Parking Garage Management System

Group 11:

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MEET THE TEAM

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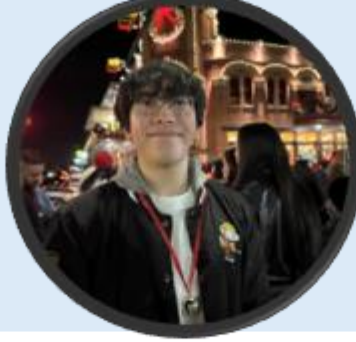
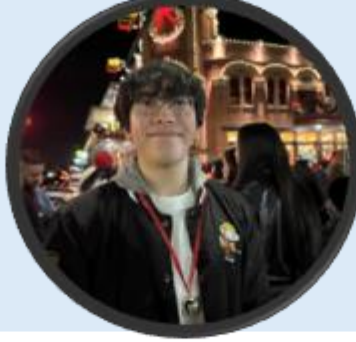
Motivation



- Busy parking garages are a pain to deal with
  - Finding parking spots during peak times are hard
  - Difficult to tell if parking garages are busy
- Dealing with permits and gates could be confusing
- For smart parking garages, systems can go down from natural disasters

Goal & Objectives



Basic Goals:

- Real time parking availability
- Navigation assistance in garage
- Security with license plate detection

Advanced Goals:

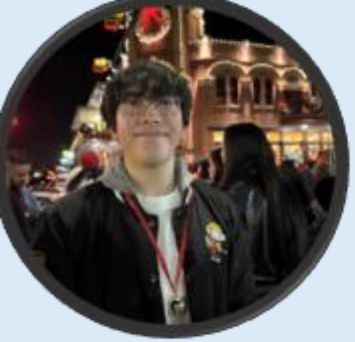
- Solar panels with a battery management system
- Notifications for users/admins
- Automated permit payments

Stretch Goals:

- Vehicle description in database
- Outdoor parking support

Objectives:

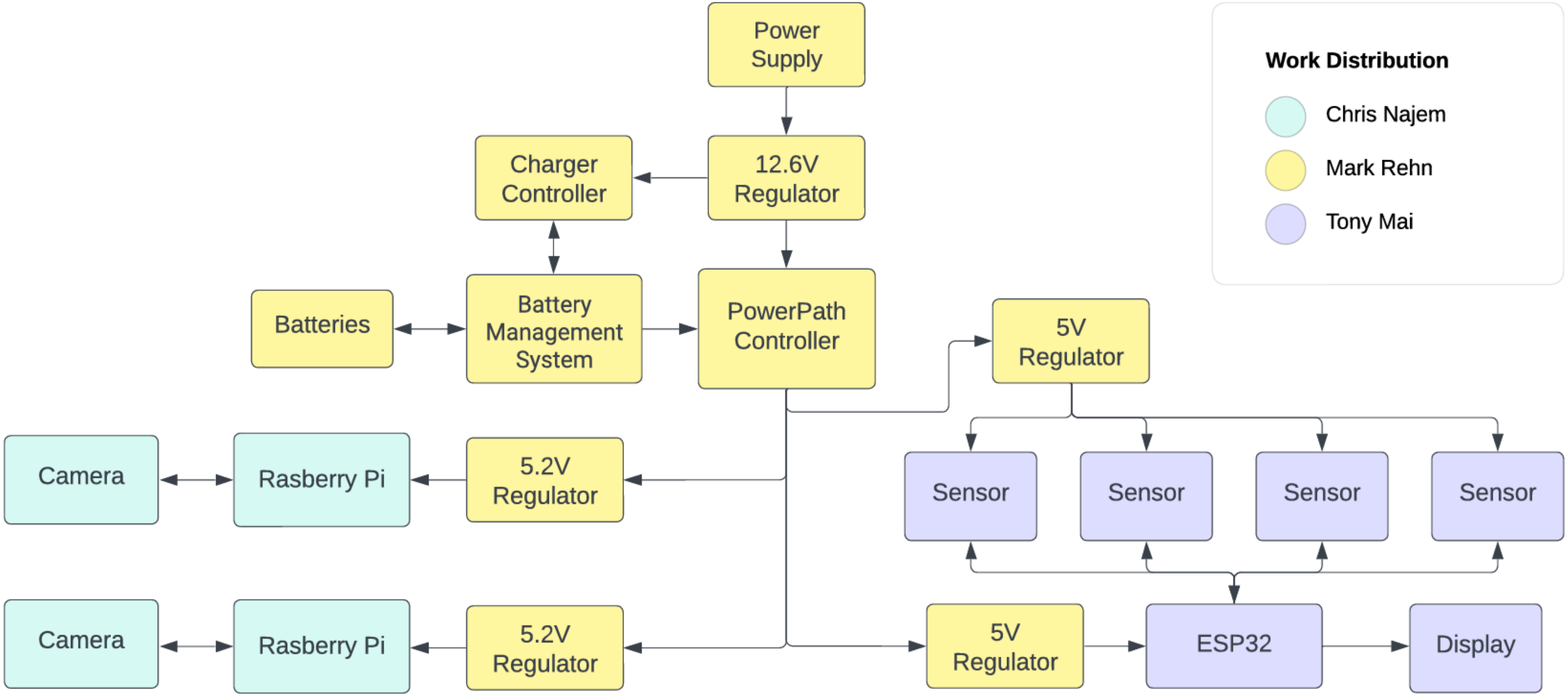
- To create an all-in-one system that provides parking availability to any parking garage, license plate detection for permits, and a battery backup system in case of emergencies



Engineering Specifications

Specification	Value/Range	Description
Parking Sensor Detection Accuracy	≥95%	Accuracy of the sensors in detecting parking spot occupancy.
License Plate Recognition	≥85%(daytime) ≥80% (nighttime)	Accuracy of LPR cameras in identifying license plates under varying lighting conditions.
System Uptime	≥99.9%	The system's operational availability over a given time period.
Real-Time Updates	<5 second	Time for parking availability updates to propagate through the system.
Battery Life	≥2 hours	Minimum operational time using battery system in case of power failure.
Payment Processing Time	<10 seconds	Time required for completing parking permit transactions.
LED Indicator Visibility	≥20 meters	Distance from which LED indicators for parking spots can be clearly seen.
Power Efficiency	≥85%	Efficiency of the battery management system in converting and using stored energy.
Backend Server Processing Speed	<500 ms	Maximum time for the backend server to process sensor and camera data.
Dashboard Alert Time	<2 seconds	Time for the admin dashboard to reflect alerts from the system.

Hardware Block Diagram



Power Supply Selection

Technologies Considered:

- Linear Power Supply
- **Switching Power Supply**
- Battery-Based Power Supply

Specifications	Linear Power Supply	Switching Power Supply	Battery-Based Power Supply
Efficiency	Low	High	High
Size	Large	Compact	Large
Heat Dissipation	High	Low	Moderate
Response Time	Fast	Fast	Delayed (battery switching time)
Complexity	Simple	Moderate	Complex
Cost	Low	Moderate	High
Backup Power	No	No	Yes
Best Use Case	Low-power	High-efficiency	Portable systems

Power Supply Selection

Part Selection:

- ALITOVE 12V 5A power supply
  - Built-in protections: OVP, OCP, SCP
  - Efficient, reliable, and cost-effective

Feature	ALITOVE 12V 5A	Mean Well LRS-60-12	T-Power 12V 5A
Input Voltage	100-240V AC	100-240V AC	100-240V AC
Output Voltage	12V DC	12V DC	12V DC
Max Output Current	5A	5A	5A
Efficiency	85-90%	90%	80%
Protections	Over-voltage, over-current, short-circuit	Over-voltage, over-current, short-circuit	Over-voltage, over-current
Reliability	High	High	Moderate
Price	$11.99	$49.99	$9.99

Voltage Regulator Selection

Technologies Considered:

- Linear Voltage Regulators
- **Switching Voltage Regulators**

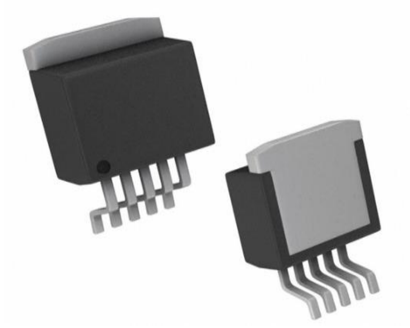
Specifications	Linear Voltage Regulation	Switching Voltage Regulation		
		Buck	Boost	Buck-Boost
Efficiency	Moderate	High	High	High
Heat Generation	Moderate	Low	Low	Low
Size	Larger	Compact	Compact	Compact
Complexity	Simple	Moderate	Moderate	High
Voltage Ripple	Low	Low	Moderate	Low
Cost	Low	Moderate	Moderate	Moderate
Best Use Case	Step-down	Step-down	Step-up	Step-up and step-down

Voltage Regulator Selection

Part Selection (Buck Converter):

- LM2596 buck converter

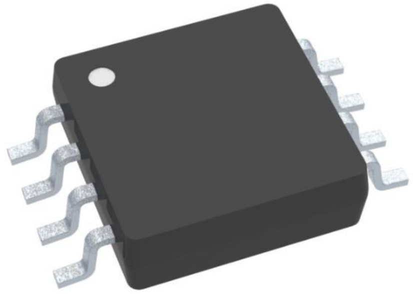
Feature	LM2596 Buck Converter	MP1584EN Buck Converter	LM2575 Buck Converter
Input Voltage	4.5V - 40V	4.5V - 28V	4.75V - 40V
Output Voltage	1.2V - 37V	0.8V - 25V	1.23 - 37V
Output Current	3A	3A	1A
Brand	Texas Instruments	Monolithic Power Systems	Texas Instruments
Price	$3.53	$4.02	$3.58



Voltage Regulator Selection

Part Selection (Boost Converter):

- LM3478 boost converter



Feature	LM3478 Boost Converter	TPS61288 Boost Converter	LM3488 Boost Converter
Input Voltage	2.9V - 40V	2V - 18V	2.9V - 40V
Output Voltage	Up to 60V	4.5 - 18V	4.5V – 12.6V
Output Current	Adjustable with an external resistor	15A	Adjustable with an external resistor
Brand	Texas Instruments	Texas Instruments	Texas Instruments
Price	$2.34	$5.33	$2.29

PowerPath Controller Selection

Technologies Considered:

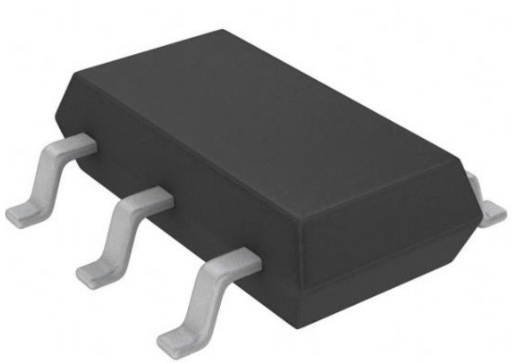
- Diode
- MOSFET
- **Dedicated PowerPath**

Specifications	Diode-based PowerPath Control	MOSFET-based PowerPath Control	Dedicated PowerPath Controller ICs
Efficiency	~60% - 80%	~80% - 90%	~80% - 95%
Size	Moderate	Moderate	Compact
Heat Generation	High	Moderate	Low
Response Time	Fast	Fast	Delayed
Complexity	Simple	Moderate	Complex
Control Features	Basic	Advanced	Advanced
Cost	Low	Moderate	High
Best Use Case	Low-power	High-power	High-efficiency

PowerPath Controller Selection

Part Selection:

- LTC4412 PowerPath



Feature	LTC4412	TPS2115A	MAX40200
Input Voltage	2.5V - 28V	2.8V - 5.5V	1.5V - 5.5V
Output Voltage	Vin ± 0.3V	Vin ± 0.1V	Vin - 20mV
Output Current	Wide Range of Current	Up to 1.25A	Up to 1A
Brand	Analog Devices Inc.	Texas Instruments	Analog Devices Inc.
Price	$5.91	$3.00	$1.27

Charger Controller Selection

Technologies Considered:

- **Pulse Width Modulation (PWM)**
- Maximum Power Point Tracking (MPPT)

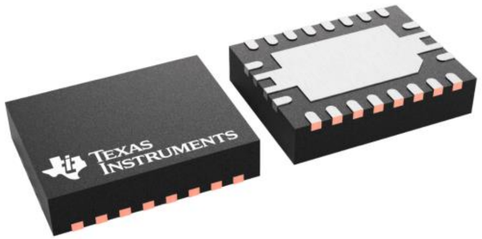
Specifications	PWM (Pulse Width Modulation)	MPPT (Maximum Power Point Tracking)
Input Power Compatibility	Best for regulated/stable input sources	Ideal for variable input sources
Efficiency	~85 - 90%	Up to ~98%
Complexity	Simple	Complex
Cost	Low	High
Best Use Case	General-purpose charging, stable DC supplies	Solar charging, variable energy harvesting

Charger Controller Selection

Part Selection:

- BQ24130 Charger Controller
  - RC-settable
  - Supports multi-cell packs

Feature	BQ24130	LT1511	BQ24650
Input Voltage Range	4.5V – 17V	11V – 28V	5V – 28V
Output Voltage	4.2V – 13.5V	1V – 20V	2.1V – 26V
Max Charge Current	2.5A	4A	10A
Efficiency	High	High	High
Protections	Overvoltage, Overcurrent, Thermal	Overvoltage, Overcurrent, Thermal	Overvoltage, Overcurrent, Thermal
Number of series cells	Up to 3	Up to 4	Up to 6
Control interface	Standalone (RC-Settable)	Programmable	Standalone (RC-Settable)
Price	$1.98	$8.12	$1.85



Batteries Selection

Technologies Considered:

- **Lithium-ion**
- Lithium Iron Phosphate
- Nickel Metal Hydride

Specifications	Li-ion	LiFePO4	NiMH
Energy Density	150-250Wh/kg	90-120Wh/kg	60-120Wh/kg
Nominal Voltage	3.6V per cell	3.2V per cell	1.2V per cell
Cycle Life	500-1000 cycles	1000-2000 cycles	300-500 cycles
Capacity Range	100mAh - 3000mAh+	100mAh - 5000mAh+	1000mAh - 2000mAh
Cost	High	High	Moderate
Best Use Case	High-performance	High safety and longevity	Moderate-power applications

Batteries Selection

Part Selection:

- Panasonic NCR18650B
    - Suitable for 3S configuration
    - Widely used

Feature	INR18650-25R	NCR18650B	MJ1
Nominal Voltage	3.7V	3.6V	3.6V
Capacity	2500mAh	3400mAh	3500mAh
Max Continuous Discharge Current	20A	6.75A	10A
Energy Density	~200 Wh/kg	~240 Wh/kg	~240 Wh/kg
Cycle Life	~250-300 cycles	~250-500 cycles	~300-500 cycles
Weight	~43g	~47.5g	~49g
Price	$3.99	$7.99	$5.99

Battery Management System Selection

Technologies Considered:

- **Centralized BMS**
- Distributed BMS
- Modular BMS

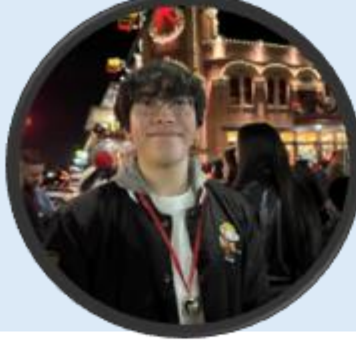
Specifications	Centralized BMS	Distributed BMS	Modular BMS
System Architecture	One central unit	Multiple units communicating	Independent units with main control
Cell Monitoring	Centralized	Distributed by individual unit	Each module monitors its cells
Communication	Single communication	Communication between modules	Communication between modules and main unit
Current Handling	~10-30A	~20-50A	~20-50A
Complexity	Simple	Complex	Complex
Cost	Low	Moderate	High
Best Use Case	Small to medium systems	High-power systems	Large-scale systems

Battery Management System Selection

- **Part Selection:**
- HX-3S-FL25A-A BMS
  - Designed for 3S Li-ion battery pack
  - Easy integration, no configuration required

Feature	HX-3S-FL25A-A BMS
Number of Cells	3S
Nominal Battery Voltage	11.1V
Max Charging Voltage	12.6V
Max Continuous Discharge Current	25A
Overcharge voltage range	4.25-4.35V per cell
Overdischarge voltage range	2.3-3.0V per cell
Protection Features	Overcharge, Overdischarge, Overcurrent, Short Circuit
Cost	Low

MCU Selection

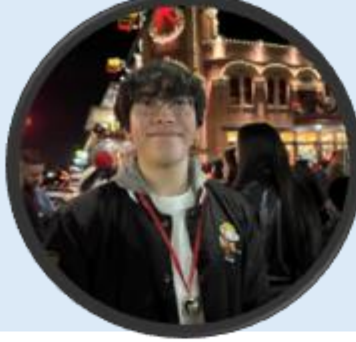


Technologies Considered:

- **ESP32**
- ESP8266
- RP2040

Features	ESP32-S3	ESP8266	RP2040
Cores	Dual-Core	Single-Core	Dual-Core
Clock Speed	Up to 240 MHz	Up to 160 MHz	Up to 200 MHz
Wi-Fi	YES	YES	NO
Bluetooth	YES	NO	NO
SRAM	512 KB	64 KB	264 KB
Average Power Consumption (mA)	120 mA	70.5 mA	24 mA
GPIO Pins	45	33	30
Cost	~$3-$5	~$7	~$1

MCU Selection

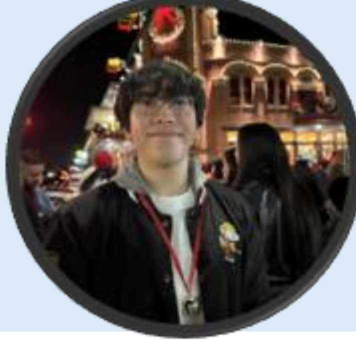


Part Selection:

- **ESP32-S3**
    - More GPIO pins
    - Wi-Fi and Bluetooth
    - Efficient
- ESP32
- ESP32-S2
- ESP32-H2

Models	Cores	Clock Speed	Wi-Fi	Bluetooth	SRAM	Average Active Power Consumption (mW)	Physical GPIO Pins
ESP32	Single/Dual-core Xtensa LX6	Up to 240 MHz	YES	YES	520 KB	78.32 mW	34
ESP32-S3	Dual-core Xtensa LX7	Up to 240 MHz	YES	YES	512 KB	78.32 mW	45
ESP32-S2	Single-core Xtensa LX7	Up to 240 MHz	YES	NO	320 KB	78.32 mW	43
ESP32-H2	Single-core 32-bit RISC-V	Up to 96 MHz	NO	YES	320 KB	78.32 mW	28

Parking Sensor Selection

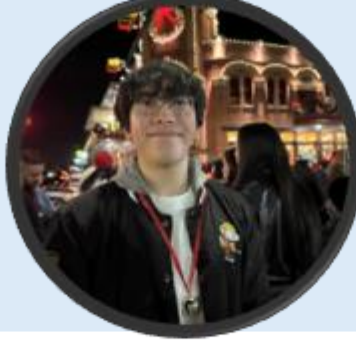


Technologies Considered:

- **Ultrasonic Sensor**
- Geomagnetic Sensor

Features	Ultrasonic Sensor	Geomagnetic Sensor
Detection Method	Emits soundwaves and detects time it takes to bounce back, using that time to calculate distance	Detects magnetic field change when vehicle parks on top of sensor
Installation	Can be installed on the ceiling, walls, or ground, wireless or wired	Can only be installed on the ground, wireless or wired
Interference	Susceptible to noise or weather interference	Not susceptible to noise and weather interference
Cost	Can be very cheap	Not very expensive but also not very cheap
Detection Range	Detects from a wider range, especially if mounted on walls	Usually detects when the vehicle is on the parking spot
Power	Wired	If wireless, battery powered
Maintenance	Since it is wired, only replace items if they fail	Will need to replace sensor when battery dies, only 5-10 years
Lifespan	Up to 22 years	Until battery dies, 5-10 years

Parking Sensor Selection

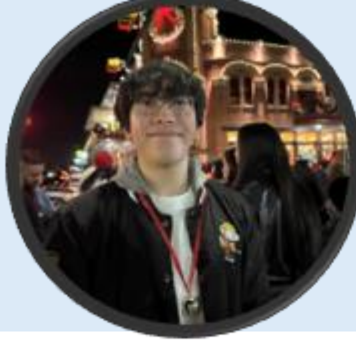


Part Selection:

- **HC-SR04 Ultrasonic Sensor**
  - Cheaper
  - Accurate
  - Prior User Experience
- MB7360
- MB1014

Features	SparkFun HC-SR04	MaxBotix MB7360	MaxBotix MB1014
Operating Voltage	5V	2.7V - 5.5V	2.5V - 5.5V
Range	2cm - 4m	30cm - 5m	15cm - 6.4m
Response Time	~50ms	~100ms	~100ms
Accuracy	±3mm	±1mm	±2.5cm
Current Draw	15mA	2.3mA - 3.1mA	2mA - 3mA
Beam Angle	15 degrees	11 degrees	44 degrees
Size	Length: 45mm Width: 20mm Height: 13.5mm	Diameter: 43.8mm Length: 65.1mm	Length: 22.1mm Width: 19.9mm Height:15.5mm
Cost	~$4	~$110	~$30

LED Selection

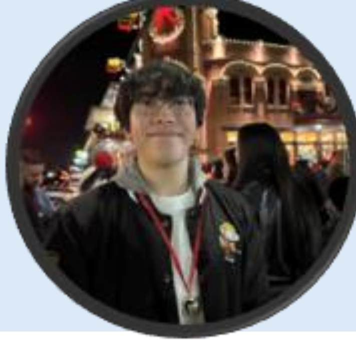


Technologies Considered:

- **SMD LEDs**
- DIP LEDs
- COB LEDs

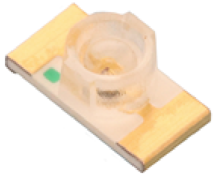
Features	DIP LED	SMD LED	COB LED
Brightness	Medium	High	High
Cost	Low	Low to Medium	High
Color Options	One color per chip	Multiple colors per chip	Multiple colors per chip
Efficiency	Mediocre	Good	Good
Use Cases	Prototyping, Simple Use Cases	Bright Indicators, RGB Applications	High-end lighting, Displays
Lifespan	100,000+ Hours	50,000+ Hours	50,000+ Hours

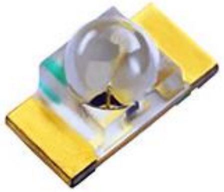
LED Selection



Part Selection:

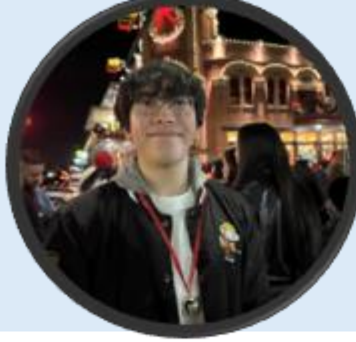
- **VFR1105W-6C9-TR LED** (Red)
- **APTL3216ZGCK-01 LED** (Green)
- APTBD3216SURKCGKC-01





Features	APTBD3216SURKCGKC-01	VFR1105W-6C9-TR	APTL3216ZGCK-01
Operating Voltage	Green: 2.1V Red: 1.95 V	1.9 V	3.3 V
Brightness	Green: 250 mcd Red: 600 mcd	985 mcd	1000 mcd
Colors	Green and Red	Red	Green
SMD Package Size	1206	1206	1206
Cost	$0.58	$0.36	$0.58

Display Selection

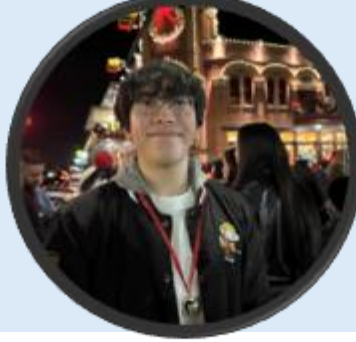


Technologies Considered:

- **LED Display**
- LCD Display

Features	LED Display	LCD Display
Brightness	Very High	Medium
Power Consumption	Medium	Low
Lifespan	~100,000 Hours	~50,000 Hours
Cost	Low, but can be High	Low
Durability	Needs full display replacement if damaged	Can replace individual LEDs

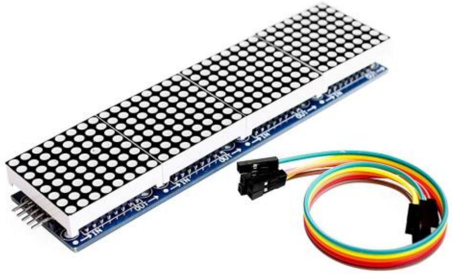
Display Selection



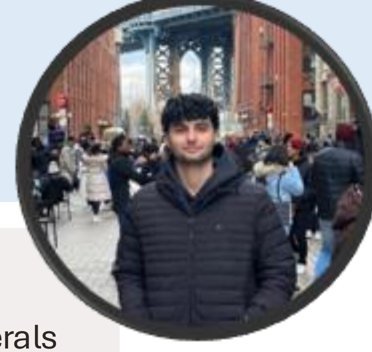
Part Selection:

- **MAX7219 Dot Matrix Display**
  - Low Cost
  - Low Power Consumption
  - Easier Usage
- TM1637
- P10 LED Display

Features	TM1637	MAX7219	P10 LED Display
Operating Voltage	3.3V - 5V	4V - 5.5V	5V
Size (mm)	66 mm x 27.5 mm	128 mm - 32 mm	320 mm x 160 mm
Power Draw	~80 mA	~67 mA	~2 A
Brightness	Mediocre	Mediocre	Good
Numbers/Text	Numbers	Both	Both
Cost	~\$3 - \$7	~\$3 - \$9	~\$20 - \$50



LPR Microprocessor Selection Overview



Crucial Role

Microprocessors are vital for real-time image recognition and data handling in embedded systems.

Key Considerations

Computational power, energy efficiency, software compatibility, and cost are critical factors.

System Integration

Seamless integration with peripherals and necessary software libraries is essential for LPR.

Parameters	Raspberry Pi 4	NVIDIA Jetson Nano	Google Coral Dev Board	BeagleBone AI-64
Cost	$65	$230	$150	$190
Power consumption	3-5W	5 W and 10 W (default)	3.2W	5W
Supply Voltage	5.1V	5v	5v	5v
Memory	2GB/4GB/8GB LPDDR4	4GB LPDDR4	1GB/4GB LPDDR4	4GB LPDDR4
Storage	MicroSD	MicroSD	8/16 GB eMMC, MicroSD slot	16 GB eMMC, MicroSD slot
Built-in WiFi/Bluetooth	Yes	Yes	Yes	Yes
Camera support	1x MIPI CSI, USB Cameras	1x MIPI CSI, USB Cameras	1x MIPI CSI, USB Cameras	2x MIPI CSI, USB Cameras
Connectivity	2x USB 3.0, 2x USB 2.0	4x USB 3.0, USB 2.0 Micro-B	2x USB 3.0, USB 2.0 Micro-B	2x USB 3.0, USB 3.0 type-C
Community support	Extensive, large user base	Moderate, smaller than Raspberry Pi	Limited compared to Pi and Jetson	Niche, minimal community support

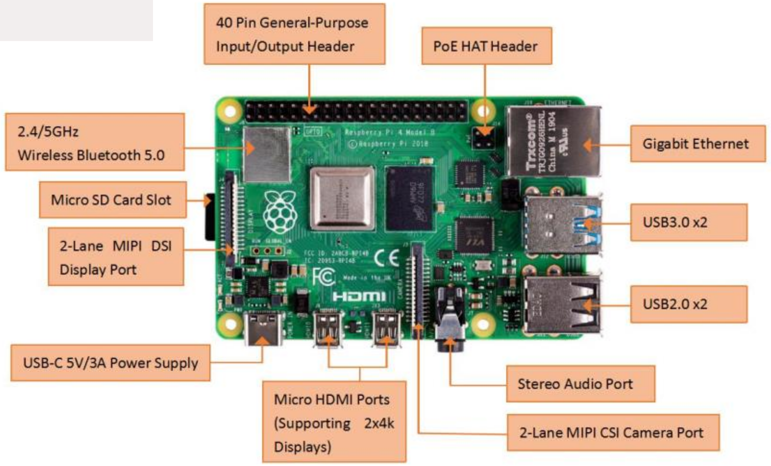
Raspberry Pi 4: The Chosen MPU

Balanced Performance

Offers a strong balance of processing power, affordability, and ease of integration.

Robust Ecosystem

Extensive documentation and community support, compatible with OpenCV.



Camera Integration

Supports MIPI CSI connector for high-resolution camera modules.

Cost-Effective

More affordable than Jetson Nano, making it practical for the project.

Camera Module Comparison

Parameter	Raspberry Pi HQ Camera Module	Arducam IMX477	ELP	OAK-D	Axis P1445-LE
Sensor	12.3 MP IMX477	12.3 MP IMX477	2MP IMX323	12MP RGB + Stereo Depth	2MP CMOS
Resolution	4056 × 3040 pixels	4056 x 3040 pixels	1080p30	4K/30FPS, 1080P/60FPS	1920x1080
Frame Rate	30/60 FPS	30/60 FPS	30 FPS	30/60 FPS	25/30 FPS
Interface	MIPI CSI-2	MIPI CSI-2	USB 2.0	USB 3.0	Ethernet (PoE)
Cost	$75	$60	$60	$249	High ($500)
AI Processing	No	No	No	Yes	Basic Edge AI
Low-Light Performance	Good (with IR lens)	Good	Excellent	Excellent	Excellent
Ease of Integration	Easy	Easy	Moderate	Advanced	complex
Weatherproof	NO	NO	NO	IP67	IP67

Raspberry Pi HQ Camera Module: Final Choice

Improved Resolution

Higher image clarity helps enhance license plate detection accuracy.

Easy Integration

Designed for seamless connection with Raspberry Pi boards.

Low-Light Solution

Supports interchangeable IR-sensitive lenses for better night performance.

Viable Option

Offers an excellent trade-off between quality, cost, and system complexity.

Database Selection Overview

MySQL

Relational database, fast reads. Fixed table structure can lead to fragmentation. Good for real-time updates.

MongoDB

NoSQL, document-based. Flexible schema, no fragmentation. Excellent for large-scale writes and real-time processing.

PostgreSQL

Object-relational database. ACID compliant, supports custom data types and JSON. More complex to manage.

Feature	MySQL	MongoDB	PostgreSQL
Data Model	Relational (SQL)	Document-Based (NoSQL)	Relational + JSON Support
Scalability	Moderate	High (Sharding)	High (Partitioning, Replication)
Read Performance	High	Moderate	High
Write Performance	Moderate	High	High
Schema Flexibility	Low	High	Medium
ACID Compliance	Yes	Limited (Transactions in newer versions)	Yes
Indexing & Querying	Standard Indexing, Foreign Keys	Indexing on Documents	Advanced Indexing, Full-Text Search
Best Use Case	Structured Data, Transactional Workloads	High-Speed Data Ingestion, Semi-Structured Data	Large Datasets, Complex Queries, Analytics

Server Selection Overview

Local Server

On-premise machine, low latency, high security. Requires manual maintenance and scaling.

Cloud-Based Server

Third-party providers, scalable, automatic updates. Internet dependent, varying complexity.

Feature	Local Server	MongoDB Atlas	AWS EC2	Google Cloud
Latency	Very Low	Moderate (Dependent on Internet)	Moderate	Moderate
Scalability	Limited	High (Automatic Scaling)	High (Manual Scaling)	High (Auto-Scaling)
Data Security	High (Private Infrastructure)	High (Built-in Encryption & Access Control)	Moderate (Requires Custom Security Configurations)	Moderate (Cloud-Based Security)
Maintenance	High (Manual Hardware Upkeep)	Low (Fully Managed)	Moderate (Cloud Admin Required)	Low (Managed by GCP)
Internet Dependency	No	Yes	Yes	Yes
Cost	High (Initial Investment)	Moderate (Subscription-Based)	High (Pay-As-You-Go)	Moderate (Usage-Based Pricing)
Best Use Case	Secure, Offline Applications	Scalable LPR Systems with Automated Management	Large-Scale Deployments with AI Integration	AI-Powered LPR with TensorFlow Support

Server Selection: MongoDB Atlas

1 Ease of Use

Simple to deploy and manage for small-scale projects.

2 Affordability

Cost-effective subscription plans, including a free tier.

3 Seamless Integration

Optimized for our chosen MongoDB database.

LPR Solution Selection Overview

OpenALPR Commercial

High accuracy, but costly with subscriptions starting at $10/month per camera. Requires IP cameras, increasing overall expense.

Plate Recognizer

Accurate and flexible, with a free trial (2,500 lookups/mo). Paid plans start at $50. Compatible with various cameras.

OpenALPR Open Source

Free, offline ALPR solution using OpenCV and Tesseract. Runs on Raspberry Pi with no subscription or special hardware needed.

Feature	OpenALPR (Commercial)	OpenALPR (Open Source)	Plate Recognizer
Cloud-based option	Yes	no	Yes
On-Premises Option	Yes	yes	Yes
Low light performance	Moderate	Basic	Strong
Focus area	Law enforcement, surveillance	Basic LPR needs	Parking management, tolling, security
Hardware dependency	Requires specialized hardware	Works with any camera	Works with any camera
License / Cost	Paid (min $10/mo/cam)	Free (AGPL licensed)	Paid (from $50/mo)
Offline capability	Limited (cloud-focused)	Full offline capability	Limited (cloud-focused)

Selected LPR Solution: OpenALPR Open Source

Cost-Effectiveness

Free core functionality eliminates recurring costs, aligning with our budget.

Hardware Compatibility

Compiles and runs directly on Raspberry Pi 4B with a CSI camera.

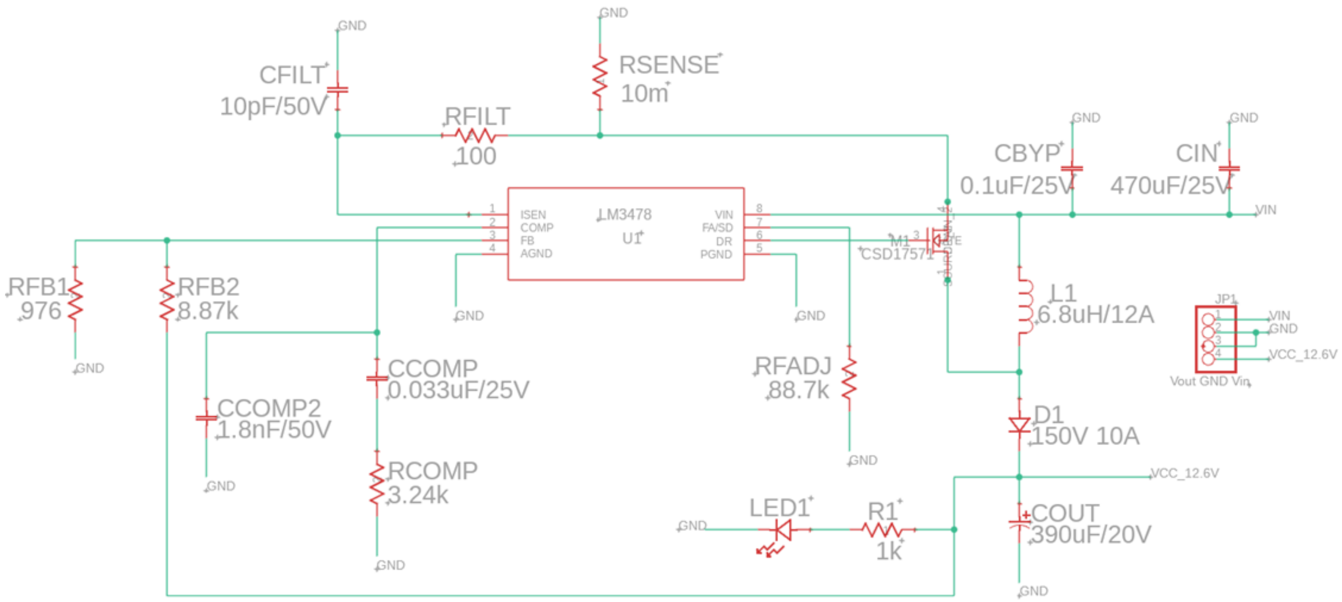
Offline Functionality

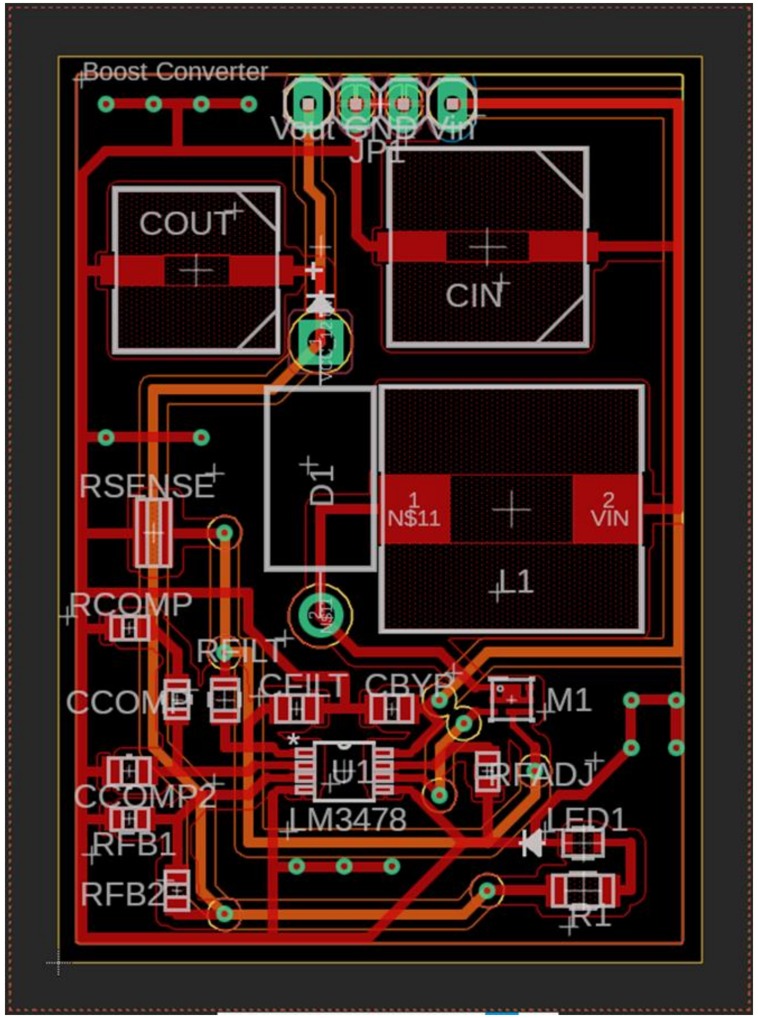
No cloud connectivity needed, enhancing reliability in various environments.

Meets Core Needs

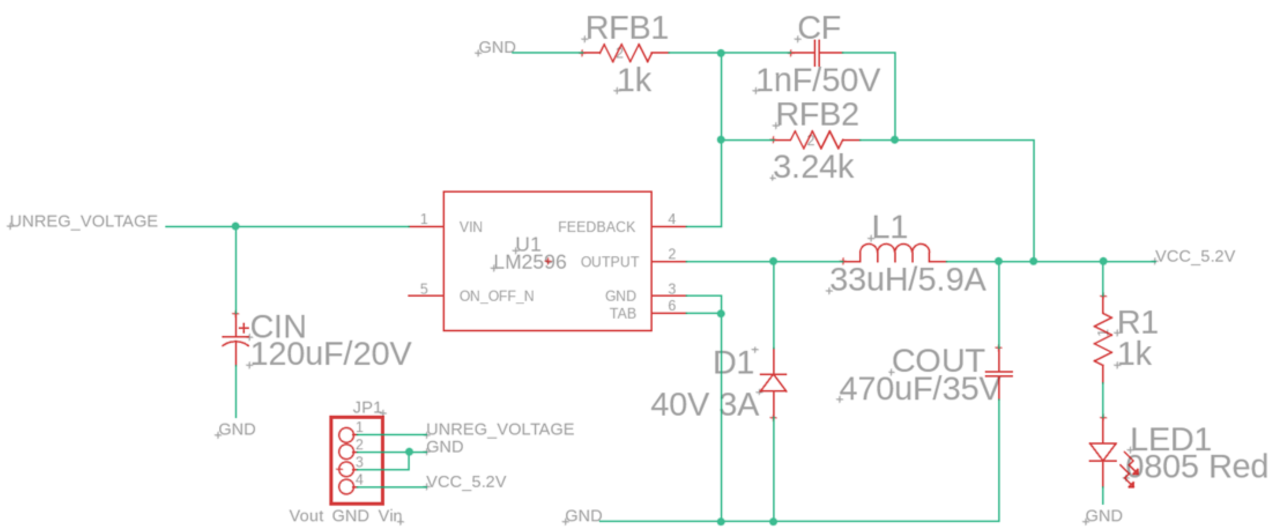
Accurately detects and logs license plate numbers in real-time, fulfilling project requirements.

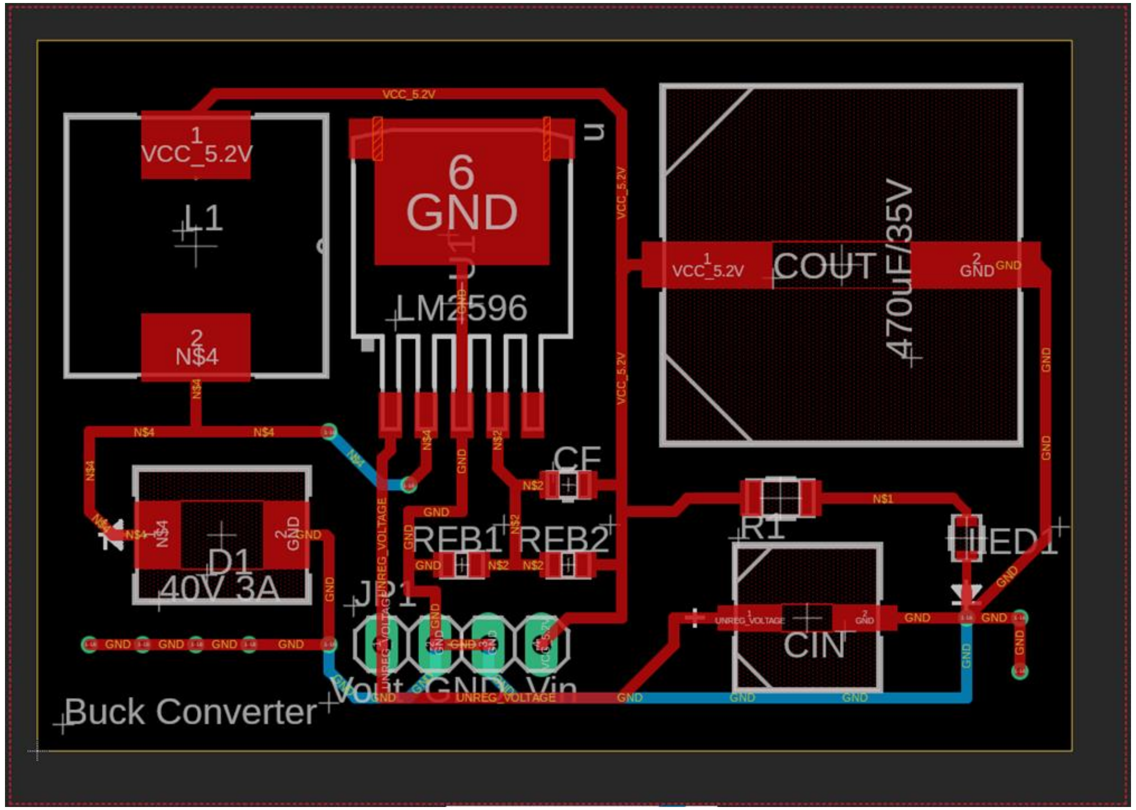
Boost Converter Schematic & Layout



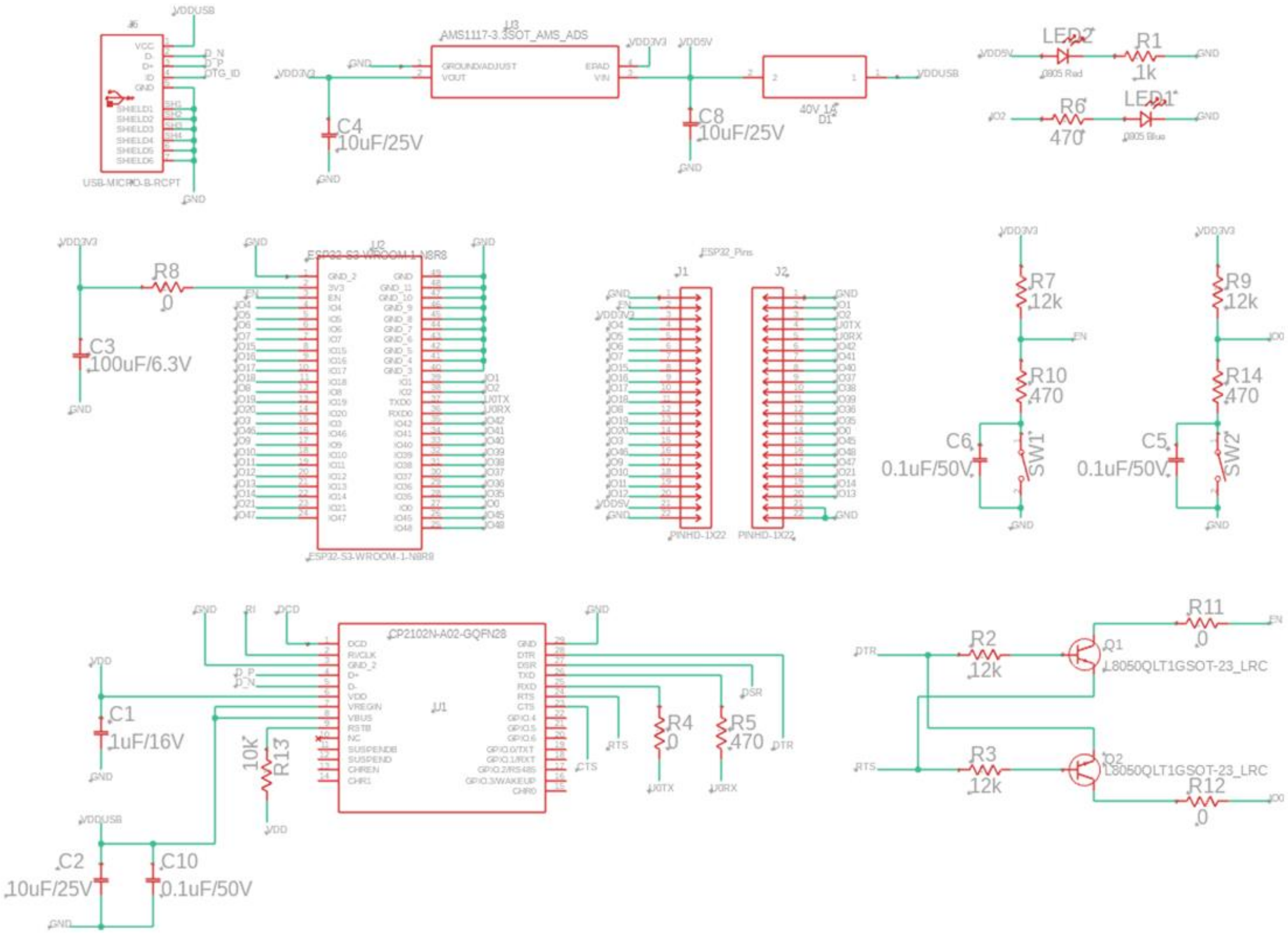


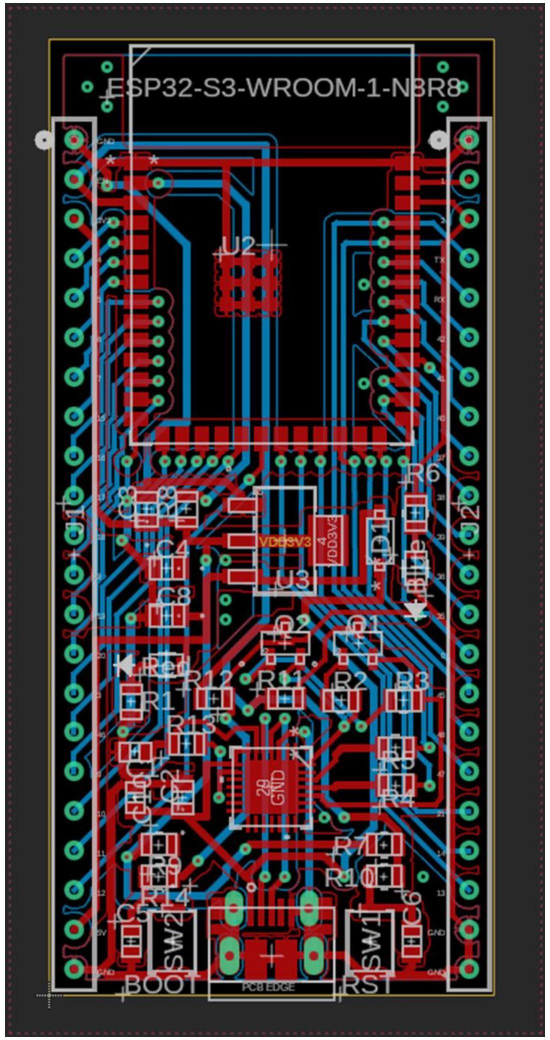
Buck Converter Schematic & Layout



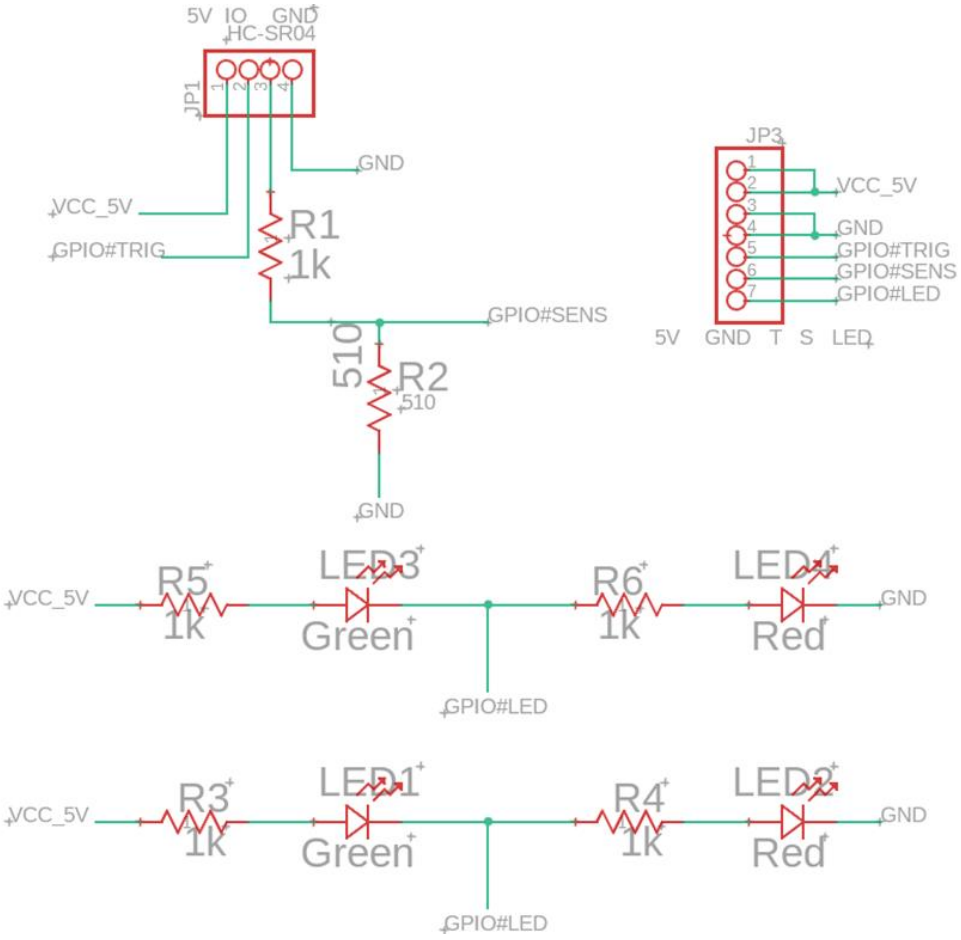


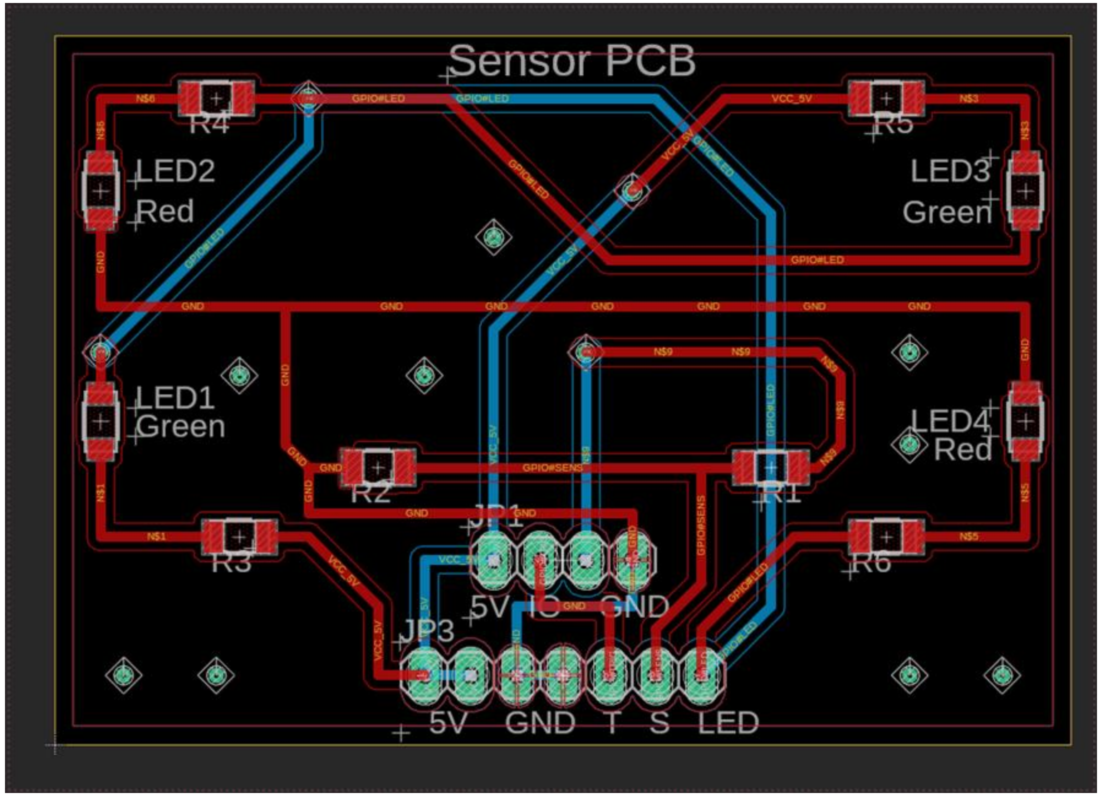
ESP32 Schematic & Layout



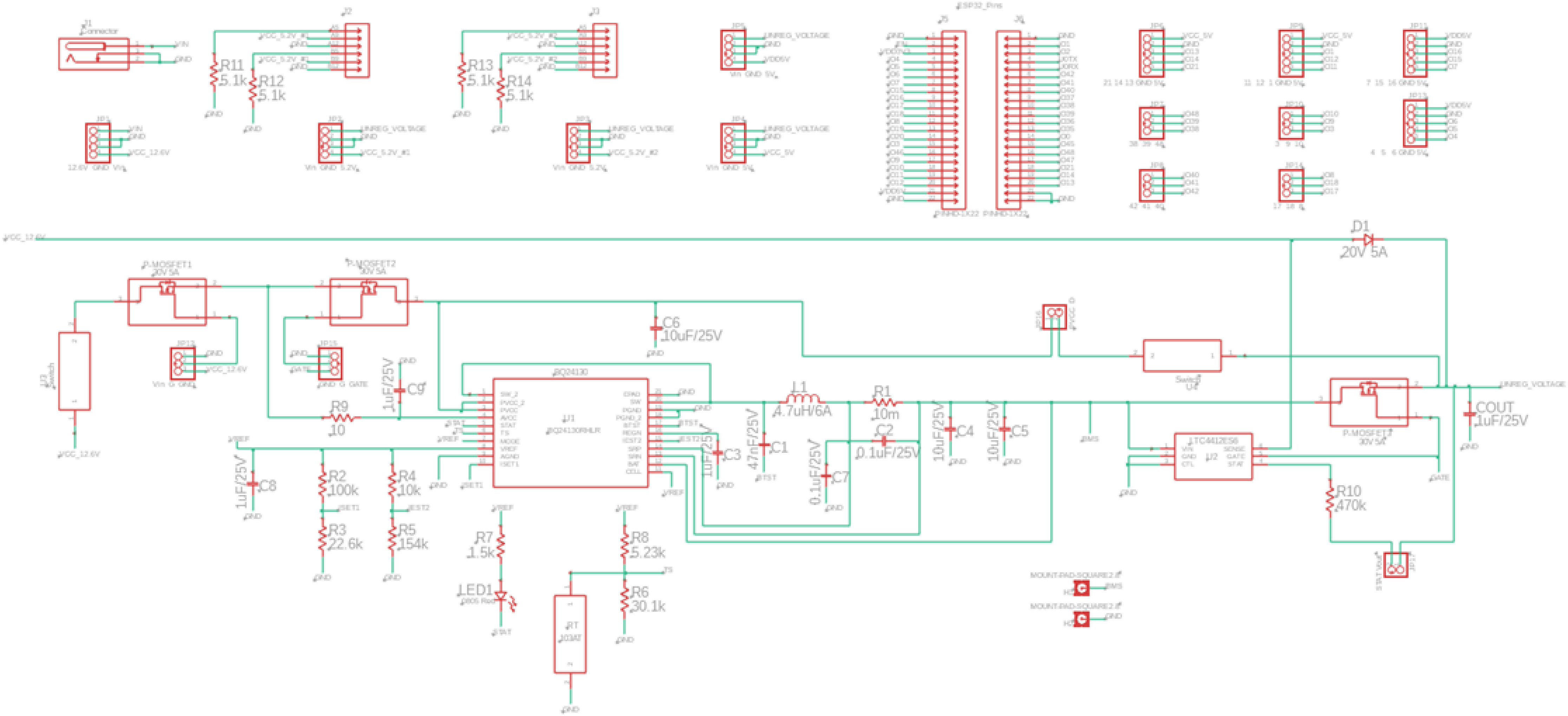


Sensor Schematic & Layout

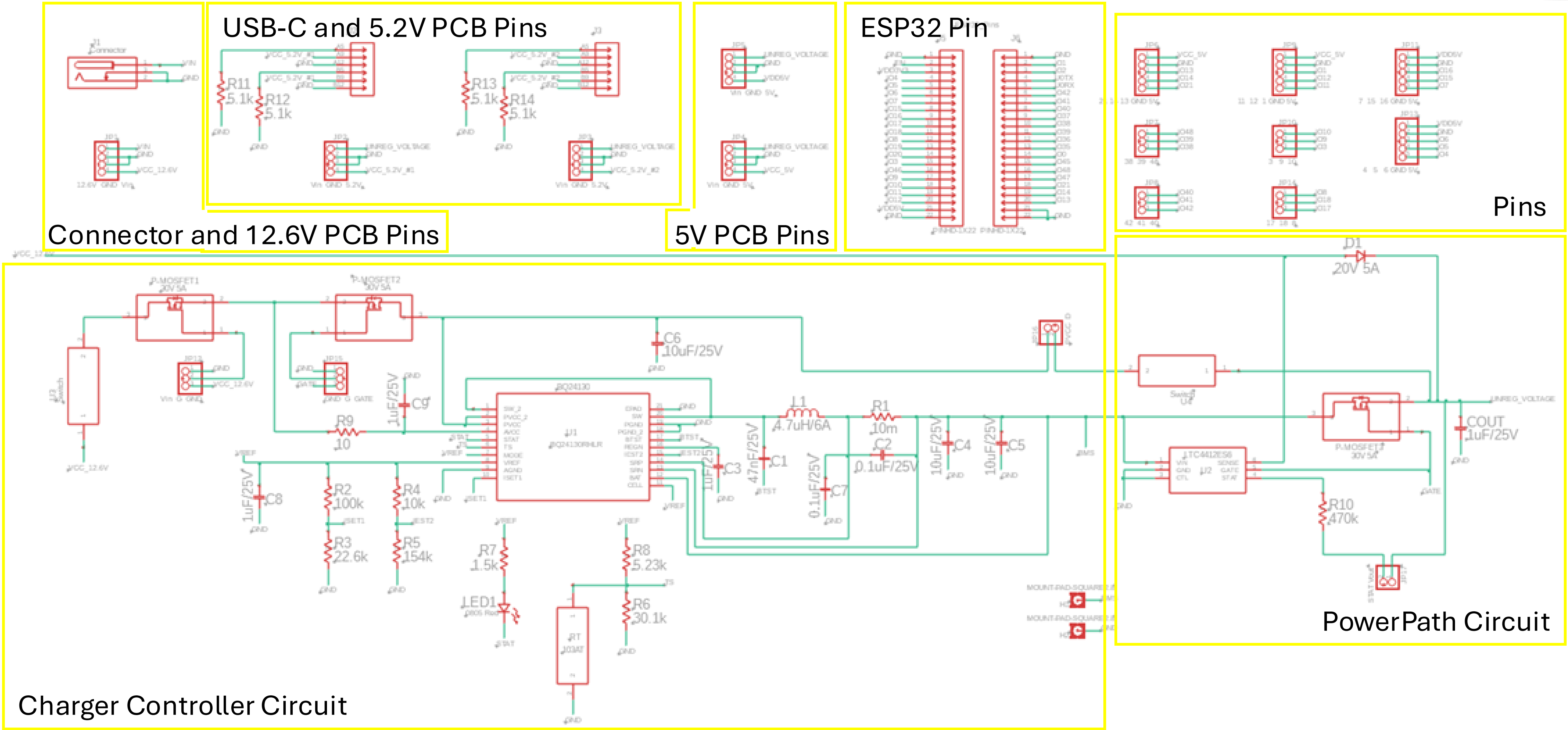




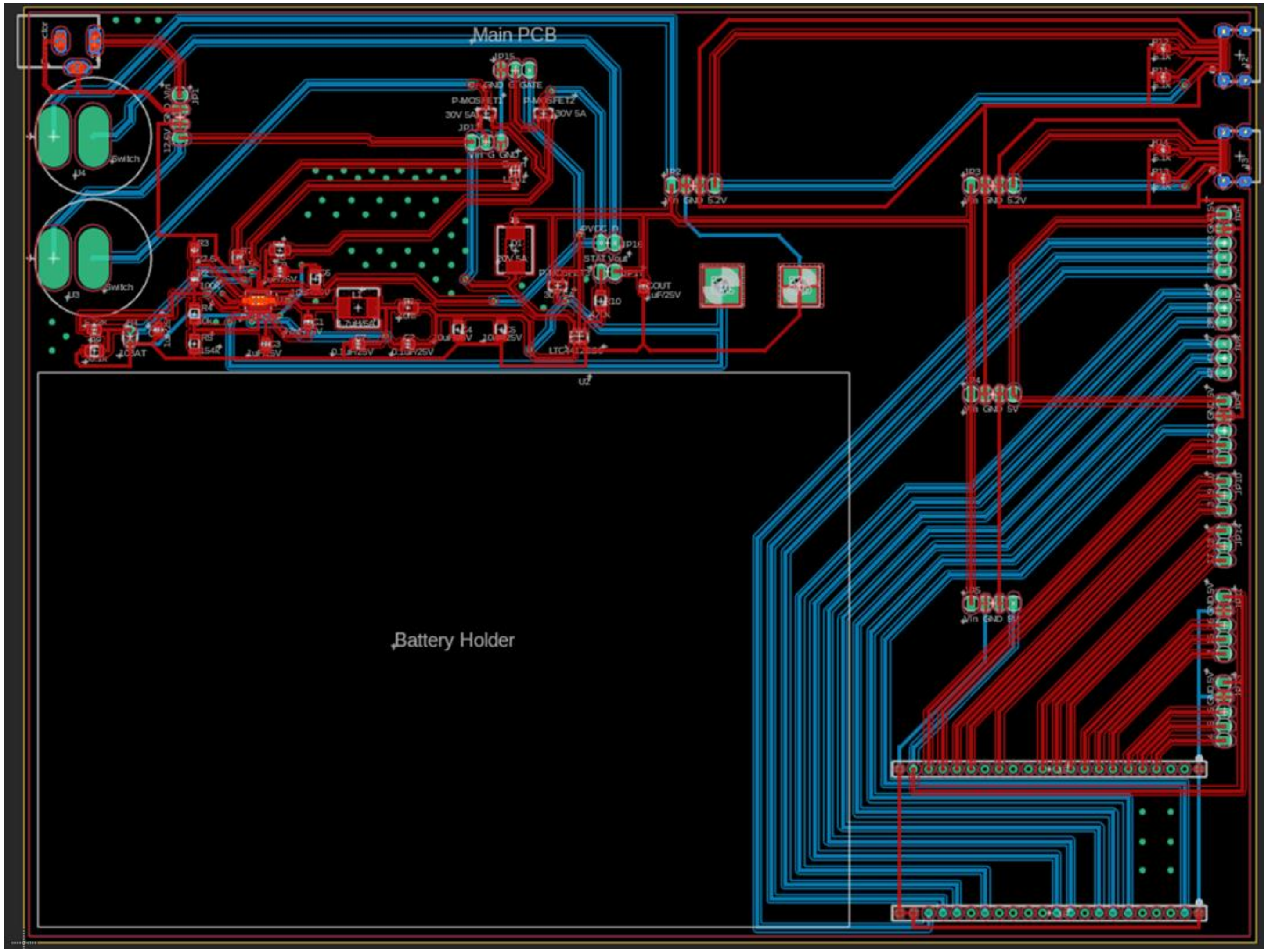
Main PCB Schematic



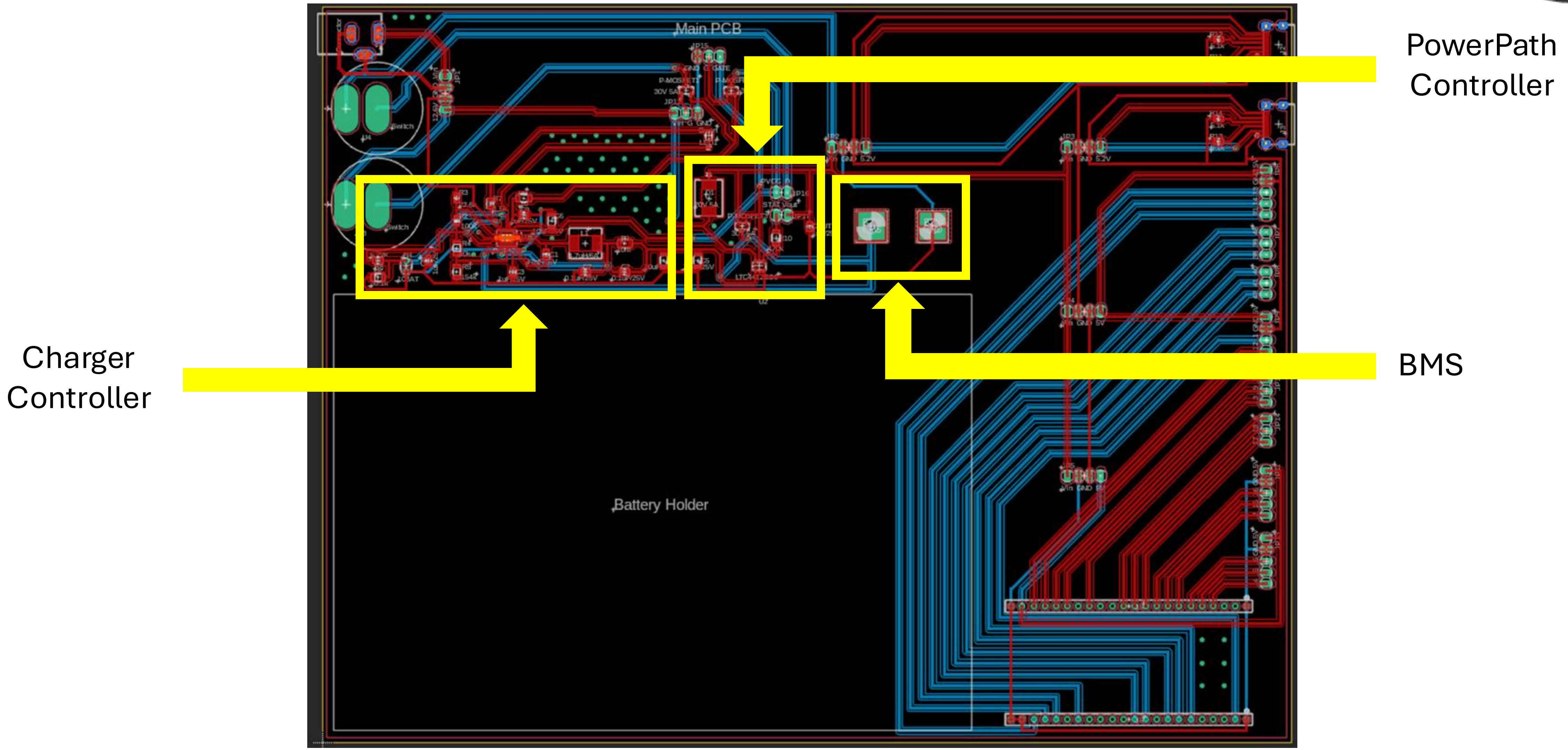
Main PCB Schematic



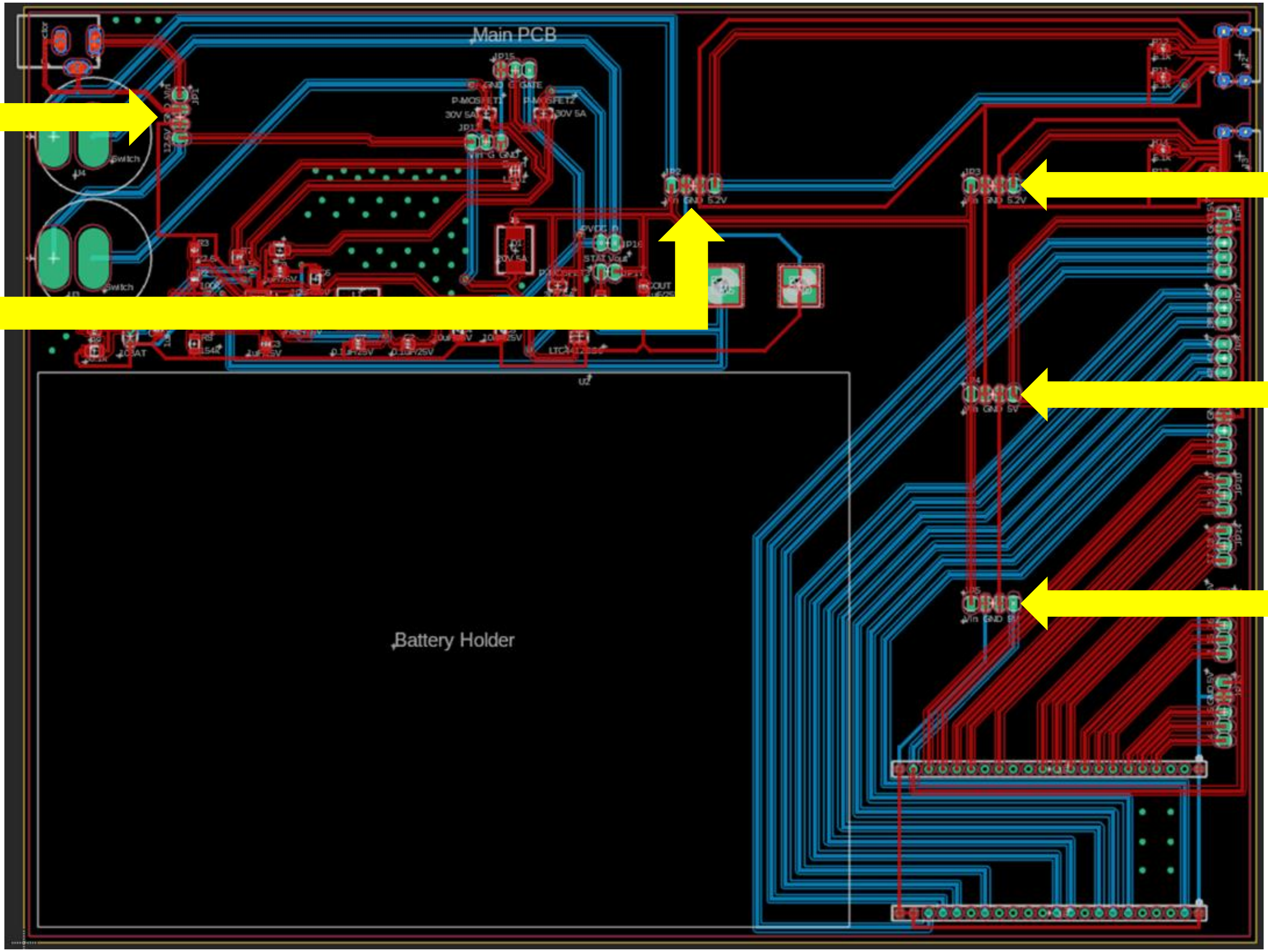
Main PCB Layout



Main PCB Layout



Main PCB Layout



12.6V voltage regulator

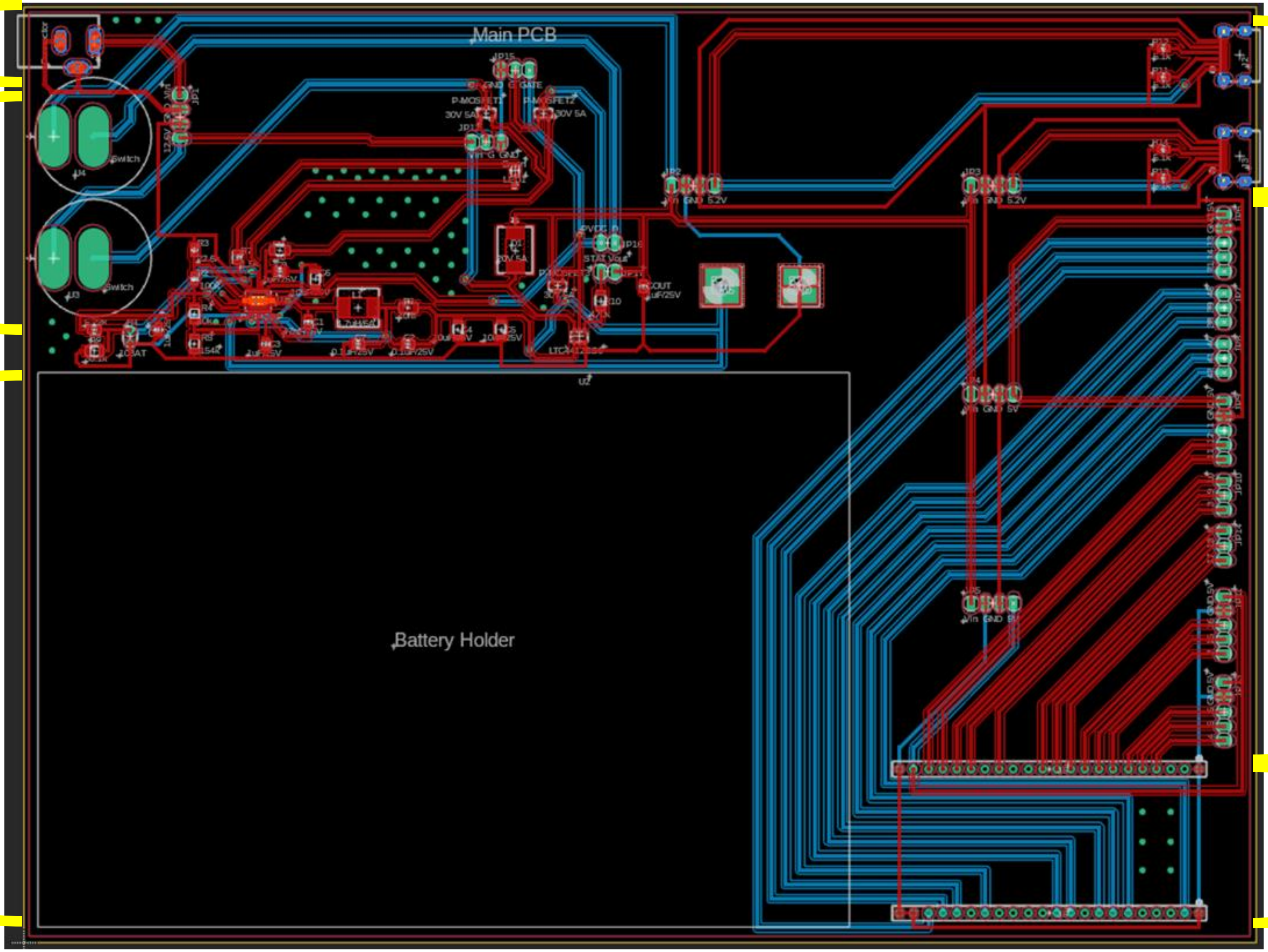
5.2V voltage regulator

5.2V voltage regulator

5V voltage regulator

5V voltage regulator

Main PCB Layout



Power supply connector

Switches to turn off the charge controller

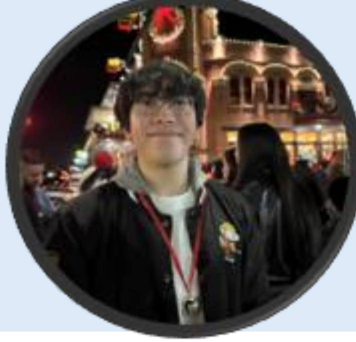
Batteries

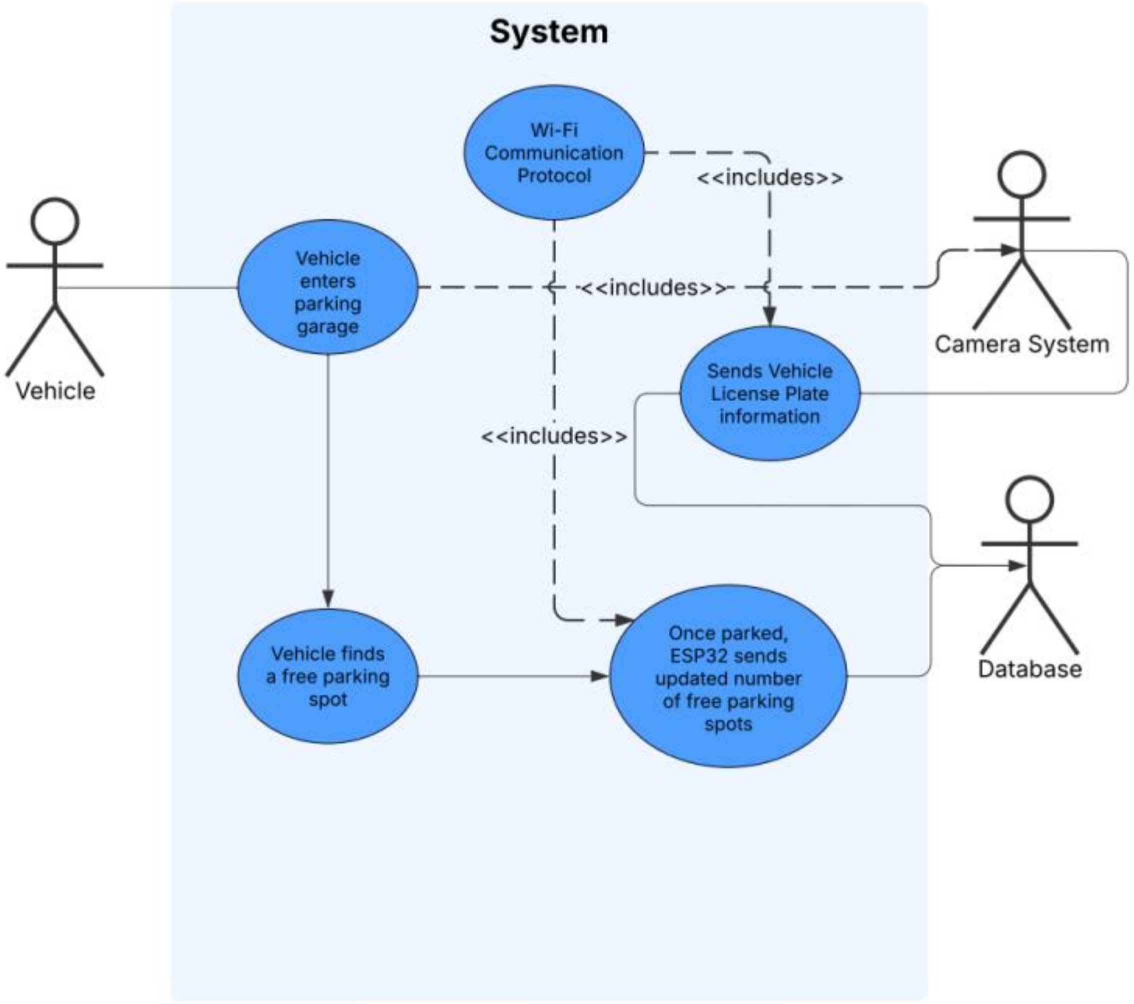
USB-C connectors for Raspberry Pi

Sensor pins

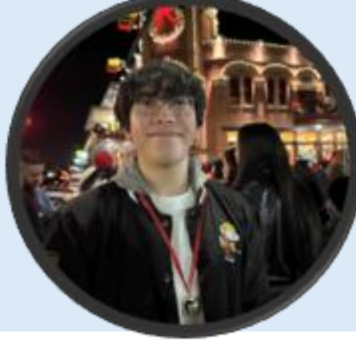
ESP32

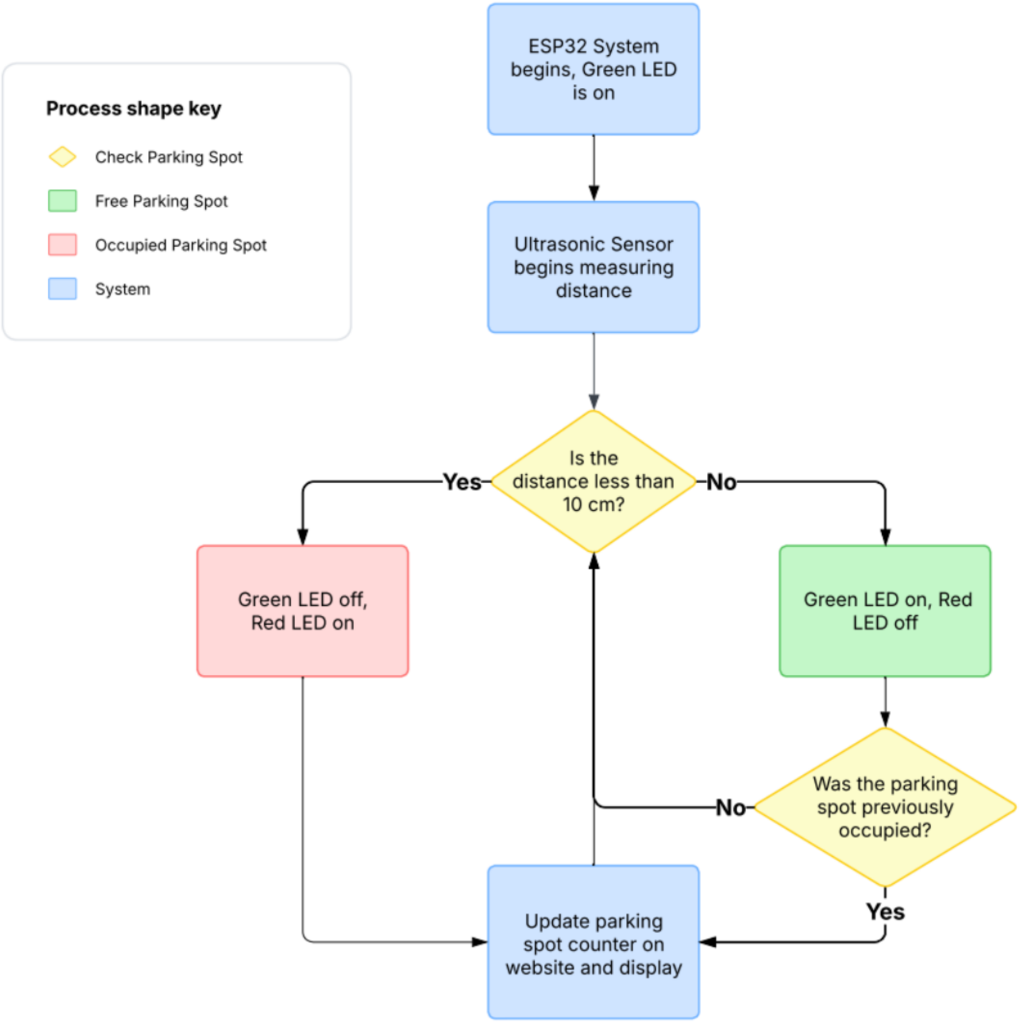
Overall Software Use Case Diagram



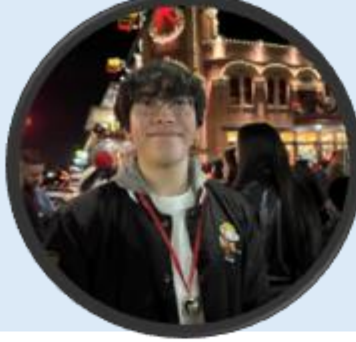


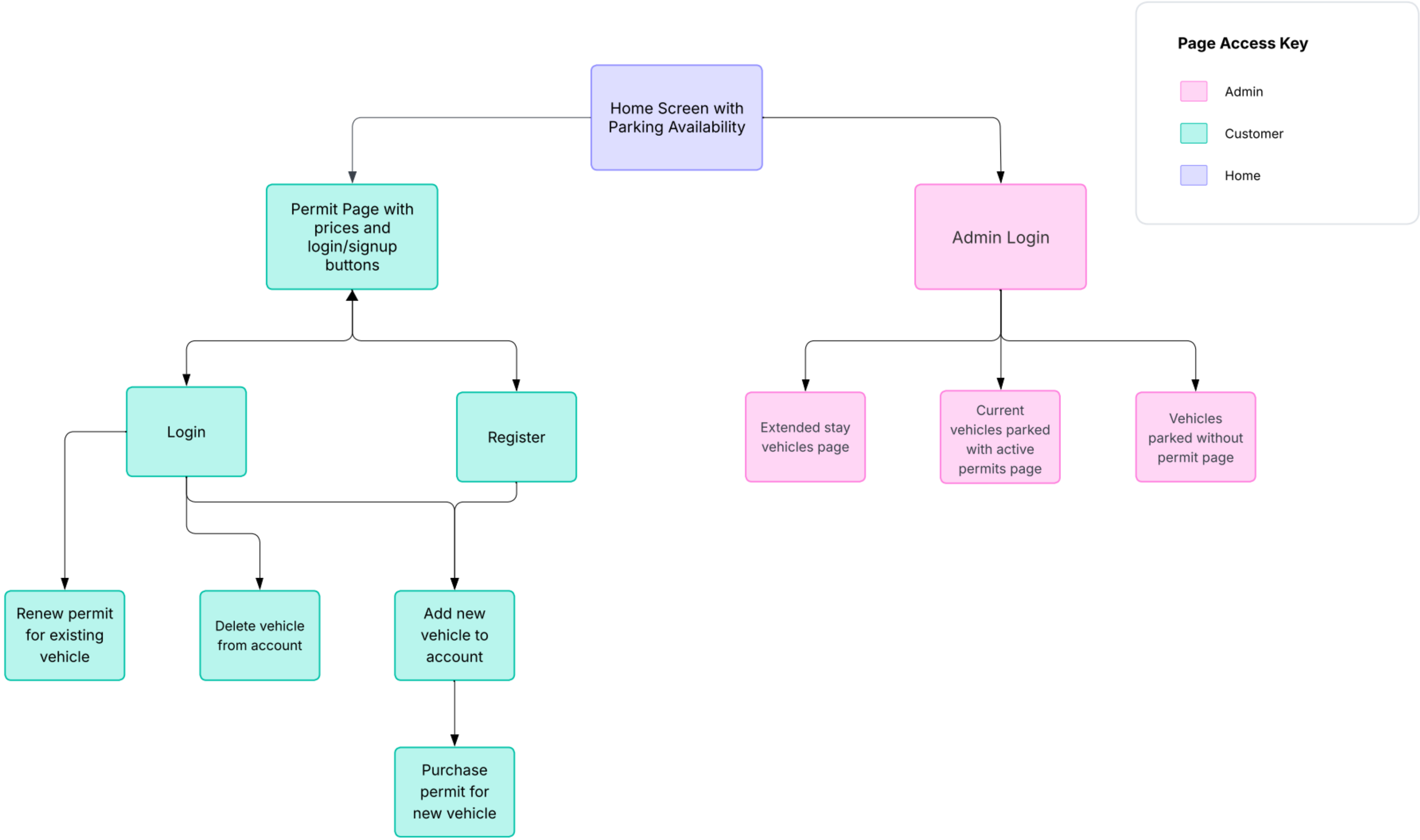
ESP32 System Flowchart



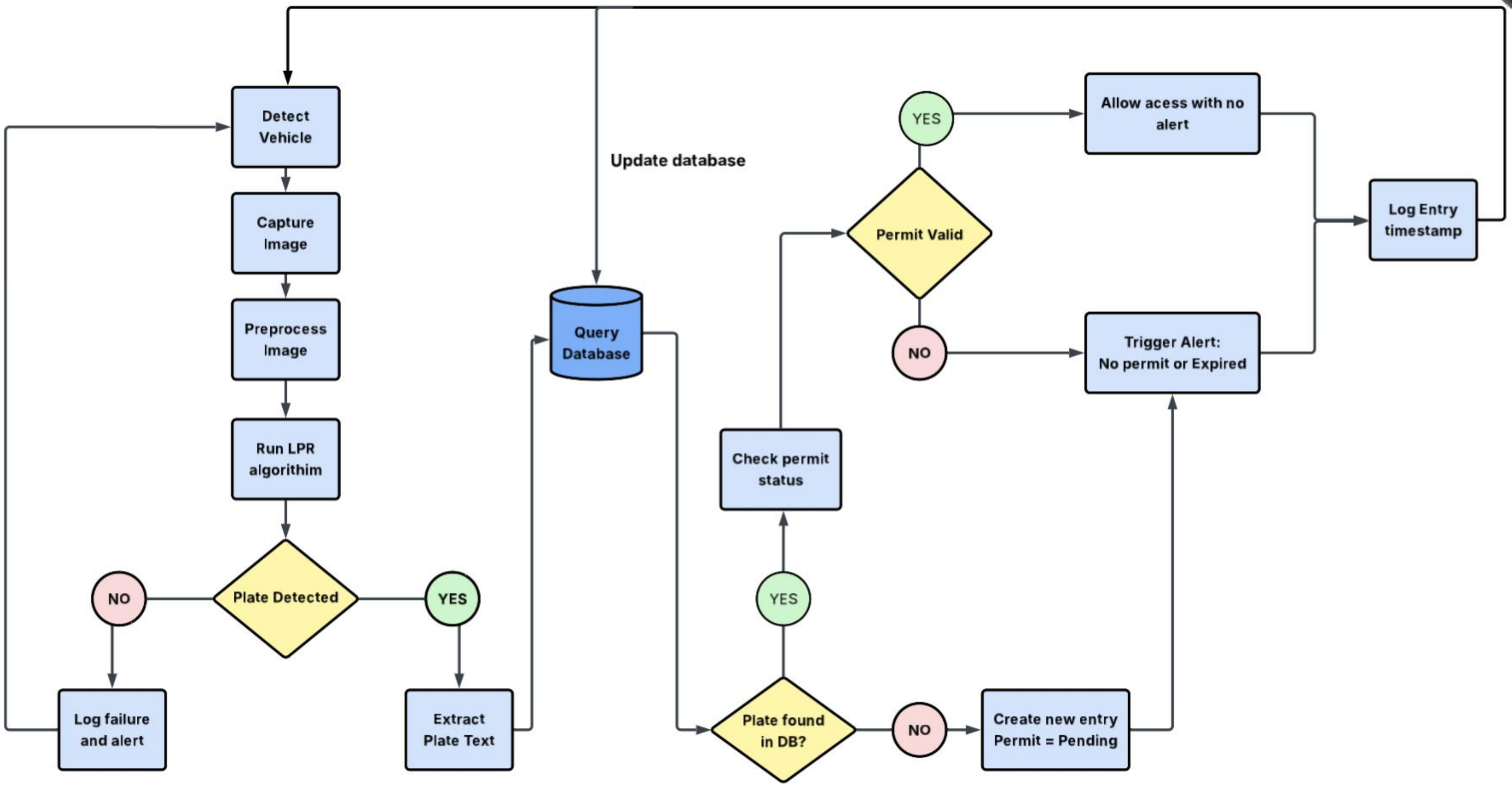


Website Flowchart



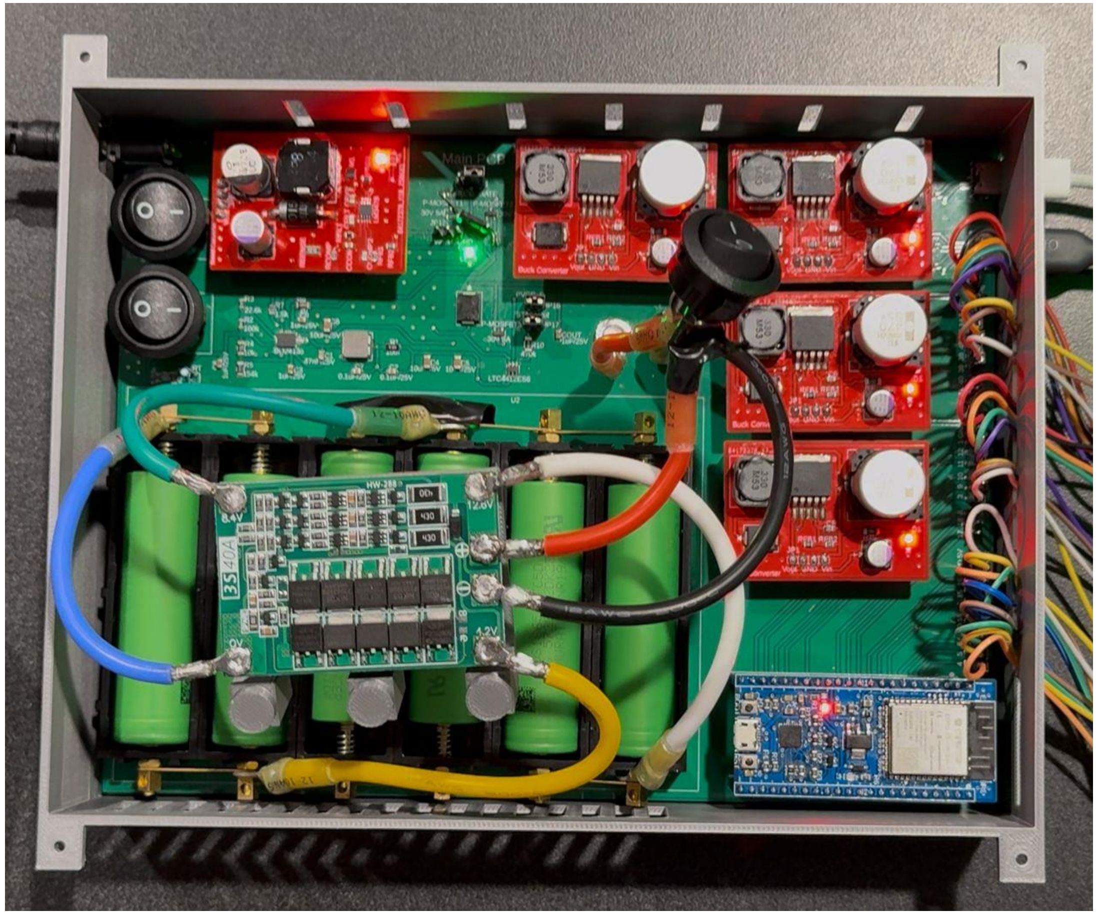


LPR System Flowchart – Logic Description

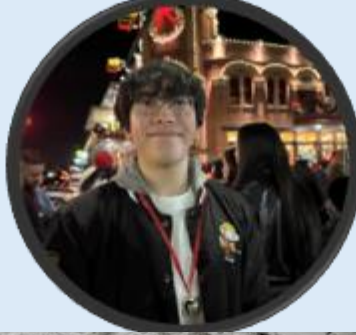


PCB Testing

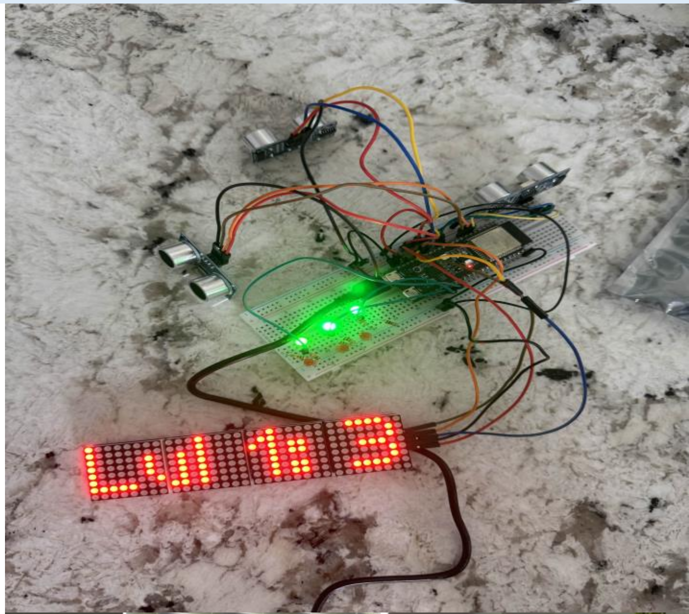
- **Testing:**
  - Boos converter PCB
    - Output voltage ~12.6V
  - Buck converter PCB
    - Regulators for ESP32 and Sensors: output voltage ~5V
    - Regulator for Raspberry Pi: output voltage ~5.2V
  - Main PCB
    - Charger controller
    - Powerpath controller
  - ESP32 PCB
  - Sensors PCB
- **Performance:**
  - All PCBs work as expected
- **Problem:**
  - Raspberry Pi low power voltage warning fixed with the regulators we designed



ESP32 System Testing



- **Testing:**
  - Used Arduino IDE for ESP32 System code
  - Used distance from Ultrasonic Sensor to trigger LEDs
  - MAX7219 LED display uses separate libraries to display text
  - ESP32 Communication to Database using Node.JS server
- **Performance:**
  - Ultrasonic Sensor detection and LED indication works as expected
  - MAX7219 Display updates as expected
  - Updates to database and website within engineering specification
- **Problem:**
  - P10 LED Display did not work with our version of the ESP32
    - Switched to MAX7219 LED display



LPR Phase 1: Static Image Testing

1 **Terminal Command**

OpenALPR was tested by feeding multiple images via the command line.

2 **Setup**

Raspberry Pi 4B, Debian 12 OS, OpenALPR, and test images were used.

3 **Verification**

The system successfully detected license plate numbers with high confidence.


```
cn20@cn20:~/Pictures $ alpr -c us car1.jpg
plate0: 10 results
    - AM74043    confidence: 92.7465
    - AM74043    confidence: 84.5317
    - AN74043    confidence: 83.7489
    - AM74Q43    confidence: 83.7289
    - AH74043    confidence: 82.5429
    - AM74D43    confidence: 81.2552
    - A74043     confidence: 80.3506
    - AM74B43    confidence: 78.3404
    - AN74043    confidence: 75.5341
    - AN74Q43    confidence: 74.7312
```

Static Test Results:

Successful Detection

The license plate "AM74043" was accurately identified.

High Confidence

The top guess had a 92% confidence rate.

Proved Capability

This phase confirmed OpenALPR's detection ability.

LPR Phase 2: Real-Time Detection

1. **Live Feed Testing**

   We used the Raspberry Pi camera's live feed.

2. **Simulated Vehicle**

   A phone screen displaying a license plate simulated a moving car.

3. **Custom Script**

   A Python script captured images every second for OpenALPR analysis.

Successful Detection

The system detected plates with an 89% confidence score.


```
✅ Plate detected:
No license plates found.

✅ Plate detected:
No license plates found.

✅ Plate detected:
plate0: 10 results
    - DZVG49     confidence: 89.4834
    - DZVCG49    confidence: 82.375
    - DZV649     confidence: 82.3435
    - DZVQ49     confidence: 81.6088
    - DZVO49     confidence: 81.1544
    - DZVG4S     confidence: 80.9121
    - DZVG4B     confidence: 80.7012
    - 0ZVG49     confidence: 80.4803
    - OZVG49     confidence: 80.4638
    - DZVG4      confidence: 80.3441

✅ Plate detected:
No license plates found.

✅ Plate detected:
No license plates found.
```

Next Steps: Challenges & Improvements

Accuracy Decrease

Accuracy dropped when plates where captures from wider angles or further distances.

Proposed Solutions

To reduce error, ensure the plate is centered and use and use an optical zoom lens to maintain clarity from further distances.

Database Integration

Connect LPR to a backend database for plate storage and key data.

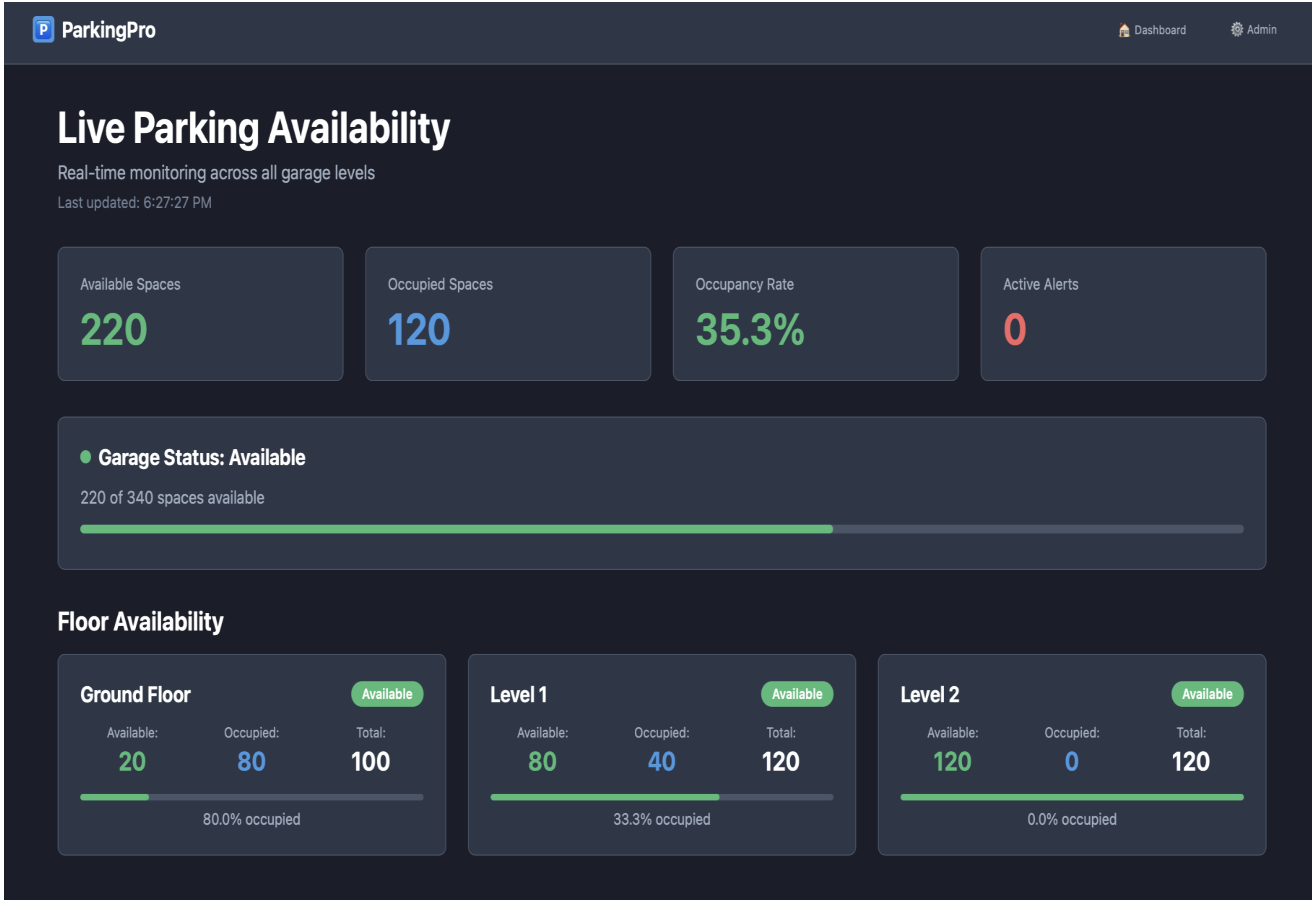
Real-World Testing

Test with a real moving vehicle in an outdoor environment.

Hardware Modifications

Improve camera stability with a tripod and add an optical lens.

Website: Main Dashboard Interface



Key Features:

Real-Time Updates
Live monitoring of all garage levels.

Total Capacity Tracking
Displays available, occupied spaces, and overall occupancy rate (e.g. 68.%)

Garage Status Indicator
Auto-updated system status (Available/Limited/Full)

Floor-Level Detail
Breakdown by level with color-coded occupancy bars

Alert System
Shows active alerts triggered by vehicle behavior

Website: Admin Dashboard Interface

Admin Dashboard

Real-time control and monitoring center

Last updated: 8:41:54 PM

Active Vehicles	Active Alerts	Registered Users	Extended Stays
342	2	3	5

System Alerts | Vehicle Management | Real-time Monitoring

Vehicle Authorization Management

+ Add Vehicle

Search by plate or owner...

Plate Number	Owner Name	Permit Type	Expiry Date	Status	Actions
ABC–123	John Doe	Monthly	2024-08-15	Active	
XYZ–789	Jane Smith	Daily	2024-07-05	Active	
DEF–456	Mike Johnson	Weekly	2024-07-10	Expired	

Bill of Materials

Component	Subsystem	Quantity	Unit Cost (USD)	Total (USD)
Ultrasonic Sensors	Sensors and Processing	10	$1.91	$19.10
HQ Camera / Lens / tripod	Sensors and Processing	2	$144	$288
LED Indicators	Sensors and Processing	20	$0.15	$3.00
Microcontroller (ESP32)	Sensors and Processing	5	$0.82	$4.10
Raspberry Pi 4	Sensors and Processing	2	$61.99	$123.98
Signage Displays	Sensors and Processing	3	$4.96	$14.90
Power Supply Adapter	Power (Batteries)	1	$15.99	$15.99
Batteries	Power (Batteries)	8	$1.95	$15.60
Voltage Regulators	PCBs and Electrical	15	$1.82	$28.23
PCB for Sensors	PCBs and Electrical	10	$0.5	$5.00
Main PCB	PCBs and Electrical	5	$4.99	$17.8
Stencil	PCBs and Electrical	5	$7.00	$35.00
Components				$243
PCB shipping / Import Duties				$105
Total				**$919**

Work Distribution

Mark Rehn (EE)

Focuses on PCB design, PSU design, and MCU communications and hardware integration.

Secondary: Responsible for all documentation formatting and final video editing.

Chris Najem (CE)

Develops License Plate Recognition software, Manages Raspberry Pi/Camera, Database, Server, and web app design.

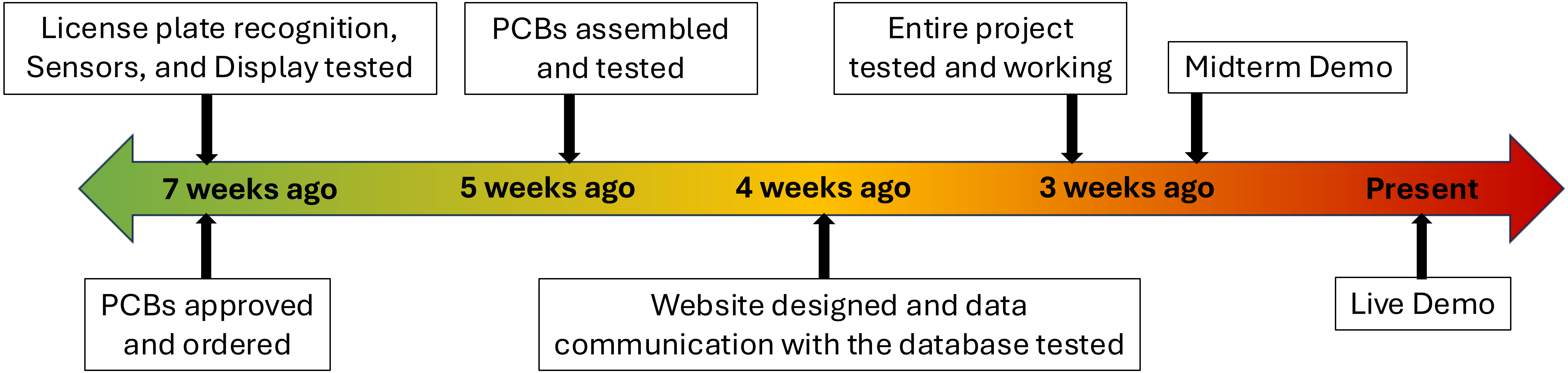
Secondary: Assisted with PCB assembly.

Tony Mai (CE)

Manages MCU connections for display, ultrasonic sensor/LED, and software for these components, web app design.

Secondary: Assisted with PCB assembly.

Progression and Future Milestones



- Hope for the project is that others improve the design and expand its use in parking garage management
- Having the Parking Garage Management System in private parking lots in companies and/or universities

Thank you for listening!