Battery Powered Car Air Conditioning

“The Chilly Dog”

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MIDTERM REPORT

Battery Powered Car Air Conditioning

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CONCEPT OF OPERATIONS

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CONCEPT OF OPERATIONS
FOR
Battery Powered Car Air Conditioning

TEAM <31>

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-	1/26/2022	Grant Franklin	Skylar Head	Draft Release
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Table of Contents

List of Tables

List of Figures

1. Executive Summary

Our project, Battery Powered Air Conditioning, will allow customers to leave their pets in the car by cooling or warming the car to a safe temperature. Our goal is to construct a device that can cool or warm a crossover SUV without being overly expensive, since most current devices can cost around $500. The device will be controlled with an application that allows the user to adjust and check the temperature on the fly while away from the vehicle. To allow for this long-distance control, the device will be equipped with a sim card as we expect that most cars will be parked in a place without a reliable Wi-Fi signal. The A/C is powered by a battery, so the car does not have to be on while the device is in operation. The exhaust air will be pushed out of the car via a hose hooked to the window to ensure that air is circulating properly. We believe this project will be very useful to people who have pets but who often struggle with bringing them places due to extreme temperatures.

2. Introduction

A car parked outside on a sunny, 95-degree Fahrenheit day can reach temperatures of up to 117 degrees Fahrenheit in just 30 minutes. This rapid change in temperature is something many pet owners do not take into consideration when leaving their pets in the car for a seemingly “harmless” trip to the grocery store. We set out to create a device that maintains suitable conditions for man’s best friend inside a parked vehicle without the need to start the engine or use the vehicle's own A/C system. Our battery-powered air conditioning unit will ensure the safety and comfort of the customers pet as well as the peace of mind for costumer.

2.1. Background

A parked vehicle on a hot day can act like a greenhouse, amplifying the heat in the cabin up to 40 degrees Fahrenheit compared to the temperature outside. A table of estimated vehicle interior air temperature can be seen in Figure 2.1. Cracking the windows has little to no effect on these numbers. While a human may be able to withstand these conditions, dogs have limited ways of regulating their body temperature.

The largest organ in the human body is the skin and one marvelous feature of this organ is its ability to perspire to cool our body temperature. While dogs do have sweat glands, they play a minor role in regulating body temperature. Dogs pant, inhaling cool air and exhaling warm air. This makes our K9 friends more susceptible to heatstroke and even death.

The winter weather is not to be neglected. Cars have insufficient insulation to combat against outside conditions. While the vehicle may shelter the pet from the wind and other elements it does not protect them from the frigid temperatures.

Estimated Vehicle Interior Air Temperature vs. Elapsed Time						
Elapsed Time (minutes)	Outside Air Temperature (°F)					
	70	75	80	85	90	95
0	70	75	80	85	90	95
10	89	94	99	104	109	114
20	99	104	109	114	119	124

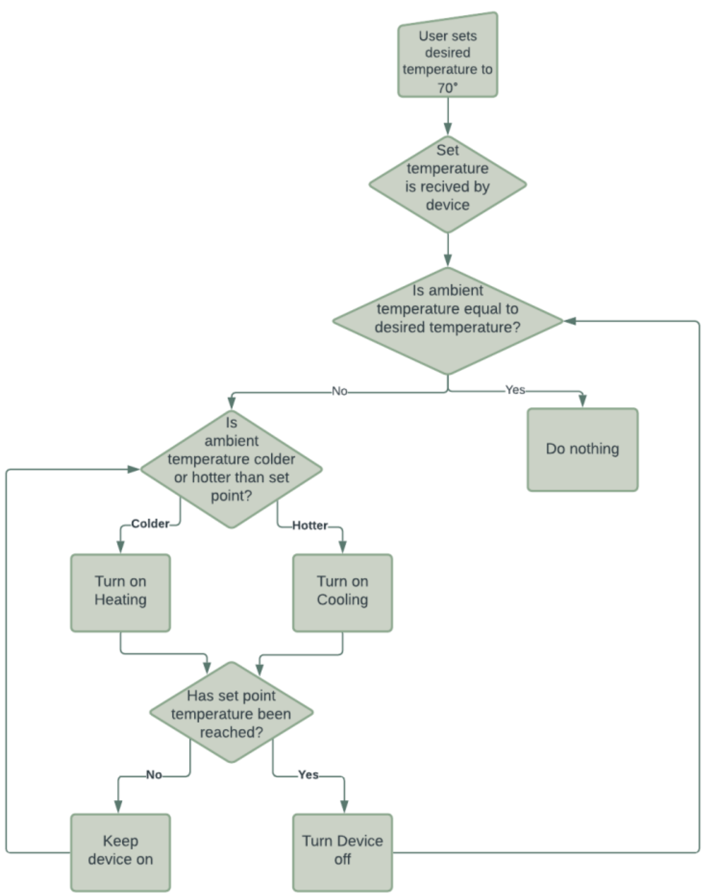
30	104	109	114	119	124	129
40	108	113	118	123	128	133
50	111	116	121	126	131	136
60	113	118	123	128	133	138
>60	115	120	125	130	135	140

Table 2.1. Estimated Vehicle Interior Air Temperature vs. Elapsed Time

2.2. Overview

The Battery Powered Air Conditioning will regulate the temperature in the vehicle, whether it be cooling or heating, to provide optimal conditions for the pet to safely stay in the vehicle unattended. The unit will be powered by a rechargeable battery making it independent and non-reliable on the engine or battery of the car. It will be accessible to the user through an app with features such as increasing or decreasing the climate, real-time readings of the temperature, and turning the device on or off. The internal climate will be read and interpreted by a sensor. That data will be sent and viewed by the user through the application. The user can then set the desired temperature and the A/C unit will output a steady flow of air to match the user's command.

Figure 2.1. Overview Flowchart



2.3. Referenced Documents and Standards

- https://www.akc.org/expert-advice/health/dogs-in-hot-cars/#:~:text=Most%20dog%20owners%20know%20that,at%20risk%20of%20heat%20stroke.&text=The%20answer%20is%20simple%3A%20You,some%20states%2C%20it's%20even%20illegal.
- https://www.akc.org/expert-advice/health/leaving-a-dog-in-the-car-in-winter/
- https://www.animallaw.info/topic/table-state-laws-protect-animals-left-parked-vehicles
- I.R. Dadour, I. Almanjahie, N.D. Fowkes, G. Keady, K. Vijayan, Temperature variations in a parked vehicle, Forensic Science International, Volume 207, Issues 1–3, 2011
- F. Belic, Z. Hocenski and D. Sliskovic, "HVAC control methods - a review," 2015 19th International Conference on System Theory, Control and Computing (ICSTCC), 2015, pp. 679-686, doi: 10.1109/ICSTCC.2015.7321372.
- IEEE 1661-2019 Guide for Test and Evaluation of Lead-Acid Batteries Used in Photovoltaic (PV) Hybrid Power Systems
- IEEE/ASHRAE 1635-2018 Guide for the Ventilation and Thermal Management of Batteries for Stationary Applications

3. Operating Concept

3.1. Scope

The Battery Powered Air Conditioning project was created because of how detrimental it can be for animals to sit in the car during the summer and winter seasons, where drastic temperature changes occur in a matter of minutes. The objective of this project is to create a machine that can manage the internal temperature of a car using an VAC unit that is controlled by a phone application.

The Battery Powered Air Conditioning will consist of:

- A main unit providing VAC capabilities
- An application that will let the user control the internal temperature
- A microcontroller that receives data from the app and sends signals to the main unit to adjust the temperature based on its temperature sensor
- A battery power supply that can be charged either from the car itself or solar panels

This project will include subsystems consisting of:

- Power supply selection and design – Grant Franklin
- Application development and connection to main unit – Martin Rennaker
- Creation of VAC system – Yarentzy Magallanes
- Microcontroller design and implementation – Yarentzy Magallanes

3.2. Operational Description and Constraints

The Battery Powered Air Conditioning will be used by any pet owner that needs to leave their animal in their vehicle for a substantial amount of time. Once the customer obtains the product, it will be installed to the floorboard of the back seat. They will install a permanent solar panel to the top of the car (Figure 3.2) as well as an application to their phone. After the installation of the solar panels, the user will plug them into the main device with the use of a power cord. This cord will be fed into the vehicle through a small opening of the backseat window secured by a clip. This gap in the window will also clip the exhaust hose of the main unit. (Figure 3.1) They will then link another cord from the device to the 12V car outlet to provide another source of charging. Once the device has power, the user will turn on the unit and connect with their cell phone via a sim card. After the unit is on, the customer will use the application to input the desired temperature, and information on their pet. Recommended settings will then appear and a temperature set point will be chosen. At this point, the user can leave their car and is able to adjust the temperature in the car if needed using the application.

The constraints on the project are listed here:

- The device will have to be pet-friendly so the pet will not injure itself, but sturdy enough that the pet cannot damage it
- The main unit will have to fit within the floorboard and single seat of a medium-sized car
- The time that the car will need to heat up will depend on the outside temperature, which varies depending on the location

- The battery will have to last at least two hours so the user will have more than enough time to leave and return to the vehicle

Figure 3.1. Basic Visualization

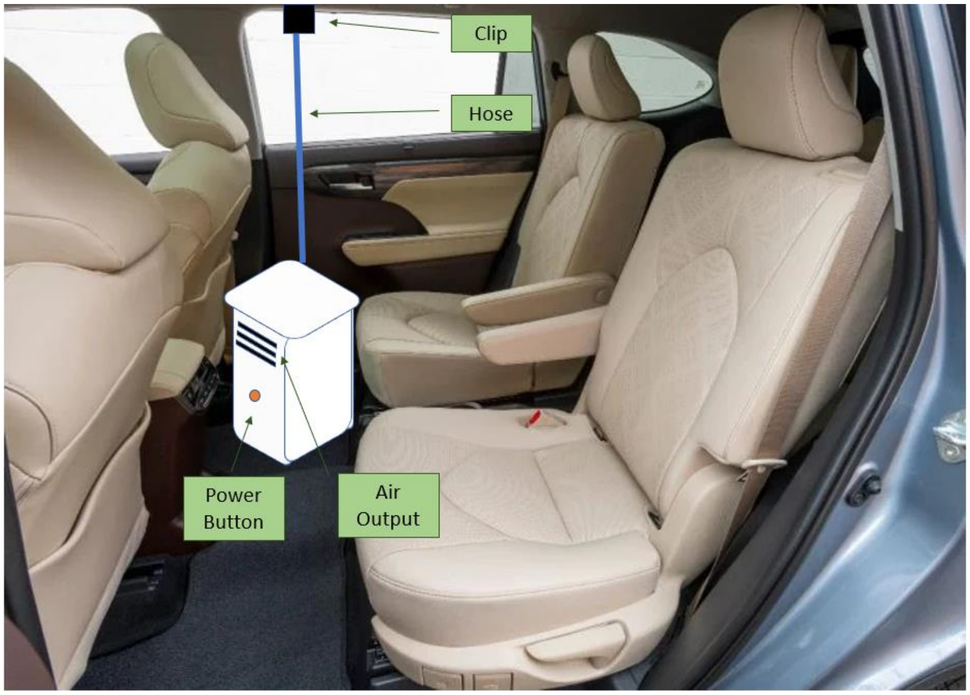
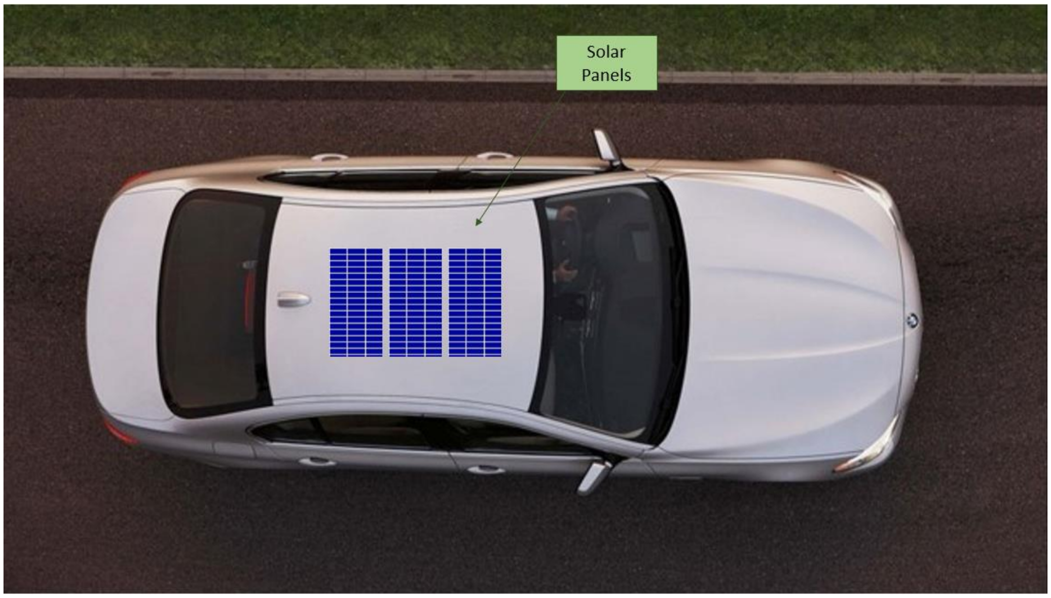


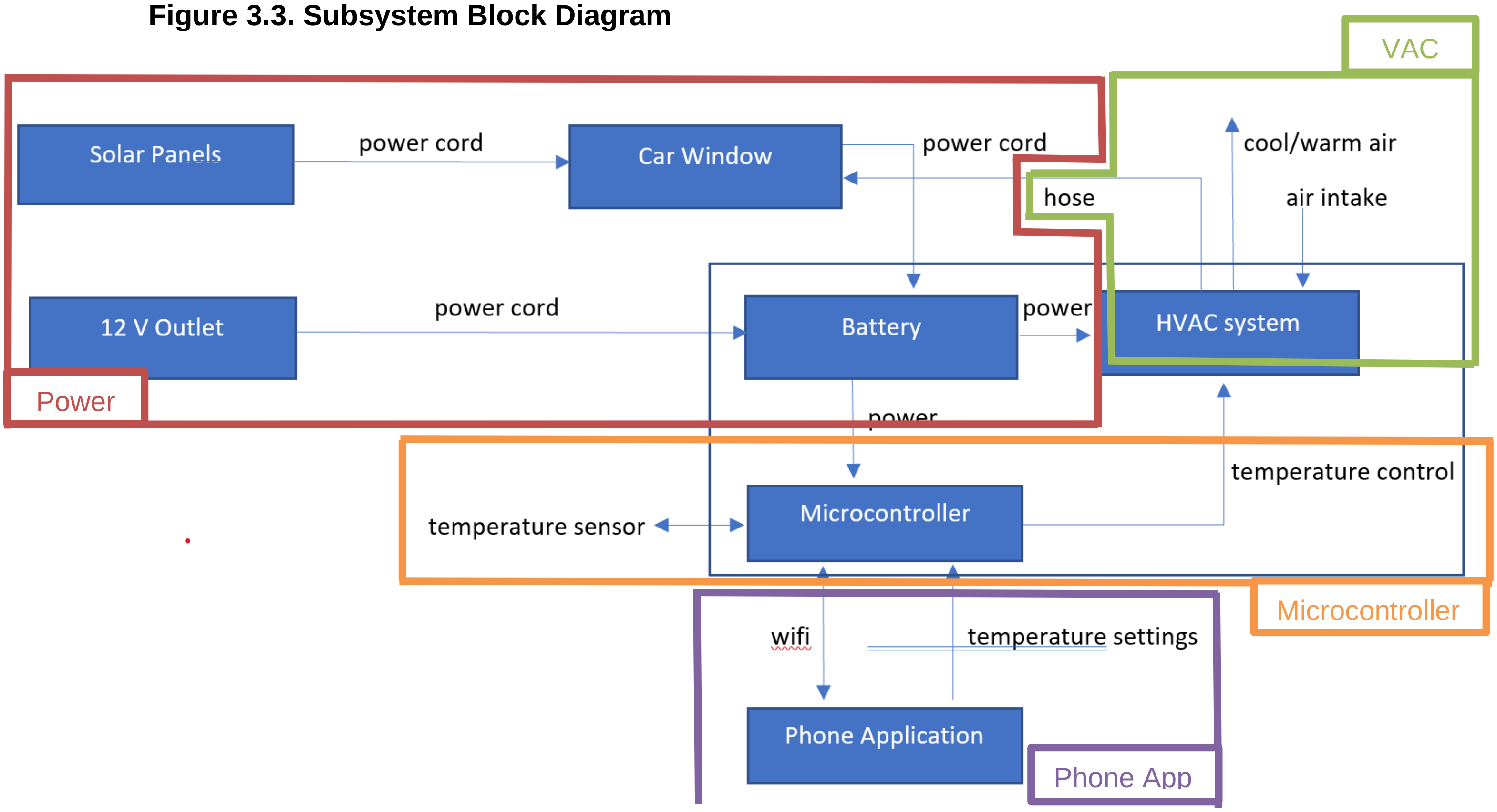
Figure 3.2. Solar Panel Visualization



3.3. System Description

As stated in the scope, the project consists of four subsystems: power supply selection and design, application development and connection to main unit, creation of VAC and microcontroller design and implementation. Figure 3.2 shows how the subsystems will work together.

Figure 3.3. Subsystem Block Diagram



The responsibilities of the different subsystems are:

- Power supply selection and design – Power will be supplied to the main unit using solar panels and from a connection to the 12 Volt car outlet as an alternate source. The user will have to install the solar panels on the top of the vehicle.
- Microcontroller design and implementation – The microcontroller system that will take information from the cell phone application and compare it to data that is showing on its temperature sensor. If the car's temperature is higher or lower than the user's desired temperature that is set on the application, the microcontroller will send a signal to the VAC unit to cool or heat the inside of the car.
- Creation of VAC - The VAC system will be built so that the car can be either heated or cooled depending on if the current temperature of the car is hotter or colder than the user's desired temperature.

- Application development and connection to main unit – The application will allow the user to interface with the microcontroller and send signals through an internet connection. The user will input data on their pet and the desired temperature for the inside of the car.

3.4. Modes of Operations

The project will have two main modes of operation: heating and cooling. Based on the input from the user, the unit will either be set to cool if the current temperature is lower than the desired temperature or heat when the current temperature is higher than the desired temperature.

3.5. Users

The people using our system will primarily be pet owners that have the need to leave their pet in the car for a long amount of time. These customers will most likely be 18+ years old since they must be old enough to drive a car and own a pet. They will not be required to have any training for the installation or operation of our product, since the only thing they will be doing themselves is putting a solar panel on top of their vehicle and downloading and using an application. The information they need will be included in the user's manual.

3.6. Support

Our product will include a user's manual that has a description of the device, gives directions on installation, provides information on where to download the application and how to use it, as well as safety warnings involved with the machine. There will also be a section in the manual that will have common questions and answers to those questions.

4. Scenario(s)

4.1. Traveling with a Pet

The primary use of the battery powered air conditioning will be to allow pets, specifically dogs, to stay unsupervised and unattended in a vehicle while the driver is away. The battery on the unit will have a duration of 2 hours and will alert the driver when low battery is detected. While conditions are met, the device will cool and heat the car as needed to maintain the ideal temperature for the dog.

4.2. Pre-Boarding Cooling and Heating

Another possible application for the project is to pre-heat or pre-cool the vehicle before the driver and passengers enters it. Using the application, the driver can turn on the A/C from virtually anywhere to prepare for their arrival and have the car warmed up or cooled down internally.

4.3. Testing Scenarios

To ensure our device is working properly, we will perform a series of tests. These tests will encompass the full functionality of our device. Listed below are a few.

- Battery Duration: the device will be left on in its cooling state for 2 hours
- Temperature Sensing: the device will be placed in a room with known temperature. We will then take a reading from the thermostat within the device to assure it matches
- Wireless Communication: the device will be left in a car parked in a lot and a user with the application will be in a nearby building. Commands will be sent via the app and the device response will be observed
- Cooling and Heating: the device will be placed in a hot car and commanded to cool to a certain temperature. Measurements will be made of the temperature of the air being output by the device. This will also be tested in a cold environment while the device outputs warm air
- Drivability: the solar panels will be placed atop the car and driven reaching speeds of up to 60 mph

5. Analysis

5.1. Summary of Proposed Improvements

- The device will have solar panels allowing it to last extended periods of time without charging
- The device will be controlled by an app allowing the user to make temperature adjustments while away from the car as well as check the current car temperature to make sure the environment is safe for their pet
- The device will have multiple temperature sensors reducing the likelihood of a malfunction as it will compare the readings and notify the user if one of them is no longer operating correctly
- The device will be cheaper than the alternatives while having substantial improvements

5.2. Disadvantages and Limitations

Limitations of the device are:

- Power supplied will be from solar panels, which will not always be active when there isn’t sunlight, and from a car outlet, which will supply zero voltage if the car battery is dead
- The target car size for cooling will be a crossover sized vehicle, meaning that if the customer wanted to put it in a larger car it may not have the power required to heat/cool that space
- There will be a decent amount of setup required as the user will have to mount solar panels to their roof rack
- There is a slight security risk as the window will be cracked for the exhaust system to work properly. However, this is something we are going to work hard to make as minimal as possible
- The device’s charge will last less time the less the sun is out when the device is in operation

5.3. Alternatives

Alternatives to this device are

- Leaving the car on with another passenger with the animal
- Leaving the pet at home
- Taking the pet into the store

While these are all possible alternatives each of them has a reason why it could not be a viable replacement for our device. None of these allow the customer to safely leave their animal alone in the car without leaving the car on. There are other battery powered A/Cs available, ours hopes to surpass the competition through the improvements mentioned above and by keeping it inexpensive to reach a larger market. One of the best alternatives to our device is the Icy Breeze, this device is much cheaper than having a full VAC system like our device has. The downside to this, however, is that the Icy Breeze must be filled with ice before every use. Our device, having a full VAC system, will simply work anytime it has power.

5.4. Impact

This device's primary function is to help provide a cool and safe environment for the customer's pet. Our device is sustainable due to our use of solar panels. These solar panels will operate while sunlight is available and will allow the user to go longer stretches of time without charging. This is important because leaving your car on produces CO2, a greenhouse gas, which contributes to global warming and is generally bad for the environment. The batteries in our device will also be rechargeable to prevent the waste from disposing of batteries in landfills. This device also promotes the companionship between pet owners and their pets by allowing them to take their furry friend wherever they go.

Battery Powered Car Air Conditioning
“The Chilly Dog”

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FUNCTIONAL SYSTEM REQUIREMENTS

REVISION – Draft
15 February 2022

FUNCTIONAL SYSTEM REQUIREMENTS
FOR
Battery Powered Car Air Conditioning

PREPARED BY:

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02/23/2022

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APPROVED BY:

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02/23/2022

John Lusher, P.E. Date

Sambandh Dhal 02/23/2022

T/A Date

Change Record

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-	2/15/2022	Grant Franklin		Draft Release

Table of Contents

List of Tables

List of Figures

1. Introduction

1.1. Purpose and Scope

Travelling with pets can be a challenge. The main factor being that there are very few businesses and buildings that are pet friendly. The responsible pet owner cannot just simply leave their pet inside the vehicle due to the fact that temperature changes in the cabin are drastic and can get hot enough to cause harm to their pet.

Our project, the Chilly Dog, will allow customers to leave their pets in the car unattended by cooling the car to a safe temperature. The Chilly Dog will actively monitor the temperature inside the vehicle using a sensor and microcontroller and send that data via cellular data to an application on the customer’s phone. Through this application, the customer will be able to see the temperature and adjust the VAC system output to their desired setpoint. The microcontroller will receive this input and the VAC unit will output a steady flow of air to match the user's command. The Chilly Dog will be powered by a rechargeable battery making it independent and non-reliable on the engine or battery of the car. This rechargeable battery will have the option of solar charge or charge by the cigarette lighter receptacle. If the battery is running low on charge, the user will be notified to return quickly through the app.

The device is intended to be used inside crossover-sized vehicles with an estimated interior of 110 square feet. It will be placed inside the vehicle and be no bigger than the area of one seat. It will include an exhaust hose to clip to the car window and solar panels that will be installed on the roof of the vehicle. A few possible configurations of installation are shown below.

Figure 1. Seat Placement

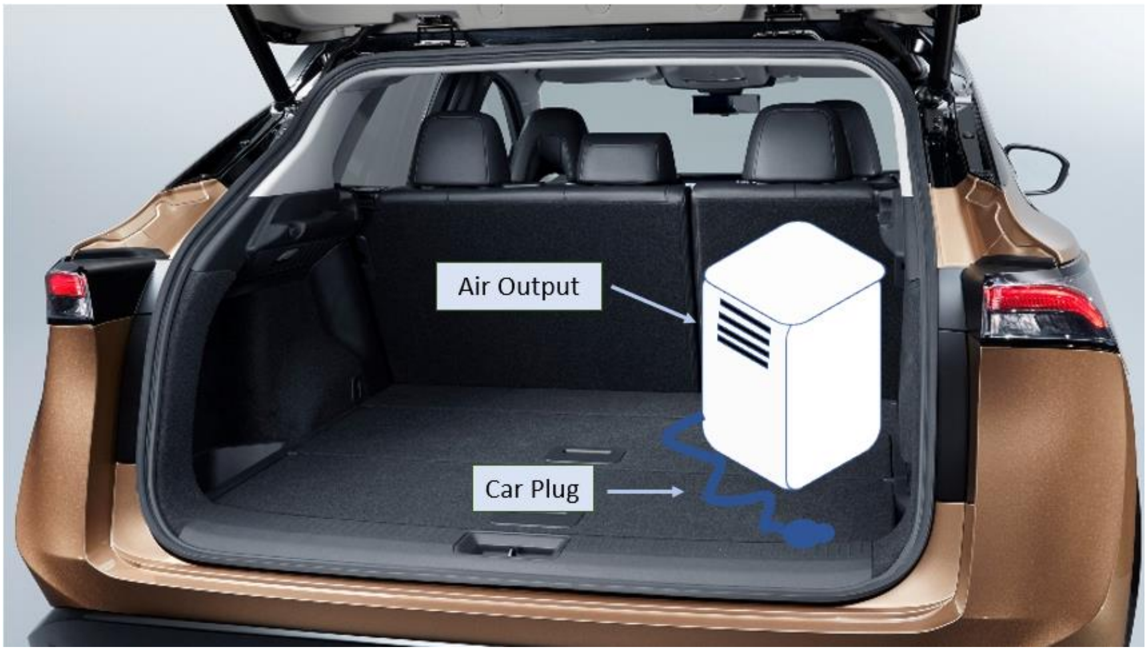

Figure 2. Trunk Placement

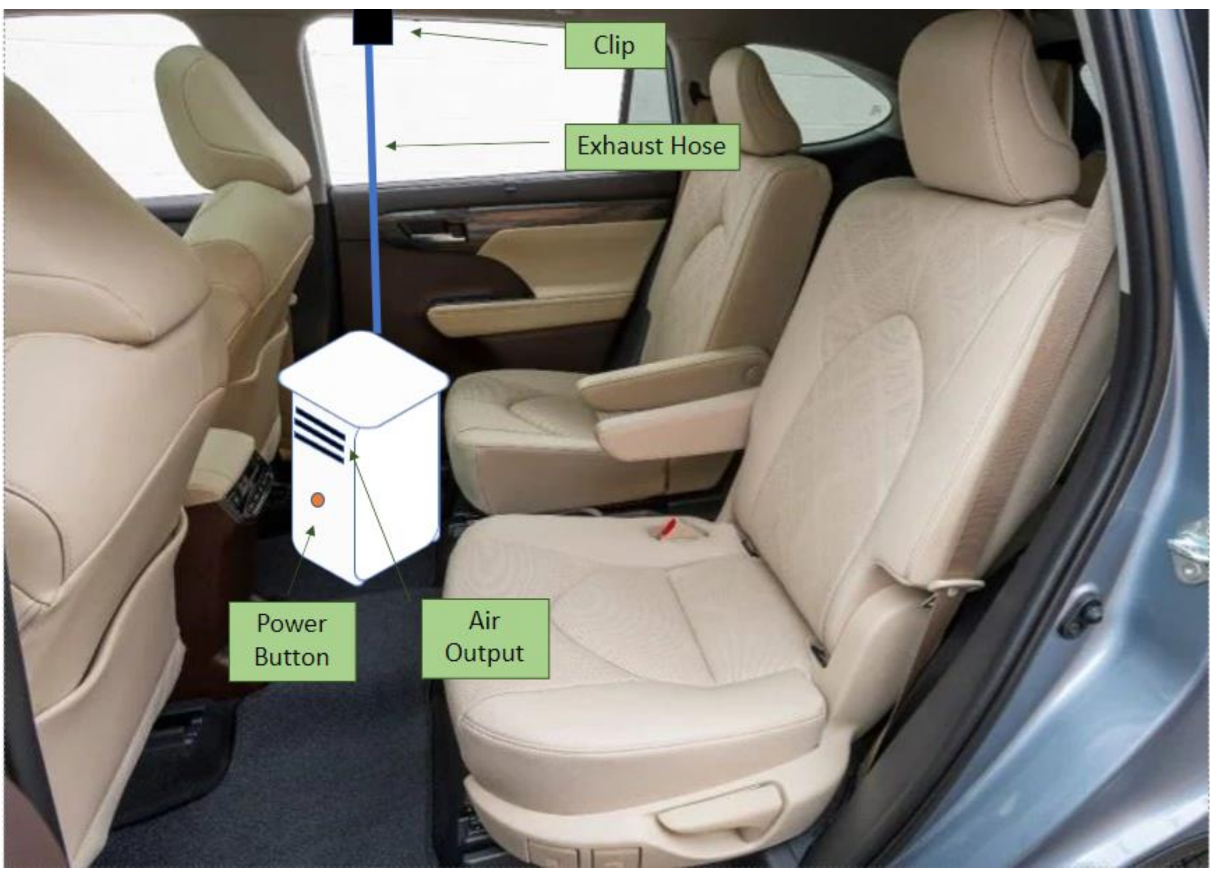

Figure 3. Floorboard Placement

1.2. Responsibility and Change Authority

The team leader, Martin Rennaker, has the responsibility of verifying the project requirements. These requirements can only be changed with the approval of the team sponsor, Skyelar Head, and the team leader. The subsystem breakdown is as follows:

Subsystem	Responsibility
VAC and MCU	Yarentzy Magallanes
Power Supply and Routing	Grant Franklin
Phone App and Interfacing w/MCU	Martin Rennaker

Table 1. Subsystem Leads

2. Applicable and Reference Documents

2.1. Applicable Documents

The following documents, of the exact issue and revision shown, form a part of this specification to the extent specified herein:

Document Number	Revision/Release Date	Document Title
IEEE 802.15.4-2011	4/2011	IEEE Standard for Local and metropolitan area networks--Part 15.4: Low-Rate Wireless Personal Area Networks (LR-WPANs)
IEEE 485-2020	6/2020	IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications

Table 2. Applicable Documents

2.2. Reference Documents

The following documents are reference documents utilized in the development of this specification. These documents do not form a part of this specification and are not controlled by their reference herein.

Document Number	Revision/Release Date	Document Title
1	April 2011	Temperature Variations in a Parked Vehicle
2	April 23, 2021	How to calculate battery run-time
3	N/A	How To Maintain Batteries

Table 3. Reference Documents

2.3. Order of Precedence

In the event of a conflict between the text of this specification and an applicable document cited herein, the text of this specification takes precedence without any exceptions.

All specifications, standards, exhibits, drawings, or other documents that are invoked as “applicable” in this specification are incorporated as cited. All documents that are referred to within an applicable report are considered to be for guidance and information only, except ICDs that have their relevant documents considered to be incorporated as cited.

3. Requirements

This section defines the minimum requirements that the development item(s) must meet. The requirements and constraints that apply to performance, design, interoperability, reliability, etc., of the system, are covered.

3.1. System Definition

The Chilly Dog is a battery powered air conditioning unit paired with an application that cools the internal temperature of a vehicle with the purpose of creating a safe environment for a K-9. The Chilly Dog is broken into 4 systems as seen in Figure 3.1. They will all work together to provide sufficient cooling to the vehicle based on the user’s desired temperature. The Chilly Dog is made up by power, microcontroller, VAC, and application subsystems.

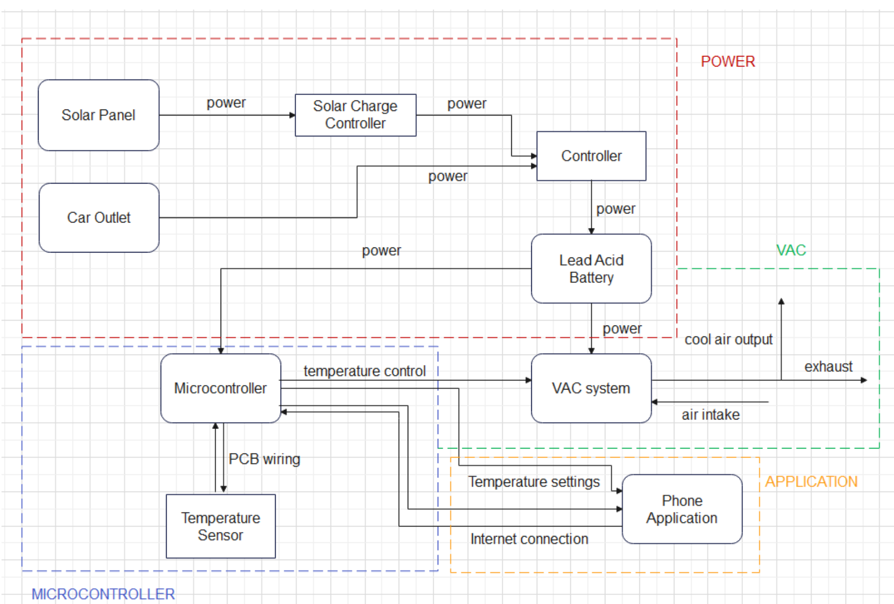

Figure 4: Block Diagram of System

The first stage of the block diagram is the power subsystem. Power is routed to the battery from a 12V, 100W solar panel, as well as a 12V car outlet. The solar panel will provide very slow recharging capabilities, so it will send power to the battery after going through a solar charge controller while the system is on. The car outlet will recharge the battery while the car is on, to provide faster charging time and allow the user to use the Chilly Dog as much as possible. This power input switching will be controlled by an MCU. The battery will send voltage to the VAC and microcontroller subsystems, after going through converters to give the necessary voltages.

The microcontroller subsystem is in charge of controlling the air output from the VAC system. It will do this by comparing the current temperature in the vehicle from a sensor reading to the data sent from the application. If the two numbers don't line up, the microcontroller will tell the VAC system to either stop blowing air if the car is too cold or to cool the car down if the current temperature is too high. The microcontroller will also read the outside temperature and battery life and send that information to the modem, which will send it to the application.

The VAC subsystem will take the input from the microcontroller and power from the battery and provide necessary cooling to the car. It will require an inverter to convert the battery input to an AC voltage, which is standard in VAC systems. Our VAC system will also handle the exhaust that comes with air conditioners.

The phone application sends data to the microcontroller based on what the user inputs through an internet connection. It will also receive the battery life, current car temperature, and outside temperature from the modem, which gets the data from the microcontroller. On the application, there will be options to input their pet's size and a recommended temperature will appear, but they can set any temperature within a certain range for their dog. This will be the primary interface the user sees, other than the panel on the box with the power button.

3.2. Characteristics

3.2.1. Functional / Performance Requirements

3.2.1.1. Frequency of Temperature Measurements

Each temperature sensor in the Chilly Dog shall take a measurement every minute.

Rationale: This frequency is expected to report accurate temperature readings to the customer while avoiding recording excessive amount of data that could become difficult to manage. This frequency will also provide sufficient time for the customer to act if the temperature rises above the predetermined safe range.

3.2.1.2. Accuracy Of Measurements

The Chilly Dog sensors will report accurate data.

Sensor	Accuracy
Cabin and Outside Temperature	+ or - 1 ° C
Battery Life	+ or - 1 %

Table 4. Measurement Accuracy

Rationale: These are standard values that most sensors of decent quality can achieve. Accuracy of measurements is key in Chilly Dog as the health and comfortability of the customers pet is of essence.

3.2.1.3. Device Environment

The components of the Chilly Dog shall function in ambient temperatures of up to 130 degrees Fahrenheit.

Rationale: The Chilly Dog must be able to withstand extreme heat as it will be placed inside a vehicle.

3.2.1.4. Battery Operating Time

The Chilly Dog shall perform its entire functionality for a span of 1.3 hours.

Rationale: Per customer request. To provide the customer sufficient time to perform their tasks while their pet is in the vehicle.

3.2.1.5. Communication from Device to Application

Every minute The Chilly Dog will send updates to the app on cabin temperature, outside temperature, and current battery remaining. The app will send any updates the user makes on desired temperature within 5 seconds of them being made. These packets will be maximum 16 bits in size. As the device will be using cellular data as long as both the phone and device are connected to a cell signal it should work from any range, but the goal will be 500 yards for testing purposes.

Rationale: The goal is to keep the user as informed as possible so they can be sure that their pet is safe in the car.

3.2.1.6. Output Temperature Ranges

The Chilly Dog shall assume the car had been recently turned off and has an internal temperature of up to 85 degrees Fahrenheit before the device is powered. The Chilly dog shall then be able to output air with a minimum temperature of 62 degrees Fahrenheit.

Rationale: The average car air conditioner has a cooling power of 17,000 BTU. This allows the car to cool quickly. The Chilly Dogs cooling power is 5,000 BTU maximum. The Chilly Dog shall be used for the sole purpose of maintaining the cabin temperature assuming it is less than 85 degrees Fahrenheit.

3.2.2. Physical Characteristics

3.2.2.1. Mass

The mass of the total Chilly Dog battery powered air conditioning unit shall be less than or equal to 127.8 pounds. This does not include the weight of the switchover circuit, microcontroller, or temperature sensor, which will affect the total weight minimally.

Current Component Mass Breakdown:

- AC Unit: 47.4 lbs
- Battery: 63.9 lbs
- Solar Panel:14.3 lbs
- Inverter: 2 lbs
- Switchover Circuit: TBD
- Microcontroller: TBD
- Temperature Sensor: 0.007 lbs
- Buck Converter: 0.0585 lbs
- Solar Charge Controller: 0.085 lbs
- Modem: .089 lbs

Rationale: The Chilly Dog will have a wide mass range to work with thanks to the carrying capacity of a crossover vehicle. It will encompass the seat of one passenger. With this said, the Chilly Dog shall weigh less than the average passenger which weighs 136 pounds. Each physical component will be less than 65 pounds. This is to avoid the need for machinery during installation.

3.2.2.2. Volume Envelope

The volume envelope of the Chilly shall be less than or equal to 26 inches in height, 14 inches in width, and 14 inches in length. The Chilly Dog will only occupy the area of one seat but can be placed on the floorboard, or the trunk if desired. More detail can be found in the ICD.

Rationale: This is a requirement specified by our customer due to the limitation of the cabin space inside a vehicle. The customer expects sufficient room for their pet even after the Chilly Dog has been installed.

3.2.2.3. Mounting and Installation

The mounting information for the Chilly Dog System shall be captured in the ICD.

Rationale: The Chilly Dog includes the VAC unit, the exhaust hose, the connecting wires, and the solar panels. These details will be described in the ICD.

3.2.2.4. Material

The material of the Chilly Dog will be “pet friendly” meaning it will be made of nontoxic material to both the pet and the human, sturdy enough to resist accidental nudging, but shall not be expected to withstand chewing of cables and any other improper use.

3.2.2.5. Exhaust

The VAC unit will also have a hose connected to the window that will push the warm air outside of the car.

3.2.3. Electrical Characteristics

3.2.3.1. Inputs

The electrical inputs for the Chilly Dog consist of the power from the solar panels and car outlet, the temperature data gathered by the sensor on the microcontroller, and the user's input information sourcing from the phone application.

3.2.3.1.1 Power Consumption

The maximum peak power of the system while recharging the battery shall not exceed the available power coming from the solar panels and the car outlet, being 100W and 210W respectively.

Rationale: The power from the car outlet will recharge the battery much faster than the solar panel, so while driving to the destination, the user will use the car outlet and while the car is off, the solar panel will recharge the battery. The solar panel recharging time would be drastically reduced if a larger wattage panel is used.

3.2.3.1.2 Input Voltage Level

The input voltage level for the battery will be 14V, as is needed for the battery to recharge. This voltage will first go through the switchover circuit, to regulate the power going to the battery. The microcontroller will take 1.8 - 5.5V, the modem will take 5V at 50mA, and the VAC system will take 115V at 7.19A.

Rationale: The battery powered car air conditioning will need to power the microcontroller and the VAC components with enough voltage for the amount of time the unit will need to be running.

3.2.3.1.3 Modem Inputs

The modem will receive desired temperature data from the application, as well as the current temperature and battery life from the microcontroller.

3.2.3.1.4 Microcontroller Inputs

The microcontroller will receive inputs from temperature sensors and the modem. The temperature data from the sensors will be compared to the desired temperature data coming from the modem. If the actual temperature inside the vehicle is different than the desired temperature, the microcontroller will command the VAC system to output cool air.

Rationale: The microcontroller will oversee regulating the amount and the temperature of air that is output into the vehicle.

3.2.3.1.5 Application Inputs

The application will receive the current temperature data for the inside of the vehicle, as well as outside, and battery life from the modem.

Rationale: The app will need to display to the user the current internal car temperature, outside temperature, and battery life.

3.2.3.1.6 Air Conditioning Inputs

The VAC will receive commands from the microcontroller to turn/off its cooling.

3.2.3.2. Outputs

3.2.3.2.1 Modem Outputs

The modem will send the current temperatures and battery level to the application using cellular data.

3.2.3.2.2 Microcontroller Outputs

The microcontroller will send the current temperatures and battery level to the modem.

3.2.3.2.3 Application Outputs

The Application will send the user's desired temperature to the modem. The application will also push notification banners to the phone to alert the user to low battery.

Rationale: The MCU will need the desired temperature from the app to know what temperature to set the car at. The app will need to notify users if there is danger to their animals

3.2.3.2.4 Air Conditioning Outputs

The unit will provide enough cool air that will bring the inside temperature of the car to the desired temperature input by the user.

Rationale: The unit will need to cool the car down fast enough so the pet inside the car will not overheat. It will also need to blow the hot air out of the car using an exhaust hose.

3.2.3.2.5 Cellular Outputs

The MCU will send both the current temperature and battery level to the app via cellular data.

Rationale: Allows the user to quickly check if the unit is operating correctly while away from the car, as well as informing them of the current battery life of the unit.

3.2.4. Environmental Regulations

The Chilly Dog will need to withstand various climates and temperature ranges since its function is to keep the pet inside the vehicle safe while the weather is dangerous outside.

Rationale: This is a requirement specified by our customer due to constraints of their system in which the Chilly Dog is integrating.

3.2.4.1. Animal Activity

The Chilly Dog will be constructed to be resistant to animals biting or scratching it. It will also, as mentioned previously, be made out of nontoxic materials to prevent poisoning an animal that does bite or scratch it.

Rationale: This is to prevent injuries to animals in the car with the device as well as protecting the device from animals.

3.2.4.2. Weather Conditions

The only component that will be exposed to varying weather conditions will be the solar panel and the wires leading to the main unit. It will have to withstand weather conditions such as rain, humidity, etc. to satisfy the claim that it can run and charge a battery in all conditions.

3.2.5. Failure Propagation

The Chilly Dog shall not allow propagation of faults beyond the Chilly Dog interface.

3.2.5.1. Battery Input Regulation

Since there are two inputs to charge the battery, there is a possibility that voltage would travel from one input to another. This chance will be eliminated by utilizing a switchover circuit, which will regulate the voltage and determine which input will send power to charge the battery.

3.2.5.2. Connection Lost Between Modem and App

If the Modem and app lose connection, an attempt will be made 5 times, once per minute, to reestablish connection. If connection is not made and the phone can still connect to cellular data itself the app will send a banner notification to the phone informing them that connection has been lost and they need to return to their car. If the phone itself is unable to connect to cellular data, it is likely that the device is still functioning, and the app will simply send a notification every 5 minutes informing the user of how long it has been since a connection has been made.

4. Support Requirements

4.1.1. Android Device with Cellular Data

To Communicate with the Chilly Dog via the application, the customer will need access to an android device with cellular credit.

Rationale: Other forms of accessing the information from the system are outside of the scope of this project.

4.1.2. Cellular Reception

The customer must have reliable cellular reception in the area where the Chilly Dog will be placed and where the customers phone will be located.

Rationale: The app and the device communicate through cellular signals.

4.1.3. Crossover Sized or Smaller Vehicle

The customer must have a car that spans 179 inches (14 feet) in length or less.

Rationale: The use of the Chilly Dog in larger vehicles will not cool as expected and could result in the cabin being unfit for pets.

4.1.4. Rolling Window

The customers crossover or smaller vehicle must have fully functioning windows that roll up and down.

Rationale: The Chilly Dog has an exhaust hose used to dispose of hot air. The exhaust hose configuration is only supported via a clip that attaches to a standard roll up window. Other configurations are not in the scope of this project.

4.1.5. Provided

- (1) VAC unit
- (1) Rechargeable Battery
- (1) MCU
- (1) Cigarette Lighter Receptacle Plug in
- (1) Surface Mount Solar Panel
- (1) User Manual and Warnings
- (1) Installation Manual

Appendix A: Acronyms and Abbreviations

lbs	Pounds
AC	Air Conditioning
V	Volts
A	Amps
mA	Milliamp
MCU	Microcontroller Unit
VAC	Ventilation and Air Conditioning

Battery Powered Car Air Conditioning
“The Chilly Dog”

Grant Franklin
Martin Rennaker
Yarentzy Magallanes

INTERFACE CONTROL DOCUMENT

REVISION – Draft
15 February 2022

INTERFACE CONTROL DOCUMENT
FOR
Battery Powered Air Conditioning

PREPARED BY:

Marrtin Rennaker
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Yarentzy Magallanes

Author Date

APPROVED BY:

Martin Rennaker

Project Leader Date

John Lusher II, P.E. Date

Sambandh Dhal

T/A Date

Change Record

Rev.	Date	Originator	Approvals	Description
-	02/15/2022	Grant Franklin		Draft Release

Table of Contents

List of Tables

List of Figures

1. Overview

The Interface Control Document or ICD discusses in depth the methods in which the subsystems of the Chilly Dog function as individuals and interact. In this document we can see what will be done in order to produce what has been described in the Concept of Operations, Functional System Requirements, and Validation Plan.

2. References and Definitions

2.0. References

IEEE Standard for Local and metropolitan area networks--Part 15.4: Low-Rate Wireless Personal Area Networks (LR-WPANs)
Document IEEE 802.15.4-2011

2.1. Definitions

ConOps	Concept of Operations
FSR	Functional System Requirements
ICD	Interface Control Document
GSM	Global System for Mobile Communications
VAC	Ventilation, and Air Conditioning
mA	Milliamp
MCU	Microcontroller Unit
mW	Milliwatt
MHz	Megahertz (1,000,000 Hz)
SUV	Sport Utility Vehicle
TBD	To Be Determined
V	Volts
WPAN	Wireless Personal Area Network

3. Physical Interface

3.0. Weight

The weight of the power supply will contain the heaviest components, since it uses a solar panel, marine battery, and a VAC system. The parts can be removed and installed individually, since they will be almost immobile together. The total weight of the system is estimated to be

Component	Weight	Estimate
Solar Panel	14.3 lbs	No
Battery	63.9 lbs	No
VAC system	47.4 lbs	No
Inverter	2 lbs	No
Microcontroller	0.00441 lbs	Yes
Switchover Circuit	TBD	TBD
Buck Converter	0.0585 lbs	Yes
Solar Charge Controller	0.085 lbs	Yes
Modem	.089 lbs	No
Temperature Sensor	0.00661 lbs	Yes

Table 1: Weight of System

3.1. Dimensions

3.1.1. Dimensions of System

The dimensions of the Chilly Dog components will be mostly confined to the back seat of a mid-sized SUV. The solar panel will need to fit on the roof of the car, while the rest of the components will be small enough to be placed in the floorboard behind the passenger seat, with the possible exception of the VAC unit.

Component	Length	Width	Height
Solar Panel	42.2”	19.6”	1.38”
Battery	12.09”	6.65”	8.48”
VAC system	12.56”	24.96”	12.96”
Inverter	8.75”	4.5”	2.5”
Microcontroller	TBD	TBD	TBD
Switchover Circuit	TBD	TBD	TBD
Buck Converter	TBD	TBD	TBD
Solar Charge Controller	2.7”	2”	0.625”
Modem	3’’	2’’	3.5’’
Temperature Sensor	2’’	0.5’’	0.5’’

Table 2: Dimensions of System

3.2. Mounting Locations

3.2.1. Mounting of Solar Panel, Charge Controller, and Battery

The solar panel will be mounted on the roof of the vehicle. The solar charge controller and battery will be placed inside of the car on the floorboard of the back seat. Possible placement diagrams can be found in the FSR.

4. Thermal Interface

The air conditioning unit chosen for the functionality of the Chilly Dog was the Midea Comfortsense. This VAC unit comes equipped with the all the proper thermal interface required to assure that the components to not overheat and maintain within operating range. This system will ventilate the air inside the cabin of the vehicle by intaking ambient air, cooling it through the VAC unit and outputting it into the vehicle. This will provide circulation of oxygen, and most importantly abides by the rules of thermodynamics of cooling an enclosed space.

5. Electrical Interface

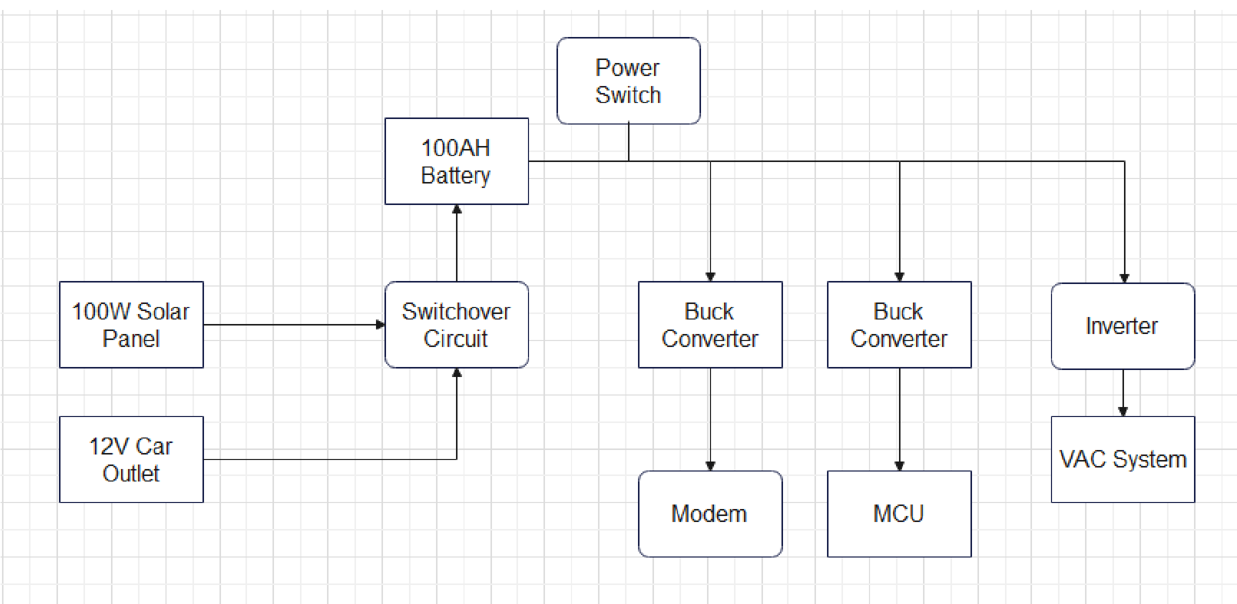

Figure 1: Power Supply System

5.1. Primary Input Power

All power to the battery powered car air conditioning will be supplied by a 12V car outlet and a 100W solar panel, which will be used to charge a 100Ah car battery. This battery will power the microcontroller and VAC subsystems for 1.3 hours. The voltage will be stepped up and down and regulated by buck converters and an inverter. The buck converters providing power to the microcontroller and the modem, and the inverter changing the power to AC and routing power to the VAC system.

5.2. Signal Interfaces

The Chilly Dog will receive and transmit wireless signals between the phone app and MCU. This communication will occur through GSM cell band, the cellular modem being used can accept 850, 900, 1800, or 1900 MHz signals, so the chosen cell carrier must support one of these frequencies of GSM. The cell signals will transmit and receive temperature information for the MCU. This information transfer will need to be at a rate of 16 bits in 5 seconds to allow quick changes.

5.3. User Control Interface

The primary way that users will interface with The Chilly Dog will be the app. This app will allow the user to change the desired temperature of the device, manage multiple devices if they have them, and see the current temperature inside the car.

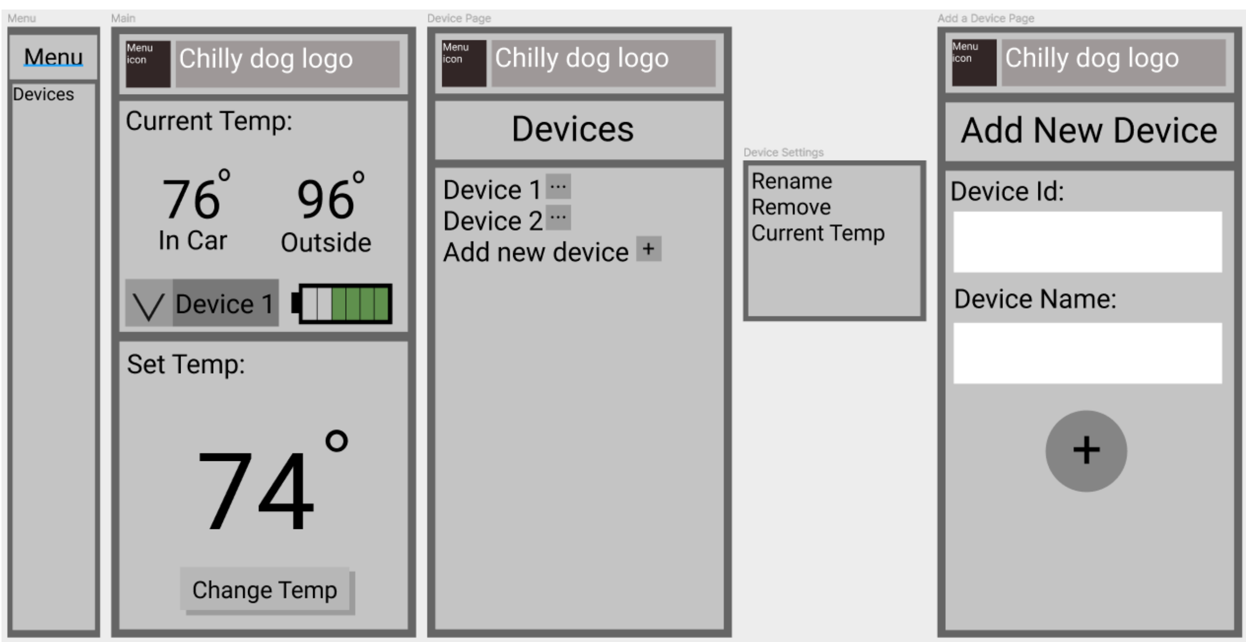

Figure 2: Preliminary Application Design

5.4. Voltage and Current Levels

The voltage and current going through the system will be regulated by the converters that are sending power to the VAC and the microcontroller. When the Chilly Dog is turned on, the microcontroller will be receiving 1.8 - 5.5V at 10mA the modem will be receiving 5V at 50mA, and the VAC will consume 115V at 7.2A. The 12V, 100Ah battery will be able to power these components at these values for 1.3 hours.

These are the maximum voltage and current inputs for each part of the power subsystem:

	Max. Voltage (V)	Max. Current (A)	Max. Power (W)
Battery	15	27	405
Microcontroller	5.5	10mA	1.67
Modem	5.2	0.45	2.34
VAC	115	15	793

Table 3: Maximum Voltage Inputs of System

These are the minimum voltage and current inputs for each part of the power subsystem:

	Min. Voltage (V)	Min. Current (A)	Min. Power (W)
Battery	12.9	0.1	1.29
Microcontroller	1.8	10mA	N/A
Modem	4.8	N/A	N/A
VAC	110	13	790

Table 4: Minimum Voltage Inputs of System

6. Communications / Device Interface Protocols

6.1. Wireless Communications (Cellular Data)

This device will have wireless communication via cellular data utilizing the IEEE 802.15.4-2011 standard for WPAN. This connection will be used to send temperature data between the app and the device

	1/24/2022	1/31/2022	2/7/2022	2/14/2022	2/21/2022	2/28/2022	3/7/2022	3/14/2022	3/21/2022	3/28/2022	4/4/2022	4/11/2022	4/18/2022	4/25/2022	5/2/2022	Owner	Date Completed
Assigned Project and Team																All	1/24/2022
Sponsor Introduction																All	1/25/2022
Brain Storm Stage										Not started						All	1/31/2022
Distribution of Subsections										In Progress						All	1/28/2022
Concept of Operations										Completed						All	2/19/2022
Research										Behind Schedule						All	2/21/2022
Research and Choose AC Unit																All	2/21/2022
Research Microcontroller Requirements																Yarentzy	2/21/2022
Choose Microcontroller																Yarentzy	2/21/2022
Download and begin testing with Android Studio																Martin	2/21/2022
Submit Preliminary Parts Request																All	2/22/2022
App layout and acquire cellular modem, sim, and antenna																Martin	2/22/2022
Functional System Requirements																All	2/23/2022
Interface Control Document																All	2/23/2022
Midterm Presentation																All	2/23/2022
Download MPLAB Software and Obtain Access to Debugger																Yarentzy	2/21/2022
Create a Blinking LED																Yarentzy	
Design PCB and schematic for switchover circuit																Grant	
Order components and parts for power supply																Grant	
Develop app to modem communication system																Martin	
Obtain access to the control functionalitlies of VAC																Yarentzy	
Configure MCU and ambient temperatrue sensor																Yarentzy	
Make connection between app and modem																Grant	
Test VAC side of power supply circuit																Grant	
Solder and test MCU/switchover components																Grant	
Validate the modem is able to send and receive the correct data																Martin	
Establish connection between AC and MCU																Yarentzy	
Test MCU commands and assure expected output																Yarentzy	
Progress Update Presentations																All	
Validate and test full power supply circuit																Grant	
Implement GUI over the app																Martin	
Validate the whole cellular subsystem is working together																Martin	
Accept Input from the application (I2C)																Yarentzy	
Design exhaust clip utilizing SolidWorks																Yarentzy	
Finalize and test full scope edge cases of MCU																Yarentzy	
Final Presentation																All	
Subsystem Presentations																All	
Final Report																All	

Item Testing	Success Criteria	Methodology	Status	Responsible Engineer(s)
Battery Output	The battery will output a DC voltage of +12V for the 1.3 hours of run time.	Set up a dummy load for the full system and see if the battery can power it for an extended amount of time.	Untested	Grant Franklin
MCU Input	The +12V DC from the battery will be stepped down to 5V for the temperature controlling MCU system.	Create an input voltage and current that mimics the battery and use a multimeter to assure that the output of the Buck converter is 5V.	Untested	Grant Franklin
Modem Input	The +12V DC from the battery will be stepped down to 5V for the modem.	Create an input voltage and current that mimics the battery and use a multimeter to assure that the output of the Buck converter is 5V.	Untested	Grant Franklin
Inverter Output	The inverter correctly changes the +12V DC from the battery to 110V AC that will route to the VAC.	Create an input voltage and current that mimics the battery and use a multimeter to assure that the output of the inverter is an AC 110-115V.	Untested	Grant Franklin
Solar Panel Charging	The mounted solar panel will provide sufficient charging for the battery at ~14V.	Route the voltage from the solar panel, through the switchover circuit, to the battery and test to see if the battery charges at an acceptable rate.	Untested	Grant Franklin
12V Outlet Charging	The +12V DC from the car outlet will provide sufficient charging for the battery at ~14V.	Route the voltage from the car outlet, through the switchover circuit, to the battery and test to see if the battery charges at an acceptable rate.	Untested	Grant Franklin
Input Power Switching	The switchover circuit will be able to correctly choose which power source to use.	When the solar panel is supposed to be routing power to the battery, use a multimeter to assure voltage is flowing in the correct place. Repeat for the 12V car outle	Untested	Grant Franklin
Data Receiving	The App can successfully send temp data to the modem and the modem will output(digitally) the correct temp	Change the desired temp in the app and, using an oscilloscope, measure the digital output and see if it matches the sent temperature.	Untested	Martin Rennaker
Data Transmitting	The Modem can successfully transmit current in car temp, outside temp, and current battery life to the app. App is displaying sent numbers	Generate a digital signal matching an expected temperature and battery % and see if the app reflects the sent signals.	Untested	Martin Rennaker
Transmit Time	The modem and app can send the 16 required bits in under 5 seconds	The app will record the exact time the signal leaves and connected to a computer, we will record the exact time the signal arrives.	Untested	Martin Rennaker
Transmit Distance	The modem and app can communicate at 500 yards apart vial cellular data	Walk 500 yards from the modem and send a signal to be received.	Untested	Martin Rennaker
Notification	The device will notify the user via popup banner if the battery drops below 15%	Send a battery life signal of less than 15% and see if the app sends a popup banner to the phone.	Untested	Martin Rennaker
Modem Power	The modem's power consumption will not exceed the 5V at 50 mA	Will use a multimeter to verify	Untested	Martin Rennaker
VAC Cooling Specifications	The VAC's minimum temperature output is 62 degrees fahrenheit	VAC unit will be placed in a crossover vehicle and data of the maximum cooling capacity capabillity will be collected	Untested	Yarentzy Magallanes
Ventilation	The VAC shall operate while maintaining sufficient oxygen (at least 20%) in the cabin of the vehicle.	The VAC will be placed inside the vehicle with the exhaust	Untested	Yarentzy Magallanes
VAC Power Consumption	Accurate Data of the power consumtion corresponding to each mode (Low, Med, High)	An electricity usage monitor power meter plug outlet will be used to measure the power consumption corresponding to each mode of the VAC unit.	Untested	Yarentzy Magallanes
Temperature Sensor	Both temperature sensors report the same measurement	Redundancy will assure accuracy. Two temperature probes will be taking ambient readings. A comparison of these inputs will assure functionality.	Untested	Yarentzy Magallanes
MCU Communication with VAC	The MCU has full functionality and control of the VAC unit. (On, Off, Low, Med, High, Temperature Output)	Test cases for each functionality as well as expected outputs will be programmed and tested.	Untested	Yarentzy Magallanes
MCU Data Receiving	The MCU can receive the user setpoint from the application as well as the battery percentage	Generate expected digital signal of setpoint temperature and battery percentage display received data.	Untested	Yarentzy Magallanes
MCU Data Transmitting	The MCU shall output temperature readings to be received by the application	Temperature will be read using the probes and interpreted into digital signals to them be outputted.	Untested	Yarentzy Magallanes
Measurement Periods	The MCU shall receive and output the temperature to the application every 60 seconds	A stopwatch will be used to measure frequency of reading and outputs.	Untested	Yarentzy Magallanes