ECE 445

SENIOR DESIGN LABORATORY

Design Document

Enhanced Golf Rangefinder

Team No. 14

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1 Introduction

1.1 Problem Statement and Solution

Golf is an extremely difficult game that requires a great deal of precision. There are a multitude of factors that can affect a single golf shot such as distance, weather conditions, and club choice. Jowett and Phillips [1] show that even the most talented golfers will have shots and scores affected by adverse external conditions.

Our group will build an enhanced golf rangefinder that can be used by golfers of all skill levels. The main problem that golfers experience with normal rangefinders is that the distance measured to the flagstick does not consider external factors such as wind speed, temperature, and humidity. These are all factors that will affect the perceived distance that a golfer must plan for when choosing their club and hitting their shot. Our new rangefinder will implement the necessary components to both measure the correct distance and provide an adjusted distance based on the external factors.

An explanation for a possible implementation would be as follows: The user aims the device at the target and presses a button, initializing the operation of the device, where the time-of-flight sensor emits a laser that strikes the object and reflects light back to measure the distance to the object. The other peripheral sensors measure the wind speed, temperature, and humidity. All the information obtained from these sensors would be passed to the microcontroller. Through programming of the microcontroller, we will implement thresholds for each external factor where the measured distance from the time-of-flight sensor can be altered accordingly to produce an adjusted distance. This adjusted distance would be shown on the OLED display. Another part that would be programmed through the microcontroller is a user interface feature where the user is provided with a club recommendation based on the adjusted distance.

It is important to note that due to budget restrictions and the fact that our project is still in the very early stages of development, we will initially only be able to work with a time-of-flight sensor that measures up to 50 meters of distance. Pending early stages of design and testing, if our device can work with measuring 50 meters, we will move forward to expanding to a sensor with a larger range depending on faculty support and/or budget expansion.

1.2 Objectives

1.2.1 Goals and Benefits

Goals:

- Create a device that measures distance accurately
- Implement functions that adjust the distance of a shot based on external conditions
- Device is as easy to use as a normal rangefinder

Benefits:

- Provides as precise a measurement as possible
- Helps golfers eliminate guesswork of the effect of weather conditions
- Gives golfers the opportunity to improve quicker by decreasing the chances of incorrect club choice leading to an off target shot

1.2.2 Features

- IR laser distance sensor (~50m)
- Modern Device Wind Sensor
- Temperature, humidity, and pressure sensor
- Push button for device activation
- OLED display
- User-based golf club suggestion

2 Design

2.1 High Level Requirements

- The rangefinder measures the correct distance from the user to the flag pin when the button is pressed. The distance should be constrained to the tolerance specified by our time-of-flight sensor's datasheet.
- When the button is pressed, the environmental sensors collect the correct data and provide the necessary adjustments accordingly.
- The user interface recommends a suitable club based on the measured distance. It is important to note that since we are starting with a limited range ToF sensor (50 meters), there would be scaling that takes place to meet this requirement. For example, if we measure 30 meters with the device but are scaling our results to reflect that of a 200-meter ToF, the simulated distance would be 120 meters, which would give a recommendation of a 9-iron for the average golfer.

2.2 Block Diagram and Programming Flowchart

This figure represents the overall device block diagram.

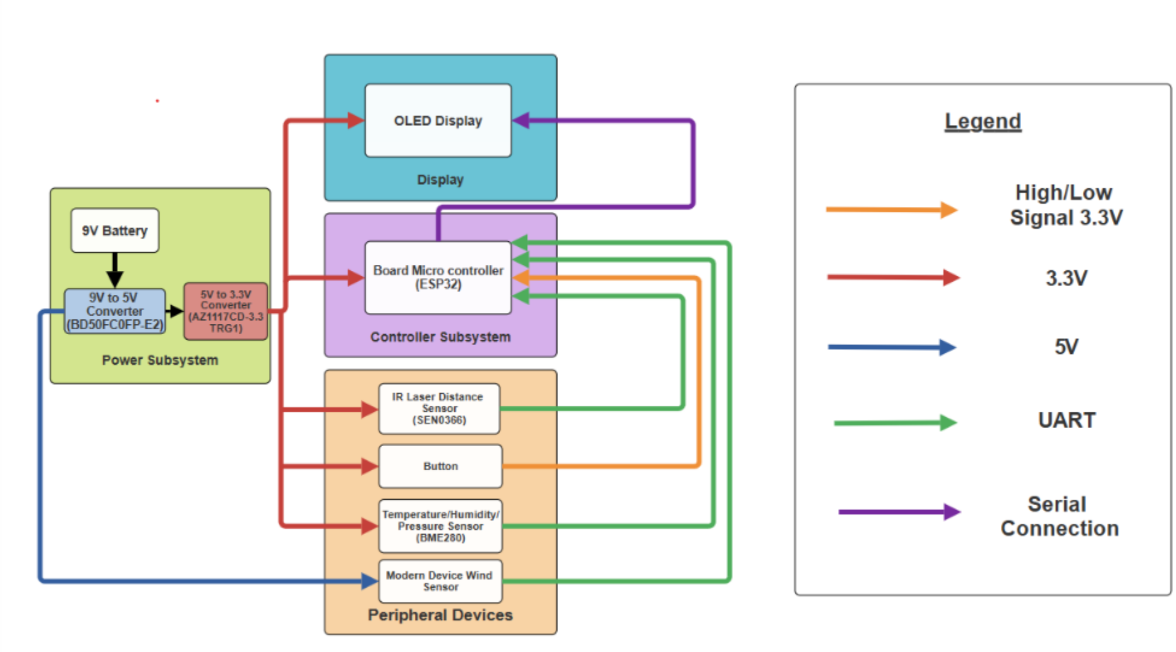

Figure 1: Block Diagram

This figure is a flowchart of how our device overall will be programmed.

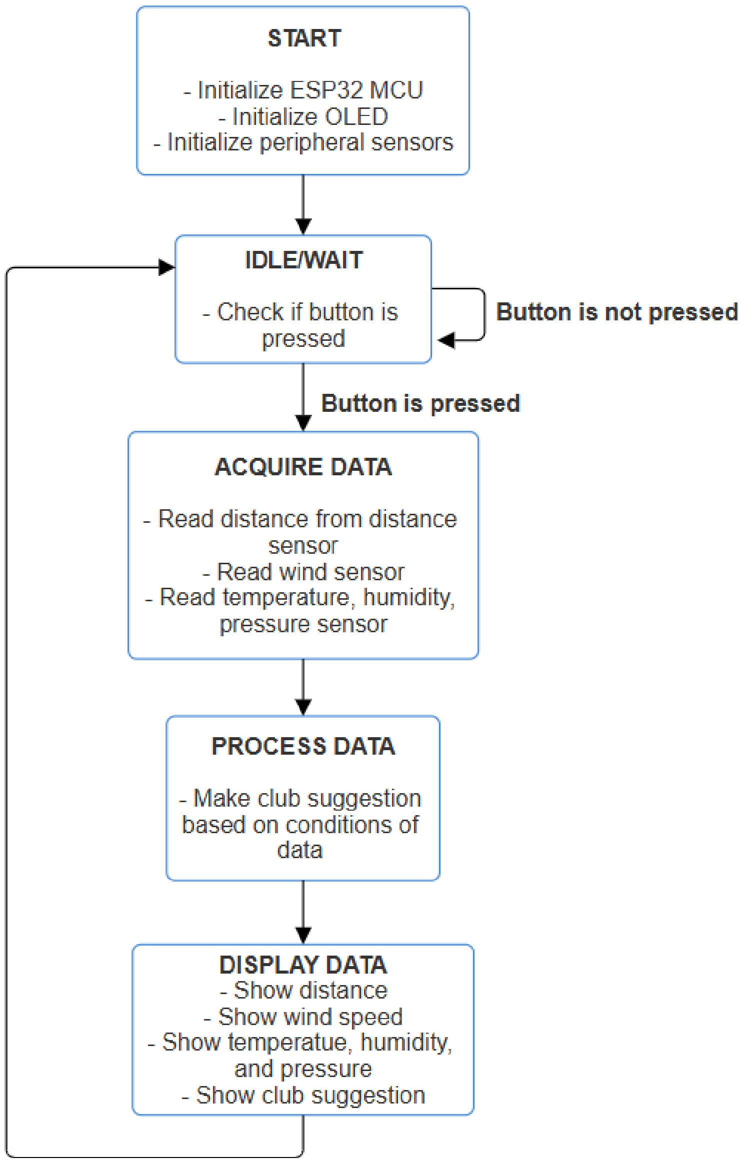

Figure 2: Flowchart

2.3 Visual Representation

Below is a 2D figure showing a visual representation of our device. The device will be handheld with the enclosure being 3D-printed.

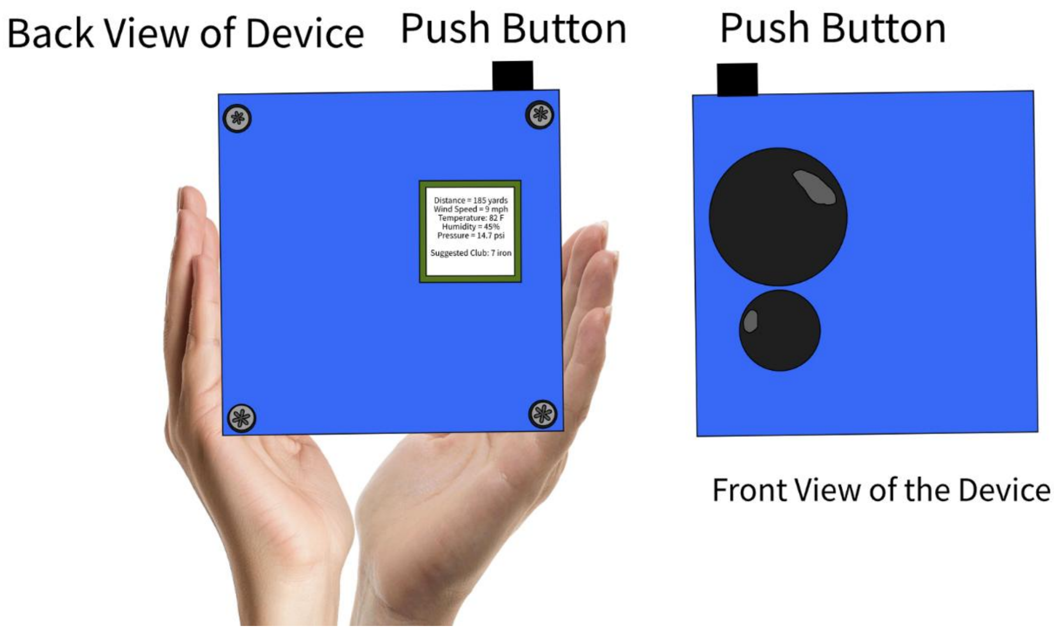

Figure 3: Visual Representation

Below is a 3D Cad Model of the enclosure with dimensions specified. We plan to mount the PCB upright within the enclosure, with the Time-of-Flight sensor and the battery to our power supply lying flat at the bottom so the laser can shoot out of the enclosure and make accurate measurements. The dimensions of the enclosure itself are 152mm long, 76mm wide, and 127mm in height. This model also demonstrates the OLED display that will be mounted onto the enclosure, two holes cut out to ensure that the laser can be emitted and received as well as provide ventilation for the PCB, and finally a push button on top which will be used to trigger the rangefinder to measure the displayed data.

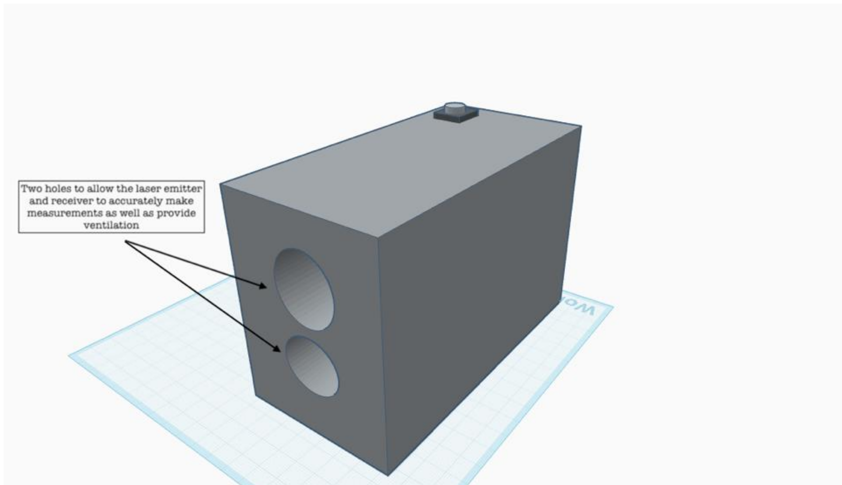

Figure 4: 3D Model of Rangefinder Enclosure (Front Side)

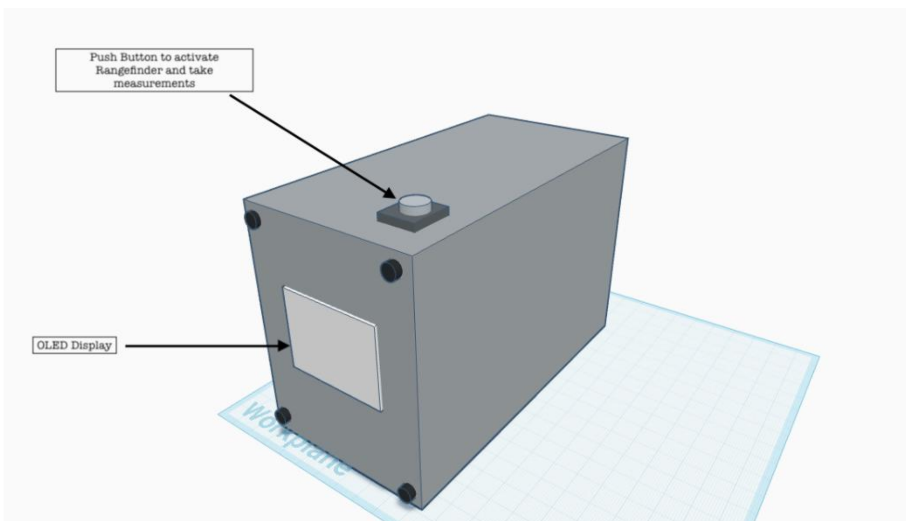

Figure 5: 3D Model of Rangefinder Enclosure (Back Side)

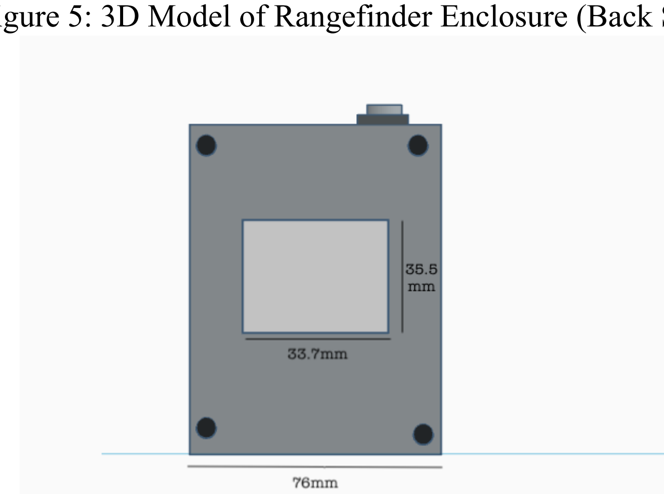

Figure 6: Width Dimension of Rangefinder Enclosure/OLED Dimensions

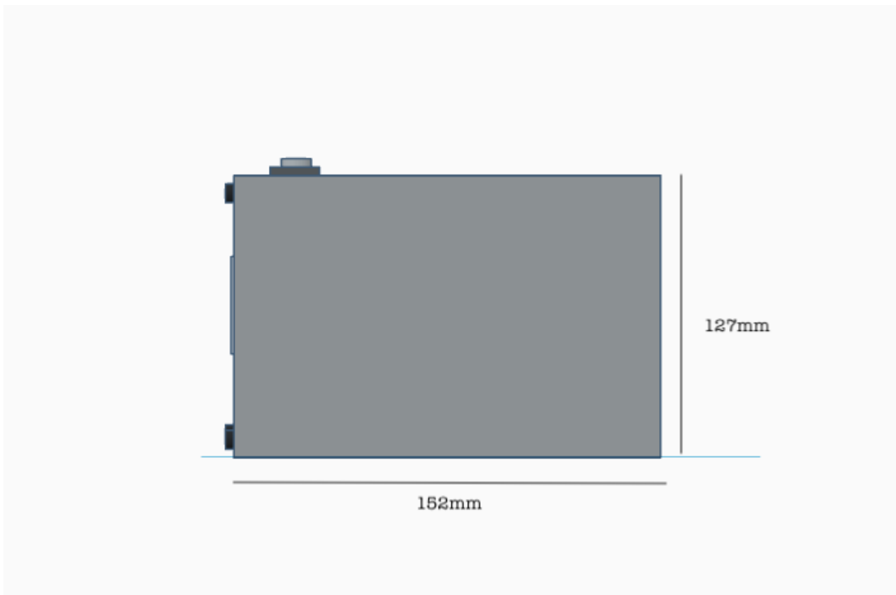

Figure 7: Length and Height Dimensions of Rangefinder Enclosure

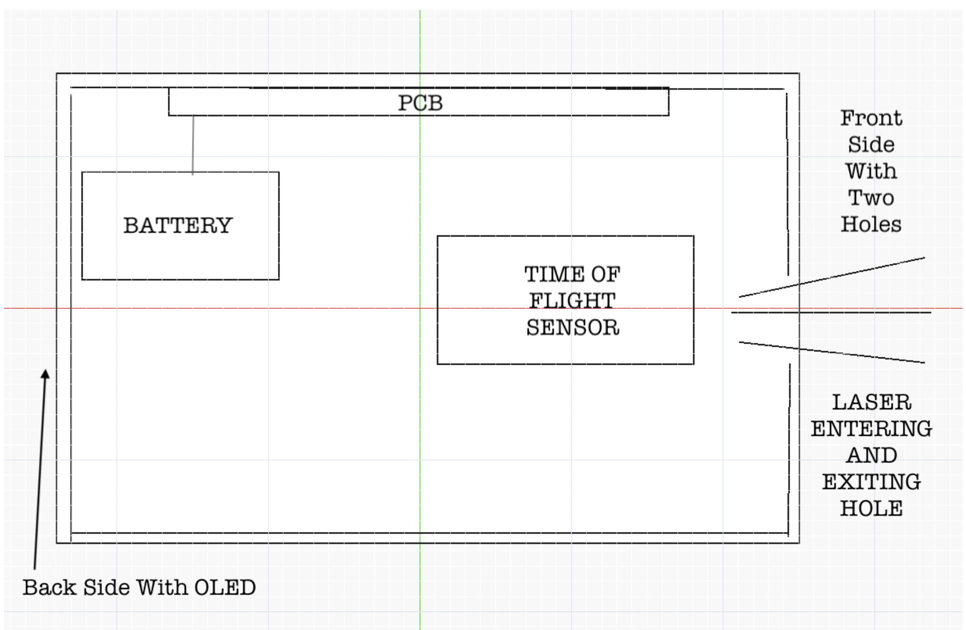

Figure 8: Top View of Enclosure (Shows the layout of the inside of the box)

2.4 Requirements and Verification Tables

Below are the requirements and verification tables for each component of our block diagram. Here we detail how each block must be able to function and describe how these functions can be verified.

2.4.1 Power Supply

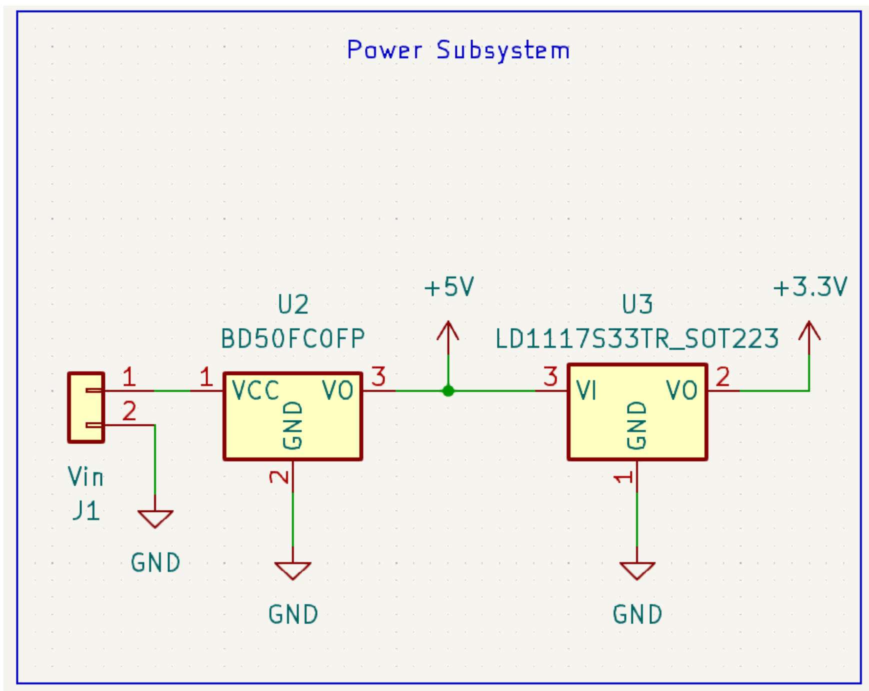

Figure 9: Power subsystem schematic

The Power Supply Subsystem is responsible for supplying sufficient power to each of our electronic components within the Enhanced Rangefinder, which includes the Controller Subsystem and Peripheral Devices Subsystem. The Power Supply Subsystem contains three blocks: Our Power Supply, which is a 9V Battery, a 9V to 5V voltage converter, as well as a 5V to 3.3V voltage converter. These voltage converters will be linear voltage regulators. The 9V to 5V converter must be able to safely power our wind speed sensor, while the 5V to 3.3V converter must safely power our microcontroller, push button trigger, humidity, temperature, and air pressure sensor, and our time-of-flight laser distance sensor.

Requirements	Verification
• The battery must be able to supply a constant 9V DC supply	• Measure the voltage using an oscilloscope, verifying that the battery is supplying 9±5% V
• The 9-5 converter must be able to successfully step down the DC voltage from 9±5% to 5±5% volts to be supplied to the wind sensor • Converter can operate within 0-1A output current • Efficiency should be higher than 80%	• Measure the voltage at the output using an oscilloscope, verifying it is 5±5% V • Connect a multimeter to the output of the converter in series and measure output current • Calculate efficiency with (Vout)(Iout)/(Vin)(Iin) equation
• The 5-3.3 converter must be able to successfully step down the DC voltage from 5±5% to 3.3±5% V to be supplied to the following components: 1. Button 2. Weather Sensor 3. Time-of-Flight Sensor 4. Microcontroller • Converter can operate within 0-1A output current • Efficiency should be higher than 80%	• Measure the voltage at the output using an oscilloscope, verifying it is 3.3±5% V • Connect a multimeter to the output of the converter in series and measure output current • Calculate efficiency with (Vout)(Iout)/(Vin)(Iin) equation

2.4.2 Controller

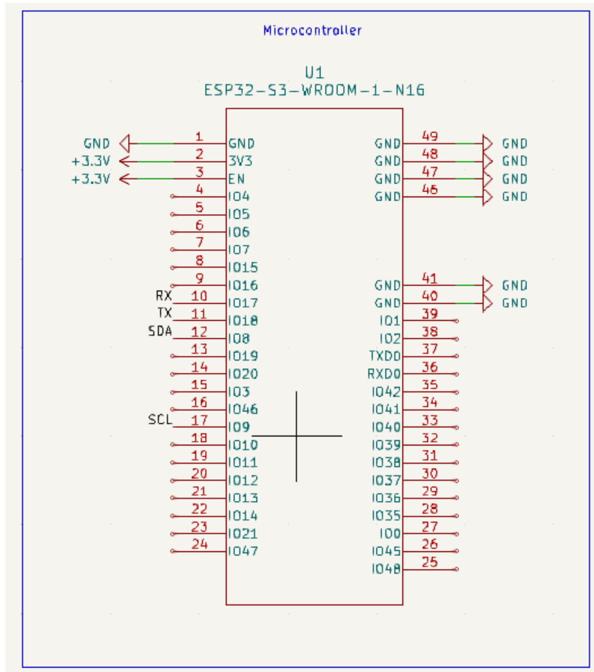

Figure 10: Microcontroller Schematic

The controller subsystem is responsible for gathering the data from the peripheral sensors when the push button is triggered and sending the data to the user on an OLED display. Information from the IR laser distance sensor, wind sensor, and temperature, humidity, and pressure sensor will be transmitted through basic UART communication to a microcontroller. The microcontroller that we will use for this subsystem is the ESP32. The ESP32 includes 34 GPIO pins, PWM support, UART interface, and it supports Wi-Fi and Bluetooth v4.2 if those features are desirable in the future. The ESP32 requires a 3.3V input voltage and a 0.5A maximum current input, making this microcontroller favorable for high performance and low power consumption.

Requirements	Verification
• The microcontroller successfully receives data from the peripheral sensors upon push button triggering. Data will be received from: 1. Weather Sensors 2. Time-of-Flight Sensor	• Observe output data on serial monitor to confirm successful communication • Ensure data is received after push button is pressed
• The microcontroller successfully delivers information to the OLED display	• Ensure correct output is displayed by comparing output data from the serial monitor to the OLED display

2.4.3 Display

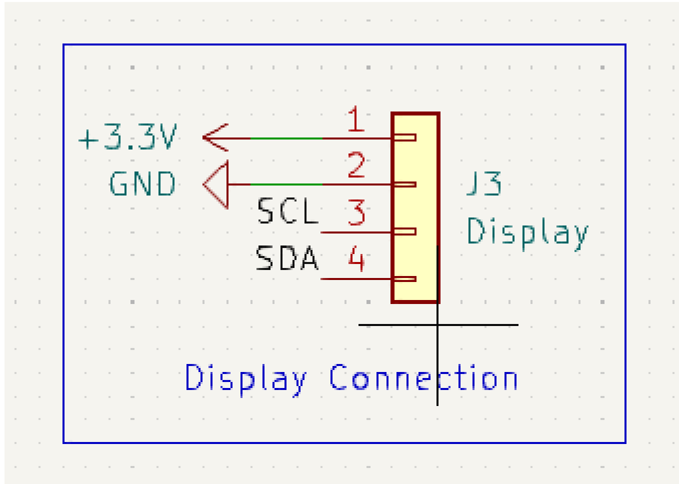

Figure 11: Display pin connection

The purpose of the display is to show users the distance between the device and the target, temperature, humidity, pressure, and wind speed on an OLED. This is necessary for users to find this data without consulting with a serial monitor output on a computer. The display will be programmed from the microcontroller to display all data listed in an organized fashion. The OLED will also display the suggested golf club to use based on the conditions given.

Requirements	Verification
• The OLED successfully displays the correct data from the microcontroller conveniently to the user	• Ensure correct output is displayed by comparing output data from the serial monitor to the OLED display • Ensure that the data is organized in a way the user can easily find information

2.4.4 Peripheral Devices

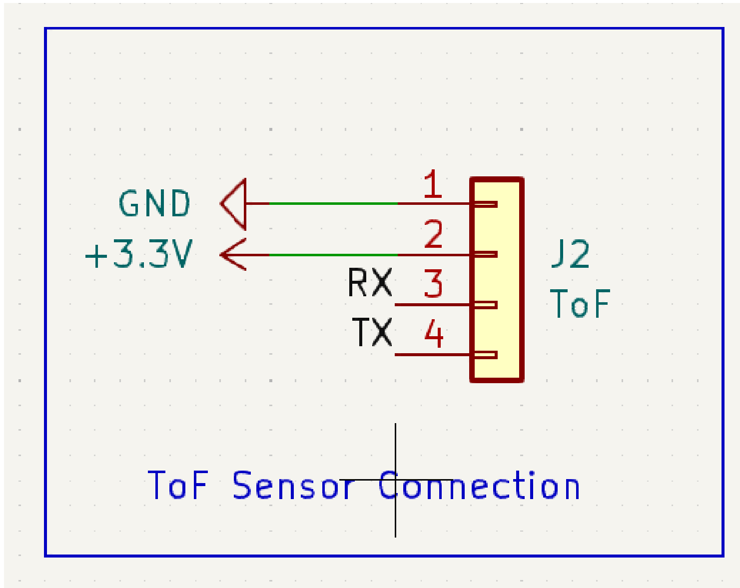

Figure 12: Rangefinder sensor pin connection

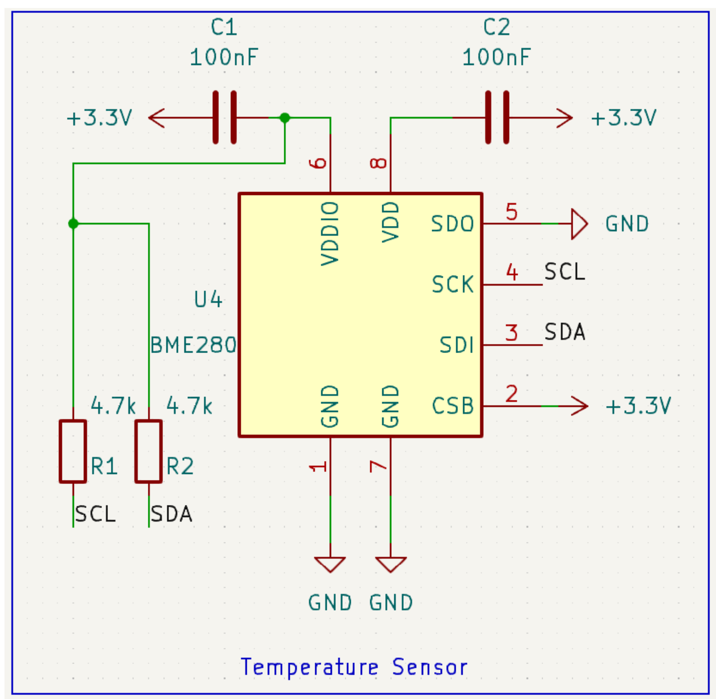

Figure 13: BME280 temperature sensor connection

The peripheral devices are what collect and send the data needed for our Enhanced Golf Rangefinder to work. The sensors under this subsystem include the IR laser distance sensor (SEN0366), the Modern Device Wind sensor, and the temperature, humidity, and pressure sensor (BME 280). The IR laser distance sensor will be used to collect an accurate measurement of the distance between the device and the target. The sensor measures up to 50 meters using a visible Class II laser (620nm~690nm). The Modern Device Wind sensor will be used to measure the wind speed conditions while the device is triggered. This data will be used to provide an adjusted shot distance if necessary. The temperature, humidity, and pressure sensor will also be used to gather important data necessary for a potential shot adjustment. All data will be taken when the user triggers a push button. The sensor data will be sent to the microcontroller through UART communication while the push button will use a high/low signal at 3.3V.

Requirements	**Verification**
• The SEN0366 IR laser distance sensor is safely powered and accurately measures the distance between the sensor and the target with +/- 1 mm accuracy at a max range of ~50m	• Verify data is being read from the sensor using serial monitor from the microcontroller • Validate distance measured by comparing a physical measurement using tape measure between the device and target to the sensor's reading on a serial output monitor o Ensure each distance is within +/- 1mm accuracy range and can reach up to 50m
• BME280 temperature, humidity, and pressure sensor measures outside temperature from device at a +/-1.0°C accuracy and pressure at +/-1hPa	• Verify data is being read from the sensor using serial monitor from the microcontroller • Ensure temperature measurement from the sensor is within +/- 1°C from actual outdoor environment using thermometer to compare results • Ensure humidity measurement from the sensor is +/-5% from actual outdoor environment using a digital hygrometer to compare results
• The Modern Device Wind Sensor measures a relatively accurate wind speed during the instant device is triggered	• Ensure wind measurements are accurate within a +/- 5% error compared to outdoor measurements with weather application

2.5 Plots

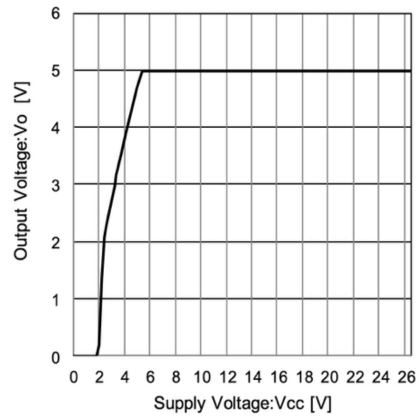

Figure 9: [3] Line Regulation Plot for 9V to 5V Lin. Voltage Regulator (BD50FC0FP-E2)

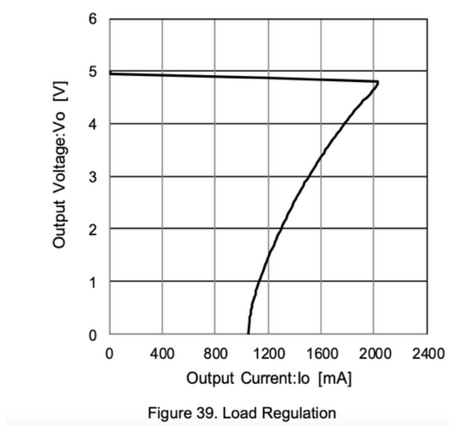

Figure 10: [3] Load Regulation Plot for BD50FC0FP-E2

The Load and Line Regulation Plots are provided to demonstrate consistent output voltage despite any power fluctuations to protect the loads and prevent any damage or malfunctions.

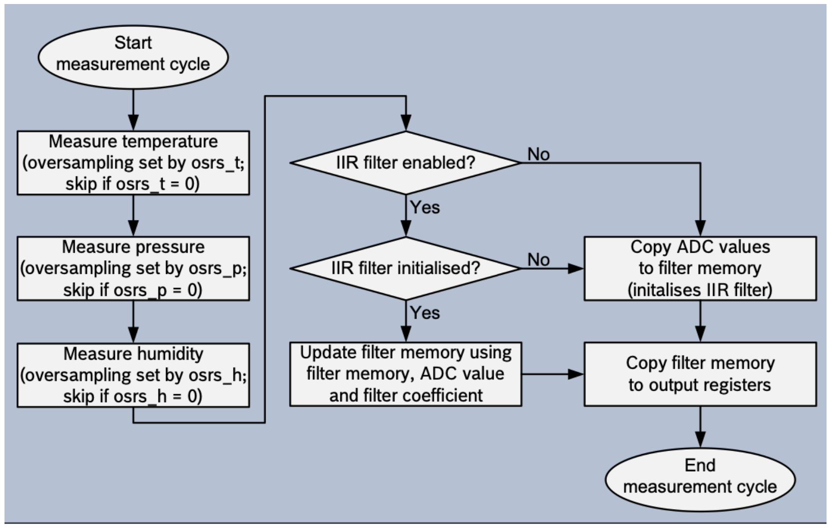

Figure 11: [7] IIR Filter Flow Plot for Temp, Humidity, and Air Pressure Sensor (BME280)

The BME280 takes constant measurements of ambient Temperature, Humidity, and Air Pressure. After each period, the pressure and temperature data can then be passed through an IIR Filter (optional). This removes any short-term fluctuations in measurement data.

2.6 Circuit Schematics

Power Supply Subsystem Schematics:

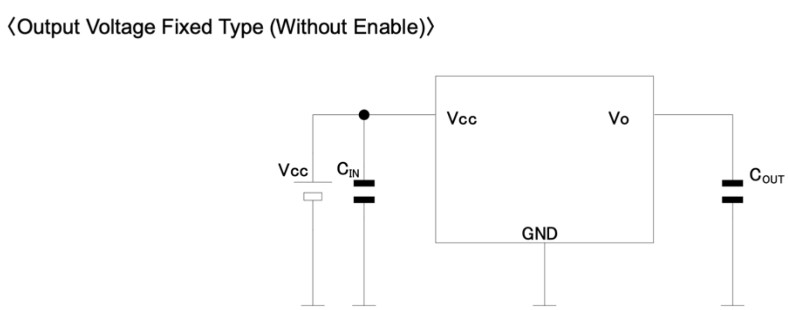

Figure 12: [3] Circuit Schematic for 9V to 5V Lin. Voltage Regulator (BD50FC0FP-E2)

C_{IN} = 1uF, C_{OUT} = 1uF to prevent oscillation.

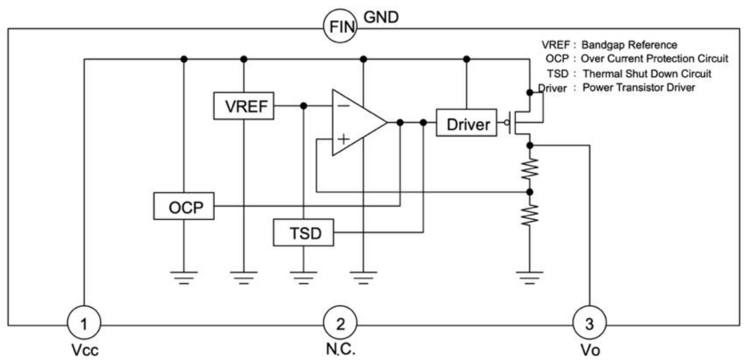

Figure 13: [3] Block Diagram for BD50FC0FP – E2

The block diagram is displayed to show the built in protection such as thermal and overcurrent, which provides the IC from being damaged as well as the loads attached to it.

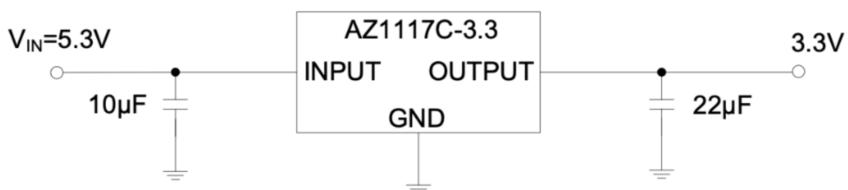

Figure 14: [4] Circuit Schematic for 5V to 3.3V Lin. Voltage Regulator (AZ1117CD-3.3TRG1)

C_{IN} = 10uF, C_{OUT} = 22uF to prevent oscillation.

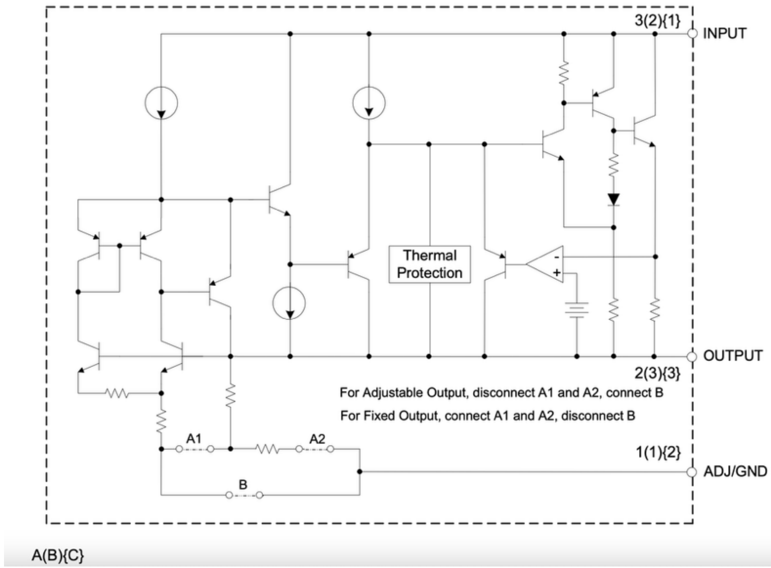

Figure 15: [4] Block Diagram for AZ1117CD-3.3TRG1

The block diagram is provided to demonstrate the thermal protection and overcurrent protection incorporated into the sensor to protect the device itself as well as loads it is connected to. This also displays how outputs can be manipulated.

Controller Subsystem Schematics:

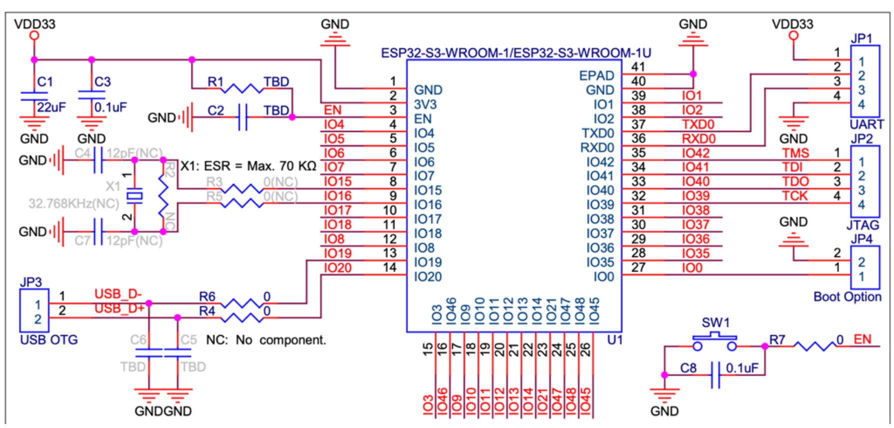

Figure 16: [5] Peripheral Schematic for ESP32-S3-WROOM-1-N16 Microcontroller

This schematic displays references for each peripheral supported by the ESP32; however, we will only be including the power supply and UART peripherals in our design.

Display Subsystem Schematics:

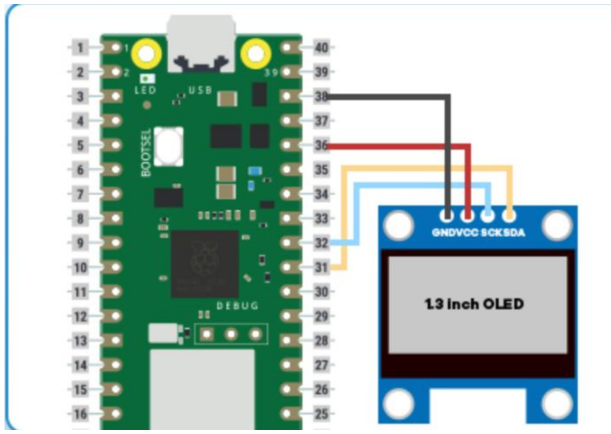

Figure 17: [9] OLED I/O to PCB Diagram, Unit Testing Example (B0C3L7N917)

Pin Layout:

V_{cc} = Input (3.3V), GND = OLED Gnd, SCK = Clock Signal of IIC Bus, and SDA = Data Signal of IIC Bus

Peripherals Subsystem Schematics:

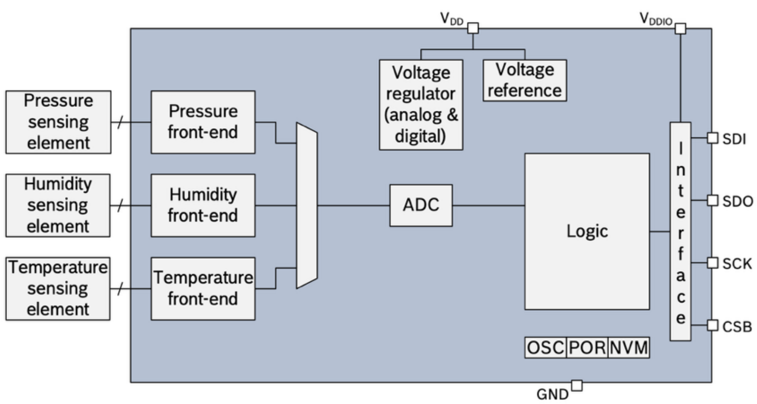

Figure 18: [7] Block Diagram for Temp, Humidity, and Air Pressure Sensor (BME280)

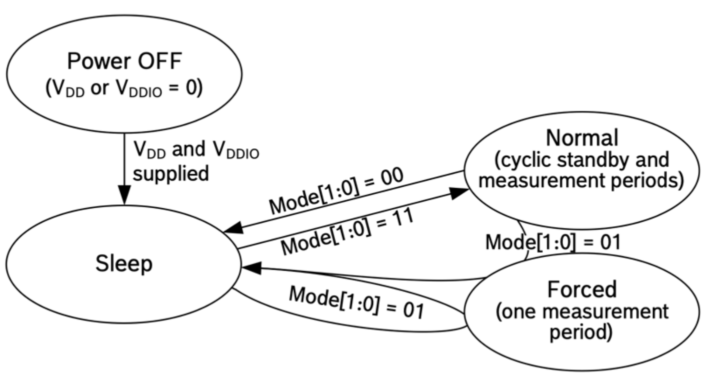

Figure 19: [7] FSM Model for BME280

The BME280 has three different sensor modes: Sleep mode, Forced mode, and Normal mode. Sleep mode means no operation is occurring and power consumption is at its lowest. Normal mode means constant cycling of temperature, humidity, and air pressure measurements. Forced mode only performs one of the three measurements, stores its results and then goes to Sleep mode.

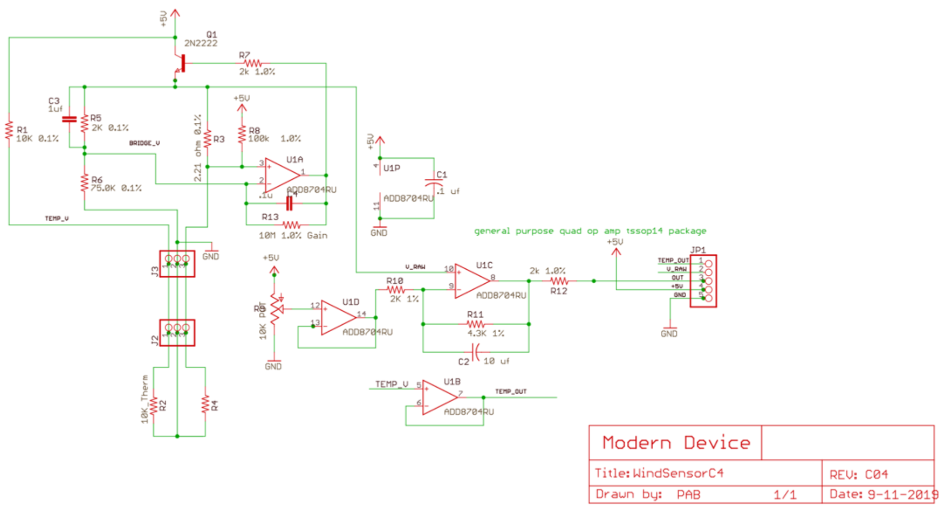

Figure 20: [6] Circuit Schematic for Wind Speed Sensor (Modern Device Wind Sensor Rev. C)

Pin Layout:

GND = Gnd, +V = 5V Power Supply, Out = Output Voltage, RV = Raw Loop Voltage (For Calibrated Output, TMP = Temperature Output

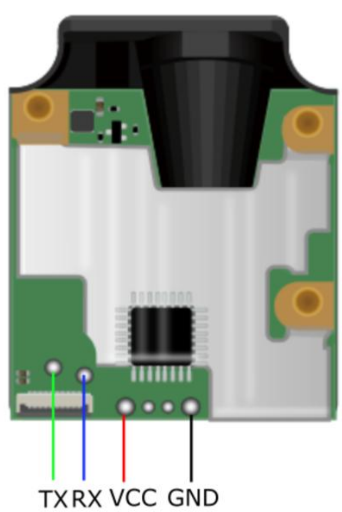

Figure 21: [8] I/O Diagram for ToF Sensor (SEN0366)

Pin Layout:

V_{cc} = 3.3V Input, GND = Gnd, TX = UART RX Input, RX = UART TX Input

2.7 Tolerance Analysis

We believe the most critical part of our project is our device's ability to accurately measure wind and provide an adjusted distance based on the measurement. Wind is the most volatile of the external factors that we will be measuring, so it is important that our device can not only measure wind speed and direction but also provide a distance adjustment within a reasonable tolerance based on the effects of the wind. The analysis of this concept will consist of highlighting the necessary math to determine the effect that certain wind speed and direction have on a golf ball as well as how accurate our device needs to be to process this information.

The main component involved in this analysis is the Modern Device Wind Sensor, residing in our peripheral devices subsystem. This sensor receives a 5±5% V input voltage from our power subsystem. The sensor then measures the wind speed and sends this information to our ESP32 microcontroller. Since we are not using the actual sensor from Modern Device but rather integrating the schematic for it to our own PCB, it is important to note the components and tolerances that are used in the sensor. Refer to the table below, where the components are references to the schematic shown in Figure 15.

Component	Description
Q1	BJT
R1	10K ± 0.1% Ω
R2	10K Ω Thermistor
R3	2.21 ± 0.1% Ω
R4	10K ± 0.1% Ω
R5	2k ± 0.1% Ω
R6	75k ± 0.1% Ω
R7	2k ± 1.0% Ω
R8	100k ± 1.0% Ω
R9	10k Ω Potentiometer
R10	2k ±1% Ω
R11	4.3k ± 1% Ω
R12	2k ± 1% Ω
R13	10M ± 1.0% Ω
C1	0.1 µF
C2	10 µF
C3	1µF
JP1	Input/output header pins
J2	Connector
J3	Connector
U1(A/B/C/D)	Op-Amp

Table 1: Components in the Wind Sensor

The most important part of this analysis is understanding the underlying math and physics as well as assumptions that need to be kept in mind when determining the effect that wind will have on a golf shot. First it is important to recognize the forces acting on the golf ball. The forces acting on the ball are gravity ($\boldsymbol{F_g}$), quadratic drag from air resistance ($\boldsymbol{F_D}$) and lift due to ball spin ($\boldsymbol{F_L}$). The equations for these forces are below. Note that vector quantities are bold.

$$\boldsymbol{F_g} = m\boldsymbol{g} = -mg\boldsymbol{\hat{y}}$$

$$\boldsymbol{F_D} = \frac{1}{2}\rho C_D A {v_{rel}}^2 \widehat{\boldsymbol{v_{rel}}}$$

$$\boldsymbol{F_L} = \frac{1}{2}\rho C_L A {v_{rel}}^2 \boldsymbol{\hat{n}}$$

Where:

m: mass of the golf ball (45.93 g)

$\boldsymbol{g}$: acceleration due to gravity (-9.81 m/s^2)

ρ: air density (1.2250 kg/m^3)

C_D: drag coefficient

A: cross-sectional area of the golf ball (.00143 m^2)

$v_{rel} = ||\boldsymbol{v_{ball}} - \boldsymbol{v_{wind}}||$

$\widehat{\boldsymbol{v_{rel}}}$: unit vector of v_{rel}

C_L: lift coefficient

Another set of equations that need to be considered are the 2D motion equations.

$$m\frac{d\boldsymbol{v}}{dt} = \boldsymbol{F_g} + \boldsymbol{F_D} + \boldsymbol{F_L}$$

$$\frac{d\boldsymbol{x}}{dt} = \boldsymbol{v}$$

Obviously, the drag coefficient, lift coefficient, and ball velocity are all values dependent on the golfer. The drag coefficient is dictated by a value known as the Renolds number Re. The Renolds number is defined as $Re = VD/\mu$ where V is linear speed, D is the diameter of the ball, and μ is the kinematic viscosity of air. Per Jenkins [10], the drag coefficient of an average golf ball sits between 0.24 and 0.7, with the lower bound correlating to higher ball speeds and the upper bound correlating to lower ball speeds. The lift coefficient is dictated by a spin parameter S. S is defined as $S = \frac{\omega r}{V}$, where ω is the angular velocity and r is the radius of the golf ball. Lift coefficient generally resides between 0.1 and 0.3. As for the velocity of a golf ball, it decreases as the club loft increases, i.e. a 9-iron will have less ball velocity than a 6-iron. Therefore, when implementing our distance adjustment system, we will pass values for the coefficients and ball speed accordingly based on the initial distance measured. If the measured distance is short, we will assume a lower ball speed due to a higher lofted club. With the lower ball speed assumption, we will assume a higher drag coefficient and lift coefficient and plug in these values as needed.

Using the motion equations from the previous page, we can model the change in distance due to wind as $\Delta R = R(\text{wind}) - R(\text{no wind})$. The range value for "no wind" will simply be the distance that the ToF sensor measures. The range value that accounts for wind will arise from plugging in all values discussed on the previous page into the correct force equations and then integrating as necessary with $R(wind) = \int_0^t v_x dx$ with v_x as the horizontal velocity component and t as the assumed time it takes for the ball to travel the measured distance.

To summarize this analysis, we utilize established physics equations while making a few assumptions for non-constant values. There is a series of equations that both the measured and assumed values will be put through to help produce the correct distance adjustment number. While there may be small variations due to the fact that completely accurate measurements of drag and lift coefficients and ball speed cannot be achieved, our mathematical model can be implemented and applied to our microcontroller to produce as accurate an adjustment as possible relative to the wind speed and direction.

2.8 Safety and Ethics

The maximum power draw for the Enhanced Rangefinder is overall low; however, there are always possibilities for error and potential harm. One area involves our power supply which consists of an Alkaline battery, which will be stepped down using voltage regulators. Additionally, our project involves the use of lasers, and the overall design will be enclosed within a box structure. In doing this, there are several critical factors we need to consider:

- Do not short circuit the battery supply, avoid leaving conductive materials near the battery
- Avoid having liquids near the battery, keep the battery in a safe and stable environment (hot/cold temperatures)
- Do not overload the battery, always be sure of what is being loaded onto the battery and maintain routine checks using the ammeter
- Correctly size wires per the expected current when breadboard testing
- Linear Voltage Regulators can dissipate voltage as heat, always maintain routine thermal checks and accommodate for ventilation if needed within the enclosure
- Ensure the battery is installed with the correct polarity

- The laser inside the Time of Flight Sensor is a Class II laser, in normal conditions this is very safe and does not cause injury; however, ensure that the user does not directly stare into the beam and never point the laser at another person's eye or any moving vehicle
- The project will be contained within a box enclosure, always make routine checks for live wires or exposed conductors to prevent shock

Additionally, all team members have completed the lab safety training prior to participating in any lab work. This includes electrical safety which provides knowledge of potential risks and methods of preventing such risks.

Our project will follow the IEEE Code of Ethics [2]:

[1] We will put the safety, health, and welfare of the first, act with honesty and integrity to avoid harm, provide clarity with risks, and minimize negative impacts on the environment by designing our system to prioritize safety, disclose known limitations, and document our testing

[2] We will work to deepen our own understanding of the technology while using it appropriately, remaining aware of the possible consequences

[3] We will be honest and realistic when describing the performance and expected outcomes of our project

[5] We will welcome any constructive feedback, acknowledge our mistakes, and give credit to others where it is due

[6] We will only take on risks for which we have proper training and fully state any limitations in our expertise

[9] We will avoid any actions that may cause harm to people, their property, reputations, or professional growth

[10] We will support our teammates and treat one another with respect as we grow in knowledge and encourage one another to uphold these ethical standards

Our device will also follow several ethical factors outside of IEEE:

- We will ensure our device is made to be intuitive and usable for people of different physical abilities
- We will design our device for modularity and repairability rather than disposal
- Our device should only be used as an aid, not as a means of cheating or an unfair advantage
- We will ensure that the data displayed is accurate and easy to interpret so users do not make poor decisions based on misread information
- We will ensure that users understand that our device provides guidance only and does not guarantee performance outcomes or replace users' skill

3 Cost

3.1 Cost Analysis

Below we have the complete cost analysis for our project. This factors in both the cost of our labor as well as the cost of the parts involved. The cost of labor is $125 dollars per hour per person according to the course website.

3.1.1 Labor

Name	Hourly Rate	Hours	Total Cost
Peter Maestranzi	$125	300	$37,500
Jake Hindenburg	$125	300	$37,500
Emma DiBiase	$125	300	$37,500

Table 2: Labor Cost

3.1.2 Parts

Part Name	Quantity	Manufacturer	Vendor	Cost per Unit	Total Cost
ESP32-S3-WROOM-1-N16 (Microcontroller)	4	Espressif Systems	ECE Shop	$6.56	$26.24
Modern Device Wind Sensor	1	Modern Device	Modern Device	$21.94	$21.94
ME280 3.3V Temperature Humidity Sensor Atmospheric Barometric Pressure Sensor Module	4	ATNSINC	Amazon	$12.99	$25.98
6 Pcs 1.3 Inch IIC I2C OLED Display Module	5	Hosyond	Amazon	$17.99	$17.99
SEN0366 IR Laser Distance Sensor	1	DFRobot	DigiKey	~$80.00	~$80.00
AZ1117CD-3.3TRG1 (5 to	1	DIODES INC	ECE Shop	-	-

3.3) Linear Voltage Regulator					
BD50FC0FP-E2 (9 to 5) Linear Voltage Regulator	1	DIODES INC	ECE Shop	-	-

Table 3: Parts Cost

3.1.3 Total Cost

Section	**Cost**
Labor	$112,500.00
Parts	$172.15
Total	**$112,672.15**

Table 4: Total Cost

4 Schedule

Below is a plan for how we will work through our project throughout the rest of the semester. This schedule is subject to change based on any additional changes we make to the Design Document prior to turning it in. All members of the group will collaborate on every assignment, however, the person assigned responsibility will lead the effort on that assignment.

Week	Task	Responsibility
09/15/2025	**Finish Proposal**	All
	Soldering Assignment	All
	Team Contract	All
	Prepare for Proposal Review	All
09/22/2025	Proposal Review	All
	Order Parts	All
	Design PCB	Emma
	Update Schematics/Study Sensor Datasheets	Peter
09/29/2025	Finish PCB Design	All
	Test Sensors/Start to Program Microcontroller	Jake
	PCB Review	All
10/06/2025	**Breadboard Demo 1**	All
	Update Design Document	Peter
	Turn in Design Document	All
10/13/2025	Update PCB and Order Again if Necessary	Emma
10/20/2025	Component Testing	Jake
10/27/2025	**Breadboard Demo 2**	All
	Finalize Programming	Jake
11/03/2025	**Individual Progress Reports**	All
	3D Print and Assemble Parts in Enclosure	Emma
11/10/2025	Testing on Entire Device	All
	Finalize Documentation	Peter
11/17/2025	**Mock Demo**	All
	Final Assembly of Device	All
	Team Contract Assessment	All
11/24/2025	Fall Break	N/A
12/01/2025	**Final Demo**	All
	Mock Presentation	All
	Finalize Presentation	All
12/08/2025	**Final Presentation**	All
	Final Papers	All
	Lab Checkout	All

Table 5: Schedule

5 References

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