Bicycle Lighting System

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Introduction

Problem

The problem we are looking to solve is that cycling in the dark (be it early morning or night) can be extremely dangerous, as cyclists simply cannot be seen by other users of the road, pedestrians, other cyclists, or most importantly, motor vehicles. Even if they are visible, the cyclist's movements and intentions can still be very hard for other roadway users to discern, causing the cyclist's movements to be unpredictable, which creates danger to themselves and others. This is an enormous problem, because countless people the world over rely on bicycles for their transportation to and from work, to the grocery store, and for any travel at all. In many parts of the world, including here in Champaign, IL, for significant portions of the year this travel would all be done outside of daylight hours; both the morning commute to work and the evening commute home would require riding in the dark. Because the consequences of a collision have a very real potential to result in serious injury or death, a solution to this problem is critical.

Solution

Our solution is to create a robust unified bicycle lighting system that allows the cyclist to be seen by other roadway users in the dark, as well as communicate their movements and intentions in the dark. We will do this by implementing a front headlight for visibility and illumination, a rear tail light for visibility, rear brake lights for communication, and turning indicators for communication. All of these lights will be under the same control system, allowing the rider to simply turn the entire system on or off as wanted with one switch. We will use sensing on the brake levers to automatically turn on the brake lights when the brakes are engaged. The lights will automatically turn off when the brakes are released. The turning indicators will be controlled by the rider via buttons on the handlebars on their respectives sides (left indicator control on left end of handlebars, right on right). The turning indicators will automatically turn off after the completion of the turn by the bike (in the same manner as a car's turn signals automatically turn off after making a turn). The implementation of these lights and indicators, all under one easily controlled user interface, will make cycling in the dark much safer for cyclists and other roadway users.

Visual Aid

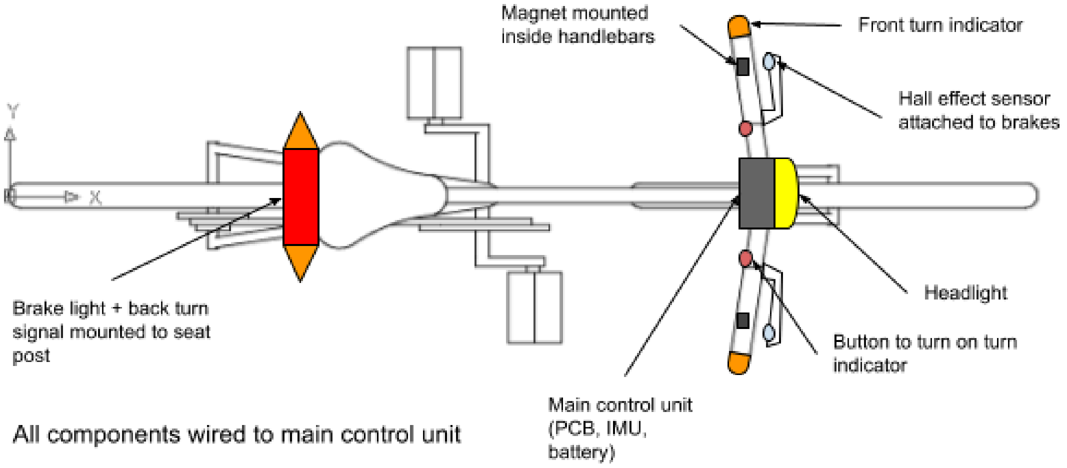

Figure 1: Visual Aid

High-level Requirements

- Brake lights turn on when brakes are engaged, and turn off when the brakes are released. The brake lights are visible and distinguishable from the tail light from at least 50 feet away.
- Turning indicators are engaged in an easy and simple manner by the rider, and automatically disengage after the completion of turns of 90 degrees or sharper.
- Front light, taillight, brake light, and turn signals all function under one unified control system. If you wanted to have all of these components on your bike you would have to turn them all on individually, but we want to have all our components all controlled by the same microcontroller and power system. The latency time to turn all the components on should be 10ms or less.

Design

Block Diagram

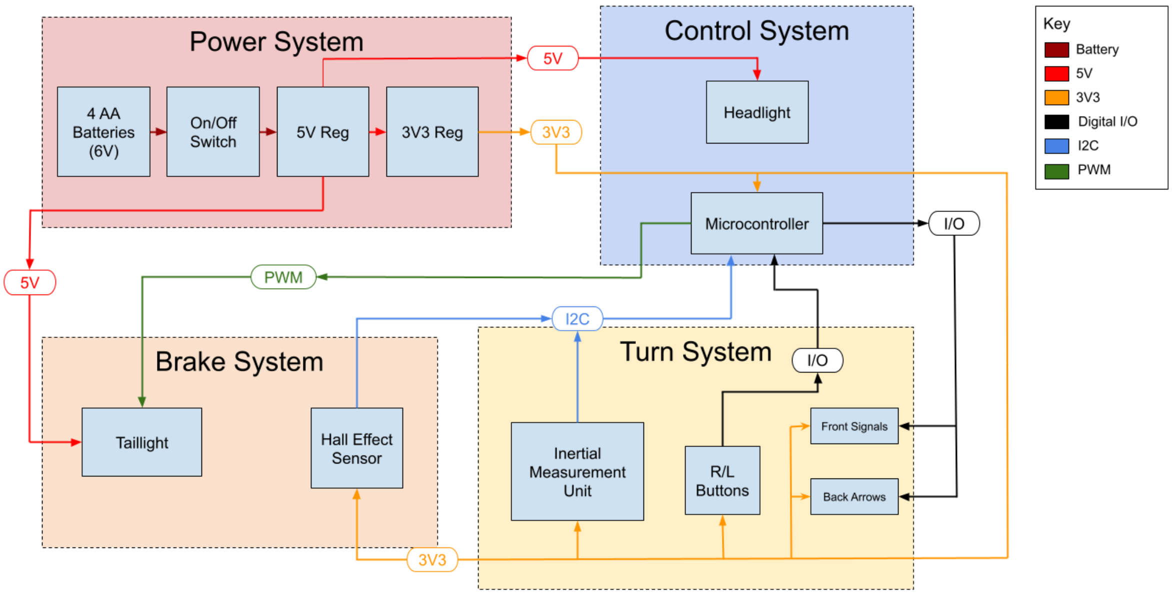

Figure 2: Block Diagram

Subsystem Overview

- Power System

The power system will consist of a 9V battery, a 5V voltage regulator and a 3.3V voltage regulator. The battery will feed directly into the 5V voltage regulator, which will go to both the lights as well as be fed into the 3.3V voltage regulator. The 3.3V output from that will go to the Control System components. This system overlaps with all three of the other subsystems, as they all need to be powered.

- Brake System

The brake system will be composed of the brake lights, the Hall effect sensors, and the wiring connecting both of the aforementioned to our microcontroller. We will be mounting magnets inside of the handlebars, with hall effect sensors attached to the back of the brake levers. As the brake levers are depressed by the rider, the sensors will sense this, and report it to the microcontroller. The microcontroller will then turn the brake lights on. When the Hall sensors sense that the brakes have been released, the microcontroller will turn the brake lights off. The brake lights will be turned on when the left, right, or both brake levers are engaged. This will overlap with the power system and control system.

- Turn System

The turn system will be comprised of the rear turning indicators, the front turning indicators, and an IMU sensor, two user interface buttons, and all the wiring connecting these to the microcontroller. The turning indicators will be turned on by the buttons by the rider. This will turn on both the front and rear turning indicators on the respective side. The turning indicators will be automatically turned off by the microcontroller once the IMU has sensed that the turn has been completed. This will overlap with the power system and control system.

- Control System

The control system is comprised of the logic inside of the microcontroller, as well as a master switch which controls power to the entire set of lights and the microcontroller. The microcontroller logic is responsible for interfacing with the brake system and the turn system. This, the control system, will also work with the power system.

Subsystem Requirements

- Power System
    - The voltage rails should not have more than a 5% ripple
    - Must operate under 125°C
    - Must provide enough power to last for at least 1 hour
    - Provides 5V to our lighting system, and 3.3 V to our control system
- Brake System
    - When the brakes are pressed by the rider by more than 0.5 cm, the back taillights get at least 2 times brighter.
    - The taillight will return to its normal state upon release of the brakes.
    - The taillight is always on and visible from at least 500 feet away.
- Turn System
    - Turn indicators, either back or front, are visible to traffic in all directions from at least 500 feet away.
    - Turn signal turns on when the user clicks a button on the handlebars, and is disabled either when the user clicks the button again or when the user has turned 90 degrees or greater.
    - The front turn indicators should be visible to the user, to ensure the signals are not accidentally left on.
    - The buttons to turn on the turn indicators should be easily accessible and usable by the user while they are riding. They should not have to take their hands off the handlebars or move their hands more than 10 cm to access them.
- Control System
    - The entire system must be activated and deactivated by the power on/off switch.
    - Headlight is visible from a distance of 500 feet.
    - The inputs to the control systems should be fast and able to send the digital signal or pulse width modulation signal within 10 ms.
    - The pulse width modulated signal sent to the taillight/brake light should be able to perform a duty ratio between 10% and 100%.

Tolerance Analysis

Voltage Regulator Analysis

We are making sure that our voltage regulators will not be giving off too much heat and break down. We are using two separate step downs, one from 9V to 5V and another from 5V to 3.3V. We are ensuring that these two step downs are feasible and better than stepping directly from 9V to 3.3V.

We do not want our regulators to exceed 50°C ambient. We got this number by finding the maximum recorded temperature in Urbana (42.7°C) [1] and knowing that the chip on the inside will be hotter than the outside temperature. This seems like a reasonable limit to set for ourselves.

The chip's maximum operating temperature is 125°C. This means that for the worst case scenario, we will have a 75°C temperature rise. According to the data sheet for the LM1117 [2] using the SOT-223 package, the junction to ambient thermal resistance is 61.6°C/W.

Using the 75°C rise in temperature we divide by the junction to ambient thermal resistance. This gets us 1.218W, which is the absolute worst case power that can draw.

Using this maximum and the equation for power, and our system if we went straight from 9V to 3.3V we would have a 5.7 volt drop, which when plugged into P=I*V gives us a maximum current draw of 213.68mA. When we compare this with our step down from 5V to 3.3V we get a voltage drop of 1.7V and a maximum current draw of 716.47mA. Our control system will be nowhere near this upper limit, so we will not need a heatsink for the heat given off by the 3.3V regulator if we have 5V as the input.

For the 9V to 5V drop, we have a voltage drop of 4V which gives us a maximum current that we can draw being 304.5mA. This means that our project will need LEDs that don't require as much current, but still is well within the range of what we'll need.

Hall Effect Sensor Analysis

We want to make sure we don't have to adjust the position/sensitivity of the hall effect sensor and the magnet too much. So we should do some analysis on different types of magnets with our hall effect sensor, ALS31313 [3]. According to the datasheet we could have a +-500, +-1000, or +-2000 Gauss sensitivity based on how we program it.

Let's also say that we don't want the magnet on our handlebars to be too thick and only use magnets that are 0.125" and smaller. Every magnet will come with a gauss level reading, most likely from the surface. We can measure the magnetic field from the center point of the magnet to the given magnetic field at the surface. Because our magnet height is 0.125”, the gauss level reading at the surface is 0.0625” from the center of the magnet.

We know that a given magnetic field will drop off in strength at the distance from the centered cubed. Gauss Strength is related to 1/d^3. We can measure the average distance on most bikes from the handlebars to where the brakes sit to be roughly 5cm. According to our Brake System specification we want the lights to trigger after 0.5cm of movement. This leaves us with 4.5 cm from the center of the magnet to where the brakes sit.

Converting 0.0625” into centimeters, we get a value of 0.15875cm. The distance between the brakes and the center of the magnet, 4.5cm, to the distance of the surface level to the center of the magnet, 0.15875cm, gives us a ratio of 4.5/0.15875 = 28.346. This means that whatever our gauss level is, we need to divide that number by 28.346^3 or 22776.99. So if we have a 4000 Gauss magnet at the surface. We would have a 4000/22776.99 = 0.175 Gauss at 4.5cm away.

If we use our sensor at the +-500 sensitivity, and our sensor has 12 bits. We can get a resolution of 500/4096, which gives us 0.122G. This should be enough to detect the magnet which is 4.5 cm away. And we will only get more sure it will detect when you pull the brakes harder and the distance between the brakes and the handlebars decreases.

Ethics & Safety

The ethical concern of our project is relevant to IEEE ethical code I.1. Our project is directly related to the health and safety of our users and the public at large. The goal of our project is to promote the safety of cyclists by increasing their visibility and declaring their intentions using a system of lights. This will decrease the likelihood of collisions and crashes that could result in injuries or even death, for the riders, or for others.

The relevant safety code that governs our project, is Illinois Law (625 ILCS 5/) [4] Illinois Vehicle Code, which states that bikes riding at night must have a white lamp on the front visible from a distance of 500 feet, and must have a red rear lamp visible from at least 500 feet. We will obey this law, and ensure that any bike using our project’s system is fully in compliance.

Citations

[1] “Averages and Records for Champaign-Urbana Illinois,” Illinois.edu, 2024. https://www.isws.illinois.edu/statecli/cuweather/cu-averages.htm#:~:text=The%20record%20high%20is%20109 (accessed Sep. 18, 2024).

[2] “LM1117 800-mA, Low-Dropout Linear Regulator.” Accessed: Sep. 18, 2024. [Online]. Available: https://www.ti.com/lit/ds/symlink/lm1117.pdf?ts=1726643965724&ref_url=https%253A%252F%252Fwww.ti.com.cn%252Fproduct%252Fcn%252FLM1117

[3] “ALS31313,” *https://www.allegromicro.com*, May 18, 2021. https://www.allegromicro.com/~/media/Files/Datasheets/ALS31313-Datasheet.ashx (accessed Oct. 03, 2024).

[4] “VEHICLES (625 ILCS 5/) Illinois Vehicle Code.” 2024 https://ilga.gov/legislation/ilcs/ilcs4.asp?DocName=062500050HCh%2E+12+Art%2E+VI&ActID=1815&ChapterID=49&SeqStart=140200000&SeqEnd=142900000&Print=True