ENSC 305W/440W Grading Rubric for Design Specification

Criteria	Details	Marks
Introduction/Background	Introduces basic purpose of the project.	**/05%**
Content	Document explains the design specifications with proper justification for the design approach chosen. Includes descriptions of the physics (or chemistry, biology, geology, meteorology, etc.) underlying the choices.	**/20%**
Technical Correctness	Ideas presented represent valid design specifications that will be met. Specifications are presented using tables, graphs, and figures where possible (rather than over-reliance upon text). Equations and graphs are used to back up/illustrate the science.	**/20%**
Process Details	Specification distinguishes between design details for present project version and later stages of project (i.e., proof-of-concept, prototype, and production versions). Numbering of design specs matches up with numbering for functional specs.	**/15%**
Test Plan	Provides a functional test plan for the present project version. (Note that project success will be measured against this test plan.)	**/10%**
Conclusion/References	Summarizes functionality. Includes references for information from other sources.	**/05%**
Presentation/Organization	Document looks like a professional specification. Ideas follow in a logical manner.	**/05%**
Format Issues	Includes letter of transmittal, title page, abstract, table of contents, list of figures and tables, glossary, and references. Pages are numbered, figures and tables are introduced, headings are numbered, etc. References and citations are properly formatted.	**/10%**
Correctness/Style	Correct spelling, grammar, and punctuation. Style is clear concise, and coherent. Uses passive voice judiciously.	**/10%**
Comments		

November 15, 2013

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

Re: ENSC 305/440 Design Specification for Unipark-1000

Dear Professor Lucky,

Attached is the design specification document for the Unipark-1000, an easy to install parking sensor from SABZ Incorporated. The Unipark-1000 eliminates the complexity of installing a conventional ultrasonic parking assist system. Anyone who knows how to operate a screw driver will be able to install the system onto their vehicle.

The design specifications document details the design of the Unipark-1000 system. The document applies mainly to the proof-of-concept build. Proposed designs for the final production build are also discussed. Also, a detailed system test plan is laid out for all prototype builds. Design improvements are also discussed in this document as well.

Should you have any question or concern about the document, please do not hesitate to contact us by emailing me at cmm10@sfu.ca.

Sincerely,

Edmond Mo
Chief Financial Officer
SABZ Incorporated

Enclosure: Design Specifications for Unipark-1000 Parking Assist System.

Unipark-1000

An Easy to Install Vehicle Parking Sensor

ENSC440 Design Specifications

Revision 3.0

Title/Name	Signature	Date
Author/Chief Executive Officer Kenny Lam		
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Chief Operations Office Will Zhang		

Executive Summary

The complexity of installing a conventional ultrasonic parking assist system has put off many consumers from purchasing the system. The goal of the SABZ engineering team is to create an ultrasonic parking assist system that will eliminate the complicated installation process while maintaining the performance and reliability level of the traditional ultrasonic parking assist system.

The Unipark-1000 consists of 1 display unit and 2 sensor modules. The sensor units are designed to be mounted on the bumper via the license plate mounting screws. All communication between the sensor module and the display module is done wirelessly. Furthermore, the sensor modules are battery operated. All this was done to make the Unipark-1000 is easy to install. This design specification gives the specifics of how this design is achieved. The following details are given in this document

- Circuit schematics used in the proof of concept prototype
- Software flow charts and pseudo code
- Solidworks models of casings used
- Parts specifications and datasheets
- Explanations of assemblies and sub components of the system.

The designs presented in this document focus mainly on fulfilling the requirements to make a working proof-of-concept prototype. Further development is required before the product becomes production ready. Where applicable, the document describes some of the design details that should be puts in place for the production build. Because the product still needs development and testing, the designs present in this specification may be subject to some changes.

Contents

List of Figures

List of Tables

Acronyms

PWM	Pulse Width Modulation
RF	Radio Frequency
SPP	Serial Port Profile

Glossary

Beam angle	An angle that determine that detection pattern of the ultrasonic transducer.
Build	A version of the device which is physically constructed.
Prototype	One of the initial engineering builds of the device used for verification and validation of design concepts and specifications
Radio Frequency	Ahigh frequency signal commonly used for communication applications.
Ultrasonic transducer	A piezoelectric device that is translates electric energy into acoustic wave and echo detection of the echo of the acoustic wave.

1 Introduction

Unipark-1000 is an ultrasonic parking assist system that is designed for easy installation. The conventional ultrasonic parking assist system requires the user to drill holes and run wires through the front and back bumper of the vehicle for installation, Unipark-1000 is designed to eliminate all the installation steps that would normally require a mechanic to perform. The goal of this project is to investigate the feasibility of such a design. We will develop a proof of concept build by Dec 2, 2013. The purpose of this prototype is to demonstrate that an acceptable parking assist system with an easy setup can be implemented.

1.1 Scope

This design specification document documents and tracks the necessary information required to effectively define the architecture and system design of the Unipark-1000. The design specifications give the development team guidance on the detailed design of the system to be developed. This document will attempt to provide as much design detail as possible for the proof-of concept build. Some design specifications for the final build will also be provided but these are only proposed designs and are subject to change if development continues on the project.

1.2 Intended Audience

The intended audience is the project manager, the develop team and the design review team.

2 System Design

Unipark-1000 consists of three physical parts, two sensor modules and a display module. The two sensor modules are physically and functionally identical. One sensor is installed at the front bumper and the other at the rear bumper of the automobile. The display module is located on the dashboard of the automobile where it will be visible to the user. Figure 1 below illustrates the physical setup.

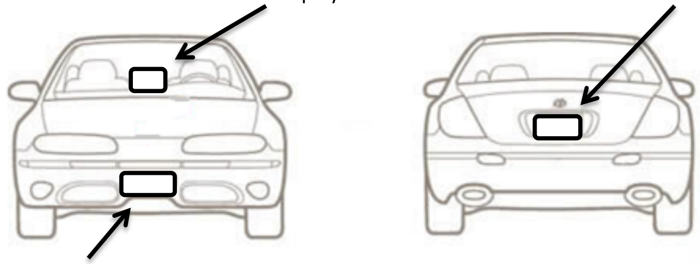

Figure 1: System Overview

The display module will wirelessly collect distance data from the front and back sensor modules and display them for the driver to see. The system has an on/off switch, which means the user must manually activate the parking sensor when they want parking assistance. The display module will refresh the distance data 3 to 4 times per second. The communication between the sensor module and display module are done through a wireless Bluetooth link. The display module has the ability to remotely switch on the two sensor module via radio frequency. This feature along with the Bluetooth communication link allows for zero wiring between the modules; therefore it dramatically reduces the complexity of installation.

The sensor module is equipped with ultrasonic transducers to measure the range of the closest object from the module. There will be memory inside the sensor module to store the collected range data. The sensor module will continuously collect range data and save only the most recent measurements into its internal memory. It will sends distance data to the display module when request to do so. The following sections will discuss key system design considerations

2.1 Choosing a parking sensor technology

There are 2 key technologies currently employed for car parking sensors. They are electromagnetic and ultrasonic. An ultrasonic system uses the reflection of sound waves off an object to detect the distance. The distance measurement is derived from the echo time. These sensors are usually installed on the bumper as shown in figure 2. The sound waves are in the range of 20 kHz to 40 kHz, above human hearing limits.

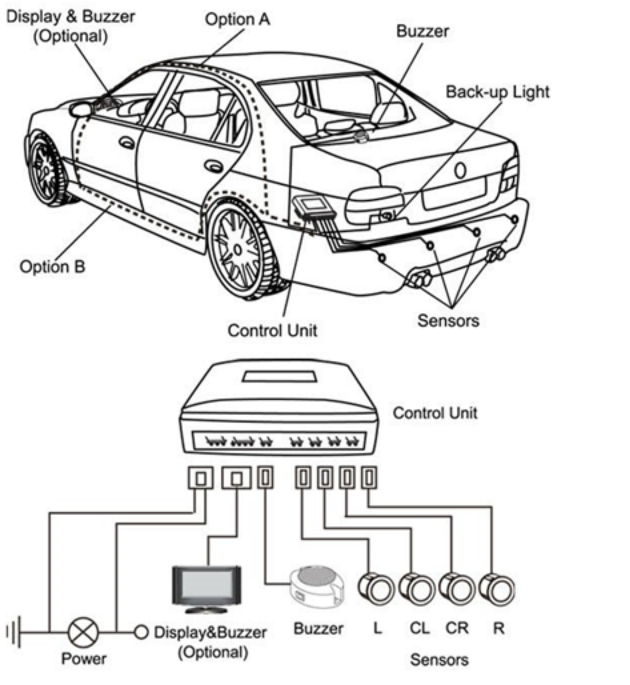

Figure 2: Typical Ultrasonic Parking Sensor Setup

Electromagnetic sensors, on the other hand, work by creating an electromagnetic field around the bumper of the car. Objects entering the field will affect a change to the field which is detected and used to calculate the distance of the object.

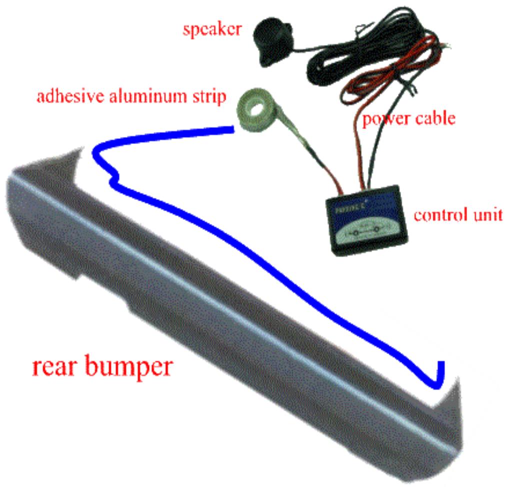

Figure 3: Typical Electromagnetic Parking Sensor Setup

We opted to use ultrasonic technology over electromagnetic technology for our design because we could not come up with a feasible design for simplifying the installation process of an electromagnetic distance sensor. The electromagnetic sensors need to be installed onto the inside of the bumper. Installing the sensor onto the inside of a bumper is a very complicated task. It requires the removal of the bumper from the car, which is something most people are not comfortable doing. We considered the possibility of placing the sensor on the outside of the bumper. However, this is not a feasible option because the sensor is just a thin aluminum strip and can be easily damaged if it is on an exposed surface. Furthermore, having an aluminum strip running along your car bumper is not aesthetically pleasing. Therefore, ultrasonic technology is the better choice for the Unipark-1000.

2.2 Simplifying the installation process

We simplified the installation process of our ultrasonic parking system with the following design features.

- Integration of sensors and control unit into one physical part (the sensor module) which is mounted onto the license plate mounting holes. The sensor module takes the form of a sensor plate frame.
- battery powered sensor modules

- wireless distance data transmission to display module

Integrating the sensors into a license plate frame eliminates the need to drill holes into the bumper for sensor installation and eliminates the need to run wires from the sensor to the control unit. Battery operated sensor modules eliminate the need to channel a power line from the car battery to the sensor module. Wireless data transmission eliminates the need to run a wire to the display module from the sensors.

2.3 Remote Switching Design

Because the sensor module is not physically connected to the display module, our design needs a means of powering the sensor module on and off remotely. Therefore, we designed a remote switching function using RF technology which will allow the display module to power on the sensor module remotely. RF (Radio Frequency) is a high frequency signal commonly used for communication applications.

We opted to use RF technology for this application because of the following reasons.

- Good Range: We can transmit a signal to a distance of about 300 feet without experiencing much attenuation.
- Simplicity: The electronics for RF transmission fits easily onto a breadboard and works well with microcontrollers to create a very simple wireless data link.
- Loss change of interference problems: These signals are transmitted at a particular frequency and a baud rate so a receiver can only read these signals if it is configured for that frequency and baud rate.

To build the remote switching circuit, a transmitter network and a receiver network was designed. The transmitting circuit is installed into the display module. The receiver network is installed into the sensor modules. The display module uses the transmitter network to transmit an "ON" signal to the receiver to turn on the sensor module. More details on the transmitter and receiver network are provided in the display module and sensor module design section, respectively.

The display module does not use the remote switching circuit to power off the sensor modules. Instead, we've decide to get the microcontroller within the sensor module to automatically power off the sensor module if there is no communication from the display module for over a minute. We decided to do it this way because of problem with our current transmitter design. When the user powers off the display module, the transmitter network is also powered off, therefore, it is unable to signal the sensor module to turn off. We did not have enough time to remedy this issue. This issue will have to be addressed in future development.

2.4 Bluetooth Communication Link

The functional specifications called for the distance data to be sent wirelessly from the sensor module to the display module. The purpose of this function is to eliminate wiring from the equation in order to simplify the installation process of the Unipark-1000. Our design employs Bluetooth communication to satisfy this requirement. Bluetooth technology is a short-range communications technology that is simple to use and secure. We opted to use Bluetooth technology mainly because it is robust, low power, and low cost.

For data transmission between the display module and the sensor module, we used Bluetooth modules with serial port profiles (SPP). SPP defines how to set up a virtual serial port between two Bluetooth enabled devices. It is called a virtual serial port because there is no physical wire connecting the two devices. The SPP defines two roles, master and slave.

- Master – This is the device that takes initiative to form a connection to another device.
- Slave – This is the device that waits for another device to take initiative to connect.

The Bluetooth modules using SPP will either be configure to be a master or a slave. When a master module connects to the slave, a serial port is formed automatically by the modules using the SPP. Therefore, devices at either end of the serial port can send data to each other. In our case, the devices at the ends are the display and sensor modules. For more information on SPP, the Bluetooth website has detailed specifications documents available for download.

3 Component Design

The following section outlines the component specific design specifications of the display module and the sensor module.

3.1 Display Module

The display module is a physical component that is mounted on the car dashboard. It serves the following functions

- Collects range data from sensor modules
- Displays the distance to the closest object on a digital LED display
- Sounds an audible alarm whose beeping frequency corresponds to obstacle distance
- Remotely power on sensor modules for distance measurements

A detailed block diagram of the Display Module is shown in the figure below.

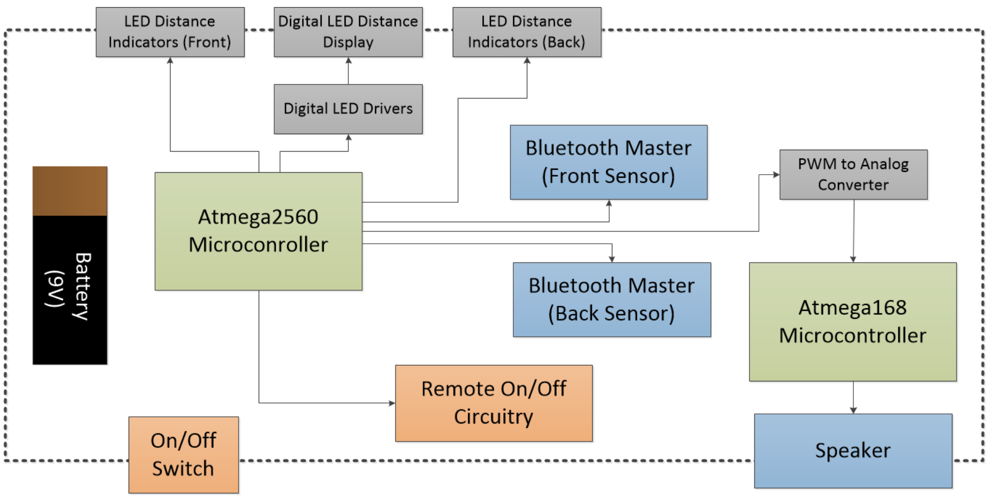

Figure 4: Display Module Detailed Block Diagram

A complete electronics schematic of the proof-of-concept display module can be found in Appendix 1. The electronics design is still subject to change upon future development. The design specification of each block is discussed in detail in the following sections.

3.1.1 Atmega 2560 Microcontroller

The display module uses an Atmega2560 microcontroller to perform its functions. The microcontroller coordinates serial communication between the display module and the sensor module, displays the distance value of the rear sensor on the 7 segment display, turns the LED lights on depending on the sensors values from the back and front sensor modules, and relays to the tone generator what alarm to play.

Hardware Information

For our proof-of-concept prototype, we used an Arduino Mega development board. The Arduino Mega is a microcontroller board which uses the Atmega2560 microcontroller. It has 54 digital input/output pins (of which 15 can produce PWM outputs), 16 analog inputs pin, 4 UARTs (hardware serial ports), and a 16 MHz crystal oscillator. This board also has 256 KB of flash memory, 8 KB of SRAM, and 8 KB of EEPROM.

We chose this board because it had the hardware features we needed. Firstly, this board has plenty of input/output pins for us to use. Currently, we are using 24 pins in total. Secondly, the board has two hardware serial ports, which we needed to interface with the two Bluetooth master modules. Thirdly, the board is easy to use and well documented. And finally, the board uses a fast 16 MHz processor. We need processing power because distances data must be fed to the user as soon as possible for it to be relevant. Specifications for the board are included in Appendix 2.

The final product will see us create our own proprietary PCB for the display module. The goal is to integrate all the electronics onto one PCB and eliminate as many unnecessary components as possible. Furthermore, we will use surface mount technology where possible to minimize the size of the PCB so that the display module can be compact.

Software Program

The follow diagram is a software flowchart for the display module main program.

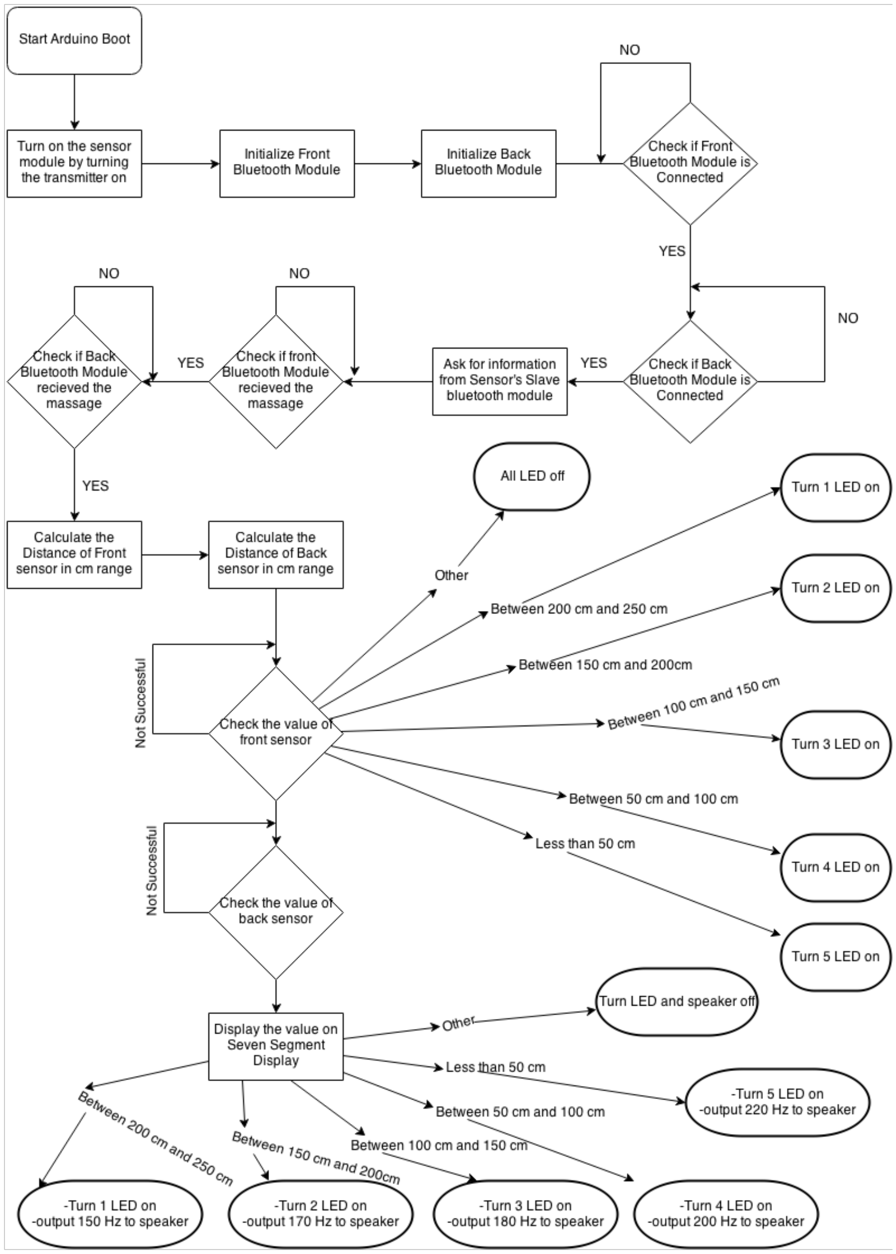

Figure 5: Main Program Software Flow Chart

3.1.2 Digit Display

The digit display is responsible for displaying the distance data from the rear sensor module only. For our design, we are using a COM-09483 seven segment display which has 4 seven segment LEDs. We are currently only using 3 of the seven segment display for our prototype. The seven segment LEDs are driven by a HEF4511BP BCD to seven segment decoder chip as well as SN74HC04N inverter chip. See Appendix 1 for the schematic of the digit display.

The purpose of the inverters is to convert the active low output of the decoder to an active high signal required by the seven segment display. Since we are only using one decoder, we needed to use switching techniques to display 3 digits. The 3 digit distance value is displayed sequentially one after another repeated at a very fast rate so that our eyes can see the flicker between one digit turn of f and the next digit turning on. The digit display does flicker when it refreshes the distance data. Below is a picture of the display used in our proof-of-concept prototype. See the appendix for the datasheet of this part.

Figure 6: 7 Segment LEDs for the Digit Display

3.1.3 LED Display

For our proof-of-concept prototype, we are using a 10 segment LED bar display for the back and front distance display (see figure 8). The 5 bars on the left will be for the back sensor distance data and the 5 bars on the right will be for the front sensor distance data. The center of the display is the zero distance spot (i.e. the car location). The Atmega2560 microcontroller receives the distance data from both front and back sensor modules use them to light these LEDs.

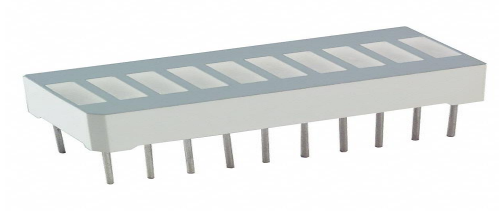

Figure 7: Bar LEDs for the LED Display

The following diagram shows how the LED states change according to distance data.

Table 1: Bar LED Setup

Back Distance Value	Bar LEDs (XXXXX)	Back Distance Value	Bar LEDs (XXXXX)
0-50	HHHHH	0-50	HHHHH
50-100	HHHHL	50-100	LHHHH
100-150	HHHLL	100-150	LLHHH
150-200	HHLLL	150-200	LLLHH
200-250	HLLLL	200-250	LLLLH
250 >	LLLLL	250 >	LLLLL

*H means the LED is on, L means the LED is off

Please see figure 10 for how the Bar LED display will look like in the final product version.

3.1.4 Transmitter Network

The RF transmitter will be signaled to start transmitting by the Atmega2560. The AD8 (pin 10) will be set to ON (LOW) initially and pin 14 will be connected to ground so it will enable the transmitting. The transmitted signal will be a "HIGH" on PIN AD1. It will take approximately one second of transmission time before the receiving circuit will pick up the signal and turn on the load. Below is the schematic for the transmitter network

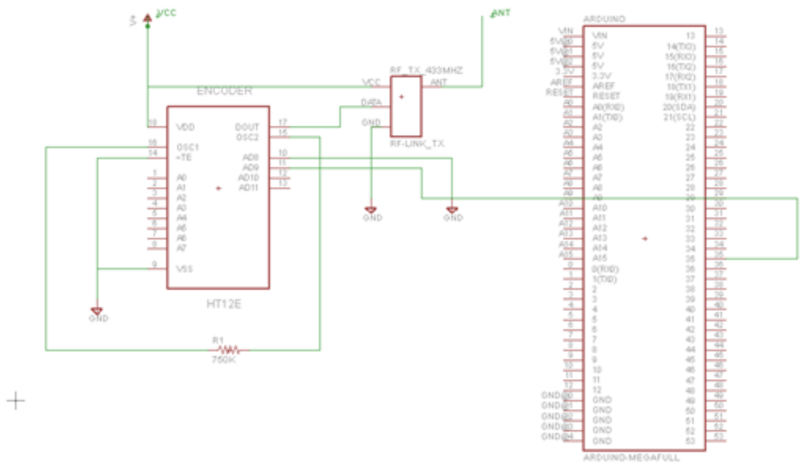

Figure 8: RF Transmitter Network Schematic

The encoder in the circuit is used to code the signal so that only the receiver network with the same code will be able to pick up the signal. For our design we used an HT12E encoder. The encoders are designed for remote control system applications. They are capable of encoding information which consists of 8 address bits (pin A0 to A7) and 4 data bits (pin 10 to pin13). Each address/data input can be set to one of the two logic states. The programmed addresses/data are transmitted together with the header bits via an RF. The capability to select a TE trigger on the HT12E or a DATA trigger on the HT12A further enhances the application flexibility of the 2^{12} series of encoders.

3.1.5 The Master Module

The master module is a Bluetooth bee standalone module. The Bluetooth bee is configured with SPP (Serial Port Profile) to emulate an RS232 connection. In other words, when the master module connects with a slave module, a serial port automatically forms between them and allow the two devices to send data back and forth using the serial port. The Bluetooth bee also has a built in Atmega168 microcontroller which can be used to control the master module. We briefly consider using this built-in microcontroller to run the main display module program but it is not powerful enough and doesn't have enough pins to support all of the display module's functions. Therefore, we bypassed this microcontroller and connected an Atmega2560 microcontroller directly to the Bluetooth module for running the main program instead. The figure below is a picture of the module.

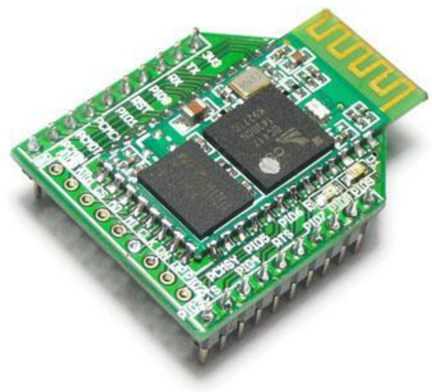

Figure 9: Bluetooth Bee Master Module

Detailed specifications for the Bluetooth bee are attached in Appendix 2. The display module uses two master modules because it must establish one virtual serial port with the front sensor module and another virtual serial port with the back sensor module. Although the SPP can allow for one master module to connect to multiple slave modules, the firmware of the master module we used did not allow for this feature. As a result, we were limited to one master and one slave pairs.

Software Information

Because the display module needed to establish two virtual serial ports, we decided to implement a Bluetooth serial port class to be used in the program. This class allowed us to implement two serial port objects without the need to create customized functions for each port. Details of the class are provided in the tables below.

Table 2: Bluetooth Master Serial Port Class

Data	HardwareSerial *btSerial; String slaveaddr; uint8_t RxD, TxD; uint8_t btstatuspin;
Functions	Public functions btmodule(HardwareSerial *bt, uint8_t tempR,

	uint8_t tempT, String addr, uint8_t pin);
	~btmodule();
	void initbt();
	void connectto();
	void sendmsg(char msg[]);
	void sendmsgf(char msgf[]);
	String checkmsg();
	boolean linked();
	Private Functions:
	void sendcmd(char msg[]);
	boolean errorcheck();

Table 3: Master Side Function Descriptions

Function	Description
Public	
btmodule()	Constructor function for instantiating the Bluetooth serial port object. Syntax: btmodule(SoftwareSerial *bt, uint8_t tempR, uint8_t tempT, String addr, uint8_t pin);
initbt()	Sets up a serial port between the Bluetooth master module and the microcontroller. Configures the Bluetooth master module to the correct default settings. Syntax: void initbt();
connectto()	Commands Bluetooth master to connect to the slave module if there is currently no connection. The master will attempt to connect to the slave with the mac address inputted when the object was constructed. Syntax: void connectto();
sendmsg()	Sends a message to the slave module via the serial port established Syntax: void sendmsg(char msg[]);
checkmsg()	Polls the Bluetooth serial port for any messages from the slave module. Returns the message as a String variable.

Function	Description
	Syntax: String checkmsg();
linked()	Checks if the Bluetooth master is connected to its corresponding slave module. Returns true if there is a connection and false otherwise. Syntax: boolean linked();
Private	
sendcmd()	Sends a command to the Bluetooth master to configure its settings. Note: This only works if the master is not currently connected to a slave. Syntax: void sendcmd(char msg[]);
errorcheck()	Checks if the Bluetooth master successfully received the command. Returns true if there's been a problem and false otherwise.

The following configurations must be set on the master module before it can pair with the slave device in the desired sensor module.

- The baud rate on master module must be set to 38400 kbps. The slave baud rate must also be set to 38400 kbps.
- The unique MAC address of the slave devices on the correct sensor modules must be entered into the program.

This technique of hardcoding the MAC addresses of the slave devices into the program was implemented to reduce the security risk of people stealing the sensor modules. It also prevents accidental connection of the master module to other BT slave devices that are in the vicinity.

The BT modules can support higher speeds but they have not yet been tested at these higher speeds. Refer to the modules specifications for details on the support speeds. The current value of 38400 kbps was used because it the default set speed. There is no need to increase the speed to higher values because we are only sending short bursts of data.

3.1.6 Tone Generator

The tone generator is responsible for generating the audible alarm for the display module. The tone generator consists of the PWM (pulse width modulated) to analog DC circuit, the Atmega168 microcontroller, and the speaker. There are six different tones that the tone generator can produce ranging from a constant beep to a short beep every few seconds. The beeping frequency increases as the object distance is smaller, with a constant beep at distance less than 50 cm. The tone choice is made by the main microcontroller (Atmega2560). The Atmega2560's tone choice output is a pulse width modulated (PWM) signal. Unfortunately the Atmega168 can't read a PWM signal. Therefore, the PWM to analog DC circuit was designed to convert the PWM signal to an analog DC signal for the Atmega168 to read on one of its analog input pins. The schematic of the tone generator is shown below.

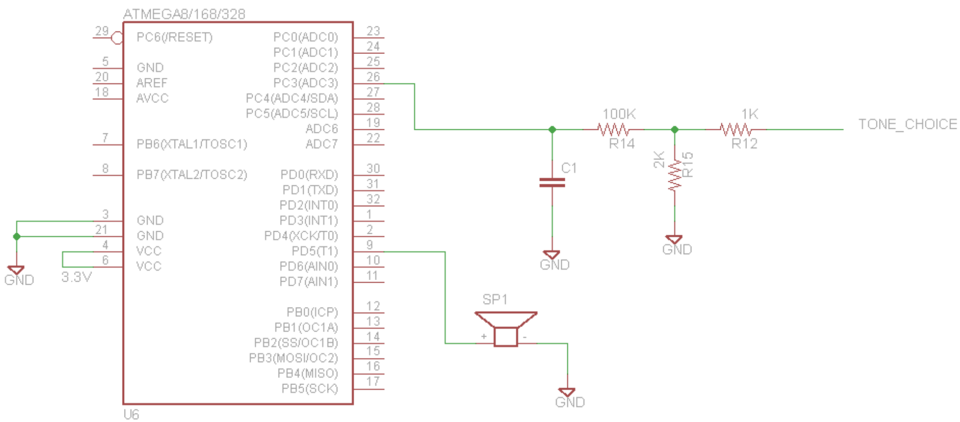

Figure 10: Tone Generator Schematic

We used a secondary microcontroller, the Atmega168, to generate the sounds for the speaker. We needed the second microcontroller because the Atmega2560 was unable to play the sound correctly while display the distance on the LEDs. More specifically, our microcontroller is single threaded and playing the sound while displaying the distance at the same time requires a double threaded operation. For the proof-of-concept prototype, we used the idle AtMega168 microcontroller on the Bluetooth master module to perform the tone generator function.

3.1.7 Display Module Casing

The case for our final product is demonstrated in the following figure.

Figure 11: Display Module Concept Case

As shown in the figure, the display module will have two sets of LEDs as well as a seven segment display and a built in buzzer. In this design, the left set of LEDs will be displaying the distance data from the back sensors. The seven segment display is also showing the distance data for the back sensor. The right set of LEDs will be showing the front distance data. We will not be able to demonstrate the prototype display module in a casing because we are using a development board which is too big to fit into this case. Instead we will be using a simple cubical case which is intended to contain the entire display module. The case will have three holes on the front side. One for the seven segment display and two for the front and back sensor bar LEDs.

3.2 Sensor Module

The sensor module is in charge of performing distance measurements and sending that information to the display module. In the following sections we discuss the design details of the sensor module.

3.2.1 Hardware Layout

The following diagram is the high level block diagram of the sensor module:

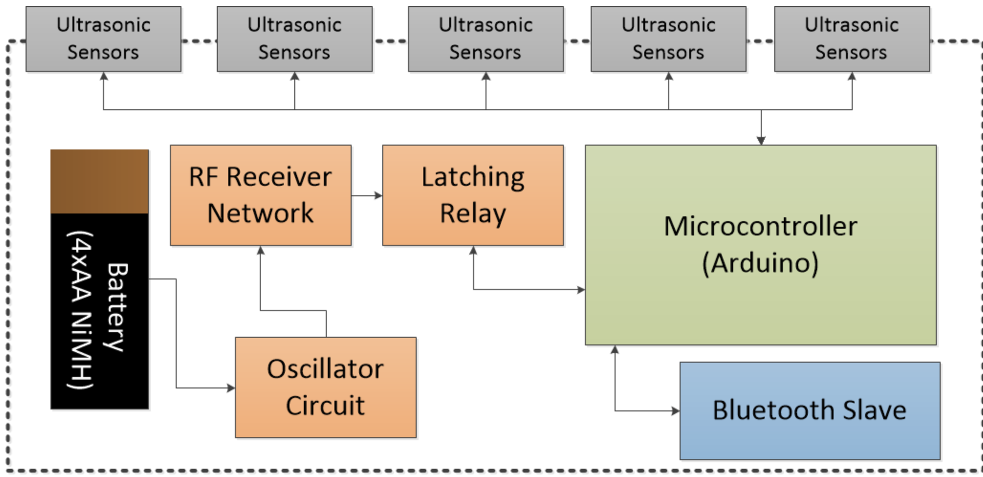

Figure 12: Sensor Module Block Diagram

The basic hardware operation is as follows. The power source of the microcontroller, the Bluetooth slave, and the sensors (we will call these components as the sensor array sub-circuit) are coming from the remote on/off sub-circuit (which are the 3 orange blocks). Normally, remote on/off circuit cuts off the power supply to the sensor array sub-circuit. The RF receiver network portion of the remote on/off sub-circuit listens for the “ON” RF signal from the display module. The remote on/off circuit will begin to supplying power to the components when it receives the ‘ON’ signal from the display module. After power is supplied to the components, the microcontroller can decide to cut off power by sending an “OFF” signal to the remote on/off circuit.

> 11/17/13 11:56 PM
> **Comment [1]:** Kenny Lam:
> @Edmund
> please verify that this diagram is correct

> 11/17/13 11:56 PM
> **Comment [2]:** Kenny Lam:
> @ edmund
> this paragraph needs to be update to match the diagram.

While power is connected to the sensor array sub-circuit. The sensors periodically collect range data, and the microcontroller samples the range data from the sensor and relay it the display module via the Bluetooth serial slave.

If the microcontroller doesn’t receive any data request from the display module for 1 minute, the microcontroller will signal the remote on/off circuit to cut-off power to the sensor array sub-circuit. This feature was incorporated into the design to simplify the user interface of the display module to only one button which just turns on sensor module. When the display module is turned off, the sensor module should not receive any data request and will shut off itself.

A complete circuit schematic of the current proof-of-concept prototype is shown below and will be referenced throughout the document. Please note that this schematic is not fixed and will be subject to change with development.

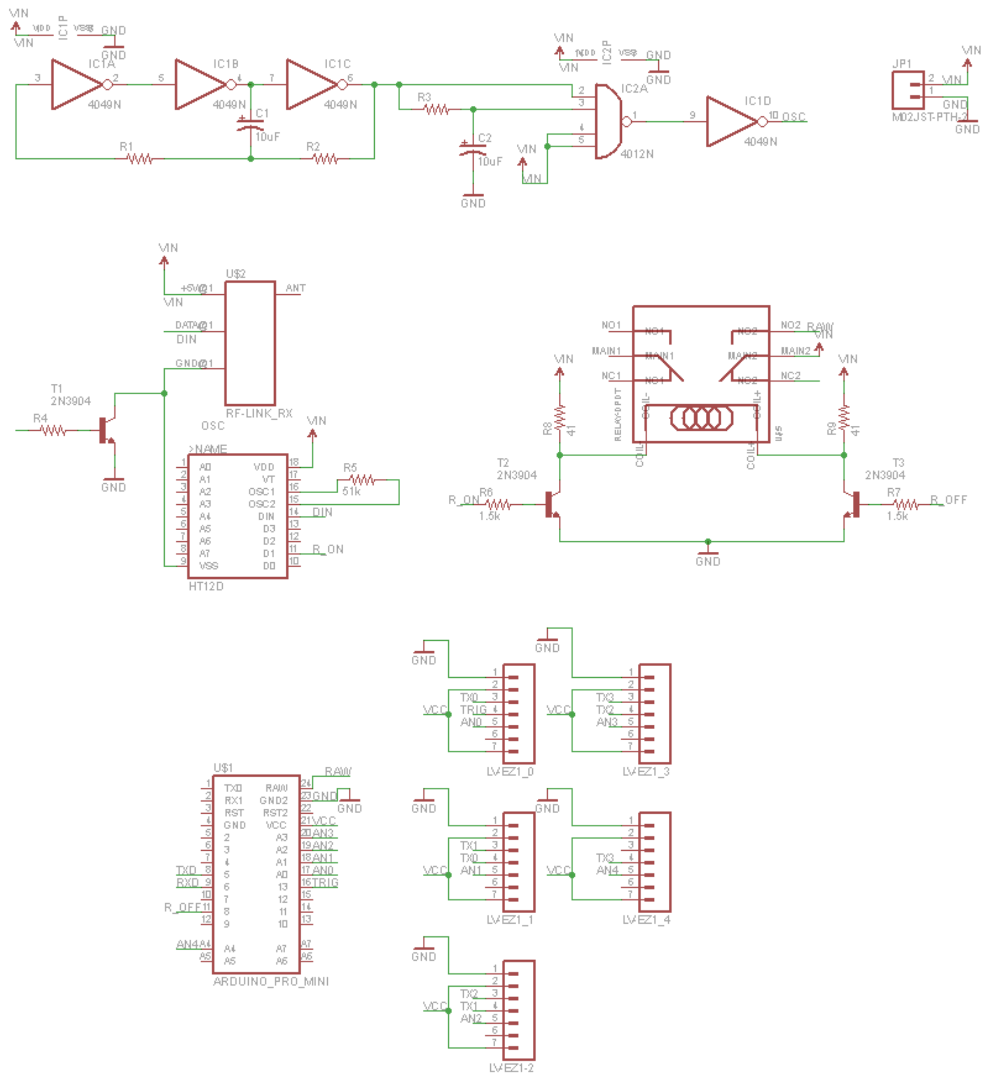

Figure 13: Sensor Module Schematic

3.2.2 Sensor Array Sub-Circuit

The following is the schematic of the sensor array circuit in the sensor module:

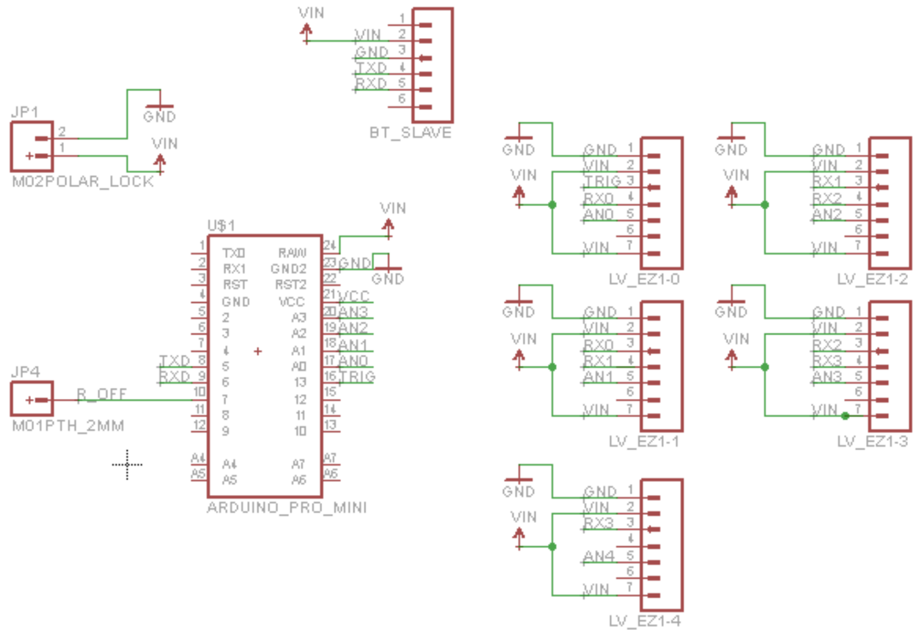

Figure 14: Sensor Array Sub-Circuit Schematic

The sensor array circuit contains a total of 5 LV-EZ1 Sonar Range Finders which are connected in a way that will trigger the range reading function sequentially starting from the first LV-EZ1 (labeled as LV_EZ1-0 in the schematic) ending at the last LV-EZ1 on the sensor array (labeled as LV_EX1-4 in the schematic). To trigger the range reading function on all connected sensors, pull the *TRIG* pin high for 20us. The range data will be ready to sample on the *AN#* pins of the LV-EZ1 after 250ms.

The range data at *AN#* pin will be an analog value ranging from 0 to Vcc (voltage on *VIN* pin). Thus, each *AN* pin from the sensors are connected to one of the channels of a 10-bit DAC inside of the Atmega328. The ATmega328 is located inside *ARDUINO_PRO_MINI*. The Atmega can decide to cut the power to the entire sensor array sub-circuit by bringing the *R_OFF* pin high for about ~1s.

The Atmega328 also has a Bluetooth Serial slave paired to the Display module of Unipark-1000. The microcontroller will transmit the collected range values if it sees a request on the serial terminal.

3.2.3 Development board - Arduino Pro Mini

Currently our proof of concept prototype uses the Arduino pro mini development board. Future development will see us designing a custom PCB containing the Atmega328 microcontroller.

The following is the schematic of our chosen development board:

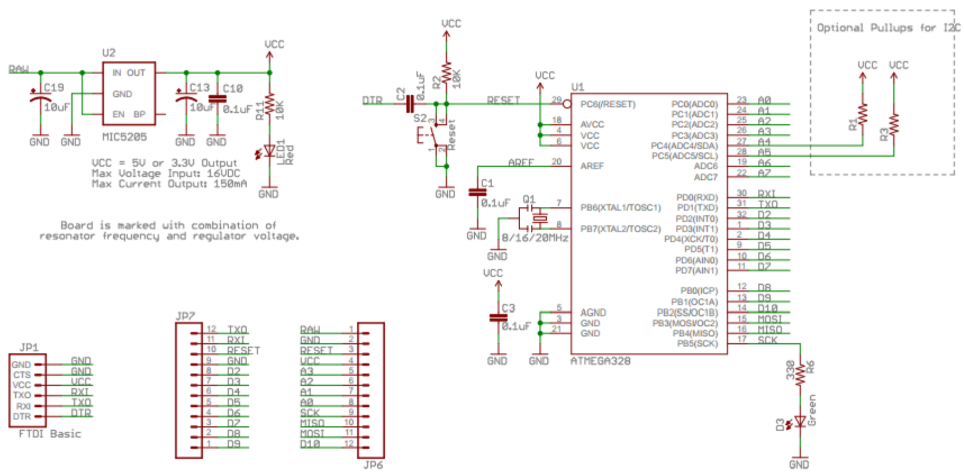

Figure 15: Arduino Pro Mini Schematic

Our development board is simply a bare bone Atmega328 plus a voltage regulator and a LED. We have decided to cut the traces of the LED to reduce the power consumption.

3.2.4 Software application

The following is the pseudo code that will be running on our microcontroller:

```
struct voltage_level_at_sensors {
        uint16  level0;         //voltage level on sensor 0
        uint16  level1;         //voltage level on sensor 1
        uint16  level2;         //voltage level on sensor 2
        uint16  level3;         //voltage level on sensor 3
        uint16 level4;          //voltage level on sensor 4
}

voltage_level_at_sensors read_range();

float calculate_shortest_distance(voltage_level_at_sensor );
```

```
bool bt_request_from_display_module();        //return true if display module request range data

void bt_send_data(uint16 );

void power_off();

void main() {
        voltage_level_at_sensors sensor_array;

        while ( ;; ) {
                sensor_array = read_range();
                if ( bt_request_from_display_module() ) {
                        bt_send_data( calculate_shortest_distance() );
                }
                else {
                        if ( no_bt_request_for_longer_than_60s() ) {
                                power_off();
                        }
                }
        }
}
```

Note that the *calculate_shortest_distance()* function will also need to perform some form of data correction to account for the fact that the some of the sensors (specifically, sensor 0,1,3, and 4) orientation are not perpendicular with the bumper.

We can use trigonometry to obtain the true distance from the object to the car vehicle, given the hypotenuse (the range data provided from the sensor), and the angle of the sensor (which is a known constant), the true distance should approximately equal to:

$$d = R * \sin(\theta)$$

where R is the range value from sensor and theta is the angle of orientation of the sensor. The following is the pseudo code implementation of the *calculate_shortest_distance()* function:

```
float calculate_shortest_distance(voltage_level_at_sensor sensors_array) {
        float shortest_distance, temp_f;
        unsigned int *a = &sensors_array;

        for ( int i=0, i<5; i++) {
                if (i==1 || i==3) {
                        temp_f = (float)*(a+i)*0.9272;
                        if (temp_f < shortest_distance) { shortest_distance = temp_f;}
```

```
                    }
                    else if ( i==2 ) {
                            temp_f = (float)*(a+i);
                            if (temp_f < shortest_distance) { shortest_distance = temp_f;}
                     }
                    else if ( i==5 ) {
                            temp_f = (float)*(a+i)*0.6820;
                            if (temp_f < shortest_distance) {  shortest_distance = temp_f;}
                     }
            }

            return shortest_distance;
    }
```

3.2.5 Ultrasonic Transducers

The ultrasonic transducer will be our key to collecting the proximity range data. The transducers are built into the sensor modules. They are facing outward at different angles in order to detect objects around the front/back of the car. In the following section, we will first briefly explain the physics of ultrasound and the object detection with ultrasound. After that, implementation details of the ultrasonic transducer employed in Unipark-1000 will be given.

Physics of Ultrasound

Ultrasound is simply a sound wave that oscillates at a frequency greater than 20 kHz. The following figure describes the classification of sound waves:

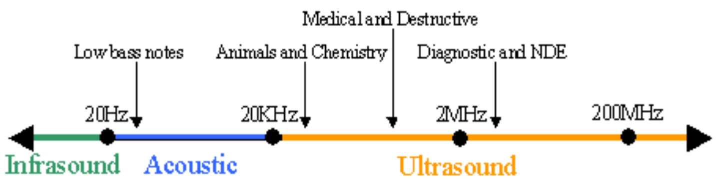

Figure 16: Ultrasound Range Diagram

Source from: http://commons.wikimedia.org/wiki/File:Ultrasound_range_diagram.png

Due the fact that our human ear behaves like a low-pass filter with an upper frequency limit of approximately 20 kHz, most ultrasound waves will be undetectable by human. Besides the fact that ultrasounds are undetectable by human, its behaviors (e.g. interfacing between two medium) are identical with other audible sound wave.

Reflection and Refraction of Ultrasound

When an ultrasound wave is passing from one medium to another, it will exhibit reflection and refraction when crossing between mediums. This reflection and refraction phenomenon of the sound wave can be described using Fresnel's reflection equation and Snell's Law. Full details of Fresnel's reflection equation and Snell's Law are beyond the scope of this document and will not be discuss here. What we need to know is that the part of the energy of the ultrasound wave will be reflected, refracted, and loss between the interface of two mediums, the amount of energy that will be reflected, and refracted will depend on the angle of incident as well as the materials of the two medium.

Object Detection with Ultrasound

The idea of object detection using ultrasound is simple. We transmit an ultrasound pulse outward to the environment and then we wait for the echoes of the transmitted ultrasound pulse, the following diagram should clearly illustrate this idea:

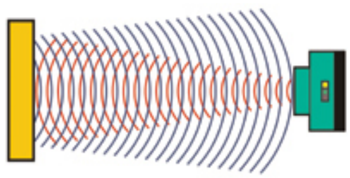

Figure 17: Object Detection with Ultrasound

Sourced from: http://www.sensorsmag.com/networking-communications/ultrasonic-sensing-challenging-environments-518

The distance between the detected object and the ultrasonic transducer can be determined with the following equation:

$$d = 1/2 * v * t$$

where d is the distance between the transducer and the object, v is the velocity of the sound wave propagating through the medium, t is the time elapsed since the transmission time to detection time, and the ½ is to account for the fact that the sound wave travelled back and forth.

Implementation detail of Ultrasound Transducer

The ultrasonic transducer we use in our Unipark-1000 is called the LV-EZ1 High Performance Sonar Range Finder made by Maxbotix Inc. The LV-EZ1 is already pre-configured by the manufacturer, and it is ready to be use right out of the box. The following shows the schematic of LV-EZ1:

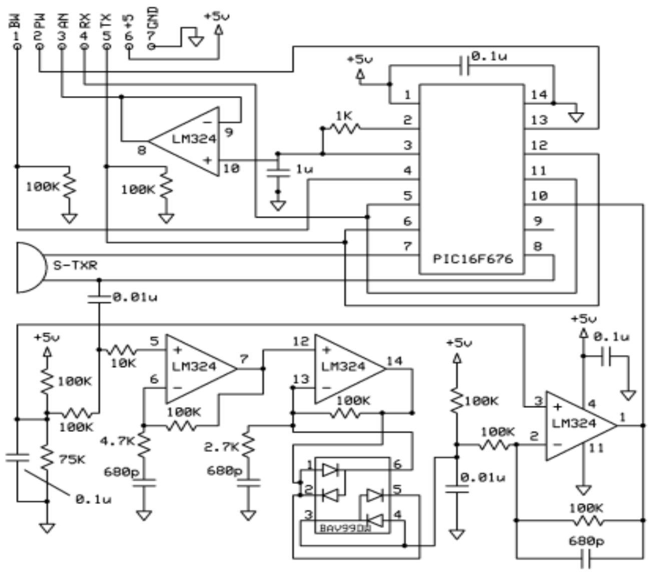

Figure 18: Ultrasonic Sensor Schematic

Sourced from datasheet of the part.

From the schematic, we can see that the ultrasonic transducer (S-TXR) is driven by an 8-bit microcontroller (PIC16F676). This suggest that range calculations and some form of software post-processing of the echoes is being performed here. For more detailed information about the LV-EZ1 High Performance Sonar Range Finder, please refer to the datasheet.

Ultrasonic Sensor Arrangement and Positioning

There will be total of 5 LV-EZ1 sensors in a single array. Each sensor is capable of producing a 30 degrees wide, 6 meters deep detection pattern. The sensors array will be aligned horizontally and placed across the entire vehicle license plate. The following diagram shows the placement and orientation of the sensors, and the detection pattern it will produce given this placement/orientation configuration:

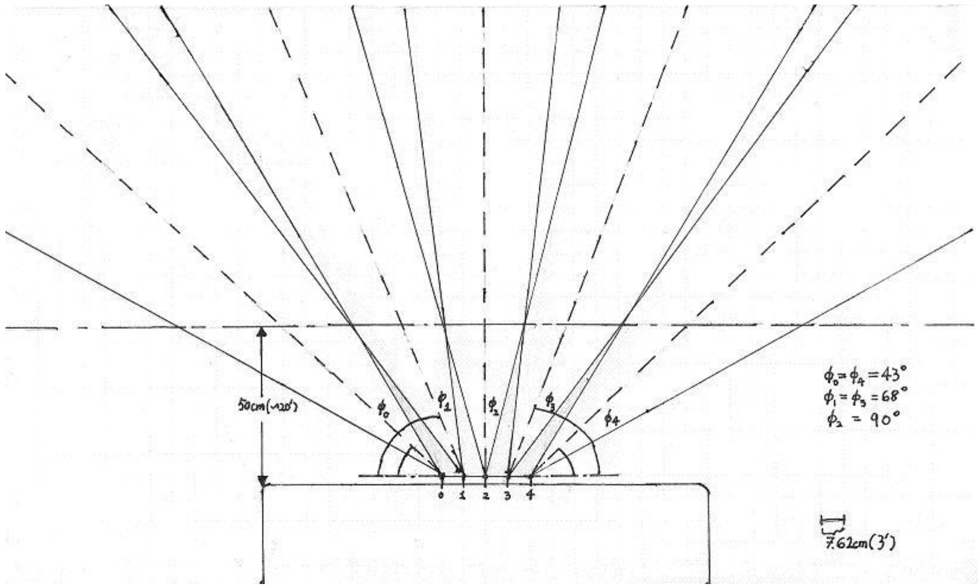

Figure 19: Ultrasonic Sensor Positional Arrangement

From the above diagram, our sensors will be evenly spaced out by 7.62cm on the vehicle license plate. Each sensor will have its face tilted at an angle given by the diagram producing the beam pattern of non-overlapping region, overlapping region (2 sensor beams), and blind region. The blind region exists within 50cm away from the front/back of a car vehicle, which is below our minimum detection distance.

3.2.6 Receiver Network

The RF receiver network is for picking up transmitted RF signal from the display module. The following is the schematic of the circuit.

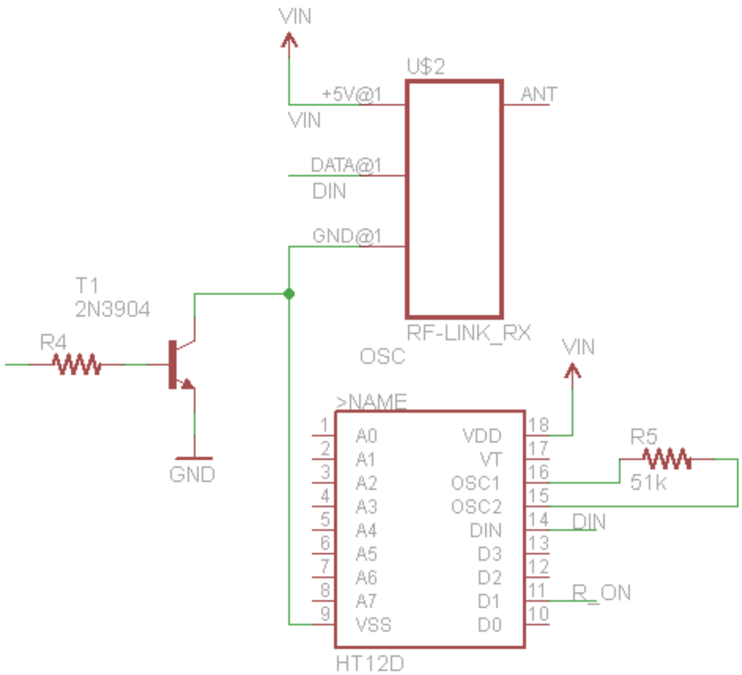

Figure 20: Receiver Network Schematic

The RF receiver network consist of a 434 MHz RF receiver (RF-LINK_RX), 2^12 decoder (HT12D), and NPN BJT. The VSS pin of the 434 MHz RF receiver and the 2^12 decoder are connected to the collector of the NPN BJT, and the base of the BJT is driven by the output clock signal of the oscillator network. Thus, when the clock signal is high, there will be about ~5V difference between the V+ line and the collector which will turn on our RF receiver network.

Once the RF receiver network is powered on, the operation is as following. At first, the power must maintain for at least 1 second before the 434MHz RF receiver can actually give received data output. After the 1s boot up time, The received, and demodulated RF signal will be outputted on the DATA pin of the 434 MHz RF receiver. The received data on the DATA pin is feed straight to a 2^12 decoder. The values on the address pins (i.e. A0-A7 pins) on the HT12D must match the address pins on the HT12E (i.e. 2^12 encoder, locate in the display module). The HT12D will decode the received data on the DATA pin and output it on the D0 to D3 pins of the HT12D. We the RF receiver receive a “ON” signal from the display module, the D1 output pin will set to high, and we use this output pin to drive the relay circuit to turn on power supply to the sensor array sub-circuit. For information about the 2^12 decoder, and the 434 MHz RF receiver, please refer to the appendix for datasheet.

3.2.7 Oscillator Network

The Oscillating Circuit is built for optimizing the current draw from the receiving circuit. Since the Receiving Circuit will always need to be on to listen to the transmitting signals. This will cost lots of power and reduce the battery life. With this Oscillating Circuit, the receiving circuit will only be on for approximately 36% of the time and it can save the power dramatically. The following is the schematic of the clock generator inside our sensor module:

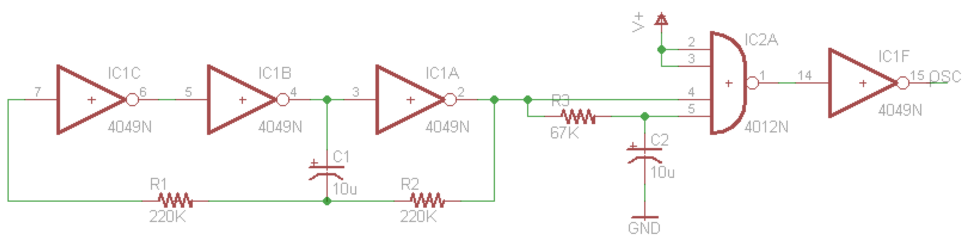

Figure 21: Oscillator Network Schematic

On the left side of the schematic of the clock generator is a simple CMOS 50% duty cycle oscillator with the frequency given by the following equation:

$$\text{frequency} \approx \frac{0.559}{RC}$$ (Fairchild Semiconductors, 2013)

where $R = R1 = R2$ and $C = C1$. With the given resistor and capacitor values, the theoretical frequency should be roughly equal to

$$\text{frequency} \approx 0.559/(220K * 10u) = 0.25409\ldots$$

and the measured frequency from the oscillator is equal to about $\approx 0.2\text{Hz}$.

We can reduce the duty cycle of the clock signal from the CMOS oscillator to about ~40%. To accomplish this, we feed the oscillator output and a delayed version of the signal to a 2-input AND gate (the schematic show a 4-input AND gate, but the other two inputs are tied to Vcc permanently, so we can assume it as a 2-input AND gate). The following diagram show the waveform at the output of the CMOS oscillator and the 2-input AND gate (channel 2 signal):

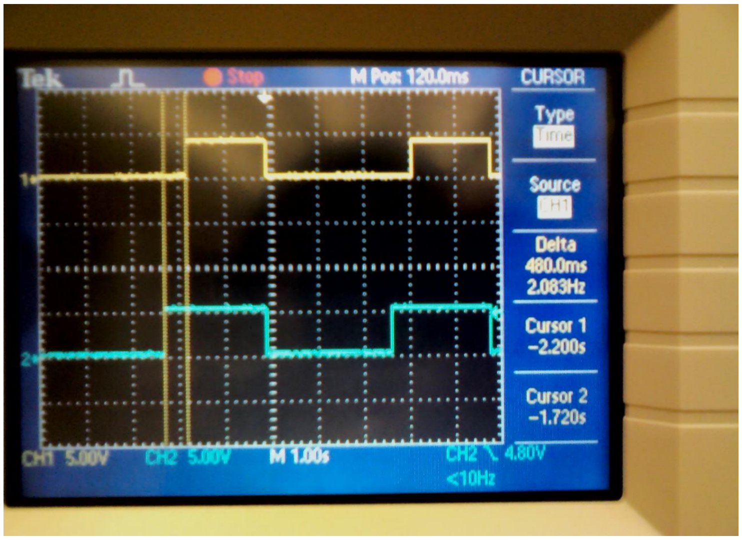

Figure 22: Oscillator Signals

According to the datasheet of the 4-input NAND gate (refer to appendix for datasheet), the typical high input voltage is equal to about ~2.75V at Vcc equal to 5V. Thus, based on our RC circuit with R = 67KOhm, and C = 10uF, we should be able to delay the low-high transition on the oscillator by a time value given by the following equation:

$$t = -R * C * \ln(1 - V/Vcc)$$

where $R = 67K\Omega$, $C = 10\mu F$, $V = 2.75V$, and $Vcc = 5.0V$. The calculated delay time is equal to ~535ms. From the above waveform, the acutal measured delay is actually equal to ~480ms. Given the delay value, our new duty cycle value is equal to:

$$\%\text{Duty Cycle} = (2.5 - 0.480)/5 = 40.4\%$$

The waveform of the reduced duty cycle clock signal is displayed in the above diagram as the channel 1 signal (the yellow line).

3.2.8 Latching Relay

A 5V DPDT latch type relay is used to control the power supply to the sensor array sub-circuit. The setup of the relay is display in the following diagram:

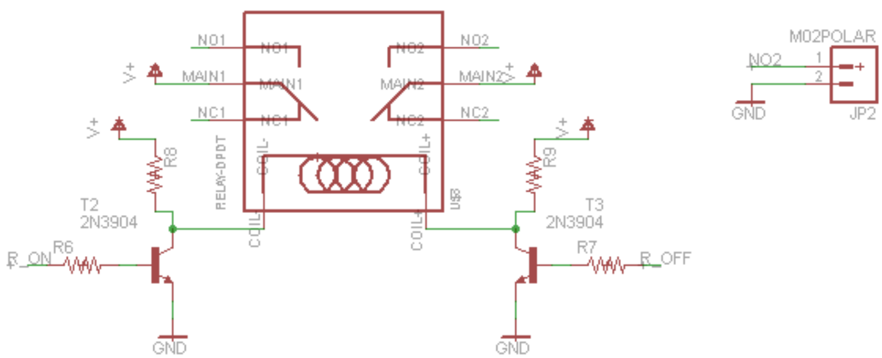

Figure 23: Latching Relay Schematic

The basic operation of the relay is as following. When the base of the left NPN BJT goes high (due to receiving a “ON” signal from the Receiver Network), the collector on the left NPN BJT goes to ground and cause a ~+5V voltage difference across *COIL+* and *COIL-*. The +5 voltage across the *COIL+* and *COIL-* will force the relay to go into the SET state where the MAIN pin flip and make contact with NORMALLY OPEN (the *NO* pin). There are two possible stable states for the relay, SET state, and a RESET state. To cause a state change from SET to RESET, the microcontroller will drive the base of the right NPN BJT to high. This will cause a ~-5V across COIL+ and COIL-, which force the relay to go into the reset state (the MAIN pin flip and make contact with NORMALLY CLOSE). From the above diagram, the *MAIN* pin is connected to the positive node of our battery pack, the *NORMALLY CLOSE* pin is connected to the VCC of the sensor array sub-circuit. Power will be supply to the sensor array sub-circuit only when our relay is in SET state.

3.2.9 The Slave Module

We chose to use the JY-MCU Bluetooth Slave Module Version 1.2 as the slave device. This module suited our purposes because the module was

- was already preconfigured by its firmware to support serial port applications.
- was reasonably priced, simple to use, and Arduino friendly.
- Was ready for use on breadboards

The baud rate of slave module must be preconfigured to 38400 kbps to allow for a success Bluetooth link to form. A picture of the Bluetooth module shown below.

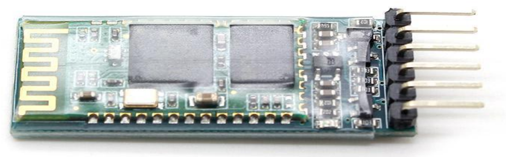

Figure 24: JY-MCU Slave Bluetooth Module Version 1.2

Detailed specifications for the module are attached in Appendix 2. Information from the following resources was helpful to developing our understanding of the module and taught us how to use it.

- http://mcuoneclipse.com/2013/06/19/using-the-hc-06-bluetooth-module/
- http://www.instructables.com/id/Success-Using-the-JY-MCU-linvor-Bluetooth-Module/

Software information

The slave side software has a much simpler design than the master module software. On the slave side, 3 functions were created to manage the Bluetooth module and set up the serial port. No class was used here because we only had one slave module connected to the microcontroller. The functions are listed and describe in the following table.

Table 4: Slave Side Functions

Function	Description
setupslave()	Configures the Bluetooth slave module to form a serial port with the microcontroller. Syntax: void setupslave();
sendmsg()	Sends a message to the slave module via the serial port established Syntax: void sendmsg(char msg[]);
checkmsg()	Polls the Bluetooth serial port for any messages from the master module. If there is a message, it will return the message in a String variable. Syntax: String checkmsg();

3.2.10 Sensor Module Casing

As already stated, we've chosen to combine all the electronics in the sensor portion into one physical component. The casing is design to not only hold the electronics but also function as a license plate frame. The casing will be mounted onto the car using specialty screws to improve security and make it more difficult to remove. Below is a Solidworks diagram of the design concept.

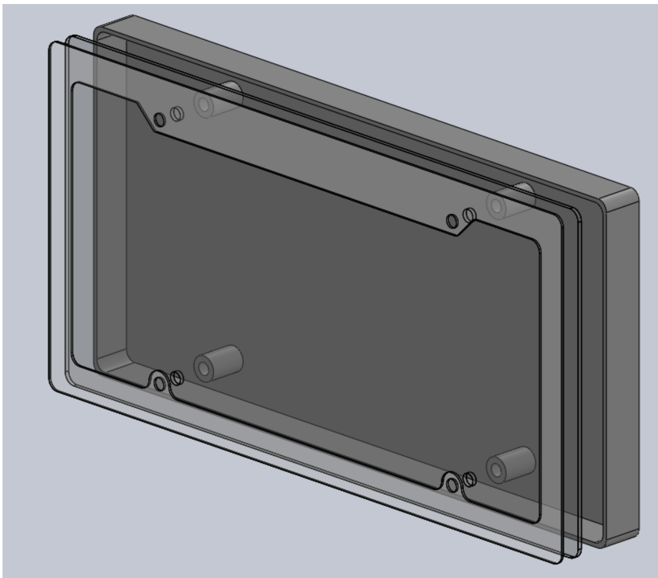

Figure 25: Sensor Module Concept Case

Currently, the model is overly simplistic and fails to fully address the environmental requirements from the functional specifications. Furthermore, the aesthetics leave much to be desired. Future development is needed to refine the design to satisfy the environmental and aesthetic requirements specifications.

4 System Testing

4.1 Requirements Classification

Each of functional requirements is documented in the following format:

[Ri-p] A functional requirement.

where **i** is the functional requirement index and **p** is the prototype index. The prototype index identifies the earliest prototypes which will meet the requirement. The prototype index legend is as follows:

1. Proof of concept build.
2. Beta Build
3. Production Build
4. Accessory requirement. May be included in production build

4.2 Prototype Definition

Proof of Concept Build

The proof of concept build is a crude prototype which will be used to explore and address key technical risks in the Unipark-1000. This build shall have basic product functionality which includes accurate obstacle distance detection and easy installation. It shall satisfy all requirements with a prototype index of 1.

Beta Build

This build is the first model of the final product. Fixes will be implemented for any flaws discovered in this build before proceeding to the next build. It will meet all requirements with prototype index 1 and 2. It may contain some components which are not used in the production build. The appearance may be different from final product.

Production Build

The production build is the final commercially sold product. It will satisfy all requirements with prototype indexes 1, 2, and 3. It will also satisfy as many accessory requirements (p =4) as economically feasible.

4.3 System Test Plan

System Test Plan (PN: 001-0001-00)

Requirement #	Requirement Description	Test Method	Pass/Fail Criteria
[R1-3]	The production cost of the final implementation must fall under $50 CAD per unit.	Sum up cost of parts in bill of materials. Visually verify that this sum is below $50 per unit.	Pass if sum is below $50.
[R2-3]	The retail price of the system will be under $100 CAD per unit.	TBD	TBD
[R3-1]	The system shall be have an install time of no more than 15 minutes	Perform installation of device on a car.	Pass if installation takes no more than 15 minutes
[R4-1]	The system shall not require more than 2 hand tools for installation.	Perform installation of device on a car.	Pass if installation was successfully complete without the use of more than 2 hand tools
[R5-3]	The system shall look aesthetically pleasing and professionally designed.	Visual inspection	TBD
[R6-3]	The system should not have any sharp edges.	Visual inspection	Pass if all exposed edges have rounded corners
[R7-2]	The system shall be battery operated with a minimum battery life time of at least 3 months under normal usage. Normal usage is defined as the device assisting with parking 6 times a day every day.	Calculate average power consumption for one day of usage. Assume the following worst case scenario: car is parked 6 times a day with each event taking 5 minutes. Extrapolate power consumption over a period of 3 months and compare with rated battery capacity.	Pass if total power consumption over the 3 month period is below the battery capacity

Requirement #	Requirement Description	Test Method	Pass/Fail Criteria
[R8-2]	The system shall draw no more than 100mA of current.	Use ammeter to measure current draw for display module and sensor modules during operation. Sum values together to get the total current draw of the system.	Pass if measured total current draw is below 100 mA
[R9-2]	The system shall operate correctly within the temperatures of -25 to 70 degree Celsius.	The following requirements will be tested by subjecting the system to the conditions outlined in standard MIL-STD-810. The test procedure will follow the test guidelines in MIL-STD-810 as well.	Pass if system is operational after being subjected to the conditions in the test method
[R10-2]	The system shall operate correctly in humidity levels ranging from 0% to 90% RH.		
[R11-2]	The system shall operate correctly in atmospheric pressures from 94 kPa to 103 kPa.		
[R12-2]	The system shall be resistant to shock.		
[R13-2]	The system shall be resistant to vibration.		
[R14-2]	The system shall not experience any mechanical or electrical failure within the first year of its lifetime.		
[R15-2]	The system shall be intuitive in term of user interface	TBD	TBD
[R16-1]	The system may require a calibration procedure after installation.	N/A. The design was implemented without the need of a calibration procedure	N/A

Requirement #	Requirement Description	Test Method	Pass/Fail Criteria
[R17-2]	The system shall comply with all applicable CSA standards [3].	Verify that CSA certifications is successful	Pass if system is CSA certified
[R18-2]	The system shall comply with ISO 26262 [4].	Verify that ISO 26262 certifications is successful	Pass if system is ISO 26262 certified
[R19-2]	The system shall comply with all applicable FCC standards for unintended radiation [5].	Verify that FCC certifications is successful	Pass if system is FCC certified

Component Test Plan

Display Module (PN: 001-0002-00)

Requirement #	Requirement Description	Test Method	Pass/Fail Criteria
[R20-1]	The display module shall display the obstacle distance in cm using a digital LED display similar to that shown in figure 2.	Visual inspection	Pass if system has digital LED that displays distance values
[R21-1]	The display module shall display the obstacle distance using the LED dot display method. Green LEDs indicate a far distance. Yellow LEDs indicate a medium distance. Red LEDs indicate a close distance.	Visual inspection	Pass if system has LED display for showing distance values as describe in specification

Requirement #	Requirement Description	Test Method	Pass/Fail Criteria
[R22-1]	The display module shall use Bluetooth communication to retrieve the proximity data from the sensor module.	Verify with design documentation that display module uses Bluetooth communication to send distance data	Pass if design documentation shows that Bluetooth communication is used to retrieve distance data.
[R23-1]	The system shall have an audible alarm which beeps faster as the object is closer and turn into a continuous tone at a distance of less than 50 cm.	Visual inspection	Pass if we can hear the alarm beeping faster as object gets closer to the car
[R24-2]	The audible alarm sound shall have an adjustable volume level with a max value of 80 dB .	Verify with design documentation that audible alarm has adjustable volume with maximum value of 80 dB	Pass if design documentation shows that the volume is adjustable and limit to 80 dB max.
[R25-1]	The display module shall refresh the range data 3 to 4 times per second.	For 10 seconds, count the number of times the data is refreshed. Calculate a per second rate from the measured value.	Pass if data is refreshed 3 to 4 times per second
[R26-1]	The display module shall have a power button to turn the system on/off.	Visual inspection	Pass if it can be spotted on the display module
[R27-1]	The display module will be mountable to the dashboard with double-sided tape.	Visual inspection	Pass if it can be spotted on the display module
[R28-2]	The display module should weigh less than 300g.	Weight the display module	Pass if the weigh recorder shows less than 300g
[R29-2]	The dimensions of the display module shall be no larger than 12 x 5 x 5 cm.	Measure the dimensions of the display module with a caliper.	Pass if the dimension matches with our requirements

Requirement #	Requirement Description	Test Method	Pass/Fail Criteria
[R30-4]	The display module can be powered by the 12V DC cigarette lighter socket in the automobile.	Power the display module using power from the cigarette lighter socket	Pass if display module operates normally
[R31-1]	The display module will use a 9V battery for power.	Power the display module using batteries	Pass if display module operates normally

Sensor Module (PN: 001-0003-00)

Requirement #	Requirement Description	Test Method	Pass/Fail Criteria
[R32-1]	The system must reliably collect proximity range data.	Test system on and start collecting distance data for 5 minutes.	Pass if system can display distance data continuously for 5 minutes.
[R33-1]	The sensor module shall provide good coverage for the front bumper if it is mounted on the front bumper and for the rear bumper if it is mounted on the rear bumper.	Using a test object, verify that the sensor can detect the object if it is located anywhere behind the bumper. To simulate the worst case scenario, we will use a cylindrical pole with a 3 cm radius as the test object.	Pass if object can be detected by sensor
[R34-1]	The system shall have a measurement error of no more than 10% or ±15 cm, whichever is greater.	Take measurements at 10 evenly disperse locations within the coverage areas using a ruler and the distance sensor.	Pass if all sensor measurements, when compared to the ruler measurement, have an error within the specified values.
[R35-1]	The sensor module shall have a maximum detection range of at least 200 cm.	Place cylinder object with diameter of ~3inch at 200cm away from the sensor module	Sensor module should report no object is detected

Requirement #	Requirement Description	Test Method	Pass/Fail Criteria
[R36-1]	The sensor module shall have a minimum detection range of no greater than 50 cm	Place cylinder object with diameter of ~3inch at 40cm away from the sensor module	Sensor should report 50 cm
[R37-1]	The sensor module shall use Bluetooth communication to send data to the display module	Verify with design documentation that sensor module uses Bluetooth communication to send distance data	Pass if distance data is communicated via a Bluetooth link
[R38-1]	The sensor is capable of being powered off/on remotely by display module	1. Turn on Display module and wait for ~5 seconds 2. Turn off display module and wait for approximately 60 seconds	1. Sensor module should power on correctly 2. Sensor module should power off correctly
[R39-1]	System shall use ultrasonic transducers for distance measurement	Visual inspection	Pass if sensor modules are using ultrasonic sensors for distance measurements
[R40-1]	The sensor module shall be mountable onto the car vehicles' license plate frame.	Mount sensor module onto car	Pass if sensor module can be mounted onto car
[R41-1]	The sensor module must allow the license plate to be mounted on it.	Mount license plate onto sensor module	Pass if license plate can be mounted securely onto sensor module
[R42-2]	The dimensions of the sensor module shall not be larger than 35 x 20 x 3 cm.	Measure the sensor module	Pass if sensor module is not larger than specified physical limits
[R43-1]	The sensor module shall be powered by a 6V DC lithium or NiMH battery pack.	Power the sensor module using 4 AA NiMH batteries. Test that sensor module is operating as specified	Pass if sensor module functions normally with 4 AA NiMH battery pack

Requirement #	Requirement Description	Test Method	Pass/Fail Criteria
[R44-2]	The system shall be resistance to out-door environments such as rain, hail, snow, and wind.	Operate the sensor module within weather conditions of rain, hail, snow and wind.	Pass if sensor module remains operational
[R45-2]	The system shall be water proof and moisture proof.	Submerge sensor module under water.	Pass if sensor module remains operational

Ultrasonic Transducer (PN: 001-0004-00)

Requirement #	Requirement Description	Test Method	Pass/Fail Criteria
[R46-1]	Ultrasonic transducer must produce a beam angle of at least 30 degrees.	Place cylinder object with diameter of ~3inch at 30 degree from the center line of the sensor	Sensor should report the correct distance of the cylinder
[R47-1]	Ultrasonic transducer must able to detect an echo within at least 75 cm regardless of the detecting objects' orientation.	Place cylinder object with diameter of ~3inch at 75cm away from the sensor	Sensor should report the correct distance of the cylinder
[R48-1]	Ultrasonic transducer must be capable of reading range at least four times per second.	Add software code that will measure the #sample collected / minute	Software should report a number that is greater than 4samples/minute
[R49-1]	Size of the ultrasonic transducer must be no greater than 2 x 2 x 2 cm.	Measure the physical dimension of the sensor	Dimension of the sensor fall within the requirement

Remote Switching (PN: 001-0005-00)

Requirement #	Requirement Description	Test Method	Pass/Fail Criteria
[R50-1]	The remote switching circuit must allow the display module to power on/off both sensor modules (front and back) remotely.	After turning on from the display module, check the status of sensor modules (front and back)	Sensor modules should be turned on
[R51-1]	The remote switching must operate as intended in a noisy environment. A noisy environment is defined as one where other RF signals are present. This represents the worst case scenario.	Turn on display module in a crowded parking lot	Pass if sensor module is powered on shortly after display module turns on
[R52-1]	The signal transmit and receive range must be at least 10 meters long.	Move sensor module at least 10 meters from the display module. Turn on the display module	Pass if sensor module is powered on shortly after display module turns on
[R53-1]	The wireless communication shall use the 433.92 MHz radio frequency with amplitude shift keying (ASK) modulation	Verify with design documents	Pass if design documents indicate that the 433.92 MHz frequency is used
[R54-1]	The transmitting portion of the remote switching circuit must be fitted into a printed circuit board in the display module	Visual Inspection	Pass if transmitter network is on a custom PCB
[R55-1]	The receiving portion of the remote switching circuit must be fitted into a printed circuit board in the sensor modules	Visual Inspection	Pass if the receiver network is on a custom PCB

Bluetooth Communication Protocol (PN: 001-0006-00)

Requirement #	Requirement Description	Test Method	Pass/Fail Criteria
[R56-1]	Bluetooth effective range must be at least 3 meters long.	Move sensor module and Display module 3 metres away from each other. Verify that Bluetooth link is still connected.	Pass if Bluetooth links are still connected.
[R57-1]	Bitrate of the Bluetooth communication must be at least 10Kbps or higher.	Verify with software that the Bluetooth serial port is configured to a baud rate above 10 kbps	Pass if Bluetooth serial port has baud rate faster than 10 kbps
[R58-1]	Pairing must be automatically done between the display and sensor module on power-up of both module.	Power on device and check that Bluetooth links successfully form automatically on start up	Pass if Bluetooth links are formed on start up
[R59-1]	The Bluetooth communication should not “accidentally” pair up with any foreign device.	Verify that design does not allow this to happen	Pass if system design does not allow this to happen
[R60-1]	Bluetooth Module should not interfere with any surrounding Bluetooth devices.	Verify that Bluetooth technology does not allow this to happen	Pass if there is documentation which confirms that interference is not an issue
[R61-1]	The Bluetooth communication link will be automatically reconnected if linked is broken	Simulate a disconnection by manually powering off the sensor module for 1 sec. Power sensor module back on and verify that Bluetooth link is re-established after a short period of time.	Pass if Bluetooth link is re-established.
[R62-1]	The Bluetooth circuit must be fitted in a printed circuit board.	Visual Inspection	Pass if Bluetooth circuit is on a PCB

Requirement #	Requirement Description	Test Method	Pass/Fail Criteria
[R63-1]	The Bluetooth master device shall be placed in the display module	Visual Inspection	Pass if Bluetooth master is in display module
[R64-1]	The Bluetooth slave device shall be placed in the sensor module	Visual Inspection	Pass if Bluetooth slave module is in sensor module
[R65-1]	The display module shall use one master and slave pairing for communication with the front sensor module and another master slave Bluetooth pairing for the rear sensor module.	Visual Inspection	Pass if display module uses one master slave pair to connect with the front sensor module and another master slave pair to connect with the rear sensor module

5 Conclusion

This design specification was written to highlight and give specific details for the design and making of the Unipark-1000. The design specification will serve as a guideline when implementing all functional requirements. The test plan provides a means for us to verify that the design specifications are sufficient to satisfy the functional requirements. We expect to complete a working proof-of-concept by the November 29, 2013.

6 References

CSA Group. (2013). *Codes & Standards*. Retrieved from CSA Group: http://www.csagroup.org/ca/en/services/codes-and-standards

ELECTRONIC CODE OF FEDERAL REGULATIONS: Part 15 - Radio Frequency Devices. (2013). Retrieved October 16, 2013, from http://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&sid=ed2208a3c3d672c5dec1d9f15c988467&rgn=div5&view=text&node=47:1.0.1.1.16&idno=47

Fairchild Semiconductors. (2013). Retrieved from Fairchild Semiconductors: http://www.fairchildsemi.com/an/AN/AN-118.pdf

ISO. (2013). Retrieved 10 17, 2013, from International Orginazation for Standardization: http://www.iso.org/iso/home.html

Nemko. (2010). *FCC Part 15*. Retrieved from Comunication Certification Laboratory: http://www.cclab.com/fcc-part-15.htm

Newelectronics. (2010, May 12). *An introduction to ultrasonic sensors for vehicle parking.* Retrieved from Newelectronics: http://www.newelectronics.co.uk/electronics-technology/an-introduction-to-ultrasonic-sensors-for-vehicle-parking/24966/

Parkingsensors.net. (2013). Retrieved from Parkingsensors.net: http://parkingsensors.net/

Wikipedia. (2013, September 25). *Parking Sensors*. Retrieved from Wikipedia: http://en.wikipedia.org/wiki/Parking_sensors