UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

Smart Tripod

Team 29

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Problem

Traditional tripods are simply not good enough. They should be used to enhance experiences in media and content creation, not hinder the user's ability to do so by adding even more challenges.

Problem Statement

Lack of dynamic adjustability

- Users must physically alter the tripod in order to get the perfect angle and positioning
- Can be frustrating and time consuming

No real-time feedback

- Users have no way of knowing how their captures turn out
- Turns the session into trial and error

No automatic subject tracking

- Most solutions do not offer automatic tracking
- Extra effort for users to ensure proper centering and aligning.

Solution

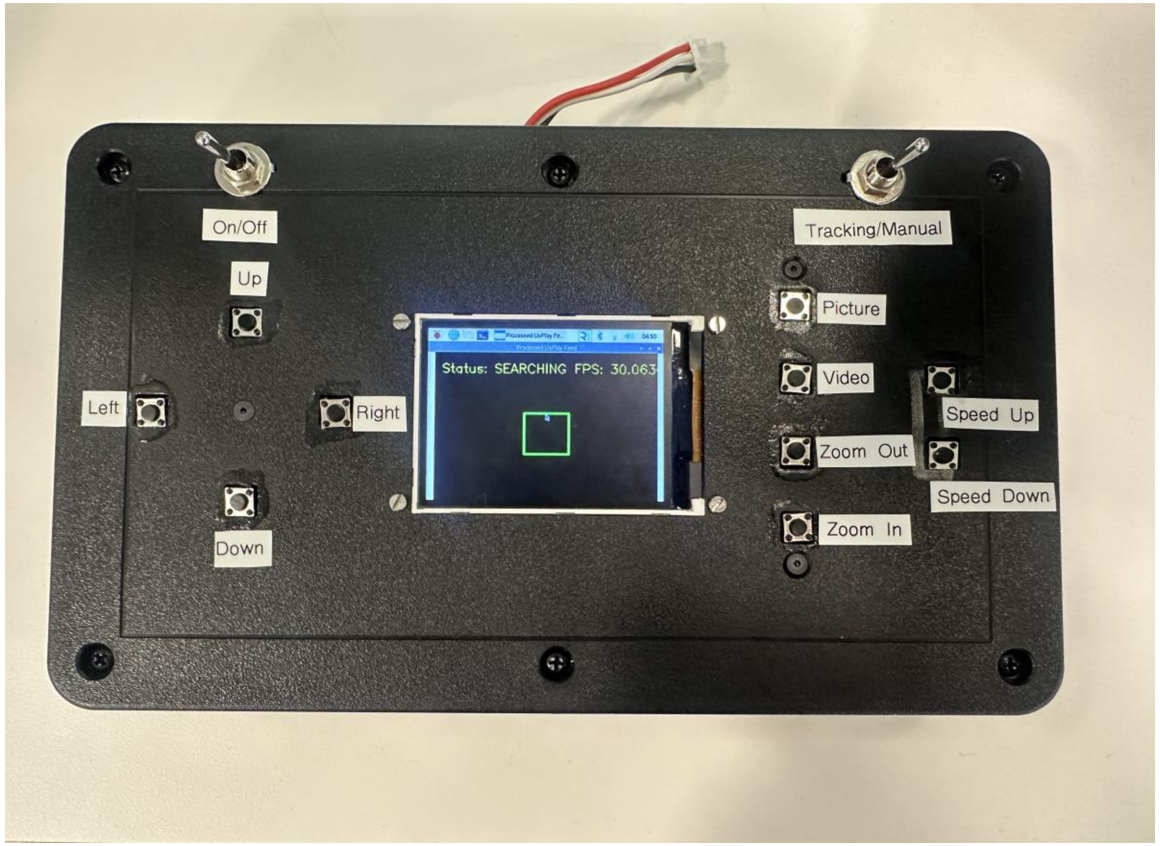
Smart Tripod!

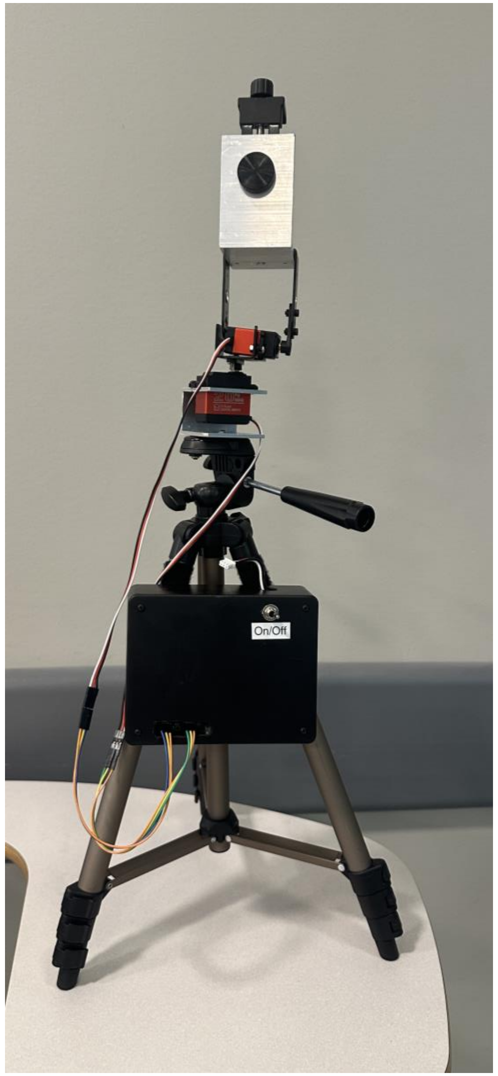
Smart Tripod Overview

Motor Controlled Tripod
- Pan and Tilt
- Wireless Control

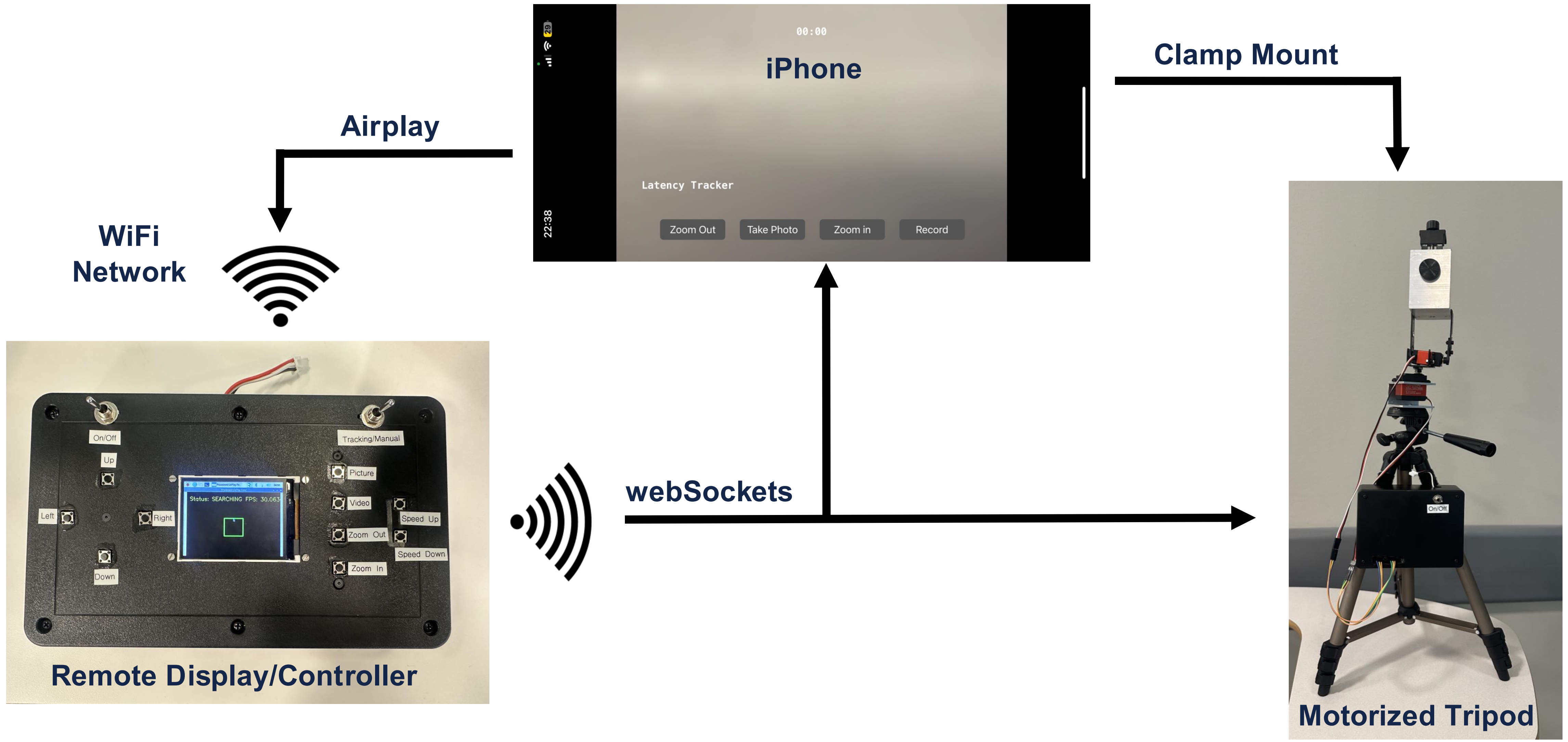
Handheld Controller
- Movement Buttons
- Camera Action Buttons
- WiFi Network

iPhone Application
- Airplay Interface
- Intuitive UI Control

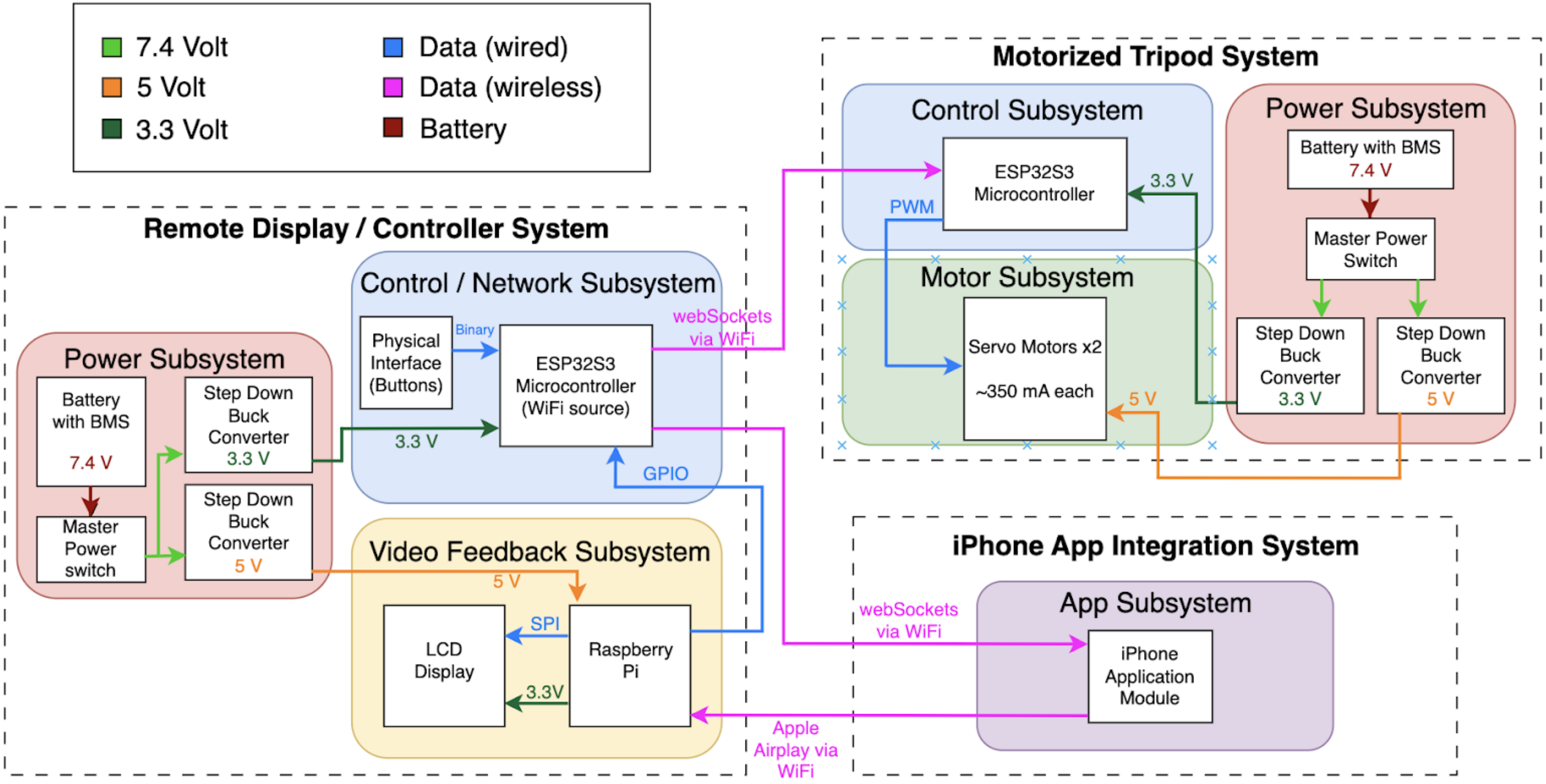




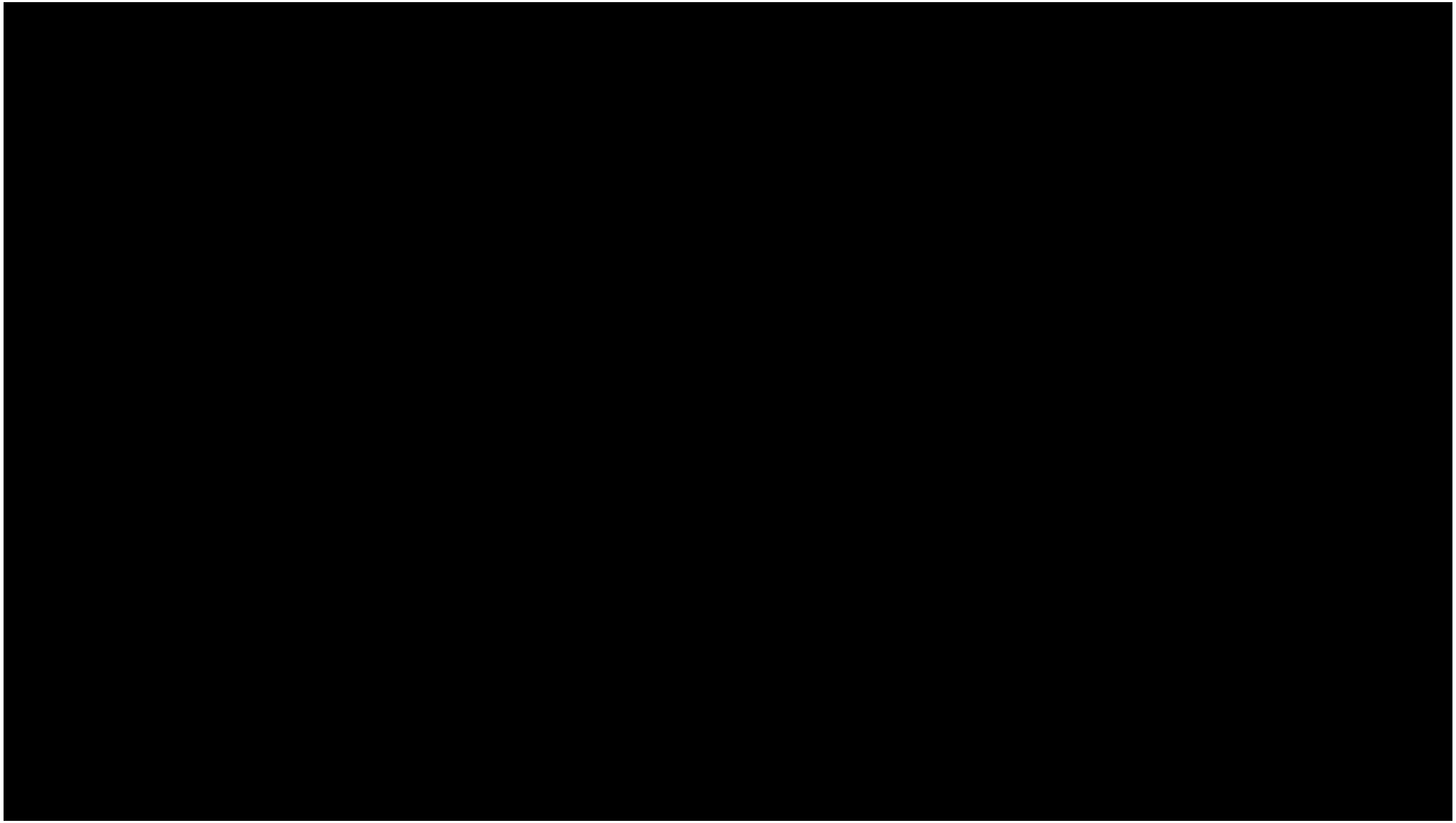
Logical Flowchart



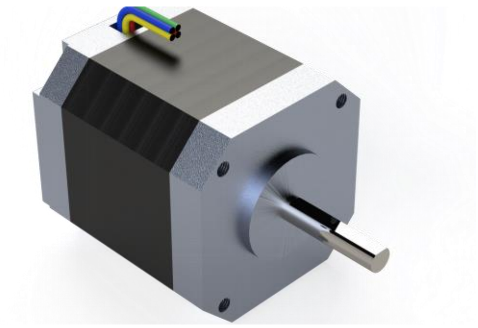
Block Diagram



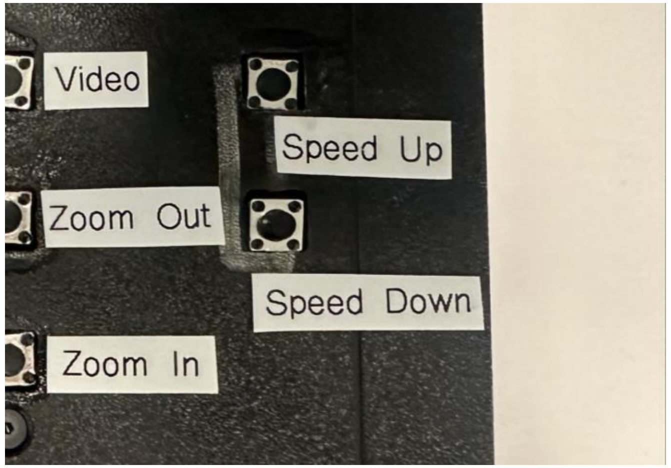
Video Demonstration



Motors
- Planned to use Stepper motors
- Changed to Servo motors
- 12v to 5v change



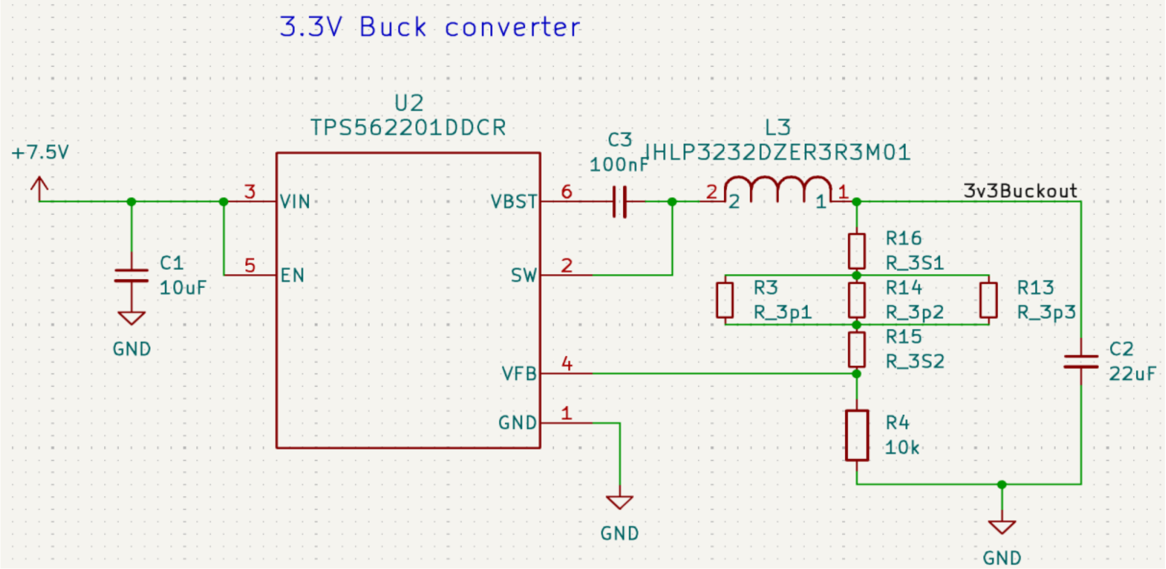
Power system
- Additional linear regulators
- Removed PMOS from power switch

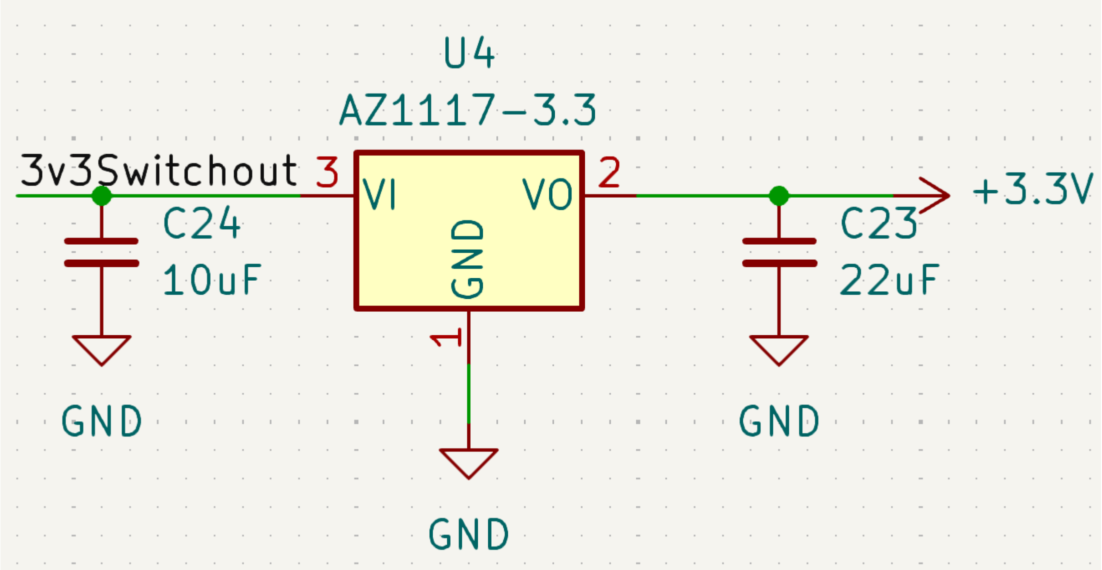


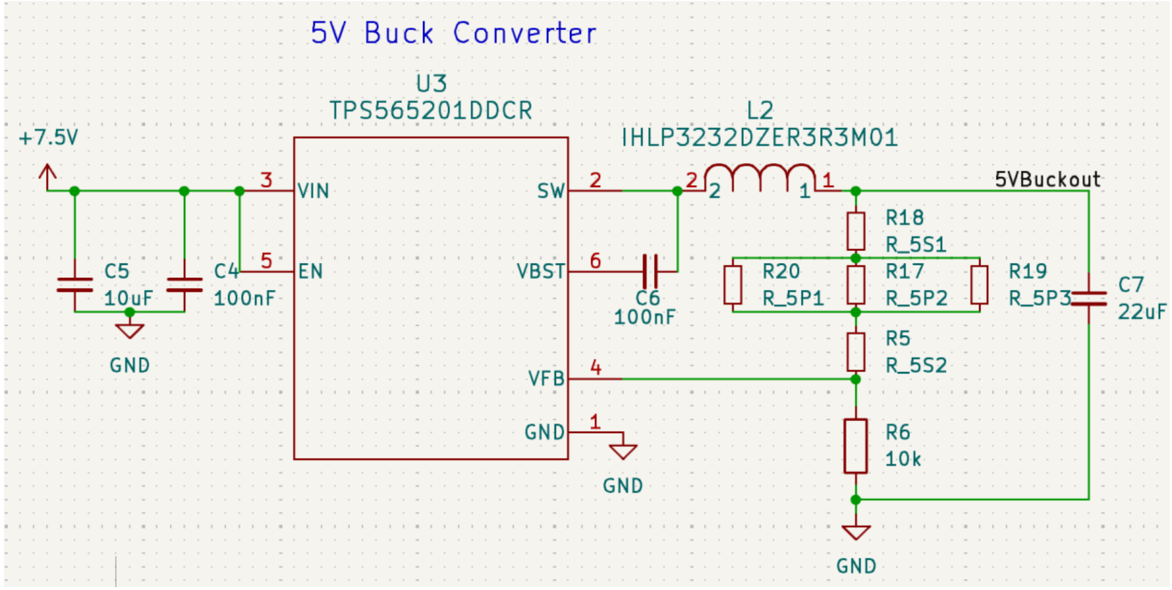
Control system
- Added Speed Control for motors

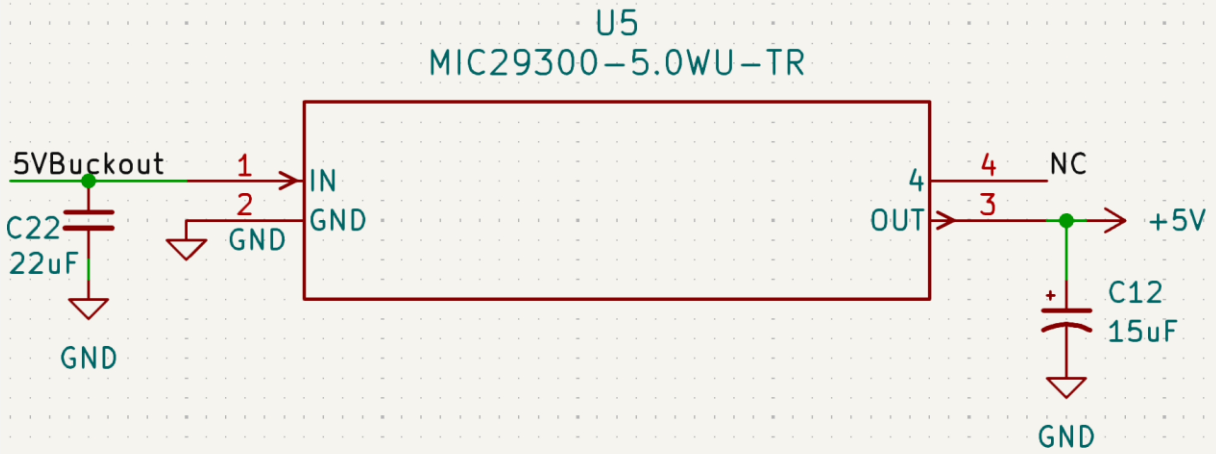
Technical Overview

Power systems

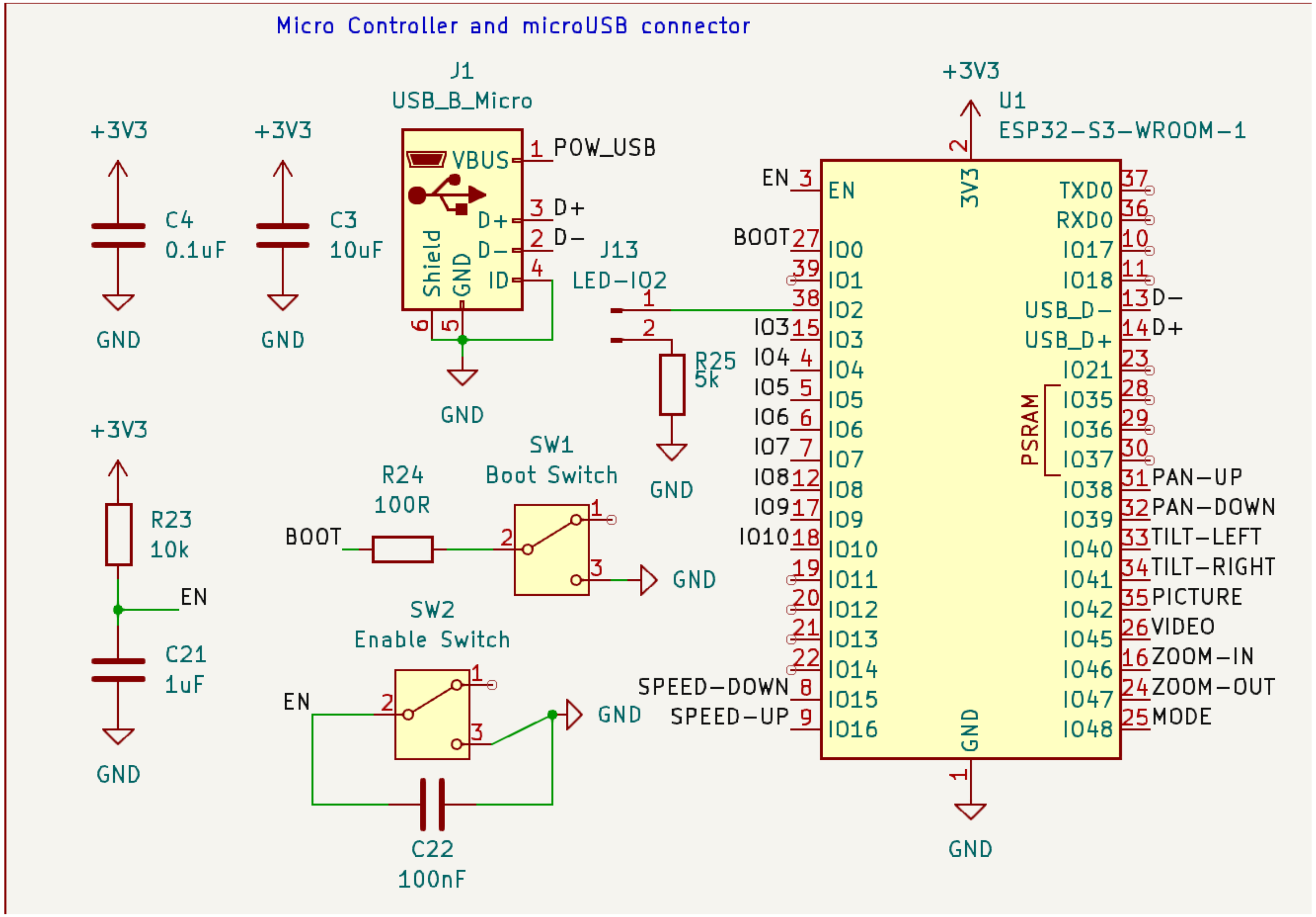


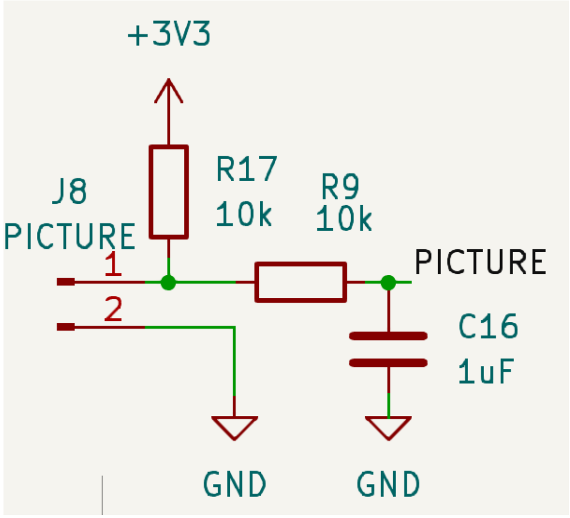


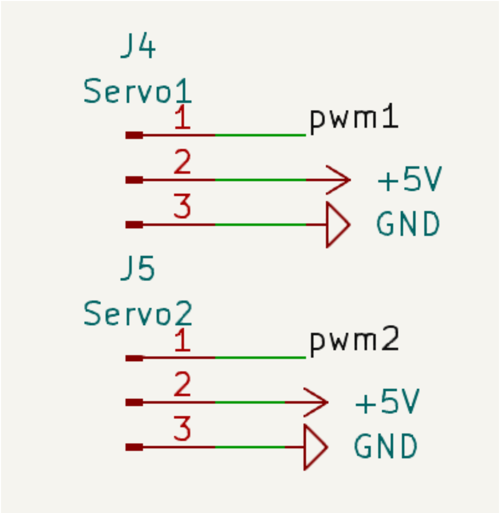




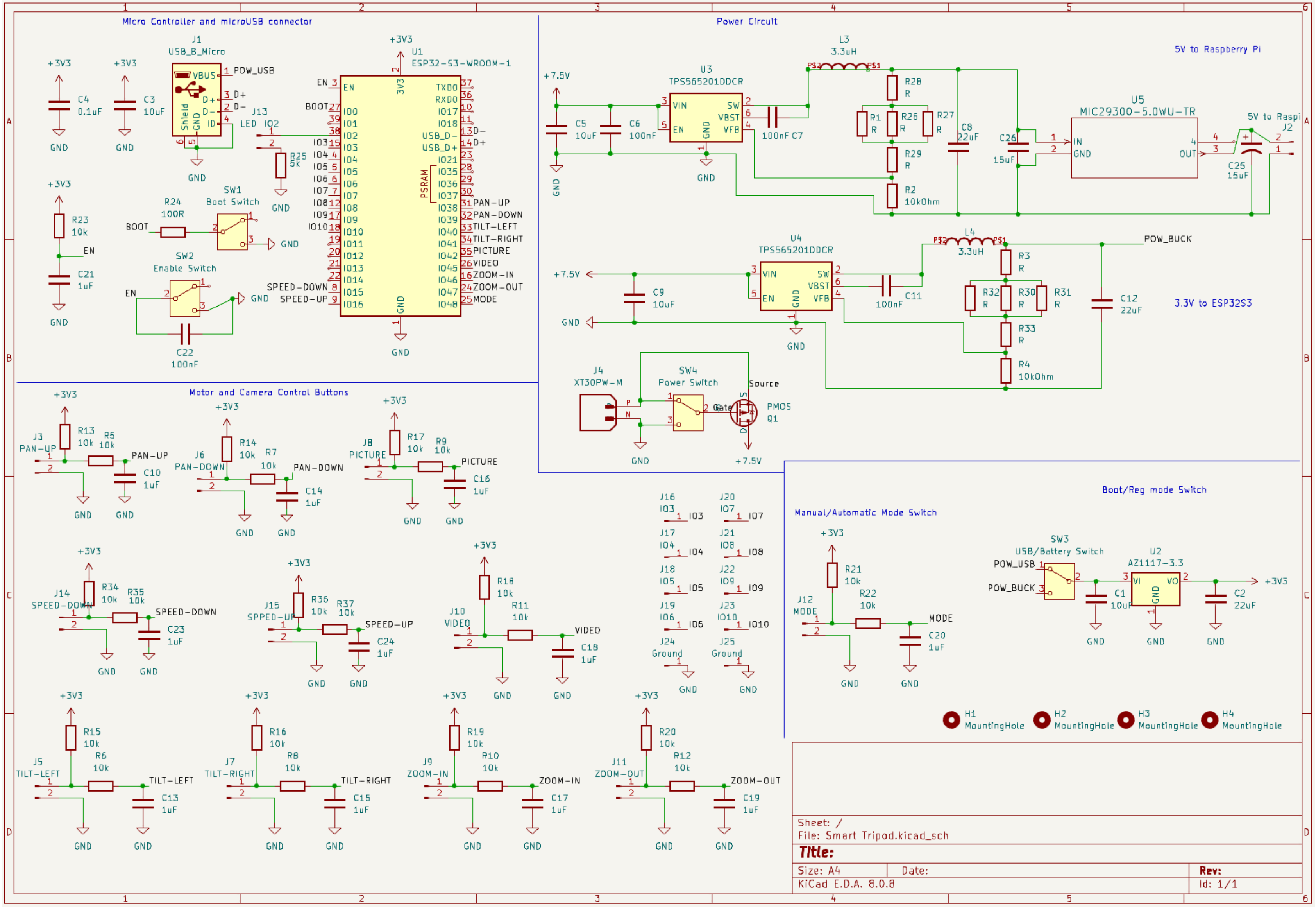
Control Circuit



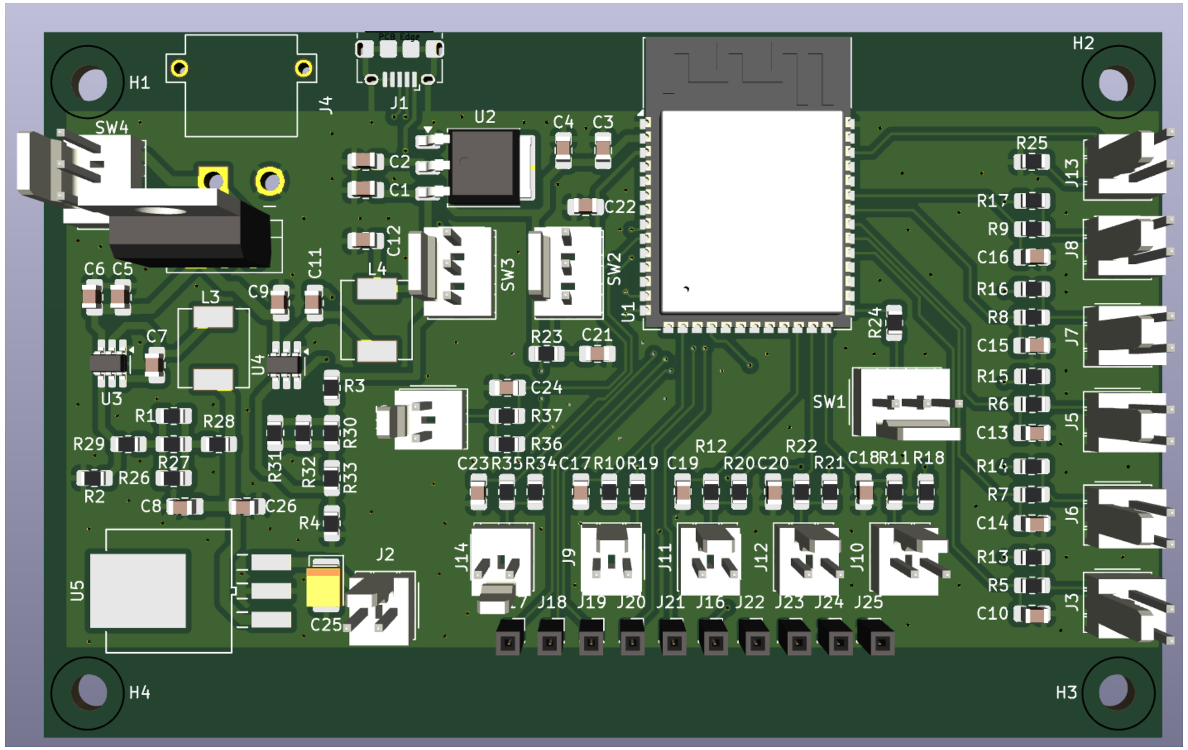




Schematic Overview – Remote Controller PCB



Remote Display/Controller



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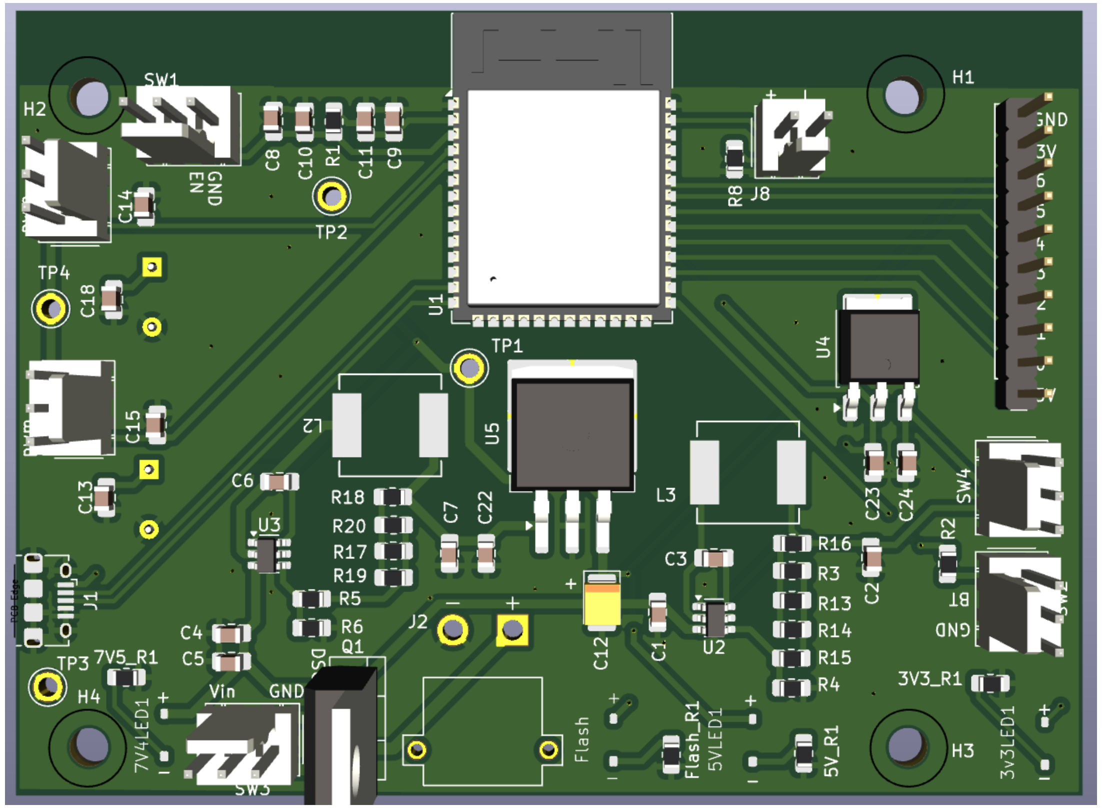
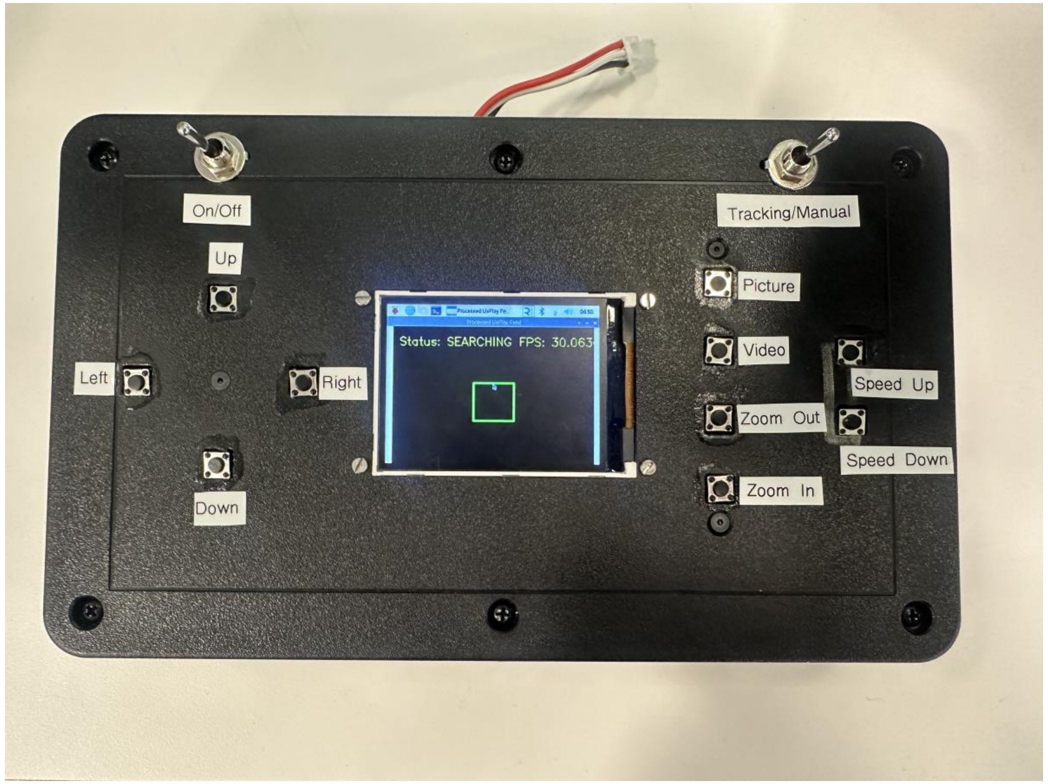
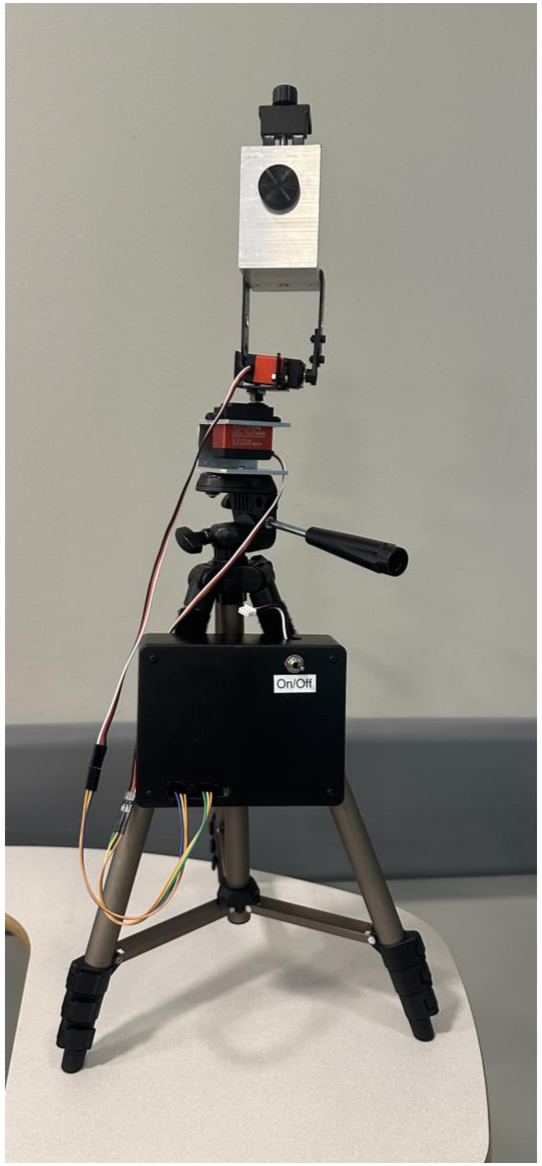
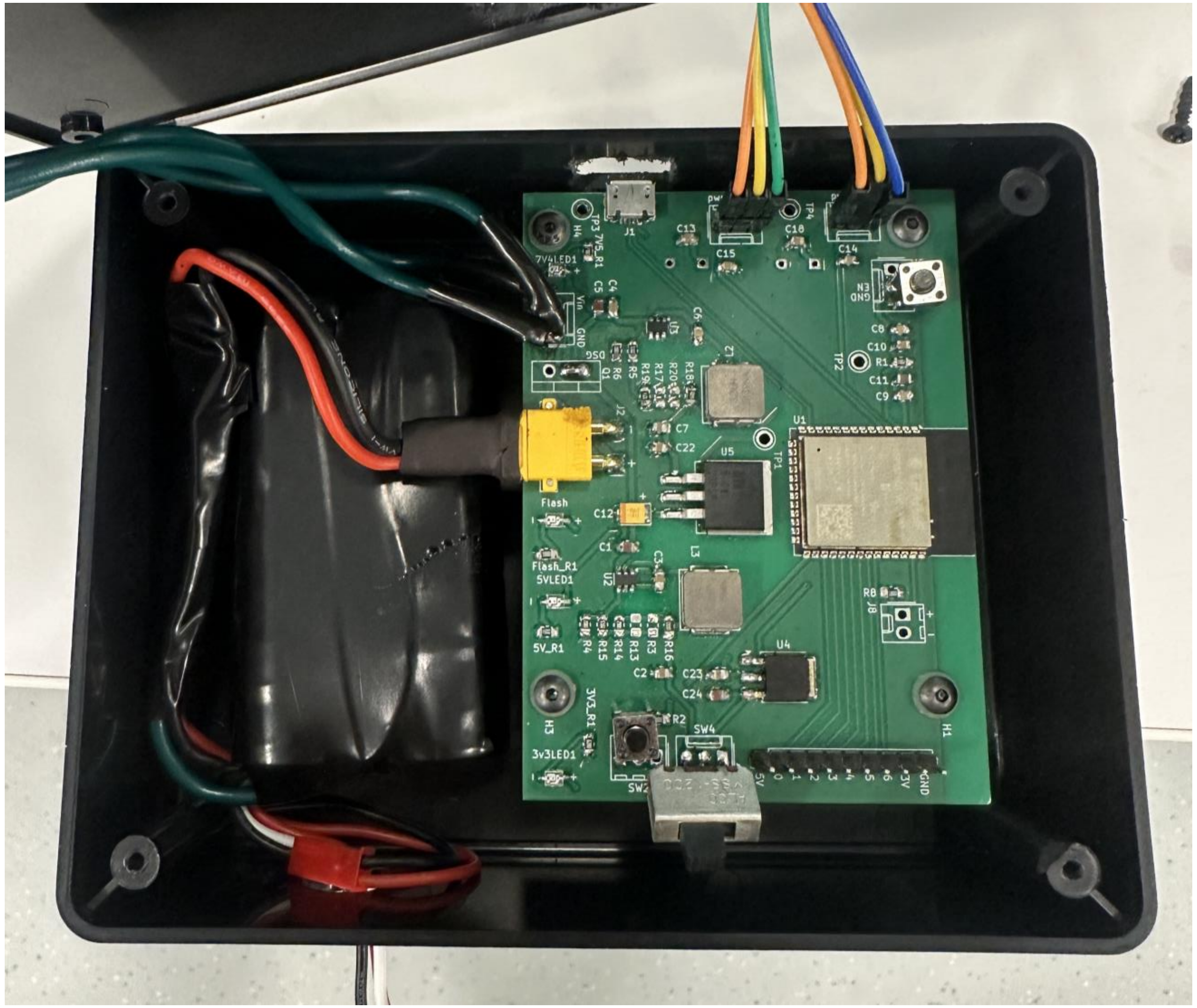


Physical Design



Physical Design





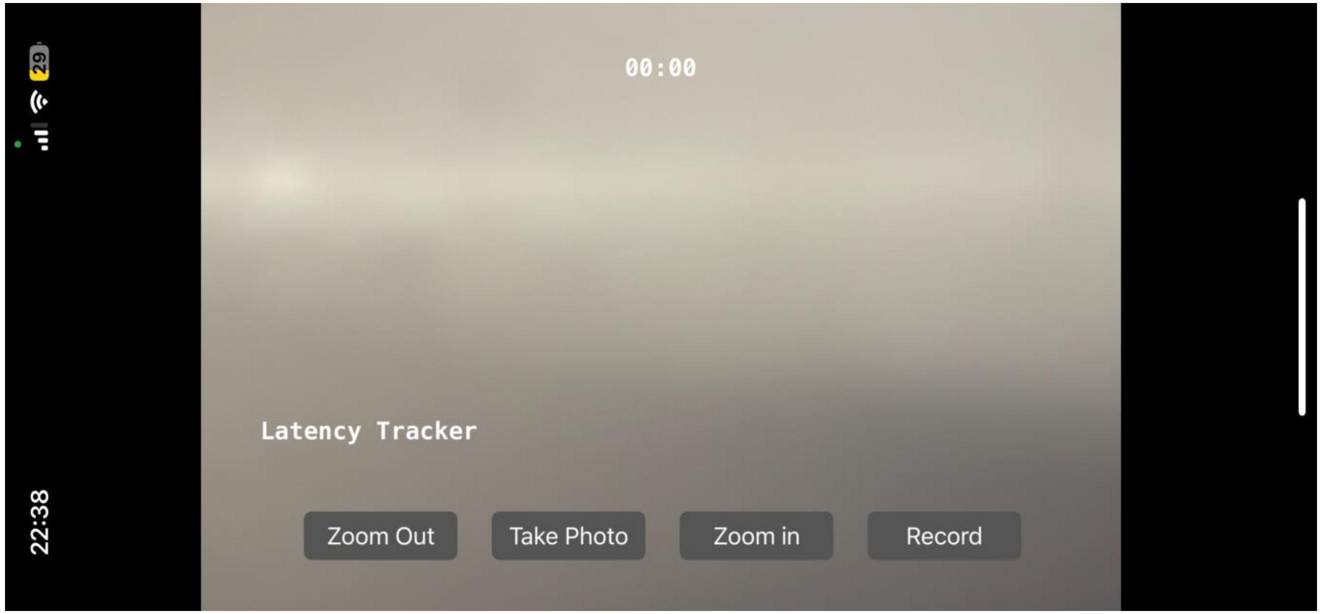
iPhone integrated App

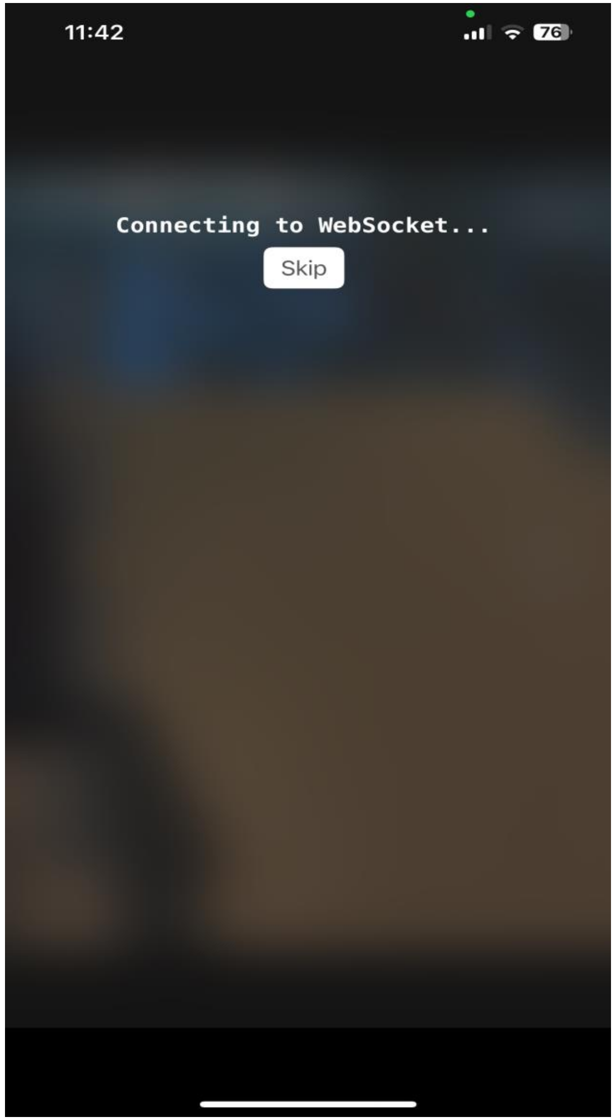
WebSockets

- Protocol that allows two-way communication between client and server
- Interprets string commands from buttons to execute respective commands to app

AVFoundation

- Apple's own full framework
- Inspecting, playing, capturing, and processing





Microcontroller/Raspberry Pi Software

Remote Display/Controller

- Establishes WiFi Network
- Creates and Maintains webSockets server
- Reads GPIO states for button and Raspberry Pi Control
- Broadcasts webSockets messages to other devices

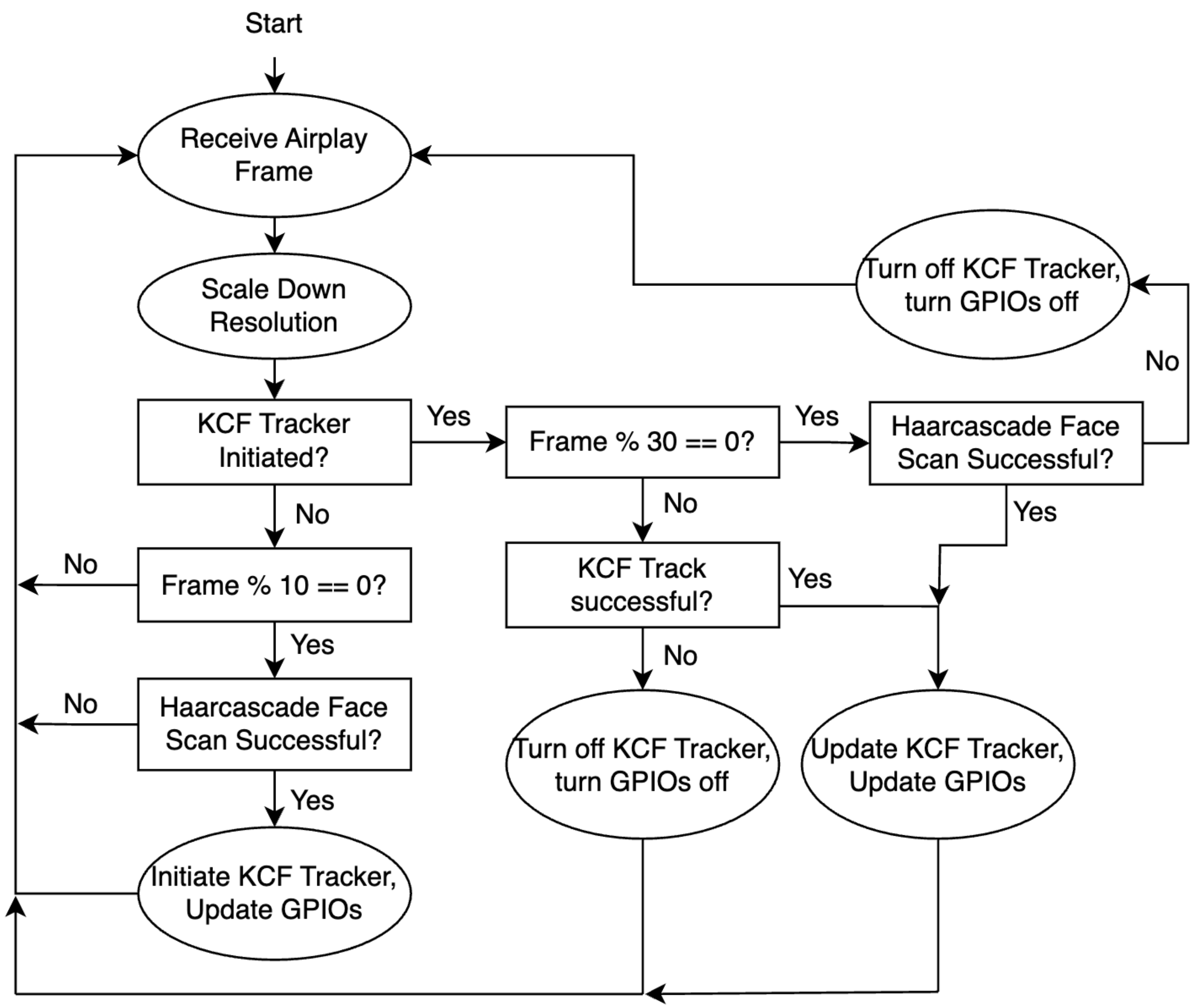
Motorized Tripod

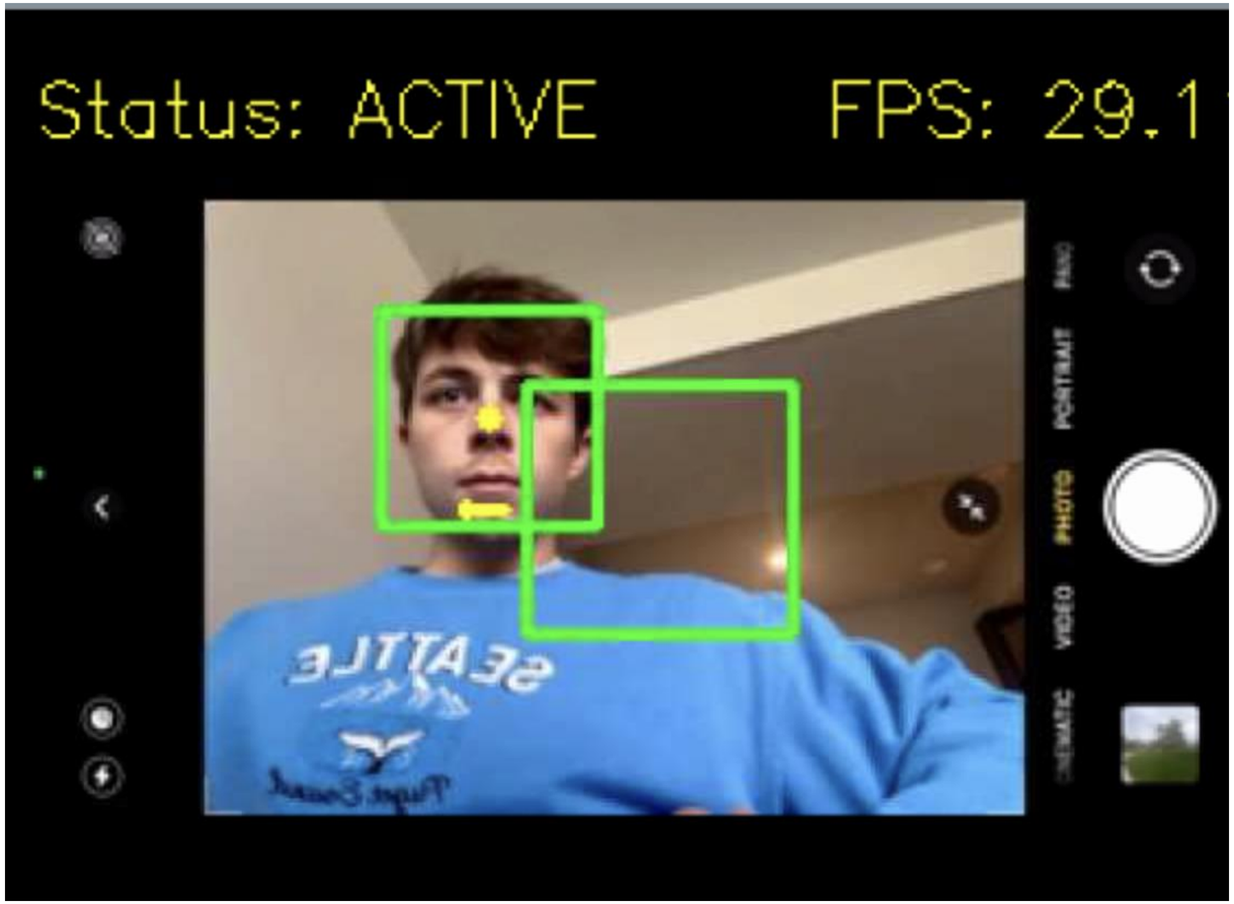
- Connects to WiFi network and webSockets server
- Controls motors via PWM output

Raspberry Pi

- Connects to WiFi network
- Utilizes UxPlay to initiate Airplay Server
- Dispalys Airplay connection and Raspberry Pi Desktop on LCD Screen via SPI
- Uses OpenCV tracking to detect faces
- GPIO control for tracking information, connected to microcontroller

Tracking Algorithm





Success and Challenges

Motor accuracy

Motors should respond to user inputs and automated tracking commands within 250ms

Motors should operate within +- 2 degrees of accuracy

Anticipated sources of delay include signal transmission, microcontroller processing, and motor inertia

Delay from Button to webSocket command sent ~ 2-4ms

```
I (43334) wifi_ws: Button press @Timestamp: 42996830 us
I (43334) wifi_ws: Sent 'start-up' to 1 clients
I (43334) wifi_ws: Websocket sent at @Timestamp: 43000403 us
I (43334) wifi_ws: Time elapsed: 3 ms
I (43644) wifi_ws: Sent 'stop-up' to 1 clients
```

Delay from command received to motor adjustment ~ 5-8ms

```
I (108606) wifi_ws_client: Received command: start-left
I (108616) CommandProcessor: Processing command: start-left
I (108616) CommandProcessor: Recieved command @Timestamp: 108270036 us
I (108616) ServoControl: Servo 1 position updated to duty: 1505
I (108626) CommandProcessor: Elapsed time: 6 ms
```

Total delay ~ 10-20ms accounting for WiFi transmission

Motor Accuracy tested using iPhone's Gyroscope/Compass ~ sub 1 degree accuracy with minimum step size

iPhone Camera Action and Responsiveness

Camera action triggered from the external remote interface should execute within 500 milliseconds.

iPhone should reliably connect to the WiFi network and allow for all Network operation.

Anticipated sources of delay include potential network congestion due to Airplay stream, and iPhone App processing.

Delay from Button to webSocket command sent ~ 2-4ms

```
I (43334) wifi_ws: Button press @Timestamp: 42996830 us
I (43334) wifi_ws: Sent 'start-up' to 1 clients
I (43334) wifi_ws: Websocket sent at @Timestamp: 43000403 us
I (43334) wifi_ws: Time elapsed: 3 ms
I (43644) wifi_ws: Sent 'stop-up' to 1 clients
```

Delay from webSocket command sent to iPhone

```
🕐 [RECORD] 'picture' at 2025-05-05 16:17:09 +0000
🧮 [CALC] 'picture' - 0.3249645233154297 ms (from 2025-05-05 16:17:09 +0000 to 2025-05-05
16:17:09 +0000)
📸 Posting CapturePhoto
📨 Message received
📩 Text: picture
🕐 [RECORD] 'picture' at 2025-05-05 16:17:14 +0000
🧮 [CALC] 'picture' - 0.23996829986572266 ms (from 2025-05-05 16:17:14 +0000 to 2025-05-05
16:17:14 +0000)
```

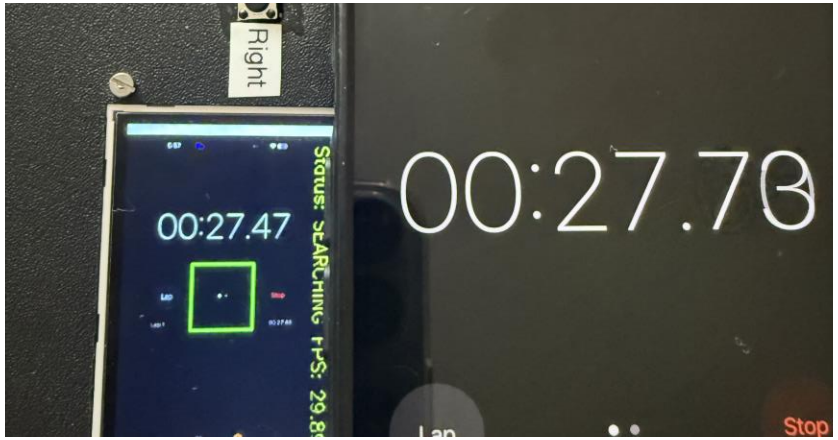
High Level requirements

Airplay and tracking

Airplay video stream should maintain at least 24 FPS with less than 1 second of latency to the Raspberry Pi

The system must perform subject detection via OpenCV and send corrective tracking commands within 500ms

Anticipated sources of delay include Airplay transmission, and OpenCV computation overhead



Frame rate ~ 25-30 FPS (without tracking)

Airplay Transmission delay ~ 200-600ms

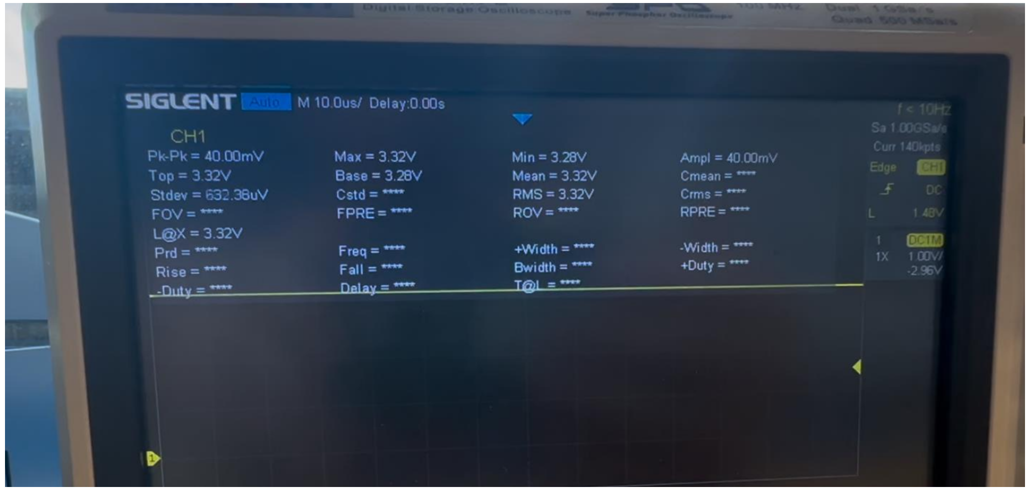
```
2025-05-03 23:53:06 - Processing at 30.01 FPS
2025-05-03 23:53:10 - Initializing KCF tracker with new face detection
2025-05-03 23:53:10 - time from frame face detect to gpio set is 47.933ms
2025-05-03 23:53:10 - GPIOs set
2025-05-03 23:53:10 - time from frame face detect to gpio set is 45.560ms
2025-05-03 23:53:10 - GPIOs set
2025-05-03 23:53:10 - time from frame face detect to gpio set is 57.079ms
2025-05-03 23:53:10 - GPIOs set
2025-05-03 23:53:10 - time from frame face detect to gpio set is 51.739ms
2025-05-03 23:53:10 - GPIOs set
```

Frame received to OpenCV detection delay ~ 45-60ms

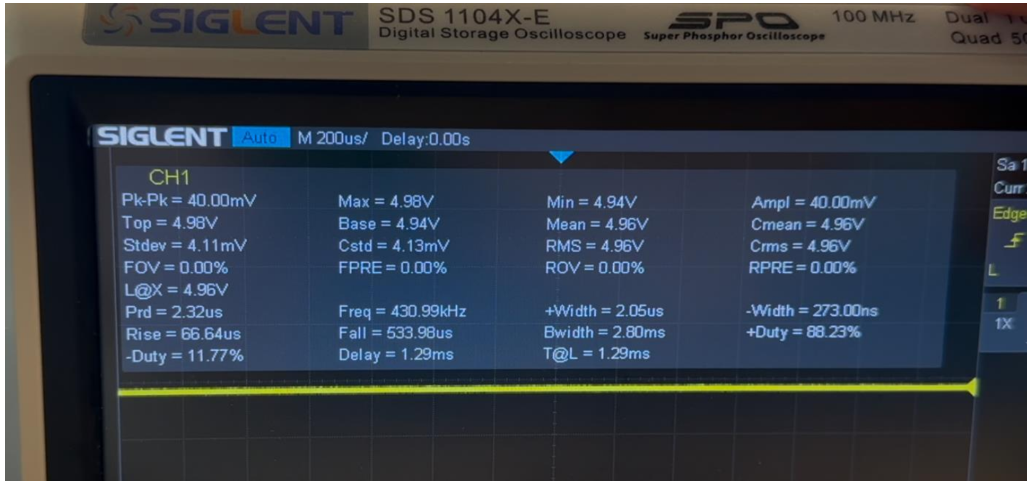
Inaccuracy of buck output
- Use of additional resistor spots for accurate tuning

Undesired noise
- Noise was nearly within margins
- Additional radiated emissions from WiFi
- Use of LDO for both 5V and 3.3V

5v power plane
- Schottky diodes vs toggle switch
- 5v → 4.6v



3.32V Mean, 40mV Peak to Peak



4.96V Mean, 40mV Peak to Peak

Challenges – Firmware and Software

Software
- Working with UI, you must explicitly set all necessary constraints with all UI elements

webSockets
- Persistent connection was giving apps problems on start-up

- Manually disconnect to ensure there is only one connection

WiFi
- Unable to monitor airplay traffic on the ESP32-S3 software

Raspberry Pi
- Deciding whether to track face or body
- Creating a more efficient algorithm
- Software vs Hardware accelerated processing

Conclusion

What we would do differently

Large over consideration in power

- Lower power draw than anticipated
- Reduction in cost and area
- Remove the 3.3V buck

Physical Component Changes

- Larger Screen size
- Remove ESP32-S3 from remote controller

Improved Tracking Algorithm

- Detect both faces and full bodies
- Run detection algorithm on iPhone

Apple allows developers to use virtually every part of the iPhone

- All sensors included
  - Such as, ambient light sensor (ALS)

- Add even more features, essentially utilizing all features of Camera App
  - Controlled exclusively with the external remote

- U.I. updates, more notifications
  - As close to the Camera App as possible

Ethics Concerns

Privacy and Surveillance

- Our features inherently involve wireless communication, screen mirroring, and data transmission
- Aligns with IEEE Code of Ethics I.1
  - Responsible handling of user data and privacy protection

Bias in Computer Vision Tracking

- Ensures that automated tracking is able to track all subjects regardless of skin tones clothing variations, and lighting conditions
- Aligns with IEEE Code of Ethics II
  - Calls for fairness and respect in technology development

Transparency and Honesty

- Users must have confidence that the Smart Tripod operates as advertised and that its limitations and risks are communicated clearly
- Adheres to IEEE Code of Ethics I.3
  - Emphasizes honesty in engineering practices

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