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Smart Tail-Light System

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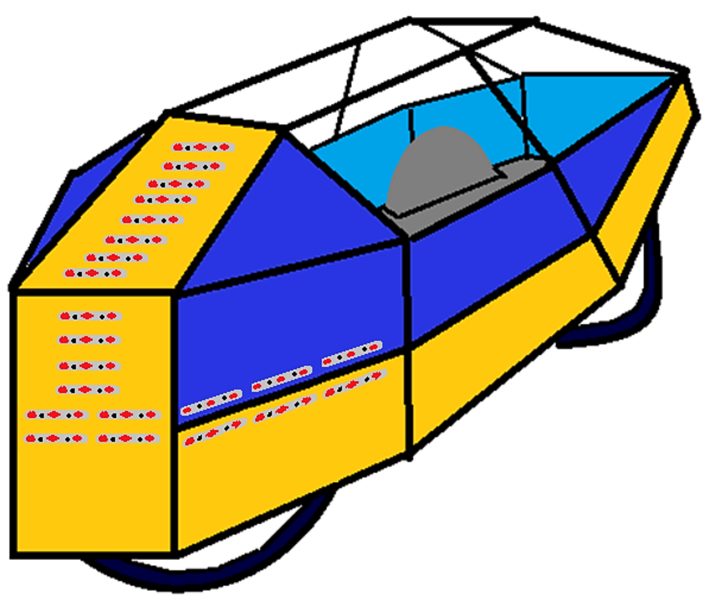
Honors Senior Design

Smart Tail-Light System

Rear Sequential Flash-Lit Velocity Dependent, Proximity Activated Tail Light & Braking System for Human Powered & Slow Moving Vehicles

In conjunction with Human Powered Vehicle Team



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INTRODUCTION

According to the National Highway Traffic Safety Administration (NHTSA) Safety Vehicle Research, 29% of all vehicle accidents are rear end collisions. Many are a result of failure to respond to a slowing or stopped vehicle. [1] The purposed LED rear lighting system will incorporate attention getting techniques to increase vehicle visibility to other drivers. Due to the small size and stature of the 2015 human powered vehicle called Joey, it will be out of the ordinary when traveling on roadways. “Three in four (72%) bicyclists who rode after dark said they tried to do something to make themselves more visible.” [2] When this vehicle is out on the road after dark, a strong notification system is essential. With this attention getting system, the probability of vehicle collisions can be reduced. The use of tail lights on bicycle is a very common occurrence. Most states require a minimum of a red reflector on the rear of the bicycle. Many bicycles are now outfitted with aftermarket lighting systems. The use of a sequential tail lighting notification system is an advanced method. More than a flashing light, the system design uses safety statistics to determine optimum attention getting flashing frequencies and patterns. [1] It is the inconsistent pattern is what alerts approaching vehicles. The phenomenon of losing touch or becoming detached while driving is call psychological disassociation. The approaching driver could be in this state of daydreaming and only alterations to the environment can break the disassociation. Vehicle taillights are the main defense to this syndrome, but they do not work for vehicles that are moving slowly but not breaking in front of a rapidly approaching vehicle. The principle of the smart light system is to generate this alteration and break the trance of the disassociation.

DESIGN BRIEF

There are many rear tail light options out on the market, including flashers, ready glow, and combination taillights. The innovative part of Joey is that the flashing sequential light with varying frequencies dependent on vehicle velocity, a braking full on override, and a proximity signal to notify a motorist if they are too close. In this design, frequencies help visibility. Increased visibility can reduce vehicle collisions. To push this advance in safety, lobbying for legislation in local government and beyond with flashing rear lights can prompt a requirement of improved lighting for all on road bicycles. As with other non-passenger car vehicle, motorists can become very accustomed to only cars being on the road, this is in line with the popular "Watch for Motorcycle" bumper sticker awareness campaign. For the sport and use of human powered vehicles to really take off, the public needs to be aware of their existence, and in a way this attention system will not only increase operator and vehicle safety, but also help make onlooker more aware of these remarkable machines.

Modern computer programs and custom programmed computer chips allow for the easy prototyping of the controller, speed sensor, and relayed high output LED sets powered by onboard batteries. The proposed attention system that Joey (the HPVT's bike) will use is a simple microprocessor controlled circuit. With the increase of powerful technology

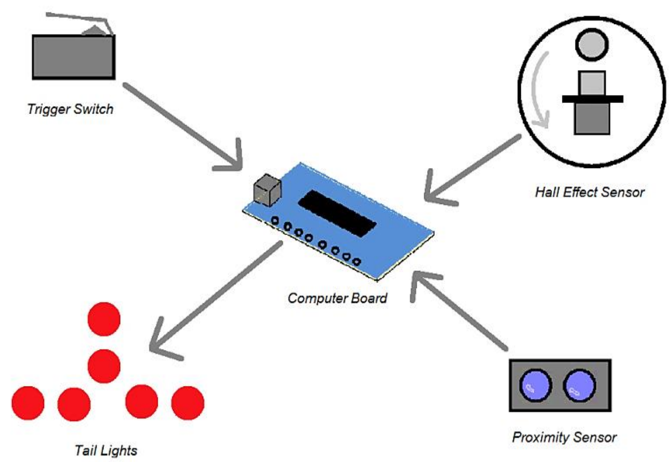


Figure 1. Prototyping tail light system

made accessible to the public, small teams can now prototype and build systems like these. A base board provided Arduino UNO will be used as the computer to system interface and controller. A simple code will be uploaded via USB port on the board to a small onboard computer. Sensors such as, wheel Hall-effect sensor for velocity input, trigger switch for braking input, and an optical sensor for proximity inputs will be fed into the board's analog and digital input pins as seen in Figure 1. The code will drive the MOSFET relays with signals from the output pins. Six 12 volt LED light groups will be triggered by the resistant dependent relays. The signal output pins will be causing a sequential pattern from top to bottom of the pattern. The relative speed of the sequencing will increase as the velocity sensor shows the bike is moving faster. This change in sequencing will notify motorists to the relative velocity of the vehicle. The sequential lights have the added effect of consuming less energy and as stated in AIESNA Conference that blinking lights have higher visibility that the same wattage light in a steady burn scenario. [3] While the bike is cruising down the road and it applies the brake, the full array of tail lights with turn on. This will include six 12 volt automotive taillights in a steady burn as long as the brake trigger switch is depressed. As soon as the brake is released, original sequencing based on velocity with resume cycling. Another important feature is the proximity sensor. When a vehicle is within a prescribed distance, which is varying based on the velocity input, the rear tail lights will display a full array blinking between 4.2 and 6.7 Hz. [3] These three key innovations should greatly improve vehicle visibility and driver safety while out on the road.

CONCEPTUAL DESIGN

A Function Structure Diagram is a way to describe an entire device or system as a single component entity and transforms inputs of energy, material, and signal into desired outputs. Figure 2 shows the function structure diagram of the inputs and outputs of the Smart Tail-Light System.

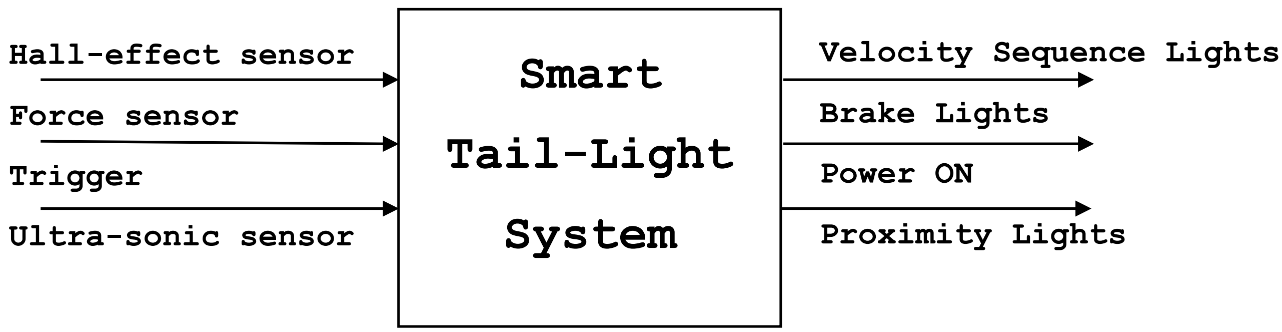


Figure 2: Function structure diagram

An Objective Tree compares the importance of the design criteria using weighting factors so that a better decision can be made when the comparisons are made at the same level in the tree. Figure 3 shows the how the lighting systems is split into importance of cost versus effectiveness in service.

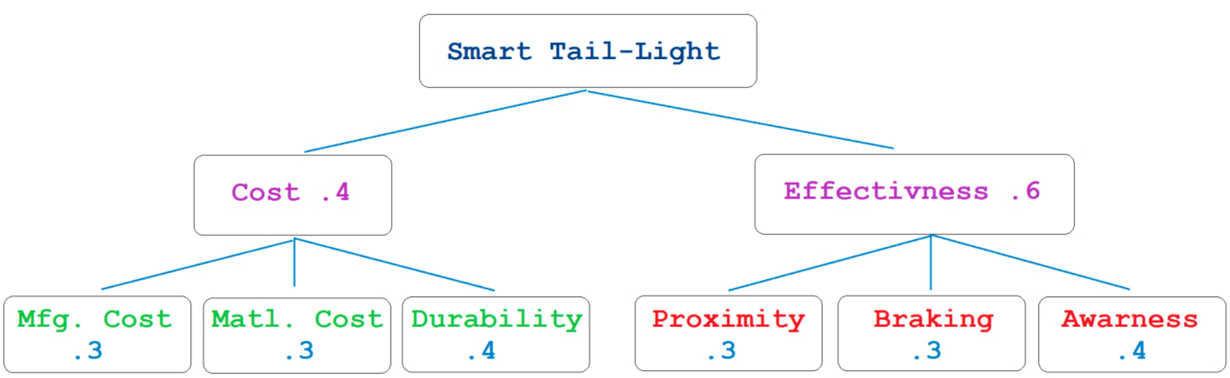
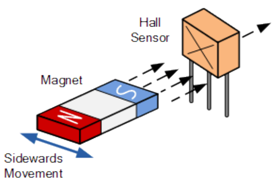
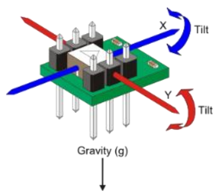
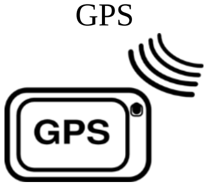
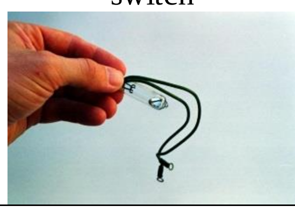
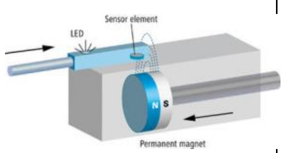


Figure 3: Objective Tree Structure

The Morphological Chart is a table used to organize the sub-problem solutions with sub-problem names as column headings and solutions as rows. Table 1 shows words and simple sketches to depict the sub problem solutions.

Table 1 Morphological chart

Velocity Pickup	**Brake Light**	**Proximity Light**	**Power Source**	**Visual Output**
Hall-effect on tire 	Switch on handle 	Ultrasonic 	Lithium Battery 	LEDs 
Magnet switch on tire 	Accelerometer 	Laser Sensor 	Off the Shelf Battery 	Light Bulb 
GPS 	Liquid metal force switch 	Optical Sensor infrared 	RC Rechargeable Cells 	Reflector 
Traction wheel 	Mechanical force switch 	Magnetic 	Traction dynamo 	LCD Screen 

A weighted decision matrix is a simple procedure to compare the design alternatives by adding up the weights for each concept. Below are the following concepts created from Table 1 and will be evaluated in Table 2.

Concepts:

1. Mag. Switch + Liquid Switch + Ultra Sonic + Off Shelf Battery + LEDs
2. Hall-Effect + Accel. + Laser + Lithium + Bulb
3. Traction + Brake switch + Ultra Sonic + Rechargeable + Bulb
4. GPS + Accel. + Optical + Dynamo + LDC Screen
5. Hall-Effect + Mech. Switch + Ultra Sonic + Lithium + Reflector

The above concepts were ranked from 1-5, with 1 being the worst rating and 5 being the highest rating. The sum of the rank of each concept by the weighting factors gives us the total score. As a result, concept 1 had the highest rating and was declared the winner.

Table 2 Weighted decision matrix

Weight	**Durability**	**Matl. Cost**	**Mfg. Cost**	**Proximity**	**Braking**	**Awareness**	**Total**
	.16	**.12**	**.12**	**.18**	**.18**	**.24**	**1**
Concept 1	5	4	5	5	5	5	4.88
Concept 2	4	2	3	4	4	4	3.64
Concept 3	2	3	2	3	2	2	2.3
Concept 4	1	1	1	2	3	3	2.02
Concept 5	3	5	4	1	1	1	2.16

Prototype 1

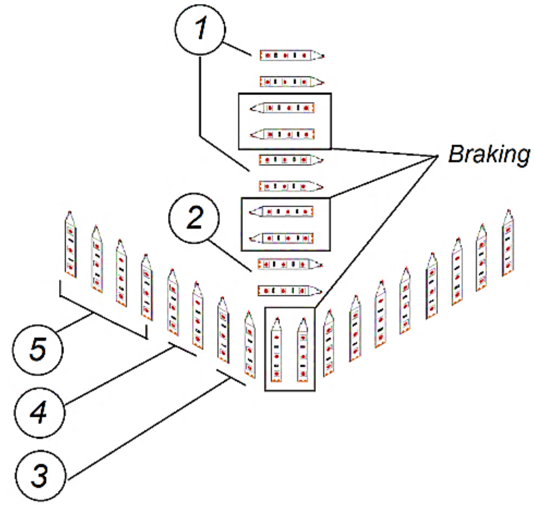


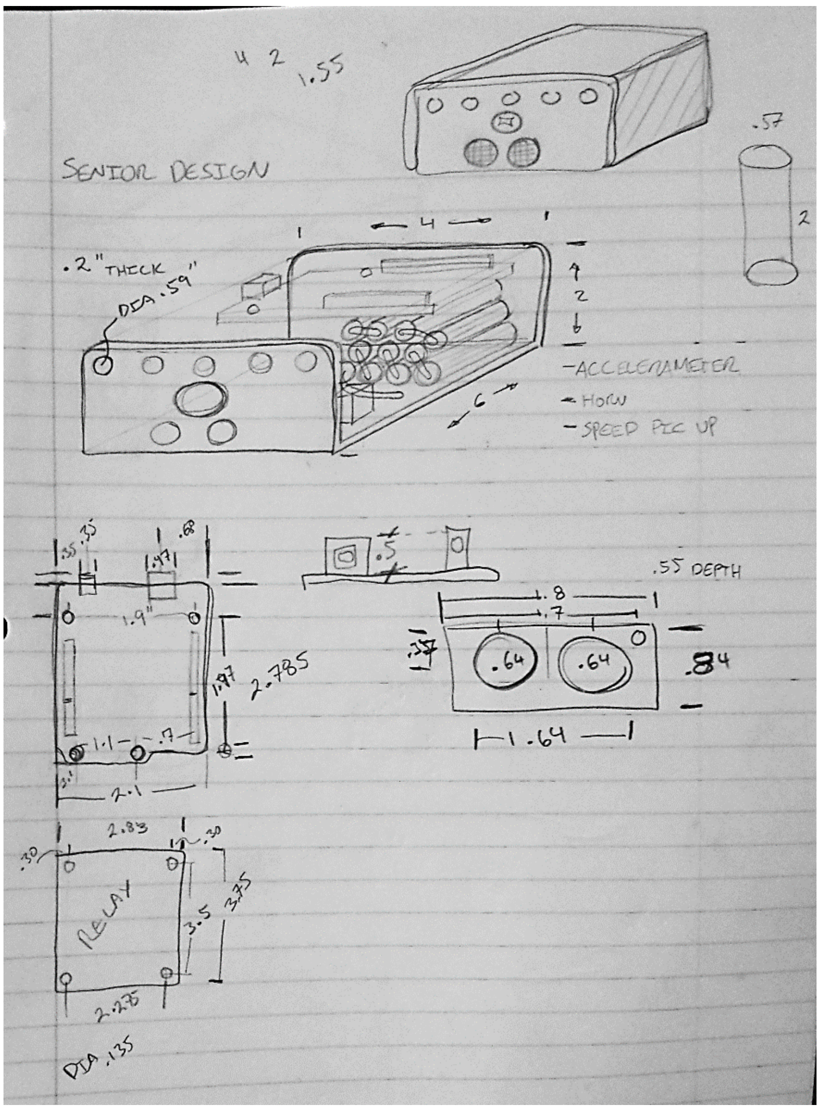
Figure 4. Rear view LED Tail Light Pattern and Sequence

The first prototype was built using an Arduino UNO board with a USB port, 6 inputs, and 12 outputs. A Hall-effect sensor was installed to one of the spokes to pick up a signal from a stationary rotating wheel. A trigger switch mimicked the brake setup. The proximity sensor was pointed in an open field of view (approximately 15 ft.). The board signals the MOSFET variable voltage power relays that run the 6 pods of LED lights in a upside down "T" pattern shown in Figure 4.

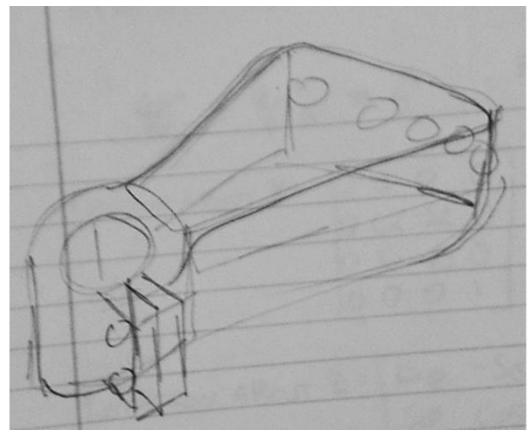
A code will be written up in the Arduino software to program the Arduino UNO board to pick-up pulses from Hall-effect sensor to frequency which is the basis to run the sequential LED lights. Building the prototype will be an essential precursor to the installation and functioning of the full scale version on Joey.

Prototype 2

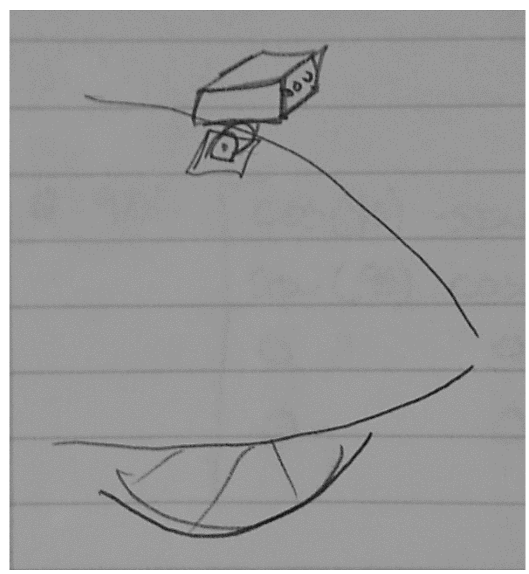
The purpose of the prototype 2 was to consolidate the technology and systems implemented on prototype 1. It was reduced in size from an integrated wiring harness to a self-sustained package. In the prototype 1 the wiring was part of the fairing on the vehicle. In the prototype 2 the circuitry is enclosed in a mountable package. The prototype 2 uses all of the same hardware as the prototype 1, but reconfigured and condensed. The prototype 2 will be used in the prototype testing phase of the project. This is so determine the effectiveness of the project as a solo unit and enable easier testing. Easier testing because it is not attached to the 2015 Human Powered Vehicle, which had been damaged in racing a transport, then salvaged for part. We decided to model the prototype 2 on the original prototype 1 junction box. Below are some initial rendering and concept sketches. In them you can see the ultrasonic sensor, the LEDs, minimized battery pack and the Arduino UNO used to drive the mechanism.



Sketch of Prototype 2 package



Clamping mechanism for rear of bike



Placement of Prototype 2 on Joey

Figure 5: Prototype 2 Conceptual Sketches

The prototype 2 allows us to work with the system in a compact functioning version. The prototype 2 will be primarily used as a test mule for programing purposes, but also be inspiration for a fixture mechanism. Seen below are some concept drawings of the prototype 2 attached to the 2016 HPV race vehicle and another possible mounting scheme for unto a conventional bicycle seat. The end goal of this project is to develop an affordable, effective, and smart rear taillight system so our major development work will be based on the conventional under seat mounting and fixture.

Prototype 3

The prototype 3 development project will be a culmination of all the prototype 1 and the prototype 2. The prototype 3 is a fully functioning alpha prototype that is a marketable miniaturization of the prototype 1 and prototype 2. The prototype 3 is roughly a third the size of the prototype 2. The goal of this device is to reduce the size, but retain all the capabilities. We will have the velocity dependent flashing, the automated break light and the proximity notification.

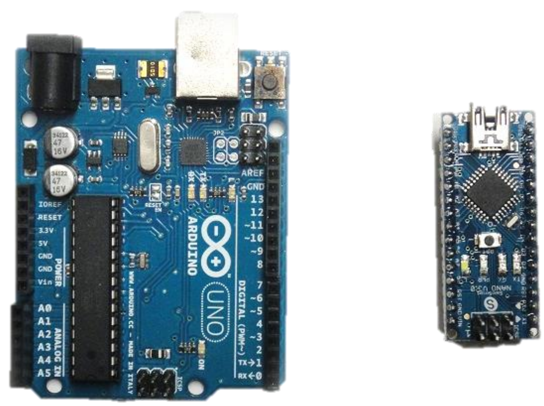


Figure 6: Visual comparison of UNO vs. Nano

One of the major size reducers will be running an Arduino Nano for our processing. The Arduino Nano has all the capabilities of the Arduino UNO, but is roughly a quarter the size and cost. We will be able to use all the same programing language, schematics and retain all or our goal features.

Table 3: Comparison of UNO vs Nano

	Processor	Operating / Input [V]	CPU Speed	Analog In/Out	Digital IO/PWM	EEPROM [kB]	SRAM [kB]	Flash [kB]	USB
Nano	ATmega168	5 V / 7-9 V	16 MHz	Aug-00	14/6	0.512	1	16	Mini
	ATmega328P					1	2	32	
Uno	ATmega328P	5 V / 7-12 V	16 MHz	Jun-00	14/6	1	2	32	Regular

The prototype 3 will also focus on the mounting a fixture development of the project. The end goal is to use this system on a bicycle. The final design incorporated a seat tube adjustable mount allows for good visibility and access to the rear tire for velocity sensor pickup.

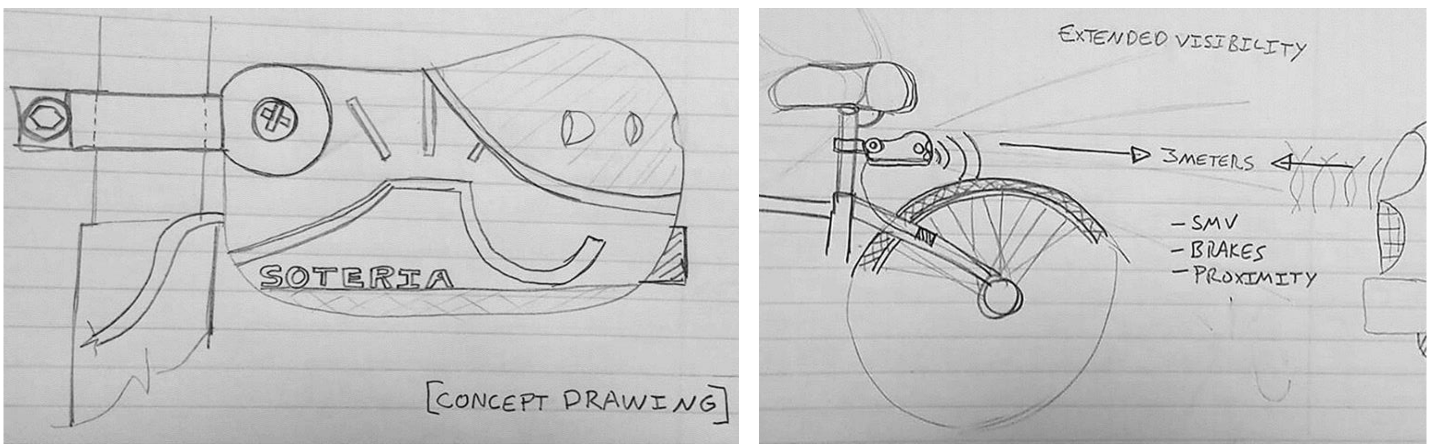


Figure 7: Prototype 3 Conceptual Sketches

EMBODIMENT DESIGN

Clarity of Function

The system is pretty centralized with the Arduino processor taking in and sending out all sensor information. The processor is key for functionality. The taillight LEDs are the only output other than the buzzer. The LEDs are the major contributor to the awareness effectiveness. The body also plays a minor roll by adding a failsafe reflective covering so even if the power runs out, the device will still have some inherent safety. The body acts as the structure, the battery case. It has integrated bracketry to mount the device to the seat column. Below are the main physical components of the taillight system and their function.

- LED- Following vehicle awareness
- Buzzer- Rider and following vehicle awareness
- Processor- reads sensor information and controls LEDs and buzzer
- Battery- powers processor and signaling system
- Inertia switch- sensor activates brake light
- Trigger switch- velocity sensor
- Ultrasonic sensor- sensor detects following vehicle proximity
- Power switch- power disconnect to system
- Case-house control items, provide protection from elements and structural mounting support.

Simplicity

The design from prototype 1 to prototype 3 has been a challenge of reducing since, complexity and cost. The alpha prototype is a simple, self-contained system. It offers all the design goals and a production cost that is reasonable. The material used are off the shelf items build with common practices and procedures. The coding used to run the system could easily be simplified even more with commercial electronics. The current coding is an open source language used to interface with the Arduino processors. The logic is simple with the most important functions higher on the logic list. First come brake lights, then proximity alarm, then sequential awareness lighting. The parts used to build the device are store bought with acceptable quality. A lot of plastics where used to reduce cost and weight, but retain appropriate strength.

Safety

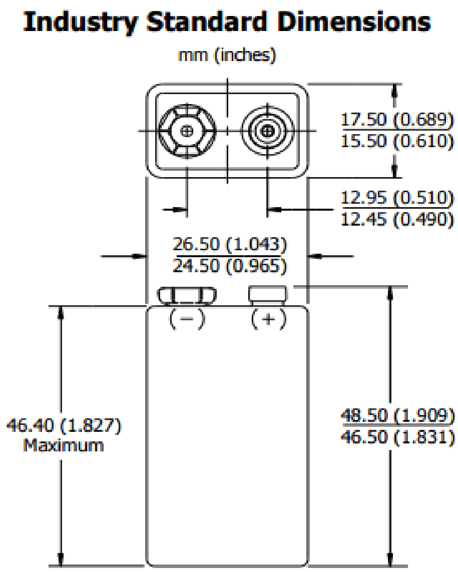
The system is safe, running on a low risk low voltage system that incorporates domestic 9 volt batteries. The Battery is contained in a watertight battery compartment, separated from the main board components by a plastic wall. The device also has the inherent safety of a standard reflector by applying reflective tape on the rear facing surface. In the case of a malfunction the lights will turn on continuously, a failsafe built into the system.

Minimal effect on the environment

The overall size of the device itself will minimize the effect of its production on the environment. The device does not emit any harmful by product other than spent batteries that through package labeling are recommended to be recycled. The material used in the device in not harmful in future model. The current prototype uses a mercury switch in the case but it will be obsoleted with an improved inertia switch. The case is made of recyclable ABS plastic also.

Power Requirements

The Arduino Nano uses around 280 mA. The seven LEDs require 20 mA per LED. At full ON all 7 LEDs will rewire 140 mA. The Standard domestic 9V battery has around 570 mAh available. This leaves at worse case, 420 mA will keep the system running for over an hour at full capacity. The device is estimated to run well over 2 hours at the lower operating power consumption range.



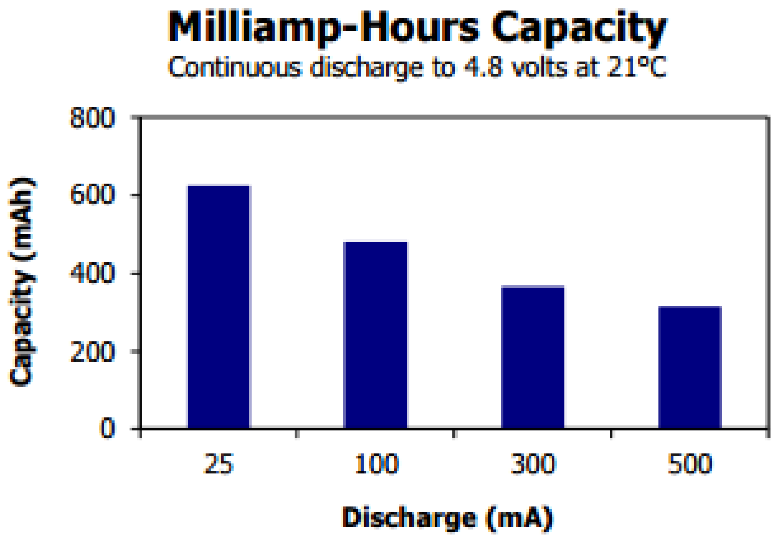


Figure 8: Battery Specifications

Prototype 1

Using the concept of inverted "T" pattern of LEDs, the LED strips were hot glued to the rear fairing according to the schematic in Figure 4. One of the difficulties of this project was that the lighting system had to be wired and built into the fairing. Wiring all the LEDs to the main junction control box required a team member to crawl into the fairing with soldering tools (see

Figure 9 left). This was a very dangerous and difficult task in the confined space. Another problem was all the clutter created by all the loose wires from every LED. This was solved by using flexible PVC pipe as a conduit to the main junction box, located at behind the driver's seat. A close up of the finished fairing is shown on the right of Figure 9.

Figure 9: Functioning Prototype 1 on Joey's Rear Fairing

Some sensor calibrations were done and the results were validated in laboratory settings. A full vehicle prototype was used to dial in the final sensor calibrations. Effects like the larger sensor wheel diameter and the sensor noise was calibrated out of the system.

During testing and development stages of the Arduino UNO code with the Hall-effect sensor, the team discovered that the sensor was extremely sensitive. Just a gentle touch to any part of the testing apparatus caused a signal impulse that immediately turned the lights on from a false sensor input. Dialing in the sensor calibration removed the signal noise. The discovery that the Arduino UNO was able to work at such low impulses was surprising. One issue encountered with full size testing is that the affective brightness of the LED strips in bright light was not as desirable. However in low to no lighting, the LEDs worked ideally as intended. Luckily, this tail lighting and braking system was intended for low ambient light settings; mainly night riding.

Figure 10: Testing Stage

From the prototype 1, the team concluded that the tail lighting and braking system proved the basic engineering concepts and thus met the safety innovation requirement. This system dose not only increase visibility, but also acts as a continuous test bed with the programmable options through the Arduino UNO board.

Prototype 2

All the hardware from the prototype 1 on Joey was used into this prototype to test our idea of a more compact and tight system package. All the hardware included: Arduino UNO, Relay circuit board, Hall-effect sensor, ultra-sonic sensor. The LEDs were switched from the strip style to the bulb type, and the 12V external battery was switched to a small AA battery pack. Using this idea of conserving space, the prototype was modelled with 2 levels vertically to hold the Relay circuit on one level and the Arduino UNO on the other (see Figure 11). On the base level, the battery pack can easily power the whole system without too much wiring.

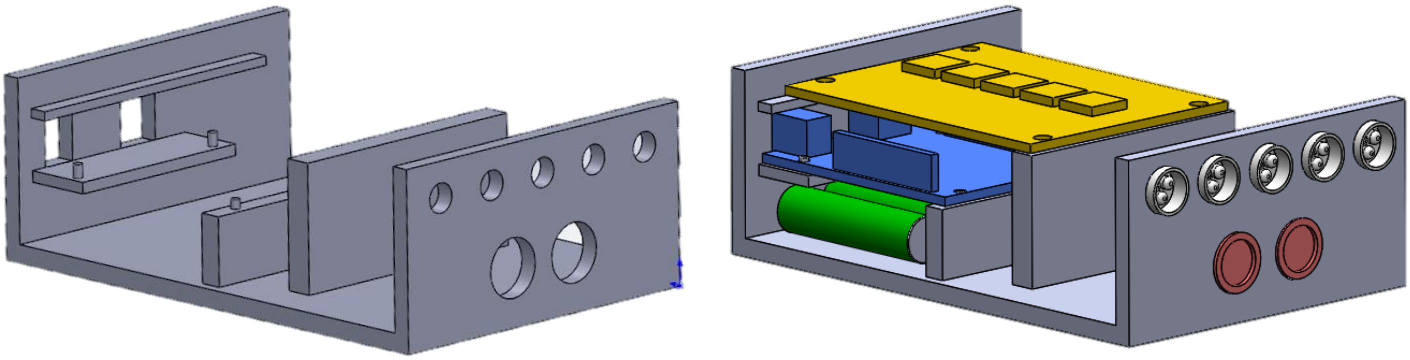


Figure 11: 3D model of Prototype 2 in SOLIDWORKS

The outer grey case from Figure 11 was converted to a STL file and 3D printed using ABS material. Some reasons for choosing 3D printing include: inexpensive rapid prototyping capabilities, time saver and easy machining if mistakes occur. The most important benefit of 3D printing this prototype was actually having a product in hand for testing, market feedback and personalizing. The ability to see and touch the product makes a difference compared to seeing it on SOLIDWORKS. The mentioned hardware was installed onto the 3D printed case and its components and levels can be seen in Figure 12. Figure 13 gives a more special representation of the fully assembled prototype 2.

With a fully assembled part, testing its lighting and sensor abilities began. Using the back USD port of the Arduino (see back view of Figure 13), we were able to upload, test and re-adjust the Arduino code to receive all the inputs from the sensors and produce the required output using the 5 LEDs.

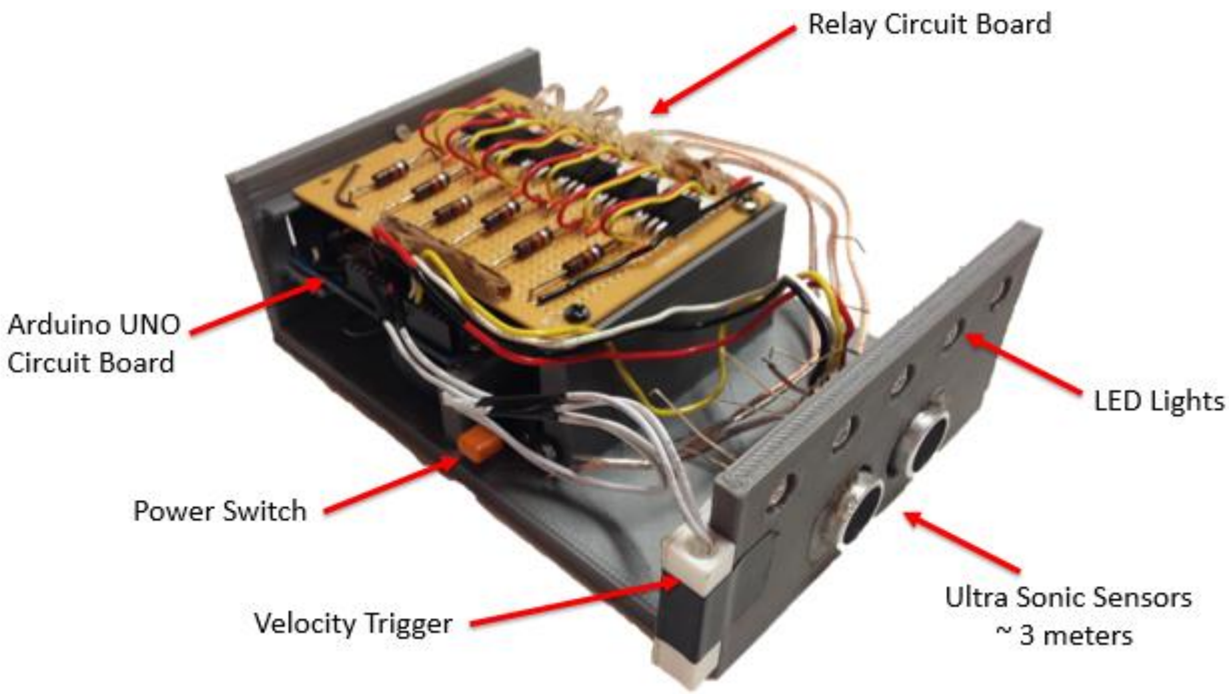


Figure 12: Different parts of fully assembled Prototype 2

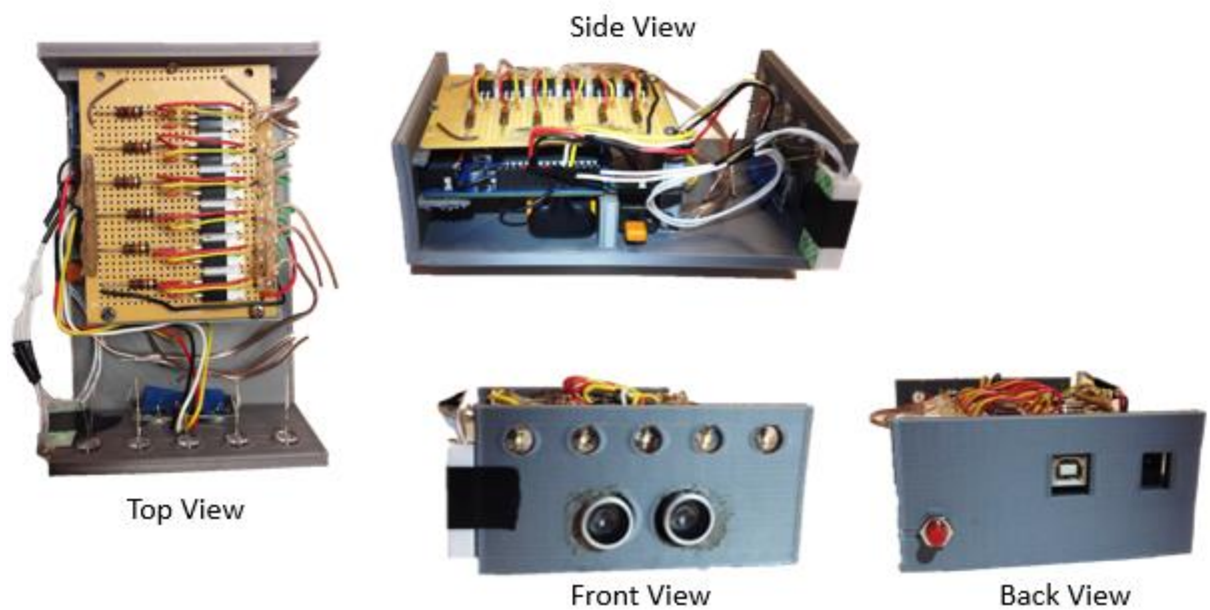


Figure 13: Views of the fully assembled Prototype 2

The sequence of the LEDs can be seen in Figure 14. The third LED acts as the center and initiator of the lighting sequence. Shortly after, the second and forth LEDs will both simultaneously light up. The first and fifth LEDs will close the sequence. This whole sequence will continue in a loop with the speed proportional to the velocity of the bike.

The brake lights occur when the brake is applied and when the accelerometer detects a decrease in speed. At this point, all of the 5 LEDs will simultaneously light up. This creates a very bright display to get the attention of vehicles behind the bike.

When the proximity of the bike and an upcoming vehicle comes to a prescribed distance, all the LEDs will light up similar to the brake lights. However, the lights will flash simultaneously together at a prescribed frequency to quickly obtain the attention of the rear driver. One of the advantages with the Arduino is the flexibility with changing all prescribed flashing frequencies and sequential speeds proportional to all the sensors (Hall-effect, accelerometer, ultra-sonic sensor).

Figure 14: Sequential and Brake Lights

Prototype 3

Prototype 3 is a hybrid design that minimizes the technology implemented in the prototype one and two. The device will retain all original functionality. To accomplish this goal we used a Arduino Nano processor, transistors to provide relay power, 5 red high output LEDs, piezo sound amplifier, a HC-SR05 ultrasonic range finder and a standard 9v domestic battery. All the components are mounted on a standard mini prototype circuit board offered from RadioShack. Below is the assembled inner components and circuitry.

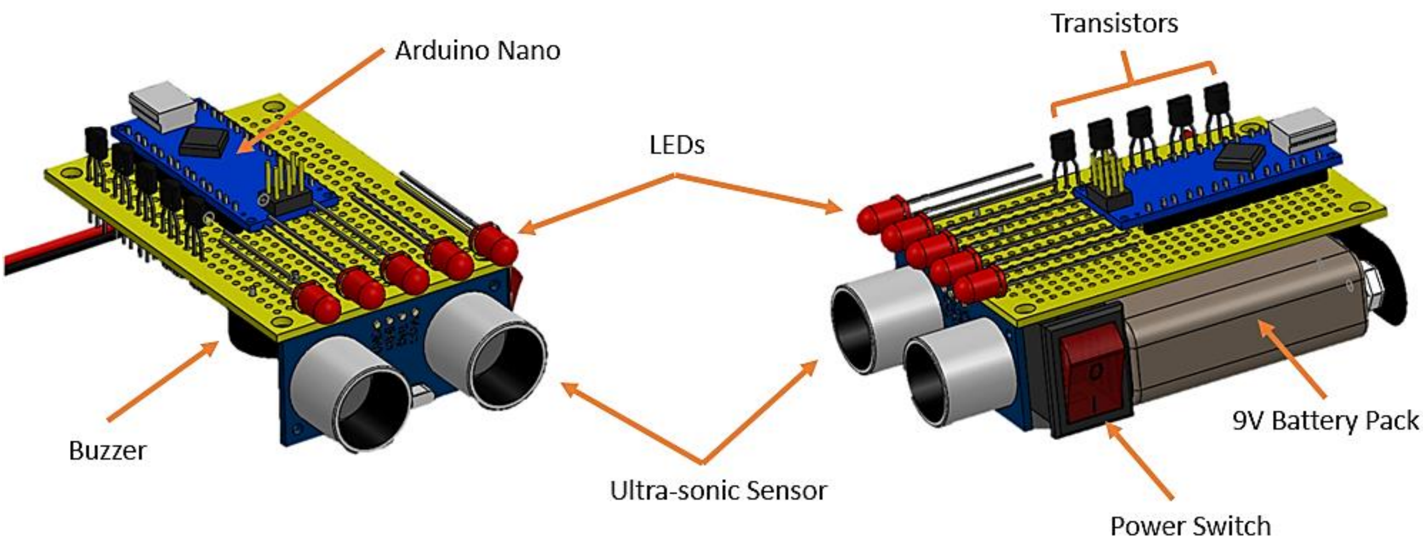


Figure 15: Components of the 3D model of Prototype 3

To surround the inner components the outer shell was developed as small and marketable as possible. Original concept sketches were the first inspiration and from there an envelope was built around the components. The basic envelope was rounded and smoothed with added visual ascetics. The fixture used to fasting the device under the bicycle seat was modelled after a run of the mill reflector bracket modeled and shown below in the 3D modeled prototype red bracket.

Commercially sold clamps 3D printed clamp

Figure 16: Clamp mechanism for Prototype 3

The bracket fixes to the seat post of a standard bicycle. The outer shell casing used the same rapid 3D print prototyping to create the UV resistant ABS shock resistant case. The case and bracket are shown in the designed location.

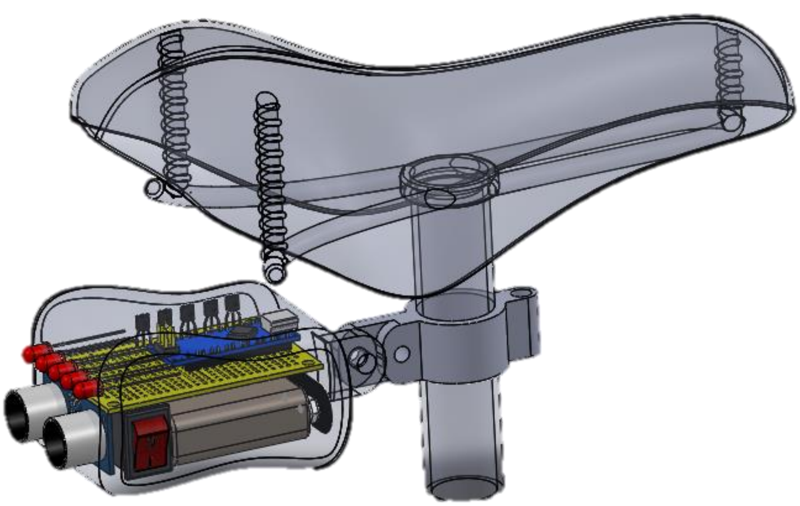


Figure 17: Final product of the Smart Tail-Light System

Some added implementations that further embody the prototype 3 are the use of a standard domestic 9V battery, and using a retractable cord to connect to velocity trigger device.

LEARNINGS

Prototype 1

Initially, front lighting was going to run the full length of the fairing, but upon initial testing the lights were found to shine too brightly in the driver's line of sight. The future headlights will be moved to a lower position on the fairing. Initial work on calibrating sensors led to a sensor noise and required a relook at the calibration. Just a single touch to the test wheel signaled the LED lights. Better input signal ranging removed the prototype sensor, removing noise and sensitivity. The prototype 1 was built too heavely. It incorporated a steel cunction box, heavy gage wires, lots of 12v automotive LEDs and wires traversing the whole inner shell of the fairing.

A negative aspect of the tail light design was that it did not incorporating a regenerative system. Batteries will either need replaced or recharged regularly. The system is designed to run for approximately six hours depending on battery life.

The *Rear Sequential Flash-Lit Velocity Dependent with Proximity Activated Tail Lighting and Braking System* is a step in a safer direction for all Human Powered Vehicles and motorists alike. The system is left open to new improvements through the capabilities of the onboard programmable Arduino UNO board. There was a lot to be learned from this initial prototype and the major issue of size and adaptability where was the main design focus for the modular prototype 2 design.

Prototype 2

Prototype two was an important step in the design process. From the prototype 1 to the prototype 2 they was a lot of special conception and component arrangement that took place. It also required a re-focus on what the visual capability of the device will be. Being 20 times smaller than the original prototype 1, the prototype 2 does not have the power or capability of the high output original system. To compensate great lengths were gone to improve visual concentration density by incorporating singular element high output LEDs. In effect creating a smaller device with comparable visual awareness effect. This was achieved with the use of seven large LEDs and standard 9V domestic battery. The biggest learnings that occurred were the use of the ultrasonic sensor, issues that arose from it, and the circuitry methodology used in the entire lighting device.

Prototype 3

With the information gained from the prototype 2, the prototype 3 was able to be reduced in size by nearly 66%. The power supply remains the same at 9V, but there is an integrated battery compartment, the case has an enclosed construction, and all the capabilities were retained even with its small size. Once again with size reduction comes, loss of visual awareness value. This stresses the importance of using techniques to improve visual awareness. Not only trying to retain the large high output LEDs, that case itself turned into an important reflective feature. The rear surface is comparable to a standard issue rear reflector and the shape was contusive. This innovation to improve visual awareness only came from study, testing, and working with these prototypes. This prototype solidified the design project objective to take the 2015 HPV team safety innovation to the next level to create a marketable platform for the technology.

MARKETING

Cost Analysis

The cost analysis for the prototype 3 is based on the items purchased to build the device. The cost of each part has been semi adapted to a manufacturing cost, so some prices have been adjusted due to the reduced cost of purchasing in bulk. All items used to build the device are purchasable over the counter at electronics shops and online. The only variable part of the device is the 3D printed case. The use of 3D printing is not necessary in a production status, so the cost basis is centered on an estimated cost of injection molded items. A manufacturing estimator helped come to the 60 cent production cost. The total manufacturing cost basis is estimated from research on comparable devices with approximate size, technology and functionality in common. Below is a cost table that tallies to total manufacturing cost of producing one Smart Tail-light device. This cost basis is an estimate only and does not incorporated, production overhead, quantity of production, or the marginal revenue. This is to determine only a base line cost not determined whether the business be independent or a purchasable product design to be sold to a larger company.

Table 4: Estimated Production Price per Product

Item	Price
Case	$0.60
Lighting	$1.00
Sensors	$4.00
Processor	$2.50
Bracketry	$0.20
Wiring and Circuitry	$0.90
Manufacturing cost	$1.00
Total Cost:	**$10.20**

Currently Market

- *Garmin Varia Bike Tail-lights [4] :*

Garmin Varia composes of 7 LEDs of 22 lumens with 2 alarm modes (solid or flashing). As light conditions change, the tail light automatically get brighter or dimmer, but only when paired with a light-sensing Edge 1000. It has a battery life of 4 hours, charging time of 2 hours and weighs 52g. It can be bought online Garmin store for the price of $70 and comes with a headlight option for an additional $200.

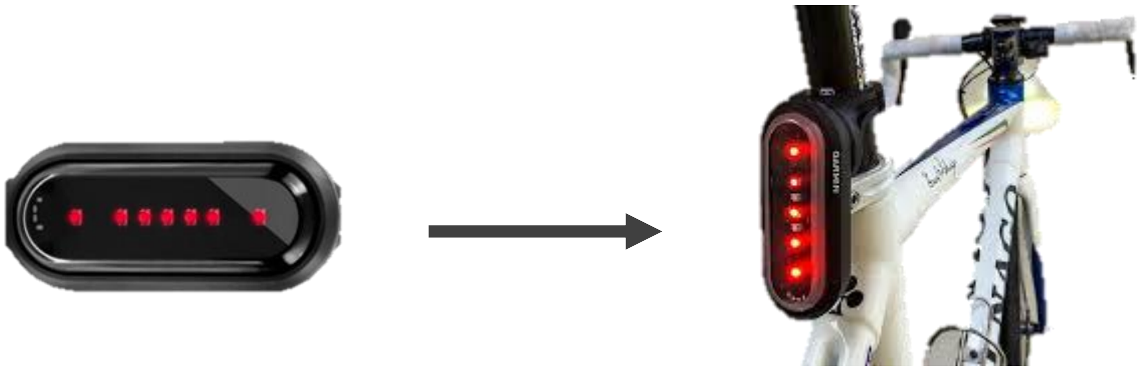


Figure 18: Garmin Varia Bike Tail-lights

- *Meilan Smart Bike Tail-light X6 [5] :*

Meilan X6 is composed of 16 LEDs of 50 lumens with 7 alarm modes. It uses a 5V input with a battery capacity of 900mAh and a total weight of 75g. This device is also water-resistant and has automatic sensing system to control the light switch. It can be bought online at Amazon for the price of $30 and comes in multiple colors.

Figure 19: Meilan Smart Bike Tail-light X6

Projected Markets

The U.S. Bicycle Market 2014 report prepared for the NBDA by the Gluskin Townley Group stated that “2014 was a comeback year for the U.S. bicycle industry, with direct effect sales of $6.1 billion, including retail sales of bicycles, related parts and accessories, through all channels of distribution. This compares to $5.8 billion in sales in 2013.” [6] The market for this kind of product is definitely promising and increasing. This product is intended to be sold to bicycle enthusiasts and riders as a gadget or add-on to their recreation. The method of sales and distribution will be to vendors (bike shops, Walmart, Trek) and to online services (Amazon, E-Bay). Depending on the vendor, this product can be sold separately or as a tag-along accessory when sold with new bicycles.

CONCLUSION

The purpose of this design project was to create an innovative and commercial Smart Tail-Light System with simple technology, from the 2015 HPVT race vehicle to a condensed, self-contained marketable version. The final version incorporates the signature sequential velocity dependent flashing lights, improved automatic brake light, a proximity notification signal and sound system. From the conception as a safety innovation submitted to HPVC in 2015, to the consolidated prototype 2 to the finally the alpha prototype 3, the project has refined and improved to the commercial Smart Tail-Light System. The design is in its proof of concept stage. Multiple prototypes have been built and are acting as test beds for the product. Improvements to the design would include specifically build circuitry, a higher output LEDs, a reflective exterior, and the incorporation of wireless transmission for the velocity sensor. Hopefully technology like this will enhance visibility of Human Powered Vehicles and Slow Moving Vehicles and reduce the risk of collision and injury while on the road. Ride on!

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APPENDIX