Pedal-Powered Smart Bike System

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1 Introduction

1.1 Objective

With rising population rates, it is without a doubt that cities across the globe will increase in population density. With over [1] 1.7 billion people living in cities in 2018, estimated to reach 2.5 billion by 2050, one can only imagine how this might further increase traffic congestion resulting in longer commute times. As a result, many individuals are opting for alternative means of commute. [2] In fact, it is estimated that the amount of individuals who use a bike to commute to work will double by 2022. Outside of commuting, biking also serves as an excellent form of exercise. [3] Cycling is great for losing weight, cardiovascular training, as well as building up muscle. [4] Cycling can even benefit an individual's mental health, improving mood, sleep, and creative thinking! On the other hand, using a bike as a primary means of transport may also be risky for a cycler, especially in large, densely populated cities. We are even seeing cyclist-related accidents increase as time goes on. [5] With over 2% of motor vehicle crash deaths, cyclists still represent a significant amount of potentially avoidable accidents every year. [6] In 2018, there were over 857 cyclist deaths due to collisions with automobiles, representing over a 6% increase in deaths from the year prior.

Our project seeks to solve multiple issues that bicyclists face on a daily basis. We plan on creating a multi-tool for bicycles dealing with three main issues: navigation, exercise, and safety. Using a microcontroller, motor, RGB screen, and various other components, we will completely power our multi-tool through user pedalling and a battery. The RGB screen will be used to display important information for the user with regards to their navigation and exercise. A GPS module will inform the user of their heading and current location. Information captured from both the motor and the GPS will capture the user's speed, distance, and exerted power. Finally, an ambient light sensor and buttons will allow the user to be visible in low light conditions as well as inform other drivers and cyclists of their intent to turn.

1.2 Physical Diagram

Figure 1.1

1.3 High Level Requirements

1. Users are able to use buttons on the device to indicate turn signaling and turn the device on/off.

2. Entire device is powered through battery and/or pedalling, no need to plug into a wall.

3. HUD provides metrics such as speed, heading, and distance travelled.

2 Block Diagram

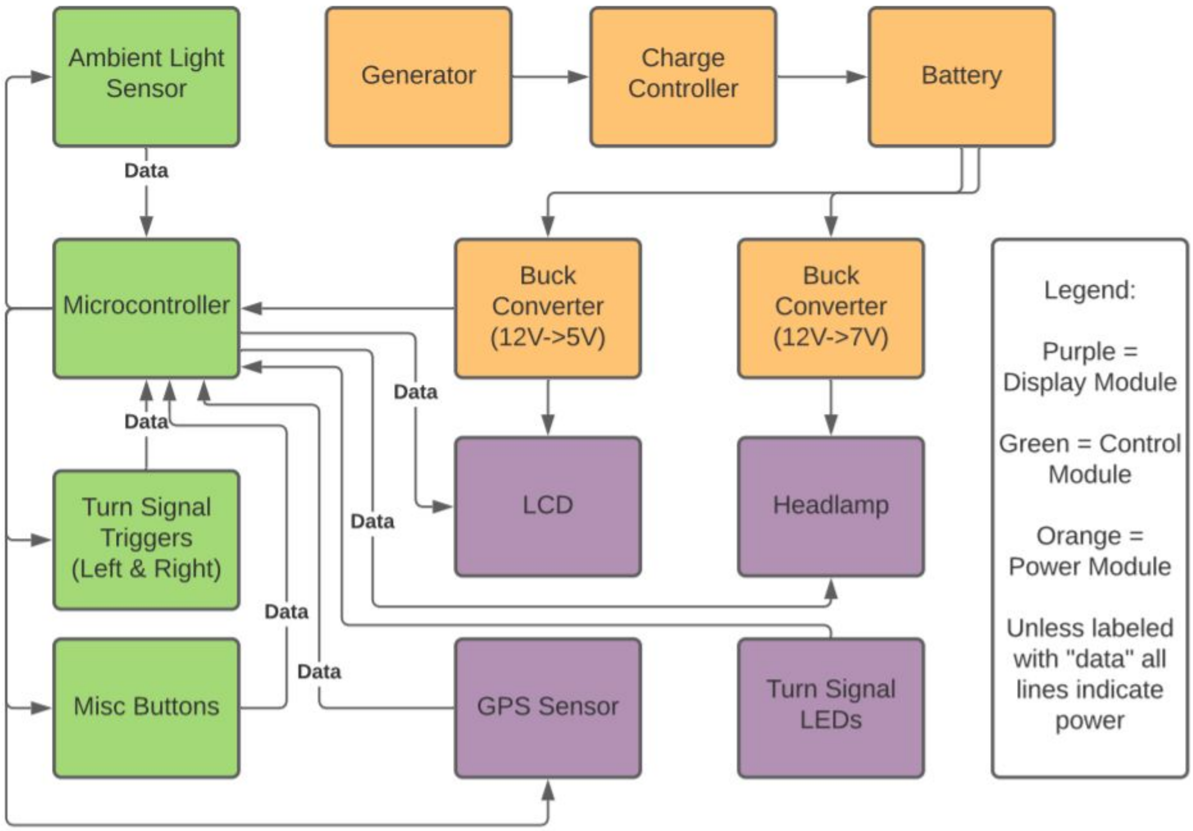

Figure 2.1

3 Components and Circuit Descriptions

3.1 Motor:

This part's function is to generate power to the whole system. It will be connected to the 12-8V battery with a charge controller in between both components. The 12-24V brush motor must also be of adequate size to withstand the torque from the user's pedaling. Each motor has an RPM (Revolutions per Minute) rate at which it produces its maximum power. The brush is usually too small to link it through a chain and it might break. That is why we use a metallic circular head/pulley that is fixed on the brush around which the chain is wrapped. We can calculate the average revolutions per minute of the gear for an average speed biker (~25Km/hour). The ratio of that value to the nominal RPM of the motor permits us to find the diameter of the pulley. A wheel with a 67cm diameter and a gear of 30cm diameter will turn $25/(67\times10^{-5} \times \pi) = 11{,}877$ times per hour, that is 198rpm. Most motors have a nominal RPM of 3,000 which yields a ratio of 15.2 . Dividing the gear diameter by that ratio gives us the diameter of the pulley = 30/15.2 = 1.9cm.

As the motor turns, it will charge the battery monitored by a charge controller to prevent overcharging and take care of the voltage and current regulation needs.

Concerning the size and weight, the average motors we would use and have been seeing online have the following specs: Weight: ~ 4 lb., Size(thickness: 3inches ; diameter: 4inches) and Power(24V, 250-300Watts, 2700-3500RPM).

3.2 Charge Controller:

The charge controller is an intermediary between our battery and our motor. Since the motor's power output is not constant, and its rated voltage will not necessarily be the same as the battery due to size requirements, we place a charge controller to regulate the voltage and current of the motor to the battery's nominal values, (24V to 12V-8V). The charge controller also monitors the battery's charge and acts as a resettable fuse to prevent overcharging of the battery which would damage the battery. Finally, the charge controller acts as a diode preventing reverse current flow from the battery to the motor. There is a wide range of charge controllers available on the market, from compact ICs to bigger solar charge controllers used to protect appliances in PV-powered circuits. That choice will be determined based on our specific needs. The charge controller is usually programmable and we will set it to stop charging the battery at 80% capacity and start charging at 30% capacity.

3.3 Battery:

The battery will be the stable DC power supply for the rest of the circuit (Microcontroller, Headlights, Display, etc…). It will be constantly recharged by the pedaling and monitored by the charge controller. The battery will be connected to 1 or 2 buck converters which will in turn each be connected to a set of components of the circuit. The battery will be a Lead acid battery and will weigh 2-4.5 lb. depending on whether we use a 8V/2Ah or a 12V/7Ah battery, although the 8V should be sufficient.
Dimensions: (Length: ~5.7in , Width: 1.7-2.6in , Height: 2.6-3.7in).

3.4 Buck Converter:

The buck converters are necessary to step down the 12/8V battery to the required voltages of the different components. The number of converters will depend on the number of voltage values we need. That is to say, if all components have a nominal voltage of 6V, then we will only need one converter. However, if two components are rated at 5V and two others at 9V, then we will need two converters. As of now, we are anticipating two converters, one for the Microcontroller and the programmable RGB display/monitor that should need 5V, and one for the LEDs, especially the headlight LEDs, which might require voltage in the range of 6-9V. There are plenty of buck converters on the market that are fairly small ICs, approx. 2in x 1in.

3.5 Microcontroller:

The microcontroller is the control center of the circuit. It will be programmed with all the data needed to have a functional smart bike. The board will be connected to and provide control instructions to the RGB display, the headlight LEDs, the rear lights and light signals, as well as the right and left buttons of the light signals.

The controller will provide GPS data through a GPS module to the RGB display. It will also receive data from the ambient light sensor and use it to control the headlights and rear lights. The buttons will also control the signal lights via the board. Our microcontroller will only provide logic to the headlights, rear lights and display as it cannot provide power to them. In order to control the power that these peripheries receive, the corresponding logic outputs of the board will connect to their controlled components via transistor-switches along with the wires coming from the buck converter. The wires connected to the board pins will close the transistor-switches when they output logic high (1) and open the switches when they output logic low (0).

The remaining peripherals (signal lights, sensor, buttons) will be both powered and controlled by the microcontroller board as these shouldn't require more than the 3.3V.

3.6 GPS Module:

The GPS module we have in mind is the NEO-6M GPS Module for our microcontroller. When used alongside the TinyGPS++ library (or a variety of other libraries that allow us to scrape data from our sensor), we can save lots of triangulated data, such as latitude, longitude, and altitude at different points in time. Other information that can be provided is heading, speed, and distance. These pieces of data will be used to provide the user with navigation and exercise statistics. Using a built in voltage regulator, our GPS module will work best with DC input of 3.3 to 5V.

3.7 RGB Display:

The RGB display we play on using is the 1.27 or 1.5" Adafruit Color LED Breakout Board. These RGB displays have a resolution of 128x128 pixels and contain 16-bit RGB color. While we intend on keeping colors simple (black and white for easier readability), we plan on using an OLED screen to maximize the amount of information we can fit onto the screen, as well as other potential weather safety considerations such as glare from the sun. OLED screens tend to deal with glare better than other screens. Our RGB display will read data from our PCB to relay information to the user. We will require a DC input of 3.3 to 5V.

3.8 SD Card:

Our SD card will be used to carry all of the logic of our microcontroller, as well as whatever locally saved map data we require. Since we will be storing a lot of data, whether it be reading local map data or writing local GPS data, we will require a large sized SD card. We believe that 16GB is a MINIMUM requirement, though more may even be required depending on the scale of the locally saved data we choose to include. Additionally, there needs to be enough space for the user to write their data. Since we will be constantly writing GPS data, we anticipate using an SD card with read/write speeds of at least 12.5 MB/s.

3.9 Headlight and Rear Light LEDs:

Both rear and headlights will need to emit enough light for the biker to see his road at night as well as be visible to cars and other vehicles. Most of the adequate headlights we have found have nominal voltages of around 8Volts which means the headlights might not even need buck converters to be powered. Both lights will be switched ON or OFF depending on how dark it is outside. The darkness threshold will be determined in the code and sensed by the ambient light sensor that will turn the lights on or off accordingly. The rear light being red, it will not need to be as strong or need as much power to turn on. It usually needs 2AAA batteries, that is 2x1.5 = 3V.

3.10 Trip-Reset Button:

This button will be connected to the HUD and microcontroller and used by the user to inform the display that a new trip has started. That way, the settings will be reset (Distance, Destination, Heading, Wattage Generated, etc …)

3.11 Control Inputs (Ambient Light Sensor and Buttons):

Depending on the light sensor's output to the board, either a HIGH or a LOW state will be given to the rear lights and headlight via the microcontroller pins which will determine whether to turn the lights on or not. As for buttons, there will be two long switch buttons, one at each side of the bike. By pressing any of these buttons, the signal light of the same side will start blinking as an indication of the biker's upcoming turn direction. The biker can turn their flasher off by pressing the button a second time.

3.12 Turn-Signal LEDs:

The turn-signal LEDs, like the rear light, will be small in size and will not need much power to turn on. Usually, they need 2AAA batteries, or 2x1.5 = 3.0 Volts. They will flash a yellow light and be placed at each side of the bike's hind in a way to indicate turns.

3.13 Transistor Switches:

We will need only one transistor to act as a switch for the headlights LEDs. This transistor will have three connections: A wire coming from the headlights logic pin of the microcontroller, A wire coming from the buck converter or battery, and a wire as output going to the LED. Most transistors can do the job. It will be a simple component on a PCB.

3.14 General ON/OFF Switch:

When the user finishes their biking workout/commute, they will have to switch the system off. Since they cannot turn a motor off because it is a mechanical device, a switch will be placed between the battery and the converters that they can press to turn the system off. It will be big and easily visible near the monitor at the front of the bike.

3.15 Risk Analysis

The biggest risk in this project is the physical force exerted on the motor. In fact, we have to fix the motor in a stable way and ensure it is positioned such that it minimizes its instability risk. To do that, the torque exerted on the pulley head must be perpendicular to the weight force of the motor so as to have a null scalar product of both forces and not push the motor to fall off. This will also be greatly feasible with the tools used to fix the motor to the frame of the bicycle. In order for the positioning of the motor to be adequate, it would ideally be placed on the back part of the bike's frame and low enough to be almost at the level of the cogs. it's chain should turn around an added plastic or metal cog-like disk on the wheel's metal rods that would revolve at the same rate as the wheel but with a smaller diameter. We can then make the wires go from there to the front of the bike by fixing them to the bike's body.

Doing this properly is critical to the functionality of the design and must be done properly to ensure performance as well as the safety of the user. The rest of this project does not present much risk as most of it is a combination of smaller projects which are themselves of minimal risk.

4 Safety and Ethics

All of this feeds into our main ethics concerns for this project, the responsible design and implementation of the mechanical components, which have the greatest potential for harm to the user.

To address this, we refer to IEEE 7.8 # 1. “to hold paramount the safety, health, and welfare of the public…” and 6. “...to undertake technological tasks for others only if qualified by training or experience…” which both guide our approach to the design. The way 7.8.1 applies is in the design itself.. By creating a system whose goal is to allow bicyclists to travel the road more safely, we are looking out for public interest. The implementation of guideline 7.8.6 will require that we consult others with more mechanical design experience to ensure that our design is both safe in principle, and practice as far as the user is concerned.

Finally, there are environmental and health concerns associated with the use of a lead-acid battery, especially one deployed on a vehicle which will likely be stored outside. To ensure that the battery cannot cause harm to the user or environment, it will have to be properly enclosed such that weather and other external factors cannot effect it.

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