Low Power Variable Optic with Automatic Distance Correction

Group 13


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Context

On the market today there are scopes that are capable of automatically correcting for bullet drop when aiming at a target. This is done by measuring the distance between the target and the scope and having the user adjust the scope's position to compensate for the difference.

Trijicon® CCAS

$31,000

- Automatic bullet-drop distance correction
- Accounts for pressure, angle, range, and movement of target.
- Programmable projectile options.

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 accurretly 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.

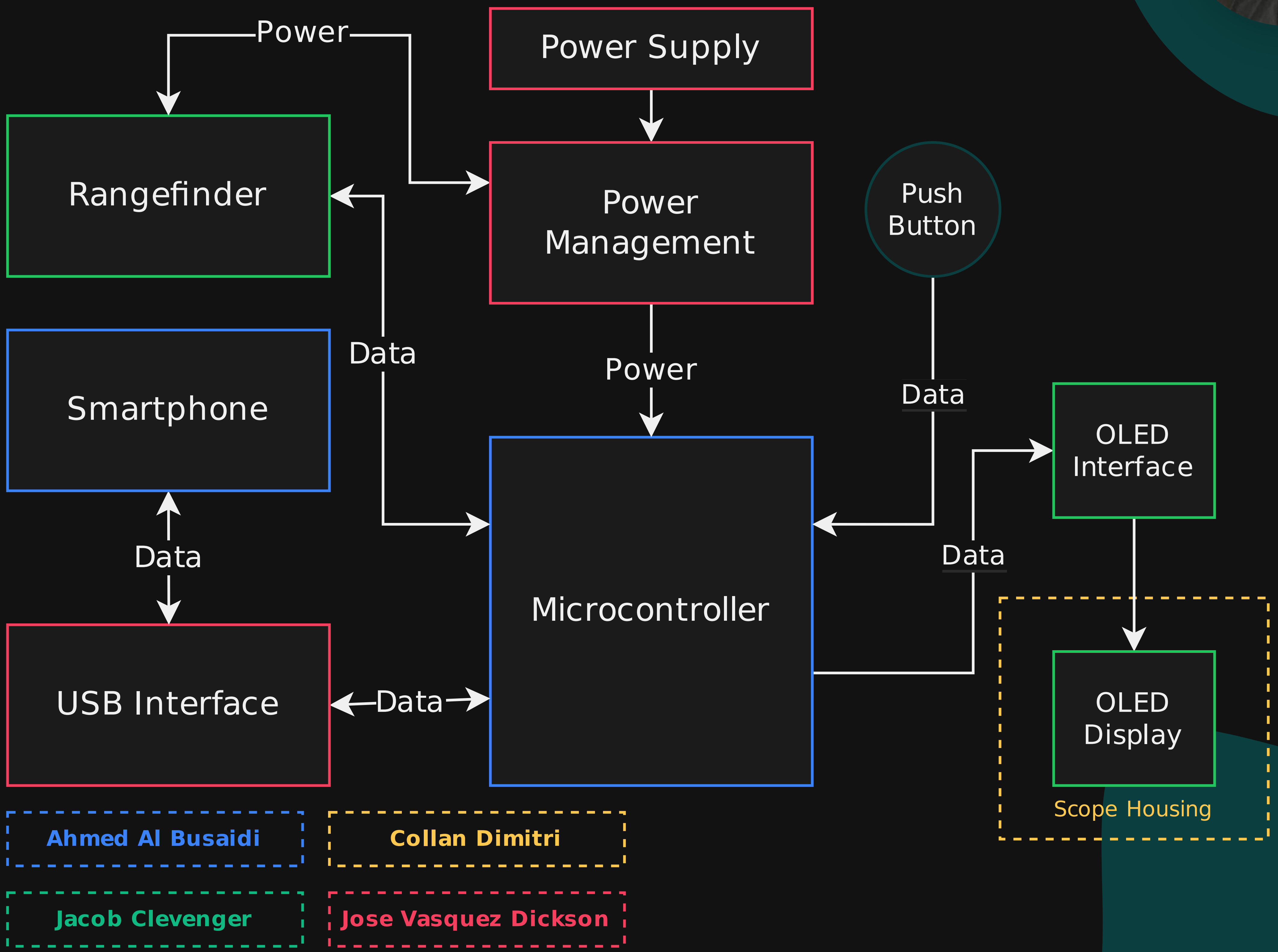
Engineering Specifications

Requirement	Unit
Lightweight	≤ 1000g
Cost-efficient	≤ $650
Accuracy	≤ 200cm
Time-efficient to determine target's distance	≤ 2s
Operating Temperature Range	0°C - 125°C
Operating Voltages	3.3V, 5V, and 12.77V
Power Consumption	≤ 20W

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

The following table gives a description of each lens in the scope.

Lens	Type	Diameter	R1 & R2
Objective	Biconvex	30mm	30mm
Image Reversal	Biconvex	25mm	25mm
Eyepiece Assembly	Biconvex	40mm, 25mm	60mm, 50mm
Eyepiece Assembly	Biconcave	25mm	100mm

Scope Housing

The scope housing contains the lens setup along with the digital display containing the scope reticle.

- 3D printed PLA, outer diameter of 50 millimeters at eyepiece.
- Integrated mounting system for easier utilization, placed on variable height Picatinny riser to accommodate multiple heights.
- Allotted space for onboard electronics; board will be placed underneath the optical system
- Ports for activation switch and rangefinder to attach

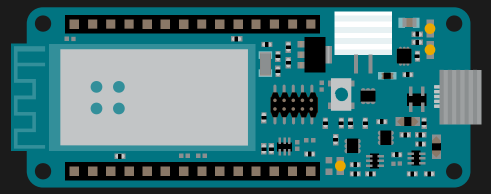
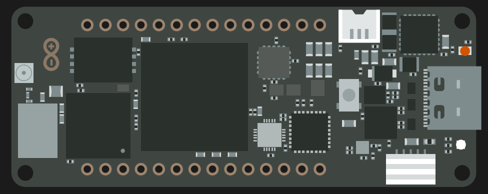
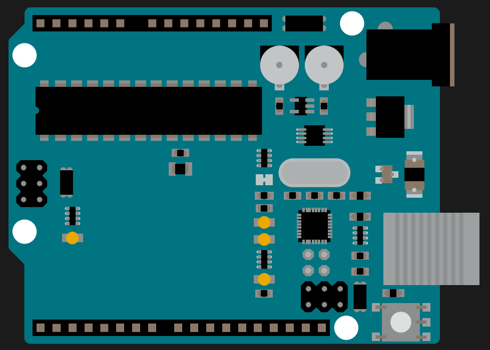
Optical Constraints

- 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

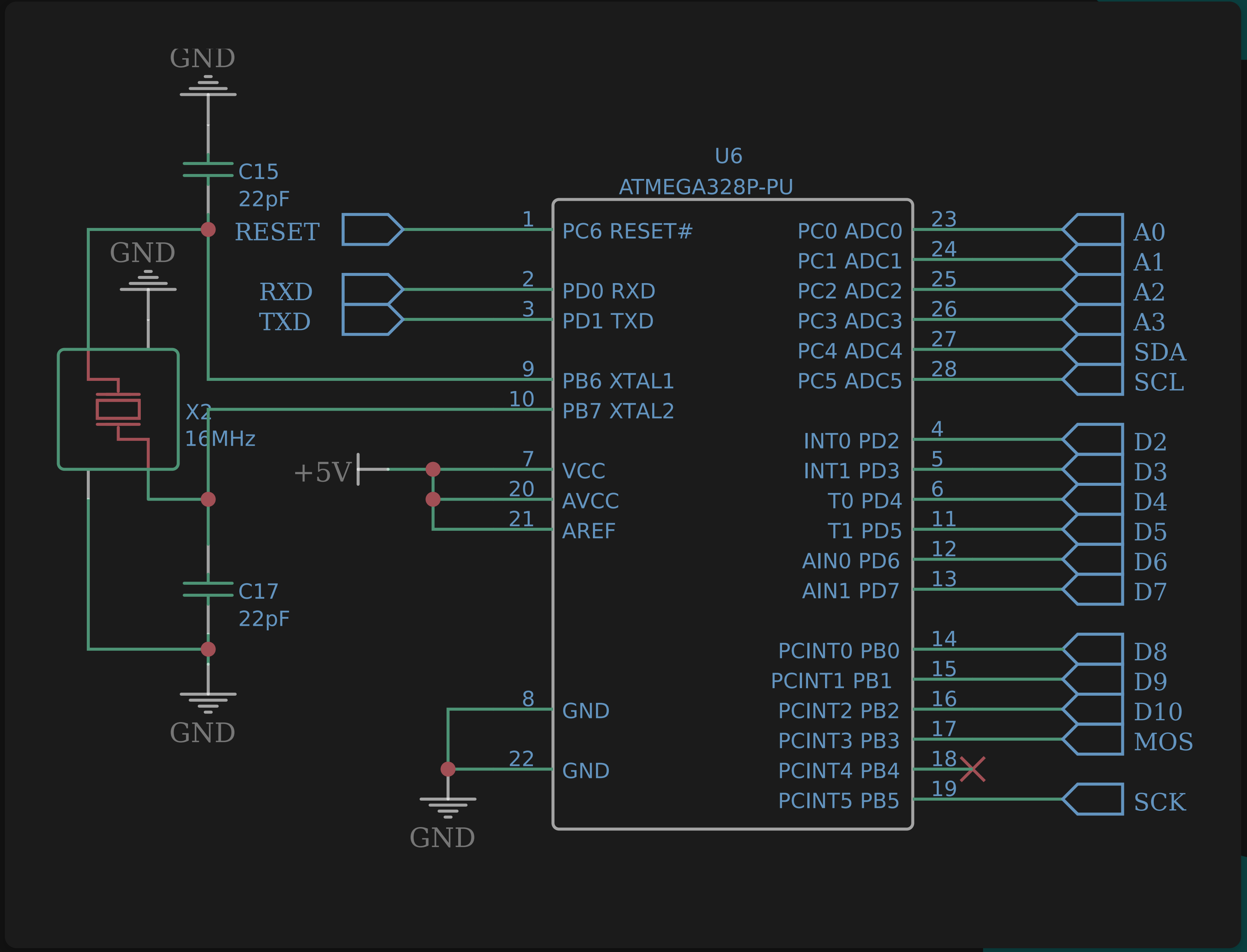
Choosing a Microcontroller

	 MKR 1000 WiFi	 Portenta H7	 Arduino UNO
Price	$36.00	$103.40	$23.00
MCU	STM32H747XI	SAMD21 32bit	ATmega328p
Speed	48MHz	480MHz	16MHz
Cores	1	2	1
	🚫 Out of Stock	🚫 Expensive!	✅ Perfect!

MCU Circuit

The circuit to the right is the circuit for the ATmega328p microcontroller.

- Circuit is powered via a 5V regulator on the board.
- 16MHz crystal oscillator is connected to the clock of the ATmega328p
- SCK, MOSI, D7, and A0 are wired to OLED interface.
- SDA & SCL are wried to USB interface.
- Remaining pins are wired to pinouts on the board for general I/O



The Rangefinder

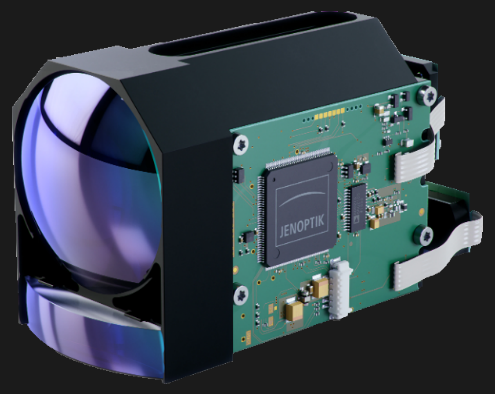
Jose Vasquez Dickson & Jacob Clevenger

Rangefinder Requirements

The following requirements were considered for the rangefinder

- 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



	DLEM 17	HR1500A
Price	Unknown	$316
Range	8KM	1.5KM
Accuracy	±1m	±2m
Interface	UART	UART

HR1500A

$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 calculations will be negligble.	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

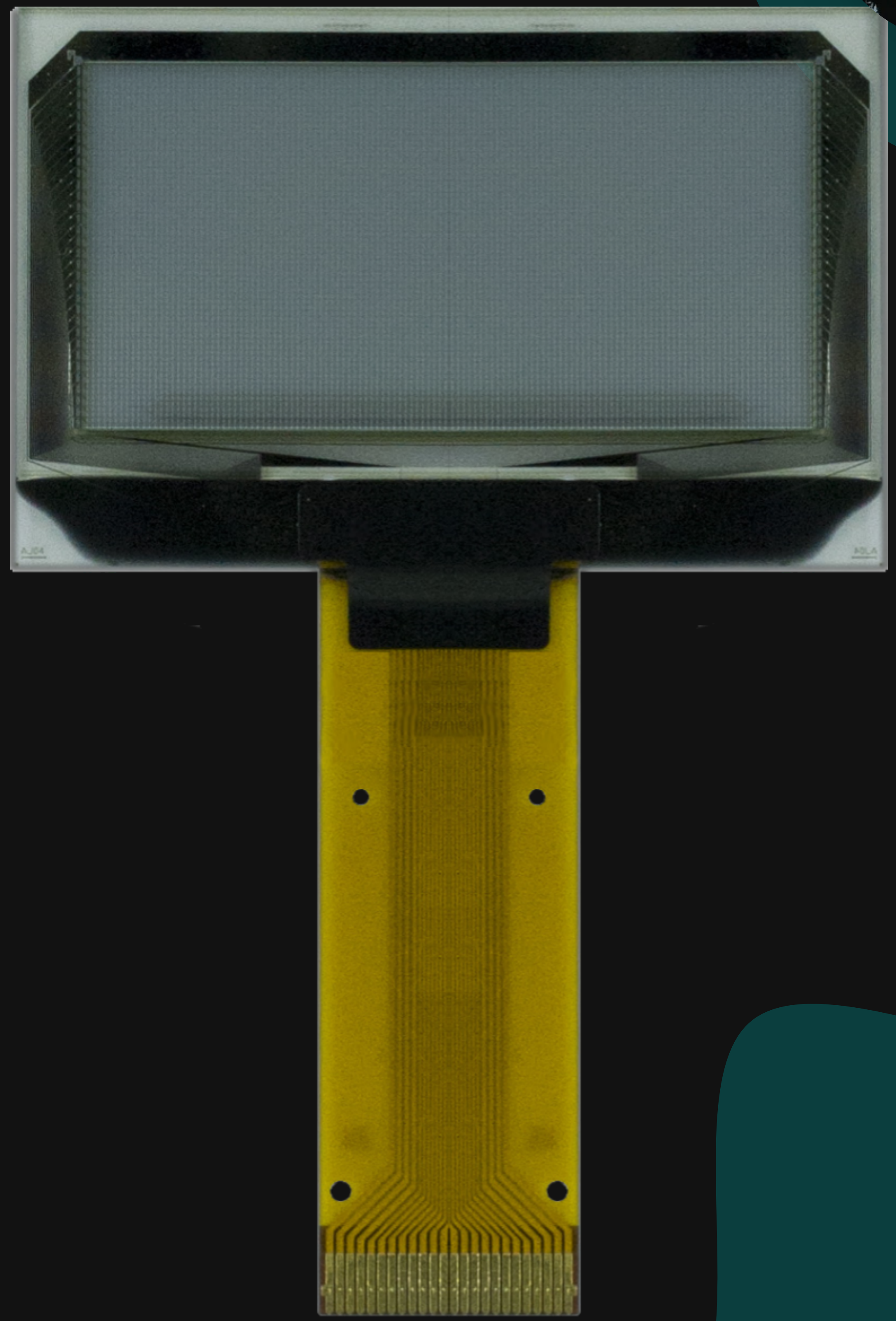
CFAL12856A0-0151-B

$26.08

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

✓ Display meets all requirments

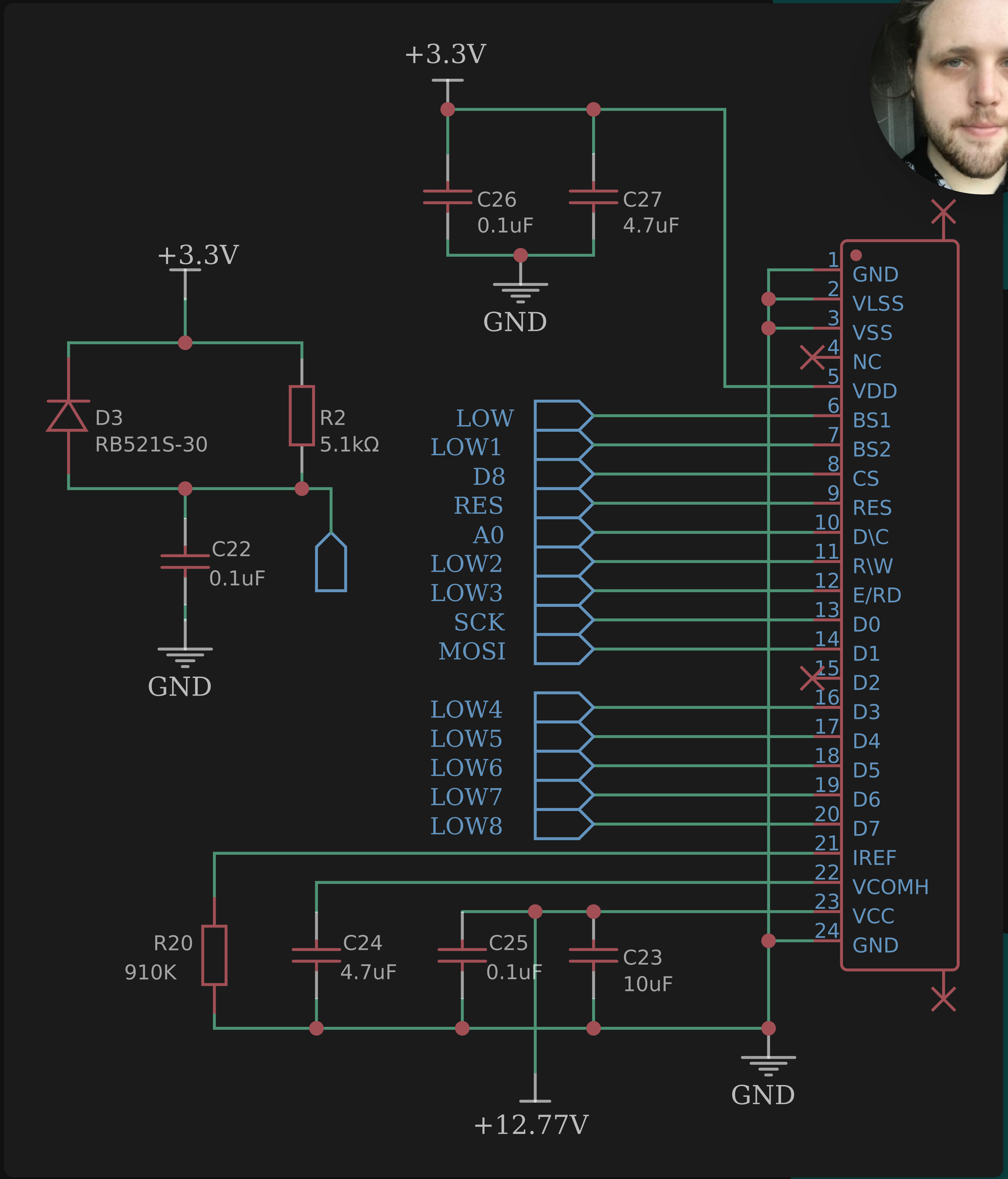
The display uses the Solomon Systech SSD1309 integrated controller which runs off of 3.3V supply. As for the panel itself, it runs off of a 12.77V supply.

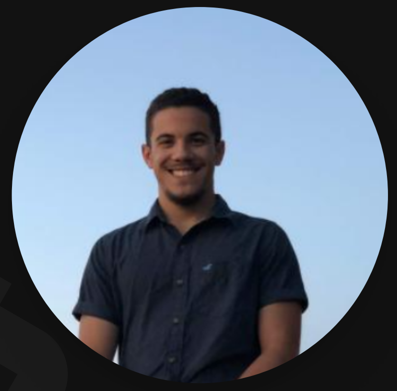


OLED Interface

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

- Enable SPI via `BS1` & `BS2` pins
- Power logic circuit with `3.3V` via `VDD`
- Power panel with `12.77V` via `VCC`
- Reset display via `RES` pin
- Pins `SCK`, `MOSI`, and `A0` carry `SPI` signal.
- Following pins pulled LOW `CS`, `RW`, `ERD`, and `LOW`
- OLED display uses ZIF connector to connect to 24-pin connector on PCB.





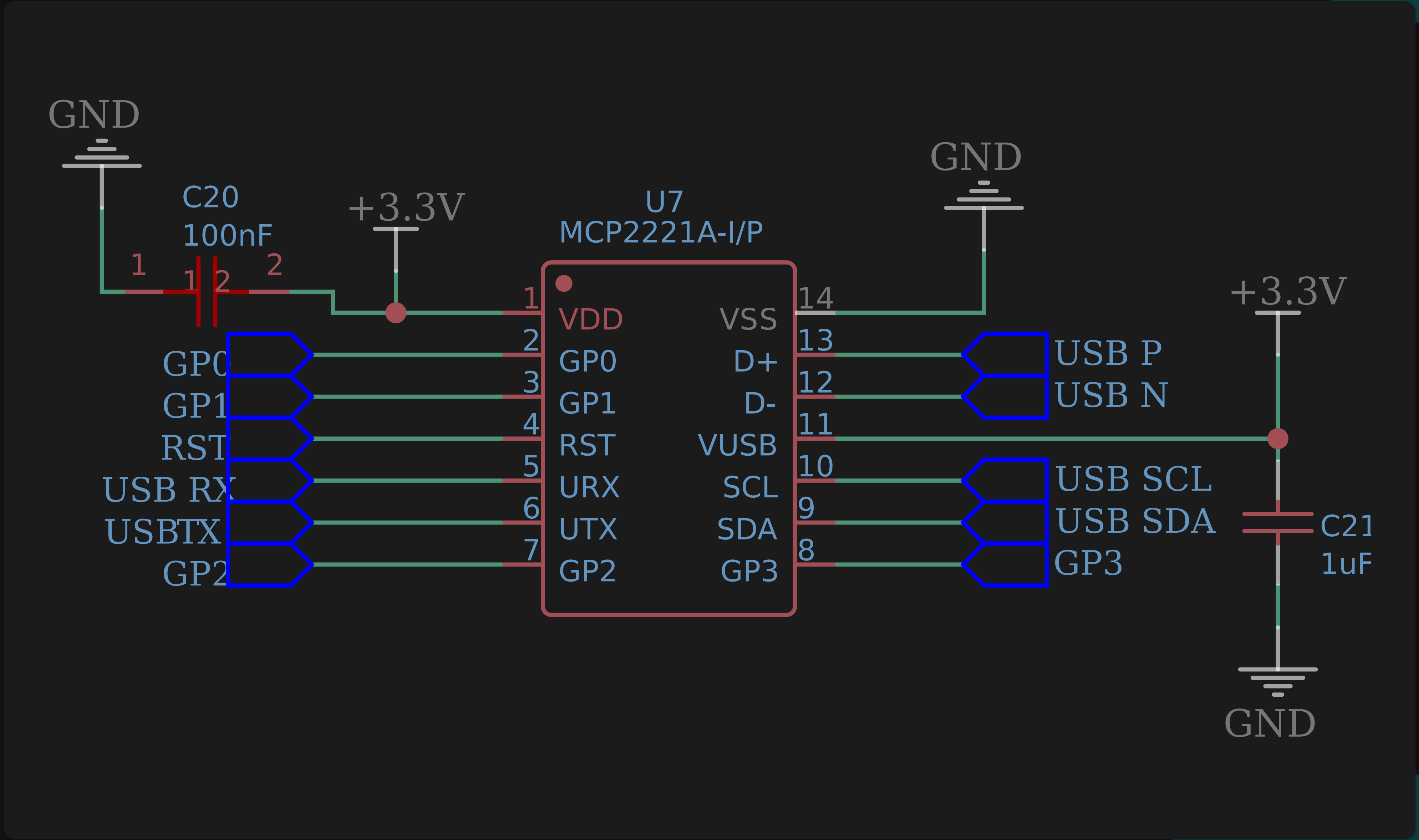
The USB-C Interface

Jose Vasquez Dickson & Jacob Clevenger

USB-to-I2C Integrated Circuit

The circuit to the right is the interconnection of the MCP2221A, USB-to-I2C converter with GPIO.

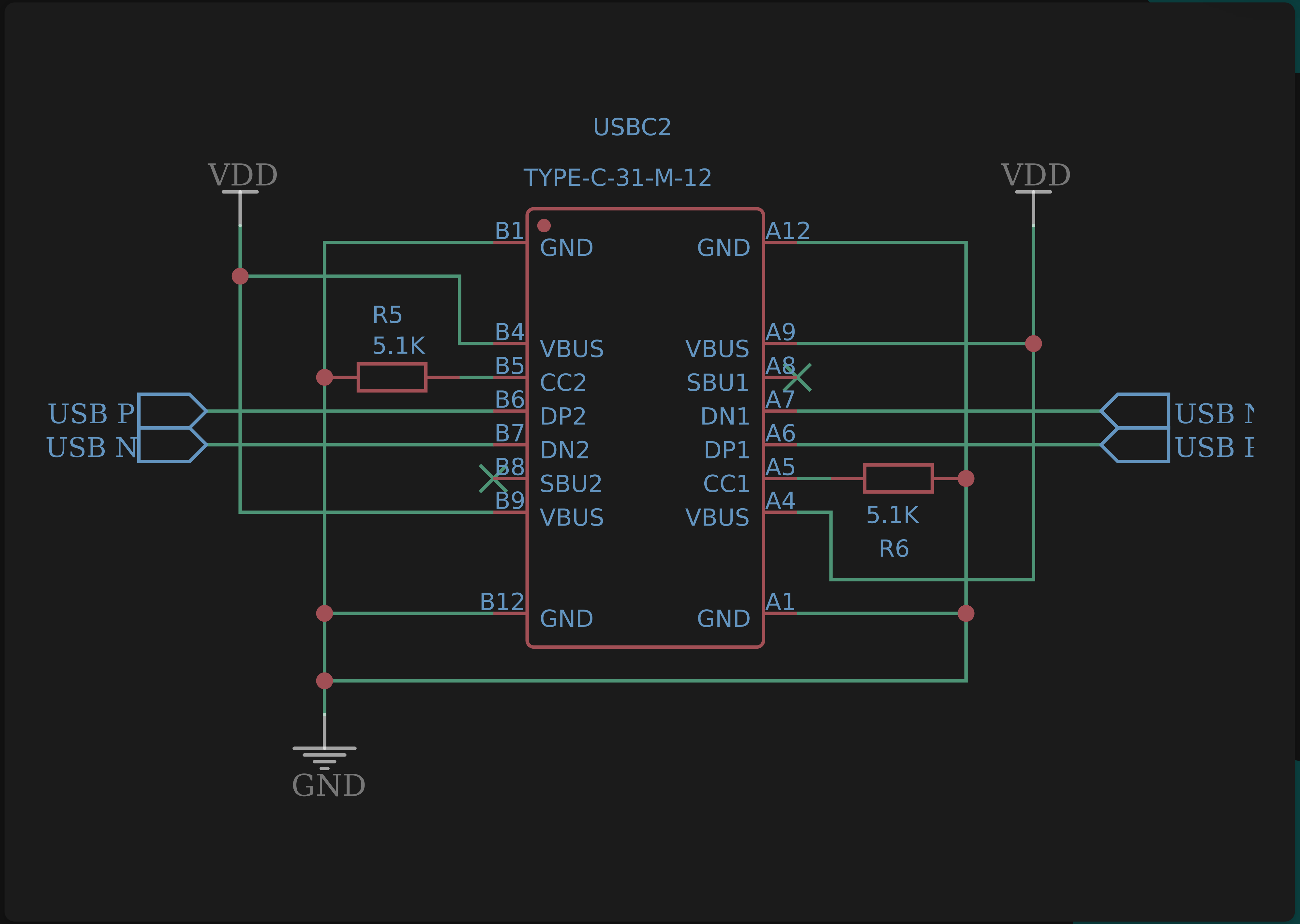
- Enables a USB connectivity in applications that have an I2C interface
- Enable this microchip via VDD pin
- Resets via RST pin
- Data lines via D+ & D- pins with USB Type C connection
- Power pin via VUSB pin to the SPI header
- GPIO pins via GP0 to GP3 pins
- Uses internal oscillator



USB-C Header

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

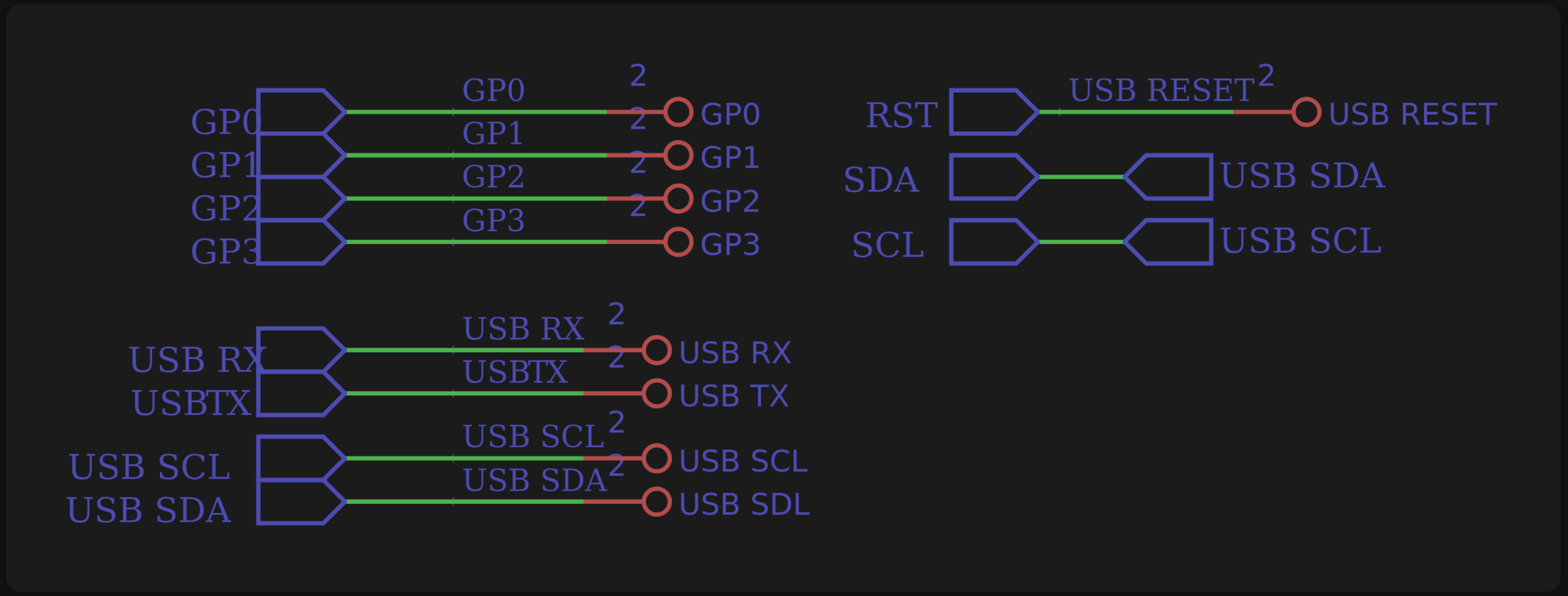
- Input power pin via VBUS pins
- Pulled down resistors on CC1 & CC2 pins
- Data lines via DP & DN pins to microchip

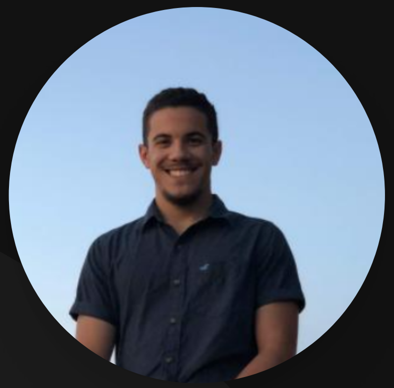


USB-C Board Headers

These circuits are the I/O pins for the USB-to-SPI Interface.

- 4 Pin board output pins for the GPIO pins
- 5 Pin board output pins for the SPI pins
- Enable USB Receive and Transmit pins via USB RX & USB TX from MCP2221A-I/P
- Enable I2C data and clock line via USB SDA & USB SCL
- Reset output pin via USB RESET



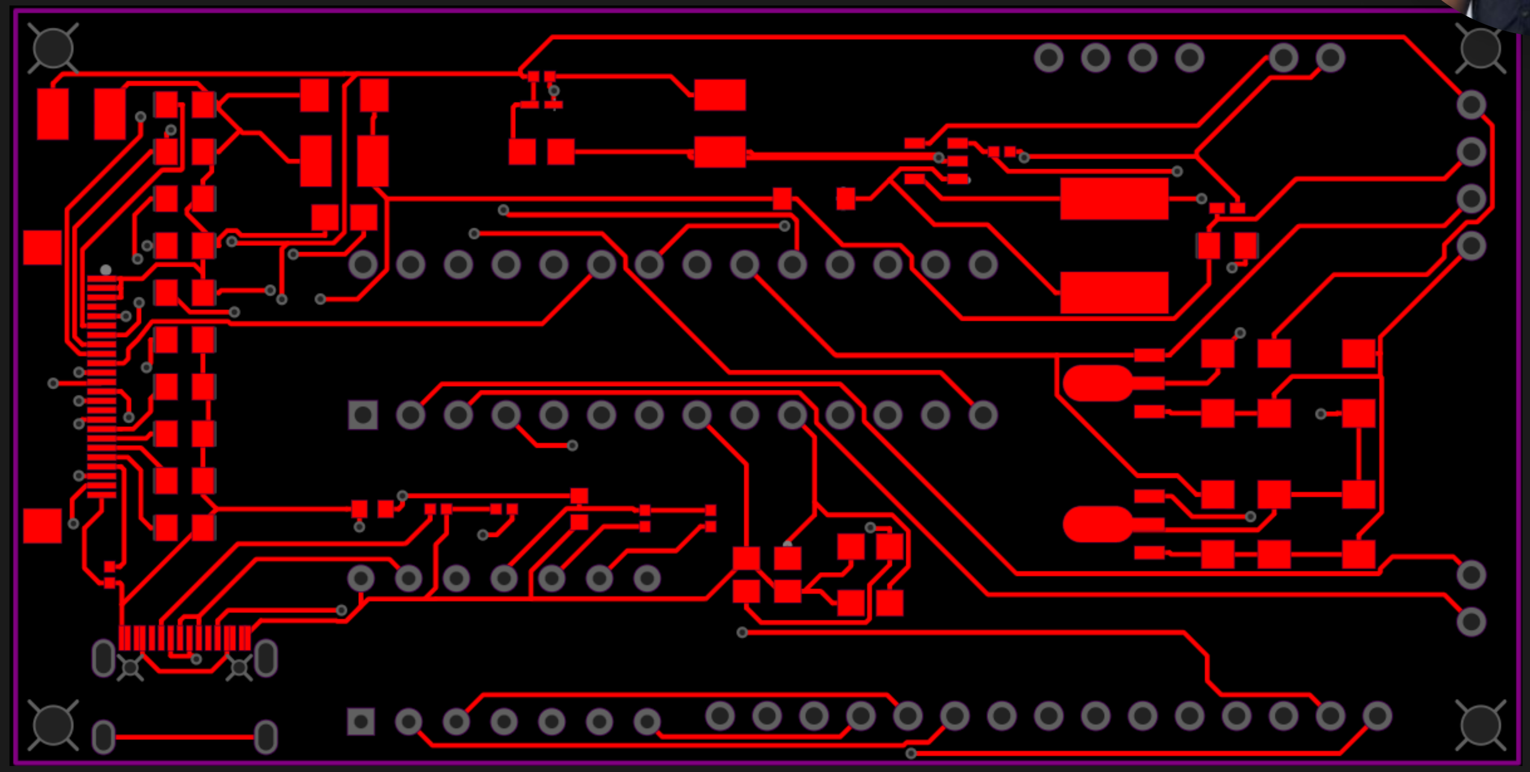


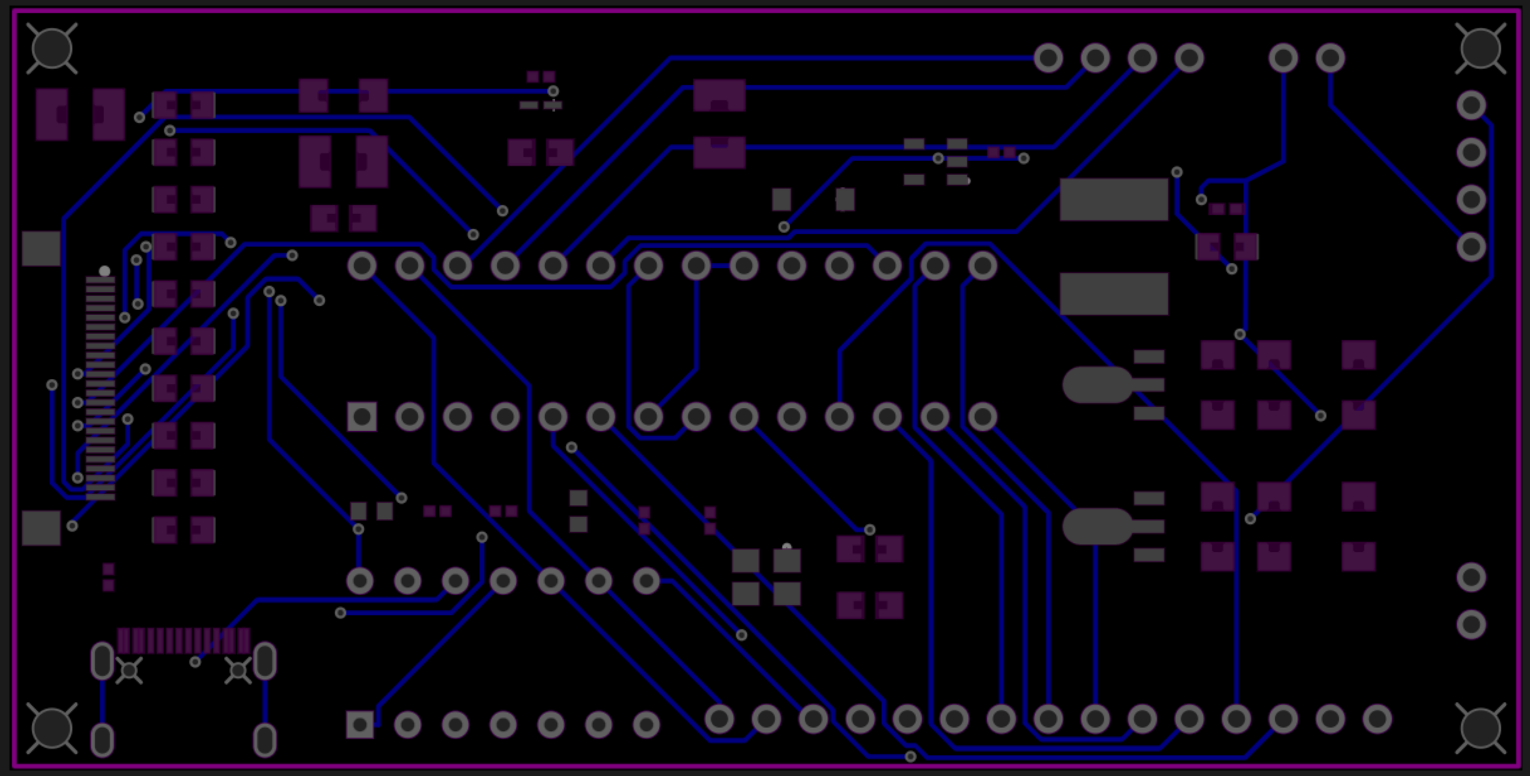
PCB Interface Design

Jose Vasquez Dickson & Jacob Clevenger

PCB Interface Design

The images to the right are the layers of the 2 layer PCB that consists of all the components in one PCB. The top layer is in red, and the bottom layer is in blue.





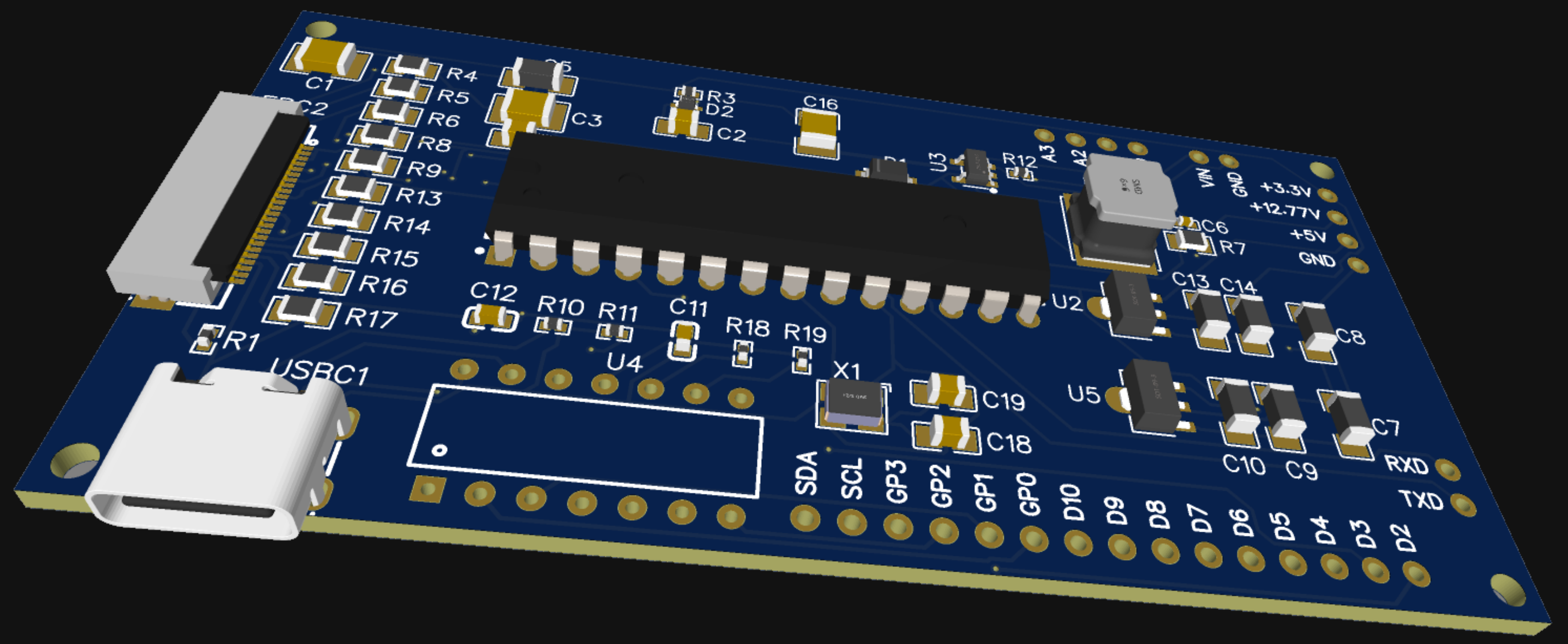
ROUTING RULES

- No 90º turns
- Track width 0.254mm
- Clearance 0.152mm
- In accordance to our PCB manufacturer
- Surface mounted for most components
- Through-hole for some components

PCB Interface Design

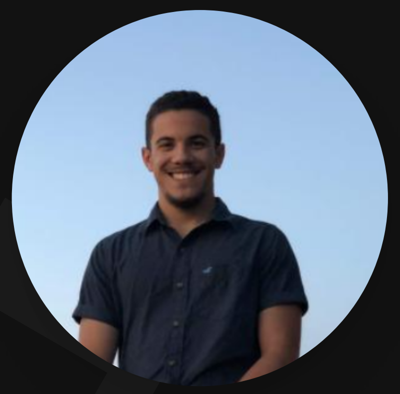
This image is the 3D rendering of the PCB Interface.

- Microcontroller labeled U1
- USB Type C labeled USBC1
- USB-to-I2C converter labeled U4
- OLED Display connector labeled FPC2
- Voltage regulators labeled U2, U3, & U5
- Capacitors labeled C1 through C19
- Resistors labeled R1 through R19
- GPIO output pins labeled GP0 through GP3
- SPI output pins labeled SDA, SCL, RXD, & TXD



The Power Supply

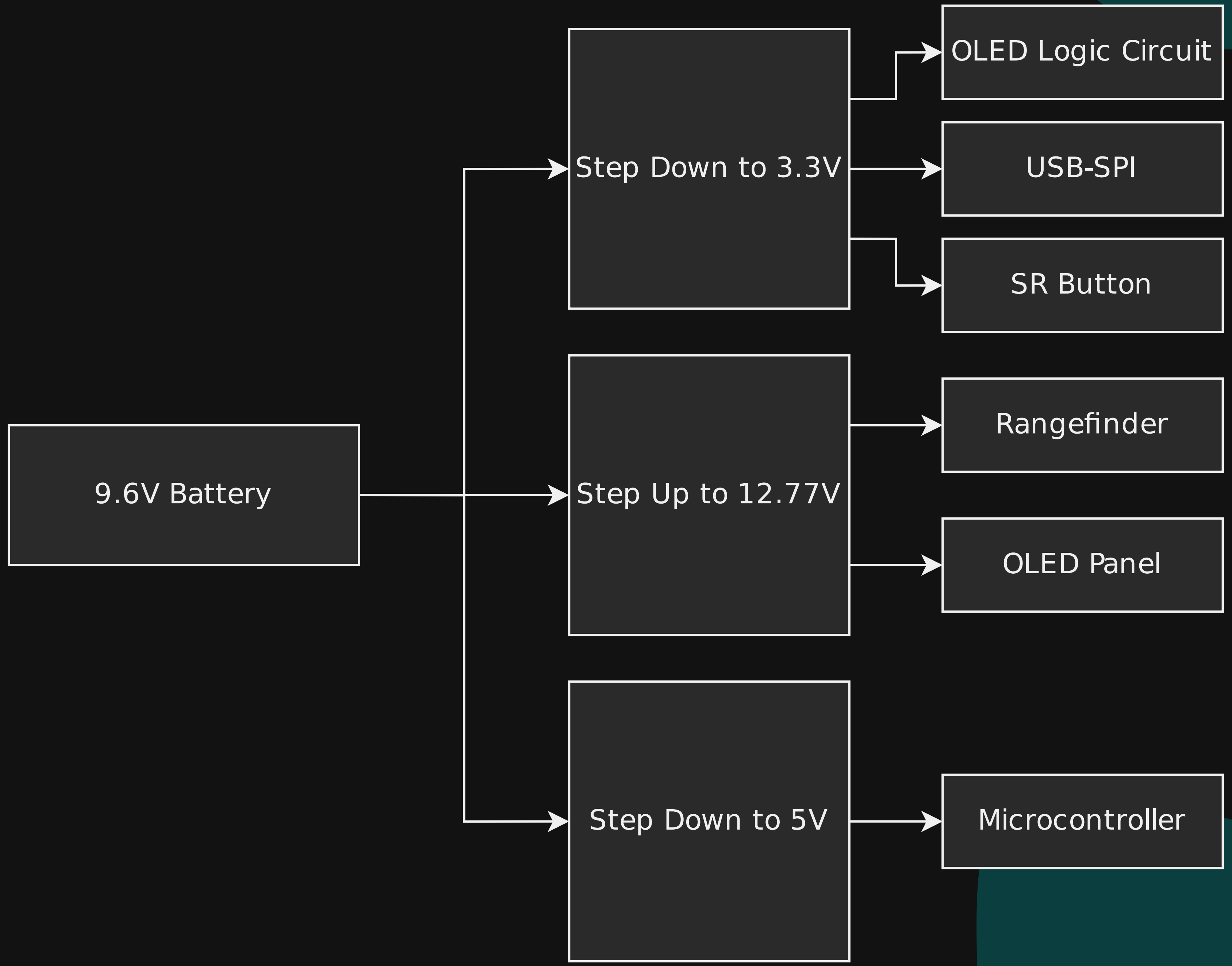
Jose Vasquez Dickson & Jacob Clevenger



Power Supply

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

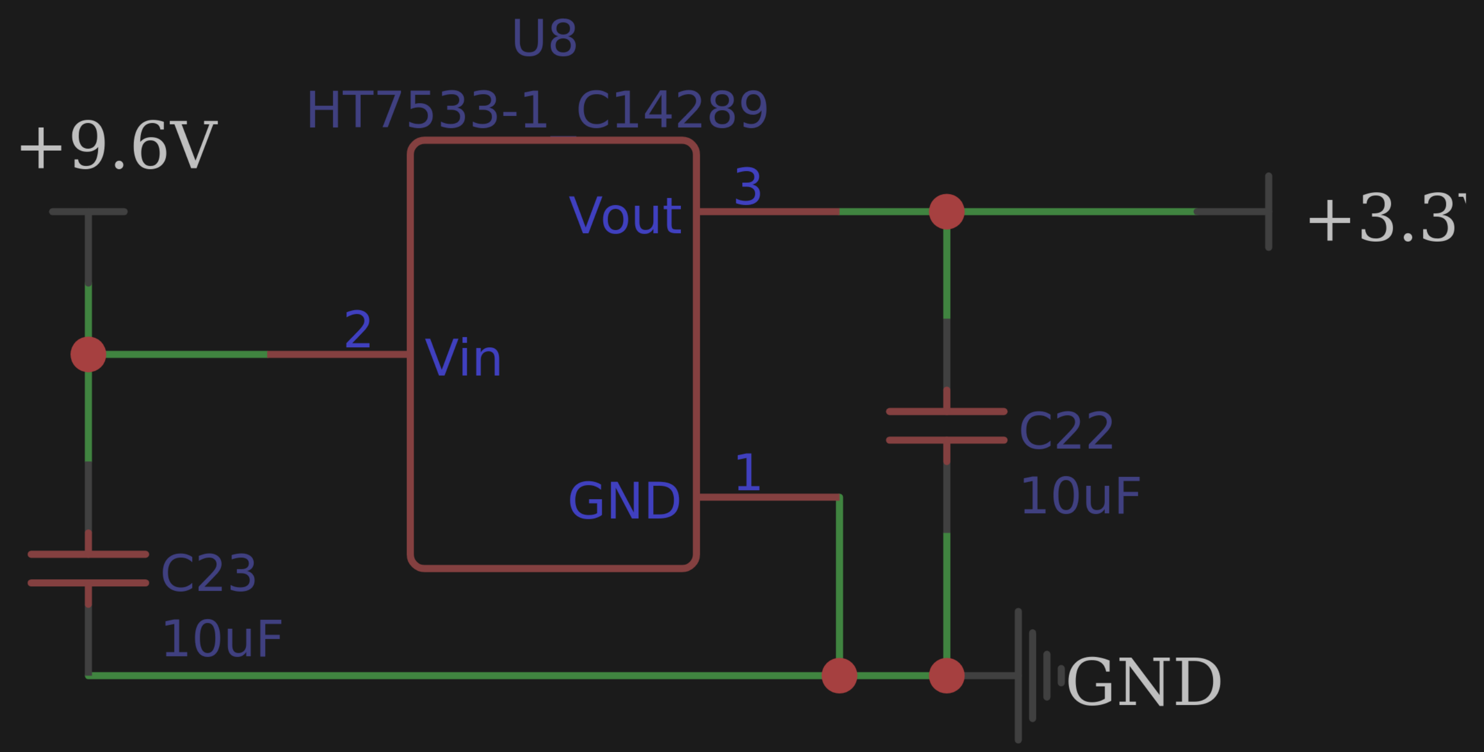
- Step down to 3.3V
  - OLED Logic Circuit
  - USB-to-SPI Interface
  - SR Button
- Step down to 5V
  - Microcontroller
- Step up to 12.77V
  - Rangefinder
  - OLED Driving Panel
- Future expansion
  - 3 voltage levels
  - Additional components and features



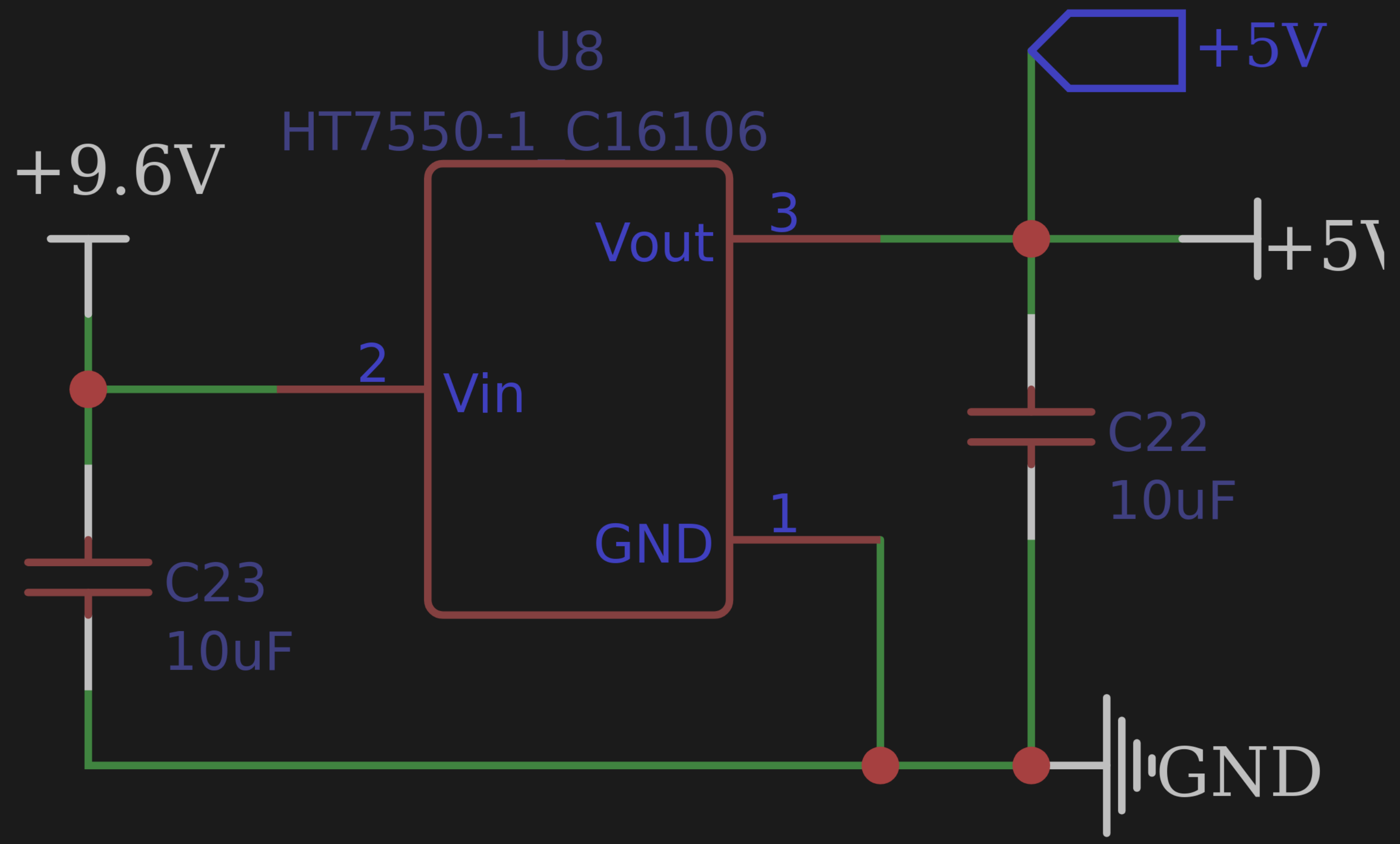
Regulators

The following circuits are used to regulate the 5V supply to the microcontroller and 3.3V supply to the dispaly.

3.3V Regulator



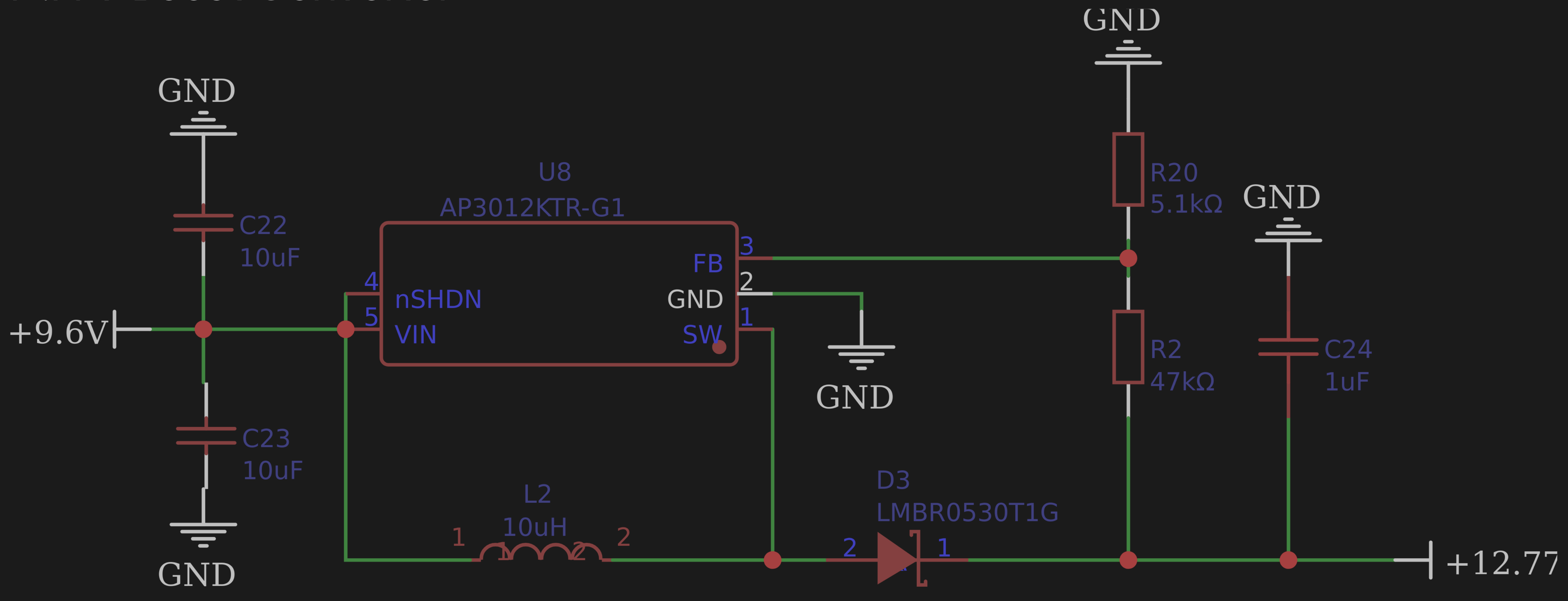
5V Regulator



Boost Converter

The following circuit boosts the 9V supply to the microcontroller up to 12.77V for the OLED display.

12.77V Boost Converter



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: 9V battery
  - Use voltage regulators to change the voltage as needed
- Pros
  - Less expensive
  - Less Space required
  - Regulated

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

Technologies Used

Arduino

Language	C++
IDE	Arduino IDE 2.0

Mobile Application

Front End	VueJS
Backend	Node.js
Libraries	MCP2221 Comm Library

UI Design

UI Design	Figma
Flowcharts	draw.io
Icons	Icones

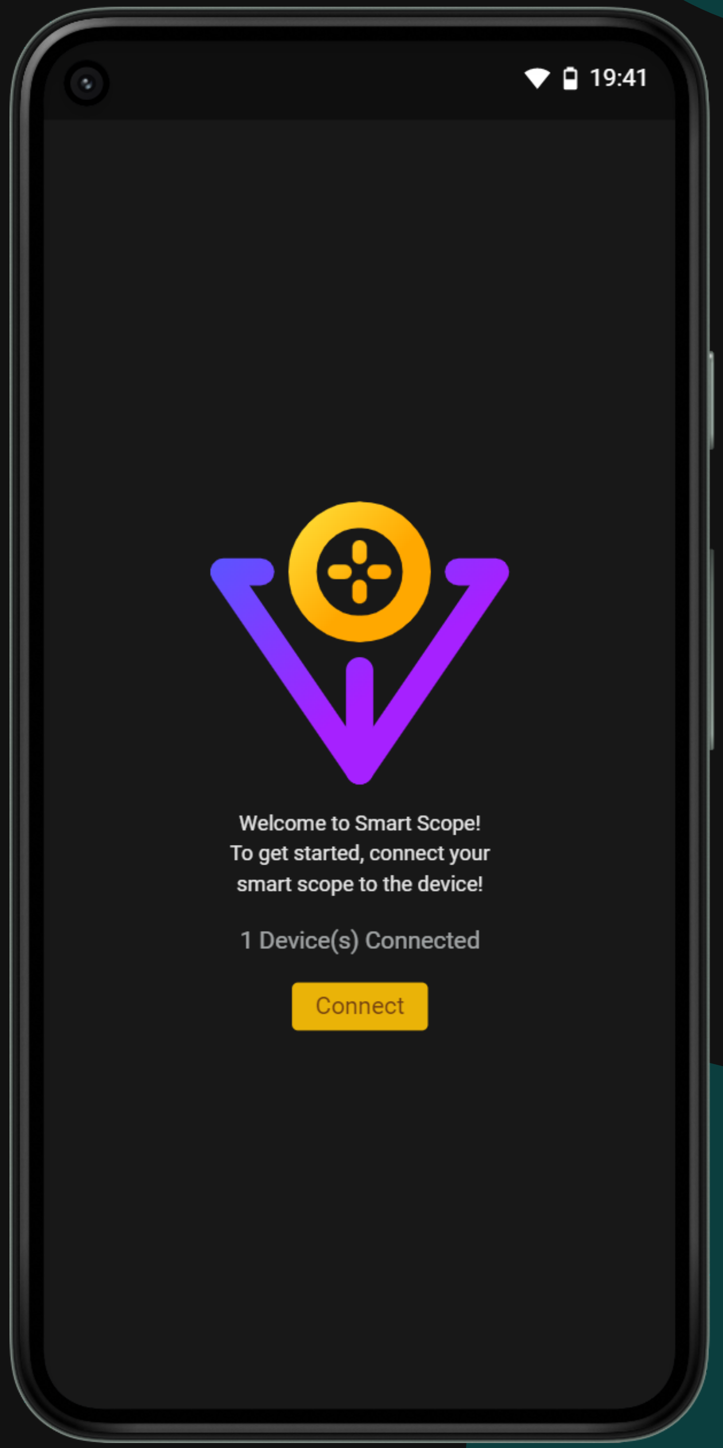
Footage Collection

Video Editing	Adobe Premire Pro
Camera	Canon EOS M50 Mark I
Audio	Blue Yeti

Mobile Application

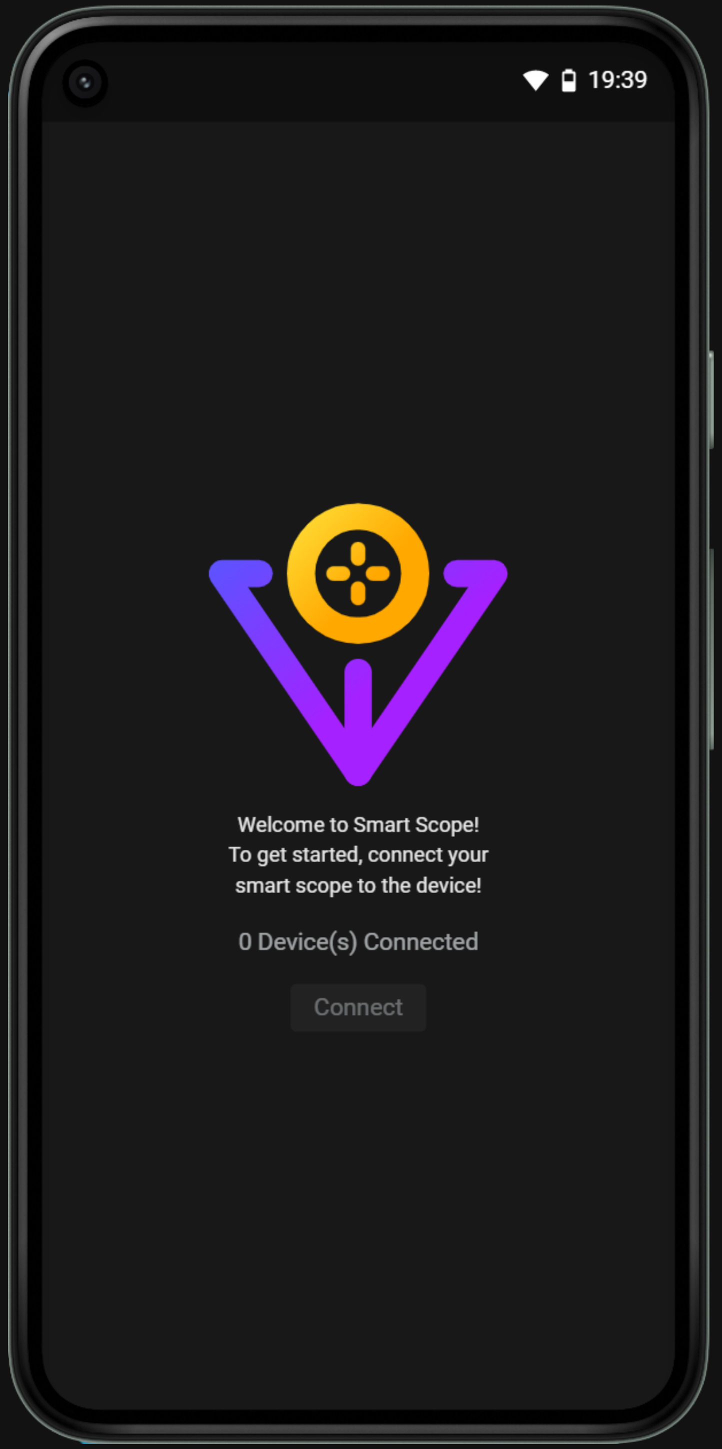
The android application was built to interface with the micro-contorller as well as to extend its functionilty to better allow the user to customise the display.

- Allow users to update display brightness.
- Configure dataset used to calculate range calculation offsets.
- Log range data from scope.
- Debug scope.

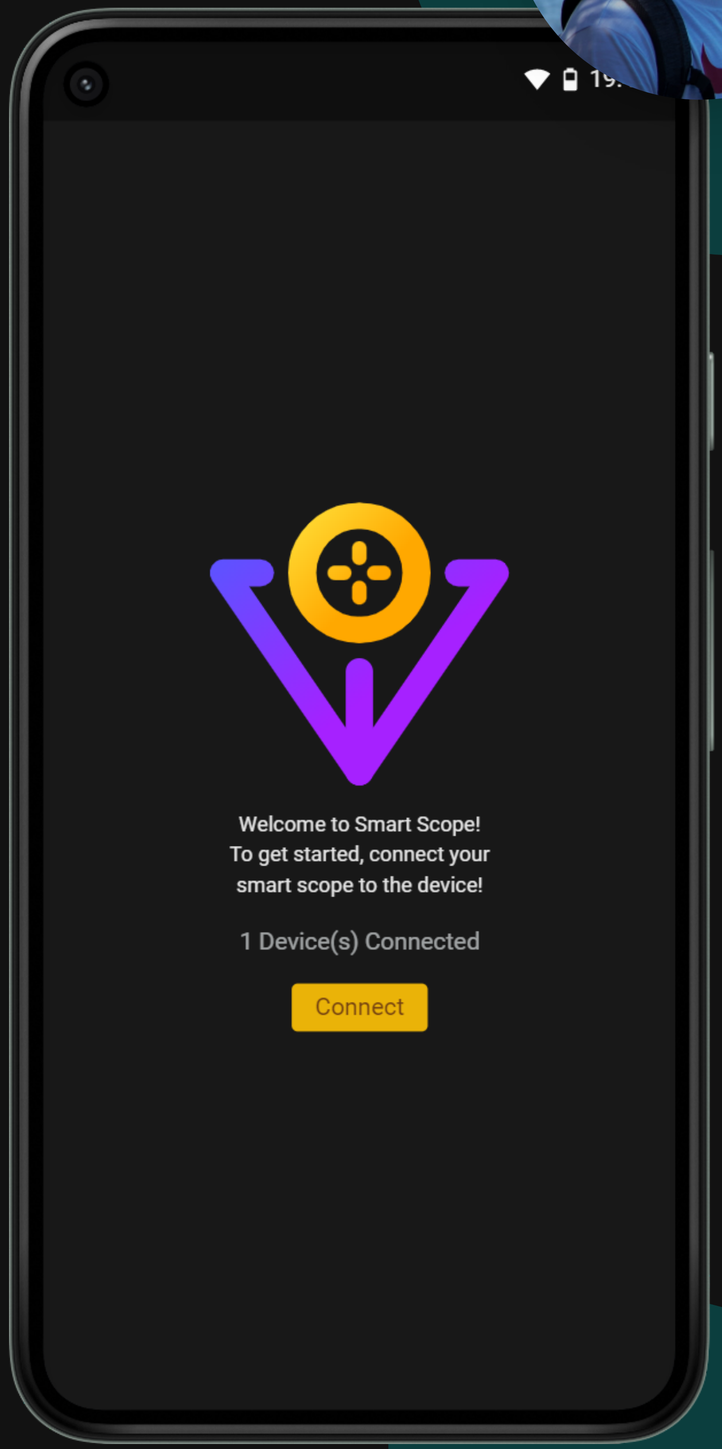


Device Connection Status

When the device is connected to the phone, the android app will automatically detect the scope. After detecting the scope, the app will display the nubmer of connected devices and give the user the option to connect to the scope.



Before USB Connected

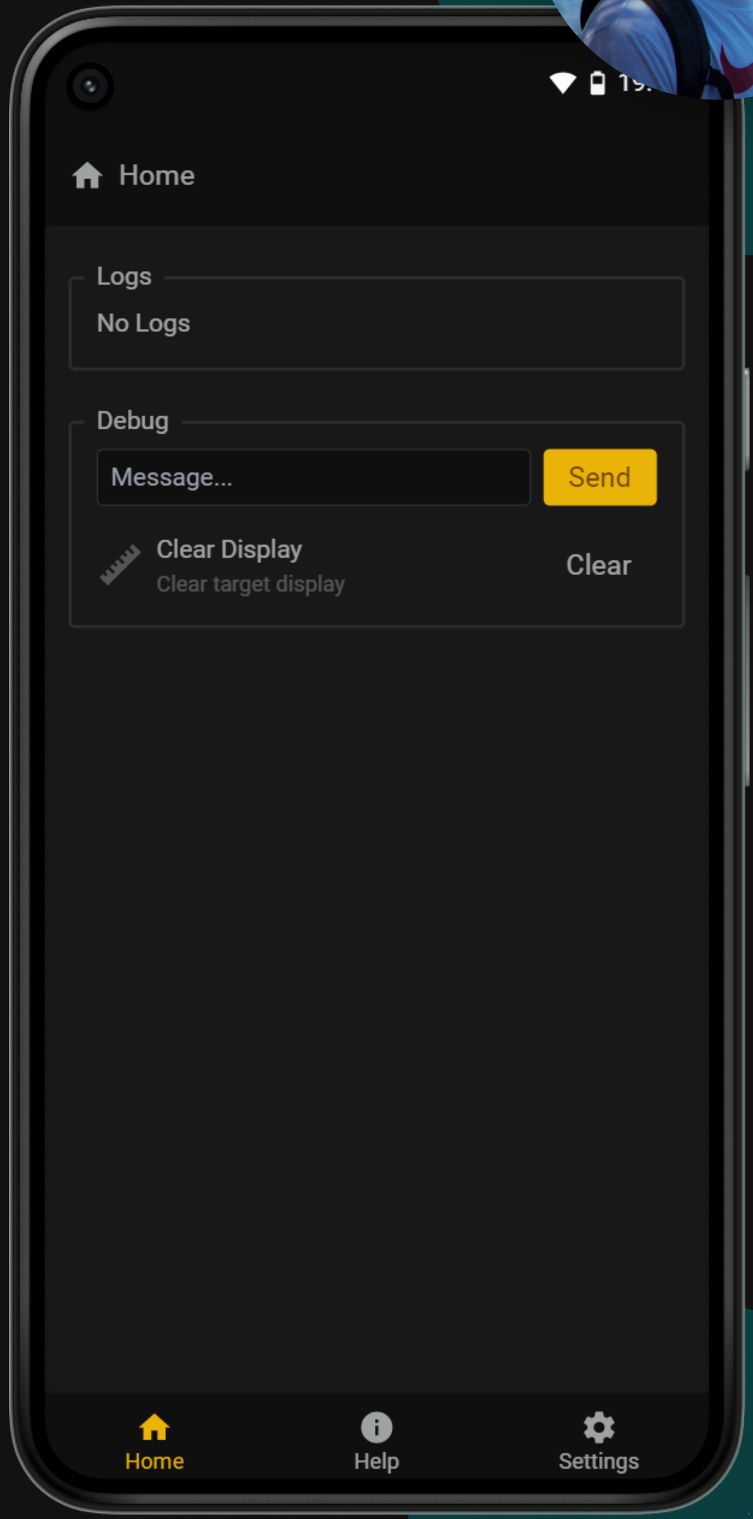


After USB Connected

App Homepage

After connecting to the scope, the user will be taken to the app homepage. Here the user can view scope logs and debug basic scope functionality.

- View Range logs
- Send messages and commands to scope.
- Clear display contents

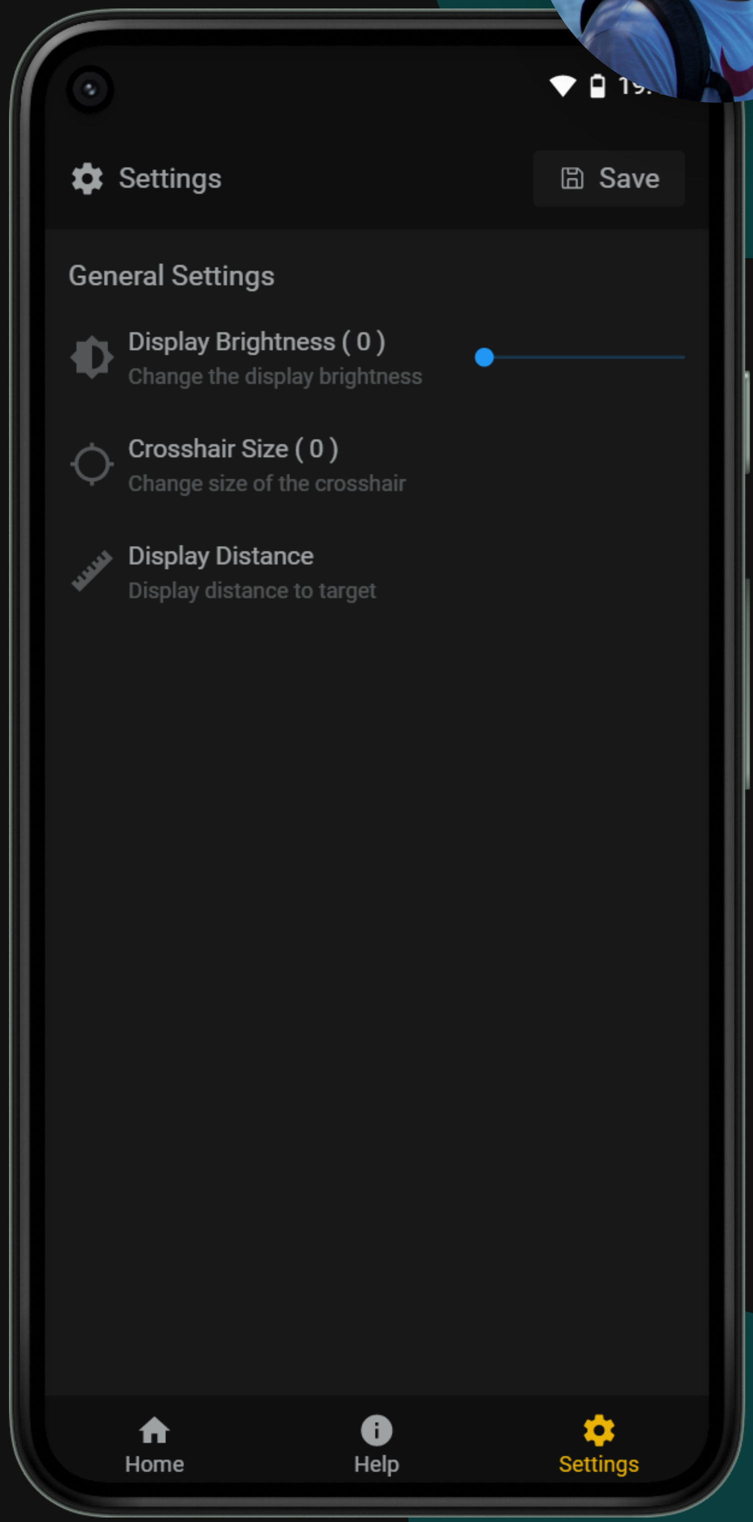


Homepage

App Settings

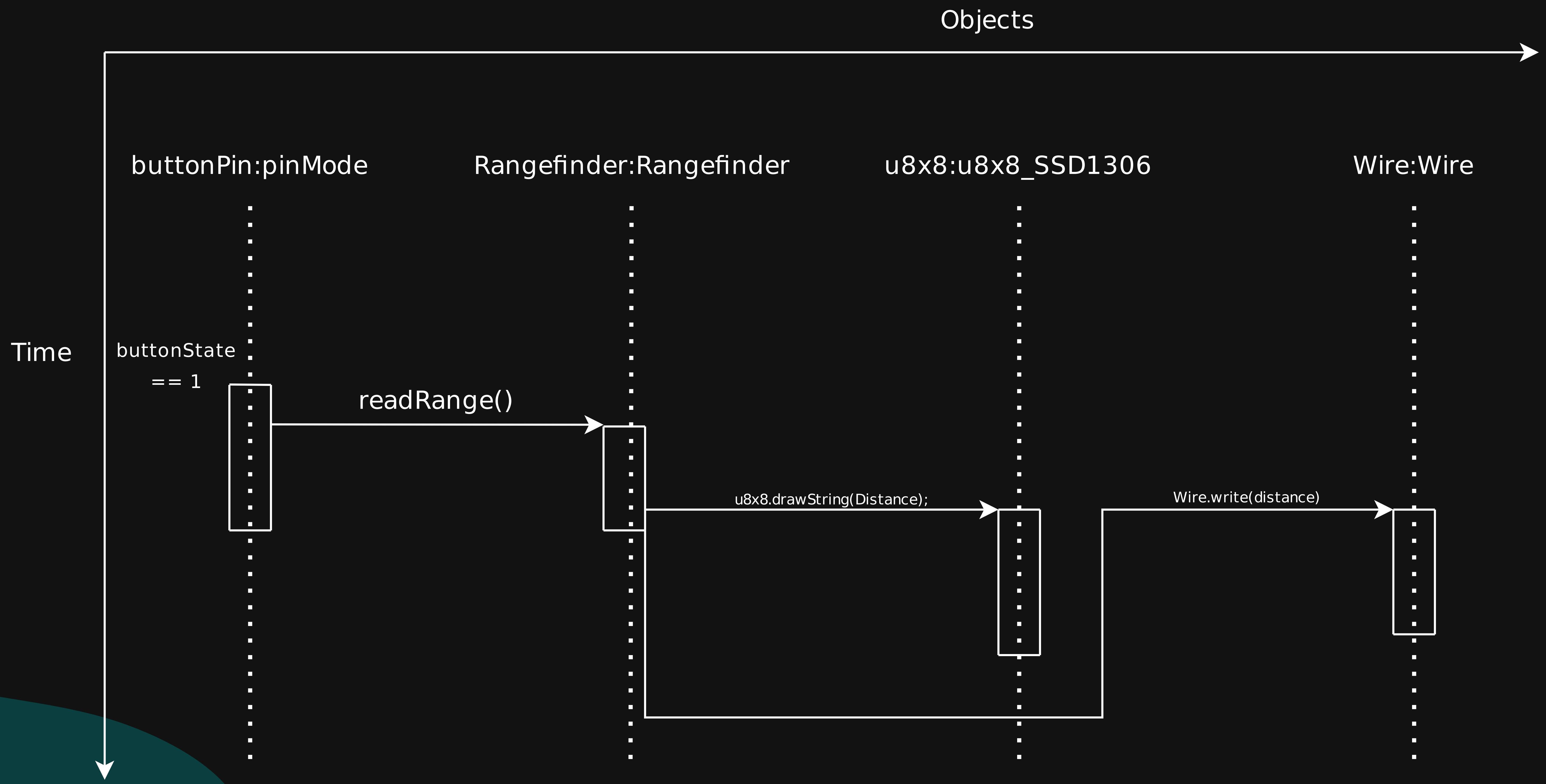
The settings page allows the user to configure several aspects of the scope such as brightness and display behavior.

- Adjust display brightness
- Configure crosshair size.
- Toggle distance display after taking measurement

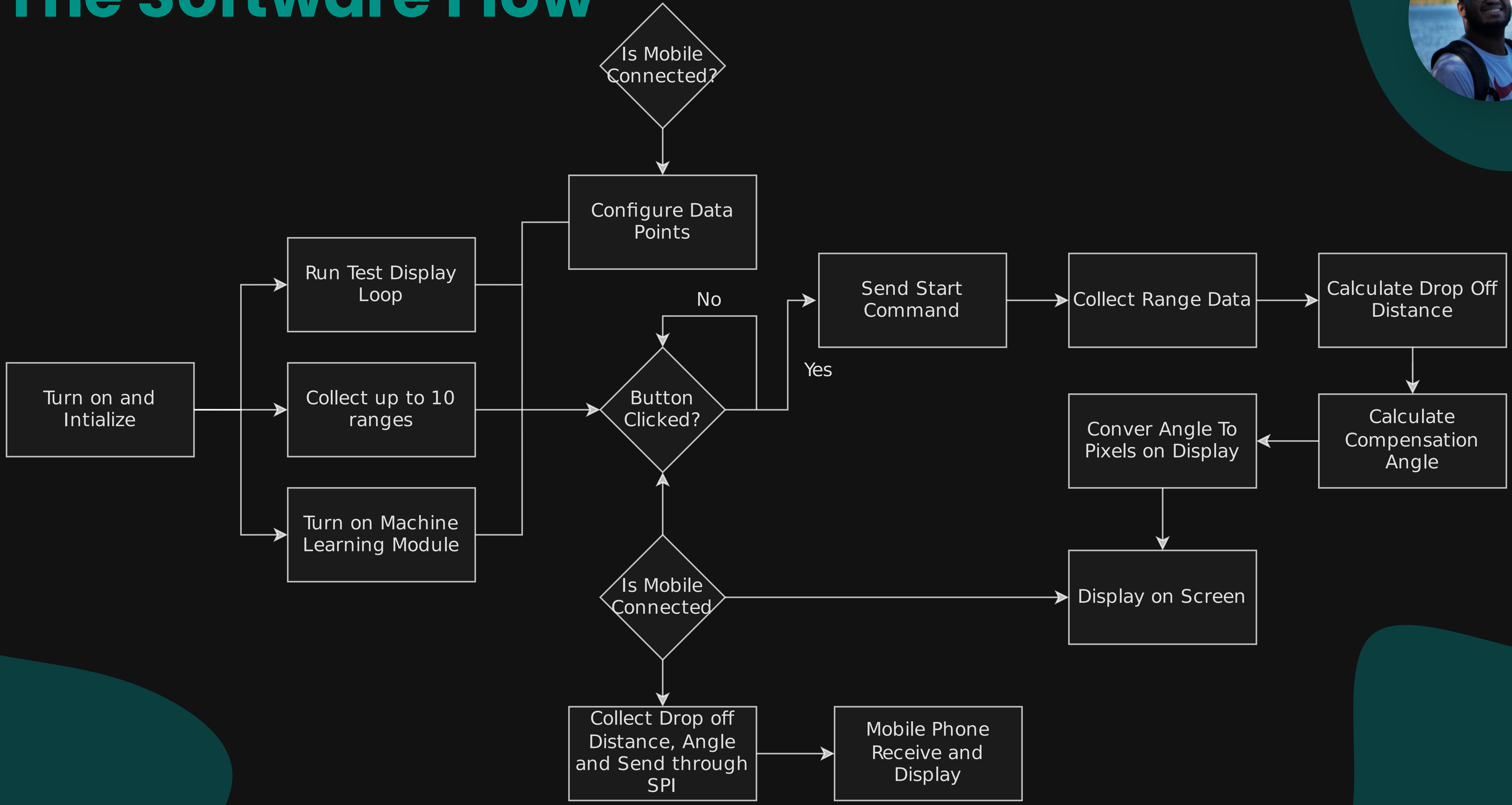


Settings

Use case diagaram



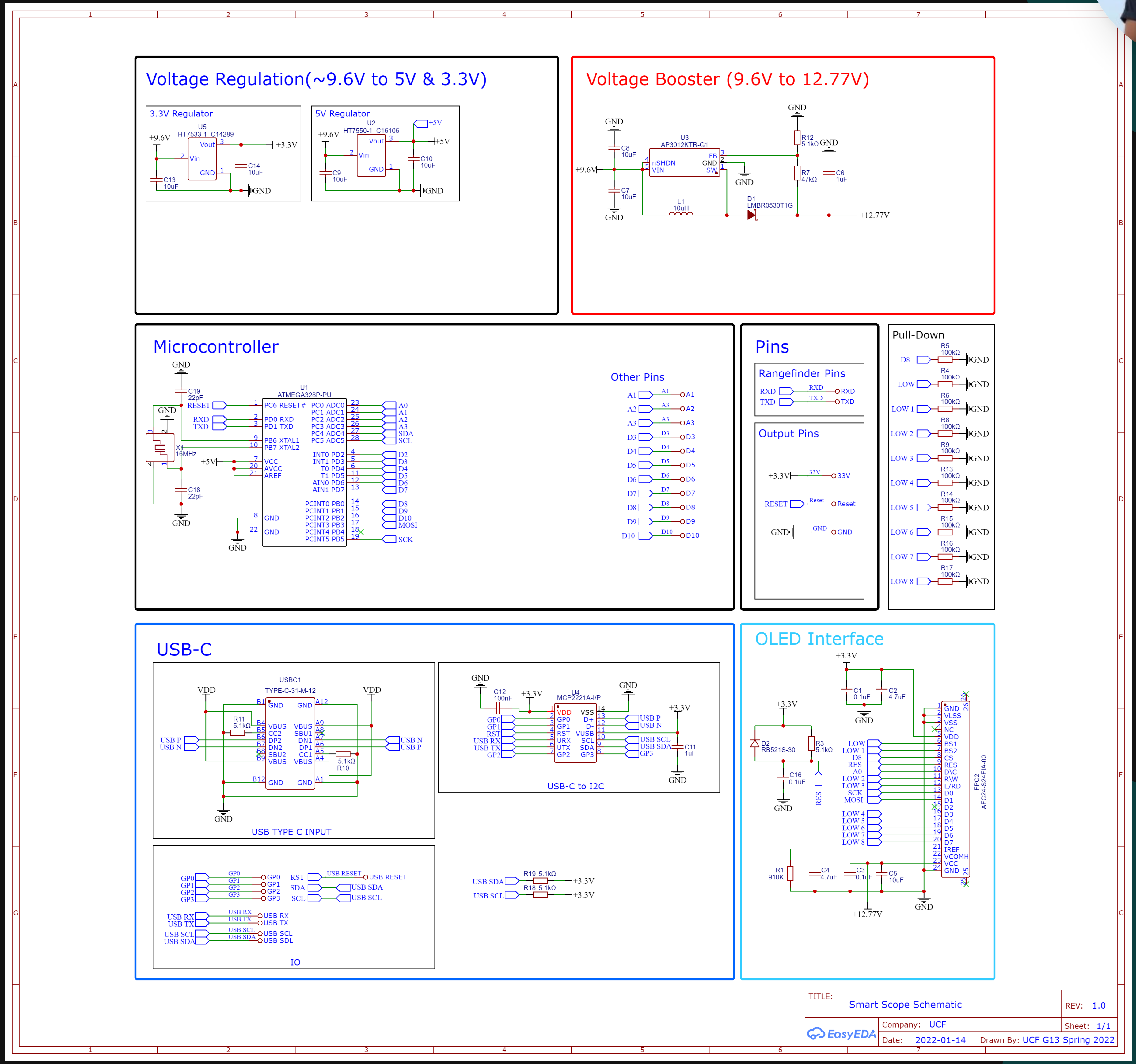
The Software Flow



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 I2C
- Voltage Regulator
  - Environmental constraints
- Voltage Booster
  - No environmental constraints
- Laser Rangefinder Interface



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	$8
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.	$72
Total		$650

Any Questions?