Rear Collision Bicycle Warning System

ECE 445 Design Document

Jusin Davis, Gus Kroll, Seongwoo Kang
Group 71
TA: Xihang Wu

1 Introduction

1.1 Objective

According to the Insurance Institute for Highway Safety (IIHS), 854 cyclists were killed and more than 47,000 cyclists were injured in motor vehicle crashes in 2018 [1]. Since 2010, the number of cycling fatalities per year has increased by 38% [2]. It has also been shown that the likelihood of cyclists suffering a severe injury resulting from a motor vehicle accident is substantially higher with SUV’s and that the overall likelihood of a collision occurring is also significantly higher for hybrids and electric vehicles[1]. With an increasing number of SUVs on US roads and the growing adoption of electric vehicles, the number and severity of motor vehicle accidents involving cyclists is likely to increase in the short-term.

To counteract this expected rise in the number of accidents and fatalities in bicycle-motor vehicle collisions, we propose an affordable rear collision warning system for bicycles. This unit will be able to detect vehicles behind the cyclists and notify them of a vehicle's presence via an audible alert. It will also include an integrated tail light that will flash when it detects a vehicle in an attempt to alert the driver of the cyclist's presence on the road. It will also function as a sort of black box for the rider. The included camera will always be on and will be triggered to save data by a collision and/or when a vehicle is detected as being exceptionally close and moving quickly next to the bike. This system will allow the rider to focus on what is happening in front of them, giving them the peace of mind that our sensor will warn them about what is going on behind them.

1.2 Background

There are currently just a few bike dash cams and only a single rear collision warning product available on the market. No one has yet combined these two features into an all-in-one bike safety device. Garmin’s product has a detection range of 150m and requires the use of your smartphone or external screen to give users notifications. This system is very expensive and also beyond the specification of what a more casual rider needs. Fly6’s camera system is currently available for pre-order and costs $229, yet only has a 4 hour battery life.

In order to reduce the likelihood of an accident and catch aggressive drivers, integrating these two systems into a product that is more affordable, and easy to use along with a longer battery life should make this product more appealing to a wider group of riders. We propose to reduce the detecting range to 75m, with the assumption that riders will not be riding in areas where the maximum speed a car will be traveling is greater than 55mph. This will give a rider a minimum of 3 seconds notification that a vehicle is approaching from behind. Then in the event of a collision or fast-moving object near the cyclist, the built-in camera will save the preceding video/audio to be used as evidence after the fact.

1.3 Physical Design

Figure 1: Device Location

#1

All of our components except the external unit (vibrating motor) will be encased in a protective box and attached to the seat support to collect data.

#2

The vibrating motor will be attached to the bottom of the seat as an external unit and alerts the user of incoming vehicles/ objects. It's intensity will vary depending on the moving object's speed and distance from the user.

1.4 High-level requirements

- Detect objects coming towards the unit at a distance of at least 75m, while maintaining a false positive rate <15%.
- If the user selects trigger mode, the device is able to trigger video and audio save based on detection of collision with the cyclist, while continuing to record (if the sensor was not damaged) until stopped by the user or memory is exhausted.
- Upon detection of an object, the time to trigger a response to the rider should be less than 750ms.

2 Design

2.1 Block Diagram

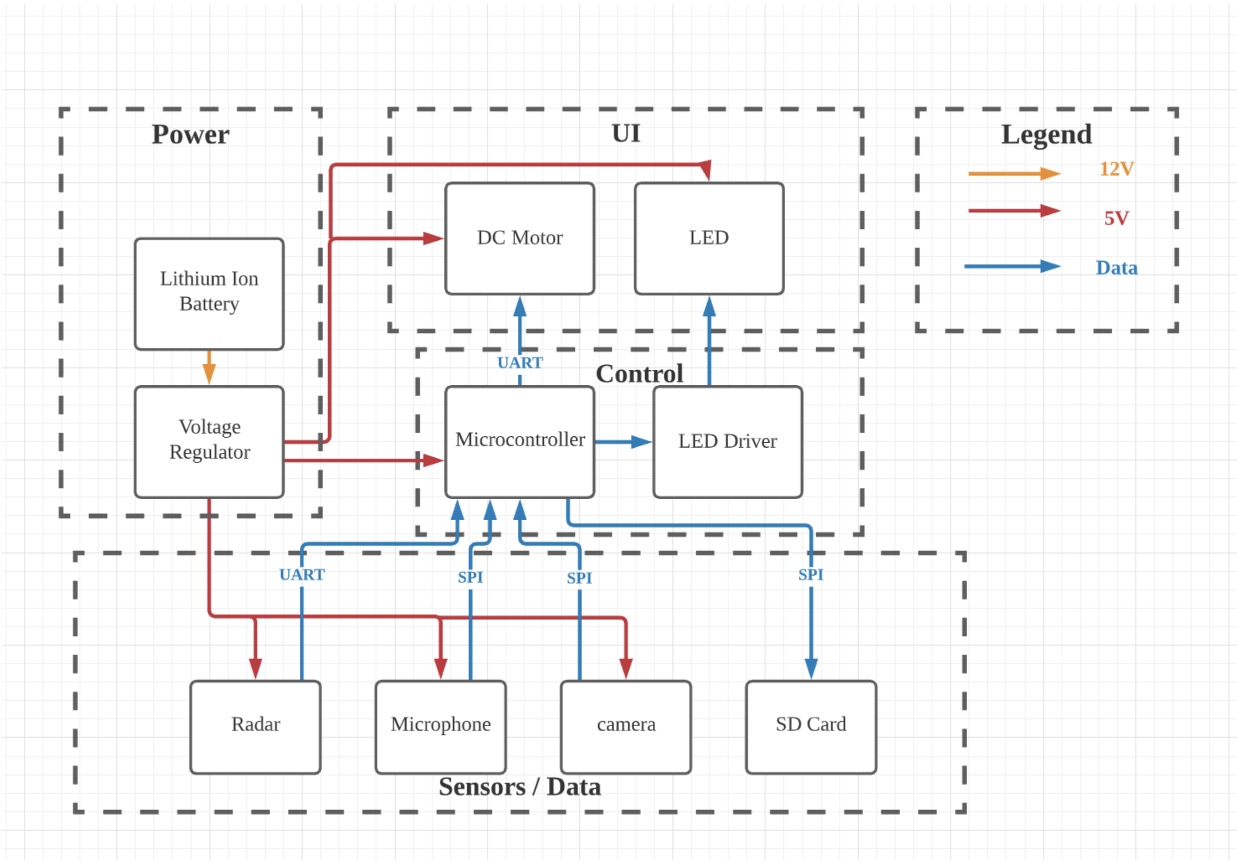

Figure 2: Block Diagram

2.2 Power

2.2.1 Battery

We will need enough battery so that the user does not have to recharge everyday. Considering our main target is riders in city for commute, their average daily riding time will be around 3 hours at most. We are aiming for the system to last at least 6 hours. We will be using 12V 6000mAh battery. Battery will be safely mounted to the case along with the whole system in the box.

Component	Requirements	Verification
Li-Ion Battery	Must supply power to the system for 6 hours.	Attach the battery to the system and run the system continuously for 6 hours, ensuring that it does not lose power for that duration of time.

2.2.2 Voltage Regulator

Since different components of our system will require a constant voltage of 5V, we will require a voltage regulator to provide this constant voltage to all the components of our system.

Component	Requirements	Verification
Voltage Regulator	Must supply constant 5V to all components of the system.	A. Attach the voltage regulator to the system. B. Take voltage readings for the voltage being supplied to each component of the system using an oscilloscope.

2.3 Control

2.3.1 Microcontroller

We will be using Atmega328p as our microcontroller, as our TA has recommended. Our main functionality lies in transporting data from camera and microphone. Since Atmega328p is easily programmable using arduino bootloader, we will be able to test our codes with less difficulties. Also, its cheap price will help us distribute our budget to other significant parts such as radar.

Component	Requirements	Verification
Atmega328p	A. Must be able to control DC motor. B. Must be be able to take inputs from microphone, radar, and camera.	A. Test the output of microcontroller to see if it can control and vary voltage up to 5V to control the DC motor. B. Test with program that take input from those sensors. In order to see the action of input, we can use LED.

2.3.2 LED Driver

This component will be used to trigger the LED to blink on and off for 5s and then turn off upon detection of an object by the sensors. The radar sensors will take care of the actual detection of the object and provide this information to the microcontroller. Once the object has been detected the microcontroller will determine if the object is close enough to the device (within 75m) and is moving towards the device. If these conditions are met, the microcontroller will trigger the LED driver to obtain the desired behavior by the LED.

Component	Requirements	Verification
LED Driver	Must be able to control the LED to blink or turn off when triggered by the microcontroller.	Provide object detection conditions to the microcontroller and ensure that these conditions prompt the microcontroller to trigger the LED driver to make the LED blink for 5s and then turn off.

2.4 Sensors / Data

2.4.1 Radar

The radar sensors will be used to detect objects within 75m of the device and determine if these objects are moving towards the device. The radar sensors will provide this information to the microcontroller which will then trigger the appropriate devices based on the information provided.

Component	Requirements	Verification
Radar Sensor	A. Must be able to detect objects coming towards the device at a distance of at least 75m. B. Must be able to communicate with the microcontroller when objects are detected within 75m.	A. Walk towards the device starting out of the range of 75m and approaching within this range. B. Set a detection flag to be printed for testing purposes on the microcontroller so that we may ensure that an object is detected at the appropriate time. C. Ensure that the appropriate devices such as the LED and DC motor are triggered when an object is detected.

2.4.2 Microphone

The microphone will be used to record audio information to the SD Card in the case of an incident such as a crash or the presence of an aggressive driver. The microphone will always be on so that when an incident occurs it can save the previous 30s of audio data leading up to the incident and save the next 30s of audio data after the incident has occurred. This will ensure that we capture the full context of the incident, which will be useful for the user to retrieve later.

Component	Requirements	Verification

Microphone	A. Must always remain on while the device is turned on. B. Must be able to record the previous and next 30s of audio data to the SD card when triggered by the microcontroller.	A. Monitor the microphone's power using a status LED connected to the same power source as the microphone. B. Manually trigger the device to record by using the microcontroller. C. Retrieve data from the SD Card and ensure that it has been properly recorded for the full minute.

2.4.3 Camera

The camera will be used to record video information to the SD Card in the case of an incident such as a crash or the presence of an aggressive driver. The camera will always be on so that when an incident occurs it can save the previous 30s of video data leading up to the incident and save the next 30s of video data after the incident has occurred. This will ensure that we capture the full context of the incident, which will be useful for the user to retrieve later.

Component	Requirements	Verification
Camera	A. Must always remain on while the device is turned on. B. Must be able to record the previous and next 30s of video data to the SD card when triggered by the microcontroller.	A. Monitor the camera's power using a status LED connected to the same power source as the camera. B. Manually trigger the device to record by using the microcontroller. C. Retrieve data from the SD Card and ensure that it has been properly recorded for the full minute.

2.4.4 SD Card

The SD Card will be used to store audio and video data recorded by the microphone and camera. The SD Card will be able to store 128 gigabytes of data. Data stored on the SD Card will be able to be retrieved later by the user. This data will be useful in the case of an incident will biking because it may help the user prove that they were not at fault for legal and insurance purposes.

Component	Requirements	Verification
SD Card	A. Must be able to store audio and video data to be retrieved later by the user. B. Must be able to overwrite the oldest saved data when the SD Card reaches capacity.	A. Manually trigger the camera and microphone to record. B. Connect the SD Card to a computer and demonstrate that we can retrieve data stored on the SD Card. C. Fill the SD Card with “garbage” data. D. Manually trigger the camera and microphone to record. E. Connect the SD Card to a computer and check that the new data has overwritten the oldest data previously stored on the SD Card.

2.5 UI

2.5.1 DC Motor

For our motor, we will be using DC Motor. The power at which the motor vibrate will vary depends on the speed in which the vehicle is approaching. In case the power of a single motor is not enough, we will attach multiple motors to the seat to increase its strength.

Component	Requirements	Verification
DC Motor Vibrator, ERM	Must be able to vibrate with enough power to notify the rider through seat.	Operate the motor with 5V input and verify with physical contact through bike seat.

2.5.2 LED

The LED will be used to alert drivers behind the user of the user's presence. The LED will only be triggered when the microcontroller detects an object based on information provided by the sensor module. The microcontroller will then communicate with the LED driver so that the LED driver can turn on the LED. The LED will then blink for 5s and then turn off.

Component	Requirements	Verification
LED	Must be able to blink when triggered by the LED driver when an object is detected.	A. Manually trigger the microcontroller to communicate to the LED driver that an object has been detected. B. Ensure that the LED blinks for 5s and then turns off.

2.6 Case

The case will protect all of the electronics from moisture, dust, and weather while attached to the bicycle in an outdoor environment. To withstand potential rain, snowfall, and other unexpected environmental conditions, the case must be able to pass the IP65 enclosure standards.

Component	Requirements	Verification
Electronic Enclosure	Must be able to pass the IP65 enclosure standards.	A. Fill inside of the enclosure with a few grams of a dyed anhydrous powder such as Kool-Aide. B. Spray the case with water from a 6.3mm nozzle at 30kPa for at least 15 minutes from any direction at a distance of 3m. C. Shake the enclosure thoroughly. D. Check that all of the powder is still white and dry; if any powder has turned into the intended dye color then it has been hydrated.

2.7 Tolerance Analysis

One of the key parts of our design is battery life. We don't want the end user to need to be recharging the battery after every use. Our battery life will heavily depend on whether microphone/camera is active or not.

Our radar sensor will consume 1.7W active, which will consume 340mA operating under 5V input. Along with other components such as microcontroller, LED, Vibrating motors, Microphone will use 0.25mA, and Camera will be using 18mA when active. Also, writing collected data from microphone and camera to microSD card will take around 100mA - 150mA. Since, we want the latest camera footage stored in a microSD card, we will be wanting for the microphone/camera/SD card to operate together, and this system alone will take 170mA at worst. WIth LED and motors added, it sums up to 200mA Most of our core functionality that consumes a significant amount of power are only activated only when radar successfully detects possible danger.

With sensors other than radar inactive, our system will last approximately 15 hours with a 6000mAh battery. However, if components continue to be active due to false positives, it can significantly reduce the battery life below 10 hours. Thus, it is a significant part of our project to program and test our radar in order to prevent false positive rates.

3 Cost and Schedule

3.1 Cost and Components

Part	Cost	Quantity	Total
DC Motor Vibrator, ERM	$1.95	1(+3 in case not enough power)	$7.80
Atmega328p	$2.20	1	$2.20
TalentCell Battery	$37.99	1	$37.99
Voltage Reg(L7806CV)	$0.49	1	$0.49
Micro SD card(128GB)	$19.99	1	$19.99
Camera(OV7670)	$9.59	1	$9.59
LED Driver (STCS1APUR)	$2.59	1	$2.59
microphone MEMS	$0.92	1	$0.92
OmniPreSense OPS243	$209	1	$209

Assorted Resistors, LEDs, Capacitors	$10.00	X	$10.00
Total		9+X	~$300

3.2 Schedule

Week	**Gus**	**Justin**	**Seongwoo**
3/8	Refine Circuit Schematic	Order Parts	Refine Circuit Schematic
3/15	Order PCB	Begin Code	Begin Code
3/22	Continue Coding	Continue Coding	Continue Coding
3/29	Assemble Device	Assemble Device	Continue Coding
4/5	Debug Hardware	Debug Hardware	Debug Software
4/12	Finish Debugging/Testing	Finish Debugging/Testing	Finish Debugging/Testing
4/19	Demo Prep	Demo Prep	Demo Prep
4/26	Demo	Demo	Demo
5/3	Final Paper	Final Paper	Final Paper

4 Ethics and Safety

Our device makes use of a haptic motor attached to the bottom of the bike seat to alert the user of incoming vehicles/objects. If the motor runs too robust, it will interfere with riding rather than serving as a warning mechanism, so the power of vibration must be moderated carefully.

Our device will be used outdoors attached to a moving bike, so it will have to sustain a significant amount of dust and water along with impact in case of collision. Thus, the device will be encased in a protective box that meets the IP65 [3] enclosure standards.

Working with Lithium Ion batteries can potentially be dangerous so we will take care to follow all of the necessary protocols when providing power to our device. We will never work near water or other liquids and will take precautions to make sure that sensitive components like the lithium ion battery and voltage regulator are always separated from potentially hazardous materials.

Even though our device alerts the user of potential danger around them, it is still their responsibility to constantly monitor their surroundings since there is always a possibility for malfunction in the device. However, being accustomed to the functionality of the device, users can often forget to do so. It is our responsibility to ensure their safety from accidents that can possibly be caused by the device, which is inline with Code of Ethics I.1 “To accept responsibility…” [4]. We will strive to accomplish this by emphasizing safety procedures in using the device and reminding the user that no device can replace the users’ carefulness.

5. Citations

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[3] "IP Rating Chart." *DSMT.Com*, 23 Feb. 2019, www.dsmt.com/resources/ip-rating-chart.

[4] "IEEE Code of Ethics." *IEEE Code of Ethics*, 2020, www.ieee.org/about/corporate/governance/p7-8.html.

[5] Chen, Yuqing, et al. "A Review of Lithium-Ion Battery Safety Concerns: The Issues, Strategies, and Testing Standards." *Journal of Energy Chemistry*, vol. 59, 2021, pp. 83–99. *Crossref*, doi:10.1016/j.jechem.2020.10.017.

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