Project Sense

ECE 445 Design Document - Spring 2023

Project # 67

Abhay Naranyan, Aakash Rangan, Jerome Dinakar

Professor: Arne Fliflet

TA: Vishal Dayalan

Contents

1 Introduction

1.1 Problem

Each year, there are a significant number of cyclist fatalities caused by collision with a motor vehicle. In 2020, there were over 1000 cyclist deaths reported, a 9% increase from the previous year in the US. Furthermore, according to a study on the subject, it was determined that environmental factors, (such as weather, lighting conditions, and the time of day) were intrinsically linked with the level of injury occurring from such crashes. These conditions of low visibility inevitably resulted in not only a more significant proportion of accidents but also greater severity of the injuries in question. Naturally, this also includes unavoidable accidents due to there being blind corners, as a large fraction of the collisions occurs in urban areas.

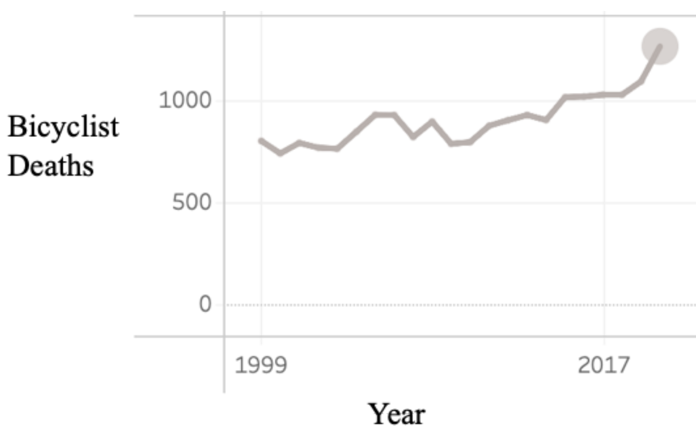


Figure 1: Plot of bicyclist casualties over 1999-2020

From the figure above, as these accidents are increasing in frequency, it is clear that none of the measures that have been taken are effectively addressing the issue. Although one might assume that camera implementation would be suitable, such an approach would be unlikely to aid in diminishing such accidents. This is because cameras are not infallible in the aforementioned visibility conditions. As such, this leaves a large gap for an appropriate solution.

1.2 Solution

To address the problem in question, it is clear that some form of warning is required for a vehicle driver before the occurrence of any unfortunate collisions. It would also be beneficial if a cyclist can be warned of a closely-approaching vehicle beforehand. The solution for the latter must be compact and clear to be easily understood by the cyclist. Therefore, a system of three colored LEDs (red, yellow, and green) could be jointly placed on the handlebar to indicate how far away a vehicle is, in ascending order. The aforementioned colors simply translate to near, approaching, and far respectively.

Now discussing the system for the vehicle, there must be a way to alert the driver on recognizing a bicycle in the vicinity (10 m). An additional method of monitoring all bicycles in a greater scope (50 m) would also be helpful. These problems can both be solved with a two-part system: one that releases a buzz-like sound upon recognizing a cyclist in a 10 m range, and another that serves as a display to depict the positions of any bicycles in the area (50 m radius). Using this system, a vehicle can be alerted about a cyclist well before actually seeing the bicycle, therefore reducing the probability of these accidents.

Note: This works by uniquely identifying bicycles and cars by IDs, which will aid in the car and bicycle easily being able to identify their counterparts approaching through the emission of signals.

1.3 Visual Aid

Note: The red location pins in the Display are the locations of the bicycles nearby.

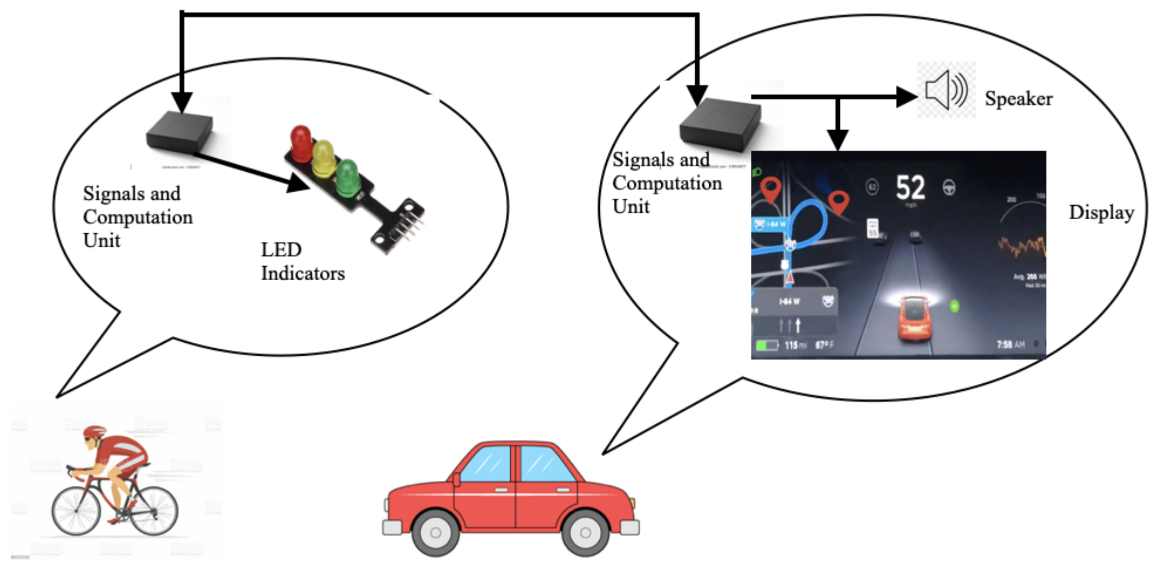


Figure 2: Visual Aid of use of Project Sense

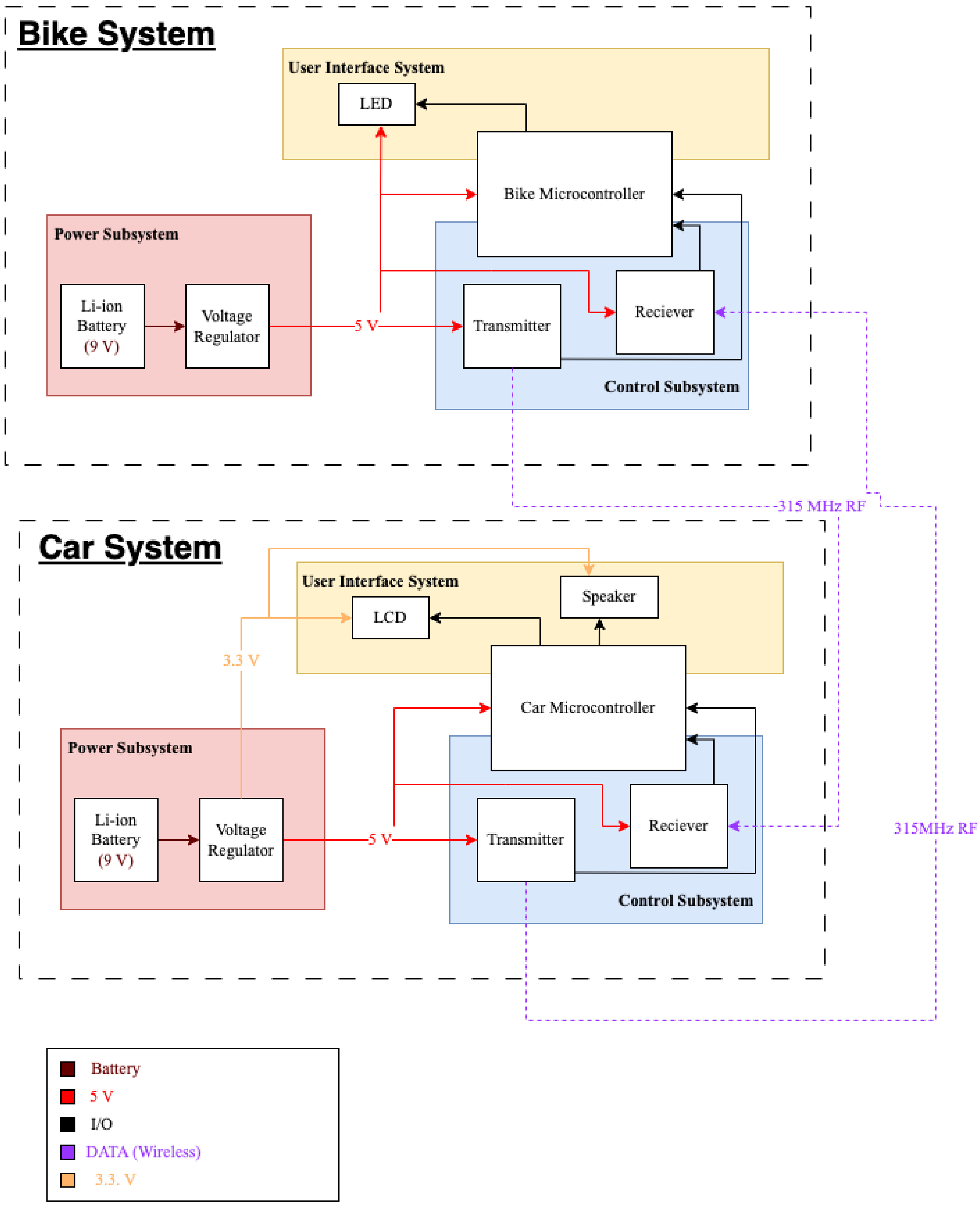
The pictorial representation is depicted above with arrows indicating data (and computation results) transfer. To summarize, the Signals and Computation Units of the bike and vehicle work in tandem, to let each other know of their respective positions, finally sending it to the LED indicators, along with the display and speaker respectively. This then informs the user according to the specifications mentioned.

1.4 High-level Requirements

- The vehicle and bicycle should be able to detect and inform the driver/cyclist about their approaching counterpart starting from the time when the distance between them is at least 10 meters. This is to give them a sufficient warning to respond to the situation.
- The vehicle and bicycle should be able to detect the movement of their counterparts that are at speeds of 10 miles/hour at the minimum. This is simply a metric to start with. If the device can detect approaching vehicles at higher speeds, it would be ideal.
- The system should update both the bicycle and vehicle regarding their counterpart's position once every 10 ms (milliseconds). This is to ensure that both the cyclist and driver always have updated information, even in a fluid situation.

2 Design

2.1 Block Diagram



2.2 Physical Design

For the bike and car subsystem, we plan on using a plastic assembly casing shown in Figure 3. The Bike system will house all of the necessary subsystems for the bike, including the battery and its associated components for the power subsystem, the user interface system including LEDs and their respective resistors, microcontroller and transmitter/ receiver. The Car system will be very similar to the Bike system with holding the same subsystems of power control, microcontroller, and transmitter/receiver. The only difference will be that the user interface subsystem in the Car system will have a 16x2 LCD screen and a tiny speaker that will emit a noise to alert the driver. The transmitter from one system will send an RF signal to the receiver in the other system to calculate and alert the user of their distance relative to the other system.

Figure 3: Assembly for Car and Bike System

The dimensions of the box can be noted in Figure 4, and we plan to secure these boxes to their respective systems using a 3d printed hinge as seen in Figures 5 and 6, secured using screws. One system will be placed on a bike's handlebars and the other system will be placed in the car vent of the car**.**

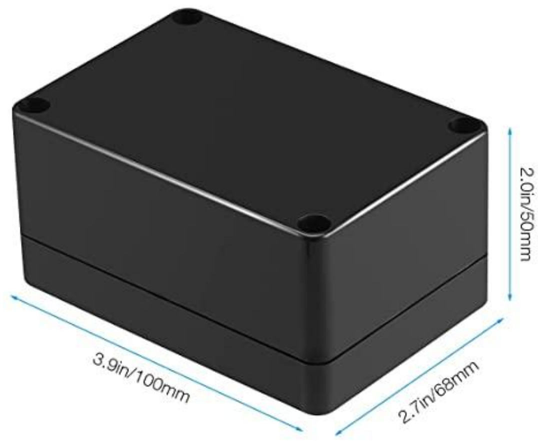
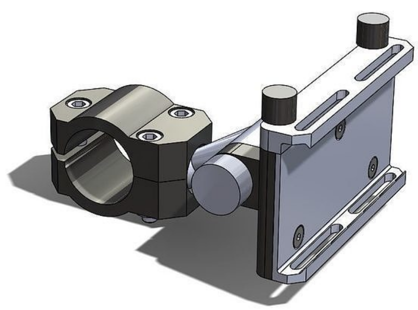
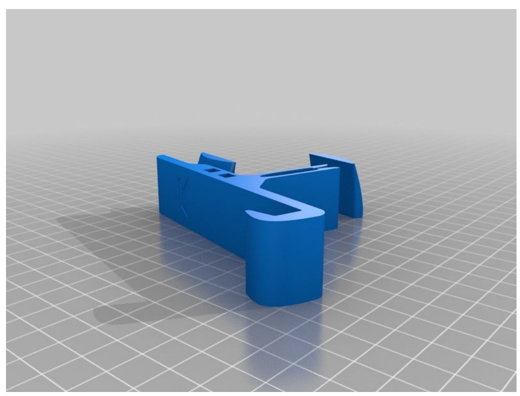


Figure 4: Dimensions of the Car and Bike subsystem (mm)

Figures 5 and 6: Bike Mount and Car Mount (3D printed) [1] [2]

2.3 Control Subsystem

The Control Subsystem contains all the necessary data signals for the device to operate and relay signals between the two systems. The control subsystem only varies with the user interface signals being sent to each system: the car's user interface subsystem will receive signals from the microcontroller to power and display the current location of the other system. However, the bike system will be a bit simpler at it will involve signals to power the LEDs and transmission gates that will power the selected LED based on the bike system's location, which is done by microcontroller and transmitter of the car system and sends its RF signal to be picked up by the bike system's receiver which would power the calculated distance's specific LED by varying voltage levels. The pin layout can be seen in Figure 7.

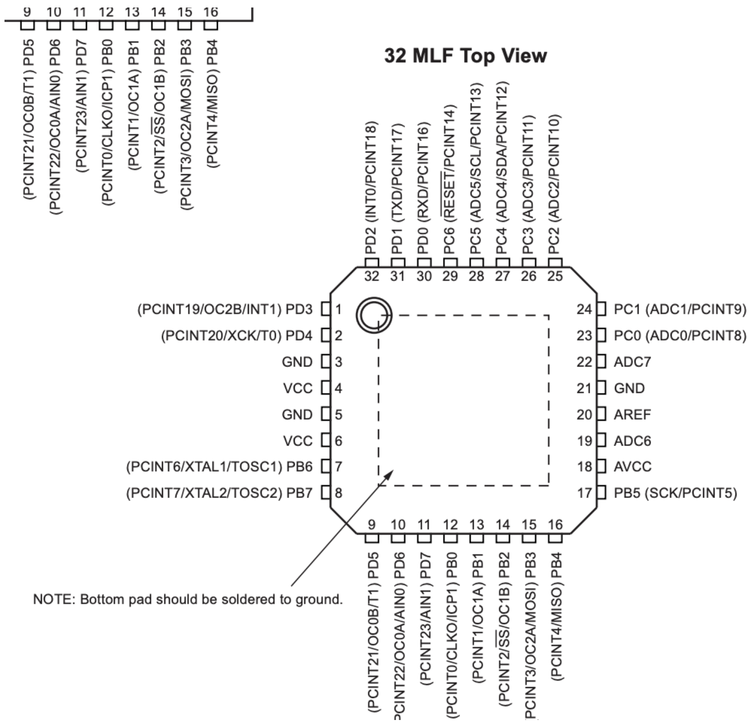


Figure 7: Pin layout of microcontroller [3]

The operating voltage for the microcontroller is between 2.7V to 5.5V, but we aim to provide the voltage at 4.5-5.5V to the V_cc pin 4. The microcontroller will also be supplied current at 1.5 mA but may vary depending on chosen operating voltage. The data outputs for the LCD screen, LEDs, and buzzer will be controlled by pins 9-16(Port B: 8-bit bi-directional I/O ports).

For the transmitter and receiver, they operate on the range of voltage at transmitter (3-9V) and receiver (3-5V) and current at 50mA or 9VDC. The two RF signals they supply are 315MHz or 433MHz at the max receiving sensitivity of -110dBm@10kbps. The maximum range of the transmitter receiver bundle is 2 km of open area without interference, which can change based on objects in between the bundle. An exported image from the data sheet in Figure 8 will show advanced details for the specifications of the transmitter and receiver.

Parameter	Value/Range
Operating voltage	Transmitter(3-9V),Receiver(3-5V)
Working current	50mA(9VDC)
Principle of work	Superhet（VCO, PLL）
Modulation	OOK/ASK
Working band	315MHz ; 433.92MHz (customize service available)
Operation Temperature	-20℃ to +75℃
Bandwidth	200KHZ
Sensitivity	-110dBm (50Ω)
Modulation rate	＜10Kbps
Decoding form	PT2272
Antenna length	18cm(Tx)、24cm (Rx)
Emission Distance	2KM(Open area without interference)
Working Output Modes	Unlocked, interlocked, self-locked

Figure 8: Specifications of Transmitter and Receiver [4]

The pins of the transmitter and receiver are very simple to connect. After powering both chips with their desired power inputs, simply connect the data pin of the transmitter to the microcontroller's data output pin PD1 (TXD) (Pin 31 on microcontroller) and the data input pin for the receiver as PD0 (RXD) (Pin 30 on microcontroller). These input and output pins are respective to the design seen in Figure 9.

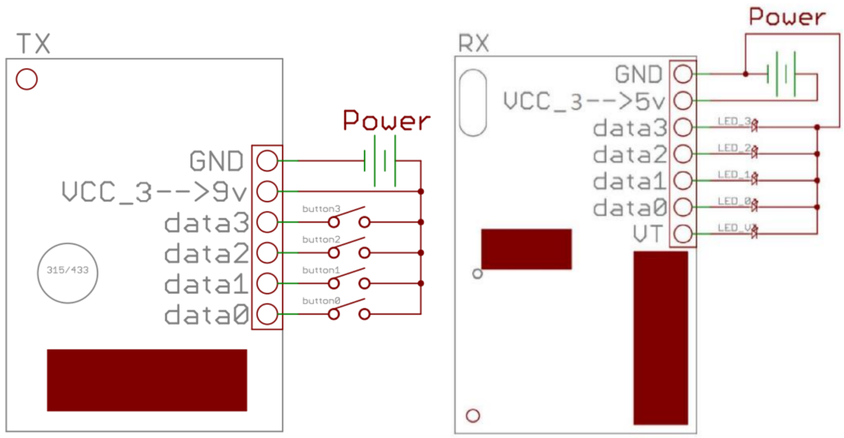


Figure 9: Connection Diagram of Transmitter and Receiver [4]

2.4 Power Subsystem

Subsystem Description

The Power Subsystem consists of all the necessary circuitry to apply ample voltage to the different components of each PCB. Both the Car and Bike PCBs largely have the same components so as seen below, we will not be repeating the voltage levels for repeated components. Here are the voltage levels of all of the components pulled from their respective data sheets.

- Transmitter: 3-9 V (Both)
- Receiver: 3-5 V (Both)
- Microcontroller: 4.5 - 5.5 V (Both)
- LCD: ~ 5-7 V (Car)
- Buzzer: 3-5 V (Car)
- LEDs: ~2.5 V (Bike)

We can consolidate all of these values to 5 V,4 V and LED voltage. For consistent functionality, all the components excluding the LEDs require a fixed input voltage regardless of battery fluctuations. For this reason we plan on using two voltage regulators to guarantee a fixed 4 and 5 V supply that are not load dependent. Our original design choice was to use voltage divider circuits with the 9 V battery as our input to generate the necessary voltages. We decided on using voltage regulators for two reasons. First, voltage dividers eliminate fluctuations in the output caused by fluctuations in the input. This reduces the chance one of our components is accidentally damaged from a surge in the voltage level. Second, a voltage regulator does not vary in voltage depending on the load voltage. While we could take into account the input impedance to our different components via their datasheets, it would be far simpler to use a voltage regulator to maintain a non load dependent voltage. Finally, for the LEDs we can use the 4 V rail along with a series resistor to account for the excess voltage.

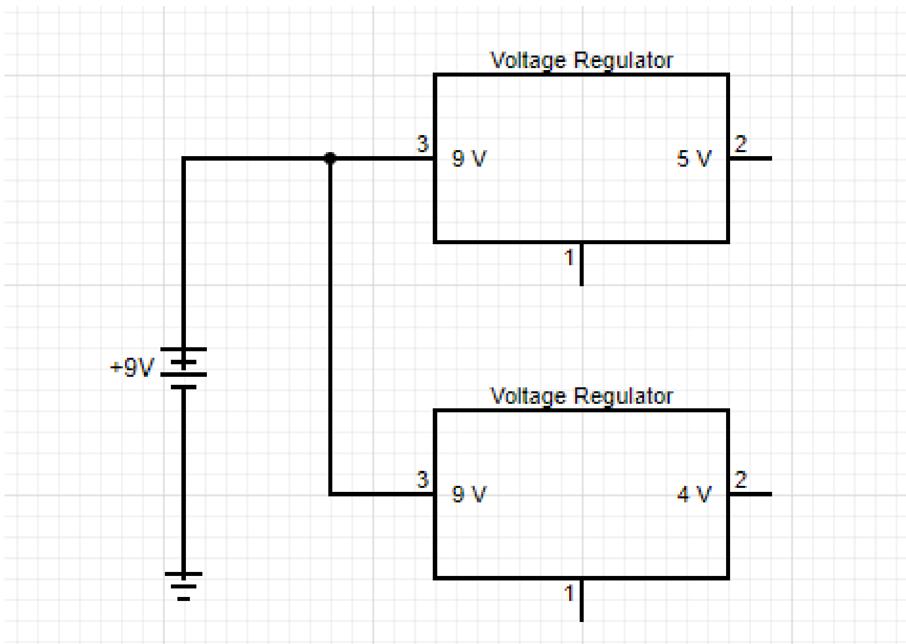


Figure 10: Power Supply Schematic

Above is a rough circuit schematic showing our Power Subsystem. We take the input 9 volts and create a 4 and 5 voltage rail in our design used by the rest of our design

Subsystem Requirements/Verifications

Requirements	**Verifications**
While varying the input voltage level, we should maintain the aforementioned 5,4,	1. Power on the PCB in standard room temperature conditions

and 2.5 volts.	2. Using a Multimeter or an Oscilloscope, measure the input pins of the voltage regulators to be 9 V 3. Measure the output pins of the voltage regulators to confirm their values at 4 and 5 volts 4. Now varying the input voltage between 5 and 13 volts, confirm the voltage regulator outputs remain at 4 and 5 volts
Since Bikers may be using our device in subfreezing or extremely hot temperatures, our circuit must operate with consistent voltage levels between -10 to 40 degrees Celsius.	Assuming the first requirement has been satisfied, repeat the first requirement in a variety of temperatures to confirm changes in resistance do not impact the expected voltage levels.

2.5 User Interface Subsystem

<u>Subsystem Description</u>

The user interface is one of the main components that differ between the Bike PCB and the Car PCB. Starting with the simpler Bike PCB, our system for showing the biker the approximate distance of the closest vehicle consists of 3 LEDs. The LEDs come in three colors, red,yellow, and green. The red LED indicates a car is within 10 meters of the biker, the yellow within 20 meters of the biker, and the green within 50 meters of the biker. In order to exert control over which LEDs are turned on, we will have 3 control signals one for each LED from the control subsystem. These transmission gates will have the 4 V rail as their input, the control subsystem signal as their control signal, and the LED as its output.

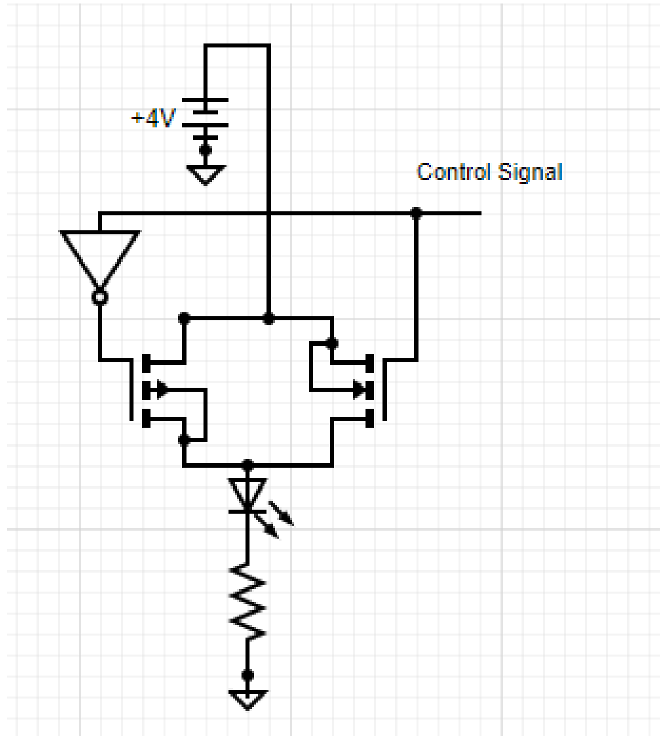


Figure 11: LED circuitry

Next for the Car PCB we have both an LCD and a speaker/buzzer. The buzzer is a simple analog buzzer that translates voltage level to frequency. We decided on our simple analog buzzer due to the constraints of our design problem. Since our job is to alert the driver of a nearby biker, what tone and pulse frequency we operate at is not particularly important. For this reason, an analog buzzer is a far simpler solution than a speaker. In terms of the functionality of the buzzer circuit, we will have an oscillator that generates a square wave in our circuit to produce the required noise from the buzzer. The capacitors and resistors for the oscillator can be selected with quite a large variation and depend on how the buzzer sounds. Similar to the LEDs, for the Bike PCB we will use a transmission gate with the input to the gate being the square wave from the oscillator, the control signal from the control subsystem, and the output connected to the positive end of the buzzer.

For our LCD, we chose to utilize a 16x2 dimensioned screen. The screen will operate as an information hub that will provide the driver with accurate information towards the other system (bike) is. The screen will flash with text information and a tiny bitmap as to where the detected bike system is located relative to the car system. As to how to operate the screen, it must be powered by 2 input power signals: one for the display V_DD = 7 V and V_in = 5 V. The supply current to the display must be in the range of 1.5-2.0 mA. Resistors can be selected by a wide variety due to the values of the electrical components, but just inputting the correct power values the display should be usable. Lastly, this is the wiring we expect to use with the selected ATMEGA328P microcontroller is in Figure 12:

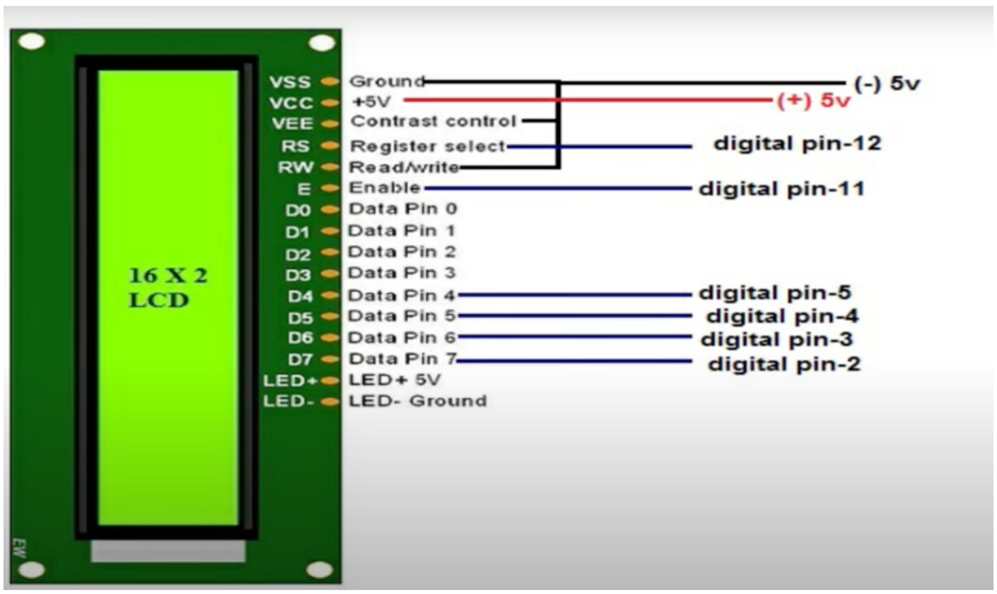


Figure 12: Wiring for the LCD Screen to the microcontroller [5]

<u>Subsystem Requirements/Verifications</u>

Bike PCB

Requirements	**Verifications**
Given any arbitrary set of control signals, the correct color LEDs should light up.	1. Power on the design and check that the necessary 4 V rail has the correct value using a multimeter or oscilloscope 2. Assuming for the transmission gates a digital 1 value is 4 volts and a digital 0 value is 0 volts, try all 8 possible digital combinations to

	confirm the correct LEDs light up correctly.

Car PCB

Requirements	**Verifications**
The buzzer must produce a beeping sound.	1. Power the board and check the 4 V rail with a multimeter or oscilloscope to confirm. 2. Using the oscilloscope, confirm if a squarewave is being produced from the oscillator. 3. Using a signal generator, test the transmission gate with both a high and low digital value to confirm the squarewave is correctly being passed to the buzzer. 4. Audibly verify the sound of the buzzer.
The buzzer must be audible with moderate background noise from driving in a vehicle	1. Power the board and verify the sound of the buzzer is audible in a silent room. 2. Play audio at around 80-90 dB while turning on the buzzer to confirm the buzzer is audible.
The LCD Screen must update every 10 ms to display the bike system location to the car system.	1. Load the code into the microcontroller to display information on LCD screen 2. Power board and verify that receiver is picking up signals from the bike system's transmitter a. Verify data and power signals are being produced using an oscilloscope. 3. Visually verify if correct output is being seen on LCD screen

2.6 Software

The core part of our software will be run by the microcontroller in the control subsystem. We plan on using it to generate data signals to the User Interface System and the transmitter / receivers data signals. Specifically, our code will receive a developed signal from one system, decode it, and relay a signal to the other system in order to fulfill communication. The decoded signal will relay critical information about the position of the system, which will in turn be converted into a data signal that will alert the user of the other system's position. The code will have to vary voltage levels to the LEDs as well as encode the LCD screen. Then the whole cycle will repeat and send data between the two systems again, accurately informing both user's of each other's locations.

Figure 13: Code to program LCD Screen [5]

2.7 Tolerance Analysis

The most fundamental aspect of our design comes down to the RF components we are purchasing. To cover some basics on the topic, our transmitter and receiver operate at 315 MHz at up to 2 km in open spaces. To start off we know RF waves decay as per the inverse square law. This means our receiver tolerates 5 * 10^(-4) times attenuation of the original transmitted RF signal.

$$\frac{K}{r} = \frac{K}{(2*10^3)} = K * 5 * 10^{-4}$$

One particular issue we were concerned about was RF shielding. Since the RF components assume travel over free space, we wanted to see how much attenuation we could tolerate. In particular, vehicles are made of a number of metal components which could create an RF shielding effect significantly attenuating our signal. To investigate the issue we found a study that a cell phone company conducted to test RF attenuation as a result of being in a vehicle [6]. The study tested frequencies from 800 MHz to 2600 MHz. While we are operating at a lower frequency, the study found no significant variation in attenuation across frequencies. Therefore it is reasonable to assume the results would be applicable to us.

The study goes on to conclude that the mean vehicle penetration loss has a median of 8.9 dB with a standard deviation of 5.6 dB. This implies one standard deviation over the mean is 14.5 dB. If we use the dB conversion formula as seen below, we find that the receiver tolerates up to 33 dB of attenuation which is significantly greater than the 14.5 dB we expect on the high end. Therefore despite attenuation from the vehicle, we can expect our receiver to receiver the expected values without issue

$$10log(2 * 10^3) \cong 33 \text{ dB}$$

3 Cost & Schedule

3.1 Cost Analysis

The total cost computed from the following figure is $84.60. After accounting for a 10% sales tax and a flat 5% delivery fee, we can expect the additional costs to be $8.46 and $4.23 respectively.

Assuming a $41/hour wage, and an estimate of 45 hours for the completion of this project, we can predict a total labor of $41/hour * 2.5 * 45 hours = $4,612.5 for each team member. For the whole team, this will mean a labor cost of 4,612.5*3 = $13,837.5.

We can compute the required grand total by summing our obtained costs from each section. That is: $84.60 + tax and a flat 5% delivery fee, we can expect the additional costs to be $97.29 + $13,837.5 = **$13,934.79**

Description	Manufacturer	Quantity	Cost ($)	Link
RF TRANSMITTER AND RECEIVER LINK	Seeed Technology Co., Ltd	2	34.00	Link
BUZZER 5V - BREADBOARD FRIENDLY	Adafruit Industries LLC	1	0.95	Link
RES 240 OHM 1% 0.6W AXIAL	TE Connectivity Passive Product	3	0.45	Link
AUTOMOTIVE VOLTAGE REGULATORS	ABLIC Inc.	2	7.08	Link
IC MCU 8BIT 32KB FLASH 28DIP	Microchip Technology	2	15.40	Link
16X2 UWVD CHARACTER LCD	Focus LCDs	1	11.06	Link

SPEAKER 8 OHM 250MW TOP PORT 70DB	Visaton GmbH & Co. KG	1	6.65	Link
Plastic Enclosure	PinFox	1	8.99	Link

3.2 Schedule

Week	Task	Member(s)
Feb 27 - Mar 6	Order listed parts on PCBway	All
	Begin work on Power subsystem for bike	Abhay
	Research systems that achieve efficient depiction and monitoring of moving bodies, bikes in this case (for the car)	Jerome
	Begin work on Power subsystem for Car	Aakash
Mar 6 - Mar 13	Establish and power connection for bike receiver and controller	Abhay
	Establish and power connection for car receiver and controller	Jerome
	Revise PCB design to improve/facilitate device function.	Aakash
Mar 13 - Mar 20	Work on appropriate communication between both transmitter/receiver pairs.	Jerome and Aakash
	Attempt using display on a smaller scale to ensure smooth communication with a microcontroller to prepare for upcoming testing.	Abhay
Mar 20 - Mar 27	Place orders on PCBway for second round for additional needs	All
	Complete signals and computation units of both bike and car	All
	Test with diagnostic LEDs if cars and bikes are appropriately detected	Aakash

Mar 27 - Apr 3	Perform connections between bike's signals & computation unit and LED system to indicate distance	Jerome
	Perform connections between car's signals & computation unit and Display to indicate bike positions	Aakash
	Perform connections between car's signals & computation unit and speaker to indicate a detected bike in range	Abhay
Apr 3 - Apr 10	Perform test runs of both sections together. Check synchronization (similar corresponding readings) between both car and bike from each unit.	Abhay and Aakash
	Revise PCB design to account for unexpected behavior.	Jerome
Apr 10 - Apr 17	Fine-tune devices to get closer to synchronization.	All
Apr 17 - 24	Deliver mock demo to TA. Demonstrate progress	Everyone
	Make final adjustments and incorporate TA feedback in time for the final demo	Everyone
Apr 24 - May 1	Deliver final demo to instructor and TAs for functionality	All
May 1 - May 4	Deliver the final presentation and complete other end-of-project assignments and formalities	All

4 Ethics & Safety

One of the tenets of the IEEE code of ethics is “to protect the privacy of others”. One particular concern that arises from this is that our device can be used to detect the location and a unique id for another driver/biker. Naturally, we understand that users may express reservations regarding privacy, as the product works by allocating unique ids for all our users. Naturally, this could be used to uniquely identify consumers. We hope to assuage these concerns by reallocating unique ids for each consumer every 24 hours to ensure user anonymity over longer periods of time.

Another tenet of the IEEE code states “to hold paramount, the safety, health, and welfare of the public”. One potential concern related to this is the detrimental effects of EM waves on humans. According to the Federal Communications Commission, the maximum RF limit for an individual from a cell phone or similar device is 1.6 W/kg. Considering such an amount is widely used safely, maintaining these values should be sufficient in assuring the user’s safety. We can verify this later in the timeline of the project by purchasing an RF meter. Please note that this has not been included in the item list in section 3.1 due to its price. We may find a more cost-effective solution in the meantime, and can always decide during the second round of PCBway orders.

In addition, considering the fact that the LED system for the bike, and the display and speaker for the car are both serving to alert the driver/cyclist, we must ensure that the notification is not jarring or overly shocking in any way. For instance, if the speaker released an extremely loud noise, or the LED was overly bright, it could distract the driver, potentially even causing an accident. As such, we must ensure that the notifications are mild in volume and brightness, while still having it be noticeable enough that the user will always receive the alert. For the bike, we can verify this by testing the brightness of the LED in different lighting conditions on different people, and ensuring that it never startles them while their focus is elsewhere. For the car, we don’t anticipate the display to be a problem. We can simply use a reasonable volume for the speaker, and test this in a similar fashion to the bike's LED. Naturally, we will ensure that our alerts are still easily noticeable by our test subjects, which will hopefully behave similarly for the users.

Works Cited:

[1] *Mountain bike Advanced phone holder 3D print model*. .

[2] ROBO3D, *UNIVERSAL SMART PHONE CAR VENT MOUNT*. 2021.

[3] “Atmega328p datasheet - microchip technology,” *Microchip*. [Online]. Available: https://ww1.microchip.com/downloads/en/DeviceDoc/Atmel-7810-Automotive-Microcontrollers-ATmega328P_Datasheet.pdf. [Accessed: 24-Feb-2023].

[4] “RF transmitter and receiver link kit - 315mhz/433mhz,” *Digikey*. [Online]. Available: https://media.digikey.com/pdf/Data%20Sheets/Seeed%20Technology/RF_Transmitter_Receiver_LinkKit_315MHz_433MHz_Web.pdf. [Accessed: 24-Feb-2023].

[5] *How To Use 16x2 LCD with Atmega328p,168,88,8, How To Burn Bootloader on Atmega8 without using XTAL*. YouTube, 2022.

[6] S. Friedner, “In car mobile signal attenuation report - Ofcom,” 08-Nov-2017. [Online]. Available: https://www.ofcom.org.uk/__data/assets/pdf_file/0019/108127/in-car-mobile-signal-attenuation-report.pdf. [Accessed: 24-Feb-2023].