UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

Autonomous Hot Car and CO Poisoning Mitigator

ECE 445 Senior Design

Team 35

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Introduction of Team

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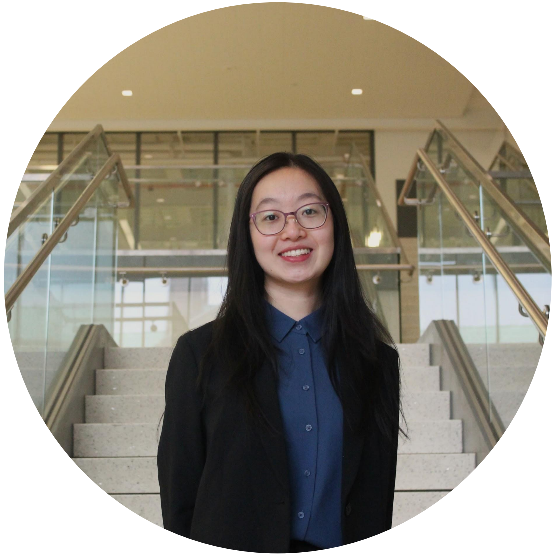

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Senior
Computer Engineering

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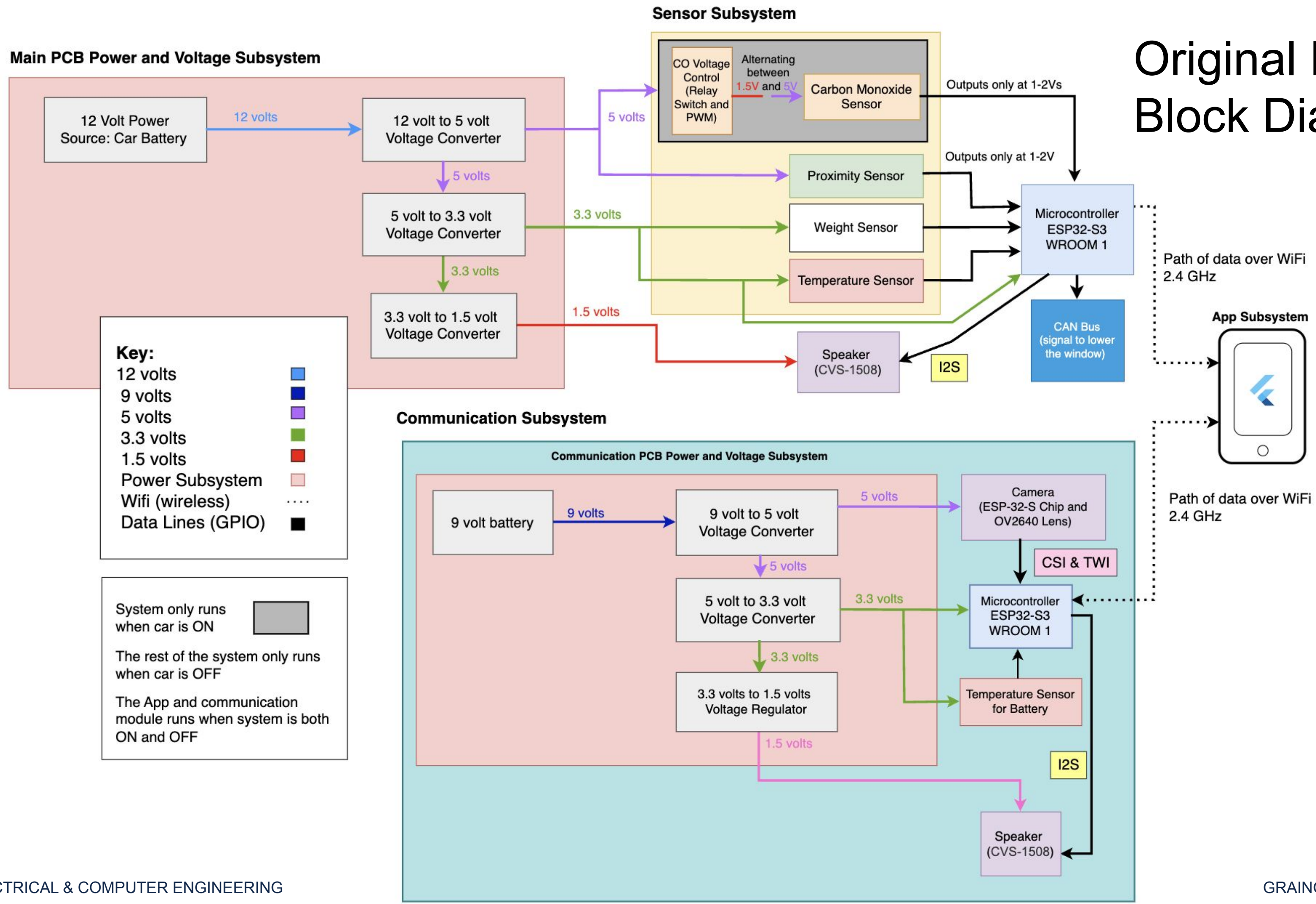
In 2024 alone, 39 kids died from a heatstroke from being in a hot car

Citation: https://www.nhtsa.gov/campaign/heatstroke

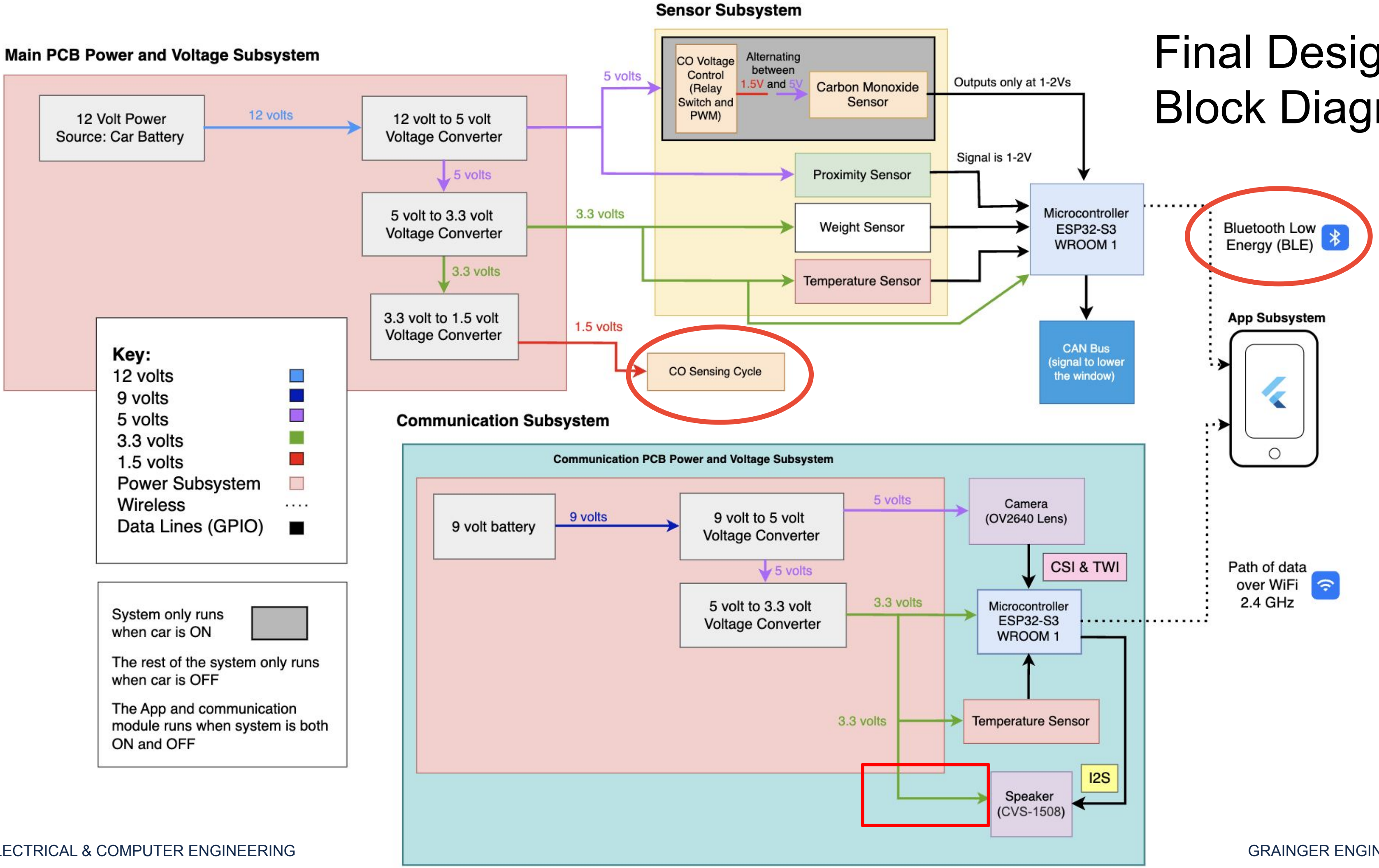
Objective

- To mitigate situations where children or pets are left in a hot car and prevent their deaths
- To detect CO poisoning early on

Original Design: Block Diagram



Final Design: Block Diagram



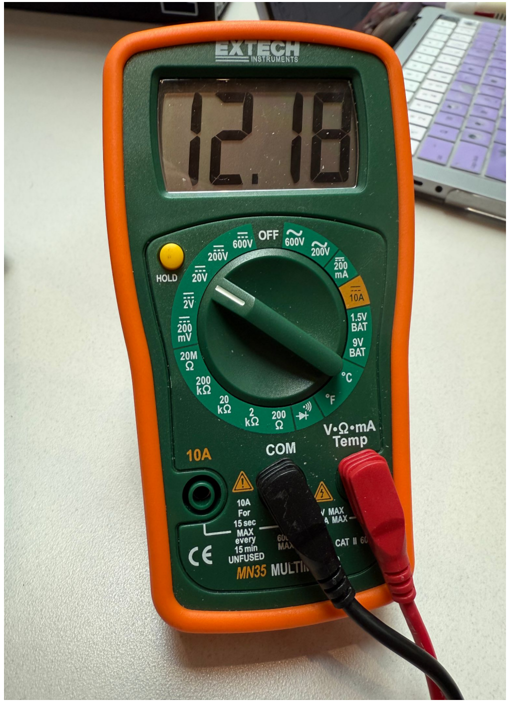
Requirements and Verification

High Level Requirements

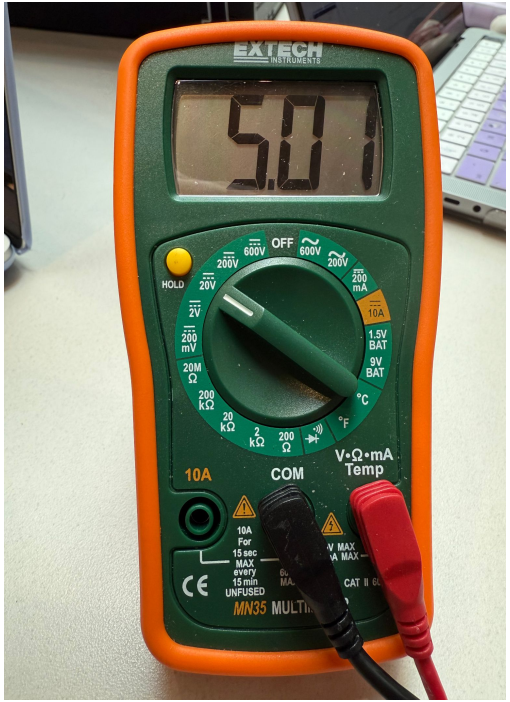
1. Once the temperature sensor surpasses the threshold temperature of 85 ℉, the windows lower to the set position within two minutes.
2. The notification for either the CO sensor or the temperature sensor should be sent to the phone application within two minutes.
3. The speaker will alert the user once CO levels within the car have reached nine or more ppm.
    a. Once the CO level reaches nine ppm, there is an increased risk of CO poisoning with minor side effects. This is a safe level to be exposed to CO for eight hours.

12-to-5 Voltage Converter Requirements

- Converts the 12 ± 0.5 V power source to 5 ± 0.5 V.



12 volt input

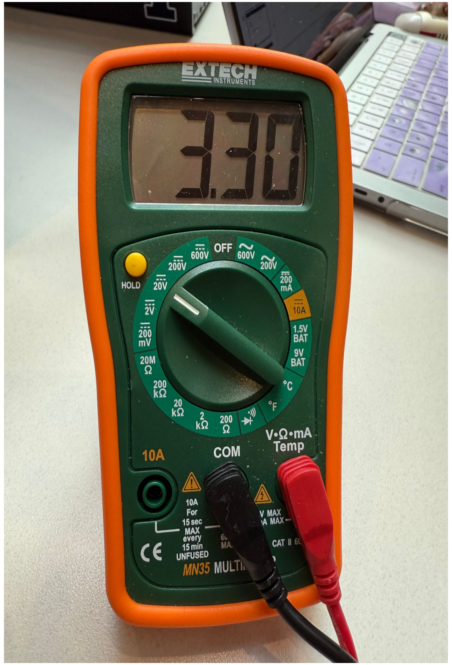


5 volt output

5-to-3.3 Voltage Converter Requirements

- Converts the 5 ± 0.5 V power source to 3.3 ± 0.5 V volts.

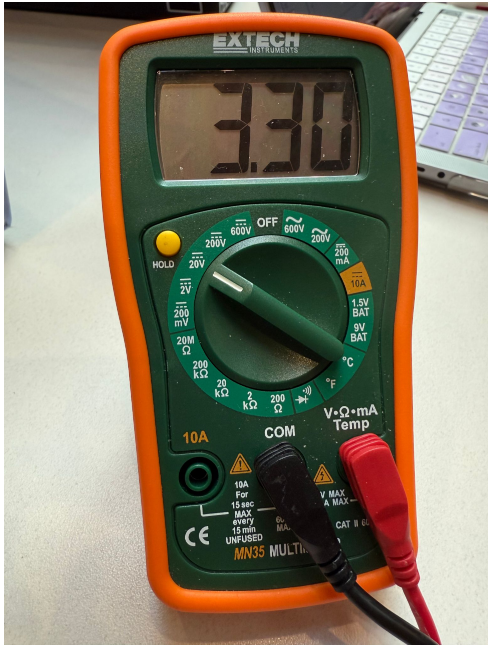
5 volt input



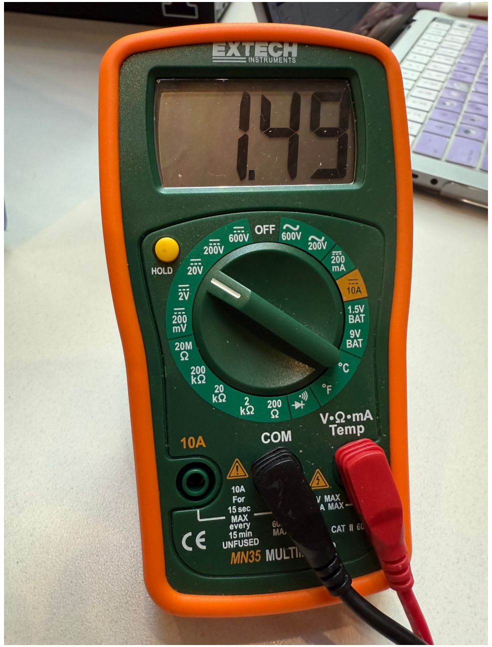
3.3 volt output

3.3-to-1.5 Voltage Converter Requirements

- Converts 3.3 ± 0.5V volts power source to 1.5 ± 0.5V volts.



3.3 volt input



1.5 volt output

9-to-5 Voltage Converter Requirements

- Converts the 9 ± 0.5 V volts from the battery to 5 ± 0.5 V volts.
- The voltage reading across the camera measures around 5 ± 0.5 V.

9 volt input

5 volt output

Function Tests: Communication PCB Power Subsystem

5-to-3.3 Voltage Converter Requirements

- Converts the 5 ± 0.5 V power source to 3.3 ± 0.5 V volts.

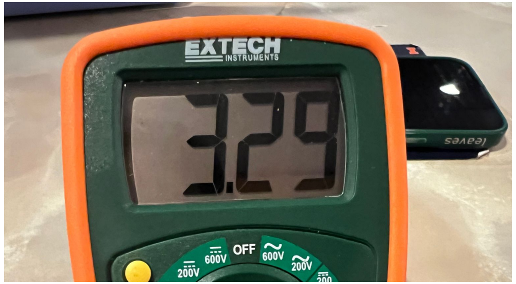
5 volt input

3.3 volt output

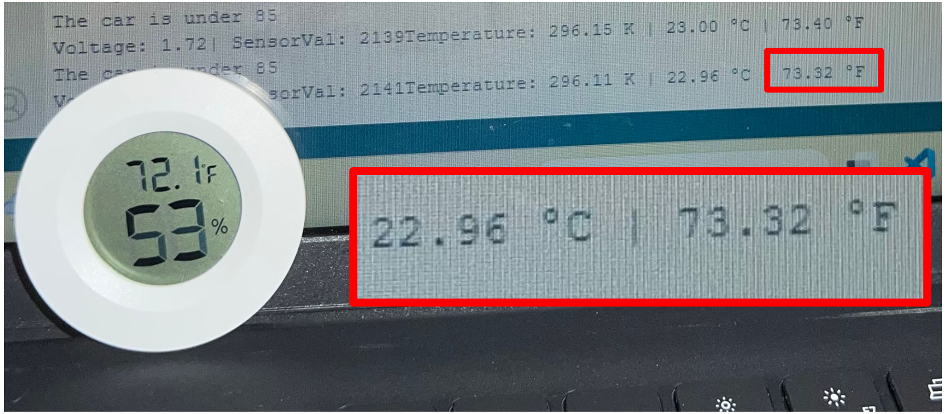
Temperature Requirements

- The voltage reading into the temperature sensor is 3.3 ± 0.5 volts.
- The temperature sensor correctly reads the temperature within ± 5 degrees.

Results:



3.3 volt input

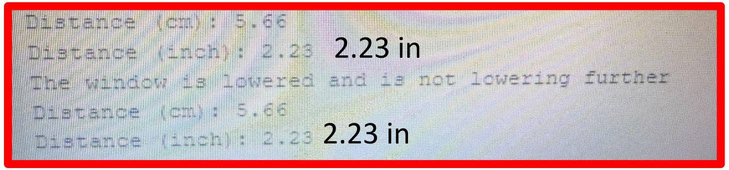


Temperature reading from Thermometer vs Thermistor

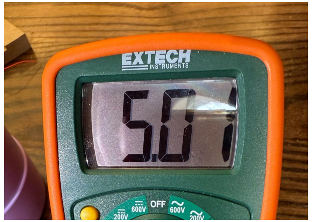
Proximity Requirements

- The voltage input to the proximity sensor is 5 ± 0.5 volts.
- The proximity sensor reads if a window is 2 ± 0.5 inches in front of it.

Results:

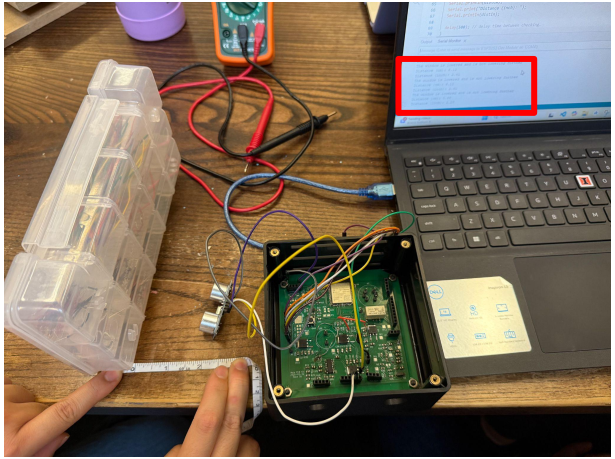


Readings on Arduino IDE



5 volt input

2 inches distance



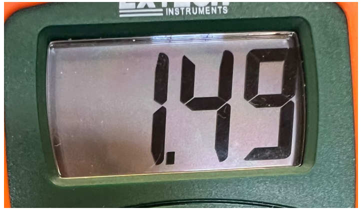
Setup

Carbon Monoxide Requirements

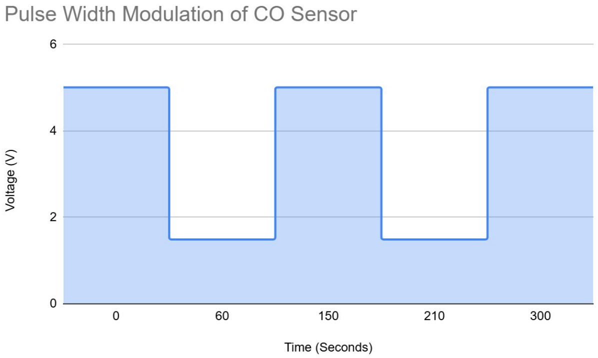
- The voltage input to the CO sensor is 5 ± 0.5 volts when heating and 1.5 ± 0.5 volts when sensing.
- The CO sensor reads the CO levels (ppm) in the car within ± 1 ppm when the vehicle is on.

Results:

5 volt input when heating



1.5 volt input when sensing



PWM of CO cycle

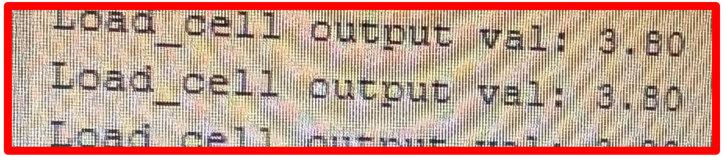
Weight Sensor Requirements

- The voltage reading across the weight sensor is 3.3 ± 0.5 volts.
- The sensor reads the weight within ± 5 lbs.

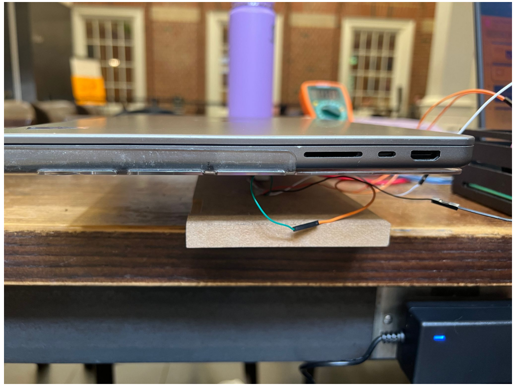
Results:

3.3 volts input

External scale measurements



Values read from sensor

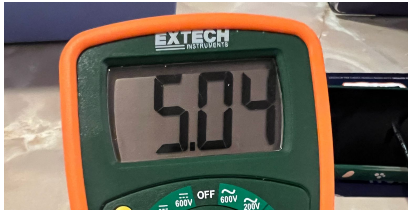


Weight sensor setup

Camera Requirements

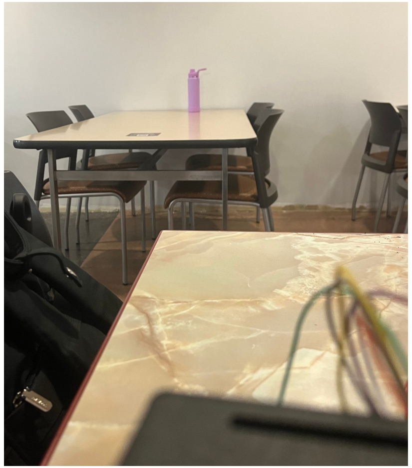
- The voltage reading across the camera should be 5 ± 0.5 V.
- The camera has a visibility of 6 - 8 feet.
- The camera video delay is at a maximum of 5 seconds.

Results:



5 volt input

Picture from PCB Camera



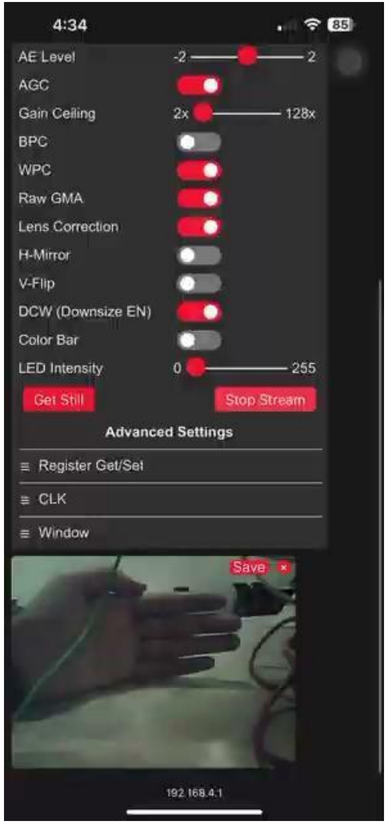
Picture from Phone

Function Tests: App and Communication Subsystem

Camera Requirements

- The voltage reading across the camera should be 5 ± 0.5 V.
- The camera has a visibility of 6 - 8 feet.
- **The camera video delay is at a maximum of 5 seconds.**

Results:

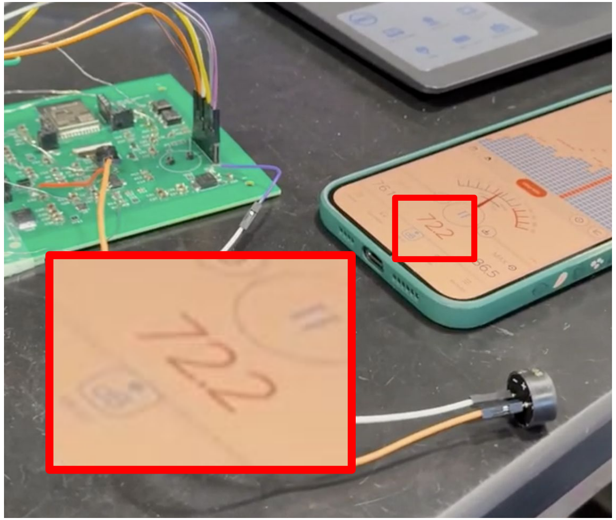


Speaker Requirements

- The voltage reading across the speaker will be 1.5 ± 0.5 V volts.
- The audio output of the speaker will measure 73 dBA ± 3 dBA.

Results:

1.5 volt input



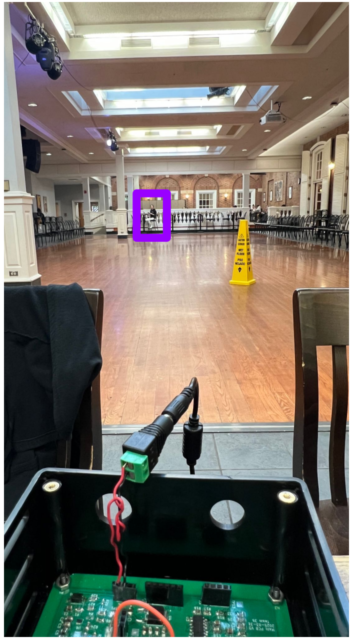
Speaker dBA readings

Function Tests: App and Communication Subsystem

App Requirements

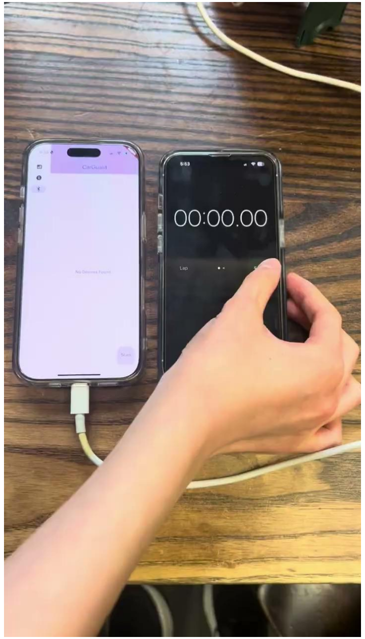
- The app is able to receive the microcontroller data at least 40 feet.
- The app notifies the user within two minutes of any changes detected in the car.

Results:



Receiving data from 40 ft away

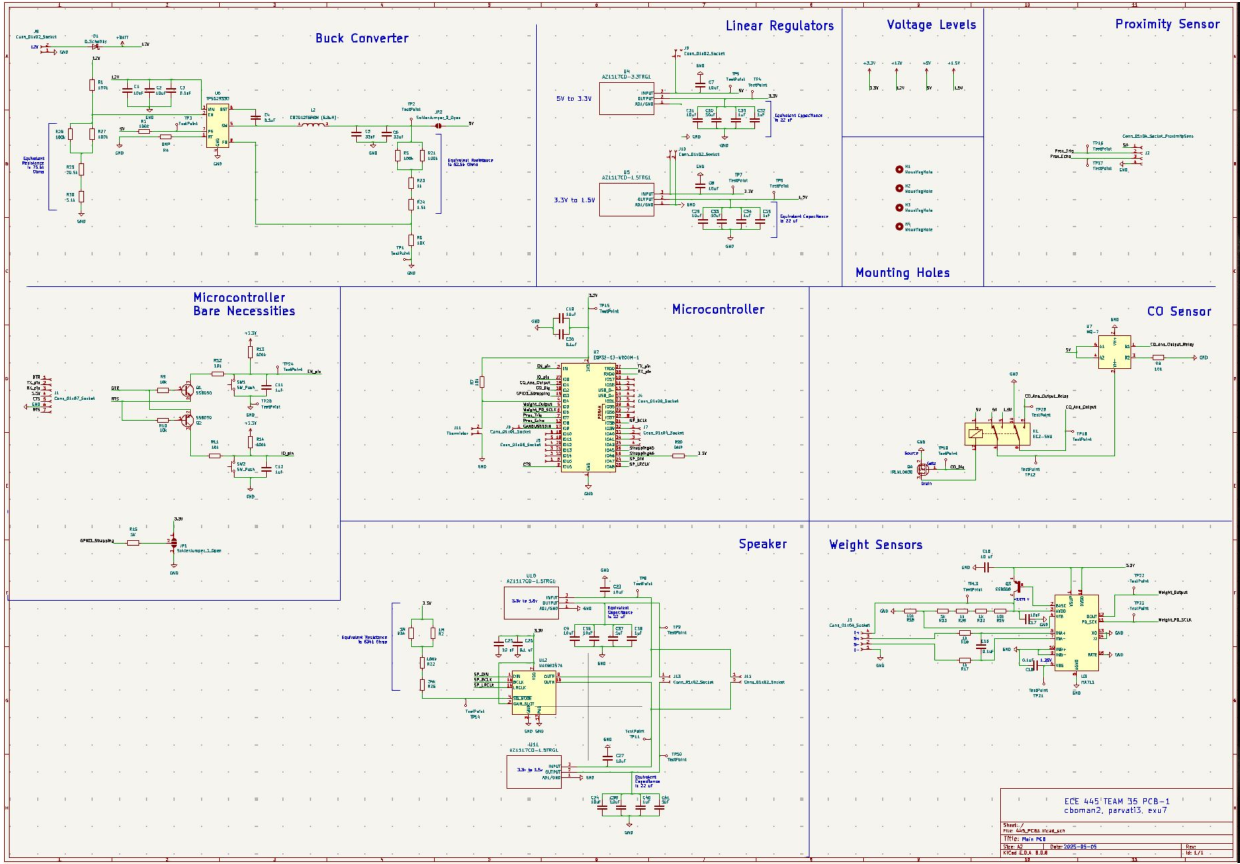
Notifications at 40 ft away



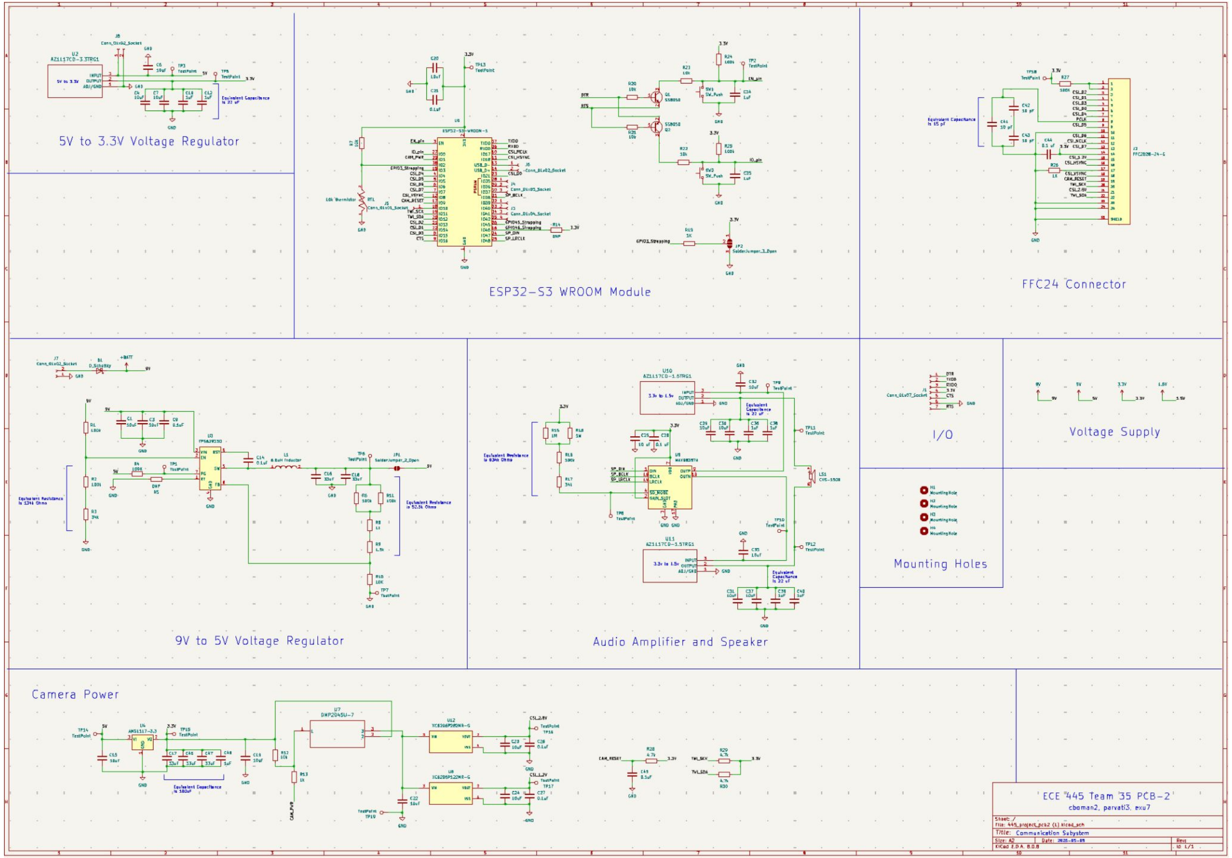
Notification delay

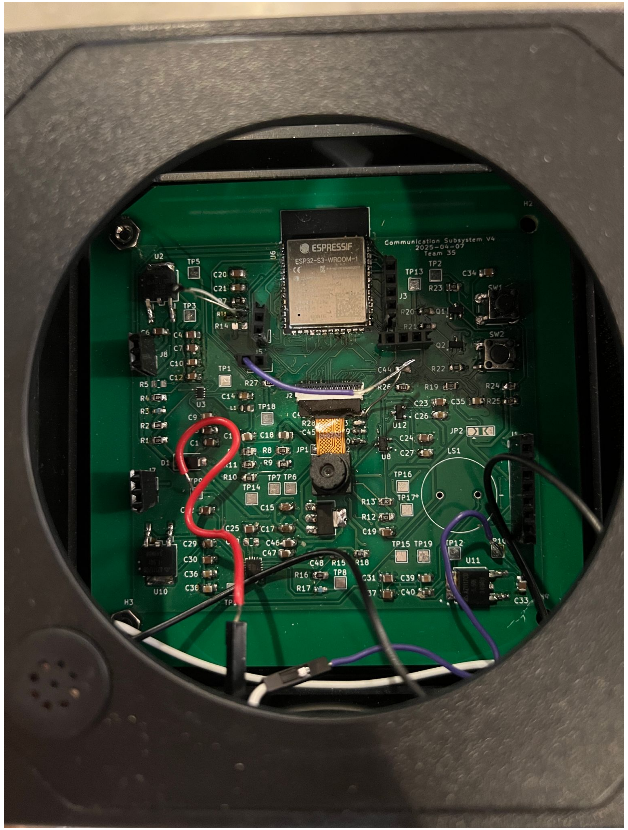
Project Build

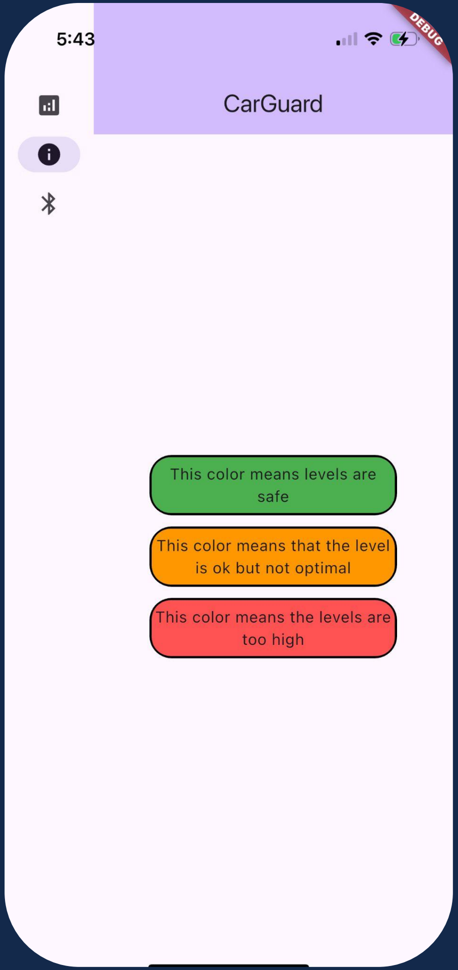
PCB Designs: Main PCB

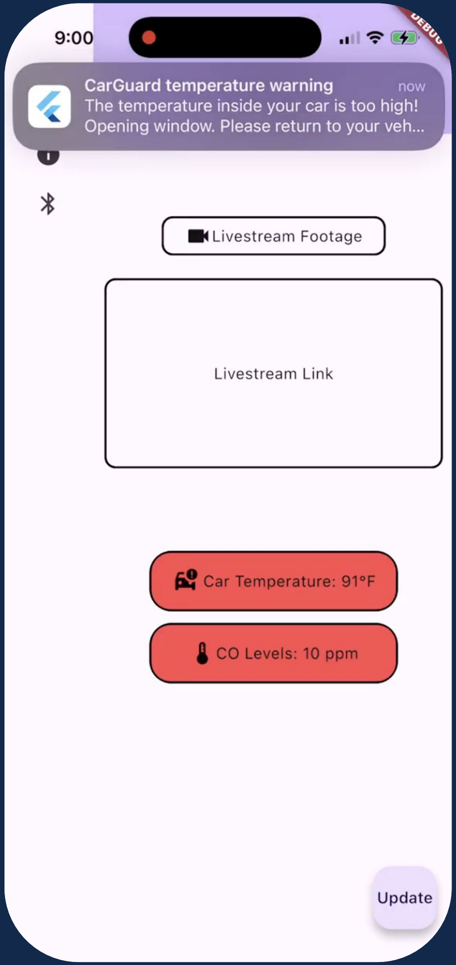


PCB Designs: Communication PCB





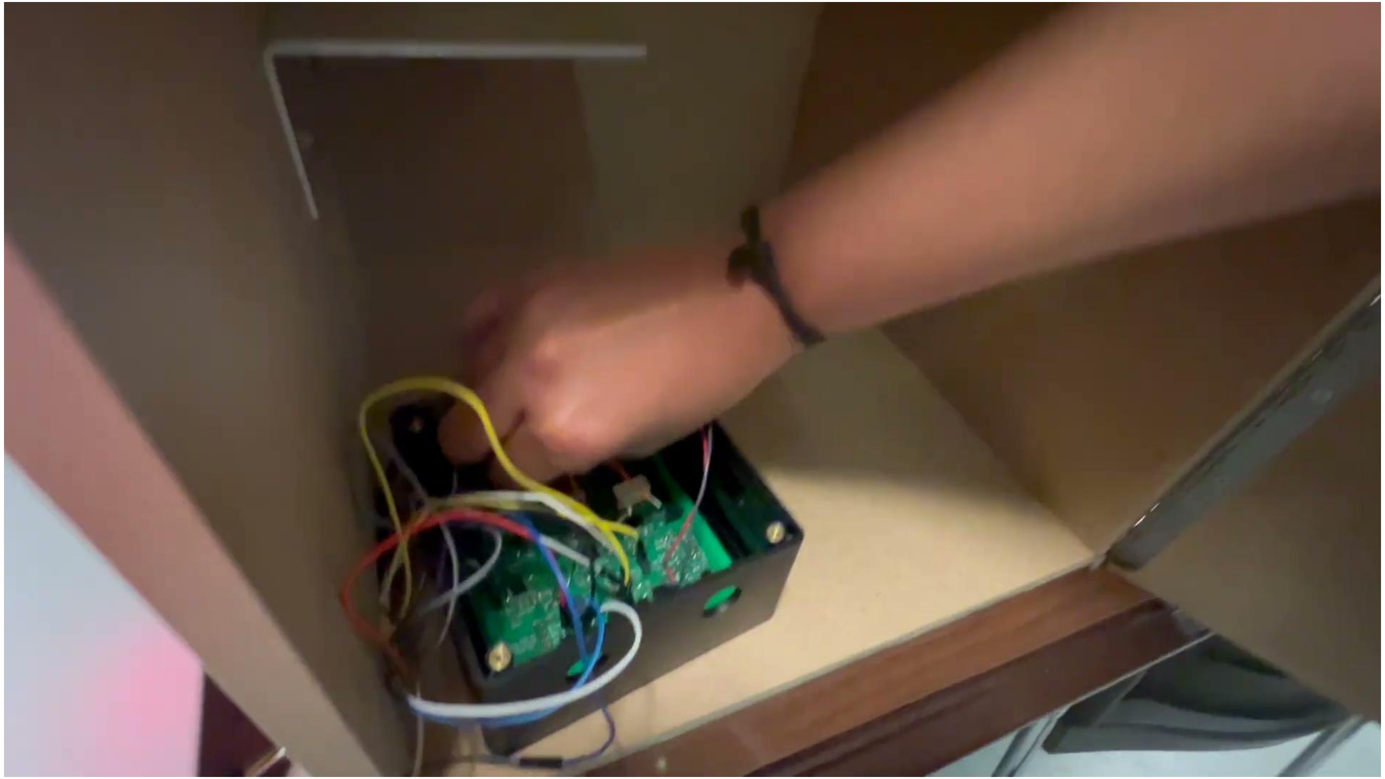




Application

- Home page
  - Camera Monitoring
  - Sensor Information
- Information Page
- Bluetooth Scanner

Demo Video



Successes

Successes

Power and Voltage Conversion

1. Buck Converter for 12V-to-5V and 9V-to-5V
2. All components powered with the correct voltage levels

Weight Sensor

1. Accurately reads weight within range

Integrations

1. Sensor components worked together for CAN Bus
2. Speaker sounds when threshold temperature is met on Communication PCB

Successes

Wireless Communication to Application

1. Set up custom WiFi channel for video transmission
2. Set up custom Bluetooth for data transmission
3. Sent sensor data in real-time to our application

Application

1. Notifications are sent when temperature or CO levels are too high

Challenges

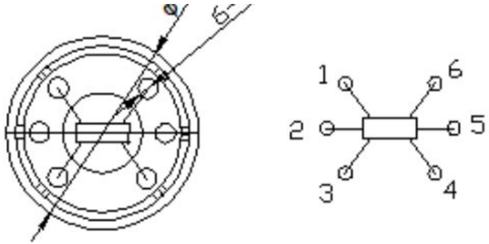
Speaker (Main PCB)

1. Inconsistent Output
2. Lower Decibels

Carbon Monoxide (MQ-7)

1. Read incorrect values
2. Did not update when CO was present

MQ-7 CO sensor



CO datasheet pin outputs

Conclusion

What We Would Do Differently

- More research into data transfer for app development earlier
- Begin testing Window Motors earlier
- Have flags that indicate whether the car is on or off

Future Work

- Embed Livestream in App
- Further development into Bluetooth connection
- Long range antenna for WiFi

What We Learned

- PCB and Electrical Circuit Design
- Soldering/Desoldering, Flux, Heat Gun, Solder Paste
- Firmware, App, Wifi, and Bluetooth Development

Ethics

- Protection of Car Components
- Sensor Safety
- CO Testing/Demo Safety

Special thanks to Professor Gruev, Rui Gong, Machine Shop, and all the other TAs that assisted us with our project!

This project would not be possible without your help.

Thank you for listening!

Any Questions?

Appendix

Verification: Main PCB Power Subsystem

Verification

- The voltages are measured by a multimeter.
  - Place the ground pin of the multimeter to GND.
  - Place the power pin of the multimeter to the respective power pin of each component.
  - The input to the 12-to-5 V buck converter will be connected to the 12 V wall adapter. The input should read 12 ± 0.5 V.
  - The output of the 12-to-5 V converter should measure 5 ± 0.5 V.
  - The input of the proximity sensor should be connected to the output of the 12-to-5 V buck. This should read 5 0.5 V.
  - The input to the power pin of the relay switch sensor should be connected to the output of the 12-to-5 V buck. This should read 5 ± 0.5 V.

Verification: Main PCB Power Subsystem

Verification

- A multimeter is used to check the voltage across the voltage converter. The input should read 5 ± 0.5 V and the output pins should read 3.3 ± 0.5 V.
  - Place the ground pin of the multimeter to GND.
  - Place the power pin of the multimeter to the respective power pin of each component.
  - The voltage reading across both microcontrollers measures 3.3 ± 0.5 V.
  - The voltage input to the temperature sensors measures 3.3 ± 0.5 V volts.
  - The voltage input to the weight sensors reads 3.3 ± 0.5 V.
  - The proximity sensor signal output reads 3.3 ± 0.5 V.

Verification: Main PCB Power Subsystem

Verification

- The voltages are all measured by a multimeter.
  - Place the ground pin of the multimeter to GND.
  - Place the power pin of the multimeter to the respective power pin of each component.
  - The input to the linear regulator is 3.3 ± 0.5 V.
  - The output of the linear regulator measures 1.5 ± 0.5 V.
  - The input to the speaker components measures 1.5 ± 0.5 V.

Verification: Communication PCB Power Subsystem

Verification

- The voltages are all measured by a multimeter. The input voltage reads 9 ± 0.5 V and the output reads 5 ± 0.5 V.
    - The voltage input to the ESP32-CAM measures 5 ± 0.5 V.

Verification: Communication PCB Power Subsystem

Verification

- A multimeter is used to check the voltage across the voltage converter. The input should read 5 ± 0.5 V and the output pins should read 3.3 ± 0.5 V.
    - Place the ground pin of the multimeter to GND.
    - Place the power pin of the multimeter to the respective power pin of each component.
    - The voltage reading across both microcontrollers measures 3.3 ± 0.5 V.
    - The voltage input to the temperature sensors measures 3.3 ± 0.5 V volts.

Verification: Sensor Subsystem

Verification

- Ensure that the temperature sensor is powered by pin 2 from the microcontroller.
- The voltage going into the temperature sensor circuitry is evaluated with a multimeter.
  - Place the ground probe of the multimeter in GND.
  - Place the power probe of the multimeter in pin 2 of the microcontroller.
  - Check that the input voltage is between 2.8 and 3.8 volts.
- In our enclosed testing environment, there is a heater, a temperature-checking meter, and the PCB with the temperature sensor together.
- Have the heater warm up the testing environment.
- Check the temperature readings from our sensor against the other temperature meter.
  - Ensure the sensor reading is within 5 degrees of the temperature meter.

Verification: Sensor Subsystem

Verification

- The voltage across the proximity sensor will be confirmed using a multimeter.
  - The GND pin of the multimeter will be placed in GND.
  - The power pin of the multimeter will be placed in the VCC pin.
  - The proximity sensor is connected to the output of our 12-to-5V buck converter.
  - Check that the multimeter reads a voltage of 4.5 - 5.5 volts.
- Place an object 1.5 - 2.5 inches from the front of the proximity sensor. The distance will be measured by a measuring tape.
  - Check that the distance reported by the proximity sensor is accurate within 0.5 inches of the measured distance.
- Check that when the sensor reads that there is an object 1.5 - 2.5 inches in front of it, a signal is sent to stop lowering the window.
  - This can be checked by observing that the window has lowered.

Verification: Sensor Subsystem

Verification

- The input to the VSUPP and DVDD pins of the HX711 chip should be connected to the output of the 5-to-3.3V linear regulator. These should be measured to 3.3 0.5 volts with a multimeter.
    - Place the ground probe of the multimeter into GND.
    - Place the power probe of the power probe of the multimeter into VSUPP and DVDD.
    - Check that both pins output 3.3 0.5 volts.
- Weigh an object using a scale.
- Weigh the same object using the weight sensor. Check that the weight from our sensor is within 5 lbs of the comparison weight.

Verification: Sensor Subsystem

Verification

- A multimeter is used to measure the voltage across the CO sensor.
  - Place the ground probe of the multimeter into GND.
  - Place the power probe of the power probe of the multimeter into pin 5.
- When the CO sensor begins the heating cycle, the multimeter measures 5 volts for 60 seconds
- After 60 seconds, the multimeter measures 1.5 volts for 90 seconds from the CO sensor.
- A jar and a candle will be used to measure the CO level to set up our verification. On the software side, a flag is used to mimic the car being on.
  - A blown-out candle releases CO. However, candles are usually lit in well-ventilated areas, so the levels are negligible. By containing the gases in a jar, we can measure the CO levels. This is because candles without enough oxygen can emit CO rather than CO_2 [17].
- Light a candle and place a jar over it to put it out.
- Place the CO sensor and the pocket carbon monoxide alarm in the jar for comparison.
- Confirm that the CO sensor and pocket carbon monoxide alarm readings match within 1 ppm.

Verification: App Subsystem

Verification

- One person walks at least 40 feet away from the system with the app.
- Check that the microcontroller data is sent to the phone.
- Time how long it takes for the notification to be sent to the user via the app with a timer.
    - The time should be within two minutes.
- Test multiple times to ensure consistency.

Verification: Microcontroller Subsystem

Verification

- A multimeter is used to confirm that the input voltage is around 2.8 - 3.8V.
  - Place the ground pin of the multimeter to GND.
  - Place the power pin of the multimeter on the 3.3 volt pin.
- Once the signal to lower the windows has been sent, a timer is used to confirm that the microcontroller waits a maximum of two minutes for the signal from the proximity sensor.
- When the CO sensor reads nine or more ppm, a notification is sent to the app, conveying that the levels are too high.
- Check the temperature sensors read 85℉ or greater.
  - The window should begin lowering.
- The proximity sensor sends the microcontroller a signal confirming that the windows were lowered.
- The windows should be lowered to at least the threshold level. This is confirmed with a measuring tape.
- The weight sensor sends the microcontroller a signal stating that the weight threshold has been met - indicating a person is in the car. The flag that indicates that a person is in the car is set.
- The microcontroller then checks the temperature in the car and deploys any necessary systems.
- Check the temperature sensors read 85℉ or greater.
- Check that the flag to lower the windows has been set.
- The window should begin lowering.
- Use a timer to check the video feed sent from the camera to the app has a maximum of a five second delay.

Verification: Communication Subsystem

Verification

- Place the positive and negative probes of the multimeter on the 5V and GND pins that connect to the camera.
- Test that the reading is 5 0.5 V volts.
- Place an object 6 - 8 feet away.
- Check that the object is within the video frame.
- Check if a photo is sent to the user in the same room.
- Check if a photo is sent to the user within 35 - 40 feet.
- Wave an object in front of the camera.
- Time the delay of the object waving in the camera.
- Place the positive and negative probes of the multimeter on the 1.5 V and GND pins that connect to the speaker.
- Test that the reading is 1.5 0.5 V volts.
- A sound is played, and a sound level meter is used to confirm the audio output level is 70 - 76 dBA.