Car Catalytic Converter Theft Prevention

Aditi Tyagi (aditit2)
Anushka Parikh (aparik28)
Shruthii Sathyanarayanan (ss57)
TA: Stasiu Chyczewski

1. Introduction

1.1 Problem

A catalytic converter is a device on cars that converts toxic gas from the car's engine into non-toxic gas. This device uses precious metals like platinum, palladium, and rhodium to convert carbon monoxide, hydrocarbons, and nitrogen oxides to carbon dioxide, nitrogen, and water vapor. These metals are extremely rare and expensive, and given the increase in prices of metals in recent years, catalytic converters have become a prime target for thieves. Catalytic converters are located at the bottom of the car behind the front wheels, and can easily be removed or sawed off by someone in less than 10 minutes [1]. Additionally, catalytic converters are prime targets for thieves because they are hard to trace [2]. Once they have been stolen, catalytic converters can be sold as scrap metal for 150 to 200 dollars a piece.

In the past year alone, car catalytic converter theft has risen by 400% [1]. These thefts are a large inconvenience to many car owners. The most common targets for catalytic converter theft are SUVs, Prius, Tacoma, and the Accord based on the thefts reported in the past years [1]. In fact, the Toyota Prius has been a prime target because its hybrid nature results in a lower emission load compared to traditional gasoline vehicles. As a result, the catalytic converter in these cars does not need to work as hard and last longer, which in turn increases the value of the precious metals and scrap metal of the catalytic converter.

Driving without a catalytic converter disables the emission system in cars and is against the law in every state [3]. On average, the costs to replace catalytic converters can be as high as $2500. According to an incident in Champaign County, the car owner paid $1,900 for replacement and repairs [4]. Most victims end up having little evidence aside from stolen converters, and low quality video evidence.

1.2 Solution

According to experts, car owners can prevent car catalytic converter theft by adding a camera, motion sensors or flood lights to deter thieves [2]. We will implement this into our solution. Our solution is to create a surveillance device for catalytic converter theft. The device would be able to detect suspicious activity, give real time notifications to the owner when the crime is happening, and would be mounted discreetly. Another feature would be having a camera functionality to solve the low quality surveillance video issue, and setting off an alarm when the suspicious activity occurred.

To create this device, we will use a vibration or motion sensor to detect if a thief attempts to move the car when it is parked. This sensor will trigger the alarm system which will scare off the thief. Then, it will send a notification to the car owner's mobile phone or device. The sensor will also trigger the camera to try to capture the thief and create evidence for the theft.

1.3 Visual Aid

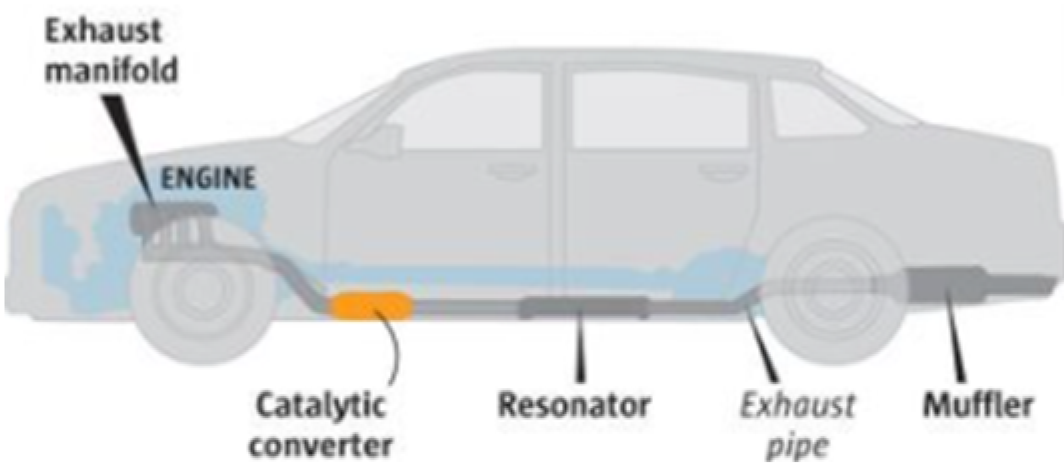

Figure 1: Traditional Exhaust System

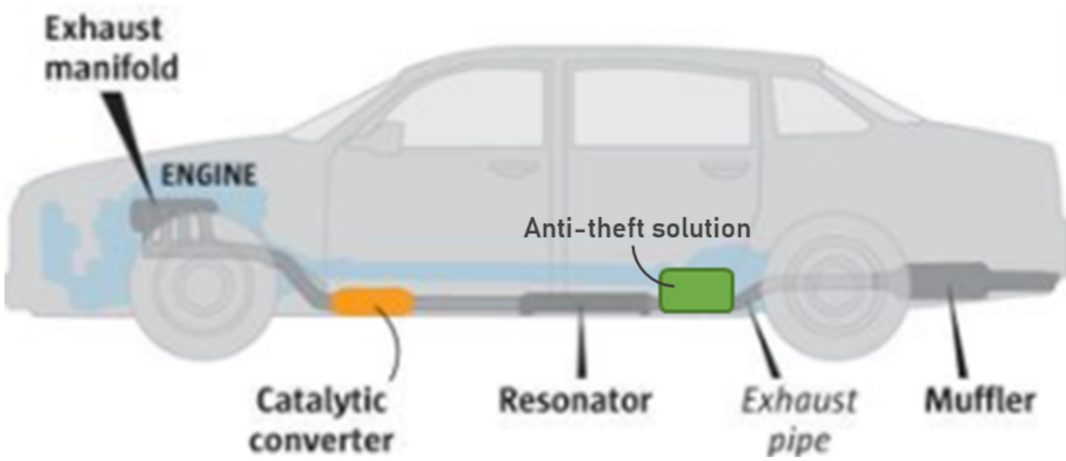

Figure 2: Location of our Device Highlighted by the Green Box between the Resonator and Exhaust Pipe

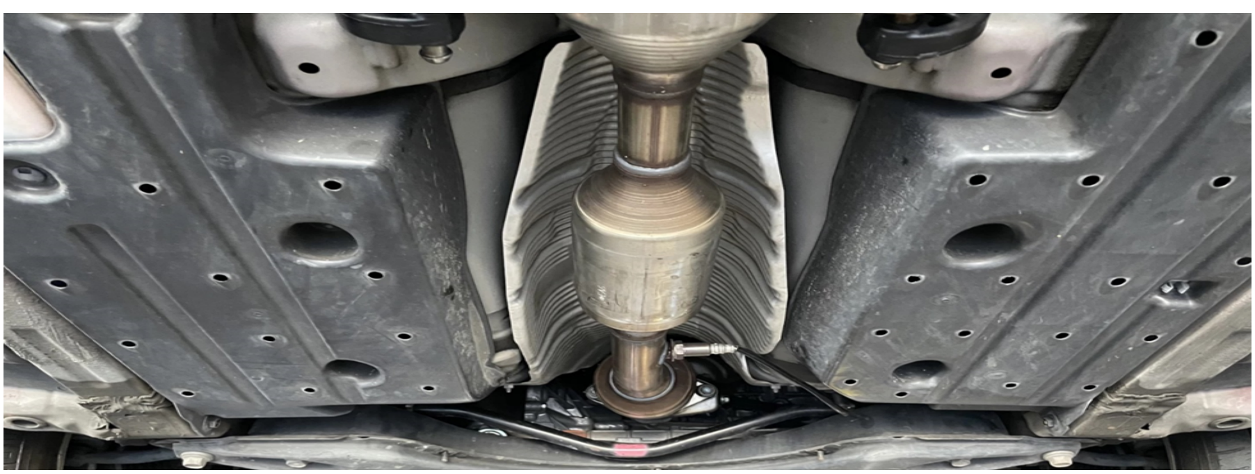
Figure 3: View of the Catalytic Converter from our Proposed Solution

1.4 High-Level Requirements

1) The device must be able to trigger the motion sensors (this includes the PIR and microwave sensors) within 5 to 15 seconds after the car has been tampered with. What this accomplishes is that it allows the system to act quickly once the converter is being tampered with. The device must also trigger the motion sensors at least 4 out of 5 times after it has been tampered which gives the device an 80% accuracy rate.
2) After the motion sensors are activated, the system must trigger the alarms and send a notification to the user within 5 to 15 seconds. The camera must also start recording within 15 seconds after the sensor has been triggered.
3) The surveillance device must have a height between 2 to 4 inches, a maximum length of 6 inches, and maximum width of 8 inches. The height constraint was determined by the camera angle and the ideal camera position to be able to record the catalytic converter and a thief attempting to steal it. The length and width was determined by the space where the device will be placed.

2. Design

2.1 Block Diagram

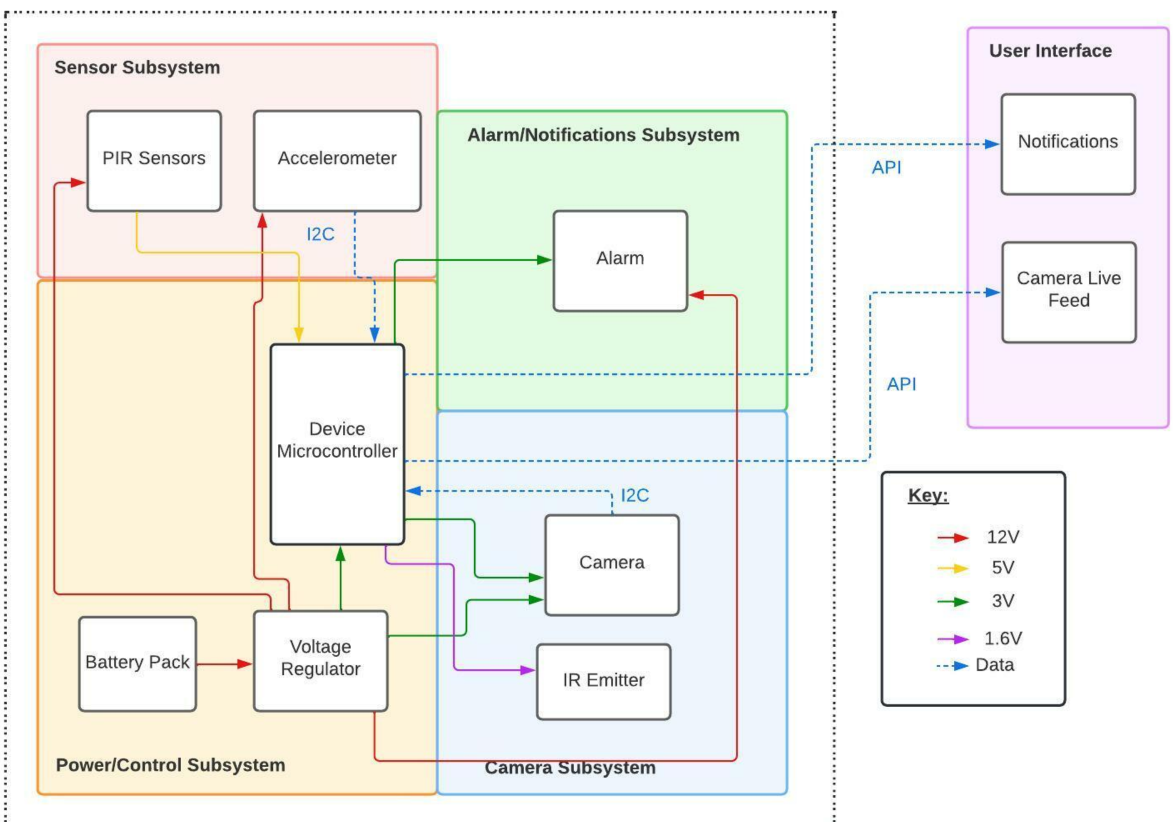

Figure 4: Block Diagram of the Solution

2.2 Subsystem Overview and Requirements

2.2.1 Power/Control Subsystem

The purpose of the Power/Control Subsystem is to be able to power the other adjoining subsystems and control the microcontroller. The power component comprises a 12 Volt Battery, that will power each subsystem. The Sensor Subsystem and Alarm Subsystem require 12V while the Camera Subsystem and Microcontroller require 3.3V. To control the voltage for each subsystem, we will build a voltage regulator and send different voltages to each subsystem.

The Power/Control Subsystem also includes the microcontroller and the components necessary for the microcontroller. Our device must be able to send data to a mobile app. For this project, we have decided to use WiFi to send the data, so the microcontroller must be compatible with WiFi. It must be able to stream videos and connect to an application.

After some research, we found the best option for the project is the ESP32-WROOM-32 [5]. We will be using this microcontroller as it has WiFi compatibility and can be used to stream video to an app [6]. This microcontroller also has modern, light, and deep sleep options which can be used when the car is in motion and to save battery.

In Figure 6, we connected the microcontroller with the necessary push buttons for the Enable and IO0. The microcontroller uses 3.3V which will be provided by the voltage divider. The microcontroller will be programmed with the CP2102 Adapter which uses a UART protocol. We plan to connect all IO pins to connectors, but this may change due to the size constraint on our device. The IO pins will be connected to the Sensor, Alarm, and Camera Subsystem, and it will be the primary communication between the subsystems.

Requirements	**Verifications**
1. The power supply provides 12V (+-5%).	1. Measure the output voltage using an oscilloscope, ensuring that the output voltage stays within 5% of 12V.
2. Voltage Regulator 1 provides fixed 5.0 V (+/- 0.5%) from 12V source.	2. Measure the output voltage using an oscilloscope, ensuring that the output voltage stays within 5% of 6V.
3. Voltage Regulator 2 provides fixed 3.3 V (+/- 0.5%) from 12 V source.	3. Measure the output voltage using an oscilloscope, ensuring that the output voltage stays within 5% of 3.3V.
4. Both regulators maintain thermal stability below 125°C	4. During verification for Requirement 2 and 3, use an IR thermometer to ensure the IC stays below 125°C
5. The microcontroller sends a 3V to 3.3V signal to turn off the alarm and a 5V to 5.5V signal to turn on the alarm.	5. Connect sensors to microcontrollers. Measure voltage at the signal for the Alarm Subsystem using an oscilloscope. Then, activate sensors by moving the device. Measure voltage at the signal for the Alarm Subsystem using an oscilloscope.

6. The microcontroller sends a 3V to 3.3V signal to turn off the camera and a 5V to 5.5V signal to turn on the camera.	6. Connect sensors to microcontrollers. Measure voltage at the signal for the Camera Subsystem using an oscilloscope. Then, activate sensors by moving the device. Measure voltage at the signal for the Camera Subsystem using an oscilloscope.
7. The microcontroller sends a 3V to 3.3V signal to turn off the sensors and a 5V to 5.5V signal to turn on the sensors.	7. Connect sensors to microcontrollers. Measure voltage at the signal for the Sensor Subsystem using an oscilloscope. Then, activate sensors by moving the device. Measure voltage at the signal for the Sensor Subsystem using an oscilloscope.

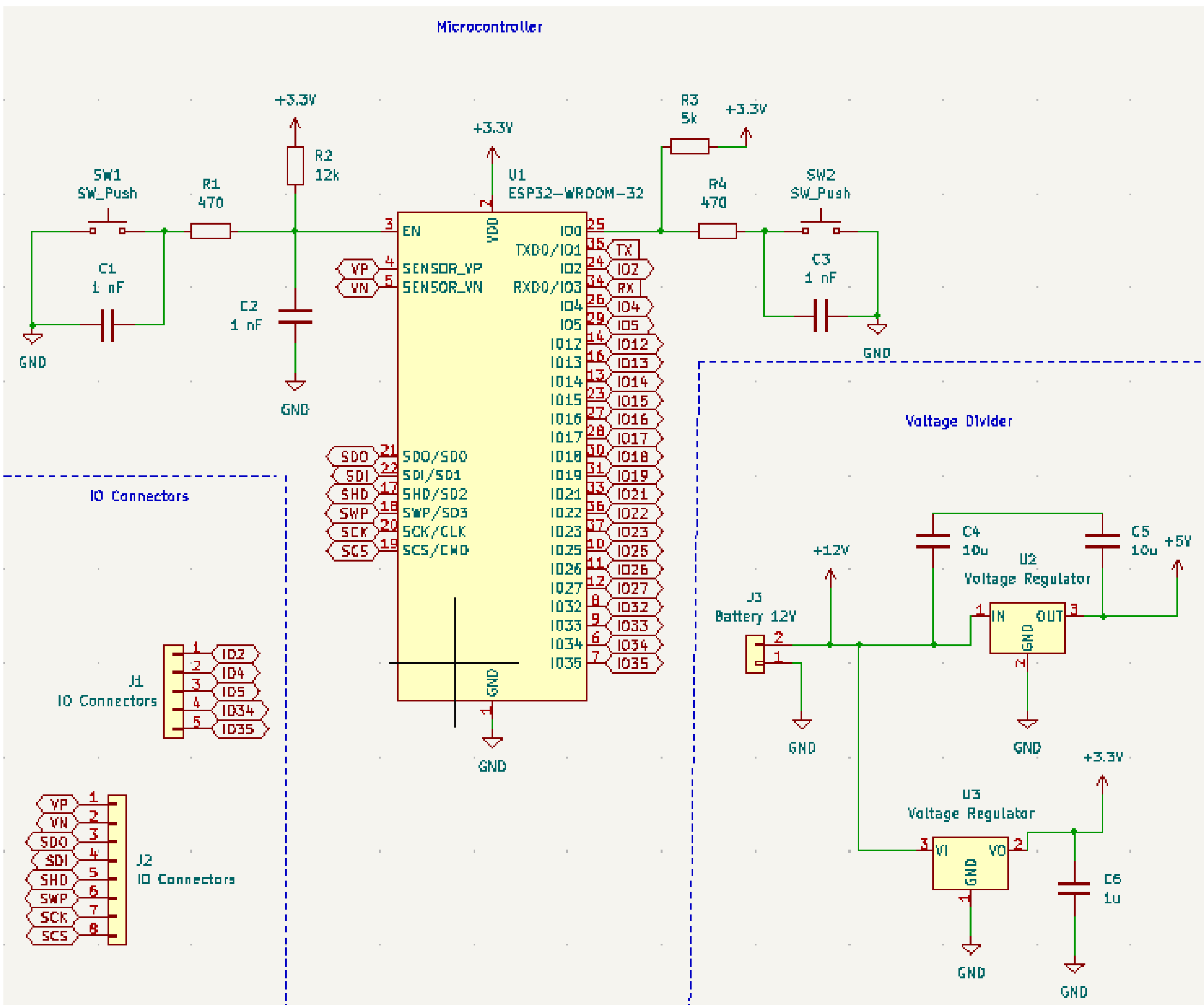

Figure 5: Schematic of Microcontroller, Voltage Divider, and IO Connectors

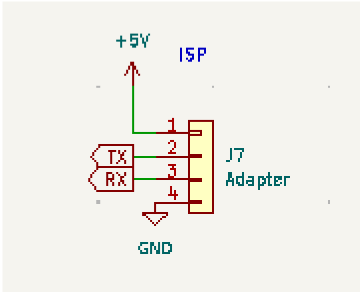

Figure 6 : Schematic of ISP

2.2.2 Sensor Subsystem

The Sensor Subsystem is made up of tilting and vibrations sensors. The main purpose of this subsystem is to be able to sense any suspicious activity occurring, and then accordingly and accurately alarm the system. The sensors will be triggered if a car that is in park is tilted or if any vibration is detected in the undercarriage.

The Passive Infrared (PIR) sensors are small, low power, easy to use, and inexpensive. The way it senses movement is by sensing the change in temperature between the background and a warm body. The sensors contain a pyroelectric sensor that detects levels of infrared radiation, which is useful as the human body emits a good amount of heat. The way the sensor works is that the PIR has two slots made of a special material that is sensitive to infrared. When the sensor senses a differential change between the two slots, this causes a pulse, saying that it has detected a movement. Due to this, the amount of false positives this sensor has is very minimal [7].

In order to detect sense of movement and vibrations, we will use an accelerometer. An accelerometer is an electromechanical device used to measure acceleration forces. Such forces may be static, like the continuous force of gravity or, as is the case with many mobile devices, dynamic to sense movement or vibrations [8]. The piezoelectric effect is the most common form of accelerometer and uses microscopic crystal structures that become stressed due to accelerative forces. These crystals create a voltage from the stress, and the accelerometer interprets the voltage to determine velocity and orientation. The capacitance accelerometer senses changes in capacitance between microstructures located next to the device. If an accelerative force moves one of these structures, the capacitance will change and the accelerometer will translate that capacitance to voltage for interpretation [9].

In Figure 7 and 8, we use this feature called a circuit breaker. We use a circuit breaker in the PIR sensor and the accelerometer to turn off the sensor when the car is parked. This preserves the battery and reduces the false positive rate of the device.

Requirements	**Verifications**
1. Once the motion sensors have been triggered, they must trigger the alarm and notification systems within 5 to 15 seconds	1. Connect circuit as shown in schematic. Record the time between the motion sensors being triggered and the alarm turning on.

2. For the PIR sensor, provide 6.8V +/- 5% from a 5V-12V source	2. Measure the output voltage using an oscilloscope, ensuring that the output voltage stays within 5% of 6.8 V.
3. For the PIR sensor, maintain a thermal temperature that is below 70 C but is above -20 C.	3. Use an IR thermometer to ensure the IC stays below 70 C but is above -20 C
4. For the accelerometer, maintain a thermal temperature that is below 125 C but is above -55 C. This is for the vibration range	4. Use an IR thermometer to ensure the IC stays below 125 C but is above -55 C
5. The weight of the accelerometer should be no greater than 10% of the weight of the surveillance device.	5. Measure the weight of the accelerometer using a scale, and do the same for the surveillance device. Mathematically calculate the 10% difference, making sure it reaches that mark.
6. For the accelerometer, provide a voltage of 4 +- 5%.	6. Measure the output voltage using an oscilloscope, ensuring that the output voltage stays within 5% of 4 V.
7. For both accelerometer and sensor, have them be placed a foot away from the catalytic converter for optimal coverage of area and surroundings.	7. Measure the placement of the accelerometer and the sensor, making sure that it is at least 1 foot away from the catalytic converter.

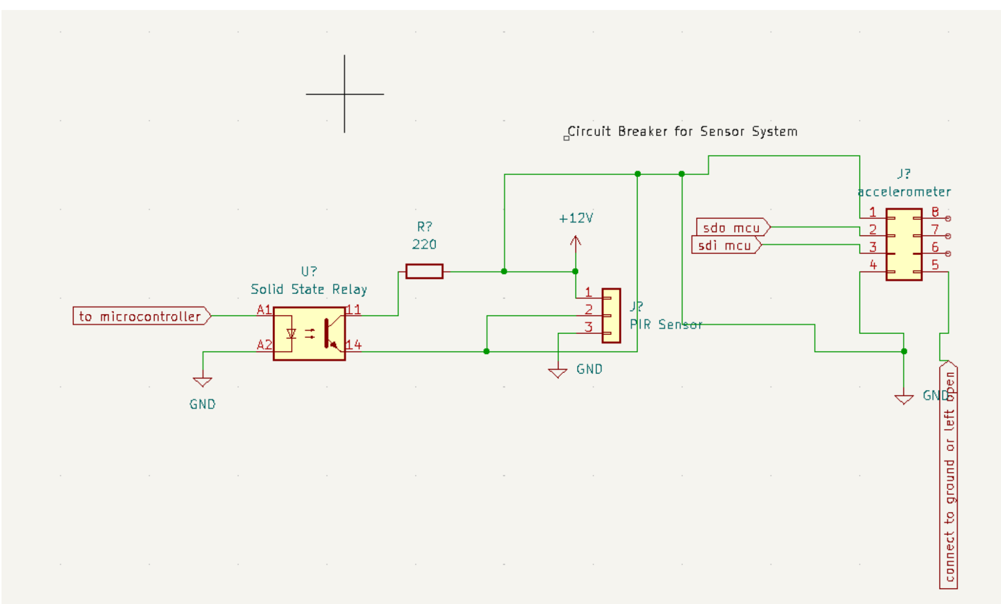

Figure 7: Schematic of PIR Sensor and Accelerometer

2.2.3 Alarm Subsystem

The Alarm Subsystem is comprised of two components: a physical alarm and a notification alert sent to the user. This subsystem utilizes a 120 dB, battery operated, voltage controlled alarm [10] and sends a notification to the car owner's phone via WiFi. The purpose of this subsystem is to set off an alarm and alert the owner if a thief attempts to steal a catalytic converter from a car. The Alarm Subsystem will be triggered by the Sensor Subsystem, i.e., when the vibration and tilting sensors are triggered. If the sensors are triggered for longer than a few seconds, the Sensor Subsystem will send a signal to the Alarm Subsystem, which will trigger the alarm to start ringing.

The 120dB alarm will be attached to the undercarriage of the car alongside the remaining subsystems and is wear resistant, impact resistant, heat resistant, and low temperature resistant [10]. These features will help combat the various temperatures and wear and tear that the alarm will be exposed to. Additionally, the alarm will continue to function even if the car heats up or overheats. Another important feature is impact resistance, which ensures that the alarm will continue to ring (to a certain extent) even if a thief attempts to break or remove it. The alarm by default will ring for 3 to 5 minutes before shutting off. However, the owner can manually turn off the alarm sooner through their phone.

When the Alarm Subsystem is triggered, a notification will be sent to the owner of the car informing them of any suspicious activity. This function will be dependent on WiFi, as the device will use WiFi to send the notification to an app on the owner's phone, alerting them of potential theft in real time.

Requirements	**Verifications**
1. Within 5 to 15 seconds of the sensors being triggered, the alarm must start ringing and a notification should be sent to the user	1. Connect circuit as shown in schematic. Trigger sensors by tilting and moving the device. Record the time between triggering the sensors and the alarm turning on/notification being sent.
2. The alarm should be turned off when the input from the microcontroller is 3V to 3.3V.	2. Connect circuit as shown in the circuit schematic. Send an input of 3V to 3.3V to the alarm subsystem. If the alarm begins to ring, increase the resistance of the resistor in the alarm circuit or decrease the input voltage.
3. The alarm should be turned on when the input from the microcontroller is 9V to 12V.	3. Connect circuit as shown in the circuit schematic. Send an input of 9V to 12V to the alarm subsystem. If the alarm does not ring, decrease the resistance of the relay coil or increase the input voltage. Input voltage should not exceed 12V.
4. The alarm should ring for 3 to 5 minutes or until the user manually turns it off through the mobile app.	4A. Connect circuit as shown in circuit schematic. Record the duration of the alarm once it has been triggered. If triggered longer or shorter than desired time, modify components between sensors and alarm and

	edit code to decrease/increase time accordingly. 4B. Connect circuit as shown in circuit schematic. Once the alarm starts ringing, attempt to turn it off via the app. Record the time taken from turning off the alarm on the app to when the alarm actually turns off. If the alarm cannot be controlled from the app, verify network connections and/or reestablish connection between the MCU and phone. If the alarm takes too long to turn off, modify components between MCU and alarm and edit code to decrease time accordingly.

The schematic of the Alarm Subsystem is shown in Figure 9. A solid state relay is used to turn the alarm on or off based on the input from the microcontroller. When the Sensor Subsystem is triggered, the input from the microcontroller to the Alarm Subsystem will increase, which then turns on the alarm to notify the car owner of a potential catalytic converter theft. The alarm that will be used has a standard voltage of 9-12V and a standard current of 100 to 150mA. Using Ohm's law, we can determine a range for the resistance required for the circuit:

$$V = I * R \rightarrow R = V/I$$

$$R = V/I = 9/0.1 = 90\Omega$$

$$R = V/I = 12/.15 = 80\Omega$$

Based on the standard values of resistors, the 82Ω resistor from the E12 series will be the most applicable to the Alarm Subsystem [11]

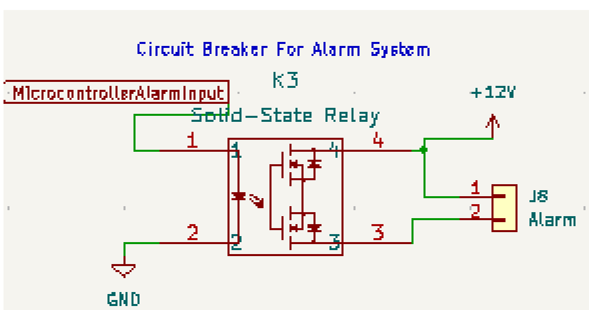

Figure 8: Schematic of Alarm System

2.2.4 Camera Subsystem

The Camera Subsystem consists of two aspects: the physical camera and the camera live footage. The purpose of the camera is to capture footage of the theft. The camera subsystem will be triggered by the Sensor Subsystem. When the Sensor Subsystem detects motion and vibrations, it will send a signal to the Camera Subsystem which will turn on the camera and record footage.

The camera must be able to send data to the microcontroller. It must be able to send colored video footage to the microcontroller. It must also be compatible with Arduino IDE. With these specifications, we decided on the OV7670 camera, as it is compatible with the ESP32-WROOM-32, the microcontroller.

For the physical camera subsystem, we must build two circuit breakers to turn off the camera when the sensors are not activated as shown in Figure 10. For this circuit, we will be using a solid-state relay. When the microcontroller sends 3.3V, the relay will turn off and when the microcontroller sends 5V, the relay will turn on. We must also consider the data sent between the camera and the microcontroller. The OV7670 camera uses the I2C Interface, which also works with the ESP32-WROOM-32. The camera will send data back to the microcontroller and the microcontroller will use WiFi and API calls to send the video data to the user interface. The S10C and S10D use the I2C interface and we have connected them to circuit breakers to turn off and on the camera.

The OV7670 camera must also be connected to a clock at the XCLK input. This clock must be between 10 and 48 MHz [12]. Other outputs like D1 to D7, VSYNC and HREF will be connected directly to the microcontrollers IO connectors.

We tested a phone camera under a car to mimic our solution. During the day, there is enough light to set a camera under the car, but we will need more light for the night. The device must be discrete, so we decided to use an IR emitter. We connected the IR emitter to another circuit breaker to turn it on when the camera turns on.

Requirements	**Verifications**
1. The camera should be turned off when the input from the microcontroller is 3V to 3.3V.	1. Connect circuit as shown in circuit schematic. Send a 3.3V signal at the input from the microcontroller. Check live footage to see if the camera is turned off. If the camera is on, add more resistance to the circuit and check the relay.
2. The camera should be turned on when the input from the microcontroller is 5V to 5.5V.	2. Connect circuit as shown in circuit schematic. Send a 5V signal at the input from the microcontroller. Check live footage to see if the camera is turned on. If the camera is off, add less resistance to the circuit and check the relay.
3. The camera will upload footage on the mobile app with at most a 30 second delay.	3. Connect circuit as shown in circuit schematic. Turn on the camera. Wave a hand in front of the camera. Record the time between waving the hand in front of the camera to the hand appearing on the mobile app. If the camera does not upload the footage within the desired time, edit the code to upload footage faster.
4. When the relay is turned on, the	4. Connect the circuit as shown in the circuit

voltage across the camera should be 3.3V.	schematic. Send a 5V signal to the relay to turn it on. Measure (using a tool like the oscilloscope) the voltage across the camera.

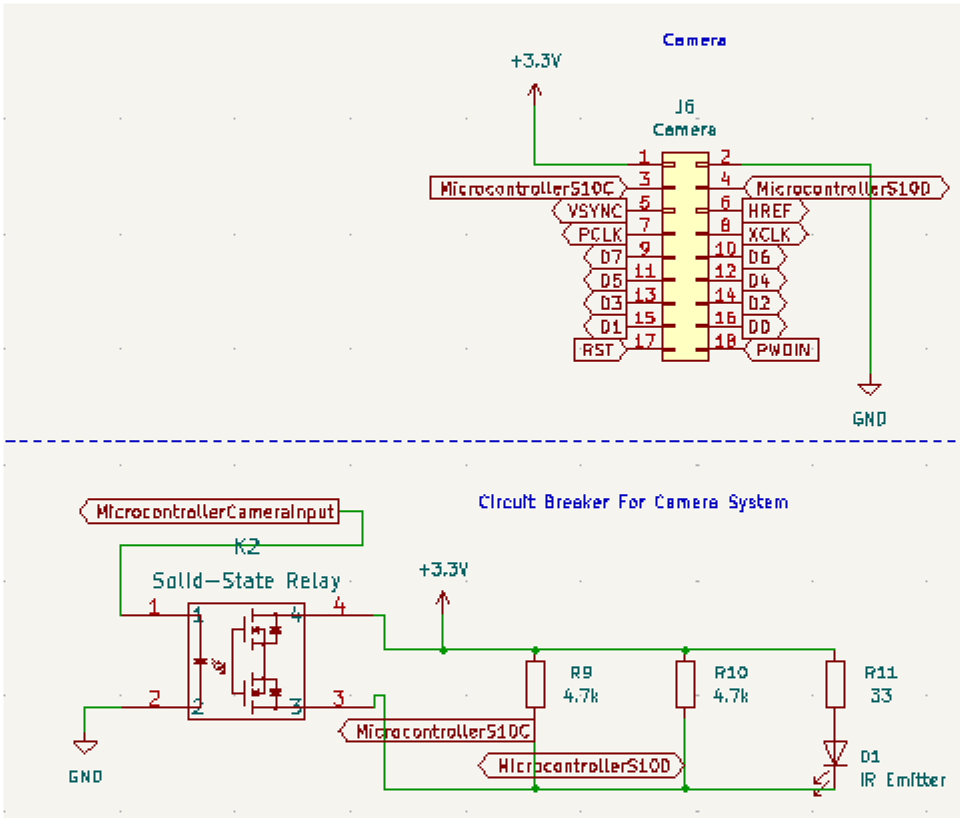

Figure 9: Schematic of Camera

2.3 Tolerance Analysis

An important part of this project is our Sensor Subsystem, and the accuracy of the sensors. For our tolerance analysis, we will look more into the PIR sensor. It is important to be able to identify if the PIR sensor is giving false positives, and if it is, figuring out a way to reduce false positives. An experiment can be performed where we have a false environment and a true environment. The true environment would consist of our device attached on the bottom of the car, and a human at various distances (1 feet, 2 feet , etc). Our false environment would also consist of our device attached on the bottom of the car, but instead have leaves ruffle under the sensors. This creates our false environment as we want our sensors to only be triggered when there's a physical person in the vicinity.

A similar experiment was carried out where a group of researchers wanted to evaluate the reduction of false alarm signals for PIR Sensors in a realistic outdoor environment. In the research paper, they consider two hypotheses, a noise hypothesis and a signal of interest hypothesis. Figure 11 is a graph of what the distribution looks like [13].

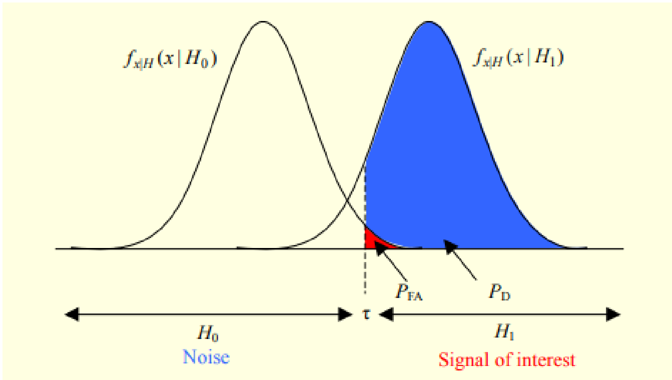

Fig. 1. Concept of binary-hypothesis Neyman-Pearson detector.

Figure 10 : Distribution of noise hypothesis and a signal of interest hypothesis

In this graph, they show the detector detecting the true environment, and take the pdf. According to the figure above, the decision of H1 when H1 is true is called the probability of detection and is denoted by PD. However, the determination of H1 even when H0 is true , which they consider as a false alarm.

In the paper, they discuss two algorithms that help them conclude statistical analysis between the data they collect later on. The first algorithm is the Window Energy Detection Algorithm (WED). The algorithm determines the existence of a moving object after a comparison of the current energy to the threshold calculated using the average energy and its standard deviation . The second algorithm they used in this research was the alarm duration detection (ADD) algorithm. They proposed time domain approaches considering the statistical characteristics of the alarm duration. By testing out both the algorithms, they were able to find some distinctive characteristics between them, defined in Figure 12 [13].

Table 1. Performance comparison between two algorithms.

	WED	ADD
Strong points	-Disappearance of few or no target alarms within the target period -Better performance in detecting targets within the target period	-Better performance in reducing false alarms outside of the target period -Requires less resources, such as memory and computing power
Weak points	-Requires more memory for the energy queue -Poorer performance in reducing false alarms	-Disappearance of several target alarms within the target period -Poorer performance in detecting targets within the target period

Figure 11: Table of performance comparisons between the two algorithms

Further on in the report, the researchers discuss how they gather real information. They make a false and true environment similar to the environment described above. Their false environment consisted of sensor nodes placed in front of bushes at one-meter intervals (from 1 m to 5 m) on a cloudy, windy day. Their true environment consisted of t data for a human adult walking in parallel with a PIR at distances of 2 m, 5 m, 7 m, 10 m, and 15 m at normal speed. They also collected data in different environments and temperatures (30 degrees Celsius, 23 degrees Celsius, and 12 degrees celsius). The data they collected was the average alarm duration in ms, standard deviation alarm duration in ms, average window energy in ms, and standard deviation window energy in ms. Figure 13 is the table of the results [13] .

Table 2. False alarm statistics.

		Total
Alarm duration (ms)	Avg.	424.0
	Std.	219.1
Window energy (ms)	Avg.	489.2
	Std.	248.8

Table 3. Target alarm statistics.

		Case 1	Case 2	Case 3
Alarm duration (ms)	Avg.	762.7	887.0	917.5
	Std.	214.5	137.9	211.7
Window energy (ms)	Avg.	808.7	836.7	839.4
	Std.	170.9	142.9	140.1

Figure 12: Table of the results from the false alarms and true alarms

By taking this data, they created a similar graph as the graph shown above by just taking the associated pdf of the data. Figure 14 is the graph that they created [13].

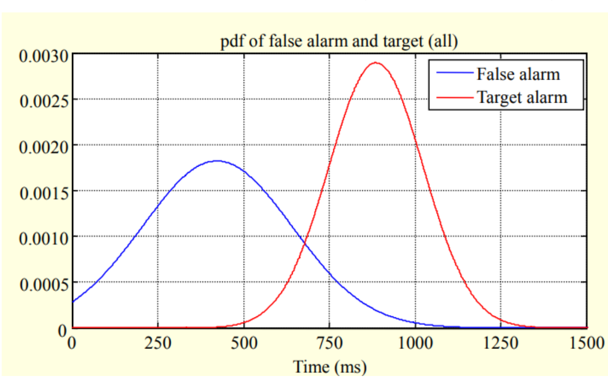

Figure 13: Distribution of the false alarms and the true alarms

By applying the WED algorithm that they used, they were able to obtain a detection rate of about 57.9%, given a 10% false alarm rate, and a false alarm rate of about 25.5%, given a 90% detection rate [13].

With all of this information, we can detect false positives in PIR sensors, avoid these false positives in PIR sensors, and understand the reliability of PIR sensors when testing them in true environments and in false environments.

3. Cost and Schedule

3.1 Cost

Cost of Labor
Salary of Labor : $40/hour
Average hours worked per week : 15 hours
Amount of time in Spring Semester : 16 weeks
Total Cost of Labor : $40/hour * 2.5* 15(hour)* 16 = $24,000 x 3 = **$72,000**

Part #	Mft	Desc	For	Price	Qty	Total
ESP32-WROOM-32	Digikey	Microcontroller	Power/Control Subsystem	$14.95	1	$14.95
OV7670	ECEB	Camera	Camera Subsystem		1	
189	Adafruit Industries LLC	PIR IR motion sensor	Sensor Subsystem	$9.95	1	$9.95
	Amazon	120dB Electronic Alarm	Alarm Subsystem	$9.99	1 pack (2 alarms)	$9.99
CP2102	Walmart	USB to TLL Module Serial Converter Adapter	Programming Microcontroller	$17.98	1	$17.98
34.81.7.012.9024	Newark	Solid-state relay	Sensor, Alarm, and Camera Subsystem	$7.05	6	$21.15
PTS645SL50-2 LFS	Digikey	Push Buttons	Power/Control Subsystem	$0.17	2	$0.34

717-7C-10.000 MBET	Mouser	10MHz Clock	Camera Subsystem	$1.60	1	$1.60
MXC4005XC	Digikey	Accelerometer	Sensor	$1.64	1	$1.64
ASJ-99H-R-HT-T/R	Digikey	Audio Jack	Alarm Subsystem	$0.55	1	$0.55
511-L7805CV	Mouser	Voltage Regulator	Power/Control Subsystem	$0.63	1	$0.63
511-LD1117V33	Mouser	Voltage Regulator	Power/Control Subsystem	$0.77	1	$0.77
QED234	Digikey	IR Emitter	Camera Subsystem	$0.72	1	$0.72

3.2 Schedule

Week	**Aditi Tyagi**	**Anushka Parikh**	**Shruthii Sathyanarayanan**
2/20	● Research parts for sensor subsystem ● Research parts for battery and power subsystem ● Make a draft of circuit schematic ● Get feedback and prepare for design review	● Research parts for camera subsystem ● Research parts for microcontroller ● Make a draft of circuit schematic ● Get feedback and prepare for design review	● Research parts for alarm and notification subsystem ● Make a draft of circuit schematic ● Get feedback and prepare for design review
2/27	● Finalize circuit schematic ● Create PCB design ● Order parts for sensor	● Finalize circuit schematic ● Create PCB design ● Order parts for camera	● Finalize circuit schematic ● Create PCB design ● Order parts for alarm and

	subsystem ● Order parts for power subsystem	subsystem ● Order microcontroller	notifications subsystem
3/6	● Research project box for machine shop	● Order PCB	● Make design for machine shop
3/13 (Spring Break)			
3/20	● Code PCB	● Solder Parts on PCB ● Code Front-End of Android App	● Code Back-End of Android App
3/27	● Test PCB	● Submit Parts to Machine Shop ● Submit Design to Machine Shop	● Test Android App
4/3	● Create tests for sensor subsystem	● Create tests for camera subsystem	● Create tests for alarm and notifications subsystem
4/10	● Test final prototype	● Test final prototype	
4/17	● Report test results ● Prepare for demonstrations	● Report test results ● Prepare for demonstrations	● Test final prototype
4/24	● Do Demonstration ● Prepare for Presentation	● Do Demonstration ● Prepare for Presentation	● Do Demonstration ● Prepare for Presentation
5/1	● Do Presentation	● Do Presentation	● Do Presentation

4. Ethics and Safety

There are several safety considerations to take into account when designing a surveillance device for catalytic converters. Catalytic converters can reach extremely high temperatures of up to 500 degrees Fahrenheit. This can potentially be a hazard depending on the placement of the device, wherein the high temperature can impact our device or even injure the car owner when they attempt to attach/detach the device when the catalytic converter is still hot. In order to ensure the safety of the user, we would determine the placement of the device such that it provides a clear view of the area from which the catalytic converter can be accessed and be placed far enough from the catalytic converter that the user will not be harmed by the high heat. In order to prevent the device from being damaged by the heat, we would consider selecting a temperature-resistant box in which the device may be placed.

A caveat with creating a detachable device is risking the chance of the device being tampered with. If a thief can easily remove the device, it defeats the purpose we aim to solve. In order to prevent tampering, we will use sensors that detect vibrations and movement, which allows us to monitor tampering of the catalytic converter as well as tampering of the device. By sealing the circuitry of the device in a sturdy box, we would be able to notify the car owner before a thief can destroy the box and the device within.

Since our device will be placed on the undercarriage of a car, it will be exposed to external environmental factors that could impact the performance of the device such as extreme temperatures, water from rain, winds, etc. To ensure our device performs well regardless of these environmental factors, we selected as many weather and temperature resistant components as possible and plan to place the device inside a weather, water, and temperature resistant casing.

Our device doesn’t discriminate against who can use it. The device can be used by any car owner. The device is open to the public, and thereby complies with section 7.8 II-7 of the IEEE Code of Ethics. Our device also abides by section 7.8 I-1 , as the device is promoting safety by trying to reduce the number of stolen catalytic devices, which increases the safety of the car itself, and the person driving the car [14].

References

1. Way, “Catalytic converter thefts: Most targeted cars listed.” Way.com. [Online]. https://www.way.com/blog/catalytic-converter-thefts-most-targetted-cars-listed/ [Accessed: 10-Feb-2022].
2. American Family Insurance, “How to Prevent Catalytic Converter Theft.” amfam.com. [Online]. https://www.amfam.com/resources/articles/on-the-road/prevent-catalytic-converter-theft [Accessed: 10-Feb-2022].
3. CarParts, "Can You Drive Without a Catalytic Converter." carparts.com. [Online]. https://www.carparts.com/blog/can-you-drive-without-a-catalytic-converter/#:~:text=Vehicles%20can%20be%20driven%20without,don%27t%20enforce%20emissions%20standards [Accessed : 24-Feb-2022].
4. The News-Gazette , “Catalytic-converter thefts have victims’ vehicles, wallets feeling the pain.” news-gazette.com. [Online]. https://www.news-gazette.com/news/local/courts-police-fire/catalytic-converter-thefts-have-victims-vehicles-wallets-feeling-the-pain/article_cc7a5545-c3a5-54f3-bbda-3ae1d1c94c5c.html [Accessed: 10-Feb-2022].
5. ESP32S2WROOM, "ESP32S2WROOM ESP32S2WROOMI Datasheet." espressif.com. [Online]. https://www.espressif.com/sites/default/files/documentation/esp32-s2-wroom_esp32-s2-wroom-i_datasheet_en.pdf. [Accessed 24-Feb-2022]
6. ESP-IDF Programming Guide, "Wifi." docs.espressif.com. [Online]. https://docs.espressif.com/projects/esp-idf/en/latest/esp32/api-reference/network/esp_wifi.html. [Accessed 24-Feb-2022]
7. Arrow, “How Do Motion Sensors Work? Types & Applications.” arrow.com. [Online]. https://www.arrow.com/en/research-and-events/articles/how-motion-sensors-work#:~:text=Motion%20Sensors%20Explained&text=There%20are%20three%20types%20of,%2C%20and%20Dual%20Tech%2FHybrid [Accessed: 10-Feb-2022].
8. Live Science, “Accelerometers: What They Are & How They Work.” livescience.com [Online]. https://www.livescience.com/40102-accelerometers.html [Accessed: 24-Feb-2022].
9. Science Direct, “Accelerometers.” sciencedirect.com [Online]. https://www.sciencedirect.com/topics/materials-science/accelerometer#:~:text=Accelerometers%20are%20sensing%20devices%20that,of%20human%20movement%20%5B7%5D [Accessed: 24-Feb-2022].
10. “Electronic Buzzer Alarm,” *Amazon*. [Online]. Available: https://www.amazon.com/Electronic-Buzzer-Security-Speaker-Burglar/dp/B0875WCSB5/ref=sr_1_13?keywords=12+volt+alarm+siren&qid=1644354141&sr=8-13 . [Accessed: 10-Feb-2022].
11. Embedded Programmer, "Hacking the OV7670 camera module (SCCB cheat sheet inside)." http://embeddedprogrammer.blogspot.com/[Online].http://embeddedprogrammer.

blogspot.com/2012/07/hacking-ov7670-camera-module-sccb-cheat.html. [Accessed: 24-Feb-2022].
12. EEPower, "Resistor Values." eepower.com [Online]. https://eepower.com/resistor-guide/resistor-standards-and-codes/resistor-values/# [Accessed: 24-Feb-2022].
13. Wiley, “ Reduction of False Alarm Signals for PIR Sensor in Realistic Outdoor Surveillance.” onelinelibrary.com [Online].https://onlinelibrary.wiley.com/doi/pdf/10.4218/etrij.13.0112.0219 [Accessed: 24-Feb-2022].
14. IEEE Board of Directors. “IEEE Code of Ethics.” IEEE Code of Policies, Section 7 - Professional Activities (Part A - IEEE Policies). https://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 10-Feb-2022].