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March 19, 2015

School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Attn: Dr. Andrew Rawicz

Re: ENSC 305W/440W Design Specification RAHS (Remote Automotive Heating System)

Dear Dr. Rawicz:

The enclosed document is the Design Specification for RAHS. We are designing and implementing the RAHS system to defrost and heat vehicles before a user enters. This system defrosts the vehicle without starting the engine and can be activated with a remote. RAHS will be equipped with a heater as well as a timing system and a remote starter.

This document outlines the Design Specification of RAHS and the required components for the system. The Design Specification is related to the Functional Specification and will explain why certain components were used. The implementation will be created with respect to the specifications for the heating system, RF transmitter system, and the timer system.

The RAHS team consists of three innovative Systems Engineering Students:
Andrew Piechnik, Patrick Krzesinski, and Joe Kuo. If you have any questions regarding this Design Specification, please feel free to contact me by email at apiechni@sfu.ca, or by phone 604.349.4328.

Sincerely,

Andrew Piechnik

Enclosure: Functional Specification for RAHS

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REMOTE AUTOMOTIVE HEATING SYSTEM

Design Specification

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Submitted to:
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Date Issued:
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Executive Summary

Vehicles are a great invention and flourish in today's market. Driving has become inseparable from the daily routines of people in the twenty-first-century. RAHS is a product that heats and defrosts vehicles before the user enters. This system is easy to use and can be operated remotely. Saving money from gasoline is now more important for car owners. The expectation can be hard to achieve especially in winter season. The fuel consumption increases from 7 - 19 percent for idling a car just to warm up the interior according to Natural Resources Canada [1]. The design of RAHS provides a way save energy and heat a vehicle.

RAHS is an electric heater that will increase the interior temperature of a car and defrost the windshield without going inside of a car. To make the operation of device easy, a remote control and an alarm system will be implemented to give better control to the system.

In this design specification document, we provide description of the design and development of prototype. The document will not only discuss the design regarding the functional requirements categorized as Rn-A and Rn-B that are described in the previous functional specification document but also justify certain choices of components. This document demonstrates the details of every sub-system of the project, hardware, software, electrical power, and logic.

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Glossary

ASK Acronym; Amplitude Modulation

RF Acronym; Radio Frequency

1 Introduction

At RAHS Tech the goal is to create a simple solution to a very common problem. The RAHS system is designed to defrost and heat a vehicle before the user enters it. Imagine it is winter and your car is freezing cold and has frost on the windshield, it would be very convenient if there was a product to prevent this. RAHS solves this problem. RAHS is a car accessory that is easily implemented into any are and heats the vehicle without starting the engine. The user can set activate the RAHS system with the timing system or the remote control device. By using both of these systems, the user avoids wasting energy. The components and the Design Specification for RAHS are explained in this document.

1.1 Scope

The Design Specification for RAHS is built off of the Functional Specification through designing the functions that need to be implemented. This document will analyze technical aspects of this project and will provide a detailed explanation for the decision of selected components were used. The timing system and remote control system are connected and will both be able to activate the heating system. The temperature sensor will be connected to the heating system to prevent wasted energy. All of these systems must be implemented to create one easy to use product. This product will also explain the test plan for each of the systems.

1.2 Intended Audience

The Design Specification is intended for all members of RAHS tech. The users of this document will use it for implementing the design. This document will also provide guidelines for the proper implementation to meet the functional requirements. The tester of this product will also use this document test the product based on the tests outlined in this document.

1.3 Background

Vehicles have become an important part of the everyday life and are constantly becoming more comfortable. One feature of vehicles that has not yet been addressed properly is defrosting and heating vehicles before the user enters. In cold winter climates such as in BC, this can cause discomfort and waste peoples time. The RAHS system will effectively and efficiently heat a vehicle before the user enters it. In order to make this product work, it needs to be easy to use and energy efficient. The design used for RAHS is efficient, easy to use, and serves a useful purpose.

2 System Overview

RAHS consist of three main systems which are: Heating system, Timing system and Remote control system. This section will provide an overview of the whole system design and functionalities. The detail of each system design will be covered in the later section separately.

RAHS is a portable system, which can be installed easily by the user on various types of household automobiles. The system assists the driver by heating the interior of the car and defrosting the windshield prior to entry. In addition the system requires only electricity which can save the fuel of the car and being environmental.

The system main components are: 12V battery, 12V 600W heater, 1 microcontroller, 1 RF transmitter, 1 RF receiver, 1 temperature sensor, and 1 user control interface. These components are implemented over three systems mentioned earlier. The battery and heater will be connected to form the heating system which is placed on the dashboard of the car. An Arduino Duemilanove, RF receiver and Phi-2 Shield will be connected and placed beside the heater as the main control unit of the system. A RF transmitter will have four buttons which will communicate with control unit wirelessly between the ranges of 50 to 100 meters. The following shows our signal/power travelling diagram, system overview clock diagram and the control unit which will be in charge of processing and executing all of the proposed functions of RAHS proof-of-concept model.

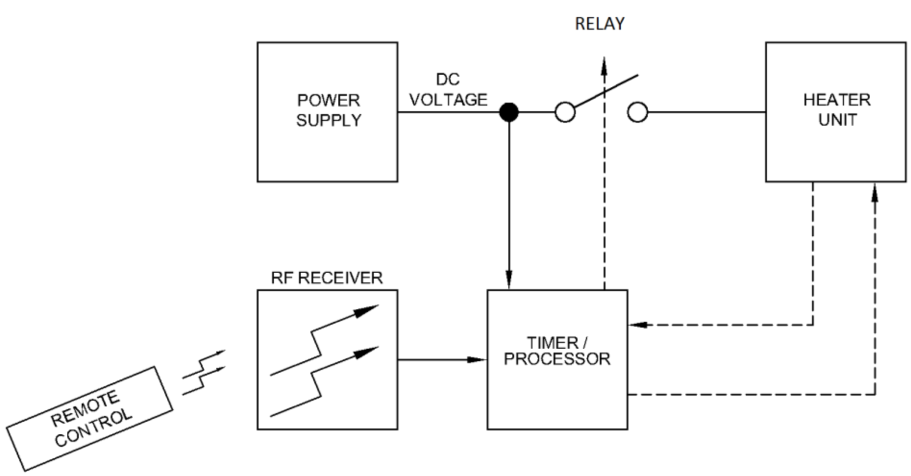

Figure 2-1-1: RAHS signal/power travelling diagram

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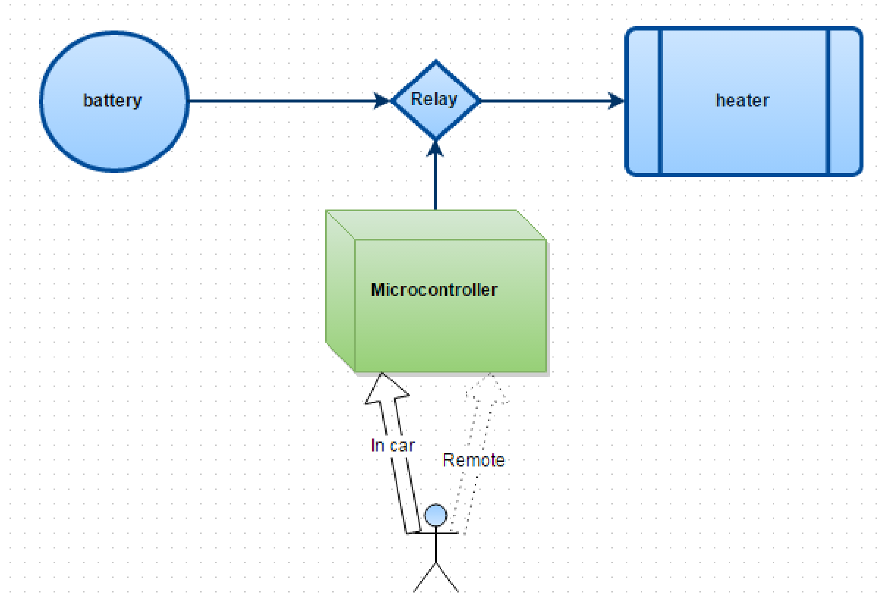

Figure 2-1-2: RAHS overview block diagram

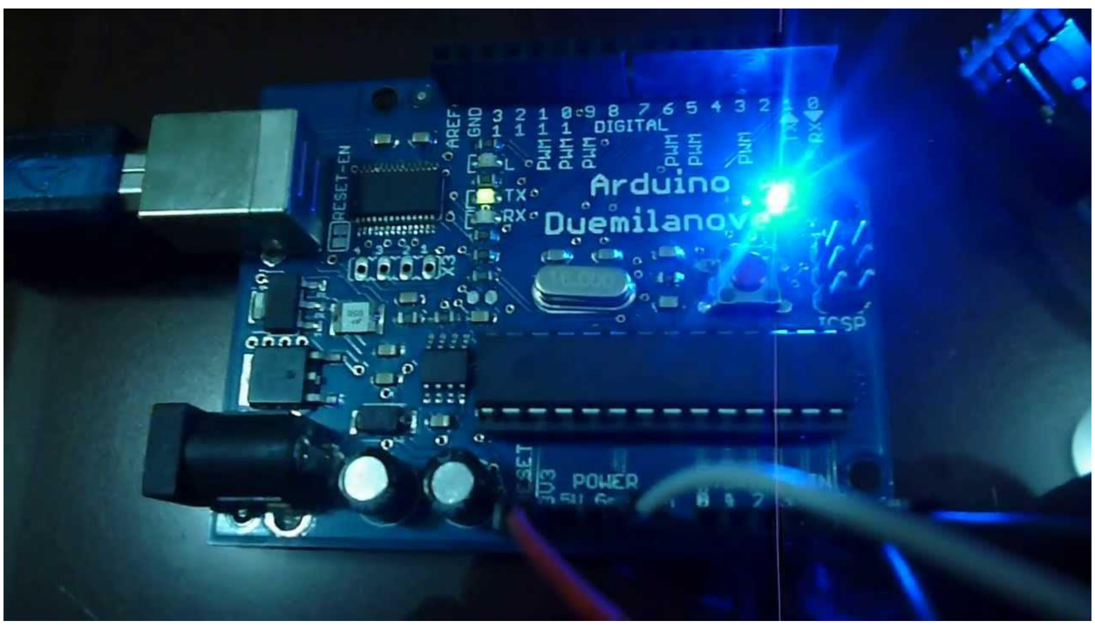

Figure 2-1-3: RAHS control unit Arduino Duemilanove

3 Timing System Design

The brains of the RAHS (the timing and alarm system) will built from a single-board microcontroller, the Arduino Duemilanove. Controlled via an all-purpose interactive Phi-2 Shield add on our system will be designed with best interactive user interface possible for the customer. All electronic parts will be encased in an anti-static enclosure away from the user except for the interactive push buttons and LCD screen.

The following requirements are met by our proof-of-concept model using microcontroller, phi-2 shield and SSR:

[R7-A] Device will operate with a 60Ah 12V standard car battery
[R8-A] Device will operate at a maximum voltage of 12V
[R9-A] Device shall not fully drain vehicle battery to non-operational levels
[R12-B] Device timer shall operate on 1 9V batteries
[R13-C] Device timer batteries to be rechargeable
[R14-C] Device timer batteries shall be easily accessible and interchangeable
[R50-A] Timer shall be set similar to an alarm clock
[R51-A] Timer will activate the heater

3.1 Arduino Duemilanove

We chose the Arduino Duemilanove for its low power consumption (runs at 5V) and tiny form factor. As well it has a resettable polyfuse that protects our circuit from shorts and overcurrent which will ensure that if more than 500 mA is applied to the USB port, the fuse will automatically break the connection until the short or overload is removed.

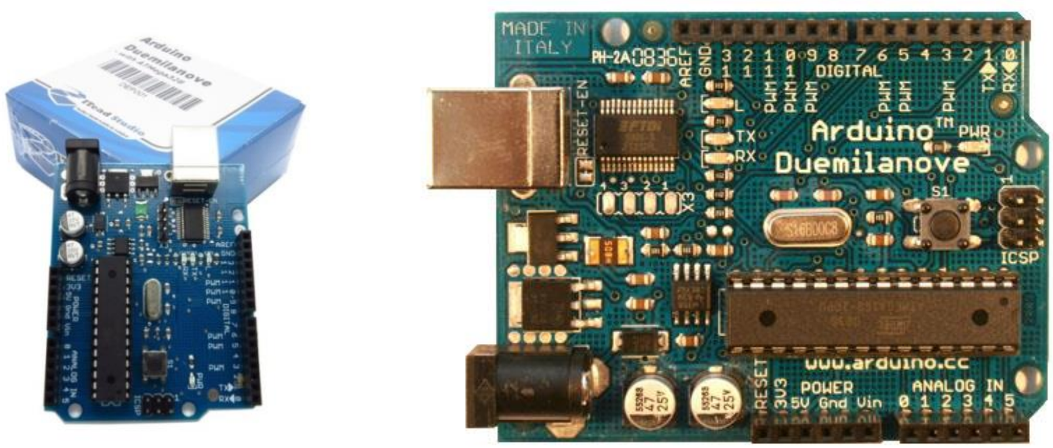

Figure 3-1: Arduino Duemilanove

Arduino Duemilanove technical specification is shown in the following table:

Microcontroller	ATmega328
Operating Voltage	5 V
Input Voltage	7 - 12 V
Input Voltage limits	6 - 20 V
Weight	25 g
Temperature Range	-40 to 85 °C
Power Consumption	0.2 mA

Table 3-1: Technical specification of Arduino Duemilanove

This particular microprocessor has maximum length and width of 68.5mm X 53.3mm respectively, so it will take up a minimal amount of space in our physical enclosure. The three screw holes allow the board to be attached to our encasing.

3.2 Phi-2 Shield

The Phi-2 Shield we are using consists of a set of peripherals designed to fit the Arduino Duemilanove with the ATmega328 processor. Weighing in at only 95.0g with a surface area of 127mm x 76.2mm, the Phi-2 Shield will be user interface for all RAHS functions. In our prototype the processor and shield components will be hidden in the anti-static enclosure to avoid being tampered with. Only the LCD screen and push buttons will be accessible to the user.

Figure 3-2-1: Picture of assembled Phi-2 Shield

The main peripherals implemented in RAHS will include:

- 16X2 LCD character display
- 6 push buttons arranged in arrow keys and two more on the side
- 2 RJ45 ports for up to 16 long and robust connections to our thermal sensors and relay mechanism
- Sensor block for the RAHS temperature, pressure, light, and magnetic field sensors.
- Two 3mm LED indicators for device operations
- Real time clock with battery backup keeps the time when Arduino is turned off
- EEPROM (24LC256 or 24LC512) to log and keep data even when power is off such as temperature settings, wake up time

The following is the Pinout schematic for the Phi-2 Shield which will be used as reference when producing our prototype [3].

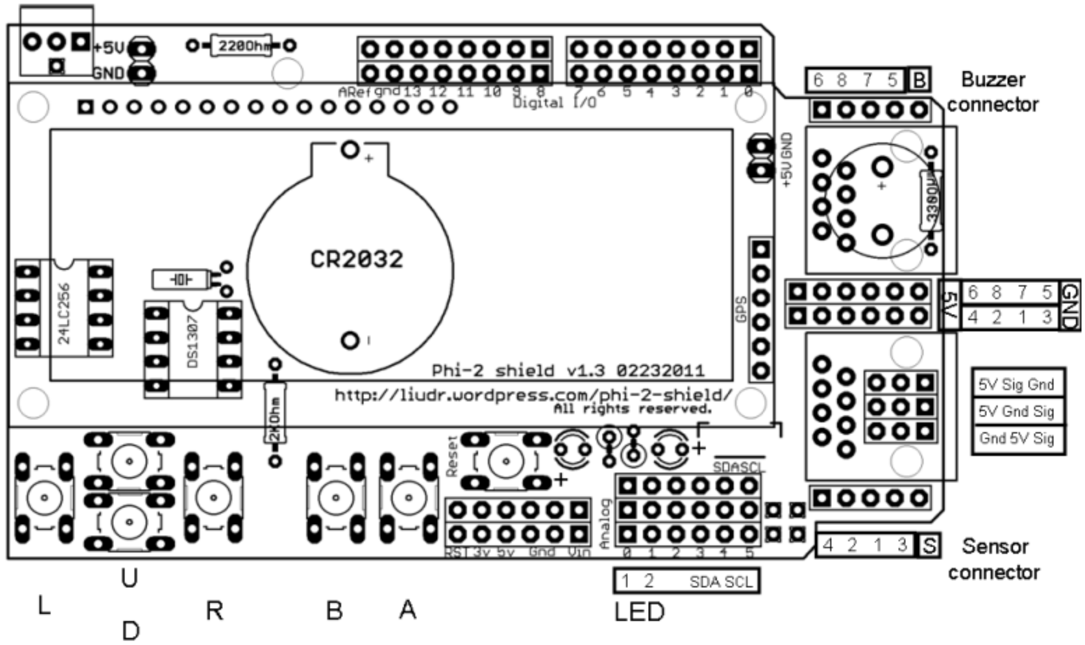

Figure 3-2-2: Pinout schematic of Phi-2 Shield

3.3 Solid State Relay

The last component we introduce in the main control system is a solid state relay. Due to the 600W power consumption of the heater unit, we need to implement a relay to prevent high current going through the microcontroller. The relay we have selected is a 100A DC to DC SSR. Even though 50A will run through the circuit we have chosen the 100A relay to prevent any overheating in the circuit. The following is a relay used in our proof-of-concept model and the wiring diagram between our timing system, battery and heater.

Figure 3-3-1: 100A DC to DC Solid State Relay SSR

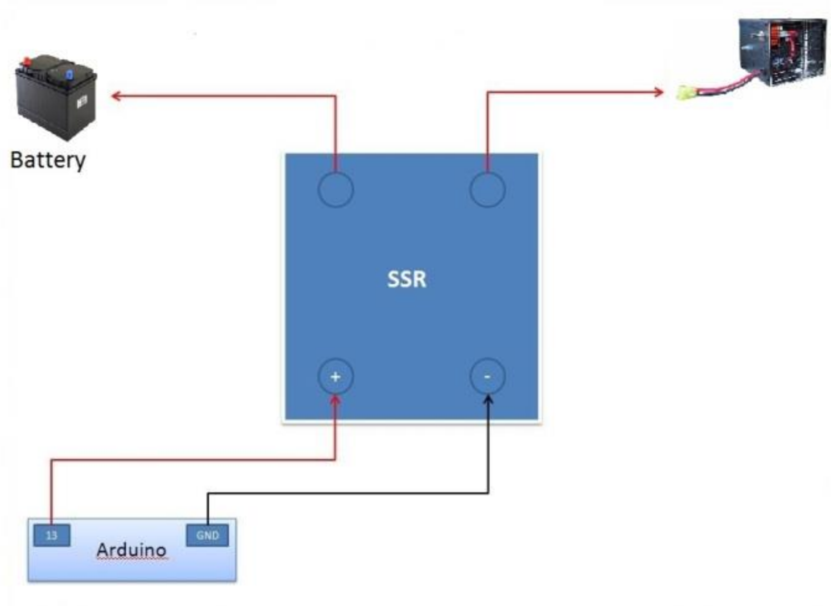

Figure 3-3-2: Wiring between heater, relay, battery and Arduino

The switching mechanism of the relay will be controlled via the Arduino microcontroller output. Once the timer is triggered or the RF receiver is activated, the Arduino will output a digital 5V signal to trigger the relay inducing current through the circuit. We made use of the relay in order to prevent damaging the board. The following shows the technical specifications of the solid state relay we are implementing.

Input Voltage	3 – 32 V DC
Control Voltage	5 – 60 V DC
Current	100 A
Size	63x46x26 mm

Table 3-3: Technical specification of Solid State Relay

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4 Heater System Design

Using an electric space heater the vehicle interior as well as windshield will be heated to comfortable room temperatures making the vehicle warm and toasty prior to entry. The windshield will now be ice free and not inhibit driving.

The following system requirements are met in our proof-of-concept model using the 12 volt heater:
[R17-A] Device can be easily handled when on or off
[R18-C] Device shall come in one package and be portable
[R19-A] Device shall reach a comfortable temperature for the user
[R20-C] Device shall generate heat to defrost the windshield
[R45-A] Device will defrost the window
[R46-B] Device will heat the air in the vehicle
[R48-B] Heater unit shall be encased in safe to handle housing
[R49-B] Heater unit shall be less than 10lbs

4.1 Heater

The RAHS heater will be a DC Thermal SA12-5000 12 Volt Heater - 10,020 BTU - Direct Hook-Up. We chose this heater as it removes the need for an inverter which was a cause of loss of power in our original concept. The two leads as seen below provide a simple connection to the relay switch which then will connect to the battery.

Figure 4-1: SA12-5000 12 Volt Heater 50 Amps/600 Watts

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Model	SA12-5000
Operation Electricity	12 V, 50 A, 600 Watts
Energy	10020 BTUs
Fan	Brushless 50000 Hour Ball Bearing Fan
Fabrication	T5052 Aluminum
Wiring	GXL Wire
Size	6”x5”x4”
Others	Thermally Protected
	HIGH, OFF, and LOW setting

Table 4-1: Technical specification of SA12-5000 12V heater

This heater was chosen due to its power efficiency and compact size. Furthermore it has a built in ball bearing fan provides force flow heated air that will be directed at the windshield. The heated air will then distribute throughout the vehicle interior until pre-set temperature or auto shut-off time is reached. The heater will be encased in a heat-resistant enclosure that can be handled safely by the user.

4.2 Temperature Sensor

In order for RAHS to operate efficiently and at proper temperatures we have implemented a temperature sensor into the device. It will display the current temperature on the devices LCD screen. The LM35 TO-92 temperature sensor will be used is compatible with the RAHS microprocessor. It was chosen due to its low cost due to wafer level trimming, and high operating temperature range. It is suitable for remote applications and does not require any external calibration or trimming to provide required accuracies.
Temperature can be resolved via the following formula:

$$T = 5 * analogRead(tempPin) * \frac{100}{1024}$$

The LM35 temperature sensor as shown in the figure below will connect with the Arduino which will constantly monitor the temperature and provide feedback on the LCD screen.

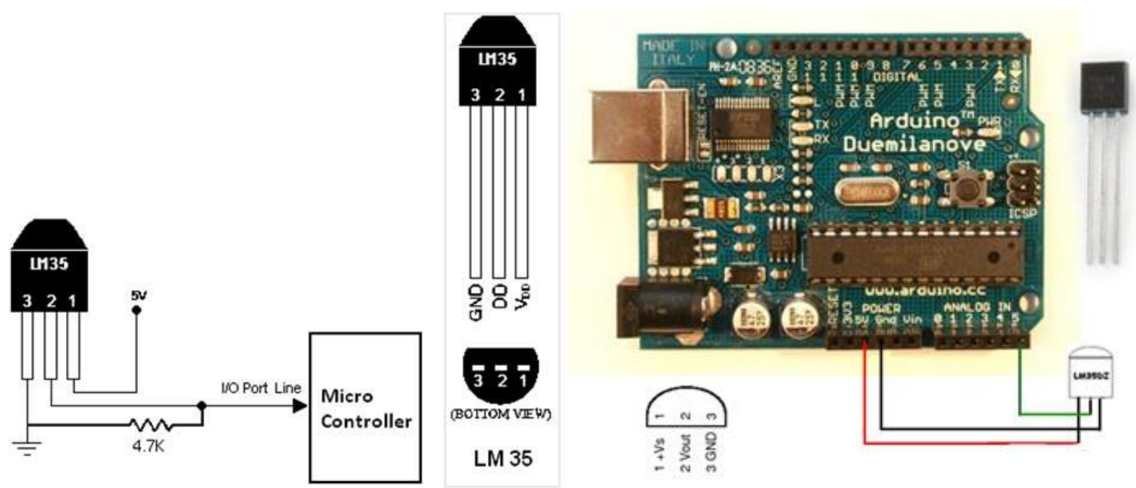

Figure 4-2-1: LM35 Temperature Sensor Wiring Diagrams

LM35 TO-92 temperature sensor technical specification is shown in the following table:

Linear Scale Factor	+10 mV/°C
Operating Temperature Range	-55 to 150 °C
Operating Voltage	3 -30 V
Current Drain	< 60 µA
Low-Impedance Output	0.1 Ω

Table 4-2: Technical specification of LM35 TO-92 temperature sensor

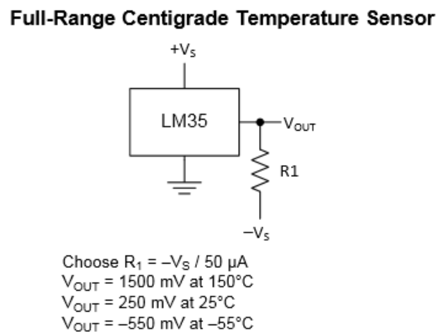

Figure 4-2-2: LM35 circuitry layout

4.3 Tilt Sensor

We have implemented a tilt sensor which is being mounted atop the heater unit into our system design for user safety. In case of any tilt greater than 30° (which may indicate heater tipping over and causing damage) the unit will be automatically shut off by the Arduino controller via the relay switching mechanism seen in section 3.3 The sensor we have chosen is the RBS 040100 tilt sensor which is compatible with the Arduino controller. The following shows the technical specifications of the RBS 040100 tilt sensor:

Contact Rating	25 mA at 24 V DC
Contact Resistance	10 Ω
Differential Angle	15 from horizontal
Operating Temperature	-25 + 70 ° C
Contacts	Gold Plated
Case Material	Polyamide – UL94V-0
Features	Non-Mercury Contacts

Table 4-3: Technical specification RBS 040100 tilt sensor

Figure 4-3: RBS 040100 tilt sensor

5 Remote Control System Design

The remote control system is composed of two components which are the RF transmitter and receiver. The RF transmitter and receiver both have simple batteries which will use almost no power which is an excellent choice for this project. The transmitter is embedded in a remote which can turn the heater on and off and be able to override the timer system. The remote control system gives the user maximum control over a vehicle in a convenient way.

The following requirements are met by our proof-of-concept model for the RF Transmitter and Receiver:

[R56-A] Transmitter will send digital signals to receiver
[R57-A] Receiver will switch RAHS on and off based on the signal
[R58-A] The signal will overwrite the state of RAHS
[R61-A] Both transmitter and receiver will consume minimum power of system
[R62-A] Signal transmitting will not interfere with other communication devices

5.1 RF Transmitter & Receiver

For the prototype model, a 315MHz 4 buttons key fob RF transmitter Receiver Module IC 2272 is been selected. Each button on the transmitter corresponds to one channel of transmission; therefore, we have choices of making one of the channels as master switch of the system and to communicate with the timing system. In addition, the range of operation is between 50 – 100 meters depending on the obstacles in between which is acceptable for driver to activate the system in car.
The particular selection of RF technology is that it requires minimal energy and operates fairly well in open space distance. On top of that, it is easy to gain access to such technology and easy to implement with our microcontroller.

Figure 5-1: 4 buttons key fob TF transmitter (left) and RF receiver (right)

IC 2262/2272 transmitter and receiver module technical specification are shown in the following tables:

	Transmitter	Receiver
Frequency Range	315 MHz	315 MHz
Modulate Mode	ASK	ASK
Operating Voltage	12 V	5 V
Transmission Range	50 – 100 m	

Figure 5-1: Technical specification of the transmitter and receiver

5.2 Integration with main system

Just as the microcontroller is mounted together with timing system, the RF receiver will be connected directly to the microcontroller as well. Upon receiving signals from the transmitter, it will communicate with the timing system and the main controller.
The following is the wiring connections between the RF receiver and the Arduino Duemilanove for our proof-of-concept model.

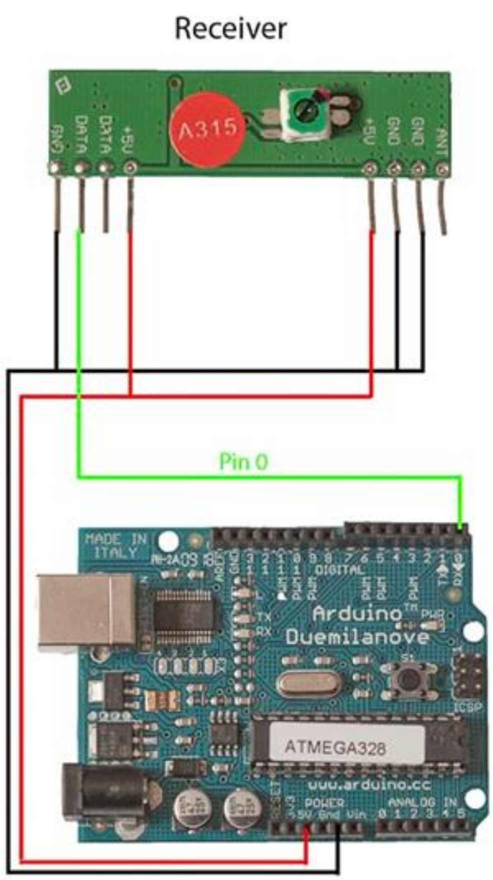

Figure 5-2: Connection between the RF receiver and Arduino Duemilanove

6 System Test Plan

The test plan will have four tests which will show that the system has full functionality. The first test is to prove that the battery works and provides enough power for the system. The timer test will show how a typical user will interact with the system. The heater test will show that the system produces heat and blow the heat onto the windshield. The remote control test will activate the system and will also deactivate the system.

6.1 Battery and Power Consumption Test

The battery and power testing procedures will include but not limited:

- Connect the heater directly to the battery for 10 minutes
- No electronic parts should be fried upon starting
- The battery should have 50% power left over before shut down
- Ideally this test will be done in cold weather conditions

6.2 Timer Test

The timer testing procedures will include but not limited:

- Set the alarm clock timer to activate the system
- The timer should activate the relay switch
- The system should stay activated for 10 minutes
- This should test will be done while the Arduino is in an idling state
- The temperature sensor should provide correct reading on display
- Phi-2 Shield should provide proper interface for user to control the system

6.3 Heater Test

The heater testing procedures will include but not limited:

- The user will turn the heater on by activating the power switch directly on the heater
- The heater will blow hot air onto the windshield
- The air will raise the temperature of the air in the vehicle
- This test will be done under cold weather conditions

6.4 Remote Control Test

The heater testing procedures will include but not limited:

- Activating the system in different distance away and between obstacles
- The system will be activated in anytime
- After the system is active by timer, press the stop button
- The system should deactivate in anytime

7 Conclusion

This report describes how we intend to meet our functional requirements of the Remote Automotive Heating System. We have described the technical aspects as well as the design methods used to design the mechanical, electronic and power units of the RAHS. Finally, test plans were designed to determine whether the design specifications meet the functionality and features that the members of RAHS Tech intend to deliver in our prototype by April 2015.

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8 Reference

[1] *"Vehicle Warm-Up"* Natural Resources Canada. Nov 2013 http://www.nrcan.gc.ca/energy/efficiency/communities-infrastructure/transportation/idling/4423

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