# Wireless Bicycle Signaling System

Kevin Tian

Larry Liu

Suriya Kodeswaran

TA: Xinrui Zhu

ECE 445 Project Design Document

Team #38

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# Contents

# I. Introduction

*1.1 Objective and Background*

In today's society, bicyclists continue to utilize hand signals to communicate their intended direction of turning to other cyclists and vehicles. We aim to eliminate the need for hand gestures as they sometimes pose a lack of physical clarity (especially at night) as well as provide more convenience for riders in keeping their hands on handlebars. "In 2015 in the United States, over 1,000 bicyclists died and there were almost 467,000 bicycle-related injuries" [1]. Numerous of these deaths result from vehicle drivers having low visibility of other road bikers either at night or miscommunication from unclear bicycle signaling. Our project aims to resolve this issue through small modules fitted to bicycles.

On the front of the bicycle, two pressure sensing handlebar pads will slipped onto the inner sides of both handlebars, which we will refer to as pressure sleeves. On both sides of the handlebars, will be accelerometers. Attached to the bottom-side of the bicycle seat will be a module holding LED lights as well as a Bluetooth receiver. The system will work as follows: When a cyclist is ready to signal turning, he/she would squeeze the pressure sleeve corresponding to the right or left turn. These pressure signals detected by our PCB board (mounted on the front-side) will transmit a Bluetooth signal to the receiver connected to the LED lights. The appropriate LEDs will light up to display the cyclist's intended turn. After the cyclist completes the turn, our accelerometers will detect the bicycle returning to a straight path. This action will trigger another wireless signal sent to the LEDs and turn them off.

Additionally, another module we'll attach to the back of the bicycle includes an encasing of ultrasonic sensors and another set of LED lights. When these sensors detect another object approaching the bicycle too closely, a signal would trigger these LEDs to start flashing. The goal is to prevent collisions when other vehicle drivers become unaware of or do not see the cyclist. There will also be a switch to turn this safety feature off.

Evidently, our approach provides more than simply convenience for cyclists, but also promotes better road safety as it's shared by countless other cyclists and road vehicles. The rest of this proposal paper will outline a list of hardware components necessary to complete this project, show various block diagrams of the connected parts in our system, discuss high-level implementations of our hardware features in more detail, elaborate on risk analysis, safety, ethics and resources.

### *1.2 High Level Requirements*

- When user presses the pressure sensor on the handlebar the respective arrow light should turn on
- After user completes the indicated turn, the turn-signaling lights should then turn off
- After a certain amount of time, the turn-signaling lights should turn off if they're still on
- A rear light on the back of the bicycle should turn on indicating when there is an object within a certain distance behind the bicycle (collision prevention).

# 2. Design

*2.1 Block Diagram*

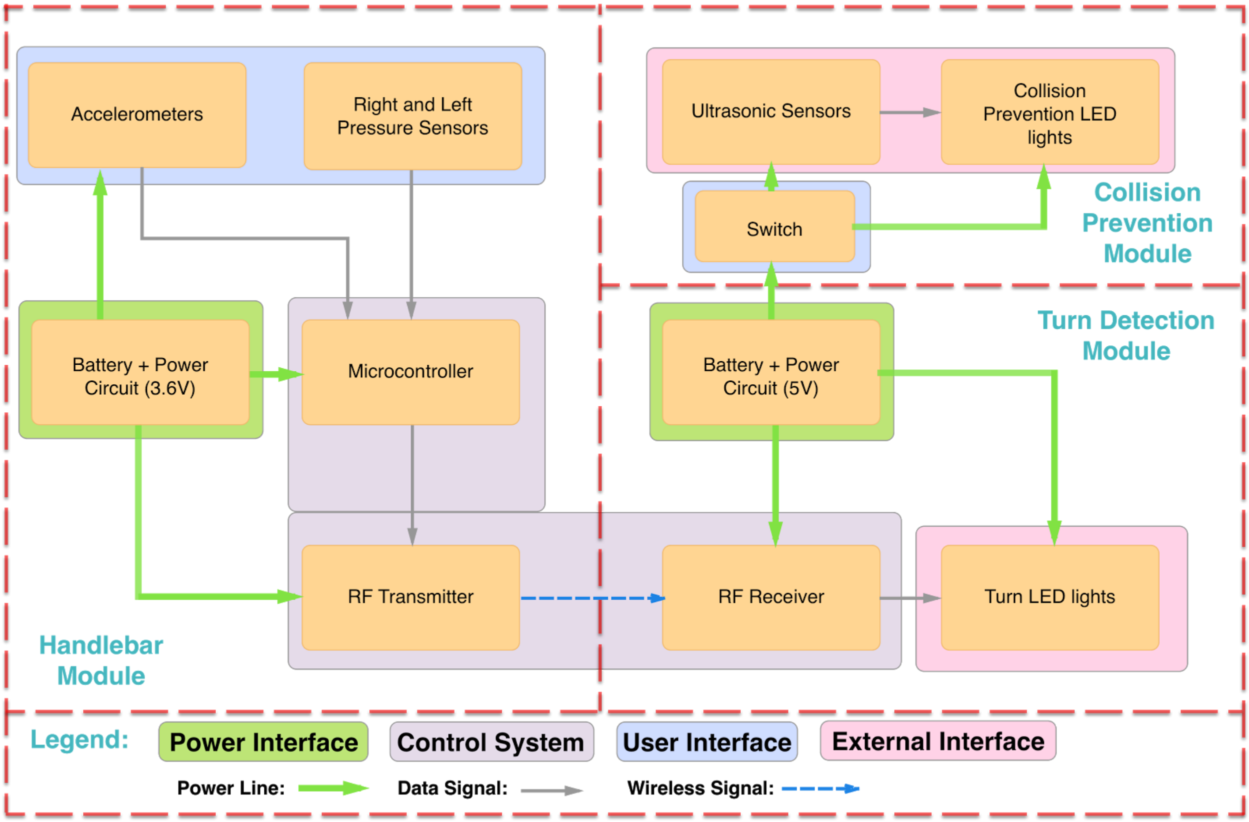


*Figure 1. Block Diagram of Wireless Bicycle System*

Our model follows an action-reaction design whereby movements by the biker influences the state of the turn-lights. The pressure sensor must be able to detect if the biker indicates that he is turning and relay this information to the lights. The lights must clearly and timely signal where the biker is turning towards with no false-positives, as they would cause confusion for other bikers/drivers. Finally, the accelerometers must be able to detect when a turn has come to a stop without needing attention from the bike. This is in order to notify other road-goers as well as creating a fail-safe against the biker forgetting to turn their signals off.

*2.2 Physical Design*

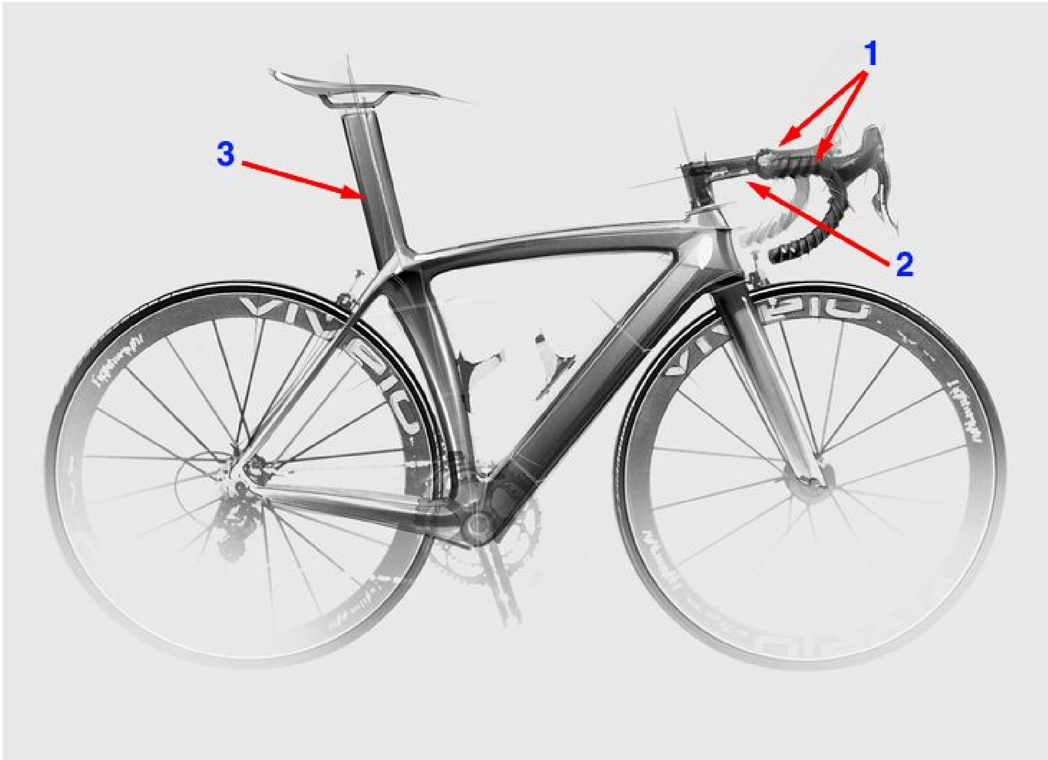


*Figure 2. Road bicycle annotated with placement locations of modules*


*Figure 3. Top-down view handlebars annotated with placement of sensors*

In Figure 3, our sleeves containing pressure sensors will be fitted on the inner sides of the handlebars as shown. These soft sleeves will be small such that it would fit fine on most bicycles. These sleeves are denoted by the '1' annotation in Figure 2. Under these pressure sensing sleeves, is a module holding our microcontroller, battery, accelerometers and RF transmitter (denoted by the '2' annotation in Figure 2). The last annotation: '3', denotes the location where our Turn Detection Module and Collision Prevent Module will be placed.

*2.3 Block Design*

*2.3.1 Functional Overview:*

*2.3.1.1 Microcontroller:*

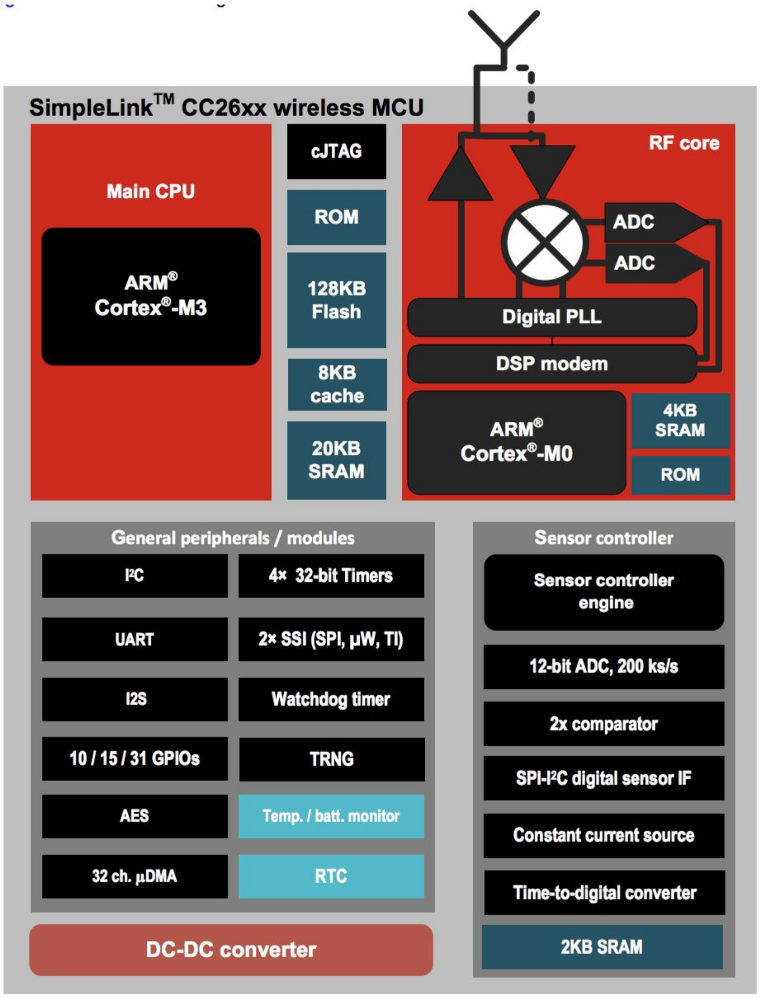


*Figure 5. TI CC2640F128RGZR Microcontroller Functional Block Diagram* [4]

Our microcontroller will serve as our processing unit for managing all sensor input signals, computing any necessary logic and outputting the desired results to the RF transmitter that is described in Section 2.3.5. The microcontroller we have decided on is the CC2640F128RGZR from Texas Instruments. We have 31 GPIOs as well as 128KB of flash and 20KB of SRAM which is more than enough interfaces and memory to communicate with the sensors we use and process the data from the sensors. We mainly chose this microcontroller because it already comes with a Bluetooth low energy module that will allow us to send the data from our sensors to the RF receiver.

*2.3.1.2 Power Sources:*

There will be two power sources, one located at the front of the bike near the handlebars, and one in the back. The power source in the front will help run the microcontroller as well the accelerometers and RF transmitter located near there. The power source in the back will power the LEDs, the RF receiver, and the ultrasonic sensor. These power sources will be 5V and will run on alkaline rechargeable batteries. Our physical design must be compact and will revolve around proper placement and utilization of the power sources. We will utilize a voltage regulator to ensure constant voltage sources to our components that require power.

*2.3.1.3 Pressure Sensor (x2):*

*Figure 6. Force Sensitive Resistor 0.5"* [3]

For our pressure sensors, we intend to use two force sensitive resistors, with one mounted on the inside of each handlebar. The sensors will only be half an inch in diameter and will be easily accessible to the biker, but will also be positioned conveniently so as to not be accidently pressed. The resistors will respond to touch and force, with more force on the sensor yielding a lower resistance. The default resistance is 1MΩ. We can design a Variable Force Threshold Switch using this sensor, such that a sufficient input force can trigger a voltage which will be relayed directly to the microcontroller. This circuit is drawn in shown and described on Figure 10. The two sensors will be independent of each other, and the microcontroller will control the logic of communicating to the turn-lights when to turn on and off.

*2.3.1.4 Accelerometer (x2):*

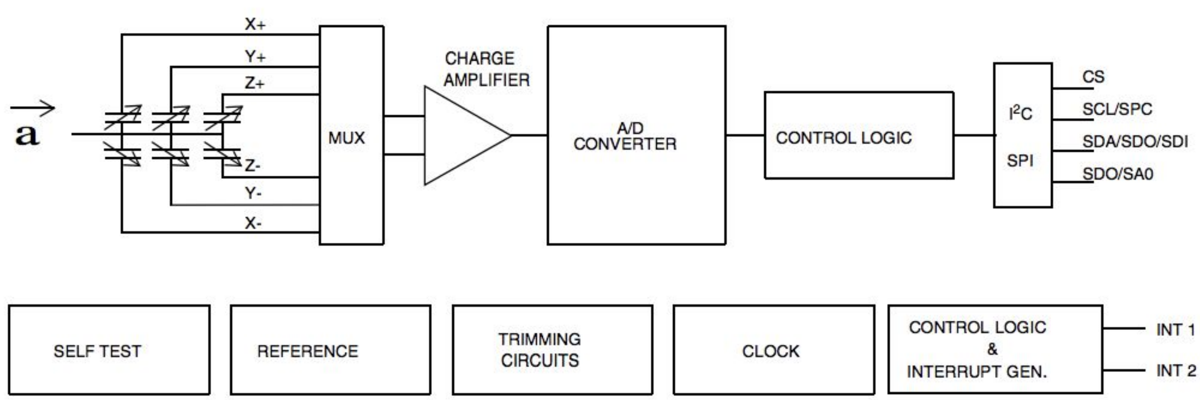


*Figure 7. Triple Axis Accelerometer Breakout - LIS331 Block Diagram* [5]

Two accelerometers will be mounted on opposite ends of the handlebar. The accelerometers should be able function on all 3 axes and detect changes in acceleration (speed and direction!) in both handlebars. Together, they should be able to accurately relay when the handlebars are done turning and the biker is going in a straight line. The biker will have initiated a turn when the accelerometers experience acceleration in different directions, caused by the swivel of the handlebar and the front wheel. When both accelerometers then experience the same acceleration in the same frontwards direction, the driver must be going straight again. The accelerometers will communicate directly with the microcontroller, which will implement the logic as well as propagate the correct command to the LEDs on the back of the bike. The accelerometers will be powered by the 5V power source at the front of the bike.

*2.3.1.5 RF Receiver:*

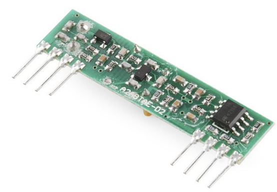

*Figure 8. RF Receiver* [6]

An RF transmitter is included in the MCU that we have selected, which will be included near the handlebar of the bike and will control message transmission from the front to the back of the bike. The microcontroller will process inputs from the accelerometers and pressure sensor, indicating what message is should convey. The messages that we want to send would be to turn left light on, left light off, right light on, or right light off. These messages can be encoded into two bits that can be sent if the microcontroller sees that the state of the lights must be changed. The RF receiver will be mounted on the back of the bike with the light submodules. Depending on the command word received from the transmitter, it will either power on or power off the respective lights. After the receiver detects the necessary command word, only circuit logic will be used to determine what action to take.

*2.3.1.6 Ultrasonic Sensor:*

*Figure 9. Ultrasonic Range Finder: LV-MaxSonar-EZ2* [7]

The collision prevention module is intended to work separately from the turn detection module. The core of the module is composed of an Ultrasonic Sensor which will be peering behind the biker to detect if a car or another biker is there. The ultrasonic sensor can take 5V of input power supplied by the batteries already located at the back of the bike. The sensors output is an analog signal that scales with distance by a factor of ~10mV/in. This sensor will control a set of collision prevention LEDs (separate from our turn-lights) which will produce a light if an object is behind the biker.

The biker can manually flip a switch to override this process and guarantee that the lights remain off, which could be useful is they are biking in a group. This module is designed to keep bikers safe in the dark by warning drivers behind them, as well as being power efficient, because the lights will only turn on when a driver is nearby.

*2.3.1.7 LEDs:*

Two sets of turn lights will be located at the back of the bike, underneath the seat. These lights will consist of bright yellow LEDs arranged in an arrow shape, which will indicate the direction the driver is going in. These lights will will receive commands from the microcontroller. The RF receiver will read in these commands and divert current to the respective section of LEDs. The LEDs will be powered by the 5V power source located in the back of the bike. Another two sets of LEDs will form an outline of an arrow shape around each of the two turn signals. These LEDs will be controlled separately by circuit logic from the Ultrasonic Sensor, most likely using a transistor, and will light up if something is detected behind the biker. These lights will stay on and show the bikers position, providing them extra safety in the dark. These LEDs are our project’s major signal to the external world and must always display accurate information.

*2.3.2 Block Requirements and Verification*

*2.3.2.1 User Interface*

| Requirements | Verification |
|---|---|
| Variable Force Threshold Switch:<br>1. When a 3 pound force is exerted on the pressure sensor we should | 1a. Connect the resistor to a 5V power source and an ammeter. Pressing the sensor should increase the current that flows through it (No specific information provided |

| | |
|---|---|
| see 5V output out otherwise it is 0V with a tolerance of +/- 25%<br>Figure 10<br>**15 points** | on data sheet, must test and set threshold ourselves)<br>1b. When there is no force applied there should be 0V outputted measured by multimeter<br>1c. With 3 pounds of force we should see around 5V measured by multimeter |
| Accelerometer [5]:<br>1. When turning left the accelerometer on the left handlebar should have a value of -4 g while the accelerometer on the right handlebar should have a value of 4 g and the reverse when the bike is turning right.<br>**10 points** | 1a. Use our MCU to read in data from the accelerometer to make sure we our values work out while simulating the a turn caused by the handlebar.<br>1b. The LED's on the seat should turn off when the turn is almost complete. |
| Ultrasonic sensor [7]:<br>When there is a car or another bike within 120 inches behind the biker a LED should turn on. We will give this a tolerance of +/- 10 inches.<br>**15 points** | 1a. Whenever we place an object within 120 inches of the sensor, with a power source of 5V, pin 3 (analog output) of the Ultrasonic Sensor should output at least a minimum voltage of ~1.2V (from datasheet)<br>1b. When object is within 120 inches then trigger a set of LED's to turn on. |
| Switch:<br>1. Controls power to Collision Prevention LEDs<br>**5 points** | 1. Supply power to the collision prevention LEDs (consult figure 10, V_IN) with a 5V source. Ensure flipping the switch turns off the lights, and flipping it back restores them again. |

*2.3.2.2 Control System*

| Requirements | Verification |
|---|---|
| Microcontroller [4]:<br>1. 3.6V at 8mA with a tolerance of +/- 10%<br><br>2. Send data across bluetooth at a rate of 4800 bps<br>**25 points** | 1. Use a multimeter to test there is a 3.6V with 8mA of current going into the MCU.<br><br>2. Send a message from the microcontroller to the RF receiver and use an oscilloscope to read the message from the MCU from the digital out pin.<br><br>3. Turn LED on when data from accelerometer indicates a turn has been completed |
| RF Receiver [6]: | 1. Use a multimeter to measure there are 5V going |

| | |
|---|---|
| 1. Operates at 5V<br>2. Reads in data at 4800 bps and different messages should trigger different LED's to turn on<br>**10 points** | into the receiver<br><br>2a. Send a message from the microcontroller to the RF receiver and use an oscilloscope to read the message from the MCU from the digital out pin.<br>2b. Given these different messages see which LED's turn on. |

*2.3.2.3 Power Interface*

| Requirements | Verification |
|---|---|
| 1. The power supply will give us 3.7 volts of power that can supply us around 2000mAh with a tolerance threshold of +/- 10%.<br>**10 points** | 1. Measure the power supply with a multimeter to see if we are getting 3.7 V with +/- 10%. |

*2.3.2.4 External Interface*

| Requirements | Verification |
|---|---|
| 1. Specific LED lights should turn on when signal is received.<br>**10 points** | 1a. When the right pressure sensor is squeezed then the LED's that correspond to the right arrow and left pressure sensor should trigger the left arrow<br>1b. When an item is detected by the Ultrasonic Sensor, the Collision prevention lights should light up. |

*2.3.3 Supporting Material*

*2.3.3.1 Circuit Schematics*

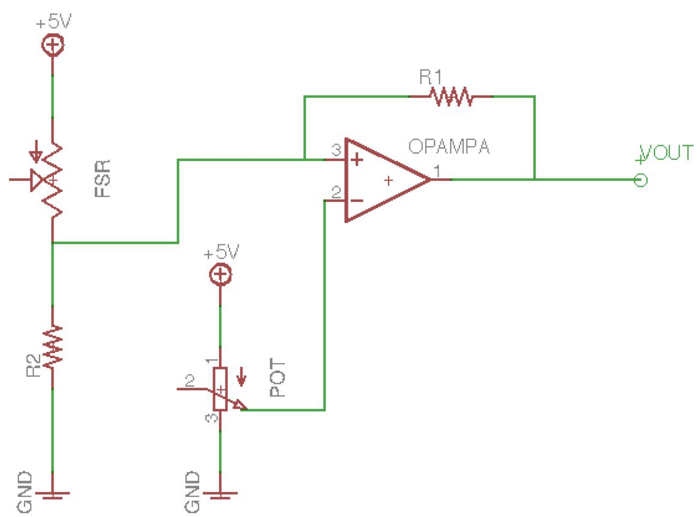


*Figure 10. FSR Variable Force Threshold Switch*

The circuit displayed above shows the design of the FSR Variable Force Threshold Switch that will be located in our circuit. There will be two of these modules located near our handlebars. The FSR component located near the top left of the circuit is a Force Sensitive Resistor, which will reduce its resistance when force is applied, which will increase the voltage inputted into the positive node of the op-amp. When the voltage at the positive end surpasses the voltage provided at the negative end through a potentiometer, the output of the op-amp will spike from 0V to a positive number. The output can be fed directly to an IO pin of the microcontroller, where the information can be processed and transmitted. The datasheet for our force sensitive resistor was not too descriptive, so we will have to test the circuit ourselves and set our own thresholds, so the values for our desired resistances cannot be given yet.

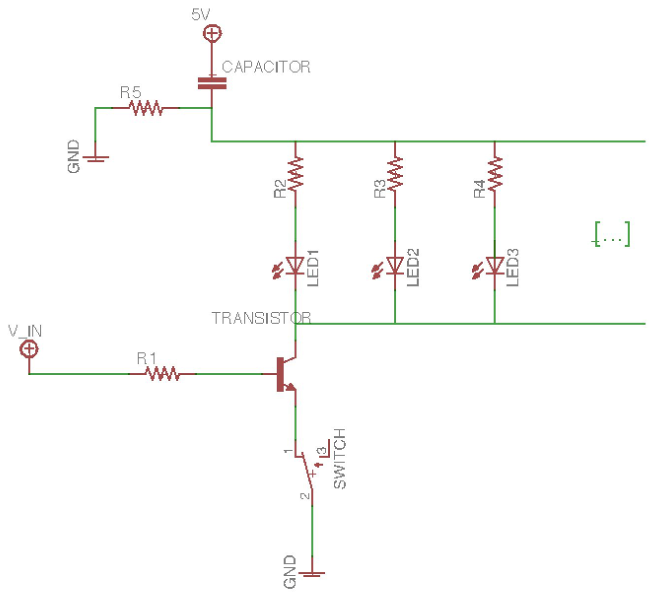


*Figure 11. Collision Prevention LEDs and Switch.*

*V_IN is typically powered by the Ultrasonic Sensor*

Above is a circuit schematic for our switch and collision prevention LED. The transistor will act as a voltage activated switch to close the connection, and will be activated when a sufficient input is given through V_IN. V_IN will be connected to the analog output of the Ultrasonic sensor, which we must test and calibrate so that we can determine R1. We include a capacitor and R5 in the top left of our circuit to denote an RC oscillator that will allow our LEDs to flash on and off. The actual specifications of the resistors, transistor and capacitor have to be tested to determine our required values. The switch will also cut the current flow of all of the LEDs, thus turning them all off it is disconnected.

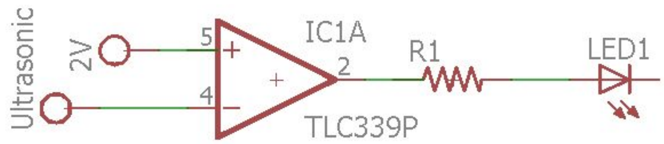


*Figure 12. Circuit to determine when LED should turn on when object gets too close to bike*

Above is a circuit schematic for the ultrasonic sensor that turns on a LED when an object is too close to the car. The ultrasonic increases in voltage as an object increases in distance away from the sensor. When the negative input terminal is greater than the positive input terminal of the comparator then the comparator outputs 0V. When an object gets too close the 2V would be greater than the voltage outputted by the ultrasonic sensor, the comparator will then output 5V which turns on the LED.

*2.3.3.2 Simulations*

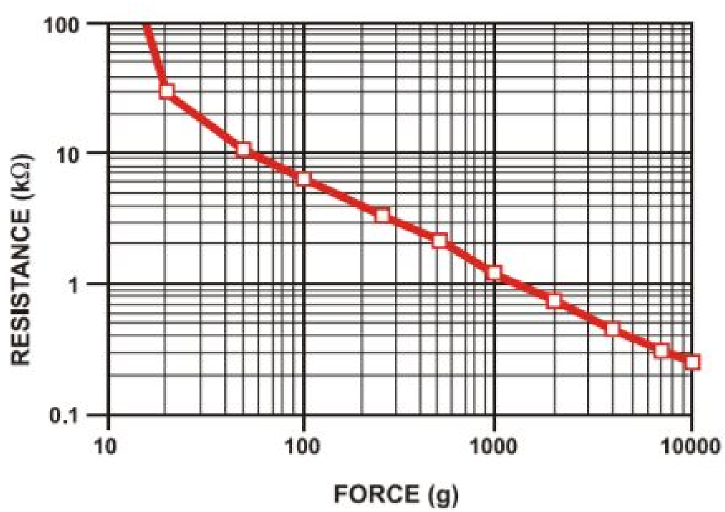


*Figure 13. Force vs. Resistance plot for Pressure Sensors* [3]

*2.3.3.3 Calculation*

1. Microcontroller Power Consumption [4]

The CC2640F128RGZR microcontroller will be powered by a 3.6V battery from the power component. The MCU has an optimal range of 1.8V to 3.8V so we set the input voltage to be 3.0V. To operate the accelerometers, pressure sensors, and the bluetooth module we require a current of 10.2mA.

$$\text{Power (P)} = I * V$$
$$= 10.2\text{mA} * 3.0\text{V}$$
$$= 30.6\text{mW}$$

Two AA batteries we are using will give is 3.0V at 2500 mAh.

This gives us 2500/10.2 = 245 hours worth of time to power the circuit at the front of our bike.

2. RF Receiver Power Consumption [6]

The RF receiver takes in 5V of power but the data sheet does not supply us with any information on required current however based off of other RF receivers it is around 5mA.

$$\text{Power (P)} = I * V$$
$$= 5\text{V} * 5\text{mA}$$
$$= 25\text{mW}$$

3. Ultrasound Power Consumption [7]

The ultrasound takes in 2.5V to 5.5V at 2mA of current draw. As a result we will set a voltage of 3.7V.

$$\text{Power (P)} = I * V$$
$$= 3.0\text{V} * 2\text{mA}$$
$$= 6.0\text{mW}$$

For the circuit at the back of the bike we estimate the LED's, ultrasound sensor, RF receiver and our logic chips will use about 15mA at 3.0V.

Using the same model AA batteries as the front of the bike we will use 2 AA batteries.

This will give us about 2500/15 = 166 hours to power everything in the back.

*2.3.3.4 Measurements*

Pressure sensor - Once the pressure sensor reaches 3 pounds of forces or above then it will trigger the respective light to turn on.

Accelerometers - To determine when the bike is turning left the accelerometer on the left should measure at least negative 4 grams of force in the x direction while the accelerometer on the right should measure at least positive 4 grams of force in the x direction and these values are reversed for when the bike is turning right.

Ultrasound sensor - The ultrasound sensor will cause a light to turn on on the handlebar once the ultrasound sensor “sees” an object at least within 120 inches from the sensor itself.

*2.3.3.5 Flowchart*

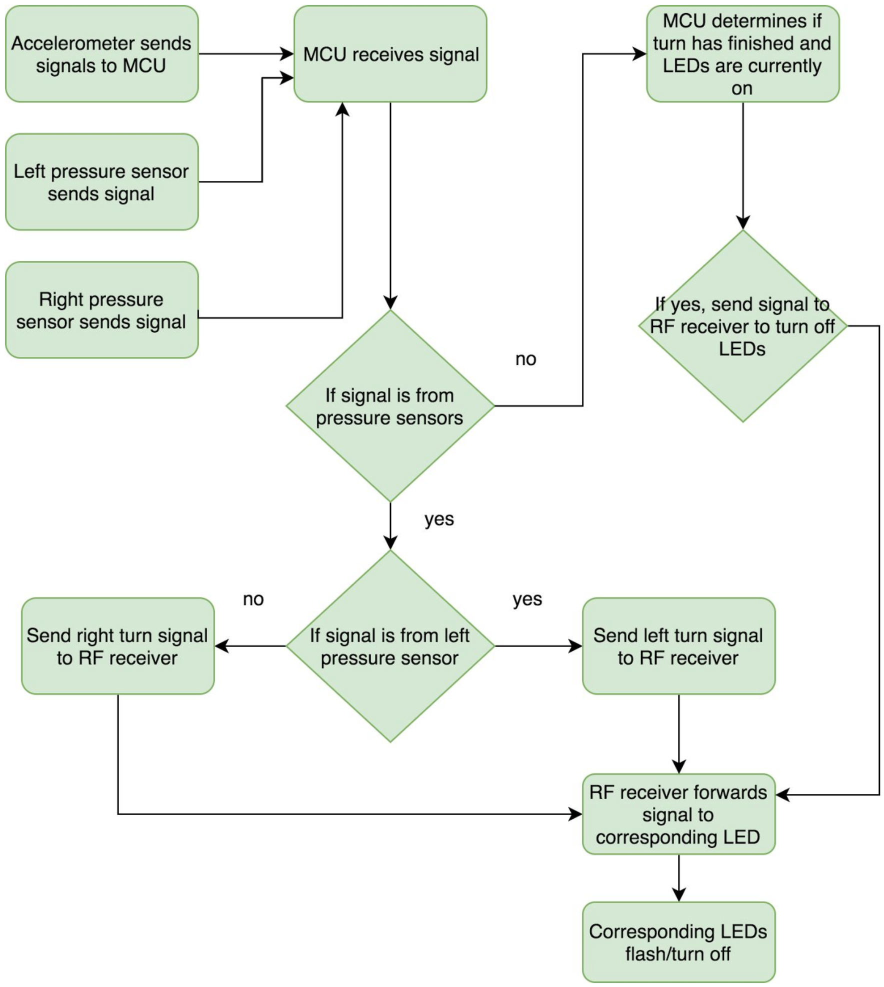


*Figure 14. Signaling System Flowchart.*

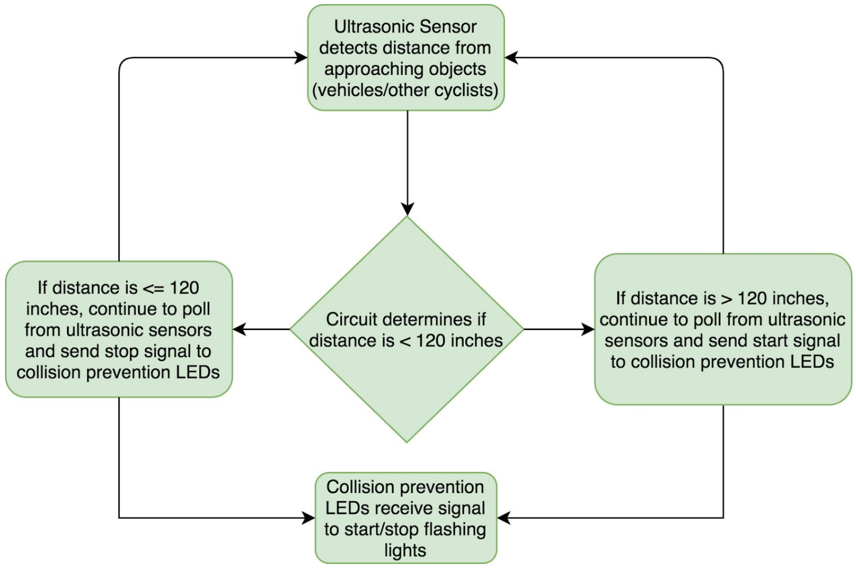


*Figure 15. Collision Prevention System Flowchart.*

*2.4 Tolerance Analysis*

We estimated the average force an average person would comfortably squeeze would be around five pounds. As a result we wanted to set our threshold for the pressure sensor to be 3 pounds which would make a person to actually squeeze the sensor and there wouldn't be any false positives.

*Risk Analysis*

The most difficult component of this project will be connecting the control system together. The microcontroller must rely on the RF transmitter and receivers to function properly in order to deliver the results of user input signals to the appropriate LEDs. We believe it will be very difficult to thoroughly test the wireless communication aspect, being Bluetooth, on various metrics such as reliability and power consumption. Moreover, if we are unable to transmit signals wirelessly, inputs from the cyclist will remain useless. As a group, none of us have any experience working with transmitter/receiver devices that are used for wireless communication. It will take much research, understanding and analysis on our parts before we can successfully integrate two major pieces of this system together through this specific communication medium.

# 3. Cost and Schedule

*3.1.1 Parts Cost*

| **Part** | **Model** | **Unit Cost** | **Quantity** | **Total** |
|---|---|---|---|---|
| Microcontroller | TI CC2640F128RGZR | $4.60 | 1 | $4.60 |
| Ultrasonic Range Finder | LV-MaxSonar-EZ2, SEN-08503 | $27.95 | 1 | $27.95 |
| Force Sensitive Resistor 0.5” | SEN-09375 | $5.95 | 2 | $11.90 |
| Triple Axis Accelerometer Breakout | LIS331 | $9.95 | 2 | $19.90 |
| RF Link Receiver - 4800bps (434 MHz) | WRL-10532 | $4.95 | 1 | $9.90 |
| Resistors | | $0.5 | 20 | $10 |
| Switch | ECE shop switch button | $1 | 0 | $1 |
| Lithium Ion Batteries (3.6 V) | Energizer AA batteries | $5 | 1 | $5 |
| Capacitors | | $0.5 | 8 | $4 |
| Inductors | | $0.25 | 5 | $1.25 |
| **Total** | | | | **$90.50** |

*3.1.2 Labor Cost*

We are estimating a fixed salary rate of $30/hr for each employee. Because there are 3 people working, we multiply this by 3, by 2.5 on the fixed rate and finally by the time of development.

3 * $30/hr * 2.5 * 12 hrs/week * 14 weeks = **$37,800**

*3.1.3 Total Cost*

The total cost of parts and labor is $90.50 + $37,800 = **$37,890.50**.

*3.2 Schedule*

| Week of: | Person | Responsibility |
|---|---|---|
| 10/2 | Larry Liu | Design Doc: Introduction, Design, Cost/Schedule, Ethics/Safety<br>Order parts |
| | Kevin Tian | Design Doc: Design: Supporting Material |
| | Suriya Kodeswaran | Design Doc: Design, Ethics/Safety |
| 10/9 | Larry Liu | Design Review, Inspected ordered parts, set-up MCU programming environment, verify schematics, continue ordering parts |
| | Kevin Tian | Design Review, pressure sensing sleeve circuit |
| | Suriya Kodeswaran | Design Review, PCB layout for control boards |
| 10/16 | Larry Liu | Create logic for MCU to process pressure sensor inputs and output appropriate wireless signals. |
| | Kevin Tian | Finish pressure sensing sleeve circuit |
| | Suriya Kodeswaran | Examine accelerometers requirements and RF receiver (both receive input signals from the MCU). |
| 10/23 | Larry Liu | Assemble control board. Work on power circuit. |
| | Kevin Tian | Start on collision prevention module: ultrasonic sensor → LED circuit |
| | Suriya Kodeswaran | Work on RF receiver circuit containing turn LEDs. |
| 10/30 | Larry Liu | Finish power circuit for signaling system. |
| | Kevin Tian | Calibrate ultrasonic sensor circuit. |
| | Suriya Kodeswaran | Calibrate accelerometers for detecting end of a turn. |
| 11/6 | Larry Liu | Create encasings for battery holder. Start on power circuit for collision prevention module. |

| | | |
|---|---|---|
| | Kevin Tian | FInish ultrasonic sensor circuit. |
| | Suriya Kodeswaran | Finish wireless signaling system. |
| 11/13 | Larry Liu | Final fixing of power-related circuits. Ensure waterproofness of battery holders. |
| | Kevin Tian | Final testing of collision prevention module. |
| | Suriya Kodeswaran | Final testing of wireless signal system. |
| 11/20 | Larry Liu | Work on final paper. Will check over intro, requirements, diagrams and ethics sections. |
| | Kevin Tian | Work on final paper. Will check over R&V section. |
| | Suriya Kodeswaran | Work on final paper. Will check over circuit diagrams. |
| 11/27 | Larry Liu | Mock demo. Responsible for ensuring physical parts for mock demo are working properly before demo. |
| | Kevin Tian | Mock demo. Responsible for taking notes on feedback. |
| | Suriya Kodeswaran | Mock demo. Responsible for working out demo timeline. |
| 12/4 | Larry Liu | Demo. Responsible for physically showing the demo. |
| | Kevin Tian | Demo. Responsible for mapping out the demo process. |
| | Suriya Kodeswaran | Demo. Responsible for bringing all parts to demo. |
| 12/11 | Larry Liu | Presentation. |
| | Kevin Tian | Presentation. |
| | Suriya Kodeswaran | Presentation. |

## 4. Ethics & Safety

The greatest ethical concern for our project is the potential of placing the cyclists and the people around them in more danger than if they have never used our system in the first place. For example, if the user gets used to routinely utilizing our product and assumes the turn lights will always turn on when the switch is flipped, there may be unexpected consequences. These negative consequences may result from broken or faulty lights; thus, putting the cyclist at more risk than he or she would normally be. Thus, this is our primary focus in ensure Conduct 1 of the IEEE Code of Ethics is not violated [2]. The rest of the conducts (Conduct 2-10) will not be concerns for us for the following reasons: there is one clear objective for this project, there will be an organized structure for how are components are verified and constructed, there is no sponsorship, there will be emphasis on following safety procedures and guidelines, we will hold the responsibility in the safety of potential users, and the agreement that we must work together in an organized, professional environment.

The first safety concern we need to address is making sure that our device does not change how the user would operate the bike normally and making sure that our sensors will not interfere with the functionality and safety of the bike. Additionally if the cyclist were to fall off the bike we want to make sure none of the components in our design could potentially shatter and inadvertently hurt the cyclist.

Additionally, we will use alkaline batteries as we were told that lithium-ion batteries pose many hazards. It will become our full focus to ensure that our project is both functional and safe; otherwise, it would defeat the purpose of the attached components mentioned in this design.

Another safety feature we need to implement is making sure our electronics and circuitry are well covered. Because the parts will be open to nature, we need to ensure that forces such as wind, rust and rain do not interfere with our circuitry. Furthermore, any electrical connections such as on our PCB or power sources must be enclosed in a casing. This is so that any rain will not cause the circuit to short and potentially harm the user. Simple cases can be bought online or printed by us after we complete our circuit and make it as compact as possible.

## 5. Citations and References


[1] Centers for Disease Control and Prevention (CDC). Web-based Injury Statistics Query and Reporting System (WISQARS). Atlanta, GA: Centers for Disease Control and Prevention, National Center for Injury Prevention and Control. Available at www.cdc.gov/injury/wisqars. Accessed on 09/19/2017.

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