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Light Saver

Group 15

Dilpreet Johal - Electrical Engineering Major

Esteban Pizarro - Computer Engineering Major

Joe McCoy - Computer Engineering Major

Daniel Guerry - Computer Engineering Major

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1. Executive Summary

Cross walks are meant to help people be able to cross an intersection in a safe manor. But as people are driving there are many distractions that can distract a driver. A few are, being in a rush that they are not paying attention and looking both ways before turning or just paying attention to oncoming traffic. Another is technology becoming more advance and popular like cell phones and drivers are texting or selecting music on different music apps like Spotify or pandora, or just being tired. As a result, there has been an increase of pedestrian accidents that happens at intersections on the cross walk. Just recently a team member of our group was jogging and while crossing a cross walk was nearly hit by a driver, who was on their phone. Lucky for this team member his wife notice this and stop him before he got injured.

According to most recent statistics provided by the National Highway Traffic Safety Administration (NHTSA), in 2018 there were 6283 pedestrian fatalities in traffic crashes. That accounts for 17.2% of all traffic deaths in that year. The most prominent age group within those statistics were ages 25-34, who composed 15.4% of pedestrian fatalities. In a broad technical study performed by Dunlap and Associates Inc, they found that Right Turn on Red laws have contributed to an increase in frequency of accidents occurring between motor vehicles and pedestrians/cyclists at intersections.

We as a team wanted to lower this number of 6283 pedestrians needlessly dying, so as a result we wanted to create a new sign to help prevent this tragic loss. A sign that well help do this that we have named the Light Saver.

The goal will be that the **Light Saver** is vital to improve pedestrian safety, and to warn the vehicles that there is a pedestrian or bicyclist that may potentially cross the road. Most drivers when approaching a right turn do not yield for enough durations to safely observe the traffic environment, or potentially the light is green, but the pedestrians still have the right of way. Vehicles can be hazardous in right turn settings, and if we can accurately warn a vehicle that a pedestrian or bicyclist is crossing. It has the potential impact to save lives and make the world a better place.

This report documents how the Light Saver design process. It will go over the background and motivations first and why we choose to do this project. Then it will move on to requirement specifications and requirements, follow by research on topics relating to the project. First, we will discuss the marketing and engineering requirements, research of relevant technologies, part selection based on project design, possible designs, and related design options. Next, we will talk about the standards and realistic design constraints related to the Light Saver. After we will go into detail on the project hardware design and software design. It will also go over the device testing and prototype review and finally we will explain the administrative content and what the budget of the project was and how the tasks were divided, as well as basic scheduling and milestone meetings.

We hope that this project can make a positive impact on pedestrian safety and lead to innovations in a society where vehicular traffic and pedestrian traffic are so entwined. This project idea was interesting for all of us as group members because the software aspect and computer vision is an emerging technology which is a glimpse into the future of even more evolutionary scientific possibilities such as Neural networks and artificial intelligence.

2. Project Description

In this section we will cover the multiple reasons and the direction we plan to go with our light saver. The light saver is a traffic signal implementation that using attention getters, in this case bright lights, communicate to a car that they have to be careful when turning right with possible pedestrians crossing the road even thought their light is green at the moment.

2.1 Project Background

This project has a start coming from an internal conversation between our group about two different scenarios that happen to our team members. Let's cover scenario one, one of our teammates is driving and as he is in his car, he arrives to the light on red. He sees another car entering the right turn merge lane. In the united states the law permits that you turn right when the light is read after you have come to a full stop and the way is clear for you to go. Sadly, this is one of those laws that is not commonly obeyed by drivers. Most driver do a quick glance to check if a car is coming and then they continue as if they had the full right of way. At this moment our teammate notices that the car has no plans to come to a full stop and also sees a pedestrian on his phone that glances at his, that is in good to walk state, but does not see the car. (as shown in figure #1). This is when our teammate has the chance to save this pedestrians life by honking at him to warn him of the possible danger taking the distraction away from his phone and making the car come to a full stop.

Figure #1: Scenario One

Now let us cover scenario two a pedestrian is using his headphones on a light at night while him and his wife are going out for a run. When the pedestrian is approaching the light, he sees that his crossing light is turned on to walk giving him the right of way. At the same time, a car that was riding at legal speed approaches his merge line to turn to the right, but his light is also in green (like the case scenario seen in figure #2). In this moment, the pedestrian dose not notice that he has a possible car that might hit him since he has the right of way. And the person in the car does not take the instance to check if there is a possible pedestrian that might be crossing the road. Right there and then is where they notice that there is a chance that the pedestrian is about to get hit in this particular scenario the wife of the pedestrian work as a warning sign letting the pedestrian know that he was going to get hit by just an inch. If this were not the case this could have ended in a very different way.

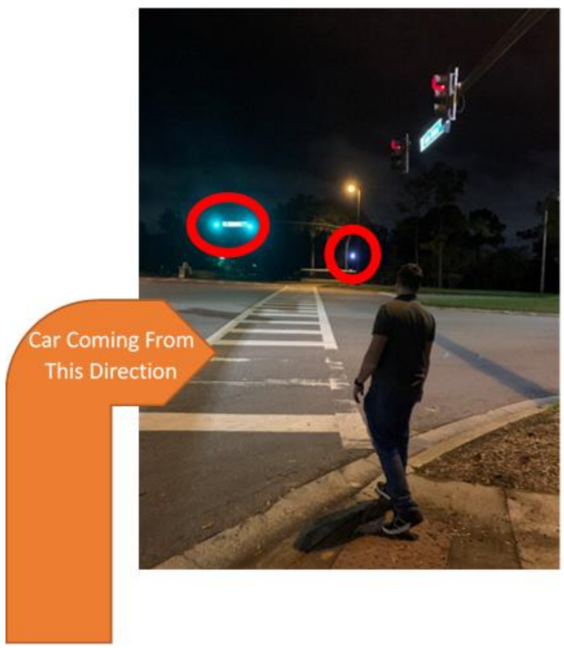


Figure #2: Scenario Two

This causes a very common scenario that probably happens daily. And is the start to our idea and project creation. Making a Light saver that acts as the teammate in scenario one and as the wife in scenario two. Many pedestrians dye every year in vain by distractions of drivers these are some of the multiple cases that can cause distraction out in the streets.

Since the turn on red has been permitted in the United States there has been an increase from 1.47% of pedestrian accidents to 2.28% of pedestrian accidents in Florida according to the Florida Department of Transportation (FDOT) Bicycle and Pedestrian Reports. Making it a slight inspiration to us trying to solve and reduce this number [1].

Our objective then was to create an object in this case a traffic light that would warn the car, since in both of these scenarios the person committing the mistake is the car, and lets it know that there is a possible pedestrian that has the right of way and is about to walk. This by using a complement of different factors into perspective. Factor like computer vision to let the sing know that it is actually the pedestrians turn to go, a motion sensor to detect when there is a pedestrian, solar pawer to reduce the use of energy and increase the usage of renewable energy.

2.2 Objectives

In this section we will present our direction and inspiration to what we wish we can present as a solution to this active problem. Giving in detail what we hope to have delivered at the end of the project.

2.2.1 Motivation

The motivation for us is to use the knowledge that we have gathers in our years of college at Valencia College and University of Central Florida to implement a solution to the constant problem with right turn pedestrian accidents. Working as a group we have gathered our skills to create a very inspiring a possible design. That we hope to create at a more affordable price than other possible solutions out there and at the same time push to help society one task at a time.

Since we have started this project has really grown to us it a factor that can changes peoples live many times these accidents are not even on purpose but may be by a small mistake of the driver that did not mean to harm a person. Having something that can give a second chance to drives to reduce this mistake motivates us and inspires us to make our best to create a product that can make a difference and maybe one day see it implemented in the streets.

At the same time the fact that this is something that we have experienced and that our team sees as a possible real implementation noticing that there is no effective solution that is out there and affordable for the states to implement makes us give our all. hopping to be proud of what we have learned though out our long and hard years in college.

2.2.2 Design A

To design a traffic signal that integrating solar panels, computer vision, and motion sensors will detect that it is the turn of the pedestrian to walk and warn the car of possible pedestrians walking.

1. Traffic light will wait to gather information from pedestrian walk sign using computer vision.

2. Then check if the motion sensor has been tripped meaning there is a pedestrian.
3. Warn the cars that will cross to be careful possible pedestrian walking by flashing red lights.

Design should be self-sustainable by charging itself using solar power and lasting a total of 24 hours without sun light.

Figure #3: Design A Projected Diagram

2.2.3 Design B

To design a traffic signal that integrating solar panels, computer vision, and lasers will detect that it is the turn of the pedestrian to walk and warn the car of possible pedestrians walking.

1. Traffic light will wait to gather information from pedestrian walk sign using computer vision.
2. Then check if the lasers been tripped meaning there is a pedestrian about to cross the road.
3. Warn the cars that will cross to be careful possible pedestrian walking by flashing red lights.

Design should be self-sustainable by charging itself using solar power and lasting a total of 24 hours without sun light.

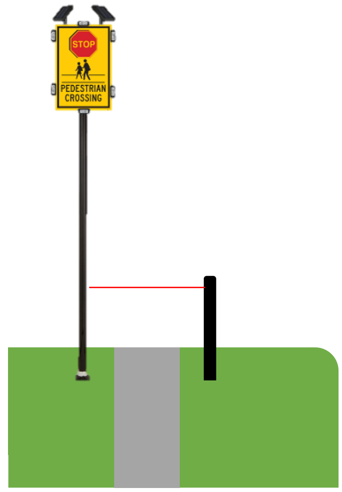


Figure #4: Design B Projected Diagram

2.3 Requirement Specifications

These requirements are corresponding to all of the implements internal and external of the light saver.

1.0	The Light Saver will detect pedestrians approaching the crosswalk within 5 feet radius using 2 directional motion sensors and Computer Vision.
1.1	The Light Saver will alert vehicles of the presence of pedestrians using 10 mounted LED lights.
1.2	The Light Saver will be self-powered, using 12V Solar Panels, with 24 hour functional operating time, Maximum 100W power consumption, utilizing battery for backup power.
1.3	The Light Saver sign will be max 600 square inches, with mounting pole not less than 5 feet height.
1.4	The Light Saver should have engineer grade reflective aluminum wrap, to enhance visibility throughout 24 hours.
1.5	The Light Saver will operate with low power mode, engaging in alert mode only when it detects pedestrians.
1.6	The Light Saver computer vision will analyze when the Crosswalk sign is in walk state, and alert vehicle of pedestrian presence

2.4 Marketing and Engineering Requirements

Key Table	
↓	negative correlation
↓↓	strong negative correlation
↑	positive correlation
↑↑	strong positive correlation
◦	no correlation
+	Positive polarity
-	Negative polarity

Marketing Requirements		Engineering Requirements: Power Output	Cost	Range of Sensor	Response time	Size	weatherproof
		-	-	+	-	+	+
Cost	-	↑↑	↑↑	↑	↓	↓	↓
Maintenance	-	◦	↓	◦	◦	◦	↓
Ease of Installation	+	◦	↓	↑	◦	↓↓	◦
Power consumption	-	↑↑	↑↑	↑	◦	◦	◦
Interaction	-	↑	↑	↑	↓	↑	◦
Target		**< 100W**	**< 560**	**~5 ft**	**< 1 sec**	**Pole Height > 5ft, Sign < 600 in^2**	**IP65**

Figure #5: Marketing / Engineering Requirements

Group Breakdown

Green = Esteban Pizarro , Joe McCoy

Red = Dilpreet Johal, Daniel Guerry

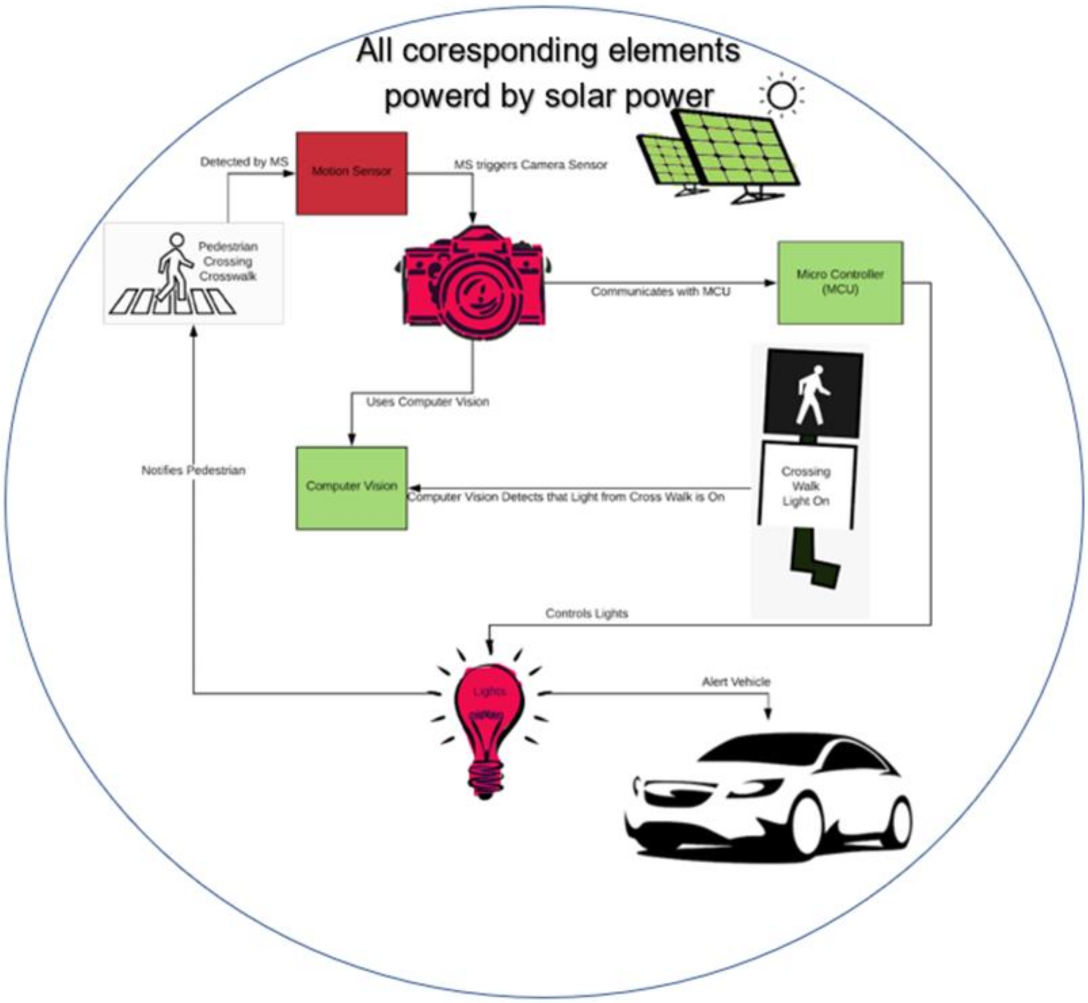


Figure #6: Block Diagram of Light Saver device

3. Research Related to Project Definition

In this section we will discuss research regarding pedestrian safety devices. The research that is listed within this section is ranging from the topics of existing pedestrian safety products, market analysis and opportunities, relevant technologies, their concepts, etc. As seen in the research given below, there is initiative at multiple levels of government and industry to promote pedestrian safety in a world with ever growing vehicular traffic. This research will assist our group in understanding existing engineering fundamentals and how to improve the Light Saver device for better market implementation.

3.1 Existing Projects and Products

Pedestrian safety is an issue that has been in the minds of engineering since the intermixing of types of traffic on public infrastructure. The techniques developed for pedestrian safety in the United States must conform to the standards set by the US Department of Transportation, Federal Highway Administration. Specifically, the US DOT FHA has issued the Manual on Uniform Traffic Control Devices (MUTCD) for Streets and Highways since 1935. It has set the standards for mobility in public infrastructure for 85 years and 10 editions updated with change in technology and the times. The goal is to have a uniform system of traffic control devices which convey clear meaning regardless of where you are in the United States. Pedestrian safety techniques and minimum standards have been constantly issued and revised with improvement in engineering. We will explore different existing products and how they conform to the MUTCD. We will break this down into the topics of non-signalized road signs, signalized road signs, and miscellaneous safety techniques that do not fit into either of the previous two topics.

3.1.1 Non-Signalized Signs

Non-signalized signs consist of capitalized block words clearly conveying a message, along a relevant familiar icon of a person or traffic warning. They are categorized as Yield to Pedestrian, Stop for Pedestrian, No Pedestrians Allowed.

Figure #7: Examples of Various Non-Signalized MUTCD Compliant Signs

The common icons that are placed within the sign are Yield sign, Stop sign, a walking person, a bicyclist, etc. In the MUTCD, these are classified as R1-6 series signs. They must have a reflective background, and icons must not impede in communication of the capitalized words. The shapes of the signs allowed are diamond, rectangular, or pentagonal. The minimum size is based on type of shape chosen, and location of placement of the sign. The sign may be installed at the edge of the road at warning location, island of road, center of two-lane road, and ahead of the location of warning.

3.1.2 Signalized Signs

Signalized signs are divided into categories based on the location of implementation and purpose of the sign. Common signalized signs are the result of improvement in solar technology and efficient LEDs to provide an upgrade to existing non-signalized signs. The concept is to embed LEDs into the approved MUTCD signs to alert oncoming vehicles to pay attention to the sign. The next category of signalized signs is at roads where a pedestrian must cross all lanes of traffic direction at an intersection with traffic lights.

These pedestrian signals consist of an array of LEDs that are programmed to generate shapes such as a “stop” hand when it is not safe to cross the road, a “walking man” when it is appropriate to travel, and some have countdown numbers to inform a pedestrian how long they have to cross the road. These may be activated using push buttons located on the pole at the intersection corner, and the pedestrian may press the button indicating which direction they intend to cross the road. They are synchronized with vehicle traffic lights to only enable when the conflicting vehicle traffic has a red light, meaning it is safe for the pedestrian to cross the road without perpendicular traffic.

Figure #8: Examples of Various Signalized MUTCD Compliant Signs

In the last photo part of the images above, the sign is most relevant to our project. It contains push buttons to initiate embedded LEDs to start flashing to alert oncoming vehicles that a pedestrian is attempting to cross the road. There are other technical upgrades such as Infrared motion sensors instead of push buttons to initiate the LEDs, and the system may be powered using mains supply or solar panels. The MUTCD provides standards which signalized signs must meet as a threshold to be road compliant. The LED lights must match the background color of the sign, and if flashing, must repeat within a rate of 50-60 cycles per minute. The LEDs cannot interfere with the clarity of message of the block words on the sign, if any. There are different companies which manufacture pedestrian safety signs with solar panels, embedded LEDs, push buttons, IR sensors, and they follow protocol set by the MUTCD. There is no product which delves into the issues with right turns at traffic intersections with parallel travelling vehicles.

The core issue arises with the right-of-way for pedestrians and their priority to cross a road with vehicular traffic. The signalized signs above provide a method for them to cross an intersection to the safety of perpendicular traffic, but many intersections have right turns occurring at the same corner where a pedestrian is crossing. A goal of the Light Saver device is to introduce turn safety for pedestrians at intersection corners in conjunction with traffic signals.

3.1.2.1 Miscellaneous

This section will briefly discuss other pedestrian safety methods which exist but do not fall into the above sub-categories. The US DOT FHWA recommends increasing visibility of crosswalks themselves using striping designs such as ladder or bar pairs rather than simple parallel lines. The striped design should be of bright, distinct color compared to roadway. Another recommendation is using curb extensions to improve sight distance between a pedestrian and an oncoming vehicle. Crosswalks may also be elevated to match sidewalks and provide a type of bump which with coloring and elevation is more visible to drivers. These techniques provide alternative reinforcements to pedestrian safety signs.

3.1.3 Computer Vision

Computer vision is an area full of multiple development and advancements now. It permits that Artificial intelligence goes to a next step. If you think of it, one of the keys of main predators in the world is sight. Giving the chance that a computer can detect when an object is present in an image lets it advance in multiple stages.

Computer vision is being implemented in areas that people do not even expect changing people’s day to day lives and making many of human tasks simples more secure and faster. For example, Amazon Fresh a new idea that amazon is implementing that involves computer vision an idea that Jeff Bezos started back in 2007 and is now a big movement in California and Seattle. This works as follows when a client arrives to the store it scans its phone to a cart in the store. At this moment, the computer has detected and synced you with the cart. All you have to do now is go the object in the super market that you are interested in taking home as soon as you grab it the computer vision recognizes that you have grabbed this object and place it in your cart the computer vision will detect what object you have grabbed and add it to your cart in amazon. At the same time, you have the ability to take out the object and it will automatically take it out of your shopping carts. As soon as you are done you walk out of the store it will notice you are exiting and chare your cart to the card you choose in your amazon app making the process seamlessly easy. In figure #9 you can see the grocery carts that have the camara involved as you see in the bottom and the screen showing you what is being added.

Figure #9: Amazon Fresh Shopping Cart

But amazon is not the only one of the days to day object you can encounter computer vision in. There is a very fast-growing business called WYZE there production is mainly in camaras one of their camaras is a 360-degree camara. And it has an amazing feature using computer vision. So not only will it detect sound but using computer vision it reads out thought multiple frame changes and when a lot of pixels are making a change it will record movement. Saving a short clip so that you can check to see what is it that is moving in your home. Even more interesting it has a built-in feature that will use this camara vision and analyze the direction that you are moving. Taking in account the direction in which the pixels are changing and shifts the camara to follow the person that is moving. Meaning if you have kids at home it will not take the eyes of your kids. A you can see in figure #10 the dog is causing the computer vision to detect movement and set a small square frame around it.

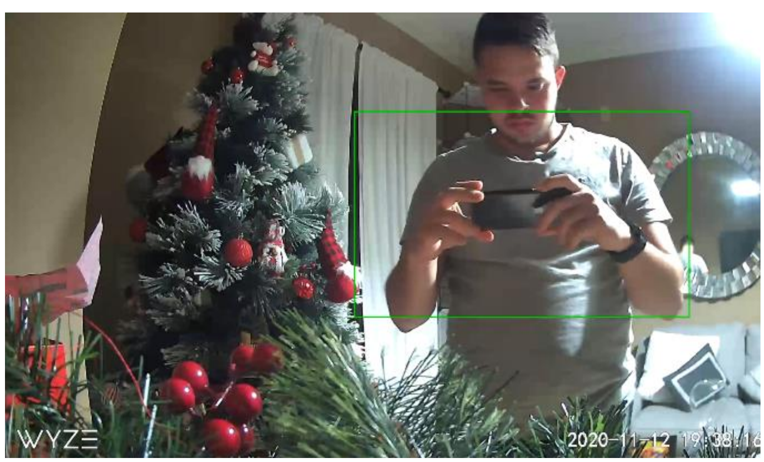


Figure #10: Computer vision detection of movement on WYZE cam

At this point computer vision has evolved to be adapted into almost anything you want it to. Being able to detect edges of a shape or even compare two images. Computer vision can be implemented to solve many problems in the many areas if not in all. Even though it has mostly been conducted with security and safety since camaras can gather information and send it around the cloud in no matter than an instance. For this we can see that it would be an amazing asset for our chances to check for the cross walks state.

3.1.4 Motion Detection

Motion detection is a very important factor in our project because it will act as a switch to activate other features. This because motion sensors are something that we see being used as triggers all the time and they show the importance and utility they can give with simple solutions.

One of the most common motion sensors out there that almost a very home with a garage has is a garage door safety trigger. This is that small black cube that is normally present on the bottom left and right frame of your garage. These two objects communicate with an infra-red laser that traverses from one side to the other and when the receiver gets the laser it confirms that it can close the door because no objects have been detected. The main purpose of this is that back in time it was created to protect accidents of garage doors closing on people or objects that could be laying on the floor where the door would land on. Protecting the door from damaging and also protecting the people or objects laying on the floor. If you have ever tied to close your door and walk out without jumping this section it will cause the door to open back up right away. This because the door has sensed movement all by the laser receiver not grabbing a signal that interruption means that some object is in the way.

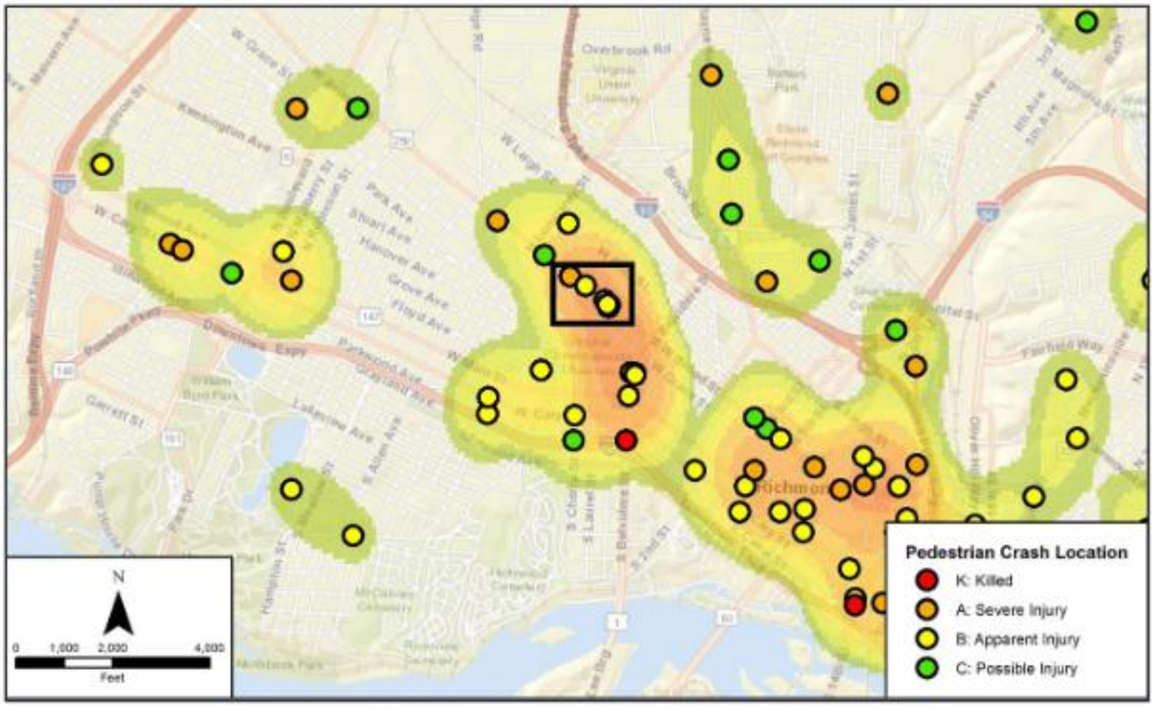
Another of the most common uses of motion sensors in the world in security systems. Most homes have motion sensors to gather data if someone is at their home. Most systems create machines that using sensors will detect certain areas to which if there is a certain movement it will be able to measure the change in heat of this areas by then noticing that there is a movement happening in the room. At the same time, you can see that these systems have been applied in multiple and many ways by measuring the depth of the laser. But the most common of all is by using ultrasound waves sending them back and forth and measuring the time it takes for the wave to bounce back to the machine. If the time is reduced by a big amount this will automatically declare a movement in the room and repost it to the costumer to let them know that someone has entered their home.

Even in doorbells at home with the know spart doorbells like Ring by Amazon. They use passive infrared motion sensors to detect when there is any movement in the front of the house. Using that it will trigger the activation of the camara to check and record what the movement is. And at the same time warn the owner of the house. This used this way to save battery and reduce the waste of energy. Keeping the system on a low battery mode. Until there is an actual necessity of using other factors that will turn on when necessary only. This is one of the biggest inspirations on the method we will be approaching in our project.

3.2 Market Analysis

The requirement for crosswalk safety is because there are many intersections and roadways where pedestrians use the streets and roadways in conjunction with vehicular traffic. Human safety should be the priority for users of roadways, especially pedestrians. There are existing pedestrian signals which communicate to pedestrians if they should walk or not walk across an intersection, but they have their limitations as pedestrian should still be cautious as it depends on the driver of a vehicle at turn signal whether they heed to the pedestrian or not. According to a study by the United States Access Board, “there are over 300,000 existing signalized intersections in the United States using a rule-of-thumb of one signalized intersection per 1000 population” [5]. Based on the US Census Bureau estimation of population growth, an additional 2550 signalized intersections are added each year. Of the existing and added signalized intersections, 90 % of them provide general standard pedestrian signals.

Using the figures above, the Volpe National Transportation Systems Center, which operates under the US DOT, 13,095 pedestrian signals are replaced or added annually at signalized intersections. This alone provides a substantial market for the Light Saver device given its feasibility for pedestrian safety. The need for pedestrian safety is also explored by the Volpe Center. According to their report which documented pedestrian crashes, in 1998, 70,000 pedestrian crashes occurred in the US, in which there were 5294 fatalities. Young pedestrians aged 5 to 9 represented nearly 14% of pedestrian crashes [3]. The need for better and safer roadways and public infrastructure is a bipartisan issue which all sides can support.



Source: Virginia Department of Transportation (2017).

Figure #11: Crash Cluster Analysis Map; Richmond, VA

A further market exploration is the installation of pedestrian safety device at roundabouts. According to a 2016 survey, there were 10,341 roundabouts in the United States, and the top three states with roundabouts were Florida (1283), California (683), and Texas (487), and that figure has most certainly increase in the past four years [4].

In Central Florida, if we study the communities of Windermere and Horizon West, there are dozens of roundabouts for localized roads connecting communities with pedestrian crossings, that do not have signalized pedestrian crossings. In several roundabouts where the pedestrian crossing is present in Windermere, there is obscurity by hedges and plants, and with bumper-to-bumper traffic through the two-lane road it is difficult for vehicles to detect pedestrian presence. There are no signs or safety mechanisms implemented for pedestrian safety. There is much potential to implement the Light Saver device to improve pedestrian safety in these types of situations throughout the country.

A branching program but related to pedestrian safety is the US DOT Federal Safe Routes to School (SRTS) Program, in which their aim is to promote children to use walking and bicycling to travel to school. According to their website, "the SRTS Program empowers communities to make walking and bicycling to school a safe and routine activity once again" [3]. This program has been established since August 2005 and it provides federal grants and funding to State Departments of Transportation to administer SRTS programs. This provides the opportunity at a state level to access funds through appropriate legislative lobbying, and providing an action plan to implement pedestrian safety devices such as out Light Saver device to accomplish the goals of improving safety of children who can travel to school safely.

The US DOT Federal Highway Administration also provides funding recommendations for initiatives to improve pedestrian safety. The Federal Highway Administration, the National Highway Traffic Safety Administration, and other federal agencies distribute grants and annual funding to jurisdictions throughout the United States for transportation safety projects, and a few named examples are the Transportation Alternatives Program (TAP), Congestion Mitigation and Air Quality program, and Surface Transportation Block Grant (STBG) [3]. These provide a myriad of opportunities to pitch the Light Saver device to local, state, and federal administrations and have a reliable funding and business opportunities.

3.3 Relevant Technologies

In this section we will cover the importance and the description of multiple technologies that will be used and represented din our project. To be able to implement these effects as we want into the development. We need to be able to understand and dissect the different usages and effects of each feature. By doing research we can see implementation factors and learn a lot from probable problems we will need to solve or even save us from committing mistakes in choosing wrong or inappropriate parts.

Research also teaches us the kind of parameters we need to attain to and lets us plan ahead to different factors that can actively change what we do in the future. By understanding all limitations and possibilities that each feature can bring thins might be able to give us multiple solutions or enhance our project as time passes by.

3.3.1 Computer Vision

Computer vision is a quite extraordinary field as it involves trying to describe the world and its details that we as humans can see and perceive, and have a computer reconstruct those details and interpret meaningful information from a picture. There are mathematical methods to extrapolate parameters of images into numerical form, and create algorithms to detect repetitions within the numbers, match templates of preset data, and allow a computer to “see” and understand an image. One of the Light Saver device goals is to use Computer Vision to detect pedestrians complementing motion detection, analyze if the standard Crosswalk sign is in walk state, and alert vehicle of pedestrian presence.

The functionality of computer vision is divided by the basis of task at hand, is the robot reacting to a situation, or is it deliberating a situation? This leads to a conclusion that we need to focus the algorithm to interpret an image with enough data to provide feedback of features detected to the main device. A basic breakdown of achieving computer vision is by understanding the physics of an image, what are the parameters of images. Then we use filtering algorithms to detect features like edges, image intensities, corners, and template matching. We can expand and use stereo cameras to gather depth perception and apply object tracking.

Hardware requirements of CV are a power source, an image procurement device like a camera, a data processor, and communication cables or protocol. We may detect visible light or use hardware accessories for camera to process other spectrums such as IR. The software aspect of CV is we may use generally any coding language such as C, C++, Python, etc., to write the code needed to process images. A widely renown library with programming functions for computer vision is OpenCV, and it is an open-source computer program originally developed by Intel Corporation in 1999. It is free to use and supports variety of operating systems and programming languages.

3.3.1.1 Camera Technology

Cameras work on the principle of capturing light within a frame of time and record this collection of photons on a light sensitive surface. These photons can be from any range.

Of the EM spectrum, A camera utilizes multiple mechanisms to control the result of the image captures. It uses either concave or convex lenses with adjustable focal length to focus the clarity of image capture. The aperture refers to the opening where light enters the camera, and its diameter can be adjusted by rotation, and is used in conjunction with the shutter to control the amount of light entering the camera. In smartphone cameras an electronic shutter is used to record data from an optical sensor at a particular timeframe.

Digital cameras capture light photons falling upon semiconductor image sensors, which are primarily two categories of Charge-Coupled Device (CCD) and Complementary Metal-Oxide Semiconductors (CMOS). These semiconductor image sensors have hundreds of thousands light sensitive diodes called photosites [7]. The photosites work by capturing the intensities of falling light upon each pixel of the sensor and recording these as discrete signals. Color images are achieved by applying filter algorithms to further measure the saturation of RGB within the intensities. The larger the array of pixel rows and columns, the more data can be captured, and the resolution of the image is more detailed. CMOS sensors are more energy efficient compared to CCD [8]. The figure #12 below shows the basic fundamentals of image processing using a CMOS semiconductor sensor.

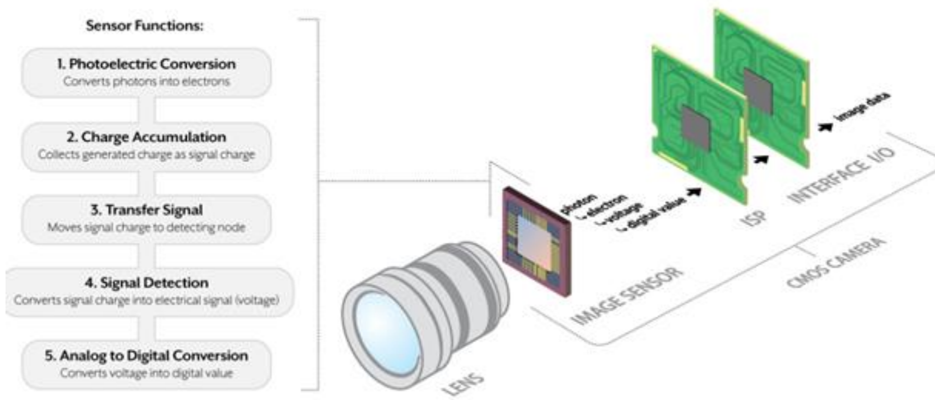


Figure #12: Semiconductor CMOS Sensor Diagram, Image Courtesy of Lucid Vision Labs

Video recording works on developing upon image capturing technology of cameras. The camera captures multiple frames of images per second and merges them so that when played it gives the illusion of motion even though they are still images captured rapidly. The higher the frames per second (FPS), the better and smoother the video quality. Smartphone technology has developed that cameras come with a standard capability of 24, 30, 60 FPS. For computer vision image processing, a lower frame rate is acceptable and less data intensive as we capture the necessary image data to interpret.

3.3.1.2 Software Technology

There is a broad variety of software written to complete different tasks as required by the device utilizing computer vision. Algorithms are written in coding language of C, C++, Java, Python, MATLAB, etc. The most popular collection of algorithms compiled is Open-Source Computer Vision Library (OpenCV), and it was started by Intel Corporation but has become a worldwide used software library that is free and accessible to all. OpenCV is released under a BSD License which means it has minimal use and distribution restrictions and is free for both commercial and academic use [6]. It is very popular due to a large user community of more than forty-seven thousand people and has been downloaded over 15 million times. It is constantly updated and upgraded.

OpenCV is written originally in C++ but has been optimized to work with other languages, and Python is popular due to ease of user interface. OpenCV contains thousands of optimized algorithms to perform tasks like facial detection, object identification, movement tracking, 3D modelling, image matching, augmented reality, etc., and we will use this for pedestrian tracking and detecting the state of the crosswalk sign for road intersections.

CV can be computationally expensive depending on the task, and we minimize this by dividing operation into two parts, a Detection phase, and a Tracking phase. Once a pedestrian is detected, we can assign a bounding box with unique coordinates, that the device will use. The Tracking phase uses algorithms to “follow” the bounding box around the frame image up to a preset boundary. It will convey this data to the processor to use. The applications of CV are optical character recognition, Mobile check deposits, vehicle collision alert systems, vehicle lane departure warnings, photo template matching, facial recognition, etc.

3.3.2 Solar Power

Solar panels are primarily split into two categories, Thermal solar panels, and Photovoltaic solar panels. Our interest is using Photovoltaic solar panels to provide electrical energy allowing for portability in installation. Photovoltaic effect is the process of excitation of electrons or charge carriers shifting them from a lower energy state to a higher energy state. Photovoltaic effect is observed in various applications such as electrolytic cells, Selenium surfaces, but todays Photovoltaic technology expands on the Silicon photovoltaic cell. These solar cells are made of silicon atoms in a crystal lattice structure, allowing for high efficiency of photovoltaic effect.

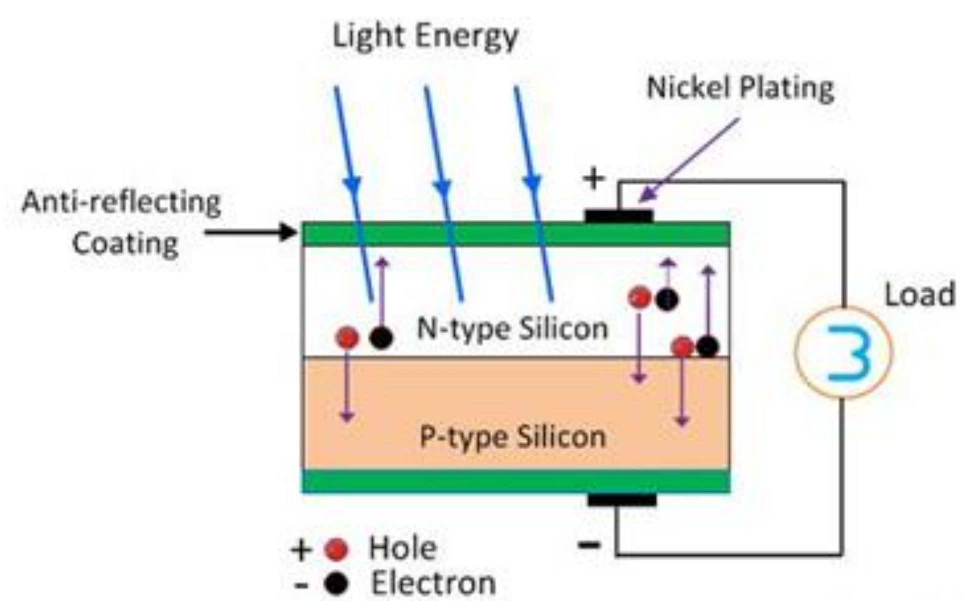


Figure #13: Silicon Photovoltaic Cell

Other methods of solar cells are thin-film solar cells, which contain a thin layer of photovoltaic material such as Copper Indium Gallium Selenide (CIGS) or Cadmium Telluride (CdTe), deposited on a supporting structure like glass, metal or plastic. Another method of solar cell development is using Organic Photovoltaic cells which contain carbon-rich polymers that are designed for sensitivity to only certain wavelengths of light. The thin-film solar cells and Organic solar cells are not as cost effective, durable, or energy efficient as Silicon photovoltaic solar cells, so the majority of solar installations are of silicon solar cells. Silicon solar cells have low cost, high energy efficiency, and long lifespan of viable use, averaging about twenty-five years or more.

Photovoltaic cells are interconnected and combined into solar modules, which in turn generate enough photovoltaic effect and provide the free charge carriers or electrons a pathway for direct current. Our design will use solar panels to gather sunlight energy and convert it into electricity to charge the battery integrated within our Light Saver system. The benefit of Solar panels is that it provides an environmentally friendly and sustainable manner to produce electricity to power the Light Saver system. It will allow us to not rely on any mains power connection, providing portable location possibilities. Florida is an ideal location for solar panels as the recorded annual average of peak sunlight hours per day is between four and five. Solar modules generally require at least four hours of peak sunlight hours to generate approximately one thousand watts per square meter.

The applications of photovoltaic cells to power electronics are expansive, and some examples are handheld devices, ground water pumps, satellites, the International Space Station, etc.

3.3.3 Motion Detection

One objective of the Light Saver device is to reduce power consumption during idle times when there is no pedestrian within the target area. Ideally the computer vision and lights will activate and use power only when triggered to a pedestrian presence, and for that purpose we will utilize motion detection. This will allow us to be in a low power mode until the device is triggered by the motion detector.

A motion detector is a type of device that detects the motion of nearby objects relative to the change in surroundings using various sensors and integrated components. Motion detectors can be either mechanical based or electrical based detectors, and for our device we will focus on electrical detectors. Electronic motion detectors use external input signals such as light, sound, vibrations, electromagnetic, etc. to detect the change relative to its surroundings. The two types of classifications of electronic motion detectors are Active and Passive detectors. Active motion detectors are devices that contain both a transmitter as well as a receiver for the transmitted signals. Examples of active detectors are microwave sensors, acoustic sensors, or optical sensors. These use more power as they are transmitting energy signals, and they can be customized to have longer detection range and increased sensitivity. Various sensor type are Ultrasonic sensors, Tomographic motion sensors, Microwave sensors, and Infrared sensors (both active and passive).

Passive motion detectors are devices which contain only an input sensory component and detect reflections or emissions of energy from external objects. One of the most common types of passive sensors is the Passive Infrared sensor (PIR Sensor) and it is used in security systems, home automation systems, lighting control, etc. We will study the working and theory of infrared technology for our Light Saver device motion sensor.

Infrared sensors work by detecting emissions of radiation that are not within the visible light spectrum. From a physics perspective, any object that has a temperature greater than 0 Kelvin or -273.15° Celsius emits black-body radiation within the infrared spectrum. The infrared spectrum is classified as the band of electromagnetic radiation contained within 780 nanometers and 1000 micrometers of wavelength. The methodology by which both active and passive sensors detect this infrared radiation is broken down below.

3.3.3.1 Active Infrared Motion Detection

Active IR motion detectors work by emitting infrared radiation that can be designed to travel and reflect off objects, and be received by an active IR sensor, or there can be a placement of the active IR sensor in a Line of Sight across from the emitter. This latter configuration is very popular in electronic setups and a common installation in households with automated garage door openers. This setup is known as the “Electric Eye” configuration [9].

The emitter is made using LED designed to radiate energy in the infrared region when powered. The emitter LED is installed two to seven inches off ground level and the active IR sensor is installed at the same height with a direct line of sight with the emitter LED. The working is based on the principal that the garage door will only close if the IR sensor has an uninterrupted transmission meaning there is nothing blocking the passage of the garage door. The garage door will sound an alarm and immediately reverse direction if the line of sight of IR emitter/receiver module is broken. This is an important safety mechanism which prevents damage to the garage door and any people or objects which may be crushed and injured by the descending door.

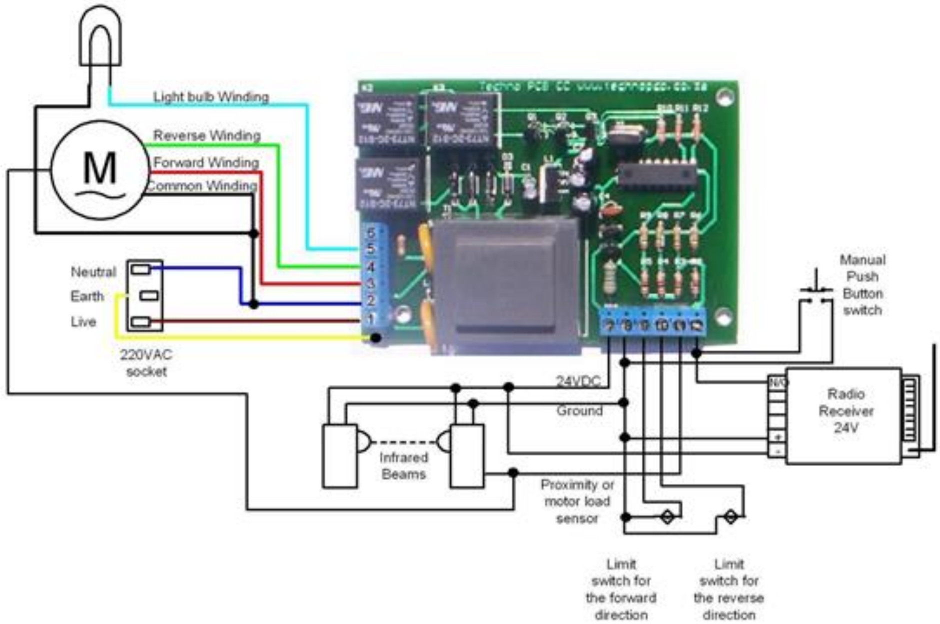


Figure #14: Active IR Sensor Schematic of Automated Garage Door

Figure #14 shows an example of how the IR detection module is integrated as part of the automated garage door opener circuitry to give feedback and interrupt the operation if the IR detection is interrupted. This can be used by Light Saver device to detect pedestrians.

3.3.3.2 Passive Infrared Motion Detection

Passive Infrared motion sensors (PIR sensors) have only an input optical sensor to detect reflected or emitted blackbody radiation of IR wavelength. Humans radiate IR at the mid-infrared wavelengths 7 to 15 micrometers, and the PIR sensor uses a Fresnel Lens to concentrate and focus IR radiation to the optical sensor. The adjustment of the Fresnel Lens focal length and geometric design allow for different detection patterns.

The PIR sensor consists of two internal sections which detect IR for a certain range from the sensor, and as there is motion of a blackbody radiation object past the PIR sensor, it passes through each internal section. When the first half of the PIR sensor detects the IR radiation, it causes a positive differential change compared between the two halves of the sensor, and as the object continues motion it triggers a negative differential change in the output signal. This is positive and negative differential change is visible in Figure #15 as we see a positive and negative amplitudes of the output signal on the graph.

The IR sensor is contained within an airtight sealed metal encapsule with a small IR transmissive window towards direction of reception. This is important to protect the sensory elements from humidity, temperature, and noise from unwanted energy reflections in the environment.

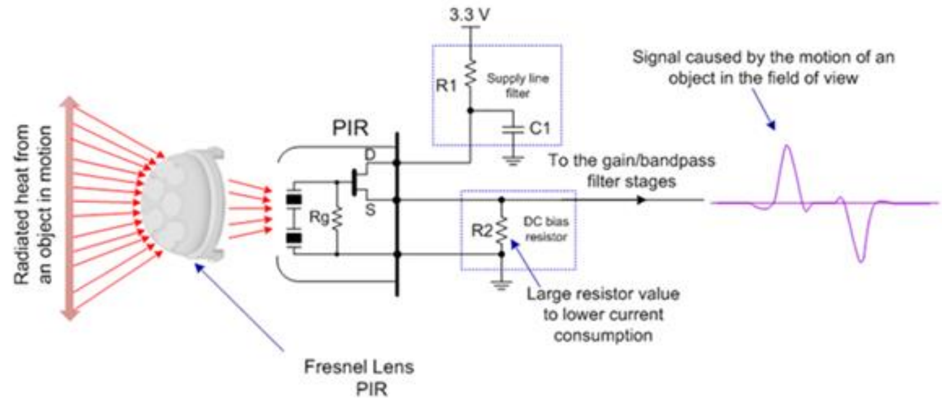


Figure #15: Passive IR Sensor Schematic and Signal Output Graph

PIR sensors contain Junction Gate Field-Effect Transistors (JFET) to amplify the signal received from the IR sensors, and buffer the output into a signal that may be processed by the microcontroller. JFETs are preferred as they are simple three terminal devices which have high input impedance, so they have higher sensitivity to input voltage signals. They have high input capacitance due to depletion layer between the p-type and n-type semiconductors, and this makes them less prone to damage. This makes JFETs more preferred to use over MOSFETs, and they are relatively cheaper than MOSFETs.

3.3.3.3 Ultrasonic Motion sensors

Ultrasonic sensors basic principle is it emits short, high frequency pulses at set intervals these pluses travel through the air in till they hit an object. Once it hits an object then the ultrasonic signal is reflected back to the emitting device and records the time in between hitting the object. The most Ultrasonic motion sensors has two main components the first being the transmitter, this emits the sound by using a piezoelectric crystal. The other main component is the receiver which captures the sound after bouncing back from an object.

To find the distance between the motion sensor and object. The ultrasonic motion sensor will measure the time between emitting the ultrasonic frequency and receiving the ultrasonic frequency. Once having that time, it will calculate the distance using the formula $D = .5T \times C$ where D is the Distance, T is the time and C is the speed of the sound roughly about three hundred and forty-three meters per second.

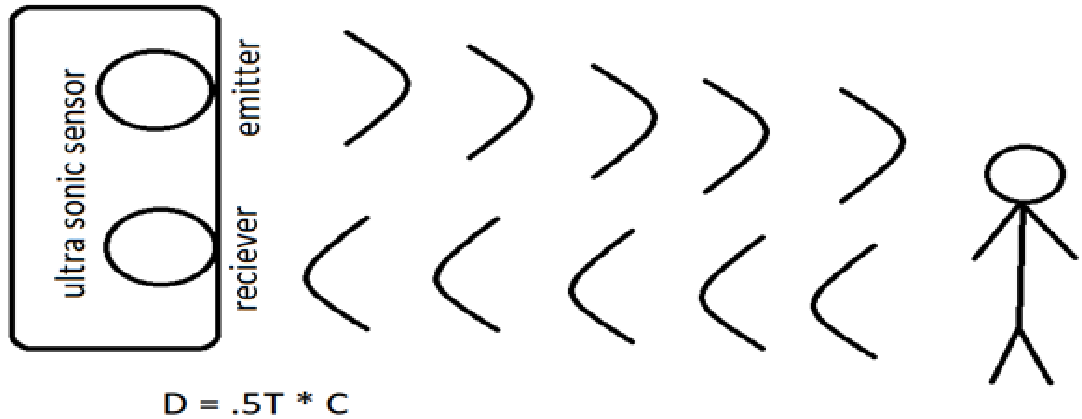


Figure #16: Basics of and ultrasonic motion sensor.

3.3.3.4 Microwave sensors (MWS)

A microwave motion sensor detection uses microwave technology to survey an environment. This is done, like the name implies, by using microwave signals. The motion sensor will send out microwave signals and records the length of the time for signal to reach back to the sensor after emitting. the time in between emitting and receiving the signal is called echo time, and this time is used to calculate the distances each and every stationary object within the zone to create a map of where every stationary object is so. This map of echo times will be used as a standard, and once an object changes the time of the echo it will realize it as motion and trigger an alarm or function tied to the sensor.

3.3.4 Lighting

The objective of the Light Saver system is to alert vehicles of the presence of pedestrians at right turn situations to prevent collisions or accidents. One method to alert the driver of a vehicle and bring their attentive focus to something externally of their vehicle is a light alert system. The Light Saver device will incorporate four mounted LED lights on the sign, and one vertical LED strip on the pole structure.

LED stands for Light-Emitting Diode, and the technology is widely prevalent in illumination and a step up from previous incandescent bulbs, which require filament and larger energy consumption. LEDs are made using diode technology. Diodes are intrinsic semiconductor materials such as Silicon or Germanium, and they are doped with impurities such as trivalent or pentavalent elements, which changes their excess charge carrier concentrations. Semiconductors that are doped excessive with holes, or positive charge carriers are known as P-type, and semiconductors that are doped with excessive electrons are known as N-type. When the two types are merged at one surface, they form a diode known as p-n junction. They allow current to pass through one direction when supplied a sufficient voltage in forward bias above their intrinsic threshold voltage limit.

LEDs are particular types of p-n junctions which emit light photons when electrons recombine with holes in the semiconductor material, and this effect is known as an optical and electrical phenomenon of electroluminescence. The color of the light corresponds to the energy difference required by the electrons to cross the band gap of the semiconductor material. This allows us to manipulate the type of semiconductor material used and doping concentrations of the material to produce a particular wavelength of light. LEDs range from infrared to visible light spectrum, and then ultraviolet light.

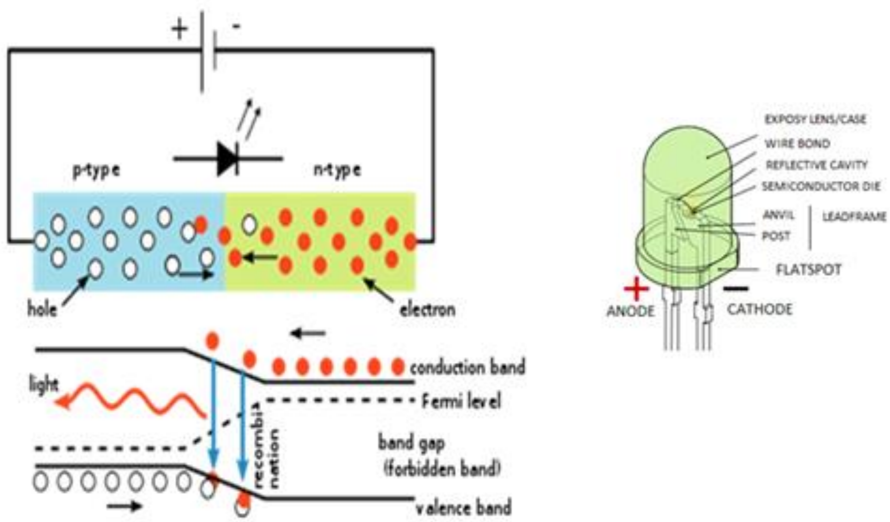


Figure #17: LED Working Principle and Construction

LEDs have many types of advantages over previous technology of incandescent light sources. LEDs can have smaller sizes, longer lifetimes, lower energy consumption, and they are utilized in numerous industries such as automotive, horticultural, medical, aviation, household technologies, etc. These advantages of the LED are the reason it will be proper to use as a light source for the Light Saver device. The LEDs we plan to use are four mounted LED lights to provide for illumination directed at oncoming vehicular traffic towards the front face of the sign board, and an LED light strip applied vertically along the pole structure to provide more illumination to the device, allowing for pedestrians or cyclist to know that this is a safety device for their utility.

LED technology is widely prevalent in road applications and is promoted by the US Department of Transportation Federal Highway Safety Administration. The DOT allows for the embedding of LEDs in regulatory signs and highway warning signs.

As mentioned on their website, embedding LEDs in regulatory signage “improves driver compliance withs regulatory signs through improved conspicuity, and enhances visibility and recognition of signs in low-light or low-visibility conditions.” [11]

There have been various studies to the benefits of embedding LEDs on regulatory signs, and according to a study by the Texas Transportation Institute in 2004, there was an approximately twenty nine percent reduction in vehicles not stopping at stop signs compared to stop signs that did not have embedded LEDs. [##] Another study by the Virginia Transportation Research Council conducted in 2007 found that embedding LEDs on regulatory signs decreased oncoming vehicular speeds by seven percent. [11]

There are regulations applicable however on how the embedded LEDs may be utilized within signs. The Manual on Uniform Traffic Control Devices Specifications dictates that the LEDs used on the sign must be the same color as the sign legend, background, or border. When activating the embedded LEDs, all the LED units on the sign installation must turn on simultaneously at a rate of more than fifty times per minute, but less than sixty times per minute. The LEDs must be embedded in a manner that does not impede the legibility or driver comprehension of the sign information. [11]

3.3.5 Voltage Regulators

Voltage regulators are devices that provide a constant voltage to a load regardless of the input voltage variations or the load current drawn. These are essential to provide electronic circuits the voltage stability they require, as electronics may become damaged if they do not operate within their stringent voltage specification range. The functioning of any electronic system, especially in our case the Light Saver device, is dependent upon receiving the proper power supply. With solar panels receiving various amounts of sunlight during the day or due to different weather conditions, we do not want the battery which stores the energy produced by the solar panels to become damaged from voltage fluctuations. We will go into detail about the types of voltage regulators and their uses.

The two main types of supply that needs to be regulated in electronics circuits is direct current power supplied by a battery, or alternating current power supplied by a mains outlet. Most electronics use a regulated DC voltage, such as computers, USB chargers, LEDs, etc. The general components of any voltage regulator are a feedback circuit, a reference voltage, and a pass element control circuit. Pass elements are semiconductor devices such as p-n junctions, bipolar junction transistors, or Mosfet used to compensate any changes of input voltage. There are two main categories of voltage regulators, and they are Linear voltage regulators and Switching voltage regulators. We will discuss the benefits and drawbacks of both types and see which applications they may be used for.

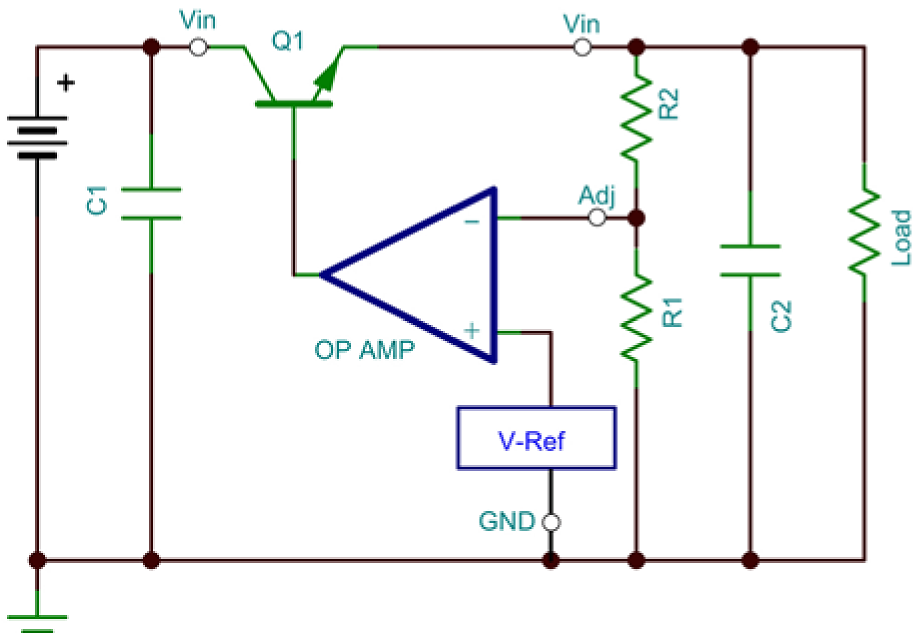


Figure #18: Linear Voltage Regulator Circuit

One method of classification of linear or switching is based on the operation mode that the pass element is in while voltage regulation occurs. Linear Voltage regulators are called as such because the pass element operates in the forward active mode, or the Linear region. The variable conductivity of the pass element allows us to maintain a fixed voltage output, and any excess voltage is dissipated as heat. The advantages of linear voltage regulators are that they are low cost, provide robust current protection, and require minimal external components to achieve voltage regulation. The disadvantages of linear voltage regulators are that output voltage must usually be lower than the input voltage, limiting our use in operation. They dissipate much of the voltage difference as heat and get very hot, and due to this energy dissipation, the efficiency for linear voltage regulators ranges below 60 % and much power is lost this way.

Switching voltage regulators are classified as such due to the pass element operating is either the cutoff region or saturation region, so it switches on or off. The two most popular switching voltage regulators are the Buck converter and the Boost converter. The Buck converter is a step-down switching voltage regulator, while the Boost converter is a step-up voltage regulator. The Buck converter is used when lower output voltage is needed.

The Buck converter can utilize an AC or DC input to provide a lower DC voltage output and is known as a Switch Mode Power Supply as it contains two semiconductor devices and an energy storage element. The capacitor is connected in parallel at input and output to act as a filter for ripple voltages to provide a continuous and smooth output.

As seen in the figure #19 below, a full wave rectifier is utilized when we have an AC input to initially convert into DC input. The switching transistor continuously toggles between the on off states resulting in a type of square wave with a frequency. We can easily manipulate the square wave with the flywheel circuit after the pass element, as the p-n junction is connected in reverse polarity, an inductor in series, and the capacitor in parallel with the load. The inductor acts as an energy storage device to supply the output with steady power during the off phases of the pass element. Along with the p-n junction and the capacitor, we obtain an approximately flat DC output, which is stepped down from the initial voltage supply.

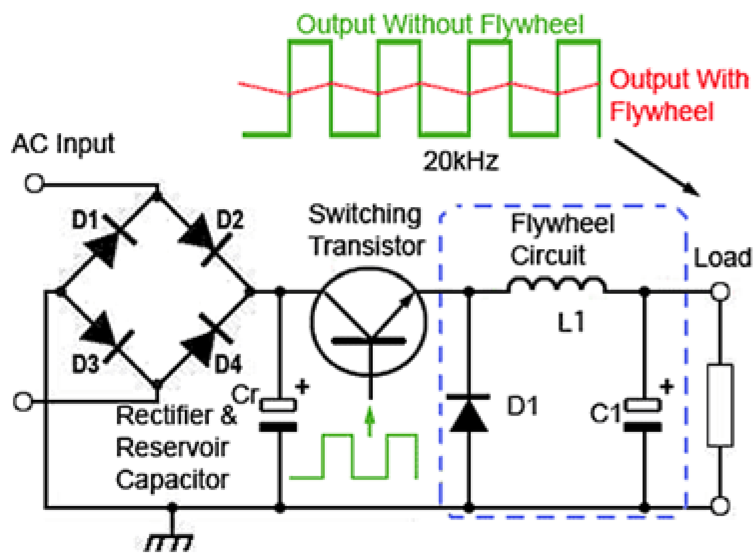


Figure #19: Buck Converter Schematic

The advantages of switching voltage regulators is that they are highly efficient, achieving up to 95 % efficiency as the pass element is cycling between cutoff or saturation mode. Energy is mainly consumed if operating in forward active mode. Another advantage is that the output voltage can be designed to be lower or higher than input voltage, and it does not require a step down or step-up transformer as in the linear voltage regulator. The disadvantages of the switching voltage regulator are that it is a more complex circuit with high noise due to constant switching. It requires more external components to implement. For our Light Saver device, we will primarily be utilizing voltages to be step down from the input, such as for the solar panel to battery circuit, and the battery to control unit circuit. The boost converter is not relevant to our research applications.

3.3.6 Battery

We will power the Light Saver device using a battery, which will store energy from the photovoltaic solar panels. It is not recommended to supply the device directly from solar panels as there is fluctuation in power outputs, and there is limited peak sunlight hours. That is why we select a Rechargeable battery to supply the device. There are two main types of batteries, non-rechargeable and rechargeable. We will focus on rechargeable batteries as they fit the scope of research for the Light Saver device requirements.

Rechargeable batteries are composed of multiple electrochemical cells which allow for multiple charge and discharge cycles with a load. Different combinations of electrodes and electrolytes are used such as lead-acid, nickel-cadmium, nickel-metal hydride, lithium-ion, etc. The two most common solar panel rechargeable batteries are Lithium ion and Lead Acid. Lithium batteries have efficiency higher then 95 %, and a faster charge rate and longer lifespan, but they are much more expensive than lead acid batteries.

Lead acid batteries have two types, Flooded Lead Acid (FLA) and Sealed Lead Acid (SLA). Flooded Lead Acid batteries require internal electrode plates to be submerged in water, and this must be replenished every 2-3 months, requiring high maintenance. SLA batteries do not require this type of maintenance and are more ideal for long term durability. SLA batteries have 80-85 % energy efficiency, and their depth of discharge is 50 %. They have long shelf life, and their idle discharge is approximately 3% per month [13]. They have broad range of operating temperatures from -35° C to 45° C. For the Light Saver device, we will be researching into various 12 V SLA rechargeable batteries. Batteries cannot be directly charged from solar panels as fluctuations may cause damage to the battery system, and we will research relevant charge controllers for batteries.

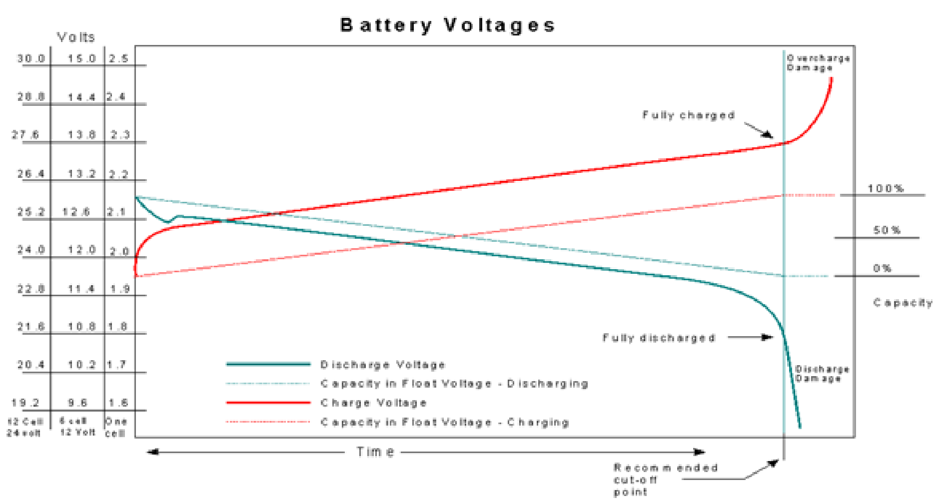


Figure #20: Lead Acid Battery Charging Graph

3.3.7 Charge Controllers

Charge controllers could be considered as a type of voltage regulation, but as we research into the operation of safely charging a battery, we see that there is more intricacy involved with charging a battery using solar panels than just maintaining a preset voltage, as in the case with voltage regulators which have an AC mains supply or DC battery supply. A charge controller is installed between the solar panel output and battery charging input. It is necessary to prevent battery damage and prolong battery health with proper charge cycles. Charge controllers prevent overcharging by limiting charging current. Charge controllers also prevent draining of battery by charging at correct voltage level and turning off circuit if battery power falls below depth of discharge, which could damage the load circuit if it operates at critically low voltages. At night there is possible reverse current to solar panels, and the charge controller prevents this.

There are two main types of charge controllers, Pulse Width Modulation (PWM) charge controllers and Maximum Power Point Tracking (MPPT) charge controllers. PWM is a technique to drive electrical power by discretizing it into short pulses. This turns analog signals into discrete digital signals. PWM is described by two parameters of modulating frequency and duty cycle. Modulating frequency refers to the rate of change of mode from on-off of the analog signal input. Duty cycle refers to the percentage of the original signal that is present as the output. For example, if a 9-volt input signal has a duty cycle of 50 % then that means we see an output of 4.5 volts across the output.

PWM controllers regulate the charging of the battery by providing series of short duration charge pulses instead of a steady charge flow. The duration and width of the pulses will vary based on the battery charge level, and if battery is fully charged, the PWM controller sends periodic short pulses to top off power. PWM controllers are simpler circuits and relatively cheaper than MPPT controllers, although a limitation is that the solar panel system voltage and the battery voltage must be the same specification for PWM controller to work.

The second type of charge controller is MPPT controller. These can take higher voltage input from the solar panel and charge a lower voltage battery. MPPT is more expensive than PWM but have higher efficiency of 94% to 98%. Their unique feature is they extract maximum power under all environmental conditions. They work on the principle of the Maximum Power Transfer theorem that when the resistance of the load in a circuit matches the voltage source resistance (as seen from its output terminals) the power transfer is maximum. MPPT controllers constantly analyze the output of the solar panel PV cells and choose the best resistance load value to extract maximum power transfer. This operating point will shift whenever the controller analyzes changes in conditions. If the battery is fully charged but solar panels are producing energy, the MPPT controller shifts operating point until generation is reduced. It may also apply this power generation to an external resistive load to prevent solar panel overheating.

3.3.8 Microcontroller

A microcontroller will be processing all the information and directing what needs to be happen on the light saver. It will be responsible for processing the signals from the motion sensor. turning on and off the camera and processing the data collected form the camera to determine if there are any pedestrians in the road with the crosswalk sign being on. If there are pedestrians in the road it will also be responsible to turn on the lights of the light saver.

A microcontroller is a compact integrated circuit that is responsible to specific operations of and embedded system and is found in various of machines, such as oven, radios, alarm clocks, and so much more. Very similar to a computer, a microcontroller shares the major components between one another shown in the figure below.

First the Microcontroller has a processor or CPU (Central processing unit). This processor is the core of the device and can be thought of as the brains of the whole entire machine. It processes all the various instructions or code that is given to it and executes the program. It also responsible for data transfers, basic arithmetic, logic, and input output operations. It will also communicate with other portions of the embedded system.

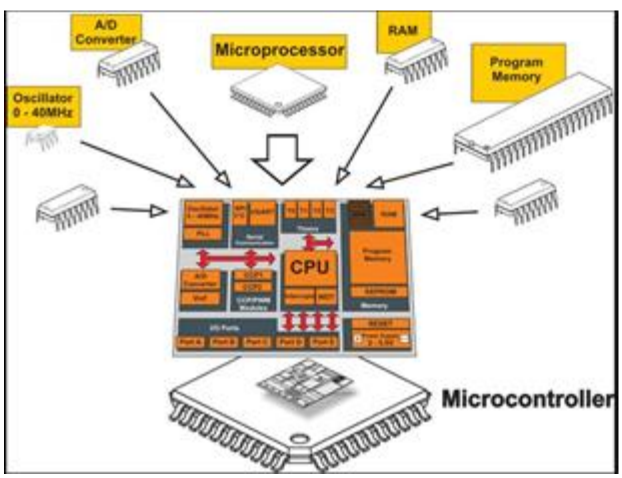


Figure #21: components of a microcontroller

The second part of a microcontroller is the memory. There are two types of memory, program memory and data memory or ram (random access memory). Program memory is the storage center for long term data that you don't want to lose. This data will remain constant and update and saves. So that every time the microcontroller comes on it will be ready to go, and it is not lot after the micro controller is turn off. The next is data memory or ram, this type of memory is volatile, meaning the data that is hold in this memory is temporary and used while the code is being executed. This memory will be loss after the device is turned off Some micro controllers will have and to digital converters (A/D converters shown in figure above. These converters will take analog signals to digital signals. This is done through sampling and quantizing. This well help support devices that uses various of sensors like the range sensor we are using in this project.

Lastly, we have input output peripherals. This function takes in inputs various of data and outputs any data that needs to be displayed.

3.3.9 Relays

Relays are device which control the connection of another circuit based on the input signal provided from an external source, beyond the source and load we are powering. A general term for them in which they are classified as is Actuators, as they control or operate an external physical process. The output may be either a binary or continuous, based on the situation we are modelling. A large benefit of relays is that they help achieve a small electrical input into a high-power output, by remaining electrical isolated from the load.

Electromechanical relays provide an electrical connection between multiple points (at least two), in response to an externally provided control signal. An electromechanical relay is a relatively simple and cheap design to manufacture on a large scale, due to the simplicity of the internal components. There is much development on the area of relays, and there are optical relays and solid-state relays, which do not use mechanically moving components.

The basic principle of relays is that they use a low voltage electrical control signal which may be DC or AC, to convert into magnetic flux which generates a strong enough mechanical force to enable contact between the internal mechanisms of the relay. This idea is displayed in Figure 22 below.

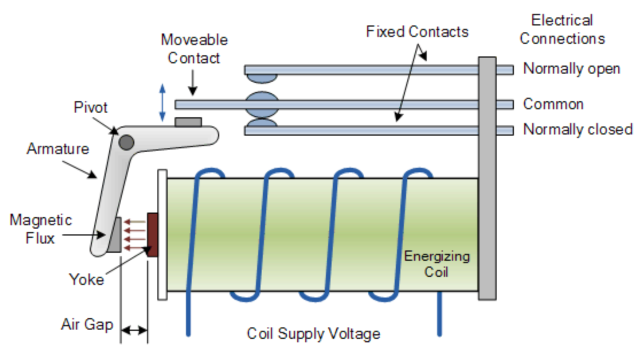


Figure #22: Principle of Electromechanical Relay

The relay operates in modes classified as normally open, normally closed modes. The normally open mode refers to the concept that the relay does not allow connection between the power source and the load. It only allows for the connection to be bridged if the relay receives an input signal from the control. While the relay receives a high output from the control signal, the connection remains between the source and the load. The normally closed mode refers to the concept that the source and the load are connected to begin with, and the connection is broken if the relay receives a high input signal from the control.

There is further classification of relays, and general terms are Single Pole Single Throw, Single Pole Double Throw, Double Pole Single Throw, Double Pole Double Throw, etc. This specification that is needed depends upon the application in which we are connecting the relay. With more poles, the relay can join more sources and loads within a single device in parallel configuration.

The next major classification is the solid-state relay, which is the emerging technology of relays. Solid State relays have the benefit of being purely electronic devices with contactless configurations.

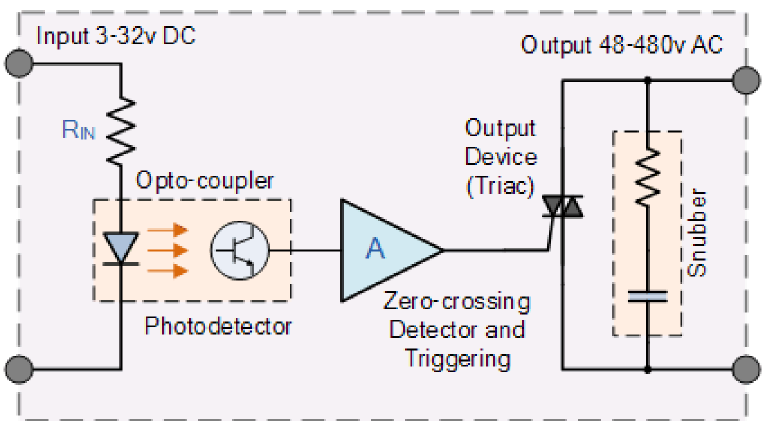


Figure #23: Principle of Solid-State Relay

As shown in Figure 23 above, the solid-state relay consists of an opto-detector and semiconductor devices such as transistors and thyristors. The benefit of solid-state relays is that they have much higher switching speeds compared to their electromechanical relay counterparts. The solid-state relays have a switching capability in the order of milliseconds, and this characteristic is going to be beneficial for us while toggling the LEDs as we need to meet the standards of how fast we need to toggle the embedded LEDs on the Light Saver device. These relays will be most likely what will be implemented in the Light Saver device. The have lower profile of size, quieter operations as they have no mechanically moving contacts, quick switching times, output resistance of the relay remains consistent based on the lifespan of usage.

3.4 Strategic Components and Part Selections

The part selection was very involved for this project. This was due to various factors and limitations that needed to be considered. One major factor that we needed to consider when selecting parts was the estimated power draw that each of these components would consume. Since we wanted everything to run from solar power, we needed everything to be as efficient as possible.

As a group we started researching proper lighting solutions that would not only be efficient but have the desired waterproof rating to survive in an outdoor environment. Also, since the lights would serve to warn vehicles, we needed them to have enough lumens to be easily visible, during daylight hours.

We saved solar panels for the last component to be selected, so that we could run our calculations to see how much Watts of power we would need for a given 24-hour period. One of the considerations that went into our calculations, is that not all of the components would need to be in a high-powered state at all times. Also, we needed to make sure that our solar panels not only met are power needs but exceeded them. This was due to numerous reasons such as a possible error in calculations, due to power consumption estimates being higher rather than lower than estimated. We wanted to ensure that our devices would be able to maintain their power throughout the day for many years given solar panel degradation. Most manufactures typically guarantee their panels to perform at 90% production for the first ten years. However, between years 15 – 20 that guarantee drops to only 80%.

3.4.1 Signage and Mounting

When it comes to Signage and mounting, we needed a solution that was both cost effect and fit our needs. We looked at many different signage variations, this included many different shapes and sizes. Picking the correct sign was a tricky process, because we needed to know as a group what all hardware was going to be used with our project, this is due to the fact that we planned to mount our hardware on the back of the sign. We needed the sign to be big enough to fit our hardware, but also not use up a lot of our projects budget, ultimately, we chose a sign that struck a middle ground between the needs of the project and the budget constraints.

As a group we researched many different mounting options for our hardware. We knew our design would be located outside, in the elements and that every component would need to be weatherproof. Also, we would need to consider the space that was needed for all the components to fit on the Sign. As shown in figure #24 you can see that the back of our sign will have a weatherproof box to store the electronics, while the exterior components will need to have a waterproof rating of IP65 or greater.

Figure #24: Sign with Components Attached

All of these components need to fit securely on the sign, fastened with Galvanized bolts and straps. Lastly, we needed to find a good height to make our sign noticeable, to both pedestrians and vehicles alike. We felt the sign needed to be at least six feet tall. So, we needed a pole that was greater than six feet so that we could mount the sign in the ground. Stop signs and other signposts found in the USA, typically are mounted below ground or in concrete 2 feet deep. So, an eight-foot post would be ideal if you wanted your sign around six feet.

3.4.2 Solar Panels

Solar panels are the food to our equipment meaning that we need to make sure that we are getting enough of it for it to be able to do as we plan it to. Choosing solar panels is a factor that is based on what will we be able to implement in other elements and how much energy will they pull away making us calculate how long will it take for our battery to fully charge using these solar panels.

Looking at this we have to understand our possibilities and their multiple advantages and disadvantages to be able to make a smart decision on what should happen. We will consider 4 types of solar panels Monocrystalline, Polycrystalline, Thin-film and Amorphous in table #1 you will see the advantages and disadvantages of all of these 4.

In table 1 below, we will compare the different types of solar panels.

Table #1: Advantages and Disadvantages of solar panels

	Advantages	Disadvantages
Monocrystalline	-Best at converting light to energy	-Most expensive out of all -Create the most waist for environment in development
Polycrystalline	-Create least waist for environment -Less expensive than Monocrystalline They do not do well in hot temperatures	-Less efficient than Monocrystalline -Still above our budget for solar panels
Thin-film	-Most affordable option of all	-Break down faster than other panels -Normally need more space
Amorphous	-Composed of multiple layers of Thin-Film -Can reach high levels of efficiency twice as Thin-film	-More Expensive than Thin-film

Analyzing the table above Polycrystalline or Monocrystalline would be the best if found at the right price since we need to have a compact space and be able to maintain a good use of power conversion. This brings us to the next step being able to find the corresponding wattage and voltage to charge our battery at good speed rates. For this we believe that we need to be able to use a solar panel that has a wattage of above 100 watts and a voltage above 12V making the process more efficient letting it charge the battery as it is being used at the same time.

In table 2 below, we will compare different solar panels which are available on the market.

Table #2: Comparison of possible solar panels

Part #	Kw1210	GS-100	B087213FLB	B07GF5JY35
Manufacturer	Umi-Motor	Grape Solar	Weize	Renogy
Power Rating (Watts)	180	100	100	100
Voltage Rating (volts)	20	12	12	12
Dimensions (inches)	56.53 by 21.02	40.16 by 26.37	36.4 by 26.8	42.2 by 19.6
Weight (lbs.)	23.05	19.66	15.8	16.5
Max Current Charge/day (Amp/hrs)	27	25	25	22
Includes Charge Controller	Yes, PWM	Yes, PWM	No	No
Material	Polycrystalline Silicon	Polycrystalline Silicon	Monocrystalline Silicon	Monocrystalline Silicon

Power Rating: This describes the power output given by the solar panel during maximum operating efficiency of peak sunlight hours. Considering at average 4 peak sunlight hours based on geographical data by the US EIA, we get 400 Watts generated per day using a 100W panel, meaning 33.33 Ah per day to charge the battery. We want a minimum 30Ah per day generated so the lead acid battery may correctly replenish.

Dimensions: We have the flexibility with selecting dimension of the solar panel, as the Light Saver device is elevated off the ground away from pedestrian obstructions. Any dimensions can be accommodated.

Weight: The mounting hardware can handle the weight of the solar panel with ease.

3.4.3 Microcontrollers

A Microcontroller is going to play a part in various aspect of our project so picking the correct microcontroller is very important, so it does what we need it to do. Majority of the hardware will be connected to it, rather it being to feed it information, receiving signals from it or outputting results. The Microcontroller will take signals from our motion sensor and change it from low power mode to active and activate the camera. The camera will then take the image of the crosswalk sign and send it back to the microprocessor so it will need the storage to contain those images. It will also need a fast-enough processor in order to process the computer vision. It will also need to be low power so it can be run on battery powered by solar power.

3.4.3.1 MSP430 GET

This launchpad uses the MSP430G2553 as the microprocessor. The MSP 430 family offers ultra-low power consumption the architecture and the five different low power modes makes it ideal to extend battery life especially in portable options. It also has only 20 pins that uses 230 micro amps at one megahertz while in active mode.

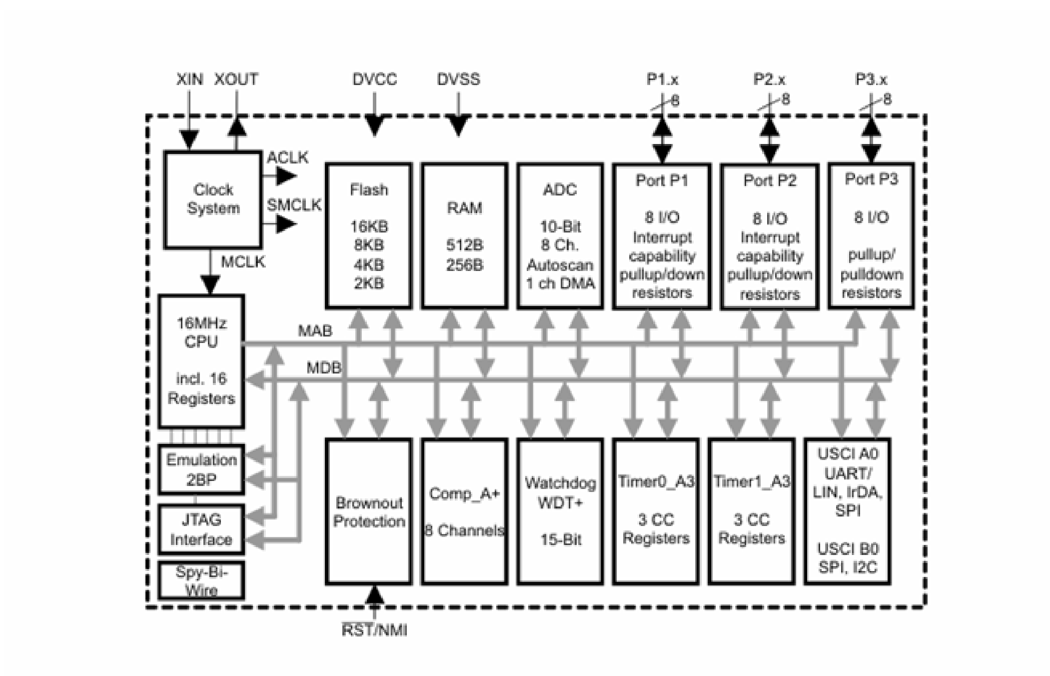


Figure #25: MSP430G2553 tech specs

3.4.3.2 Raspberry Pi 3

The raspberry Pi 3 offers many options for use to in our project. It has a large ram options with the smallest being two gigabits and up to eight gigabits. It also offers USB 3 and USB 2 for fast data transfer.

In the figure 26 below, we can see the multitude of specifications and detailed descriptions of the Raspberry Pi 3 board.

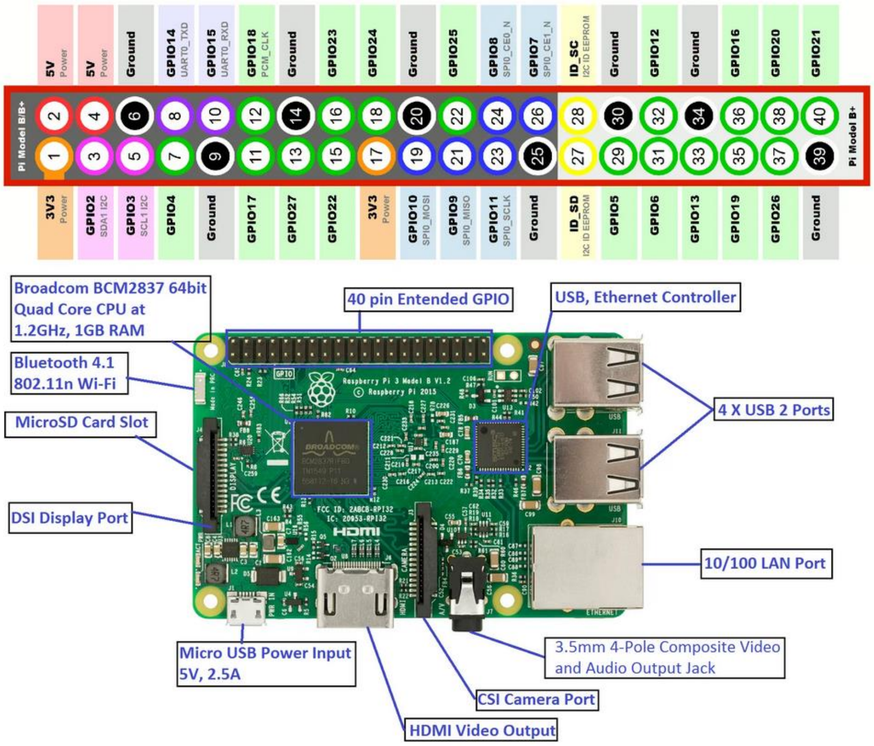


Figure #26: Raspberry Pi 3 Tech Specs

3.4.3.3 Arduino MKR WAN 1300

The Arduino MKR WAN 1300 is a powerful board is cost effective solution and requiring low power. It also allows for LoRaWan communications allowing different sensors to communicate with the devices. It also has the capability to be power by wo 1.5 V AA or AAA batteries or an external 5 volts.

Figure #27: Arduino MKR WAN 1300 Permission given

3.4.3.4 Microcontroller comparison

After researching the three microcontrollers (MSP430G2ET, Raspberry pi 4, Arduino MKR WAN 1300) they all other offer different advantages over the others but we still need to make budget while still making doing what need and not more. If we get a microcontroller that is over power, then the scope of our project then then it will waste more power which is a constraint since the sign is powered by solar power. But on the other size if we get a microcontroller that can't handle what we need the project won't work. We will have to look at cost, memory size, power consumption, general-purpose input and output pins or (GPIO) clock frequency's as these topics will play a part in the choice of microcontroller.

Table #3: Comparison of possible microcontrollers

Feature	MSP430G2553	Raspberry Pi 3	Arduino MKR WAN 1300
Operating Voltage	1.8-3.6V	5V	5V
Temperature Range	-40°C to 85°C	0°C to 50°C	-40°C to 85°C
Memory	16 KB Flash, 0.5 SRAM	1GB SDRAM	256 KB Flash, 32 KB SRAM
Max Clock Frequency	16 MHz	1.2 GHz	48 MHz
GPIO Pin Count	20	40	16
Low Power	Yes	No	Yes
Power Consumption Active mode	1.14mW	3.6W	280mW
Camera Port	No	Yes, 2 lane MIPI CSI	No, but has LoRa protocol
Board Price	~$20	~$35	~$40

3.4.3.4.1 *Cost*

Cost is a big part of the project the more inexpensive the product is the more likely for the signs to be built and put up which will save precious lives. Now having a cheap product does not mean anything if the product does not work so will need a micro controller that is that we do what we need no more and no less.

In table 4 below, we will look at different microcontroller costs.

Table #4: Microcontroller cost

Microcontroller	Cost
MSP430G2ET	$9.99
Raspberry pi 3 model B 1(GB)	$35.00
Raspberry pi 4 model B 2(GB)	$35.00
Raspberry pi 4 model B 4(GB)	$55.00
Raspberry pi 4 model B 8(GB)	$77.00
Arduino MKR WAN 1300	$40.76

As shown above the MSP430G2ET is the most inexpensive option we can also see the Raspberry pi 4 model B 2(GB) is a little bit more than half the cost as the Raspberry pi 4 model B 8(GB) for the scope of the project as the Raspberry pi 4 model B 8(GB) with its 8 gigabits of ram many be overkill since it is only doing computer vision computations and should making the 1 gigabyte and 2 gigabyte better options.

3.4.3.4.2 Power Consumption

Battery life is a factor going into the microcontroller decision. The light saver will be fueled by a battery that is charged by solar power. If the microcontroller draws more power, then solar power can keep up then the system will die. This will result in the light saver not functioning and potential life's to be lost,

Table #5: Power Consumption Comparison

Microcontroller	Lowest operating voltage	DC current	Power Consumption (mW)
MSP430G2ET	1.8 V	0.23mA	.414mw
Raspberry pi 3 model B	5.0V	2.5A	12.5w
Arduino MKR WAN 1300	5V	20mA	66 mw

3.4.3.4.3 Memory size

there are two types of memory in microcontrollers. The first is the being Flash memory, this type of memory will stay on the microcontroller even if the device gets turn off. This will hold all the code that we want to do with the light saver. The more Flash memory that we have the more complex and efficient our code can be. The other type of memory is RAM (Random Allocated Memory) which all the temporary data is hold. This memory holds all the data that is used to for computations, but this data is erased and reset every time the microcontroller is turned off.

Table #6: Microcontroller Memory comparison

Microcontroller	Flash memory	RAM
MSP430G2ET	16KB	64KB
Raspberry pi 3 model B	SD card expansion	1-8GB
Arduino MKR WAN 1300	256Kb	32KB

As shown in the table above we can see the Raspberry pi has flexible and high options for memory. We also see that the Arduino MKR WAN 1300 has more flash memory then the MSP430G2ET but less RAM. With computer vision we will need to process and store images which may be more than the MSP can handle seeing how some images are megabits.

3.4.3.4.4 General Purpose Input/Output pins

A general-Purpose Input/Output pins are pins on the integrated circuit that does not have any specific functions by themselves. They are instead customizable pin controlled by the software embedded in the microcontroller. The GPIO pins allows for communication from the board into any input or output devices. the more pins we have on our board the more customizable it is and the more we can add to it. Another thing we must look at is the max output current per port. We need the pins to send out the minimum current to output connections to work or we will have to impose some type of amplifier.

Table #7: Microcontroller GPIO pins and Current

Microcontroller	GPIO Pin Count	Max Output Current per port
MSP430 GET	20	48 mA
Raspberry Pi 3	40	16 mA
Arduino MKR WAN 1300	16	7mA

As shown above we can see the Raspberry Pi 3 has the most pins meaning it will have the most customizable options it also rated in the middle of the three microcontrollers in terms of current output. The Arduino MKR WAN 1300 has both the lowest pin count of all three and the lowest max output current per port of the three as well. In this aspect the Raspberry Pi 3 and the MSP430 GET are good options in what we need to do with the light saver.

3.4.3.4.5 Clock Frequency

The clock frequency or speed is how fast the processor is. This is measured by the if instructions the Central processing unit can executes per second. For the light saver we will be computer vision to check so the microprocessor will need to compute the information provided by the image of the camera, so it can light up the light saber in a timely manner.

Table #8: Microcontroller Clock Frequency

Microcontroller	Clock Frequency
MSP430G2ET	16MHz
Raspberry Pi 3	1.5GHz
Arduino MKR WAN 1300	48Mhz

As we can see from the table above the Arduino MKR WAN 1300 is about 400 percent faster than the MSP430G2ET. We also see the raspberry Pi 3 has a significant edge on the other two microprocessors. This 1.5 giga hertz should be able to run any algorithm we use in the computer vision.

3.4.3.5 Microcontroller Decision

Looking at the previous comparisons the Raspberry Pi 4 model B 2GB is a solid choice for the light saver. The cost May be more than the MSP430G2ET but we will get more pins out of it so we won't have pins as a constraint of our project. We it will also have a two gigabyte RAM allowing for faster computations as well as more variables being able to use as we program the computer vision which was a big determining factor when picking a microcontroller. We also see it has a scientifically faster clock speed allowing for the program to be faster and the light saver to be more reactive. It also has an expanding memory storage removing that as a constraint in programming. The only advantage that the Arduino MKR WAN 1300 had over the raspberry pie was the low power setting and overall lower power consumption. This will be a constraint that is passed on to the battery and solar power equipment.

3.4.4 Motion Sensor

Picking the right motion sensor is a vital part of the Light Saver, with its help it will detect pedestrians in the cross walk which will then send a signal to turn on the microcontroller from low power mode and turn on the camera to run the computer vision program to confirm that there is a person in the cross walk, and they have the right of way. Failure to detect the people will result in the light saver not turning on and not warning the driver that there is someone in the road.

Table #9: Pros of ultrasonic vs infrared vs Microwave motion sensors

Ultrasonic	Infrared	Microwave
Not affected by color or transparency of objects	Low power consumption	Wide range of coverage
affordable	Good response time	Can detect motion beyond the walls or behind doors
Can be used in dark environments with no effect to the detection ability	Can be used in dark environments with no effect to the detection ability	High precision and reliability
Not as affected by environmental factors (i.e., Dirt, dust, moisture)	Detects soft materials that would not be able to be detected by ultrasonic	Low maintenance
Better accuracy over infrared	Has a very strong noise immunity	Not affected by heat
Good range for scope of project better then infrared	Not effective by corrosion or oxidation	

Generally, in the market in security systems or in-home device applications, the typically used motion sensor is an infrared motion sensor, as these can operate with technical low cost, and are feasible to implement in different power modes and applications. They have a good accuracy measurement for detection with respect to the other types of sensors, but they are more affordable and convenient to use.

In table 10 below, we will look into the different cons of the types of motion detection methods.

Table #10: Con of ultrasonic vs infrared vs Microwave motion sensors

Ultrasonic	Infrared	Microwave
Soft materials may absorb the waves and thus creating inaccurate measurements	At high power can damage people's eyes if they look at it	Prone to false alarms a leaf blowing in the wind can trigger it
Won't be able to use underwater	limited range	More energy consumption
Sensitive to variation of temperature	Affected by environmental conditions such as rain fog or dust	Could be a health concern
Not a long range in general		

The infrared motion sensor was chosen for our project due to its affordability, range of the sensor fits the scope of our project, and accuracy. This type of sensor will be a good fit to our sign and will allow for accurate results and help warn drivers when pedestrians are in the road.

Table #11: Comparison of possible motion sensors

Part #	BKC1219	B01IU8CT0M	HC-SR501	EP12100
Manufacturer	Supernight	E-Age	Low Voltage Labs	Jcheng Security
Voltage Rating (volts)	24	12	4.5	3.6
Dimensions (inches)	6 by 3.4 by 0.4	6.1 by 2.28 by 1.8	1.33 by 1.18 by 0.94	5.82 by 2.95 by 2.12
Weight (lbs.)	0.10	0.08	0.10	0.12
Material	Plastic	ABS	ABS	ABS
Range (meters)	0-7	0-12	3-7	0-12
Angle (degrees)	140	140	100	100
Technology	PIR	PIR	PIR	MW/PIR
Price	$13	$12	$6	$30

Range: The range of most motion detectors is minimum 5 meters, but for the Light Saver device we do not need as long range as we are detecting pedestrian near the device at the crosswalk entrance. So, range capability for various models is suitable.

Angle of Detection: For the Light saver device we do not want an extended angle of view as that may conflict with vehicular traffic. As our device is located near the crosswalk, the lower the field angle view the better. So, 100° angle view is sufficient for the device.

3.4.5 Camera

Having the right camera is import to the light saver. The camera will be responsible for taking the pictures of the cross walk and seeing if the crossing sign is signaling for pedestrians to pass. If the motion sensor is detecting a pedestrian and the camera sees the pedestrian sign is signaling to cross the light saver will be illuminated. There are various aspects that goes on picking a camera for the computer vision based on what you are doing.

3.4.5.1 Area scan Vs Line Scan

The first being area scan Vs line scan. Line scan is great when you only need to have a narrow field of vision that you want to examine. Then benefit of this is that there is less information to process allowing the computations to be faster data management to be easier. Less memory storage overall for the pictures to be taken and to be compared to. A disadvantage is because of the narrow range it is more possible for things to be missed. On the other side other end, if we need to survey a broad view of an area then we will need a camera that has that area scan. This is beneficial because unlike the line scan this type of scan can give you a more in-depth inspection of the area you are scanning. The disadvantage of this to the line scan is it will require more power and analysis on your code because you have more information to process and compare to.

3.4.5.2 Monochrome vs color

Monochrome vs color works exactly how it sounds. Monochrome is taking pictures in just without a color filter, so it only sees in black and white. This every beneficially if what you are doing doesn’t require colors comparison. These types of cameras tend to be more sensitive compared to the color cameras and as a result will produce a more detail images, this in turn all to more accurate computations of the computer vision. Color cameras also be very effective and contains more information despite being less detailed. With color images we are able to abstract different information quicker for example if we were looking at a stop light and see if its red, we can just examine the section of pixels and see if they are red which is simpler, quicker and accurate then if we were to code it up using a black and white picture and checking the grade of grey to see if it's on which could be independent on the time of day

3.4.5.3 CMOS Vs CCD

CMOS (Complementary metal-oxide-semi condor), cameras will convert the light into electronic signals that are integrated into the surface of the sensor. as a result, the rate in which the data is transfer is scientifically quicker. Another benefit of the CMOS cameras are they less expensive compared to the CCD cameras. CCD (Charge Coupling Device does not have the conversion on the sensor's surface. This allows the camera to capture more light which results in many benefits. One being a lower noise factor, meaning a less distorted image and better accuracy. Another benefit is higher color fidelity, meaning the colors are better allowing for computer visions to do color comparison easier. the downside to having these better images is that the CCD cameras do cost more.

3.4.5.4 Resolution

Resolution also plays a role on what camera we will select. Resolution is determined by the number of pixels in a digital imaged and it called based on the dimensions of the number of pixels in the rows by columns. An example of this is 1920 x 1080 has 1920 pixels vs 1080 pixels for a total of 2073600 pixels. Or 2 megapixels. Digital cameras are often just given their resolutions in just mega pixels. The more megapixels we have the clearer and more contrast of image which will help greatly to get better accuracy in our computer vision. The downside of having more megapixels the camera will end up costing more overall.

3.4.5.5 Project needs

Overall, for this project, both line scan and area scan are valid options depending on the placement of the pole. Line scan will work best since we will be just checking the crosswalk sign and it will reduce the size of the image allowing for smaller image and less data the processor will have to examine and handle. For this project we are going to need a camera with the color option, this will help with determining if the crosswalk is signaling for the pedestrians to cross, we can easily do this by checking if the sign has a solid red hand or a white walking person. As for CMOS (Complementary metal-oxide-semi condor) camera or CCD (Charge Coupling Device) regardless of what we pick does not matter for the scope of our project CMOS camera will be nice for a quicker transfer rate but the CDD camera will allow for a better image. Lastly resolution, we still need a camera that will give us a clear enough image but not one that is going to make us go over the budget. Therefor the resolution should be in the range of 2 mega pixels to 20 mega pixels.

3.4.5.6 Possible camera selection

There are plenty of cameras that can do what we need for this project. Some being, Arducam Camera 5MP, the Raspberry Pi High Quality Camera, Logitech C920 HD Pro Webcam. The scope of this project requires a camera will take a picture of a cross walk sign to see if it is signaling for pedestrians to cross. To do we will use color detection in our computer vision algorithm. So, this means we will need a camera with color and good enough quality to capture the sign from a across the street.

3.4.5.6.1 Arducam Camera 5MP

The first camera we will be looking at is the Arducam camera 5MP. This camera has five mega pixels plus 49enteral purpose SPI. As seen in the figure below it is small. It is CMOS (Complementary metal-oxide-semi condor), meaning this camera will convert the light into electronic signals that are integrated into the surface of the sensor. as a result, the rate in which the data is transfer is scientifically quicker. The Arducam is also very affordable.

Figure #28: Arducam for Raspberry pi 5MP

3.4.5.6.2 Raspberry Pi High Quality Camera

The raspberry Pi High Quality camera is a 12.7-megapixel Sony IMX477 sensor. it is very flexible with accepting CS-mounted lenses and with an adapter it will also accept C-mount lenses. This model of camera offers a higher quality of resolution and is compatible with the Raspberry Pi. For the purpose of the Light Saver device, we will take this quality into consideration based on the distance of the target image that we are trying to analyze and if we need greater resolution for the algorithm to analyze the input data. This will be looked into further during the computer vision analysis and research into the requirement and environmental conditions in which the device will operate.

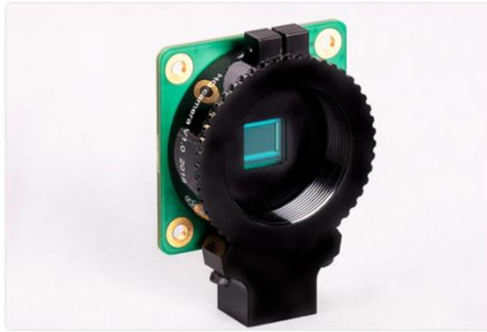


Figure #29: Raspberry Pi High Quality Camera Permission Given

3.4.5.6.3 Logitech C920 HD Pro Webcam

The Logitech C920 HD Pro webcam delivers Full HD (1080p at 30fps or frames per second). It also has a HD auto light correction. The Logitech as offers a autofocus and a glass lens allowing for clearer pictures. It also plugs in to the microcontroller via USB.

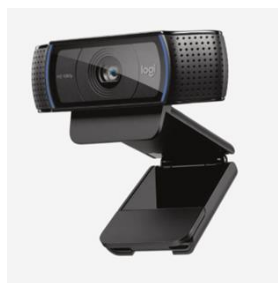


Figure #30: C920 HD pro webcam

3.4.5.7 Camera comparison

After Researching the three different cameras (Arducam camera 5MP, raspberry Pi High Quality camera and the Logitech C920 HD Pro webcam) they all other offer different advantages over the others but we still need to make budget while still making doing what need and not more. We still must be mindful of the power usage since the light saver will be solar power.

3.4.5.7.1 Cost

Cost is a big part of the project. The more inexpensive the product is the more signs can be built, leading to more lives to be save but the camera must be able to do its job. Failing to take accurate pictures will lead to false negatives in our computer vision so the sign will not illuminate to warn the drivers.

In Table 12 below, we will compare different costs of the types of cameras that we may possibly implement.

Table #12: Cost Comparison camera

Camera	**Cost**
Arducam camera 5MP	$15.99
raspberry Pi High Quality camera	$50.00
Logitech C920 HD Pro webcam	$79.99

As we can see from the Table above the Arducam is more than a third of the cost of the raspberry Pi High Quality camera and a fifth of the cost of the Logitech camera. This does make the Arducam the best cost-efficient part between the three cameras.

3.4.5.7.2 Resolution

The Light saver will be using computer vision to help determine in the crosswalk sign is on and signaling the pedestrians to cross. In order to do this, it will need to process an image and compare the pixels to what it is looking for. So, resolution will play a part in what camera we are picking. If we have a camera that has a lot of mega pixels, this will cause the computer vision to do more computations which could lead to wasted energy. This could be an issue since the light saver will be solar powered. Now on the other hand, it is possible that the if the camera does not have a high enough resolution which could be problematic. If there are not enough pixels the microcontroller might give a false negative causing the light saver not to light up when the pedestrian in the street has the right of way. So, we will need a camera with enough resolution to have a good enough picture such that we don't get a false negative but not too much that it not processing too much and wasting power.

Table #13: Resolution comparison camera

Camera	**Resolution**
Arducam camera	5 MP
raspberry Pi High Quality camera	12.3 MP
Logitech C920 HD Pro	2.07 MP

As we can see from the graph above the Logitech C920 HD Pro has the lease number of mega pixels. This is due to the picture being in 1980 by 1080p. we can see the Arauca camera offers more than the Logitech C920 HD Pro roughly about 2.5 times more meaning our image is going to be better and have a higher resolution leading to a more accurate image for the computer vision to check. Lastly, we have the Raspberry Pi High Quality Camera with 12.3MP. the Raspberry Pi High Quality Camera is about six times more pixels than Logitech, it is also about 2.5 times greater than the Arducam. While the Raspberry pi High Quality camera offers the best resolution and the most accurate pictures it will also need a lot of computation from the microcontroller leading to more power consumption. After comparing the three cameras we will be selecting the Arducam camera due to the mid rage resolution allowing for both accuracy and efficiency.

3.4.5.7.3 Size & weight

The camera we select will have to be mounted on the sign rather being on the electric box or on the pole itself. The lighter and smaller the camera is the easier the mounting it. The we already have a few components inside our electric box as is like the wiring, the battery, the charge controller meaning we will have to have it being small to be in there as well, with a tiny whole for the lenses if not we will have to have it outside the box leaving it more vulnerable to outside forces like weather.

Table #14 Camera size comparison

Camera	**Height**	**Width**
Arducam camera	34mm	24mm
raspberry Pi High Quality camera	38mm (not include lenses)	38mm (not include lenses)
Logitech C920 HD Pro	43.3mm	94mm

As we can see from above, the Arducam is the smallest camera of the three cameras allowing it to be the most efficient in terms of space management. The raspberry Pi High Quality camera is not too far from the Arducam in terms of size but this camera can be bigger depending on what lens is attached to it. And the Logitech is at least double the sizes of the other two.

Table #15 Camera weight comparison

Camera	**Weight**
Arducam camera	20g
raspberry Pi High Quality camera	53g (this is with the 6mm wide lens the smallest and lightest one needed for the camera
Logitech C920 HD Pro	162g

In the table above we can see the Arducam is not only the smallest but it is also the lightest. It is a third of the weight of the raspberry Pi High Quality camera with the lightest lens attached. We can also see that the Logitech C920 HD Pro is about an eight of the weight of the Arducam.

3.4.5.7.4 Camera Choice

Looking at the previous comparison and taking those into consideration we will be selecting the Arducam camera for the Light saver. The Arducam camera much considerably cheaper than the other two cameras, at about a third of the price of the raspberry Pi High Quality camera which was the next step up making it ideal for our budget and cost savings. Next, we look at the resolution, and for this aspect we needed a camera that gave us enough pixels to do the job without being too much. The Arducam camera was perfect for this. It was in the middle with the raspberry Pi High Quality camera being double the number of pixels causing or microcontroller to do more computations, leading to more power consumption as well as more time needed to run the algorithms need to see if the cross walk is signaling for the pedestrian to cross. The Arducam camera had more than the Logitech C920 HD Pro camera. By selecting the Arducam we will be getting a better image then the Logitech C920 HD Pro but it's not straining our microcontroller like the Raspberry Pi High Quality camera. Lastly, we look at weight and size. In these aspects Arducam camera was both the lightest and the smallest camera allowing for more space efficiency in the light saver.

3.4.6 Battery

In this section we will discuss different types of battery types to store the power generated from solar panels and supply the Light Saver system. The battery is a crucial part of the device as it will allow for portable powering of the Light Saver, and we must consider the specifications of the battery in terms of being appropriate to connect with the Solar panels.

Table #16: Comparison of possible Batteries

Part #	ML50-12SLA	LFP12100	RNG-AGM12	EP12100
Manufacturer	Mighty Max	Weize	Renogy	Expert Power
Voltage Rating (volts)	12	12	12	12
Dimensions (inches)	7.76 by 6.50 by 6.89	12.8 by 6.8 by 8.5	13 by 6.8 by 9	7.7 by 6.5 by 6
Weight (lbs.)	30.02	67	66	13
Amp Hour Rating	50	100	100	50
Regular Maintenance	No	No	No	No
Composition	SLA AGM	SLA GEL	SLA AGM	LiFePO4
Price	$99.90	$199	$210	$450

Capacity Rating: The measurement of a battery's capacity is given as a standard Amperes per Hour rating, or a Watts per Hour rating. We will use the defined Amp hour rating. The rule of thumb for batteries is that you do not want them to discharge below their threshold limit as it degrades the battery life, and they are not built to operate below their depth of discharge. For lead acid batteries it is approximately fifty percent. So, when calculating the expected load power consumption per day, we want to double that number when looking for potential battery solutions. Lithium batteries have a greater depth of discharge value and better power density, but they are much more expensive than lead acid batteries. Lithium batteries are also more volatile compared to their lead acid counterparts.

Dimensions: Battery of both types have rectangular dimensions that will be able to install on mounting components. This will conform to the rectangular housing we plan to install for hardware safety and weatherproofing.

Weight: The weight of the battery is the heaviest external component that will be mounted on the device. It is important as we must have a balanced center of gravity, and if needed we may lower the height at which the battery is mounted to ensure greater stability of the mounting pole.
Another aspect which we are exploring is having multiple batteries to supply the device, as the computer vision and processing is more power consuming, and the LEDs are less power consuming. By using multiple batteries, we can save money and have better power density if we use Lithium batteries for the lower power consumption components. The lithium batteries are more affordable for lower battery capacity and have higher efficiency levels.

3.4.7 Charge Controllers

We will explore different types of charge controllers to power the battery using solar panels, as we cannot connect them directly together. Several parameters that we want to consider when selecting an appropriate charge controller for the systems is that it should be suitable to use with the battery type which we select, as there are many different types of charge controller models which are only suitable for a specific type of battery, such as lithium ion, lead acid, etc. We also want to consider the efficiency in charging that the device will be able to provide, as we want to utilize as much energy as possible that is generated from the solar panels, to allow for the battery to be charged in sub-optimal conditions or have enough power to not rely on solar generations on cloudy or rainy days.

In the Table #17 below, we will compare several parameters of different type of charge controller devices.

Table #17: Comparison of possible Charge Controllers

Part #	RCC20VOYP-G1	GS-100	Tracer2210AN
Manufacturer	Renogy	GHB	EPEVER
Voltage Rating (Volts)	12	12	12
Current Rating (amps)	20	20	20
Max Input Power (watts)	260	240	260
Weight (lbs.)	0.37	0.65	2.07
Discharge Stop (volts)	10.7	10.5	10.5
Charge Controller Type	4-stage PWM	PWM/WPC	4-stage MPPT
Suitable Battery Type	Lead acid	Lead acid	Lead-acid or Lithium
Price	$20	$30	$84

Charge Controller Type: Comparing various products in the market, we see that Pulse width modulation charge controllers are much cheaper than their MPPT counterparts for the same rated current. MPPT charge controllers are much more efficient in energy conversion, with ratings above 90% efficiency. PWM on the other hand have around 75% to 85% efficiency. But weighing the cost versus energy output, we may use the PWM charge controller, as our solar panel will have enough power capacity to charge the battery regardless of the charge controller efficiency. In table ## above, we can see that PWM charge controllers of comparable ampere ratings are more than fifty percent cheaper than similar MPPT controllers.

Voltage Rating: It is important to have solar panels and battery to have the same voltage rating to obtain proper energy transfer. The panels and battery we are using is 12V, so it is appropriate to use a 12V charge controller for the Light Saver system.

Discharge Stop: To preserve the battery life, it is important to have a good discharge stop rating of the charge controller so that it protects the cells within the battery and prolongs the battery life. For lead acid batteries which we will most likely utilize in the Light Saver system, we do not want them to cross the discharge depth of fifty percent. The ratings of the compared charge controllers are well above the discharge depth and are sufficient to protect the battery.

3.4.8 LEDs

In this section we will explore different options for LEDs that we may implement in the Light Saver device.

Table #18: Comparison of possible LEDs

Part #	12B-R-B	194-xHP5-CAR	20-LED
Manufacturer	SuperBrightLEDs	SuperBrightLEDs	Yifengshun
Current Rating (Amps)	0.05	0.05	0.25
Voltage Rating (volts)	9-14.5	10-30	12-24
Power Rating (Watts)	0.45-0.725	0.5-1.5	3-6
Diameter (inches)	0.45	0.42	4.4 by 1.61 (Rectangular)
Wire Length (inches)	7.5	Pin out	18
Intensity (Lumens)	55	85	100
Wavelength (nanometers)	590	630	590
Beam Angle (Degrees)	110	360	360
Price	$2.95	$4.95	$7.22

Current Rating: LEDs have a current rating indicating the standard current draw of the LED at the rated operating voltage. The goal of the Light Saver device is to be self-sufficient solar powered, and the less power consumption of the system, the better this goal may be achieved. Even though LEDs are well known to be much more power efficient than their fluorescent bulb counterparts, a lower current rating is better. Optimally a current rating of 50mA is good as it will have minimal load on battery rating of 50 Amp Hours. The LEDs will only be blinking when initiated, and not continuously on for the entire period of 24 hours, so the current drawn will be even less.

Material: Although not listed on the table above, the material from which the LED and its casing is constructed is very important for the structural integrity of the diode. As the Light Saver device will be utilized in an outdoor environment where there is constant weather variations and temperature changes, the integrity of the structure of the LED is crucial to ensure that the LED does not break easily or become damaged by elements such as rain. The LEDs we have chosen for the Light Saver device have a metal encasement and the lens type is glass. This provides a solid structure along with protection from the weather. The LED enclosure is rated the Ingress Protection code 65, or IP65. This means that it is airtight from dust and has protection against water projected directly against it. Furthermore, the bolt threaded metal housing allows for easy installation to embed the LEDs into the sign of the Light Saver device.

Voltage Rating: The operating voltage of the LED is an important factor as we are using a DC battery supply to power the LEDs. This is important because the voltage range in which the LEDs can operate will set any criteria for voltage regulation that we may need to provide to the LEDs. A linear voltage regulator may be used as they a cheap, use less components and are simple circuits, and in this situation with the LEDs the voltage difference from the source to the load is small. The problem with linear regulators is if there is a large difference of input to output voltage, that difference causes us to waste energy in the form of heat, and our objective is energy efficiency. Therefore, since voltage difference between 12-volt lead acid battery and LEDs operating voltage is minimal, we may be able to avoid using a more expensive switching voltage regulator.

Intensity and Beam Angle: Another important aspect to the decision of which LED to implement within the Light Saver device is the intensity of the light being emitted from the diode, as well as the beam angle. Since the Light Saver device will be operating during both daylight hours and nighttime hours, the objective is to ensure that the LEDs are bright enough to be visible to individuals observing the sign during the day. 55 lumens are bright enough to be visible during the day. The beam angle is important as we want to ensure the light is properly directed towards the drivers in vehicles.

3.4.9 Relays

In this section we will explore different options for the relay that we may implement in the LED configuration. We need a method to toggle the LEDs according to the specifications and guidelines set by the Manual of Uniform Traffic Control Devices, stating that the LEDs if flashing must be set at a defined rate of 50 to 60 flashed per minute. Direct connection between the microcontroller and the LEDs cannot be done as the current requirements of the LEDs and the safe threshold limits of the GPIO pins do not allow. But we can provide a control signal from the microcontroller that will trigger the relay. So, an important parameter which we will consider is the response time and lifespan of the relay, as those are essential for the Light Saver device.

In the Table #19 below, we will compare several parameters of different type of relay devices.

Table #19: Comparison of possible Relays

Part #	B07ZM84BVX	B00LW15A4W	B0798CZDR9
Manufacturer	Youngneer	HiLetgo	CHENBO
Current Rating (Amps)	10	10	10
Voltage Rating (volts)	30	30	25
Power Consumption (Watts)	0.45	0.51	0.50
Dimensions (inches)	2.76 by 0.67 by 0.79	1.97 by 1.02 by 0.71	2.76 by 0.67 by 0.79
Response time (ms)	20	20	18
Input voltage (Volts)	3.3	5	3.3
Single Socket Length (Inches)	0.30	0.28	0.30
Channels	1	1	1
Price	$3.67	$2.90	$4.85

Response Time: One of the specifications which we want to focus on is the response time of the relay, as that will be critical for our LED configuration as the embedded LEDs will be toggled based on the input conditions of the peripherals and software decision. The relays all have a response time in the order of milliseconds, which provides an appropriate method to toggle the LEDs with respect to the detection capabilities of the human eye.

Input Voltage: The relays which we have compared have several different input voltages, and the common low voltage inputs are 3 V, 3.3V, and 5V. We want to

select 3.3V or less, as the specifications of the Raspberry Pi 3 model GPIO pins are constraint to 3.3V. If we were to accommodate a higher voltage, that would require us to build an external power supply using another switching regulator to specially feed the relay circuit, but that is unnecessary cost which can be avoided by choosing an appropriate relay. We want to use a one channel relay as we are controlling a single circuit branch supplying the LEDs, which will further split into ten parallel branches. The current draw of the LEDs is not expected to be well below one ampere, so the relays are well suited with a capacity of 10 amperes.
The dimensions of the relays are suitable for PCB application, and we will see during the Eagle schematic design that they are ergonomic.

3.5 Possible Designs and Related Diagrams

Our design is composed of an Arduino that works as the MCU or brain of our project. From there we have the hart that will be represented as the battery. This battery will be connected and wired to power multiple things first and foremost the Arduino. Second the motion sensor that will be informing the Arduino of motion of a person in the surrounding areas of the sidewalk. The battery will also power the camara that will be activated when the motion sensor gets triggered and it will check for the pedestrian walk light until it reads that it is in a walk state for the pedestrian. This will then activate the LED light also powered by our hard the battery and inform the user meaning the person driving the car that there is a possible pedestrian crossing. From here we have to take in account the fact that this battery is charges by the solar panels that act as the food that keeps the system working.

Our design must be made to withstand string quantities of rain and storm since this will be set in ground. Reason for which we give it a solid body. A strong tubular post attached to a waterproof electrical box that also hold the sign in place. We get good solar panels that are made to withstand outside environments and do not degrade fast in harsh conditions. And at the same time, we make sure our light has a long lifespan and that they are water resistant.

3.6 Parts Selection Overview

Our project will be self-funded. In table #20 you see the selection of parts that will go into the development of the project. You can also see the manufacturer that they come from its price and its part number.

Below is given each item description, along with price estimate, as these numbers may vary given taxes or shipping costs.

Table #20 Part Selection

ITEM	Part #	Vendor	PRICE ESTIMATE
Aluminum Sign	K-2845-EG	SuperSign	$42.36
Mounting Pole	315 34X120	Lowes	$20.99
Mounting Hardware	--	Lowes	$25
LED mounted lights	12B-R-B	Super Bright LED's Inc.	$20.95
Solar Panel (12V)	100W-12V	Renogy	$103.02
SLA-AGM Battery	L50-12	Mighty Max (Walmart)	$99.99
Motion Sensors PIR	--	E-AGE (Amazon)	$11.99
Raspberry Pi 3 Model B	--	Adafruit (Amazon)	$35.00
Charge Controller PWM	RCC20VOY P-G1	Renogy	$38.24
Camera for CV	OV5647	Arducam (Amazon)	$9.99
Relay	B07ZM84B VX	Youngneer (Amazon)	$3.67
Custom Enclosure	--	Amazon	$50

The objectives which we kept in mind during part selection is that we want our Light Saver device to be cost effective and high in quality at the same time. We do not want to compromise quality to save money, and in some cases saving a few bucks from one subsystem would end up costing much more when related to another subsystem. The goal is to have parts within our hands by the end of the first phase of this project, so that we can begin prototype testing of the individual subsystems, and that way we can make changes to the design if the testing results deem it to be necessary.

In some cases when ordering parts, we had options to buy the parts at a cheaper rate, but the manufacturer would be in a region where quick shipping was not possible. So, we ultimately decided that time was more important, and we purchased parts from vendors that could deliver them to us in a timely manner.

4. Related Standards and Realistic Design Constraints

In this section we will discuss standards which we can apply to our Light Saver design, as well as the realistic design constraints faced.

4.1 Related Standards

Standards are an essential part of the design process. Designing our Light Saver was no easy task, it required us to look at many different standards. We decided as group to get our standards from the IEEE Standards Association. Besides the IEEE there are many different organizations which provide standards, one such organization is The American National Standards Institute (ANSI), which is a private non-profit institute that was "Founded in 1918, the Institute works in close collaboration with stakeholders from industry and government to identify and develop standards- and conformance-based solutions to national and global priorities" [16]. They are also sponsoring of the NSSN: A National Resource for Global Standards, which is a free, web-based information service, which allows you to search for information on approved standards. Standards are good practice that can help multiple systems be compatible.

When it comes to designing our Light Saver, we also need to take a look at IPC standards. IPC is an Association Connecting Electronic Industries, they act as a "hub of knowledge in the electronics industry, IPC provides standards, training and certification, market research, education and public policy advocacy to help member-companies achieve their goals" [16], also the IPC is accredited by the American National Standards Institute (ANSI) and is known throughout the world. One of the great things about the IPC is they have the most widely used and accepted standards in the electronics industry to date. The IPC standards include PCB manufacturing, electronic assembly, design, and printed circuit boards just to name a few. Although only a few standards were named exclusively, IPC standards cover every facet of the electronic industry. Every standard will not directly impact our Light Saver design, but they will apply to the manufacturing process of the components in our design. If these standards were not in place, the manufacturer could have a harder time finding supported components which could delay the manufacturing process. So even though the standards are not directly related to the Light Saver design, they are important standards associated with the underlaying components in our design.

The ISO/IEC is a joint technical committee that provides information about standards and everything that comes with it to its stakeholders. ISO/IEC stands for the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC).

All of the committees and organizations referenced above, which make up the standards used in our Light Saver design make up only a small portion of all the organizations that provide standards. Our design's governing subsections can be found below. Lastly there are many organizational standards that are practiced, between different organizations, companies and even internationally, this is the reason why there is an abundance of organizations dedicated to the creation of different standards.

4.1.1 Battery Standards

The IEEE standard we used for the Battery is the IEEE Std 1013™-2007. This standard explains the "IEEE recommended practice for sizing lead-acid batteries for stand-alone photovoltaic (PV) systems" [17]. Using this standard will provide us a means to safely and efficiently determine the correct battery that will fit our needs when designing the Light Saver. Upon inspection of this standard, we discovered that there are two different types of lead-acid batteries, valve regulated and vented. Solar panels produce an output voltage and current on its own, this is referred to as a photovoltaic (PV) system. According to this standard if you have a system where the system load exceeds the output of the solar panel or PV array, then a battery is required. With this reasoning in mind a battery would be necessary for the function of the Light Saver in sub-optimal conditions, such as cloudy days, temperamental weather conditions or at night, when the solar panel is unable to meet the power demands of the components within the Light Saver.

The *Autonomy* clause can also be found in this standard. It references the battery being used while the panel is not able to output power, which we will go in more detail below. According to this *Autonomy* clause "the length of time that the stand-alone PV system's load should be supported solely by its fully charged battery, is established by system design requirements" [17]. In this section several considerations need to be made. These considerations include but are not limited to solar irradiance variability, recharge capability, accessibility of site, predictability of load, system application, and system availability.

Other things to consider are the length of time that our systems will be running only on battery power, and the load that the battery will need to support during that time frame. When referencing the load that the battery must have, we are equating that the dc load current that is drawn from the battery, in the given time frame previously referenced. Once the maximum daily load is calculated we will then cross reference this value with the different battery sizes to determine what battery size is suitable to sustain these loads. When factoring in the correct size of battery to use we must also take into consideration the starting current, which is the current when the system is first turned on, and how much running current the design will require. Also, both the minimum and maximum volage required for proper operation of the system should be considered.

These results of the various load calculations will help us to both determine the functional-hour rate and battery capacity. The rating that battery manufacturers use for lead-acid cells are “maximum depth of discharge (MDOD), maximum daily depth of discharge (MDDOD), and end-of-life (EOL) capacity” [17]. One consideration to be made is the temperature that the systems will be operating. For this type of battery, the cell capacity rating is standardized at 25 °C, in most cases. So, outside those temperatures the capacity will vary. Temperature and capacity have a direct relationship in this instance. If the temperature increases so too does the capacity, where the reverse is true if the temperature decreases, so too does the capacity.

Overall, the steps outlined in this standard allow for an optimal experience in both efficiency and safely sizing lead-acid batteries, in stand-alone PV systems. Below is a summary of the steps required to do this correctly. Starting off you must understand how often the battery will be used and how long the battery will be used to solely power the load. Next, understand how much current the battery supplies over a given period, this determines the discharge rate and battery capacity. Lastly the number of series connected cells needs to be determined, this is set by the system’s voltage limits. After everything has been concluded then the correct battery choice should be profoundly easy to make.

4.1.2 Design Impact of Battery Standard

Without the battery the Light Saver design is not possible, the Raspberry Pi board would not have power to run its detection solution to see if the crosswalk sign is lite thus not triggering the motion sensor to check for pedestrians on the sidewalk. In fact, none of the electrical components would be able to work. With this in mind, it is easy to see how the battery is the base for our Light Saver design, and each of its subsystems. Hypothetically if we did not have a battery in our Solar panel configuration our devices would only be able to function on days that were optimal conditions. That is why it is so critical that we match each of the subsystems that require batteries with the appropriate battery. Just because we used the battery standard for the solar system above does not mean we need to stop there; we can also use the same standard to provide insight into which batteries we select for the other components in our project.

For instance, the Raspberry Pi board that we are going to use for the computer vision portion of our project, will have a multitude of options to choose from. Some of these options include using a premade battery pack such as the battery pack for Raspberry Pi 3 b+ which can supply 4000mAh and is adhesive so it would be an easily mountable solution. The other is a PiJuice Hat the comes with an 1820mAh battery that can sustain the unit for four to six hours which is shown in figure #31.

Figure #31: PiJuice Hat with 1820mAh battery, Image Courtesy of Pi Supply

Also, there is support still for an even larger battery, that in theory could power the Raspberry Pi board for 24 hours. We could also design our own power pack with AA batteries in which we connect them to a UBEC this device is “a power regulator that prevents batteries from damaging the Pi, so should be considered a vital component” [19]. Lastly, we could opt to plug the Raspberry Pi board directly into our solar panel. The problem with this however is that the Solar panel voltage output is an analog source and the Raspberry Pi has no analog GPIOP pins, in order to get around this we would need an ADC or analog-to-digital converter.

4.1.3 Programming Languages Standards

IEEE std 1855TM-2016 – is a standard which helps us use the Fuzzy Markup Language (FML). This standard uses XML specifications to represent Fuzzy Logic Systems (FLS) in a more hardware independent and human readable way. With the help of this standard coders can apply FLS more easily, without requiring a deeper understanding of the underlying platforms. One goal of this standard is to facilitate extensibility such as the definition of a new functionality regarding fuzzy operators, or defuzzification methods, through the custom methods without requiring modification of the FML grammar.

There is also a JFML module for embedded systems which assists in the implementation and deployment of fuzzy controllers on both the Raspberry Pi and

Arduino boards. JFML uses the java API called JAXB, this API provides convenient and fast way to bind W3C XML documents, as well as Java representations. The way that this works is that JFML binds the java code to the XML Schema document (XSD), which is the same document used by the IEEE standard above. It also provides ways to read FML documents into Java content objects and writing java content into XML documents, all the while it still verifies all the constraints in the schema of the standard.

This Standard is useful to our group because it has a Python wrapper component called Py4JFML, this will allow us to use all of the functionalities of JFML in Python, which happens to be the coding language our group wants to use.

4.1.4 Design Impact of Programming Language

Using standard *IEEE std 1855^{TM}-2016* will allow us to write more advanced code for any system that incorporates this standard, such as but not limited to, the case of the Raspberry Pi above. The impacts of this standard will in no way inhibit our design but only serves to make integrating the subsystems found within easier. Proper use of this standard will further expand our coding capabilities and introduce the possibilities to include complex systems in our design. These possibilities would not be obtainable without the use of Fuzzy Markup Language (FML) or the Python wrapper component Py4JFML.

4.1.5 Computer Vision Standard

Machine vision was first unveiled over ten years ago. Since then, there has been many different and emerging standards that the industry has been following. Some included camera link, CoaXPress, point to point, are just to name some. In 2018 the release of version 2.0 CXP a stand and that promised speeds of 12.5 Gbps data rate and 42 Mbps uplink channel, operational forward error connections. The international Vision Standard Meeting (IVSM) meets twice a year in the spring and fall at various locations around the world. During the event which are about a weeklong they go over new standards for the industry.

4.1.6 Design Impact of Computer Vision Standard

Using the stands set by the industry is going to impact the light saver. There are various aspects that will adhere to. The first is going to be the camera interface standards and this includes both hardware (i.e., camera link, camera Link HS, coaXPress, GigE vision) and software (i.e., IIDC2, genlcam). It will have to follow camera performance standards, Lens mount standards, and lighting standards. It will also have to follow system integrator standards. when setting up the camera and the computer visions

4.1.7 Sign Standards

For the sign standards we needed to go to our local authority on the matter which is the Florida Department of Transportation. Since our sign is going to be used for pedestrian crossing, we will need to follow the specific ruleset that applies to Pedestrian signs. Found in the Traffic Engineering Manual section 2.29.2.1, shows specific rulesets that pertain to our pedestrian crossing sign. The standards for the pedestrian crossing portion of our sign must meet one of the follow rules to be considered a valid placement. The Sign must be placed where pedestrian crossings occur on a designated home to school route, and a specific request must be made by the local government. Alternatively, if there are two or more documented crashes involving pedestrians with injuries then it is also ok. Or if there are visibility problems for the drivers and or a combination of heavy pedestrian presence and high vehicle speeds are documented, the latter being backed up by law enforcement citations, then placement of a pedestrian crossing sign is ok.

Besides the need to consider the standards in place for pedestrian crossing signs we need to look at the structural aspects of the sign we intend to use. For safety purposes FDOT closely regulates many structural factors on each of their signs found throughout Florida. For single column ground signs, we look to the FDOT Design Standards index No. 11860. Depending on the size and profile of our sign, and the wind zone expected we will need different types of brackets and mounting solutions for the sign. Using these standards as a guide is crucial if we intend to make the final design a marketable solution to help with an ever-growing problem of pedestrian safety when crossing the road. Lastly since our Sign will have warning lights, we also need to follow the warning light standards that are in place by the FDOT. It is also noted that depending on the local agency (city/county) may choose to adopt less strict standards, but it is always a good practice to over engineer rather than under engineer something. According to the FDOT Design Standards, the use of Type B High Intensity Flashing Warning Lights is permitted if they are mounted on the channel post or on the upper edge of the sign nearest the traffic.

4.1.8 Design Impact of Sign Standards

The design impacts of these standards have a great effect on the potential outcome of the project. If these standards are not followed to the letter, parts of our project would need to be reworked to accommodate some of these constraints. One such impact of this is the mounting solutions needed for the sign in question. The hardware for the most part needs to be hidden behind the sign, with the exclusion of our lighting and solar panel solutions. Depending on the overall size of our hardware and housing we would need to opt for a bigger size sign. With a bigger size sign, we would need bigger brackets and be held to different design constraints based on the overall square footage of our sign. If the brackets become larger, we might need to opt for a two-part housing method, which would effectively separate our components. This would lead to us needing to use weatherproof cables and connectors to maintain interconnectivity between the two boxes for wiring purposes.

Another impact of these standards is area, depending on the area we want to use the signs in there is different standards for each area, school and work areas will have a different rule set than say construction areas. The last foreseeable impact of this standard is the impact on our lighting systems. We need to make sure that our lighting solution is effective and visible to the drivers, but within the design standards put forth by the Florida Department of Transportation.

4.2 Realistic Design Constraints

To make the project be its best there has to be a certain number of Constraints that limit and at the same time control the quality of the product. In this section we will cover multiple design constraints that will represent factor in real live. That have to be considered in the development of the product. In this case we will evaluate constraints as separate factors and then look at them as holes making it a very precise and opened minded point of view reducing error and making the project realistic.

4.2.1 Economic Constraints

Economic constraints are definitely one of the most impactful constraints that can affect the project we have set a lower budget in which we limit the dispersion of money around different parts. Many of these parts have very high-quality options, to start looking at the first types of solar panels being able to get a good 180W 24V Monocrystalline panel that will give us a very high and effective light conversion and that it is set in a smaller dimension instead of a big panel. Will normally cost between $400-$1000 dollars rages that will automatically take us out of budget by even just buying on part. Pushing us to consider different options like Amorphous solar panels. Same scenario when looking at our batteries. Batteries can get to be a very expensive equipment they have multiple factors that can make them have ranges of values. These factors are like size, the fact that is rechargeable, the power they can supply, live span of the battery. All of these factors and more can cause batteries to be priced at $200-$400 dollars. This making us have to look at more affordable batteries that bring us to the edge of what we have as objective in being able to run all for about 24 hours. Increasing the challenge that creating the experiment can be.

Another factor that is affected by the economic constraint is the sign even though it is a simple object that seems to be easy to get these sings are legal bindings that represent laws that can be broken. Meaning that you must pick the correct one. Making sure that it follows the correct parameters and gaining a sign that can do all of this can be up to $200 dollars. A similar situation happens when you are looking for the electrical box that represent a waterproof cover to all of the important electric parts. Making sure this box no only withholds water but also dose it for longer periods of time protecting all of these other expensive parts that we are taking about above. A complex and efficient box of these that works at the size we need can go for up to $250 dollars.

In the end if we would like to go for the best and most expensive experience just taking about these 4 parts can cost us from $1050-$1850 dollars. Making these big constraints in our project limiting us and pushing us to use other resources trying to get the parts in different methods and that still satisfy what we need.

4.2.2 Time Constraints

Time constraints is one of the most affecting constrains that we can encounter. Creating a project like this require dedication thought and research. As students we all encounter a full-time schedule some of us even more than full time. Already limiting the amount of time that we can give to the project. To that you can include that we all are employed and work to be able to subsidize our day to day lives and even be able to afford this project itself. And most of us a married meaning we have a family to get home to and dedicate time. Time is a thought constraint to cover because time management is a key of a good complete student. Even though we all are going thought this our team has done an amazing job to be able to communicate and work together to get all of the objectives done in time using time management and task encouragement.

At the same time another factor is getting the corresponding parts on time COVID-19 has created a limitation in the world that we are all going through. Most of the parts that we will need can take over a month to come at the affordable trice we can have them since these parts come from china. Meaning that if we make a small mistake or these parts do not work it can delay us by a enormous amount of time making us plan ahead trying to buy parts in multiple months of advance before we do our first model attempt.

4.2.3 Environmental Constraints

The environment is a big factor in our project since the light saver is a outside element. At the same time is an element that can be presented to almost any type of weather in the United States. Weather like snow meaning that all components must be able to resist low temperatures. Also take in account the inclination so that snow dose not stay on top of the solar panels. You must make sure that snow dose not enter the enclosed electrical box and that it does not depreciate the batteries live at a quicker pace.

We also must consider desert like weathers where temperatures are drastically changing. Absurd amounts of sun that make parts of components wearing off at a quicker pace. But at the same time, they must be able to handle the cold at nights and still work under bought conditions.

Moreover, rain we must consider possible daily environmental problems that happen every year like hurricanes and tornados. Meaning that we must create a very steady poll that can at the same time bend a bit in case of big winds. Meaning we want to make sure the lights, solar panels camaras and motion sensors are mounted strongly and safely confirming that we do not loose these elements in high winds and sideways rain environments. These high wind environments can also cause a lot of movement meaning that we want to make sure somehow that our sensor is not getting activated for longs periods of time wasting and depreciating the battery with no need.

We have to be careful of many factors that the environment brings like long periods of time with lack of sun. for which we have planned to at least get the post to survive for a period of about 24hrs without the opportunity to charge and at the same time do our best so that it can charge fully in less than half a day of sun.

Tries can be another element to take in consideration to where the light saver can be places in places where tries are giving shade all day causing that no sun falls straight on the rays. Meaning we have to take in consideration the possible factor of having to trim some trees and reduce the space and time this poll might receive light taking in account what is mentioned above.

The direction of the sun is another environmental constraint that affects our daily decisions with the project. Sun is not a static object it changes in may positions around the day and year. Having to account for different directions so that sun light falls on the solar panels. For this we have thought of two directions in the panels and cause them to gather sone on the morning in one panel and on the afternoon in the other.

4.2.4 Social Constraints

Our project dose embraces the simplicity and awareness for the driver and the pedestrian. Meaning that we need this machine to be socially adjustable to communicate the corresponding data in a very friendly and positive way to society.

A lot of people do not get excited when situations like this happen since it is taking time and habits away from them. For this we do the strung and subtle flashing lights. One of the studies done by the Florida Department of Transportation mentions the positive impact of including flashing led light [2]. Flashing is a common alert to humans that are distracted to let them know that there is an actual satiation happening to which they need to attend to.

At the same time, you must take in consideration that pedestrians need to respect the light. There are many pedestrians that are very impatient and prefer to cross the road if there are no cars in their sight. Or if they believe they can run faster than the time it takes the car to approach the position they are at. And even more important having pedestrians that respect the law because many times you see that pedestrians prefer to cross the road on other places even thought they might be just a couple of steps away from a cross walk.

4.2.5 Political Constraints

A political constraint that affects our project is working with the law so that our sing can be validated and conveys the correct message. Why say this because each sign has its purpose this meaning color, shape, image, they all convey a different message to the driver. This limits us to a number of very limited possibilities making it hard to obtain the correct one and at the same time make sure that this one is also covering the corresponding size and material it is made of.

Another political constraint that we can encounter is representing the law that people must obey and respect the order of the light. meaning that at certain points people forget how has the right of way and forget that pedestrians must be treated with respect. For this reason, we must communicate to the car that they have to stop and not communicate the pedestrian that they must be careful.

Another political constraint we encounter is choosing the correct color of the lights that conveys the corresponding information to the vehicle. When you look at light in the traffic world there is an order of almost 4 colors one is normal cool bright to illuminate signs at night, then you have green that represent good to go, yellow that represents caution but not having to stop and for this reason we went with red that is the representation of you do not have the right of way at the moment. This does invoke another problem that is maybe causing a confusion to other lanes that might have a green light this is why we would place the light on the Light saver itself and not on the light post that all cars have to look at.

4.2.6 Ethical Constraints

Ethical constraints that can arise from this is the actual usage of computer vison a lot of people do not like to permit machines to handle their faces and work with their private information something that can be ethically correct is the way we can assure people that what we are doing is to protect and not to harm the society. That the information we handle is not stored for longer periods but its only to identify the state of the light for this we can focus the camara on the light and not on a full intersection.

We also want to be careful with what our sign dose display in it since we want to make sure everyone feels comfortable with what is being portrayed. In many case scenarios we want to make sure this machine works equally for all meaning this is why we prefer to use a motion sensor pointed at the ground since this makes us generalize on the light and perspective of how is crossing including dogs or pets that might be involved.

At the same time, we want to implement a sing that is here to reduce people getting injured or even die. Possible accidents are our main gold and what we are trying to solve making this our number one constraint saving lives. By producing this sign, we want to make sure that our lights are doing their job and protecting pedestrians of getting hit giving pedestrians a hope to protect themselves using this as a protection against distracted car drivers.

4.2.7 Health Constraints

Or project does not have a big amount of health constraints but it does have to very important ones one is mentioned above in the ethical constraints and that is the protection of the pedestrian and the driver to where the sing has to present is purpose and act as a defender of bought of theses persons health. But at the same time there is one more health constraint that dose paly to this project and this is protecting the drivers' eye by choosing the correct lights that will not blind the driver prohibiting him from causing an accident and even more from affecting his eye sight of saying these lights very often.

With respect to the health of our apparatus we do have certain constrains and this is the durability of all parts. Meaning that when we build this machine, we want to reduce the number of maintenance times that is has to be address. For this we have to choose very durable parts that will last for very long periods of time giving the machine a longer health spam but affecting other things like cost by making higher standards of durability on the parts that are chosen.

4.2.8 Safety Constraints

This is where most of our constraints come in first, we have to talk about the electricity. Since we are working with electricity, we have to make our machine safe enough so that there is no possibility that some one can get hurt from maybe being too close to the box and causing this person to get electrocuted. At the same time, we must make sure our batteries our safe and do not turn on fire when they are going thought all of these harsh conditions that they will be exposed to.

Second, we have to consider two things that have already been mentioned above one is the strength of the lights and the other is the protection that the slight dose produce. Making this a safety constraint also. At the same time, we must take in account height of the sign since we have to be careful that no one around the sign is being in danger of cutting or hearting their head with the sign. Doing this by making the poll at a height of at least 6.5 feet since most of the society will be below this height with a small amount of exceptions.

We also must make sure our sing is visible at night since this is what will keep people safe. For this we use reflective grade aluminum for the sign and make sure that the light will shine the sing so that people can read what it says at night when needed.

4.2.9 Manufacturability Constraints

With respect to manufacturability our most affected constraint is COVID parts are not only delayed but they are being developed in smaller amounts making it harder to obtain the parts that we need for this we have resorted in having to wait longer times. At the same time, we are working from home where none of us actually have a lab in which we can develop and attempt to put together the project we are hoping to be able to take full use of all of UCF's tolls next semesters letting us use the labs and all of the corresponding tolls to make our prototype.

At the same time when we think of developing in high demand standards there are multiple constraints that affect us. Most of these parts are very expensive and normally come with back orders when ordered in big quantities. Meaning that to be able to create many of these we would have to get a big investor to use this money in the development before the y are sold.

4.2.10 Sustainability Constraints

This is one of the biggest factors that enter into most of the decision we have made to start we have to look at the ability to work in remote places. Be able to constantly work meaning that in many places we will not be able to get power. So, we would want to gather our power using renewable sources for which we choose solar power making us take a step towards may decisions on what micro controller to take what battery to take. How to run this for a longer period of time in case of an emergency. So that it has the ability to gather the power into the battery in enough time of the day where there is sun present. And make this power to dissipate as slowly as possible. So that we can make sure it will sustain itself for a long period of lime including the nights to where it will do the recharging. This we have done by then including a possible low battery mode into the system where the camara vision is only activated when there is a pedestrian that is sensed by the motion sensor activating the camara to actually evaluate the sign and warn the car of the pedestrian.

Also making sure all part will last for a long period of time reducing the amount of maintenance that have to be done and making sure that the machine will be protected from outside sources like animals and harsh winds. Causing it to sustain harder environments.

4.2.11 Constraints All Together

As a conjunction this has taken us to make the best products as you know if you can gather all of your hurdles and put them together you are preparing to get the best product that will have a lower chance of failing. When you put all of this in one you will get a grate design that is not only attractive, but it is affordable it fixes the problem that we are trying to solve it also will withstand and survive for a long enough time. Making us consider every single part and make sure we can deliver at the best but keep the result between our constraints.

5. Project Design Details

In this section we will discuss the design details of the Light Saver device. This topic will be split into two sections of hardware design and software design. The hardware design aspect will cover the major functional blocks of the Light Saver device such as the solar panels, battery, charge controller, voltage regulators, microcontroller, and LEDs. The software design aspect will cover the functionality of the Light Saver device, such as toggling LEDs, using Computer Vision, etc. It will explain the software functionality, description of algorithm, flow charts and features, etc.

As the Light Saver device goal is to be solar powered and completely energy self-sufficient, the design of the power systems is very important. We must design our system keeping efficiency of each stage from power generation, power storage, and power consumption to be high as possible. The main components in the Light Saver device that we are powering are the Raspberry Pi 3, LEDs, motion detector, and camera. We will explore different configurations of these items to provide the optimum solution overall for the system.

The software design section will explore into the techniques and algorithms of computer vision and utilizing it to provide real time information to the Light Saver device. It will explore various methods to perform analysis of real time images captured by the camera, and we also want to choose the method most optimum and not computationally costly, so that we may be energy efficient with processing and the CPUs. We will also explore the logic algorithms of the Light Saver device to perform activation of LEDs based on the environmental factors of the moment, i.e., pedestrian presence, traffic signal indication, etc. We will also discuss the mechanical design aspect of the mounting of the sign, solar panel, LEDs embedded within the sign, battery, and PCB mounting, etc.

The software design section will explore into the techniques and algorithms of computer vision and utilizing it to provide real time information to the Light Saver device. It will explore various methods to perform analysis of real time images captured by the camera, and we also want to choose the method most optimum and not computationally costly, so that we may be energy efficient with processing and running the CPUs. We will also explore the logic algorithms of the Light Saver device to perform activation of LEDs based on the environmental factors of the moment, i.e., pedestrian presence, traffic signal indication, etc. We will also discuss the mechanical design aspect of the mounting of the sign, solar panel, LEDs embedded within the sign, battery, and PCB mounting, etc.

5.1 Project Hardware Design Details

There are two sides of the light saver, the software and the hardware side. Hardware is all the physical components in the system. In this project this will be the solar panels, battery, LED, camera, signage, and motion sensor. in the next few sections, we will be discussing the design details, starting with the solar panels and solar power. Then we will talk about the battery to the microcontroller. Next, we will touch on the linear voltage regulator and how that will work and how the switching will work. After we will move on to LED configurations and how they will be place on our sign. We will then move on to how the microcontroller will be connected to the LEDs. After that we will discuss the sign and how it will be mounted. Finally, we will talk about the storage unit containing everything to help keep it protected and secured on the pole. Figure 32 below gives our initial design flow diagram which we have for the Light Saver device, along with the group members and their expected contributions.

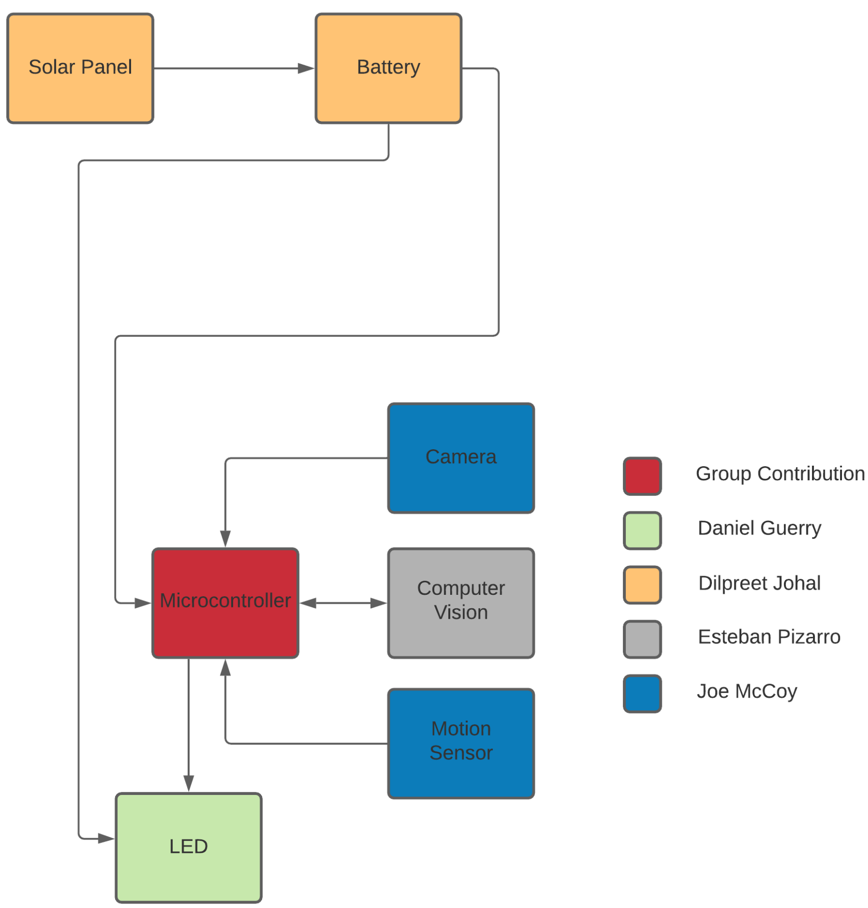


Figure #32: Initial Design Flow Diagram

5.1.1 Solar Power

One of the main blocks of the Light Saver device is the solar panel and power generation. The solar panel will be used to charge and replenish power to the 12V SLA AGM battery which will power the device. As seen in the figure below the solar panel will be the only method of recharging the battery.

The solar panel is a Renogy 12V 100W Monocrystalline panel and this is important as having the solar panel and the battery voltage to be the same is important for the charging process. If the solar panel and the battery are different voltages, this causes unnecessary hurdles and extra design steps before they can be combined within the system. The solar panel and the battery will be connected through a charge controller in between the two devices to ensure protection for the panel and the battery. The charge controller is also a Renogy 12V 30Amp 4 stage PWM device. For low power solar panels, a charge controller is not necessary, or a simple ON/OFF charge controller may be designed and used to maintain output voltage from the panels during sunlight exposure. But for higher power capacity solar panels a PWM or MPPT charge controller is necessary as it is a “smart” device which efficiently charges the battery and maximizes power output from the panels. It ensures battery safety and prolongs lifespan of higher capacity batteries like our 50Ah battery. A simple designed charge controller would not suffice to ensure battery safety and efficient charge/discharge protection.

5.1.2 Battery to Microcontroller

The battery we are using is 12V, but the Raspberry Pi 3 requires an input voltage of 5V. This means we must provide a step-down voltage regulator to supply a DC voltage equal to the input voltage requirement of the microcontroller. One aspect of the voltage regulator which we must keep in mind is the load current capacity, as we want to be able to supply the peripherals that we are connecting such as the Camera to enable computer vision through the Raspberry Pi 3. The voltage regulator must have at least a 10% current capacity buffer with respect to expected current load.

5.1.2.1 Linear Voltage Regulator

One technique which we may use to implement a step-down voltage regulator is the linear voltage regulator. Below in figure #33 is given a circuit design of the linear voltage regulator that we will construct on breadboard and implement a 5V output regulation. We may use a 7805 to implement linear voltage regulation using various passive components, and we can test different input voltages and measure the output voltage results. This will help us analyze the feasibility of implementing the linear voltage regulator in the Light Saver device.

We build the circuit in figure #33 using the 7805 regulator and add a 1000 Ω load resistor.

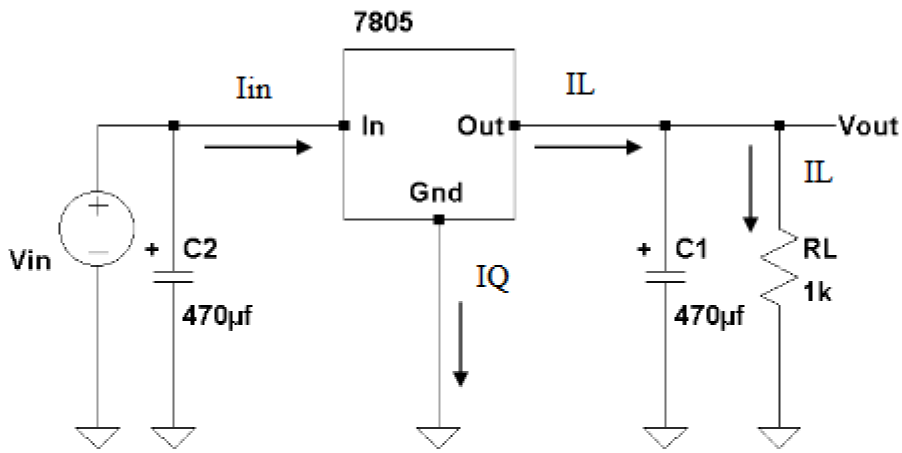


Figure #33: Linear voltage regulator circuit diagram

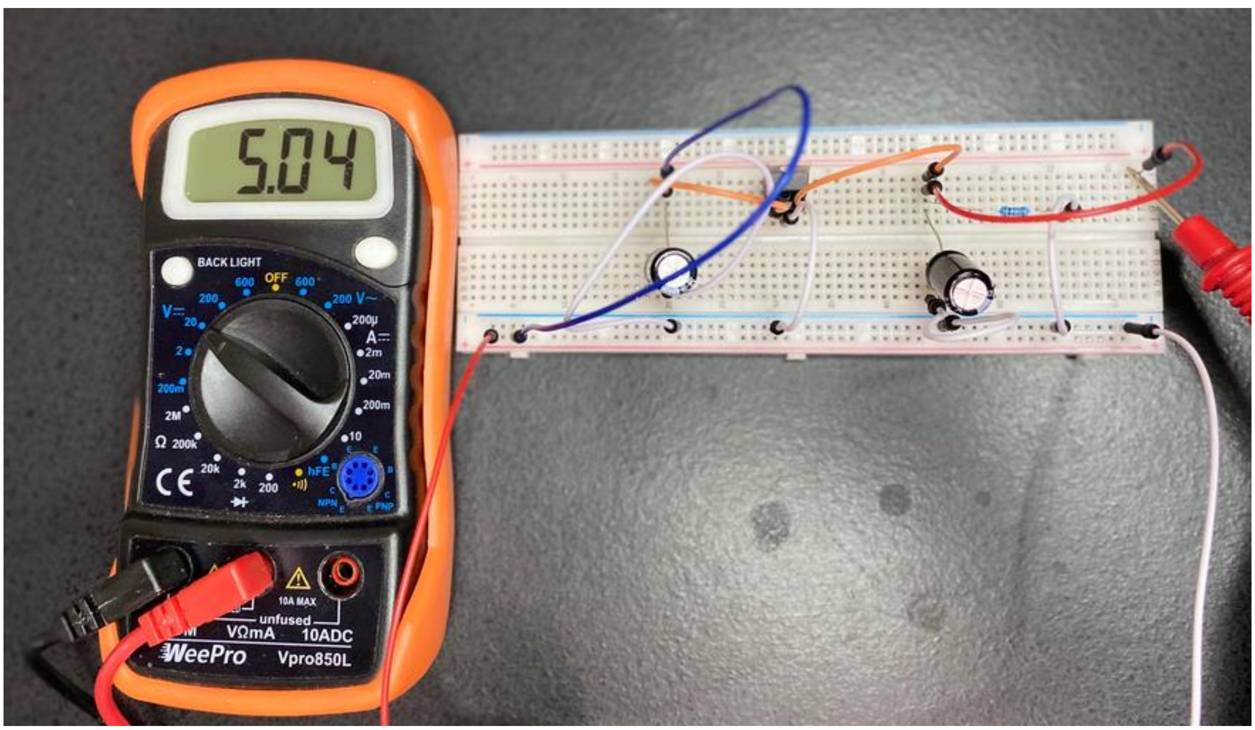


Figure #34: Linear voltage regulator circuit breadboard test

As shown above in figure #34, we built the linear voltage regulator circuit and tested various input voltages using a multimeter, and the multimeter displays one of several output voltages which we recorded as results. We used DC batteries in series to adjust for several different input voltages, along with voltage divider circuits using different combination of resistors. The results of this testing are displayed in Section 6.1 Table #26: Linear Regulator: Input vs. Output Voltage Data. A few interesting observations which are seen is that the output voltage of the 7805 regulator does not stabilize to 5V until we reach a minimum input voltage of approximately 8V. For a 5V input, we observe only a 3.6V output. But for all input voltages above 8V up to 20V, we maintain a fixed output voltage of approximately 5V. We must take into consideration that the practical 12V battery does not always provide exactly 12V and may fluctuate within 1-2V above or below depending upon the charge level.

Table #21: Components used for Breadboard Linear Regulator Design

Component	Value	Part Number	Type
C1	470 µF	CKSM1436	Capacitor
C2	470 µF	CKSM1436	Capacitor
RL	1kΩ	Smraza	Resistor
U1	-	7805	Linear regulator

The use of this linear voltage regulator may not be the most power efficient design which may be implemented in the Light Saver device for powering the Raspberry Pi 3. As observed during the breadboard testing of this circuit, for an input of 12V we do have an output of 5V, but current for the Raspberry Pi 3 is rated as 2.5A (with peripherals), and this leads to 17.5 W of power wasted during the conversion process. A switching regulator will be better suited for the microcontroller application. Based on further design and testing, we may use this linear voltage regulator to supply the LEDs as they have a closer operating voltage range of 9-14.5V compared to the battery output of 12V. So, the linear regulator will be a simpler and cheaper method to supply the LEDs.

5.1.2.2 Switching Voltage Regulators

Based on conclusions from the previous sections, we will explore types of switching voltage regulators to provide 5V to the Raspberry Pi 3. The voltage regulator which we will explore in this section is the LM2576T-ADJ, and this allows us to modify and have various output voltages, which may be beneficial for voltage regulation for other components within the Light Saver device. The benefits of this switching voltage regulator are that according to the WEBENCH power design tool, this has an 84.7% efficiency, and the different efficiency rating based on output current are given in figure #35 below.

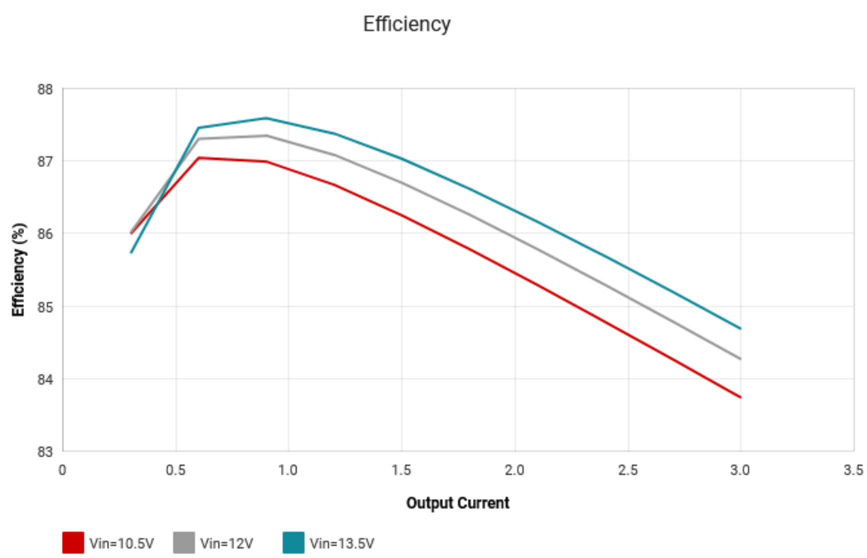


Figure #35: LM2576 voltage regulator efficiency graph

This is very important to achieve power sustainability of the Light Saver device. Given below in table 22 are some specifications which are relevant to our design for this switching voltage regulator.

Table #22: LM2576 Datasheet Specifications

LM2576	Test Conditions	Min	Typ	Max
Output Voltage (Volts)	$0.5A<I_L<3A$ $8V<V_{IN}<40V$ 25°C	4.8	5	5.2
Output Voltage (Volts)	$0.5A<I_L<3A$ $8V<V_{IN}<40V$ -40°-125°C	4.75	5	5.25
Duty Cycle	--	--	42.26%	--
Ripple Voltage	--	--	180.54mV	--
Footprint	--	--	198.21 mm^2	--
Price	--	--	$1.05	--

From the datasheet specifications we can analyze that this switching regulator is appropriate for the desired voltage output of 5V, and that in fluctuating operating conditions such as heat (as the Light Saver device will be outdoors) will not affect the output voltage.

Using the datasheet for the LM2576T-ADJ switching regulator, as well as the WEBENCH power design tool, we will research different configurations to supply the Raspberry Pi 3.

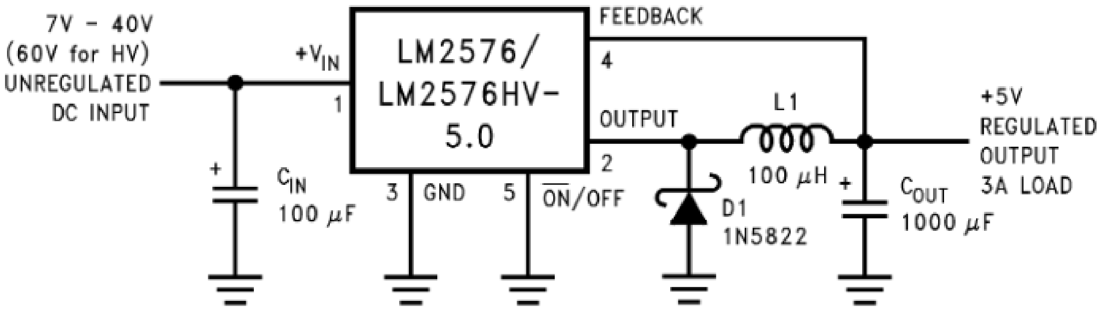


Figure #36: LM2576 voltage regulator circuit design from datasheet

The Raspberry Pi 3 does not require 3A for the maximum current load. But researching into the attachment of peripherals and utilizing the Raspberry Pi 3 to its fullest extent, the recommendation is that the microcontroller should have a 2.5A current load capacity. As we generally want to keep device protection in mind, we keep a 10% buffer amount depending upon load conditions. So, with these numbers, our aim would be to have at least 2.75A maximum load current capacity. This switching voltage regulator is ideal as 3A, and even though it is slightly higher than our required conditions, having a larger buffer region only enhances device safety.

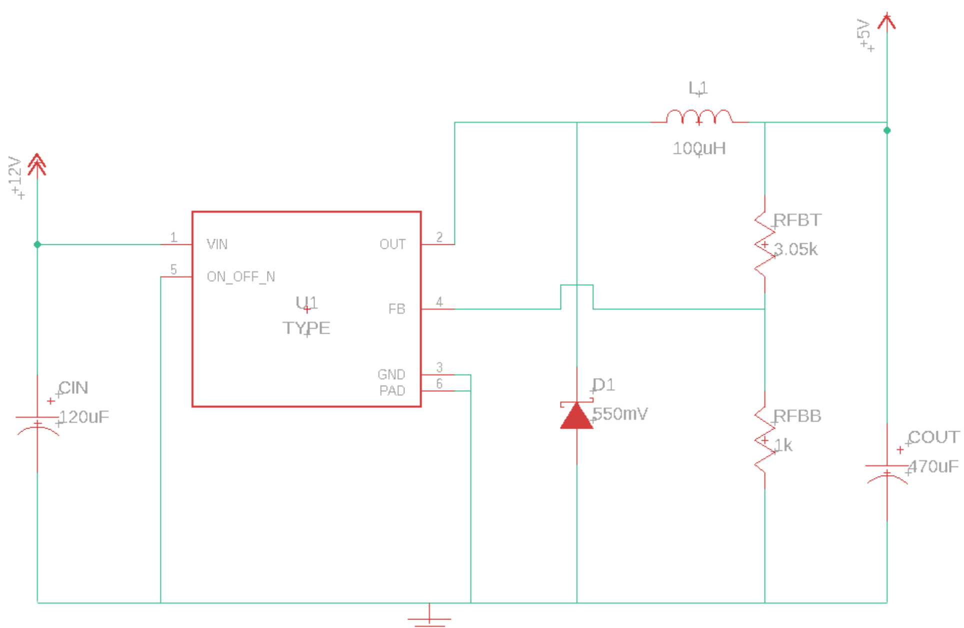


Figure #37: Schematic of switching voltage regulator design

We export the chosen voltage regulator power design from WEBENCH as an Eagle file. The designed schematic is shown above in figure #37. This is based on the design that we will supply this circuit from 12V battery, and output 5V to the Raspberry Pi 3 module. We will perform the breadboard testing of this voltage converter using the 5 Pin TO-220 KC Package, and for the printed circuit board, we may use the 5 pin DDPAK/TO-263 KTT Package.

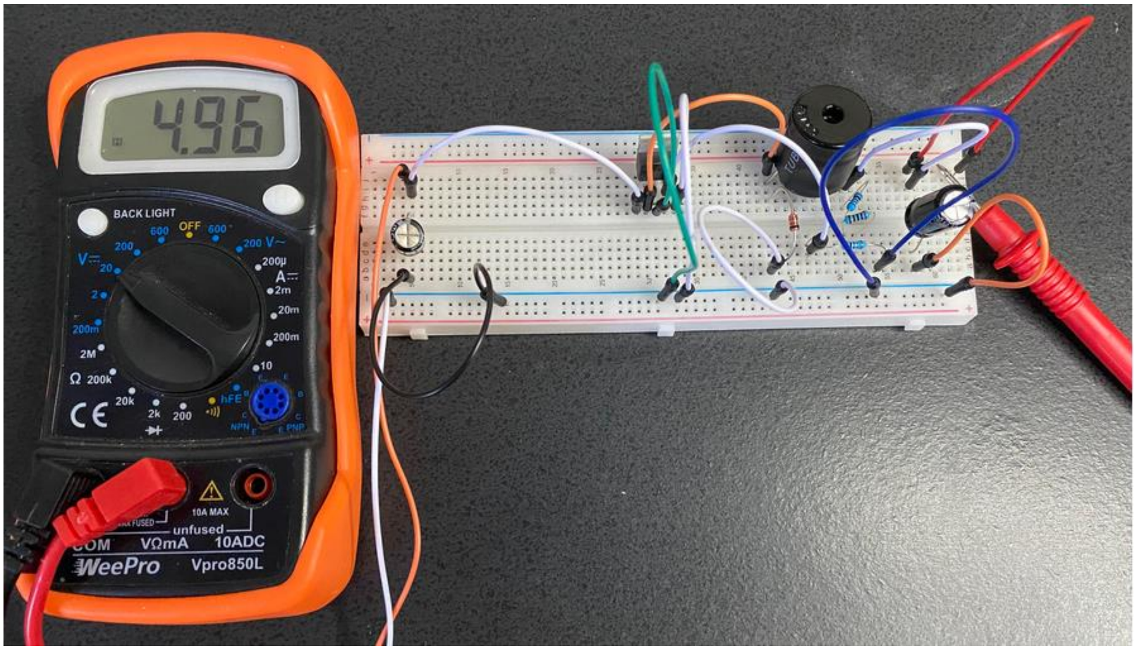


Figure #38: Switching voltage regulator circuit breadboard test

As seen in figure #38 above, we assembled the circuit design on the breadboard to test the LM2576 switching voltage regulator. This will allow us to measure and observe if certain criteria and parameters are met for the Light Saver device. We verified through the specification datasheet of from the manufacturer that the package of the LM2576 we use for the breadboard test has same characteristics of the surface mount package, and we used the datasheet to confirm the pin outs of the regulator when connecting it to the breadboard for testing. When connecting the components, one precaution we must take is that there is a common ground for all parts assembled upon the breadboard. We want to avoid any ground loops which may occur if we use separate ground nodes for different sections of the components. Figure 39 below shows the board layout for the switching voltage regulator.

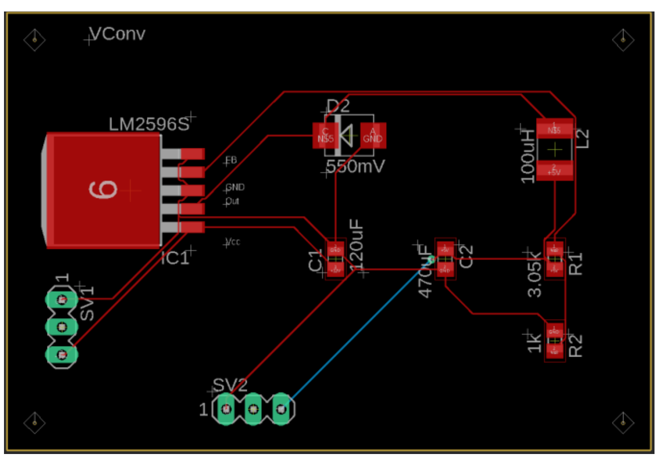


Figure #39: Board Layout of Switching Regulator design

The main requirements of the switching regulator are that we supply the appropriate voltage input and current to the Raspberry Pi 3 board, to ensure its proper functioning and safety. First, we test the voltage output of the switching regulator by providing input voltages varying from 0-15V. The battery itself has a minimum recommended threshold voltage of 10.5V, and the charge controller will disconnect the load if it detects the battery voltage is too low, but it is still appropriate to test for a wide range of voltage inputs into the regulator to study its characteristics of the design. The results of this testing are displayed in Section 6.1 Table #27: Switching Regulator: Input vs. Output Voltage Data. We observe that the range of output voltages remains within a few millivolts of the designed output, so this is an acceptable design.

We also have a requirement that the output current be stable and not exceed the input current tolerance of the Raspberry Pi 3 board. To test the current output from the switching voltage regulator, we attached a 50-ohm resistor to as a sample load, and we observe the output current is approximately 70mA. We cannot yet perform complete current testing as we must verify all the peripherals that will be attached to the Raspberry Pi 3 and take into account the total current draw based on the processor usage while running the computer vision software.

Table #23: Components used for Breadboard Switching Regulator Design

Component	Value	Part Number	Type
Cin	120 µF	69K18	Capacitor
Cout	470 µF	CKSM1436	Capacitor
L1	100 µH	RL2444	Inductor
RFBT	3kΩ	Smraza	Resistor
RFBB	1kΩ	Smraza	Resistor
D1	-	Supplied in Lab (E1)	Zener diode
U1	-	LM2576-ADJ	NPN Transistor, Epitaxial Silicon

These components were chosen to test the design and observe initial results, and the components we will choose for the fabrication of the final design may vary in part number and specification as we will prefer to use surface mount components and will choose the best parts based on design and manufacturing cost. Within this initial breadboard test, we use a 470uF capacitor at the output due to lack of availability of 170uF capacitor, and it does not drastically alter our results. The purpose of the output capacitor is to smooth the output voltage, and during system fabrication we will use the appropriate capacitor.

We will proceed with using this switching voltage regulator design to supply the Raspberry Pi 3 from the battery power supply. We may use the linear voltage regulator principle to stabilize the voltage supply to the LEDs if it seems necessary based on further testing and research on the requirements of that design block.

5.1.3 LED Configurations

Many factors needed to be determined to properly configure the LED lights into our sign. One of these factors was the dimensions of the Sign we were going to use. This largely determined how many LED's we would need to place and in turn how much power would be needed to power the LED lights. For our Sign we decided to do a rectangular design, measuring 18" x 24" inches. We wanted the LED lights to be evenly spaced and have LED lights positioned in each of the four corners of the sign, we would use a total of 10 LED lights for the sign. So, after some consideration we went with a 6-inch spacing per LED light, around the outside edge of the sign. This would mean each hole drilled in the sign was 6-inch on center. So, would need to drill a total of 10 holes in the sign to mount these LED lights as shown in the figure 40 below:

Figure #40: Pedestrian Crossing Sign with mounted LED Lights.

The holes drilled on the sign would need to be made with a 29/64 drill bit since the diameter of the LED lights is 0.45 inches or 11.43 millimeters. Once the holes are drilled, we would then slip each LED through the hole and secure it with the nut provided. Thread-locking fluid could be used on the threads as A preventive measure to prevent loosening of the bolts due to vibrations, it also helps to prevent leakage and corrosion. Each of the LED lights come equipped with a 7.5" inch wire, with a pig tail connection. This wire is 22 gauge and comes equipped with 3 led modules in each light, the module LED's are referred to as chip on board (COB). More specifications on the LED lights can be found below:

Table #24: LED specifications and parameters

Part Number	Color Temperature	Current Draw at Operating Voltage	Intensity	CCT / Wavelength
12B-A-B	Amber	0.06A	12 lm	590 nm

Once the LED's are fastened to the sign, we need to route the wires to the microcontroller, in our case that would be the Raspberry Pi 3 Model B. We need to connect one lead to pin 6 which is the ground, and the other connection needs to come from pin 7 GPIO 4. A resistor must be in place going from the positive lead coming from pin 7 GPIO 4 to the positive side on the LED, this is used to lower the current acting on the LED lights. Normally you would be able to power the Raspberry Pi 3 with a battery and have the LED lights connected to each of the outputs of the Raspberry Pi 3. The recommended amps per pin is 16mA and 50mA overall. Unfortunately for the number of amps that our lights would draw we would run the risk of burning out the raspberry Pi 3, so we Will need to use the external battery to power the LED lights and then use the raspberry Pi 3 to make the lights come on and off at certain intervals. So, since we need to use the main battery a voltage regulator is required to be installed before the voltage gets the LED lights, so we do not burn out the lights.

To find the optimum current flowing through the parallel branches of the LED's from the power source, we can perform breadboard testing to observe the different current flows based on resistor selection for each branch.

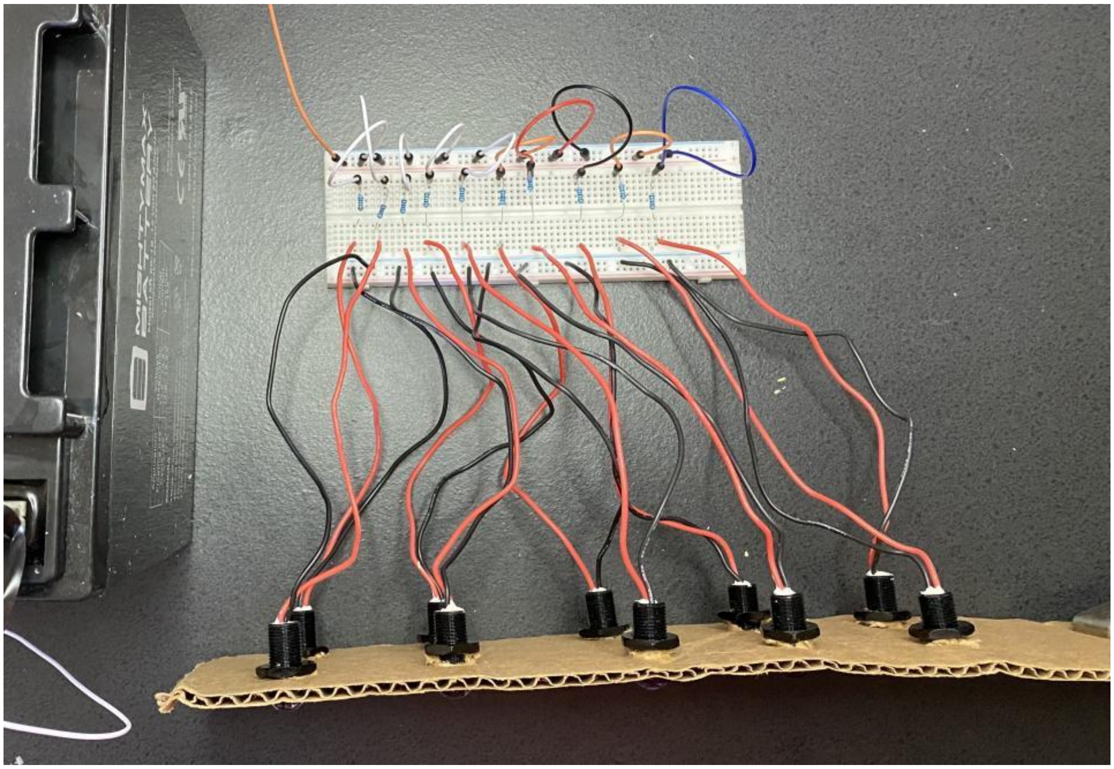


Figure #41: LED Breadboard Testing

As shown in Figure #41 above we can see that the best configuration to connect the LED’s to the power supply is as parallel branches. Connecting the LED’s in a series configuration is not recommended as we can observe that the initial LED’s connected to the power supply will have brighter illumination, but the LED’s towards the end of the circuit will not be illuminated properly. The reason the LED’s at the end are not lite up as bright is because in series configuration there is not enough current draw for all of the LED’s to illuminate correctly. That is why in parallel configuration each of the ten branches have a fixed voltage input and we can control the current flow through each branch by changing the value of the resistor connected in series with the LED. The reason that a resistor should be connected in series with the LED in this parallel configuration is that it controls the current flow within the branch. By increasing or decreasing the resistance in each branch, we will observe in the breadboard test that the current flow also increases and decreases, respectively.

Figure #42: LED Breadboard Illumination Testing

As shown in the figure 42 above, this is a picture of the parallel LED configuration with an input voltage from the 12-volt battery supply and with 2 kΩ resistors in each branch. One precaution that we had to be careful about that each LED branch had a resistor properly connected, otherwise if we accidently connected the LED directly to the power supply rails on the breadboard, we risk damaging the LED permanently. We also had to be careful when measuring the current with the multimeter through the individual branches as the multimeter configuration we were using has a 500-mA max fuse limit.

As we varied the resistor values from 1 kΩ up to 6.1 kΩ, we observed on the multimeter that the current flow through the branch decreased with an increase in resistance value. Along with varying the resistor component values, we also changed the input voltage power supply and connected a 9-volt battery to see how this would affect our observed data from the multimeter. The full results of this breadboard testing are displayed in section 6.1 Table #29: LED Input Voltage vs. Output Current Data. An interesting observation seen during the breadboard testing, but as expected from our basic electrical engineering concepts, is that a higher voltage input with fixed resistor values resulted in greater current flow through the respective branches.

The components used for breadboard testing of the LED configuration are shown in table #25 below. We only needed 10 LED’s from the part selection based on the design of the Light Saver device, but we ordered 15 LED’s to account for any potential damages during breadboard testing or prototype construction.

Table #25: Components used for Breadboard LED testing

Component	Value	Part Number	Type
Bolt Beam 12mm LED	Yellow 55 Lumen	12B-x	COB
RL	1kΩ	Smraza	Resistor
	2kΩ	Smraza	Resistor
	5.1kΩ	Smraza	Resistor
	3kΩ/6.1 kΩ (Used series combination of other base values)	Smraza	Resistor
PSupply	12.8V	ML50-12	DC battery
	9.6V	1604D	DC battery

The resistors used in the breadboard test were first individually measured to verify the component value. As part of the DIY electronics kit the common base resistor values were 1kΩ, 2kΩ and 5.1kΩ. We accordingly connected and built the other resistance values as needed for breadboard testing. From testing we found that the 2kΩ resistor allows for 2.43 mA of current within each branch of the 10 LED's. This means that if the LED's are illuminated continuously for 1 hour, we will use 20.43 mA of current. We could power the LED's for 24 hours continuously with high power efficiency. Also, this value of the resistor provided the optimum illumination which we require for the Light Saver device. Based on further outdoor testing, we may adjust the resistor value if we deem that more illumination is necessary.

For the Light Saver device, we expect to provide a power source to the LED's and use energy as efficiently as possible and keep manufacturing cost down. Based on the breadboard testing we can see that the LED's have a flexible and wide operating DC input voltage. We could effectively illuminate the LED by using a 9-volt power supply input along with a lower resistor and recreate the same illumination by using a 12-volt power supply with a higher resistor value. The benefit of this operating voltage flexibility is that we may possibly supply the LED's directly from our 12-volt sealed Lead-Acid battery, as the minimum operating voltage of the battery is recommended to be 10.5 volts from the manufacturer data sheet. We do not expect the battery to operate below 10.5 volts. The upper operating voltage of the LED's is 14.5 volts and we don't expect the battery to exceed that level in any scenario, so the LED's are flexible to operate in any possible voltage supply within the device from the battery.

This flexibility allows us to avoid using a more expensive switching voltage regulator, as we must use in the case of supplying the raspberry Pi 3 device. We can supply the LED configuration directly from the battery, or as good practice use a simpler linear voltage regulator to fix LED input voltage with simpler and more cost-effective components.

5.1.4 Microcontroller

Our microcontroller we will be using for the Light Saver design is the Raspberry Pi 3 Model B. This controller will have a multitude of different jobs, that are required for our design to function properly. One of these tasks is the ability to blink the LED lights under certain conditions, at the interval we specify. To accomplish this, we will need to connect our LED lights first to the Lead-Acid battery and then into the Raspberry Pi 3. From there we will run a code using python that when executed correctly will switch the LED lights on and off when certain conditions are met. These conditional statements will be linked with some other accessories to create the necessary conditions to trigger the lights.

One of these accessories is the Camera that we will be using to check for the pedestrian crossing sign using computer vision. Once the pedestrian crossing sign has been triggered to allow pedestrians to walk across the crosswalk lawfully, the motion sensor will be triggered. When the motion sensor is triggered it will check for the presence of a pedestrian in the immediate vicinity and this will be the last condition to allow the LED lights to trigger. Shown in the figure 43 below, is a diagram of each accessory that the Raspberry Pi 3 is connected to.

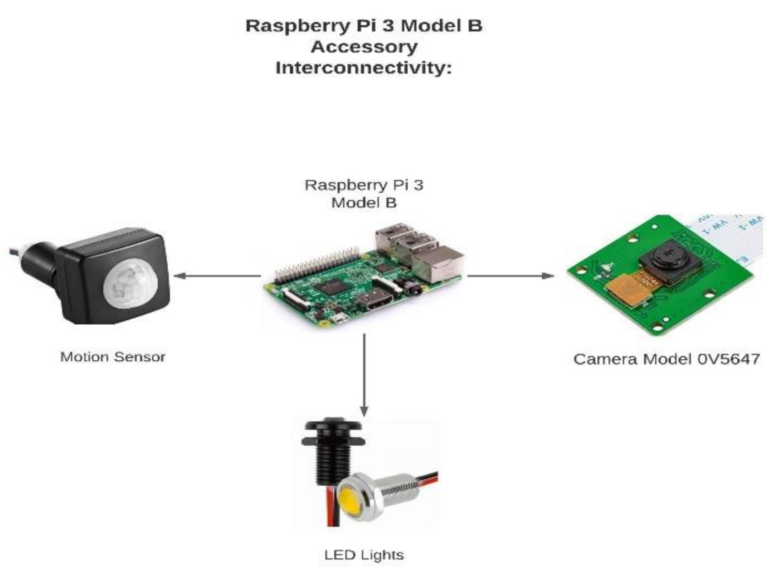


Figure #43: Raspberry Pi 3 Model B, accessory interconnectivity.

5.1.4.1 Microcontroller to LED

As discussed in the previous section of LED configuration, we cannot connect the 10 LEDs directly to the Raspberry Pi 3 as the current draw from the LED toggling would burn out the microcontroller as it is not designed to handle large current amounts. During the breadboard testing, we see that implementing a 12V input supply with 2kΩ resistor in series of each parallel LED branch, we have a current flow of 2.43 mA. To mimic battery charge voltage range, we also implemented a 9V input supply with 2kΩ resistor in series of each parallel LED branch, we have a current flow of 0.82 mA. If we calculate the current draw for all LEDs turned on simultaneously, the Raspberry Pi 3 cannot safely operate by supplying above 20mA of current through 10 separate GPIO pins, as we also must consider the supply needed by the camera feeding input to the computer vision.

One of the methods we designed to avoid potential damage to the Raspberry Pi 3 module but solve the requirement of supplying the LEDs and toggling them according to conditional requirements, is to build a separate circuit to supply power from the battery to the LEDs, and control it using a relay. The GPIO pins of the Raspberry Pi 3 are rated 3.3 V, so we will use a 3V relay power switch, 1 channel optocoupler. We can connect this to the circuit branch providing power supply between the battery and LED inputs, and the LEDs will only illuminate if we provide a digital input from the Raspberry Pi 3 GPIO pin.

Table #26: SRD 03VDC SL-C Datasheet Specifications

Coil Sensitivity	Coil Voltage Code	Nominal Voltage (VDC)	Nominal Current (mA)	Coil Resistance (Ω) ±10%	Power Consumption (W)	Pull-In Voltage (VDC)	Drop-Out Voltage (VDC)	Max-Allowable Voltage (VDC)
SRD (High Sensitivity)	03	03	120	25	abt. 0.36W	75%Max.	10% Min.	120%
	05	05	71.4	70				
	06	06	60	100				
	09	09	40	225				
	12	12	30	400				
	24	24	15	1600				
	48	48	7.5	6400				
SRD (Standard)	03	03	150	20	abt. 0.45W	75% Max.	10% Min.	110%
	05	05	89.3	55				
	06	06	75	80				
	09	09	50	180				
	12	12	37.5	320				
	24	24	18.7	1280				
	48	48	10	4500	abt. 0.51W			

Based on Table #26, given above, we can see that the datasheet specifications of the relay meet the criteria for the control of the LEDs and battery circuit. Based on further research into the datasheet, we have that maximum allowable voltage is 28 volts DC, and the maximum allowable current is 10A. This is well above the values of voltage and current which we expect to handle to power the LEDs.

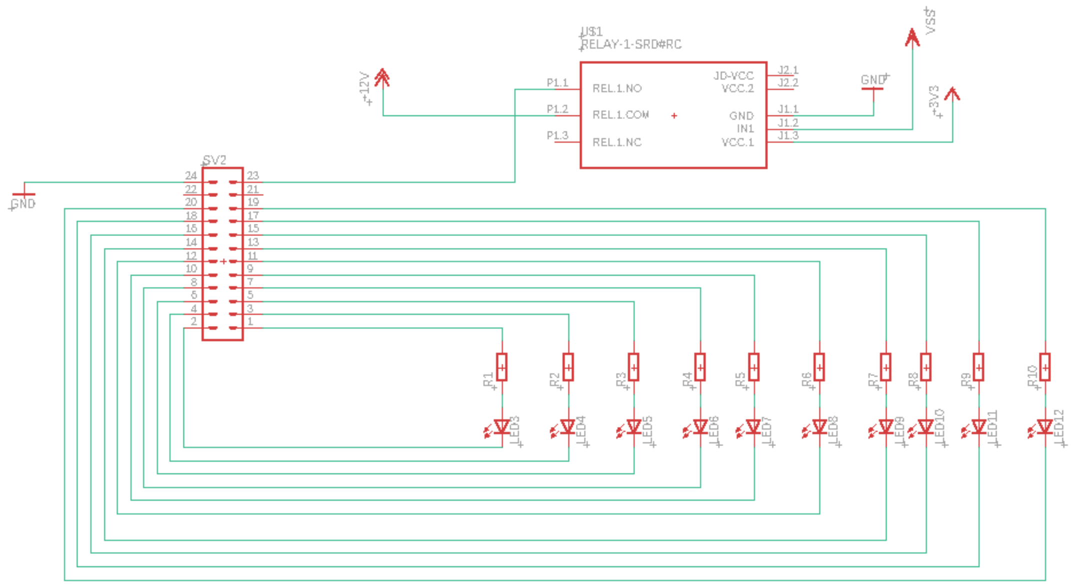


Figure #44: Schematic of LED Configuration design

Given in Figure #44 above is a possible layout of the LED configuration we plan to implement for the control of the relay connecting the 12V battery and the LEDs. The relay input signal control will be connected to one of the GPIO pins configured as an output on the Raspberry Pi 3 microcontroller. If certain conditions are met based on the data obtained from the camera input to the computer vision software, the motion sensor to detect the presence of a pedestrian, and the software algorithm will enable the GPIO pin that is connected to the relay as ON or a high signal. The relay is configured in the normally open setting, meaning that the LEDs will only be triggered to turn on if the relay receives an input signal for the Raspberry Pi 3.

The pin header in the schematic is an example of how we can create a parallel branched setup for the LEDs to receive 12V input, as we did in the breadboard testing. We may solder the pins adjacent to create a simple and condensed 12V rail. One difference between the schematic and board layouts is that the LEDs we are using are bolt beams, with a 22 AWG wire input and output connection. They will be located on different locations of the sign, and their connections will be attached to the pin header within the small PCB of the relay located in the enclosure. We do not need to have the PCB line routed to each LED, as that will cause unnecessary size of circuit board, leading to inefficient cost management.

The 2kΩ resistors will be surface mount components which we may solder after fabrication of the circuit board. We will use an appropriate gauge wire to connect the GPIO pin of the Raspberry Pi 3 to the signal input of the relay. Based on further testing we may alter the input of the relay, but based on current research we will use the Raspberry Pi 3 to connect a 3.3 V power supply to the relay, and similarly feed the ground to the microcontroller. If deemed necessary, we can design a switching regulator module for the relay to keep the current draw low on the Pi module as we do not want to damage it.

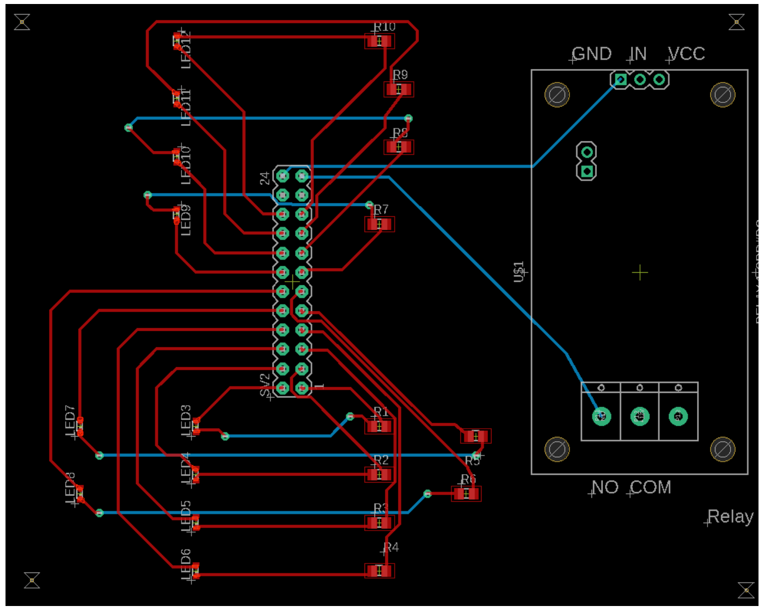


Figure #45: Board Layout of LED Configuration design

Given in figure #45 above is a board layout designed in Eagle, for the LED configuration. We may alter the components used based on further testing and research done during the process of the project.

5.1.5 Sign and Mounting

When it comes to mounting the Sign used in the Light Saver design, it was no easy process. Many different factors had to be considered. One such factor was how we would position the sign in such a way that would make it easily visible to motorist but would also give us a clear uninterrupted line of site to the cross-walk sign, which is needed for our computer vision to work. Another factor we considered was that we would need to be in a position that allowed for easy detection of pedestrians with our mounted motion sensor. Shown as red circles in the figure below is where we believe would be the best mounting location of our device, that would allow us to use all the features of the Light Saver, to the fullest extent.

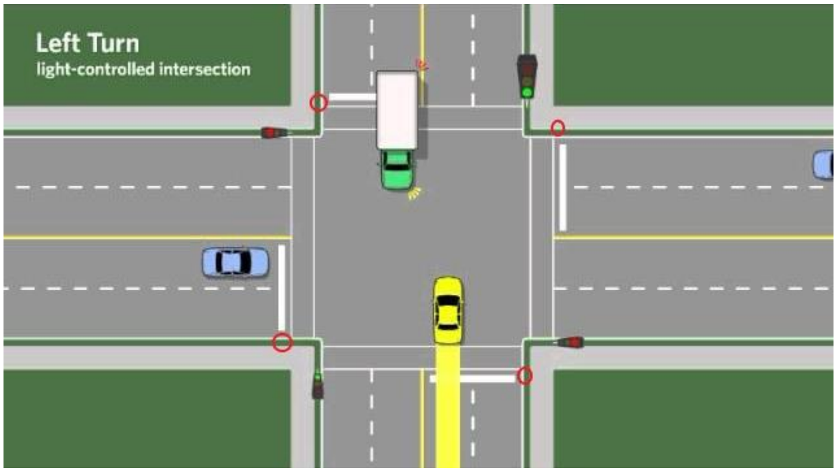


Figure #46: Best Sign mounting Location

For pedestrian crossing signs there is many valid mounting applications, depending on where the sign is needed. Not only are there different applications to secure the sign into the ground, but there are also many different valid fastening methods as well. For instance, you could use a metal channel and drive it into the ground and secure the sign with bolts, nuts, and washers. Alternatively, you could use a metal pole with a U-bolt fastener to secure the sign to the pole, and then either drive the pole into the ground or anchor it into the concrete using a core driller to make the hole and driving it further down with a post driver or sledge hammer. The easier method to anchor the post into concrete is to use a surface mount angle iron base, that can be bolted into the concrete and then the sign can be bolted into the floor mount. An example of this is shown in the figure 47 below.

Figure #47: Sign being mounted into the concrete

For our application however we will go with a mobile approach for general testing purposes since drilling through the concrete is not ideal and would require permission from the county. We will be using a platform around our post, that will allow the sign to stand upright while we conduct our testing and finetune the positioning of the sign for maximum implementation of our computer vision and driver awareness. An example of this platform can be found in the figure 48 below.

Figure #48: Mobile platform for sign

When it comes to attaching the pole to the sign, we are going to use a piece or rigid conduit that is threaded on the end. This threaded end will be screwed into a floor flange that is the same measurement of the pipe. This floor flange will then be bolted directly into weather-proof storage unit, which will be elaborated on in the next section. The weather-proof storage unit will then be fastened directly into the sign with weatherproof bolts, nuts, and washers. Silicone caulking may be used to make sure that moisture cannot enter the storage unit. This is shown in the figure 49 found below.

Figure #49: Pole with flange mounted to weatherproof box.

5.1.6 Storage Unit (to put all stuff on pole)

The way in which we store all the components in our Light Saver design needed a lot of research. Once we finalized the parts for our project, we needed to check the dimensions of each of these parts to make sure we were getting the right size storage units for the design. Also, we needed to make sure that these units would be weatherproof since it would be used in an outdoor environment. We initially believed we could use one weatherproof box to house all the accessories in the project, but we underestimated the size of some of the components, more specifically the lead-acid battery. Looking at the dimensions of the lead-acid battery that we would need to power all the components it measured 7.76 inches x 6.50 inches x 6.89 inches. So, we decided on using two weatherproof boxes instead. One box is used to house the lead-acid battery which would have been too thick to be stored in most normally sized containers, since the containers lacked the depth required to fit the battery. The other weatherproof box is used to house all the other accessories. This is shown in the figure below.

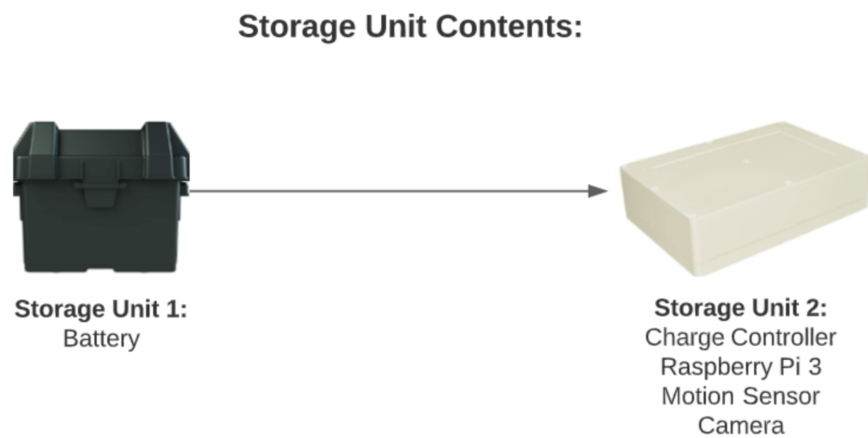


Figure #50: Two Storage Unites labeled with contents.

The boxes also needed to be compatible with the weatherproof fittings and tubing we needed to use for the interconnections between the two Storage units. If they were not compatible, we would need to fabricate a solution that would not only work but also be weatherproof. Lastly the Storage units and the tubing would need to be strapped and secured to the pole and the sign.

5.2 Summary of Hardware Design

For the subsections found above in Section 5, many iterations of the hardware design can be seen. These iterations were built upon and modified from the original design diagram, that was created at the start of the project. Each of the design aspects of the Light Saver device has been thoroughly researched, tested and discussed in depth. The results of our testing and research of the Light Saver device have led to the final design diagram shown below.

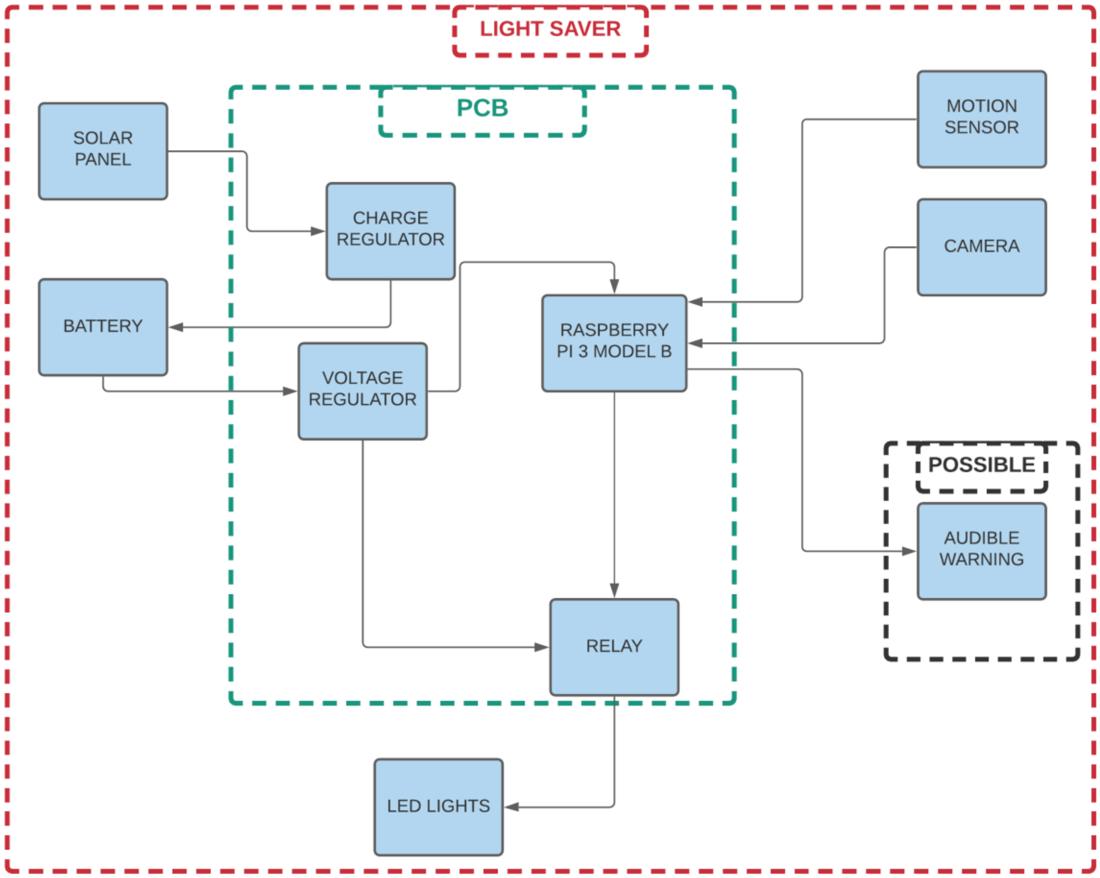


Figure #51: Final Hardware Design Diagram

Taking a closer look at the figure 51 above you can see an outline of a possible feature that given enough time we could implement into our device. This feature would in theory give us a way to audibly warn motorist of pedestrians crossing the road. The main focus of this project however will be everything that is not found in the possible outline.

The hardware design has become increasingly more fleshed out as we researched each problem, held group discussions, and crunched numbers and tested components. When deciding on what are hardware design should be, we had to take into consideration design constraints, standards, and hardware specifications.

5.3 Project Software Design Details

For the software portion of the Light Saver design, we will implement our code on the Raspberry Pi 3 Model B that will take in INPUTS and produce different OUTPUTs, which will be used within the code. The code will have three main tasks to carry out. These tasks are as followed: Turn on the accessories, such as the LED lights, motion sensor and camera. Gather information from these accessories.

Lastly given the information that is gathered from these instruments, it will execute the appropriate OUTPUT.

5.3.1 Software Functionality

The software functionality is broken up into multiple parts. The first part involves turning on the camera and waiting for the pedestrian crosswalk sign to illuminate. Using the OpenCV library and Python we will be able to use computer vision to detect the change in pixel color from the do not walk sign, to the walk sign and record this data. When this condition is satisfied the software will turn on the motion sensor camera which will detect motion within the immediate area, which will then relay this information to the software. If both conditions are true, then the software will toggle the LED lights to blink on and off at an interval set in the software.

Computer Vision Software Functionality

The strategy we are using for the detection of the state of the pedestrian traffic signal is based on the implementation of the traffic signals. The traffic signals for pedestrians that are commonly installed at major intersections consist of a Stop indication using the symbol of a hand, which is colored in a deep orange and red tone. The indication to allow a pedestrian to cross the intersection based on the vehicle traffic lights is given as a person Walking, and the Hand symbol disappears. The color of the person walking symbol is bright white, and the background of the signal box is dark black. We can base our strategy for computer vision using the principles of color detection of these unique state conditions.

Figure #52: Example of Pedestrian Traffic signal

As shown in Figure #52 above, we can manipulate the algorithm of the computer vision to detect the state of cross or do not cross by using OpenCV color detection algorithms, and we can illustrate what the computer vision is detecting using contour illustrators and other processes to detect the center of the tracked object (traffic symbol state).

The way the OpenCV algorithms detect the appropriate match of the programmed object is by converting the input video feed from the traditional Blue, Green, Red breakdown basis, into the Hue, Saturation, Vue scale of describing image characteristics. We set a lower boundary and an upper boundary of the HSV color space to focus on the desired object to be tracked. A method to obtain the appropriate color breakdown in BGR mode is using Microsoft Office color palette, which allows for very detailed color selection and it displays the exact breakdown of the color chosen. We use a conversion function to obtain the HSV values, and code them into the algorithm.

There are also further algorithms to mask and center the location of the detected object. We keep the camera module to have lower frame rate to reduce processing strain, and that we are not trying to extract multiple unknown parameters from the input video, we are trying to ascertain between predicted known states.

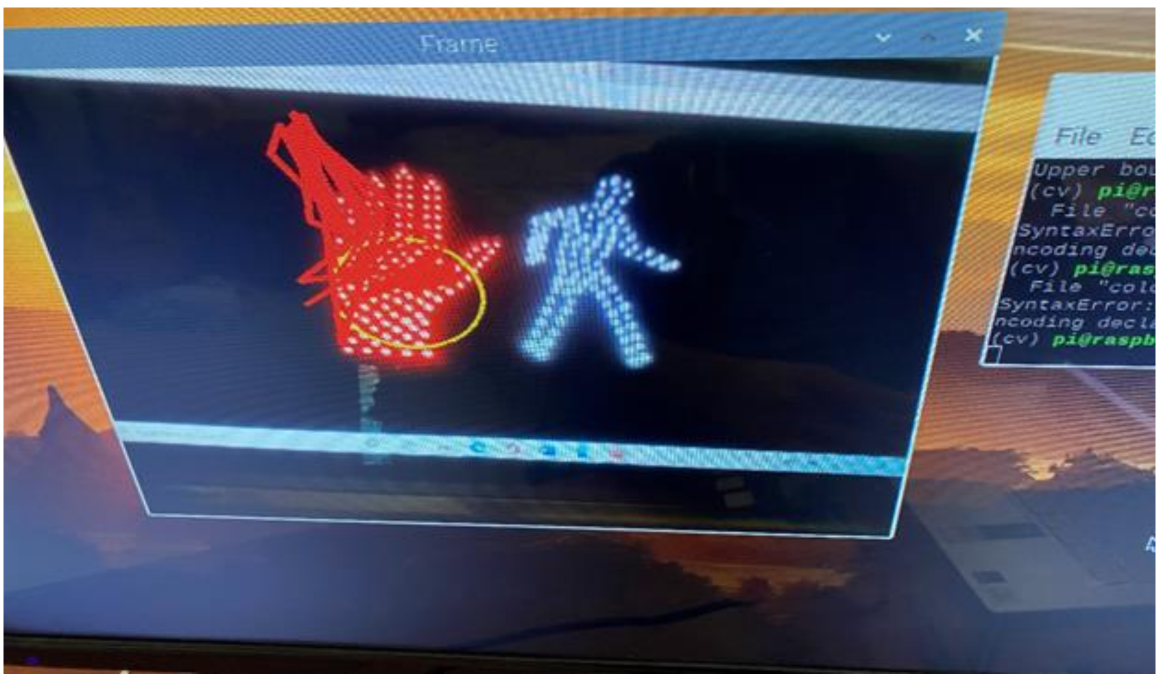


Figure #53: Illustration of Computer Vision detection Scenario 1

Figure #54: Illustration of Computer Vision detection Scenario 2

As seen in the Figure 53 and 54 above, we perform preliminary testing of the Computer vision algorithms to distinguish and detect the stop symbol on pedestrian traffic signals. These represent a type of breadboard testing for the software and are good preliminary indicators for the proper implementation of the algorithm in an indoor environment. In this setup, we connect the Raspberry Pi 3 to a screen using an HDMI cable so that we can view the results of the computer vision. The OV5647 camera module is connected to the appropriate port on the Raspberry Pi 3 which is located near the HDMI port. We do not want to accidently connect this to the similar looking port near the GPIO pins. We then enable the camera port by going into the Pi settings.

We save the scripts of the algorithm using the Thonny IDE and save them to a unique file which we may specially call for the purpose of computer vision. We are under the assumption that a new user has already configured and installed the Pi 3 with an operating system. We will explain in detail how to configure the operating system in a different section if required. We install the OpenCV library as well as Python 2.7, which we will use to run OpenCV. We execute the scripts in the terminal, and we run two different detection scenarios for the initial indoor testing of the algorithm. We open the testing images on a separate screen and point the camera to input video feed from the second screen which will display the test images.

As shown in Figure 50: Illustration of Computer Vision detection Scenario 1, the test image is the stop symbol and the walk symbol compared side by side on a black background. The computer vision algorithm successfully detects the Stop hand symbol and distinguishes it from the Walk symbol. We can confirm this based on the yellow detection circle that the algorithm generates, and with the red tracking lines. The red tracking lines are produced due to us moving the camera angle up, down, left, right to see how it impacts the detection algorithm and if it can locate the center of the detected object. The computer vision successfully tracks the center of the detected hand symbol, and the yellow matching circle also stays focused on the hand symbol.

As shown in Figure 54: Illustration of Computer Vision detection Scenario 2, the test image which we display on the second computer screen is that of an actual traffic signal located at an intersection, with walk state and stop state displayed within the same image side by side. The computer vision algorithm once again successfully detects the stop hand symbol as seen with the yellow matching circle. If we look closely, we will also see a red dot at the center of the yellow circle, which indicates that the algorithm has also detected the best fit center of the object. We do not rotate the camera during this test which is why there are no red lines scribbled as in the first test scenario.

A unique and interesting observation which is accomplished during these preliminary tests of the computer vision algorithm is that there are many different colors shown on the test images, but the algorithm only detects the designated symbol. This is even more so interesting in Scenario 2, as we observe that the color of the building wall in the background of the traffic signal is also a red orange mix, and the algorithm does not get confused by any background color noise. The hand symbol and the wall are relatively close in perception of color, but our algorithm successfully detects the symbol and centers it. This provides us with assurance that any noise and unwanted signals detected by the camera during real world applications will be possible to filter so that we only identify the designated symbol.

5.3.2 Algorithm Description

This code will be implemented in several different sections. Each of the sections will be dedicated to a specific task. Each of these tasks will have clearly defined variables. At the start of each code, the inputs, and outputs as well as the headers and library functions will be initialized at the start of the code. Each subsequent task will be broken down, having its procedure listed to show what the processor will be compiling in descending order.

5.3.3 Camera Algorithm description

- set flag to 0 for crosswalk off to microcontroller

while on

- Process image
- Check region for cross walk sign for white pixels
    - If white pixels set flag to 1 so that the microcontroller knows the cross walk is signaling for pedestrians to cross and counter to 0
    - Else keep checking
- If flag = 1 check for region till white pixels are gone
- Once white pixels are gone then see if the sign is flashing
- If all black reset counter to 0
- If only red pixels in region increment counter plus 1
- Once counter is to 10 then set flag to 0 to let the microcontroller that the sign is off
- Repeat

5.3.4 IR motion sensor algorithm description

- Set flag to 0 letting the microcontroller know that there is no one near the light saver for the intial condition
- Get initial value or temperature
- Loop
- Get a reading of the area
- If that reading it greater then the value then motion is detected then set flag to 1 so the microcontroller knows how to turn on led if other condition is met
- Get another reading
- When that reading goes back to initial value then set flag to 0 to let microcontroller know to turn off the led
- Repeat

5.3.5 Led algorithm

- LEDs are off
- Check if both flags from motion sensor and computer vision is on
- If they are flash LEDs at set interval
- Once one or both flags turn off then turn LEDs off
- Repeat

5.3.3 Coded Flow Chart

This flow chart represents the development ad order of functions that explain how our algorithm works making our project have a logical order as follows.

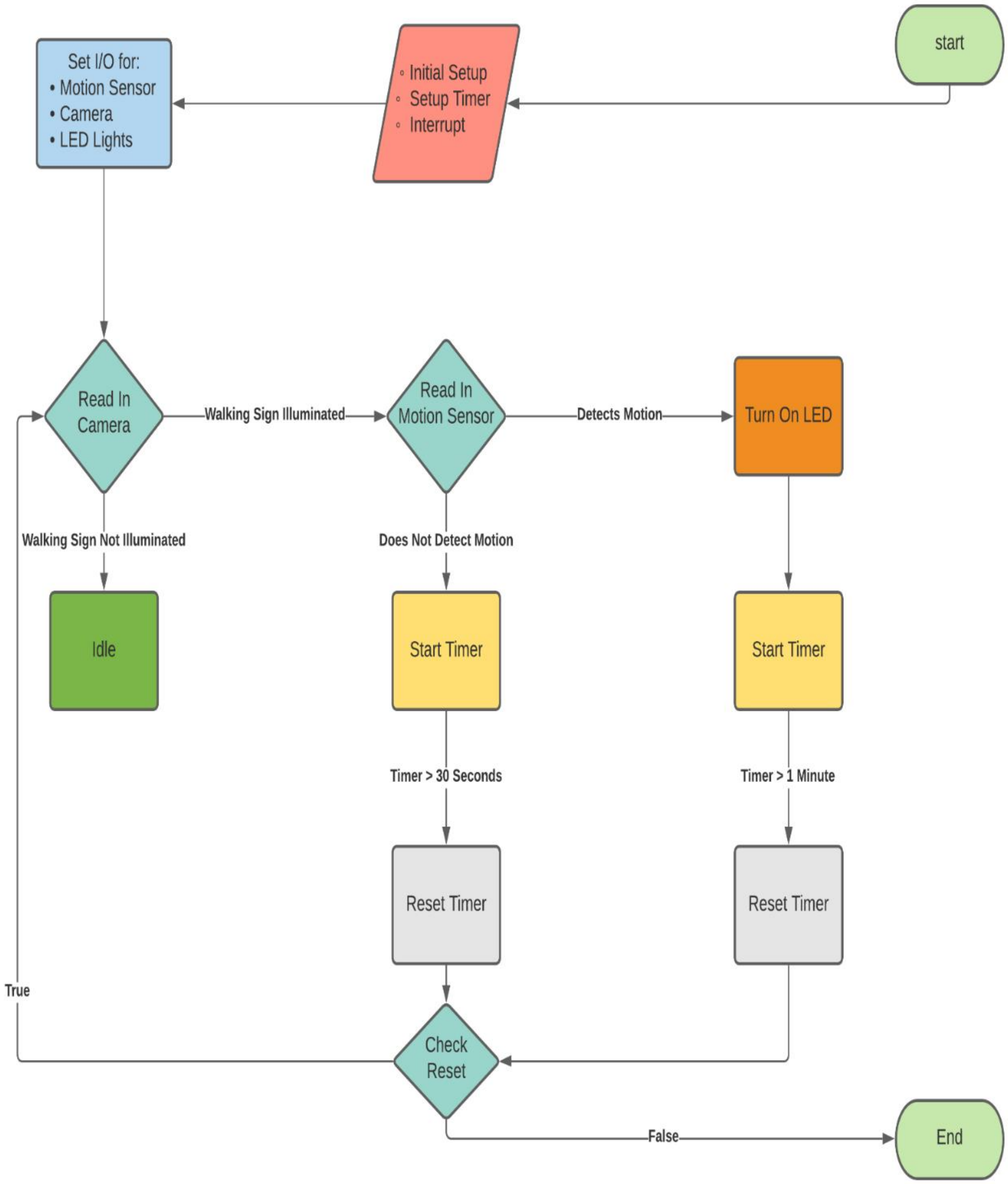


Figure #55 : Coded Flow Chart

6 Project Testing

In this chapter and the following sections, we will undergo testing of different subsystem of the Light Saver device. We will first undergo hardware testing of the various subsystem, and then go into the software testing. The constraints related to the testing of the respective systems is a unique situation because of COVID-19 and the lack of accessibility to regular testing equipment as used in university laboratory facilities.

Environment: The majority of the hardware testing is done in the home environment of the group members. We purchased a digital multimeter to gather observations of different parameters. We utilized passive components such as resistors, capacitors, and inductors for DIY electronics kits which were purchased from Amazon. We verified the component integrity and value to check if it matched as specified by the manufacturer before we implemented them in the circuit. We had access to many higher end components such as voltage regulators, transistors, diodes, comparators, etc., by preserving them from in-person lab instructions setting from UCF during the pre-remote learning period when labs and classes were held in person learning.

Multimeter Specifications: WeePro Vpro850L Serial #: 2003001202

- DC Voltage: 200mV-600V ±(0.5%±2dgts)
- AC Voltage: 200/600V ±(1.2%±10dgts)
- DC Current: 200uA-10A ±(1.0%+2dgts)
- Resistance: 200Ω－2MΩ ±(0.8%±3dgts)
- Power supply: 9V,6F22
- Max. display: 1999
- Diode: Yes; Dynatron: Yes; LCD Backlight: Yes; Continuity Buzzer: Yes;
- Input Impedance for DCV: 1MΩ
- 9: Sample Rate: 3times/S
- 10: LCD Size: 70 x 40mm

6.1 Hardware Testing

Hardware testing will be performed to check the proper working of the subsystems of the Light Saver device and analyze each subsystem thoroughly to ensure the constructed prototype will perform according to the requirements of the design. This will also allow for analysis and adjustments to the design if deemed necessary by the test results.

For certain sensitive components such as the LEDs, we will perform virtual simulations of the circuit using the online free student version of Multisim Live. This will allow us to avoid damage to components during the actual hardware test, as the current sensitivity of certain components is in the order of milliamperes.

Linear Regulator

Testing is performed for the linear voltage regulator, as shown in the Device Under Test figure 56 shown below. We will use the battery that will be installed in the Light Saver device to provide voltage supply, and we use the multimeter to confirm the terminal voltage of the battery before performing the tests.

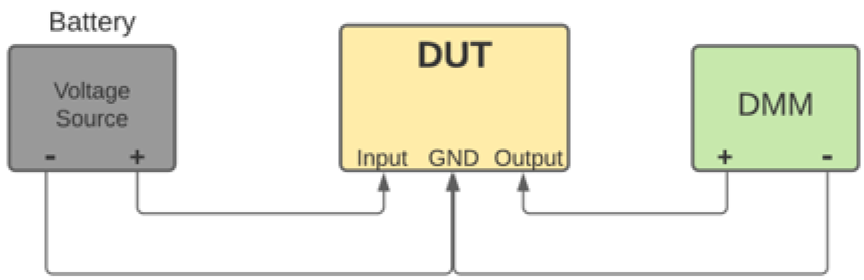


Figure #56: Device Under Test Diagram Linear voltage regulator

In Section 5 we outlined the breadboard testing and the component outline of the device. The objective is to provide a consistent output 5V power supply from the 12V battery. We want the output voltage to stay within appropriate range based on the fluctuations of the battery voltage level based on how much it is charged. We will test through a range of voltages to see the behavior of the charge regulator. As observed in the results, the voltage of the output from the linear voltage regulator fluctuates within 0.04V, which is within the requirement range of the device.

We ensure that all components are connected correctly such as the pin out of the 7805, and double check the wiring of the circuit. We ensure there is only one ground node, to avoid ground loops which may cause error in our measurements. The measurements from the testing are shown in Table #26 below. We provide varying input voltage by configuring batteries in series, as well as using voltage divider circuit to obtain needed input test voltage, which we then connect to the device under test.

Table #27: Linear Regulator Input vs. Output Voltage Data

Input Voltage	Output Voltage
0V	0.0mV
1V	0.19mV
2V	0.34mV
3V	1.46V
4V	2.49V
5V	3.61V
8V	5.02V
10V	5.02V
14V	5.03V
18V	5.03V
20V	5.03V

Switching Regulator

Testing is performed for the switching voltage regulator, which is located between the SLA battery and the Raspberry Pi 3, as shown in the Device Under Test figure 57 shown below. We will use the battery that will be installed in the Light Saver device to provide voltage supply, and we use the multimeter to confirm the terminal voltage of the battery before performing the tests.

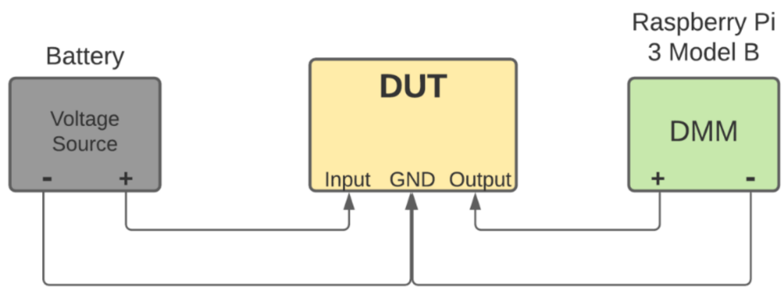


Figure #57: Device Under Test Diagram Switching voltage regulator

In Section 5 we outlined the breadboard testing and the component outline of the device. The objective is to provide the Raspberry Pi 3 with a consistent 5V power supply from the 12V battery. We want the output voltage to stay within appropriate range based on the fluctuations of the battery voltage level based on how much it is charged. We will test through a range of voltages to see the behavior of the charge regulator. As observed in the results, the voltage of the output from the switching voltage regulator fluctuates within 0.1V, which is within the requirement range of the device.

We ensure that all components are connected correctly such as the polarity of the Zener diode, pin out of the LM2576, and double check the wiring of the circuit. We ensure there is only one ground node, to avoid ground loops which may cause error in our measurements. The measurements from the testing are shown in Table #27 below. We provide varying input voltage by configuring batteries in series, as well as using voltage divider circuit to obtain needed input test voltage, which we then connect to the device under test.

Table #28: Switching Regulator Input vs. Output Voltage Data

Input Voltage	Output Voltage
0V	0.00mV
1V	0.02mV
3V	9.62mV
5V	4.00V
6V	4.93V
7V	4.89V
8V	5.01V
10V	5.04V
12V	5.06V
15V	5.08V

LED configuration

Testing is performed for the 10 LED’s which will be imbedded upon the sign of the Light Saver device, we will power the LED’s using the SLA battery and various resistor configurations to obtain the optimum current flow through the branches of the LED circuits, as well as obtain optimum illumination for the design specification. We will use the multimeter to confirm the terminal voltage of the battery before performing the tests. The setup is as shown below in figure #58 for the device under test.

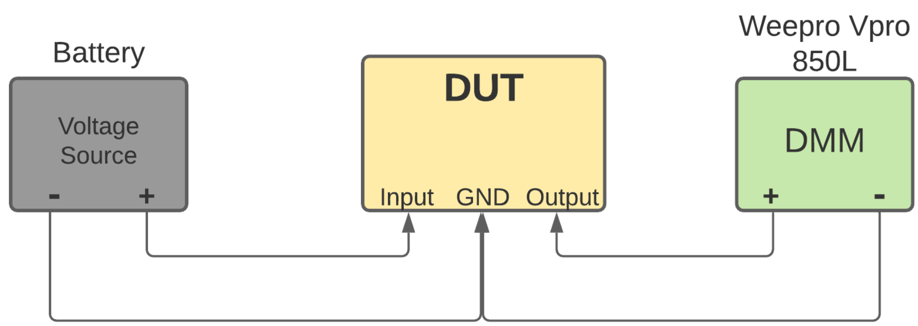


Figure #58: Device under test diagram LED configuration

In section 5 we outlined the breadboard testing and configuration of the LED's to mimic the circuitry of how they will be imbedded within the sign of the Light Saver device. We must take into consideration the threshold current limit of the light emitting diodes as we do not want to burn out the devices during testing. We must study all possible voltage input scenarios based on the battery charge level, so we obtain optimum illumination. We must also study the effect of choosing various resistor component values, as they will affect the current draw of each branch and the overall illumination.

We provided two different voltage inputs using the 12-volt SLA battery and using a 9-volt Lead battery. The actual terminal voltages of each battery are displayed in table #28 below. We alter the resistor component values between 1kΩ and 6.1kΩ. We used standard resistors from DIY electronics kit. From the results and data measured, we choose the 2 kΩ resistor as the optimal choice for our circuit setup. When we fabricate the PCB, we will design a central unit which will incorporate surface mount components as their resistors and pinouts for connecting the LED's. The LED's themselves have 22 AWG wiring so that we may imbed them at any location upon the sign. This is crucial to lowering the fabrication cost of the PCB for this subsection.

Table #29: LED Input Voltage vs. Output Current Data

Input Voltage	Series Resistor	Current in LED Branch
12.83 Volts	1kΩ	4.45mA
	2kΩ	2.43mA
	3kΩ	1.62mA
	5.1kΩ	0.99mA
	6.1kΩ	0.834mA
9.59 Volts	1kΩ	1.02mA
	2kΩ	0.82mA
	3kΩ	0.58mA
	5.1kΩ	0.37mA
	6.1kΩ	0.30mA

6.2 Software Testing

Like in hardware tests, the software will need to be tested and run to ensure the light saver is working correctly and does what it needs to do. Shown in the figure below the light saver will need two inputs to be triggering in order for the LED lights to flash and warn the incoming cars that is a pedestrian in the road which will hopefully save lives. The first trigger will be the motion sensor. with the motion sensor we need to program the sensor to let the microcontroller know when it detects a person in the cross walk. The second thing that will be needed to be the computer vision will need to be test to ensure that the cross walk is signaling for pedestrians to cross. We also need to sure that once these two conditions are met then it illuminates the LED and once one or both of the conditions is fulfilled, i.e., the pedestrian is out of the cross walk or the hand sign stops calling for the pedestrians to cross the LED lights turn off as well. In the next few sections, we will be going on how we will be testing the computer vision, the motion sensor, and the microcontroller.

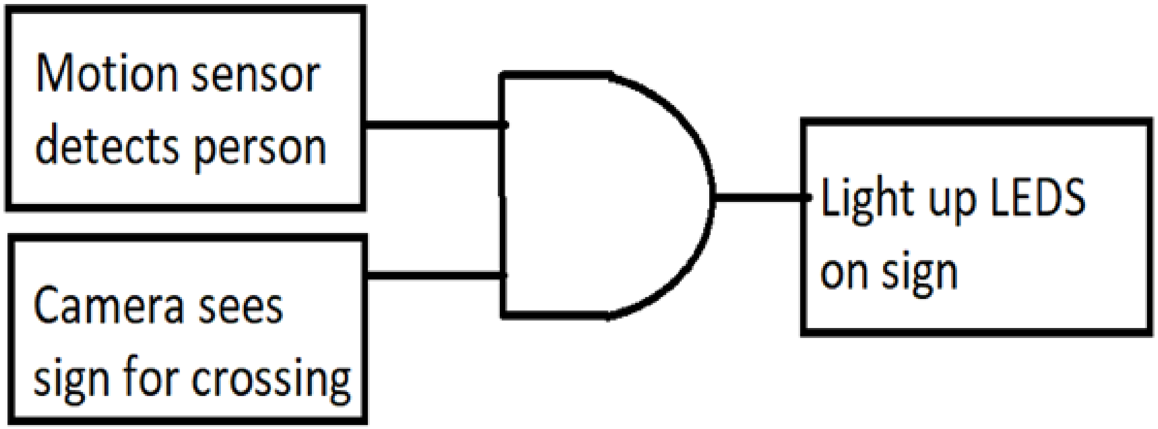


Figure #59: the logic of the light saver.

6.2.1 Computer Vision Testing

We wanted to test the computer vision algorithm in a manner to ensure that the results seen in the initial setup would be properly replicated in an accurate manner. We perform the testing using the selected ArduCam and Raspberry Pi 3 with an external computer displaying the test photos.

Table #30: Computer Vision Algorithm Detection Results (Preliminary Testing)

Computer Vision Algorithm Preliminary Tests	Test #	Scenario 1 Image Detect Correct Symbol (Hand)?	Scenario 1 Image Detect Correct Symbol (Walk)?	Scenario 2 Image Detect Correct Symbol (Hand)?	Scenario 2 Image Detect Correct Symbol (Walk)?
	1	Yes	Yes	Yes	Yes
	2	Yes	Yes	Yes	Yes
	3	Yes	Yes	Yes	Yes
	4	Yes	Yes	Yes	Yes
	5	Yes	Yes	Yes	Yes
	6	Yes	Yes	Yes	Yes
	7	Yes	Yes	Yes	Yes
	8	Yes	Yes	Yes	Yes
	9	Yes	Yes	Yes	Yes
	10	Yes	Yes	Yes	Yes
Success Rate		100%	100%	100%	100%

The method with which we tested the computer vision setup was by toggling through random photos and suddenly appearing the test scenario photo onto the screen at which the camera was pointed. Another method we used was to block the view of the camera and unblock the camera lens at random intervals to see if the algorithm would detect the correct symbol. We performed a small sample of 10 tests per symbol per scenario, and the results are displayed in Table #: Computer Vision Algorithm Detection Results (Preliminary Testing).

Practically speaking the sample size of the tests performed is small, so with longer duration and more thorough testing during the construction of the Light Saver device, we may not get a one hundred percent rate of success. But the ideal outcome is to maximize the success rate to be as close to one hundred percent as possible. We will also face different environmental scenarios based on the outdoor setting, such as external signal noise (such as background or passing colors), light intensity difference based on weather patterns such as rain, etc. During the second phase of this project, we will focus on creating more realistic testing environment to push the algorithm to its limits and possible fix any errors or bug which may arise.

6.2.2 Signal from Motion Sensor

The motion sensor will need to be calibrated and tested. When designing the software, the software it will need a base value which will be the outside temperature since the light saver will be outside. Once it established the outside temperature it will detect any major changes to temperature which will be assumed as motion. Since it is looking for major changes it will not be affected by the temperature changes though out the day since these changes will be gradual and will update the base value ever so often and send a signal to the micro controller and if the camera is showing a crosswalk sign. Below shows the table shows the test case for two different distances with that max being 5 since they sign should be close to the cross walk.

Table #31: Motion sensor testing

Motion sensor algorithm preliminary tests	Test	1ft	5ft
	1	pass	pass
	2	pass	pass
	3	pass	pass
	4	pass	pass
	5	pass	pass
	6	pass	pass
	7	pass	pass
	8	pass	pass
	9	pass	pass
	10	pass	pass
Pass rate		100%	100%

6.2.3 Microcontroller Testing

Testing the microcontroller is key to making sure this project works. We will be needing the controller to get the motion sensor data and to be accurate which will need a series of test. Once the infrared motion sensor is giving a positive output, we need to test the computer vision and see if the results and true. Then we need to make sure only when both conditions are meet the microcontroller is telling the LED lights to turn on.

Table #32: Truth table o

Cases	Motion sensor detecting pedestrian	Computer vision seeing cross walk sign signaling to cross	LED Lighting up
1	False	False	False
2	False	True	False
3	True	False	False
4	True	True	True

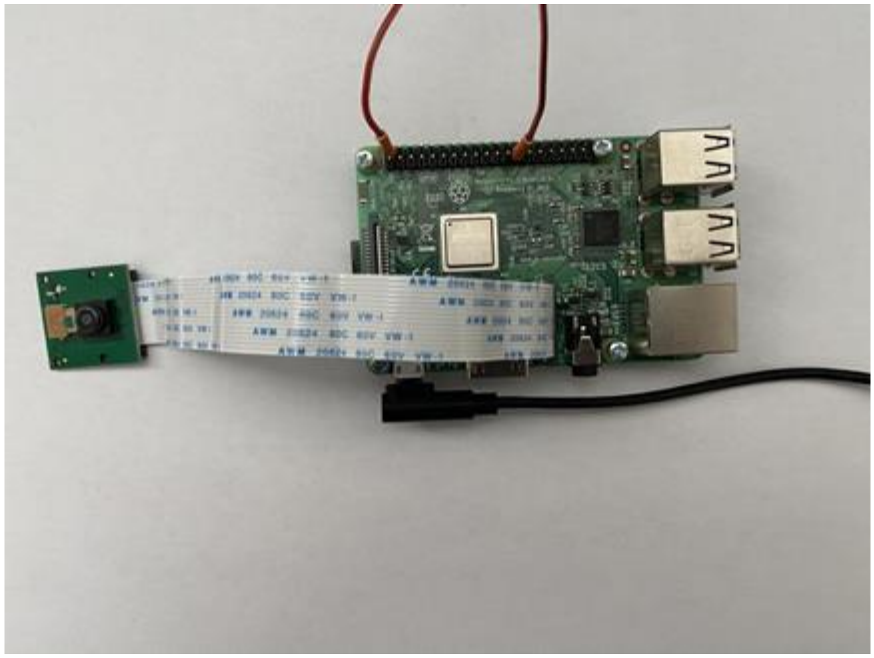


Figure #60: microcontroller with camera input

6.3 Prototype PCB

We want to choose an appropriate PCB vendor which can deliver both quality products as well as deliver them on time. As most of this project is done remotely, and with limited interaction due to COVID-19 safety protocols and procedures, we want to ensure the process is as smooth as possible. As we are self-funding the project, we also want to keep our budget in check, and ensure that the money we spend towards PCB fabrication is well spent and does not have any hidden costs or sub-par quality.

The benefit of printed circuit board fabrication is that we can neatly organize and create a single board which houses and interconnects the different functionalities and components of the project. It basically acts as the hub for the device, and we can design different layers of the PCB to be conducting planes and insulating planes. We will design our PCB using the free version of Eagle software, which allows us to make a schematic for the different device subsystems and verify the exact component specifications that will be inserted onto a board layout. We can then arrange the board with the components as our device requires and export this file to a PCB manufacturer. New technologies and processes allow us to have a faster turnaround on the PCB manufacturing time, as there are companies that may use 3d printers and drilling machines to create the necessary layout.

The cost of manufacturing will range based on the quality, tolerance, and number of layers of the PCB design. As this is a costly process several companies allow the ordering of prototypes 1.6 mm PCB, and if needed there are different options such as multiple layers, thinner boards with more copper, flexible two-layer boards, etc. Based on general research of different PCB manufacturing websites, the price for manufacturing a PCB is based on the square inches of the board you are printing. A basic cost estimate is $5.00 per square inch for a classic 1.6 mm two-layer prototype PCB. The material used would be a Kingboard copper clad laminate which has high mechanical and heat resistance properties with a goal of achieving high durability. If we were to order a four-layer PCB prototype the price is approximately double and will cost $10.00 per square inch.

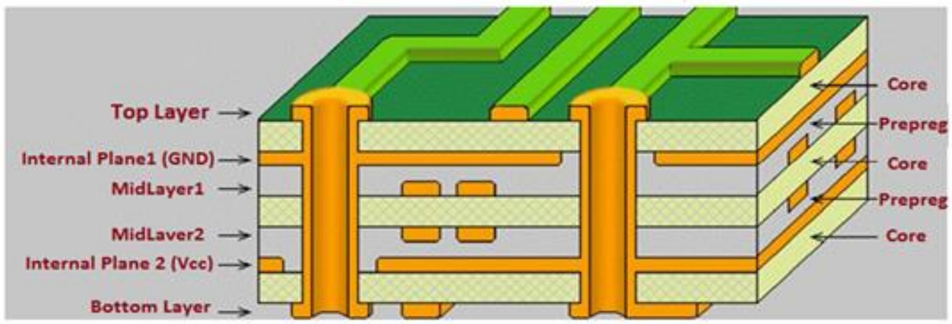


Figure #61: Layered PCB

One of the main objectives during the creating of the PCB schematic is that we appropriately choose the parts and are carful with their dimensions, orientations, and final board layout. Within Eagle software, we can click the board generation button after our schematic is created, and it will place the footprints of the components of the schematic onto the board space. We must align the components on the board space according to how we want the printed PCB. Initially we want as few air wires overlapping so that our wire routing will be proper with as few overlaps as possible. When routing the wires on the PCB we want to make sure they have proper clearance and width space to avoid noise and unwanted interference during the operation of the device. If wire overlap is unavoidable, we may utilize Vias to provide traces from a different plane to connect the respective components.

We want to ensure that the designed PCB does not violate any rules using the DRC function in Eagle. This will help us to avoid any design violations that will interfere in the manufacturing of the board and will help us achieve a good signal quality and electrical performance.

The components that we will choose for the PCB during the schematic design are surface mount components, which are generally classified with the numbers 0805, and we must ensure that we select the correct component during the design process as when we add the parts to the schematic, a single part will have multiple package options. The surface mount components will allow us to manually solder the components to the board. Soldering surface mount components on the PCB is a tricky process that must be undertaken with precession and safety. You will need to use a proper soldering iron that reaches the appropriate temperature and maintains that temperature. The right solder is also important, for our PCB design we will most likely use rosin core solder, as that has the recommended internal properties for electrical applications and PCB part placement.

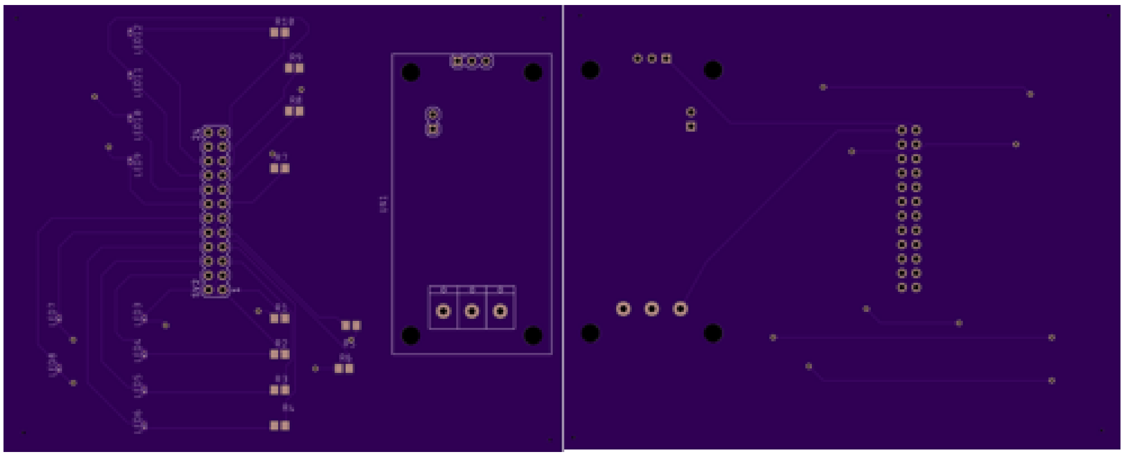


Figure #62: PCB Prototype LED/MCU

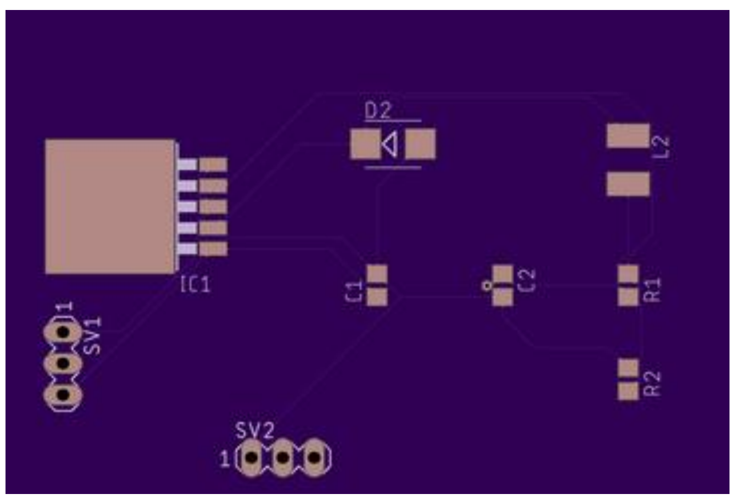


Figure #63: PCB Prototype Switching Regulator

We can see in Figures 62 and 63 our initial PCB prototypes for the MCU and with connections to LEDs and motion sensors. An initial issue we faced is that the silkscreen we created for details within the Eagle software did not get picked up through the OSH Park website, which generated these PCB layouts, but we will ensure the final PCBs have detailed silkscreens which will assist us in detailing the components and setting up the Light Saver device further.

7. Project Operation

In this section we will cover the idea of what will be a user manual a place where the people that need to use the implement can go to when they have any questions even thought our project is made to reduce the actual interaction the user or pedestrian in this case must do. This since we made this project in a season of pandemic where you must be careful on what and where you touch, or you can be getting contaminated.

7.1 Safety Precautions

First and foremost, we must take in consideration our entire project is for a safety precaution and this is driving with care. This element will still not prohibit drivers from breaking the law or even mistaken the idea and turn by mistake. Meaning that pedestrians must still be careful when turning since their life is at stake.

Secondly, we must take in consideration attention when walking being on your phone or distracted does not help prevent accidents. When humans give their most attention to their main jobs, we can be the best at all we do so keep your eyes on the road and do not get distracted.

Also take in account this element should not be touched it is made to protect pedestrians from getting any electrocution. But it does still carry high voltage battery and solar powers that can cause strong energy management, pedestrians should abstain themselves from touching the box sine it can be dangerous.

Sign is also made at a tall height making sure that most pedestrians do not bump their head. But for precautions always be attentive of where you walk you do not want to have an accident by hitting your head with the equipment.

The light savior will only grab motion in the ramp to the road where people will head out. For your safety do not cut road peace walk over the grass since the sign will not warn cars that you are walking down the road meaning that you are outing yourself at risk. At the same time make sure you walk to the corresponding cross walk and do not cross the road in the middle of the block where no cross walk is present this is not safe, and it is against the law you are not only putting your life at danger but the lives of the people in driving can be at danger to.

7.2 General Information

The light saver is an apparatus composed of multiple parts that all together are meant to reduce your chance of fatality crossing the road. This apparatus is using a combination of two sensorial technologies to make sure it is precise as possible and reduce mistakes. One is motion sensors that will detect movement of some animated object moving towards the road this object is mostly meant to be pedestrians, but it will sense other object that pass thought here also like bikes or dogs. It will also use computer vision this is a camara that uses the images it obtains and detects if there is a certain desired object in that image in this case we are checking to see if the pedestrian walk sing is in a walk or a wait scenario. From this we will use lead light that will portray to the drivers turning right that there is a pedestrian crossing the road that has the right of way asking them to stop and let the pedestrian cross the road. This by flashing its lead lights. This apparatus does use solar power to maintain its usage at its best since it reduced nonrenewable energy and helps the environment. And at the same time, it is durable enough to last for an entire day with no charge at all.

7.3 Using the Light Saver

The light saver is a very easy implement to use it is made to be easy the only real thing the pedestrian or used must do it respect the law by walking in the sidewalks they will trigger the motion sensors and wait for their turn to cross. At this moment the light saver will flash their led lights letting the car know that they must stop for a pedestrian protecting the pedestrians live.

7.4 Troubleshooting Tips

Troubleshooting is not much for the user as it is for the mechanic one of the long-term goals of the project is permitting the pedestrian to let the mechanic know if the machine is not working. This meaning that the lights are not flashing even though they have passed through the corresponding area. This might mean the battery is not charged at all it might mean that the sensors are bad or it might mean that the lights might have to be changes but the pedestrian does not have any troubleshooting to do. If there is any problem with the light make sure to cross with care.

8. Administrative Content

This section of the document will be discussing the logistics of this paper and the milestones of the completion of the design, prototyping, and testing of the Light Saver device. The time and due dates of the milestones of the project will be divided starting from initial project idea to the final presentation and completion. We will also discuss the budgetary breakdown, design problems, project roles, and future potential of this device.

8.1 Milestone Discussion

In this section you can see what our calendar and milestones have happend and will happen in the procedure of developing this project.

Table #33: Project milestones and important dates

Number	Milestone	Start
Senior Design I		
1	Brainstorm ideas	August 28th 2020
2	Project selection and roles assignments	September 10th 2020
3	Initial divide and conquer document	September 18th 2020
4	Research upon selected project idea	September 21st 2020
5	Final divide and conquer document	October 2nd 2020
6	Project description, research, standards	October 8th 2020
7	Solar panel	October 15th 2020
8	Voltage controllers / Power supply	October 15th 2020
9	Microcontroller	October 15th 2020
10	PCB design	October 15th 2020
11	Document review meeting (W / Dr. Wei)	November 17th 2020
12	Order parts	November 18th 2020
13	System Design / Integration and testing	November 23rd 2020
14	Final document due	December 8th 2020
Senior Design II		
15	Assemble prototype	TBD
16	Testing and redesign	TBD
17	PCB fabrication	TBD
18	Finalize prototype	TBD
19	Peer report	TBD
20	Final documentation	TBD
21	Final presentation	TBD

8.2 Budget and Finance Discussion

Due to covid-19 and the unique situation of the university classes being held remotly nationwide, with UCF also included, there were heavely reduced possibilities of obtaining financing for senior design projects. There were some possible project ideas that were sponsered by companies, but they did not fit our group outlook. So we decided to choose the project idea based on brainstorming and what interest us the most. This lead to the conculsion that our project would be self financed and that group members would make an equal commitment to see the project through. Compiling a list of nessesary parts for this project, we estimate that our cost of materials will be in the range of 600.00 dollars.

Table #34: Estimated Cost Table

ITEM	QUANTITY	Vendor	PRICE ESTIMATE
Aluminum Sign K-2845-EG	1	SuperSign	$42.36
Mounting Pole 315 34X120	1	Lowes	$20.99
Mounting Hardware	1	Lowes	$25
LED mounted lights 12B-R-B	10	Super Bright LED's Inc.	$20.95
Solar Panel (12V) 100W-12V	1	Renogy	$103.02
SLA-AGM Battery L50-12	1	Mighty Max (Walmart)	$99.99
Motion Sensors PIR	1	E-AGE (Amazon)	$11.99
Raspberry Pi 3 Model B	1	Adafruit (Amazon)	$35.00
Charge Controller PWM	1	Renogy	$38.24
Camera for CV OV5647	1	Arducam (Amazon)	$9.99
Custom Enclosure	2	Amazon	$50
PCB Fabrication	1	TBD	TBD
TOTAL (Estimated Cost)			~$457.53

8.3 PCB Vendors

We looked through several different options of choosing a PCB vendor to manufacture the designed boards. The main sites we compared were 4PCB and OSH Park. The first website does have some student special deals for self-funded projects, but the cost was still high as there was a base price exceeding $30 each, and minimum order quantity was three boards. We found the OSH Park to be more competitive in pricing, although their turn around time is slightly longer than the initial manufacturer. The OSH Park company does manufacture the PCB boards within the US, so we may expect faster shipping versus choosing an overseas vendor. We listed various comparisons in Table #34 based on the possible specifications and PCB board types that we may order.

Table #35: PCB Type Comparison

	2 Layer Order	4 Layer Order
Cost (per Sq. Inch)	$5.00	$10.00
Minimum Order Quantity	3 copies per order, multiples of 3	3 copies per order, multiples of 3
Turn Time	<12 days	<14 days
Board Thickness	63 mill (1.6 mm)	63 mill (1.6 mm)
High Temp	Yes, FR4 175Tg or higher	Yes, FR4 175Tg or higher
PCB Finish	ENIG (Gold)	ENIG (Gold)
Copper Specs		
Copper Weight	1 oz	0.5 oz (inner), 1 oz (outer)
Trace Spacing	6 mil (0.1524mm)	5 mil (0.127 mm)
Trace Width	6 mil (0.1524mm)	5 mil (0.127 mm)
Annular Ring	5 mil (0.127 mm)	4 mil (0.1016 mm)
Via Plating Thickness	1 mil (0.0254 mm)	1 mil (0.0254 mm)
Drill Specs		
Minimum Drill Size	10 mil (0.254 mm)	10 mil (0.254 mm)
Minimum Annular Ring	5 mil (0.127 mm)	4 mil (0.1016 mm)
Minimum Slot Size	20 mil (0.508 mm)	20 mil (0.508 mm)
Drill Size Tolerance	Max: +/- 2.5mil (0.0635mm) Typical: +/- 1.0mil (0.0254)	
Drill Positional Tolerance	Max: 2mil (0.0508mm) Typical: <1mil (0.0254mm)	

We will assemble the surface mount components of the board using soldering equipment which we may purchase depending on if we will have access to the soldering stations and equipment at the university based on safety protocols.

8.4 Project Design Problems

During the design process for the Light Saver device, we encountered several problems, both in the concept design, as well as the technical details within the subsystems. We will detail the problems encountered, and understand the issues causing them.

8.4.1 Battery and Power Management

Initially our Light Saver design was going make use of two different batteries. We wanted to maximize the power efficiency and power density of supplying the device, because different subsystems require different levels of power. An illustration of this is that the LED's consume low energy in the order of less than 20 watts if running continuously for 24 hours. Based on our design objects the LED's will only turn on in the scenario that the software meets the different input criteria of the motion sensor and the computer vision allowing so. However, if we compare different subsystems of the Raspberry Pi 3, it requires near of 100 watts of power. We expect the Raspberry Pi 3 to run continuously, and along with the peripherals such as the camera, we will draw a significant amount of current.

The specifications of the Light Saver device are that it will operate 24 hours without stop, and we must take into consideration environmental and weather conditions that may not allow the solar panels to replenish the battery to allow for this specification to be met. So, the initial plan was to use a Lead Acid battery for the Raspberry Pi 3, and a Lithium-Ion battery for the LED's. But this led to many technical issues which would expand the design cost of the Light Saver device.

One such technical issue is that it is not recommended to use a single solar panel to charge two different types of batteries, especially those of different chemical compositions. This leads to the risk of damaging both batteries, and Lithium-ion batteries are notoriously flammable. Many charge regulators must be revolved around specific models of batteries. This would lead us to either install two separate solar panels, with separate subsystems of charge controllers going to the two different types of batteries.

Installing two separate solar panels of varying wattages to accommodate the different power needs of the batteries supplying the different subsystems would lead to mounting issues and ensuring that each panel has enough clearance to allow maximum peak sunlight falling upon the panels. The better method which we decided to proceed with was to upgrade the capacity of the Lead acid battery to power all the subsystems within the Light Saver device to meet the specifications. This will save money in terms of part ordering, mounting issues, PCB fabrication, etc. The one drawback however from having one battery is that Lead acid batteries have a high discharge percentage threshold, meaning we will have to purchase a larger capacity battery which will increase our cost in that respective.

8.4.2 Person Detection System

This is one of our biggest problems we encountered since we wanted to start and stop the sign when the pedestrian started crossing the road and finished crossing the road. We were looking for a method that was precises safe and was not hard to implement. For this we first thought of using pressure ads at the exit positions of the cross walks meaning that we could have the pedestrian pressure the first pad and then the light would turn on until the pedestrian would get to the other side. This came with multiple problems first would be since the pressure pad would be placed not on the poll but on the floor, we would need to run wiring from the pressure pad to the poll.

For this same reason it would only cover the entrance of the cross walk and it would have a certain thick ness that meant that people might not step on this mat and if they would not the machine would not notice or activate when needed. If this would happen this could even cause a bigger confusion of the person stepped on the mat at the other side since then the light would think there would be someone at the other side but there is actually someone exiting the cross walk. Also, this meant if there were people crossing from the same side this would mean that we could cause a confusion on when to actually stop since you can measure when one person crossed compared to the other going the opposite way.

Another problem could be other things that are not people pressuring on the pad let us say someone dropped something out of a car or an animal is walking around. This can cause that the pressure pad activates. At the same time there is the biggest problem by having wired parts like pressure pads we would need communication across the road meaning that we would have to add Wi-Fi or Bluetooth connection to transmit the radio signal of the pressure pad being activated on the opposite side of the road.

Then after discarding the pressure pad solution we tried by implementing computer vision, but this came with some of the similar problems above and included the fact that we needed to account for stronger battery time since we would have the processor running all day trying to analyze of there was people walking In the street and make sure they do not get activated by other things around. In the end we decided to take away the idea of conveying and saving time by getting information from across the road and are suing just amotion sensor to read when a person is present to cross the road. But we are using the present cross walk sings to know when it is the turn of the person to cross the road.

8.4.3 Crossing Time

In our project we are also letting people cross the road, at the begging we expected the ability to overcome the placebo effect that those buttons on each corner of the streets telling the streetlight that there is a person there. One of our objectives was to actually create an implement that would take away this saving time on the light by only giving pedestrians the right of way when there was actually a pedestrian. This was not easy because we first encountered the fact that to do this, we needed to communicate with the light somehow to know when it was actually the pedestrians turn to check if there was a pedestrian and this communication is not something that is easy for us to gain. Also, it if not reliable for testing since we would need to constantly test it at a light that would have to be down or not working for us to be able to not cause an accident.

8.4.4 Mounting and Correct Positioning

One other problem we have encounter is getting the corresponding pole and make it so that it is sturdy enough to handle different weather changes meaning that we need this cylindrical pole to go with the laws that are implemented din the united states. And at the same time make sure that this pole can handle the weight that we are giving it. We looked at many options, but this also meant that we had to get a way to mount our box of implements to t and this was a situation to where multiple ideas were passed around until we were able to come with the final design that is not like the ordinary, but it still does what the law requires and follows what we need. This is a pole that is under ground and comes up to which we get a holder that goes around the pole and drills into the bottom of the box and then we mount the sing to the box, making this method efficient and possible.

Another problem we have encountered is the positioning of where our Light saver will be going. When we started the entire ideas at the beginning, we considered tackling left and right turns but then we noticed that what we really wanted to solve was mostly just right turns since they were the mayor problem. Meaning that we needed to position the light saver where it does not get covered by other signs but at the same time it is far ahead so that cars have enough time to stop and give the right of way, so it has too farther back. Also, it must be close enough so that the camara can implement computer vision on the crosswalk light meaning that it has to be able to see if pedestrians have the right of way. This placing us in the position to place it close to the sidewalk to be able to since people and the pedestrian light bit also have enough time for the cars to get alerted by the sign and have time to stop.

8.4.5 Processor Decision

When it came to choosing between a Raspberry PI a Texas Instrument and an Arduino. It causes some complications we had not al experience with all of these processors, so we did not know which was the best fit for us since we needed it to handle all of the processing of our project and the same time, we needed it to use the least amount of energy to extend the time it really required us to make the project work in darker situations. For this we meat with a computer vision professor at University of Central Florida to ask for advice on what processor really permitted us to run computer vision on without needing large amounts of processing time and space. For this we concluded that a Raspberry Pi was our best route but at the same time we needed to choose which one was the best for us to be at a good energy management and with the corresponding research we decided to use a Raspberry Pi 3 since it was not only the best energy efficient for our necessities, but we had some experience with the usage of it.

8.4.6 Sign Decision

The sign was one implement that caused a problem when preparing and choosing our project implements. This because we did not expect the sing to be a major dent in budgeting. When choosing the sign, it meant that we needed to follow the corresponding sing laws of the united states so that we can use this project around all of the us. To start we needed the sing to be reflective aluminum. Second, we needed the sign to portray the correct message to the drivers and be illuminated at night when the weather is not at is best.

When we started looking at signs, we noticed each sing that was f the corresponding size was over 200 dollars when done with the correct reflective aluminum and portrayed the corresponding message. For this we considered getting the sing maid by us by gathering a right shaped piece of stainless steel and wrap it with reflective aluminum grading paper with the sign as we would like to portray the message. This was also not reliable, so we continued searching and changed our idea by opening to possible sings that also gave the same message and noticed that we were looking for the incorrect sign.

8.5 Project Roles

In this section we will explain in more detail what each participant of the group will be taking responsibility for and what they will have to develop to hand in at the end of the semester. This does not mean we will not be helping each other or working as a team but each person will be lead in each on of this section.

8.5.1 Dilpreet Johal Roles

Dilpreet is the member that has the highest knowledge in electrical engineering. This making him the head of direction when it comes to topics in this area. For this we will be taking command in the following tasks.

- Making sure that the solar panels are working properly and transforming solar rays to energy.
- Configuring the batteries to charge using the solar energy gathered
- Connect camara and motion sensors
- Make sure power is being dispersed correctly
- Working on microcontroller connections

8.5.2 Daniel Guerry Roles

Daniel has some great knowledge on both areas but does feel stronger toward the electrical side he will still be participating on both sides since he has the ability to. The tasks he will be lead on are as follow.

- Daniel will be taking control of mounting the implements all together
- He will take control over making sure the LED lights are programs correctly
- Making sure the LED lights are using the corresponding amount of power
- He will also be helping with the microcontroller connections and programing

8.5.3 Joe McCoy Roles

Joe has encountered some knowledge with computer vision before starting the project. Meaning that he will be taking over more of the software side of things.

- Joe will be setting up the motion sensor to point in the corresponding direction
- He will also be programing this motion sensor to activate the led
- He will be programing the camara to concentrate in the corresponding position to read the images needed.
- Working on the microcontroller

8.5.4 Esteban Pizarro Roles

Esteban has also had past knowledge on computer vision and robot vision giving him the command on the software side to detect the lights state. The task he will be taking on are.

- Programing the computer vision to check on the state of the pedestrian light

- Helping program motion sensor activation
- If sound does gets implemented, he will be taking on this task (extra)
- Working on the micro controller

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10. Permissions

Information Permission University Student (Final Year Project Paper)

DJ

Dilpreet Johal
Fri 11/6/2020 2:26 PM
To: inform@xtronics.com

Hi,

I am a Senior Electrical Engineering student at the University of Central Florida, and I would like to request permission to use photos of your research (from your official website) as part of my group's final year project documentation.

Thank You!

Dilpreet Johal

Reply | Forward

Re: Information Permission University Student (Final Year Project Paper)

N

norma <norma@xtronics.com>
Fri 11/6/2020 2:57 PM
To: Dilpreet Johal

No problem, good luck.

Best regards,
Norma

On 11/6/2020 1:31 PM, Dilpreet Johal wrote:
> https://nam02.safelinks.protection.outlook.com/?url=https%3A%2F%2Fxtronics.com%2Fwiki%2FSealed_Lead_Acid_Battery_Applications.html&data=04%7C01%7Cdjohal%40Knights.ucf.edu%7Cd2c7abab5be14ba3061e08d8828e3cec%7C5b16e18278b3412c919668342689eeb7%7C0%7C0%7C637402894700678019%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C1000&sdata=zPR3iFR1tlZmvhHo8NKXdhVXTWGkothOtJ3hcmrAwIE%3D&reserved=0
> Sealed Lead Acid Battery Applications - xtronics.com
> <https://nam02.safelinks.protection.outlook.com/?url=https%3A%2F%2Fxtronics.com%2Fwiki%2FSealed_Lead_Acid_Battery_Applications.html&data=04%7C01%7Cdjohal%40Knights.ucf.edu%7Cd2c7abab5be14ba3061e08d8828e3cec%7C5b16e18278b3412c919668342689eeb7%7C0%7C0%7C637402894700678019%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C1000&sdata=zPR3iFR1tlZmvhHo8NKXdhVXTWGkothOtJ3hcmrAwIE%3D&reserved=0>

FW: Information Permission University Student (Final Year Project Paper)

Renata Sprencz <renata.sprencz@thinklucid.com>
Fri 11/6/2020 6:21 PM
To: Dilpreet Johal

Hello Dilpreet,

Thanks for reaching out. Please refer to our media kit on our website for the proper use of our images.
https://thinklucid.com/media-kit/
If you use our product images, please make reference to us "Image Courtesy of Lucid Vision Labs."

Thanks and regards,

Renata

From: Dilpreet Johal <djohal@Knights.ucf.edu>
Sent: November 6, 2020 8:47 AM
To: Sales <sales@thinklucid.com>
Subject: Information Permission University Student (Final Year Project Paper)

Hi,

I am a Senior Electrical Engineering student at the University of Central Florida, and I would like to request permission to use photos of your products (from your official website) as part of my group's final year project documentation.

Thank You!

Dilpreet Johal

Reply | Forward

Sara Therner (Trademark) <trademark@arduino.cc>
Thu 11/12/2020 10:14 AM
To: Joseph McCoy

##- Please type your reply above this line -##

Your request (188189) has been updated. To add additional comments, reply to this email.

Sara Therner (Arduino)
Nov 12, 2020, 16:14 GMT+1

Hi Joseph,

Thank you for asking. Of course you may use the product photos for your school project. Should you after graduation continue to work with Arduino technology and develop something public or commercial you can contact us again, because in those circumstances other rules may apply.

Best Regards,

Sara Therner
Trademark & Licensing Manager

This message is confidential and may be legally privileged or otherwise protected from disclosure;
you must not copy or disclose the contents of this message or any attachment to any other person.

Joseph McCoy
Nov 12, 2020, 5:21 GMT+1

#body:
Hi,
I am a Senior Computer engineering student at the University of Central Florida and would like to request permission to use photos of your products (from your official website) as part of my group's final year project documentation.

thank you and Kind Regards,
Joseph McCoy.

Re: New customer message on November 13, 2020 at 1:10 am Inbox ×

Pi Supply sales@pi-supply.com via freshdesk.com
to me

Hi Danielrguerry,

We have a lot of photos on our unsplash page that are free to use https://unsplash.com/collections/8314937/pijuice

Maybe something there is useful?

Best wishes,
Aaron Shaw

NEW! We now offer a number of customisation / kitting services. Click here to learn more.

On Fri, 13 Nov at 1:10 AM , Danielrguerry <danielrguerry@gmail.com> wrote:

You received a new message from your online store's contact form.

Name:
daniel

Email:
danielrguerry@gmail.com

Body:
Greetings.
My senior design group is working on a project that requires the use of the Raspberry Pi board and would like to request permission to use a photo found on this website labeled: PiJuice / HAT PIS-0212

any help would be greatly appreciated.

NE Nicola Early <info@raspberrypi.com>
Wed 11/18/2020 7:55 AM
To: Joseph McCoy

Joseph

Thank you for your interest in Raspberry Pi.

You are welcome to use the images we have available on our website under creative commons, (share-alike and attribution license), please see https://www.raspberrypi.org/creative-commons/.

Good luck with your project.

Regards

Nicola

Reply | **Forward**

On Thu, 12 Nov at 2:44 AM , Joseph.mccoy <joseph.mccoy@knights.ucf.edu> wrote:

Your name

Joseph McCoy

Your email

joseph.mccoy@knights.ucf.edu

Subject

Something else

Your message

Hi,
I am a senior computer engineering student at the University of central Florida, and I would like to request permission to use photos of you products as part of my groups' final year project documentation.
Thank you