Light Saver: Pedestrian Safety Smart Sign

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Abstract — An electrical and computer engineering project, the Light Saver: Pedestrian Safety Smart Sign is an innovative and creative experiment to improve pedestrian safety at intersections. This project aims to rethink the traditional aspects of crosswalk safety and utilize a more inventive approach to create safe conditions for persons and vehicles at intersections. This project will analyze real-time road conditions using sensors and cameras, and if conditions are met, our device shall alert vehicles to the presence of pedestrians using traditional visual alert systems and have an implementation of an in-cabin vehicle alert system. This shall enable the driver of a vehicle to be more aware of the surrounding conditions and cautious to the presence of pedestrians, even if the driver does not notice the roadside sign visual alerts.

I. INTRODUCTION

The development of the project evolved around inspiration to create safer crosswalk conditions based on personal experiences and public safety data. This is also inspired by the development and direction of technologies to increase communication between vehicles and infrastructure to improve public safety. The Light Saver is a high-level electrical and computer engineering design project, and the techniques used aim to encourage proof of working concept. The project is designed to be implemented as an enclosure box mounted on a sign and pole on the side of a roadway as per National Highway Traffic Safety Administration rules and regulations. The device will utilize Infrared sensors to detect approaching pedestrians and utilize camera video feed to analyze the crosswalk to detect persons crossing the road. These conditions will be input real time to the device microcontroller, which will activate two alert methods to improve pedestrian safety. The two alert mechanisms are the roadside alert and the in-cabin vehicle alert. The roadside alerts consist of mounted LEDs on a NHTSA approved sign, flashing at a rate of 50-60 times per minute to follow official Manual on Uniform Traffic Control Devices (MUTCD) guidelines. [2] The in-cabin vehicle alerts consist of a displayed message on an LCD screen, and an audible sound alert to warn drivers of pedestrian presence and to drive cautiously. The roadside device shall communicate these alerts wirelessly to approaching vehicles only if conditions are met.

According to the NHTSA, 17.2 % of traffic deaths in 2018 were pedestrian fatalities which amounted to 6283 persons. Even though traffic laws give pedestrians the right of way at crosswalks, many factors such as Right Turn on Red laws have contributed to a 60% increase in pedestrian crashes. [1] The objective of the Light Saver device is to contribute to safer road conditions for pedestrians as per the Safe Routes initiative of the US Department of Transportation. [3]

A. Microcontroller

The main control of the device is the Atmel ATmega328P microcontroller. The ATmega328P is chosen for its balance of cost, power efficiency, built in functions, and wide operating temperature. This microcontroller provides adequate 32 KB flash memory, 2KB SRAM, several communication protocols such as SPI, I2C, USART, and many other features. The microcontroller runs at 16MHz, which is important for the variety of operations. The operating temperature is -40°C to 125°C, which is an important factor for device longevity in outdoor conditions. The Arduino IDE is used to write and develop the microcontroller. We implemented this microcontroller for the controlling of the operations both in the Light Saver enclosure and the vehicle alert system in the car.

B. Raspberry Pi 3

We require a method to analyze the video feed of the crosswalk conditions using computer vision techniques. We use the Raspberry Pi 3 computer to install the computer vision software such as YOLO and Tensor Flow to analyze the crosswalk conditions. This computer is compact and provides fast processing speed of 1.2 GHz, has 1 GB RAM, and a microSD card slot to expand memory as needed. We can connect a peripheral camera such as the OV5647 to take video input, and it has HDMI video output so we may view the results of video analysis.

C. Communication Module

We require a method to wirelessly communicate between the Light Saver device node at the intersection and the approaching vehicle to provide alerts. We explored different concepts such as Wi-Fi, Bluetooth, and radio protocols such as LoRa, 433MHz, etc. We chose the nRF24L01 based on requirements of transmission range, speed, and data that may be transmitted. This is proof of concept method to communicate with vehicles, and in a regulated viewpoint we would use V2X protocols if non-commercially available to users.

D. Motion Sensor

We require the ability to detect pedestrians approaching the crosswalk intersection. For this we will use motion sensor located at sidewalk edges to detect persons before they reach crosswalk. We explored different options but ultimately decided to use M18 IR Break Beam sensors, as they provide good working range of 0-5 meters to meet our specifications and higher accuracy as compared to passive IR sensors, which may give false positives from passing vehicles and outdoor objects. These operate at 6-36V and are designed for outdoor use.

E. Embedded LEDs

To provide roadside visual alerts, we researched the guidelines and rules set by the NHTSA for which all roadside signs must comply. There are specific standards designated for mounting lights on signs, such as the allowed color, the flash rate of a light between 50-60 times per minute, brightness, etc. [4] We followed these protocols and used bolt-beam super bright LEDs of 590 nm wavelength (yellow) which matches the background color of the sign, following the set guidelines. The LEDs have an operating range of 9-14.5V, and have 55 lumen intensity and 110 degree beam angle.

F. Battery

A specification of our project is that the system should be portable and off-grid. We accomplish this by utilizing a battery to power the device. We need to take account of several factors such as battery capacity, power density, longevity, cost, etc. We decided that a 12V 50Ah lead-acid battery is the best option for the project as it meets the power specifications for the device.

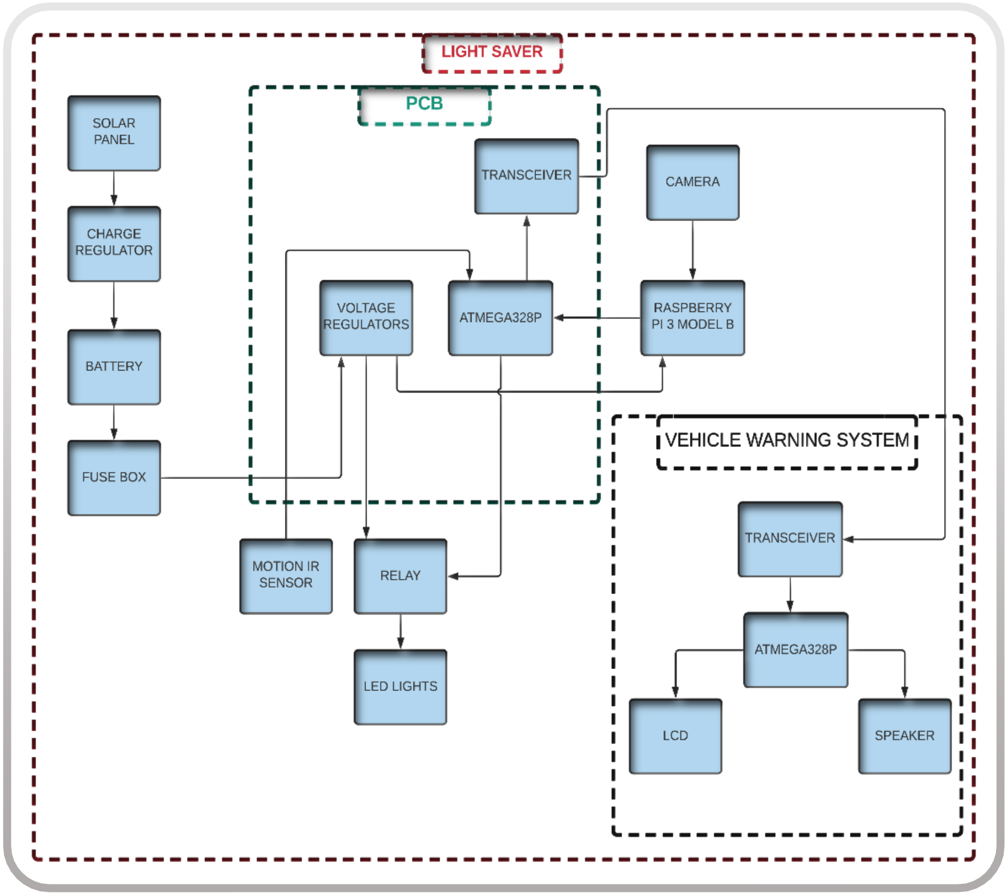

Figure 1: Hardware Block Diagram

G. Solar Panel and Charge Controller

To allow the device to be portable and off-grid, we chose to use a solar panel system to recharge the device battery. When selecting a panel, we considered various factors such as conversion efficiency, power rating, cost, etc. Based on geography and EIA estimations that Florida receives approximately 4 peak sunlight hours per day, we selected a 12V 100 W Monocrystalline solar panel. We chose a 4-stage pulse width modulation charge controller to maximize the charging efficiency of the battery, and to protect the solar panel and battery.

H. Vehicle Alert

To provide an in-cabin alert to the driver of the vehicle, we implemented a vehicle alert component to the project. We designed a unique PCB with an ATmega328P microcontroller, and this PCB hosts a transceiver, LCD, and audio module to receive and present alerts from the Light Saver node on the road near the crosswalk. In concept, these alert systems may be installed or potentially integrated to vehicle electronics to create a mesh network of integrated alert systems.

III. Hardware Detail

In this section we discuss the hardware design of the project.

A. Power Systems

For the Light Saver device, we implemented an off-grid power system, so many calculations went into deciding the appropriate battery and charging system. The Load requirements of the device were calculated from individual components located in the main hub. The vehicle alert device is not factored as that will use a vehicle as power source.

	Input Voltage	Input Current	Total Power	Supply Method
Raspberry Pi 3	5 V	0.72A	3.6W	PCB
ATMEGA328P Microcontroller	5V	12mA	0.06W	PCB
IR Sensor	12V	300mA	3.6W	Fuse Box
nRF24L01 Module	3.3V	12mA	0.04W	PCB
Camera	5V	0.25A	1.25W	Pi 3 Board
LED (x8)	12V	0.07A	6.72W	Fuse Box
Relay	3.3V	0.07A	0.231W	PCB
Total Power			15.501W	
(24 Hours)			372.02W	

Table 1: Power Consumption Breakdown

We found the 24-hour supply requirement for the device and is approximately 372 Watts. We explored various battery options and considered the Depth-of -Discharge allowed per the chemistry of the battery type. Lithium batteries have 80% DOD, whereas Lead-Acid batteries have 50% DOD. Performing a cost comparison, Li-Ion batteries are $9 per Ah, versus Lead-Acid costing $2 per Ah. As our project is self-funding, we decided to use a Lead-Acid battery. We selected a 50 Ah capacity as this provides 600 Watts, 300 watts with 50% DOD. The most power consumption is the LEDs, but they are not running continuously for a 24-hour period. As per MUTCD guidelines, they may only be toggled at a rate 50-60 times per minute and will only turn on for limited time when pedestrian is crossing the road, which allows sufficient battery capacity.

We selected a 12V 100 W monocrystalline solar panel as this will produce approximately 400 Watts of power considering our region receives 4 peak sunlight hours per day. This is ample to recharge the battery system. We chose a 4-stage PWM charge controller and purchased a manufactured unit to ensure more efficiency of energy conversion versus a self-designed linear regulator. This will also protect the battery and panel from any voltage fluctuations or damage.

We require three power rails for the device, 12v, 5V, and 3.3V. We distributed the 12V connections via the fuse box. We designed a 12V to 5V buck converter and implemented it on our PCB, using TI Webench. We used a TPS563201DDCR buck converter with an efficiency of 90.2%. We designed the 3.3V regulation on our PCB using a L78L33 linear regulator.

B. Peripheral Systems

We have several peripheral devices connected to our PCB. We use pin headers to simplify their connections. The Raspberry Pi 3 connects an Arducam OV5647 camera to provide input video feed to analyze using computer vision software. The results of this analysis are provided to the microcontroller as a digital input using the GPIO pins. The IR Sensors also provide a control signal depending upon their line of sight being disrupted. We feed this as a digital input to the microcontroller. We do not use the microcontroller to toggle the LEDs on the sign directly, as the pins of the ATmega328P have a max 20mA current rating, and the eight LEDs will require 560mA of current. We toggle them using software, and a digital output from the microcontroller.

The nRF24L01 transceiver connects to the microcontroller using SPI interface. We provided all pin headers to the necessary connections to the ATmega328P to allow us to expand or change any code details and utilize more functions if necessary.

C. Vehicle Alert System

The vehicle alert component shall provide an in-cabin alert to the driver of the vehicle. We designed a unique PCB for this module with an ATmega328P microcontroller and used pin headers to connect the peripherals such as the nRF24L01 transceiver, I2C 1602LCD, and the MP3 audio module. We chose the nRF24L01 transceiver because of its low power consumption of 0.04 Watts, good working range of 250 meters, and GFSK transmission protocol. It allows us to potentially expand and interface several alert modules to the same transmission node. The power systems of the vehicle module PCB consist of a similar 12V to 5V buck converter, to power through the car battery, but we implemented a USB input connection to power it through the vehicle USB port. We used the L78L33 3.3V linear regulator to power the transceiver module.

IV. Software Detail

We had several software sections in our project. We will discuss the software breakdown with respect to their implementation in the project. Given below is the software flowchart for the project.

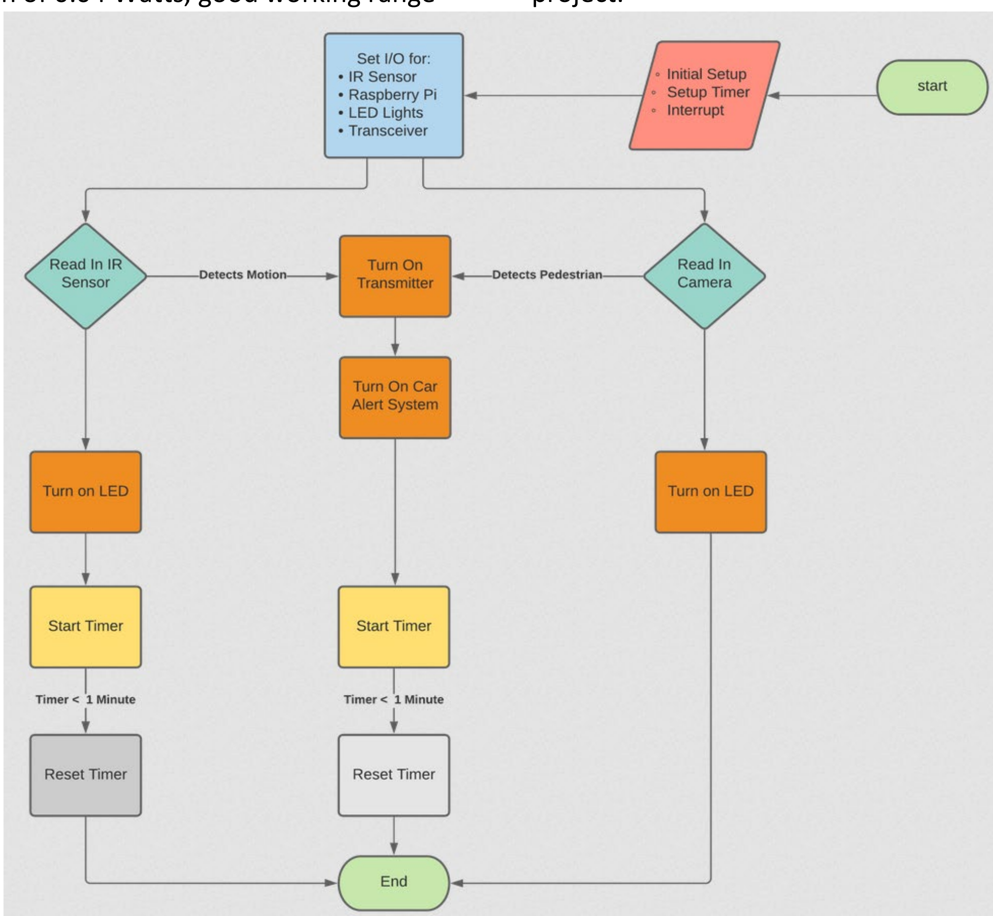

Figure 2: Software Block Diagram

A. Video Feed Analysis

One key feature of the project is that we analyze the video input of the crosswalk and provide a conditional input to the main microcontroller to whether there is a pedestrian on the crosswalk. We achieve this by using computer vision techniques such as YOLO. The YOLO software works by taking the input video and using its image frames to do feature extraction. It applies several convolutional layers and compares with the pre-trained data that we teach the software to recognize, in our case is persons. The software then applies a bounding box prediction of its estimation of a positive match with the pre-trained data. We have setup that if a pedestrian is detected, the GPIO pin of the Raspberry Pi will send a digital high to the main microcontroller to process as a conditional input. We installed TensorFlow and OpenCV software on the Raspberry Pi, and programmed it using Python in the Thonny IDE built-in to Raspbian OS.

B. Light Saver Microcontroller

The software programmed on the ATmega328P is designed to read the input conditions from the Raspberry Pi and the IR sensors as digital inputs, and if the conditions are met and person is detected, the device shall initiate the roadside and vehicle alert protocols. We programmed the microcontroller using the Arduino IDE and implemented variable states for the input conditions. We program the microcontroller to toggle the LEDs via control signal to the relay and use software to control the flash rate to be MUTCD compliant. A sample of the code is shown below.

The transceiver is activated, and it communicates the vehicle alert. The nRF24L01 uses serial communication with the microcontroller, and we configured pin 8 and 9 as the chip select and enable.

```
val_cam = digitalRead(cam); // read camera input pin
val_motion = digitalRead(motion); // read motion input pin
if( (val_cam == 1) && (val_motion == 1) )
{
 int i=0;
 for(i=0; i<10; i++)
 {
 digitalWrite(ledPin, HIGH);
 delay(500);

 digitalWrite(ledPin, LOW);
 delay(500);

 //Send message to receiver
 const char text[] = "Pedestrian Crossing!";
 radio.write(&text, sizeof(text));
 }
```

Figure 3: Microcontroller Sample Code

C. Vehicle Alert Microcontroller

The software programmed on the ATmega328P on the vehicle alert module is designed to detect an alert transmission from the Light Saver, and the device shall display the alert message on the 1602 LCD and activate the audible alert sound to notify the driver of the pedestrian presence. We programmed the microcontroller using the Arduino IDE. We chose an I2C LCD due to the nRF14L01 transceiver utilizing SPI communication protocol with the microcontroller, and we avoid complex daisy chain configurations by using I2C communication protocol with the LCD to display the alert message. The Audio module uses UART protocol and connects to microcontroller using RX TX pins configured within the code.

V. PCB Design

We created several PCB prototypes and versions to fit the needs of our project. The final PCB we implemented is our version 2 design. The PCB consists of 5 V and 3.3 V regulator circuits, the ATmega328P microcontroller, crystal oscillator, nRF24L01 transceiver, pin headers to provide connections to the microcontroller, etc. The first PCB schematic and board design were made using Eagle software. We made our second version using EasyEDA software, and found it to be more user-friendly, providing part selection and availability while designing the schematic. We designed a two-layer PCB board, using the bottom layer a ground copper pour. We used 0.504mm trace width routing for the power connections, and 0.254mm trace width for signal routing. We ordered the final PCB from JLCPCB, and assembled components that were not machine soldered as part of the order.

VI. Results

We have seven specifications for the Light Saver device, of which we chose three to be our main focus and demonstratable items. The three demonstration specifications were the following: (a) The Light Saver will detect pedestrian presence on the crosswalk video feed with specified range of operation of 0-25 feet. (b) The Light Saver shall engage alerts if conditions are met within specified time of 2 seconds. (c) The Light Saver shall engage vehicle-side alert with specified range of operation of 0-60 feet. Through the different phases of the project such as prototyping and testing, we ensured that the device would meet these specifications. The reason we chose 0-25 feet of pedestrian detection is that an average car lane is 12 feet in width, so we want two car lanes of observation. The time of two seconds allows reaction time for the vehicle driver. A range of 60 feet allows for slowing the vehicle and engaging the brakes. During the testing of the Light Saver device, we observed the following data as recording in the given table.

	System Specifications	Units	Actual
1.4	The Light Saver will detect pedestrian presence on crosswalk video feed with specified range of operation.	0-25 feet	52 ft
1.5	The Light Saver shall engage alerts if conditions met within specified time.	2 seconds	1.65 seconds
1.6	The Light Saver shall engage vehicle-side alert with specified range of operation.	0-60 feet	159 ft

Table 2: Specification Data

VI. Conclusion

We designed and completed this project with success, meeting the specifications and objectives for the device. Each member of the group learned invaluable skills over the two-semesters of this project, both technical and non-technical with respect to the engineering process. It was a team-building experience which improved our professional demeanor and problem-solving skills. We aim to provide this project as a proof of working concept that will improve pedestrian safety in the future.

Acknowledgements

Our group is grateful and appreciates the mentorship and assistance of Dr Lei Wei. He provided valuable feedback and guided our project through its various phases and assisted in the success of this engineering project. We appreciate Valencia College for allowing us to demonstrate our project in a safe roadway environment at their West Campus. We thank the UCF professors who have kindly agreed to review our project.

Biography

Dilpreet Singh Johal will graduate and receive a Bachelor's of Science in Electrical Engineering in May 2021. His primary interests are in Communications and RF work.

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Esteban Pizarro will graduate and receive a Bachelor's of Science in Computer Engineering in May 2021. His primary intents are in software devlopment and problem solving.

Joe McCoy will graduate and receive a Bachelor's of Science in Computer Engineering in May 2021.

His primary interests are in software devlopment mobile and game development.

References

[1] "Bicycle and Pedestrian Reports." *FDOT*, 2019, www.fdot.gov/safety/4-Reports/Bike-Ped-Reports.shtm.

[2] "Use of Animated LED 'Eyes' Pedestrian Signals to Improve Pedestrian Safety." *Florida Department of Transportation*, 31 Jan. 2000, www.fdot.gov/docs/default-source/safety/4-reports/bike-ped/led_eyes.pdf.

[3] "Safe Routes To School." *U.S. Department of Transportation/Federal Highway Administration*, 21 May 2018, www.fhwa.dot.gov/environment/safe_routes_to_school/.

[4] "Embedded LEDs in Signs - Safety: Federal Highway Administration." *Safety*, May 2009, safety.fhwa.dot.gov/intersection/conventional/unsignalized/tech_sum/fhwasa09006/.