ECE 445

Fall 2017

RC Car Alert and Detection System

Final Design Review Document

Team 26

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1 Introduction

1.1 Objective

The problem with R/C cars is that it is very difficult to understand where the car is within the relative range of the vehicle. While they may have a specification of a certain range, say 40m, the user is not cognizantly aware of how the range is affected by battery or interference by trees and buildings. Therefore, the user may lose control of the R/C car due to not knowing the range of the transmitter. This can be very frustrating to the user, as they must locate the R/C car and keep the R/C car within a perceived range.

Our project goal is to limit the frustration on the user, and develop a range detection and alert system that will allow the user to able to maximize the range while understanding the relative position of the car. This can be implemented by using Bluetooth and GPS to communicate between the controller and the R/C car and relay information back to the controller and display it on an OLED display. The OLED display will act as an alert system as it will display warnings when the R/C car is near the end of its range and will also indicate the relative direction the R/C car is from the user.

1.2 Background

As Professor Oelze pitched a similar project for implementation on an R/C boat, he expressed frustration for the range of his R/C boat. When the boat would lose signal or lose power, the R/C boat would need to be received from the lake. This step, which would require a boat or a strong swimmer, is frustrating to the user, but it is also preventable. Another problem for R/C vehicles is that it is very easy to lose sight of the car which can result in the user searching endlessly for it or result in the user losing the vehicle completely. Both of these situations can be highly frustrating.

Due to the limitations of access to water, we aim to solve Professor Oelze's frustration while implementing it on an R/C car rather than on a boat. This project is important as it aims to prevent the user from unknowingly driving the R/C car out of range, while still giving the user full control of the R/C car. Through the detection system, the user will know the relative remaining range of the vehicle. This will allow the user to be both aware of how far the vehicle is from them in the event they lose sight of it and allow the user to maximize the range of the car. Additionally, the alert system will be able to notify where the car is relative to the user regardless of whether the R/C car is within range of the controller.

By implementing both a range detection and alert system, we are able to limit the amount of frustration a user may feel while operating an R/C car. The alert system is important because it provides the user with valuable information regarding the location of the car. In the event that the user loses sight of the car and is unable to find it, the user is able to use the alert system to determine a relative location of the car. This allows for the user to easily find the vehicle with minimal searching and prevents the user from completely losing the R/C car.

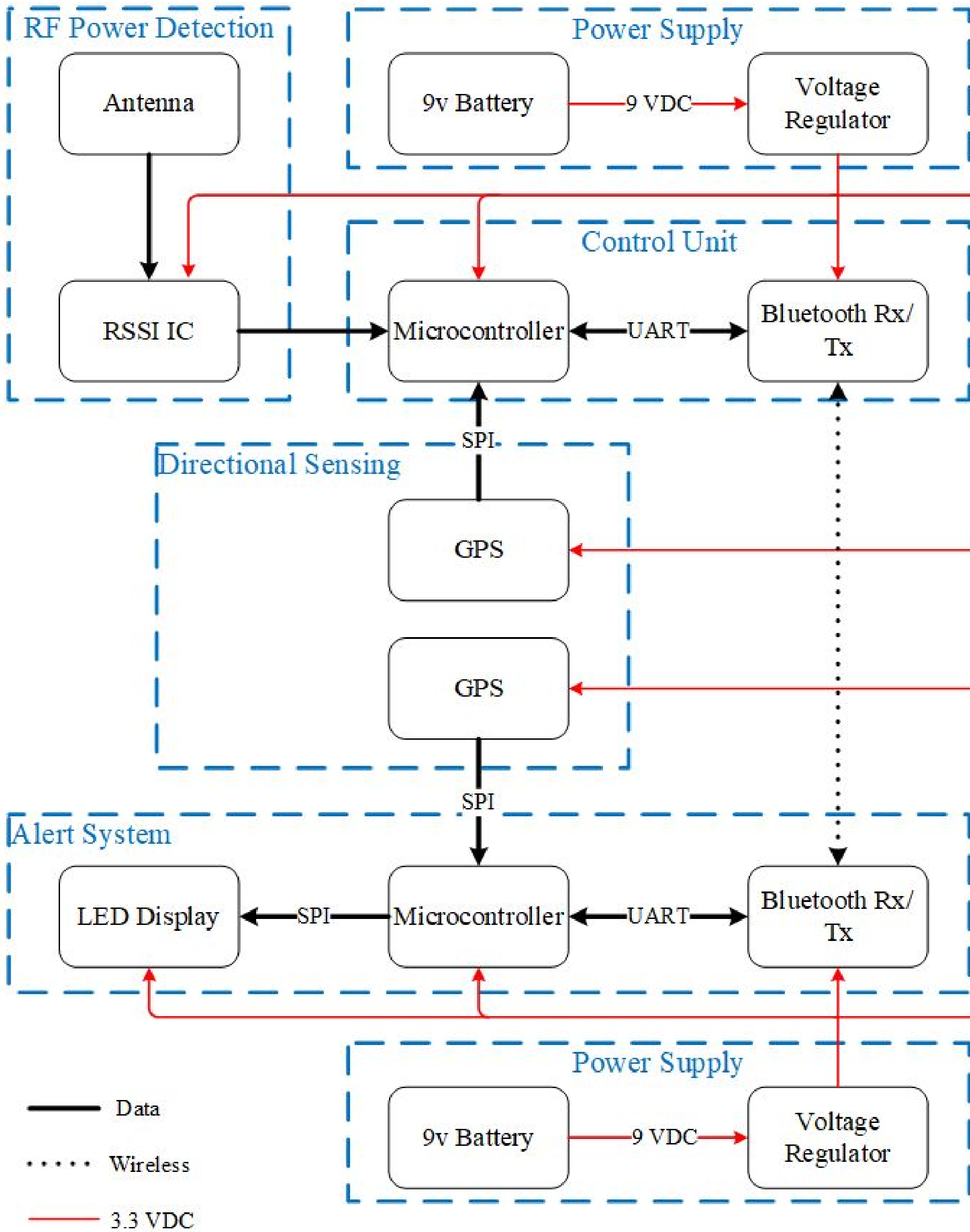
1.3 High-Level Requirements List

For our project, we propose to complete the following three high-level requirements:

1. Detection System - The detection system shall be able to determine the distance from the controller based on the RF signal and shall be able to determine the relative location of the R/C car from the controller..
2. Alerting System - The alerting system should be capable of alerting the user of the R/C car when the R/C Car is nearing the end of the RF range and capable of alerting the user where the relative location of the R/C car is.
3. Communication System - The communication system shall be able to maintain a communication link with the controller over a distance greater than the RF Range of the R/C car (~40m).

2 Design

2.1 Block Diagram



2.2 Physical Design

Figure 2-1 shows the physical R/C Car we will be utilizing for the project. This R/C Car was chosen for its ability to remove the body off of the chassis, allowing for the electronics and battery to be installed underneath such that the system remains discrete in its implementation and operation. Figure 2-2 shows the body separated from the chassis.

For the controller, we will implement a system that can be attached to the current controller. Figure 2-3 shows the controller. The implementation will take into account the orientation of the controller in respect to the user and the size of the PCB board.

Figure 2-1: Physical R/C Car

Figures 2-2 (Left) and 2-3 (Right): The Chassis, Body, and Controller of the R/C Car

2.3 Functional Overview

2.3.1 Power Supply

A power supply is required in both the car and the controller to provide adequate power to each of the blocks and its subcomponents.

2.3.1.1 Battery

The battery must be able to keep the circuits continuously powered during use of RC car, preferably multiple uses.

Requirement	**Verification**
1. The battery must be able to provide at least 160 mA at 8.6-9.2V for the duration of 1 hour.	1. a. Using a multimeter, verify a new 9V battery supplies between 8.6-9.2V. b. Apply a consistent 160 mA draw against the battery for 1 hour. c. Measure the voltage output after 1 hour, ensuring the voltage is within 8.6-9.2V range.

2.3.1.2 Voltage regulator

The integrated voltage regulator supplies the required 3.3 V to the entire system. The regulator must be able to handle the peak voltage of 9.6 V.

Requirement	**Verification**
1. The voltage regulator must provide 3.3V +/- 5% from a 8.6-9.2V	1. a. Measure the voltage

source.	regulator output voltage using a multimeter. b. Ensure the voltage is within 3.3V +/- 5%.

2.3.2 Control Unit

The control unit is responsible for obtaining the data from the RSSI to determine RF signal strength as well as from the GPS in order to determine the car's location relative to the user. It will communicate with the remote controller to relay this information.

2.3.2.1 Microcontroller

The microcontroller, chosen to be an 8-bit AVR RISC based controller from Microchip (ATmega328P), will interface with the RSSI, GPS, and Bluetooth modules [1]. It will read the analog signal strength (dB) from the RSSI chip and compare it to a threshold to determine the integrity of the RF signal strength from the controller. The microcontroller is also responsible for relaying the car's location from the GPS relative to the remote controller. This data will be sent via the Bluetooth module to the alert system on the remote controller to alert the user of the car's range and direction.

Requirement	**Verification**
1. The microcontroller must be able to handle the following peripherals for the RSSI, GPS, and Bluetooth module: a. Analog Input b. SPI c. UART protocol	1. Verify using the ATmega328P 32-pin TQFP Datasheet [1] for the following peripherals: a. Analog Input b. SPI c. UART protocol

2. The microcontroller must be able to refresh the I2C peripheral for the GPS information at a speed no less than 10Hz to maintain the GPS refresh rate.	2. Verify using the ATmega328P 32-pin TQFP Datasheet [1] that the operating speed of the microcontroller is faster than 10Hz.

2.3.2.2 Bluetooth IC (on car)

The car and the controller will communicate with each other through Bluetooth. The range of the Bluetooth module should be greater than the range of the car, so we chose the RN-41, which has a range of 100 m. It will be used on the SparkFun Bluetooth Mate Gold, as the interface between the module and the microcontroller.

Requirement	**Verification**
1. The Bluetooth module must have a greater range than the car.	1. a. Drive the R/C car out of range of the transmitter b. Measure the distance between the R/C car and the controller c. Add 10m to the distance to get verification distance d. With the Bluetooth modules the verification distance away from each other, send test signal from the R/C car microcontroller to the controller microcontroller. e. Indicate the receiving of

2. The Bluetooth module must be able to communicate with the microcontroller over UART.	the signal by lighting up an LED light attached to the controller microcontroller.. 2. a. Configure Bluetooth modules with microcontroller using the UART connections. b. Send test data between Bluetooth modules. c. Verify the test data was transmitted. d. Verify the test data was received. e. Send test data between Bluetooth module f. Probe transmitting terminals to verify data link g. Probe receiving terminals to verify data link

2.3.3 RF Detection

The remote signal from the controller will be received by an antenna in order to determine the signal strength using a logarithmic detector.

2.3.3.1 Antenna

A 2.4 GHz antenna is responsible for picking up the RF signal from the remote controller. It will be optimized to allow for maximum throughput and maximum range. The range will need to be greater than the range of the car itself.

Requirement	Verification
1. The antenna must be matched at 50 Ω +/- 5% between 2402-2484 MHz.	1. a. Test the antenna with a network analyzer. b. Verify that the impedance is within required range from 2402-2484 MHz.
2. The antenna must have a greater effective area than the car antenna.	2. a. Move the car and the antenna until the car is out of range. b. Verify that the antenna is still detecting the signal.
3. The antenna must be omnidirectional to within 6dB.	3. Rotate the antenna through all six 90° orthogonal orientations and verify that the RSSI does not vary by more than 6dB.

2.3.3.2 RSSI Detector

The RSSI detector must be able to detect signals coming from the antenna at the 2402-2484 MHz range. It will be able to scale the signal logarithmically (dB) to help determine the signal strength [2].

Requirement	Verification
1. The RSSI detector must maintain accurate log conformance for signals in the 2402-2484 MHz range.	1. a. Connect the RSSI circuit to a signal generator. b. Generate signals with

	frequencies ranging from 2402 to 2484 MHz and input power set to -60dBm. c. Verify that the log output is accurate for all signals.
2. The RSSI detector must have an input impedance around 50Ω for the 2402-2484MHz range	2. a. Connect INHI and INLO on the chip to a network analyzer b. Sweep over the 2402-2484 MHZ range and verify the input impedance is around 50Ω.

2.3.4 Directional Sensing

This unit is responsible for providing the relative location data between controller and car. This data includes cardinal direction, degree of direction, and GPS coordinates. This will be implemented with two GPS IC's - one on the car and one on the controller.

2.3.4.1 GPS IC

The GPS module chosen to implement this unit is Adafruit's Ultimate GPS module built around the MTK3339 chip. It will be able to update the car and controller's location at a rate up to 10 Hz and send this data to the microcontrollers for processing over NMEA protocol.

Requirement	**Verification**
1. The GPS module must able to update the location data at least 10 times a second to provide	1. a. Connect GPS chip to microcontroller and send

meaningful data ($\geq 10Hz$)	GPS data to controller b. Print output data to terminal and check timestamps to verify data is updating at at least 10 Hz
2. The GPS module must provide accurate location data to $\pm 1 \circ$	2. a. Place GPS connected to microcontroller at known location where coordinates and direction is known b. Have GPS output NMEA data to microcontroller and save data c. Read saved GPS data to verify accuracy of location data
3. The GPS module must provide cardinal direction with degree of direction as well as the GPS coordinates	3. a. Place GPS connected to microcontroller at known location where coordinates and direction is known b. Have GPS output NMEA data to microcontroller and save data c. Read saved GPS data to verify that NMEA data includes

	direction(N/E/S/W), degree of direction, and GPS coordinates

2.3.5 Alert System (On Controller)

The alert system will be attached on the controller in view of the user. It will be able to receive data from the car and relay information about the car's range and relative location to the user.

2.3.5.1 Microcontroller

The microcontroller here will be the same one used on the car [1]. It is responsible for receiving the data from the car via Bluetooth and sending the correct information to display on the LED display [3].

Requirement	**Verification**
Refer to section 2.3.2.1.	Refer to section 2.3.2.1.

2.3.5.2 LED Display

The LED Display will be responsible for giving the user useful information about the car, including if it is about to go out of range and its direction relative to the remote controller [3].

Requirement	**Verification**
1. The LED display must be able to refresh display at at least the rate that new information comes to the remote controller from the Bluetooth module on the car.	1. a. Verify by looking at OLED display to determine if there are frame drops.

2.3.5.3 Bluetooth IC

The car and the controller will communicate with each other through Bluetooth. The range of the Bluetooth module should be greater than the range of the car, so we chose the RN-41, which has a range of 100 m.

Requirement	**Verification**
Refer to section 2.3.2.2.	Refer to section 2.3.2.2.

2.4 High Level Requirements Summary

Module Name	**High Level Requirement**	**Points**
Power Supply	This module should successfully regulate the 9V battery to a steady 3.3V supplied to the circuit.	5
Alert System	This module should successfully alert the user to the relative direction of the car and the percentage of range remaining.	10
Directional Sensing	This module should successfully interact with the control unit to relay the GPS information regarding the location of car and controller.	15
Control Unit	This module should successfully interact with the different modules to communicate the GPS and RF range data to the Alert System.	10
RF Power	This module should successfully determine the signal strength of the R/C car's transmitter.	10
	Total	50

2.5 Schematics

2.5.1 Voltage Regulator

Figure 2-4 shows the schematic for the voltage regulator. The base circuit come from the typical application circuit provided by TI in the datasheet, which provides a 3.3V regulator for Vin between 4 and 37 V. Based on the variability of standard 9V batteries, it is desirable that the voltage regulator is able to handle the 9V battery as it discharges. Therefore, the following schematic accounts for the variability as the voltage regulator chip, LM317M, is an adjustable voltage regulator capable of handling an input voltage range from 1.25 to 37 V. The two diodes provide protection against short circuits on either the Vin or the Vout lines, while the two capacitors reduce the noise on both lines.

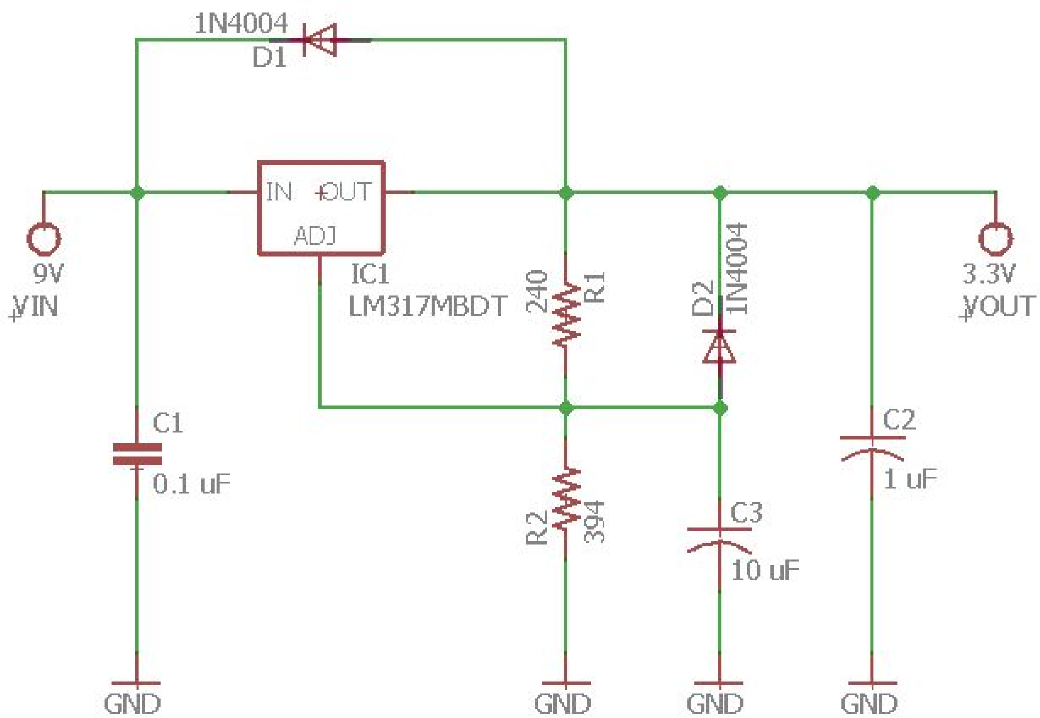


Figure 2-4: Voltage Regulator Circuit

2.5.2 Control Unit

Based on the UART/USART protocols needed for the communication between the microcontroller and the Bluetooth module, Figure 2-5 provides a block schematic of the links between the two devices. Due to the plug-and-play technology of the Bluetooth module, no circuit protection is needed between the two devices.

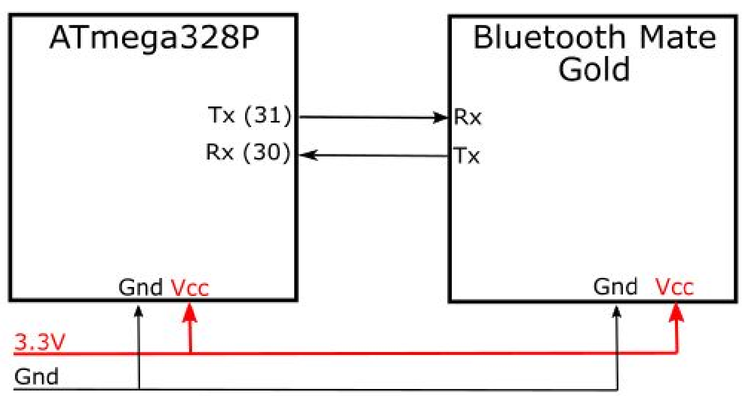


Figure 2-5: Control Unit Block Schematic

2.5.3 RF Detection

The circuit shown in Figure 2-6 is used to accurately measure signal strength at 2.4 GHz. R1 combines with the internal input impedance to give a broadband input impedance of about 50Ω. C1 and C2 are DC-blocking capacitors. R7 is used to optimize the internal temperature compensation network. From the datasheet, 8kΩ optimizes 1.8GHz to 3.2GHz. R2 and R3 control the magnitude of the slope of VOUT. With 10kΩ for both of them, the slope is approximately -44 mV/dB. C4 and C5 are power supply decoupling capacitors. In addition to these two, a 0.1µF capacitor will be placed nearer to the power supply input pin.

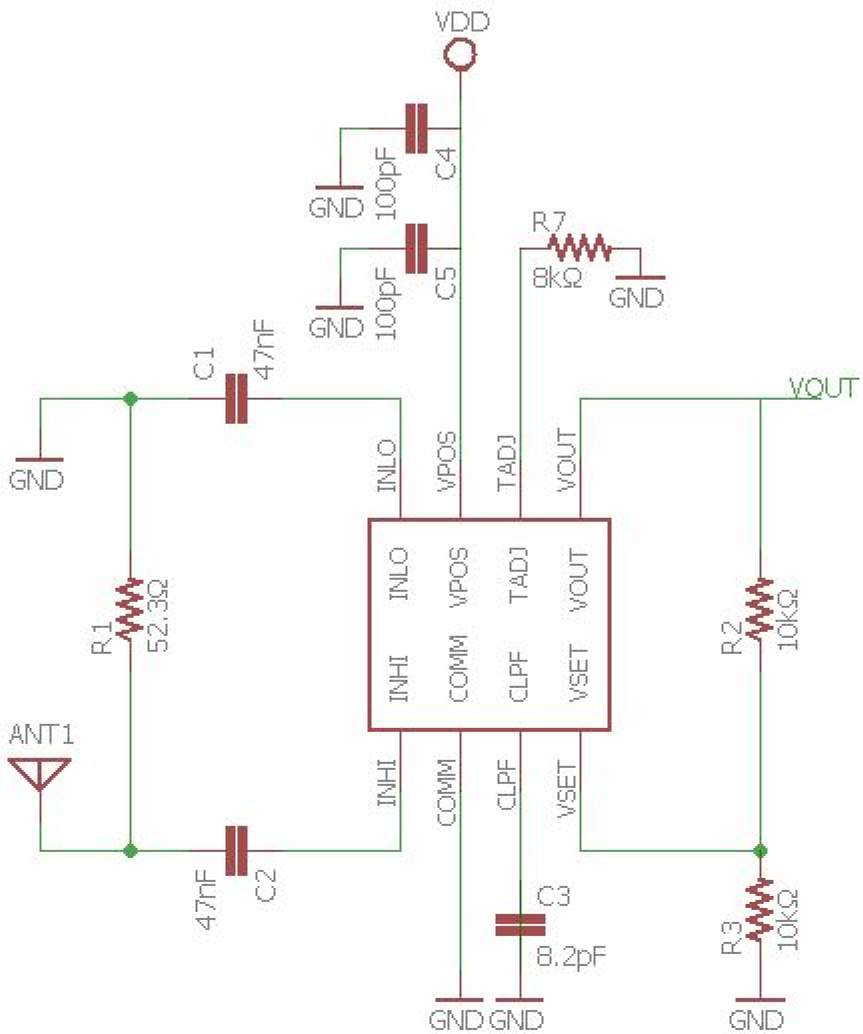


Figure 2-6: RF Detection Circuit

2.5.4 Alert System

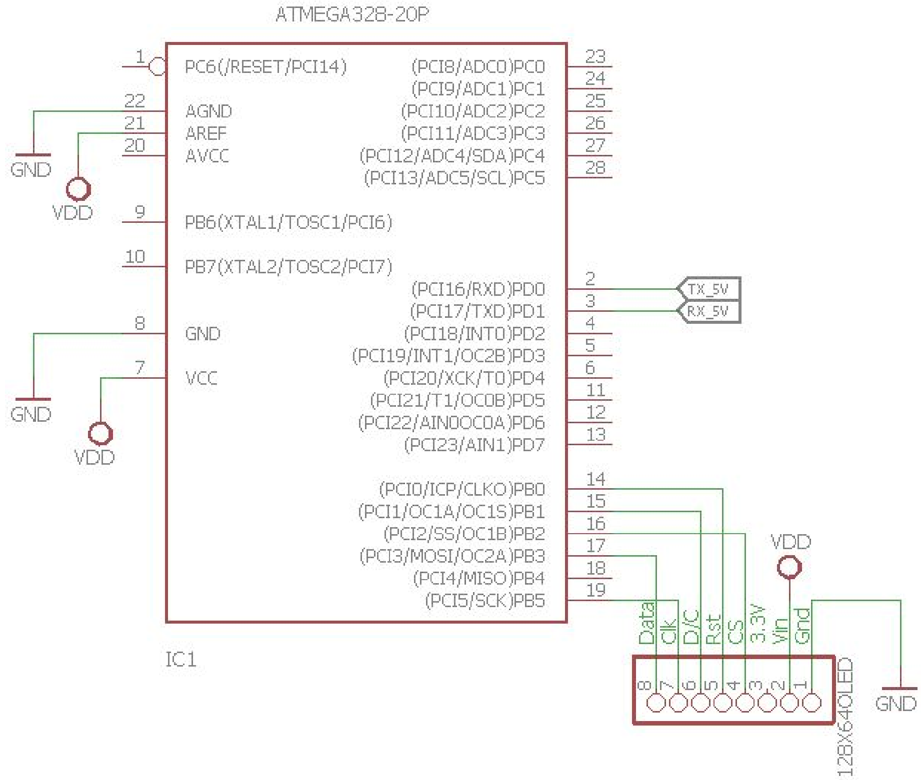


Figure 2-7: Alert System

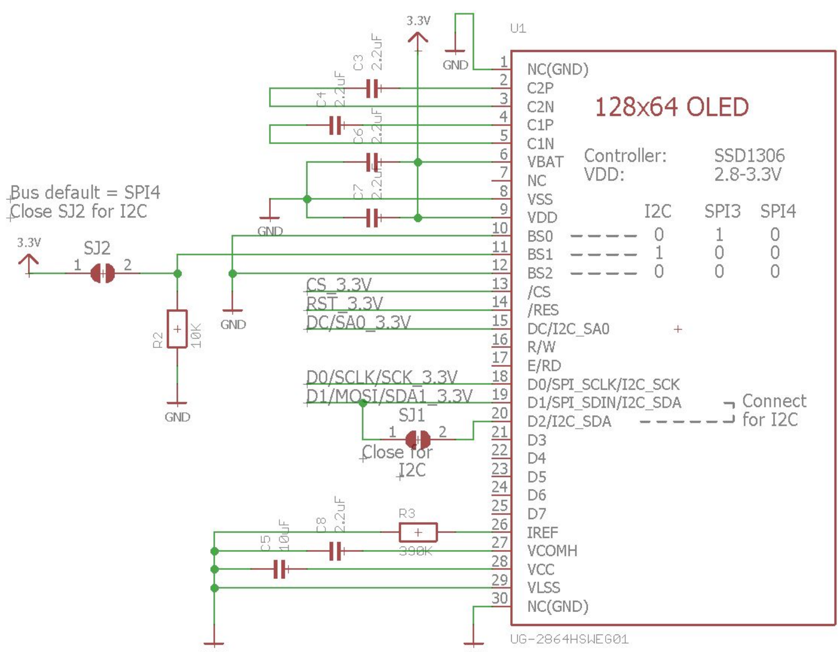


Figure 2-8:OLED Display

2.5.5 Directional Sensing (Both Car and Controller)

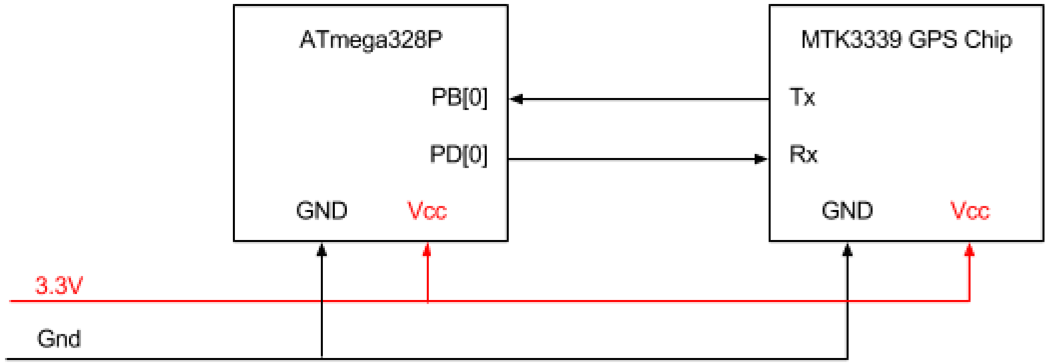


Figure 2-9: Direction Sensing Block Schematic

2.6 Circuit Calculations

2.6.1 Voltage Regulator

For the voltage regulator circuit, the Figure 2-10 show the base circuit. From the base circuit and the LM317M datasheet, the equation for V_{out} is

$$V\,out \;=\; 1.25(1 + \tfrac{R2}{R1}) \tag{1}$$

[4][5]. With the R1 = 240Ω, R2 must be 394Ω. Based on these values, the R1 and R2 values may be adjusted for depending on resistor value availability.

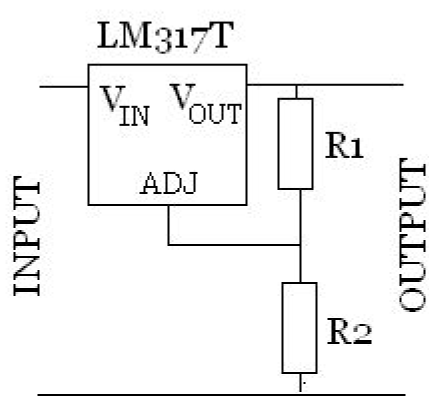


Figure 2-10: Base Voltage Regulator Circuit

2.7 Software Diagram

Based on our design, we will need to code both microcontrollers separately to provide the correct functionalities at each end of the system. Each microcontroller will need to take the information in from the GPS and communicate with the bluetooth module. Figure 2-11 shows the flow diagram that the software will follow. The diagram is color coded for each of microcontrollers and their interactions.

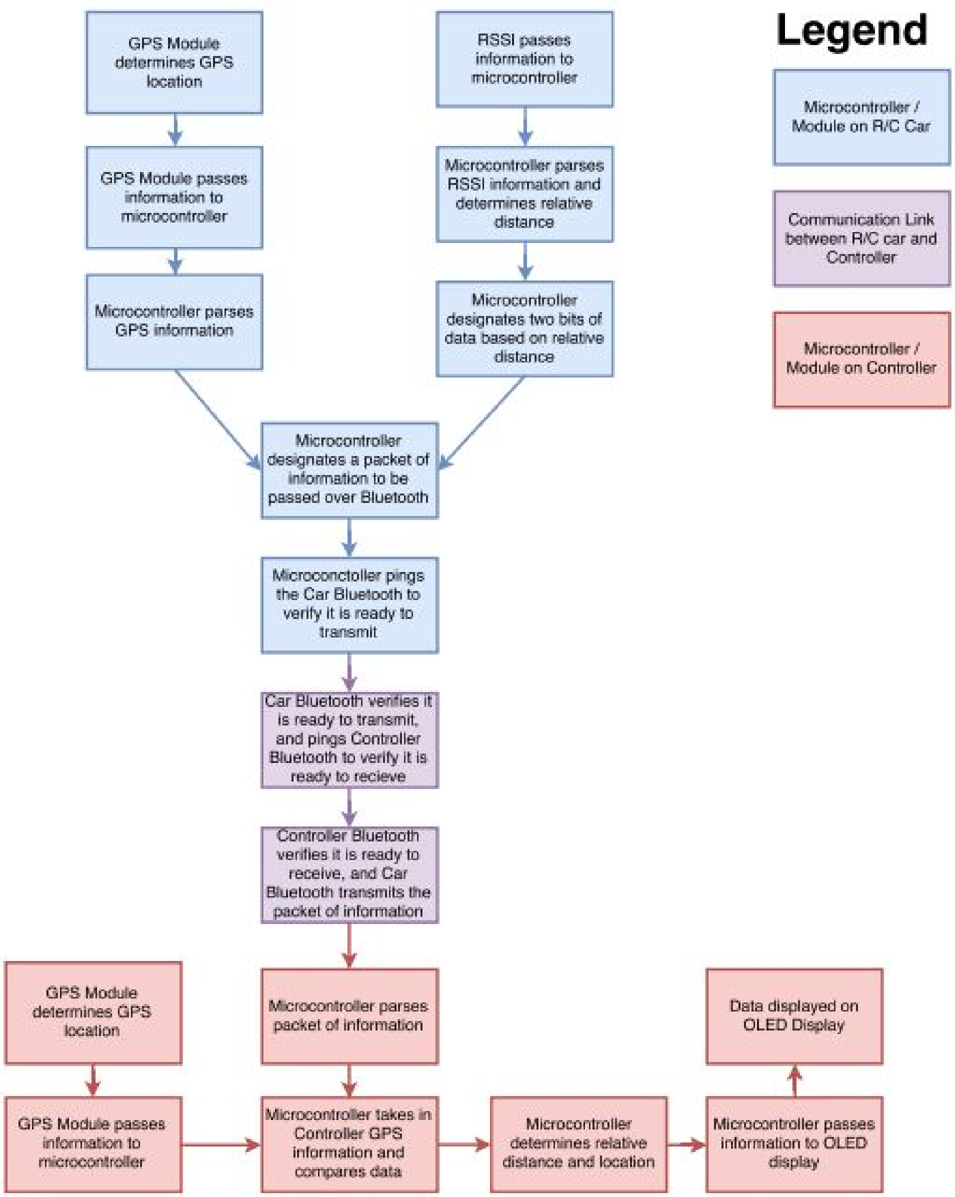


Figure 2-11: Software Flow Diagram

2.8 Tolerance Analysis

In our implementation, the critical component in this circuit is the voltage regulator circuit. Based on the dependencies of the other circuits on the continuous 3.3V supply voltage, it is critical that the voltage regulator circuit supplies the correct voltage while the 9V battery fluctuates. One of the factors in this analysis is the the relative ratio of R1 and R2. If these values do not remain within a specific range, there is a strong possibility that the 3.3V supply voltage may fall out of +/-5% range necessary for the component operations. The ratio that the resistors must maintain is

$$1.508 \leq \frac{R2}{R1} \leq 1.772 \tag{2}$$

While it is optimal to ensure that R1 is greater than 120 Ohms due to minimum current in the circuit, R1 and R2 may take on values as long as the ratio requirement is within the range specified. Based on Texas Instruments Typical Application circuit, R1 should take on a resistance value of 240 +/- 5% Ohms [5]. Therefore, R2 should take on values from

$$344 \leq R2 \leq 404 \tag{3}$$

Ohms. Figures 2-12 and 2-13 show the two voltage sweep simulations for the upper and lower bounds of R2, verifying that the output voltage will be within the 3.3V +/- 5% range specified for the requirements.

For the stability of the circuit, the diodes and capacitors provide additional tolerance stability. Overall, the diodes and capacitors provide protection in the event the battery is suddenly disconnected or that the battery is not supplying a consistent voltage. While these components are valuable in the circuit, their values are chosen based on suggestions from TI, and the tolerance of the components is assumed to be +/-5% [5]. Using the two diodes in the circuit, there is protection from the capacitors discharging into the regulator. Since there is not a power supply filter circuit, C1 allows for sufficient bypassing in the circuit, therefore, providing stability in the circuit. In addition, C3 prevents the amplification of ripples as the circuit is powered on. This improves the ripple rejection of the circuit.

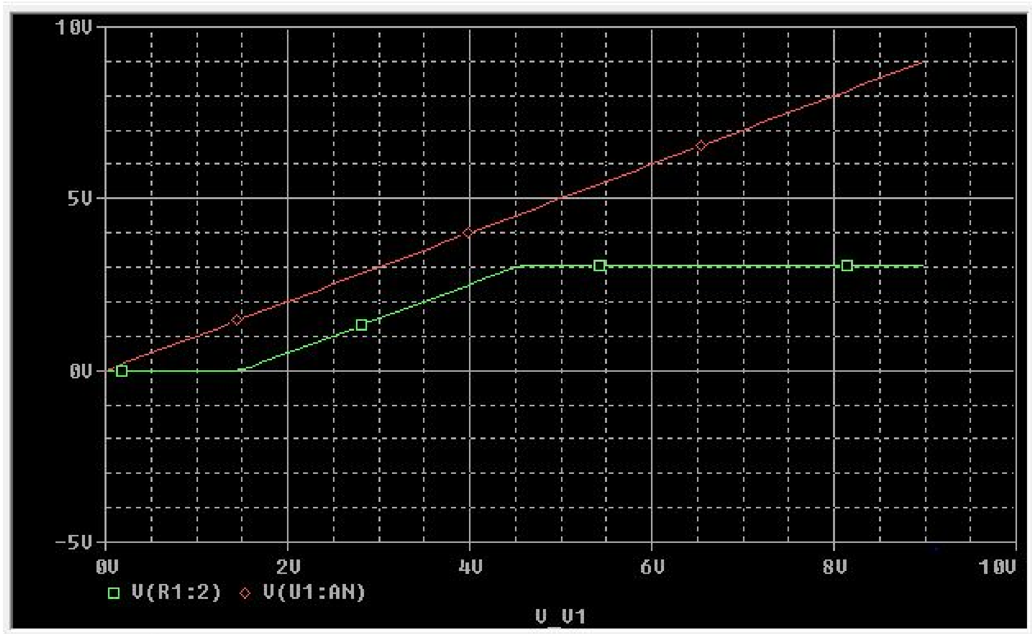


Figure 2-12: Input Voltage (Red) Sweep with corresponding Output Voltage (Green) for R2 = 344 Ohms

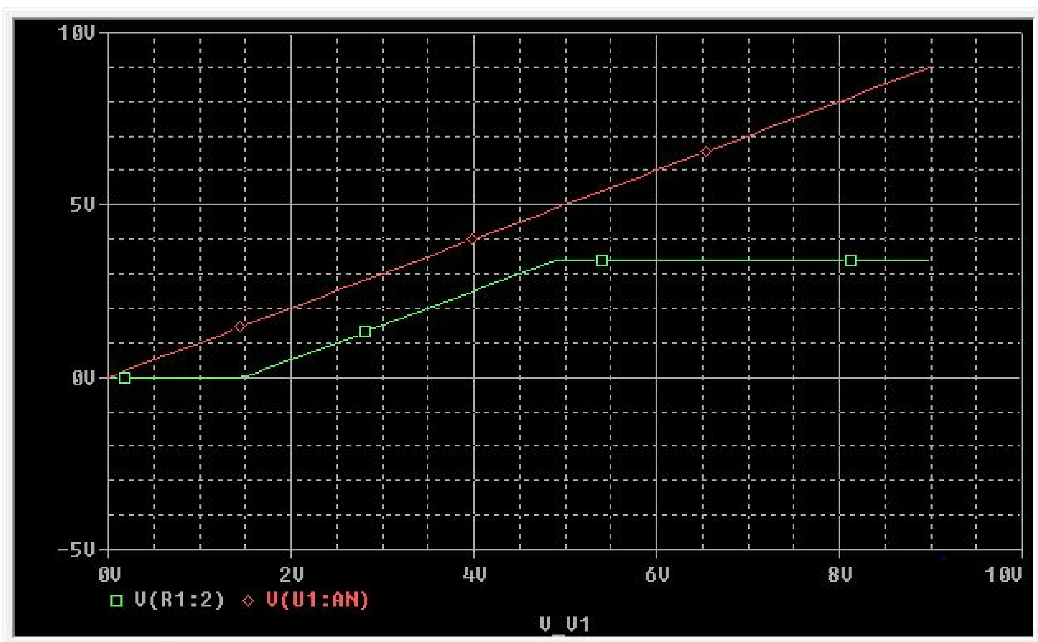


Figure 2-13: Input Voltage (Red) Sweep with corresponding Output Voltage (Green) for R2 = 404 Ohms

3 Costs

Our fixed development costs are estimated to be \$40/hour, 12 hours/week over the 16 week course for three people.

$$3 \cdot \frac{\$40}{1\ hr} \cdot \frac{12\ hr}{1\ wk} \cdot 16\ wks \cdot 2.5 = \$57,600$$

Part	**Qty**	**Total Cost**
Bluetooth Mate Gold (WRL-12580)	2	\$69.90
Microcontroller (ATmega328P-A)	2	\$4.16
Adjustable Voltage Regulator (LM317MDCY)	2	\$1.82
PCBs (PCBWay)	5	\$5.00
Assorted resistors, capacitors, ICs (Digikey, etc.)		\$10.00
OLED Display (Adafruit, Monochrome 1.3" 128x64 OLED)	1	\$19.95
RSSI IC (Analog Devices, AD8317)	1	\$6.50
9v Battery (Amazon)	2	\$3.00
GPS Chip (Adafruit Ultimate GPS)	2	\$80.00
Total		**\$200.33**

4 Schedule

Week	Aaron	Rebecca	Sameeth
10/8/17	Version 1 schematic	Breadboard version 1 schematic	Preliminary testing with GPS, Bluetooth, and RSSI modules with Arduino microcontroller
10/15/17	Version 1 PCB Design	Test voltage regulator schematic	Preliminary code for microcontroller and GPS module
10/22/17	Finish and order version 1 PCBs	Breadboard microcontroller and bluetooth module setup	Verify GPS and microcontroller processing
10/29/17	Prototype version 1 design	Preliminary code for microcontroller and bluetooth communication	Verify Bluetooth and microcontroller processing.
11/5/17	Test impedance matching of antenna and RSSI	Verify voltage regulator design on PCB	Verify RSSI and microcontroller processing
11/12/17	Test range of RF detection	Test bluetooth range/connection using the R/C car	Code overall system and FSM
11/19/17	Finalize hardware	Test and record R/C car implementation	Finalize microcontroller software and processing
11/26/17	Prepare for demonstration	Prepare for demonstration	Prepare for demonstration
12/3/17	Prepare final presentation	Prepare final presentation	Prepare final presentation

5 Ethics and Safety

According to IEEE Code of Ethics, “We … in recognition of the importance of our technologies in affecting the quality of life throughout the world, and in accepting a personal obligation to our profession… agree: to accept the responsibility in making decisions consistent with the safety, health, and welfare of the public…” [7]. As the primary focus of this project is to expand and build on our personal and professional careers, must uphold and remain consistent in our diligence for safety and ethical decisions. Therefore, as a team, we will ensure that we utilize proper safety precautions in the lab and during testing.

Since the car has design capabilities to potentially limit or remove the user’s control of the car, we must follow IEEE’s #2 Code of Ethics, “to avoid real or perceived conflicts of interest whenever possible, and to disclose them to affected parties when they do exist” [7]. Therefore, the user of the car will be cognizant and aware that the car is taking in GPS signal and processing the relative location between the car and the user. Additionally, the user will be aware of the functions of the car, and that the car may operate at a range that the user is unable to see the car. In this event, there may be potential for conflicts if the car encounters another individual or object. As such, we will recommend that the user operates the car where visual contact can be maintained, or that another individual is able to maintain visual contact with the car and able to communicate back to the user when a safety risk is encountered.

By IEEE Code of Ethics #9, “to avoid injuring others, their property …”, we must be aware of the safety risks of operating a 9V battery on a moving R/C car [7]. While the 9V batteries are potentially hazardous on their own, the risks of a dragging battery are high due to the operation of the car. To aid in the safety of everyone around and using the R/C car, the battery will be securely mounted to the chassis of the R/C car underneath the body of the car. This will limit the ability to snag any wires running from the battery to the PCB board and limit the ability for the battery to be jarred off the car and dragged underneath. Additionally, the R/C car may be operated in areas where water is present, where there is a potential that the circuitry within the body of the car can be shorted, including the battery. These safety hazards can be addressed by ensuring that the circuitry is properly cased such that the circuitry will not be dragged underneath and water does not enter. It will have to be tested in various environmental conditions to make sure that the circuitry can withstand any terrain the user can put it through. It will also be recommended to the user to use caution when operating the vehicle and not put it through too much stress.

Since the R/C car is small, and capable of being mobile at moderate velocities, we must be aware of our surroundings, making sure that it is tested and used in open areas where pedestrians and other mobile peoples are not present. In addition, we must remind users to use caution when operating the car to avoid injuring others and themselves.

4 References

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