ECE 445 Project Proposal

Automotive Icing Preventer

Team #58

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1 Introduction

1.1 Problem:

In colder climates, vehicle owners often face the challenge of ice formation on their vehicles. According to the Federal Highway Administration of the US Department of Transportation, “nearly 70 percent of the U.S. population lives in these snowy regions.” This means that the majority of the U.S. population could face ice formation during the winter. This ice accumulation can affect visibility, vehicle functionality, and overall safety. Removing ice manually by scraping or using chemical deicing can be time-consuming, labor-intensive, and sometimes ineffective, especially in severe weather conditions. Also, frequent scraping and chemical de-icers can damage a vehicle's exterior. While many cars may already be equipped with air vents that direct hot air onto the windshield to mitigate this issue, the car has to be started and the process can be slow. This delay is critical, especially during rushed mornings or in severe weather conditions, underscoring the need for a more efficient solution.

Consequently, the motivation for the automotive icing preventer is to enhance safety, convenience, and efficiency for vehicle owners in cold climates. By preventing ice formation on vehicles automatically without starting the car or needing to be in close proximity to the car, this solution aims to eliminate the time delay necessary for manual/air vent de-icing, saving vehicle owners considerable time and effort, especially during early morning starts. Also, it ensures clear visibility and unobstructed vehicle operation, crucial for safe driving in winter conditions.

1.2 Solution:

Our solution is to design an automotive heating system attached to the inside of the vehicle onto the windshield. The device will contain heating elements within a carefully selected burn-resistant casing, with a fan to transfer the heat to the windshield, heating the windshield from the inside to ultimately reduce the icing. To fully secure the attachment to the windshield, we will be using four suction cups on each corner of an aluminum box where all the components such as the heating elements, fan, and the subsystems found in our block diagram will be included. The suction cups will create a desirable gap between the box and the windshield creating a path for the air to spread across the windshield. Fans will be mounted on the surface towards the windshield and the heating system will be above the fan within the box.

1.3 Visual Aid

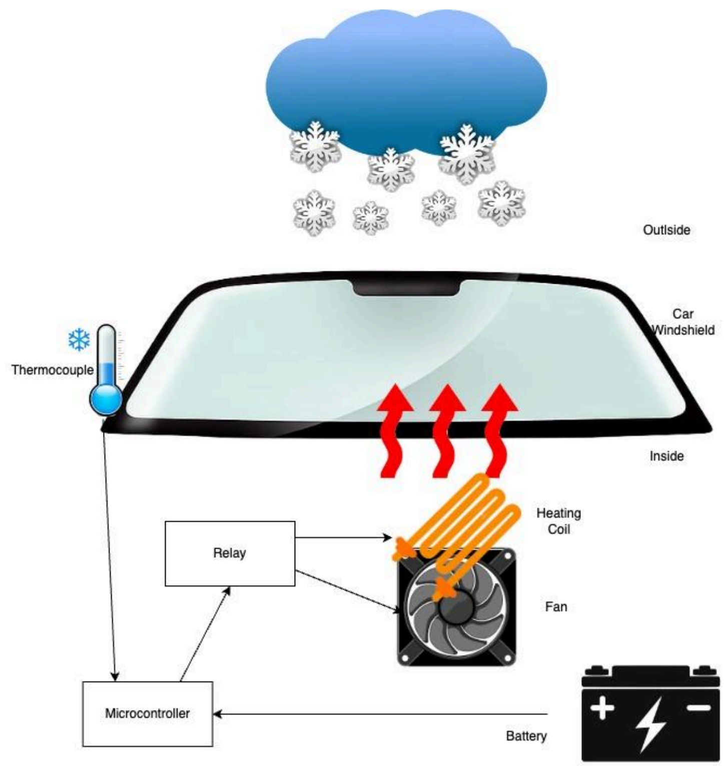

Figure 1: Top level diagram of the feature

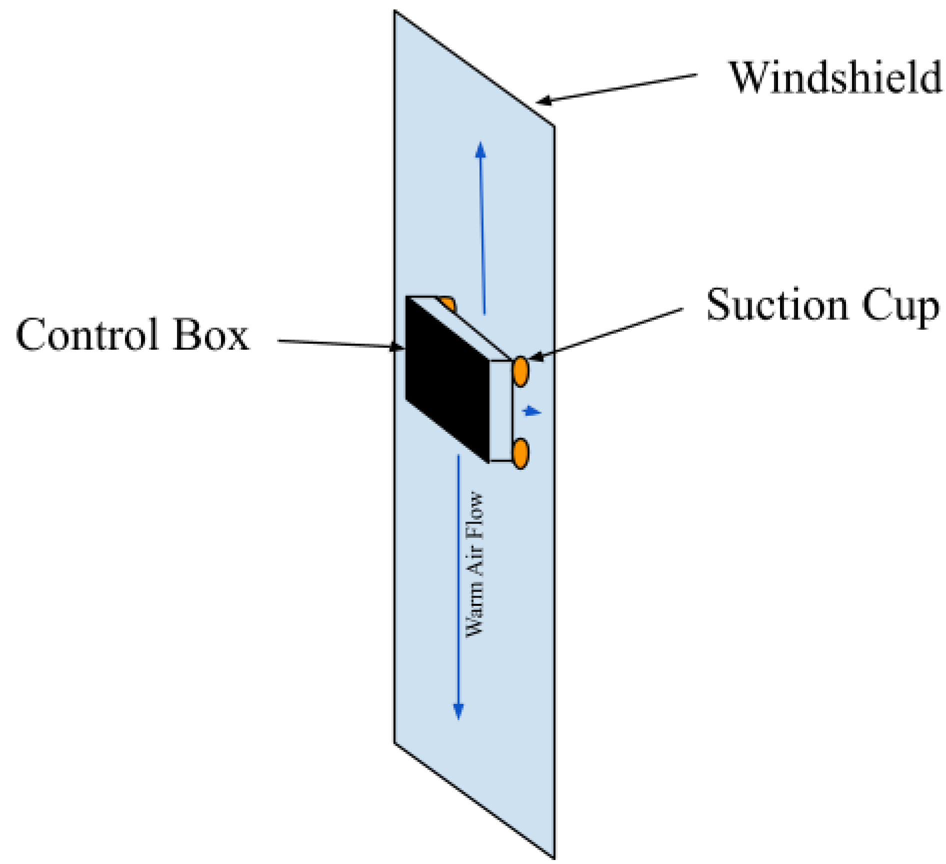

Figure 2: Visualization of how the Control Box would deliver heat.

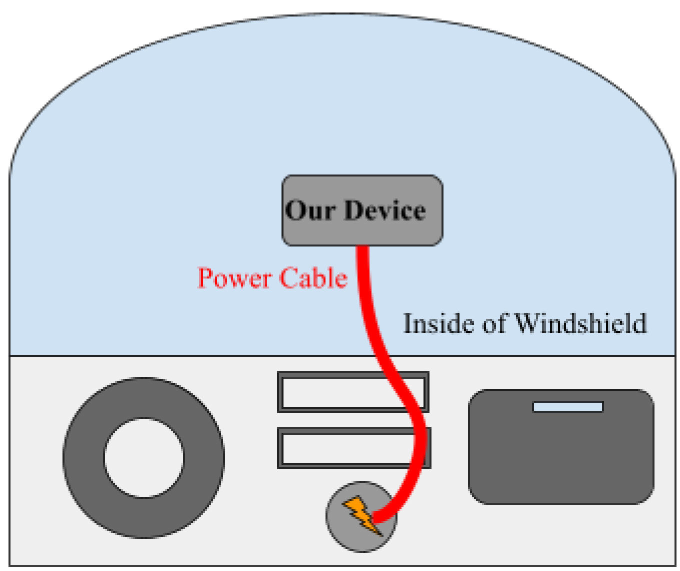

Figure 3: Visualization of how the Control Box would be attached inside the windshield.

1.4 High-level requirements list:

- Surface Temperature Regulation: The system will output power when the vehicle's surface temperature is detected at 0±1°C, and maintain the vehicle's surface temperature regulation until a temperature above 10±1°C is detected to ensure that the window stays above freezing temp.
- Power Regulation: 12V will be applied to the microcontroller (with built-in step-down converter), amplifier (max rated for 36V), and heating subsystem in conjunction with relays (supplied with 3.3V microcontroller output voltage). The microcontroller will correctly supply 3.3V when indicated by the sensor subsystem to the relays to begin powering the heating subsystem.
- Thermocouple Analysis: The thermocouple will provide an output of 0mV to the amplifier when freezing temperature is detected. The amplifier will output 2.7mV to the microcontroller, and the microcontroller will supply power to the relays to begin the heating process. The thermocouple will provide an output of 0.2mV to the amplifier when 5°C has been detected, and the microcontroller will stop supplying power to the relays and end the heating process.

Since we are going to have to demonstrate our project in April, the weather will not be cold enough for ice to form on windshields. Consequently, we will have to demonstrate indoors. To achieve this, we will have a small piece of glass representing the windshield and demonstrate our project by attaching it to the glass and manually putting dry ice over to rapidly decrease the temperature and indicate the icing preventer to begin heating the glass. The icing preventer will be plugged into a 12V wall outlet, similar to a car battery.

2 Design

2.1 Block Diagram:

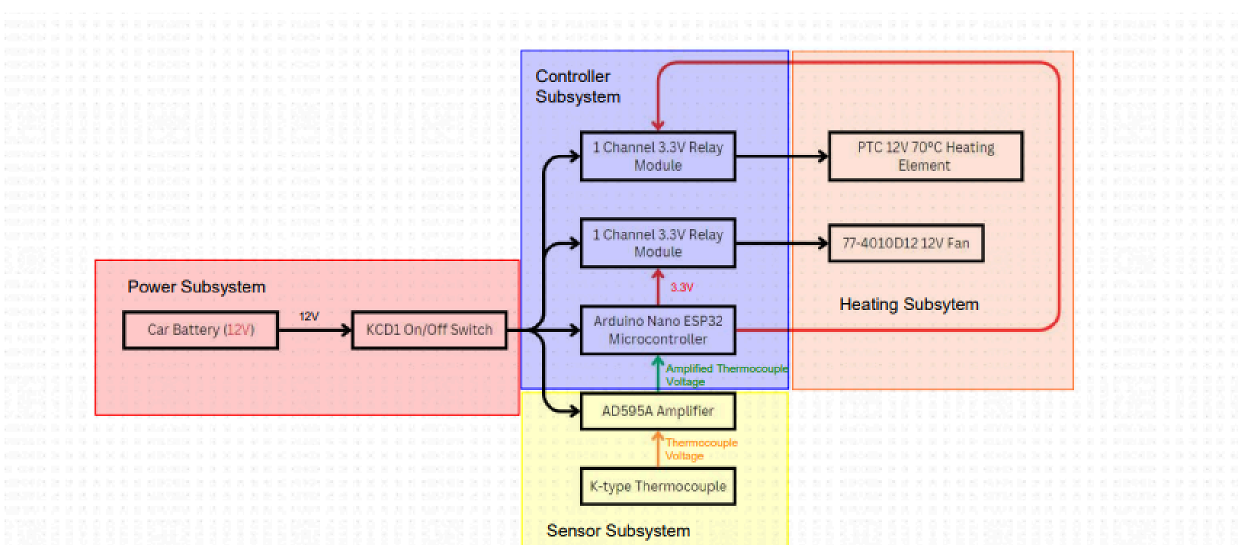

Figure 4: Top Level Block Diagram

2.2 Subsystem Overview:

- **Power Subsystem**
    - Sourced directly from the car battery, the power unit will be the source of every other subsystem's functionality. The icing preventer will be plugged into the car using a 12V adapter. The system will turn on and off with a switch, and all components will receive 12V. The relay modules will be necessary for the microcontroller to indicate that the 12V needs to be supplied to the heating subsystem when necessary.
- **Control Subsystem**
    - The microcontroller will be able to read and interpret feedback voltage coming from the sensor unit and heating unit. It will be programmed to take input from the sensor unit, and depending on the feedback voltage, indicate the relay modules to either supply to or remove power from the heating subsystem.
    - We will incorporate Arduino Nano ESP32 for our microcontroller as it satisfies our project requirements: 2 main output sources(heating coil and LED display), 1 digital input source(temperature sensor), and 1 power supply. Arduino Nano ESP32 utilizes a USB power input which will be driven with the power unit. The microcontroller has a voltage step-down converter within which makes the microcontroller perform at 3.3V-5V. Additionally, the microcontroller allows us to efficiently program the device using the Arduino Software.
- **Sensor Subsystem**
    - The sensor subsystem will consist of a thermocouple that delivers feedback to the microcontroller based on the detected temperature. While the device is powered on, the thermocouple will continuously feed in the temperature read from the surface of the windshield. The basis of this system relies on accurate feedback from the sensor unit, so it will need to be very carefully implemented to sustain high-quality output from all other subsystems.
    - We will utilize an AD595A amplifier associated with a K Type Thermocouple, which will read the temperature and step up the voltage to be interpretable by the microcontroller.
- **Heating Subsystem**
    - The heating subsystem will be the main result of this project. The elements are heavily reliant on accurately reading feedback voltage from the sensor subsystem to the microcontroller, which will provide voltage to the relays to indicate that power must be supplied to the heating elements and fans.
    - We will implement multiple PTC heating elements into our system, each with an operating voltage of 12V and a consistent peak heating temperature of 70°C (as

per rated).
  - We will also implement 12V circuit fans that are relayed power from the microcontroller using the relay modules to blow hot air onto the window.

2.3 Subsystem Requirements

All subsystem metrics will be met with a 5% error tolerance as agreed upon to be reasonable with our project TA.

- **Power Subsystem**
  - The system must provide a stable DC power supply of 12(±0.6)V to the microcontroller, amplifier, relay modules, and heating elements.
  - The system must be capable of switching on and off using a QTEATAK switch.
- **Heating Subsystem**
  - 12V PTC heating elements will reach 70(±3.5)°C as per rated for.
  - 12V 77-4010D12 fans will blow heat from PTC heating elements towards the windshield to increase surface temperature above 0°C.
- **Controller Subsystem**
  - Arduino Nano ESP32 must be able to interpret a voltage input of 2.7mV from the AD595 amplifier (this indicates that the thermocouple has detected 0°C as referenced in the AD595 datasheet) as an indication to supply 3.3(±0.165)V to the relay modules.
  - Arduino Nano ESP32 must be able to interpret a voltage input of 101mV from the AD595 amplifier (this indicates that the thermocouple has detected 10°C as referenced in the AD595 datasheet) as an indication to stop supplying 3.3V to the relay modules.
- **Sensor Subsystem**
  - Type K thermocouple must be properly integrated with the AD595 amplifier to relay temperature voltages.
  - A voltage of 0mV relayed from the thermocouple indicates a temperature of 0°C. The AD595 amplifier must output 2.7mV to the Arduino Nano ESP32 in response.
  - A voltage of 0.397(±0.01985)mV relayed from the thermocouple indicates a temperature of 10°C. The AD595 amplifier must output 101mV to the Arduino Nano ESP32 in response.

2.4 Tolerance Analysis

Our project heavily depends on the accuracy of voltage interpretation by the microcontroller from the AD595 amplifier. Given these voltages will still be relatively small (mV), precise accuracy is imperative for the project to succeed.

As indicated in the subsystem requirements, the voltage required for the AD595 amplifier to supply and queue the microcontroller to send 3.3V to the relays is 2.7mV. This means that the amplifier has received 0mV from the thermocouple, and therefore the car windshield is at 0°C.

With a general tolerance for the AD595 amplifier at 5%, this will provide us with:

- A Lower Limit of 2.565mV
- An Upper Limit of 2.835mV

This will ensure that a 5% error will still allow for the microcontroller to read the voltage as an indication of 0°C detected on the windshield, with an estimated temperature threshold of -0.5°C to 1°C (estimate due to datasheet's temperature voltage conversions only changing by increments of 10°C).

Similarly, the voltage required for the AD595 to supply and queue the microcontroller to shut off voltage to the relays is 101mV as an indication that the surface temperature of the windshield is at 10°C.

Applying the same 5% tolerance to ensure the microcontroller reads a voltage indication of 10°C, we will set:

- A Lower limit of 95.95mV
- An Upper Limit of 106.05mV

3 Ethics and Safety

In the development of the automotive icing preventer, ethical and safety considerations are paramount, guided by the principles set forth in the IEEE and ACM Code of Ethics.

3.1 Ethics

A significant ethical consideration for this project is ensuring equitable access to the technology. Addressing equitable access involves adopting an inclusive design strategy, making the system adaptable to various environments. It also necessitates effective cost management to keep the system affordable, potentially through efficient design, and manufacturing processes.

Following the IEEE Code of Ethics, our team commits to engaging with and valuing the feedback received from our professors and teaching assistants concerning the automotive icing preventer's development. We will schedule regular meetings to discuss our design and prototype progressions, ensuring any feedback is thoughtfully considered and integrated. This iterative process will be underpinned by rigorous research and proper citation of utilized resources, reflecting our dedication to integrity and innovation in our technical work.

Moreover, we pledge to foster an environment of fairness and respect within our project team and in interactions with mentors. Our communication strategy includes a blend of modern digital platforms—group texts for quick updates and a shared Google Drive for accessible documentation and resource sharing. We will ensure that every team member's contribution is valued and respected.

3.2 Safety

Safety concerns, especially given the proximity of heating elements to both vehicle occupants and the vehicle itself, are addressed through a comprehensive safety strategy. This includes the introduction of an automatic shut-off mechanism that activates based on a preset timer or detects extended vehicle inactivity, effectively mitigating risks of overheating or potential fires. To prevent injury in the event of the device detaching from the windshield, our design incorporates fail-safe mechanisms, such as using materials that remain cool to the touch and securing the device with robust attachment methods to minimize detachment risk. An emergency shut-off feature is also integral to our design, providing users with the means to immediately deactivate the system if necessary.

Ensuring regulatory compliance and conducting extensive testing form the foundation of our project. This encompasses adhering to electrical safety standards and vehicle safety regulations, ensuring environmental compliance, and undertaking rigorous testing to affirm the system's safety, reliability, and effectiveness under varied conditions, including extreme weather simulations.

Furthermore, our project rigorously adheres to laboratory safety guidelines, with a proactive approach to managing the inherent risks associated with working with electrical components. Despite the anticipated minimal safety hazards in our design, our awareness of the potential risks posed by current and voltage guides our commitment to ensuring a safe development environment.

By weaving these ethical considerations and enhanced safety measures into the fabric of our project, we aim to deliver a responsible and effective solution to vehicle icing challenges. This approach not only prioritizes the safety and convenience of winter driving but also upholds our commitment to societal well-being and ethical integrity, ensuring the automotive icing preventer contributes positively to the community at large. I, JoonHyuk Song, Jiwon Bae, Taseen Karim, adhere to this.

References

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