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ENGINEERING
TEXAS A&M UNIVERSITY

ECEN 404 Final Presentation
Team 30: Ember Bot

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TA: Roman Venegas

Project Overview

Problem Statement:

Traditional firefighting methods place firefighters in direct danger, exposing them to conditions that significantly threaten their safety and livelihood.

Solution Proposal:

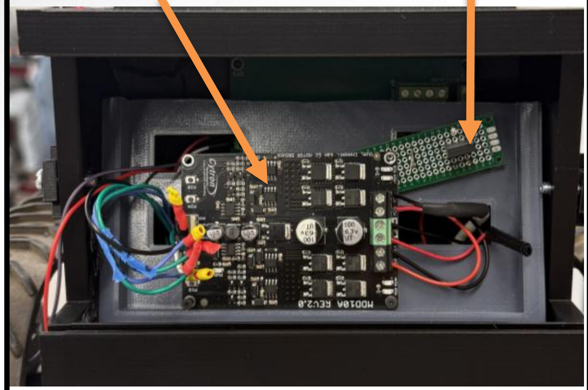
Ember Bot introduces a remotely operated robotic vehicle that allows firefighters to combat fires from a safe distance.

Integrated Project Diagram

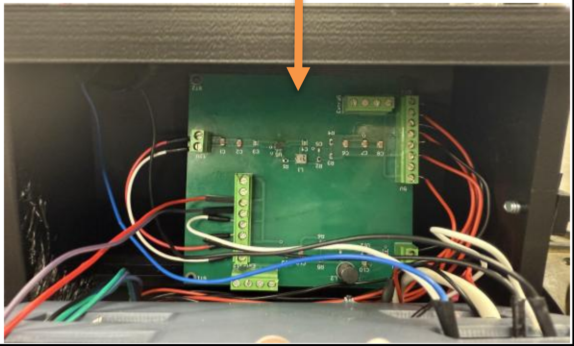
Back:

Motor Drive

Water Pump Switch



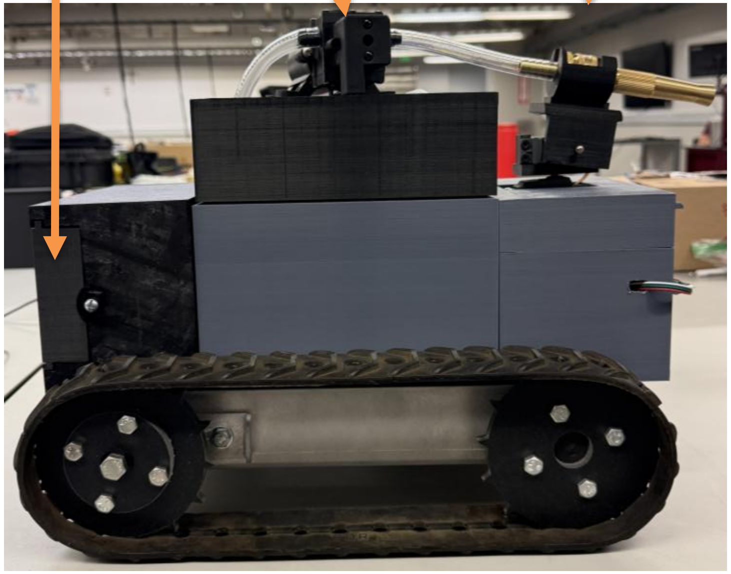
22.2V to 12V
12V to 5V



Cooling Fan

Water Pump

Nozzle with Servos

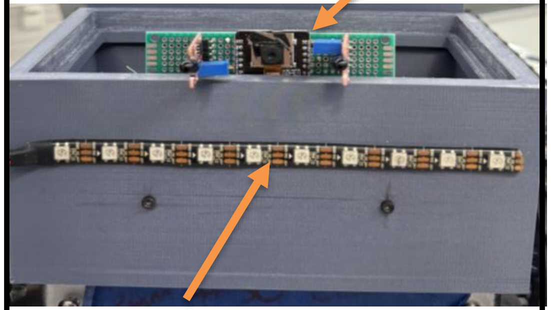


Inside:
2 - 24V DC Motors
2 - 11.1V Li-Po Battery
Water Bag

User:
Mobile App

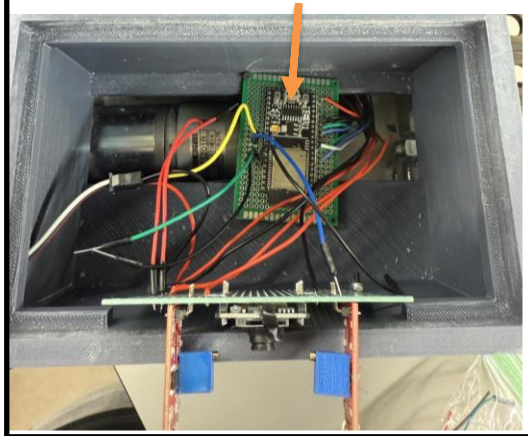
Front:

Camera & Infrared Sensors

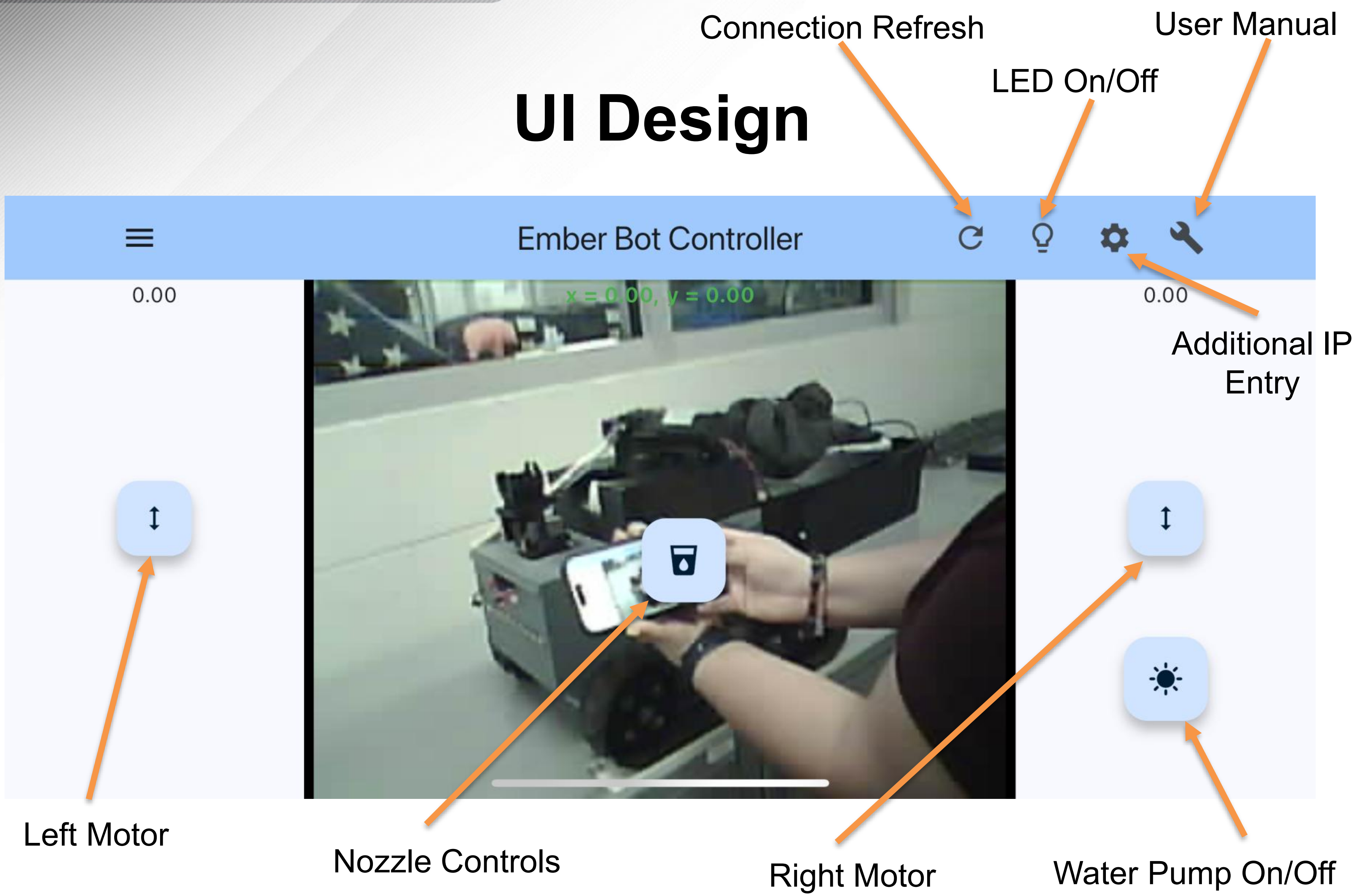


LED Strip

ESP32



UI Design


Connection Refresh
User Manual
LED On/Off
Ember Bot Controller
0.00
x = 0.00, y = 0.00
0.00
Additional IP Entry
Left Motor
Nozzle Controls
Right Motor
Water Pump On/Off

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User Manual Page

User Manual

1. Connect to EmberBot

- Automatically connect your phone to the same Wi-Fi network as the ESP32 boards.
- Open the Settings page from the gear icon.
- Enter your own server IPs if using the app for your own devices

2. Camera View

- The center panel shows the live video stream.
- The nozzle control button appears on top of the video.
- The green X/Y values indicate the current nozzle aim.

3. Left/Right Track Control

- Drag the left/right vertical buttons up or down.
- Movement is proportional to the drag distance.
- Use both paddles together to move forward or backward.

5. Nozzle Aiming

- Drag the nozzle button across the video area.
- Horizontal movement changes X.
- Vertical movement changes Y.
- Releasing the button sends the updated aim.

6. LED Control

- Tap the lightbulb icon on the top app bar.
- The icon lights up when the LED is ON.

7. Water Pump Control

- Tap the shower icon button on the right column.
- When highlighted, the pump is active.
- Aim safely before using the pump.

8. Safety Tips

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Engineering Design Accomplishment

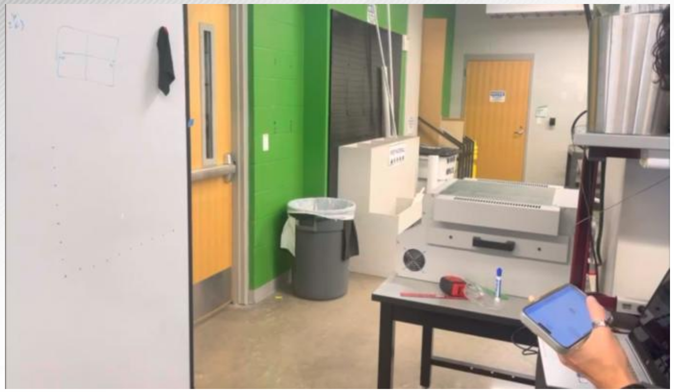
Kevin Rivera

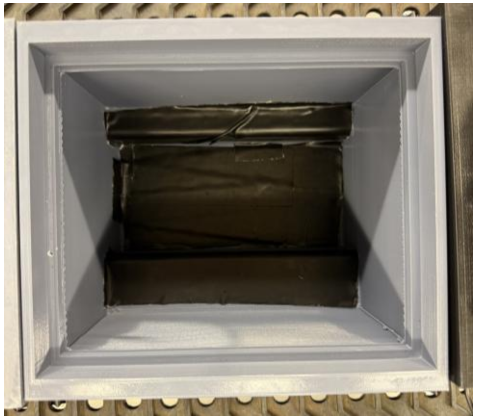
- 2 - 24V DC Motor
- Motor Driver
- 12V Water Pump
- 2 - 5V Servos
- Foldable Water Tank
- Vehicle Framing
- 12V Cooling Fan

Parameter	Result
Nozzle Accuracy	Mean: 0.975 inches Standard Deviation: 0.764 inches
Water Storage	0.92 Gallons
Water Output	40 mL/s
Water Spray Max Range	7ft
Total Robot Weight	24.3 lbs
Maximum Speed	Mean: 1.72 mph
Obstacle Capability	Max: 2.1 inches (44% tread height)

Engineering Design Accomplishment

Kevin Rivera





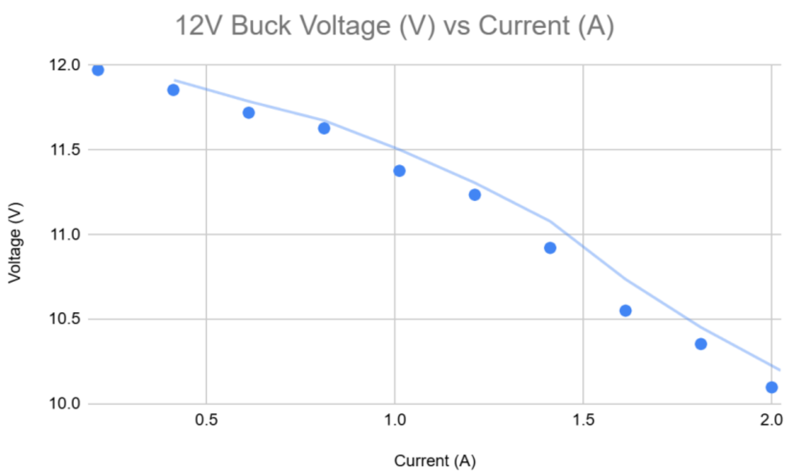
Challenges	Solution	Status
Increase Nozzle Accuracy	Modify code to microseconds instead of angle values	**Resolved –** Accuracy improved from mean 1.6 inches to 0.975 inches
Ensure All Electronics Remain Dry	Plastic water tank instead of pouring water directly into 3D print design.	**Resolved –** Plastic water tank safely stores water, further actions currently undergoing to ensure plenty of safety nets
Increase Nozzle Maneuverability	Swap high pressure, threaded tubing for standard tubing.	**Implemented –** Range of motion increased by 13.5 inches in x-direction. Y-direction needs further testing
Maximize Total Water Storage	Attach plastic water tank directly to surface of container	**Not Implemented –** Attaching directly will be done before final demo

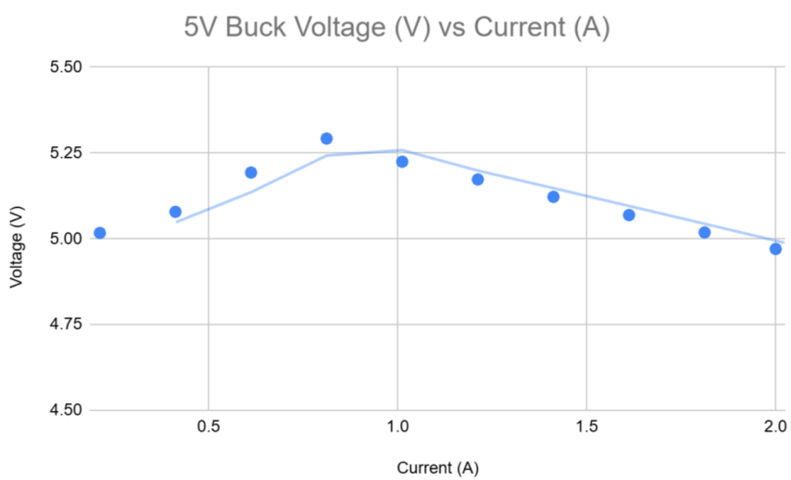
Engineering Design Accomplishments

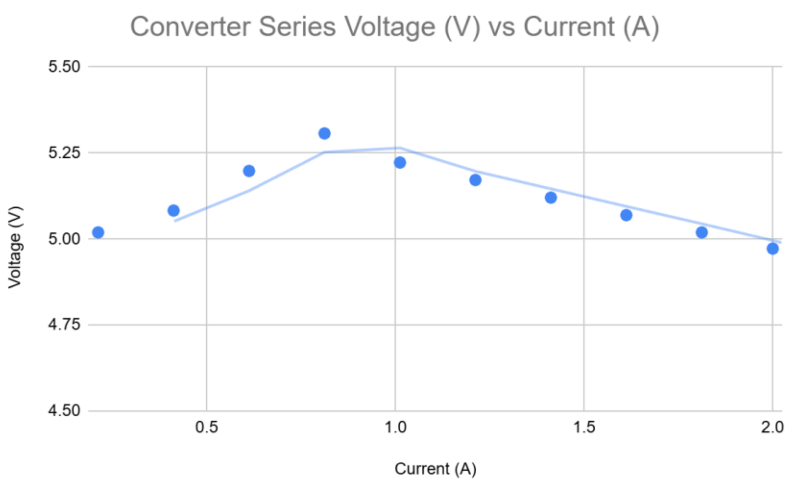
Nancy Ramirez Castillo

DC E-Load Current Sweeps

Converter	Average
22.2V -> 12V	11.254 V
12V -> 5V	5.106 V
Series (Both)	5.108 V







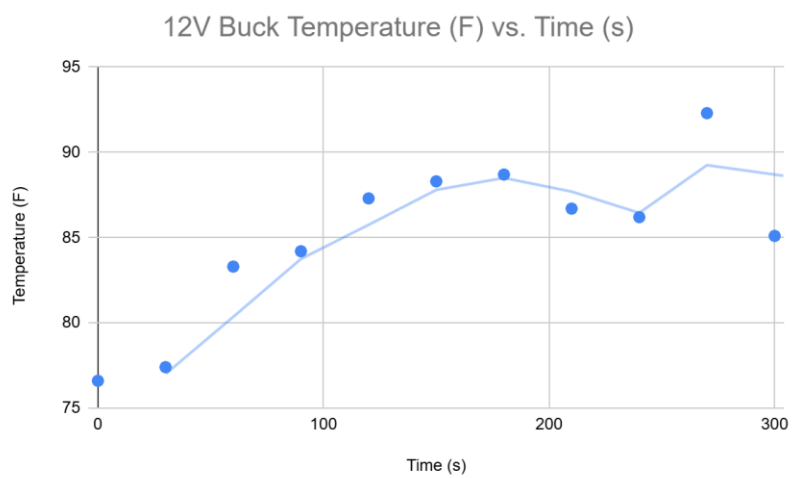
Engineering Design Accomplishments

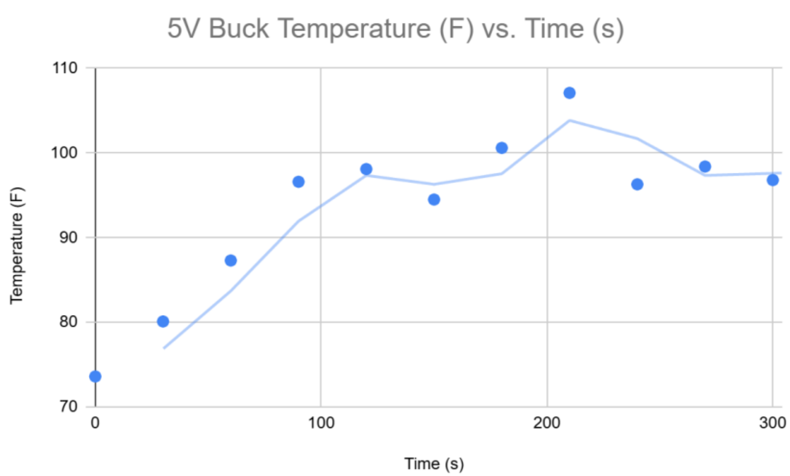
Nancy Ramirez Castillo

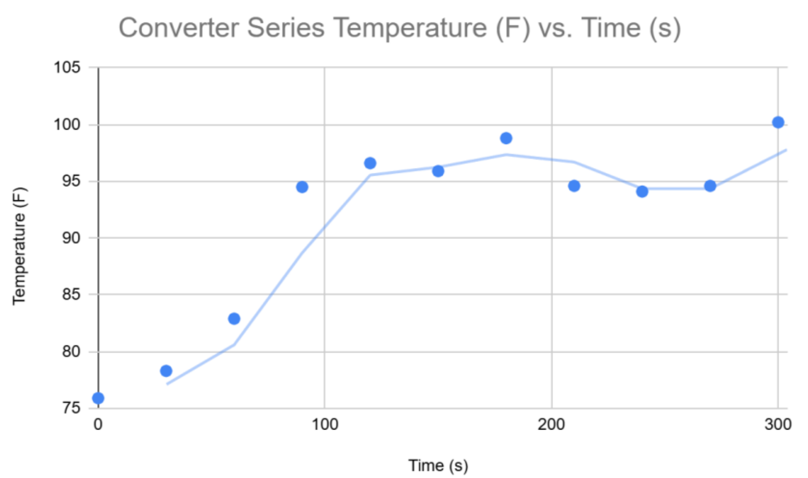
Thermal Test with Max Load & NO Fan

Converter	Average
22.2V -> 12V	85.1°F
12V -> 5V	93.58°F
Series (Both)	91.49°F

Max current drawn: 1.94 A

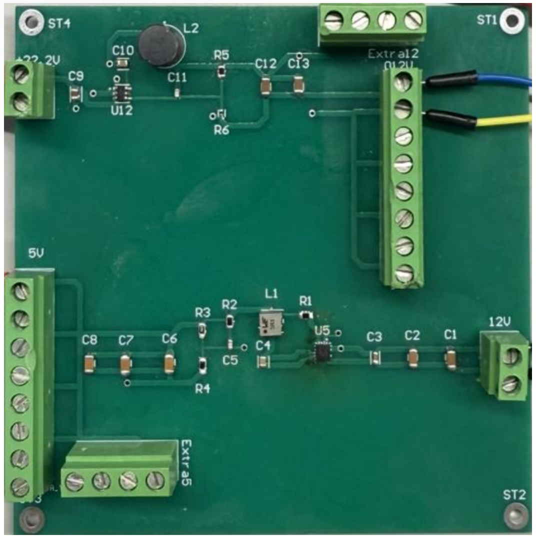






Engineering Design Accomplishments

Nancy Ramirez Castillo



Challenges	Description	Status
12V -> 5V Failure	Unit worked initially, then stopped producing Vout or feedback after ~24 hrs.	**Resolved** — Replaced IC and inductor; converter now functional
Start-up Delay	Water pump and LED require pressing on/off twice before powering.	**Unresolved** — Likely power sequencing or current-limiting delay.

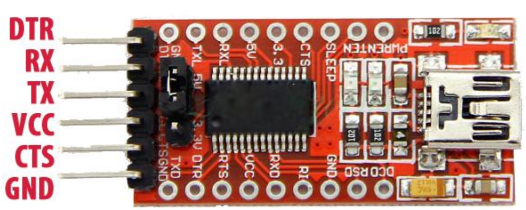
Engineering Design Accomplishment

Jonathan Chen

- **ESP32 Web Server:** Receives JSON from Flutter app and translate to control motors, servos, pump, and LED.
- **ESP32-CAM**: Direct HTTP streaming (fit to scale) with static IP for use with app

Distance (approx)	Typical RSSI (dBm)	320×240 — Native resolution	640×480 — Non-native resolution
0–5 m (0–16 ft), same room, line of sight	~ -30 to -60	~40–52 FPS	~12–15 FPS
5 Feet	-42	44.44 FPS	14 FPS
5–20 m (16–66 ft), indoors with walls/obstacles	~ -50 to -70	~30–45 FPS	~8–14 FPS
20–100 m	~ -60 to -80	~10–35 FPS	~2–8 FPS; visible/faulty stream
100–300 m	~ -80 to -90	1–10 FPS	≤2 FPS
Edge cases / very poor signal (thick walls, interference)	≤ -90	0–2 FPS	0–1 FPS

Challenge: ESP32-CAM isn't streaming as intended with independent power



FTDI USB to TTL adapter

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Engineering Design Accomplishment

Jonathan Chen

```
09:41:09.207 -> Tag = 44, Parsed coords: leftMotor=0, rightMotor=0, NozzleX=0, NozzleY=0, Pump=0, LED=0
09:41:10.628 -> Tag = 45, Parsed coords: leftMotor=-27, rightMotor=0, NozzleX=0, NozzleY=0, Pump=0, LED=0
09:41:11.567 -> Tag = 46, Parsed coords: leftMotor=-35, rightMotor=0, NozzleX=0, NozzleY=0, Pump=0, LED=0
09:41:12.054 -> Tag = 55, Parsed coords: leftMotor=-110, rightMotor=0, NozzleX=0, NozzleY=0, Pump=0, LED=0
09:41:16.320 -> Tag = 58, Parsed coords: leftMotor=0, rightMotor=0, NozzleX=0, NozzleY=0, Pump=0, LED=1
09:41:20.533 -> Tag = 59, Parsed coords: leftMotor=0, rightMotor=0, NozzleX=0, NozzleY=0, Pump=0, LED=0
09:41:25.224 -> Tag = 60, Parsed coords: leftMotor=0, rightMotor=0, NozzleX=0, NozzleY=0, Pump=1, LED=0
09:41:27.125 -> Tag = 61, Parsed coords: leftMotor=0, rightMotor=0, NozzleX=0, NozzleY=0, Pump=0, LED=0
09:41:29.462 -> Tag = 62, Parsed coords: leftMotor=0, rightMotor=0, NozzleX=-5, NozzleY=-3, Pump=0, LED=0
09:41:31.814 -> Tag = 63, Parsed coords: leftMotor=0, rightMotor=0, NozzleX=-7, NozzleY=3, Pump=0, LED=0
```

Challenge: ESP32 has latency in data handling from delays in processing incoming JSON files

Solution: Implemented a tagging system with integrity and timing checks as well as multiple JSON validation functions.

Control	Result (Response < 500 ms)
Left Motor & Right Motor	✅
Nozzle X & Nozzle Y	✅
Pump	✅
LED	✅

Tests Conducted Per Variable	100
Average Response Time	483 ms

ESP32 Internal Diagnostics

```
Writing at 0x0010dc39 [============================> ]  97.4% 622592/639068 bytes...

Writing at 0x00113b50 [============================> ] 100.0% 638976/639068 bytes...

Writing at 0x00113bd0 [==============================] 100.0% 639068/639068 bytes...
Wrote 1063888 bytes (639068 compressed) at 0x00010000 in 56.9 seconds (149.6 kbit/s).
Hash of data verified.
```

```
========== System Info ==========
CPU Frequency: 240 MHz
Available RAM: 227168 bytes
Lowest Free RAM since Boot: 226768 bytes
Largest Allocatable Block: 110580 bytes
Flash size: 4194304 bytes
=================================
```

Mobile App Design Accomplishments

Yuwen Zheng

- Designed and built a mobile app as a controller for the Ember Bot using Flutter
- The mobile app can automatically connect to the Ember Bot when opened
- The App can support functionalities such as moving the robot, turn LED ON/OFF, video streaming, reconnecting to the Ember Bot and shooting waters
- Provide user manual guide for users in the app
- Designed a different version for iPads

Mobile App Validation

- All functionalities are successfully tested on iOS/Android emulators, 4 different iOS devices and on the physical Ember Bot
- Tested the accuracy of the App when sending motor control signals
- Tested how easily users can understand the user manual guide
- Cannot test on Android physical devices due to lack of product but tested on the android emulator

Tested Devices & Accuracy

Devices	Results	
iPhone 16 Promax	Loaded	Successfully connected to Ember Bot
iPhone 16 Pro	Loaded	Successfully connected to Ember Bot
iPhone 16 Pro	Loaded	Successfully connected to Ember Bot
iPhone 13	Loaded	Successfully connected to Ember Bot
iPad Air	Loaded	Successfully connected to Ember Bot
Android Emulator	Loaded	Successfully connected to Server

Using scenario	Average % of Accuracy
Motor Button Dragging Slowly	97.55%
Motor Button Flicking	91.10%

The accuracy tends to be lower when the data set is larger and when user flick buttons faster.
This does not affect the motor behavior

Integrated System Results

- **Test Parameter:**
  - Drive Ember Bot 10 ft to a point 5 ft away from the target.
  - Aim and shoot the nozzle to hit the target
  - Volume of water landing inside to be tracked
- **Result:**
  - Ember Bot successfully controlled through mobile app.
  - Target was hit after moving the nozzle with user adjustment.
  - **Total volume shot:** 490 mL
  - **Total volume inside target:** 250mL
  - **Target total volume shot:** Minimum 75% of volume inside target (438 mL)

Conclusion

Issue	Original Assumption (ConOps/FSR/ICD)	Design Change / Mitigation
IR Flame Sensors don't work outside	KY-026 Sensors would function as a flame detector in working scenarios – Inside Situation **(ICD 5.2)**	Removed Flame Sensor Detection for Outside Cases, left for additional features if desired in the future
Multiple Connections to ESP32 Access Point	Only one connection would be needed from App to Microcontroller **(FSR 4.1.1)**	Used multiple connections: HTTP `/coords` server runs independently from camera streaming using static IPs
High pressure threaded tubing being inflexible	The tubing would be able to deliver water in a high-pressure manner to ensure maximum range **(FSR 3.1.2.5)**	Swapped out high pressure tubing for standard tubing
22.2V -> 24V Boost Converter	Originally planned boost to 24V to achieve motor top speed. **(FSR 3.2.1.3)**	Removed as it's not required after weight & test data showed 22.2V is sufficient.

Current Status: Full Integrated Complete, on Final Testing & Minor Debugging, Final Demo Testing Course Preparation

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Questions?

Thank You!

Ember Bot

Jonathan Chen, Kevin Rivera, Nancy Ramirez Castillo, Yuwen Zheng

TA: Roman Venegas