LECTURE IV

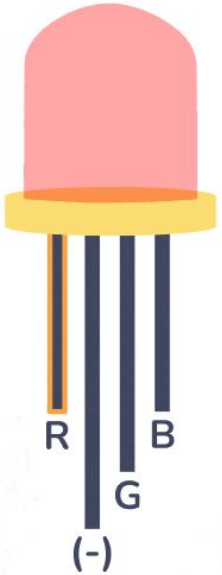
ESP32 Programming Pt. 2

SECTION I

Project III Review

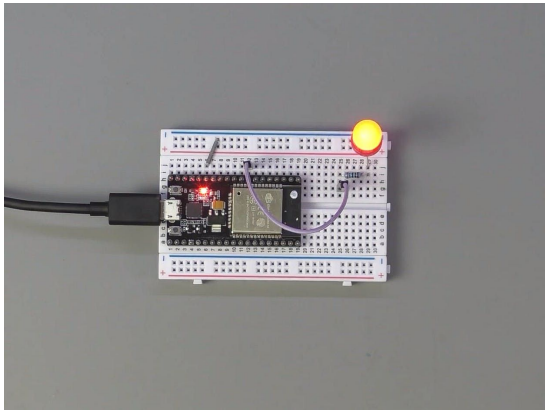
Project 3 Review

- Official Due Date: Friday, Week 9 by 11:59PM
- Ask questions and seek help (online or @Lab Hours), so you can finish it on time!



Learning Concepts:

- Embedded Systems
- Microcontrollers
- ESP32
- Arduino IDE
- Pulse Width Modulation (PWM)



New Deadlines

- For the full $20 refund for Fall Quarter, Final Project Deadlines will be:
  - Project 1: By the end of Finals Week (12/13/2024 at 11:59PM)
  - Project 2: By the end of Finals Week (12/13/2024 at 11:59PM)
  - Project 3: By the end of Winter Break (1/5/2025 at 11:59PM)
  - Project 4: By the end of Winter Break (1/5/2025 at 11:59PM)

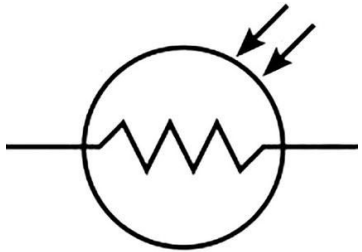
- Ask project-specific questions in the **#ops-help** channel on the Discord. We'll answer during the break!

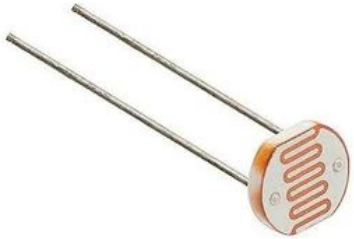
SECTION II

Project IV

Project 4 Overview

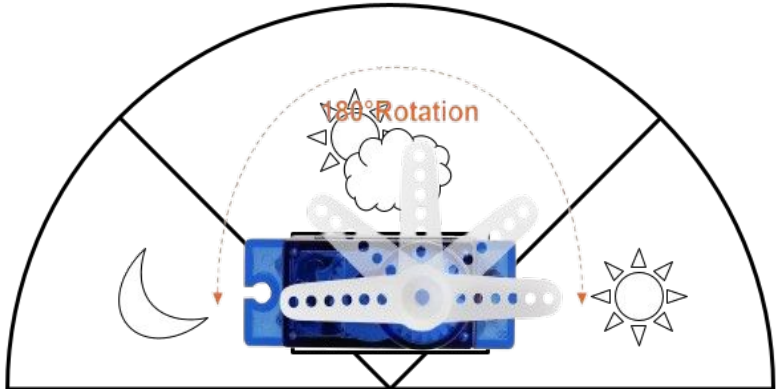
- Build a sundial that measures the brightness of your room by controlling a **micro servo** with an **ESP32** and **photoresistor**.





You will learn:

- ESP32 (Continued)
- Servos
- Arduino Libraries
- Tips for Programming in Arduino IDE

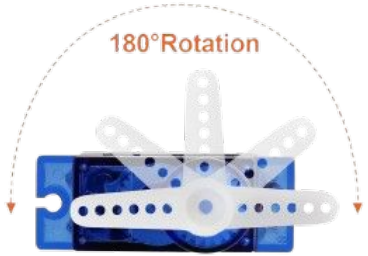


SECTION III

Servos

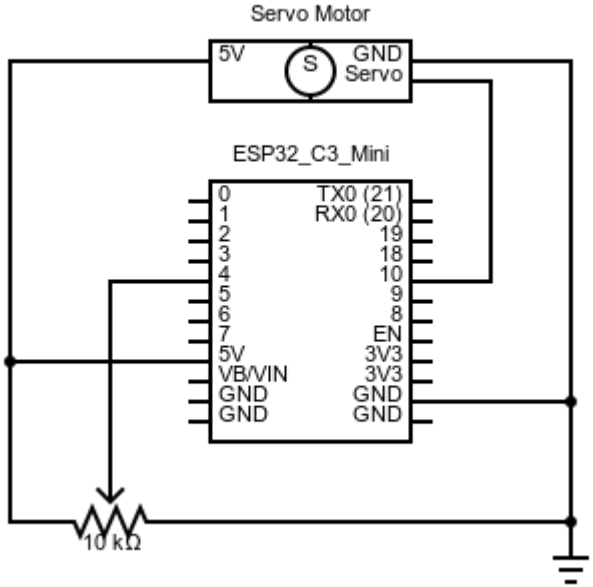
Servo

- A **servo motor** is a type of motor that converts electrical energy into mechanical energy to achieve precise control between 0°-180°
- Has three different wires; the power (red), ground (brown), and pulse-width modulation (orange) wires
    - Insert jumper wires into the female end of the micro servo and to connect it to the ESP32 on a breadboard
- You will be controlling the position of the servo with a photoresistor to make a sundial



Servo Pinout

- Connect the power (red) to 5V pin of the ESP32
- Connect the pulse-width modulation (orange) wire into a GPIO pin of the ESP32
- Connect the ground (brown) to GND of the ESP32

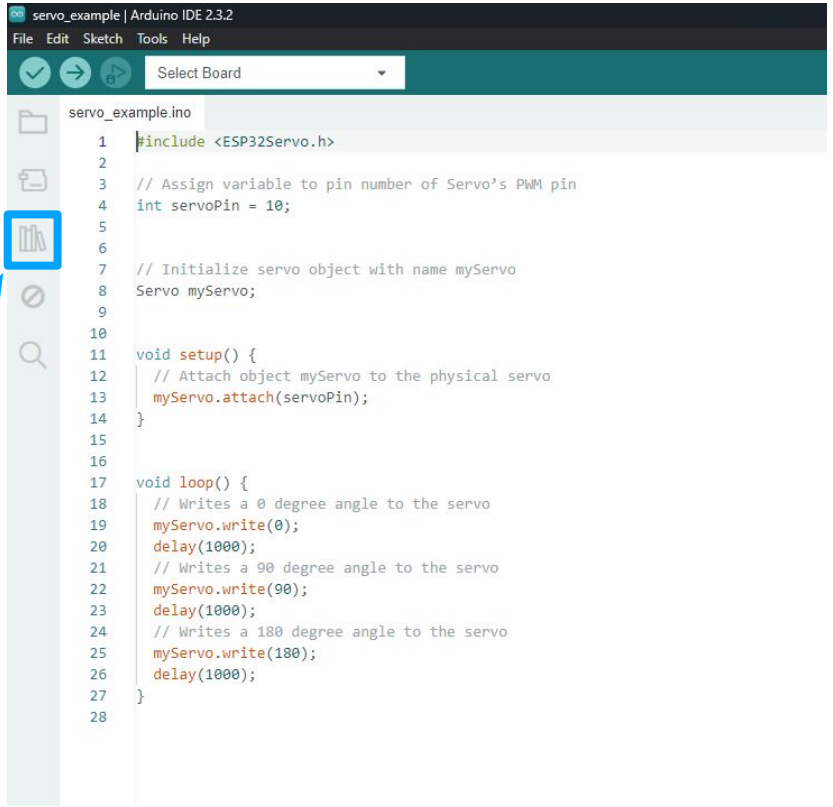


SECTION IV

Arduino Libraries

Arduino Library

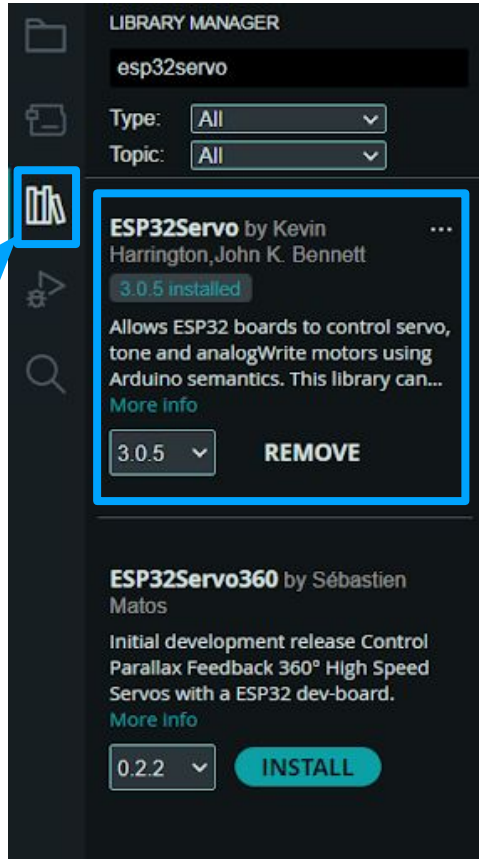
- A collection of pre-written code that makes it easier to interface with hardware or perform specific tasks
- Libraries made by Arduino's development team or Arduino community members
- Libraries can be downloaded from the library manager



Servo Library

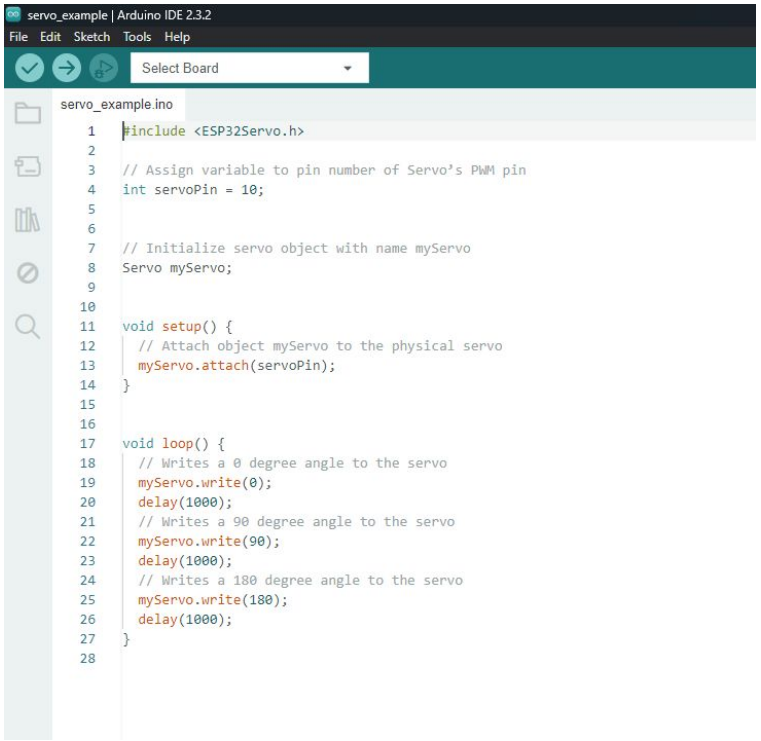
- The **ESP32Servo** library will need to be installed to control the Servo in Project 4

1. Click on the Library manager icon
2. Type in ESP32Servo
3. Download the first result by Kevin Harrington, John K. Bennet



Servo Library (Continued)

- Must #include <ESP32Servo.h> to use the library
- `Servo your_servo_name`
  - Initializes servo object with whatever you want to name the servo object
- `your_servo_name.attach(int pin)`
  - Links the servo object to physical pin `int pin`
- `your_servo_name.write(int angle)`
  - Moves the servo to a specified degree (0°-180°)

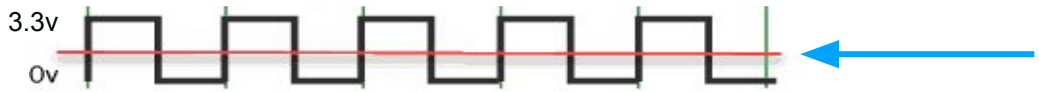


SECTION V

ESP32 Concepts

PWM

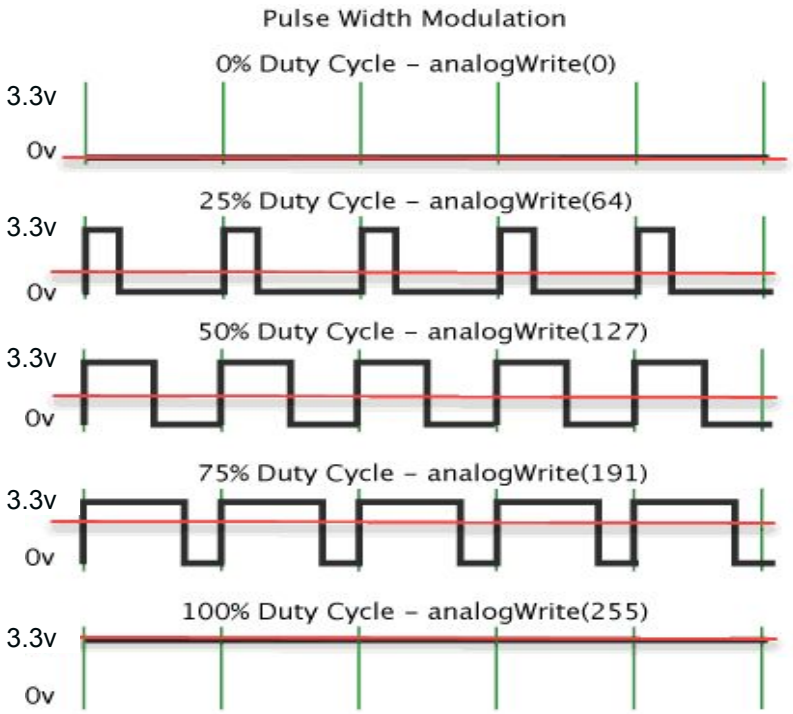
- The ESP32 board is a **digital source**, meaning it can only output a `HIGH` (3.3V) or `LOW` (0V) voltage
  - Then how does `analogWrite` output analog signals?
- **Pulse Width Modulation** (**PWM**) is an oscillating digital waveform that emulates an analog output
  - By oscillating a signal from `HIGH` to `LOW` quickly, the average voltage over time will be *between* `HIGH` and `LOW` - an analog value



The average value, the *analog value,* of this waveform is **1.65V**

PWM Duty Cycle

- The **duty cycle** of the PWM wave is the percentage of time where the signal is `HIGH`
  - For example, a 50% duty cycle translates to an average value of 1.65V (50% of 3.3V)
  - Allows us to output a continuous range of voltages between `HIGH` and `LOW`
  - Duty cycle is **controlled by a timer** inside the ESP32 microcontroller

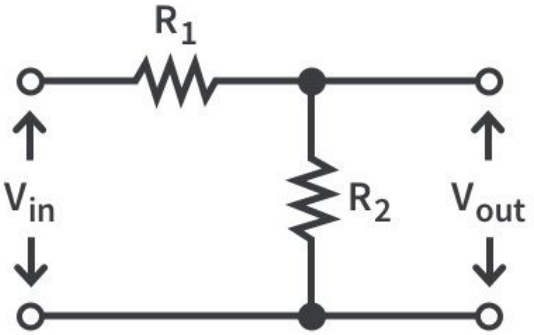


ADC and `analogRead`

- `analogRead` **utilizes the analog-to-digital converter** inside the microcontroller to **measure the real-world, analog signal** and **convert it to a digital signal**
    - The measurement resolution is 12 bits, which is why the function returns values from `0-4095`

Resistor Divider

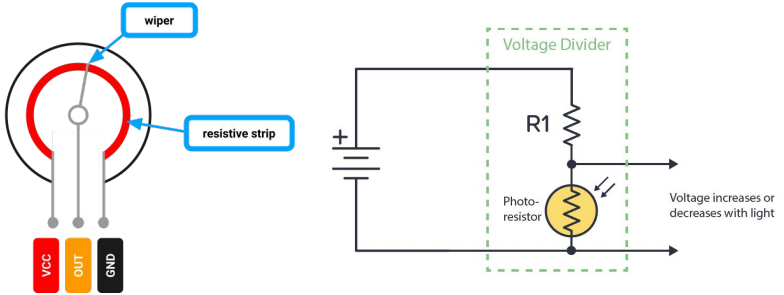
- A circuit configuration with **two resistors** that is used to scale down a voltage (**Vout**).
- Creates a ratio of two resistors to achieve a desired output voltage
  - **R1** and **R2** are connected in series
  - **Vin** is the input voltage
  - **Vout** is the output voltage across **R2**

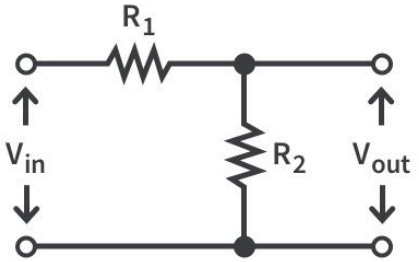


$$V_{out} = \left(\frac{R_2}{R_1 + R_2}\right) V_{in}$$

Resistor Divider in Project 4

- A **potentiometer** is an adjustable resistor divider
  - A wiper/slider divides the resistive element into two adjustable parts
- A **photoresistor** in series with a 4.7kΩ resistor is a light-dependent resistor divider
  - Photoresistor's resistance changes with the intensity of light to sense light levels
  - Resistor divider converts this change into a voltage that can be easily measured





$$V_{out} = \left(\frac{R_2}{R_1 + R_2}\right) V_{in}$$

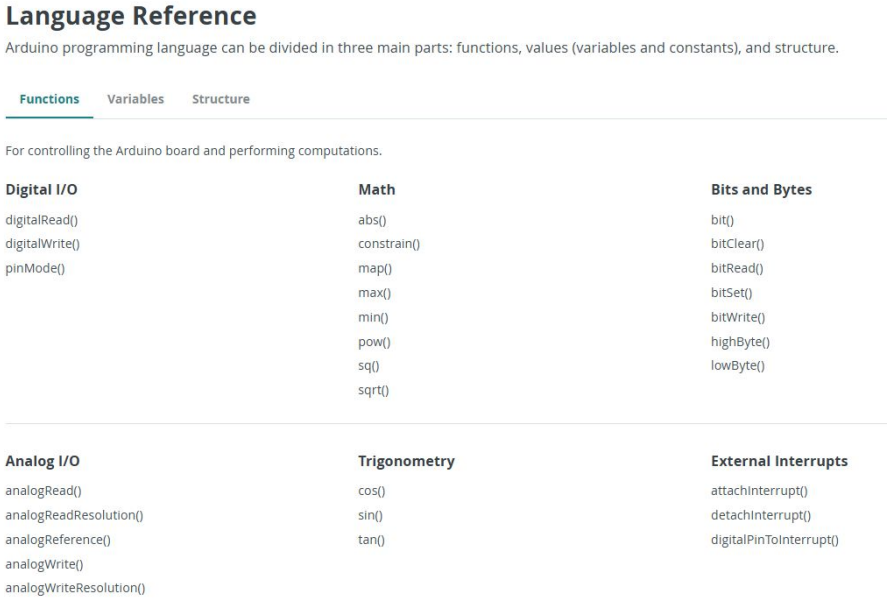
SECTION VI

Tips for Project 4

Arduino Functions

- Understand the purpose of each function in a code (Don’t just blindly copy and paste code!)

- Visit the Arduino Language Reference for an explanation of the most common Arduino functions



Language Reference

Arduino programming language can be divided in three main parts: functions, values (variables and constants), and structure.

Functions | Variables | Structure

For controlling the Arduino board and performing computations.

Digital I/O

digitalRead()
digitalWrite()
pinMode()

Math

abs()
constrain()
map()
max()
min()
pow()
sq()
sqrt()

Bits and Bytes

bit()
bitClear()
bitRead()
bitSet()
bitWrite()
highByte()
lowByte()

Analog I/O

analogRead()
analogReadResolution()
analogReference()
analogWrite()
analogWriteResolution()

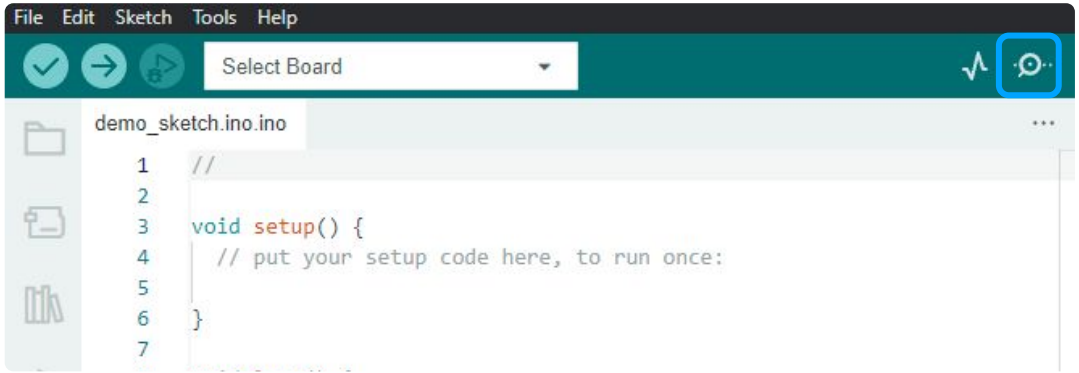
Trigonometry

cos()
sin()
tan()

External Interrupts

attachInterrupt()
detachInterrupt()
digitalPinToInterrupt()

Using the Serial Monitor



- `Serial.print` is an excellent tool to **help debug programs** and **tune sensors**
    - Print values to track the photoresistor's value in the resistor divider
        - Find the photoresistor's value when the room is **bright**, and when the room is **dark** to determine the range of the photoresistor between `0-4095`

Map Function

- Re-maps a number from one range to another
- `map(int inputValue, int min_range_1, int max_range_1, int min_range_2, int max_range_2)`
  - `min_range_1` and `max_range_1` are the min and max values of the first range, and `min_range_2` and `max_range_2` are the min and max values of the second range

Map function in Project 4 Checkpoint 1:

- You will need to map the range of the potentiometer (0-4095) to the servo range (0-180)

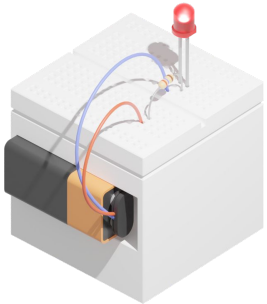
Ex.

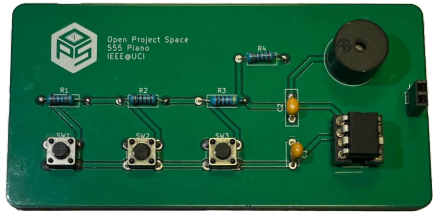
```
potValue = analogRead(potPin)

map(potValue, 0, 4095, 0, 180)
```

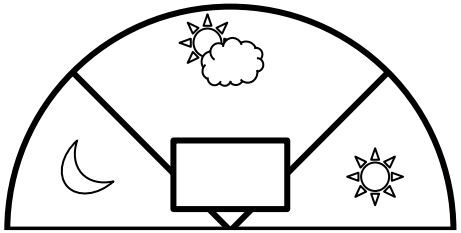
Fall Quarter Recap

- Completed 4 Projects in total!
  - LED there be Light
  - 555 Piano
  - LED RGB Wizard
  - Sundial





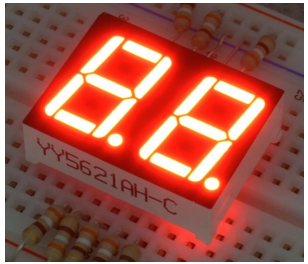
- Main Learning Concepts:
  - Ohm’s Law
  - Breadboarding & Soldering
  - Basic Circuit Analysis
  - ESP32
  - Programming in Arduino IDE

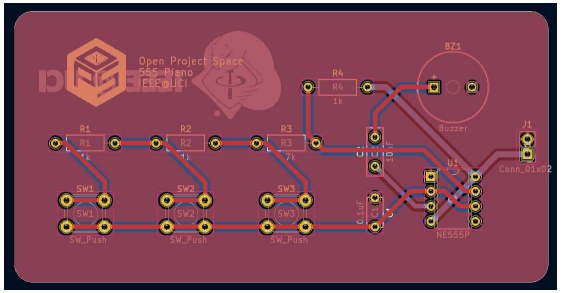


Winter Quarter

- 4 New Projects!
  - iPoduino 2.0
  - Weather Station
  - Digital Stopwatch
  - Capstone PCB Design

- Main Learning Concepts:
  - Communication Protocols (UART, SPI, I^2C)
  - Interrupts, Timers
  - PCB Design





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