Coil Gun Control System and User Interface

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1 INTRODUCTION

1.1 Multi-stage Coilgun System Overview

The multi-stage coilgun is a device that fires a small projectile at high speeds through the use of electromagnetics. It works by generating a large current in a coil that winds around a projectile with a conduction path in the same direction as the winding. As mentioned in Ampere's law, a magnetic field is generated in the projectile's conducting path and by Faraday's law, the induced current in the projectile will create a magnetic field opposing that of the core. The projectile is then accelerated by the repelling fields.

The purpose of this project is to shed light on the many applications of electromagnetics. We chose this project because of the technical challenges it presents and also because it aligns with the skills and academic focus of our group. Professor Reinhard hopes that this project can one day be used at EOH in order for this project to be used as an education tool.

1.2 Objectives

The goal of this project is to design and build a control circuit and a user interface for the coil gun. The function of the control circuit is to accurately determine when to trigger the coils in order to increase the velocity of the projectile as it passes through. The goal is for the final speed of the projectile to be between 15-17 m/s. The launch speed and estimated distance travelled will be displayed on the user interface. We also need to ensure that our project is safe and adheres to the rules and regulations of IEEE and the university.

1.3 Benefits and Features of the coil gun:

Benefits:

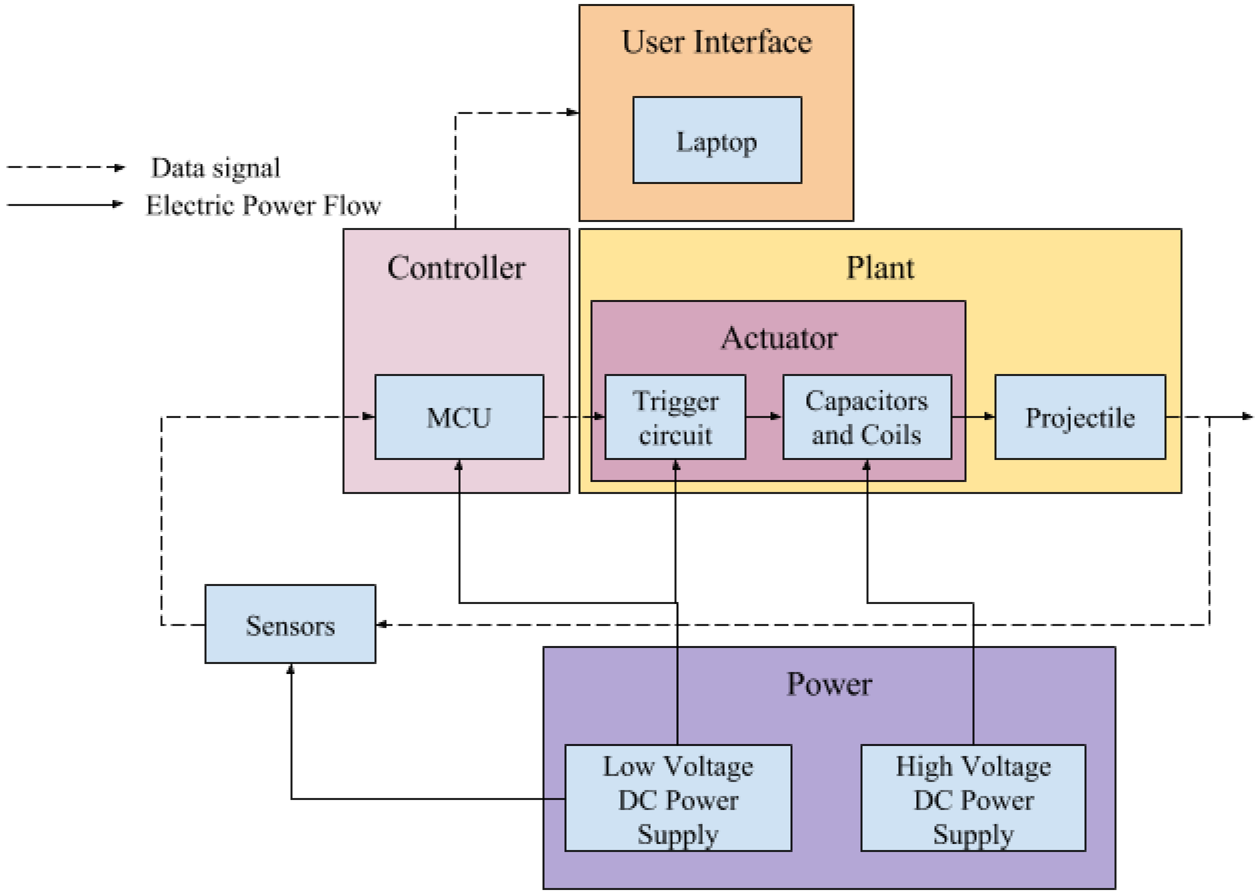
- Entertainment.
- Can be used as a teaching aid to display the effects of electromagnetism.
- Portable and easy to set up.
- Good application of power electronics and control systems.

Features:

- User Interface
- High mobility and easy set up
- Launching a projectile at speeds of 15m/s and above.

2 DESIGN

2.1 Block Diagram



Control system block diagram for the coil gun

2.2 Functional Overview

<u>Sensors</u>

Position sensors are placed at specific distances along the barrel to detect location and calculate the speed of the projectile. Time of flight sensors may also be used to calculate the distance the projectile has travelled.

Requirement: The sensors must sample at least 700 Hz.

<u>Microcontroller</u>

The microcontroller will use the information from the sensors to calculate projectile location and speed. It will then calculate the estimated time required for the projectile to reach the next coil and send an impulse to the trigger circuit at that time. We will design a PCB for the microcontroller and sensor signals with appropriate routing.

Requirements: Need the microcontroller to process the control algorithm and output it in under 5.2 milliseconds.

Power

The power module consists of low voltage and and high voltage DC supplies. The low voltage supply provides power to the microcontroller and sensors. High voltage supply is used to charge the capacitors that store charge for firing the projectile at a later stage.

Requirements: High voltage power supply should be able to supply 10W at 200V. The low voltage power supply should be able to supply 5W at 5V.

Actuator

The trigger circuit consists of an isolated transformer connected to a silicon controlled rectifier (SCR). This circuit will be completed by the other team working on the project.

Requirements: An 18V impulse needs to be provided to the transformer which causes the SCR to allow current to flow from the capacitor banks to coils.

Projectile

A lightweight aluminum cylinder is used as the projectile. It has a low resistivity to electric current flow.

Requirements: A 200 gm aluminum projectile shaped as a smooth cylinder with a one inch diameter.

User Interface

The user interface would be a GUI that would display projectile information, like the speed profile, expected distance of shot, etc.

Requirements: A laptop with a USB interface.

2.4 Risk Analysis

Position detection using sensors poses a significant risk to the overall functionality of the project. The projectile behaves as a solenoid coil and there exists a mutual inductance between the projectile and the gun's coils. Variation in the mutual inductance with time causes a force to be applied on the projectile. This force will have different values depending on the position of the projectile with respect to the center of the gun's coil. If current is passed into the gun's coil before the projectile crosses the halfway point of the gun's coil, force will be applied in the direction opposite to the direction of firing. This can potentially damage any equipment placed near the barrel of the coil gun.

The major challenge in position detection is that the projectile travels at a speed of about 15 m/s. This requires very high bandwidth sensors, sampling near the kiloHertz range. This places an extremely stringent requirement on the sensors.

There exists a time delay in applying a trigger signal to the trigger circuit and coils being energized. This time delay would depend on the circuit components and topology. If this timing has a large error in estimation, it would also cause the coils to be energized when the projectile is at the wrong location.

Very strong electromagnetic fields exist in the area around the coils and the current carrying wires which may cause false signals to be sent to the microcontroller which might cause the algorithm to miscalculate projectile position and triggering times.

3 ETHICS AND SAFETY

3.1 Ethics

We understand that this project has many applications including military purposes, however we would like to reiterate that we are doing this purely out of interest and for the purpose engineering. We do not have any ambitions to cause harm or danger of any kind and we will uphold both the university and IEEE code of ethics

The most important code in the IEEE code of ethics for our project is #1. “to accept responsibility in making decisions consistent with the safety, health, and welfare of the public, and to disclose promptly factors that might endanger the public or the environment” [2]. This project involves making a weapon that could hurt people. It is important that guidelines are laid out in order for everyone to stay safe. Another important rule is #9, “to avoid injuring others, their property, reputation, or employment by false or malicious action” [2]. This project is meant to teach people about electromagnetics and it should not be used for malicious actions.

3.2 Safety analysis

This project involves the use of high voltage and current and fast moving projectiles. Appropriate safety precautions will be put in place in order to prevent undesirable and unforeseen circumstances. Some of these safety features include:

- Not pointing the coil gun at other people.
- Making sure the power is off before changing any of the circuit connections.
- Checking and testing for faulty equipment before use.
- Making an efficient discharge circuit in case we choose not to fire projectile after charging capacitors.

Some safety rules to follow:

- Never point the coil gun at something you do not want to shoot.
- Always assume that the capacitors are charged.
- Always discharge capacitors if stowing away for a long time.
- Always keep the gun pointed in a safe direction.
- Do not place your finger on the trigger button unless absolutely sure that you are ready to fire.
- Make sure everyone around you is following the safety rules.
- Do not directly touch the capacitors.
- The coil gun should never be operated by persons under the influence of alcohol or drugs.
- Children must never be left alone with the coil gun.

4 REFERENCES

[1] Reinhard, K., “A Methodology for Selecting an Electromagnetic Magnetic Gun,” M.S. thesis, Dept. Elect. Eng., Univ. of Texas, Austin, TX, 1992.

[2] IEEE, “IEEE IEEE Code of Ethics”, 2017. [Online]. Available: http://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 8-Feb-2017].

[3] Dagdagan, J., Ko, Y., Nanavati, S., “Multistage Coil Gun”, 2013. [Online]. Available: https://courses.engr.illinois.edu/ece445/projects.asp. [Accessed: 1-Feb-2017].