Low Power Variable Optic with Automatic Distance Correction

Group 13

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Motivation

- Existing solutions are expensive and exclusive
- The current market is still analog, there are few products that incorporate any sort of sophisticated technology
- Designing a system that would be a step forward in the industry will test our knowledge and provide us will more real world problem solving skills

Goals & Objectives

Lightweight

The scope design should remain as lightweight as possible as to not fatigue the user. It should also be balanced as to not throw off the user.

Slim

Rifles are designed to be slim, we don't want to break this design with our scope. This means the placement of the components should avoid adding bulk.

Inexpensive

Many similar scopes on the market are very expensive. To be competitive the scope design should be as inexpensive as possible to be affordable.

Easy to Use

The user should be able to use the scope without thinking about it. So we must design it to be very intuative and not distract the user.

Accurate

It should be able to accuractly determine the drop of the projecticle and relay that information to the user, allowing them to accurетly hit a target.

Time Efficient

One of the primary goals is to save the user time. The scoped is designed with this in mind to reduce the amount of time it takes the user to aim.

Pejsa's Projectile Drop Equation

$$F_m(R) = F_0 - (0.75 + 0.00006 \cdot R) \cdot n \cdot R$$

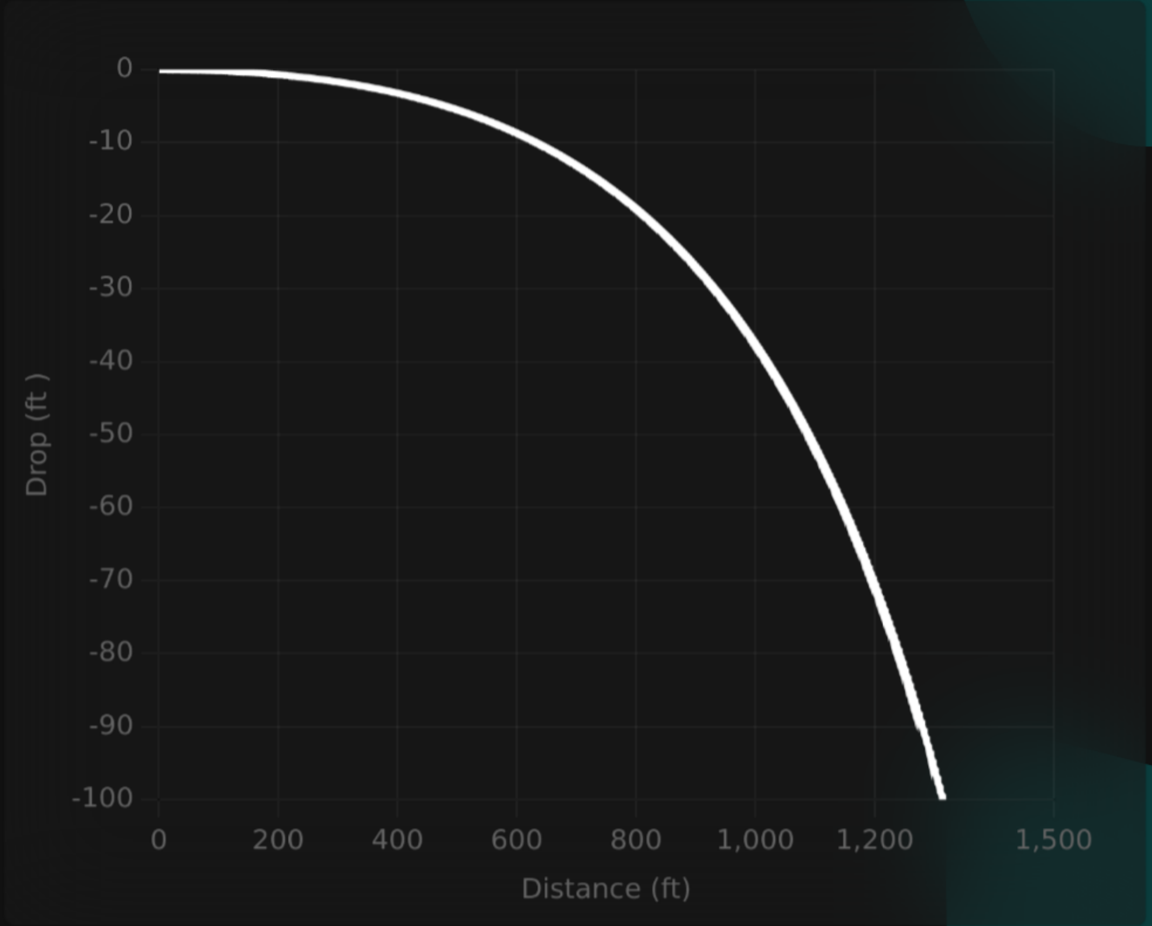
$$F_m = 2600.00$$

$$D = \left(\frac{\frac{G}{3200\,ft/sec}}{\frac{1}{1500\,ft} - \frac{1}{F_m(1500\,ft)}} \right)^2 = 178\,ft$$

Distance (R)

Velocity (V)

$G = 41.697 \quad n = 0.5 \quad F_0 = 3230$



https://www.mathscinotes.com/2015/05/pejsas-projectile-drop-versus-distance-formula-part-2-of-3/

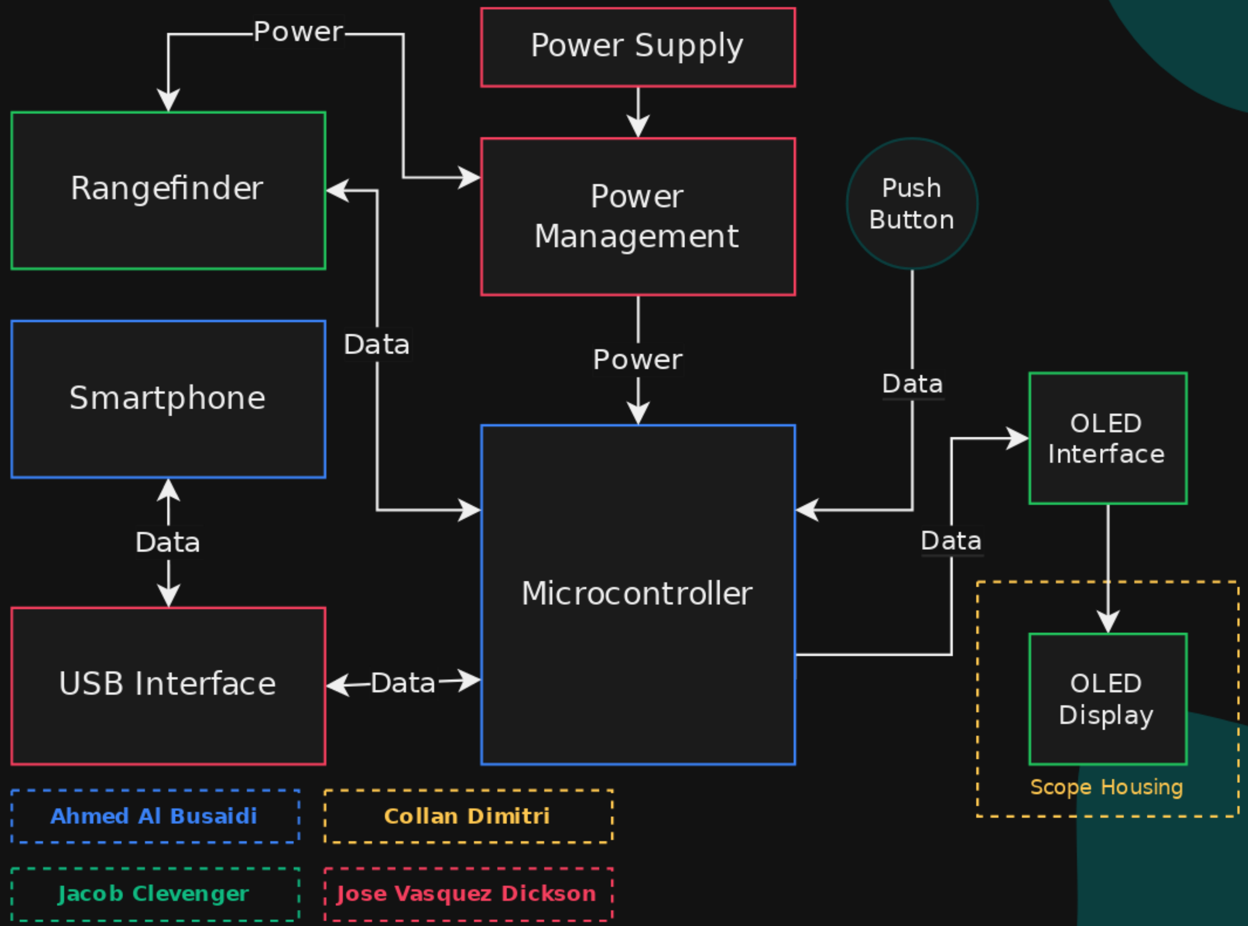
Specifications

Requirement	Unit
Variable Magnification Optical Set-Up	1x-6x Magnification
USB Type-C	12 Mbps
Microcontroller	16 MHz
Laser Rangefinder	500m - 1500m
OLED Display	128 x 56 Resolution
Push Button Interface	5V
Battery	9.6V

Design Block Diagram

The diagram to the right is an overall block-level diagram of the overall project.

Each block is color-coded to indicate which member will focus on which part. Although, it will often be the case that members will colaberate on parts together even if not indicated in the block diagram.



The Scope

Collan Dimitri

Lens Setup

Objective Lens

Lens Type	Biconvex
Diameter	30mm
R1 & R2	30mm

Image Reversal Lens

Lens Type	Biconvex
Diameter	25mm
R1 & R2	50mm

Eyepiece Assembly

Lens Type	Biconvex
Diameter	40mm, 25mm
R1 & R2	60mm, 25mm

Lens Type	Biconcave
Diameter	25mm
R1 & R2	100mm

Scope Housing

- Machined aluminum, one piece construction for added shock absorption
- Integrated mounting system for easier utilization
- Allotted space for onboard electronics; board will be placed underneath the optical system
- Ports for activation switch and rangefinder to attach

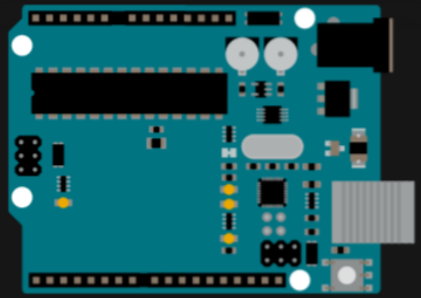
Optical Constraints

- Keeping scope compact does not allow for as many adjustments to focus or parallax.
- Financial constraints on lenses, every lens is uncoated. Changes overall clarity of optical system.
- OLED screen acts as reticle, but lacks clarity of glass lenses

The Microcontroller

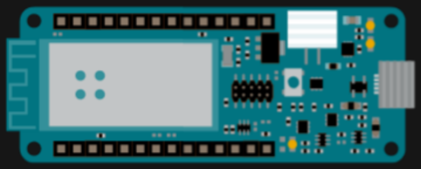
Jacob Clevenger & Ahmed Al Busaidi

Choosing a Microcontroller



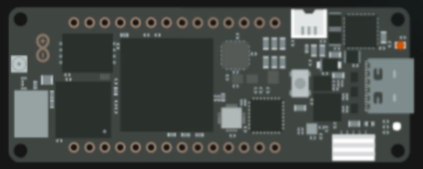
Arduino Uno

Price	$23.00
MCU	ATmega328P
Speed	16 MHz
Interfaces	UART, I2C, SPI
Cores	1



MKR 1000 WiFi

Price	$36.80
MCU	SAMD21 32bit
Speed	48 MHz
Interfaces	UART, I2C, SPI
Cores	1



Portenta H7

Price	$103.40
MCU	STM32H747XI
Speed	480 MHz
Interfaces	UART, I2C, SPI
Cores	2

The Rangefinder

Jose Vasquez Dickson & Jacob Clevenger

Rangefinder Requirements

- Must be able to measure at least 1km, ideally 2km.
- Low-Power, should be able to be powered by our 9.6V battery.
- Relatively small, should be small enough we can affix it to a rifle.
- Have an interface we can use with a microcontroller, such as I2C, SPI, or UART.

Rangefinder

$316

Model	HR1500A
Operation Wavelength	905nm
Voltage	7-12V
Interface 8-bits at 19.2K baud rate	UART
Distance Minimum distance of 3m and a maximum of 1500m	1500m
Saftey Class Exposure not harmful to humans	Class 1
Accuracy Precise enough that error in calculation will be negligible.	1-2m

The OLED Display

Jose Vasquez Dickson & Jacob Clevenger

Choosing a Display

When choosing a display to use in the scope, we made a list of requirements that needed to be met if we were to use the display.

- Must be transparent
- Small enough to fit in the scope housing
- High enough resolution to display information to user.
- A common interface so it can be controlled via a Microcontroller.
- Must be within budget, less than $100.
- Has to be accessible as a consumer. Many companies will only sell to other companies it has contracts with.

Only one display on the market fit these requirments!

The Crystalfontz OLED Display

CFAL12856A0-0151-B

$26.08

✓ Resolution	128x56
✓ Interface	I2C
✓ Dimensions	42.04mm x 27.22mm
✓ Transparency	70% when not lit

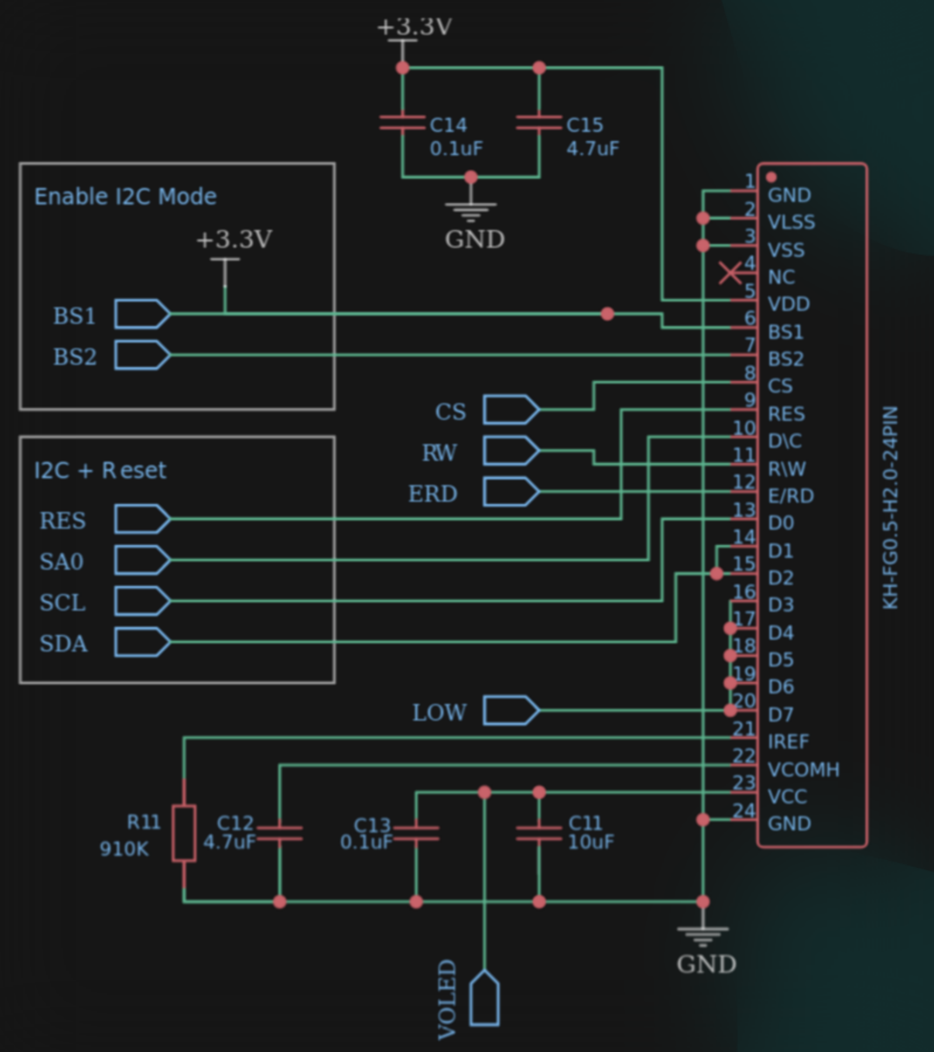
✓ Display meets all requirments

The display uses the Solomon Systech SSD1309 integrated controller which runs off of 3.3V supply. As for the panel itself, it runs off of a 12.77V supply.

OLED Interface

The circuit to the right is reponsible for powering the OLED display and facilitating communication between the microcontroller and the OLED display.

- Enable I2C via `BS1` & `BS2` pins
- Power logic circuit with `3.3V` via `VDD`
- Power logic circuit with `12.77V` via `VCC`
- Reset display via `RES` pin
- Pins `SA0`, `SCL`, and `SDA` are carry `I2C` signal.
- Following pins pulled LOW `CS`, `RW`, `ERD`, and `LOW`
- OLED display uses ZIF connector to connect to 24-pin connector on PCB.



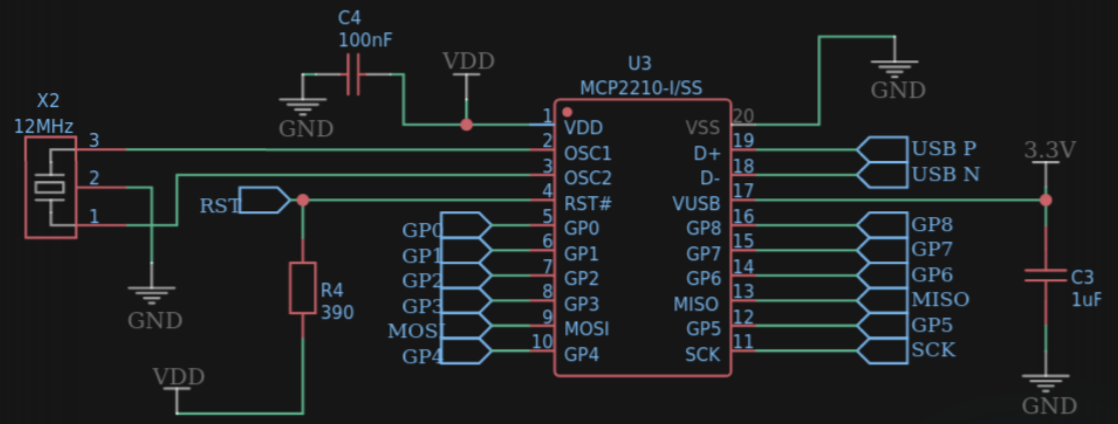
The USB-C Interface

Jose Vasquez Dickson & Jacob Clevenger

USB-to-SPI Integrated Circuit

The circuit to the right is the interconnection of the MCP2210, USB-to-SPI converter with GPIO.

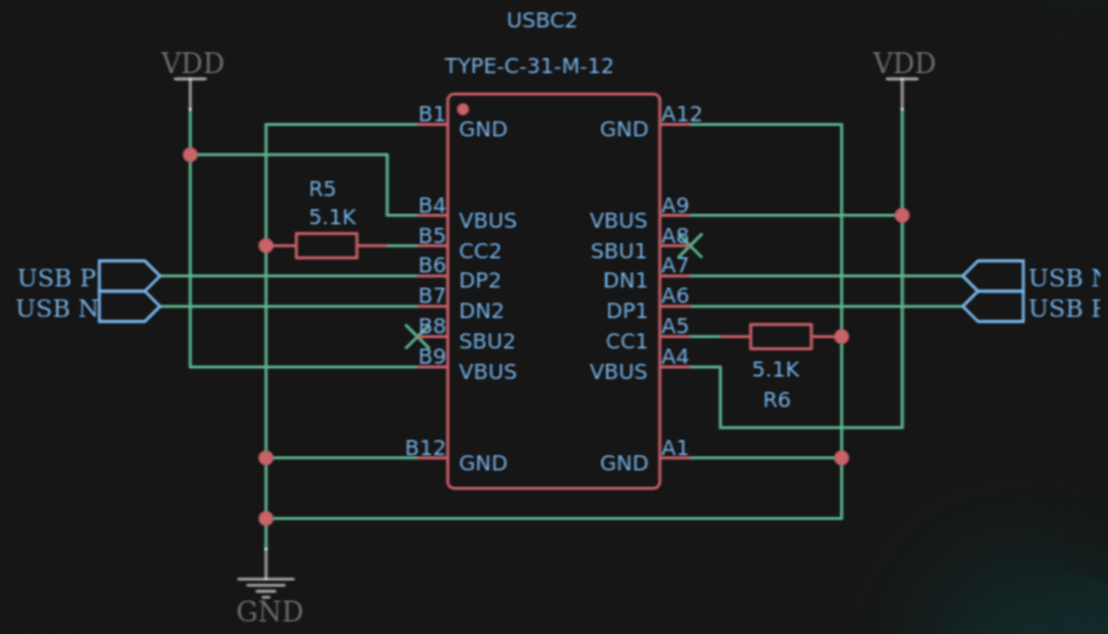
- Enables a USB connectivity in applications that have an SPI interface
- Enable this microchip via VDD pin
- Ceramic oscillator via OSC1 & OSC2 pins
- Resets via RST pin
- Data lines via D+ & D- pins with USB Type C connection
- Power pin via VUSB pin to the SPI header
- GPIO pins via GP0 to GP8 pins



USB-C Header

The circuit below is responsible for the USB Type C input.

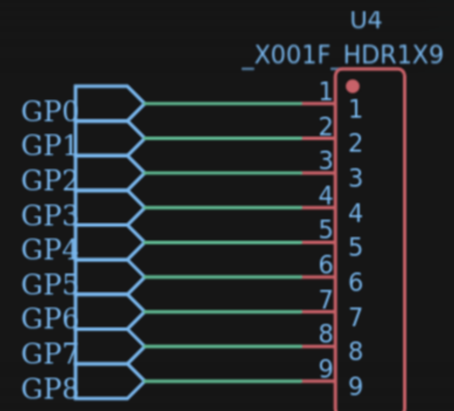
- Input power pin via VBUS pins
- Pulled down resistors on CC1 & CC2 pins
- Data lines via DP & DN pins to microchip



USB-C Board Headers

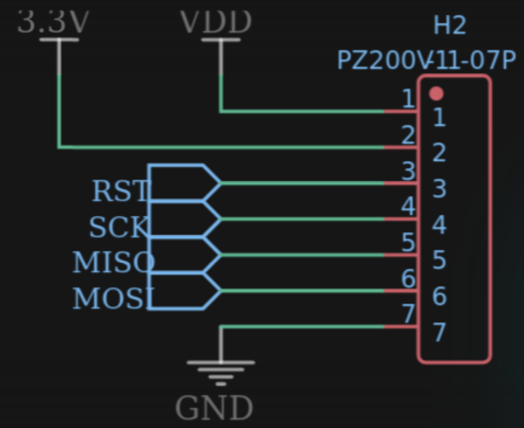
The circuit with header U4 is responsible for the GPIO pins.

- 9 Pin board header
- Interconnection with GPIO pins on the microchip



The circuit with header H2 is responsible for the SPI pins.

- 7 pin board header
- Enable power with VDD pin
- Power pin via 3.3V pin

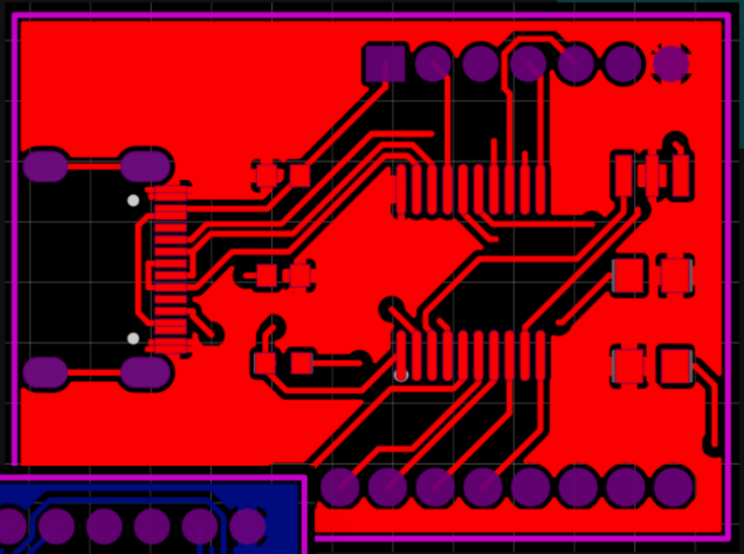


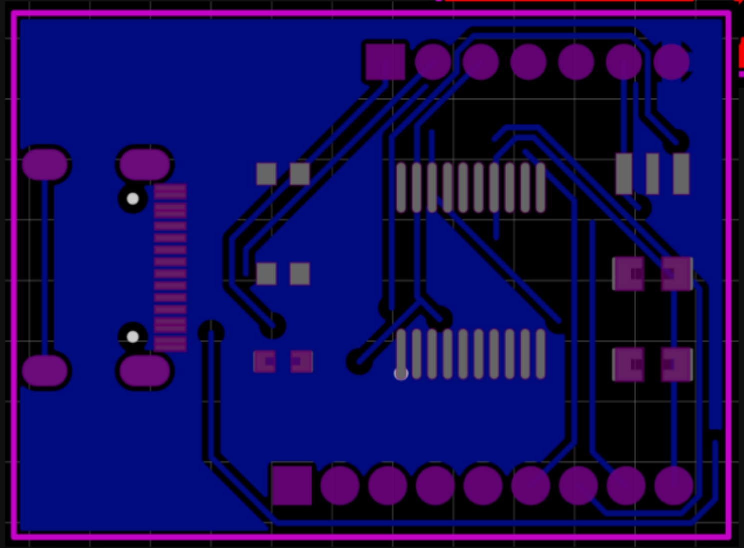
USB Interface PCB Design

The images to the right are the layers of the 2 layer PCB for the USB interface. The top layer is in red, and the bottom layer is in blue.

Routing Rules

- No 90º turns
- Track width 0.254mm
- Clearance 0.152mm
- In accordance to our PCB manufacturer





USB Interface PCB Design

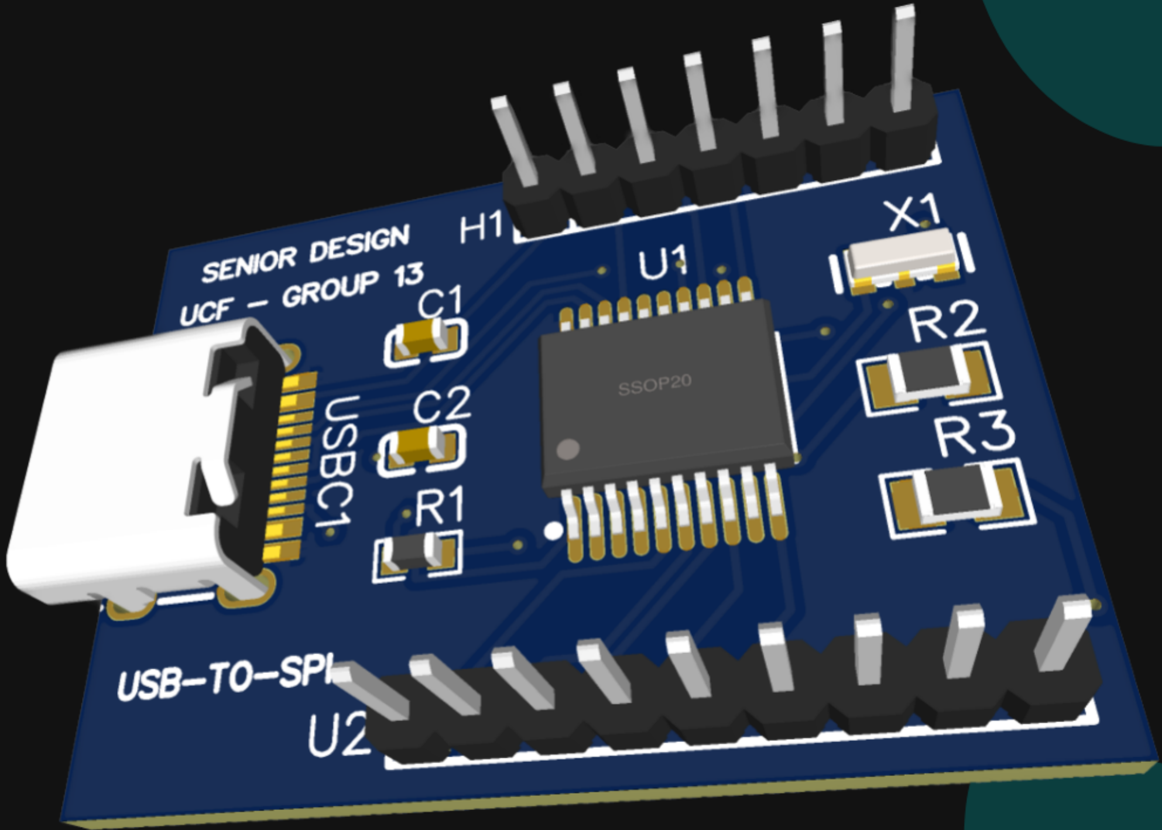
This image is the 3D rendering of the USB-to-SPI Interface.

Components

- USB Type C labeled USBC1
- USB-to-SPI converter labeled as U1
- Capacitors labeled C1 & C2
- Resistors labeled R1, R2 & R3
- Oscillator labeled X1
- GPIO header labeled as U2
- SPI header labeled as H1

Board

- Thickness 1.6mm



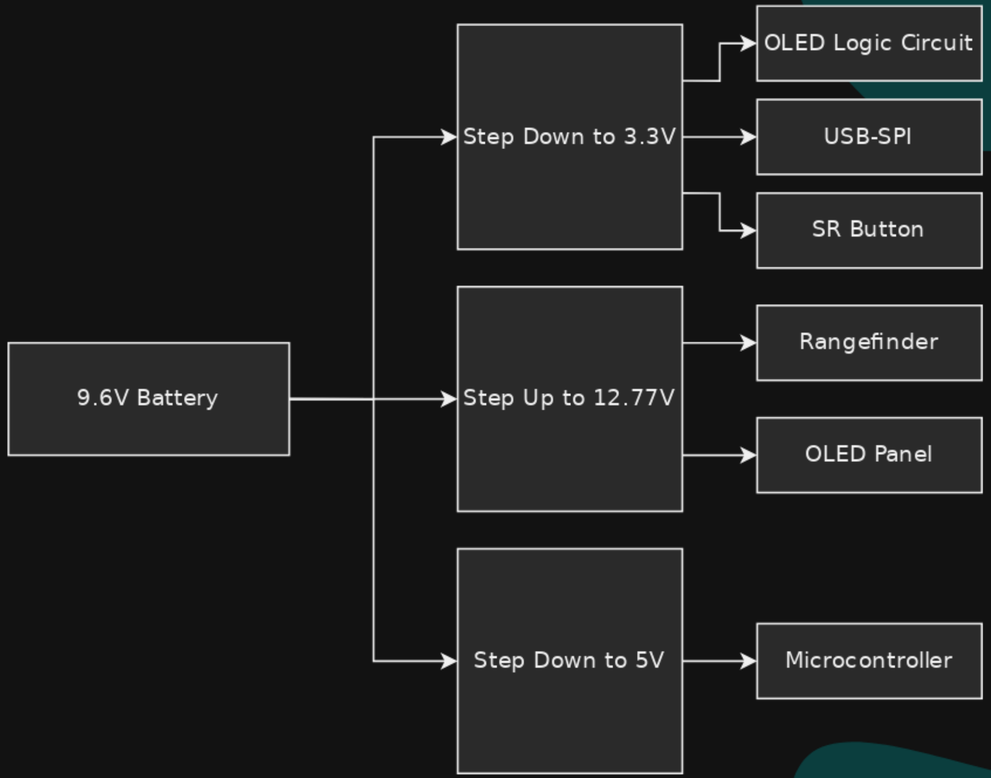
The Power Supply

Jose Vasquez Dickson & Jacob Clevenger

Power Supply

The following one-line diagram demonstrates the distribution of power from the power source to the different components.

- Step down to 3.3V
  - OLED Logic Circuit
  - USB-to-SPI Interface
  - SR Button
- Step down to 5V
  - Microcontroller
- Step up to 12.77V
  - Rangefinder
  - OLED Driving Panel
- Future expansion
  - 3 voltage levels
  - Additional components and features



Battery Decision

We had to make a significant design decision to change the way our project was going to be powered by the power supply.

Original Plan

- Use 2 batteries for the power supply design: 5V and 12V battery
  - Feeds the necessary voltage directly from the battery
- Problems
  - More expensive
  - More space required
  - Unregulated

New Plan

- Use 1 battery for the power supply design: 9.6V battery
  - Use voltage regulators to change the voltage as needed
- Pros
  - Less expensive
  - Less Space required

Standards

- Both designs classify for Extra-Low Voltage (ELV)
- Wires protected by basic insulation which is Polyvinyl Chloride (PVC)

The Software

Ahmed Al Busaidi & Jacob Clevenger

Primary Modules

OLED Display

Interfaces with OLED display via I2C to draw and erase graphics on display.

Pins	SCL & SDA
Connection	I2C
Control Flow	Unidirectional

Range Finder

Interfaces with Rangefinder via UART to take distance measurements.

Pins	TX & RX
Connection	UART
Control Flow	Bidirectional

SR Button

Controls state of system by triggering an interrupt on user input.

Pins	Digital Pin 7
Connection	Pull Up Resistor
Control Flow	Unidirectional

USB-C Interface

Responsible for interfacing with user connected mobile phone.

Pins	SPI
Connection	10, 11, 12, 13
Control Flow	Unidirectional

The OLED Class Breakdown

- Constructor to intialize an OLED object currently using SPI to test but easily convertable to I2C through a new constructer

```
U8X8_SSD1306_128X64_NONAME_4W_SW_SPI u8x8(/* clock=*/ 13, /* data=*/ 11, /* cs=*/ 8, /* dc=*/ A0, /* reset=*/ 9);
```

- I2C Constructor

```
U8X8_SSD1306_128X64_NONAME_HW_I2C([reset [, clock, data]]);
```

- Main functions

```
- u8x8.drawString(xPosition, yPosition, String s);
- u8x8.setFont(/*Font Family*/);
- u8x8.drawTile(unint8_t tiles[16]);
```

- Pipeline

```
- Constructor of our Choosing
- u8x8.begin();
- u8x8.drawString(range);
- u8x8.clearDisplay();
- u8x8.drawTile(rectile);
```

The Rangefinder Class Breakdown

- UART is a Serial Connection

```
Serial.begin(baudRate) /*Baud Rate = 115200 per Rangefinder Docs*/
```

- Send start command & Read incoming data into a temporary buffer

```
const unsigned char startCommand[] = {0xD, 0xA, 0x4F, 0x4E, 0xD, 0xA};
Rangefinder.write(startCommand, 6);

for(int i = 0; i < 3; i++) {
  tempBuff[i] = Rangefinder.parseInt();
}
```

- Send Stop Command

```
const unsigned char stopCommand[] = {0xD, 0xA, 0x4F, 0x46, 0x46, 0xD, 0xA};
Rangefinder.write(stopCommand, 7);
```

- Pass data around accordingly such as

```
u8x8.drawString(1, 3, tempBuff);
```

The Button Class Breakdown

The button is simple to program but comes with a host of problems

- Start by declaring pin type

```
pinMode(buttonPin, INPUT_PULLUP); /* buttonPin = 2 */
```

- Attaching an Interrupt

```
attachInterrupt(digitalPinToInterrupt(buttonPin), range, RISING);
```

Android Application

- Connects to arduino through a serial connection
- Be able to change values of bullet to better suit the gun that we are utilizing
- As well as the ability to send information about current bullet drop to the phone
- Only built in using Android Studio / Kotlin
- Swift is an expensive language to implement
- Code will always be checking for an android serial connection

```
void loop(void) {

  while(!androidSerial.isAvailible()) {
  // Do Nothing
  }

  if(writeFlag) {
    writeToMobile(rangeData); // Write to mobile device once data is received
  }
}
```

Write To Mobile Loop

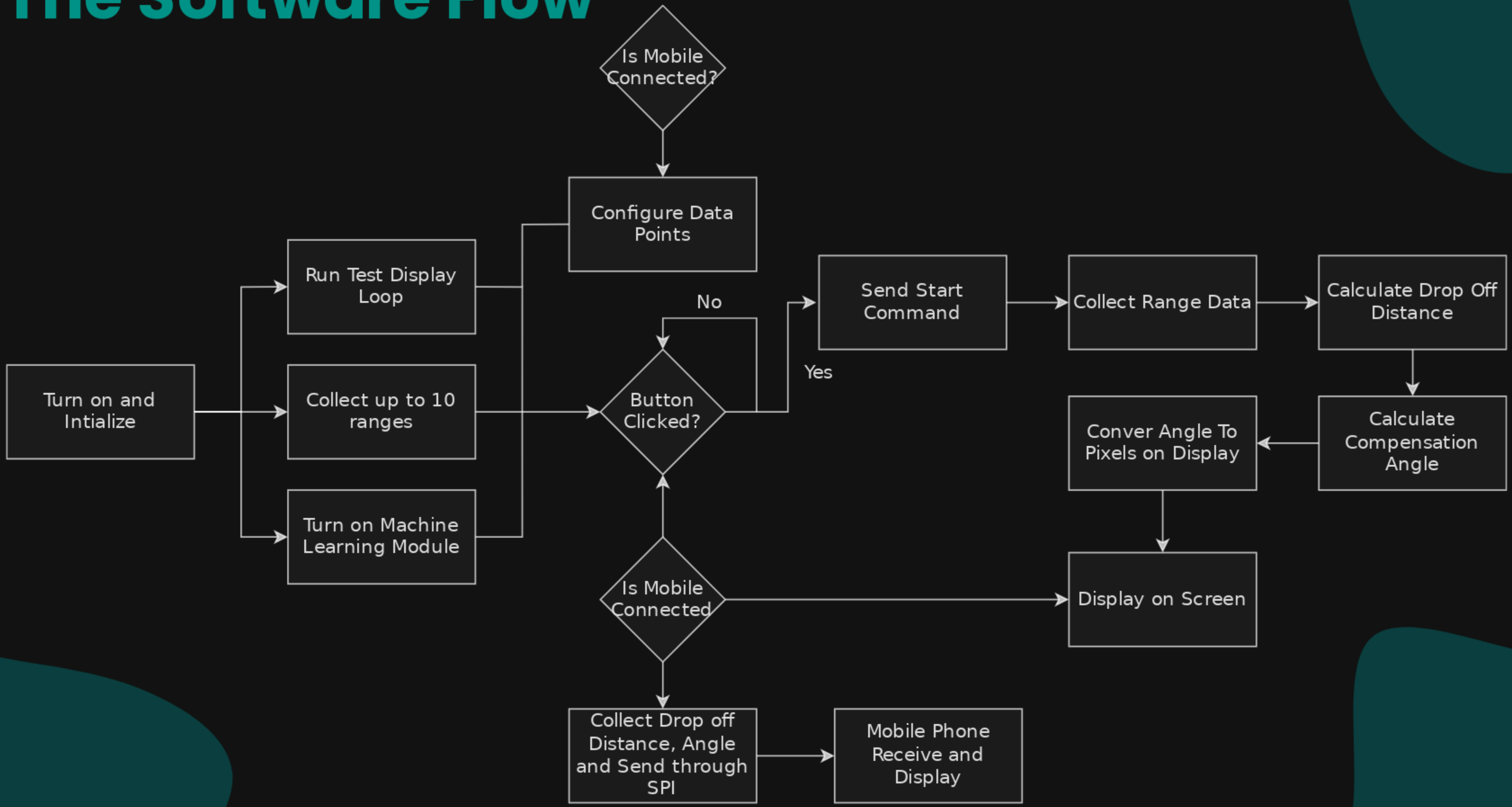
```
String YOUR_DEVICE_NAME;
byte[] DATA;
int TIMEOUT;

USBManager manager = getApplicationContext().getSystemService(Context.USB_SERVICE);
Map<String, USBDevice> devices = manager.getDeviceList();
USBDevice mDevice = devices.get(YOUR_DEVICE_NAME);
USBDeviceConnection connection = manager.openDevice(mDevice);
USBEndpoint endpoint = device.getInterface(0).getEndpoint(0);

connection.claimInterface(device.getInterface(0), true);
connection.bulkTransfer(endpoint, DATA, DATA.length, TIMEOUT);
```

- Pipeline
- Create our object and find devcies
- Connect to device of choice and collect data

The Software Flow



Machine Learning Module

- Integrated Module to object track and record not useful at long ranges
- Seperate module to collect data, object track and record
- Using machine learning modules to learn as you use device

HOG Detector

Basic Model

Time	Very fast
Quality	In a controlled enviorment good
Data Required	Single Image

Faster R-CNN

Region - Convolutional Neural Network

Time	Proportional to amount of data
Quality	Inversely proportional to amount of data
Data Required	Higher data higher quality

YOLO

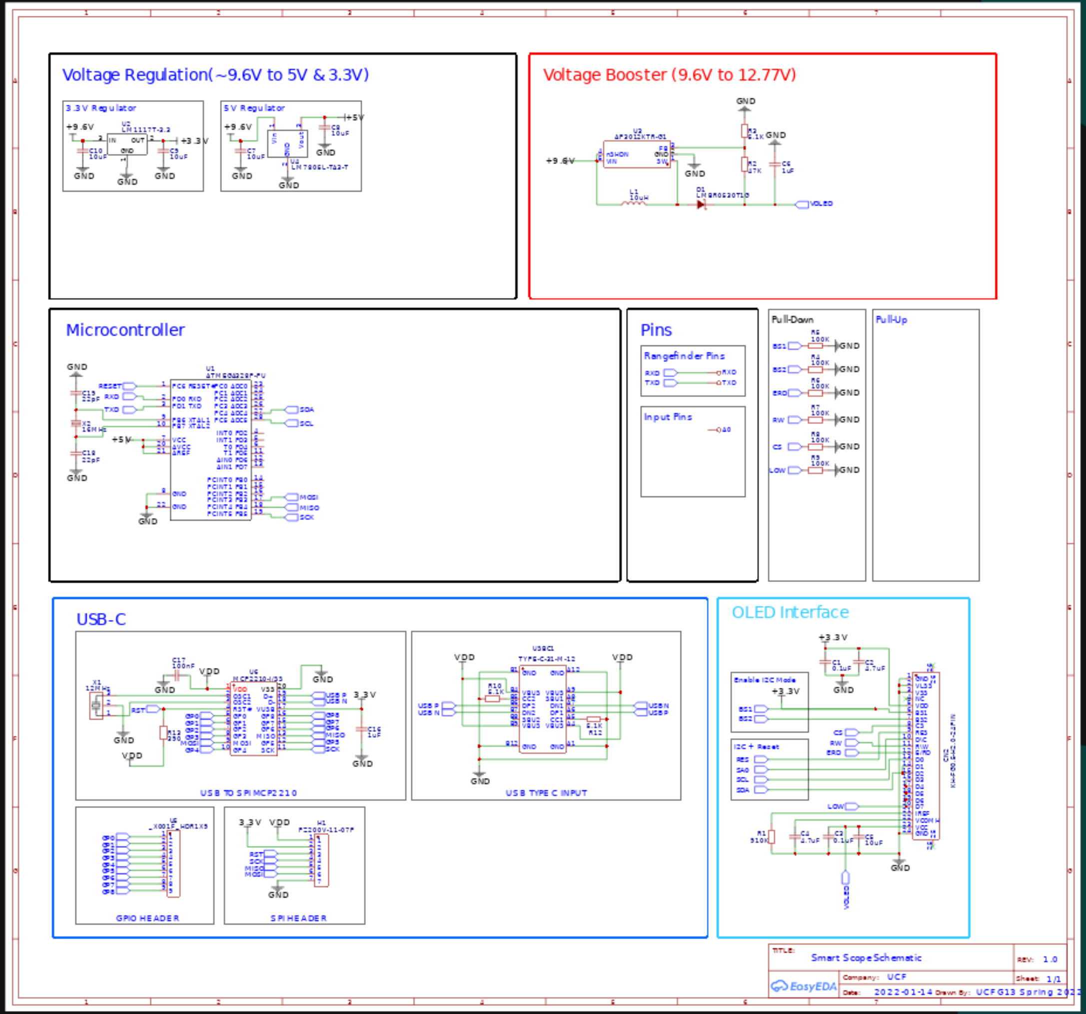
Fully - Convolutional Neural Network

Time	Uses video instead of image so instant
Quality	Perfect for our usage
Data Required	Higher data higher quality

Overall Schematic

To the right is the overall schematic of our design. It includes the following components

- Microcontroller
- OLED Interface
- USB-C Interface & USB-C to SPI
- Voltage Regulator
- Voltage Booster
- Laser Rangefinder Interface



Current Progress

Research	70%
Design	70%
Software	30%
Hardware	70%
Testing	30%
Overall	30%

Successes & Difficulties

Successes

- Magnification was attained: 1-6x
- Switched to a cheaper microcontroller saving around $70 in overall design.
- Targeting lens works as expected and interfaces well with the microcontroller.
- Rangefinder measures more than enough distance for the design to work like expected.

Difficulties

- Lens system does not account for parallax as well as some commercial models
- Rangefinder is larger than initially planned: compact models do not allow for realistic budget of unit
- Bluetooth units are currently hard to purchase and would add excess cost. So a USB-C connection was substituted instead.
- Incorporation of rectangular OLED display requires nonconventional scope shape

Cost Analysis

Component	Use	Cost
Lenses	Provide magnification and basis of optical system	$191
Scope Housing	Creates a secure environment for components	???
OLED Display	Provides targeting information	$38
Rangefinder	Gathers information on distance from user to target	$316
Arduino Uno	Used for testing to ensure working system	$25
PCB	Board which will contain MCU and interface with components.	???
Total		$500

Todo

- Order PCB and mount components
- Design and Order Housing
- Integrate systems together
- Testing