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March 9th, 2013

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, BC
V5A 1S6

RE: ENSC Functional Specifications for Blind Spot Detection System

Dear Dr. Rawicz,

The enclosed document contains the design specifications for the Blind Spot Detection System BSDS. This product is an upgrade of the current vehicles which will enhance safer driving experience with blind spot detection and warning system, and real-time blind spot video. It is also easy to use and cost effective.

The design specifications in this document details from low-level to high-level requirement that fulfills each of functional in previous document Functional Specification. This document will outline the design for the proof-of-concept prototype of the BSDS. All members of Urban Wheel Inc. will refer to this document to ensure all design specifications are met.

The Blind Spot Detection System team is comprised of five fourth-year electronic engineering students; Howard, David Cao, Emmanuel Yeung, and David Zhong. Each member brings unique skill sets and experiences to this project.

Thank you for your time for reading over our design specification. For any inquiries or comments regarding our project, please contact our team through our contact person, Emmanuel Yeung via email at hhy6@sfu.ca.

Sincerely ,

Howard Sun
Chief Executive Officer
Urban Wheel Inc.

Howard

Enclosed: Design Specification for Blind Spot Detection System

Design Specification For

Blind Spot Detection System

Urban Wheel

Project Team: Howard Sun
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Submitted to: Dr. Andrew Rawicz – ENSC440
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Issued: March 9, 2013

Executive summary

This document specifies the detailed design specification and implementation for the prototype of the Urban Wheel Blind Spot Detection System (BSDS). The component choice, component specifications, design and installation details, individual component and integrated test plan are explained in detail.

The BSDS is designed to be an add-on product for existing vehicles. BSDS consists of three main modules, the detection module, the visual module, and the warning module. The detection module includes the microcontrollers and the ultrasonic distance sensors, which handles the distance measurement and processing; the visual module includes the video cameras and LCD display, handling the real time video feedback depending on the turn signals status; the warning module contains the vibration motor, buzzer and LEDs, they are responsible for giving appropriate warnings to the driver depending on different sensor measurements. All three modules are integrated together to help the drivers to prevent any potential blind spot related accidents.

The design specification covered in this document will be followed to produce the BSDS prototype. Future prototype will be aimed to have a more compact and efficient design, lower energy consumption, and improving the aesthetics of the design. Additionally, more functions such as lane position assist, satellite navigation, and back up camera will be considered and will be able to integrate to the existing system.

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Glossary

BSDS - **B**lind **S**pot **D**etection **S**ystem
EEPROM - **E**lectrically **E**rasable **P**rogrammable **R**ead-**O**nly **M**emory
I2C - **I**nter-**I**ntegrated **C**ircuit
LCD - **L**iquid **C**rystal **D**isplay
LED - **L**ight **E**mitting **D**iode
RCA connector - audio/video connector designed by **R**adio **C**orporation of **A**merica

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1. Introduction

Urban Wheel Blind spot detection system (BSDS) is a highly accurate electronic driving aid for motor vehicles. The primary objective is to provide customers with safer driving experience their current vehicles. The BSDS is intended to be capable of detecting obstacle hidden in either side of the vehicle's blind spot, and notify the driver accordingly to avoid accidents. The detailed functional requirements for the BSDS are described in this documentation.

1.1 Scope

This document outlines and details the functional requirements which must be met by the BSDS. The specifications in this document fully describe the functionalities of our proof-of-concept prototype, and will serve as a basis for future iterations of the product. Possible design, modification, and optional features of future implementation will be included in this documentation.

1.2 Intended Audience

The functional specification is intended to be used by all members of Urban Wheel Inc - BSDS branch. The project manager shall refer to the functional requirements as an actual measure of progress throughout the development phase. Design engineers shall refer to the requirements as overall design goals to be kept in mind from product design throughout the implementation. Test engineers shall examine the functionality of the actual system by referencing to this document in order to aid testing.

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2. System overview

The system consists of two microcontroller, six ultrasonic distance sensor, three night vision cameras, two LCD displays, one video selector, six LED lights, one vibration motor, and one buzzer. The ultrasonic sensor and night vision camera are sending outputs to the microcontrollers, and the microcontrollers will enable the LED, vibration motor and buzzer depending on the situation. The video selector will switch to the appropriate camera depending on the car turn signal state.

Below is the system block diagram of the BSDS:

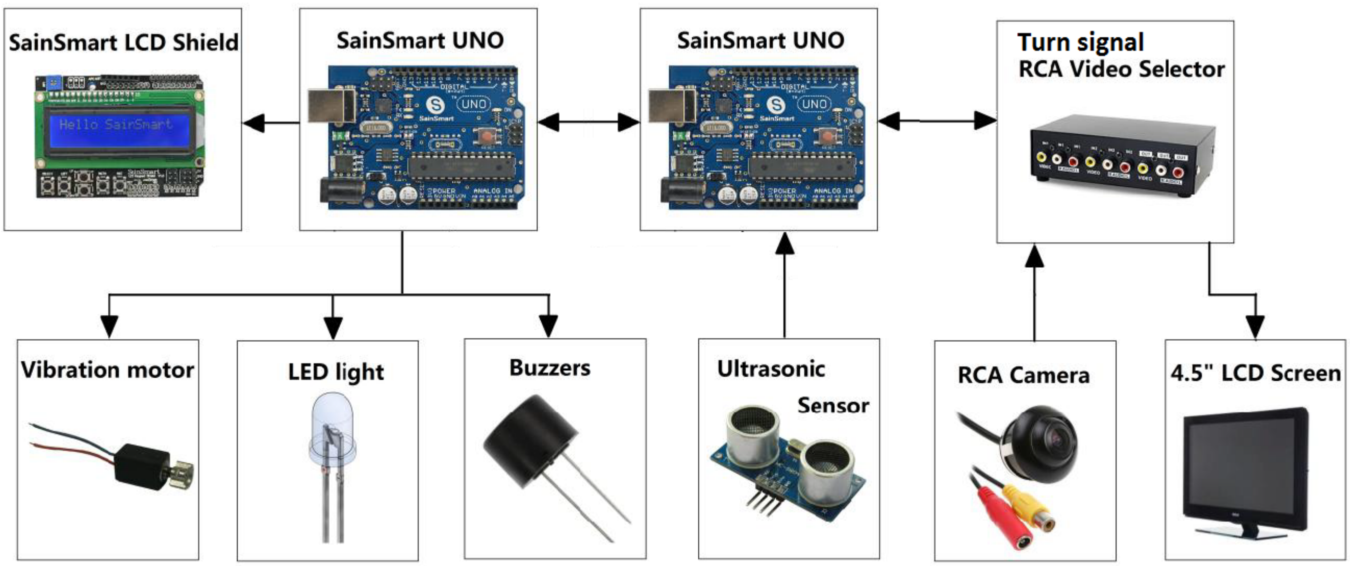

Figure 1 - System Block Diagram of the BSDS

The BSDS operation can be summarized in four stages below

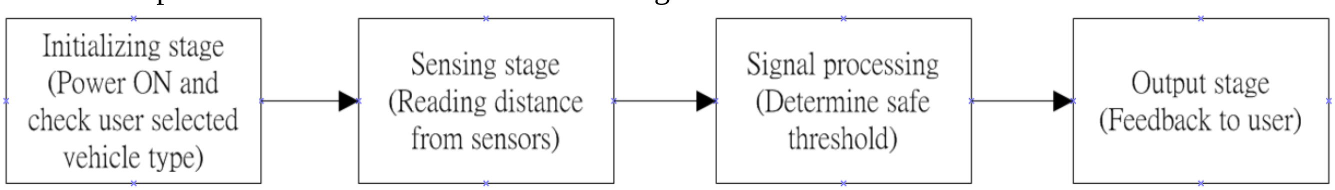

Figure 2 - Stages of Operation for the BSDS

Once the system is powered on, the ultrasonic sensor will be reporting the distance to the SainSmart UNO microcontroller board every 2 microseconds, and the microcontroller board will determine if the distance between the vehicle blind spot is within the predetermined threshold distance. For example, with sensor mounted to the side of the vehicle, the safe distance will be determined as 3.6 meter, which is calculated based on the average road land width, and assuming both drivers are on the furthest side of the lane.

When the threshold distance is breached, depending on the state of the turn signal, if the turn signal is turned on the left, then the left LED, buzzer and vibration motor will be enabled, the

LCD screen will be switched to the video reported by the left camera. If no turn signal is turned on, only LED will be switched on, and the screen will show the video from the front camera.

2.2 Overall System Design

The BSDS consists of both software and hardware systems. The software system handles the processing of the signals and utilizes the hardware components to give appropriate feedback to the driver.

2.3 Software Design Overview

The software component of the BSDS will all be handled by the SainSmart UNO microcontroller. The software running on the UNO will be written in a customized wiring-based language. The software will be monitoring the distances reported by the ultrasonic sensors, determining the safe threshold, and return the correct warnings.

2.4 Hardware Design Overview

The hardware components of the BSDS is chosen specifically to suit the purpose, meeting all the necessary requirements. The components and the mountings are designed to be as compact as possible, and the sensors mounting are designed to have minimal wind resistance. All hardware components and the mountings will not jeopardize the safety features of the automobile, and the safety of the driver.

3. Subsystems

3.1 Detection system

The detection system consist of the ultrasonic sensors and the UNO boards, the system handles the distance sensing and determining the threshold for the error system.

3.1.1 Ultrasonic sensors

There are many possible solutions that include using ultrasonic sensors, infrared, radar, and camera with image processing. After comparing all the possible solutions, we decided to build our system using ultrasonic sensors. We have chosen to use the HC-SR04 ultrasonic sensor because it has a high cost performance ratio. The sensors have 4 pins, two are used for power supply and ground, one is used for trigger and is clocked at 100 Hz, and the last one is an output pin for distance reporting. This refresh rate matches with the [R054-II] standard.

3.1.1.1 Technical Specification

Below is the specification table for the HC-SR04 ultrasonic sensors: [1]

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Table 1 - Operation Specification for the ultrasonic sensors

Working Voltage	DC 5V @ 15 mA, which matches [R042-II] standard
Max Range	4 m, which matches [R040-II] standard
Min Range	2 cm
Measuring Angle	15 Degrees
Trigger Input Signal	10 microseconds TTL pulse, which matches [R045-II] standard
Echo Output Signal	Input TTL lever signal and the range in proportion
Dimension	45 × 20 × 15 mm

The ultrasonic sensors constantly calculate the distance by taking the time difference between each transmitted and received sound wave. The speed of sound can be calculated by the equation V_{sound} = 331.3 m/s + (0.6 × temperature ºC) [2]. In real world situation, temperature is not extreme; cars don't travel very fast. Therefore it is safe to assume that there's no relativity issue for the sensors.

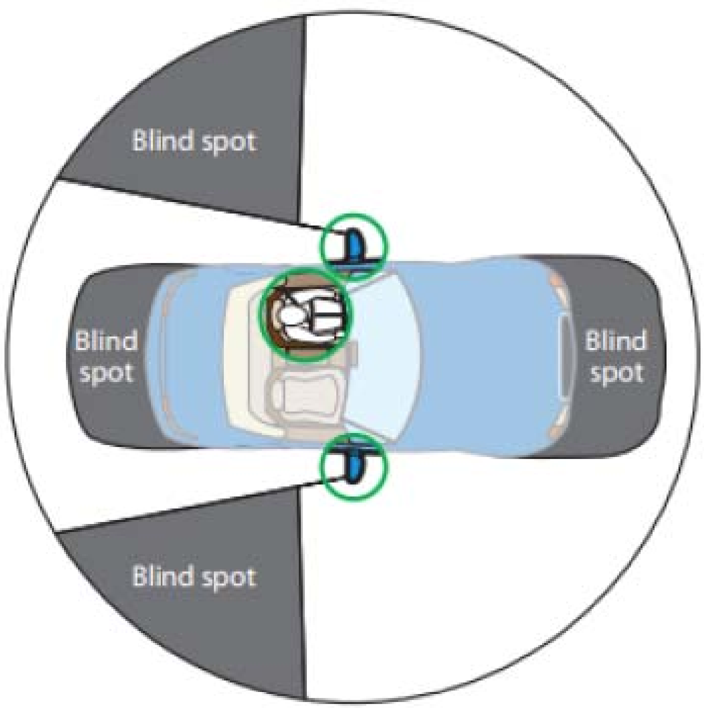

Figure 3 - blind spot area of a car

3.1.1.2 Sensor Placement

According to Figure 3 from ICBC, blind spot area of a car is defined as areas that cannot be seen by the side mirrors. According to the U.S. Interstate Highway System uses a 3.7-meter standard for lane width.3.4-meter lanes are found to be acceptable by the Federal Highway Administration for automobile traffic [3]. Figure 4 illustrates the optimized sensor positions on a car

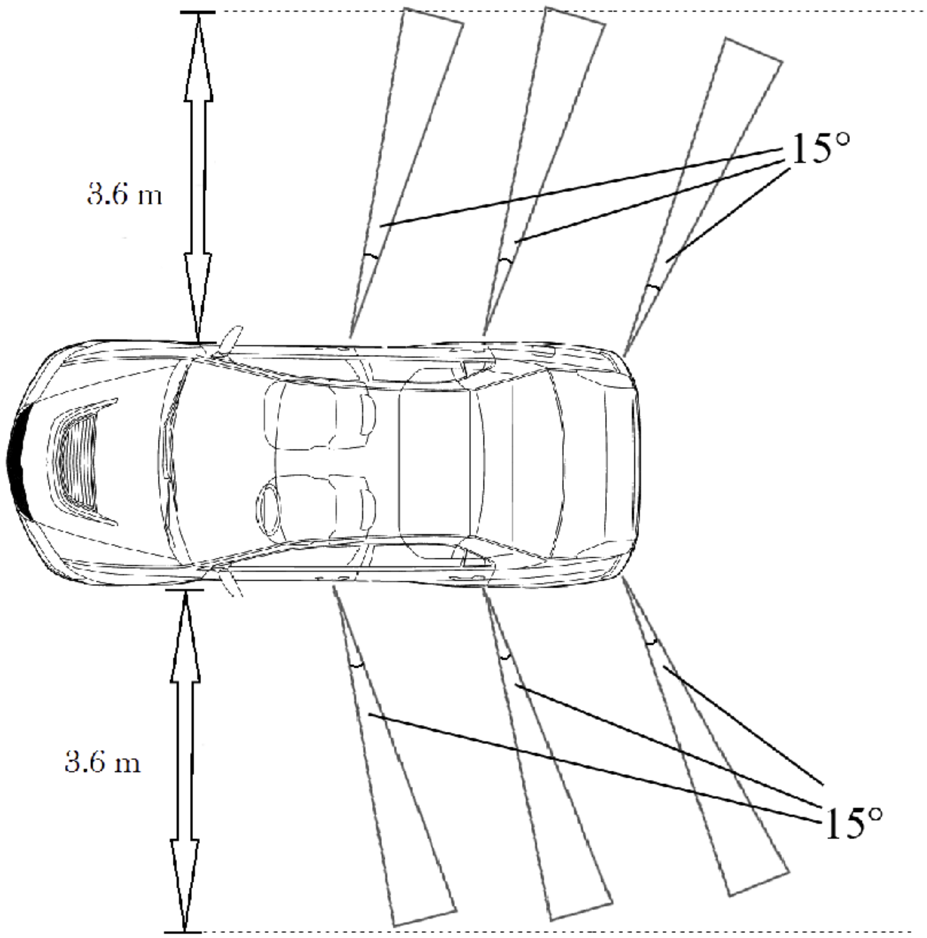

Figure 4 - sensors position and range

The sensors have maximum range of 4 meters and a 15 degree angle [1], with the use of three sensors per side, it is sufficient to fully cover all blind spot area at one side of a car. They will be sealed inside protective shields and tape on the body of the car using Scotch 3M double-sided tape [4]. The shields are able to protect the PCB component of the sensors from water damage. Also, holes are drilled under the transmitters and receivers of the sensors to drain any water in the sensor.

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3.1.2 SainSmart UNO

3.1.2.1 Technical Specification

The BSDS will utilize two UNO boards. The first one is connected to the ultrasound sensors and calculates the distance. The second one is treated as a warning system. The push buttons are used to select desired language and display unit. The boards have a compact design and can be fitted in a antistatic enclosure. The boards are powered by USB power supply. The sensor components are not powered by the board. Below are the specification tables of the board:

Table 2 - SainSmart UNO specification

Microcontroller	ATmega328
Operating Voltage	5 V
Input Voltage	6 - 20 V
Digital I/O Pins	14
Analog Input Pins	6
Clock Speed	16 Mhz
DC Current per I/O Pin	40 mA , which matches [R055-II] standard
Flash Memory	32 KB
SRAM	2 KB
EEPROM	1 KB

Below is the PIN assignment for the two UNO boards:

Table 3 - SainSmart UNO pin arrangement

Pins	UNO 1	UNO 2
2	Left Sensor 1	Overflow line
3	Left Sensor 2	Left/Right line
4	Left Sensor 3	LCD D0
5	Right Sensor 1	LCD D1
6	Right Sensor 2	LCD D2
7	Right Sensor 3	LCD D3
8	Shared Trigger output	LCD RS
9	Overflow line	LCD Enable

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10	Left/Right line	Left LED 1
11	Motor	Left LED 2
12	Buzzer	Right LED 1
13	Ground	Right LED 2
A4	I^2C Clock	I^2C Clock
A5	I^2C Data	^{I2}C Data

Below is the graphical representation of the PIN connections:

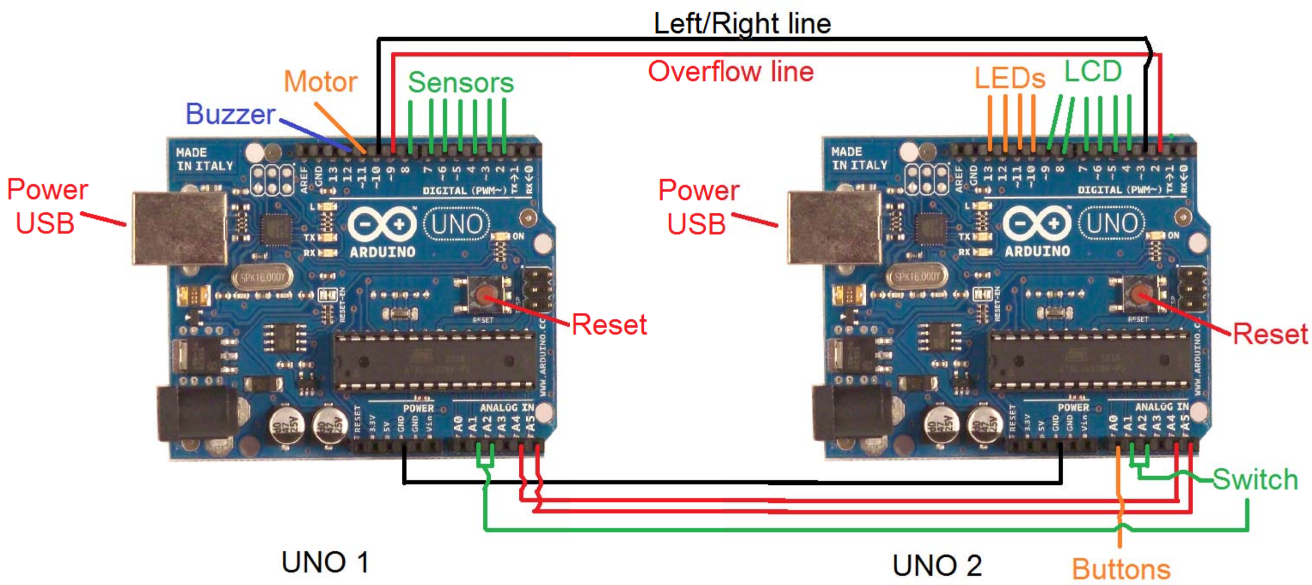

Figure 5 - PIN connections on the UNO boards

3.1.2.2 Software Specification

The program is consisted of two stages. The first stage only runs once on when the board is powered up. When the board is powered up the first time, it initialized all the sensors and it prompts the user for the language and whether Imperial or Metric unit will be used. These data are saved in the EEPROM so that the user will not be prompt again unless the board is factory reset. The user can change the language and display unit at anytime by pressing the appropriate button. A system check is performed to ensure that all the hardware components are working properly. If unspecified error occurred, such as sensors reporting a distance of zero, which only occurs when the sensors are not powered or triggered correctly, an error message will be displayed on the LCD module and the user will be warned. The error reporting mechanism matches with the [R003-II] and [R057-II] standards.

The second stage loops continuously. The program calculates the distances based on each sensor's output. If the distance is within the danger threshold, the program will send out a signal to the warning system to notify the driver.

After the system is initialized, the SainSmart UNO will sent out trigger signals to all six ultrasonic sensors and receive echo signals sent back to the UNO. Distance data will be compared by the UNO and the smallest distance value from both sides will be displayed on the LCD screen. Depending on the distance value, the UNO will send out signals to turn on LEDs accordingly.

When the turning signal is activated, the UNO will send out various patterned signals to the vibration motor and the buzzer according to the detected minimum distance.

The two boards are connected via I^2C channel, a overflow line, and a Left or Right identifying line. The distance data will be sent through the I^2C channel. However the I^2C channel only support one byte of data to be transferred, therefore the overflow line is used to determine if the distance is larger than 255 centimeter, the overflow line will be set to HIGH. Since the UNO can only manage to do one way traffic on the I^2C channel, we have to use a Left to Right line to identify if the distance reading is for the Left or the Right side, if it is the left reading then the line will be set to LOW, otherwise HIGH.

4. Warning System

The purpose of the Blind Spot Detection System is to detect objects/vehicles in the blind spot for the drivers. So the warning system should effectively warn the drivers without distract them from driving. We used three kinds of warning mechanisms vibration, visual and auditory to ensure the effectiveness of the warnings.

4.1 Vibration motor

The vibration motor is powered by the SainSmart UNO and it will produce vibrations based on the pattern that is generated by the SainSmart UNO. The vibration motor only actives when the turning signal is activated. The vibration frequency gets higher when the detected distance gets smaller. The vibration motor is placed behind the steering wheel to prevent the driver’s failure to sense the vibration [Figure 6]. The specified pattern is generated to help the driver to distinguish the difference between other vibrations that are generated by other devices or the vehicle itself.

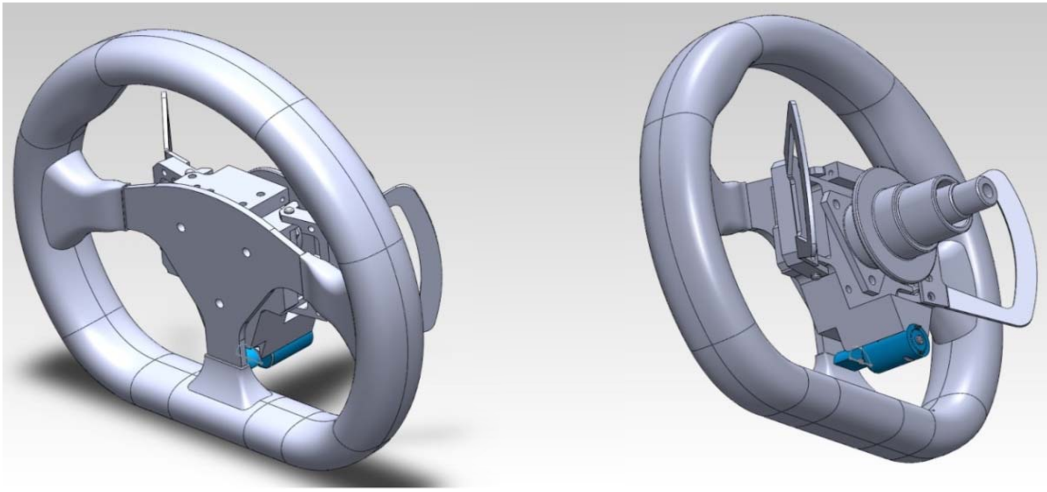

Figure 6 - Vibration motor location in blue

4.2 LED

Four LEDs are powered by the SainSmart UNO and they will be turned on based on the detected distance. There are two LEDs for each side and placed underneath the hood of the dashboard [Figure 7]. The LEDs are activated after the system is turned on, , which matches with the [R082-II] standard.

The LEDs have two different colors orange and red. When the detected distance is between 3.6 meters and 2.0 meters, the orange LED will be turned on. When the detected distance is between 2.0 meters and 1.0 meter, all two LEDs will be turned on. When the detected distance is less than 1.0 meter, all two LEDs will be blinking rapidly to warn the driver of the potential danger. The LEDs are arranged in a way such that it is intuitive for the driver, which matches [R087-II] standard.

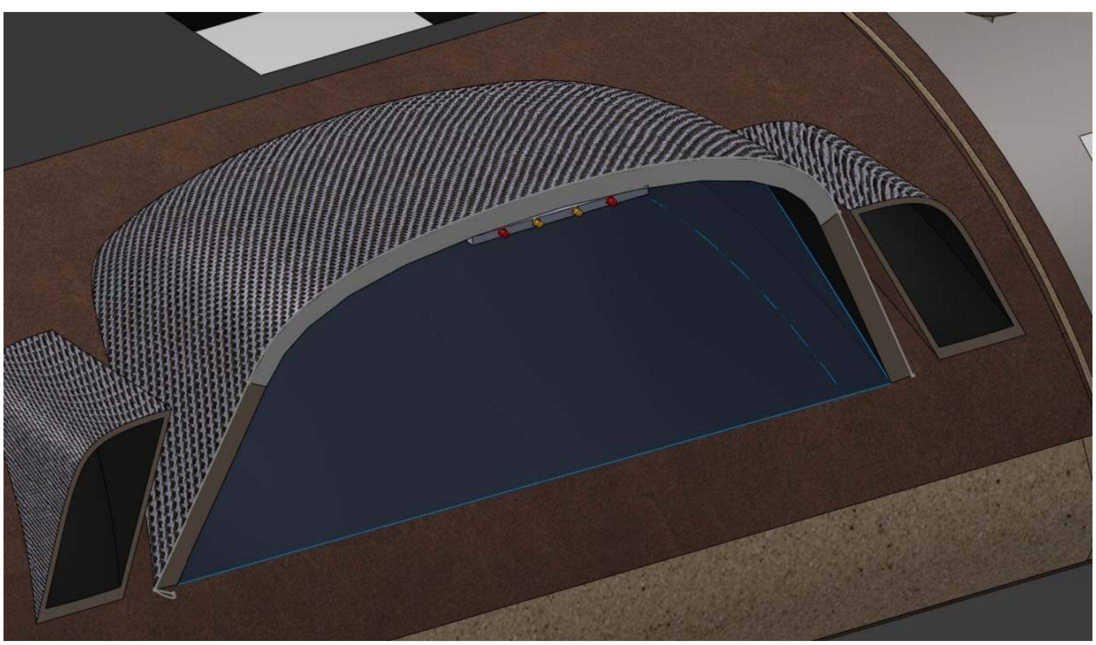

Figure 7 - LED light position

4.3 Buzzer

The buzzer is powered by the SainSmart UNO and it will produce vibrations based on the pattern that is generated by the SainSmart UNO, and the pattern will be synchronized with the vibration pattern. The buzzer will be turned on after drivers activated the turning signal. The buzzer is placed inside the control system box [Figure 8]. The buzzer sound will be loud enough to get the drivers' attention but not too loud to distract the drivers. The buzzer sound matches with the [R081-II] standard.

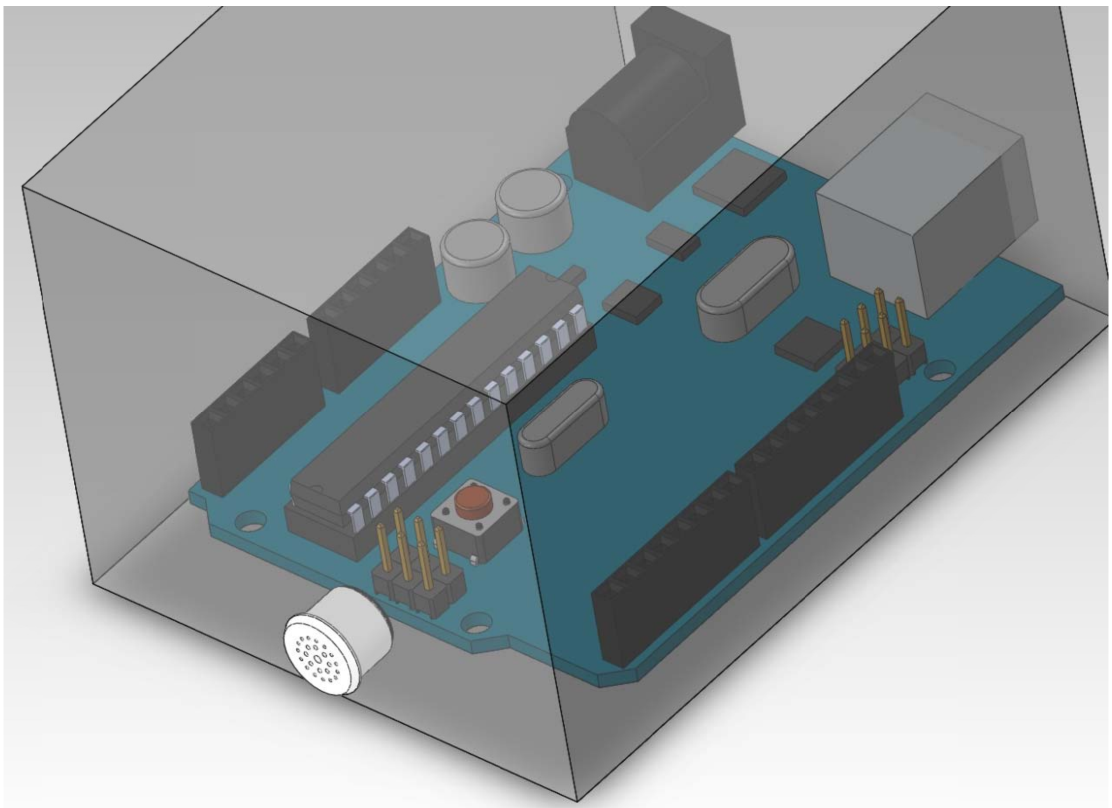

Figure 8 - Mounting Enclosure

5. Visual System

Visual system is responsible for reporting the correct real time video from the correct side**.**

5.1 Cameras

Two RCA night vision cameras are used to show the real time video of the blind spot area. The chosen cameras have an effective resolution of 648×488, and a lens angle of 120 degree, the high resolution will reproduce a clear image, and the wide angle ensure the blind spot area is covered, meeting both of [R091-II] and [R092-II] standards. The chosen cameras also have infrared light for night vision, meeting [R093-II] standard. The cameras is powered by DC 12 Volts directly from the car power line. The cameras are designed to be mounted outside of the vehicle and able to survive all weather conditions. It meets the [R019-II] requirement.

5.2 Video Switcher

The video switcher is used for switching between left and right side camera depending on the turn signal. When the left signal is engaged, the video switcher will be switched to the left side, and then the LCD screen will be displaying the video from the left camera. The video switcher circuit is placed in the system box and the switch is integrated with the turning signal add-on switch. The video switcher consists of a three way switch and RCA connectors. The circuit contains only passive components. The schematic can be represented as the block diagram below. Figure 9 shows the circuit schematic of the video switcher:

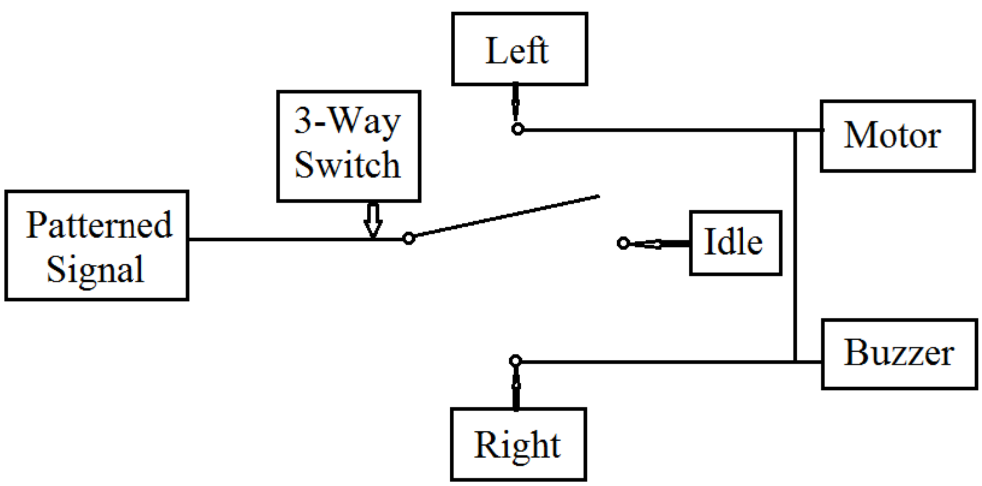

Figure 9 - circuit schematic for the switch (Three poles: Left, Idle, Right)

6. Mountings

6.1 Mounting mechanism for sensors and camera

Ultrasonic sensors and cameras are attached to the car using tapes that are qualified for attach car badges. Sensors are placed on both sides of the car and aligned in specific angles to cover pre-determined maximum area [Figure 10]. Cameras are placed underneath the rear view mirror [Figure 11].

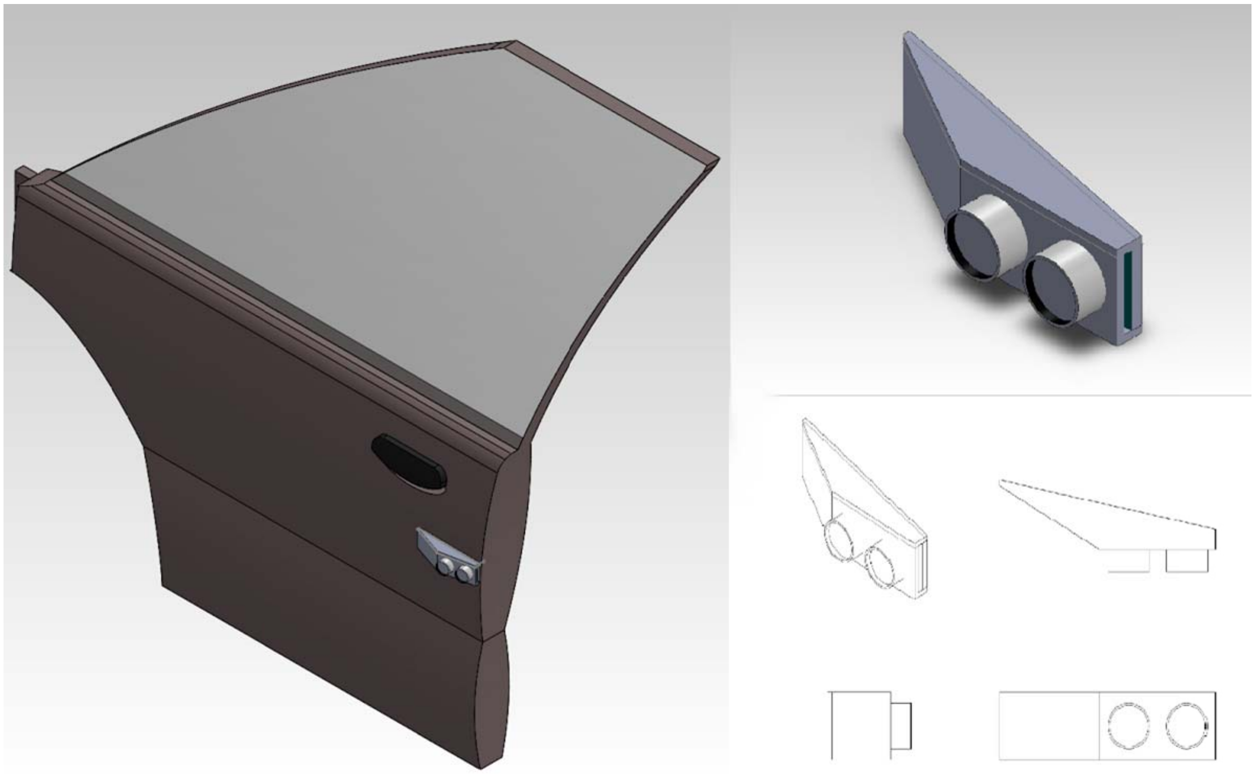

Figure 10 - Sensor mounting and enclosure

Figure 11 - Camera mounting

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6.1.1 Technical specification

The ultrasonic sensors are covered by plastic aerodynamic cases. The cases are designed compactly to reduce size and minimize the appearance change of the vehicle after attachment.

6.1.2 Safety specification

The tapes are strong enough to prevent sensors and cameras from falling of gravity and strong wind. No open wire is exposed outside to prevent damage to the system and damage to the user, which matches with [R005-II] standard. The overall safety rating is not affected after attached the whole system.

6.2 LCD display

LCD display and LCD screen are placed in the display box and mounted on the dashboard. The display box is taped on the dashboard. It has a matte screen to provide clearer display quality under sunlight, and the LCD screen is LED backlit. This display matches with the [R069-II] standard.

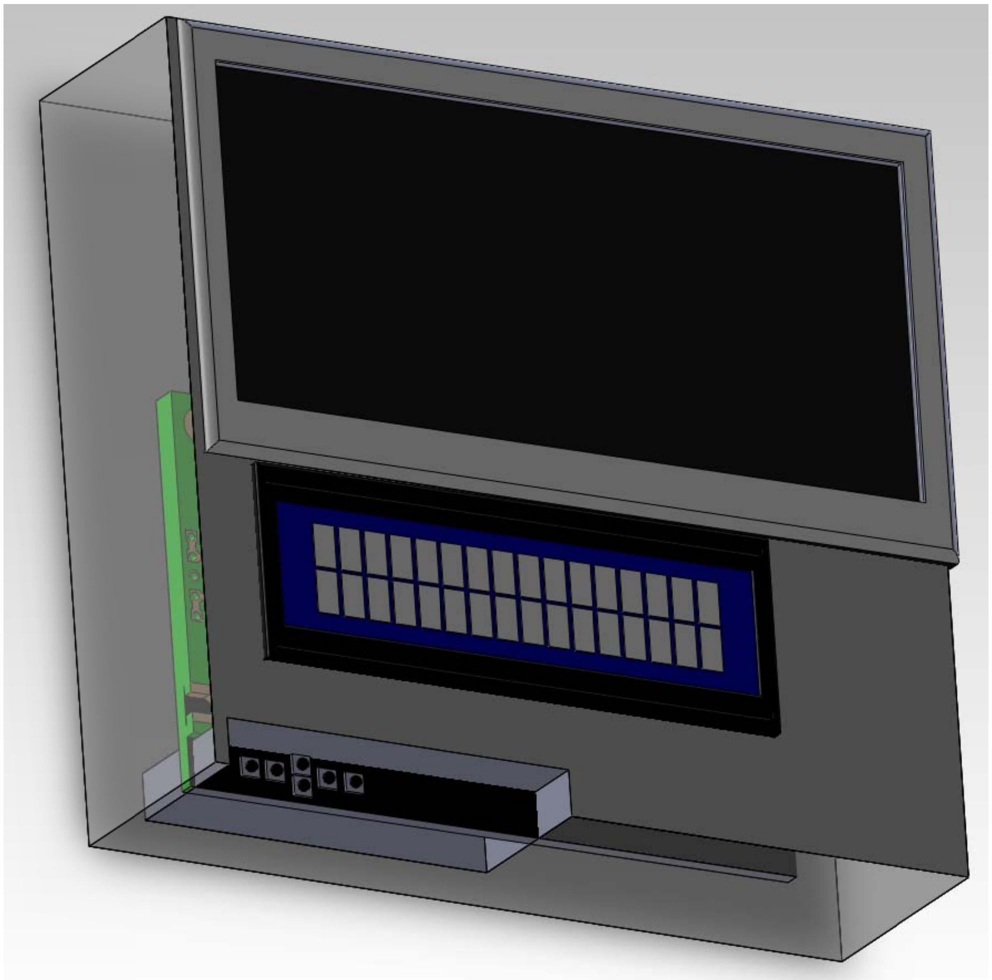

Figure 12 - LCD display, push buttons, and monitor as one unit inside the enclosure

6.2.1 Technical specification

The LCD display specification table is listed below

Table 4 - LCD Specification:

Screen size	4.3 inch
Aspect Ratio	4:3
Resolution	440×272
Screen type	Matte anti-glare, which matches [R042-II] standard
Power Supply	DC 12V

6.2.2 Safety specification

The display box has a compact design minimize the sight compromising of the driver. The tape is strong enough to hold the whole box during normal shock that is created during standard driving.
All components inside the box are able to take temperature from -40ºC to 85ºC, which matches with the [R065-II], [R074-II], and [R089-II] standards. The whole box will not interfering with any pre-existing system in the vehicle.

7. Test Plan

In order to verify if the BSDS is working properly, components need to be checked separately. Also, combined modules integrated system should be tested. Therefore, we need to perform the following test plan.

7.1 Unit Testing

7.1.1 Ultrasonic Sensor on UNO

	SainSmart UNO
Test description:	Power up SainSmart UNO
Condition:	The green indicator light should be on.
Procedure:	Connect with SainSmart UNO with USB power

	Ultrasonic-Sensor with SainSmart UNO
Test description:	Power & Connectivity
Condition:	Ultrasonic Sensor will be able to power up by the SainSmart UNO board and return data to SainSmart UNO pins.
Procedure:	1. Connect the Ultrasonic Sensors to the board pins 2. Use simple code to check if every sensor can successfully return data

	Ultrasonic-Sensor - Functionality
Test description:	Ultrasonic-Sensor connects with SainSmart UNO and run the ultrasonic scan program
Condition:	Ultrasonic Sensor will return the correct distance data to the SainSmart
Procedure:	1. Connect a ultrasonic sensor to the board pins 2. Use simple code to check if every sensor can successfully return data 3. Put the paper in front of ultrasonic sensor with specify distance (< 3m) 4. Check the distance result from the program comparing with test distance

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7.1.2 UNO LCD Monitor

	UNO LCD - Power & Connectivity
Test description:	UNO LCD screen can connect correctly and power up by the SainSmart UNO board
Condition:	UNO LCD screen shows blue background light when it is powered up by the SainSmart UNO board
Procedure:	1. Connect the UNO LCD screen onto the SainSmart UNO board 2. Connect the USB power cable with SainSmart UNO board 3. Check if the screen is powered on and shows blue background light

	UNO LCD - Display
Pretest:	Computer installed Arduino 1.0.3
Test description:	LCD screen can connect correctly, power up by the SainSmart UNO board, and display correct test result
Condition:	Computer installed Arduino 1.0.3
Procedure:	1. Connect the LCD screen onto the SainSmart UNO board 2. Connect the USB power cable with SainSmart UNO board 3. Check if the screen is powered on and shows blue background light 4. Run a simple program in Arduino 1.0.3 (which program for display) 5. LCD screen should display the correct program result

7.1.3 LED testing

	LED - Functionality
Test description:	Power up the LED by using function generator
Condition:	LEDs can be powered up successfully
Procedure:	1. Set power supply to 3v 2. Connect LED with power supply Check if the LED is lighted up successfully To test many LEDs all at once: 1. Put all the LEDs which want to be tested in parallel in the breadboard 2. Connect positive and negative of the LEDs to the power supply 3. Check if all the LEDs are lighted up successfully

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7.1.4 Buzzer testing

	Buzzer - Functionality
Test description:	Check buzzer can be powered up and produce sound
Condition:	Buzzer can produce desired sound
Procedure:	1. Connect buzzer to function generator 2. Increase frequency of the function generator 3. Check if it can produce desired sound correctly

7.1.5 Vibration Motor testing

	Vibration Motor - Functionality
Test description:	Check if the vibration motor gives enough noticeable oscillation
Condition:	Vibration Motor can produce noticeable vibration.
Procedure:	1. Turn on power supply 2. Connect vibration motor to power supply 3. Check if the vibration is noticeable by place hand on the other side of the table

7.2 Module Testing

7.2.1 Detection Module

	Ultrasonic Detection Module - Connectivity & Functionality
Test description:	Check if Ultrasonic Detection Module can be powered up by the SainSmart UNO board
Condition:	Ultrasonic Detection Module can be turned on when connected with powered up SainSmart UNO board
Procedure:	For connectivity: 1. Connect Ultrasonic Detection Module with unpowered SainSmart UNO 2. Power up SainSmart UNO board by connecting to computer through USB cable 3. Run the Ultrasonic Detection program in Arduino 1.0.3 4. The program should display the detected distance For functionality and on-going: 5. Put the paper board right in front of one of the ultrasonic sensor 6. The program should display “0” for the distance 7. Repeat step 5) and 6) for each of the ultrasonic sensors

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7.2.2 Visual feedback module

	Camera & 4.5" LCD display - Power & Connectivity
Test description:	Try to power up camera and 4.5" LCD display, and the captured image will be displayed on the LCD display
Condition:	Cameras can be successfully connected to the 4.5" LCD display through the switch. Both devices can be powered by the power supply provided
Procedure:	1. Connect one camera and the 4.5" LCD display 2. Power up both cameras and 4.5" display by the power supply 3. Check if the 4.5" LCD display presents the camera's real time capture

	Cameras & 4.5" LCD display - Functionality
Test description:	Check if switch position gives the correct feedback to the camera
Condition:	4.5" LCD display can successfully display video signals sent out by the cameras correctly when switch is flipped.
Procedure:	1. Connect 4.5" LCD display with night vision camera system 2. Select the switch to choose left camera 3. Check the image display on 4.5" LCD if match the left side scene 4. Select the switch to choose right camera 5. Check the image display on 4.5" LCD if match the right side scene 6. Select the switch to choose left cameras 7. Check the image display on 4.5" LCD if it match the right side scene 8. When the switch in idle, check the image on 4.5" LCD display if it matches the right scene of the back

7.2.3 Warning Module

	Warning Module – Connectivity
Test description:	The warning module contains three parts, the LED, vibration motor and buzzer which are controlled by the UNO. Warning module should able to pass correct warning signal to the user
Condition:	All three parts of the module should be able to successfully connect and powered by the UNO
Procedure:	1. Connect the LED, vibration motor and buzzer to UNO board 2. Connect the Warning Module with Detection Module 3. Power up both modules 4. Put both modules in warning condition 5. Check the warning system if give correct corresponding alerts

	Warning Module – Functionality
Test description:	After the warning module passes the connectivity test, section different condition to test different warning responds
Condition:	All three parts of the module should be able to perform correct warning based on different warning signal sent out by the UNO
Procedure:	1. After pass "Warning Module – Connectivity" test 2. Put a obstacle right in front of left ultrasonic sensor system within 3.6m 3. The left LEDs warning should be "ON" 4. After selecting the left switch 5. Buzzer and vibration should be triggered on 6. Repeat the same steps(from 1) to 5)) to check the warning system work for right side

7.3 Overall System Testing

7.3.1 Connection & Functionality Testing

	Overall BSDS Connection & Functionality
Test description:	Connection and functionality test will be performed to ensure the complete system is connected and functioning properly
Condition:	All module can be correctly integrated together and function normally
Procedure:	1. Connect all modules according to the design 2. Simulated testing condition will be performed 3. Check if all modules will perform properly and match the test results with each components' test results

7.3.2 Mounting Testing

	Mounting Test
Test description:	Mounting testing will be performed to ensure all parts will survive everyday driving after attached
Condition:	Outside mountings will not fall off when driving. Inside mountings will remain in the same positions and remain the same functionalities
Procedure:	1. Ultrasonic Detection Module will be mounted outside refer to the technical guide line 2. Check the outside mounting will not fall off during everyday driving 3. Spray water onto the outside mountings 4. Check the outside mounting will not fall off after the spray water test

7.3.3 Error Testing

	Overall System - Error Testing
Test description:	Error testing will be performed to make sure any ultrasonic sensor error will be reported to the user correctly. Display error will not be reported since it is obvious.
Condition:	All malfunction sensors can sent out error signal to the LCD screen
Procedure:	1. Power up the BSDS system 2. Disconnect the trigger pin one of the sensor 3. Check if an error message is sent to the LCD screen

8. Conclusion

The design specification document presents technicalities of the BSDS which meet the proposed design solution. In the document, it demonstrates the choices of hardware requirement of the BSDS depending on suitability, price, and performance details. This document also specifies the software solution which combines and utilizes the functionality of the hardware of the system. The specifications and requirements will follow this document as guideline of safe to use, troubleshooting and constructing the user manual.

9. Reference

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