gaps, and adjust the gaps accordingly.
- Complete the Ragowski coil and achieve correct current readings from our circuit.
- Implement triggering devices that allow for safe operation and follow safety regulations.
- Continue the integration of the system to test output current and voltage.

Acknowledgements:

This Electrical Engineering Senior Design Team would like to thank the following for their contributions, facilities, and resources:

- Trine University Electrical and Computer Engineering Department
- Dr. Kevin Woolverton
- Joe Thompson