Multistage Coil Gun

Final Presentation

Team 3

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ECE 445

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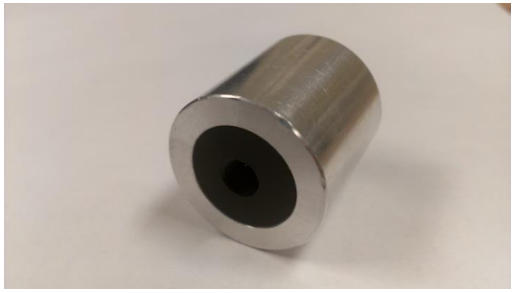
Objectives

- Eject projectile at speeds of 12-17 m/s
- Trigger successive stage efficiently
- Ensure operator and system safety
- Design for modularity
- Make project permanent EOH exhibit



Benefits

- Controllable projectile speed
- Portable, easy to assemble
- Educational tool to teach electromagnetism

Features

- Isolation of high voltage components
- Sensing capabilities in launch barrel
- Fast capacitor recharge time

Coil Gun Theory

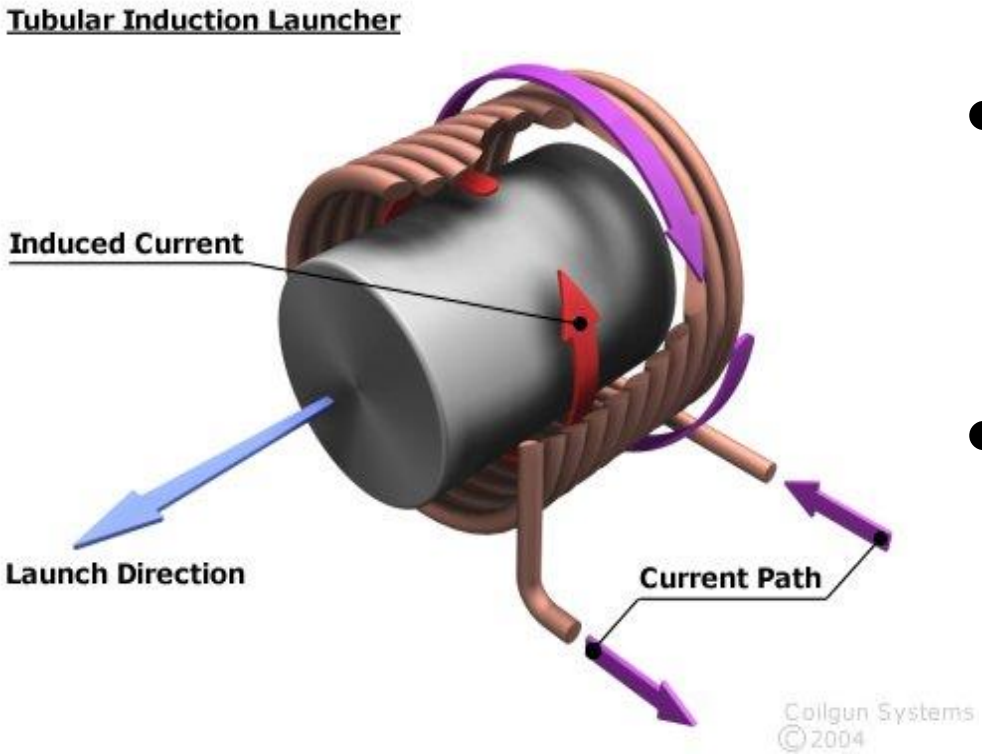
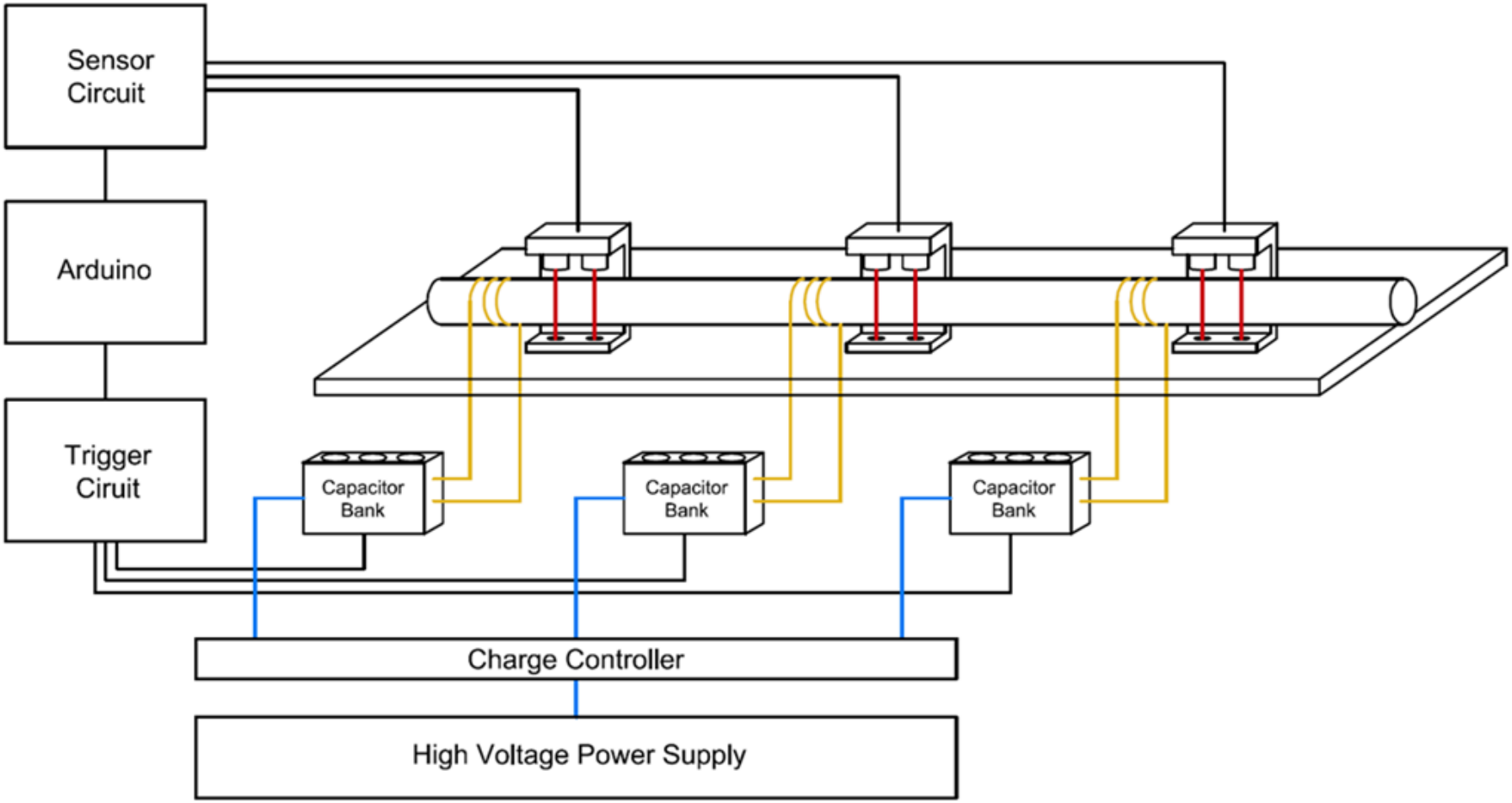


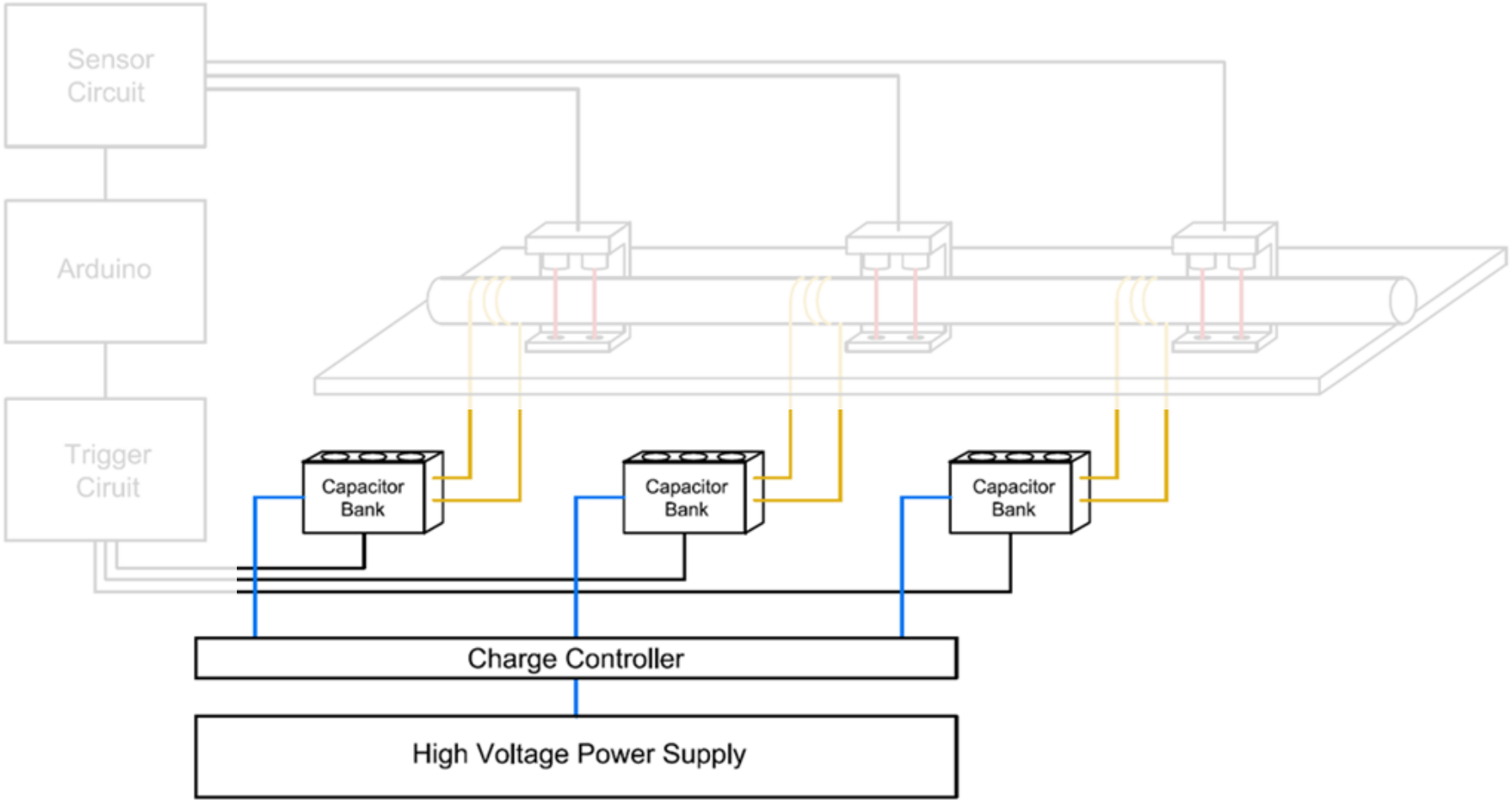
Figure taken from [2]

- Lenz's Law
  - Induced surface currents
- Opposing currents repel each other

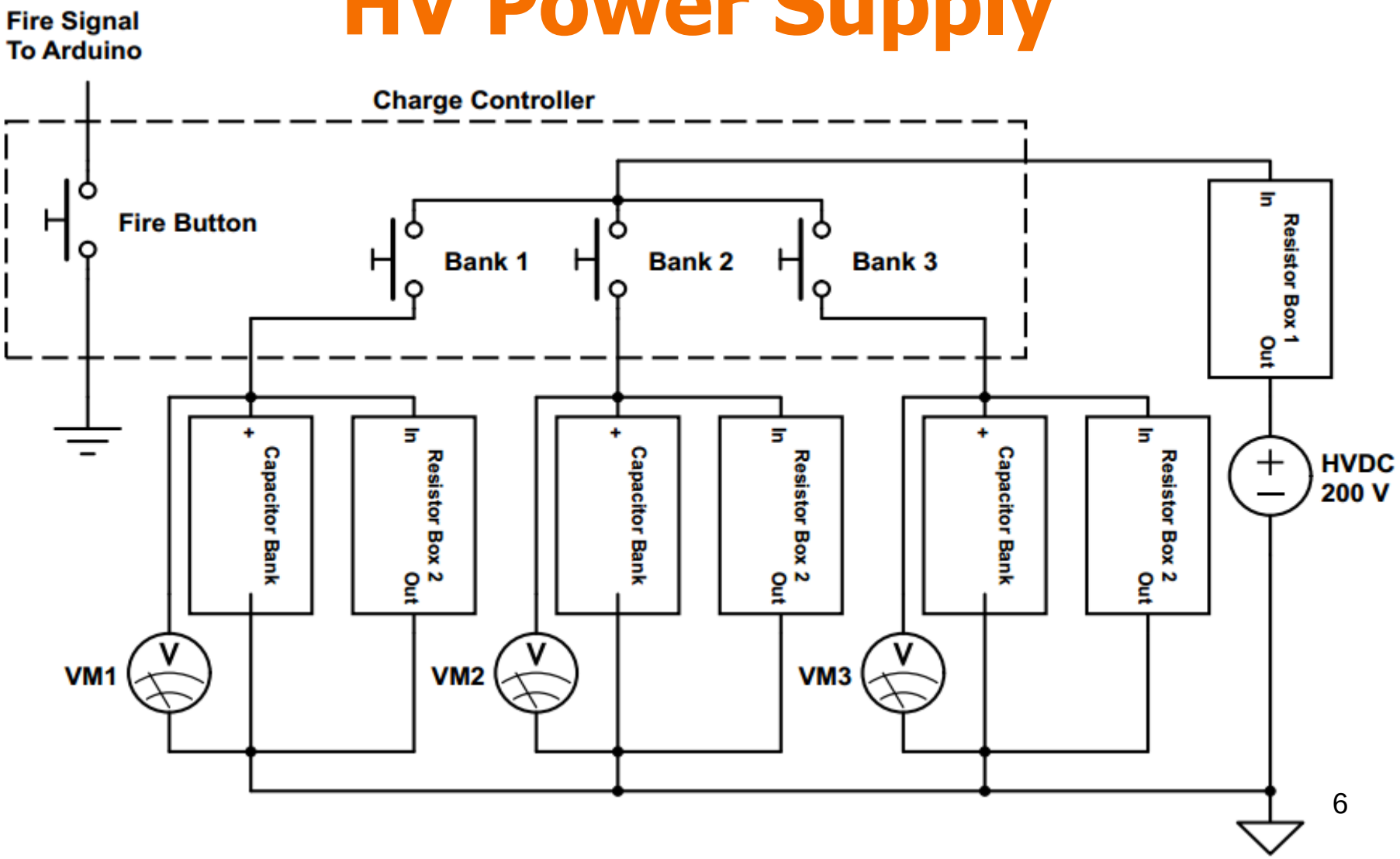
Overview


Sensor Circuit
Arduino
Trigger Ciruit
Capacitor Bank
Capacitor Bank
Capacitor Bank
Charge Controller
High Voltage Power Supply

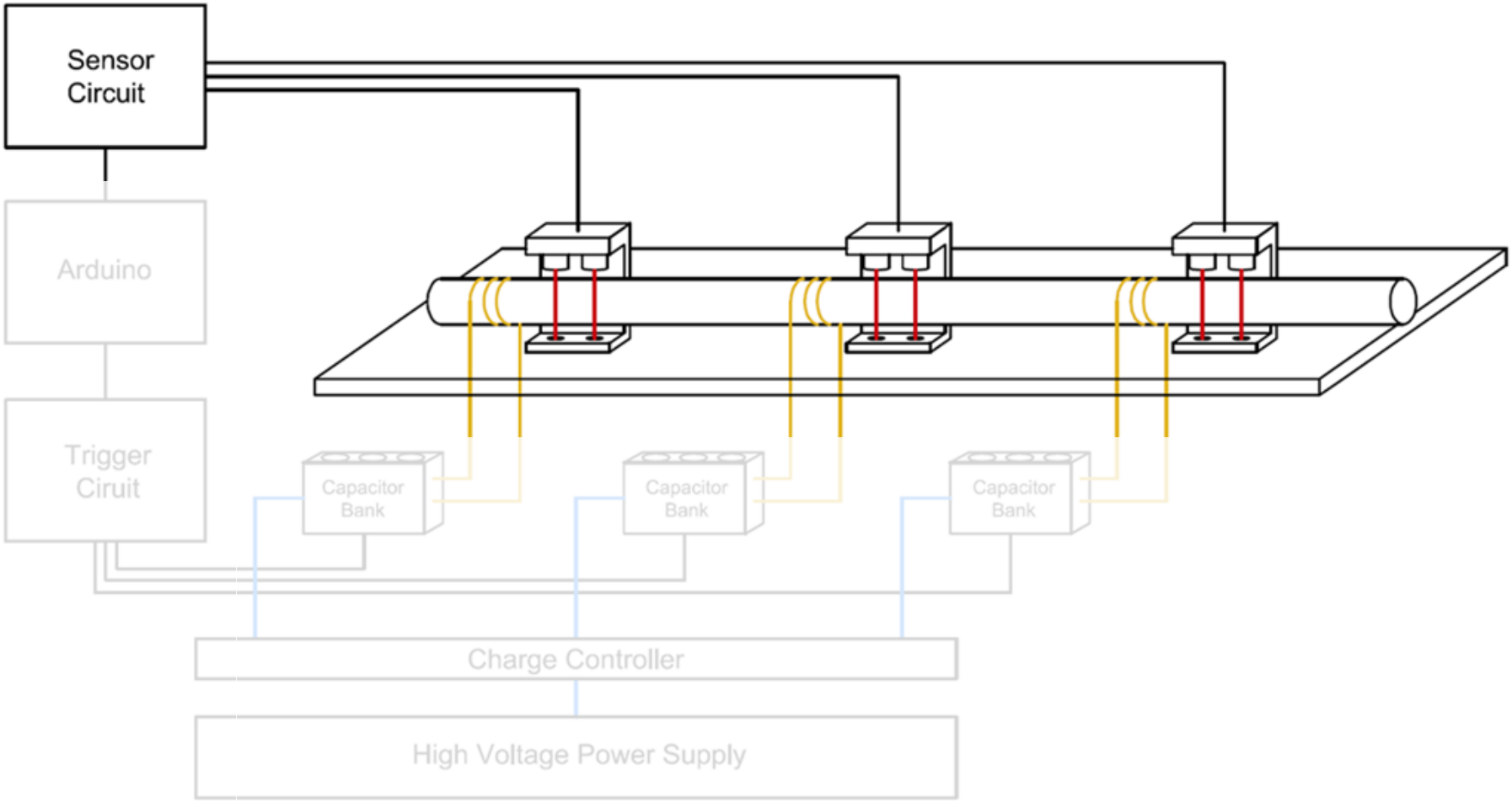
Charge Controller and HV Power Supply



Charge Controller and HV Power Supply

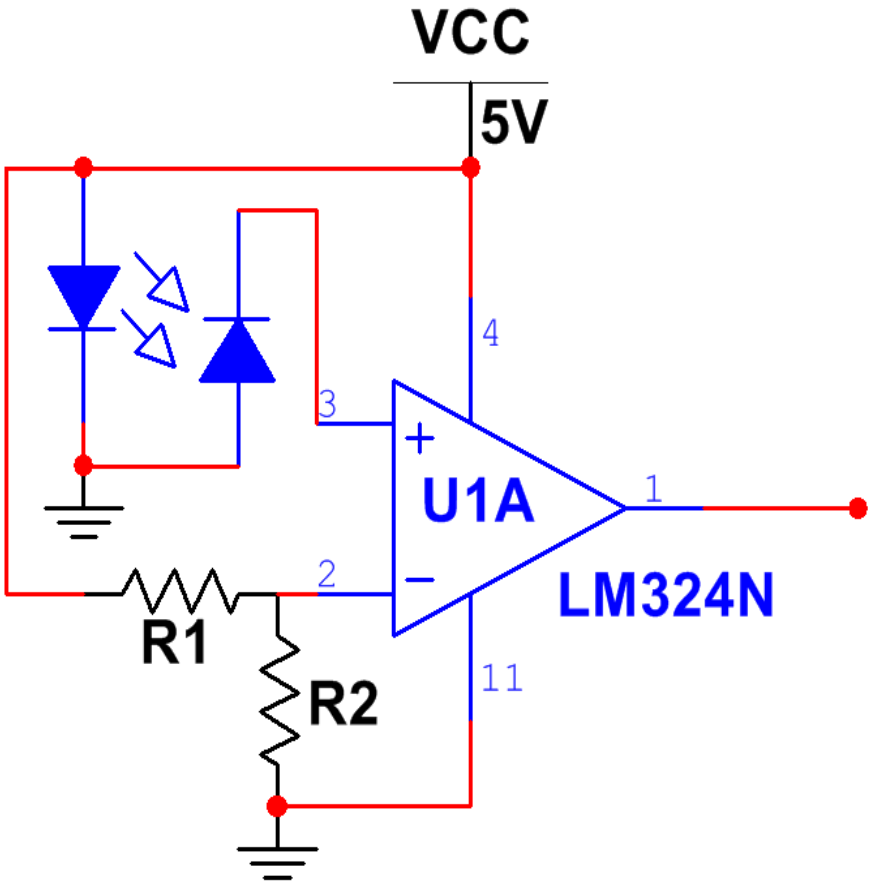


Sensor Circuit

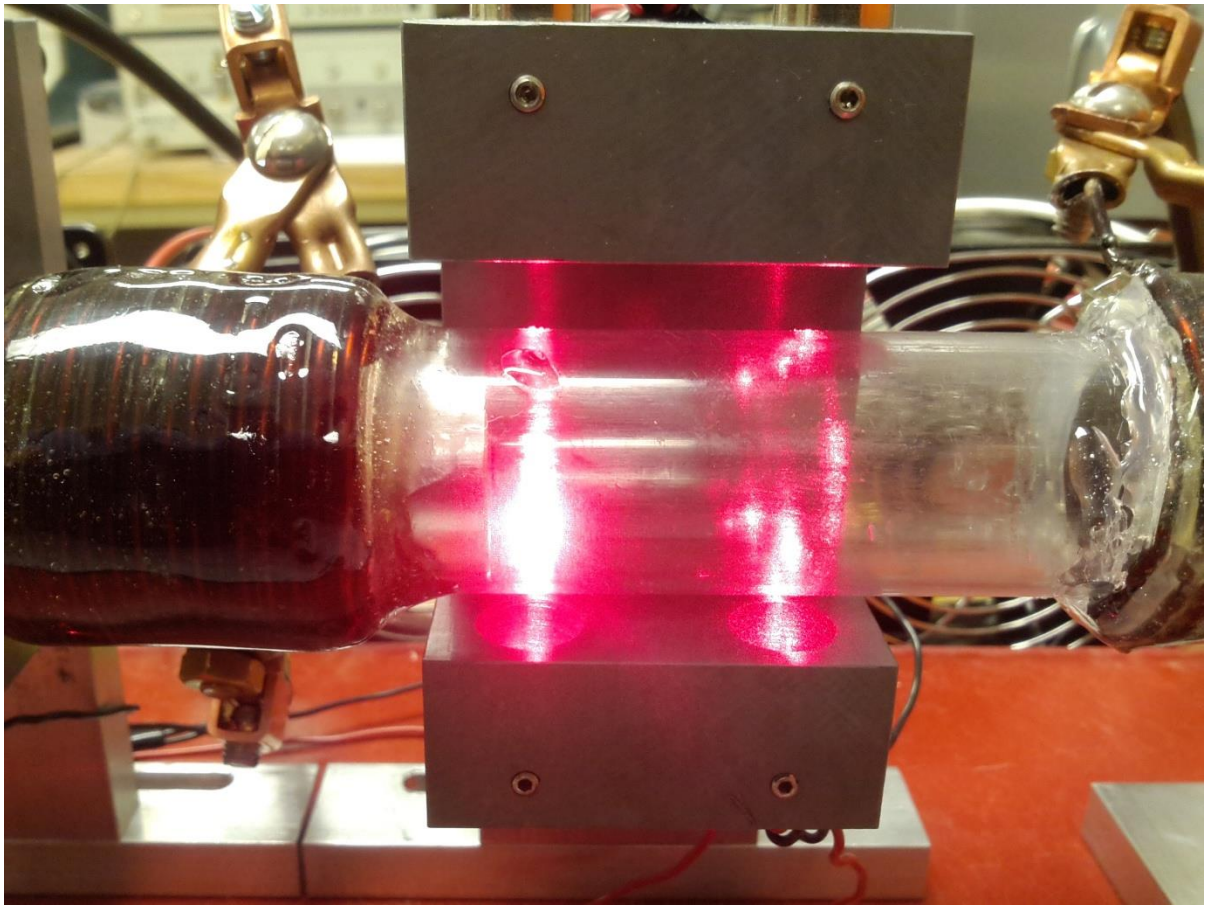


Sensor Circuit

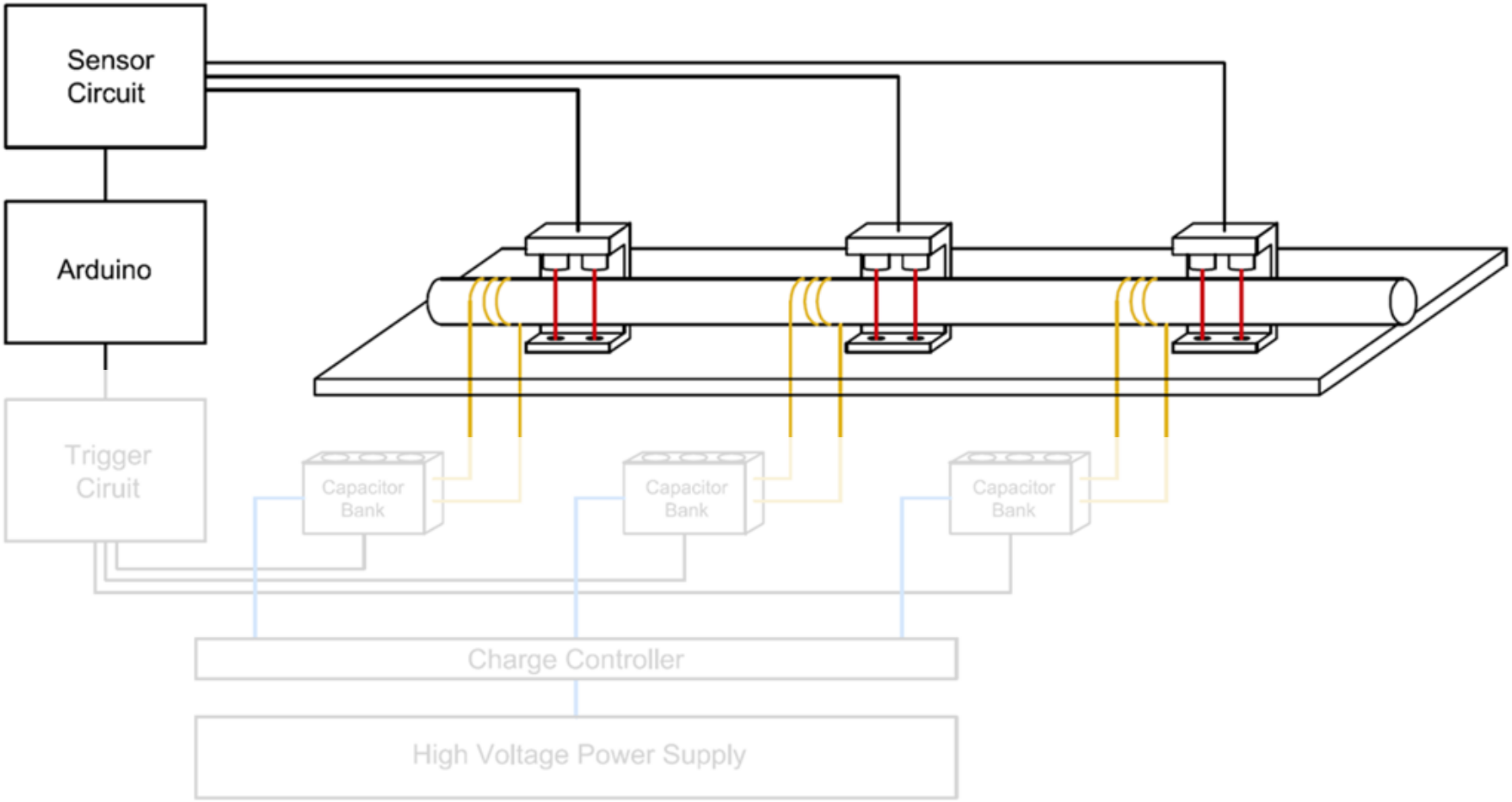
- Interface between lasers and Arduino
- Detects voltage drop when projectile passes lasers
- Outputs stable signal to Arduino



Sensor Circuit

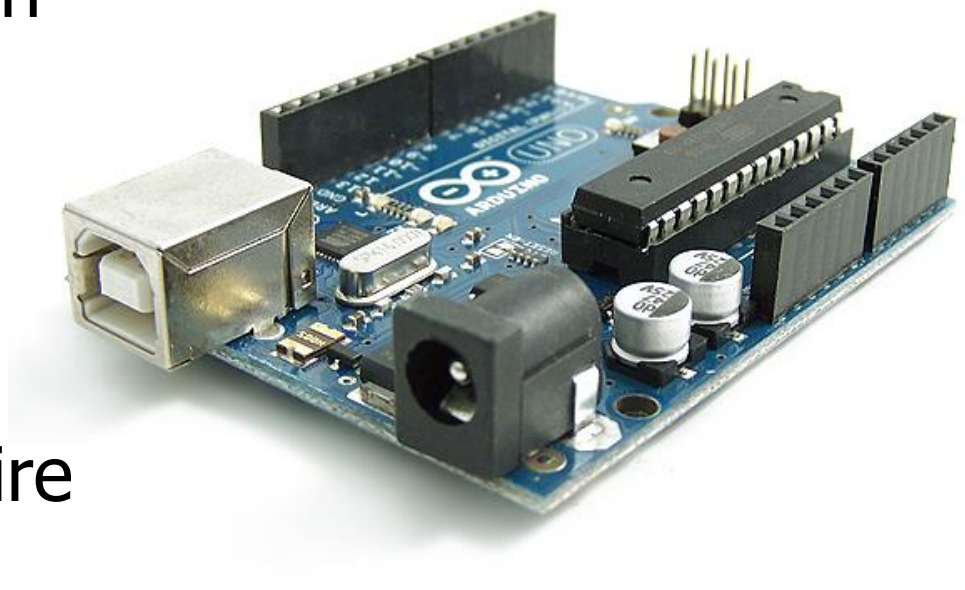


Microcontroller

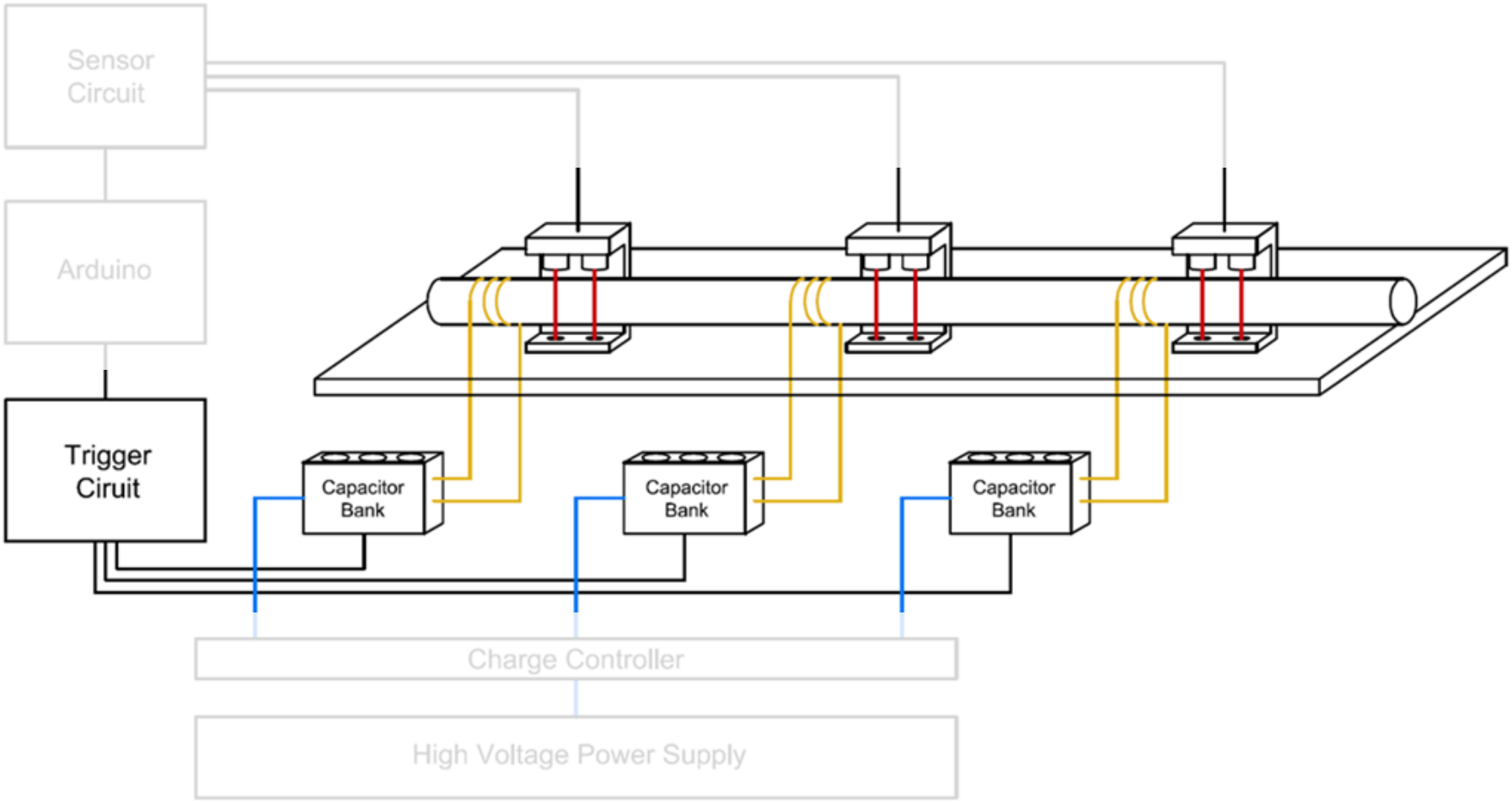


Microcontroller

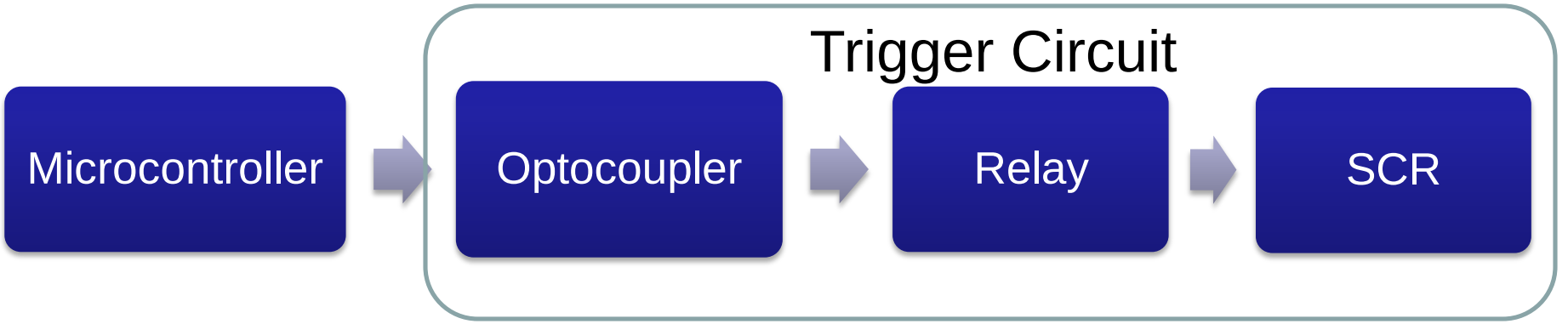
- Uses Arduino Uno
- Records times at which voltage of photodiode drops
- Calculates speed of projectile
- Determines when to fire next stage



Trigger Circuit

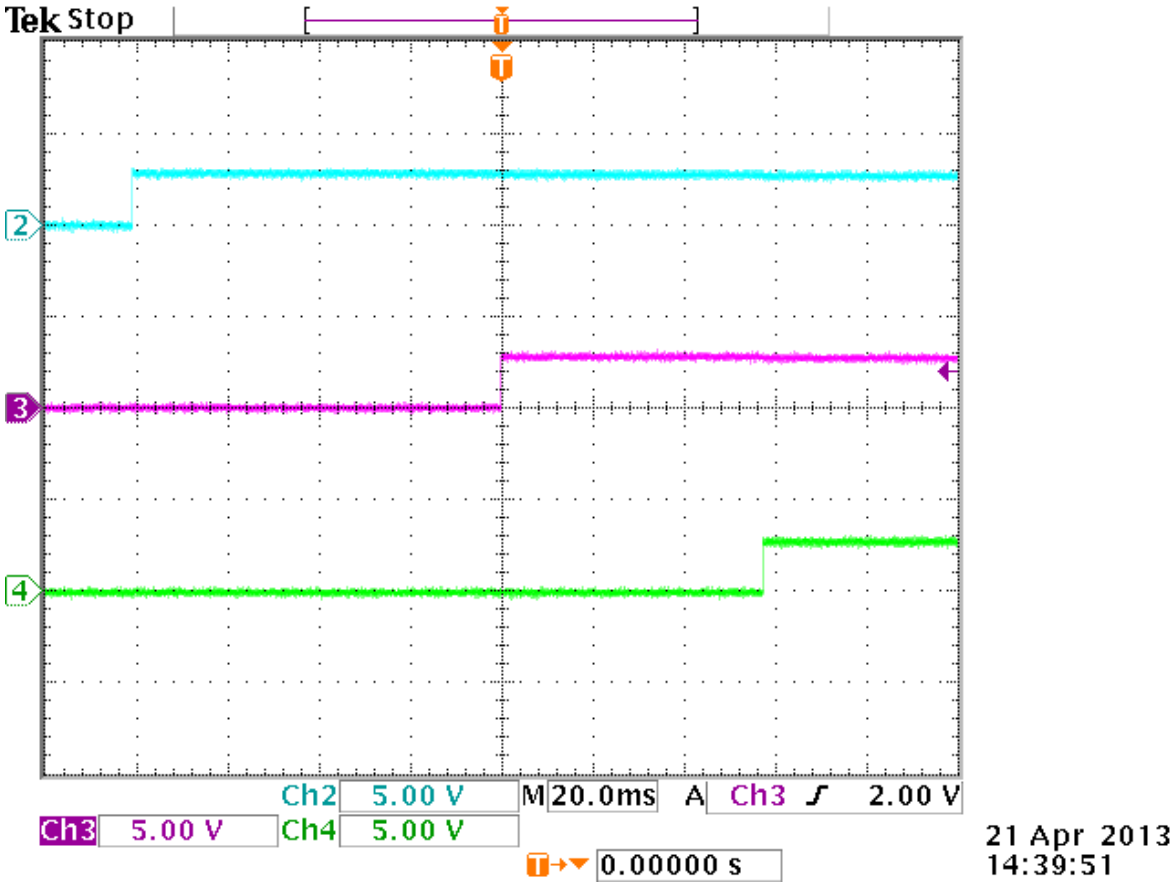


Trigger Circuit



- Optocoupler provides isolation from HV power supply
- Relay drives the gate of SCR to turn SCR on
- SCR remains latched on until all current is discharged

Trigger Circuit

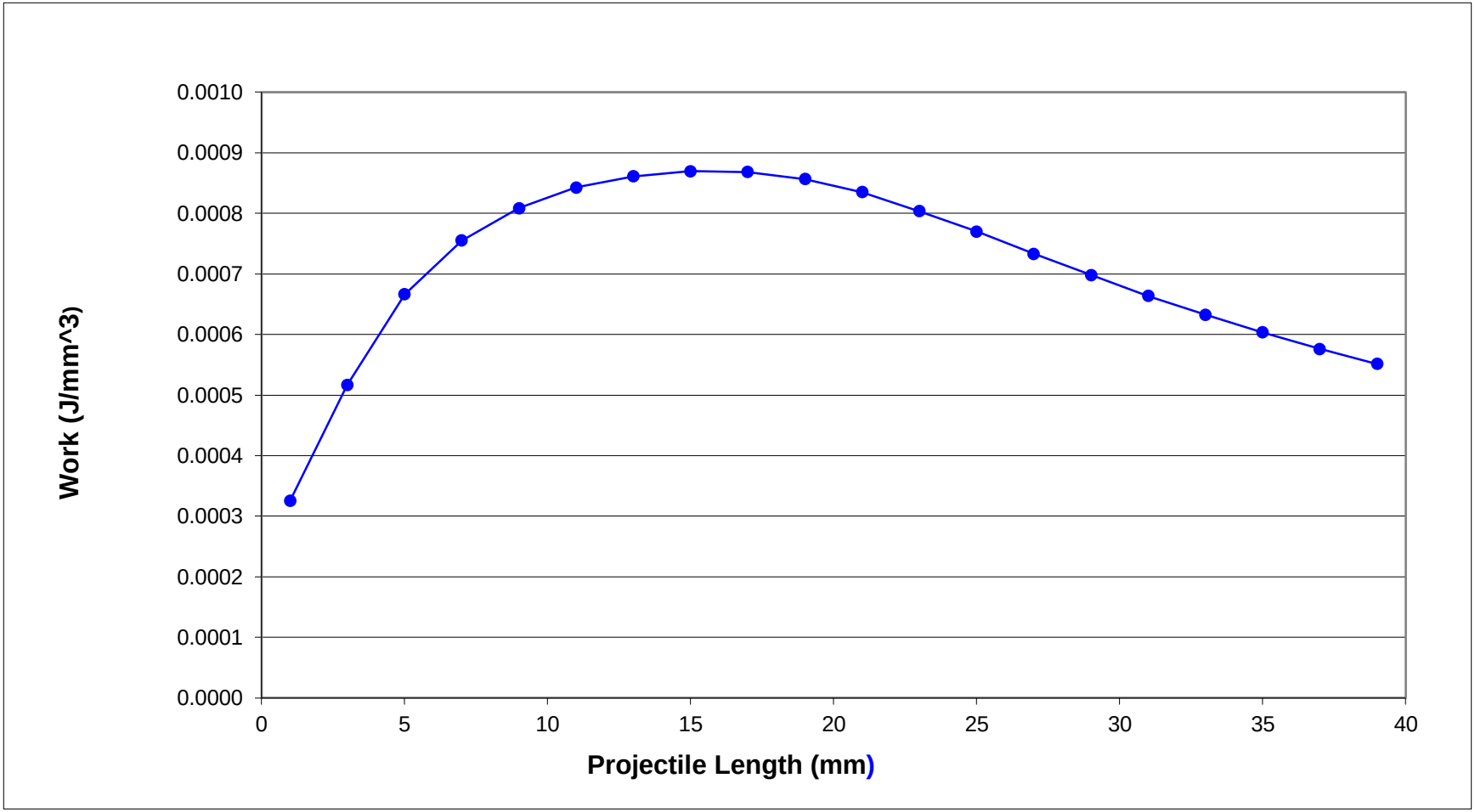


Sequential Triggering of Capacitor Banks

Coil Windings

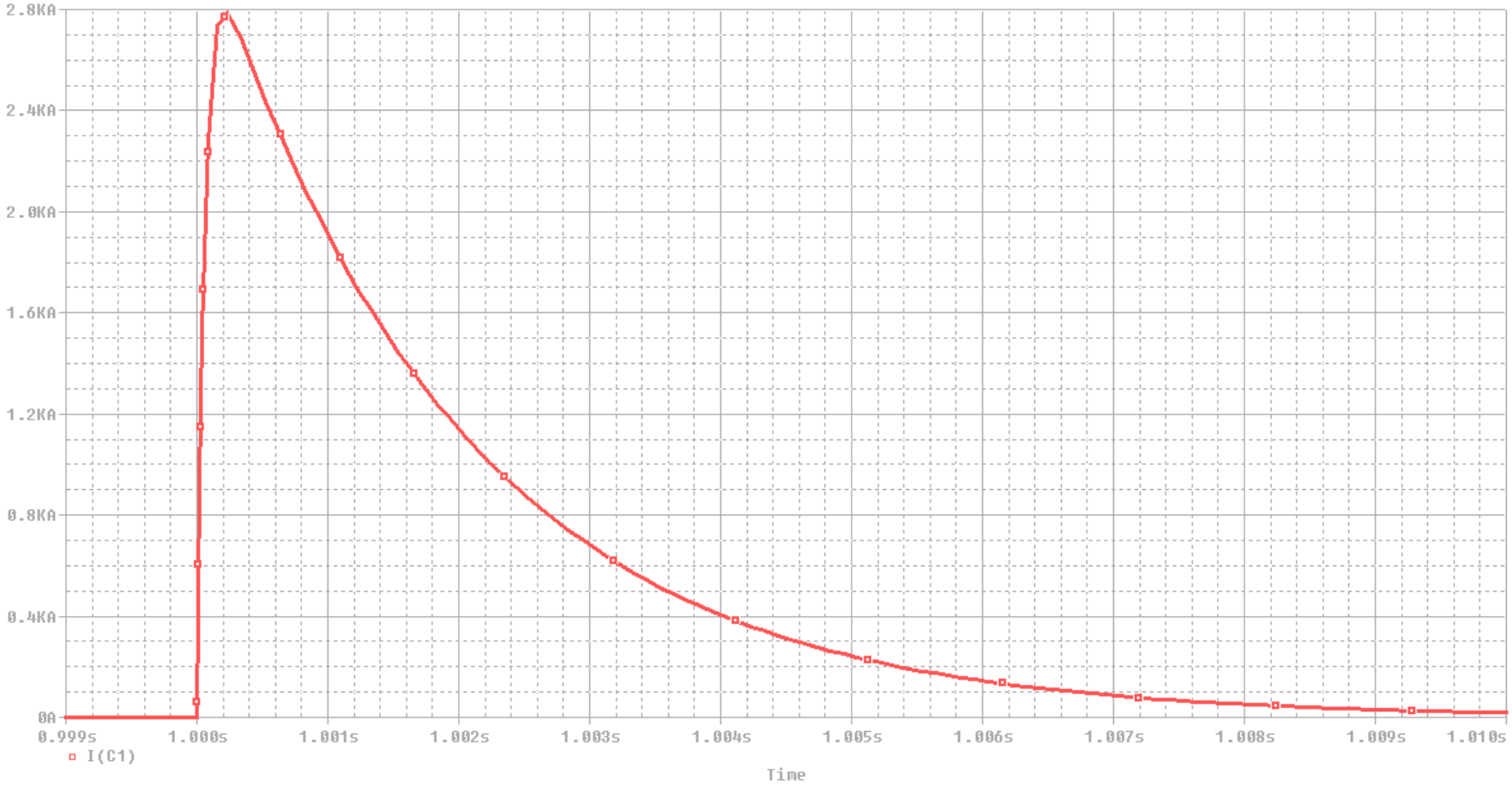
- Coil windings connected to each capacitor bank
- Design Considerations
  - Minimum resistance
    - Place two windings in parallel for each stage
  - Maximum mutual inductance
    - length of winding = length of projectile
    - diameter of winding = diameter of projectile

Simulations



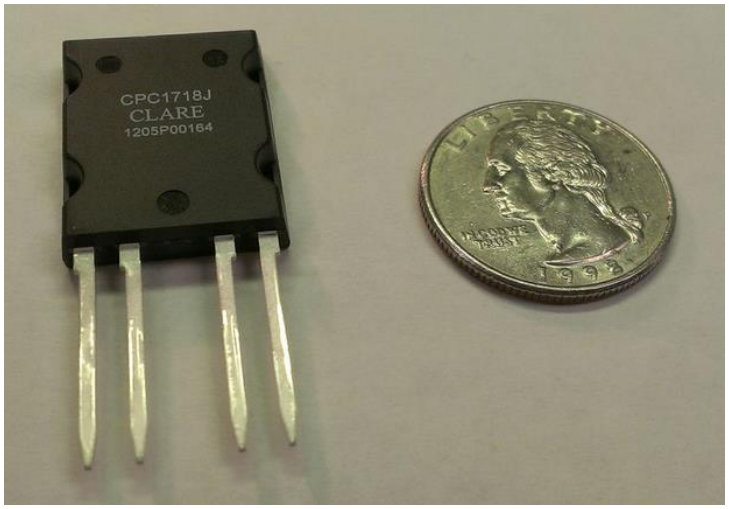
Energy per Volume (20mm coil) vs. Projectile Length [1]

Simulations



Peak Current Plot

Requirement	Verification
• Calculate and use speed of projectile to obtain discharge time	• Push projectile through barrel and ensure monitor displays logged times and speed
• 2400 V isolation between HV power supply and Arudino	• Ensure resistance across DC power relay is in 10MΩ range
• Relay output signal powerful enough to activate SCRs	• Ensure relay outputs 3V±20% with 500mA±20%



Challenges	Solutions
• False triggering from noise	• Decoupling capacitors
• High component stress	• Smaller diameter barrel • Operate at lower voltage
• High voltage safety	• Capacitor bank enclosure • Safety procedures
• Magnetic field interference	• Twisted wires to cancel magnetic fields • Shielded wire
• Arduino failure	• Proper grounding practice

Ethics

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.*

3. *To be honest and realistic in stating claims or estimates based on available data.*

7. *To seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others.*

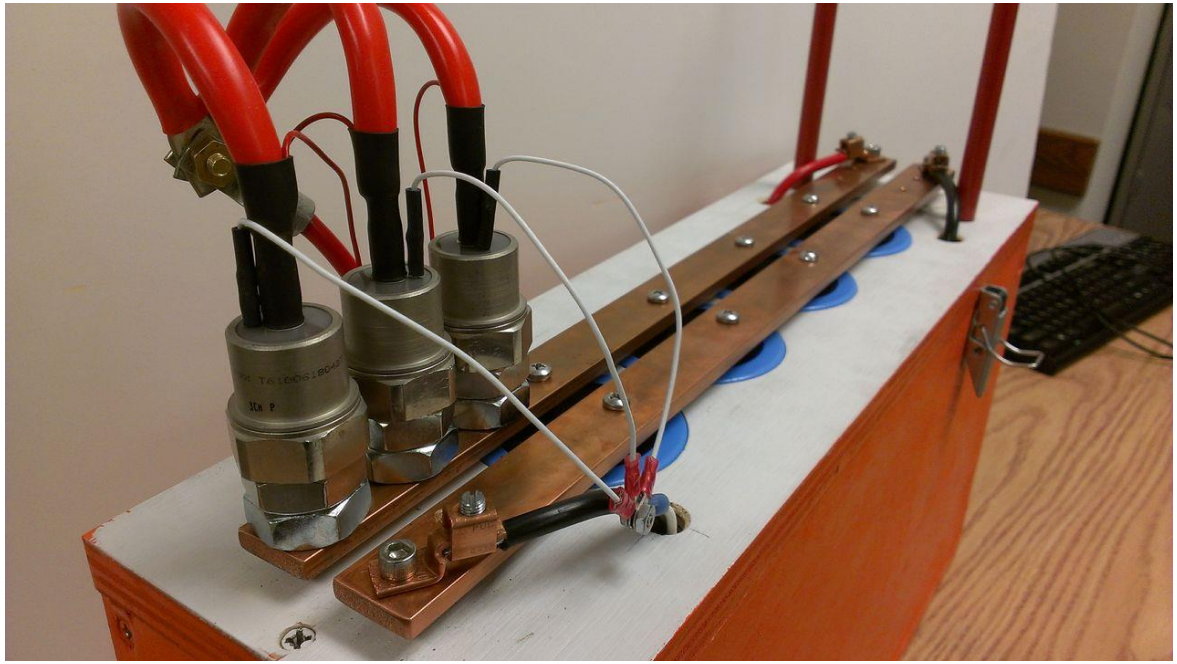
9. *To avoid injuring others, their property, reputation, or employment by false or malicious action.*

Safety Features

- Capacitor bank enclosures
- Capacitor bank shorting rods
- Side insertion plugs for wiring modularity

Safety Features

- Use of multiple SCRs in parallel
- Safety plans for connect/disconnect/operation



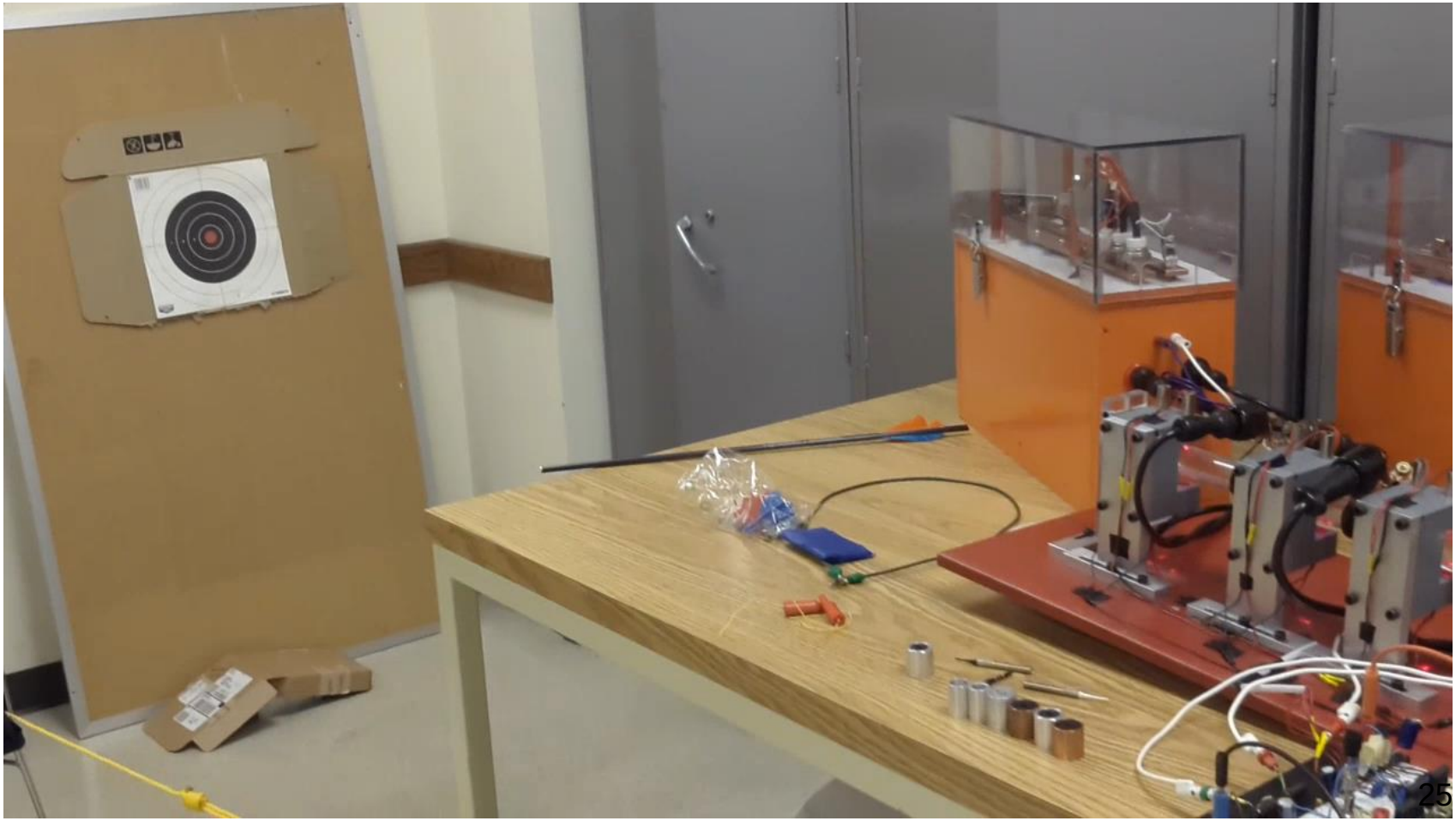
Engineering Open House

- Prototype demonstration successful
  - Won 2nd in "Back to School" category
  - Operated over 100 times over two days
  - Consistently achieved projectile speeds of 14-17 m/s

Engineering Open House

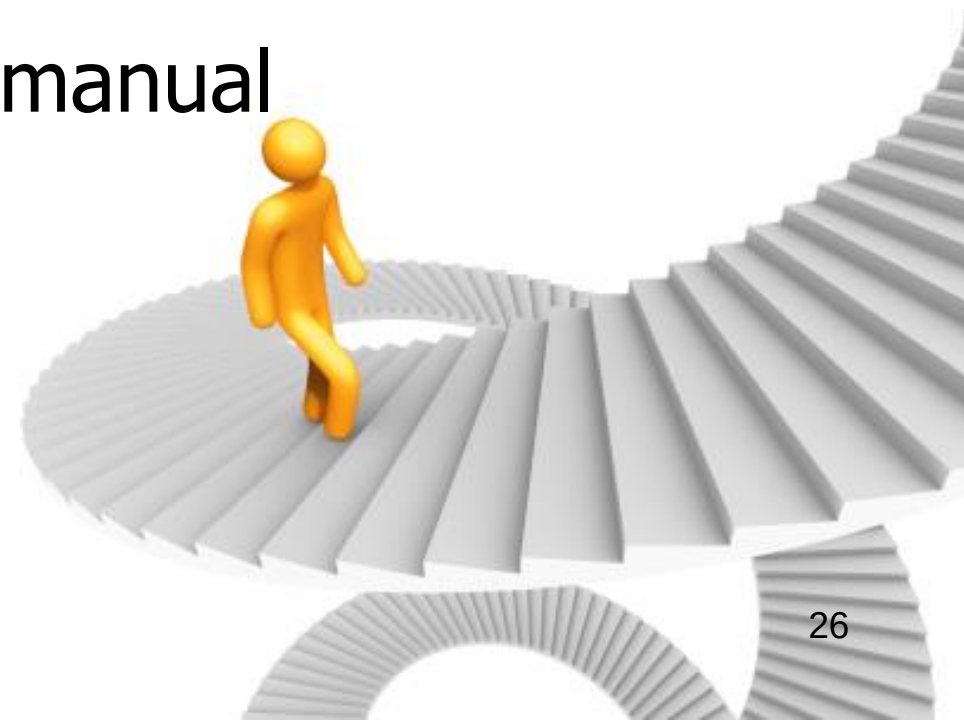
- Lessons Learned
  - Windings need to be more secure
  - Signals need to be immune from field interference
  - Need to lower current stress levels on SCR
  - Capacitor voltages can rise after disconnection

Functionality Demonstration



Next Steps

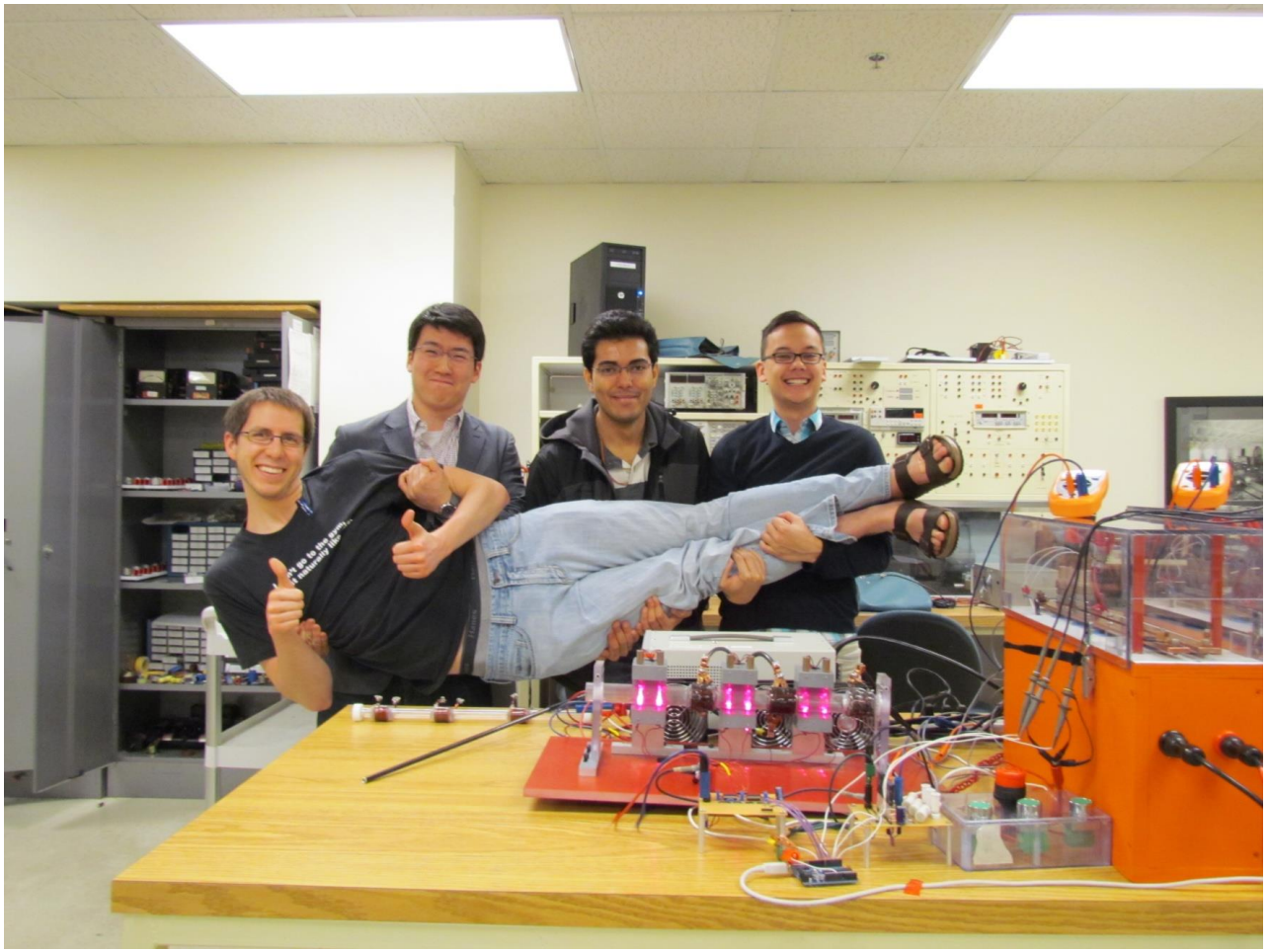
- Continue Coil Gun EOH exhibit
- Silk-screened PCB
- Enclosure for barrel
- Create operational manual



Thank You

- Special thanks to:
  - Ryan May
  - Karl Reinhard
  - Shawn Reinhard
  - Christopher Barth
  - Dr. Scott Carney
  - Friends from the Machine and Parts shop
  - Kevin Colravy

Questions?



References

[1] Hansen, Barry. (2013) *Solving Solid Cylindrical Projectile of various lengths.* Available: http://www.coilgun.info/femm/projectile_length/projectile_length_results.txt

[2] Paul, James. (2006) *Coilgun Basics.* Available: http://www.coilgun.eclipse.co.uk/coilgun_basics_1.html