ANTI-THEFT SYSTEM FOR CATALYTIC CONVERTER

Team: Theft-Away

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I. QUAD CHART

Anti-Theft for Catalytic Converter

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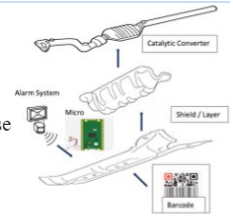
Objective:

- To design and improve an electromechanical, theft prevention system, for catalytic converters to deter thieves and reduce the number of converters stolen each year.
- Catalytic converters theft is up over 1200% since 2019 and continues to rise in 2022.
- With over a quarter billion vehicles registered in the US alone millions of people are in need of our product.

Concept:

Anti-theft device for a catalytic converter that comes with a shied/cover, detection system, and alarming system. It shall be able to actively identify theft attempts with high accuracy. In case of identifying theft attempts, the alarm system shall be triggered with minimal latency to alarm the owners and to discourage the thieves.



Approach:

Protect the converter itself by employing:

- High-cutting resistance materials such as fiberglass, reinforced steel, titanium, etc

Detection system compose of:

- Lift detection, cutting detection, motion detection, availability detection (barcode)

Alarming system consists of:

- Horn with siren sound, high-power lighting, notification sent via phone call/text

Analyses and RRP:

Analyses:

- Thermal conductivity from converter to various materials and resultant surface temperatures.
- Heat retention and dissipation analysis.
- Cutting resistance of various materials
- Efficiency of cutting detection system using test-current in conductors
- Detection of theft attempt using lift detection
- Infrastructure needed for sending notification via phone call/text

RRP

- Scale model
  - Reliability of cutting detection system and lift detection (detect > 90% attempts)
  - Withstand cutting for at least 30 seconds
  - Send notification to phone.

II. PROBLEM STATEMENT AND RESEARCH SUMMARY

In modern cars, to minimize environmental impacts from burning gasoline, catalytic converters have been used widely to filter out harmful exhaust gases such as NO_x, SO_2, etc. To efficiently remove these gases, the filters are made from precious metals such as rhodium, palladium, or platinum. Recently, the number of catalytic converter thefts across the nation has skyrocketed, from 1,298 reported thefts in 2018 to 14,433 in 2020, which also observed a 325% increase compared to the previous year[1]. Replacement may cost as high as $2500, and it may take up to 8 weeks to get replacement parts[2]. Although anti-theft systems for catalytic converters do commercially exist, thieves usually can easily bypass them, as shown in one of the videos from Donut Media[3]. Many existing systems only offer passive protection such as engulfing the converter in a reinforced steel cage. Because catalytic converters often operate at high temperatures of 500-800 ^oF and may reach 1200 ^oF[4], it is incredibly challenging to mount any electronic system for active detection and prevention onto the converter itself. Our project aims to leverage the existing systems, which mostly consist of passive protection such as encasing the converter in a metal cover, by incorporating them with an active detection system and an alarming system capable of preventing theft.

III. INITIAL PROJECT STATEMENT

Our team plans to design an anti-theft system capable of detecting thefts and alarming the owners. It shall be able to withstand high operating temperature of catalytic converter itself, while reliably detecting thefts. It shall consist of passive protection such as steel bars around the converter, while also having the ability to detect theft attempts actively and accurately. In case of detection, the alarming system shall be responsive and shall discourage thieves while notifying the owners.

IV. CUSTOMER DESCRIPTION, CRITICAL FEATURES, AND PRIORITIES

Customer types:

- This product will target vehicle owners, insurance companies, car manufacturers, and even thieves. For vehicle owners, especially those who live in areas with high crime rate, the additional layers of protection and alarm will significantly reduce the chance of catalytic converters being stolen.
- From an insurance company perspective, as of now, the rising number of catalytic converters thefts is escalating the number of claims for catalytic converter loss. Thus, companies are paying enormous amounts of money, which leads to increasing insurance rates. By having catalytic converters reliably protected, insurance companies can be confident that the number of thefts significantly reduced, thus allowing them to reduce the insurance rate.
- Car manufacturers, by having a protected catalytic converter, can also advertise the system as a premium feature, thus allowing them to sell more cars.
- However, anti-customers for the system are the thieves. They may study the system to find a counter-method.

Critical features:

1. ***Mechanical Protection:***
    - Provide passive protection, such as a case from steel to the converter. The mechanical layer will make cutting the converter more difficult and buy some time for the alarming devices to discourage the thieves.
2. ***Detection***
    - The system consists of various sensors and mechanisms to detect thefts actively and accurately.
3. ***Alarming***
    - Alarming devices will immediately fire up in case of theft to discourage the thieves and alarm the owners. The system can also send a notification to the phone.

Priorities:

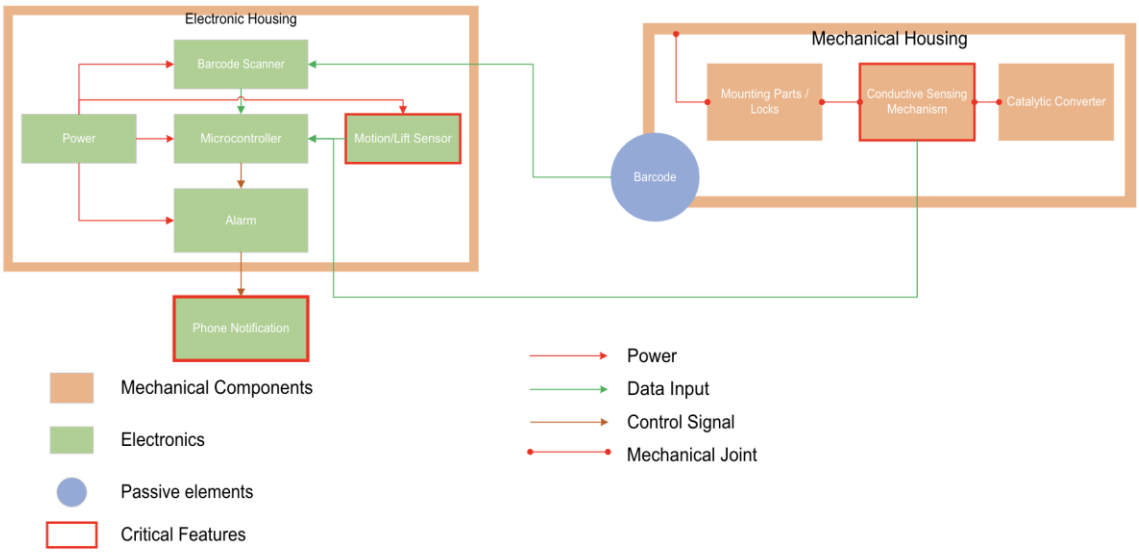
- Detection Accuracy: 20

- Responsiveness: 20
- Environmental Durability: 20
- Safety: 10
- Cost: 10
- Redundancy: 10
- Ease of installation: 5
- Size: 5

Priorities explanation:

- Detection Accuracy – 20: The system needs to accurately predict and detect theft attempts. The main purpose of the anti-theft system is to prevent thefts from happening, thus it needs to have reliable and accurate detection mechanisms. In case of theft, detection is the first mechanism to activate, thus detection accuracy should have the highest priority. The system should precisely detect >90% of all attempts.
- Responsiveness – 20: The system will always be on stand-by mode, and it will be sensitive enough to trigger with minimal latency in case of theft to discourage the thieves and to protect the catalytic converter. The effectiveness of the system relies solely on how fast the alarming system can be triggered when detecting theft.
- Environmental Durability – 20: Because the system is installed near the converter, heat is a major concern. Moreover, as weather factors such as temperature and humidity vary a lot across regions, the device should be able to withstand various harsh weather conditions such as extreme temperature, wetness, etc. Thus, durability is also a high priority in the list.
- Safety – 10: As the system will consist of many electrical components, some of which may cause electric shock, the device will undergo engineering tests to ensure its safety before reaching the hands of the customers. There will not be any unexpected explosions due to electrical malfunctions.
- Cost – 10: To compete with other commercially existing systems, the cost of manufacturing should be minimized.
- Redundancy – 10: Sensors, as well as other electrical systems, are subject to failure. By having multiple backup solutions, redundancy will ensure proper operations.
- Ease of installation – 5: Installation should be straightforward, and instructions should be easy to understand, so any technician can quickly install the system.
- Size – 5: The system should be as compact as possible, while still reliably doing its job.

V. TEAM FINAL DESIGN



The converter is surrounded by a metal case. A barcode will be etched on there. The barcode scanner will periodically check for the barcode to verify that the converter is still there. Around the metal case, electrically insulated steel bars are installed, and a current will run to those bars. Upon cutting, there will be no current anymore. By detecting this, the microcontroller can sense if the case is damaged. There is also a sensor to determine the height from ground to the bottom of the car. When the car is lifted, the sensor will know because of changing in height. If a thieve slides under the car to cut, the measured height will be lessened, thus triggering other mechanisms. Thus, the lift sensor can also act as a motion sensor. In case of theft, the controller will trigger an alarm system, which also sends a message to the vehicle owner's phone.

VI. ENGINEERING ANALYSIS LIST

- **Power Consumption** – Compute total power needed for each electronic subsystem: sound alarm system, microcontroller, sensors, readers.
- **Thermal analysis** – Measuring how hot the catalytic converter will get under full load and how thermally conductive it will be to our outer casing. This will let us move forward with our thermal design considerations.
- **Heat Dissipation** – As a part of thermal analysis we will most likely need to analyze various methods for allowing the catalytic converter to effectively dissipate heat. The catalytic converter already gets very hot, and it would not be wise to trap it in an environment that would hold it at even higher temperatures. I will need to see what heat the converter may retain under a heavy load with a cover of varying materials and thicknesses.
- **Material Property Analysis** – Analyzing varied materials for their physical and thermal properties and discerning the most appropriate materials for our mechanical systems. Materials will need to be thermally resistive and be able to protect our sensitive electronics. They will also need to have a high cutting resistance to ensure the safety of the catalytic converter.
- **Dimensional/Spatial Analysis** – To analyze the most common structures of car exhaust systems and get measurements to fit our proposed housing under the most affected cars and trucks.
- **Microcontroller** – Program microcontroller to interpret data received from its I/O peripherals and process that data to perform designated tasks.
- **Motion/Lift Detection Sensor** – Analyze condition of a 'lift': how much change in height from ground to bottom of the car. Also analyze how to adjust the sensor setting, so that the system won't accidentally turn on by a cat passing by.

VII. RISK REDUCTION PROTOTYPE DESCRIPTION

Electrical:

- **Microcontroller programming:** Each sensor has its own library. We still cannot fully understand the documentation of many commercially available sensors. Sensors may have a

compatibility problem with the microcontroller itself, which has happened many times during junior design class. Moreover, programming language is another challenge. C/C++ doesn't have an automated garbage collection library, and its syntax is very confusing.

- **Motion/Lift detection sensor:** We will try out different sensors such as ultrasonic distanced sensor, IR emitter/receiver to choose the most suitable sensor. Processing data from the sensors may require processing using Matlab/python, or any computing languages, and the processing data also needs to communicate with the microcontroller. For RRP, we plan to build and test the sensor to figure out what type of controller we need, the accuracy of the sensor, and programming challenges.
- **Microcontroller:** Programming a microcontroller is always difficult since each type of microcontroller has its own compatibility set of sensors and devices. For RRP, we will try out many different microcontrollers, so we can analyze the compatibility and programming ease of each type.

Mechanical: We have not done a lot of applicable thermal analysis for design; this will be critical for our product to work effectively. The chosen design and material must allow for thermal dissipation from the catalytic converter. They must also provide a strong resistance to cutting to increase the time it will take the thief to complete their job. Importantly, they must protect the electrical components from overheating in the harsh environment. For the RRP we propose to perform thermal analysis on many different materials, possibly using simulations, but most definitely using hand calculations. We will also test the time it takes to cut each material and weigh the pros and cons for each aspect of design.

VIII. BILL OF MATERIAL (BOM)

Item	Description	Quantity	Vendor	Unit Cost	Amount
1	IR motion sensor	1pck(5pcs.)	Amazon	$9- $10	$10
2	Battery	1(2pcs)	Amazon	$12	$12
3	Proximity Sensor	1	Amazon	$11-$12	$12
4	Barcode Scanner	1	Amazon	$15-$20	$15

5	Ultrasonic Distance Sensor	1	Amazon	$10-$11	$11
6	Internet module (ESP-32)	1	Amazon	$11	$11
7	Fiber glass insulation or Norton abrasives SG25 tape	1	Amazon	$20	$20
8	Gold Intake Heat Reflective Tape Wrap Self-adhesive	1	Ebay	$10	$10
9	Self Adhesive Heat Shield (2000F) Aluminized Insulation	1	Ebay	$9.99	$9.99
10	Sheet Metal/Steel Bar	1	Online Metals/Mcmaster-Carr	$16.17/ft<$36/ft^2	$50
				Total:	$161

IX. RISK REDUCTION PROTOTYPE SPECIFICATIONS:

Spec ID	Requirement	Threshold (Shall)	Objective (Should)	Validation Method	Why this threshold value	Relates to critical feature(s)
RRP001	Detection accuracy of the ultrasonic motion sensor	80%	95%	Each attempt lasts for 3 seconds, counting number of successes out of 20 attempts	Demonstrates the efficiency of the motion sensor	2, 3

RRP002	Detection accuracy of the electrical continuity sensor	80%	95%	Each attempt lasts for 3 seconds, counting number of successes out of 20 attempts	Demonstrates the efficiency of the sensing mechanism	2, 3
RRP003	Thermal resistivity and component Isolation	Keep sensitive electronics under 75 degrees C, while being subjected to a >=600F environment for at least 5 minutes	Keep sensitive electronics under 60 degrees C, while being subject to a >=800F environment for at least 5 minutes	Use MAPGAS or propane torch to create a simulated thermal environment. Place mechanical housing material and other shielding between the electronics and heat source. (no contact with housing) Measure electronic temperature with a digital heat sensor	This will demonstrate the ability of the housing to thermally isolate the electronics and allow them to function at acceptable operating temperatures.	1
RRP004	Material cutting resistance	Take at least 30 seconds to cut completely through two ends of housing material using reciprocating saw.	Take at least two minutes to cut completely through two ends of housing material using reciprocating saw	Physical test on housing material with a reciprocating saw	On average current systems increase the time it takes thieves to cut out the converter by approximately 30 seconds we seek to improve on that time.	1
RRP005	Time from triggering phone messaging to receiving message on phone	<60s	<15s	Use timer	Prove the ability to quickly send message in case of theft	3

X. REFERENCES

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XI. APPENDIX

Team biographies including roles

Ryan Budd (Mechanical Engineering)

I am a hardworking and motivated fourth year mechanical engineering student at Seattle Pacific University. Growing up, I had a passion for cars, working with my hands, and building things. As one of the current directors of SPU Baja SAE I get to put these passions to work, designing, manufacturing, and racing an offroad vehicle. SPU Baja has allowed me to gain valuable experience and practice important skills that will be crucial for my future in mechanical engineering. These skills and experiences allowed me to gain an internship working for Rice Lake Weighing Systems during the summer proceeding my senior year, I will continue to work for them this upcoming winter as well. I hope to use my skills in Solidworks, manufacturing, documentation, communication, leadership, and problem solving to help team Theft-Away build and Industry leading anti-theft device for catalytic converters.

Minh Le (Computer Engineering)

I'm a curious and quite nerdy student in Computer Engineering. My dad used to be an electric technician, so I did many small electrical projects, which motivate me later on to study Computer Engineering. I hope I can use my skill and knowledge alongside with other members of Theft-Away to engineer an anti-theft system for catalytic converters.

Nguyen Tang (Electrical Engineering)

I am a highly motivated and diligent senior-year electrical engineering student at Seattle Pacific University. I am also a member of the SPU IEEE. As a young child, I was inspired by the works of Nikola Tesla. His famous inventions and contributions to the science of energy as well as development of hundreds of technologies have made an enormous impact on our daily lives. Knowing that I would never be like him, but I hope that I can utilize the valuable experience and important skills that I learned from SPU to help creating products that are useful for this society, starting with the anti-theft catalytic converter first.

Joey Giducos (Electrical Engineering):

I am a Senior student at SPU, pursuing a major in Electrical Engineering, and a member of IEEE. At an early age, I was always fascinated by how things work, like gadgets, electronic devices, etc. I love to collect gadgets and love to learn how they work. I am also interested in renewable energy projects, and last year from my junior design class, my team and I built a multi-source power bank. I hope my experience will help build this project for an anti-theft catalytic converter device more efficiently and creatively.

Team Mission and Vision

Vision:

We strive to deliver a world where everyone can enjoy peace of mind while preventing the theft of catalytic converters.

Mission:

To engineer the most effective anti-theft system for car owners, using robust and cost-effective devices

Team Contract:

5. Complete tasks on time and deliver well-prepared work
6. Be open to innovative approaches and listen to new ideas.
7. Avoid blaming in case of error. Instead, reflecting past work to identify and prevent future mistakes.
8. Ensure everyone participates.
9. Get input from the entire team before a decision is made.
10. Address concerns in a public and healthy manner.
11. Choose an appropriate time and place to discuss and explore the conflict.
12. Listen openly to other points of view.

13. State points of view in a non-judgmental and non-attacking manner.
14. Regular meetings will be held outside of class at least once a week.
15. In case of not being able to attend the meeting, team members must communicate with the whole team as soon as possible.
16. Meetings will begin and end on time.
17. Team members will come to the meetings prepared.

Signed by:

1. Le, Minh
2. Giducos, Joey
3. Budd, Ryan
4. Tang, Nguyen

Date: 10/10/2022