# Autonomous Hot Car and CO Poisoning Mitigator

ECE 445 Spring 2025

Project Proposal

Team 35

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# Table of Contents

**1 Introduction......2**
1.1 Problem Statement......2
1.2 Solution......2
1.3 Visual Aid......3
1.4 High-Level Requirements......3
**2 Design......4**
2.1 Block Diagram......4
2.2 Subsystem Overview......5
2.2.1 Sensor Subsystem......5
2.2.2 App Subsystem......5
2.2.3 Power and Voltage Control Subsystem......6
2.2.4 Microcontroller......6
2.2.5 Monitoring and Communication Subsystem......7
2.3 Subsystem Requirements......8
2.3.1 Sensor Subsystem......8
2.3.2 App Subsystem......8
2.3.3 Power System......8
2.3.4 Microcontroller......9
2.3.5 Communication Subsystem......10
2.4 Tolerance Analysis......10
**3 Ethics and Safety......17**
**References......19**

# 1 Introduction

## 1.1 Problem Statement

Every year, many children and pets die from heatstrokes in hot cars or carbon monoxide poisoning when they are left in a locked vehicle. Parents often forget or knowingly leave their children and pets behind in a hot, locked car. Even if the parent leaves for a quick 10-minute errand, there are still concerns about heatstrokes since temperatures inside can rise as much as 20 degrees in that short duration of time [1]. In 2024 alone, 39 kids died from a heatstroke from being in a hot car [2]. Despite laws and modern car technology, this issue is still prevalent today. Thus, it is critical to add protection and safety measures to vehicles to prevent further deaths.

Currently, there exist devices on the market that remind users to open the back door or check the backseat [3]. However, the volume of these alarms can be reduced, and as a result, parents can forget they are going off. There are no autonomous solutions that work to mitigate the situation when the car's interior temperature is unsafe. Additionally, there are carbon monoxide detectors on the market today, but these devices simply sound an alarm when a certain threshold is reached. However, if the user is not in the vicinity, they might get notified of the incident too late.

## 1.2 Solution

Our device create ventilation for passengers to prevent deaths in a hot car and alert users of a defective exhaust system. The device has a temperature and carbon monoxide sensor which is attached near the driver's window (without obstructing the driver's view) that will lower all four windows using a signal. If the vehicle's temperature is too high and passengers are detected inside, then the device will lower the car windows. If the carbon monoxide levels are too high, the system will alert the user and recommend they get their exhaust checked.

When the temperature or the CO levels pass the threshold, the car's owner will be alerted through an app that the windows have been lowered. Furthermore, the vehicle has an intermittent alarm that sounds until the temperature levels are safe. The alarm shuts off automatically once the levels are safe or once the car is turned on. A camera that is attachable to the rearview mirror streams footage to the app. Through the app, the user can monitor the inside of their car and talk to the passenger.

## 1.3 Visual Aid

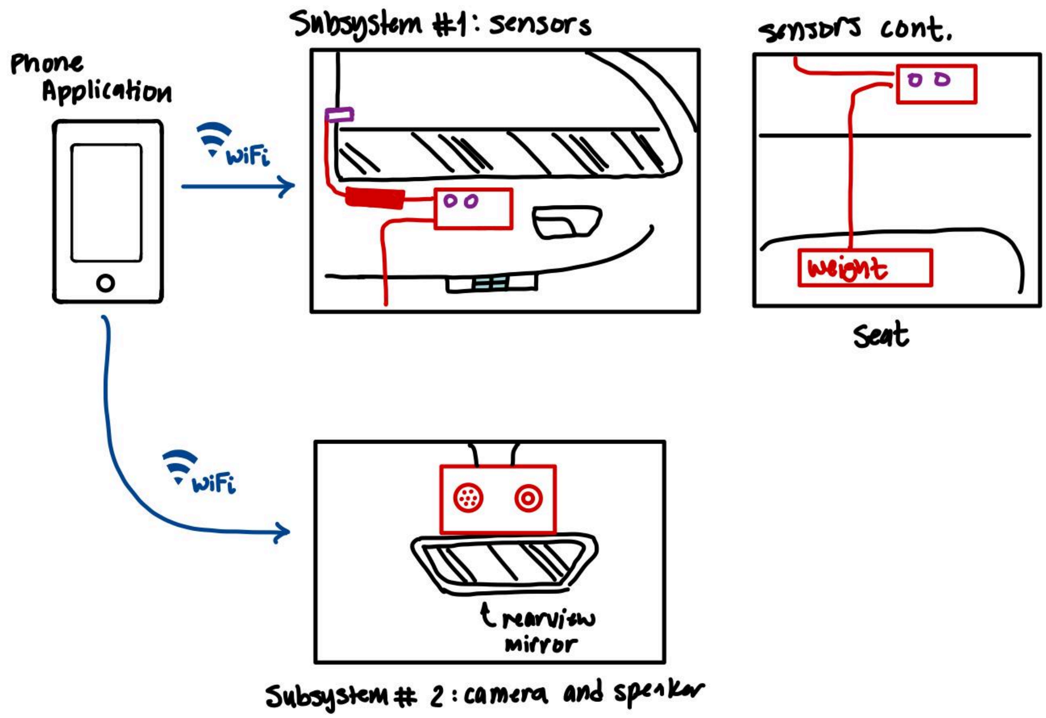


*Figure 1: Car System Layout*

## 1.4 High-Level Requirements

1. Once the temperature sensor surpasses the threshold temperature of 85 ℉, the windows will 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 9+ ppm.
    a. Once the CO level reaches 9 ppm, there is an increased risk of CO poisoning with minor side effects. This is a safe level to be exposed to CO for 8 hours [4].

# 2 Design

## 2.1 Block Diagram

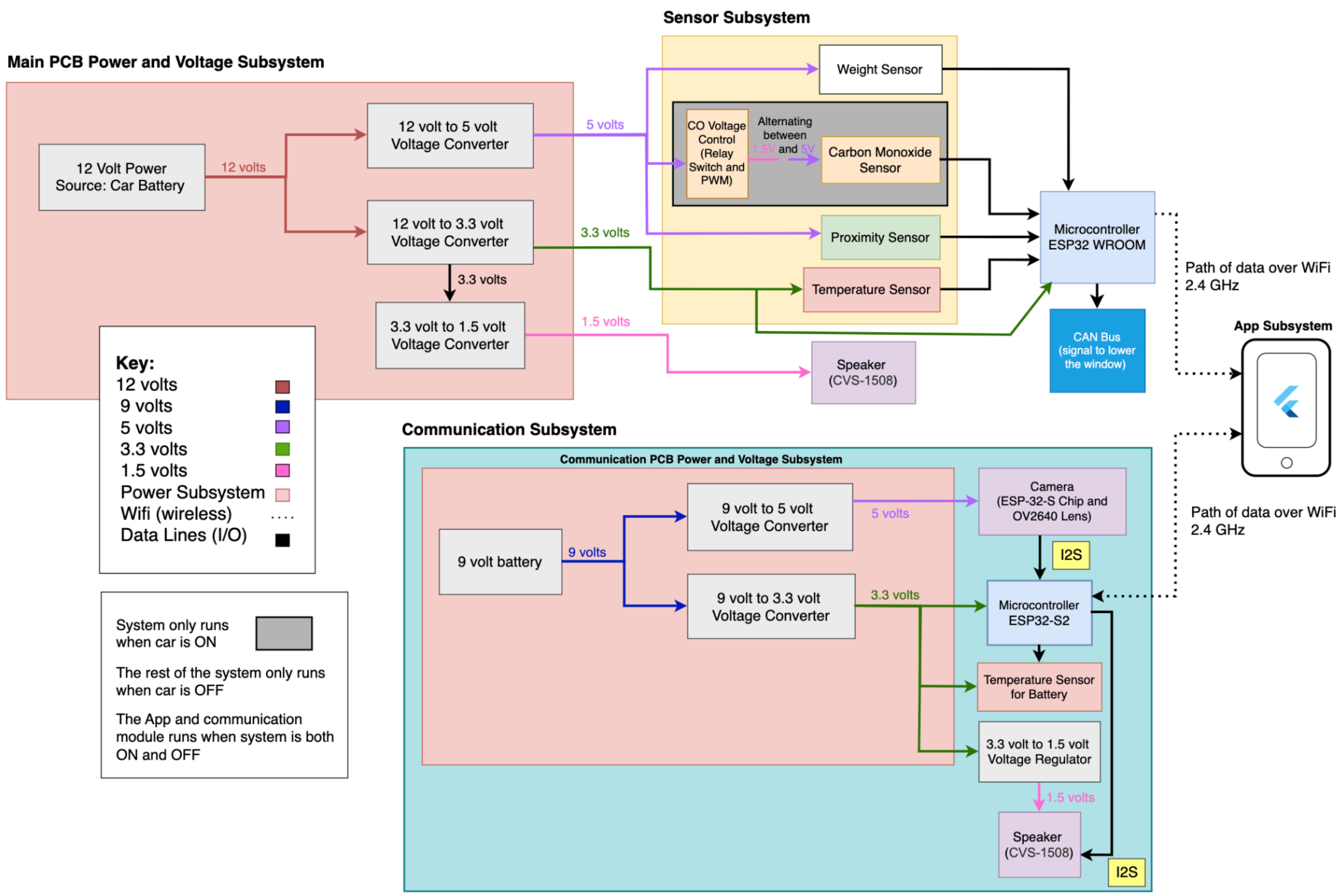


*Figure 2: Car System Block Diagram*

## 2.2 Subsystem Overview

### 2.2.1 Sensor Subsystem

The sensor subsystem holds all the detection tools to monitor the car's state. The temperature sensor measures the car's internal temperature and will relay it to the microcontroller for further processing. The proximity sensor detects whether or not the window has been lowered enough. Once the proximity sensor no longer senses the window, it will alert the microcontroller. The weight sensors will measure up to 200 kg (440.925 lbs) and send the data to the microcontroller. The purpose of the weight sensor is to detect the presence of passengers; if sufficient weight is detected, then the window-lowering system will be enabled. Otherwise, even if the temperature in the car exceeds the temperature threshold, it will not open the windows. The CO sensor will periodically measure the CO levels in the vehicle when it is on. It will communicate with the microcontroller if the levels are at or exceeding 9 ppm. All four of these sensors are powered by the Power and Voltage Control Subsystem: the CO, proximity, and weight sensors will connect to the 12-to-5 volt voltage converter, while the temperature sensor is connected to the 12-to-3.3 volt voltage converter. Additional processing is done for the CO sensor to accommodate its unique voltage requirements (more in-depth analysis can be found in section 2.4, "Tolerance Analysis"). Thus, the 12-to-5 volt voltage regulator will go through a "CO Voltage Control" circuitry to properly power the sensor. The temperature, proximity, and weight sensors will be activated when the vehicle is off.

### 2.2.2 App Subsystem

The app allows the user to remotely monitor their car's interior through the camera in real-time. If needed, the user can also talk to any passengers in the car through the speaker. This is done through wireless communication (Wifi) between the microcontrollers and the app. When the temperature inside the car has reached the threshold, the app also alerts the user that the car windows have been lowered. If the CO levels reach 9+ ppm, the app will notify the user and recommend the car exhaust be changed.

### 2.2.3 Power and Voltage Control Subsystem

The Power and Voltage Control subsystem manages the system's power needs. This subsystem consists of multiple step-down voltage converters that convert the voltage from the main power source to the required lower voltage for each component. In total, this subsystem has two voltage regulators for converting to 5 volts, two voltage regulators for converting to 3.3 volts, and two voltage converters for converting to 1.5 volts. For our main PCB, which sits on the car door, the input voltage is 12 volts. This voltage comes from the car battery and is considered the car's resting voltage. The carbon monoxide and proximity sensors require 5 volts, thus, a voltage converter is used to convert the 12 volts to 5 volts. The temperature sensor and ESP-32 WROOM require 3.3 volts. A second voltage converter will be used to convert the 12-volt power source to 3.3 volts. The communication module PCB (second PCB) will be powered by a 9-volt alkaline battery. The camera requires 5 volts to be powered. The 9-to-5 volt voltage converter will power the camera. The ESP-32-S2 and temperature sensor (this sensor ensures the battery temperature is at a safe level) need 3.3 volts and will use a 9-to-3.3 volt voltage converter.

### 2.2.4 Microcontroller

There will be two microcontrollers within our system: an ESP32-WROOM and an ESP32-S2 [5].

1. The sensor microcontroller (ESP32-WROOM) manages the values from the sensors and computes the necessary actions. The microcontroller is powered by 3.3 volts from the 12-to-3.3 voltage converter. After the microcontroller reads the temperature sensor output, it computes if the output is greater than or equal to the threshold. If so, the microcontroller sends a signal to the CAN Bus to lower the windows. The microcontroller will also send a notification via the app to notify the user that the windows have been lowered and the temperature in the car is too high. This microcontroller also accepts the values from the weight, carbon monoxide, and proximity sensors. For the weight sensor, when the value is above the threshold, the microcontroller will record that passengers are present in the car. This will allow the system to check if the windows should be lowered when the temperature is above the set threshold. The system will not check the temperature if no one is in the car since we do not want the windows to lower in an empty car. The carbon monoxide sensor will send the level of CO in the car in ppm to the microcontroller. The microcontroller will then compare this value to the threshold. If the value is higher than the threshold, then the microcontroller will have the speaker announce that the CO levels are high. The microcontroller will also send a notification to the app to notify the user that their car's CO levels are too high and they need to get their exhaust checked. Lastly, the proximity sensor will send a signal stating

whether or not a window is lowered. The microcontroller will use this signal to confirm that the windows were lowered and send a notification to the app. If this fails, the microcontroller will alert the user that the temperature is high, but windows cannot be lowered.

2. The secondary microcontroller (ESP32-S2) manages the data from the camera and the speaker module. The microcontroller is powered by a 9-to-3.3 volt voltage converter, and it takes in values from the OV2640 lens and streams the camera footage to the app over Wifi. Furthermore, this microcontroller receives microphone data from the app through Wifi and transmits that information to an external speaker (CVS-1508) within the car. Lastly, the microcontroller takes in readings from a second temperature sensor which monitors the internal temperature of the communication apparatus. This is to ensure that none of the components (especially the battery) overheat.

### 2.2.5 Monitoring and Communication Subsystem

The monitoring and communication subsystem allows the user to monitor their car remotely from the app. The data from the camera and speaker is stored in the ESP32-S2 microcontroller, which feeds wirelessly to the app through Wifi. The system consists of a camera that relays the interior of the vehicle in real-time and a speaker for remotely communicating with any passengers inside. Since the communication subsystem will be located above the rearview mirror, a second PCB will be used for this system, which is connected to the ESP32-S2 chip and OV2640 lens via an FPC-24 connector. This system is powered by the Power Subsystem. This camera is powered by a 9 volt battery that goes into a 9-to-5 volt voltage regulator since the voltage reading across the camera will be 5 volts. The speaker is powered by a 9-to-3.3 volt voltage converter chained with a 3.3-to-1.5 volt voltage converter since the voltage reading across the speaker is around 1.5 volts. A second temperature sensor will be used to regulate the battery’s temperature since the system will be located in a heated setting simulating the environment of a hot car.

## 2.3 Subsystem Requirements

### 2.3.1 Sensor Subsystem

- CO Sensor:
  - The voltage input to the sensor is 5 volts.
  - The sensor reads the CO levels (ppm) in the car within $\pm$ 1 ppm.
- Proximity Sensor:
  - The voltage input to the sensor is 5 volts.
  - The sensor reads if there is a window 2 $\pm$ 0.5 inches in front of it [6].
- Temperature Sensor:
  - The voltage reading across the sensor is 3.3 volts.
  - The sensor correctly reads the temperature within $\pm$ 5 degrees.
- Weight Sensor:
  - The voltage reading is 5 volts.
  - The sensor reads the weight within $\pm$ 5 lbs.

### 2.3.2 App Subsystem

- The app is able to receive the microcontroller data within a 1 km radius [7].
- The app notifies the user within two minutes of any changes detected in the car.

### 2.3.3 Power System

- 12-to-5 Voltage Converter:
  - Must convert the 12 volt power source to 5 volts.
  - The voltage reading across the proximity sensor should be around 5 volts.
  - The current reading should be 15 mA for the proximity sensor.
  - The voltage reading across the Carbon Monoxide sensor should cycle between around 1.5 volts and 5 volts.
    - When the Carbon Monoxide sensor is sensing the CO levels, the voltage should be around 1.5 volts.
- 12-to-3.3 Voltage Converter:
  - Must convert the 12-volt power source to 3.3 volts.

  - The voltage reading across the microcontroller should be around 3.3 volts.
  - The voltage reading across the temperature sensor should be around 3.3 volts.
- 3.3-to-1.5 Voltage Converter:
  - Must convert the 3.3 volts from ESP32-WROOM to 1.5 volts.
  - The voltage reading across the speaker should be around 1.5 volts.
- 9-to-5 Voltage Converter:
  - Must convert the 9 volts from the battery to 5 volts.
  - The voltage reading across the camera should be around 5 volts.
- 9-to-3.3 Voltage Converter:
  - Must convert the 9 volts from the battery source to 3.3 volts.
  - The voltage reading across the microcontroller should be around 3.3 volts.
  - The voltage reading across the temperature sensor should be around 3.3 volts.
- 3.3-to-1.5 Voltage Converter:
  - Must convert the 3.3 volt from ESP32-S2 to 1.5 volts.
  - The voltage reading across the speaker should be around 1.5 volts.

**2.3.4 Microcontroller**

- The voltage reading across the microcontrollers is 3.3 volts.
- The ESP 32-WROOM microcontroller waits at max two minutes for the proximity sensor to confirm the windows have been lowered.
- When the ESP32-WROOM reads a value of 9+ ppm, it will warn the app of abnormal CO levels.
- When the ESP32-WROOM reads a temperature of 85 ℉ or greater, the windows will lower.
- When the ESP32-WROOM reads that there are no objects detected in front of it $2 \pm 0.5$ inches away, the windows will stop lowering.
- When the ESP32-WROOM reads that there are 40+ lbs, it allows the window-lowering system to be activated.
- The ESP32-WROOM will send a signal to the CAN Bus to lower the windows.
- The video feed of the ESP32-S2 microcontroller sent to the application has at maximum a 5 second delay.

**2.3.5 Communication Subsystem**

- The voltage reading across the camera will be 5 volts.
- The camera has a visibility of 6 feet.
- The camera video delay is at a maximum of 5 seconds.
- The voltage reading across the speaker will be 1.5 volts.
- The audio output of the speaker will measure 73 dBA ± 3 dBA [8].

## 2.4 Tolerance Analysis

One of the most important aspects of our project is the Carbon Monoxide Sensor. This sensor measures the level of carbon monoxide that is in the car when it is running. Since CO is an odorless and colorless gas, it checks that the user does not have a faulty engine and that the car is safe to drive in.

There are two requirements to ensure that the CO sensor is correctly functioning: the sensor is preheated ahead of time, and the voltage cycles between 1.5 and 5 volts [5, Table.1], [9]. The sensor measures the level of carbon monoxide in the environment during the 1.5 volt cycle. These cycles can be done with a Pulse Width Modulation (PWM) [10], [11].

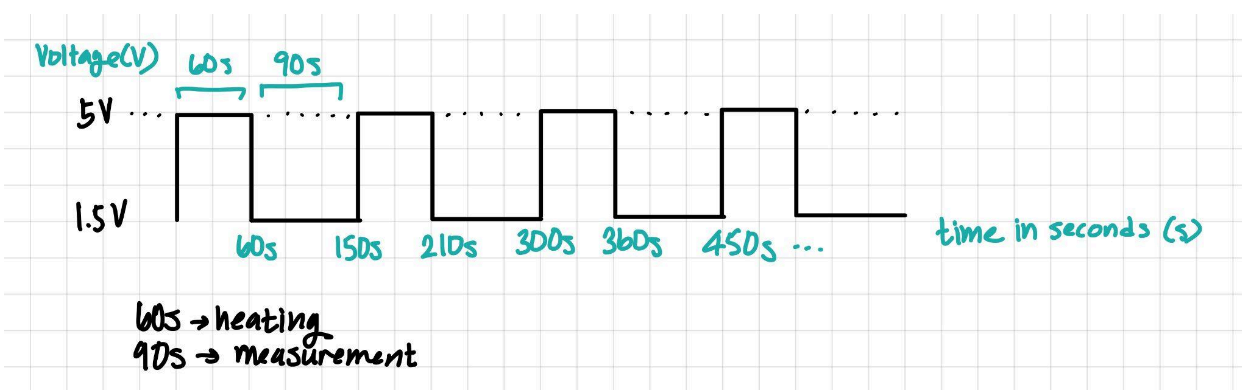


*Figure 3: Graph of the Pulse Wave Modulation for How the Voltage of CO Cycles*

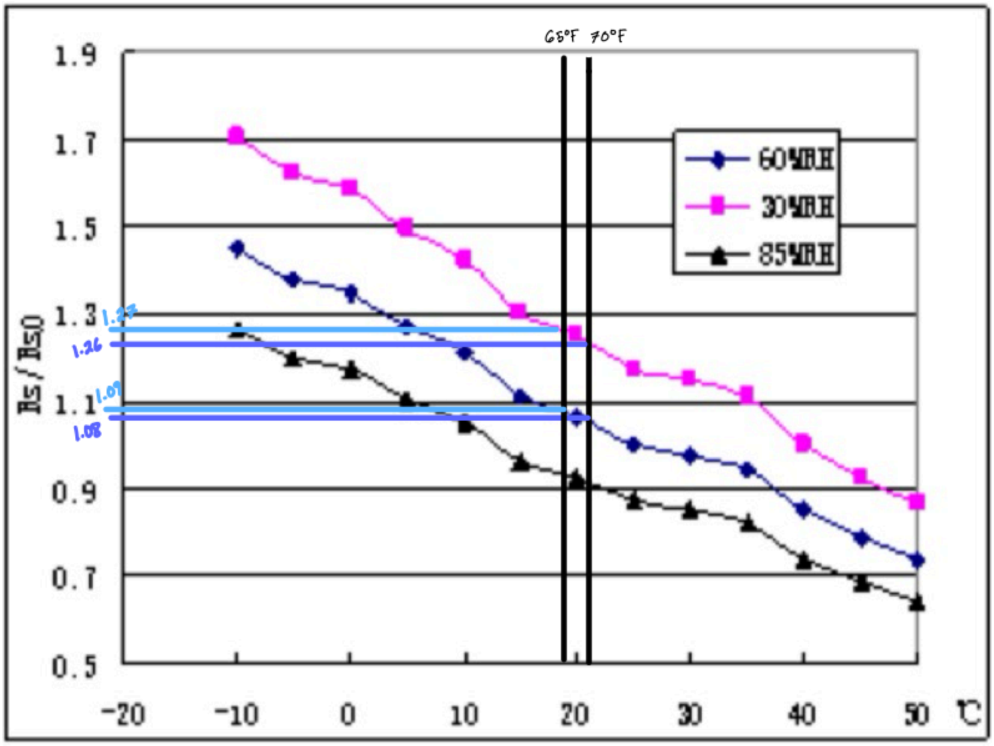


*Figure 4: Graph of the Ratio of Resistance of the Sensor Based on Temperature and Humidity. [9, Fig.4] and annotations done by Parvati Menon*

The MQ-7 datasheet [9, Fig.4] provides the range of resistances the sensor will have under different temperature and humidity conditions. This is displayed as a ratio (Rs/Rso), with Rs being the resistance of the MQ-7 sensor under adjusted conditions, while Rso is the resistance under the manufacturer's standard testing setting. Thus, the approximate resistance of the sensor in our system can be calculated.

Since carbon monoxide is a potential threat that can only happen when the car is on with the exhaust running, the average condition of the MQ-7 will be in AC. This means that the temperature will most likely be around 65 - 70℉ (18.33 - 21.11℃), a comfortable temperature for people to be in. Additionally, the average humidity level inside a running car is around 27.5%-49.3% [12]. Thus, humidity levels between 30% and 60% are analyzed.

| Temperature | Humidity | Rs/Rso (resistance ratio) | Resistance |
|---|---|---|---|
| 65℉ (18.33 ℃) | 30% | 1.27 | 36.83 $\pm$ 3.81 Ω |
| 70 ℉ (21.11 ℃) | 30% | 1.26 | 36.54 $\pm$ 3.78 Ω |
| 65 ℉ | 60% | 1.09 | 31.61 $\pm$ 3.27 Ω |
| 70 ℉ | 60% | 1.08 | 31.32 $\pm$ 3.24 Ω |

*Table 1: Resistance across CO sensor based on the Temperature and Humidity*

Given the Rso value of 29 $\pm$ 3 Ω [9, Table.1], we calculated the resistance across the CO sensor for the upper and lower bounds of the temperature and humidity.

For 65℉ and 30% humidity:

$$\frac{Rs}{Rso} = \frac{Rs}{29\,\Omega} = 1.27 \rightarrow Rs = 36.83 \pm 3.81\,\Omega \quad (1)$$

For 70℉ and 30% humidity:

$$\frac{Rs}{Rso} = \frac{Rs}{29\,\Omega} = 1.26 \rightarrow Rs = 36.54 \pm 3.78\,\Omega \quad (2)$$

For 65℉ and 60% humidity:

$$\frac{Rs}{Rso} = \frac{Rs}{29\,\Omega} = 1.09 \rightarrow Rs = 31.61 \pm 3.27\,\Omega \quad (3)$$

For 70℉ and 60% humidity:

$$\frac{Rs}{Rso} = \frac{Rs}{29\,\Omega} = 1.08 \rightarrow Rs = 31.32 \pm 3.24\,\Omega \quad (4)$$

At 1.5V, the CO sensor is sensing CO levels.

Equations 5-7 are calculated for 65℉ and 30% humidity.

$$P = \frac{V^2}{R} = \frac{1.5^2}{33.02\ \Omega} = 0.068\ W \tag{5}$$

$$P = \frac{V^2}{R} = \frac{1.5^2}{36.83\ \Omega} = 0.061\ W \tag{6}$$

$$P = \frac{V^2}{R} = \frac{1.5^2}{40.64\ \Omega} = 0.055\ W \tag{7}$$

Equations 8-10 are calculated for 70℉ and 30% humidity.

$$P = \frac{V^2}{R} = \frac{1.5^2}{32.76\ \Omega} = 0.069\ W \tag{8}$$

$$P = \frac{V^2}{R} = \frac{1.5^2}{36.54\ \Omega} = 0.062\ W \tag{9}$$

$$P = \frac{V^2}{R} = \frac{1.5^2}{40.32\ \Omega} = 0.056\ W \tag{10}$$

Equations 11-13 are calculated for 65℉ and 60% humidity.

$$P = \frac{V^2}{R} = \frac{1.5^2}{28.34\ \Omega} = 0.0.079\ W \tag{11}$$

$$P = \frac{V^2}{R} = \frac{1.5^2}{31.61\ \Omega} = 0.071\ W \tag{12}$$

$$P = \frac{V^2}{R} = \frac{1.5^2}{34.88\ \Omega} = 0.065\ W \tag{13}$$

Equations 14-16 are calculated for 70℉ and 60% humidity.

$$P = \frac{V^2}{R} = \frac{1.5^2}{28.08\ \Omega} = 0.080\ W \tag{14}$$

$$P = \frac{V^2}{R} = \frac{1.5^2}{31.32\ \Omega} = 0.072\ W \tag{15}$$

$$P = \frac{V^2}{R} = \frac{1.5^2}{34.56\ \Omega} = 0.070\ W \tag{16}$$

At 5V, the CO sensor stops sensing CO levels.

Equations 17-19 are calculated for 65℉ and 30% humidity.

$$P = \frac{V^2}{R} = \frac{5^2}{33.02\ \Omega} = 0.757\ W \tag{17}$$

$$P = \frac{V^2}{R} = \frac{5^2}{36.83\ \Omega} = 0.679\ W \tag{18}$$

$$P = \frac{V^2}{R} = \frac{5^2}{40.64\ \Omega} = 0.615\ W \tag{19}$$

Equations 20-22 are calculated for 70℉ and 30% humidity.

$$P = \frac{V^2}{R} = \frac{5^2}{32.76\ \Omega} = 0.763\ W \tag{20}$$

$$P = \frac{V^2}{R} = \frac{5^2}{36.54\ \Omega} = 0.684\ W \tag{21}$$

$$P = \frac{V^2}{R} = \frac{5^2}{40.32\ \Omega} = 0.620\ W \tag{22}$$

Equations 23-25 are calculated for 65℉ and 60% humidity.

$$P = \frac{V^2}{R} = \frac{5^2}{28.34\ \Omega} = 0.882\ W \tag{23}$$

$$P = \frac{V^2}{R} = \frac{5^2}{31.61\ \Omega} = 0.791\ W \tag{24}$$

$$P = \frac{V^2}{R} = \frac{5^2}{34.88\ \Omega} = 0.717\ W \tag{25}$$

Equations 26-28 are calculated for 70℉ and 60% humidity.

$$P = \frac{V^2}{R} = \frac{5^2}{28.08\ \Omega} = 0.890\ W \tag{26}$$

$$P = \frac{V^2}{R} = \frac{5^2}{31.32\ \Omega} = 0.798\ W \tag{27}$$

$$P = \frac{V^2}{R} = \frac{5^2}{34.56\ \Omega} = 0.723\ W \tag{28}$$

The average car battery capacity is 48 amp hours [13], and the maximum number of hours it is safe for one to drive continuously without a break is 8.5 hours [14]. We are considering the worst-case scenario. To support this drive, the car battery supplies 5.647 amps.

$$I = \frac{48\ amps*hrs}{8.5\ hrs} = 5.647\ amps \tag{29}$$

When our sensor operates at 1.5 volts, the minimum power consumption is 0.055 watts, and the maximum power consumption is 0.080 watts. The resulting current is $0.037$ amps and 0.053 amps, respectively. These two values are less than 5.647 amps, thus, while the sensor is checking the CO levels in the car, it is not consuming more current than the car battery supplies.

At 1.5 volts, using minimum power

$$I = \frac{P}{V} = \frac{0.055\ W}{1.5\ V} = 0.037\ amps \tag{30}$$

At 1.5 volts, using maximum power

$$I = \frac{P}{V} = \frac{0.080\ W}{1.5\ V} = 0.053\ amps \tag{31}$$

When our sensor operates at 5 volts, the minimum power consumption is 0.615 watts and the maximum power consumption is 0.890 watts. The resulting current is 0.123 amps and 0.890 amps, respectively. These two values are less than 5.647 amps. Thus, while the sensor is in the heating cycle, it is not consuming more current than the car battery supplies.

At 5 volts, the using minimum power

$$I = \frac{P}{V} = \frac{0.615\ W}{5\ V} = 0.123\ amps \tag{32}$$

At 5 volts, using maximum power

$$I = \frac{P}{V} = \frac{0.890\ W}{5\ V} = 0.178\ amps \tag{33}$$

Considering the worst-case scenario time that the car is on, the carbon monoxide sensor draws a very low current from the car battery. This sensor is safe to use within our system since it draws a small amount of current to operate and does not cause the car battery to excessively lose charge.

## 3 Ethics and Safety

Our project follows the IEEE Code of Ethics [15].

Ethical Concerns: Leaving your child or pet in a locked, hot car is illegal and dangerous. This project is in no way promoting or condoning this behavior. Instead, it is a safety measure to mitigate any potential heatstrokes or deaths in the case that a child/pet is left in the hot car. Our project strives to "comply with ethical design and sustainable development practices" as defined by the IEEE Code of Ethics 7.8.I.1 [15].

Concerning electrical safety:
Battery Safety: We are using the ECE Shop's alkaline 9 volt battery. This is the safest option out of lead acid and lithium battery. This battery is non-toxic and does not leak chemicals. We will have thermal insulation pads to ensure the battery does not overheat. We will also have a divider to prevent contact with the other components. In addition, we will "hold paramount the safety, health, and welfare" as defined by the IEEE Code of Ethics 7.8.I.1 [15].

Data Privacy: Our device asks the user for consent to record them and use their voice. This data is not used anywhere else. This is "to protect the privacy of others and to disclose promptly factors that might endanger the public or the environment," as defined in the IEEE Code of Ethics 7.8.I.1 [15].

Protection of Car Components: We use the CAN Bus signal to communicate with the buttons to lower the windows. A problem that can arise is the window getting stuck instead of going down. This would lead to the motors continuously running, which ruins the user's car window [16]. To prevent this, we will ensure the signal is only being sent for two minutes. Our proximity sensor will be an additional layer of prevention by sending a signal to stop the window from lowering past a defined threshold. This preventative measure is meant "to avoid injuring … their property … by false or malicious actions," as defined by the IEEE Code of Ethics 7.8.II.9 [15].

Sensor Safety: We will use a multimeter to test the current reading across the CO sensor to ensure we do not consume too much power by exceeding the maximum it allows. This is also to ensure that we “hold paramount the safety, health, and welfare” as defined by the IEEE Code of Ethics 7.8.I.1 [15].

Concerning heat safety:

Component Heat Protection: Our system is built to last in high heat conditions since it is meant to sit in a hot car. We will place thermal insulation pads to protect the heat-sensitive components. This ensures the components are not damaged by excessive heat, which will “hold paramount the safety, health, and welfare,” as defined by the IEEE Code of Ethics 7.8.I.1 [15].

All group members have completed the required lab safety training before beginning the project. Additionally, we have read the “General Battery Safety” document [17], which outlines the safety measures for using batteries to power our system.

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