Wireless Vehicle Collision Avoidance System

Team Design Report

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May 14, 2007

1. EXECUTIVE SUMMARY

This report is divided into several sections. A short synopsis of each section is shown below:

Introduction

Professor Steven Bibyk of The Ohio State University, or OSU, presented the task of implementing a wireless sensor network to solve back-over problems in the automotive industry. The project would be completed by a cooperative effort with a group of Electrical and Computer Engineering students. The network will use an ultrasound system mounted at the rear the vehicle to detect objects. The data collected will then be transmitted wirelessly to a Graphical User Interface (GUI) mounted in the front of the vehicle to alert the driver. Our scope of the project entails the reception of the wireless signal to be displayed to the GUI and the overall design of the GUI mount.

Background Research

The goal of this project is to design a system that will help alert drivers of objects behind their cars so they can avoid back-over accidents. This system will especially aid drivers of large vehicles that have large blind spots. Current solutions in the market today are expensive and often difficult to install. Not only that, current solutions which use infrared, laser, or microwave technology all have limitations. Another solution we discovered, the *Backstopper CA-5004 Reverse Parking Sensor*, uses ultrasound technology. This system suits our needs but is hard to install, requiring a 50 foot cable to connect the control system at the rear of the car to the GUI.

Design Approach

To implement this system we used parts from Texas Instrument and various Digikey parts. Rather than use an existing ultrasound sensor circuit as originally planned, we decided to build our own ultrasound sensor circuit based upon the Cricket design. For the wireless connection, two microcontrollers (TI MSP430) will be used. One will be used as the interface to the display and the buzzer and another one will be used to process the signal from the ultrasound circuit. Two transceivers will be needed to transmit and receive data and each will be connected to the microcontrollers. As for the power supply to the microcontrollers on the user interface side, a solar panel will be used to output power and a step up transformer chip will increase the voltage to meet the specifications and requirements. We will also use the 12V power supplied by the brake lights on the car to supply power to the ultrasound sensor circuit.

Report of Work

Work performed for this project include obtaining parts for design, interfacing of LEDs and buzzers to the microcontroller, soldering of components, and further refinement of design. We also researched more on using IAR to program the microcontrollers.

Resources

In addition to team members, resources included the ECE computer labs, Professor Steven Bibyk, an IDE interface to work with the MSP430 microcontroller, and the expertise of other faculty members. These resources will also be available to members of the team moving on with this project.

Schedule

The time allotted for the manufacturing of the prototype was ten weeks. The first couple of weeks were spent on purchasing and obtaining supplies. The remainder of the time was spent implementing the interface, soldering components, and also preparing for presentations and reports.

2. TABLE OF CONTENTS:

List of Figures and Tables

3. INTRODUCTION

3.1 Purpose

The purpose of this report is to outline our design process of a wireless sonar detection system with applications of the automotive industry such as alerting drivers to the presence of children in blind-spots while backing. The report will focus on the design process as well as the progress made implementing the design.

3.2 Problem Statement

In accordance with the requirements presented by Dr. Bibyk of the Electrical and Computer Engineering Department of The Ohio State University, our team proposes a wireless network solution to the back-over problem in the automotive industry. The proposed network will use position and velocity data collected from an ultrasound system mounted on the rear bumper of the vehicle to determine if objects are present in the backing vehicle's path. This ultrasound system will be connected to a mote that has the capability to transmit, receive, and process the sensor data. This data will be transmitted wirelessly to a user-interface in the front of the vehicle that will alert the driver of these objects.

3.3 Scope

Our team's scope for this project was to design a working system, which receives data from the ultrasound sensors, provided by another team, and displays it in a friendly manner in via a GUI. A TI MSP430 and a TRF6901 were used to transmit data wirelessly from the sensor network to 7 segment displays.

4. BACKGROUND

As the size of today's largest vehicles increases, so do their blind spots. Two children are killed each week in back-over accidents that might have been prevented if drivers had been aware of the presence of children [http://msnbc.msn.com/id/13281953/1]. Currently aftermarket and OEM (original equipment manufacturer) systems can be integrated into vehicles to help prevent these types of accidents. The problem with these solutions is that the OEM systems are expensive and the aftermarket systems are difficult to install. There are several different technologies employed in the design of these systems, each with shortcomings. One of these designs uses a camera attached to the bumper of the car and a display screen placed in the front. This gives the driver live video of exactly what is behind them in their blind spot [2]. The problem with this system, however, is that it requires active participation from the driver and, consequently, the driver might be careless and not pay attention to the display screen. Also, a child still might not be visible to the driver even with the camera system.

Other systems use sensors at the rear of the vehicle to detect objects. Currently, systems can be purchased that use Infrared, Laser, or microwave technology. Depending upon how these sensors are integrated with a driver alert system, they could be more effective than a backup camera. Unfortunately, these systems also have limitations. Infrared technology can become temporarily 'blinded' by bright sunlight and can fail to differentiate heavy clothing from landscape during low temperature situations. Also, infrared systems have only average distance accuracy. Laser technology is heavily dependent upon the light reflectivity of the object it is designed to detect and also suffers from only average distance accuracy. Microwave technology functions only when either the obstacle or vehicle is moving and will have no effect if both vehicle and obstacles are stationary. The microwave system has the poorest accuracy of all the backup alerter technologies, usually +/- 2 feet [4]. Our team will design and implement a cost-effective wireless ultrasound sensor system that will detect an object up to 20 feet away and wirelessly transmit that distance to a display at the front of the vehicle.

5. DESIGN APPROACH

5.1 Engineering Analysis

For the wireless connection, two microcontrollers (TI MSP430) will be used. One will be used and programmed as the interface to the display and the buzzer and another one will be used to process the signal from the sonar. Two transceivers (TRF6901) will be needed to transmit and receive data and each will be connected to the microcontrollers. As for the power supply to the microcontrollers, display and buzzer, solar panels will be used to output power and a step up transformer chip will increase the voltage to meet the specifications and requirements.

The wireless device should reliably transmit data about 5 to 10 feet in the noisy environment of the car. The microcontrollers are predicted to process data for years without any problem. Our team will have to do extensive testing to make sure that the wireless components consistently work in a variety of cars. Also the display unit will be designed in such a way that it is easy for the driver to quickly read. This allows the driver to focus their concentration on driving rather than on reading the display. It is important that these requirements are met so the collision avoidance system can work effectively. If any component were to not work consistently, there would be a significant danger of the driver backing into something.

5.2 Design Details

Our team has completed a thorough analysis and review of each major component of their proposed design. The components selected meet the desired requirements and specifications that the team has outlined for the system. This section details the individual components of the system and how they will be utilized to achieve the team's overall design goals.

5.2.1 Wireless System

To set up a wireless connection we need two TI MSP430 microcontrollers and two TRF6901 transceivers. One microcontroller will be programmed to receive data from the ultrasound sensors circuit from section 5.2.1 and process that data into an understandable format to be wirelessly transmitted with the TRF6901. Another MSP430 microcontroller will be used in conjunction with the TRF6901 to receive that data to be displayed on the user interface. The TI MSP430 microcontroller itself is plugged in directly to the TRF6901 so no necessary wiring will be needed (shown in figure 1). The TRF6901 can establish a single frequency PC-to-PC 32 Kbaud bidirectional RF datalink within the US 902-928 MHz ISM band. The MSP430 microcontroller will come preprogrammed with baseband communication routines. The PC serial port will be used as a connection between the PC and the microcontroller

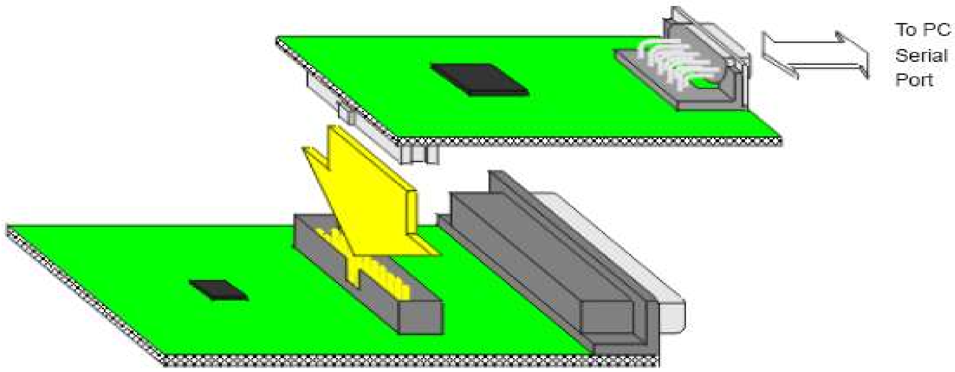

Figure 1. Direct connection between TI MSP 430(above) and TRF 6901(below)

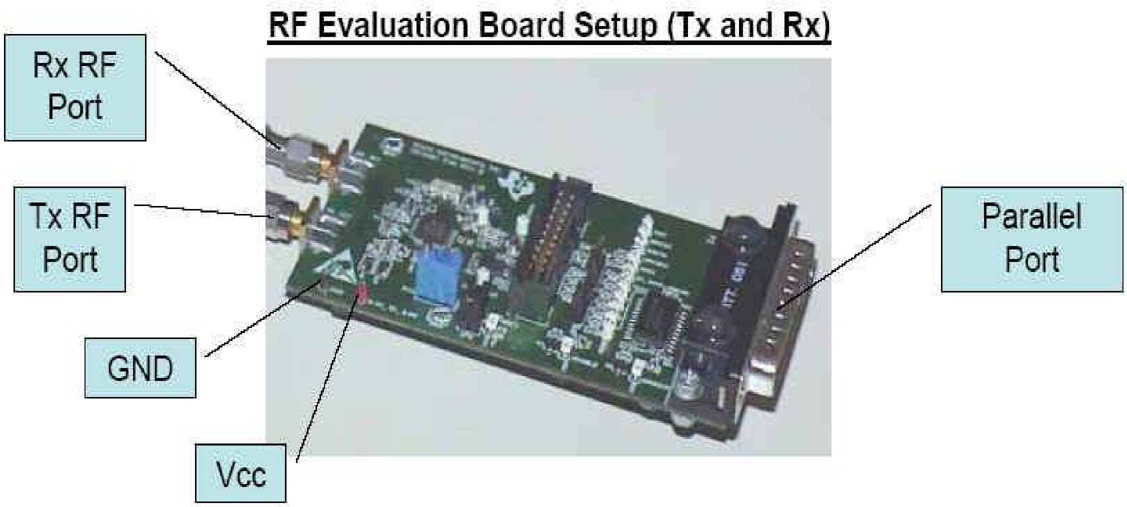

Figure 2. Actual TRF6901 Transceiver

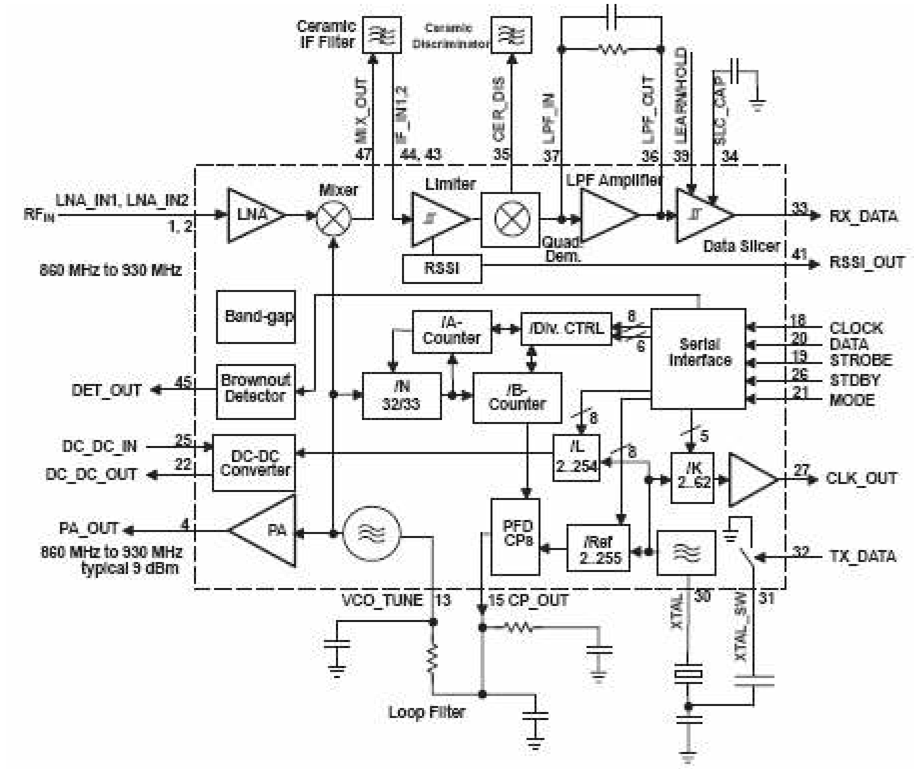

Figure 3. TRF6901 Block Diagram

5.2.2 User Interface

Two LTS-4801B 7-segment displays will be used to show the range of the object detection and those will be interfaced with Port 4 and Port 6 of the microcontroller in the receiving part. The conversion and calculation will be programmed into the microcontroller before outputting to the display. The Piezo Buzzer is interfaced by connecting one of the pins to the first port of Port 1 and another pin to the ground. As the range of the object detection gets smaller then the buzzer will beep faster.

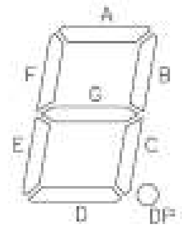

Figure 4. Piezo Buzzer(left) and 7-segment display(right)

The CEM-1601 Piezo Buzzer has an operating voltage of 1-3V with mean current of 20 mA and sound output of 88 dB (typically), while the LTS-4801B 7 segment display has a 3.8V (typical) operating voltage with power dissipation of 115 mW. Figure 5 shows a schematic of the user interface and table 1 describes the proper connections required to interface the 7 segment displays.

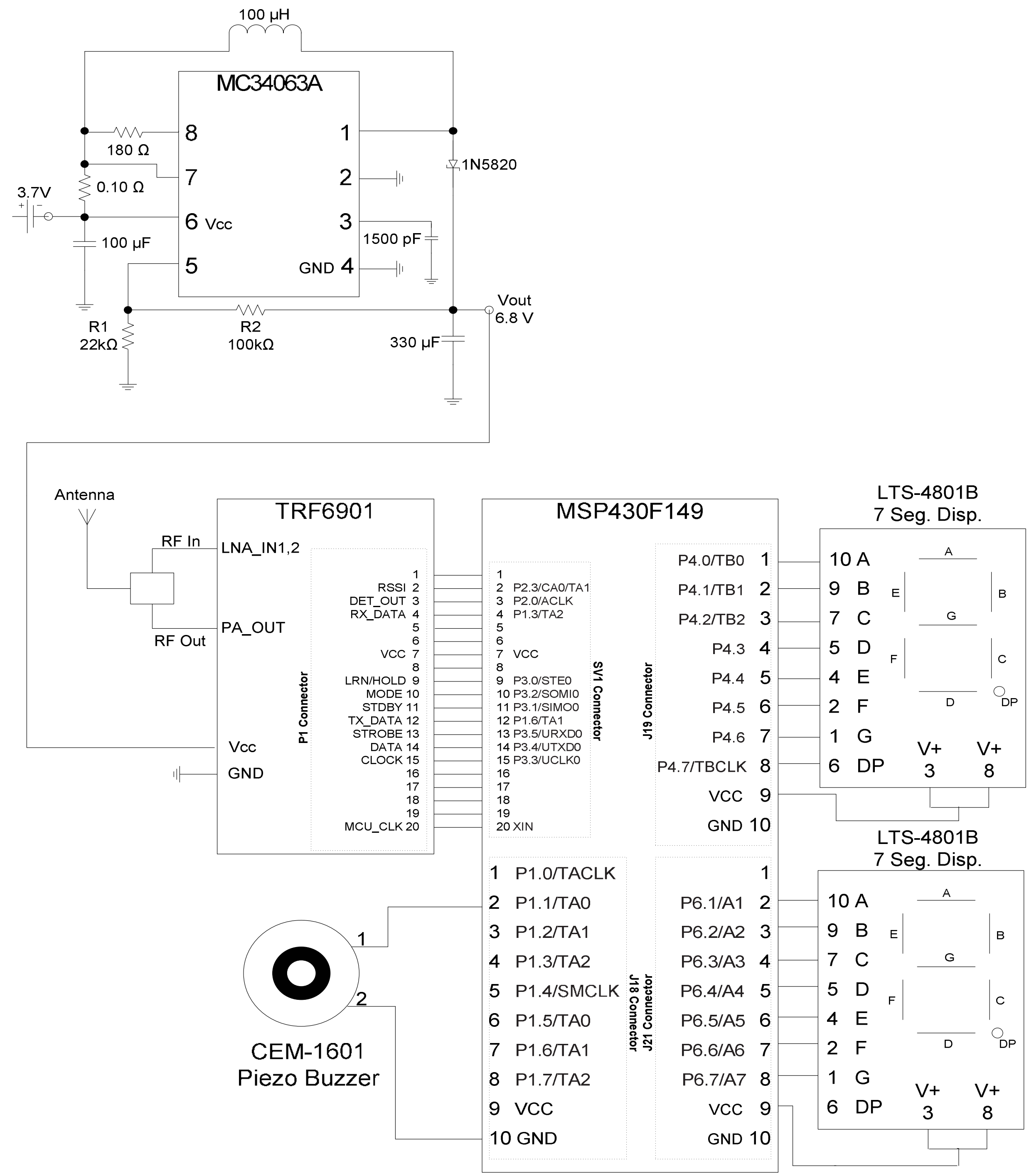

Figure 5. User Interface Schematic

TI MSP 430 J19 connector		7 segment display	
Ports	Pins	Ports	Pins
P4.0	1	A	10
P4.1	2	B	9
P4.2	3	C	7
P4.3	4	D	5
P4.4	5	E	4
P4.5	6	F	2
P4.6	8	G	1
P4.7	9	DP	6
Vcc	10	V+	3,8
GND	11		

TI MSP 430 J21 connector		7 segment display	
Ports	Pins	Ports	Pins
P6.0	1		
P6.1	2	A	10
P6.2	3	B	9
P6.3	4	C	7
P6.4	5	D	5
P6.5	6	E	4
P6.6	8	F	2
P6.7	9	G	1
Vcc	10	V+	3,8
GND	11		

Table 1. MSP430 Port Connections

5.2.3 Programming

IAR Embedded Workbench was used to program the MSP 430. IAR Embedded Workbench for MSP430 is an integrated development environment for building and debugging embedded applications. An interface common to the assembler, C/C++ compiler, project manager, editor , build and debugger tool ensures ease of use.

5.2.4 Power Supply

The receive chain portion of the back-up system would not be hardwired into the system. This was done so that the display could easily be placed anywhere and there would be no wires to interfere with anything else in the vehicle. This would also be done to maintain consistency as a fully-wireless system and to maintain all of the advantages that a wireless system had the ability to provide.

To create this type of system, a solar panel would be used to charge a rechargeable battery to power the entire front display. There were solar panels on the market used to recharge a car battery when it is not being used. The panel to be purchased was relatively cheap, so it would not add an exorbitant amount to the overall cost of the system, even were it to be put into a mass production. This specific charger from smarthome.com did not have detailed specifications available, but the current from it was reasonable for this application.

This solar charger would then be hooked to a battery charger and then to the battery itself. To do this, the Texas Instruments BQ24100EVM would be used to charge a single-cell, 3.7 V, Li-Ion/Li-Polymer battery. This type of battery is commonly found in cell phones among other similar type devices. The particular battery purchased for this was specifically designed for use in a digital camera, but meets the ratings for this charger. The charge controller's settings were set at the factory to work for a 1.4A maximum charging rate and a 4.2 V cut-off. This matches exactly the specifications given for this battery.

From there, the 3.7-4.2 V coming from the battery needed to be stepped up to between 6 and 8 V for the MSP430 EVM. To do this, another Texas Instruments chip, the MC34063A, was used. This particular chip is versatile as it can be used to step-up, step-down, or invert. However, this was the only chip found from TI which met the specifications necessary and also came in the DIP format for easy use with the breadboard. This chip required several types of external components: resistors, inductors, capacitors, and a Schottky-Diode barrier. The acceptable ratings for these items were calculated from the MC34063A datasheet, were purchased, and put into testing. Upon receiving 3.7-4.2 V from the battery, the chip consistently output approximately 6.8 V. This was then hooked into the MSP430 EVM and was found to power the device without any problems.

5.3 Components Used

The following contains all of the components used in the design of our system.

5.3.1 Components List

TI eStore	DIGIKEY
MSP430F149 (Microcontroller)	160-1515-5-ND (7 seg. display)
TRF6901 (RF Transceiver)	102-1112-ND (Piezo buzzer)
BQ24100 EVM (Battery Charger)	PL-063465 (Lithium Ion cell)
MC34063A (Step up converter)	

5.3.2 TI Analog Chips

TI-MSP430F149 - Microcontroller configurations with two built-in 16-bit timers, a fast 12-bit A/D converter (not implemented on the MSP430F14x1 devices), one or two universal serial synchronous/asynchronous communication interfaces (USART), and 48 I/O pins. The MSP430 will be used to process the data from the wireless transmission and display and output the results in a 7-segment display and the piezo buzzer.

TI-TRF6901 - The TRF6901 single-chip solution is an integrated circuit intended for use as a low cost FSK or OOK transceiver to establish a frequency-programmable, half-duplex, bidirectional RF link. The TRF6901 will be used as transceivers (one for transmitting and one for receiving) for the wireless data transmission.

TI-BQ24100 EVM - The bqSWITCHER™ series are highly integrated Li-ion and Li-polymer switch-mode charge management devices targeted at a wide range of portable applications. The bqSWITCHER charges the battery in three phases: conditioning, constant current, and constant voltage. Charge is terminated based on user- selectable minimum current level. Accepts a wide input-voltage range from 3 V to 40 V (3.7-4.2 V for our system) and will output 1.25 * (1+ R2/R1) when the connections are made. The BQ24100 will be used to charge the Li-Ion battery so that the battery can run perpetually without getting depleted.

TI-MC34063 – The MC34063 are easy-to-use ICs containing all the primary circuitry needed for building simple dc-dc converters. These devices primarily consist of an internal temperature-compensated reference, a comparator, an oscillator, a PWM controller with active current limiting, a driver, and a high-current output switch. Thus, the devices require minimal external components to build converters in the boost, buck, and inverting topologies. The MC34063A will be used to step up voltage from the battery so that it can supply the necessary power for the microcontrollers and the transceivers.

Digikey Parts – 7 segment display and piezo buzzer used to implement the transmit/receive chains and the user interface.

PL-063465 - Prismatic Polymer Li-Ion Cell, 3.7V, 1400mAh. Used to deliver power to the entire system.

6. REPORT OF WORK

The quarter began by finalizing design, researching and ordering parts (from TI and Digikey). After we received all of the parts, we researched and figured out the necessary connections of each ports of the MSP430 with the 7-segment display, piezo buzzer and power supply. We also began to interface them on a breadboard. Research about the programming of the MSP430 with IAR and the solar panel for the power supply was also done extensively at this stage. A 14-pin JTAG ribbon cable was not included with our MSP430F149 module so we had to modify an existing ribbon cable to fit into the connectors of the microcontrollers.

7. RESOURCES

7.1 Personnel

Our team consists of two talented Electrical & Computer Engineering students in The Ohio State University's College of Engineering.

- **Hermann Lau** worked on the user wireless interface/display. Hermann is experienced in programming in C# and various assembly languages. He also has internship experience in programming and data analysis at JPMorgan Chase and General Electric.

- **Erwin Rosli** worked on the wireless interface/display for this project. Erwin is experienced in microprocessor assembly language programming. He is also very proficient in programming with C, C++ and C#.

7.2 Facilities and Equipment

The facilities used for this project will be located at The Ohio State University. The MISES Laboratory will be used for the physical design of our system, and the computer labs at Caldwell Laboratory and Dreese Laboratory will be used for programming.

8. SCHEDULE

8.1 Schedule

In order to successfully complete and implement the design, our team needed to develop a wireless transmitter/receiver system that reads in the control signals from the base unit, transmits the signals to a receiver, and recreates and feeds the signals to the GUI. Table 2 shows an approximate breakdown for the project during quarter.

	WEEK									
TASK	1	2	3	4	5	6	7	8	9	10
Finalize Proposal										
Purchase Supplies										
Receive Supplies										
Write/Test Wireless Interface										
Implement Wireless Testing/Changes										
Finalize Wireless Interface										
Integrate Transmitting and Receiving Devices										
Write Final Reports										
Write Final Presentation										

Table 2: Projected Timeline for Project Implementation

	WEEK									
TASK	1	2	3	4	5	6	7	8	9	10
Finalize Proposal										
Purchase Supplies										
Receive Supplies										
Build										
Researched Programming										
Implement User Interface Circuit										
Program the wireless connection										
Write Final Reports										

Table 3: Actual Timeline for Project Implementation

9. DESIGN REVIEW

After our status review/presentation, we took some of the advice from our professors and were able to get closer to completing to the report. We were able to get much done on the wireless communication network from feedback we received and were able to complete a final connection schematic of the wireless system. However, we were constricted by our heavy course load and lack of time. Also, we spent a lot of time waiting for parts to come in after we ordered them.

APPENDIX A: REFERENCES

1. http://msnbc.msn.com/id/13281953/
2. http://www.boston.com/news/local/articles/2005/02/28/standard_system_sought_for_vehicle_backup_safety/?page=1
3. http://www.cs.brown.edu/people/tld/courses/cs148/02/sonar.html
4. http://www.bak-talk.com/technology.htm
5. http://www.crimestopper.com/backstopper.htm
6. http://www.moteiv.com/products-tmotesky.php
7. http://www.solio.com/v2/explore-solio/what-is-solio.html
8. http://www.tinyos.net/
9. http://en.wikipedia.org/wiki/TinyOS
10. http://www.smarthome.com/9279.html