Automotive Icing Preventer

ECE 445 Design Document Spring 2024

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 de-icer 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 with small holes drilled into the box to deliver the hot air to the windshield.

1.3 Visual Aid

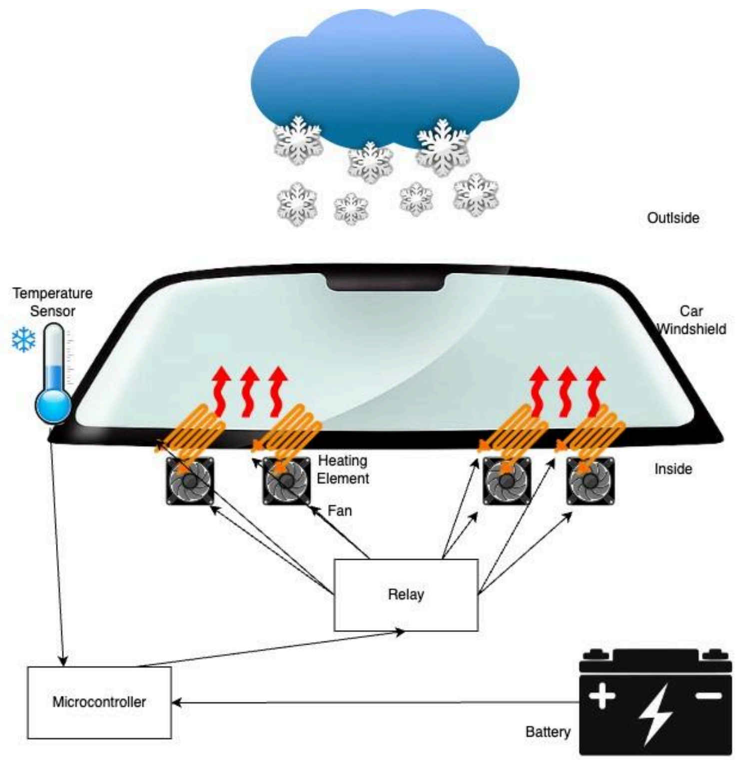

Figure 1: Top level diagram of the feature

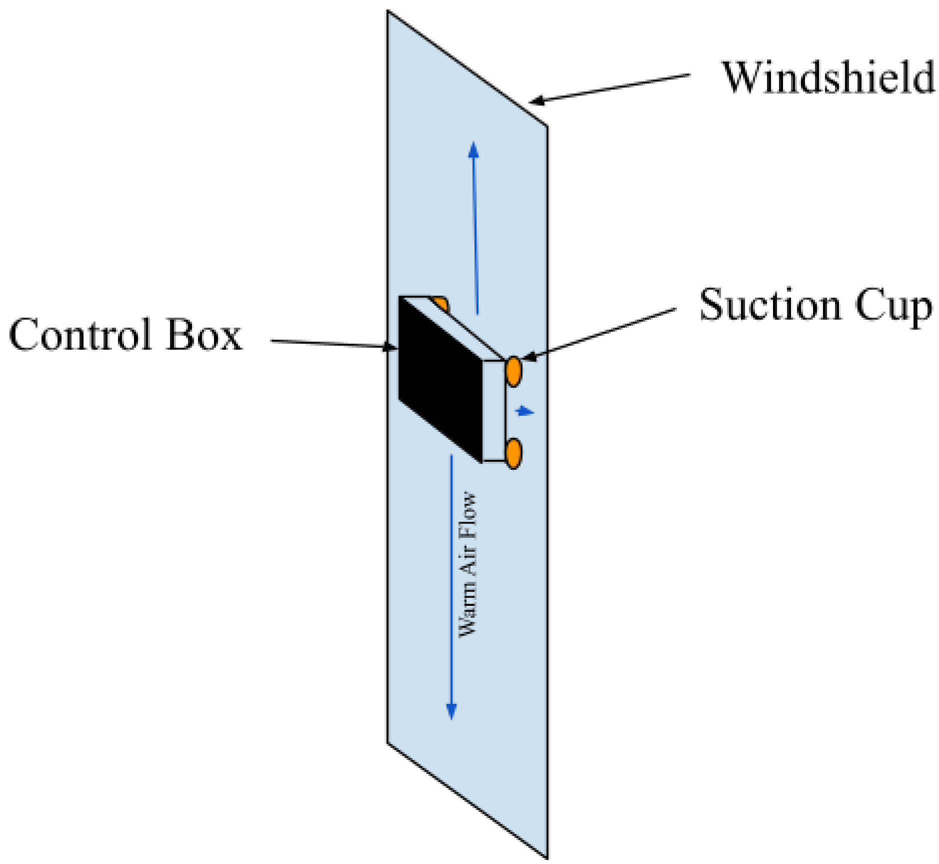

Figure 2: Visualization of how the Control Box would deliver heat.

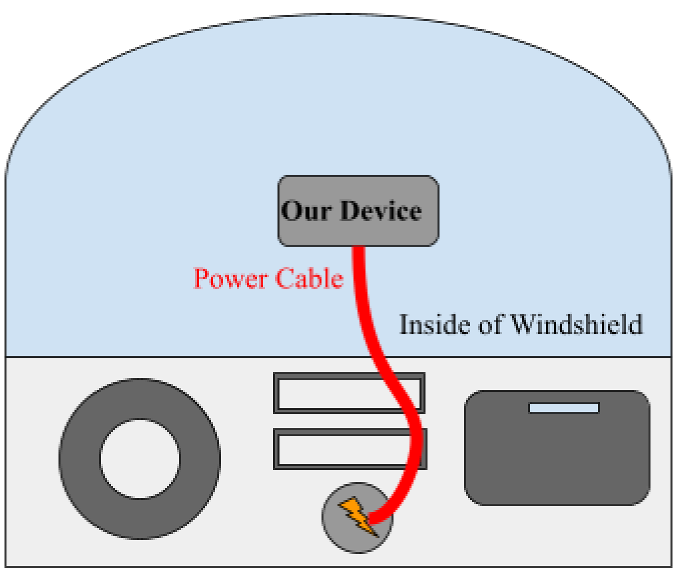

Figure 3: Visualization of how the Control Box would be attached inside the windshield.

1.4 High-level Requirements

- 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 in doors. 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 Physical Design

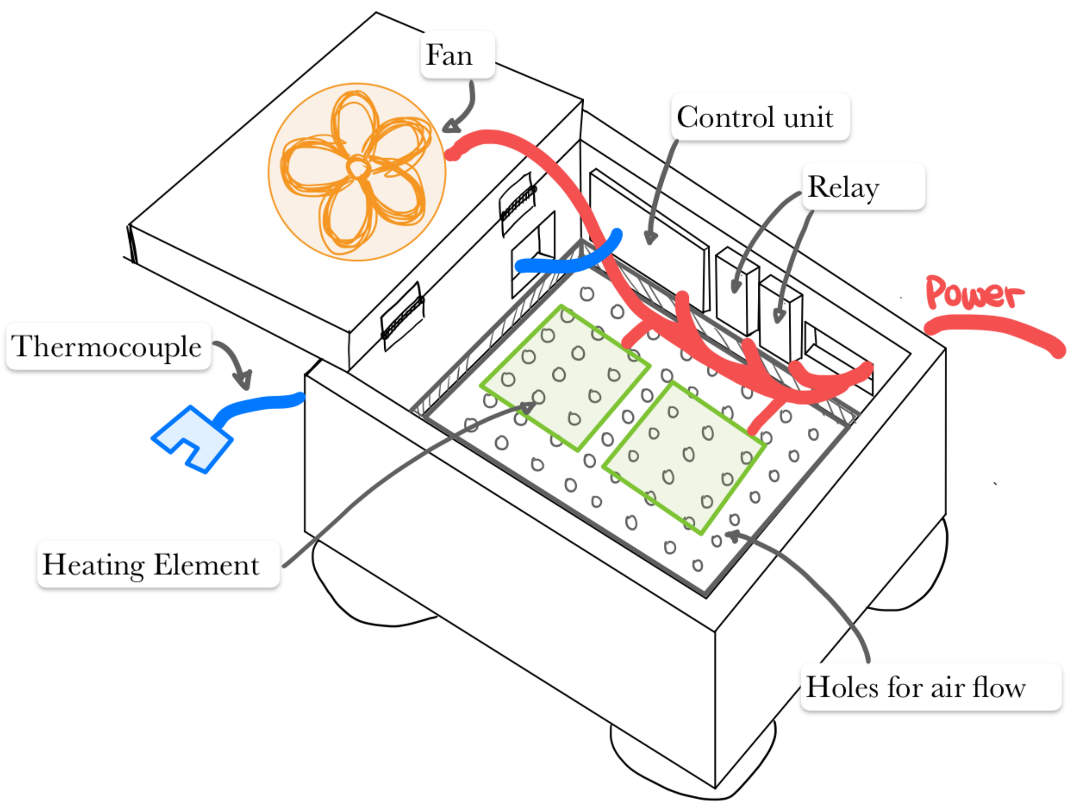

Figure 4: Physical Design

Our device is a box shaped heating system where it will be attached to the inside of the car's windshield with suction cups. The suction cups will elevate the device a small amount, so once the heating system is on, the fan will blow the warm air generated from the heating element through the small holes and the elevated gap, ultimately de-frosting the car's windshield. The thermocouple will be mounted outside of the box making direct contact with the windshield, while the PCB, consisting of the control unit, amplifiers, and relays, will be mounted on the interior wall.

2.2 Block Diagram

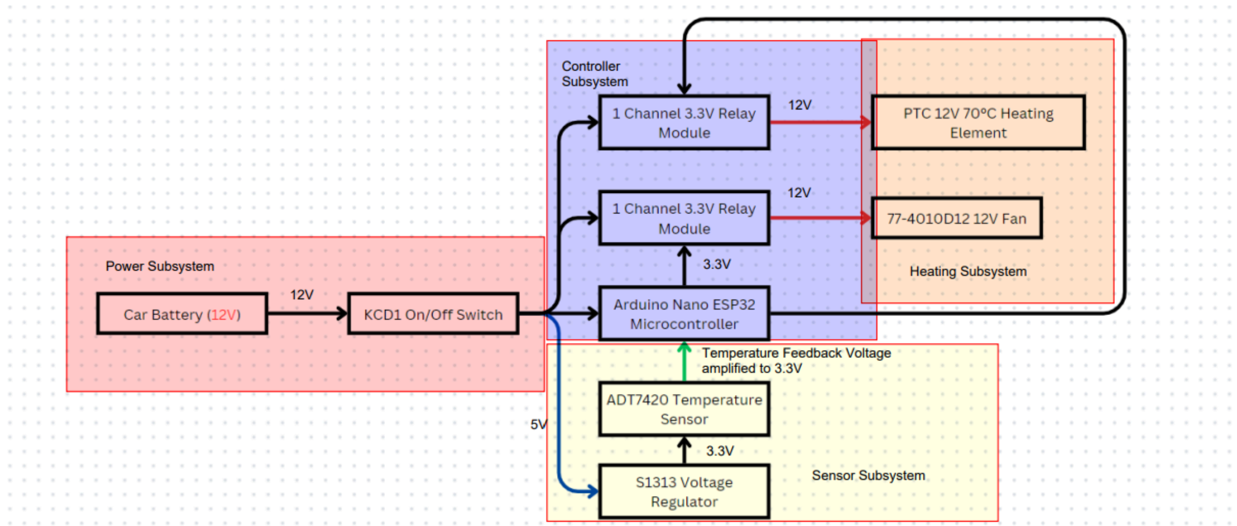

Figure 5: Top Level Block Diagram

2.2 Block Diagram 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 regulator 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 a Voltage Regulator to step down the voltage to be rated for the ADT7420 Temperature Sensor, which will read the temperature and step up the voltage using an amplifier to be interpretable by the microcontroller.
- **Heating Subsystem**
    - The heating subsystem will be the main result of this project. They 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.
- ○ 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 and Verification

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

Requirements	**Verification**
The system must provide a stable DC power supply of 12(±0.6)V to the microcontroller, amplifier, relay modules, and heating elements.	● Connect the primary input to voltage supply. ● Check voltage readings with a multimeter to ensure output voltage is 12V ±5%.
The system must be capable of switching on and off using a QTEATAK switch.	● Connect the primary input to voltage supply. ● Verify that when the switch is open, the system does not receive any voltage. ● Verify that when the switch is closed, the system receives 12V ±5%.

Table 1: Power Subsystem - Requirements and Verification

- **Heating Subsystem**

Requirements	**Verification**
12V PTC heating elements will reach 70(±3.5)°C as per rated for.	• Connect heating elements to any 12V power supply. • Use a thermometer to ensure surface temperature reaches 70 ±5% °C.
12V 77-4010D12 fans will blow heat from PTC heating elements towards the windshield to increase surface temperature above 0°C.	• Connect the primary input to voltage supply. • Close the switch and verify the system is receiving 12V using a multimeter. • Verify relays are receiving 3.3V from microcontroller to queue fans to receive voltage supply from 12V source.

Table 2: Heating Subsystem - Requirements and Verification

DC OPERATED							
NTE Type No.	Rated Voltage	Max. Input Current	Max. Input Power (W)	Speed ±10% (RPM)	Max Air Flow (CFM)	Max Acoustical Noise	Diag No.
77–4010D12	12	0.10A	1.24	7000	7.73	36dB(A)	F1a

Figure 5: 77-4010D12 Fan Ratings

- **Controller Subsystem**

Requirements	**Verification**
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 ±5% V to the relay modules.	• Provided sensor subsystem output is verified, verify input voltage to microcontroller is 2.7 ±5% mV using a multimeter. • Ensure at this stage the microcontroller is programmed to supply 3.3 ±5% V to relay modules. • Verify output from the microcontroller is 3.3 ±5% V using a multimeter. • Verify the input to relay from the microcontroller is 3.3 ±5% V and output is 12 ±5% V using a multimeter.
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 ±5%°C as referenced in the AD595 datasheet) as an indication to stop supplying 3.3 ±5% V to the relay modules.	• Provided sensor subsystem output is verified, verify input voltage to microcontroller is 101 ±5% mV using a multimeter. • Ensure at this stage the microcontroller is programmed to stop supplying 3.3 ±5% V to relay modules. • Verify output from the microcontroller is 0V using a multimeter. • Verify the input to relay from the microcontroller is 0 V and output is 0V using a multimeter.

Table 3: Control Subsystem - Requirements and Verification

Parameters

Working Voltage	DC 3-3.3V
Working Current(VCC)	65mA
Trigger Current(IN)	3mA
Main Components	EL817, SRD-DC03V-SL-C
Flyback Diode Protection	Yes
Channel	1 channel
Compatible Load	10A 250VAC / 10A 30VDC
Response Time	<20ms
Size	70mm*17mm*20mm(LWH)

Figure 6: ICStation 3.3V 1 Channel Relay Switch High Level Trigger Module Ratings

- **Sensor Subsystem**

Requirements	**Verification**
A voltage of 0mV relayed from the thermocouple indicates a temperature of 0°C. The AD595 amplifier must output 2.7 ±5% mV to the Arduino Nano ESP32 in response.	• Supply 12 V to the amplifier. • Apply an ice cube to the thermocouple and verify the input voltage to the amplifier is 0mV using a multimeter. • Verify the output from the amplifier is 2.7 ±5% mV using a multimeter.
A voltage of 0.397 ±5% mV relayed from the thermocouple indicates a temperature of 10°C. The AD595 amplifier must output 101mV to the Arduino Nano ESP32 in response.	• Supply 12V to the amplifier. • Since most refrigerated items are kept around 10°C, verify using a thermometer that a refrigerated item has reached 10°C. • Apply the refrigerated item to the thermocouple and verify the input to the amplifier is 0.397 ±5% mV using a multimeter. • Verify the output from the amplifier is 101 ±5% mV using a multimeter.

Table 4: Sensor Subsystem - Requirements and Verification

Note: Refer to below Figure 7 for rating information regarding Arduino Nano ESP32. Refer to below Figure 8 for temperature to voltage rating information regarding AD595 Amplifier.

Symbol	Description	Min	Typ	Max	Unit
V_{IN}	Input voltage from VIN pad	6	7.0	21	V
V_{USB}	Input voltage from USB connector	4.8	5.0	5.5	V
$T_{ambient}$	Ambient Temperature	-40	25	105	°C

Figure 7: Arduino Nano ESP32 Ratings

Thermocouple Temperature °C	Type J Voltage mV	AD594 Output mV	Type K Voltage mV	AD595 Output mV
–200	–7.890	–1523	–5.891	–1454
–180	–7.402	–1428	–5.550	–1370
–160	–6.821	–1316	–5.141	–1269
–140	–6.159	–1188	–4.669	–1152
–120	–5.426	–1046	–4.138	–1021
–100	–4.632	–893	–3.553	–876
–80	–3.785	–729	–2.920	–719
–60	–2.892	–556	–2.243	–552
–40	–1.960	–376	–1.527	–375
–20	–.995	–189	–.777	–189
–10	–.501	–94	–.392	–94
0	0	3.1	0	2.7
10	.507	101	.397	101
20	1.019	200	.798	200
25	1.277	250	1.000	250
30	1.536	300	1.203	300
40	2.058	401	1.611	401
50	2.585	503	2.022	503
60	3.115	606	2.436	605
80	4.186	813	3.266	810
100	5.268	1022	4.095	1015
120	6.359	1233	4.919	1219
140	7.457	1445	5.733	1420
160	8.560	1659	6.539	1620
180	9.667	1873	7.338	1817
200	10.777	2087	8.137	2015

Figure 8: AD595A Output Voltage vs. Thermocouple Temperature Chart

2.4 Tolerance Analysis

Our project heavily depends on the accuracy of voltage interpretation by the microcontroller from the ADT7420 Temperature Sensor. The ADT7420 provides a digital output to the microcontroller depending on the temperature. To ensure that our microcontroller will provide an output to the relays given minimal temperature flux, we will set the following tolerance parameters:

- Digital outputs from -0.0625℃ to 0.0625℃ (outputs being 0x1FFF, 0x000, 0x001) will enable the controller to send voltage to the heating subsystem (temperature ratings per datasheet). Selecting this threshold will ensure that temperature fluctuations do not affect our system and we are still able to send power to the heating subsystem.

2.5 Cost Analysis

The total cost for parts as seen below in Figure X before shipping is $123.17. After shipping and handling ($8.99) and tax collected ($11.08), the order total comes out to $141.51. Estimating 80 hour completion time, we can expect a salary of $40/hr x 2.5 x 60 hr = $6000 per team member. The total cost comes out to $141.51 + ($6000 x 3 team members) = $18,141.51.

Description	Manufacturer	Quantity	Price
37W DUAL PORT FAST CAR CHARGER WITH 3.3FT USB CABLE	Belkin	1	$24.49
IC THERMOCOUPLE A W/COMP 14CDIP AD595AQ	Analog Devices Inc.	2	$25.38
DC 1 CHANNEL OPTOCOUPLER 3V/3.3V RELAY	Teyleten Robot	5	$9.99
HIGH SPEED FAN 77-4010D12	NTE Electronics	1	$10.34

PTC HEATING ELEMENT PLATE	PTCYIDU	2	$11.99
3 METERS K TYPE MINI-CONNECTER THERMOCOUPLE	Weewooday	5	$11.99
ARDUINO NANO ESP32 ABX00092	Arduino	1	$22.00
ON/OFF BOAT ROCKER SWITCH 2 PIN 2 POSITION SNAP	QTEATAK	5	$6.99

Table 5: Parts Cost Analysis List

2.6 Schedule

Week	Task	Person
2/19	Order parts for prototyping	Everyone
2/26	PCB Schematic Draft PCB Design PCB Components	Everyone Jiwon Joon and Taseen
3/4	Finish PCB Schematic and meet with ECEB Parts shop to finalize mechanical design	Everyone
3/18	Receive Parts Solder parts onto PCB Start subsystems	Everyone Taseen Jiwon and Joon
3/25	Continue working on project	Everyone
4/1	Check power and sensor subsystems work as intended	Everyone
4/8	Integrate entire project systems	Everyone
4/15	Mock Demo, Test and Debugging	Everyone
4/22	Final Demo / Paper	Everyone
4/29	Final Presentation/Paper	Everyone

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 Section I.5, “to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, to be honest and realistic in stating claims or estimates based on available data, and to credit properly the contributions of others,”[7] 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, as stated in the IEEE Code of Ethics Section II, “to treat all persons fairly and with respect, to not engage in harassment or discrimination, and to avoid injuring others.”[7] 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. This way, 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 abnormally high temperature, 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 Guide [8], 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.

4 References

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