Portable Coilgun

Sponsored by Boeing

Group 1
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Daniel Josol Omeed Baboli

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Motivation

- Project provides design work for both Computer and Electrical disciplines
- Designing a mobile firearm that doesn’t rely on gunpowder
- Projectiles accelerated by magnetism will act as a natural silencer
- Creating a hand held coil gun

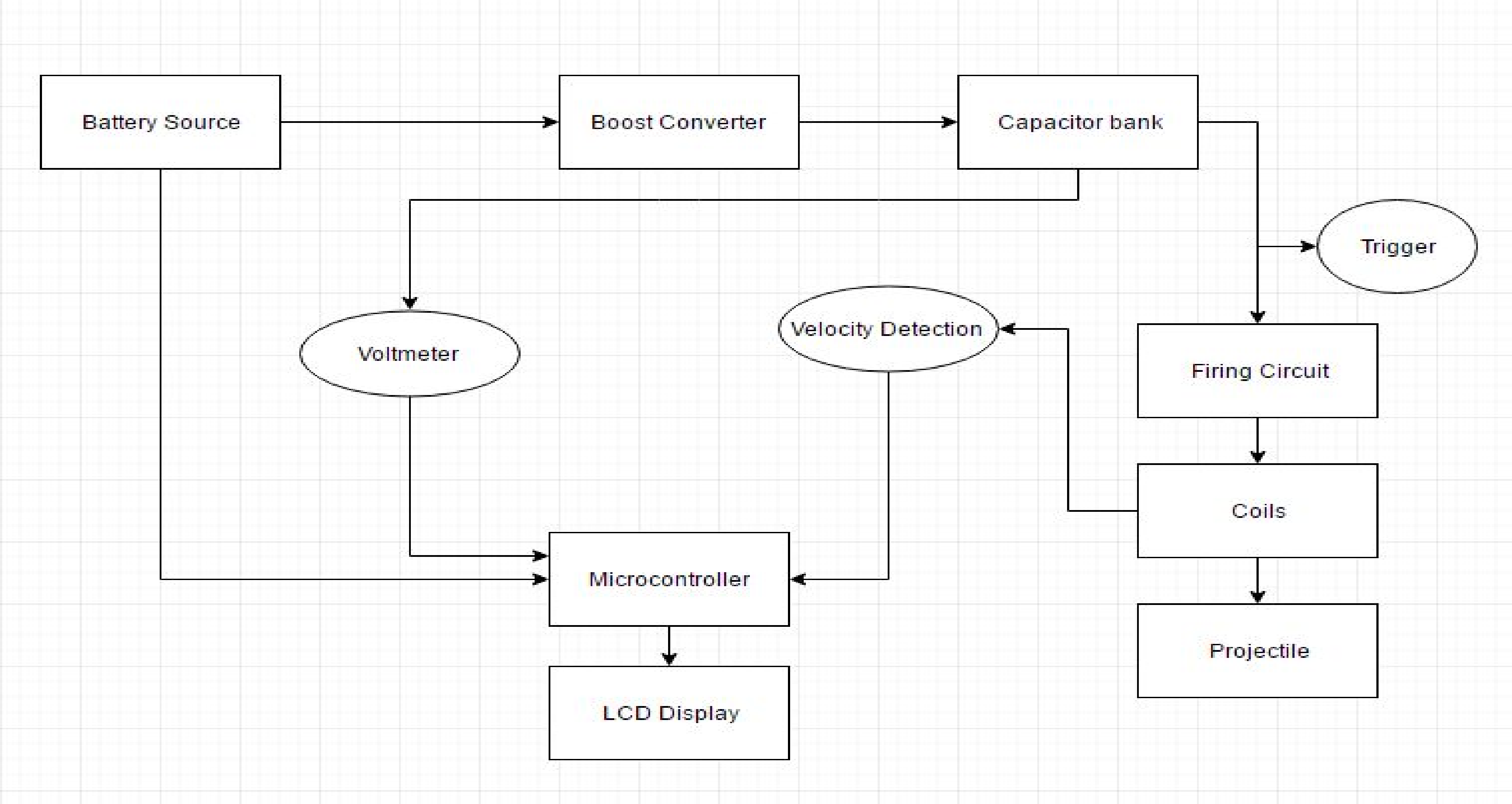
Task / Roles

Name	Primary Objective	Secondary Objective
Daniel Bears	Charging Circuit	Firing Circuit
Ian Fuentes	Firing circuit	Coil Design
Omeed Baboli	Microcontroller	Sensors
Daniel Josol	Microcontroller	Frame

Project Goals and Specifications

Product Capabilities	Desired	Accomplished
Charge Time	<20 secs	27 secs
Muzzle Velocity	100 feet per second	50 feet per second
Accuracy	< 6 in. from desired target shot at 5 yards	TBD
Firing rate	single - shot	Achieved
Hand Held	lightweight, able for the user to be relatively mobile	Achieved

Project Block Diagram



Power Supply

Battery	Tenergy
cost	$24
Type	Nickel Metal Hydride (NiMH)
Voltage	12V
Capacity	2000mAh
Dimensions	2.8”X 2”X 1.2”
Weight	9.6 oz

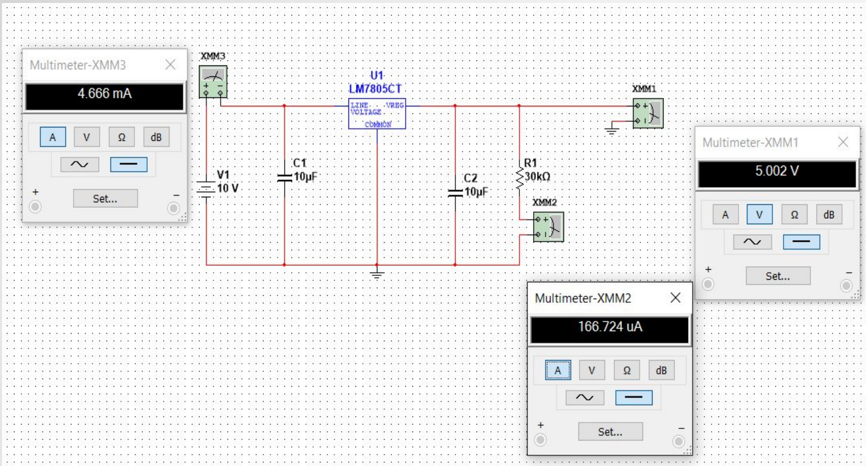
Benefits:

- High Energy Density
- Durable
- Can be stored charged or discharged
- Fast charge time

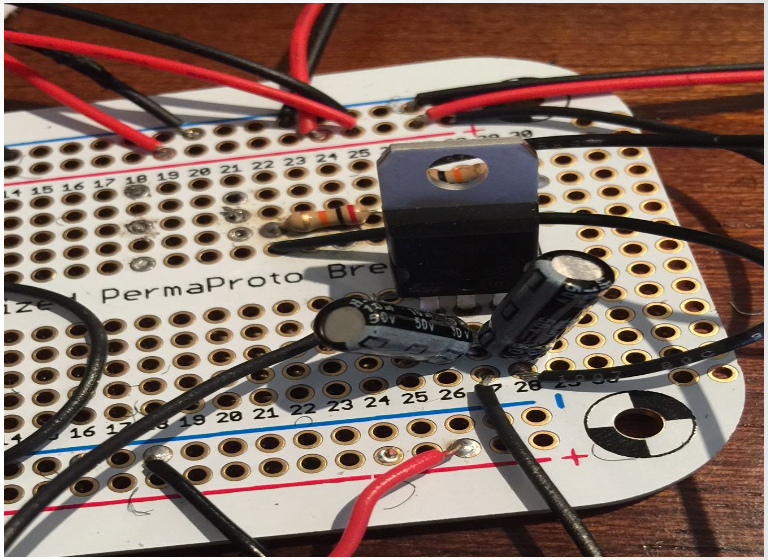
Power supply(cont.)

Battery	Tenergy
cost	2x$12=$24
Type	Nickel Metal Hydride (NiMH)
Voltage	9.6V
Capacity	2000mAh
Operating Voltage	9.6V
Dimensions	4”x2.3”x0.5”
Weight	8 oz

Linear Regulator



Brand	LM7805CT
Input Voltage	9.6V
Output Voltage	5.002V
Operating Voltage	5.002V



- maintain a constant voltage to the PCB
- Load Resistance of the PCB is constant
- Constant output current

Boost Converter

Brand	SMAKN
cost	$15.99
Input Voltage	10-32V
Output Voltage	45-390V
Output Current	0.2A
Operating Voltage	390V
Dimensions	60mm x 50mm x 22mm
Weight	2.4 oz

Capacitors

- 2x 400V 6300uF electrolytic capacitors
- U=(½)C*(V)^2

Ideally,

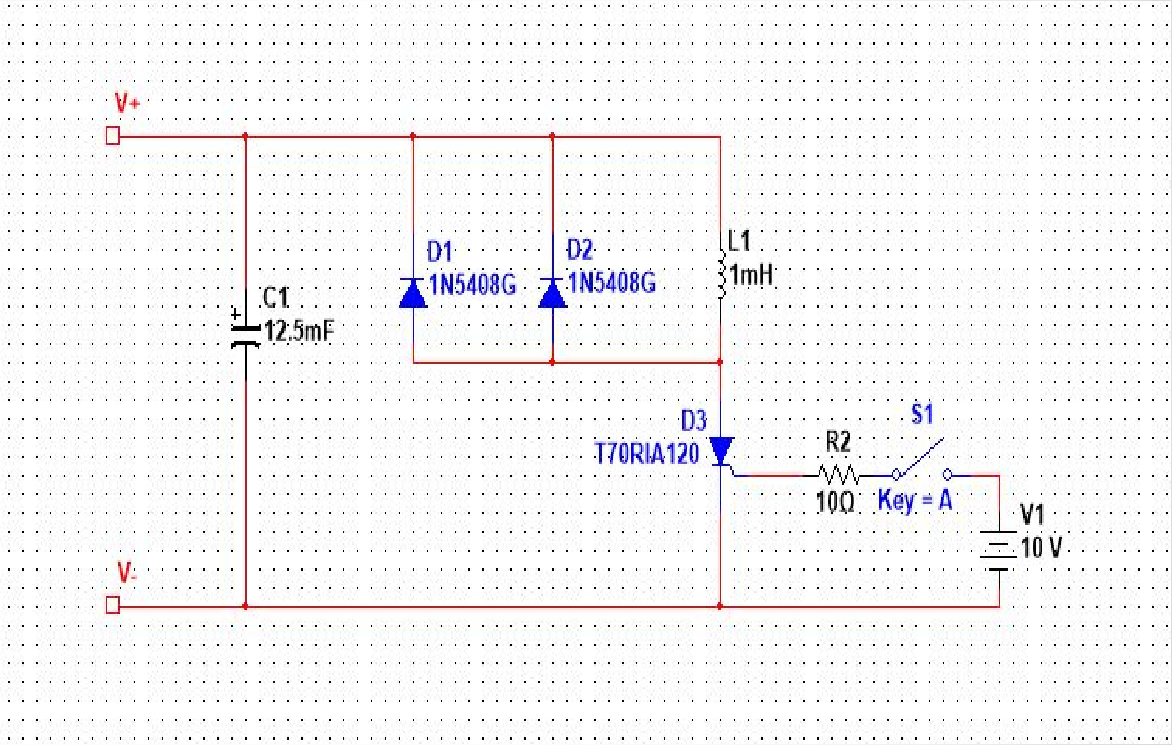
U=(½)*(6300e-6)*(360)^2

U=408.24J

2*U= 816.48J

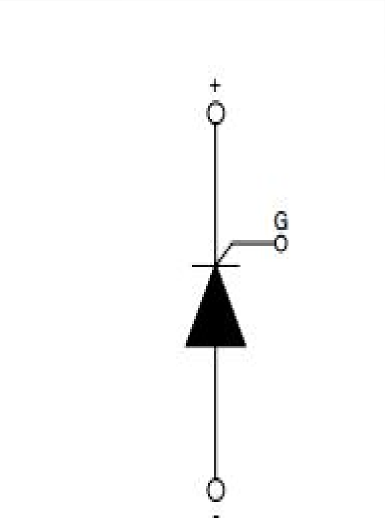
Firing Circuit

- Input is the the 350 V from the charging circuit.
- Using an SCR to control the current flow into the coils.
- Diodes are placed in parallel with coil to prevent back emf into the capacitor.
- Projectile will fire out of the inductor when the switch is closed.



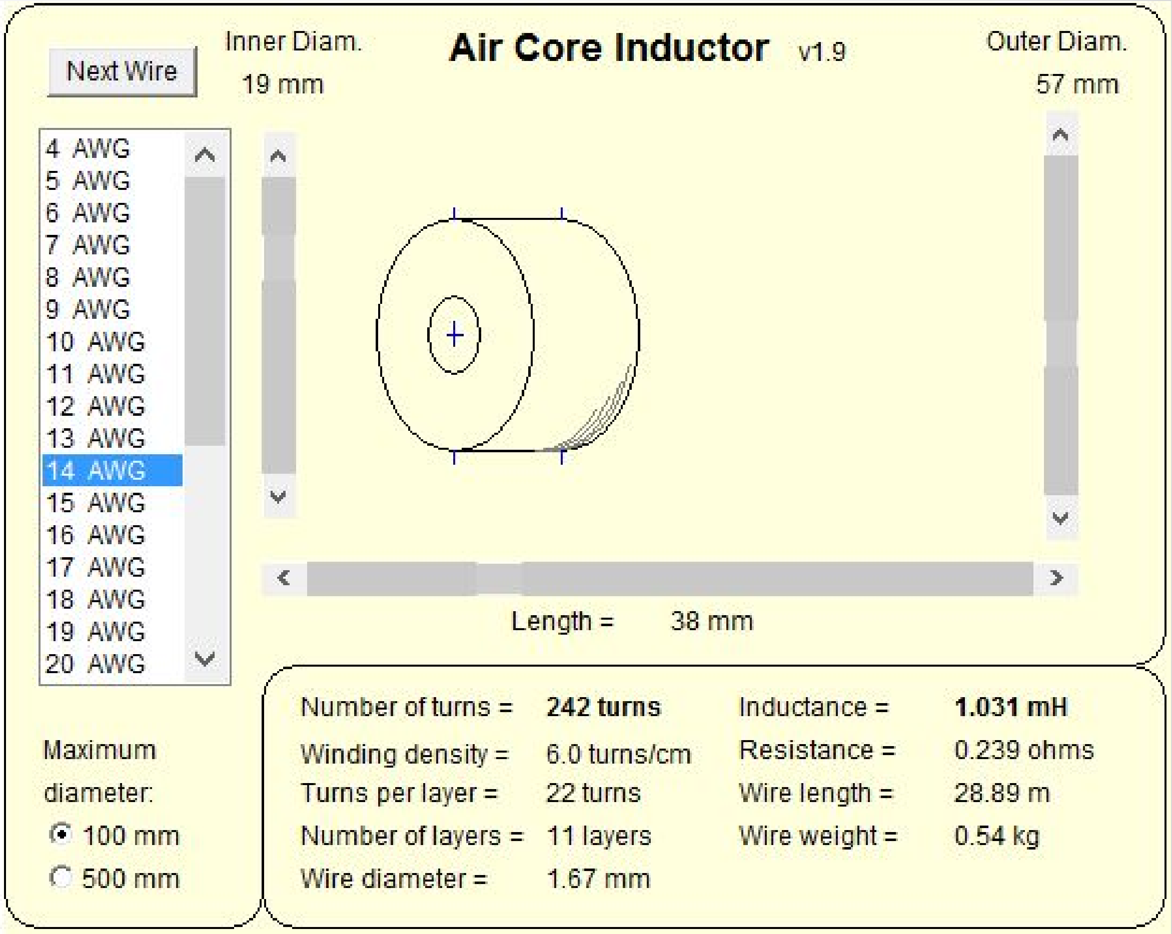
T70RIA120

Gate Trigger Current - Igt	100 μA
Gate Trigger Voltage - Vgt	2.5 V
Non Repetitive On-state Current	1660 A
Maximum Operating Temperature	125 C
Cost	$34.54



Coil Design

- 14 AWG Magnet Wire
- Magnet wire was chosen because it's thinner than regular copper wire and is also insulated.
- The coil is going to be wrapped tightly around the barrel to minimize air gaps.
- The magnetization of the projectile will be maximum at a given input when the outer diameter is three times the inner diameter.

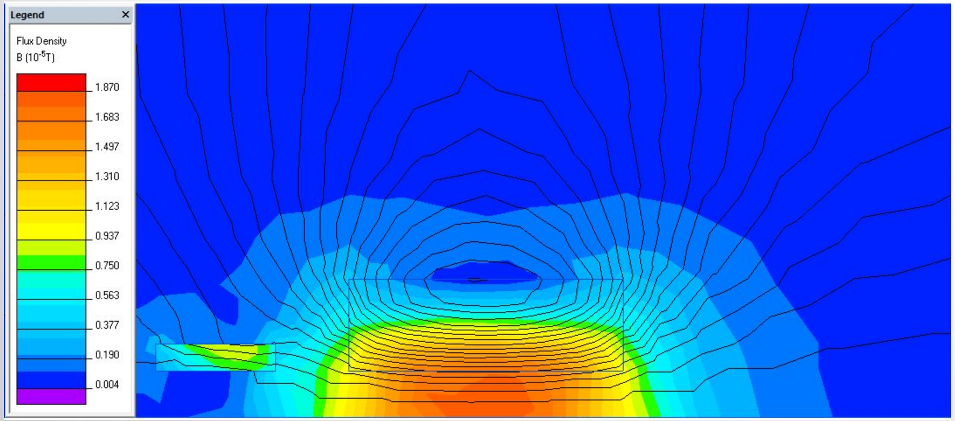


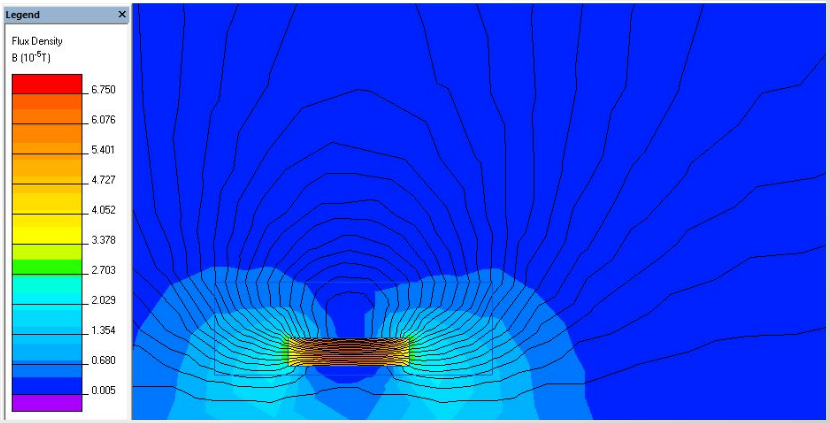
Projectile

- Projectile made out of ferromagnetic material due to high magnetic permeability.

- The projectile should also be long and thin in order for magnetic field to maximize its effect on projectile (most common case is a nail).

	Material	μ_r (H/m)
Diamagnetic	bismuth gold silver copper water	0.99983 0.99986 0.99998 0.999991 0.999991
Paramagnetic	air aluminum platinum	1.0000004 1.00002 1.0003
Ferromagnetic (nonlinear)	cobalt nickel iron (99.8% pure) iron (99.96% pure)	250 600 5000 280,000



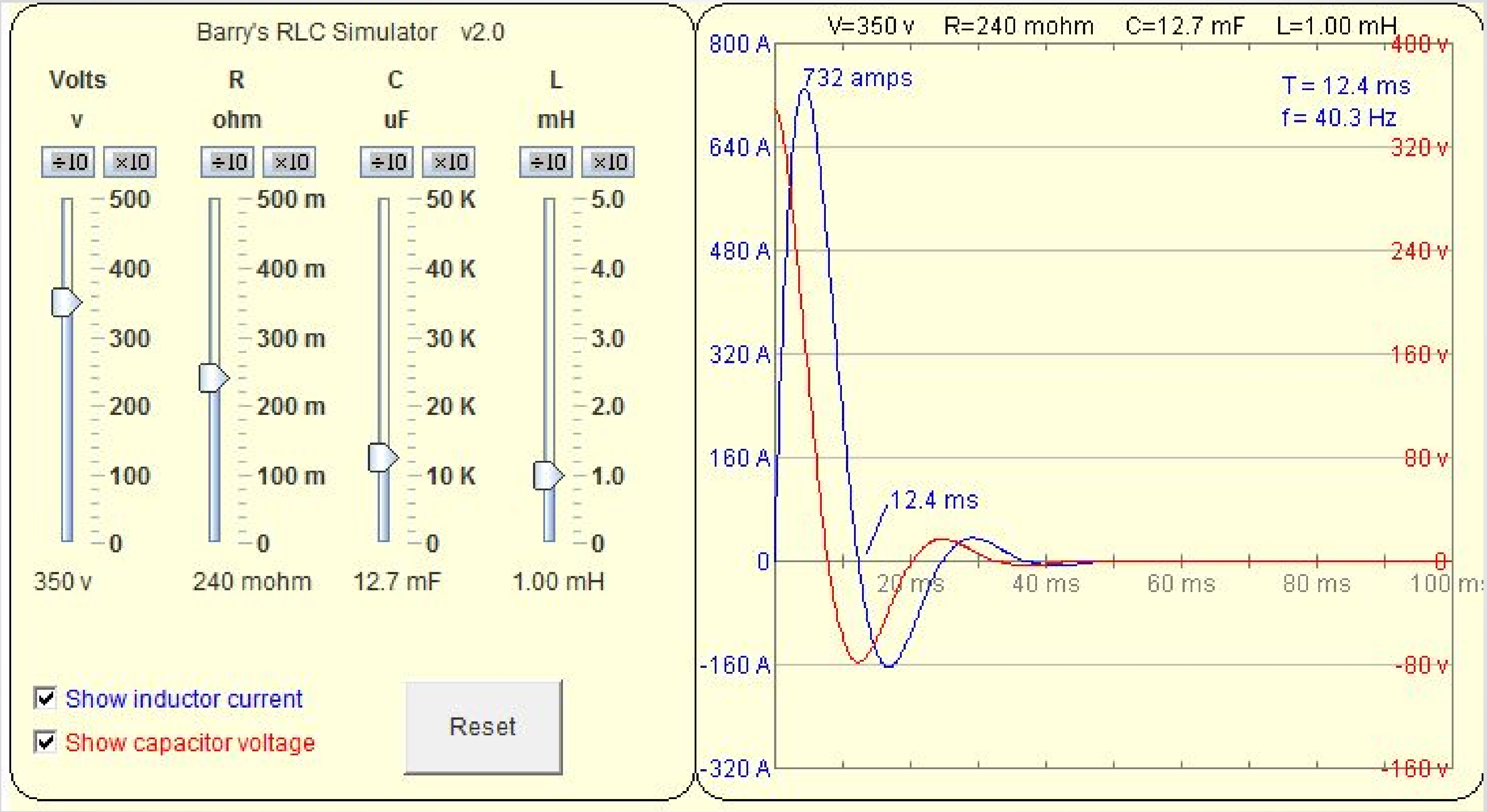


Projectile

4130 Alloy Steel	97.3-98.22% Iron
Diameter	0.5 Inches
Length	1 Inch
Mass	22 Grams

- Purchased as 24 inch rod of 4130 Alloy Steel
- Cut down at Machine Lab in Mathematical Sciences Building

Discharging



Velocity Calculations

- PE=(1/2)CV^2
- KE=e(PE)
- KE= (1/2)mv^2
- Mass of the projectile is going to be about 22 grams
- The common efficiency found amongst other coil gun project is around 5%

PE= (.5)(6300uF)(360V)^2
= 408.24 j

KE = (.05)PE = 20.412 j

KE = (.5)(.022kg)(V)^2

V= 43.0771 m/s = **141.3291ft/s**

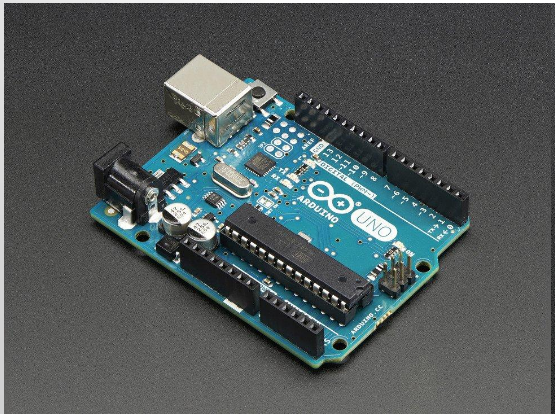
Microcontroller

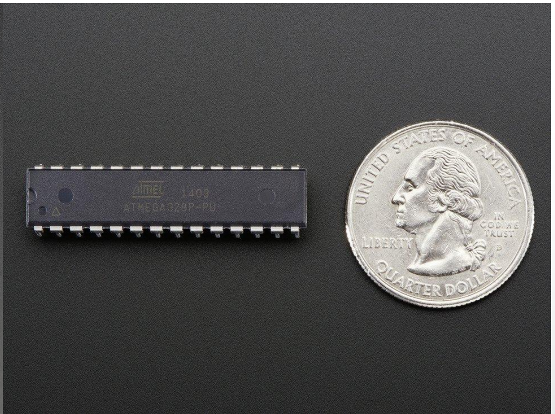
Increase user experience by providing the shooter with real time data of voltage when charging the capacitors and velocity of the projectile after the shot.

Main Benefits

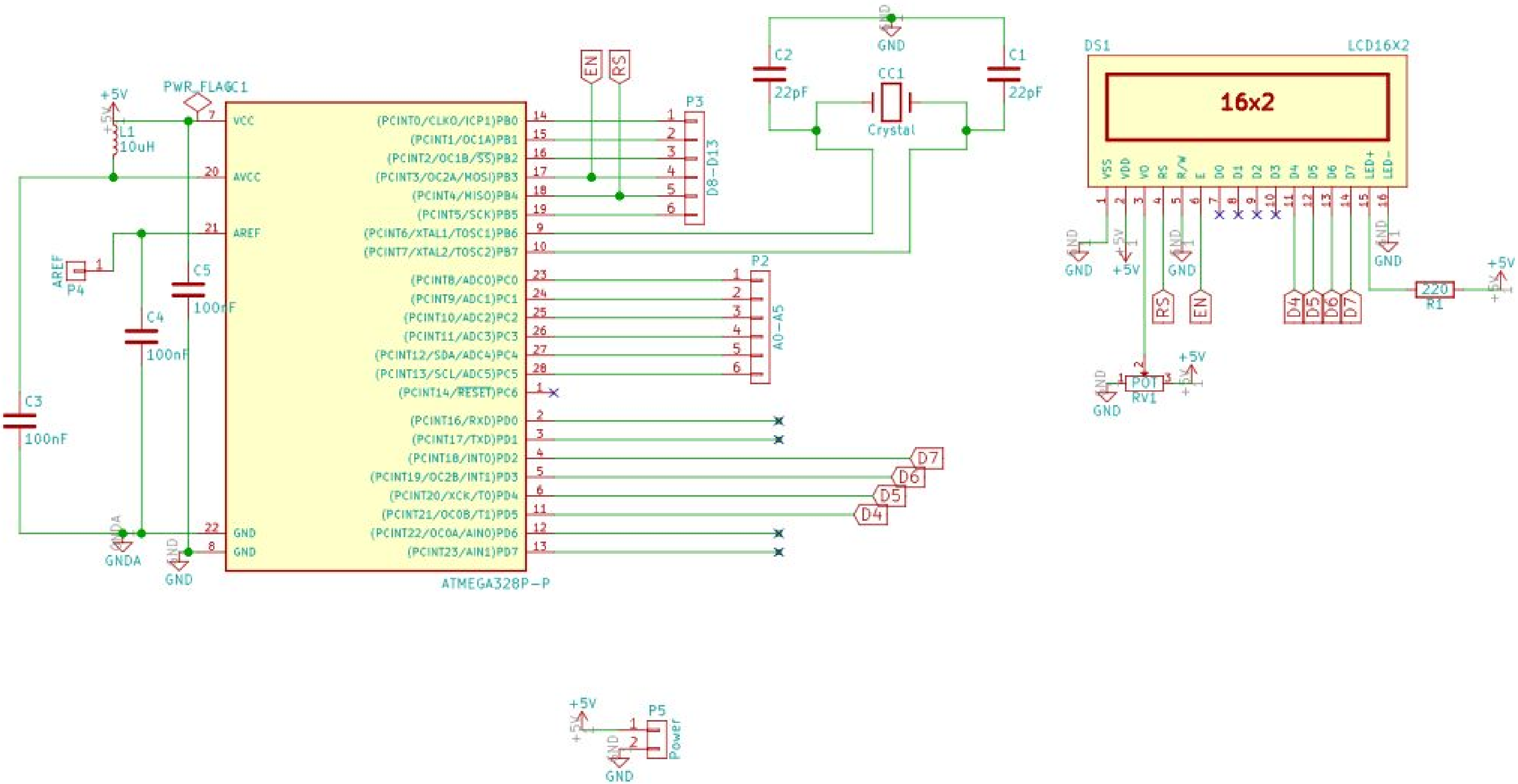
- ❑ Easy Development/Arduino IDE
- ❑ Open Source (access to design files and large amounts of online resources)
- ❑ 6 Analog Inputs (ADC) 10-bit resolution

Dev board	Arduino Uno
Dev board Cost	$25
Microcontroller	Atmel ATmeag328P
Microcontroller Cost	$4
CPU Clock	16 MHz
Operating Voltage	5V
Digital Pins	20 (6 PWM)
Analog Pins	6
Flash Memory	32KB
SRAM	2KB
Input Voltage	7-12V





Microcontroller Schematic



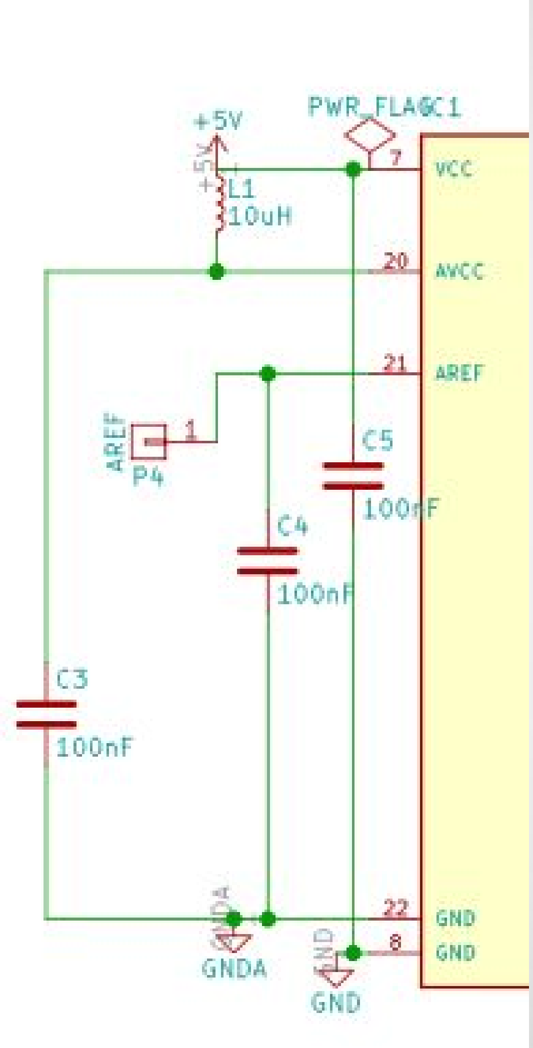
Supply Voltage

VCC -Digital supply voltage

AVCC - Analog supply voltage

"The AVCC pin on the device should be connected to the digital VCC supply voltage via an LC network" -Atmel datasheet

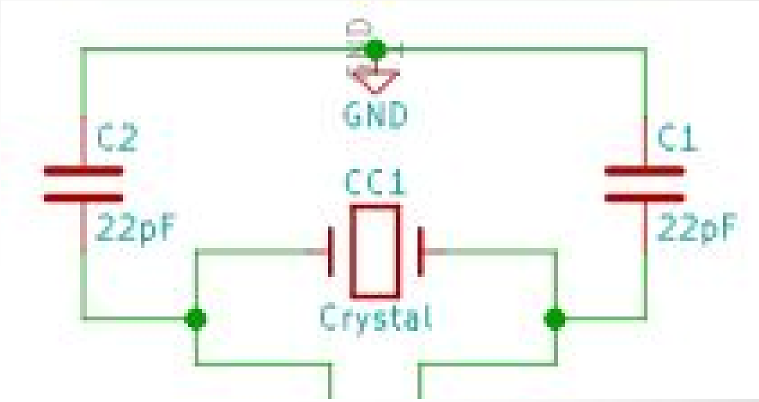
- AREF is used as an external reference in case we want more precise measurements.
- For even better noise performance we use a bypass capacitor on the AREF line



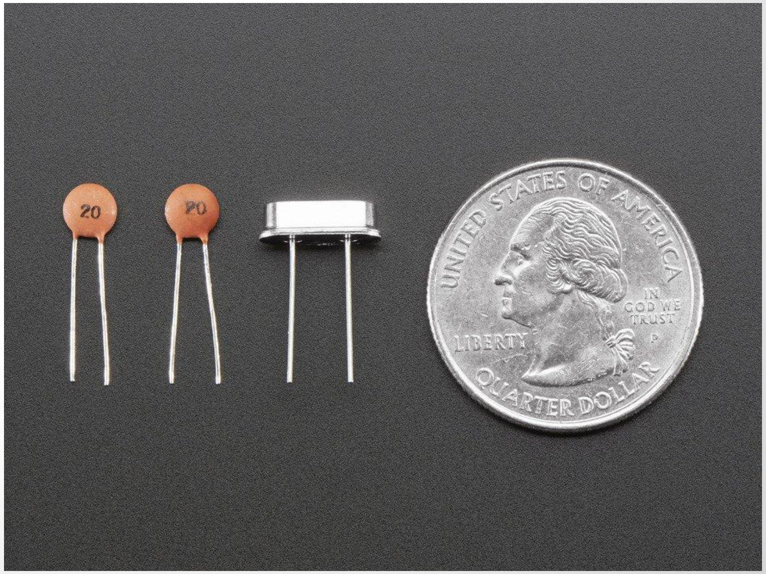
External Crystal

Atmega328P comes with many options for a clock source. We choose the Low Power Crystal Oscillator (CC1).

- ❑ Manufacturer recommends a load capacitance of 12-22pF



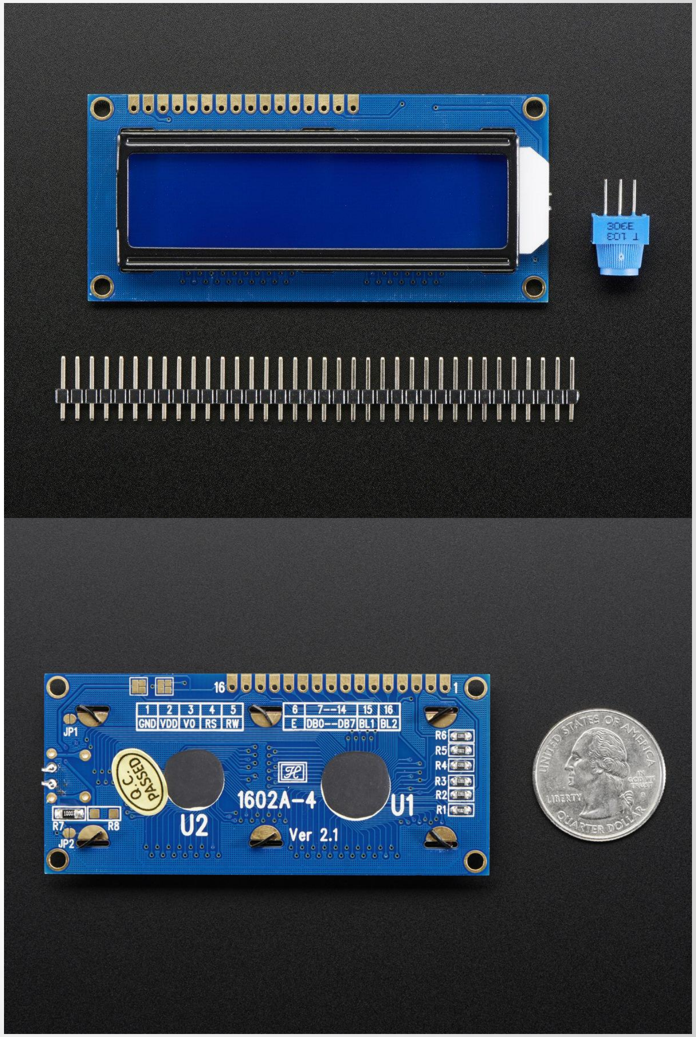
Type	Quartz Crystal
Load Capacitance	22pF
Crystal	16 MHz
Cost	$0.75



Display

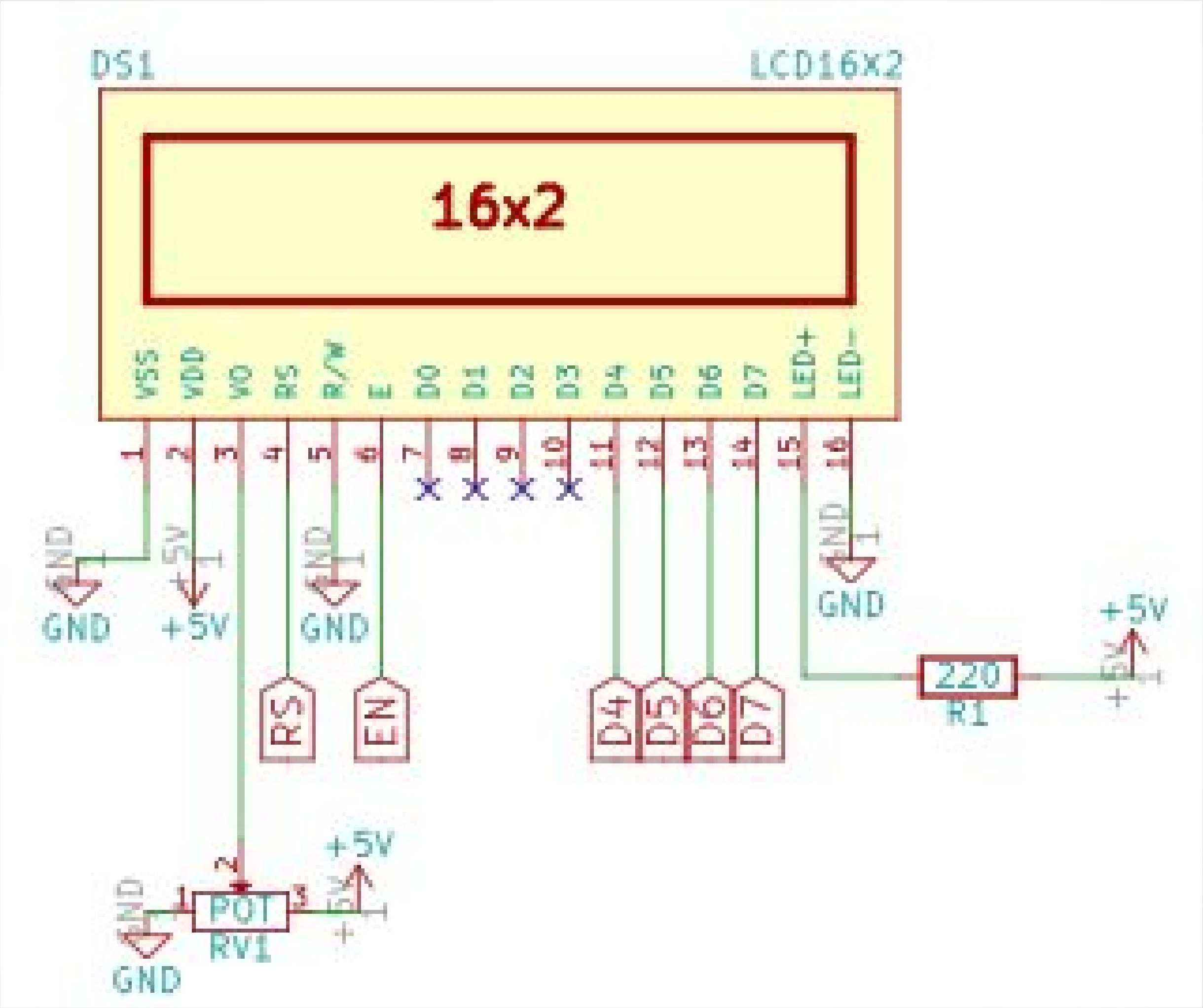
Standard 16x2 LCD Display

Manufacturer	Hitachi
Part	HD44780U
GPIO requirements	6 Digital Lines
Cost	$10



<u>Digital Lines</u>
RS: Signal for selecting registers
EN: Enable line tells display when data is ready
D4-D7: Bi-directional data bus

Display Schematic



Volt Meter

- Atmega328p has a max analog input voltage of VCC +.5 (5.5V)
- At full charge the capacitors will read 350V, to protect the MCU we will us a voltage divider.
- Voltage Divider will divide by 100 meaning the Volt Meter will read 3.5V at max charge.
- We build a voltage divider on prototype board instead of the PCB because of the high voltage input

PCB Design

2-layer PCB

- ❑ Layer 1: Dedicated to power plane and logic traces
- ❑ Layer 2: Analog and Digital Ground planes

Programmer?

- ❑ Using a socket for the MCU gives us the ability to swap the MCU back into the dev board to program.

Through hole components are used on the PCB except for the inductor which is SMD

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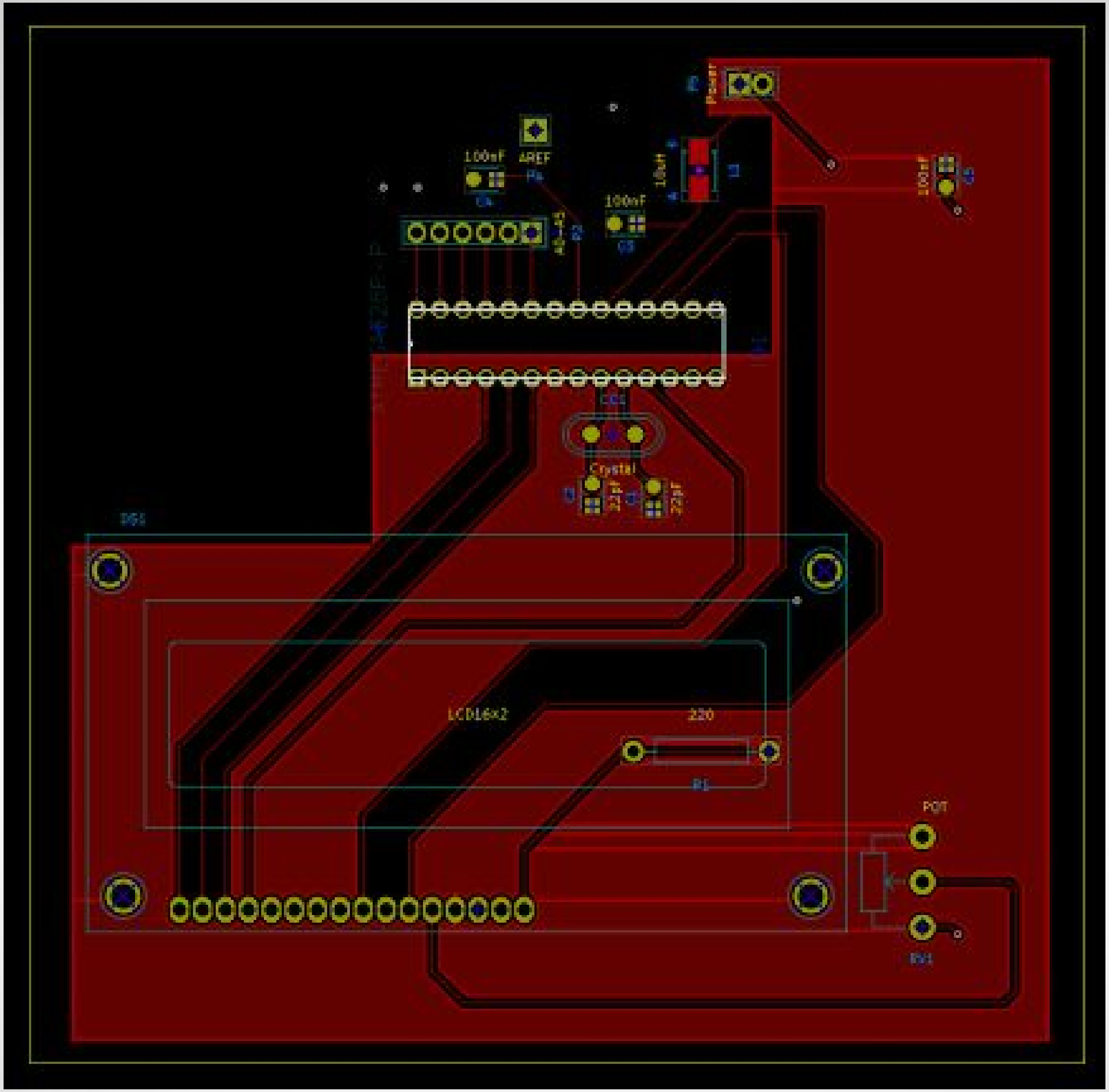

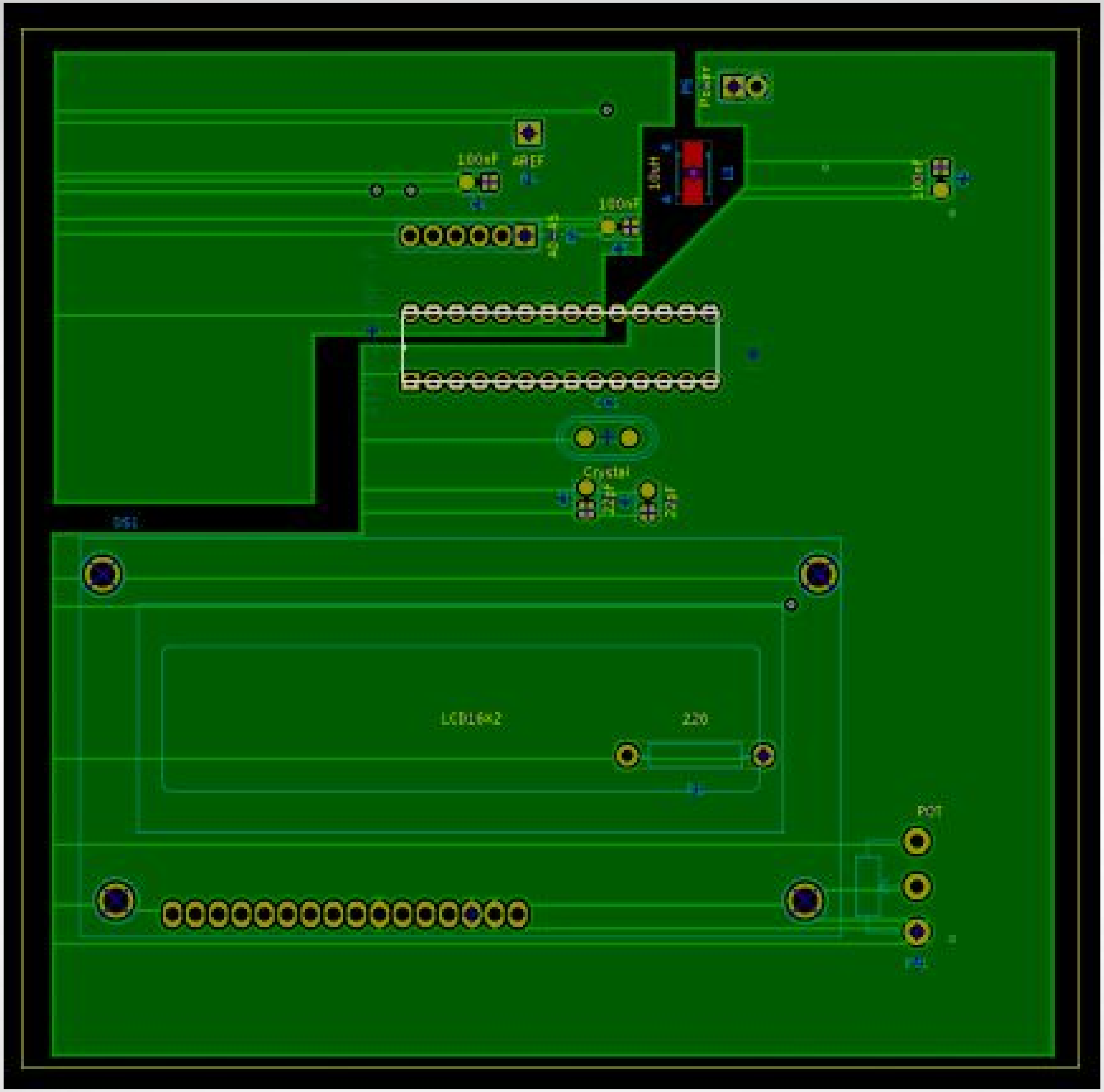
100nF
AREF
100nF
10uH
Crystal
22pF
22pF
LCD16x2
220
POT

Velocity Sensors

To calculate muzzle velocity we use two IR Break beam sensors

Using an IR receiver (left) and IR transmitter (right) to detect motion within 25 cm

Steps:

1) First IR sensor detects projectile
2) Begin Hardware Timer
3) Second IR sensor detects projectile
4) Stop Hardware Timer

Operating Voltage	3.3 or 5V
Cost	$2
Digital Lines	1 on receiver

Programming Design

Libraries included:

Liquid Crystal (Display)

Chrono (Hardware Timer)

- Boot up: 2 seconds
- Takes an analog read of capacitors every 300 milliseconds and checks if the first IR break beam sensor has detected motion
- If that first IR break beam sensor detects motion it enters a function which starts the Chrono timer until the second IR break beam sensor is detected.
- At that point we can stop the timer and calculate the velocity
- Continue reading voltage to make sure capacitors are fully discharged

Frame Design

Purpose of the frame is to keep the gun and all of its components in tact. It also helps out in the following areas:

- aesthetics
- exposure
- stability
- ease - and reuseability

Frame Design

Laser-cut wood was chosen as the desired frame over 3d-printed Asb plastic

Advantages

- Very cheap ($7.00 for a 2x4 ft board)
- Faster to make (20 minutes vs several hours
- Laser-cut can create larger objects vs 3d printer
- Does not bend easy
- Larger room for error if design is not perfect

*Comparisons made between policies / performance of the laser cutter and 3d printer in the Texas-Instruments lab

Frame Design

Three boxes were created and glued together:

- ❑ Large box (3.5x3.5x21 in) held the two capacitors
- ❑ Small box (2.5x2.5x14) for the pcb
- ❑ Medium box (3x3x15 in) held the rest of the components
- ❑ LCD displays attached on the outside of the frame
- ❑ Boxes were created with interlocking edges using makercase.com

Problems

- Velocity Measurements
- Frame Aesthetics
- Complete charge capability
- Power to the PCB

Budget

Quantity	Part(s)	Cost/unit
3	Battery	$15.00
4	Capacitor	$15.00
4	Wood	$7.00
2	Copper Wire	$27.10
1	Arduino Uno	$15.00
1	Boost Converter	$15.00
2	LCD Display	$5.00
1	Battery Charger	$15.00
1	Buck Converter	$8.00
4	Molded Plastic Pipe	$5.00
1	PCB	$200.00
2	SCR	$40.77
Total	**28**	**$551.74**

Part List

- 4x 400V 6300uF electrolytic Capacitors
- 6x1N5408 Diodes
- 12V Tenergy 2000mAh NiMH Battery
- 9.6V Tenergy 2000mAh NiMH Batteries
- 1x Boost Converter
- 1X Buck Converter
- ½” diameter PVC pipe
- Arduino Due
- RGB backlight positive LCD 20x4
- Sheet plastic
- 2x Infrared LEDS
- 2x Infrared Detectors
- 1x PCB
- 2 x ¼ in wooden sheets (2x4 ft)

Future Versions

1. Trigger Placement
2. Compact and ergonomic Frame
3. Accurate Velocity Detection
4. Additional Coils
5. Loading Mechanism
6. Higher muzzle velocity
7. Increased Accuracy

Questions?