Ohio State University

Affordable Vehicle Collision Avoidance System

TI Design Contest

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2007

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Executive Summary

The project team was assembled to address the problem of personal injury as a result of poor visibility while backing vehicles. To this end we designed a low-cost aftermarket solution that would be compatible with a wide variety of vehicles and also reliable.

The design called for an ultrasound transmitter and receiver that used a TI microcontroller to handle timing and generate output alerts to the driver that an obstacle was in the backing path of the vehicle. Due to inexperience in designing sonar systems we attempted to modify a similar system to accommodate TI components.

Most of the difficulties associated with this project involved long turnaround time while ordering parts, small part packages that required a considerable amount of skill and effort to integrate with our breadboard design system. Perhaps the greatest difficulty was finding time to work on the project as much as we wanted given that all of the members had heavy course loads.

Purpose

This document outlines the process we used to design an Affordable Vehicle Collision Avoidance System. The completed design will have applications in industry anywhere the inexpensive ability for drivers to detect the presence of obstacles in blind spots is required. The report recounts progress toward the final design achieved in ECE 582 and ECE 682 under Dr. Bibyk and with the assistance of Brian Dupaix.

Engineering Analysis

In Autumn quarter of 2006, our design team (named “Green Fang”) formed in ECE 582. The objective of this class was to identify a problem that we could work to solve as part of the TI design contest. This initial phase primarily involved identifying a shared concern among team members and assessing the feasibility of the project.

The team was interested in researching detection devices for use in the consumer market space though ultimately we identified promising uses for the technology in industry. Our team also felt that it was important for our project to have some kind of social value. With that in mind we set out to find an area where detection technology could be used to reduce instances of personal injury and death. With these factors in mind, we decided to approach the problem of accidents involving a vehicle with poor visibility backing into or over a child.

To achieve this, we planned to design an ultrasound system that could be mounted on the rear of the vehicle to alert the driver to obstacles. In addition to this primary project goal, our device would output a signal that could be used to relay sensor information to other parts of the vehicle.

Scope

Green Fang's Scope for 682 was to design a working ultrasound detection system with an additional component that enabled the transmission of sensor data to a vehicle operator to assist in collision avoidance. Due to a lack of experience in developing ultrasonic sensors, we opted to use the MIT Cricket design as a guide while substituting several components with TI parts.

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 [**Error! Reference source not found.Error! Reference source not found.**]. 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. Several different technologies are employed in the design of these systems, each with shortcomings. One common design uses a camera attached to the bumper of the car and a display screen placed within the drivers field of view. This gives the driver live video of exactly what is behind them in their blind spot [**Error! Reference source not found.**]. A problem with this system is that it requires active participation from the driver and, consequently, the driver might carelessly ignore the display screen. Additionally, a child may not be visible to the driver even with the camera system.

Other systems use sensors at the rear of the vehicle to detect objects. Available systems 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 is the least accurate technology, usually +/- 2 feet [4]. Green Fang will design and implement a cost-effective wireless ultrasound sensor system that will detect an object up to 20 feet away and provide a signal that could be used to wirelessly transmit the data to a driver alerter in the front of the vehicle.

Design Approach

System Design

During ECE 682, Green Fang changed its design plan from the initial design researched in ECE 582. Rather than use an existing ultrasound sensor circuit, we decided to build our own ultrasound sensor circuit based upon the MIT Cricket design. The Cricket design works by first triggering the ultrasound sensor with a pulse. The sensor would then send out an ultrasound pulse which would bounce off of an object bounce back to the receive sensor. The device would time how long it took the pulse to make it's round trip. Once the pulse came back, the distance of the object would be calculated by multiplying the speed of sound by the time it took to receive the reflected pulse. The resulting product would be divided by two because the ultrasound pulse had to travel to the object and back. Finally the circuit would output a pulse with a width corresponding to distance of the object. The process would be periodically repeated by continuously triggering the sensor with electric impulses.

Green Fang's collision avoidance system must be able to meet some basic performance requirements. The ultrasound sensors must be always able to detect any large object without fail. This includes objects less than 10 feet behind the car and objects very low to the ground. It is important that these requirements are met so Green Fangs collision avoidance system can work effectively. Component reliability is important to reduce the likelihood of the driver backing into something due to a false sense of security.

Design Details

Green Fang 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.

Ultrasound Sensor Circuit

For our design, we chose to use only part of the cricket design. Our design consisted of the transmit and receive chain of the cricket design integrated with some TI parts substituted into the circuit. As their names imply, the receive chain is used for detecting the incoming ultrasound pulse, and the transmit chain is used to transmit an ultrasound pulse. Also, instead of using much of Cricket's complex circuit design, our design uses a TI MSP430 microcontroller to calculate the distance of the object. Our design plan also required us to get power from the brake lights which used 12 V. To accomplish this, we used a MSP156 DC/DC converter to convert the 12V supply to 5V. Figure 1 shows the schematic of the overall ultrasound sensor system while figure 2 and 3 shows a detailed schematic of the transmit and receive chains.

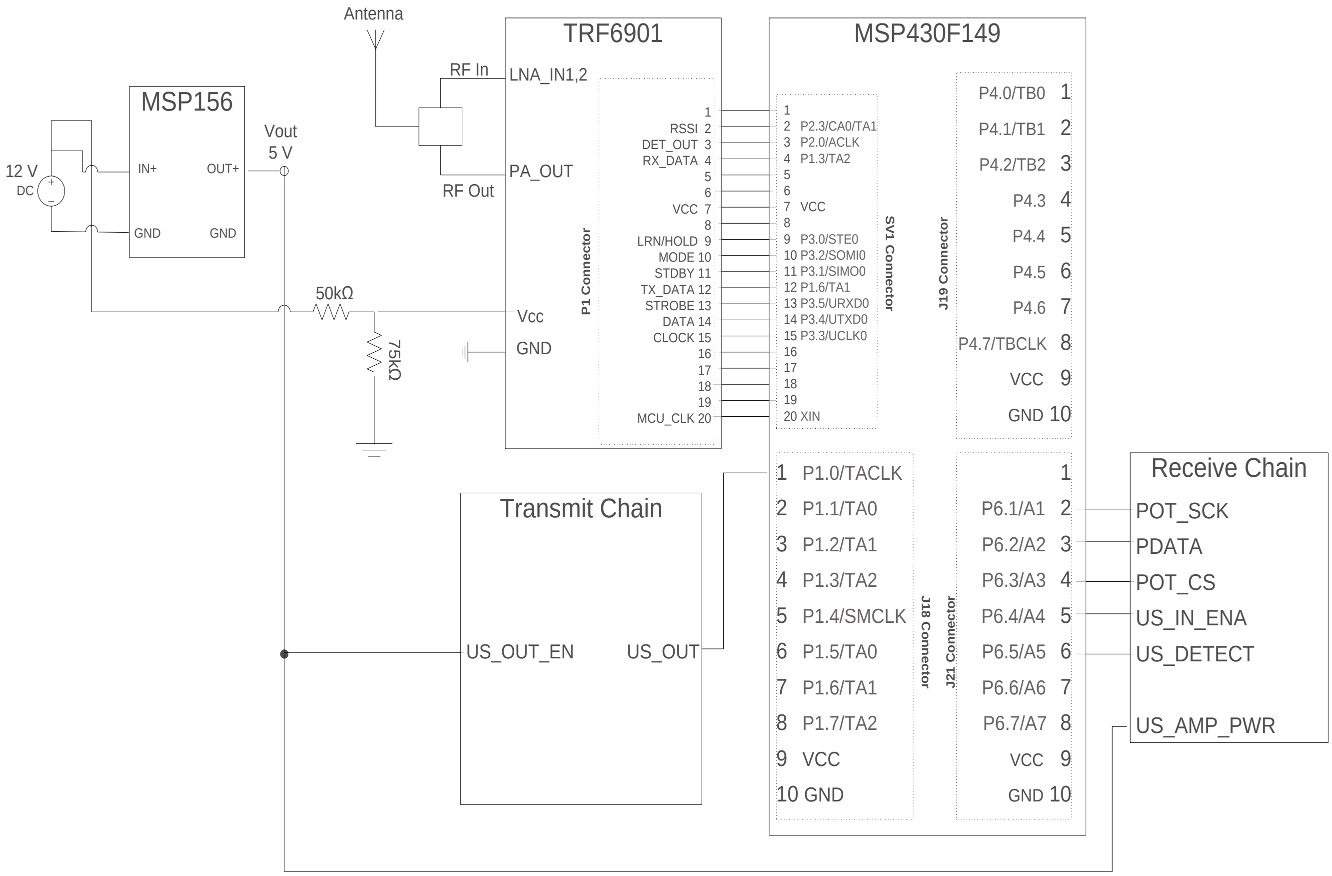
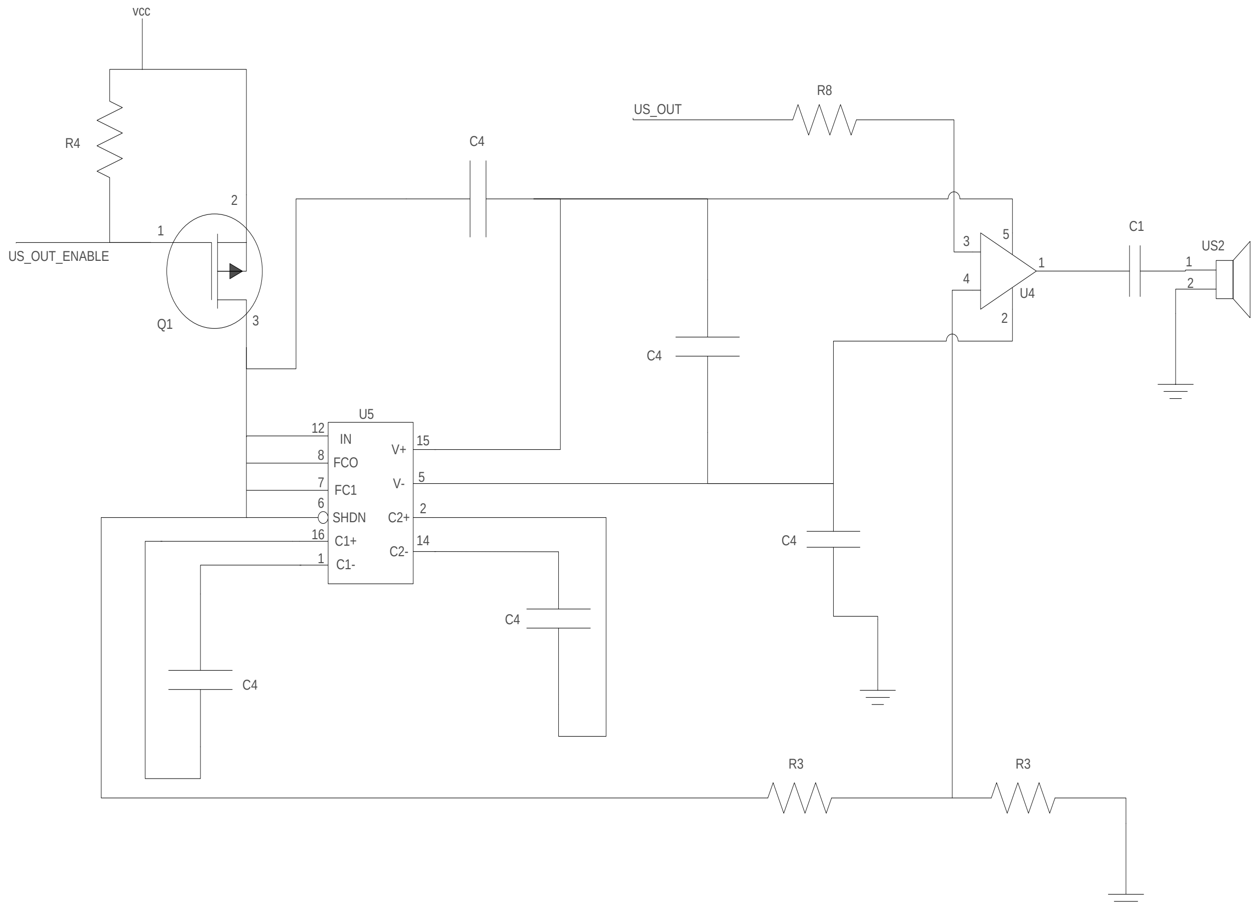
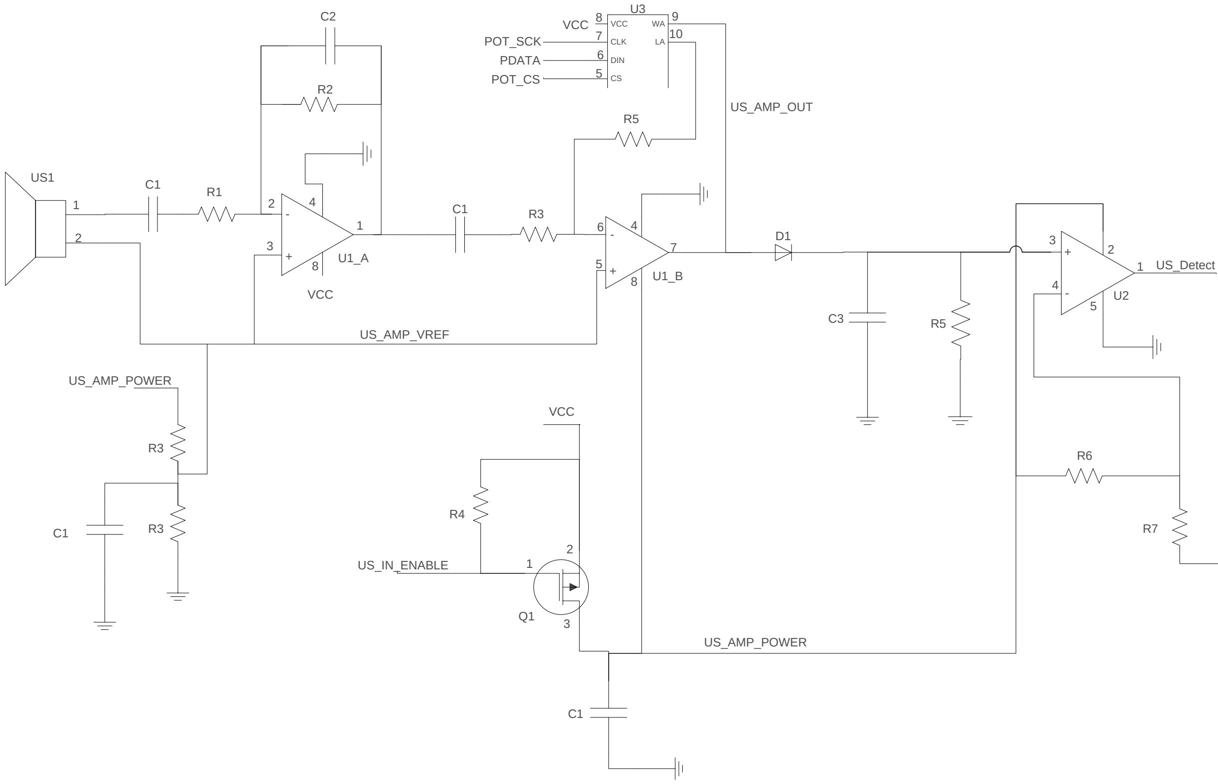


Figure 1: Ultrasound Sensor Circuit



Component	Quantity	Value	Description	Manufacturer	MFG P/N
C1	1	0.1 uF	Capacitor	Panasonic	ECQ-E1104KZ
C4	5	1 uF	Capacitor	Panasonic	ECQ-E1105KZ
R3	2	10 K	Resistor	Panasonic	ERG-1SJ103
R4	1	100 K	Resistor	Panasonic	ERG-2SJ104
R8	1	2.21 K	Resistor	Yageo Corp.	MFR-25FBF-2K21
US2	1		Transducer		
U4	1		Op-Amp	National Semiconductor	LM8261M5/NOPB
U5	1		Charge-Pump	Maxim	MAX864EEE
Q1	1		MOSFET P-CH	Zetex Inc.	ZXM61P03FTA

Figure 2: Transmit Chain



Component	***Quantity***	***Value***	***Description***	***Manufacturer***	***MFG P/N***
C1	4	0.1 uF	Capacitor	Panasonic	ECQ-E1104KZ
C2	1	0 uF	Capacitor	N/A	N/A
C3	1	1000 pF	Capacitor	Panasonic	ECQ-P1H102GZ
R1	1	4.22 K	Resistor	BC Components	5063JD4K220F12AF5BC
R2	1	1.8 M	Resistor	Panasonic	ERD-S1TJ185V
R3	3	10 K	Resistor	Panasonic	ERG-1SJ103
R4	1	100 K	Resistor	Panasonic	ERG-2SJ104
R5	2	82.5 K	Resistor	BC Components	5063JD82K50F12AF5BC
R6	1	110 K	Resistor	Yageo Corp.	CFR-50JB-110K
R7	1	120 K	Resistor	Yageo Corp.	CFR-50JB-120K
US1	1		Transducer		
U1_A	1		Dual Op-Amp	Texas Instruments	LMV822DGKR
U1_B	1		Dual Op-Amp	Texas Instruments	LMV822DGKR
U2	1		Comparator	National Semiconductor	LMC7215IM5
U3	1		Potentiometer	Maxim	MAX5405EUB
Q1	1		MOSFET P-CH	Zetex Inc.	ZXM61P03FTA
D1	1		Diode Schottky	Diodes Inc.	SDM10K45-7-F

Figure 3: Receive Chain

Programming

IAR Embedded Workbench will ultimately be 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.

Power Supply

The device was designed to be powered by 12 V delivered by the automotive electrical system via the backing light circuit. To power our device, this supply voltage needed to be stepped down to between 6 and 8 V for the MSP430 EVM. To do this, another Texas Instruments chip, the MSP156, was used. The acceptable ratings for these items were calculated from the MC34063A datasheet, were purchased, and put into testing. The chip output was exactly 5 V. This was then hooked into the MSP430 EVM and was found to power the device without any problems.

Components List

TI eStore	DIGIKEY	Maxim/Dallas
MSP156 (DC/DC-CONV)	296-17406-1-MD	MAX5403 (digital potentiometer)
EZ430-F2013	E1104-ND (capacitor) (0.1µF)	MAX864 (DC/DC)
EZ430-T2012	E1105-ND (capacitor) (1.0µF)	
	P3102-ND (capacitor 1000pF)	
	BC4.22KXCT-ND (4.22Kohm)	
	P10KW-1BK-ND (10Kohm)	
	BC82.5KXCT-ND (82.5Kohm)	
	110KH-ND (110Kohm)	
	P1.8MBBCT-ND (1.8Mohm)	
	120KH-ND (120Kohm)	
	P100KW-2BK-ND (100K ohm)	
	2.21KXBK-ND (2.21K ohm)	
	LMC7215IM5CT-ND (LMC7215 comparator)	
	SDM10K45-FDICT-ND (diode)	
	LM8261M5CT-ND (Op-amp)	
	ZXM61P03FCT-ND (transistor)	
	AD5273BRJ50-R2CT-ND (digital potentiometer)	

Table 1: Components List

TI Component Utilization

How each component was used and how each component benefitted the project design.

MSP156

The DC/DC-CONV is a DC/DC buck converter which provides a 5 V or 3.3 V output at up to 2.5 A with an input voltage range of 5.5 V to 12 V. This enabled us to use the cars 12 V electrical system via the backing lights to power the sensor. By powering the device from the backing circuit we could ensure that the device was disabled when the vehicle was not in reverse, eliminating the possibility for false alarms while parked or moving forward.

EZ430-F2013

The eZ430-F2013 is a complete MSP430 development tool including all the hardware and software to evaluate the MSP430F2013 and develop a complete project in a convenient USB stick form factor. The eZ430-F2013 uses the IAR Embedded Workbench Integrated Development Environment (IDE) to provide full emulation. This component was selected to enable more flexible development than a hardware only design. It also allows for the possibility of future upgrades to the echolocation software.

EZ430-T2012

The eZ430-T2012 includes three MSP430F2012-based target boards for the EZ430-F2013. These allowed for multiple hardware breadboards to be connected to the same MSP430 and also allowed for a standardized interface between the two microcontrollers used in development.

MAX5403

The MAX5403/MAX5404/MAX5405 is a family of dual linear taper digital potentiometers. Each device has one 3-terminal potentiometer and one 2-terminal variable resistor (Figure 1). The MAX5403/MAX5404/MAX5405 operate from +2.7V to +5.5V single-supply voltages and use an ultra-low supply current of 0.1µA. These allowed us greater flexibility in the development of the hardware portion of the design by allowing for small adjustments to the resistance of various components of the circuit.

Design Creativity

The quarter slated for construction and prototyping began by finalizing design, researching and ordering parts (from TI and Digikey). The group was then divided in to two sub-groups with one group working on the ultrasound portion of the system and the other group working on the user interface portion.

Once our parts arrived, we were able to assemble the receive chain in the short time we had. We had hoped to be able to all of the components with our breadboards. However, the op-amps, as well as many other parts, had to first be soldered onto a surface-mount board (shown in figure 4). This required some delicate soldering as we connected wires to the surface-mount board to assist in interfacing the component with our breadboard. A basic ultrasound sensor was attached by attaching wires to the existing ultrasound sensor circuit.

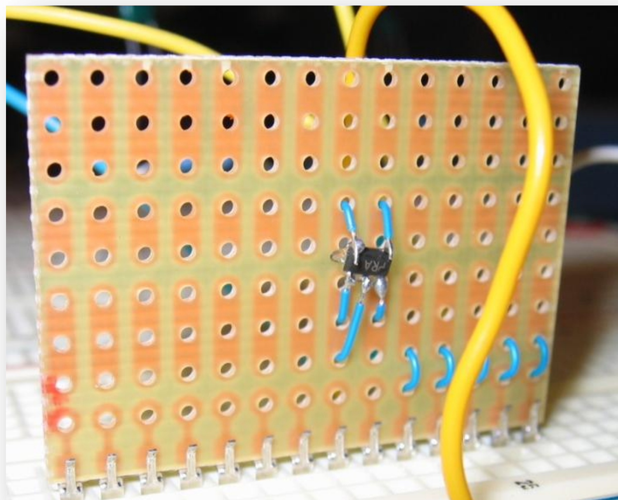


Figure 4: Soldering detail of surface-mount board

Resources

Personnel

Green Fang consists of six talented Electrical & Computer Engineering students in The Ohio State University's College of Engineering.

- **Brian Carroll** will be working on the ultrasound sensor aspect of the project. Brian has taken extensive coursework in Communications and Signal Processing. He has also taken various courses in Electromagnetics, control, Circuits, and Power.
- **Eric Eiben** will be working on the ultrasound sensor aspect of this project. Eric has completed coursework in Communication and Signal Processing and RF IC. He also has internship experience in control product development at Rolls-Royce.
- **Mark Noble** will handle all of the control code for this project. Mark is a professional programmer of 10 years with experience programming in Java, C++, and C#. He was also on the inaugural OSU Sunrayce Team assisting in the design and construction of a prototype vehicle.

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.

Schedule

In order to successfully complete and implement the design, Green Fang 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. **Error! Reference source not found.** shows an approximate breakdown for the project during the ECE 682 design 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

Table 3 depicts an updated timeline that illustrates time spent to date. Some of the tasks were slated for future development so that we could focus our efforts on completing the final reports. The teams relating to this project were unable to finish the core components of their respective projects so we were unable to establish a wireless interface between the two components as we had hoped.

	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										
Implement Sonar Sensors										
Write Final Reports										

Table 3: Actual Timeline for Project Implementationation

Summary

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 finish building the receive chain following advice to solder the parts onto a surface-mount board. We were constrained by our heavy course load and lack of time and spent a lot of time waiting for parts to come in after we ordered them.