AUTOMATIC BIKE LIGHT

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Abstract

Our project is an automatic bike light. There will be a button that turns the whole system on. If the bike is not moving for over a minute when the switch is on, determined by an accelerometer sensor, the lights turn off. A light sensor measures the amount of ambient light in the air to determine if it is day or night, and if it determines that it is day the front light will be set to a strobing setting, while if it is night then there will be two constant brightness settings depending on the amount of light in the area. The rear visibility light will always be on. There will also be a LiDAR sensor on the back of the bike that will alert the user if a car is approaching within 40 meters by turning on a rear-alert light on the handlebars. Additionally, the biker will provide user input, using two pushbuttons, that controls a rear turning light indicator to let drivers behind them know they are turning.

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1. Introduction

1.1 Problem

Bicycles that drive on the road legally must have a light on the front allowing them to be visible for 500 feet and have a rear reflector or rear light in the state of Illinois. It is also recommended that a bike is visible for at least 100 feet for vehicles approaching from behind.

The majority of bicycle lights currently in the market do not have systems in place to automatically adjust their brightness, in the same way cars have automatically adjusting headlights. Additionally, they often lack a method for cyclists to indicate when they are turning and which direction they are turning, which can cause confusion if the cyclist doesn't use hand signals to indicate their turns.

Even if cyclists have lights on their bikes, they can forget to turn them on. Similarly, cyclists can forget to turn their lights off, thus draining the battery and making the lights useless. Furthermore, the luminosity of the bike light might not be appropriate for the light level of the environment. Having a light that is too dim for the environment reduces the bicyclist's visibility, while having a light that is too bright wastes the battery of the device.

While there are bicycle lights in the market that address some of these problems, they are often too expensive for the average consumer. The most similar product to our own is the Garmin Varia which is a bike light and radar system which retails for $200. This price barrier can prevent most cyclists from accessing these features for their bicycles.

1.2 Solution

We propose to create an affordable set of bike lights that automatically adjust based on the amount of ambient light in the environment. This system would include a white light in the front that has three different output settings; a flashing mode for riding in the daylight, a bright constant beam for low-light nighttime environment, and a dim constant beam for well-lit nighttime roads. Additionally, a red light would be included on the back that is always on for constant visibility. The system would contain a light sensor that detects the light-level of the environment and each light in the system will switch to the appropriate setting based on the input from the sensor.

The system would also include an accelerometer that detects when the bike is moving. When the accelerometer is activated, it will enable the light sensor to detect the ambient light and set the bicycle lights to the appropriate light level. This system would operate on a timer, automatically shutting off when the sensor hasn't detected any activity for five minutes. Additionally, a push button would be in place to manually turn the lights on and off.

In addition to the red LED, the rear light module would contain a LIDAR sensor that detects objects behind the bicycle. If a vehicle were to approach the bicycle from behind, the LIDAR would detect it and send a signal to an alert light at the front of the bike.

There would also be two turn signals LEDs on the back of the bike that the user can use to indicate their turn. The front of the bike would include a left and right button that corresponds to the respective turn signal light.

1.3 Visual Aid

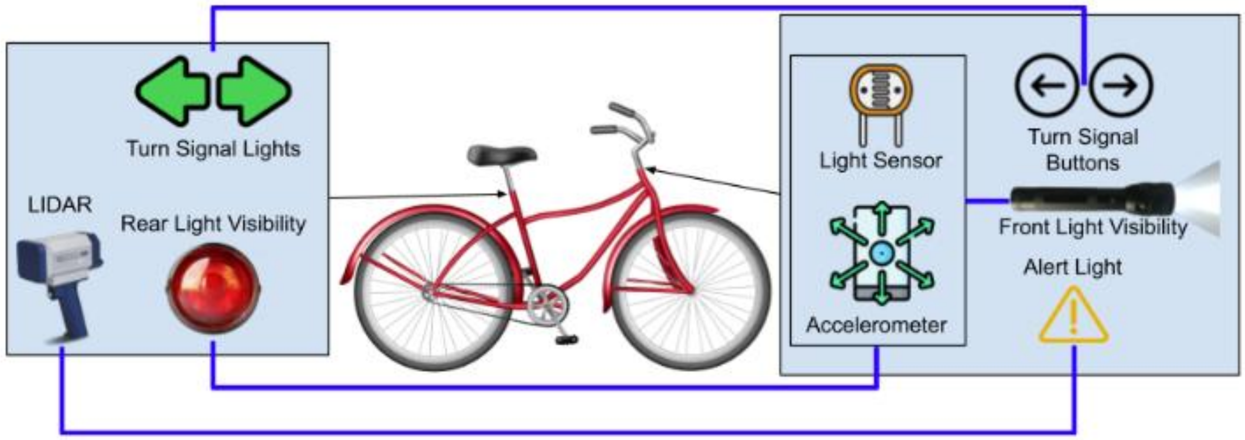

Figure 1. High Level Diagram

1.4 High-Level Requirements List

For the automatic bike light project to be considered a working solution to the problem statement described above, the following high-level requirements must be met:

- The light sensor must determine it is daytime when the ambient light it detects is greater than or equal to 1,000 lumens, and must determine it is nighttime when the ambient light it detects is less than 1,000 lumens.
- The radar sensor must detect an approaching object behind the bike within a range of 40 meters.
- When the bike is not in use, the lights must automatically shut off after a minute of inactivity.

2. Design

2.1 Block Diagram

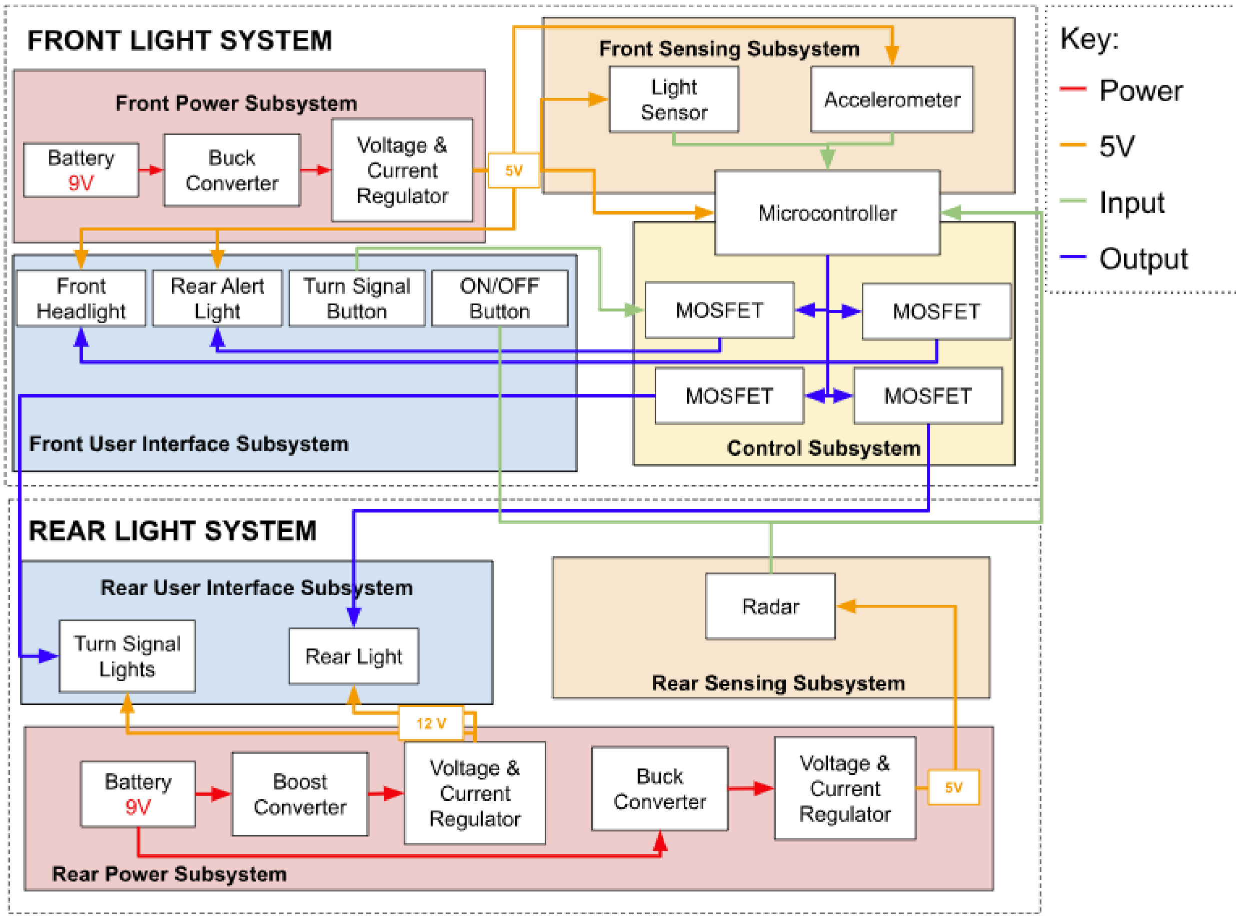

Figure 2. Block Diagram Design

2.2 Subsystem Overview

2.2.1 Front Power Subsystem

The front power system provides power to the front sensing subsystem and the front control system.

2.2.2 Front Sensing Subsystem

The front sensing subsystem detects the amount of light in the environment and determines whether or not the bike is moving.

2.2.3 Control Subsystem

The control subsystem interfaces with all of the other subsystems, converting the inputs from the sensors and push buttons to outputs for the bike lights indicator signals.

For the front light system, the control subsystem takes the light sensor and accelerometer inputs and sets the bike lights to the appropriate light setting. The microcontroller also determines whether to override the signals from the sensors upon user input to the pushbuttons.

For the rear light system, the control subsystem is used to control the rear light to indicate the direction the cyclist is turning based on the user input buttons on the front of the bike. It is also used to send information to the front of the bike on whether or not an approaching object is within 40 meters behind the bike.

2.2.4 Front User Interface Subsystem

In the front user interface subsystem, the front headlight of the bike is set to a strobing setting during the day and a constant light setting at night. A small rear-alert light on the right handlebar is connected to the rear control subsystem and turns on when the rear control subsystem detects an approaching object within 40 meters behind the bike. Turn signal buttons (one button for right and one for left) on the left handlebar are used to indicate the direction the cyclist intends to turn and sends this information to the rear control subsystem.

2.2.5 Rear Power Subsystem

The rear power subsystem provides power to the rear sensing subsystem and the rear control subsystem.

2.2.6 Rear Sensing Subsystem

The rear sensing subsystem detects if an approaching object is within 40 meters behind the bike and sends this information to the front user interface subsystem.

2.2.7 Rear User Interface Subsystem

The rear user interface subsystem includes the turn lights on the back of the bike that indicate if the user is turning as well as a rear light that is always on for visibility purposes.

2.3 Subsystem Requirements

2.3.1 Front Power Subsystem

The front power system consists of a 9V/5Wh battery that is connected to a buck/boost converter depending on the desired voltage and current and then passed through a voltage and current regulator which is then used to power the other subsystems on the front of the bike. The battery interfaces with the front sensing, front user interface, and control subsystems. To ensure compatibility with the other components in the subsystem, the 9V is stepped down with a buck converter to 5V. The stepped down voltage is regulated to ensure a stable output voltage of 5V +/- 0.1V. The battery distributes the following power requirements to the loads: 0.5 W to the light sensor, 0.5 W to the accelerometer, 0.27 W to the headlight, 0.075 W to the rear-alert headlight, and 0.055 W the microcontroller. To be considered functional, the front power subsystem must output a steady 5V +/-, enable all the sensors to stay on and provide a sufficient light source in all of the operating modes for the front headlight.

2.3.2 Front Sensing Subsystem

The front sensing subsystem contains the light sensor and accelerometer that the bike lights depend on to turn on. The light sensor detects the level of ambient light in the area and sends this information to the microcontroller. Based on the amount of light detected, the microcontroller communicates what mode the front headlight should be in. If the light sensor detects an ambient light level of at least 1000 lux, the sensor will communicate to the microcontroller that it is daytime outside. If the lux readings are between 10 and 100, the environment will be considered well lit. If the lux readings are less than 10, the surrounding will be considered poorly lit enough to warrant the brighter constant beam setting.

The subsystem will also contain an accelerometer that communicates with the microcontroller and turns off the front and rear lights if no movement is detected in the bike when the system is turned on. The sensor is also connected to a timer. If the accelerometer hasn't detected motion in one minute, the sensor will communicate to the microcontroller that the lights should turn off.

2.3.3 Control Subsystem

The control subsystem controls the input and output components for the front and rear bicycle lights. This subsystem is housed in the front light module and contains a microcontroller and a MOSFET for each of the output loads. The microcontroller receives input signals from the sensors from both the front and rear sensing subsystems as well as the button inputs from the user interface systems.

Both the light sensor and accelerometer from the front sensing subsystem deliver information to the microcontroller that determines whether or not the lights will turn on. If the accelerometer is not detecting movement, the microcontroller will set a timer to turn both the front and the rear lights off after one minute, regardless of the light sensor input. If the ON/OFF button in the front user interface subsystem is toggled while the accelerometer is reading a signal, it will override the sensor and turn the lights off. If the accelerometer is reading a signal and the ON/OFF button has not been pressed, the microcontroller will read the input from the light sensor and set the lights to operate in the appropriate mode. If the accelerometer is not reading a signal and the ON/OFF button is pressed, the microcontroller will override the sensors and turn the light on.

The control subsystem would also interface with the rear light system by receiving information gathered from the light sensor and vibration sensor in the front and delivering it to the front light module and the back light module. It would also deliver information from the radar sensor to the front control system. Information from the radar on the back of the bike is sent to the front of the bike and the microcontroller receives information from the light and vibration sensor on the front of the bike and uses that information to operate the rear light.

2.3.4 Front User Interface Subsystem

The front user interface subsystem consists of the front headlight, the rear-alert light, the turn-signal button, and the on/off button. The front headlight is powered by the front power subsystem and is controlled by a MOSFET in the control subsystem, which receives its setting instructions from the microcontroller. To be considered functional, the headlight must be set to a strobing setting during the day and one of two constant light brightness settings at night. The rear-alert light is a small indicator light on the right handlebar that is powered by the front power subsystem and is controlled by a MOSFET in the control subsystem, which receives instructions from the microcontroller on whether the light should be on or off. To be considered functional, the rear-alert light must be on when an approaching object behind the bike is within 40 meters and must be off otherwise. The turn-signal buttons, one for left-turn and one for right-turn, are located on the left handlebar and send information on the direction the cyclist is turning to the microcontroller. To be considered functional, when the left-turn button is pushed, the button must send the direction to the front control subsystem that the cyclist is turning left. When the right-turn button is pushed, it must send the direction that the cyclist is turning left. If the button is pushed a second time, it must send the direction to the front control subsystem that the turn signal should be reset.

2.3.5 Rear Power Subsystem

The rear power subsystem consists of a 9V battery, a buck converter, a boost converter, and two voltage regulators. It is connected to the rear user interface subsystem, and the rear sensing system. The buck converter takes the nine volts from the battery and decreases it to five volts to be compatible with the radar sensor and components in the other parts of the circuit. The boost converter takes the 9V from the battery and increases it to 12V to be compatible with the rear light and turn-signal lights. The voltage regulators then take either the 5V or 12V from the output of the buck and boost converters and maintains these outputs as steady, constant output voltages of 5V +/- 0.1V or 12V +/- 0.1V to protect the other parts of the circuit from voltage fluctuations. To be considered functional, the rear power subsystem must output a steady 5V +/- 0.1V and power radar sensor, and it must output a steady 12V +/- 0.1V and power the turn-signal lights and rear light.

2.3.6 Rear Sensing Subsystem

The rear sensing subsystem consists of a radar sensor, which is powered by the rear power subsystem. The radar sensor is positioned so that it faces the area behind the bike and sends information about whether there is an approaching object behind the bike to the microcontroller in the control subsystem. To be considered functional, the radar sensor must detect if there is an approaching object behind the bike within 40 meters and send this information to the microcontroller.

2.3.7 Rear User Interface Subsystem

The rear user interface subsystem is composed of turn signals that operate based on user input transferred from the control subsystem, which indicate if the rider is turning right or left, as well as a rear visibility light. All lights are powered by the rear power subsystem. To be considered functional, the rear visibility light must be continuously on and the turn signal lights must correctly indicate whether the cyclist is turning left or right, based on the user input.

2.4 Tolerance Analysis

An aspect of the design of this project that poses a risk to successful completion is the lifespan of the battery. The battery must be able to power all of the required sensors and circuit components and last for a reasonable amount of time.

Battery 1: 9V battery power rating = 5 Wh

Battery 2: 9V battery power rating = 5Wh

Battery 1:

Light sensor power: (100mA)(5V) = 0.5 W

Accelerometer: (100mA)(5V) = 0.5 W

Headlight: (30mA)(9V) = 0.27 W

Rear-alert light: (15mA)(5V) = 0.075 W

Microcontroller: (11mA)(5V) = 0.055 W

Battery 1 total power: 0.95 W → 5.26 hours of power

Battery 2:

LiDAR sensor power: (100mA)(5V) = 0.5 W

3 Rear Lights: 3(50mA)(12V) = 1.8 W

Battery 2 total power = 2.3 W → 2.17 hours of power

So, the 9V battery for the front-light system and a separate battery for the back system will provide the necessary power for a sufficient amount of time.

3. Costs

3.1 Parts

Table 1. Parts Costs

Part Name	Part Number	Manufacturer	Retail Cost ($)	Bulk Purchase Cost ($)	Quantity	Actual Cost ($)
UV/IR/Vis Light	SI1145 (supply	adafruit	$9.95	N/A	1	$0

sensor	cabinet)					
LIDAR Sensor	LL-905-PIN-01 (supply cabinet)	Garmin	$124.95	N/A	1	$0
Buck Regulator	MAX636ACPA	Maxim	$0.0075	$9.24 / 124 chips	3	$0
Voltage Regulator	LP2951 (Student self service)	Texas Instruments	$0.598	N/A	2	$0
MOSFET	2n2222 (student self service)	Various	$0.34	N/A	4	$0
9V Battery - Alkaline	EN22 (supply cabinet)	Energizer	$3.04	N/A	2	$0
9V Battery Clip	233 (supply shop)	Keystone Electronics	$0.84	N/A	2	$1.68
Accelerometer Sensor	1528-1516-ND (digikey)	Adafruit Industries LLC	$4.95	N/A	1	$4.95
Microcontroller	ATMEGA328P-PU (Student self service)	Microchip Technology	$2.89	N/A	2	$0
Cable	9540-001 (supply center)	N/A	$1.57 per foot	N/A	5 ft	$7.85
Front lights	N/A (Amazon)	Super Bright LEDs	$5.99	N/A	1	$5.99
On/off/turn button	MPB-1 (supply center)	Hammond Manufacturing	$1.28	N/A	3	$3.84
Rear Lights (clearance lights)	N/A	Autozone	$5.89	N/A	3	$17.67
Indicator Light	5102H5-5 (ECE store)	VCC	$3.89	N/A	1	$3.29

Total						**$66.99**

4. Ethics, Safety, and Societal Impact

Some important considerations are the possible safety impacts of our work. If the lights are too bright, we risk blinding drivers and pedestrians which could cause an accident. To mitigate this risk, we will ensure that our lights are under 1,000 lumens and point the lights in a downward direction to avoid a driver or pedestrian making eye contact with the light.

Another important consideration is possible radar malfunction. The user would not be informed that there is a car behind them, and they could get into a car accident because they did not expect there to be a car behind them. To minimize this risk, we have a safety metric that. Additionally, if our turn signals don't work correctly then surrounding traffic will not know where the bike is going, which could cause an accident. To ensure that our sensor communication reliably works we will follow the IEEE wired network standard 802.3.

We also intend to comply with all IEEE ethical standards as well as UL wiring standards to prioritize the health and safety of users of our device.

Finally, our strobing lights have the possibility of negatively affecting individuals in society with epilepsy, which is an important consideration in terms of the overall impact of our product. We will ensure our lights are of a similar brightness level to existing street/car lights to prevent harming bystanders.

5. Conclusion

In conclusion, we are proposing an automatic front visibility bike light that turns on when the bike is moving, strobing during the day and is on constantly at night with two levels of light depending on ambient light. We also have a constant rear light for visibility. We will determine if the bike is moving using an accelerometer and determine day and night using a light sensor. Additionally, the bike will have a LiDAR sensor on the back of the bike that will warn the rider with a front warning light if a vehicle is approaching them within 40 meters. The rider will also have a turn signal level on the left handlebar to control turn signal lights on the back of the bike.

We must consider important safety concerns about possibly blinding drivers and pedestrians, and possible repercussions of if features like the LiDAR and the turn signals malfunction. For future work beyond the scope of this semester students could work on making this system wireless.

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