Multistage Coil Gun

ECE 445 Project Proposal
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1 Introduction

1.1 Multistage Coil Gun

The Multistage Coil Gun is a device which ejects a small projectile at great speeds solely through the use of electromagnetics. Besides the visual display, the purpose of our project is to create an educational exhibit to show how electromagnetic force, if harnessed properly, can be used for many applications. We chose this project because of the technical challenges it poses. In addition, we are excited about the accessibility this project holds. Young students can easily see and understand the general scientific principles interacting in our device.

1.2 Objectives

The project goal is to safely demonstrate a coil gun which launches a one inch diameter projectile at 15m/s. We also want to display the launch speed on a monitor and control the capacitor discharge using I/O signals. We need to ensure our project functions safely and operates in accordance with all rules and regulations of IEEE and the university.

<u>Benefits</u>

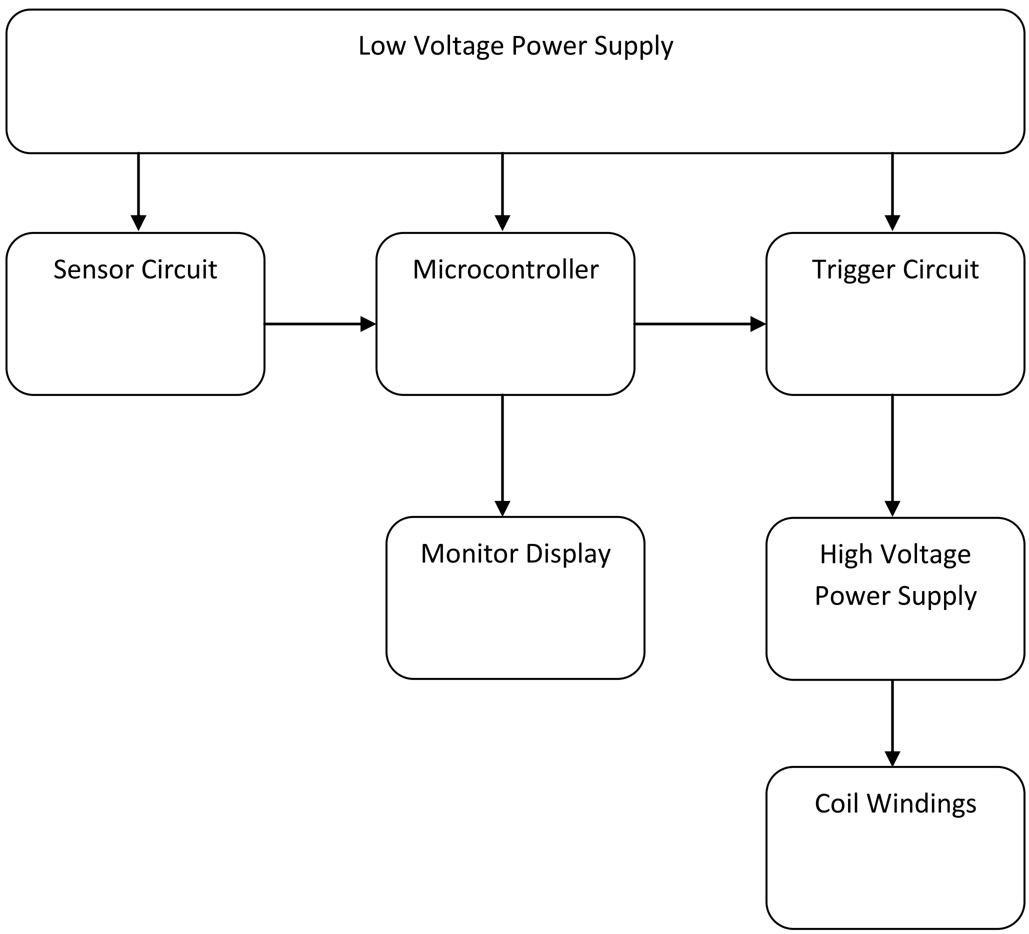
- Educational tool which utilizes electromagnetic force. Our project can be used by professors teaching electromagnetism to demonstrate the effects of strong magnetic fields
- Portable and easy to set up
- Entertainment for viewers

<u>Features</u>

- Launch 1" diameter projectile at speeds of 15 m/s
- High mobility with easy set up
- Clear distinction of components for educational purposes

2 Design

2.1 Block Diagram



2.2 Block Description

<u>Low Voltage Power Supply</u>

The low voltage power supply is used to power the sensor I/O circuits and the microcontroller.

<u>Sensor Circuit</u>

The sensor circuit is the primary interface between the photodiodes and microcontroller. Using a series of potentiometers and op-amps the circuit takes the analog signal from the photodiodes and translates them to clear, stable digital inputs for the microcontroller.

Microcontroller
Once the microcontroller receives the input signal, it calculates the optimal timing to trigger the consecutive coils. The microcontroller completes these calculations by measuring the speed of the projectile between the first two sensors. After extracting the necessary information from the input signal, the microcontroller will relay the signal to the trigger circuit.

Trigger Circuit
The trigger circuit receives the signal from the microcontroller to trigger the thyristors. The circuit will allow electrical isolation between the high voltage power supplies and the microcontroller and amplify the output signal from the microcontroller to trigger the thyristors. In other words, the trigger circuit will enable the discharge of the capacitors.

High Voltage Power Supply
The high voltage power supply consists of the capacitor bank and the high voltage DC power supply. The capacitors store charge to provide the power for the projectile launch. The capacitors will be in an enclosure as to prevent them from being exposed. The high voltage power supply receives signals from the trigger circuit which control the capacitors to discharge to the three sets of coil windings. Each capacitor will be controlled by a thyristor.

Coil Gun Windings
The Coil Gun windings are three sets of coils connected to each set of capacitor banks. The current will be discharged through the first coil when the launch is triggered. The consecutive capacitors will be controlled to discharge current to the second and third coils by the microcontroller.

Monitor Display
A monitor will be used to display the launch speed which is calculated by the microcontroller.

3 Requirements and Verification

3.1 Requirements

Low Voltage Power Supply

- Power the sensor input circuit, sensor output circuit, and the microcontroller

Sensor Circuit

- Receive analog signals from the photodiodes
- Amplify the analog signal and convert to a digital signal
- Output digital signals to the microcontroller

Microcontroller

- Collect data from the sensor circuit and log the times when the projectile passes through a sensor
- Calculate the speed of the projectile and calculate the time to trigger thyristor
- Must be able to output signal to the trigger circuit

Trigger Circuit

- Takes in signal from microcontroller
- Amplify the microcontroller signal and output signal to trigger thyristor
- Must provide isolation from the High Voltage power supply to the microcontroller

High Voltage Power Supply

- Supply High Voltage DC power to charge the capacitor banks
- Discharge current, when thyristor receives input from trigger circuit, to the coil gun windings
- Be able to manually discharge capacitors safely
- Be able to verify complete discharge of capacitors for safety purposes

Coil Gun Windings

- Allow current to flow within safe tolerances
- Cover any exposed leads

Monitor Display

- Receive input from the microcontroller
- Display final calculated speed

3.2 Verification

Low Voltage Power Supply

- Check for clean and constant DC voltage using multimeter

Sensor Circuit

- Use multimeter to test:
    - Verify photodiodes operate properly
    - Potentiometers are set to correct reference voltages
    - Op-amps output appropriate digital voltages

Microcontroller

- Verify that proper drivers are installed
- Ensure that code logic is sound, utilizing breaks within the code
- Use oscilloscope to check different pins, for proper input and expected output

Trigger Circuit

- Ensure that the trigger circuit is receiving signals from the microcontroller
- Verify that there is electrical isolation between the microcontroller and the high voltage power supply (wiring, grounding etc.)
- Make sure the components are operating within their current ratings

High Voltage Power Supply

- Check to see that none of the capacitors are blown
- Make sure that the HV DC power supply is functioning properly

3.3 Tolerance Analysis

The component that most affects the performance of our project is the capacitor. More specifically, the amount of energy we store into the capacitors will not only affect the speed of the projectile, but also cause stress to certain components in the control circuit. The power lab is able to charge our capacitors up to 120V DC, however for our purposes we will be using up to 100V to attain our desired speeds. In order to promote safety – for viewers and for our project – our coil gun will operate at ±10% of 100V. The thyristors must be able to handle high levels of current and the trigger circuit must be able to endure decent levels of current stress as well.

3.4 Safety Analysis

It is understood that our project poses certain dangers regarding high voltage electricity and moving projectiles. Appropriate safety precautions will be put in place in order to prevent any undesirable circumstances. A deeper analysis regarding safe voltage levels and projectile speeds will be determined in the design review.

4 Cost and Schedule

4.1 Labor

Name	Hourly Rate	Total Hours	Total Labor Cost (Hourly Rate*2.5*Total Hours)
Jon Dagdagan	$40.00	150	$15000
Yohan Ko	$40.00	150	$15000
Shashvat Nanavati	$40.00	150	$15000
Total	$120.00	450	$45000

4.2 Parts

Item	Cost($)	Quantity	Total Item Cost($)
Photodiodes	1	6	6.00
Lasers	5	6	30.00
Op-amps (LM324)	0.10	2	0.20
Potentiometers	.25	3	.75
Arduino (A000006)	23.95	1	23.95
PVC Pipe	1.50	1	1.50
Capacitors	70.00	9	630.00
Launch Base	3.00	1	3.00
Capacitor Enclosures	6.00	3	18.00
Windings	1.00	6	6.00
Total Parts Cost ($)			
			719.40

4.3 Total Cost

Labor	$45,000
Parts	$719.40
Grand Total	$45,719.40

4.4 ***Schedule***

Week	Objective	Assignment
1/21	Restructure frame Begin writing and finish code using Arduino Design and build sensor circuit	Yohan Jon Shashvat
1/28	Design and build trigger circuit Begin Proposal Debug Arduino code Attend safety modifications meeting with Kevin Colravy	Yohan Shashvat Jon All Members
2/4	Test and generate fully functional sensor I/O circuits Begin modifying and testing capacitor banks Schedule mock design review Attend EOH Safety Meeting, Submit Proposal	Yohan Jon Shashvat All Members
2/11	Operating Coil gun: Assemble and Test Consult machine shop to create safer capacitor covers Determine methods to reduce friction within barrel	All members Shashvat Jon
2/18	Optimize: Obtain launch speeds up to 15m/s Display launch speed on monitor Transfer breadboard circuitry into PCB's	Jon Shashvat Yohan
2/25	Check HV isolation and protection for circuits Transports all components to portable bench and determine optimal layout	Yohan, Shashvat Jon
3/4	Make final adjustments and get ready for EOH	All Members
Post EOH	Focus on optimization, cosmetics, and additional safety enhancements, if necessary, for future EOH usage	All Members