Helmet Safety Indicator

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1 Introduction

1.1 Objective

In 2017 the number of bikers hit a staggering 47.5 million individuals [7], or about 12 percent of the total American population [4]. With this many bicyclists, cities have taken notice to accommodate cycles through separated bike lanes and paths. Even then, a vast majority of cities do not accommodate bikes and bikes are forced to ride alongside vehicles on the open road. In these situations, bicyclists are placed in a position of elevated risk and require more measures to ensure their safety. The two most risky situations are turning at intersections and getting overtaken by vehicles or other bicyclists [2]. Bicyclists are expected to indicate speed changes and turns via their arms, but many drivers are not aware of these signals, and at high speeds, extending one arm out of the bike at high speeds is less than ideal for the bicyclist. These arm signals ultimately fail at providing a safe and effective method of indicating messages to car drivers or other bicyclists. In addition, bicyclists ride very close to cars and can only be aware of cars near them by physically turning their head, which can also be a potentially risky maneuver which will leave them unaware of potential threats in front of them.

Our proposal is to create a safety system that is simple for riders to use and can be installed on a variety of bikes. The safety system will comprise two parts: indicators for other drivers and indicators for the bicyclists. The indicators for the driver would work by having attachable triggers the user could attach to their handlebars and brakes which will send signals via bluetooth to a light attachment to the user's helmet. The lights would be placed on the back of the user's helmet to be directly in the line of view for cars behind the rider and they will display left and right turns as well as slowing down. For the bicyclist's indicators, in order to provide the rider feedback of approaching cars or other bicyclists from behind, there will be distance sensors to track other bicyclists or motorists. These sensors will alert the bicyclist via a light up indicator the user can attach to the handlebars.

1.2 Background

In 2018, 2% of motor vehicle crash fatalities in the United States were bicyclists, resulting in 857 deaths. There were in total 45,000 reported bicycle accidents [2]. Many of these motor vehicle accidents were preventable as two of the primary causes for these accidents were drivers not properly acknowledging the bicyclists and the cities not being properly planned for bicyclists and drivers to share the road. This shows that at least until American cities reach a higher safety standard for bicyclists, there needs to be a method that bicyclists can elevate their safety on their cycles. We believe that by allowing bicyclists to attach indicators to their helmets and handles bars, the product can ensure that there is adequate signalling to both other cars on the road and bicyclists as well as also promoting the usages of helmets by bicyclists.

The proposed solution is unique and stands out against other LED indicators on the market as well as Project 8 from Fall 2017, Bicycle Street Notification System. The Bicycle Street Notification System created a solution that included large lights that were directly attached to the bicycle which can be used as indicator lights for breaks and turns. This both was a permanent fixture on the bicycle and in addition the lights' large size added significant bulk and loss of aerodynamics to the cycle. Certain bicyclists may have many different bikes for different purposes, as well as different helmets based on factors such as weather and how fast they are trying to ride. We hope that by providing a simple to install and remove system, we will accommodate all bikers, whereas the Bicycle Street Notification System focuses on having it be installed on a single bike and being a more permanent fixture for bikes that were not intended to be too high speed. Secondly, by attaching these indicators to the helmet, they are placed in a position that is much more easily seen from up close compared to under the user's seat. In the Bicycle Street Notification System the fixtures are attached onto the bicycle itself, and particularly for users with smaller bicycles or with larger vehicles being behind the user, having the signals on the bicycle might place them out of view. Finally, even though there are certain Helmets that include indicator LEDs such as those produced by the company *Lumos*, they focus on providing signals to other bicyclists or motorists [6]. We have focused on creating a system that also informs the bicyclist. By including the distance detectors the user can see when motorists or bicyclists are coming too close to them allowing them if extra precaution is needed to be taken.

1.3 High-level requirements list

- Helmet LED indicators must be activated when turning or braking based on the trigger inputs on the handlebar and the handlebar LED indicator must be activated based on the input from the ultrasonic sensor in the helmet.
- Light indicators and buttons must be easily attachable and stay securely fixed to the bicycle and helmet when attached.
- The rear distance sensor on the helmet must be able to pick up objects and vehicles that are 3 meters behind the bicyclist.

2 Design

2.1 Overview

The device is designed with four primary submodules, as shown in Figure 1, which will be spread over two separate devices. The first submodule is the input module, this consists of the buttons to indicate braking and turning as well as the distance sensors on the helmet. These input modes will communicate with the control unit module. Both of the devices which are attached to the handlebars and the helmet will have their own control unit components. The inputs on the handle bar will communicate with the control unit component that is within the handlebar attachment and the sensors will communicate to the helmet's control unit component. From the control unit RF transmitters will be used to send data between the two separate devices which will then be relayed to the indicator submodule which will illuminate the appropriate indicators on the device. Finally, there is the power submodule, both of the components will have a 5 volt lithium ion battery which can be charged via a Micro-USB port.

2.2 Block Diagram

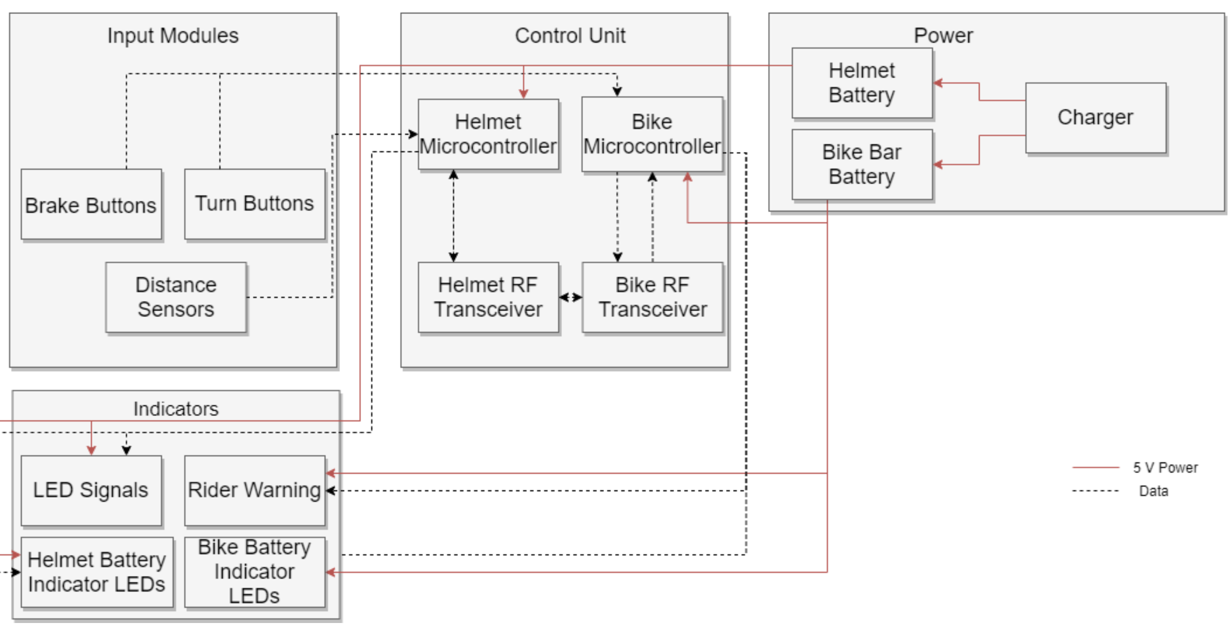

Figure 1. Overall block diagram showing power and data connections between functional units.

2.3 Physical Design

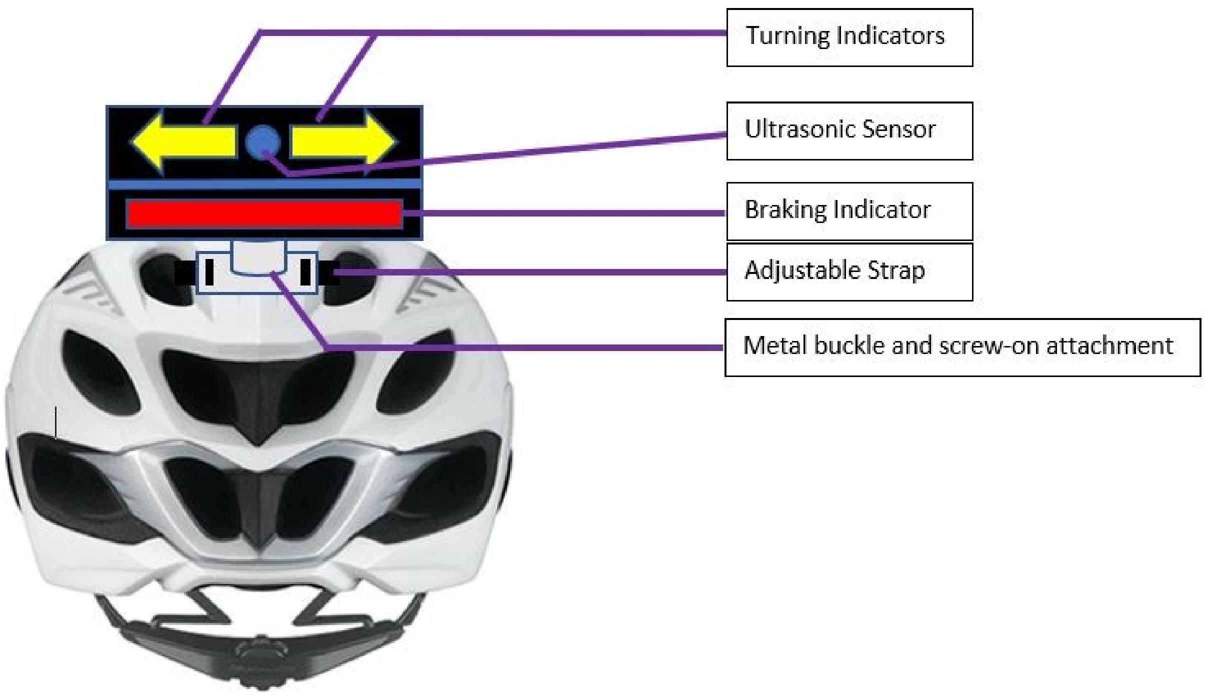

Figure 2. Rear view of placement of LED box and attachment to helmet.

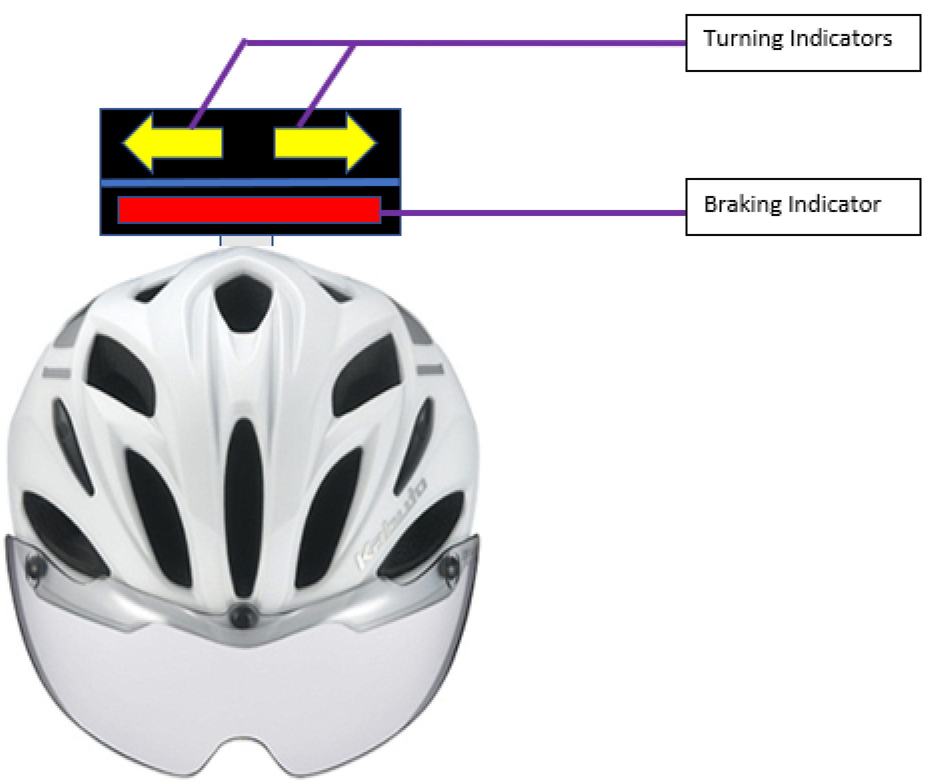

Figure 3. Front view of placement of LED box and attachment to helmet.

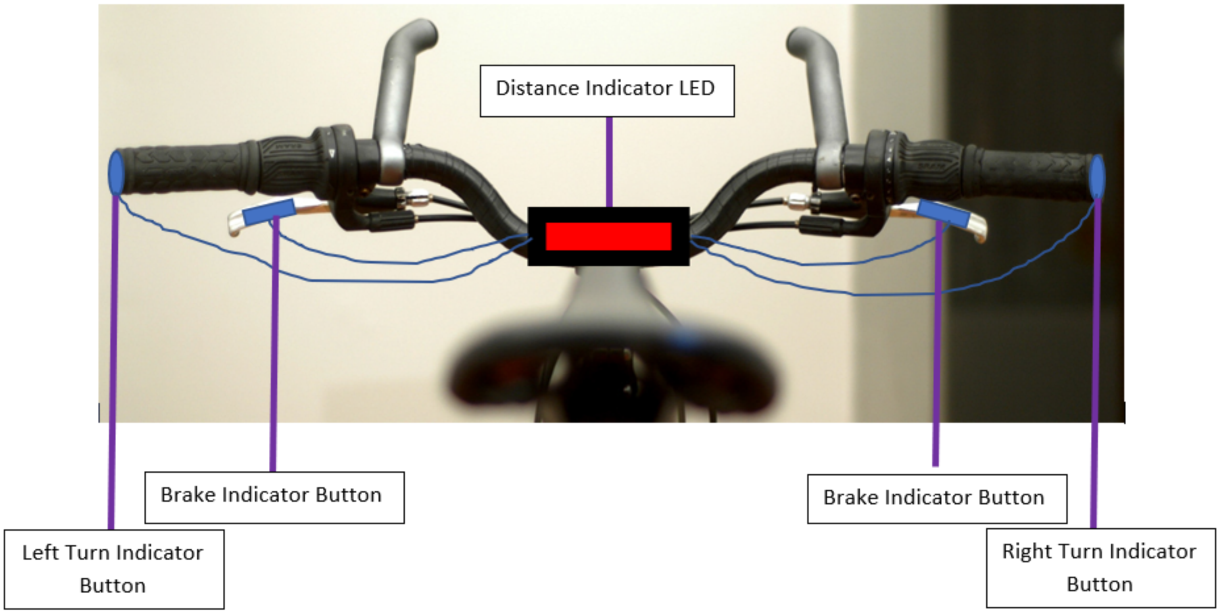

Figure 4. User view of placement of distance indicator LED, brake and turn indicator buttons on traditional bicycle handlebars.

The physical design of the product will consist of two separate parts. The first part will be attached to the top of the rider's helmet through an adjustable strap as shown in Figures 1 and 2. The turning and brake indicators on the helmet attachment will screw onto a metal plate attached to the adjustable strap for secure attachment. The handlebar design shown in Figure 4 will be strapped in a similar fashion to the rider's handlebar and will have four wires coming out of it for the brake and turn indicator buttons. The brake button will be on the front of the brake where the user's hand will go when braking. In Figure 4, the brake indicator buttons would actually appear on the other side of the brake lever, but we have included a box for it so the location of it is understood. The helmet and handlebar designs will be enclosed and weather resistant, including the exposed wires.The battery, microcontroller, etc. will be stored in the large boxes in both parts.

2.4 Functional Overview

2.4.1 Input Modules

The input modules take data from the user and distance sensors to provide the right signals and data to the microcontroller. The user input data comes from the two triggers on the right and left brakes as well as the two triggers on the ends of the handlebars that indicate a right and left turn respectively. The distance sensor located on the helmet will send distance data to the helmet microcontroller for when an object is within three meters behind the user.

2.4.1.1 Brake Buttons:

As seen in Figure 4, our design will include break buttons for the user to attach to their braking system on their bicycle. This allows for easy accessing, in order to trigger the light. Both buttons will trigger the break lights on the back of the helmet. The signals from these buttons are relayed to the control unit located on the device attached to the handlebars which will then relay the signal to the LED indicators on the helmet.

Requirement: Buttons should be monostable switches that should be pressed to activate the RF signal relayed to the helmet component for as long as the breaks are held.

2.4.1.2 Turn Buttons:

As seen in Figure 4, there are two buttons that can be placed anywhere on left and right handlebars, by the bicyclists, wherever is most convenient for them. The left button activates the left turn signal and the right button activates the right turn signal. The signals from these buttons are relayed to the control unit located on the device attached to the handlebars which will then relay the signal to the LED indicators on the helmet.

Requirement: Buttons should be monostable switches that should be pressed to activate the signal for a certain amount of time and should turn back off when not pressed.

2.4.1.3 Distance Sensors:

There will be one distance sensors placed at the rear of the helmet that will detect the objects and vehicles that are approaching the bicyclist. This sensor will provide data regarding the distance of objects behind the bicyclist to the control system which can be processed and determine whether there is an approaching bicyclist or motor vehicle within the threshold distance.

Requirement: Ultrasonic sensor should be able to detect any approaching vehicle or bicyclists within 3-meter range from the rear of the bike.

2.4.2 Indicators

The indicators will be used as the outputs from the microcontrollers. The battery indicator LEDs will show the current battery level of each battery to the user. The LED signals will be turned on in appropriate fashion when the user is signalling left, right, or is braking. The rider warning LEDs will also turn on when there is an object detected within three meters behind the bicyclist.

2.4.2.1 LED Signals:

LED lights will be placed at the top of the helmet to indicate if the bicyclist is turning or braking. This will caution other bicyclists and drivers with clear, visible signals to prevent accidents. These LEDs will be attached to the helmet mounted device which will be in the line of sight of anyone behind the user and will clearly relay to them if the bicyclist has triggered the left or right turn signals or the brake.

Requirement: LED lights should be programmable to display the input it gets from the brake or turn buttons.
Requirement: It must be clearly visible for up to 100 feet for anyone behind the bicyclist regardless of whether they are in a car or a bike.
Requirement: The indicators must clearly relay the action of the bicyclist to other riders or motorists based on how the LEDs are being illuminated. This is to ensure the message of the LED is clear and can not be confused with anything else.

2.4.2.2 Battery Indicator LEDs:

LED lights which are placed on both the helmet attachment and the bike will indicate the charge level of the device to the user. These LEDs will connect to the corresponding battery in order to be able to display the current charge value for that device.

Requirement: Battery indicator circuit with four-channel voltage monitoring chip should be used for both helmet and bike to display the charge levels.

2.4.2.3 Rider Warning:

This will be an LED indicator array that the rider can place in front of them on the handlebars in order to be able to receive the information provided by the ultrasonic sensor attached to the helmet. It will show a solid red light to clearly inform the rider of approaching traffic.

Requirement: The indicator must illuminate once another bike or vehicle enters within 3 meters behind the bike.

2.4.3 Control Unit

The Control Unit comprises the microcontrollers and transceivers of the system. This unit is responsible for deciphering the data that is sent to it from the input system and will either relay the data to the other component, either helmet or handlebar component, or will output a signal to the appropriate indicator on the device.

2.4.3.1 Helmet Microcontroller:

The helmet microcontroller has two responsibilities: being able to decipher signals from the ultrasonic sensor and illuminate LEDs based on the bicyclist's inputs. It will receive the data from the turn/brake buttons on the bike handlebar component via the transceiver. Based on the data that it receives, the microcontroller must turn on the correct indicator LEDs. It will also receive the signal from the ultrasonic sensors on the helmet and determine based on the signal whether the distance threshold has been breached by an incoming vehicle and then transmit the response to the transceiver so that it can be sent to the transceiver on the handlebar component to illuminate the rider warning.

Requirement: Must be capable of being programmed to calculate distance thresholds based on ultrasonic sensor input.
Requirement: Must be able to send power to different programmable LEDS based on a given input.

2.4.3.2 Bike Microcontroller:

The bike microcontroller has two responsibilities: being able to relay inputs based on the type of button pressed and illuminate the rider warning LED array based on a given signal. Once a turn or break button is pressed, the microcontroller will decipher which button the signal is coming from and send the appropriate signal to the transceiver. This signal will then be converted to the LED output on the helmet and after a time interval will indicate that the LED must be turned off. In addition, based on the data it receives from the transceiver, the microcontroller must be able to turn on the rider warning, if a vehicle is within the three meter threshold.

Requirement: Must be able to encode the button presses into particular data packets to send over the RF transceiver.

Requirement: Must be able to calculate time intervals in order to indicate the signal shut off time.
Requirement: Must be able to illuminate an LED array based on signals that it receives.

2.4.3.3 RF Transceiver:

RF transceivers will be used to connect both the helmet and handlebar components using radio signals. Inputs processed in the microcontrollers of each of the components must be relayed via these RF transceivers to the other microcontroller so that the appropriate indicator can be illuminated.

Requirement: RF transceivers should use General ISM with 433 MHz frequency, which is suitable for short range connections.

2.4.4 Power

The power will be provided to the remaining subsystems through two separate lithium ion batteries. Both these batteries operate at five volts and provide data to the LED battery indicators. The batteries will be chargeable through a Micro-USB connection.

2.4.4.1 Helmet Battery:

The helmet battery consists of a lithium ion battery with a charging circuit and USB-to-serial converter. The battery will power the components of the helmet mounted device, which includes the helmet microcontroller, LEDs, transceiver and ultrasonic sensors.

Requirement: Battery produces output voltage of 5V and is rechargeable.

2.4.4.2 Bike Bar Battery:

The bike bar battery consists of a lithium ion battery with a charging circuit and USB-to-serial converter. The battery will power the components of the bike handlebar mounted device, which includes the bike microcontroller, transceiver and rider warning indicator.

Requirement: Battery produces output voltage of 5V and is rechargeable.

2.4.4.3 Charger:

A Micro-USB charging wire will be used to charge the lithium ion batteries in the helmet and handlebar devices.

Requirement: Micro-USB charging cable should recharge the battery within 2 hours of charging

2.5 Risk Analysis

A major challenge with this design is creating an effective way for both of the devices to communicate with one another. This issue resides with ensuring that the Control Unit is able to appropriately coordinate the different signals that it will receive and transfer. There is a major transfer of data between the component attached to the helmet and the component attached to the handlebars. This includes signals indicating a button was pressed, whether a car is within the safety radius and whether or not an LED indicator is to be illuminated. Ensuring that this process is adequately coordinated will require careful engineering and signal processing.

Also, integrating the ultrasonic sensor in the indicator system poses a great challenge since the use of ultrasonic signals might be skewed by the speed of the vehicle and some faster vehicles may not be picked up. The sensors must be able to accurately relay the presence of a vehicle to the bicyclist so it is vital that the placement or capacity of the sensor is able to account for the situation of a quick vehicle, or if a single sensor is not able to,then explore if the usage of multiple sensors can mitigate the problem.

3 Ethics and Safety

When working on developing this device, our group will take many precautions to ensure our safety and the safety of those around us. All members of the group have completed and passed the required lab safety training and will follow Campus Environmental Health and Safety policy #RB-13, in which we will be responsible for maintaining and creating a healthy and safe environment for our team and the UIUC community [3]. We will make sure to not modify circuits while the power is connected, as well as be vigilant of any burning parts to make sure we do not start a fire. The lab will also be equipped with a fire extinguisher in case of emergency. Additionally, our group will have at least two members present when working in the lab to help prevent accidents. In the situation the group needs to work with equipment that the members of the group are unfamiliar with, we will ensure that there will be the necessary supervision to validate the proper usage of the equipment. Finally, the group will not use other individual's work without the proper citations, and certify that the idea and design of the project is original and unique [1].

Since this device will be used outdoors and can potentially have close contact with the human body, extra precautions are necessary to protect the user. The outside of the helmet LED box and the handlebar LED box will have insulating, waterproof, heat-resistant casing that will make sure no water can come in contact with the electrical components stored inside. Heat resistant plastic will be used to prevent the casing from warping under heat from the sun. This will minimize the risk the user faces when using the device while it is raining outside as well.. Although lithium ion batteries have become the standard in rechargeable consumer products, there is still a level of risk that must be mitigated when using them. The battery will be purchased from a reputable company with a protection circuit built into the battery. The protection circuit will prevent the battery voltage from getting too high or too low and will cause the battery to cut out at 4.0V. This also prevents the other circuitry in the device from shorting or being damaged by improper power input. The noise susceptibility of the 5.0V battery will also be lower than a 3.3V battery, making it more stable. The manufacturer recommended charger for the battery will also be used to prevent malfunctions in the battery. The charging will have three stages: a preconditioned charge, constant-current fast charge, and a constant-voltage trickle to top the battery off. These stages prevent overcharging of the battery. There will also be a voltage detection circuit that can visibly notify the user when the battery has charged. The exposed wires on the handlebar will also have weatherproof, heat resistant insulation so that there will be no exposure to the elements.

Since we are promoting this product as a replacement to traditional hand signals, it is imperative that our product works under duress and can work for up to eight hours. Rigorous testing will be conducted on prototypes to ensure consistent results. Bicycle signaling is required by law in the United States. In order to prevent situations where the device has lost battery and signals are not being output, visible battery indicators will be on the handlebars. Riders will be encouraged to monitor the battery levels of both the helmet and handlebar components to ensure that the device is still charged and responding. This is in accordance with #5 in the IEEE Code of Ethics in which we are urged to improve the understanding of individuals on the societal implications of our technology [5]. Additionally, in compliance with #1 in the IEEE Code of Ethics, we will ensure that all safety precautions are taken in the construction of the device to ensure that there is very minimal risk of harm to the user [5]. If any such risk exists, information would be provided to the user to inform them of the proper usage to avoid said risk.

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