#20 - Direct Drive Solar Powered Arcjet Thruster

SPONSOR – NASA, MARSHALL SPACE FLIGHT CENTER, HUNTSVILLE AL

ADVISORS – DR. GUO, DR. KWAN, DR. ANDREI

SENIOR DESIGN COORDINATORS – DR. AMIN, DR. FRANK

Team Members

Date – 10/24/13

Chris Brolin - ME
Cory Gainus - ME
Gerard Melanson - ECE
Tara Newton - ME
Griffin Valentich - ME
Shane Warner - ECE

Griffin Valentich

Agenda

- Background
- Objectives
- Mechanical Designs
- Electrical Designs
- Potential Challenges/Safety
- Future Plans

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Background

- Electrical propulsion systems
    - High specific impulse – low thrust
  - Electrothermal thruster– arcjet
    - Produce thrust by heating gas propellant (Ar) and expelling through C-D Nozzle
  - Electromagnetic thruster – MPD
    - Accelerates particles with applied magnetic force
- Purpose of Electric Propulsion Systems
  - Station keeping – lower overall lifetime costs
  - Satellite altitude adjustment
- Power Processing Unit (PPU)
  - Expensive and complex
  - Largest prohibitive component to electronic propulsion systems
  - Converts input power to correct current and voltage

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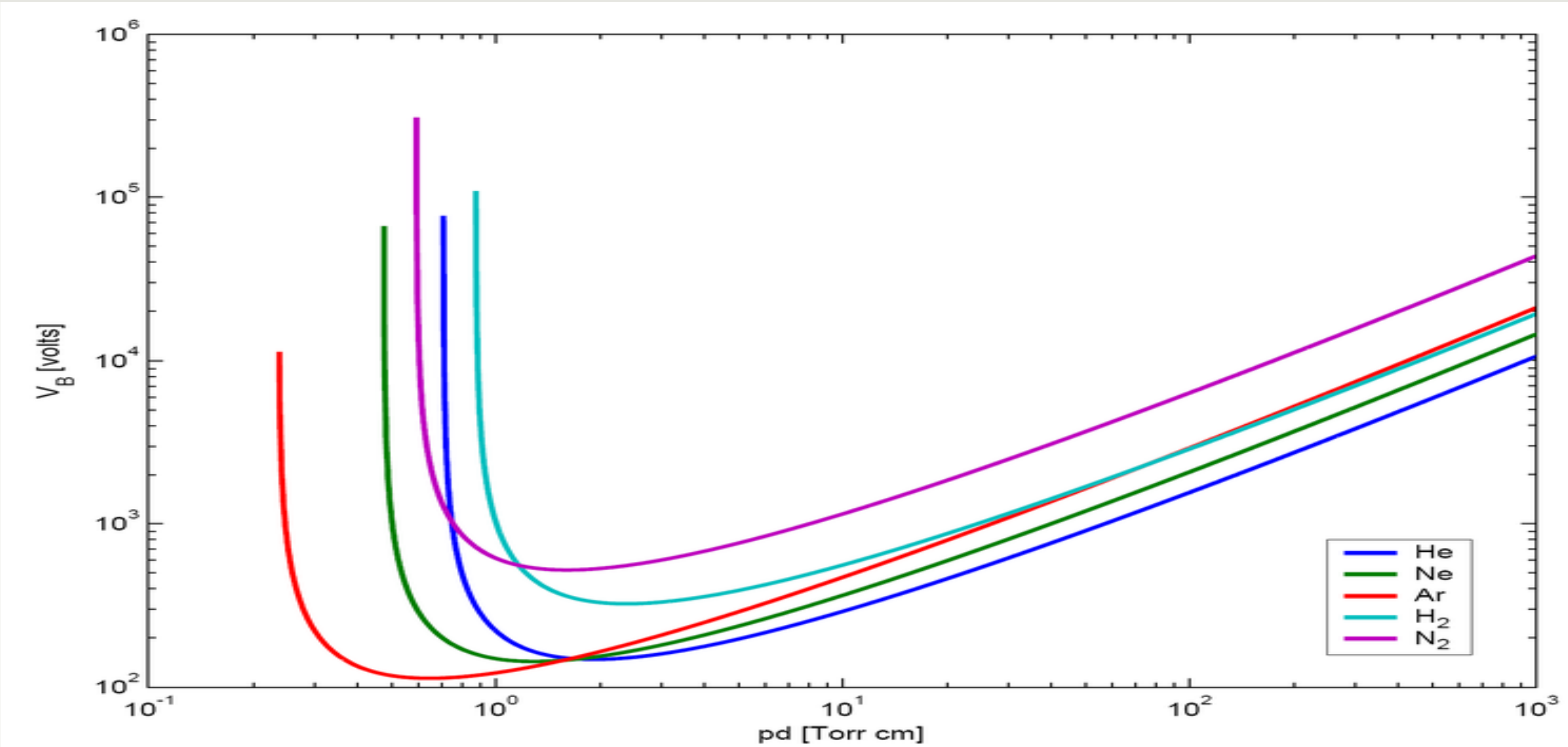
Paschen’s Curve



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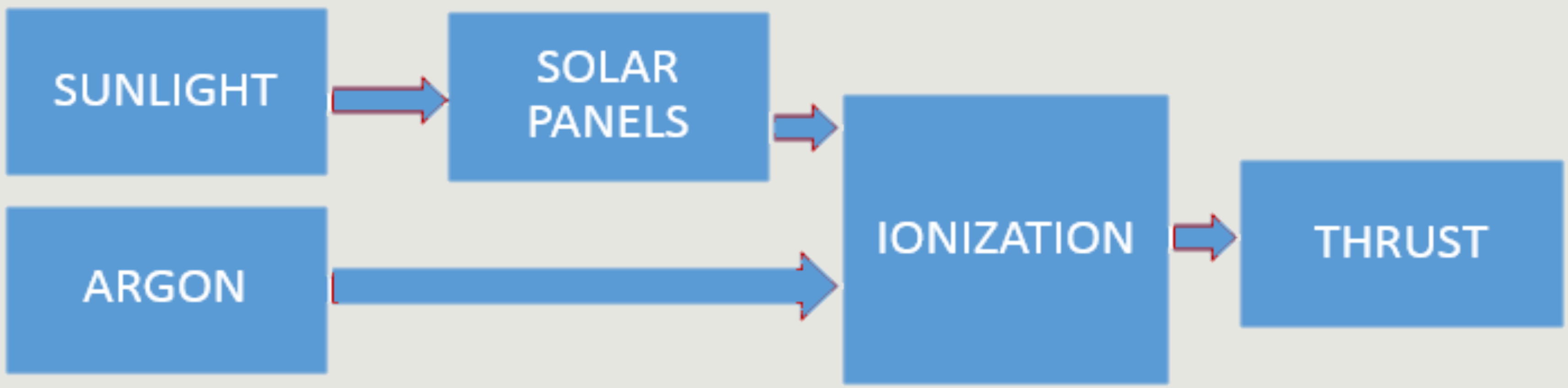
General Flow Diagram



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Objectives

- **Eliminate the PPU**
  - Enable thruster to operate in Direct-Drive Mode
  - Obtain power directly from solar panels
- Design, manufacture, and test an arcjet thruster
  - Utilize permanent magnets to confine plasma
  - Independently control propellant flow
  - Create vacuum chamber
  - Measure thrust produced
- Quantify the range of operating conditions over which thruster is effective

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Mechanical Designs

- Required Components
  - Cathode/Anode – Tungsten / Stainless Steel
  - Fuel Supply – Argon / Helium Gas
  - Heating Chamber
  - Nozzle
  - Vacuum Chamber

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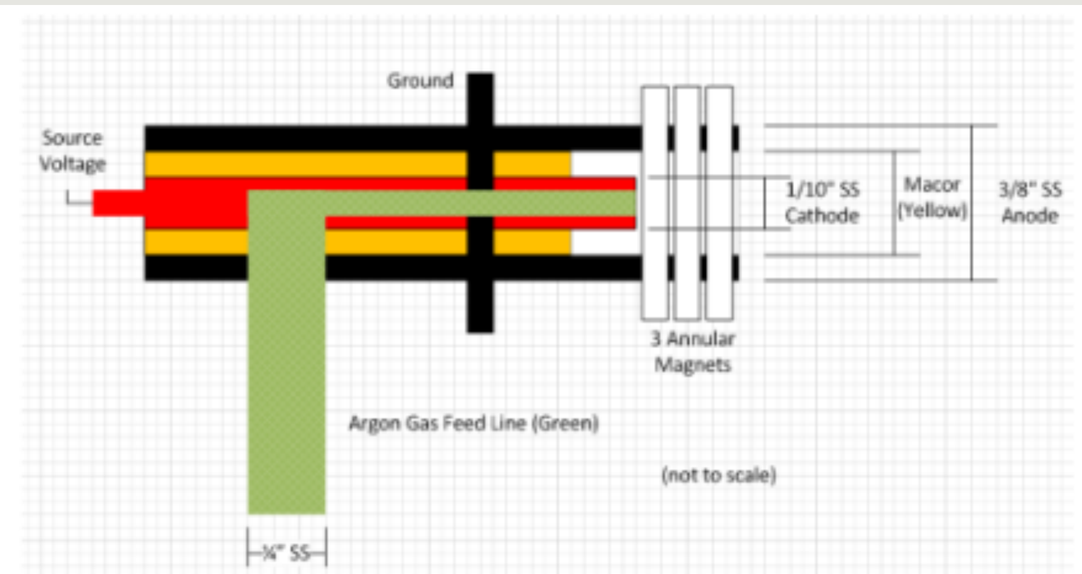
Design 1



Design by Nicolas Rongione

Characteristics

- Straight Channel Nozzle
- Gas fed through cathode tube
- Cathode concentric with Anode
- Magnetic Nozzle

Pros

- Simple Design
- Well insulated
- Easy to connect to circuit

Cons

- Gas flow through arc in question
- Low Thrust
- Expensive Materials (Macor)

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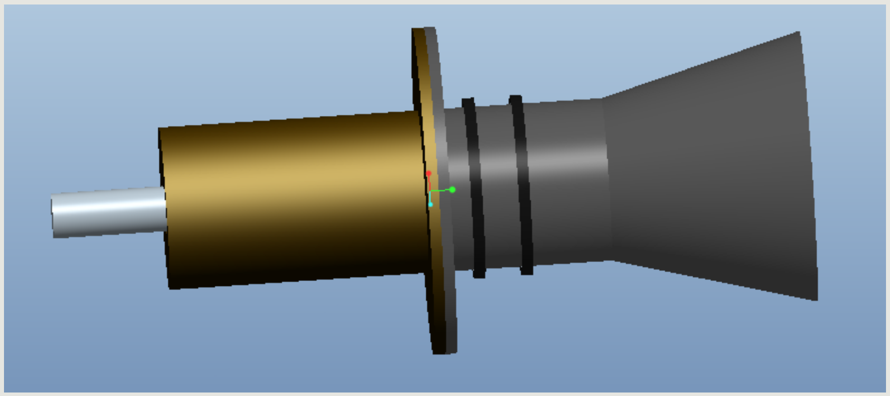
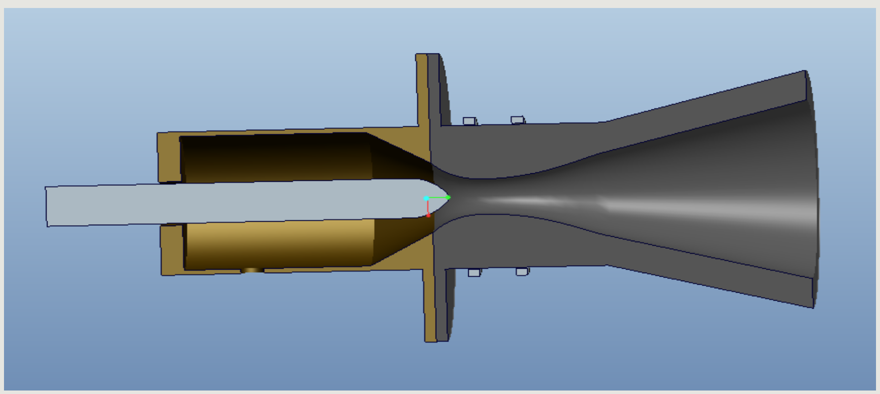
Design 2





Characteristics

- C-D Nozzle
- Gas injected perpendicular to cathode
- Nozzle acts as anode
- Nozzle magnetized by permanent magnets

Pros

- Minimal number of mechanical components
- Potential for more thrust with C-D nozzle
- Easy to complete circuit

Cons

- Difficult to manufacture with flange placement show
- Uncertainties in how magnets will interact with meta
- Magnet placement

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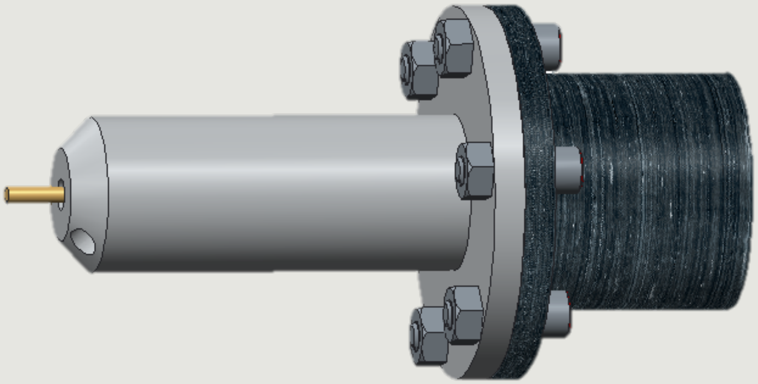
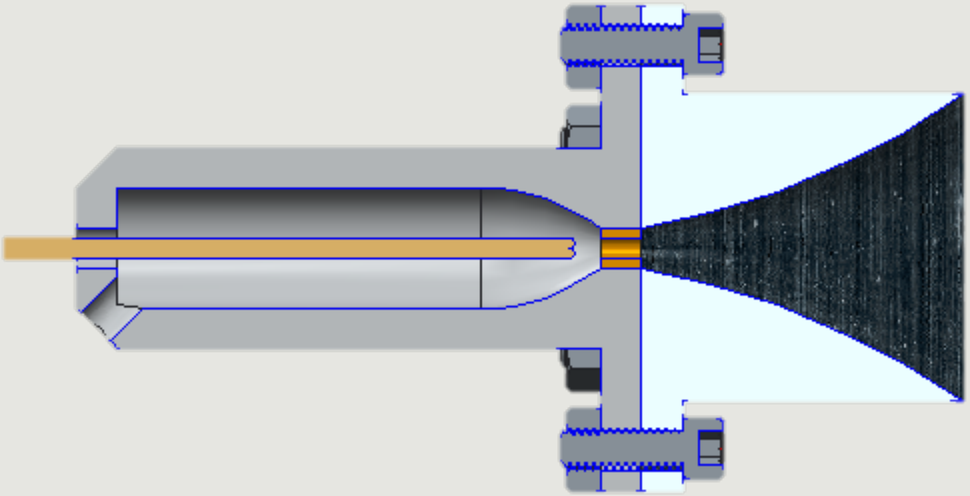
Design 3





Characteristics
- Gas injected at angle
- Annular anode insulated from rest of nozzle
- Magnets more evenly spaced over nozzle

Pros
- Swirling gas helps to keep nozzle walls cool
- Metal nozzle is not part of circuit
- Magnets on diverging nozzle protect nozzle wa
- Conventional nozzle construction

Cons
- More difficult to place magnet at throat with flange location
- Difficult to complete circuit due to anode placement

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Electrical Designs

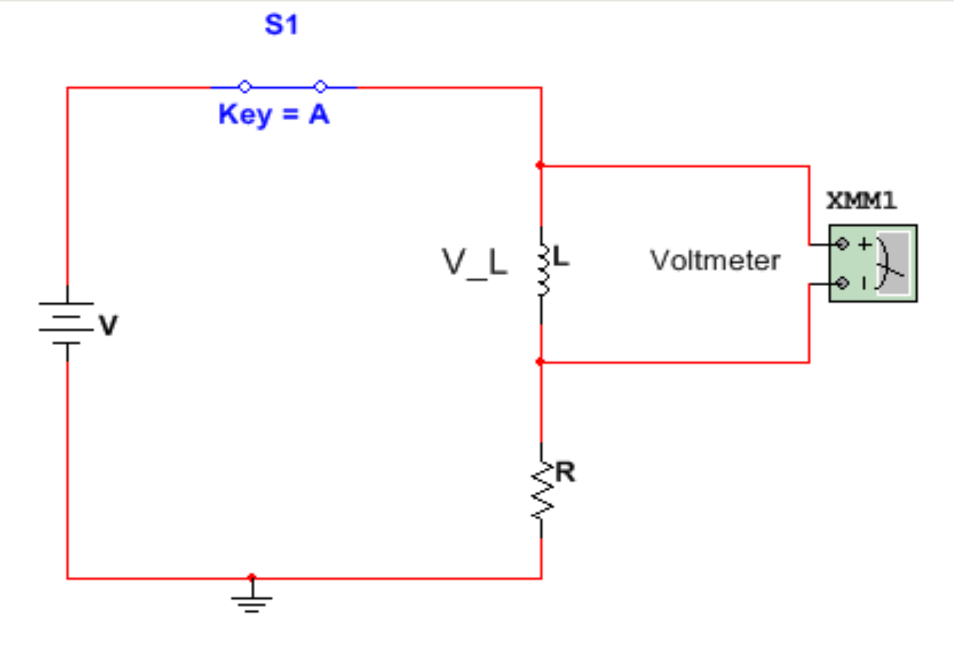
2 Major Designs Needed

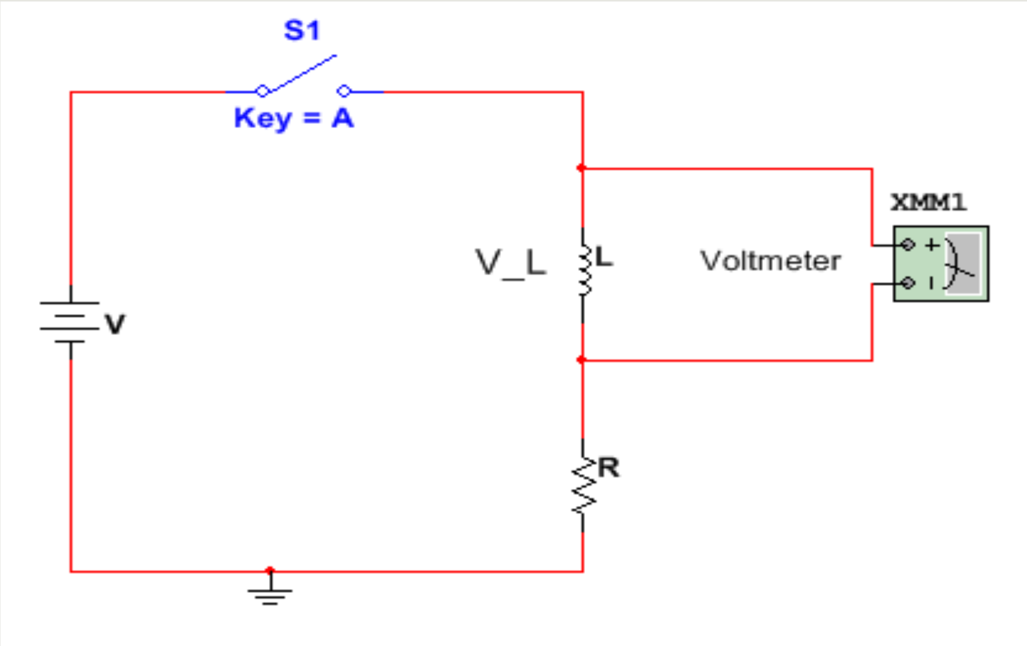
1.) Design a circuit that uses the four Aleko 100 W solar panels to first generate a voltage spike across the anode-cathode region high enough to achieve breakdown of the gas, and then produces a high enough current to maintain the plasma field

2.) Design a magnet configuration that focuses the positive ions in order to both increase thrust and also protect the thruster from the heat

Gerard Melanson

Inductor Circuit Explained





Once in steady state: I = $\frac{V}{R}$

When the switch opens: $V\_L = L\frac{di}{dt} = L\frac{I-0}{dt}$

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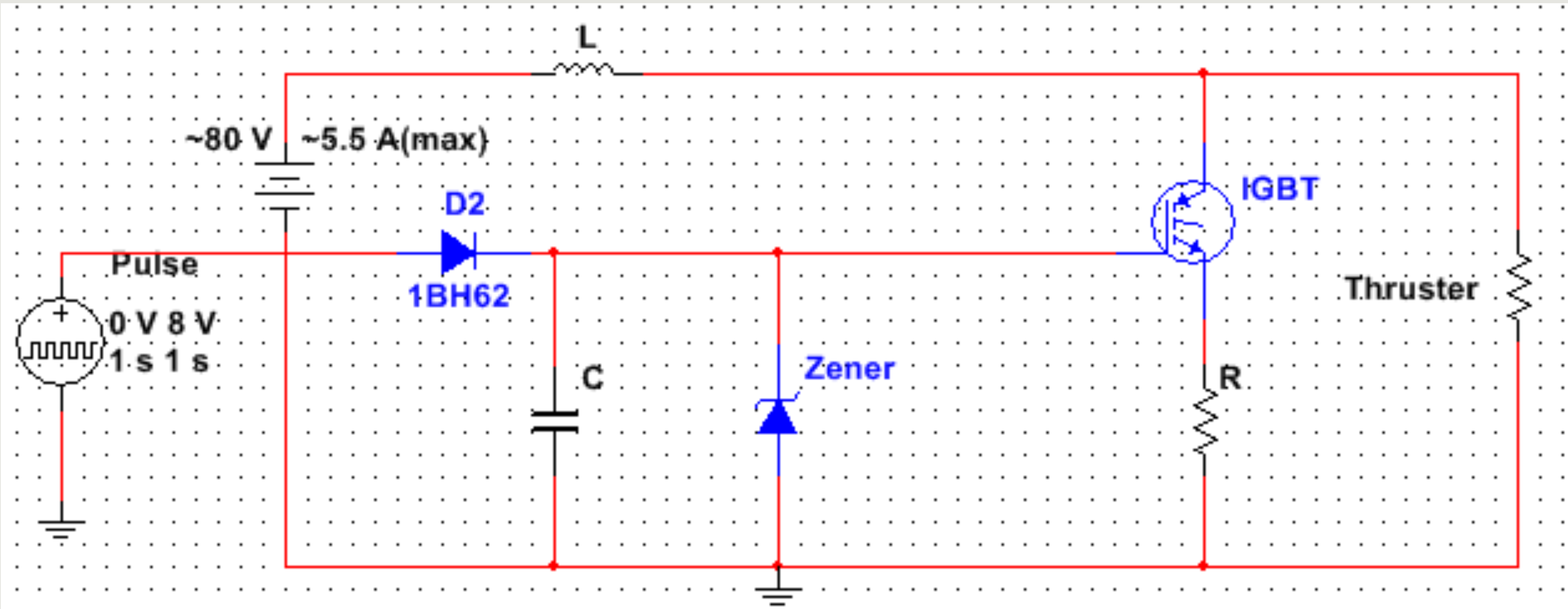
Full Circuit Design



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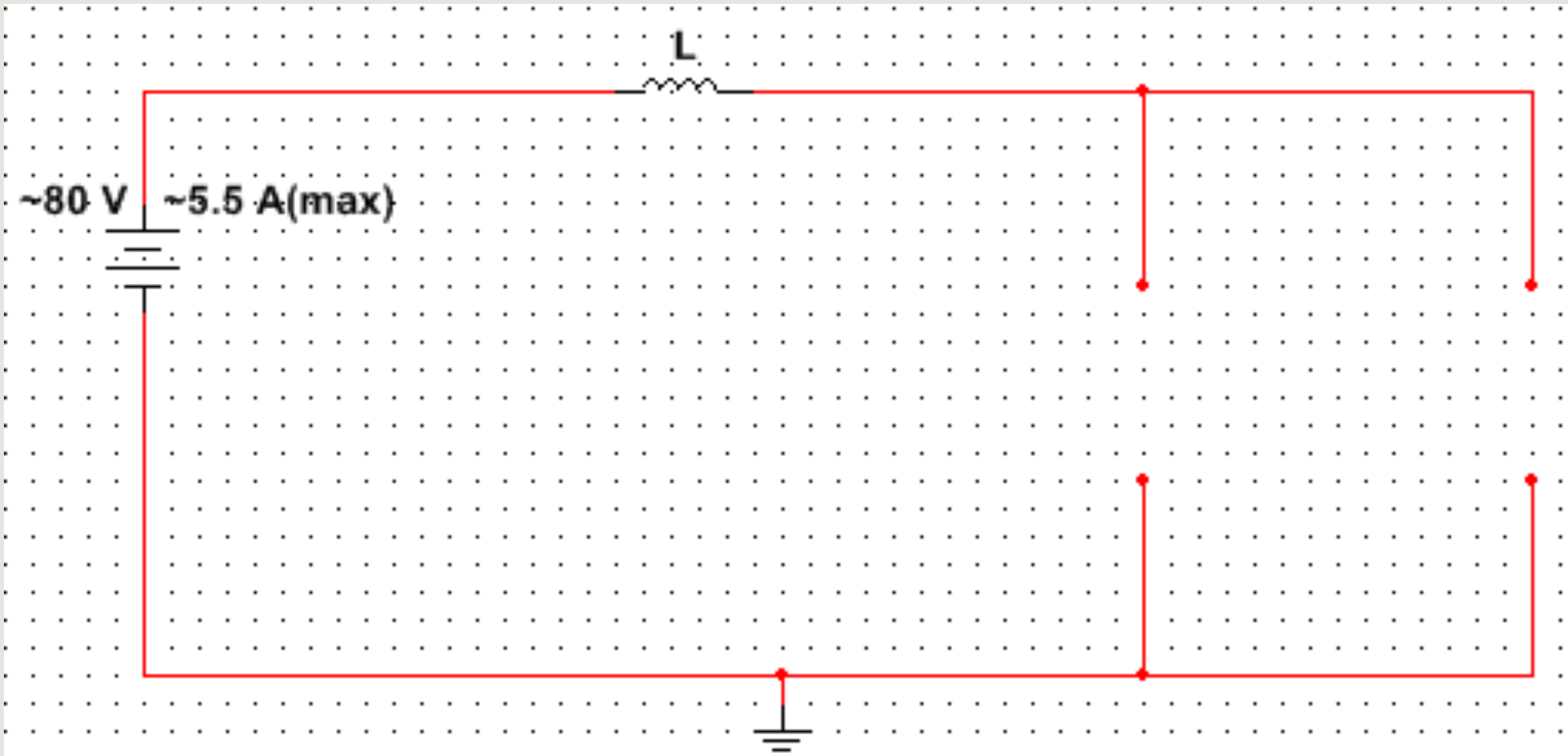
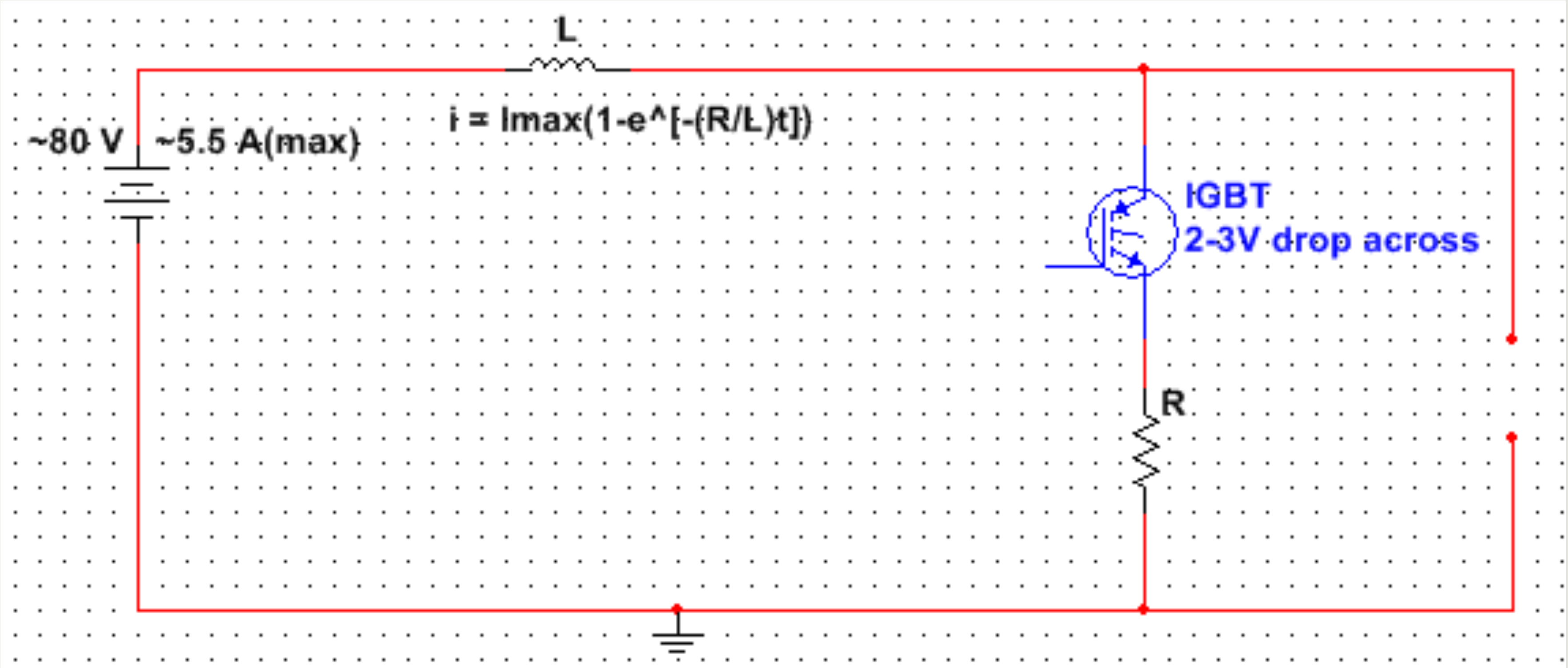
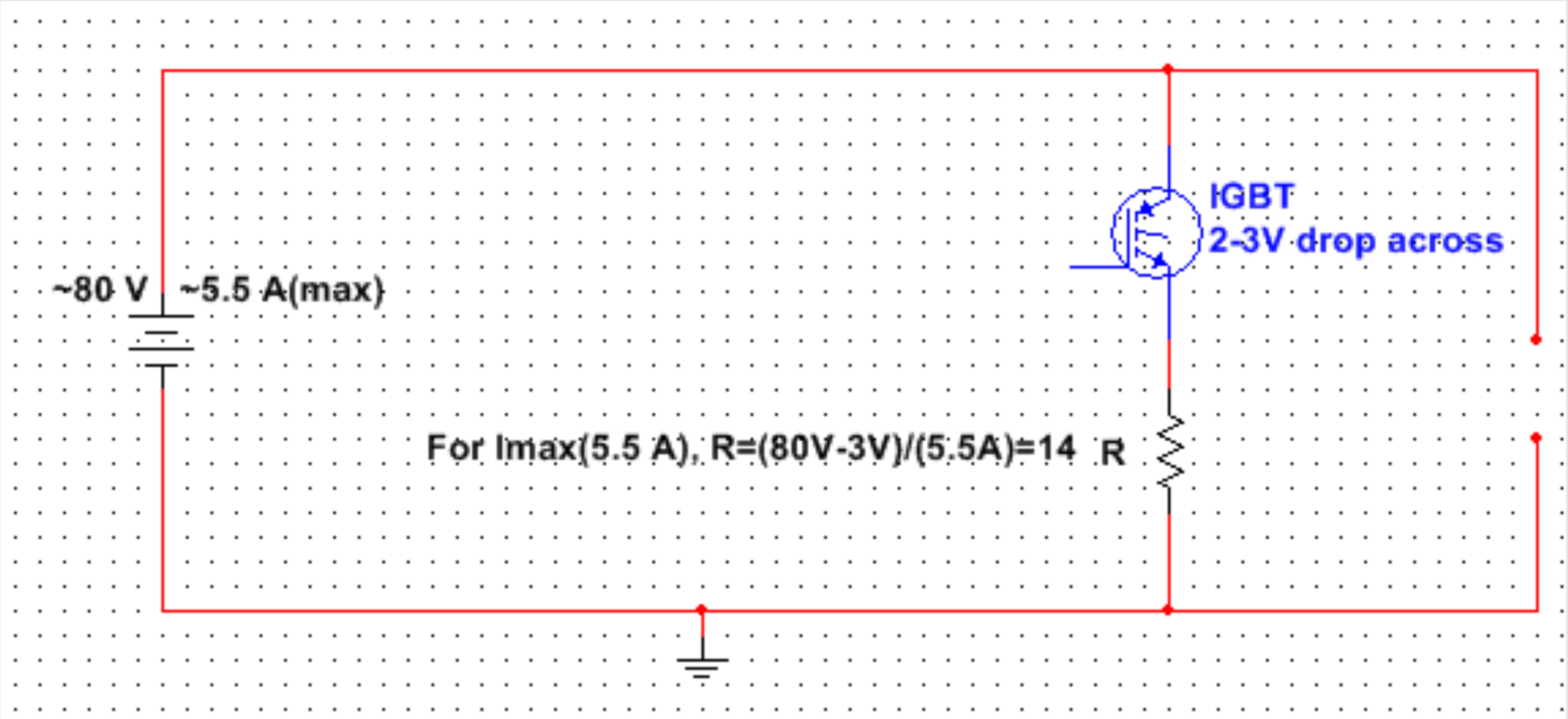
Before Pulse



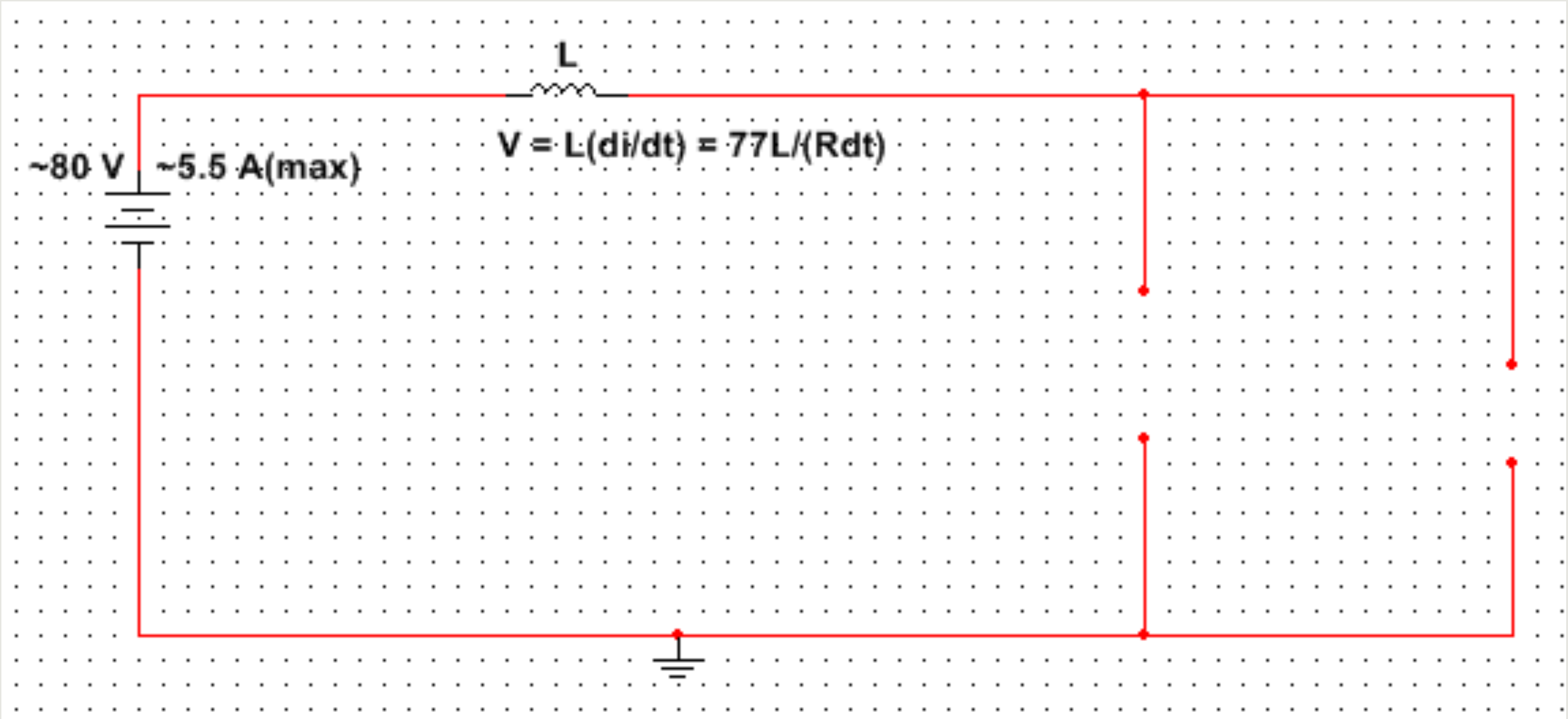
Right After Pulse Starts



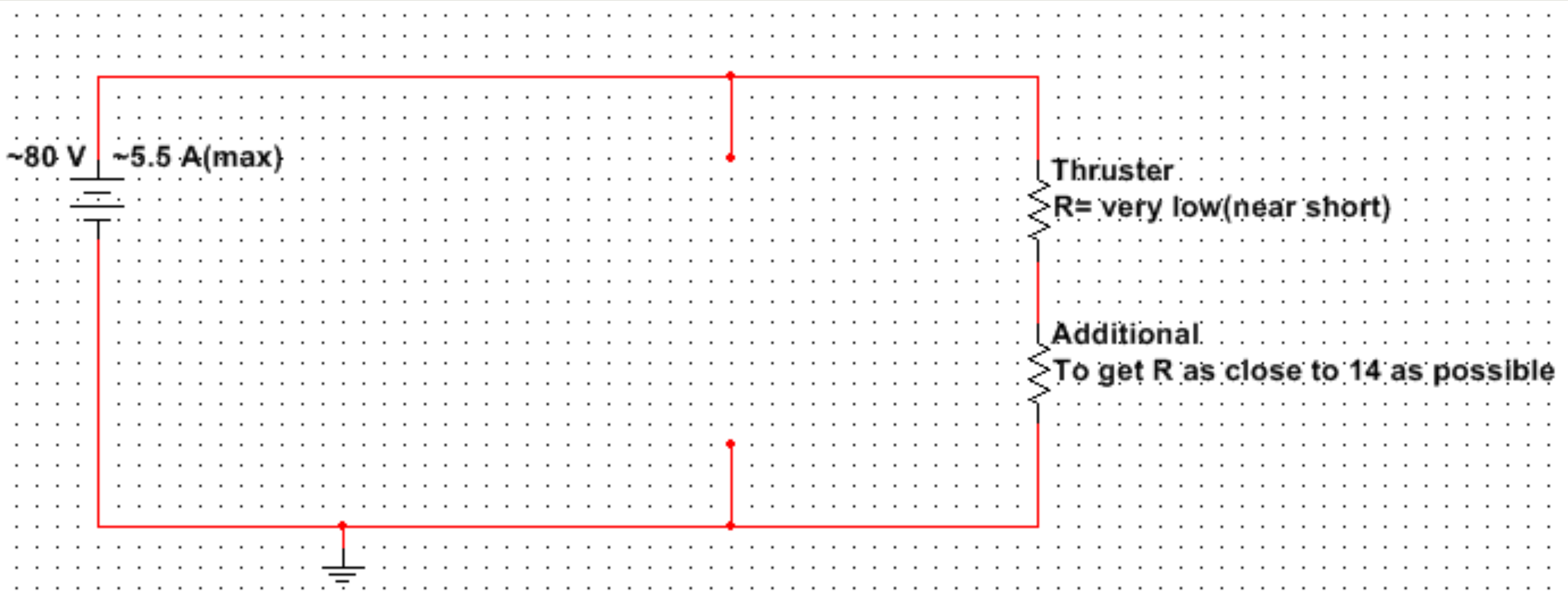
After Reaching Steady State



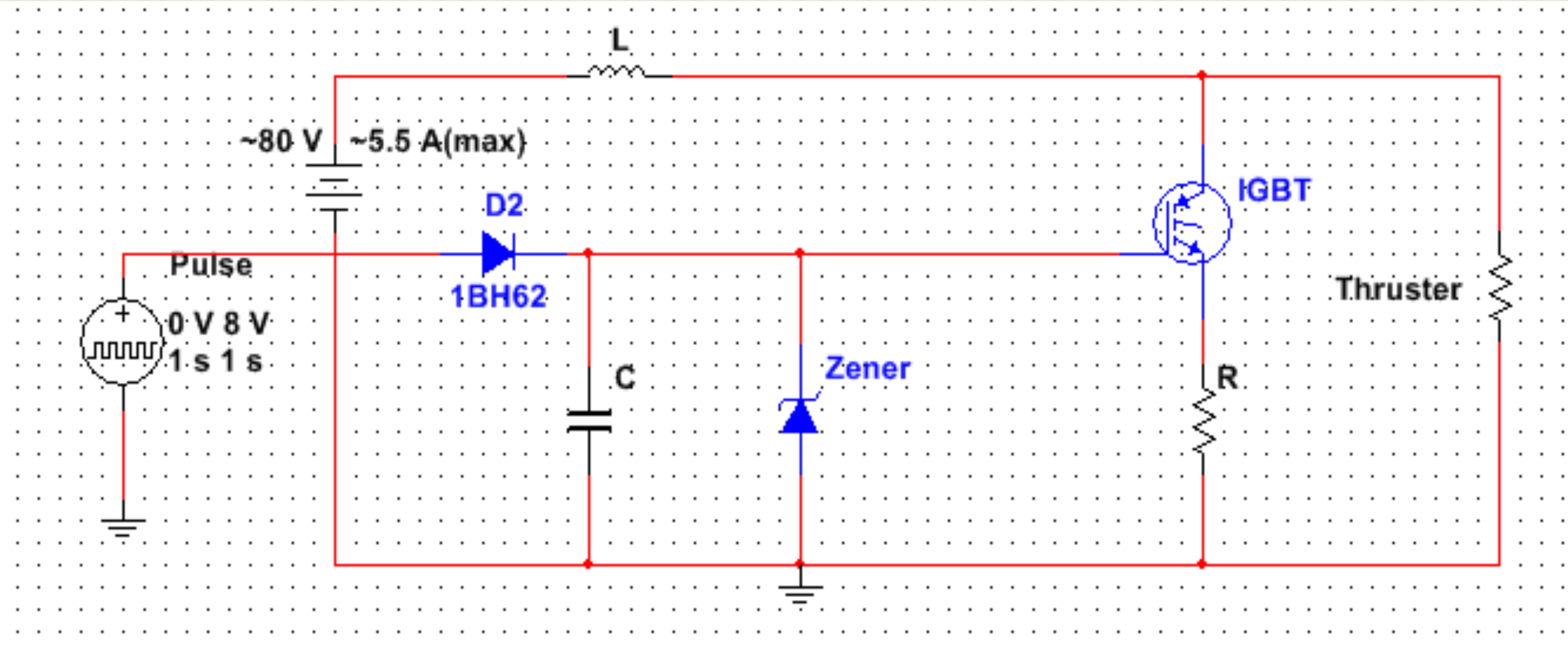
When Pulse Ends



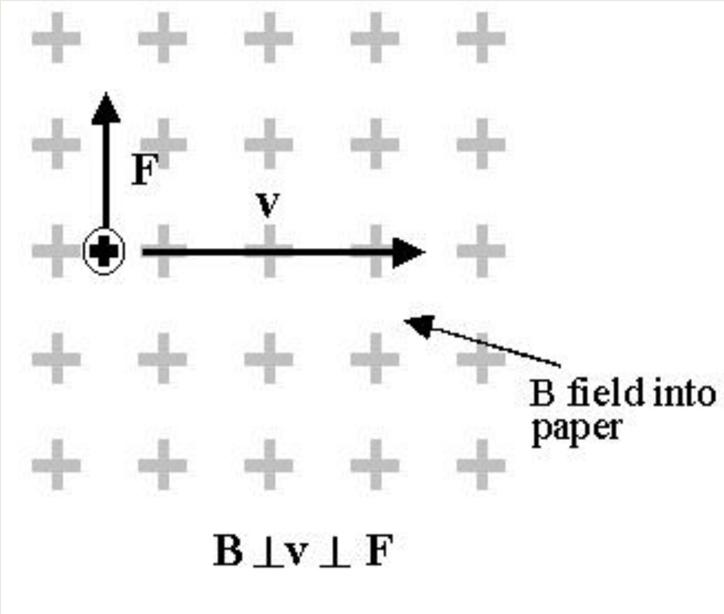
After Reaching Steady State



Full Circuit



Magnet Design



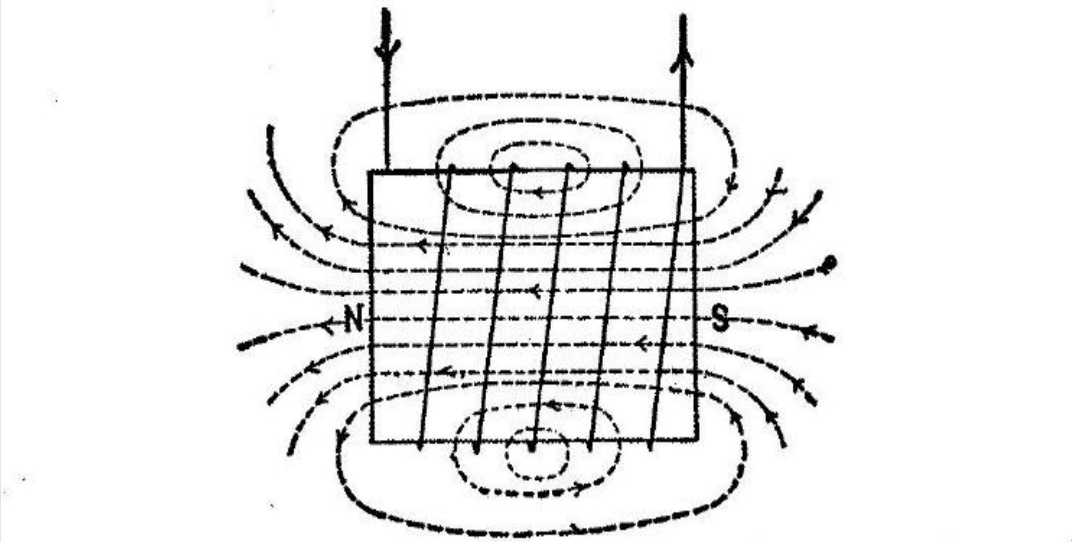
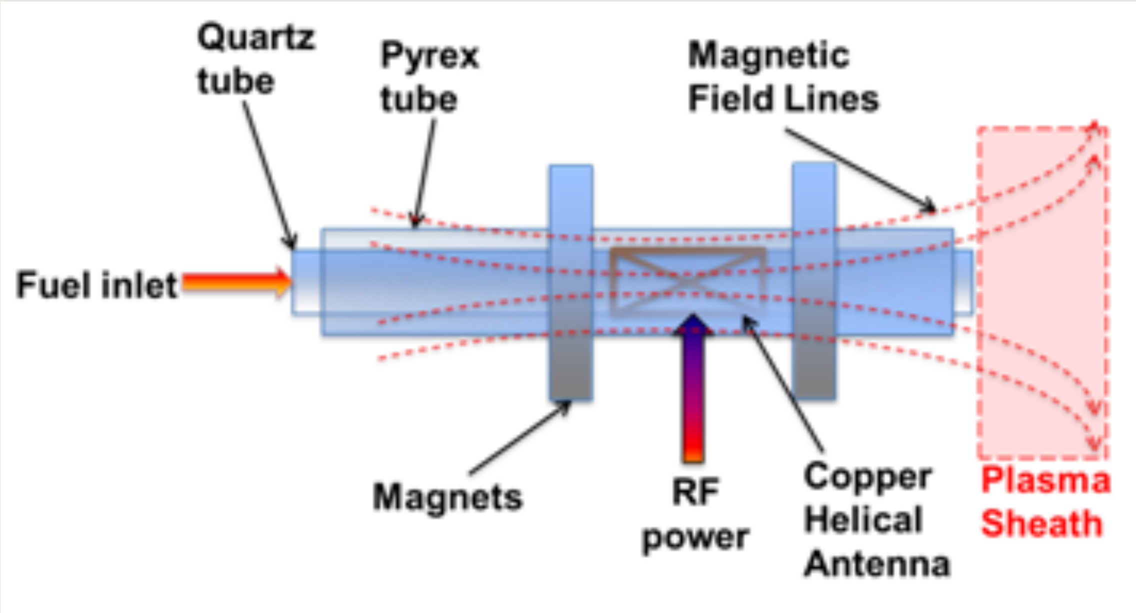
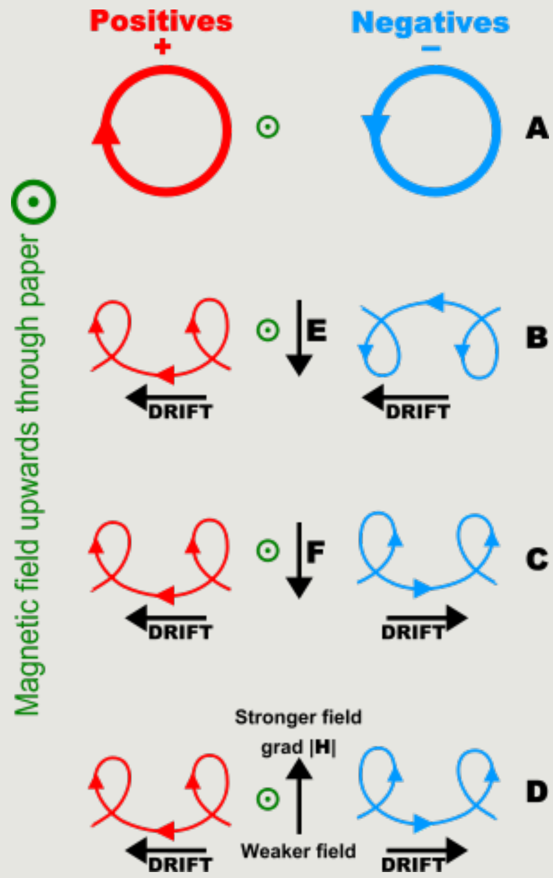


Fig. 145. Diagram of an Electro-magnet Showing Relation of Current and Winding to its Polarity and Lines of Force.

Gerard Melanson

Magnet Design Cont.





Magnet Strength Calculations

$$F = q(U \times B) = qUB$$

$$F = (mU^2)/r$$

$$(mU^2)/r = qUB$$

Result

$$B = 1.044 \times 10^{-8} * u/r$$

Potential Challenges/ Safety

Safety

- High voltages/currents
- High temperatures
- Ar gas – asphyxiant

Challenges

- Must build test environment
  - Costly
- Lots of assumptions

Cory Gainus

Future Plans

- Select and price materials
- Create detailed CAD drawings of thruster and components
- Test voltage spike of circuit
- Calculate resistance of plasma
  - Determine whether to insert additional resistor or transconductance amplifier
- Design / obtain Vacuum chamber
- Design test plan and apparatus

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Questions?