Bicycle Street Notification System

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1. Introduction

1.1 Objective

Even as cars become more available to the average civilian, many people still choose to ride bikes for either economical, physical, or environmental reasons. There are over 66 million cyclists in the United States [1], which equates to over 12 percent of Americans [2] biking around. Many cities and towns have biking trails and specialized areas for cyclists, but more often than not, a cyclist must share the road with pedestrians and motorized vehicles. As they share the same roads with cars, they also share the same accident risks that car drivers face but without the same warning signs or safety measures. Bike riders must depend on signals formed by the cyclist's arms and hands. In order to perform these signals, the cyclist must take their focus off the road. This makes riders a hazard to themselves and others on the road.

We want to implement a system to make it safer for cyclists to share the road. With this thought in mind, we want to create a bicycle light system similar to that of a car. This system includes left and right turns signals, a brake light, and hazard lights. There will be switches for user control of the turn signals, an accelerometer monitored braking system, automated turn off for the turn signals once the cyclist has completed their turn, as well as a speedometer. The lighting fixtures will make cyclists a more visible presence on the road and allow other road users to be more aware of what is happening. The addition of the automatic turn off, along with the accelerometer brake lights, allows cyclists to focus on what is happening on the road.

1.2 Background

While cars have continued to advance from the beginning of their creation with new additions to make them faster, more comfortable, and safer, the bicycle has been left behind. Its shape has changed, but no extra safety measures have evolved along with it. Current statistics show that there were 818 bicycle traffic fatalities in 2015, a 12.4% jump from the previous year [3]. Current street notification systems for bicyclists consists of cyclists using their hands and arms to notify other road users of their intent to turn, to stop, or even to alert those around the biker of an emergency. There are also bike systems already made to make cyclists visible using flashing headlights or wheel lights, and there are turn signal systems that cyclists can buy and put on bikes. Each of these systems have major fall backs that can create confusion on the road and lead to accidents that could easily be prevented. For the hand signal system, the signals are not used by all cyclists, and many non-cyclists do not know that these signals exist or how to interpret them. The visibility systems currently on the market are just small lights placed on the front, back, or wheels of the bike and are constantly on. They do not give any indication as to the next movements of the rider, but they serve to be a distraction to other road users. Looking at current turn signal systems like the Meilan X5 Bicycle Laser Rear Tail Light [4] and the Wireless Bicycle Turn Signal [5], we see that these systems have switches on one console placed somewhere between the handlebars and must be turned off manually. This requires the cyclists to take their focus off the road. Their hands must come off the handlebars to focus on finding the console to operate the lights. These systems are not effective for helping protect cyclists and will do nothing to help the increasing fatality rate. However, a system to put cyclists more on par with motorized vehicles would definitely help decrease the fatality rate.

1.3 High-level requirements

- The product shall have automatic turn off for left and right turn signals once the gyroscope detects that a turn, with any turning radius, has been completed.
- The product shall use an accelerometer to create a sensitivity limit for turning on the brake light when the user begins to press on either brake.
- The product shall display a speedometer reading with no more than +/- 2 mph error.

2. Design

2.1 Block Diagram

The sensors will be used to achieve three of our high-level requirements. A gyroscope will be used to detect if a turn has been completed in order to automatically shut off a turn signal. When a turn has been made, the gyroscope detects an orientation change and communicates this information to the microcontroller, which will shut off the turn signals. An accelerometer can detect if the cyclist is braking or is significantly decelerating, as determined by a sensitivity threshold of our choosing, and will cause the brake light to turn on. The magnetic reed switch attached to the frame will detect magnets, which are fixed to the wheels, to determine how quickly the wheels are spinning. This will be used to calculate an accurate speed to display on the speedometer of the bicycle. Utilizing these three sensors, we will be able to achieve our three requirements.

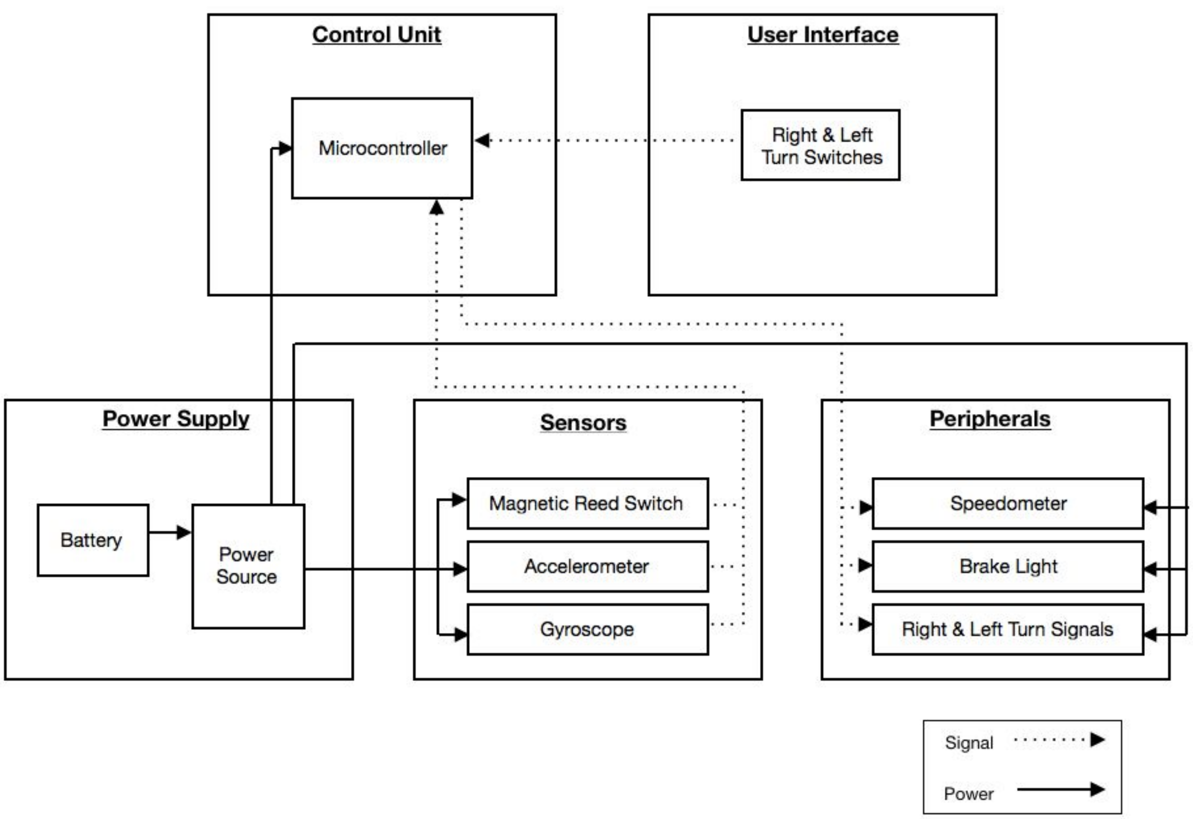

Figure 1: Block Diagram of System Design

2.2 Physical Design

Figure 2: Placement of Sensors and Actuators

Figure 2 shows the placement of the sensors and actuators on a standard bicycle. Below we have listed the justifications for each of the numbered areas on the bike.

1: Main bar below the seat **-** This will be the location of the main circuit board, along with the batteries and accelerometer. There will be wires leaving the casing, which will connect to the other sensors and peripherals. This location is ideal for the largest component of our design because it will not obstruct the rider's legs in any way.

2 & 3: Handlebars **-** This is the location of the switches, front turn signals, speedometer, and gyroscope. The gyroscope will receive the most accurate reading from this location because the handlebars move more than any other part of a bike during a turn.

4 & 6: Back wheel **-** The magnetic reed switch will be located on the support closest to the rear wheel, and there will be several evenly spaced neodymium magnets placed along the bikes spokes to trigger the switch. This sensor could have been placed on the front or the back of the bike, but placing it on the back is more ideal so that the wires do not obstruct turns.

5: Below the seat - The rear lights will be affixed below the seat. This is where most reflectors on bicycles are placed, so it was the ideal choice for rear lights. This location also allows people from behind to clearly see the turn signals in the case that the cyclist blocks the front lights with his or her body.

2.3 Functional Overview

2.3.1 Power

The battery will supply energy to the power supply, which consists of regulators for varied-voltage rails. This will provide the energy necessary to power our entire bicycle light system. Many components of this system require power to operate: the magnetic reed switches, accelerometer, gyroscope, turn signals, brake lights, and speedometer display. All are driven by the microcontroller, which will also require some power. A power supply is crucial to the correct functioning of the bicycle light system, since nearly all components depend on it.

2.3.2 Microcontroller

The microcontroller unit will consist of a processor on a circuit board, which will conduct all of the necessary computations so the system will operate properly. The microcontroller will take each sensor's input and send the output information to each of the peripherals. The microcontroller will be the brain of our system. It determines whether the signals sent from the sensors trigger an action or not. If the gyroscope detects a turn but the user has made no turn, then it will not do anything. If the accelerometer detects the bike decelerating slowly due to friction, the controller will do nothing until the deceleration passes the set threshold.

2.3.3 Turn Switches

The bicyclist will manually turn on the left or right switches as desired. A signal will be sent to the microcontroller to activate the LED turn signals. When the left switch is pressed, the left LED turn signals will activate. Similarly, when the right switch is pressed, the right LED turn signals will activate. When both switches are flipped on, both LED turn signals will flash. This will be referred to as the hazard lights in our system.

2.3.4 LED Turn Signals/Brake Light

The LED turn signals and brake light receive a signal from the microcontroller. The microcontroller receives an input signal from the user by pressing the turn switches located on the handlebars. The signal to activate the brake light comes from the accelerometer. When a decrease in speed is detected, which is determined by a threshold set by us, this information is sent to the microcontroller. As a result, the brake light will activate.

2.3.5 Magnetic Reed Switch

A magnetic reed switch is a sensor that will complete a circuit when a magnetic field is induced upon it. We will use this device to calculate the speed of the bicycle and send the signals to the speedometer so that the user can see how fast they are traveling. After connecting the magnetic reed switch to the bike, we will affix six neodymium magnets to spokes of the rear bicycle wheel, each located at equal angles apart. We will use the magnets to calculate the time between each impulse on the switch. The formula for angular velocity, ω, is $\omega = \Delta\theta/\Delta t$. Knowing the change in angle and measuring the change in time, we can get the wheel's angular velocity and use the relation of $v = \omega * r$, where v is the speed of the bike and r is the radius of the tire. This can be used for a bike tire of any size.

2.3.6 Gyroscope

A gyroscope is a gadget typically made up of discs, a frame, and a gimbal around a spin axis. The discs are free to move with three degrees of freedom, while the spin axis orientation does not change. This sensor will be useful for detecting bike turns. When the cyclist makes a turn with any turning radius, the gyroscope discs will alter position and send this information to the microcontroller. The microcontroller will send a signal to turn the proper LED signal off.

2.3.7 Accelerometer

An accelerometer is a sensor that detects whether an object is changing its acceleration. This can be used to determine whether the bike beginning to stop or not. If the cyclist presses on the brakes, there will be the initial jolt which can be detected by the sensor as a deceleration. It will use that information as a signal and tell the microcontroller to turn on the brake lights.

2.4 Block Requirements

2.4.1 Power

Based on initial research, we have come to find out that a single AA battery at 2100mAh can operate an LED for 35 hours continuously. Our design has more components but will not be operating as continuously, so we have estimated that 3 AA batteries should be able to power our circuit. We should see that our power supply can keep the system running for a total of 24 - 36 hours.

2.4.2 Microcontroller

The microcontroller must have an error percentage (i.e., where it say turns off a blinker when it's not supposed to or turning the brake light on when the brakes haven't been pressed) between 0% and 3% when performing its tasks.

2.4.3 Turn Switches

The switches are a mere binary on/off mechanism of our design, as such they do not have a quantitative measurement.

2.4.4 LED Turn Signals/Brake Light

The turn signals on the bike should begin blinking within a ½ to 1 second delay from when the switch is flipped. The brake light should have similar tolerances.

2.4.5 Magnetic Reed Switch

The speedometer should be accurate within 1-2 mph.

2.4.6 Gyroscope

The gyroscope should be able to discern between a swerve on the road and a left or right turn. If the user is changing lanes and indicates so with the blinker, after completing the lane change the sensor should indicate to the microcontroller to turn off the blinker.

2.4.7 Accelerometer

The accelerometer will be able to distinguish whether we are slowing down or speeding up, and should not activate the brake lights in the event that we are speeding up. Also the accelerometer should not send a signal to turn on the brake light if deceleration is less than ¼ mph. Any slower than this does not constitute a need for a brake light.

2.5 Risk Analysis

We believe the biggest risks of our project will be in the sensor block. Our design depends on the sensitivity of our magnetic reed switch and our gyroscope in order to provide accurate information to the microcontroller. The information from the sensors will be used by the microcontroller to determine the speed of the bike, as well as when to turn off the LED signals. If these sensors are too sensitive, the system will perform actions when it is not needed. If they are not sensitive enough, the system will not receive data as needed. As a result, the design will not operate properly. Another concern is the possibility that the gyroscope accidentally signals the automatic light turn-off while the system is in hazard mode.

3. Ethics and Safety

We have several safety concerns to worry about with this project, mostly due to the product being a battery operated, outdoor product. We have chosen to use an alkaline-based battery to power our system. Batteries of these types are long lasting and output high energy. They are susceptible to corrosion and leaking of potassium hydroxide, which can cause irritation to the skin, eyes, and respiratory system [6]. We will create our system so the batteries receive proper wiring, can be closed off to protect them from outside harm, as well as make them easily accessible by the user to replace.

As an outdoor product that uses electrical current, in order to prevent any short circuiting for sake of the product and the user, we must follow the IP67 guidelines. IP67 holds us accountable for having the device protected by errant dirt, dust, and sand-like objects. It also means the device must be able to withstand water contact for at least 30 minutes [5].

We have based our ethical concerns on the IEEE Code of Ethics. Below we have gone through the ethical code [7] and have determined whether we will have an issue and why, or if we will not.

Conduct 1: This conduct is our main concern. This states that we are responsible for making decisions with the safety of our users in mind, as well as disclosing all factors that might endanger our riders or the environment. This relates back to our safety concerns.

Conduct 2: This conduct will not be an issue as we all have the same goal to complete this project within the specifications given to us by the ECE 445 course directions and those written by ourselves.

Conduct 3: This conduct will not be an issue because we will research all our components thoroughly and test them all, as well as our end product, before making any final claims.

Conduct 4: This conduct will not be an issue for we are not being sponsored.

Conduct 5: This conduct will not be an issue as we are striving to bring the bike into the modern world using the technological knowledge we have gained at the University of Illinois.

Conduct 6: This conduct will not be an issue as we have read and understand the safety practices required by ECE 445.

Conduct 7: This conduct will not be an issue as we understand to finish this project within the time limit, we must work together in a professional manner amongst ourselves and the rest of the ECE staff we encounter.

Conduct 8: This conduct will not be an issue because we understand that as a diverse team we will have our differences, but we are professional enough to discuss any issues we may run into.

Conduct 9: This conduct holds us to our responsibility to make decisions with the safety of our users in mind.

Conduct 10: This conduct will not be an issue as we understand that we will have to work together to help further our understanding of technology, as well as be fair partners to one another.

References:

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IEEE Code of Ethics

1. to accept responsibility in making decisions consistent with the safety, health, and welfare of the public, and to disclose promptly factors that might endanger the public or the environment;
2. to avoid real or perceived conflicts of interest whenever possible, and to disclose them to affected parties when they do exist;
3. to be honest and realistic in stating claims or estimates based on available data;
4. to reject bribery in all its forms;
5. to improve the understanding of technology; its appropriate application, and potential consequences;
6. to maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations;
7. to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others;
8. to treat fairly all persons and to not engage in acts of discrimination based on race, religion, gender, disability, age, national origin, sexual orientation, gender identity, or gender expression;
9. to avoid injuring others, their property, reputation, or employment by false or malicious action;
10. to assist colleagues and coworkers in their professional development and to support them in following this code of ethics.