Environment Adaptive Automotive Headlight

Automotive lighting system that adapts to environmental conditions such as ambient light and weather conditions.

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Senior Design 2

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1 PROJECT OVERVIEW

The project being proposed is the Adaptive Headlight. The Adaptive Headlight will enhance the safety of nighttime driving by sensing environmental changes and adapting to them by maximizing the illumination of surroundings. Members of the group who will be working on the project are Michael Zeiher, Justin Kleier, Justin Owle, and Ivan Bernal Garcia. Michael Zeiher and Justin Kleier are Photonic Science and Engineering majors. Ivan Bernal Garcia is an Electrical engineering major, and Justin Owle is a computer engineering major. Currently there are no sponsors for this project.

For the advancement in safety of ourselves and those around us while commuting we are proposing the idea of designing an environmentally adaptive headlight. This headlight enables betters the visibility of the driver by adapting to the best option of lighting through optimizing the field of view, brightness and position of the projected light. Factors considered will be the weather conditions and ambient factors such as ambient lighting. As for the safety of oncoming traffic we aim to reduce visual impairments of bright headlights by adjusting the light path to keep the light in essential areas like the road and off the driver’s windshield.

For the electrical side we will research car batteries to learn the amount of power the battery could output when the car is on verse when it is off. Research different current drivers, broken up into two type constant current and constant voltage. Using the data sheet of the selected LEDs we will decided at what voltage and current to run the LEDs at without damaging them. This research will help us decide which LED driver would be most ideal when factoring in things like cost, efficiency and practically. Additionally, if the led drivers do not offer features which allows us to control the LEDs via a microcontroller, we will look into power switches as well to act as a main cutoff line for all of the LEDs. Once the research was completed all the major components needed for the project are to be ordered and tested to show proof of concept. Once the testing is done, we will consult with the all the group members to see which LED driver will be used in the design project. Then make an overall schematic showing with PCB design that will incorporate all the major components.

For the optical portion of this project we will be looking into free space optics and light emitting diodes for light sources. Due to the nature of the project basic optical components such as reflector buckets to steer the LED source light and adjust the divergence and beam density using a lens system. The choice for LEDs is to be able to modernize the headlight system to a brighter more efficient system as LEDs have a lifespan of 50,000 hours compared to the standard halogen bulbs at 500 to 1,000 hours. The second reason for LEDs is that we are to address each LED within a matrix in order to be able to change full beam pattern on the whole system. The rate at which the beam shape needs to change is on the sale of how fast cars pass. Halogens do not immediately dim or turn off whereas LEDs response times are well beyond our needs. To properly analyze the environment to assess the proper LED states we need a variety of sensors such as a camera in which we will look for oncoming cars as well as backscatter conditions from fog, smoke and rain. We will further decide just how fast the camera and analysis system needs to be in order to change our light conditions within appropriate time to make the system truly useful. We will also need to address when the lights need to initially come on. To decide just when to turn the headlights on in the evening we will use an electrooptical device such as a photodiode or phototransistor and processes the return signal through a microcontroller to be able to define at which threshold we need the headlights on for safety and legal reasons.

To verify the condition between rain, fog and smoke when the camera states there is large back scatter, we need to have a sensor to decide when it is raining compared to the other conditions. This is due to fog and smoke needed the fog lights on where rain we do not wish for fog lights as they just produce more glare to oncoming drivers than they benefit the actual sight conditions of the operator. To accomplish this we can solve this solution with an electrical based water sensor, but to add to the optical aspect of the project we will use a laser diode coupled into a medium at an angle of total internal reflection and using simple method of index of refraction interface changes water can cause the laser diode energy to leak and scatter through the interface losing a portion of the transmitted power. We can measure this difference using a phototransistor and be able to distinguish water from rain compared to moist and or dry air in the case of fog and smoke.

2 PROJECT DEFINITION

Within the following subsections we will discuss the motivation of our project and define our goals and objective of which will define our projects capabilities. The capabilities will be consistent to meet not only our goals, but also be able to meet our specified requirements. These specifications are decided by standards within the Department of transportations and other common specifications within the automotive industry. We further the specifications with setting quantifiable aspects of assessing just how well the system will perform and by setting minimum performance criteria in which we should exceed.

The aspects included also are the base methods in which we shall approach the meeting the goals and objectives we define. We present a house of qualities in which we see just how each engineering and marketing requirements affect one another. We break down the entire project into subsections to show just what exactly we need to achieve on a block style breakdown all the while breaking down the responsibilities of each section to a specific member. To further define out project we take a look into some of the headlights that automakers are already implementing into new high-end vehicles.

2.1 MOTIVATION

When driving at night, our field of vision is reliant on the illumination of ambient light (i.e. Street lights), and the headlights on the vehicle. In rural areas illumination can be even poorer due to a lack of ambient light. The risk of being in a fatal crash is three times higher at night versus the day. One of the factors increasing the danger of night driving is compromised night vision. Our depth perception, color recognition, and peripheral vision can be compromised in the dark. Even the glare from oncoming vehicles can temporarily blind drivers. As humans age our reflexes slow down and it takes us longer to recover from being dazed by bright oncoming lights increasing the hazards for nearby drivers. Our goal is to help increase nighttime vision to make nighttime driving safer by creating an adaptive headlight.

2.2 GOALS AND OBJECTIVES

We will start with a brief outline of our goals and to be able to check mark these goals we will define some objectives. The goal of the system is to increase safety of everyone on or around any moving vehicle. The first and foremost objective is to increase the ability to see and be seen, this leads us to we must increase the overall clarity of one’s vision during the night hours. To complete the objective at hand we need to increase the intensity of the headlights such that one can fully illuminate the road and those around it. Another aspect is to adjust the angle of headlight such that the beam is thrown farther. However, this creates the predicament of potentially disorienting and causing temporary blindness to oncoming drivers and potentially the diver of the vehicle of there is a highly reflective sign such as many newer street signs. To meet the goal of a safer experience for all we must have an objective to keep from causing glare from the more intense headlight from reaching oncoming drivers and being retroreflection the operator of the source vehicle. The solution to this is the objective of creating an adaptive system that will take into account the scenarios of what lays in the path ahead and be able to adjust the beam path and intensity such that oncoming vehicles and signs still have enough light projected onto them to be seen but as little direct light to be incident upon them to aid in reducing the afterimage associated with bright headlights. The next goal we wish to achieve is to provide a safer driving experience with inclement weather.

Many people improperly use their headlights such as leaving their high beams on when it actually hurts visibility especially with heavy fog and smoke and with this condition many people do not use their fog lights at all. A big issue especially here in Florida is the not using proper lighting when driving in the rain. Many drivers forget to turn on their headlights when it starts to rain thus making it hard to see them and just as bad many people turn on their high beams which does nothing but irritate and cause visual strain on those in front of them. On top of causing strain to others if the rain is heavy enough the added light will cause more reflections back from the water droplets causing a snow tunnel effect. To also call out snow as a weather condition is necessary but due to our environmental factors, we cannot go into deep analysis of those conditions only theoretical in which many all lighting conditions from rain will apply.

To meet these goals, we have broken down a key few aspects of our method that will assist in completing the objectives. In which will lead us to our best case of achieving our complete goal to create a safer experience for all associated with a routine task of driving. In the following paragraphs there is a breakdown per subject category to isolate the area of expertise of the members of this project.

For optical features we will produce a full retrofit for low and high beams using high output LED’s. The high beam will consist of a bucket reflector to flood the path in front of the vehicle. In depth design of the of the low beam will consist of several LED’s that each will be set to cover a portion of the total FOV such that we can address each LED individually to dim or turn off the LED that is directed at oncoming drivers. As for weather sensing the rain detector will consist of a system of a light source ideally a laser diode, sent through a medium and a detector at the end to measure the power coupled through. The theory for this rain sensor is light is coupled through the material using the physical phenomenon of total internal reflection and when contaminants such as water land on the medium the TIR angle will change due to the different index of refraction at the interface allowing for light to escape lowering the transmitted power at the end of the medium. This will be used as a true false logic for the image processing to decide between rain and foggy conditions.

In this project a car battery will be used to power the components. The electronics associated with this project will be several high-power LED’s for which we will find whether a voltage or current source will be more stable for our demands. As of now there will be 3 major subsystems that need to be powered, the optical sensors, the LED array and the microcontroller or single board computer to control the LED array. The voltage and or current source will be able to be controlled by the microprocessor in which each LED can be controlled in brightness and on off state. To further the power supply demands a main PCB will be established to power the microprocessor, camera and associated sensors.

The camera needed for our application does not need to be of high resolution due to the generic tracking of bright spots and an overall backscatter flooding condition. We are looking into processing options that will be able to handle the ability to process images in a quick manner such that the headlight can operate real time and consistently. We will need a light sensor as a verification of our ambient light state given by image processing this sensor does not need to be much more than a photodiode as it will be more as a double check safety feature to keep headlights from turning completely off in a condition of someone direct oncoming with high beams completely saturating the camera.

To control the brightness of the LED a current limiting transistor can be use. There will be a row of five of LEDs how the low beams which will be controlled by the microcontroller, two LEDs for the fog lights and 2 LEDs for the high beams so a total of around 9 LEDs will need to be powered, 18 LEDs in total if we do both headlights. While in the prototyping phase we plan to either use an AC-DC converter connected to a wall outlet to act as a car battery so we to power the components or use the power supplies in the senior design lab. For the prototype through hole components will be used in order to test out ideas and adapt to a method that works. Once the circuits are realized on a prototype board the next step is designing a PCB board.

2.3 REQUIREMENTS SPECIFICATIONS

Below in Table 1 we list the specifications we must meet for this project. The specifications range from condition-based legality to objective based specifications to quantify the performance of the system. FDOT implements laws in which a headlight must be used leading us to define that the headlights most be triggered off conditions such as it being night, raining, and the presence of fog and smoke. Our objectives are to decrease the negative effects on oncoming drivers so we must effectively reduce the intensity of the light directed at them as they cross through the entire field of view of the headlight.

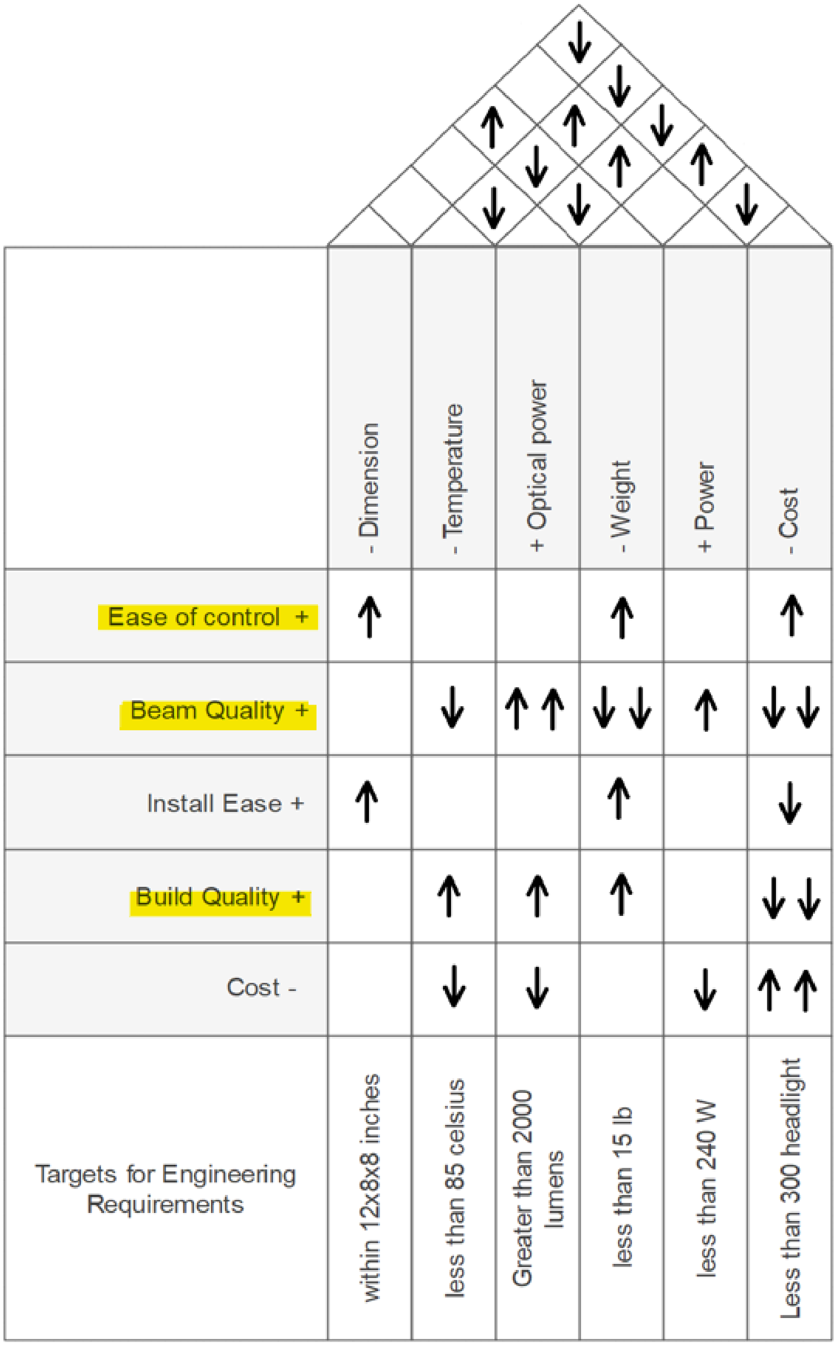
Additionally, we want to set goals for ourselves to achieve in this project. Such as controlling the LEDs using pulse width modulation instead of just having then simply turn off and on. Since having the segments of the headlight turn off fast can be distracting to the oncoming drivers. Another obstacle we have is that the headlight unit must be self-functioning by the power supplied by the car battery. Since the microcontroller we are using is not that powerful we feel is sensor sampling rate of 2-5 Hz can be achievable and responsive enough to sense the light coming from an incoming car.

1.	FDOT (Florida Department of Transportation) standards
2.	Rain, fog and ambient light sensor to signal headlights to turn on
3.	Image processing/ software to control the LED brightness and on off state
4.	Measure a significant drop in intensity within the FOV of the oncoming light source. (Significance of the dimming)
5.	12V at 20 Amps supply limit from car battery (Measure both turn on and constant state)
6.	Control current to LED
7.	Low beam LEDs Controlled by a microcontroller
8.	Sensor sampling 2 - 5 Hz
9.	Must determine if there is an oncoming car
10.	Determine the position of the car or light source
11.	Consider back scatter from the headlight to help determine weather
12.	Measure effective sensing distance
13.	Measure effective response time

Table 1. Specifications

2.4 HOUSE OF QUALITY

The house of quality shown in figure 1 aims to corelate some of our major engineering requirements to market requirements. The purpose of making this diagram is to help us analyze our designs in a more practical way and seeing how changing certain variable can affect other seemly unrelated ones. For senior design 2 we plan to demonstrate the ease of control, beam quality, and build quality of the headlight unit. We feel we can best demonstrate these qualities given our time frame and our confidence from initial research.



	- Dimension	- Temperature	+ Optical power	- Weight	+ Power	- Cost
Ease of control +	↑			↑		↑
Beam Quality +		↓	↑↑	↓↓	↑	↓↓
Install Ease +	↑			↑		↓
Build Quality +		↑	↑	↑		↓↓
Cost -		↓	↓		↓	↑↑
Targets for Engineering Requirements	within 12x8x8 inches	less than 85 celsius	Greater than 2000 lumens	less than 15 lb	less than 240 W	Less than 300 headlight

Figure 1. House of quality

2.5 OVERALL BLOCK DIAGRAM

Figure 2 features the project block diagram, which gives an overall summary of the tasks of each group member. For a project of this size it is important to split of the work evenly so no one member is over burdened, and it is fair to everybody.

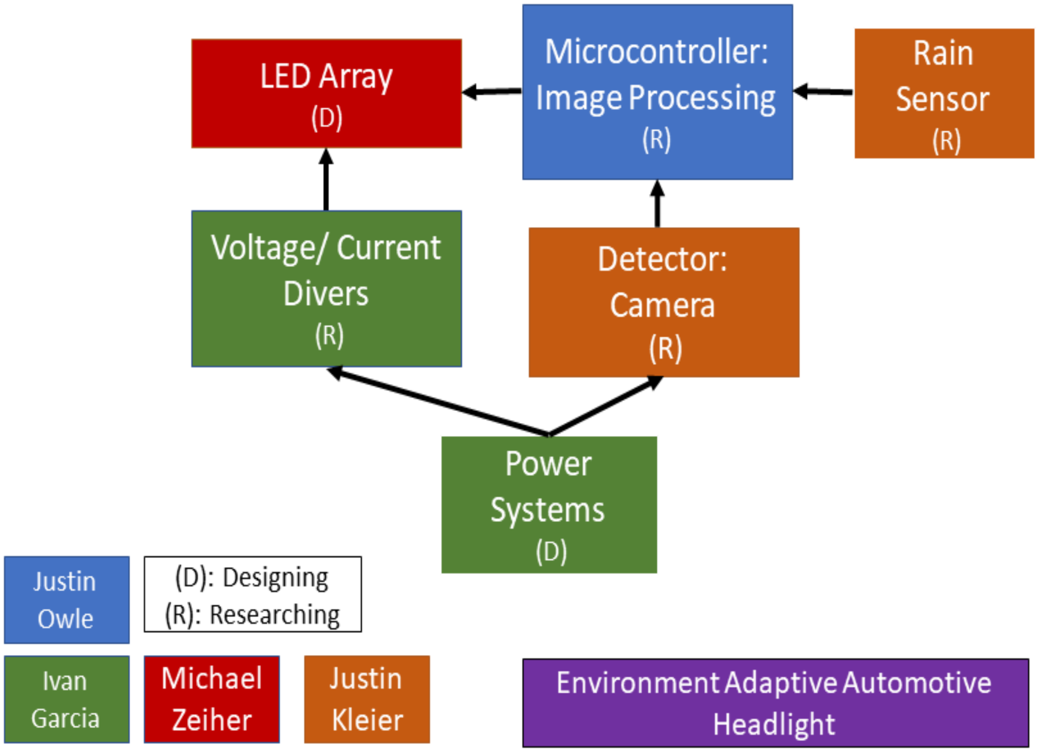


Figure 2. Block diagram of systems and responsibilities.

2.6 SIMILAR PRODUCTS AND BACKGROUND

Current standards prohibit technology that can manipulate the beam of current headlights to be used on the road in the US. Standards permit headlights that only possess two beams, a low beam and a high beam. However, with LED headlights it is possible to create an adaptive driving beam (ADB). By arranging these LEDs into an array, we can toggle power to each LED individually and shape our beam to accommodate a higher illumination of surrounding areas. By being able to illuminate the surrounding areas while driving we can increase the safety of both the driver of the vehicle, and the safety of other drivers on the road. This not only affects drivers but also pedestrians and wildlife that come in proximity with the road. Being able to identify any potential hazards at a further distance increases the driver's reaction time and can prevent accidents.

According to the National Safety Council, approximately one fourth of the driving we do is at night. However, about half of traffic deaths occur during the night. The main cause of this is due to reduced vision, current headlights with the high beams on limit your vision to around 500 feet, or 250 feet with normal headlights. If a car is within 500 feet, the headlights must be dimmed from any oncoming drivers so that they are not dazed. Within 200 to 300 feet of following in a vehicle then the low beams must be used. When driving at higher speed this limits our reaction time and increases the danger to ourselves, and other drivers on the road. If there are hazardous conditions on the road combined with our limited visibility increases the chances of being involved in an accident. Approximately one third of accidents that occur happen during the night.

One solution to improving the safety of night driving is to allow the use of ADB headlights. Having ADB headlights in vehicles on the road can help to make nighttime driving safer due to the heightened visibility of the road and surrounding areas. However, there are concerns with this technology that it may also create its own set of hazards. One concern of this technology is the effect of dazing other drivers if the headlight is not able to properly track oncoming cars. If other drivers were to be dazed it would reduce their visibility and decrease their reaction times. This effect also increases in severity with older drivers. Older drivers have an increased time to recover from being dazed. This technology serves to prevent any dazing of oncoming drivers and effectively cure this problem.

By being able to adaptive drive the headlight beams we can create a safer road environment for all drivers, pedestrians, and wildlife. With ADB we can control what areas the headlights beam is illuminating. Effectively we can control and shape the beam to dim or shut off certain areas to prevent any dazing of oncoming drivers. The beam is also able to be turned toward turns so that the illumination around corners is greater. By using some motors that align with the steering wheel we can effectively able to steer the beam at an angle less than 90 degrees in front of the car. When driving around corners our headlights don’t adapt to the terrain in front of us. They only illuminate the road directly in front us within a certain field of view leaving what’s around the corner poorly illuminated.

When we incorporate a motor to steer the beam around the corner, we can also effectively increase the illumination and increase our reaction time to hazards that lie around corners. For example, if a car were broken down on the side of the road with poor illumination (i.e. rural areas) then they may not be seen until it is too late to slow down and safely pass. This may force drivers to swerve into the oncoming traffic lane to avoid hitting the disabled car and potentially hit an oncoming car or lose control of their vehicle in adverse weather conditions.

Another way these headlights can increase safety is by detecting cars that are being followed. When the high beams are on and a car is being followed the driver of that car can be dazed by the reflections of the headlights through the side view and rearview mirrors. By detecting these vehicles, we can change the shape of the beam to block out the area around the car. When we block out the area around the car the driver is able to see clearly in front of them and have an easier time driving without being blinded. There are a few ways in which this technology can be achieved.

In the current market some vehicle manufacturers have been developing ADB headlights to put into their cars. Currently, a few manufacturers that have developed their own versions of the technology are Toyota, Mercedes-Benz, Audi, and BMW. In this section only Toyota, Mercedes-Benz, and Audi's headlight will be discussed. BMW's headlight will not be discussed because they do not have much information into how they are shaping and adapting the beam to the environment. All the above manufacturers use the same technique in sensing the oncoming drivers. Their technique is to place a camera behind the rearview mirror facing the road. The camera has a wide field of view of approximately 180 degrees so that it can tell when cars leave the field of view of the headlights.

2.6.1 MERCEDES-BENZ MULTIBEAM

In Mercedes-Benz Multibeam LED headlight has an array of 84 LED's in 3 columns as seen below in Figure 3. After the LED chip array, there is a three-stage precision optical system. While the details of the three-stage precision optical system are not known, we can infer that it is made of an aperture, and a collimating lens system to image the beam out at infinity. The aperture allows for each LED's beam to be segmented so that there is minimal overlap in the divergence of the beams bath at large distances. This allows for a tighter edge of the beam when certain LED's are toggled on and off. The tighter edges allow for the beam to be imaged better and prevent any overlapping edges. This prevents and residual light from dazing the oncoming driver.

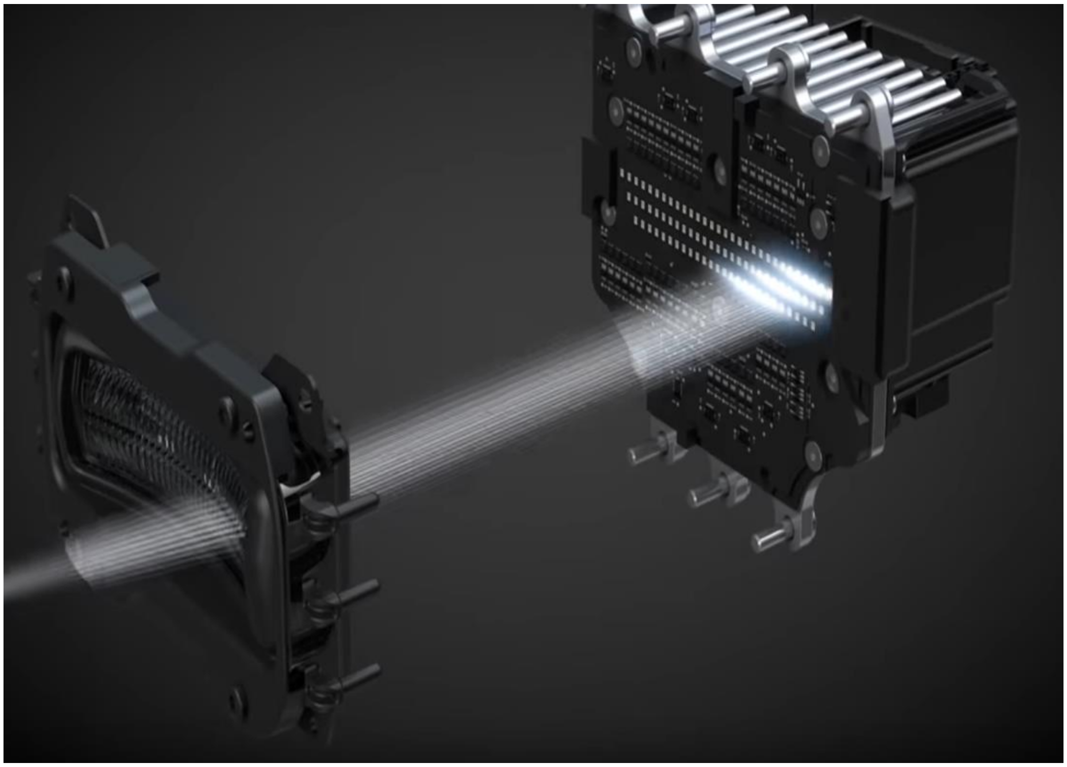


Figure 3. Mercedes-Benz Multibeam

The aperture and matrix of Mercedes-Benz Multibeam LED. The Aperture narrows the beam of the LED’s. Each LED can be individually controlled.

The Multibeam headlight can precisely turn on and off each individual LED. This allows the headlight to concisely be able to control the shape of the beam pattern and maximize illumination of the surrounding areas while minimizing illumination of oncoming cars. This is in part due to the aperture placed in front of the LED array. With the collimating optics imaging the beam out at infinity the image of the beam is able to be shaped by the individual driving of each LED. Since we are can dim or block out the beam shining at the oncoming cars, we can mitigate the dazing effect of our headlights while being able to see the surrounding areas better. This allows for the driver to have a better reaction time to potential hazards on the road as seen below in Figure 4. Also, displayed in Figure 4 is the headlights ability to detect cars that are being followed and turning off the beam shining at that vehicle. This reduces the dazing effect on the operator of that car.

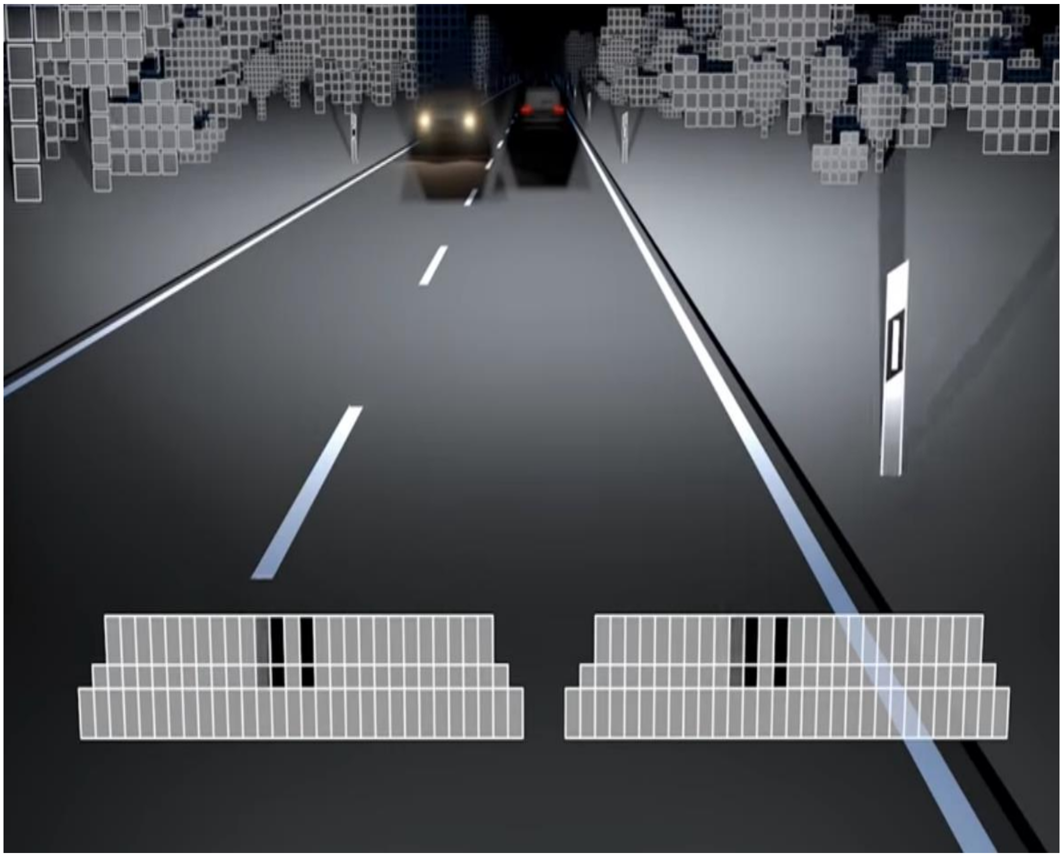
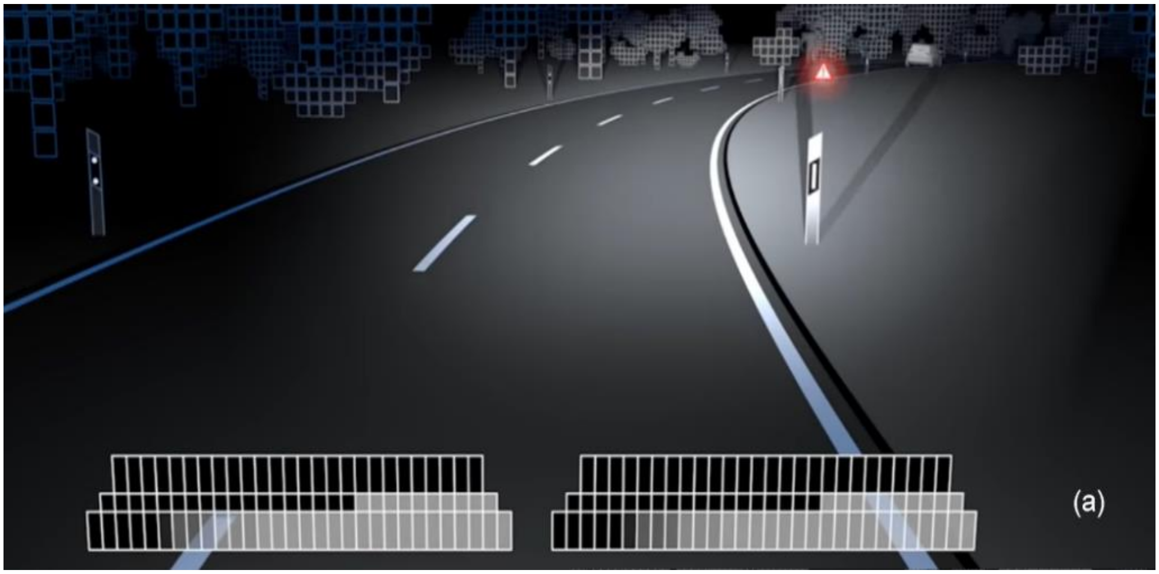


Figure 4. Demonstration of tracking oncoming vehicles and following vehicles while turning off individual LED’s in the array.

As demonstrated above Mercedes-Benz is able to toggle each individual LED and detect oncoming cars and cars being followed. Another feature of the Multibeam LED headlight is the ability to steer the headlight round corners to better detect hazards. Traditional headlights only illuminate the are directly in front of the vehicle and then a small field of view around the front end of the car. However, when driving around corners this minimal illumination is not enough to be able to see and react appropriately to hazards such as disabled cars, pedestrians, and wildlife. When the beam is able to be steered, we are able to allow the driver to detect and react to these potential hazards.

In rural areas where the ambient illumination is minimal increasing the illumination of the road around corners and bends in the road is critical to safe driving. As seen below in Figure 5, when the beams are steered into the corner the area of illumination on the road is greater and allows for an increased reaction time, and larger viewing angle of the road. Also, shown below in Figure 5 is the headlights ability to detect street signs reflections. Being able to reduce the reflections from street signs allows for a higher contrast on the sign making them easier to read. Knowing the rules of the road and being able to read directions from the sign gives the drivers of the road a better driving experience with less erratic behavior creating a safer environment.

Another feature of Mercedes Multibeam LED headlight is the ability to dim LEDs in order to avoid glare from wet roads. When it rains the water on the road can scatter and reflect lighter due to an interface with a lower refractive index. Due to the increased reflections it can become increasing difficult to see the lines on the road with more clarity.



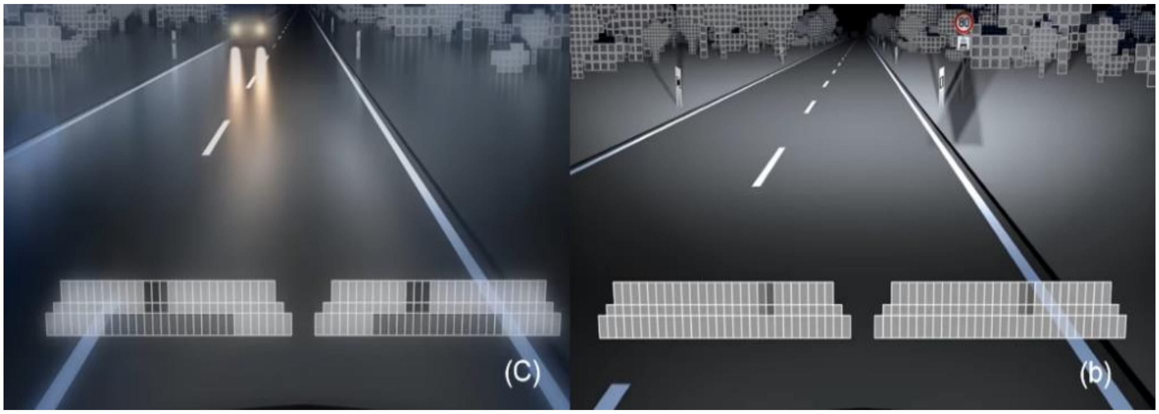
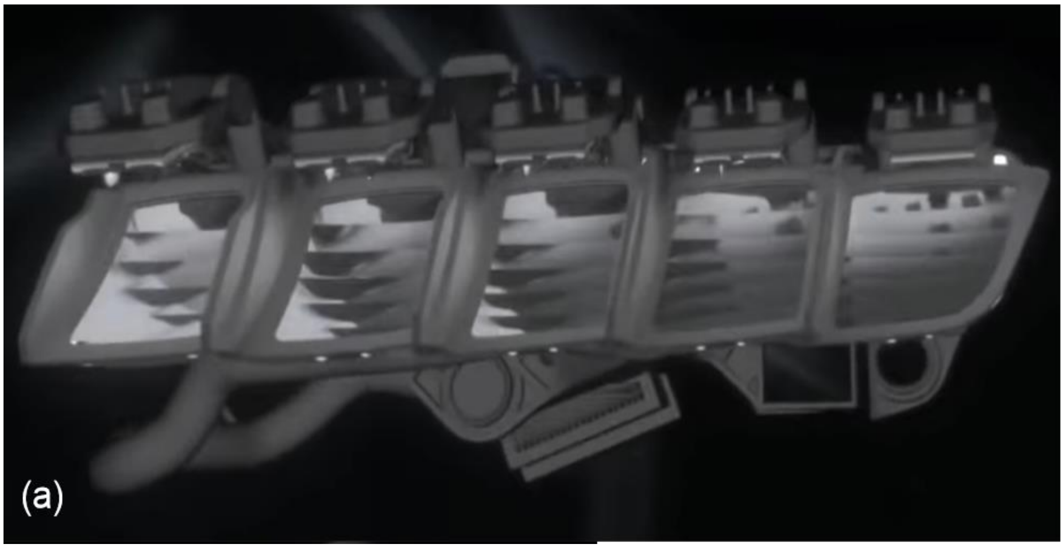


Figure 5. (a) Steering of the low beams around corners for better illumination. (b) Detection of street signs and diming effect of headlights to reduce reflections. (c) Dimming of low beams during adverse weather conditions to reduce reflections from wet surfaces.

2.6.2 AUDI HD MATRIX LED

Audi's design of their headlight is quite different than Mercedes-Benz. Audi has an array of 25 LED's, that are divided into 5 groups. Each group of 5 is placed overhead of a reflector. When the headlight is placed in the automatic setting, the vehicle will automatically turn on the high beams when it detects the car is out of a township and at speeds greater than 18.6 mph or 30 km/h. The matrix LED dims the LED's in 64 stages, while masking out other vehicles creating millions of possible beam patterns. Oncoming traffic and cars being followed are masked out while illumination of adjacent areas and between masks are still fully illuminated. The design of the headlight can be seen below in Figure 6.



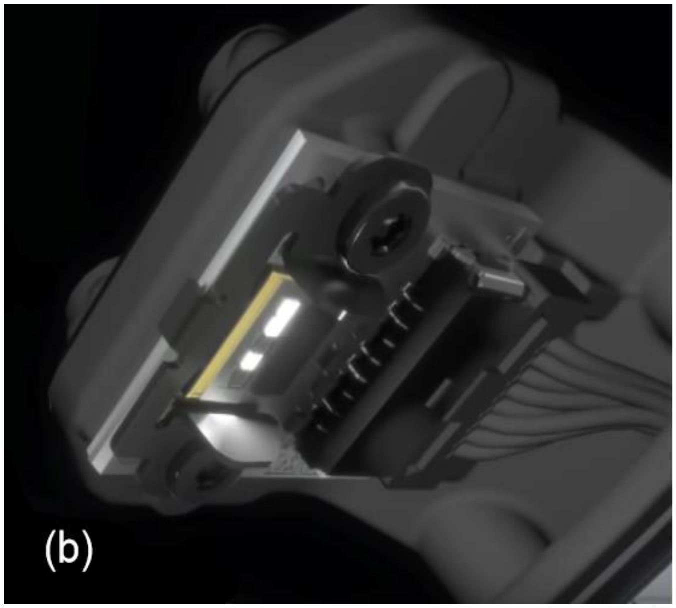


Figure 6. (a) The reflector design of the headlight with the overhead LED modules. Each LED reflector module has its own segment for the overall field of view of the headlight, allowing for masking of oncoming vehicles. (b) LED module with individually controlled LED’s.

The car detects vehicles within 300-400 feet in front and lowers from high beams to low beams, and then masks the car in front. Having the high beams on more often allows for greater visibility, especially around corners. With the enhanced visibility it allows drivers to detect hazards an additional 30 m away which allows for an extra 1.3 seconds to react compared to conventional headlights which can be seen below in Figure 7. The Matrix LED headlight system can mask up to 8 different road users with a mechanism free headlight.

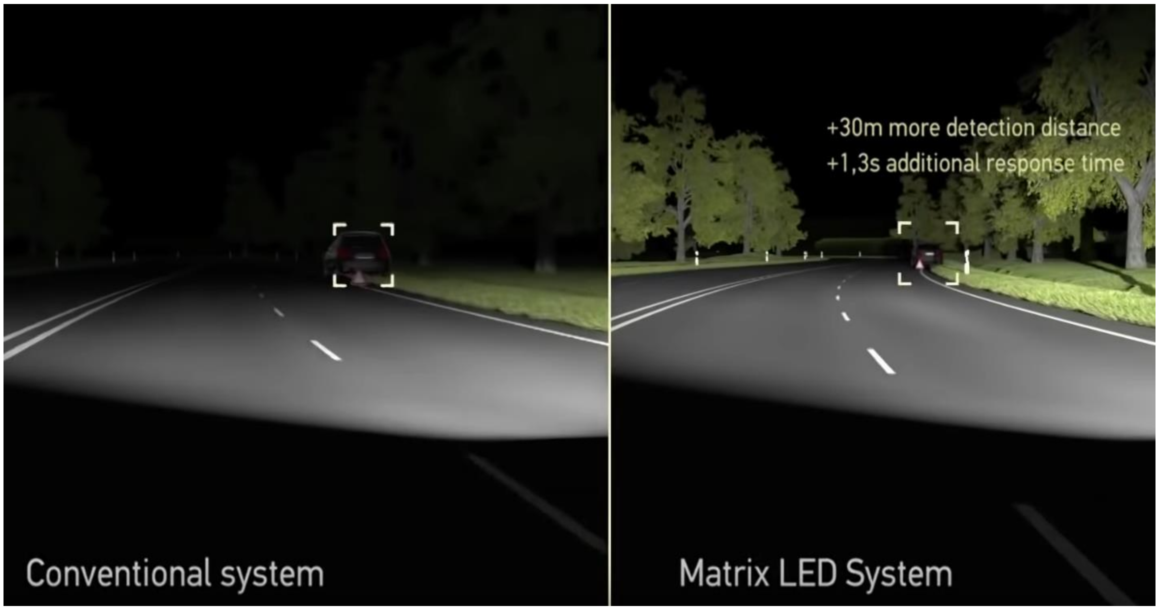


Figure 7. Conventional vs Matrix LED

Audi's Matrix LED system allows for greater illumination of the road and surrounding areas. This increased illumination gives drivers more time to react to hazards on the road.

2.6.3 TOYOTA ADAPTIVE HEADLIGHT

In 2011 Toyota developed their first ADB headlight using motors and levers to mask out oncoming and preceding cars. When the camera system detects an oncoming car, it rotates the headlight toward the oncoming car and then actuates two levers to block part of the beam. In order to achieve this Toyota has a motor attached to the headlight casing and rotates it horizontally so that the center of the high beams is directed at the oncoming vehicle. Then to block part of the beam, there are two levers inside of the headlight casing that are then moved in both the X and Y planes of the beam. The levers are on opposite sides of the headlight with one being on the left and the other being on the right. The two levers are moved and overlapped at the center of the headlight as seen below in Figure 8. Only the overlapping parts of the levers block the light, so we can infer that they may be using polarizers to block most of the light from that part of the beam.

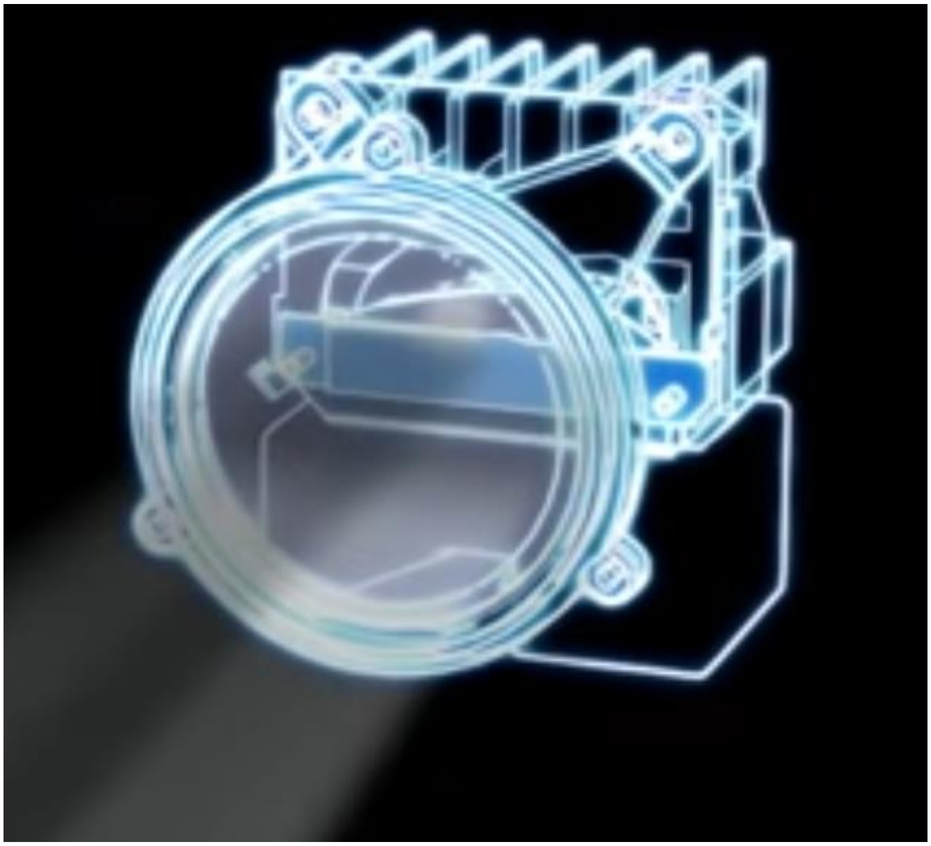


Figure 8. Toyota's ADB headlight using motors to steer the beam left or right, and then using another set of motors to control each lever to mask oncoming cars and block the beam.

Polarizers work by only allowing light with a certain orientation or polarization to pass. Light from an LED source is randomly polarized, meaning that there is light of any polarization being generated. When unpolarized light is shined through a liner polarizer, then only light that was linearly polarized is passed through the polarizer. This allows for a dimming effect since the amount of light passed through a system is reduced. This effect can be seen below in Figure 9. When multiple polarizers of different orientation are overlaid then we can effectively “turn off” the beam in that area.

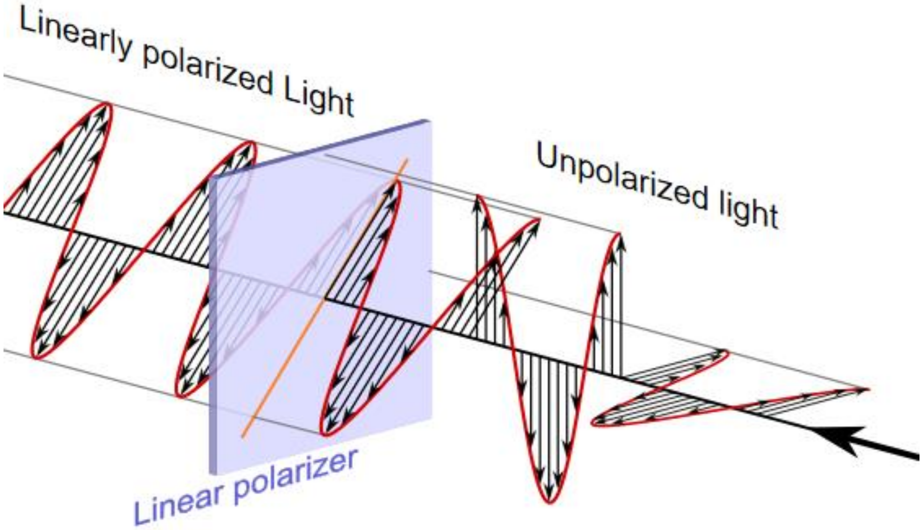


Figure 9. The effects of a polarizer on unpolarized light (i.e. LED). Any incident light on the polarizer that is not linear does not pass through.

Toyota also developed an LED array headlight a few years later. The system controls an LED array according to the driving environment. The illumination is controlled by dimming the high beams in areas to avoid dazzling preceding and oncoming drivers while maximizing illumination of adjacent areas. The system looks to be comprised of a camera module behind the rearview mirror, and a headlight made up of three sectioned LED’s which can be observed below in Figure 10. Each headlight has a center section LED and a left and right LED. With the center LED array controlling the central portion of the field of view and the left and right illuminating their respective sides.

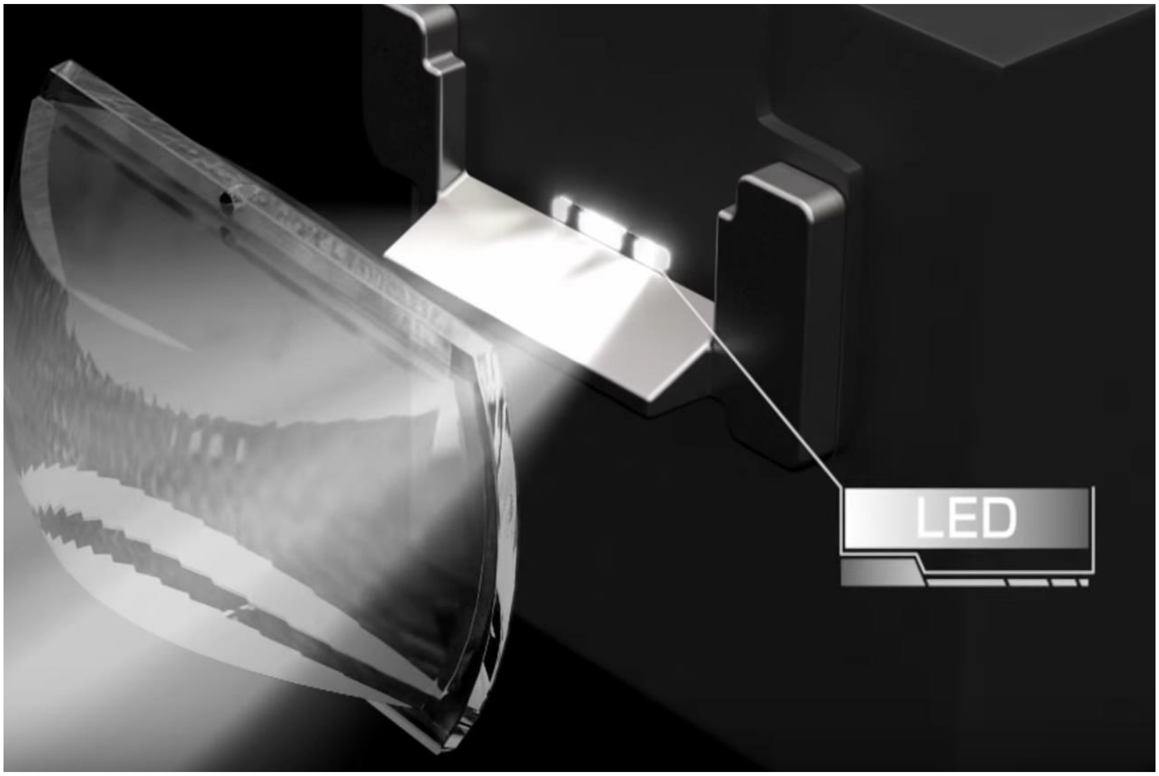


Figure 10. Toyota’s LED Array comprised of three LED sections that illuminate the center, left, and right field of views.

With the segmented design of the LED it allows for the headlight to control the beam with greater accuracy and make more accurate masks for oncoming and preceding vehicles, as opposed to their initial mechanical method. The electronic method of controlling the beam also allows for smaller power consumption, further increasing the efficiency of the car. Using an LED array can also accommodate more vehicles on the road. By creating individual masks for each car, we can illuminate the areas in between the cars. If a mechanical method was used, then we could only block out one large section of the headlight effectively nulling the impact of the driving beam. Using a mechanical approach, we could create more masks but that would incorporate the use of more mechanisms which increases the inefficiency of the headlight. Using an LED array ensures optimal illumination and dimming. The LED array is able to mask and track preceding and oncoming cars as seen below in Figure 11.

Figure 11. Toyota’s LED array masking out a preceding car and an oncoming car while maintaining illumination of adjacent areas.

Since the LED array is able to maintain optimal illumination, and keep adjacent areas illuminated the driver is able to see potential pedestrians crossing behind oncoming cars. Approximately 70% of all fatal pedestrian crashes happen at night. As seen below in Figure 12, Toyotas Adaptive High Beam System (AHS) allows for better detection of pedestrians or potential hazards in the road. By being able to detect these hazards sooner it gives the driver a longer response time so that they can appropriately react to the situation. Better detection and illumination can help to decrease the number of fatal pedestrian crashes at night due to the increased illumination.

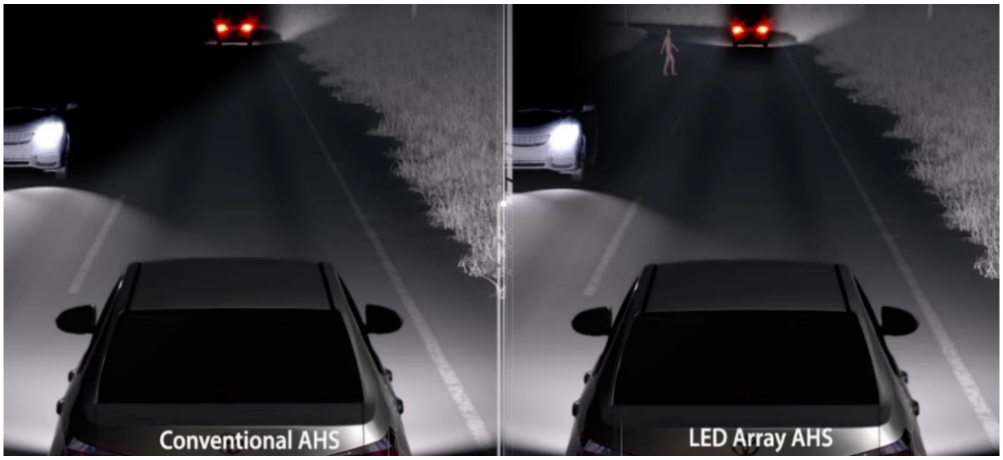


Figure 12. Toyotas conventional AHS system has poor illumination of adjacent areas and is not able to illuminate the pedestrian crossing the road behind the oncoming care. The LED Array AHS allows for a greater illumination of surrounding areas and can illuminate the pedestrian.

The LED array is able to optimize coverage by accounting for vehicle speeds and ambient light coverage. When the vehicle is at lower speeds and in residential areas or urban areas the beams are angled low and with a lower optical power to not dazzle pedestrians. When the vehicle is traveling at higher speeds the headlights are angled up and focused further ahead to increase visibility further ahead. The different focusing of the AHS headlight can be viewed below in Figure 13. Being able to focus the light depending on the environment and driving situation help to increase driver safety and create a safer environment.

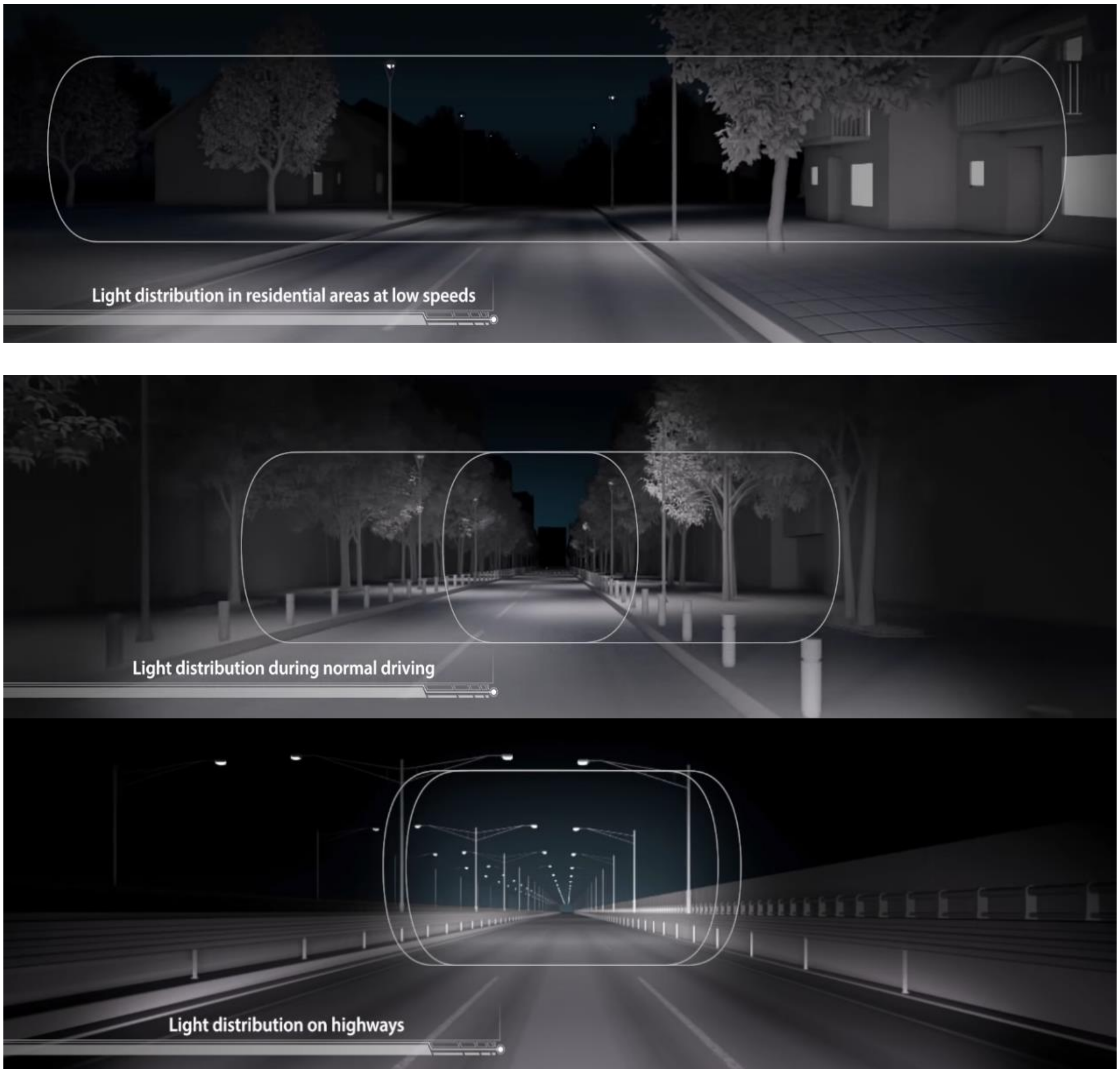


Figure 13. The car focuses the light in different areas to maximize the illumination based on the environment and driving situation.

There are multiple techniques used for creating an ADB headlight. A few of the techniques are used take advantage of being able to individually drive LED's and control them electronically. While another method takes advantage of the polarization property of light and uses mechanisms to move block the light out from individual portions of the field of view. Overall, there are many advantages to using ADB headlight as opposed to standard LED's headlight, or HID headlights.

However, the technique for creating an ADB using mechanisms is inefficient in multiple ways. First, the mechanical components of the headlight are in constant use and have a higher failure rate than using an electronic form to manipulate the beam. The levers only allow for one section of the beam to be masked, as well. This creates an issue when there are multiple oncoming vehicles in the field of view of one headlight. While one diver may not be dazed, other drivers adjacent to the masked car may be dazed. In order to accommodate for multiple cars on the road a larger portion of the headlight would have to be masked out, which would negate the purpose of the headlight all together.

Another issue arises in the manner of electrical power. The headlight is always on and in the high beam setting. The masks just subtract light out from the total beam. Light is still being emitted in the area of the mask; this system is just subtracting that light out. Compared to the Mercedes-Benz or Audi system where the beam is controlled by many different individually controlled LED's. With individually controlled LED's we can effectively block out portions of the beam but shutting off the LED associated with the part of the field of view. This method gives the headlight a greater power consumption efficiency and increases the lifetime of the headlight. Since all the controlling mechanisms are now electrically controlled, we can more accurately turn parts of the beam off and allow for multiple portions of the field of view to be masked while still illuminating the adjacent areas. LED's also have a longer lifetime as opposed to mechanical parts. If one of the mechanical parts were to fail while active, then the masking effect of the headlight would be compromised, and the vehicle would be a safety hazard during nighttime driving.

With multiple different methods for controlling and imaging the beam at infinity, using an LED array and controlling the headlight by electronics provides a higher efficiency for Adaptive Driving Beam headlights. This allows for better control of the field of view of each headlight, and for multiple masks to be created. The more masks that are created the less overall illumination will be present. However, by creating the masks around other vehicles on the road it allows for better illumination of adjacent areas. Illumination of these adjacent areas can help to better detect pedestrians that may be crossing the road and prevent any fatal accidents. Using the control of each individual LED allows for better steering of the beam, which can then be used to illuminate around corners. Better illumination around corners gives drivers a better chance to detect and react to potential hazards on the road.

3 DESIGN CONSTRAINTS AND STANDARDS

The project is defined and limited to real world factors we call constraints and our project must meet specific standards. Both constraints and standards can be self-defined as well as defined by industry, governments and nonprofits. We will cover Constraints some major ones will be economic, time, safety and legality. The necessity of these standards and constraints present the reason in which we can effectively produce our project and be able to make this fall within preset standards for compatibility, quality and safety.

3.1 DESIGN CONSTRAINTS

Design constraints are factors that limit what can be achieved in the project. In order to have a successful project we must identify our constraints to then be able to set realistic expectations of what our project can be. Having constraints limits our choices in what we can design and how we are able to implement those designs. In the following section we discussed six major constraints we have identified and discuss how we will design our project to work around those limitations to build a successful senior design project.

3.1.1 ECONOMIC

We are limited by a budget of around 500 dollars or around $125 per team member, which is the about the same price of a new college textbook. Since this project is self-funded, we believe it is important to keep everything as cost effective as possible. This limits our abilities to create a successful project in several ways. The number of components we can test is limited. We must thoroughly research the part we want to test in order to avoid incompatibles and failure to meet requirements. We must also order parts in bulk, sometimes an item can cost a dollar and shipping would be ten dollars. Each team member buying their components individually would exponentially increase the total cost.

This also limits our ability to prototype. For example, the larger the PCB size you get the more it is going to cost. Therefore, we must take great care into design a PCB that utilizes the board space adequately. You can reduce the size of the PCB by adding more layers, however there is a trade off in cost. The limit is usually around two layers. One-layer PCB cost about the same as a two layer one and having more than two layers becomes more expensive than just having a bigger PCB. Additionally, an error in the design can make the PCB useless and then we would have to reorder, which will cost more money and if we need it to arrive faster it will cost even more. So, this is something we want to get right the first time to avoid those additional cost.

3.1.2 TIME

There are various time constraints that will affect the overall outcome of this project. Most importantly the deadlines for the class. This project is broken up into two parts (semesters). In the first semester we must complete a detailed outline of what the project should be an what we are trying to accomplish. We only have around 3 months to have a finalized detailed report. In addition to the report we must test all the major components to have a proof of being able to make the project work. This time frame limits our abilities to research components, do revisions and order major components. This draft will serve road map in the second semester when it is time to execute our design.

Additionally, since this is a group project, we must make time to meet up, discuss and plan. This time frame affects the team members differently, which then affects the outcome of the project. Not everyone is going to be available at the same time due to time obligations to a job, other classes, and family. So, we must plan accordingly and make sure all of the team members get the information they need and that we meet regularly.

Since time is limited extra care must be taken into ordering components. Some manufactures need lead time in the order week for a single component. Some components may arrive next day, but some can take up to a week or two. This is problematic for the design and prototyping process because ordering a wrong part or forgetting to order a part can put the project on hold. These delays can slow down the whole team if the success of one team member depends on another team member ordering the right part in time.

3.1.3 DIMENSIONS

Standard automotive headlights range in size from small projector housings about 4” in diameter and 5” in depth to large molded assemblies that incorporate the driving lights and turn signals at roughly 14” x 8” x 12”. Since this is aimed more towards an aftermarket retrofit solution, we will aim to make this unit as close to the smallest we can as to fit more applications. We defined our size constraint to be less than 12” x 8” x 8”. We decided upon this constraint such that the unit is still smaller than most molded headlights while still providing ample room for the components as this will be a prototype so not all aspects of components will be as small as they possibly be. The reason for a less refined project is due to our time and budget constraints. Ideally if time and money was less of a concern we can shift and redesign our components and overall structure to make for a smaller unit.

3.1.4 ENVIRONMENTAL

For this project we would like to hold our standards as close to a production standpoint. To achieve this, we need to meet environmental standards as closely as possible. One major environmental compliance standard we will adhere to is RoHS which stands for Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment. To achieve this constraint, we will use components that are RoHS compliant and for any parts we manufacture or modify we will be sure to abide by the compliance guide lines. Our biggest run in with this compliance will be most solder and PCB boards due to high use of lead.

We will use a primarily tin based solder for our PCB boards we will opt for copper traces and if buildup of traces needed, we will use a non-lead-based material such as tin. To further reduce our environmental impact, we will aim to use as many recyclable materials as all cars eventually come to an end and will be recycled.

3.1.5 SAFETY

Safety is our biggest concern as this project revolves around increasing the safety of all those who drive or are around moving vehicles. To achieve safety through implementing proper beam selection for environmental conditions and increase lighting dynamics. Actions that allow more light is to be put forward to see further down the road all while decreasing light in areas such as the eye of oncoming drivers.

Our concern for safety is not just and end goal but a priority throughout the project. One of our key components to this project is high output light emitting diodes. These diodes emit a broad spectrum of high intensity light, these LEDs are rated to emit upwards of 1100 lumens which is the equivalent of a 75 W lightbulb. The luminous power is the total output of the LED measured in lumens high output LEDs are for the most part eye safe as they emit over a large area. Since we are modifying the beam, we will be confining the light to a smaller area increasing the Lux (lm/m^2).

Our eyes are sensitive to high intensity lights in the sense that flash blindness can occur. This flash blindness is the temporary or permanent visual impairment caused by high intensity light. The level of impairment is dependent on the intensity and the time of exposure. This impairment can be identified by the afterimage of a dark spot to even full blindness for a short period of time to permanent if the incident was of high enough intensity or if exposure time was long enough. In figure 14 below we can actually see the burn permanent damage of a laser pointer when exposed to the beam for a prolonged time of just a few seconds. Even though most small laser pointers are deemed low risk due to our natural blink reflex if one deliberately looks into the beam or even has it catching the corner of the eye permanent damage seen below can occur.

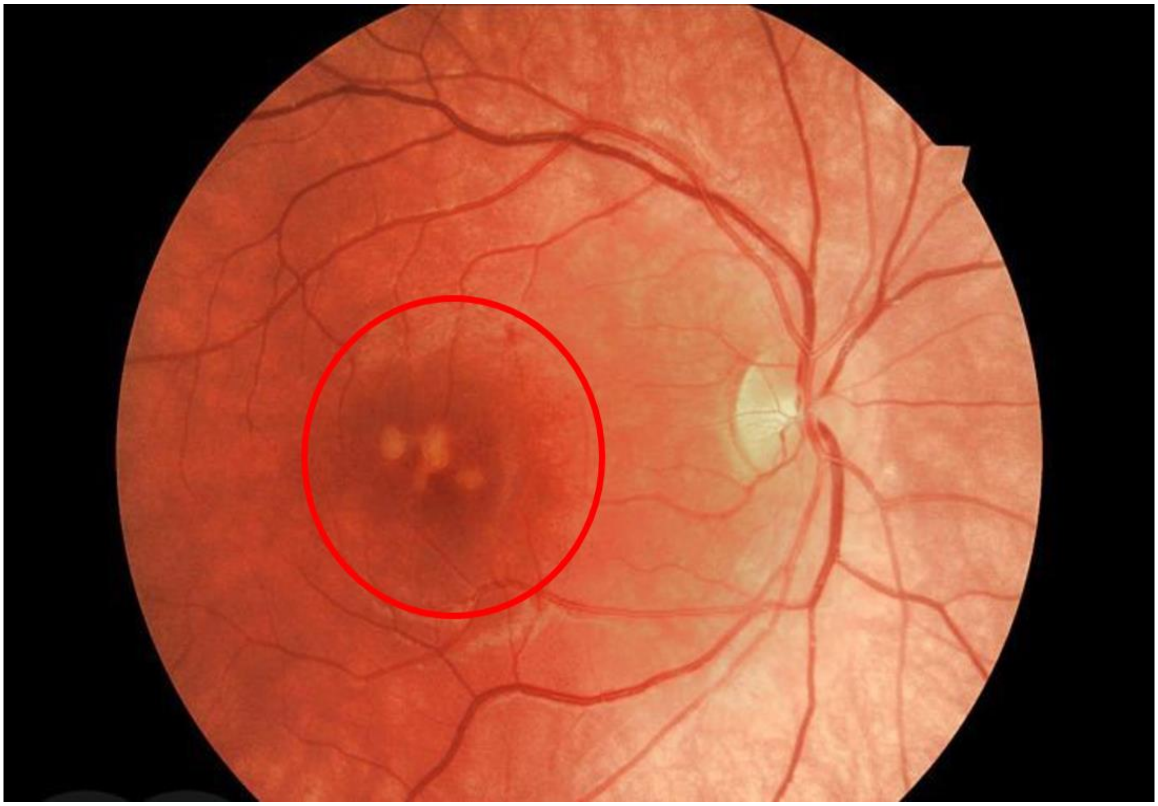


Figure 14. In this figure we see the image of a retina in this case a damaged one. The region circled in red highlights the scaring of the retina caused by prolonged exposure to a handheld laser pointer. Retinal scaring is severe in this image and is irreversible.

Our body has a natural reflex to close our eyes due to exposure to intense lights. Whenever we glance at the sun which should never be done. We feel discomfort and our eyes will naturally close and if we fight this reaction our eyes will water. Fighting this reflex only causes more discomfort and can lead to further impairment or even permanent damage. The choice for LEDs has come down to only sources that emit a light intensity that emit only across the entire visible spectrum and very limited ultraviolet and infrared as our eye does not respond to those wavelengths and we can accidently permanently damage our eyes before we realize what has happened.

Ultraviolet light also causes the lens of our eye to become cloudy. This damage however isn't necessarily just caused by a onetime intense exposure, exposure over time leads to the same result of a clouded lens that is described medically as having a cataract. Below in figure 15 we can see an eye with cataracts and how the clouding causes the incoming light to scatter and reduce image clarity along with decreasing light making it to the retina. The reducing of light to the retina greatly decreases the ability to see clearly or even at all when lighting levels are very low. We care about reducing ultraviolet light exposure even though night driving and headlamps in general do no emit much ultraviolet, but since damage to the lens is cumulative over our lifetime any point to reduce exposure helps.

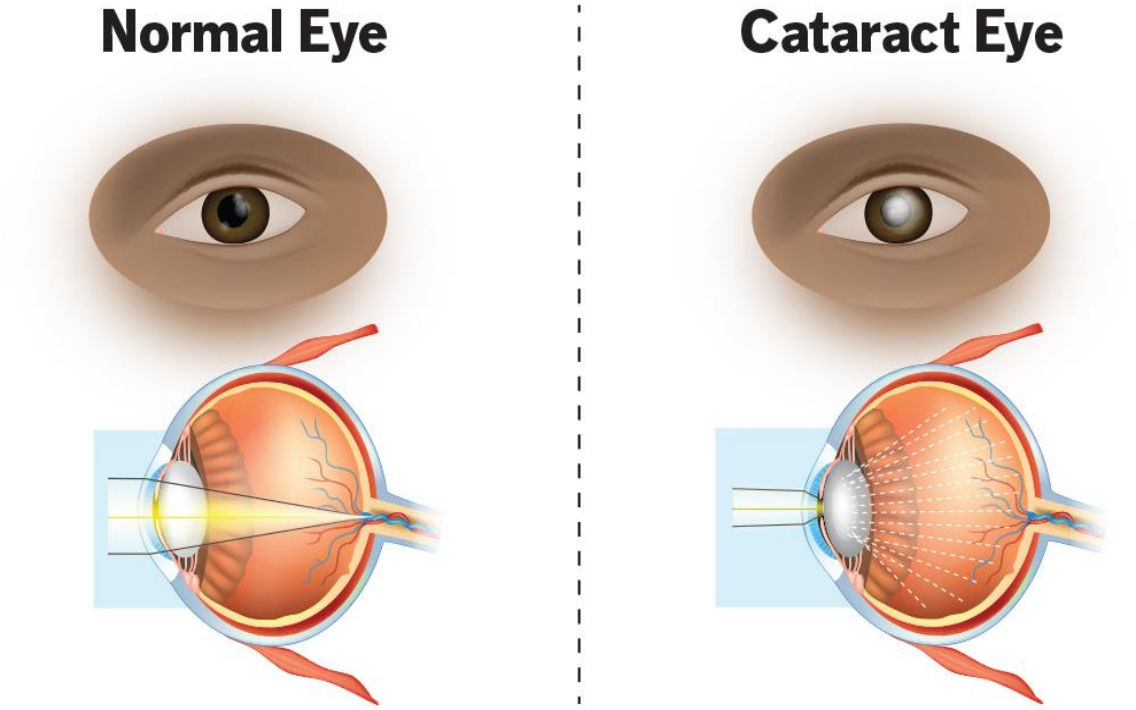


Figure 15. On the left we see a normal eye with a clear lens taking in light and focusing it down to a spot on the retina. Due to exposure to ultraviolet rays throughout our lifetime our lens may become cloudy and have a cataract. This cloudiness causing the incoming light to be scattered and ne be able to properly focus on an object making eyesight blurry. Also, the haziness absorbs a portion of the incoming light limiting one's ability to see in low light conditions.

To further limit exposure to the direct light the headlight must be able to dim and/or turn off when an onlooker is within the projected path. This limits the exposure. Even though our eyes wish to close in the presence of intense light we are sometimes forced to keep them open, one such example is night driving and when the oncoming car misaimed headlights we tend to be exposed to light intense enough to cause some sort of flash blindness whether it be discomfort or the afterimage in the location of the oncoming headlights. This situation normally is not enough to cause enough of an impairment to keep a driver from keeping it safely in their lane but does lead to enough of an impairment to cause discomfort and situations of not being able to see nonreflective objects in the roadway.

Our next concern for safety falls into the category of electrical issues. We must ensure the safety of the user and those installing the project. Vehicles use a variety of standard plugs for headlight bulbs. This helps reduce the risk of shocks and shorting out of supply wires to the chassis. We also will abide by this and make the project in a package that can be simply plugged into the standard headlight supply wire socket. Since we are using high intensity LEDs although more efficient than halogen bulbs, we will be using several such that the current draw on the system will be high upwards of the current higher than a standard halogen or even high intensity discharge bulb.

We will define the current and total power draw of the system to be within the rating of majority of production vehicles. Most vehicles use a standard 12 Volt system and the wiring is fused to a limit of 20 amps in most cases. This will provide ample power to supply the project. In the interest of efficiency and longevity for both the headlamp and the vehicle we will reduce the total power of the system whenever possible without adversely affecting the performance. The LEDs use a fair amount of current roughly 1.5 Amps to 2.5 Amps at 6 Volts, this produces a large amount of amount of light but also heat. To reduce chances of an LED blowing out due to heat soak we will efficiently install heatsinks and avoid heat buildup. By effectively wicking excess heat away reduces the chance of a fires and component failure for all electronics.

3.1.6 ETHICS

Being ethical is the basis of every proper and successful group. For ethical constraints we must abide by standards of quality and honest testing. We do not have any ethical issues with any community, group or amongst ourselves due to the base nature of this project. Our biggest constraint with ethics will come down to testing. We cannot use the headlamp on any public roads due to potentially breaking laws set in place for safety reasons. To be ethical and honest with our data collection we will collect as much real-world evidence on private property. Anything we cannot test on private we will try to simulate in a closed scenario one such incident might be rain and fog testing of which we can simulate in a manufactured environment.

3.1.7 MANUFACTURABILITY

This project must be a complete functioning package that will be able to sustain our testing requirements as a standalone system. For constraints of manufacturability we must design the system such that most of the parts are able to be purchased or be able to feasibly be modeled in such a way that a production manufacturing could be possible. The goal within this constraint is to use as many off the shelf components as possible by designing the system around common specifications. The purpose of the off the shelf ideology is to limit the overall cost and aid in the standpoint of being able to obtain required parts. The parts must be purchasable on the sub component level, we will design out own custom printed circuit boards for all the electronic components (power supplies, microcontroller, and LED arrays) the only component to be purchased as a full component is the

CCD camera so that we will not have interfacing issues and increased cost efficiency.

3.1.8 LEGAL

This project will be designed for implementation on vehicles that will use public roads. Therefore, we must abide by all local rules and regulations. To be clear we will not be testing on public roads as adaptive headlights are not currently legal due to beam pattern regulations instated on the federal level. We will test in a controlled environment as to be able to safely test common conditions that cause safety issues when driving. Since we are aiming to improve safety conditions, we must do our part to test our project in the safest and most ethical means.

As part of our commitment to safety we must do everything in our power to abide by current federal and local regulations. The local level regulations are more relaxed and tend to be less specific than federal regulations at least for headlights and the conditions of use. Federal level regulations tend to apply to production systems of which at this stage the project will only be a prototype and with time and cost constraints we cannot address every aspect. Our compromise State level regulations tends to apply to any system both factory and aftermarket. Our project will be considered an aftermarket and a prototype a means of demonstrating an adaptive system. Since the state level tends to be the least restrictive and defines more of when and how headlights should be used, we will address Florida state standards first.

The first standard we will address is statute 316.220 as stated below.

“Statute 316.220 - Every motor vehicle shall be equipped with at least two headlamps with at least one on each side of the front of the motor vehicle, which headlamps shall comply with the requirements and limitations set forth in this chapter and shall show a white light. An object, material, or covering that alters the headlamp’s light color may not be placed, displayed, installed, affixed, or applied over a headlamp.” [21]

From which we can take away a vehicle must have a headlight on each side and must consist of a white light. Since this is a demonstration, we will construct one headlight but will design the assembly to be usable in both the passenger and driver positions. This is to provide the means that the assembly will operate as a system that will abide by the legality of having a headlight on each side of the vehicle. The statute clearly states a white light of which we assume the definition of white to be a broad-spectrum source covering the visible spectrum. For this project we will use an LED source, this is due to the efficient nature of the devices. We will address different LED color rating from cool to bright white to see which will be best fitting for our defined goals.

The next defining statute pertains to when headlights should be on as defined in Florida statute 316.217.

“Statute 316.217 (1a) - At any time from sunset to sunrise including the twilight hours. Twilight hours shall mean the time between sunset and full night or between full night and sunrise.” [21]

To address this condition of having the lights on during the night we will introduce a light sensor. This light sensor will consist of a photodiode or phototransistor to collect the ambient light and convert to an electrical signal. This electrical signal will be processed by an onboard microcontroller to determine the proper state in which the light should operate. There are also other conditions defined in which the headlight should operate, this statement is as follows.

“Statute 316.217 (1b) - During any rain, smoke, or fog.” [21]

This section of the statute states the headlights must be in during the listed environmental conditions that impair driving. To address all of the above issues we are going to implement a camera into our system that will take into account the conditions ahead of the vehicle. To distinguish a clear day from adverse conditions such as fog, smoke and rain we will specifically look for large amounts of backscatter from the particulates in the air. To do as such we will need a microprocessor capable of image processing and comparison. Of which we will further discuss in another segment.

In theory the light scattering back from the particulates will allow us to infer their presence and roughly how severe the conditions are. The severity will be taken into account when deciding which beam should be on and potentially the overall intensity of the light. There comes a problem with such generalization we know when to turn on the headlights and whether we can use full brightness, but the issue remains how do we tell each condition apart from one another. For lighting conditions both with smoke and fog we will treat them the same as they have a high back scatter that requires us to implement the use of a lower positioned light conveniently named a fog light. During rain we do not need this as the light tends to be low and consist of a wide beam, this will cause reflections off the wet road causing a glare effect to oncoming drivers.

The beam for rain will consist of strictly a low beam as to benefit the oncoming driver. In reality we need to only be able to isolate a raining condition out of the three and this is because it’s the only one that needs a separate beam pattern. Out of the possible conditions that will be triggered by the processing of the camera image they will trigger the same thing a large back scatter. To identify rain, we will use a rain sensor. We will look into two possibilities for rain sensors both an optical and electrical based detector. Whichever detection system we find to be more reliable we will implement into the final build.

Now that we have covered the environmental bases of when must look into the legality of using lighting equipment with multiple beams. The limitations and regulations pertaining to the project are outlined in Florida Statutes 316.237, 316.238. To paraphrase 316.237 titled Multiple-beam road-lighting equipment, every vehicle equipped with headlamps that have both a high and low beam must abide by the following subsection

“(a) There shall be an uppermost distribution of light, or composite beam, so aimed and of such intensity as to reveal persons and vehicles at a distance of at least 450 feet ahead for all conditions of loading.” [21]

This subsection states that the beam that is steered the highest must be intense enough to see both vehicles and people from the distance of 450 ft or greater. The next subsection states,

“(b) There shall be a lowermost distribution of light, or composite beam, so aimed and of sufficient intensity to reveal persons and vehicles at a distance of at least 150 feet ahead; and on a straight level road under any condition of loading none of the high intensity portion of the beam shall be directed to strike the eyes of an approaching driver.” [21]

This subsection allows us to define the point at which we will need the system to turn the high beams off and swap to the low beam. Along with setting the point of aim for the low beams to see at least 150 ft but also low enough to not strike the drivers eye. The second statute pertaining to when high beams should be turned off. Per Florida statute 316.238

“(1a) Whenever the driver of a vehicle approaches an oncoming vehicle within 500 feet, such driver shall use a distribution of light, or composite beam, so aimed that the glaring rays are not projected into the eyes of the oncoming driver. The lowermost distribution of light, or composite beam, specified in ss. 316.237(1)(b) and 316.430(2)(b) shall be deemed to avoid glare at all times, regardless of road contour and loading.” [21]

Per this statute we must maneuver the beam out of the drivers’ eye at any point within 500 ft of an oncoming vehicle. As this law states one must use a distribution of light must be aimed such that the glaring rays are not projected into the oncoming drivers’ eyes. The key word being “aimed”, this allows us a loophole or better defined as an exception into the Florida law in which we will try and demonstrate the maneuvering beam path.

We will have a true high beam, but we will more than likely have to consider our low beam as potentially as higher angle beam due to our attempt to better the drivers’ visibility, we will be using LEDs that might go over the limit of 20,000 cd set by FMVSS No. 108. The work around will be the fact that the headlight will dim and even cut out portions of the beam such that no part of the beam will be directed at an oncoming driver therefore effectively eliminating the reasoning behind the maximum intensity per the federal standard. [22]

The federal standards depict that manufactured headlights abide by SAE J1383 APR85. Within this standard is specifications on durability over time and temperatures and chemical exposure. We will not test this due to these parts of the standards due to the scope of the project and equipment limitations. The standard does define specific points within the field of view of the headlight that must abide by intensity standards. The figure found in Figure 16 depicts the intensity requirement at specific angles from the horizontal and vertical intersect that the headlight must abide by.

For the upper beam specified points are defined by primarily minimum intensity values as well as a window point at the centermost point as this is the brightest point on most standard headlights, The maximum value is declared as to reduce the after image caused to the oncoming driver by the upper beam at farther distances in which the upper beam can legally be used. The minimum intensities are specified such that one can view the road ahead with a beam that is uniform about the vertical axis and provides enough lighting to be aware of all hazards that lay ahead. [23]

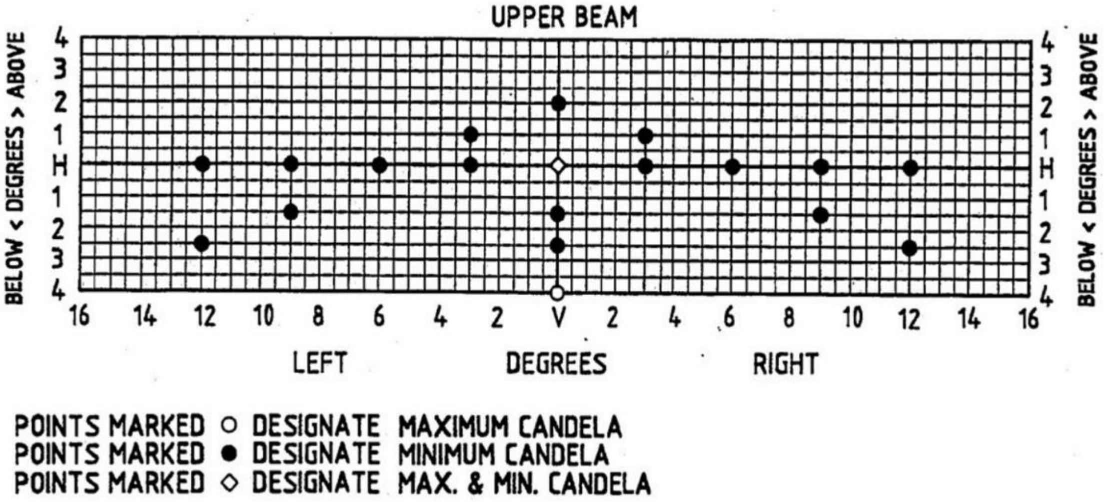


Figure 16. Upper beam point of aim intensity limits. Here we can see there is only one point in which the intensity has an upper and lower limit found at the (0º,0º) point. There is point at (0º, -4º) in which the beam has a maximum intensity limit. Most of the upper beam has only minimums specified this will allow us to be able to produce a very bright high beam and stay within standards.

In Figure 17 below the lower beam depicts more maximum ratings due to the use of the low beam whenever another driver is near. The standards at the test points below are defined such that the beam shape is to have the brightest spot towards the centermost position so that the road is sufficiently illuminated while not so bright that the glare is deemed dangerous to other drivers.

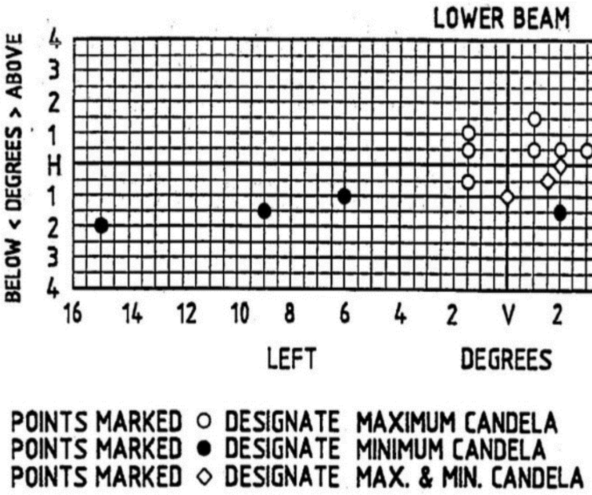


Figure 17. Lower beam point of aim intensity limits. The lower beam is stricter as it has more points of specified maximums due to the nature of use when other drivers are present. So, in an attempt to reduce glare, the intensities were capped at a set standard.

Given our limitations and constraints we will aim to have the beam as a uniform distribution such that visibility is increased. The beam as a whole should be sufficiently intense such that when a LED is turned off or dimmed that there is enough overlap and scattered light to still illuminate any objects in the associated FOV while removing as much glare as possible from onlookers in that same position.

3.2 RELATED STANDARDS

As years pass by, standards come in and out. They are constantly being updated and changed. Although standards are written up to make products safer, easier to use, and easier to build, they do not need to be followed. If you live in a country where a certain standard doesn't exist, you can always adopt other countries standard. Here are a few standards that we are following in our project from both the hardware and software side of standards.

3.2.1 HARDWARE

PD IEC 62861:2017 – This standard comes to us from the UK and is a guideline for principal component reliability testing for LED light sources and LED luminaires. This is a good example of a standard that was made in another country (British Standards Institution) and then adopted by our own because ANSI (American National Standards Institution) adopted it as a standard.

3.2.2 SOFTWARE

Software standards are typically used when there are more than one computer programmer working on a program or the product is well developed. This project will only have one person changing the code so there is no need for any self-standards. In the realm of headlights, almost none of them have code standards that go with them because, if they need them, they haven’t been thought of yet. This piece of technology doesn’t really use a lot of computer code in the first place.

3.2.3 DESIGN IMPACT OF RELATED STANDARDS

The standards and constraints we have defined will guide our project as it outlines the form, function and parts requirements. We must keep our project within budget of 500 dollars due to economical constraints. The project must progress from research to a prototype in a time frame of eight months to design build and present our project as we must deliver by the end of the spring semester for assessment and grading. We have designated a size limit so the unit is to small enough that it can be retrofitted onto vehicle. The dimensions we have designated to be 12” x 8” x 8” this should allow for flexibility as the unit will be designed to be more compact than the given dimensions so that we can allow for any issues that may arise such as a need for larger heatsinks or if the printed circuit boards are not as compact as they can be. With the concerns of environmental health and sustainability we will compose our project of components and materials that are RoHS compliant.

The largest constraint we need to make the project revolve around is safety so we will take all precautions to limit exposure to onlookers as well as shielding the electronic components so that risk of short out and fires is mitigated. We are using voltages 12 V and below so risk of shock is minimal, but due to the high current nature of the LEDs we must properly dissipate the radiated heat from the circuitry. This is heat is dissipated by incorporating the heatsink as part of the housing. We must choose a material that is easily machined, cheap and good at dissipating heat.

We are designing our project to be easily manufactured as the theoretical goal of this unit is to be a retrofit unit therefore it needs to use parts that are easily obtained and must be able to be built in a timely manner and is a consistent and repeatable fashion. The constraint and standards that define the full operation and conditional circumstances for the function of the headlight is the legality of the system. It is defined at what point the headlight needs to be turned on based on the sunrise and sunset as well as the need for them to be on during adverse weather conditions.

These conditions include but are not limited to rain, fog and smoke. The direction and pattern of the beam is defined but the goal of the projects adaptive beam is to eliminate the current legality of beam pattern by allowing the beam to shape in affect to oncoming lights increasing a drivers visibility while decreasing glare and the adverse effects of intense lights creating afterimages or even dazing a driver. These are the primary constraints which will most prominently impact our designs.

4 RESEARCH

In this section we aim to breakdown our research process and discuss different elements our project will have. Additionally, compare the different technologies that are out there and how they functions in order to help us understand and that will help us realize our project. We will discuss the pros and cons and try to narrow down the parts that we will order and test and finalize our decision.

4.1 LEDS

One of the main goals of this project is to increase the visibility of the driver so that we can provide a safer experience for all. To do this we need brighter sources than halogen bulbs. This led us to high intensity LEDs, more specifically ~1,000 lm LEDs that are compact enough that allows us to pack several into a standard size headlight. This allows for an overall increase in the total optical output of the system to well over the ~700 lm provided by a halogen low beam and with the combination of multiple we can provide an output higher than the ~1,200 lm output provided by the high beam.

While brighter light sources can benefit the driver, it does not benefit the incoming traffic as more light leads to more glare and eyestrain for others. To address that issue, we decided we should make the system such that we can dim the portion of the beam that aligns with oncoming drivers. The best solution for sources that could do this once again was LEDs due to their compact size, addressability and response time they are ideal for an adaptive headlight. While we investigate several LED possibilities, we are finding the power consumption to be high compared to that of an individual halogen headlight. This is due to the extremely high output of these LEDs so in terms of efficiency of output per power the LEDs are orders of magnitude more efficient.

4.1.1 LOW BEAM

The lower beam as defined by FMVSS No. 108 “A beam intended to illuminate the road and its environs ahead of the vehicle when meeting or closely following another vehicle.” [2] The Low beam will be sufficiently bright and have the potential to be brighter than the legal limit which is set by the same FMVSS standards at 20,000 cd at the centermost horizontal position of the beam path. This standard is set based on the fact that intense light causes a glare and can disorient another driver by causing afterimage. As we defined in the legal section the state of Florida does not have a statute defining the maximum limit of intensity for any of the beams. However, Florida does define that the low beam must be intense enough to identify vehicles and people from a minimum of at least 150 ft. Most manufactures specify the alignment of the headlight such that the output path is propagated below the horizon at an angle (θ) that is sufficient enough to reach out to a far distance for visibility without the beam reaching above the horizon where it can cause a glare to reach oncoming drivers. This concept is picture below in Figure 18.

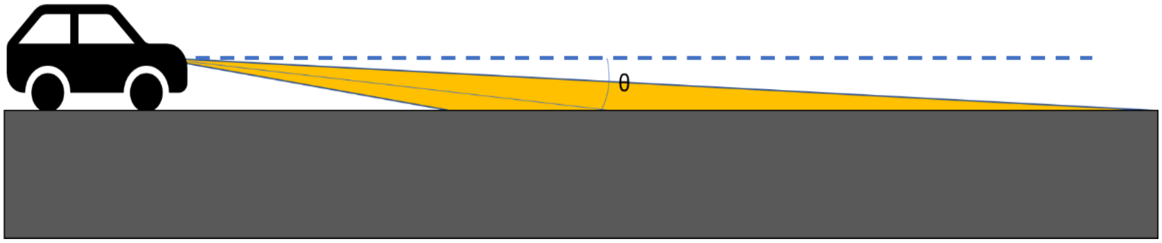


Figure 18. Low beam headlight path of aim. For industry standards the low beam center path of propagation is aimed at a slight downward angle so that the beam does not aim perfectly straight forward at a centerline. By establishing this downward aim, the amount of glare on oncoming drivers is greatly reduced.

Our proposed beam path is demonstrated below in Figure 19. We can justify this beam path as the best for forward visibility. This beam projection is not legal due to the fact that it is possibly the worst projection for glare to oncoming drivers. Our system will look for oncoming drivers and will attenuate or even turn off the LED that is associated with the field of view of the individual LED.

Figure 19. Proposed lower beam path of aim. With our low beam being able to vary intensity of the beam when an oncoming driver is approaching, we propose being able to aim the beam closer to the horizon such that the low beam truly has a farther reach increasing visibility.

For the physical construct of the low beam we will be using several high intensities LEDs each one will cover a portion of the entire field of view covered by the headlight assembly. We are proposing the idea of five segments such that cost is kept down and keeping each portion covered by an individual LED is small enough that the road can still be illuminated indirectly from the adjacent LEDs. The smaller the segment of the field of view covered per LED allows for a more stable and smooth lighting projected down the road. The benefits of more LEDs would be greater overall output intensity of the system along with a more refined selection of which LED to dim or cutoff when an oncoming driver is within the field of view of the headlight. Our proposed beam shape is depicted in Figure 20 below.

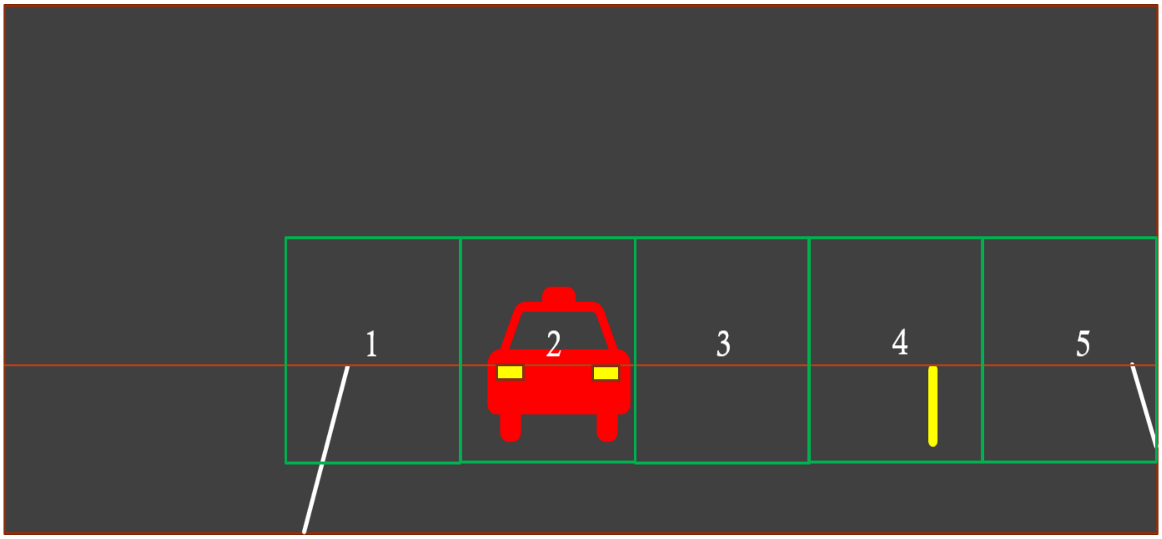


Figure 20. Driver side headlight field of view segmenting. Within this image we can see the FOV breakdown in which the camera will image, and the microcontroller will give true/ false output as to whether a car is present so that we can adjust the beam intensity accordingly

The figure is from the viewpoint of the headlight mounted on the drivers' side in which the centermost path depicted as segment five will have a slight overlap with the centermost beam of the passenger side headlight. We believe five segments should suffice; we will investigate using more LEDs to further provide a physical justification of the proposed benefits of segmenting the beam into smaller portions to cover the whole field of view.

4.1.2 HIGH BEAM

The high beam also called the upper beam will consist of a more conventional design. The upper beam as defined by FMVSS No. 108 "A beam intended primarily for distance illumination and for use when not meeting or closely following other vehicles." [2]. We will investigate two different designs for the high beam. In both cases we will still be using an LED light source. The first of the designs was a standard headlight design since the very first ones and even till now we still see the simple bucket style high beams demonstrated in Figure 21 below the LED is mounted close to center of the reflector bucket ideally very close to the focal point of the semi-spherical to even parabolic reflector. For a spherical mirror the focal point will be at $\mathrm{F} = \mathrm{r}/2$.

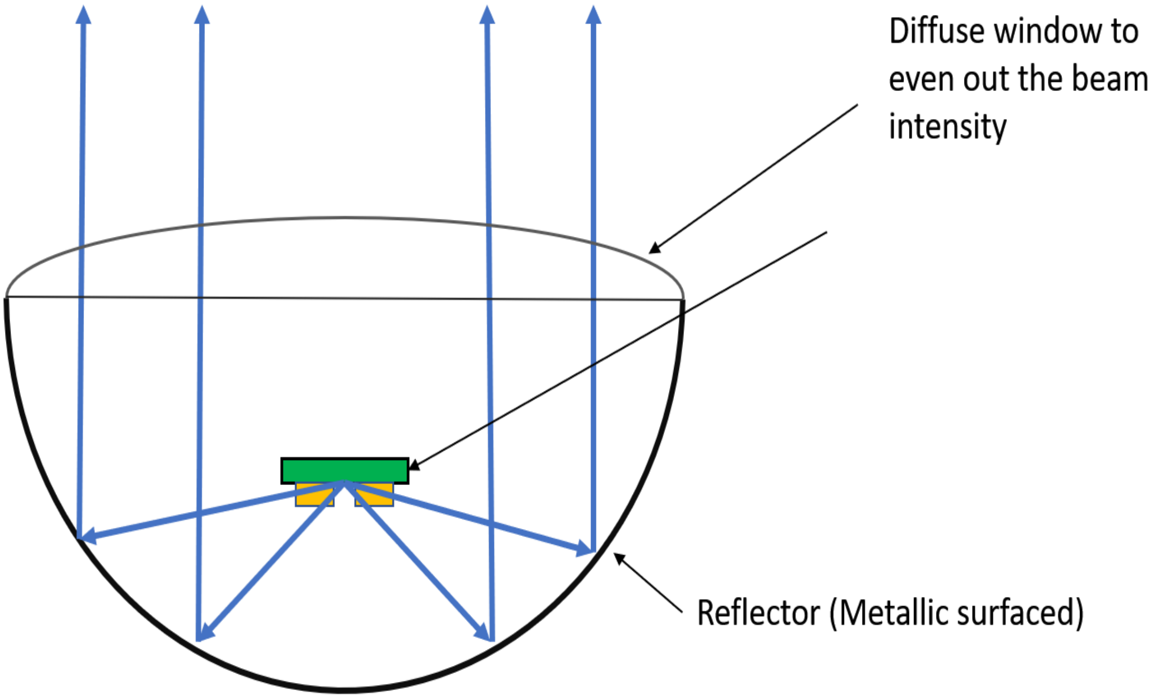


Figure 21. Reflector bucket housing design. The LED assembly will face the reflector such that the beams will reflect back in a near collimated fashion. Ideally, we would like the beam to spread slightly. The outer lens is slightly diffuse and will help scatter some of the light such that more area is visible while still having ample light projected down the road to see out as far as we can.

This allows for the light coming from the LED array theoretically to be projected out to infinity. Knowing that the LED array will not be perfectly at the focal point due to having a width to it and not all of the output being at the absolute center the beam will not be perfectly collimated but rather will have a diverging effect. The slight divergence is ideal as it will spread the high beam out as such to illuminate the surrounding area while being focused enough to provide enough throw toward the centermost forward path from the assembly.

The second design for the high beam will be a projector style assembly, the design is demonstrated in Figure 22. This figure depicts an LED matrix like before but is at the focal point of the convex lens so that the light can be collimated forward.

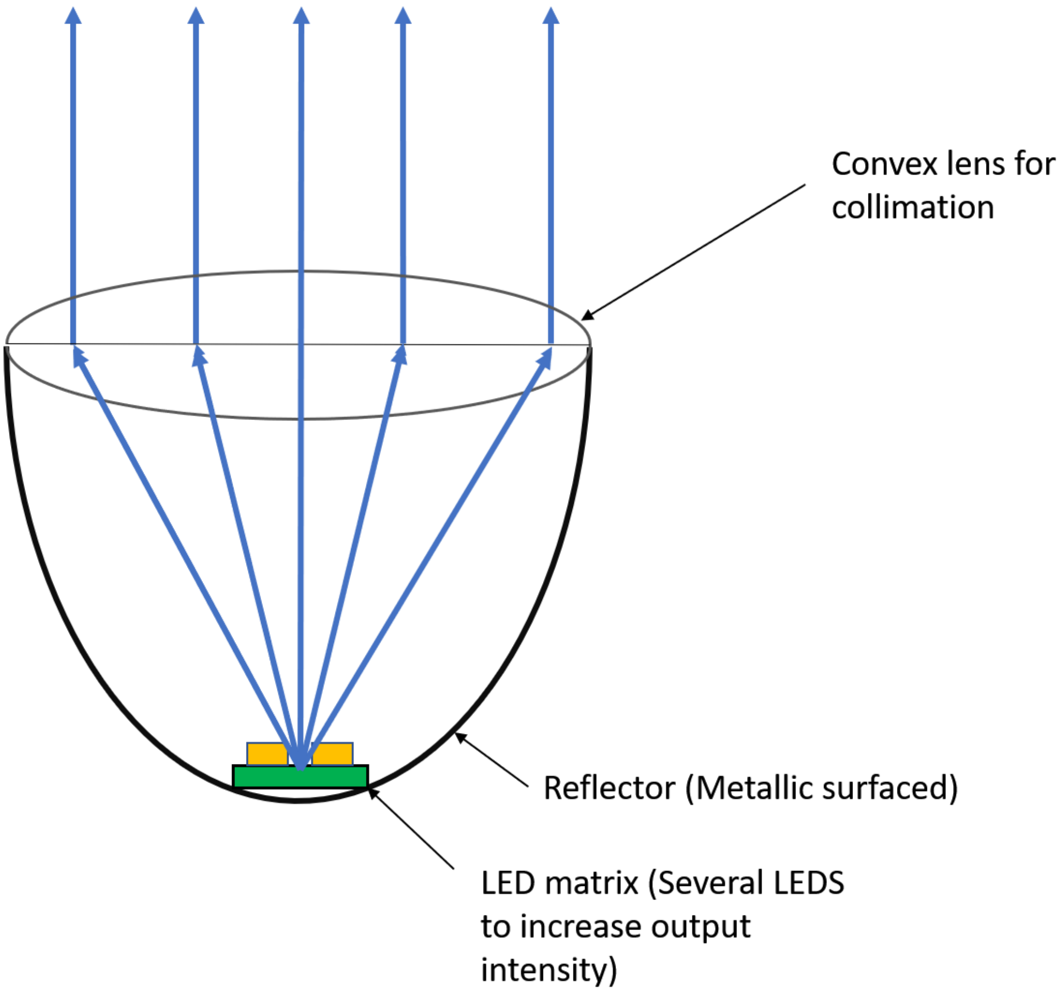


Figure 22. Projector headlight assembly. In this set up the LED is emitting towards the direction of beam propagation the light is near being collimated by a positive lens so that the light can slowly diverge to cover a larger area while still being able to project to far distances.

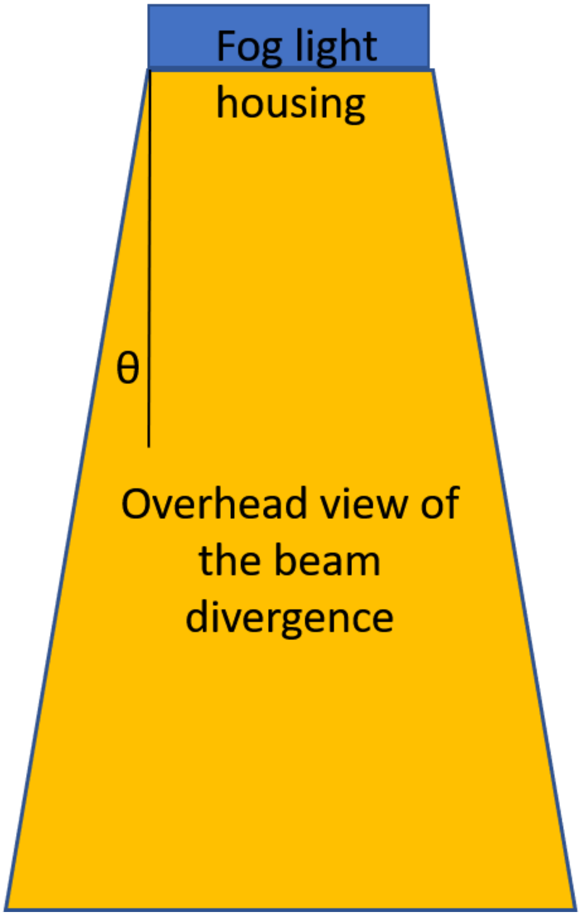
Just like the bucket reflector we will not have perfectly collimated light due to the physical geometry of the LED along with the output angle of the light. This misalignment will allow for some of the light to diverge from the centermost path. This light is good for illuminating potential hazards to the sides of the roadway along with lighting both street and overhead signs.

The benefit of the high beam housing design seen in figure 21 is that it will provide a more even beam distribution due to the frosted window scattering the source light. This however does cut down the total light intensity due to the scattering effect of a frosted window. This design is also very simple, and reflectors of the necessary shape are easily produced with in house equipment. This design also allows for the purchase of a reflector that can be modified to fit the custom LED matrix. The perks of the projector design from figure 22 is that the output is of higher intensity due to the benefit of the higher transmission through a clear lens when compared to that of a frosted window. Another behavior of this design is to produce a collimated hot spot along the optical axis. Now this can be desired for a farther-reaching upper beam, but this limits the amount of light that is scattered for nearby visibility for hazards along the roadside. This lack of scattering can be compensated by keeping the low beam active. The issue that might arise with keeping both beam patterns on is power constraints, if this becomes an issue, we can use a dimmed low beam to provide supplemental light to the nearby roadsides without drawing too much current through the system.

4.1.3 FOG LIGHTS

Fog lights are intended for used during thick fog in which a normal beam is will not suffice due to the scattering nature of fog. When driving through fog it is difficult to see the road due to immense backscatter from the water droplets and other particulates in the air. Many people mistakenly turn on high beams to try and provide more light down to the road to be able to see more, but to their surprise vision is reduced even farther from the glare of the high beams with the backscatter from the fog. The solution from many manufactures is to install fog lights which are mounted low and tend to diverge very quickly only lighting a few feet ahead enough to see the lines at best. Our solution would be to increase the intensity of the fog light to reach further but keep the beam path spread wide enough to see the lines but highly constrained on the vertical optical axis such that the beam does not rise into the fog. This in theory will reduce the glare caused from backscatter due to the beam being projected along the roads surface just beneath the level of fog. Depicted below in Figure 23 is the proposed beam shape.

1a)



1b)

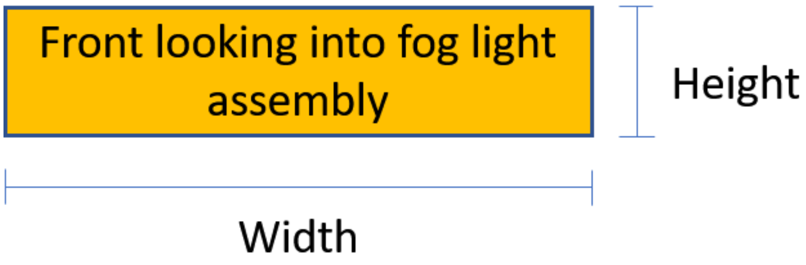


Figure 23. Fog light beam propagation profile. a) This is an overhead view of the fog light beam path the beam is to have a wide profile that diverges at a quick rate such that the edges of the lane can be illuminated along with the entirety of the lane. b) In this image we are looking directly at the front of the fog light output. The beam is to propagate with a width that expands at a greater rate than that of the height. The height as discussed above is to be kept to a minimum to

project the light further down the road before the light is high enough above the ground to shine into the fog.

The fog lights for this system will be similar to that of the first proposed design of the upper beam. In which there will be a back reflector and the beam will be collimated back forward but without the reflector being spherical as we wish to shape the beam into a rectangular propagation more so confined vertically while diverging upon the horizontal axis. As we are trying to direct the light further down the road, we need to minimize the beam distortion. When compared to the upper beam reflector there will not be a frosted window, although it would even the intensity distribution out it will also cause beam distortion and scattering in all directions. We aren't too much concerned of the horizontal scatter as this light would still be too low to cause glare upon the driver. The vertical scatter cause by the window would be unacceptable so for the benefit of overall visibility we will sacrifice the even intensity distribution which we aimed for with the similar high beam design.

4.2 REFLECTOR

For the reflectors in this system they will be of basic design. Ideally, we would find reflectors that we can incorporate into our system and design the physical layout and geometry around the mass-produced reflectors. If we must produce our own due to desired specifications, then we will do such out of aluminum as it is affordable, easily machined and has a reflection band that covers the entirety of the visible spectrum. The reflector is a key aspect for our system as it helps narrow our LED angle of emittance along with shape the beam. This allows for us to adjust the angle of divergence to solely the lens while still being able to transmit as much of the light out of the system in a predictable way.

4.3 LIGHT SENSORS

To sense the surrounding environmental condition of night or day we will need a light sensor to detect if there is a need to turn on the headlights. We will be able to do this with a phototransistor by setting the threshold point at which it is dark enough to turn on the headlights. To take this a step forward we will use this same sensor to help determine if the high beams should be on. We know that there is no need to use high beams on well-lit roads since there is ample lighting to warn of hazards. So, to conserve energy and increase headlight life expectancy it would be of no benefit to leave them on. We will use the microprocessor to determine at which current level we need to adjust the lighting from off to on and determine is the high or low beam needs to be actuated.

4.4 WATER/RAIN SENSORS

Florida law requires headlights to be on at any point when is rain is present no matter how light it might be as conditions change drastically. Therefore, we need the system to take in an input from a sensor to determine if it is raining to quickly and efficiently abide by this law and provide the benefit of being able to be seen by other motorists. We are looking into two different ways of detecting the physical presence of rain. The first method is electoral based in which there is an open circuit that has several contact pads very close so that the presence of moisture even as light as a mist will complete an electrical path providing a signal back to the microprocessor in which the proper lighting can be turned on. The second method is to take a laser diode and couple its output into a material such as an acrylic at the critical angle. This is presented below in Figure 24.

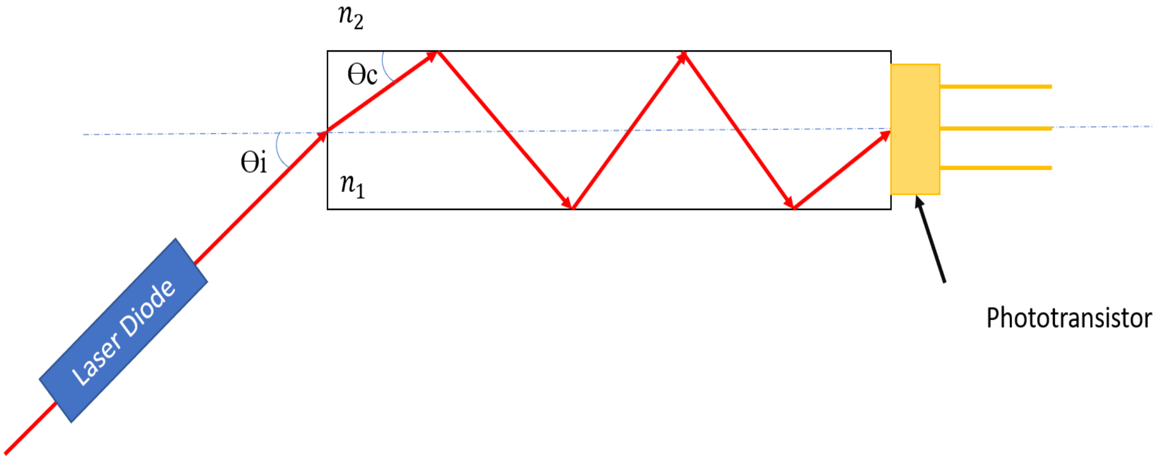


Figure 24. Light coupling by total internal reflection demonstrated using a laser diode, transparent medium and a phototransistor.

This allows the light to be coupled through and at the point of exit we can place a photodetector to measure the output. The theory behind this principle is that the critical angle is dependent upon the index of refraction difference at the material interface. When the index of refection difference is large with the index of the traveling medium larger than that of the outer medium the light will be totally internally reflected up to a certain angle. Now if the outer index of refraction is to change such as water on the propagation medium the critical angle to keep all the light contained will actually be decreased. In principle if we align the system at the air surface interface all the light will be coupled but when a contaminant such as water lands on the surface the laser light will leak out of the interface causing a drop in the power of light coupled at the far and of the propagation medium. This is imaged in Figure 25.

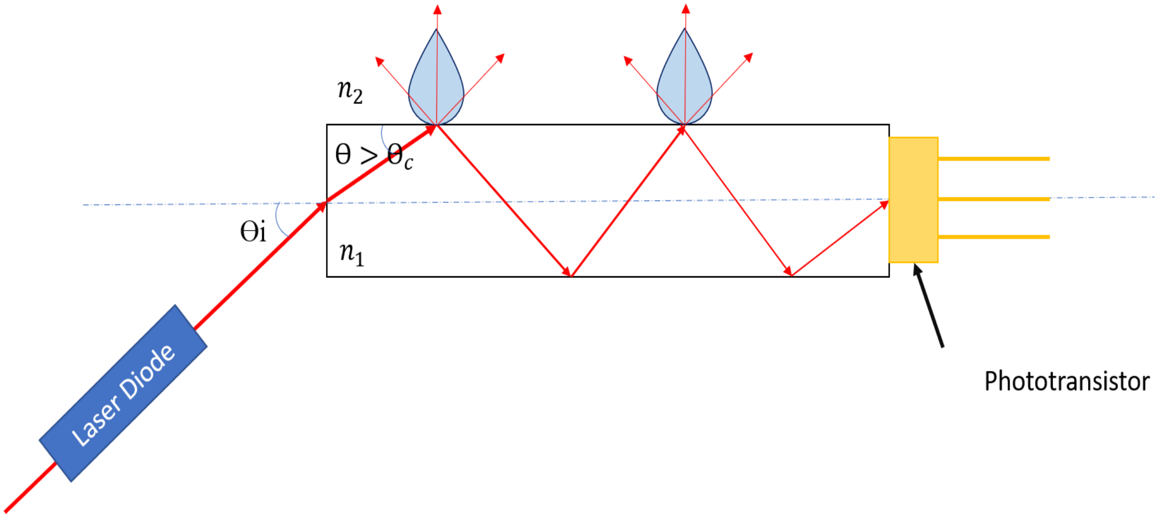


Figure 25. Light coupling and loss by internal reflection and scattering due to mismatched index of reflections at the interface demonstrated using a laser diode, a transparent medium and a phototransistor.

In order to create total internal reflection, the material where we want to constrict light to has to have a higher refractive index. By hitting the critical angle and constricting light into a material we create waveguide. The critical angles dependence on the refractive indices of the interface are characterized by Equation 1 shown below.

$$\textbf{(1)}\quad \theta_C = \sin^{-1}\frac{n_2}{n_1}$$

4.5 POWER SUPPLY

In this section we will discuss the power needs of the project and how we will address those needs. Additionally, we will discuss the different technologies that are out there used to power high brightness LEDs and lower power devices such as microcontrollers and sensors

4.5.1 CAR BATTERY

For this project the headlight unit will be powered using a car battery. Most batteries are Lead-acid meaning they have lead plates immersed in acid and that chemical reaction produces a voltage and a current. A typical car battery can supply 12 V at 20 amps for a total power of around $\mathrm{P} = \mathrm{V} * \mathrm{I} = 12\mathrm{V} * 20\mathrm{A} = 240\ \mathrm{W}$. The car battery is meant to a sufficient amount of current to the starter motor to turn on the engine on.

When the car is turned off the battery supplies the power to the car however it can only do this for a short period of time before being completely drained. Once the battery turns on the car engine the alternator takes over and supplies the power to the car and charges the battery for the next startup via AC to DC conversion and voltage regulation as outlined in figure 26. For a typical sedan the alternator supplies around 1260 Watts or 12V at 105 Amps [1]. The alternator supplies a slightly higher voltage than 12 at around 13.5 to 14.5 V to be able to charge the battery.

For this project we are going to assume that we are always getting power form the car battery since the difference between the power being supplied is not significant and the headlights will consume less than the 240 Watt any way. In this project we will use a Vin range of 10 – 15 unregulated voltage from the battery. As shown in Table 2. the charge of the battery drastically declines by a small 0.5 change in voltage. Small changes in voltage can cause a big difference in the brightness of an LED but the LED drivers should be able to adequately regulate the output.

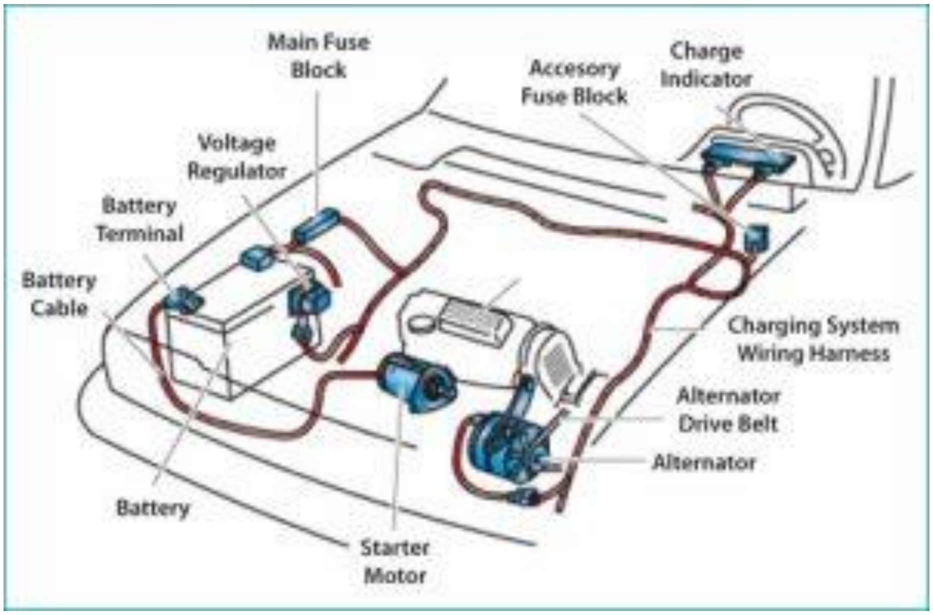


Figure 26. Car Battery power distribution, permission pending

Car battery Voltage	Percentage charge %
12.6	75-100
12.4	50-75
12.2	25-50
12	0-25

Table 2. Car Battery Voltage verses percentage charge

4.5.2 LED POWER SUPPLY

To power the LEDs in this project we are going to research and eventually test whether to power the LEDs with a constant voltage source or a constant current source. LED drivers help power the LED while controlling forward voltage and current, which helps the longevity and efficiency of the LED. An LED is a PN junction the anode is the positive terminal and the cathode is the negative terminal that can emit light when in forward bias mode. The forward current flows through the die and that recombination of holes and electrons causes the die to emit photons. The brightness of an LED is controlled by the current going through the semiconductor die. Connecting the LEDs directly to the battery would destroy the LEDs. Using a resistor would work if you were dealing with low power LEDs, however in this project we will be using LEDs that can draw several amps. So, a high enough power rated resistor would be needed, which would be very inefficient and would still not protect the LED from voltage and current changes.

The forward voltage of an LED changes with temperature. The forward voltage is the amount of voltage an LED needs to turn on. As the LEDs and the car gets hotter the forward voltage reduces which causes the LED to get brighter and hotter and at some point, the LED will be irreversibly damaged, which is referred to thermal runaway. The event were the LED draws more current than it is rated for due the resistance of the LED increasing with temperature. In choosing our LED drivers we must keep our power requirements in mind. For our project we will be using high powered LEDs for which a small change in forward voltage can cause a large change in the forward current flow. For example, according to the data sheet a change in forward voltage from 5.50 to 6 volts will cause the forward current to change from 600 mA to 2400 mA. This gives us a hint that a constant current source would be ideal to prevent these large changes in current flow. Additionally, uncheck current flow can be responsible for the LED failure, so having a limit of how much current flows to the LED and letting the voltage fluctuate seem like the way to go.

There are several formulas and characteristics associated with an LED we need to be aware of. The power of an LED is defined as their forward voltage times their forward current. The junction temperature of the LED is also affected by the ambient air temperature. Since the headlight unit will be close to the engine block which can easily reach over 150 degrees Fahrenheit, we should take that into consideration. The junction temperature can be given by $\mathrm{Tj} = \mathrm{Ta} + \mathrm{Rja} * \mathrm{P}$ (the ambient temperature plus the thermal resistance between the LED and air times the power dissipated) will tell us at which forward current we can run our LEDs without breaking them.

For the LEDs being used in this project there are two ways of customizing this LED. There is a 12 volt and the 6-volt option. Each LED module has 4 LEDs, you can either power them by having 4 of them in series or having them in parallel with 2 strings with two LEDs on each string with each. Each LED has its own turn on voltage when place in the series configuration this causes us to use a higher voltage to properly turn all of the LEDs on. The tradeoff of this configuration is we need to supply less current. When placed in the parallel configuration we need to supply less voltage, but more current has to be supplied in order to have the LEDs light up the same amount as the series layout. We believe it is best to use the 6-volt configuration that way that way we can just use a buck convert instead of a buck boost converted in case the battery voltage drops lower that the 12-volt threshold

4.5.2.1 VOLTAGE DRIVERS

The goal of a voltage source is to deliver a constant voltage to any kind of load or loads you are trying to power. However, based on the load the current will vary. In our case we are going to power multiple Cree Xlamp MK-R LEDs that have a typical forward voltage of 5.85 volts at 1.4 amps and can output a max power of 15 W, 6 V at 2.5 A. The voltage that the car battery supplies will be needed to be stepped down to keep our LEDs with operational range. Since we are trying to step down the voltage a buck regulator will be used. However generally voltage drivers for LEDs are used when you have a large number of low power LED arrays such as an LED strip since the current does not vary strongly and current limiting resistors can be used. regardless we will try and researcher whether it is ideal to use one in our project.

LM2596:

the LM2596 is a switching step down voltage regulator with an adjustable output voltage and a mas output current of 3 amps by Texas Instruments [5]. The IC can provide great efficiency at high load and does not require many output components. Additionally, it has thermal and current limiting protection and it has an enable pin that allows you to control the off and on state of the converter with a simple logic high or low from a microcontroller. Additionally, the design of using this IC can be make easier using the power designer tools from TI. On the down side it does require large capacitor values for stability, which are expensive and take up room in the PCB board,

LMZ12010:

The LMZ12010 by Texas Instruments is a DC to DC step down switching converter that is able to drive up to a 10-amp load and a max power output of 50 watts [4]. This IC has many features, an integrated inductor so fewer external components to worry about, current, temperature and short protection. Due to the high efficiency of around 92 % of the chip there is no external heat sink needed. We also have the benefit of having an enable line to control the IC with a microcontroller. The only possible limiting factor is the need factor is the low max output voltage. If we were to put two 5-volt LEDs in series this IC could supply the 10 volts needed. This IC seems difficult to work with due to the type of external components.

TPS56339:

The TPS56339 is a synchronous buck converter capable of outputting 3 amps with high efficiency by Texas Instruments [6]. By far this IC is our nest contender in terms of constant voltage drivers. It has a wide output voltage range, its small form factor and its price point. Additionally, it does not need many external components and it has and it has and enable line for easier controllability. The IC also features cycle by cycle current limiting and runaway current limiting which is power we face while using these high-power LEDs. Overall this voltage driver meets our expectations, is set at an affordable price and uses widely available external components that also have a small footprint.

LM1085-ADJ:

The LM1085-ADJ is a low drop voltage high efficiency regulator by Texas Instruments [3]. The IC is able to output 3 amps and has a load regulation of 0.1 %. Implementing the circuit is not a difficult task since it is a linear voltage regulator and only capacitors for stability and 2 resistors to set the desired output voltage. It comes with current limiting and thermal protection. Overall, its simple implantation is plus, it is a linear regulator and it is very inefficient and running at 5 V 2.5 amps it would need to dissipate around 15 W of power which would require a heatsink which is not ideal due to our budget and space limitation.

4.5.2.2 Comparing Voltage drivers

All of these Voltage drivers are capable of meeting our power requirements for the LEDs. They are also all buck converters and fundamentally function the same way. In Table 3. we have summarized the main characteristics and features of each voltage driver. The one that stands out is the LMZ12010 it overpowered with the max 10 amps and also expensive at 15.25 per chip which multiplied by nine would be way too much money. For this project we want something overall cheap and simple since we are only dealing with one light and we are basically going to repeat the design for each of the LED drivers.

Overall the LM2596 and the TPS56339 seem like the ideal choice for our project they are at an affordable price and can more than meet our requirements for the LEDs. Additionally, the since the chips are from Texas instruments there are a lot of design resources and well documents guides that will help us customize the chip to our specific needs.

	LMZ12010	**LM2596**	**TPS56339**	**LM1085**
Vin (V)	6 - 20	4.5 - 40	4.5 - 24	2.75 - 29
Vout (V)	0.8 - 6	1.23 - 37	0.8 - 16	1.2 -27.5
Max Iout (A)	10	3	3	3
Efficiency (%)	92.3	82.2	93	83
Cost ($)	15.25	5.72	1.28	2.63
MCU controllable	Yes	Yes	Yes	No
Implementation difficulty	Medium	Low	Low	Low
Package	TO-PMOD-11	TO-263 (7)	TSOT-23-6	TO-263 (3)
Manufacture	Texas Instruments	Texas Instruments	Texas Instruments	Texas Instruments

Table 3. Voltage driver comparison summary

4.5.2.3 Current drivers

The downside of voltage sources is that they try to keep the voltage at a fixed point, and this causes the current to fluctuate, this can be troublesome since the brightness of the LEDs depends on the current passing through it, and too much current can permanently damage the LED. On the other hand, current sources aim to keep the current being outputted at a constant value and letting the voltage fluctuate. The way a majoritic of constant current circuits control the current is by using a shunt resistor that has a predetermined value and reading the voltage across that resistor. In datasheets the resistor is usually referenced as the R_{sense} resistor. Using a transistor to control the current flow would be inefficient since the excess power will be dissipated through heat. So instead we will research different dedicated constant current sources to determine which one fits the needs of our project.

A6211:

The A6211 is a constant current LED driver by Allegro MicroSystems with PWM Dimmable Buck topology Regulator LED Driver by Allegro Microsystems [2]. They are a dedicated LED driver IC. It can provide a max output current of 3 amp and it has thermal shutdown and short protection. And the current limit can be easily set using an external sense resistor. The chip comes with an integrated MOSFET chip with would get rid of the need for external MOSFET switches. Additionally, the driver comes with an adjustable switching frequency to reduce the ripple current. The efficiency of the device does take a hit when the input voltage is lowered. Overall It is a simple circuit to implement, with not too many components to deal with and its small form factor makes is ideal.

LED2000:

The LED2000 is 3 Amp step-down current source designed for high brightness LED applications by STMicroelectronics [7]. The integrated circuit is capable of having the current adjusted and features pulse width modulation to easily control the brightness of the LED with a microcontroller. The IC is able to maintain the output current to a tight tolerance of +/- 7% and has thermal shutdown protection, overcurrent protection, and short circuit protection. Additionally, the IC comes with ad soft start feature to prevent an initial high input of current. The circuit can be easily implemented since it does not need many external components and the datasheet provides the equations necessary to produce the desired output current. As well as the LED manufacturer offers a free design studio to finely tuned the schematic to our power needs. It comes in two form factors S08 with solder leas and the QFPN-8 that has no solder leads just pad directly on the chip.

MAX16820ATT+T:

The MAX16820 by Maxim Integrated is a step-down (buck) constant current voltage regulator dedicated for high brightness LEDs [8]. This is a higher end current driver by maxim integrated with a max output of 25 watts. The IC features current sense and pulse width modulation for controlled dimming and is able to deliver a current with +/- 5% accuracy, which can be set by using a R_{sense} resistor. The IC features a wide temperature range of -40 C° to 125 C ° making it ideal for use inside the engine compartment of the car. The one downside of this IC is that it requires an external MOSFET. Overall however it only requires a small number of external components to function adequately.

LM3409

The LM3409 is a high-power constant current LED driver by Texas Instruments that that can output 5 amps made by TI [9]. The IC is a step-down current regulator with cycle to cycle current limiting and pulse width modulation. An external p-channel MOSFET is needed for the current regulation. The MOSFET has a low adjustable threshold voltage allowing us to analog dim the LEDs, which allows us to maintain the high efficiency.

4.5.2.4 Comparing Current drivers

In Table 4 we can find the summary of the current drivers we researched. Generally, all these drivers can theoretically work on our project. However, we need to consider things like cost and implementation defugalty. By implementation difficulty we mean we consider things like number of pins, number of external components, size of external components and chip. The A6211 and LED2000 are great contenders for our application in terms of price ease of use. The MAX16820 is a great chip with lots of features however having all these features greatly increases the board size has many superfluous components. The purpose of this components mainly serve as protection features for the chip to ensure reliability but for our purposes that will not be necessary.

	A6211	**LED2000**	**MAX16820**	**LM3409**
Vin (V)	6 to 48	3 - 18	4.5 – 28	6 - 42
Vout	6 - 48	0.1 - Vin	≤ 28	1.24 - 42
Iout (A)	3	3	5.55	5
Efficiency	84% (5.5 Vout 2.5 A Iout)	92.5	92	93
Cost ($)	0.99	0.775	2.28	1.36
MCU controllable	Yes	Yes	Yes	Yes
Implementation difficulty	Low	Low	High	Medium
Package size	8-SOIC	8-SOIC	6-WDFN	10-TFSOP
Manufacture	Allegro MicroSystems	STMicroelectronics	Maxim Integrated	Texas Instruments

Table 4. Current driver comparison overview

4.5.3 MICROCONTROLLER AND SENSORS POWER SUPPLY

To power these systems a DC to DC converter is going to be used since we are going to use a 12-volt source. Typically, microcontroller and sensors require 3.3 and 5.0 Volts. Is also known as a step down converter is a DC to DC power converter that takes a variable input DC voltage and then outputs a fixed DC voltage level. In stepping down the voltage causes the current to step up. There are two main types of converters linear and switching. They both fundamentally work in different ways and we will discuss in the following sections which would be best to us in our project given the things we have to power and how we would implement that technology.

However, to power these devices we do not need to worry too much about constant current or being able to control the power flow. We only need to supply the proper voltage and try to pick converters that reduce voltage ripple that can damage the device. As for current we typical just need a certain chip that is able to meet our current draw needs. This is not difficult considering a typical microcontroller for example an ATmega328 only consumes around 1.5 mA and a pixy2 camera for image tracking only 140 mA at 5 volts. So generally, these are low power devices and that need a constant voltage.

4.5.3.1 SWITCHING DC TO DC CONVERTER

Switching converters are vastly more efficient than linear converters. Switching converters typically have a MOSFET that turns off and on at a specific frequency that can be either controlled by PWM (pulse with modulation) or by the internal clock that the chip comes with. The turning off and on helps to control the voltage, for example if you are constantly outputting 12 volts then on average you will output 12v voltage. Now if your outputting 12 volts half the time and the other time 0 volts. Then on average your outputting 6 volts.

Another component of the buck converters is the inductor that smooth out the high current spikes from the off and on switching and a capacitor the smooths out the output voltage. When in the on stage the source voltage charges the capacitor and when in the off state the change in current causes the inductor to generate a magnetic field that provide the voltage to the capacitor. Lastly, we have a diode is used to prevent the back flow of current.

A switching DC to DC converter seems like the most ideal topology to have when powering component whose regulated output voltage varies significantly form the unregulated output voltage. Since we are running off a car battery that ideally will be constantly charging the great efficiency of switching regulators will mainly benefit us from reducing the amount of heat generated on the board.

TPS561201DDCR:

The TPS561201DDCR is a step-down DC to DC converter by Texas instruments that is capable of supplying up to 1 amp [11]. The IC feature short circuit protection, soft start circuitry and over temperature protections making it ideal for automotive use. The converter uses a high 2.5 MHz switching frequency which allows us to use a smaller inductor saving us space on the PCB. In terms of efficiency the IC is vastly more efficient than the linear ICs. However overall the power consumption of this chip is fairly negligible compared to the power consumption of the microcontroller and LEDS. The one point of concern is the Vin max of the controller is 17 volts which cutting it close the 15 volts supplied by the alternator while charring the battery

4.5.3.2 LINEAR DC TO DC CONVERTER

Linear DC to DC converter as known as an LDO (Low-dropout) regulator. A benefit they have over switching converters is that there is no switching noise so no need for an inductor so it easier to implement and there is a reduction in PCB size since there are less components. The major downside of a linear converter is its efficiency, for example if you want to power a senor that need 3.3 V at 0.3 A then the power need to be dissipated by the regulator would be $\mathrm{P} = (\mathrm{Vin} - \mathrm{Vout}) * \mathrm{I} = (12\ \mathrm{V} - 3.3\ \mathrm{V}) * 0.2\ \mathrm{A} = 1.74\ \mathrm{W}$ dissipated power via heat.

If additional heat is created needed a heat sink would need to be include which adds to cost and dimensions. As you can tell by the formula the efficiency of the regulator increases the more Vin = Vout. However, in our application we need voltage regulators to output 3.3 and 5 volts at around 0.2 amps. So, using these types of converters would be efficient. However, since our input voltage and the output regulated voltage we want to have is very different depending on the load we have attached to the to that converter like the MCU and multiples sensors, the chip can run the risk of getting really hot and possibly failing.

TPS715:

The TPS715 by Texas instruments is a low voltage dropout voltage regulator designed for use in ultralow power microcontrollers [10]. The IC comes in different variations the 5-volt output (TPS71550) and the 3.3-volt output (TPS71533) Linear DC-DC converter. The circuit for this regulator is simple to implement with only needing two capacitors. From looking at the datasheet the efficiency of this converts is drastically low. Linear converters are more ideal when in use when the input voltage and the output voltage do not vary by a lot.

	TPS561201DDCR		**TPS715**	
Vin (V)	3 - 17		2.5 - 24	
Vout	3.3	5	3.3	5
Iout (mA)	1000		50	
efficiency	72.4	81.1	22	33.3
Cost ($)	1.79		0.87	
Implementation difficulty	Medium		Low	
Package size	TSOT-23-6		5-TSSOP	
Manufacture	Texas Instruments		Texas Instruments	
Topology	Buck		Linear	

Table 5. Microcontroller and sensor power supply comparison overview

4.5.4 POWER SWITCHES

The last element we need is a switch to control the headlights. We need switches to control the on off status of the hi beams, low beams and fog lights. We might select a LED driver that can control the on/off state of the LEDs but in case we do not have the option to fully cutoff the power going to an LED segment a switch will be necessary. Additionally, the LED drivers may have pulse with modulation capabilities, but we may want to opt out of that and just use a power IC switch to control the LED. Lastly approximately three of the segments in the high beams need to be controlled individually to cut off the light beam hitting the opposing driver. The switch should be controlled by a maximum 5-volt high signal from a microcontroller and capable of handling 15 watts of power or 2.5 amps at 6 volts.

MOSFET (Metal-oxide Field effect transistor):

The most prevalent IC switches are MOSFET switches they are ideal for their small form factor, ease of use and simple interfacing with microcontrollers. MOSFET switches can control the flow of power by either placing the MOSFET in cutoff or saturation mode by changing the gate voltage. The low drain to source resistance will allow us control up to 2.5 amps without having to worry about power and loss and heat generation.

We are considering the NTD18N06L a single N-channel power MOSFET that can handle up to 18 amps and 60 volts [16]. It can handle high switching speeds making it ideal to handle the instantaneous switching needed for controlling the headlight unit. With only 1.8 volts needed to turn the MOSFET on or off it can be easily controlled by any microcontroller. The MOSFET also features a low drain source resistance of 50 milli Ω, which if running 4 amps through it would only generate around 0.2 watts of heat making it very efficient. It lead free and RoHS compliant making it environmentally friendly and safe to use

BJT (Bipolar junction transistor):

A BJT is a current controlled switch that are also a good choice for when you want to control loads with a small current. The small base current of the BJT controls the high current flow the collector to emitter. There are two types of BJT configurations, NPN and PNP, for practical power switching the configuration is NPN is generally used since it has better suited properties of current amplification and better switching capabilities. They are referred as small voltage large current deceives since it can handle large amounts of current but not at high voltage. Modern day power switching is typically done using MOSFETs and IGBTs since they are easier to implement and use and controlling the voltage at the gate is easier than controlling the current at the base.

Another alternative power switch is the 2STD1665, a is fast-switching NPN power transistor [17]. It features a low collector to emitter saturation voltage for low voltage control from a microcontroller. Additionally, the transistor's fast switching is ideal for our project. Its high efficiency is idea for minimize the heat dissipation need for all of the other integrated circuits that will be in the PCB.

IGBT (Isolated gate bipolar transistor):

The IGBT is combination of MOSFETs and BJTs are also good choice for controlling large amounts of power with only a small gate voltage**.** This type of switches is generally on higher end in terms of cost and performance. Their only downside is their switching frequency is small compare to MOSFETS. IGBT also have lower on state resistance compare to MOSFETS making IGBTs dissipate less heat. One of their key features is their high breakdown voltage and high collector current ratings.

One IGBT switch we are considering is the STGD10NC60KDT4 a 10-amp 600 volt rated transistor [12]. It additionally comes with and integrated diode that prevent the back flow of current that can damage are LEDs and LED drivers. This transistor does need a higher saturation voltage than the MOSFET or BJT. Its high collector current limit does gives us more than enough room to adequately control an LED, even multiple LEDs like in the fog lights or hi beams.

	NTD18N06L	**2STD1665**	**STGD10NC60KDT4**
Breakdown V	30	65	600
Vce / Vgs	1.8	0.38 @ 0.3A	2.5
Iout (A)	18	6	30
Cost ($)	0.44	0.94	1.47
Max power	120 W	15	65
Manufacture	ON Semiconductor	ST Microelectronics	ST Microelectronics
Package size	CASE 369C	DPAK	DPAK
Technology	MOSFET	BJT	IGBT
Implementation difficulty	Low	Medium	Low

Table 6. Power switches comparison overview

4.6 MICROCONTROLLER

A microcontroller is a compact integrated circuit designed to govern a specific operation in an embedded system [13]. A typical microcontroller includes a processor, memory and input/output (I/O) peripherals on a single chip. Microcontrollers work the same as a computer someone would use in their day to day life. Desktop computers work by loading programs into their RAM and executing commands based on the programs and the input from the user. Microcontrollers only have 1 program that they load into their RAM. This program will run until the chip is turned off or dies off. It will take input and dictated outputs based on its program. The microcontroller is embedded inside of the housing unit of our project so in order to replace it if it dies, everything would need to be taken apart because the microcontroller is the brain of the headlight. This project will require a microcontroller that has all these features as well as a processor that is powerful enough to process images from a camera.

4.6.1 MICROCONTROLLER USES

Microcontrollers are used in multiple industries and applications, including in the home and enterprise, building automation, manufacturing, robotics, automotive, lighting, smart energy, industrial automation, communications and internet of things (IoT) deployments.

The simplest microcontrollers facilitate the operation of electromechanical systems found in everyday convenience items, such as ovens, refrigerators, toasters, mobile devices, key fobs, video games, televisions and lawn-watering systems. They are also common in office machines such as photocopiers, scanners, fax machines and printers, as well as smart meters, ATMs and security systems.

More sophisticated microcontrollers perform critical functions in aircraft, spacecraft, ocean-going vessels, vehicles, medical and life-support systems, and robots. In medical scenarios, microcontrollers can regulate the operations of an artificial heart, kidney or other organ. They can also be instrumental in the functioning of prosthetic devices.

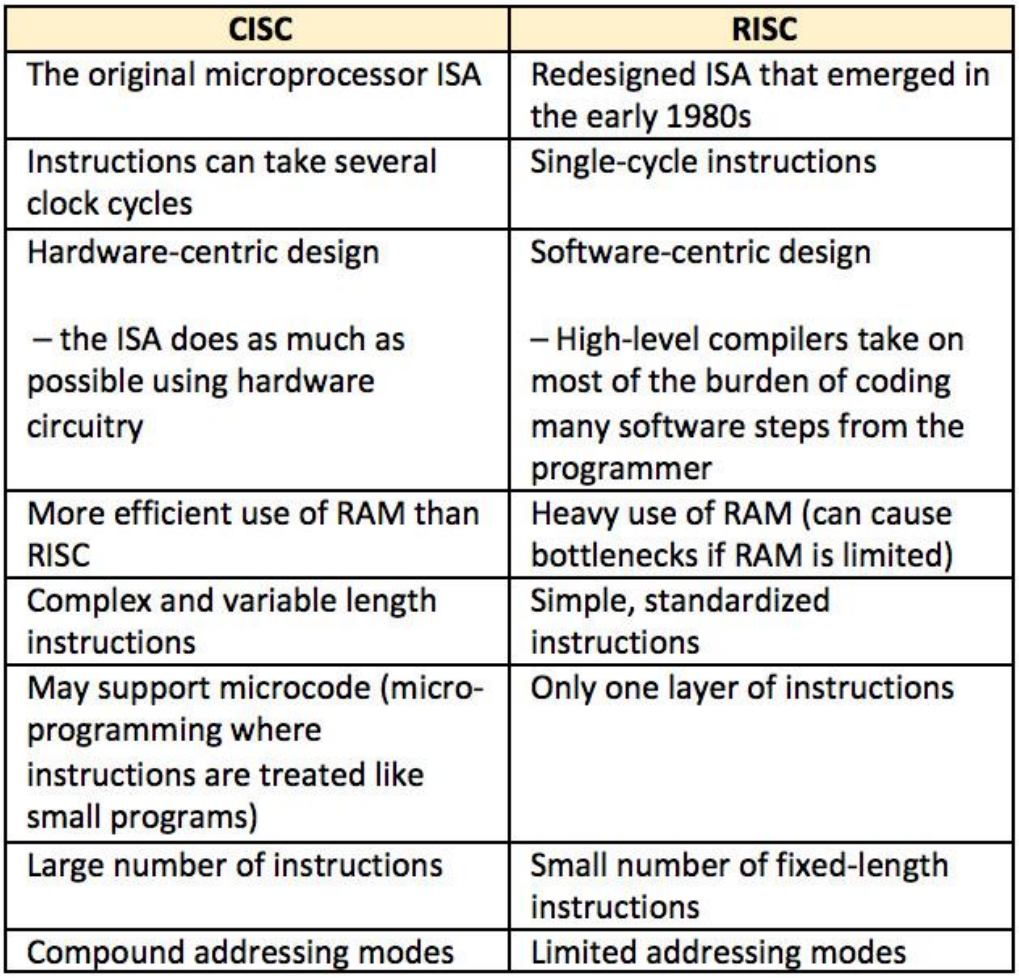
This excerpt was taken from [20].

Our project will use a microcontroller to facilitate its multiple inputs and outputs, process images, and overall regular our project. It will be the brain of the headlight unit. This part will need to be connected to every sensor, and every LED so that through our coding, it will determine which LEDs will be on, dimmed, or off based on the sensors and image processing.

4.6.2 INSTRUCTION SET ARCHITECTURE

Instruction Set Architecture a.k.a. ISA, is the type of language the processor inside the microcontroller uses in order to execute its instructions. There are two major instruction sets that microprocessors use. They are Complex Instruction Set Computer (CISC) and Reduced Instruction Set Computer (RISC). When the first integrated chip was designed in 1958, the ISA it used was a primitive version of CISC. Once computers started to advance, their ISA started to become more complicated because the developers wanted them to do more, faster.

So, the developers would come up with these complex commands that would take many clock cycles to complete. CISC got to a point where the complicated commands were so long, the length of the smaller commands had to match their length and it was taking up too much processing time or clock cycles that IBM developed a reduced version of CISC. The new ISA was RISC and was a reduced Instruction of CISC. RISC didn’t have any of the complicated and long instructions so the length of each instruction could be shortened significantly. There were some trade-offs though. RISC instructions couldn’t execute the complicated instructions that CISC could in one line. This wasn’t a problem though because RISC could compute the instruction in two or three lines. Below is a table of the major differences between the RISC and CISC ISAs.



CISC	RISC
The original microprocessor ISA	Redesigned ISA that emerged in the early 1980s
Instructions can take several clock cycles	Single-cycle instructions
Hardware-centric design – the ISA does as much as possible using hardware circuitry	Software-centric design – High-level compilers take on most of the burden of coding many software steps from the programmer
More efficient use of RAM than RISC	Heavy use of RAM (can cause bottlenecks if RAM is limited)
Complex and variable length instructions	Simple, standardized instructions
May support microcode (micro-programming where instructions are treated like small programs)	Only one layer of instructions
Large number of instructions	Small number of fixed-length instructions
Compound addressing modes	Limited addressing modes

Table 7. CISC vs RISC

This table and information about RISC & CISC come from resource number [14].

4.6.3 ARM

ARM stands for Advanced RISC Machines. They are a line of microprocessors that utilize the RISC ISA. ARM makes 32-bit and 64-bit RISC multi-core processors. RISC processors are designed to perform a smaller number of types of computer instructions so that they can operate at a higher speed, performing more millions of instructions per second (MIPS). By stripping out unneeded instructions and optimizing pathways, RISC processors provide outstanding performance at a fraction of the power demand of CISC (complex instruction set computing) devices. ARM processors are extensively used in consumer electronic devices such as smartphones, tablets, multimedia players and other mobile devices, such as wearables. Because of their reduced instruction set, they require fewer transistors, which enables a smaller die size for the integrated circuitry (IC). The ARM processor's smaller size, reduced complexity and lower power consumption makes them suitable for increasingly miniaturized devices.

ARM processor features include:

- Load/store architecture.

- An orthogonal instruction set.

- Mostly single-cycle execution.

- Enhanced power-saving design.

- 64 and 32-bit execution states for scalable high performance.

- Hardware virtualization support.

The simplified design of ARM processors enables more efficient multi-core processing and easier coding for developers. While they don't have the same raw compute throughput as the products of x86 market leader Intel, ARM processors sometimes exceed the performance of Intel processors for applications that exist on both architectures.

Information about 4.6.3 was taken from resource [15]

4.6.4 ATMEGA

Most commonly known as AVR microcontrollers, the ATmega AVR microcontrollers are a set of MCs that use flash memory, so they use less energy. It uses 8-bit RISC in its microprocessor. Here is an excerpt from microchip.com about megaAVR chips [18].

megaAVR microcontrollers (MCUs) are the ideal choice for designs that need some extra muscle. For applications requiring large amounts of code, megaAVR devices offer substantial program and data memories with performance up to 20 MIPS. Meanwhile, innovative Atmel picoPower®technology helps minimize power consumption. All megaAVR devices offer self-programmability for fast, secure, cost-effective in-circuit upgrades. You can even upgrade the Flash memory while running your application.

These chips are used in headlights today as well as other projects like toasters, remotes, and lots of simple electronics because they are cheap and effective. These chips cost anywhere from $0.62 to $4.00. If our project were to be mass produced, the prices on each of these chips would be considered but for our headlight, we will only make a few so a few dollars won't matter much at the size of production.

4.6.5 RASPBERRY

Raspberry Pi is the name of a series of single-board computers made by the Raspberry Pi Foundation, a UK charity that aims to educate people in computing and create easier access to computing education.

The Raspberry Pi launched in 2012, and there have been several iterations and variations released since then. The original Pi had a single-core 700MHz CPU and just 256MB RAM, and the latest model has a quad-core 1.4GHz CPU with 1GB RAM. The main price point for Raspberry Pi has always been $35 and all models have been $35 or less, including the Pi Zero, which costs just $5.

All over the world, people use Raspberry Pis to learn programming skills, build hardware projects, do home automation, and even use them in industrial applications.

The Raspberry Pi is a very cheap computer that runs Linux, but it also provides a set of GPIO (general purpose input/output) pins that allow you to control electronic components for physical computing and explore the Internet of Things (IoT).

This was an excerpt from opensource.com [19].

In our project we are only going to use a microcontroller. We are not going to put the whole development board into our headlight because that would be a waste and we don't need anything except the Microcontroller. The Microcontroller that is in a Raspberry Pi is an ARM Microprocessor.

With that being said though, using a Raspberry Pi would make our image processing job a lot easier because there are a lot of tools out there already for analyzing data through a Pi board. We will analyze the board with the other controllers and see how they compare against each other. With the Raspberry Pi, we get a large word size at 64 bits as well as 4 core processors. The clock speed is nothing to scoff at as well. This would be huge if we did decide to do any kind of image processing that required a large amount to resources to execute. For this project, we are not going to be doing this kind of image processing but if we were to market or sell our headlight unit, we would need to implement this kind of image processing. For this project, the Headlight unit just needs to work as intended.

4.6.6 MICROCONTROLLER COMPARISON

In table 8 we summarize the different microcontrollers we have researched.

Development Board	Arduino Due	Arduino Uno	Raspberry Pi 4 Model B	Raspberry Pi 3 Model B
Microcontroller	AT91SAM3X8E	ATmega328P	Cortex®-A72	ARMv8
Architecture	32-bit ARM	8-bit AVR	Quad Core 64-bit ARM	Quad Core 64-bit ARM
Clock Speed	84MHz	16MHz	1.5GHz	1.2GHz
Operating Voltage (Recommended)	7-12V	7-12V	5V	5V
I/O Pins	54	14	40	40
Flash Memory	512KB	32KB	1-4GB	1GB
SRAM	96KB	2KB	X	X
Manufacture	Arduino	Arduino	Raspberry	Raspberry
Price	$38.50	$22.00	$40.00	$35.00

Table 8. Microcontroller comparison

The architecture of each board will play a big role in which board we choose because our image processing needs to be quick enough for our headlights to change at a fast rate. Having an 8-bit architecture like the Uno will slow that process down significantly. On the road, the reaction time needs to be as fast as possible or else our lights will miss their timings. The same goes for the Clock speed of the chip. Operating voltage doesn’t matter for image processing, but it matters a lot in the overall project for power consumption. Less power consumption is always better if you get the same result in the end. I/O pins needed for this project are 3 sensors, and 7 outputs putting us at 10 pins. Each of these boards have the required amount but if we wanted to go through and add additional sensors, controlled LEDs, or any other I/O pins, having more will allow us to achieve that. Memory in our system needs to be enough the store the image from our camera as well as our code. The size of a picture can be determined by multiplying the number of pixels by the bit depth for color. In our case, our colors will be black and white, so our bit depth is 8-bits. Then divide that number by 8 to get the Bytes. For a low-quality image 640x480 pixels, we need 307,200 Bytes Which is around 300 KB. SRAM is used in these devices as cache. I couldn’t find the Pi’s cache data, but I am sure they have it in them. Higher amount of cache means less cache misses which leads to a faster computation of a program. The last comparison we are looking at is the price. The price being lower is better if we do not lose processing power or speed over it.

4.6.7 MICROCONTROLLER CONCLUSION

These micro controllers are all great. They all work with what we are trying to do in this project. Some of them have drawbacks if we did use them though. For instance, the Uno micro controller unit from Arduino doesn’t have enough I/O pins to simply hook up each LED to one pin. We would need to implement a multiplexing device so that they could function properly. This is not ideal as it would bring in extra parts just because a microcontroller doesn’t have enough functionality. This could also pose a problem if we ever wanted to expand the number of LEDs or add another sensor of some kind. For these reasons, we will not be using the Uno in our final project. We will still use it to test things because all microcontrollers should have the same type of functionality and it is easier to use the Uno due to it having less components. Down to three microcontrollers to choose from, The one that we will more than likely use in our project is the Due. It is inferior to the ARM processors in almost every way but the one thing that the Arduinos have over the other microcontrollers is that they have a huge amount of support for them in the hobbyist community. These boards have been tried and tested by many people over many disciplines. The extra value that the ARM boards give in terms of physical resources, in our eyes, does not outweigh the value from the resources online that the Due will have.

4.7 PROGRAMING LANGUAGES

A programming language is a formal language, which comprises a set of instructions that produce various kinds of output. Programming languages are used in computer programming to implement algorithms.

Most programming languages consist of instructions for computers. There are programmable machines that use a set of specific instructions, rather than general programming languages. Early ones preceded the invention of the digital computer, the first probably being the automatic flute player described in the 9th century by the brothers Musa in Baghdad, during the Islamic Golden Age.[1] Since the early 1800s, programs have been used to direct the behavior of machines such as Jacquard looms, music boxes and player pianos.[2] The programs for these machines (such as a player piano's scrolls) did not produce different behavior in response to different inputs or conditions.

Thousands of different programming languages have been created, and more are being created every year. Many programming languages are written in an imperative form (i.e., as a sequence of operations to perform) while other languages use the declarative form (i.e. the desired result is specified, not how to achieve it).

The description of a programming language is usually split into the two components of syntax (form) and semantics (meaning). Some languages are defined by a specification document (for example, the C programming language is specified by an ISO Standard) while other languages (such as Perl) have a dominant implementation that is treated as a reference. Some languages have both, with the basic language defined by a standard and extensions taken from the dominant implementation being common.

4.7.1 C/C++

C & C++ are both programming languages, but they are very different in how they are written. C is a general-purpose high-level language while C++ is an object-oriented language. Both languages have their own set of pros and cons. Here is a short definition of C from Guru99’s website [24].

C is a general-purpose programming language that is extremely popular, simple and flexible. It is machine-independent, structured programming language which is used extensively in various applications.

C was the basics language to write everything from operating systems (Windows and many others) to complex programs like the Oracle database, Git, Python interpreter and more.

It is said that 'C' is a god's programming language. One can say, C is a base for the programming. If you know 'C,' you can easily grasp the knowledge of the other programming languages that uses the concept of 'C'

For most basic microcontrollers, C is used to program them. It is easy to use, and microcontrollers usually don’t pull a lot of processing power. The code they run is very “simple” compared to a program you would see running on a desktop. This simple, fast, and easy to use style would make C a good choice for the language we’ll use in our headlight.

Object oriented programming is a style of programming where you define objects with traits and behaviors then tell those objects how to interact. C++ is a great programming language because you can code anything that you could in C. The perks of coding in C++ over C are that it can be more powerful at times when running your code.

4.7.2 PYTHON

Python is an interpreted, object-oriented, high-level programming language with dynamic semantics. Its high-level built in data structures, combined with dynamic typing and dynamic binding, make it very attractive for Rapid Application Development, as well as for use as a scripting or glue language to connect existing components together. Python's simple, easy to learn syntax emphasizes readability and therefore reduces the cost of program maintenance. Python supports modules and packages, which encourages program modularity and code reuse. The Python interpreter and the extensive standard library are available in source or binary form without charge for all major platforms and can be freely distributed.

Often, programmers fall in love with Python because of the increased productivity it provides. Since there is no compilation step, the edit-test-debug cycle is incredibly fast. Debugging Python programs is easy: a bug or bad input will never cause a segmentation fault. Instead, when the interpreter discovers an error, it raises an exception. When the program doesn't catch the exception, the interpreter prints a stack trace. A source level debugger allows inspection of local and global variables, evaluation of arbitrary expressions, setting breakpoints, stepping through the code a line at a time, and so on. The debugger is written in Python itself, testifying to Python's introspective power. On the other hand, often the quickest way to debug a program is to add a few print statements to the source: the fast edit-test-debug cycle makes this simple approach very effective.

This description was taken from python.org [25].

4.7.3 ASSEMBLY

Assembly is the first (and only) language that is not a high-level language we are looking at in this report. Here is a brief definition from techterms.com [26].

An assembly language is a low-level programming language designed for a specific type of processor. It may be produced by compiling source code from a high-level programming language (such as C/C++) but can also be written from scratch. Assembly code can be converted to machine code using an assembler.

Since most compilers convert source code directly to machine code, software developers often create programs without using assembly language. However, in some cases, assembly code can be used to fine-tune a program. For example, a programmer may write a specific process in assembly language to make sure it functions as efficiently as possible.

Assembly language, written correctly, can be very powerful. This language is the base of most other languages in the world. Whenever you wrote C code, Java, or Python, the compiler translated those languages into Assembly first. With all that being said, the reason Assembly doesn’t have a large amount of people coding in its base language is that it’s hard to write. The language itself is a lot of very basic commands with very hard to understand if you are new to writing in the language. If your project is rather large, just managing your registers alone might drive someone insane.

This will not be the language that we code our headlight in because coding in Assembly is not fun, complicated, and hard to make compatible with everything else.

4.8 IMAGE PROCESSING

For environmental condition sensing we plan to do image processing to track headlights and ambient lighting conditions. The tracking condition will be used to determine where in the FOV an oncoming driver is located such that we can address the state of the LED associated with the position of the driver. The environmental conditions we will consider with the camera is ambient lighting such that high beams can be appropriately used. We will verify ambient lighting with a light sensor as well to make sure the proper conditions are met and verified to avoid misuse of the high beams.

There are conditions in which we would want lower lighting systems such as low beams and fog beams when it is raining or there are foggy conditions. The image conditions for such weather events is a large back scatter from the headlights and to determine the verification as to which condition the rain sensor described in the optical design and feature section will be used.

When it is determined that a car is oncoming or being followed, in a mask part of the headlight will be dimmed to block out the regions where an illumination source is detected. Due to limitations of our system and time frame constraints, our detection of light sources will be limited to a true false program. If there is light detected, then it is true that a car is present in that mask. When the program reads true for a mask, only then is the headlight dimmed. Since most headlights are made of two separate light sources, when we detect any cars, we will only be detecting one bright spot. In order to only detect one bright spot, we will be limiting the field of view of the camera to detect any bright spot which will be then determined to a vehicle. Below in Figure 27 is an example of the field of view set by the camera’s masks, and then the blocking of parts of the headlights once a true or false has been generated by the program.

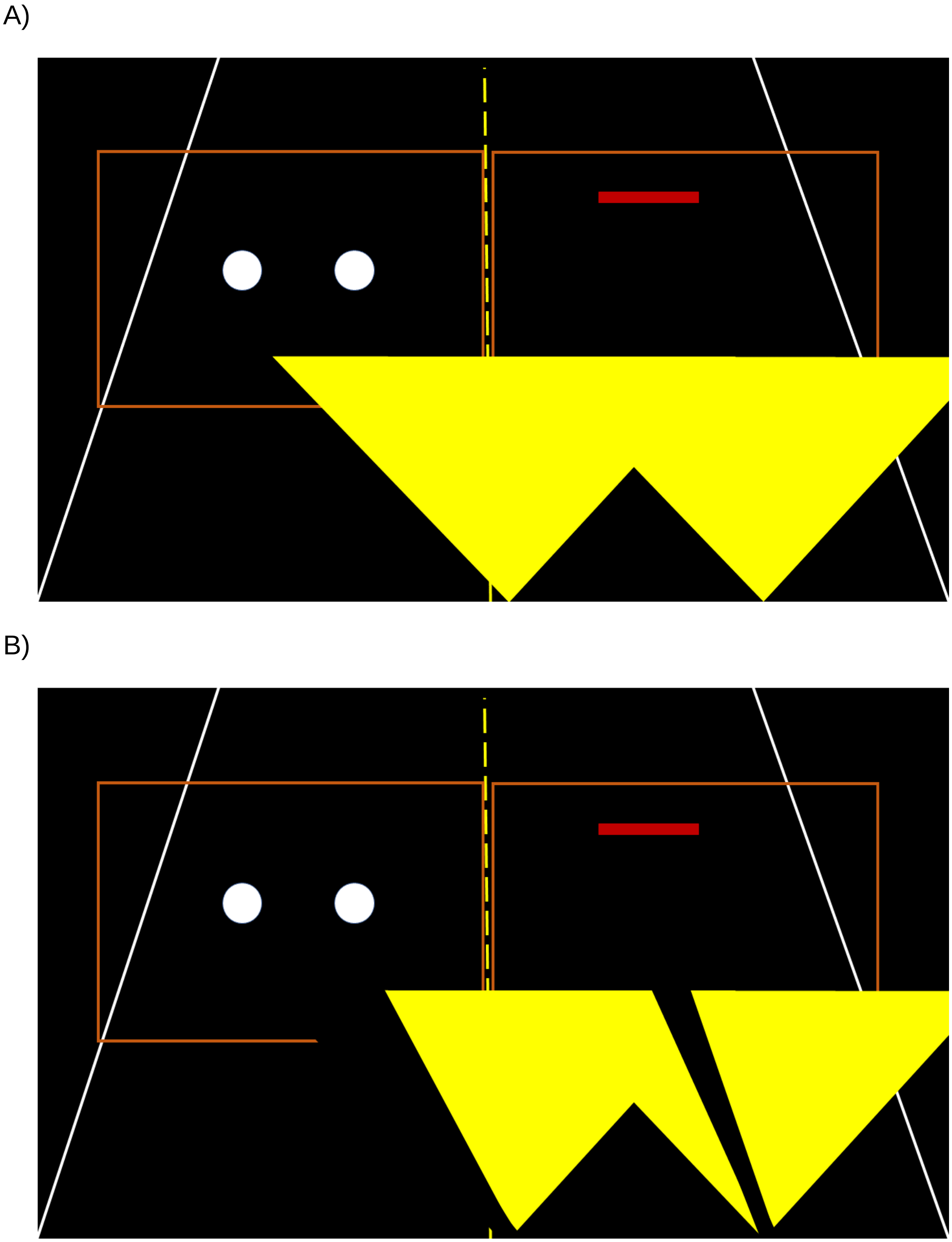


Figure 27. A) The orange rectangles represent the masks from each camera's field of view, the white circles are the headlights of an oncoming car and the red bar is the taillight of a preceding car. B) When the camera images the road and determines that there is an illumination source then part of the headlight associated to that field of view will be toggled off.

Besides detecting oncoming and preceding cars, we will also be looking for a large amount of reflected light. In foggy conditions high amounts of light is scattered and reflected into the cameras. When we detect a high volume of incoming light from these reflections then it will trigger a kill command for the high beams so that only the low beams and fog lights will be turned on. As seen below in Figure 28, when there is fog present there is a larger reflection of light which reduces visibility. The reflected light from the fog differs from any detected headlights in the area of illumination. A headlight only illuminates a narrow portion of the camera sensor highly, with the reflections from fog the sensor will have a lower volume of light but over a larger area.

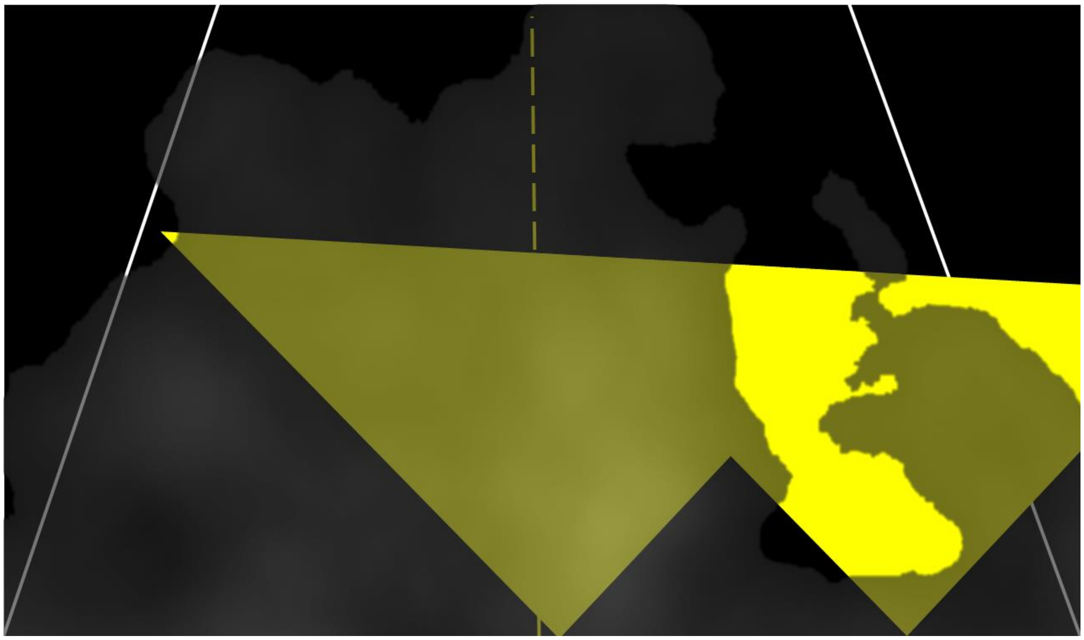


Figure 28. When fog is present it diffuses the light and reduces visibility. When there is a large amount of light present then the fog reflects a large portion of the light back. When we detect the large amount of reflected light then the system will switch to low beams and turn on the fog lights.

4.8.1 CAMERAS

This section will discuss different cameras that we looked into while we were researching our project. The major requirements we want to fulfill are high enough picture quality to “see” oncoming cars, cost effective, and small enough to fit inside our housing unit.

4.8.1.1TLL Serial Camera

This camera is sold by many distributers and has some pretty good specs for the price range we are looking at. It can go all the way down to a 160x120 resolution. This is good because we want as little resolution that we can get away with in order to use less of the flash memory in the MC. When the images are stored into data, they are converted into a JPEG file so they might be a little harder to interpret through image processing.

4.8.1.2 Pixycam2

The Pixy2 is a camera that is specifically made for image processing. They advertise that the camera works well with the Atmel microcontrollers. More specifically they advertise the ease of use with Arduino and Raspberry. The developers have released libraries for those boards. We will not be using one of those boards, but the camera is still able to interface with UART, SPI, and other forms of communication with our microcontroller. The problem with it is that it is expensive to use in just a small project like this. They are $70.00 each. This is a good example of a product that was made specifically for this but does not work for our project because of our budget. We could not find any datasheet on the Pixy2.

4.8.1.3 CCD B&W

The CCD B&W camera is a cheap low-resolution camera that is great for low quality image processing.

This is a list of specifications of for this camera

- Black & White CCD Video Camera.
- NTSC (standard North American) Format.
- PCB Board-Mounted.
- Built-in CS lens mount.
- Resolution: 752 x 582 (H x V) active pixels
- Dimensions: 42mm x 42mm x ~21mm (1.65 x 1.65 x 0.81) (Includes mount)

Features

- High Resolution 570 TVL, <0.05 lux at 50 IRE (F1.2)
- External Synchronization - H&V Lock
- Interlaced/Non-Interlaced Scanning
- Iris Signal Output
- CS-Mount Mount Integrated Lens
- Applicable to Machine Vision

These cameras are around $5.00 each. This is great because we spending less money is always a plus. The huge downside is that the data sheet is less than a page long and mentions almost nothing that a datasheet should mention. Getting this camera to work in our project would take a lot of outside help to understand how cameras like these work.

4.8.1.4 Camera Comparison

In table 9 we compare our camera systems.

Camera	TTL	CCD B&W	Pixycam
Cost	$25	$5	$59.90
Size	32mmx32mm	40mmx40mm	1.5inx1.65in
Resolution	160x120 320x240 640x480	752x582	1296x976
Operational voltage	5V	Unknown	5-10V
Ease of use	well documented	Hard	Well Documented and widely used
Manufacture	Adafruit	Sky Craft	Pixy Cam

Table 9. Camera options

At first look, the cost of the Pixycam sticks out by a huge margin over the other cameras. Being almost sixty dollars really turned us off to it at first but after seeing how well documented this camera was, it because a viable option. The size doesn’t matter that much in our headlight but the smaller it is, the more area we have for our other parts in the housing unit.

The resolution in the cameras is one of the main aspects of the camera that we would like to control. Having too low of a pixel count could bring problems for our image processing while having too high of a pixel count would make it very hard to store the picture into our memory to process it. The TTL camera has a variable resolution which makes this camera a likely candidate for our selection.

The cameras could use a voltage up to 12V because that is the max input we are getting from the 12V car battery. These cameras don’t exceed that. Having a variable Voltage input on the Pixycam could be good in case something goes wrong in our circuit. The last thing that we compared in the table was ease of use. The CCD camera might be unusable to us because it does not have enough documentation on the camera to implement it into a system without having a better understanding of how cameras work in general. The other two cameras on the other hand have great documentation on them. They have everything we would need to know about being able to connect them to a microcontroller to test them out.

4.8.1.5 Camera Conclusion

The Pixycam is a very well thought out, well documented and versed camera that is used in many hobbies today that process images. It is fast, small, and has great resolution. The downside to having these features is that is costs almost $60. The other cameras are both under twenty-five dollars and the reasons that we need this camera are for very minimal pixel count. Having such a high resolution on this project will not be good because we only have limited space in the flash memory of our board. The CCB camera looks good at first sight being the lowest costing while fitting all our needs. A huge problem with it is that there is no documentation on them. We think a big reason why they are five dollars is because nobody knows how to use them. This brings us to our final thoughts on the TTL camera. It looks great on paper and it works great in person. We will be using the TTL camera because it has a low resolution, low cost, and is well documented.

4.9 SENSORS

These are the sensors that are inside of our headlight. They are what we connect to the input pins of our microcontroller unit. The sensors will give information to our microcontroller for the appropriate criteria to be met. When the appropriate criteria are met for certain commands then the command will be issued. For example, when the light sensor is detecting small amounts of ambient light it will enable the high beams to be turned on. But when we receive a set threshold amount of light then it will be determined that the high beams should be turned off.

Most of these sensors only require a low voltage low current input to work which makes it ideal for the project and enables us to have less components. Additionally, with these sensors can work with almost any microcontroller. This gives us a lot of flexibility when deciding what microcontroller to get.

4.9.1 RAIN SENSOR

The rain or moisture sensor is going to be able to detect when there is rain, or any water present outside of the headlight. Our sensor will be a simple piece of glass or clear plastic, with a laser diode, and a photodetector. The working principle of the sensor is total internal reflection. The laser diode will be set up so that the beam is entering the glass or plastic layer at the critical angle. When light enters a material with a higher refractive index than the surrounding material, it bends towards the higher refractive index. At the critical angle the material the light is propagating through acts as a waveguide, and light is transmitted internally through the material with no light leaking out.

For this sensor to work, the light from the laser diode will be set up for total internal reflection. At the other end of the glass or plastic waveguide will be a photodetector. The photodetector will measure the power of the transmitted light. Since all of the light being coupled into waveguide will read out a constant power whenever there is a change in the power the system will read that there is water present. When water comes into contact with the waveguide it will change the angle for total internal reflection. Since water has a higher refractive index then air, the critical angle will change, and light will be able to leak out of the waveguide causing a drop-in power. This drop-in power at the photodetector is what will let the microcontroller know to make sure the headlights on.

In order to power the system, we will use the 5 volts coming off of the DC to DC converter we will have that will also power the MCU. Electronically wise the implementation of the rain sensor is simple enough and does not require a lot of components on the physical PCB board.

4.9.2 LIGHT SENSOR

In order for the microcontroller to determine when the high beams should be on or off, we need to be able to detect the ambient amount of light present. The light sensor will work in tandem with the camera as a dual verification system. Since we already have a sensor detecting and determining the position of light within the field of view of the headlight, there should be a secondary method to confirm that there is light present. For our light sensor we will be using a photodetector and measuring the voltage generated by the sensor. A threshold voltage will be set so that a set amount of light has to be present in order for the microcontroller to issue any commands.

The light sensor as mentioned previously will be a secondary verification tool to verify the reading from the camera. The camera will be reading if light is present and where light is present. The light sensor will only be determining if there is ambient amount of light for control of the high beams. In order to avoid any false positives being sent to the microcontroller a threshold reading will be set to avoid any dark current triggering. Dark current is caused by the randomness and quantized nature of photons. Also, due to the thermal energy of our system we may generate thermal noise. In order to prevent any false positives generated by the light sensor we are programming the microcontroller to only turn off the high beams if both the camera and light sensor are in agreement.

4.10 COMPONENT SELECTION SUMMARY

After thoroughly researching various ways of powering the LED we have settled on testing three LED drivers. The first one the constant current driver A6211 by allegro. This IC was chosen because of the simplicity of design, it does not require external MOSFET to function, only basic capacitor, resistor, inductor and a small diode. Additionally, there are many resources for which to help the guide the design of this component which will greatly aid in the component selection process. The constant current driver LED 2000 by STMicroelectronics is another dedicated LED IC what very easy to work with. The can more that handle the necessary current demands of the LEDs and the ease of use with a microcontroller.

The last LED driver we choose was the constant voltage TPS56339 by Texas Instruments. It is not dedicated LED driver, but it can meet our current and voltage well enough. Additionally, it has the benefit of being customizable by using the WEBENCH power designer tool from Texas instruments to pick out the proper components for our ideal output and best efficiency. Using the TPS56339 can be a challenge when trying to control the current since a small fluctuation in voltage can damage the LED.

For the microcontroller and sensor, we will test the switching DC to DC converter. The TPS561201DDCR is buck converter from Texas instruments it comes in two versions a 3.3 volt and 5 volts. We will order the 5-volt version since the chooses microcontroller can handle 5 volts and chosen sensors with most like work well with a 5-volt supply. For the switches we are going to order the NTD18N06L MOSFET by ON Semiconductor. However, depending on how testing goes we may not end up using this switch and instead use the enable line on the LED drivers and controlling them with the microcontroller. Just using the microcontroller would be the smarter option since it would get rid of the need of having 9 MOSFETs which would take up a lot of board space.

The MCU we will be using is a 32-bit RISC based ARM MCU called the AT91SAM3X8E. This chip is great for our project because the headlight is not that complicated, so RISC ISA is perfect. We don’t want CISC because our project doesn’t need to do any complicated commands. Another chip that has RISC ISA is the ATmega MCU. This is a great chip as well but the thing that drew us towards the AT91 was that is AT91 has more I/O pins and more flash memory so that we can store the image easier and process it faster.

After testing and purchasing multiple Cree LEDs, two LEDs were chosen to be used for the headlight. The LED used for the low beams is mentioned in a future section. The low beam device has a warm white color of 5700 K with a brightness of 900 lumens. The max operating temperature of the LED is 150 ºC. The fullwidth half max viewing angle of the device is 120º.

The second LED that was chosen was another Cree LED going to be used for the high beams of the headlight. A different device was chosen for the high beams because it had a higher brightness. A higher brightness was desired since the high beams are used to illuminate objects at a farther distance. The selected LED has a brightness of 970 lumens, and a white white color. A maximum junction temperature of 150 ºC is specified by the data sheet. The full width half maximum viewing angle is also 120 º.

Our camera we are choosing will be the TLL serial camera from Adafruit. This camera is perfect for us for a few reasons. The first reason is because the resolution in variable. Once we put everything together in our system, if we see that the camera resolution is too low, we could increase it to help differentiate between images. On the other hand, the resolution could be too high because we are storing our image in flash memory which is very limited. Some smaller reasons for choosing this camera are that the price was lower than our expected cost, it is small, and the camera has extensive documentation on implementing it.

5 DESIGN PLAN

The design plan breaks down the entire Environment Adaptive Automotive Headlight down into each main category from the headlight as a whole to the microcontroller and circuits to meet the power requirements. Discussed in detail is components and method of which we are considering and analyzing of which would be most suited towards out objectives and our constraints. While still maintain within our budget and meeting our requirement specifications

5.1 USER INTERFACE

The interfacing between the headlamp unit and user will be simple a switch that the user will trigger. This sends a signal to the microcontroller, which will then send a low voltage signal to the power MOSFET. The MOSFET will then let current flow to the low beams. From there on the all other functions will be handled automatically by the microcontroller.

5.2 HEADLIGHT DESIGN

We need to complete further testing of a variety of subcomponents that are discussed in previous sections so that we can pair up the system as a whole and provide a direct design plan. The known design will consist of two main beams a lower beam for most driving conditions that we will be able to manipulate to keep as much light on the road while reducing glare to a minimum. The second beam will be a high beam that will be more intense than the low beam and more collimated to project farther down the road. While this beam will not be able to be manipulated it will be controlled by the microprocessor in order to determine when it is needed to be on based on environmental conditions. This allows for more appropriate use when driving therefore increasing visibility for the driver and eliminating glare on oncoming traffic due to people using high beams when its unnecessary due to lack of knowledge or situational awareness.

5.3 POWER REQUIREMENTS

From initial research controlling the brightness of the LED can be better done by controlling the current instead of controlling the voltage. Since having a small voltage change can meaningfully affect the brightness of the LED. The LEDs used in the project will be the same for the high, low and fog lights. The main difference is the directional in which they are pointing and the number of LEDs modules there are. In figure 29 we give an overview of the power subsystem and how the components will be powered and how to MCU will generally interface with the sensor and LED drivers.

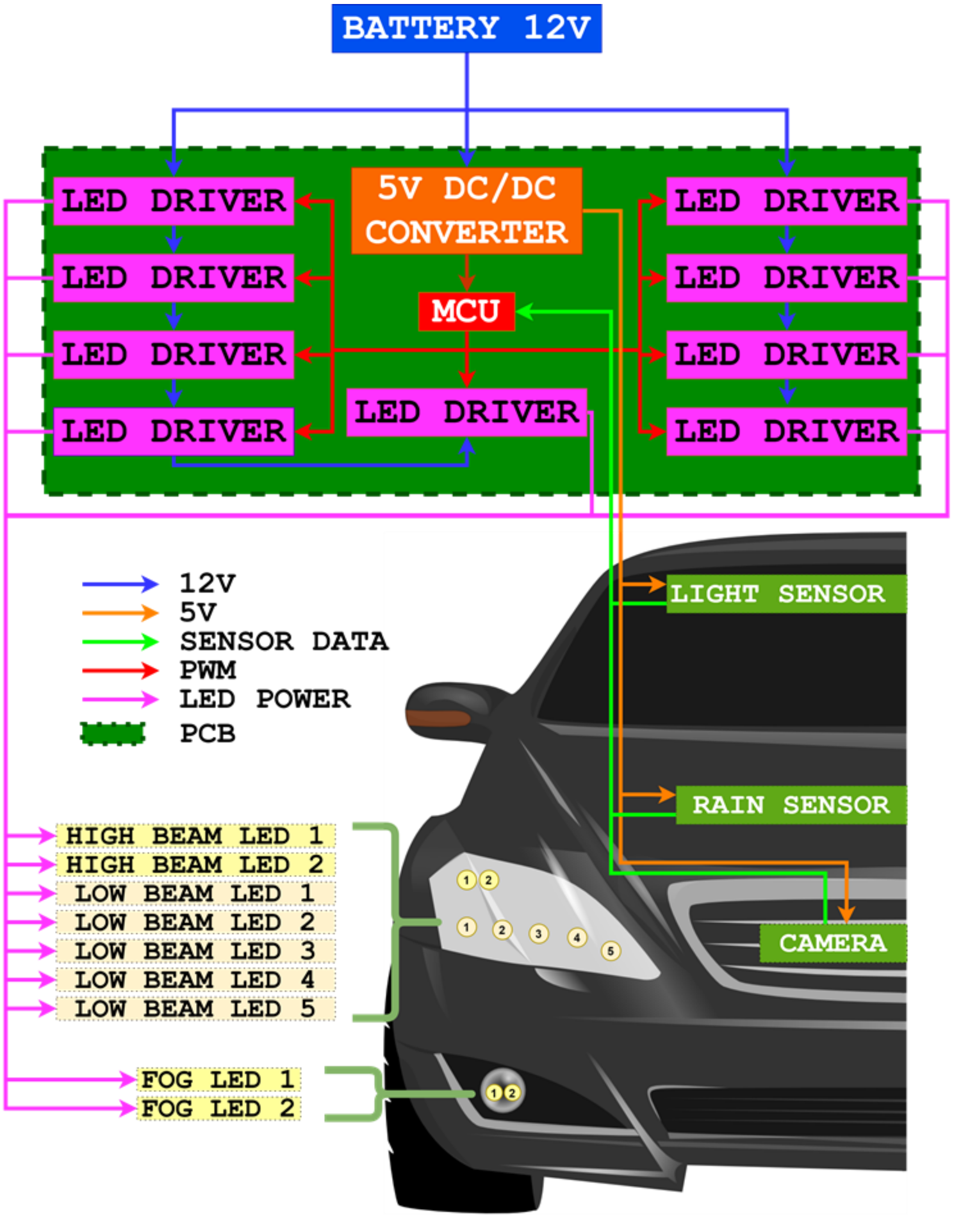


Figure 29. Simplified Block diagram of the power supply unit for the entire system.

5.3.1 Headlamp power supply

The lighting unit is broken down into three sections. The high beams will have two high powered LEDs. The low beam LED array will consist of five LEDs three of the five LED modules need to be able to be turned completely off or dimmed to a certain threshold. Lastly the fog light LEDs will be made up of two LEDs. In total there are 9 LEDs that need to be powered. For simplicity all of the LEDs will be the same brand and style and will run at that same voltage and current.

5.3.2 A6211 LED driver design

We will start with the A6211 LED driver. Figure 30 show the sematic of the A6211 LED with the appropriate value to generate and constant current of around 2.6 amps. For the actual finished project, the LEDs with be working at around a current of 2.5 amps. Since the LEDs are expensive and we have a limited number of them, we want to be on the safe side and make sure we run them at a current they are able to handle in order to avoid damaging them.

Figure 30 shows the layout schematic of the A6211 chip. The way we set the current we want is by setting the value of the Rsense resistor, which is R2 in our schematic. The way the chip knows the current is that the current passing through the LEDs with pass through the Rsense resistor that will produce a voltage this voltage is then measures and compares to a predetermined voltage Vcsreg which is pin 4 on the chip. This voltage is typically 0.2 volts, the way we set the current is by choosing a Rsense resistor that when 0.2 volts is divided by Rsense will give us our constant current limit. We went with a Rsense resistor of 0.075 Ω since we did not have too many options of what was in stock in terms of very low Ohm through hole components. Using this resistor will yield the approximately 2.66 amps which the LED can handle.

The next value we need to select is the switching frequency since this is a buck regulator. The switching frequency is the rate at which the IC turns off on to regulate the output. Higher frequency does not necessarily mean better performance, it can affect current limit accuracy for the worse and affect the size of the components making the inductors smaller and the output capacitor filter smaller [31]. For this LED driver we choose a switching frequency of 1 MHz by setting the Ron resistor to 63.4 kΩ which is the recommended value from the manufacturer. The inductor size was chosen by looking at the manufacturers chart that compared switching frequency verses LED current, so we settled on a 10 μH inductor capable of handling the high current. Another optional feature is if current being produced by the A6211 chip is producing a lot of ripple current then capacitor can be attached to the output of the LED terminals.

There are different ways to turn on the A6211 chip, you can either control it by using a logic high voltage and the LED driver will stay on for as long as the high logic is stays high. If the logic goes low for longer than 17 ms the IC will enter lower power mode to save energy and the next time it starts up again it will have a 130 μs delay. The alternative method is by using the PWM pulse with modulation at around 200 Hz the dimming duty cycle can dim the LED from 100% to 1%. From figure 31 we can see the approximate PCB layout with all components for the A6211 chip it approximately measures 26.67 mm * 23.9 mm = 636 mm^2 which is about one square inch. As we can see form the schematic the largest components are the inductor and capacitor. However, the number of components is fairly manageable. For the actual PCB we will need 9 of these drivers for each of the bright LEDs, so even though one chip has a small footprint we need to keep in mind there will be 9 of them.

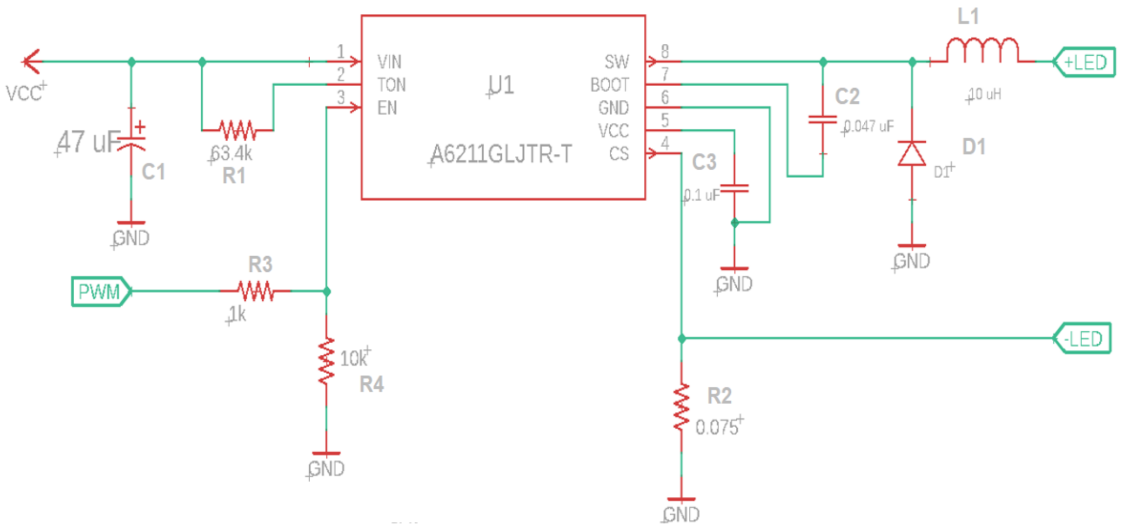


Figure 30. Schematic of the A6211 (rev 1)

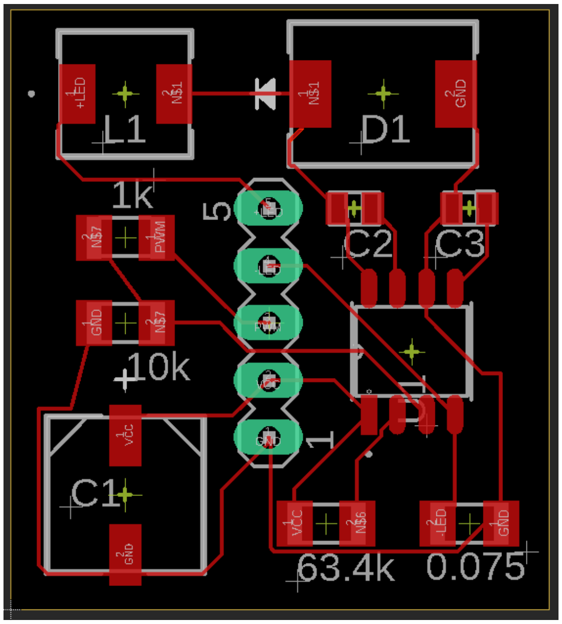


Figure 31. PCB layout of the A6211 (rev 1)

5.3.3 LED2000 LED driver design

The next IC we choose to test was the LED 2000 driver by STMicroelectronics is a buck converter like the A6211. This manufacture also allows us to simulate the IC using eDesignSuite in order to test different component values to give us the desired output. This board is very similar to the A6211 board in the way it functions and performs one of the key differences is the frequency is fixed to 850kHz. This gets rid of the resistor needed to set the frequency for. A similar method is used to set the current limit on the IC. By using resistor R1, the Rsense resistor, we can set the current limit. For this IC we set our desired current to be 2.5 amps so our

Rsense resister would be $\frac{0.1\ volts}{2.5\ amps} = 0.04\Omega$ .The voltage to through the Rsense resister is measure by the FB (feedback) pin which compares it to 100 mV. Based on the voltage read from the pin if it is more than 100 mV it will regulate the output to reduce the current output. If goes higher than the 100 mV threshold the current flow will be reduced until the system is back at around 100 mV.

Additionally, similar to the A6211 IC the enable pin on the LED2000 is turned on by a high logic voltage. The PWM is similar implementation to that of the A6211 and generally only needs a resister to manage the current flow. The LED2000 by far has the simple design and implementation, it is not the smallest in board size but the component arrangement allows us to keep everything in the single side of a PCB board.

In we figure 33 we demonstrate the approximate PCB layout of the LED2000 circuit. It has a smaller sized compared to the A621 measuring in at 131.496mm * 19.05mm = 600 mm^2. The two main reason for the smaller size is due to having a smaller 805 package input capacitor and it does not utilize a diode, since it is internally integrated. The only sizable component is the inductor which generally we can not do much about since there is not generally a wide selection of well documented SMD inductors with our specific requirements.

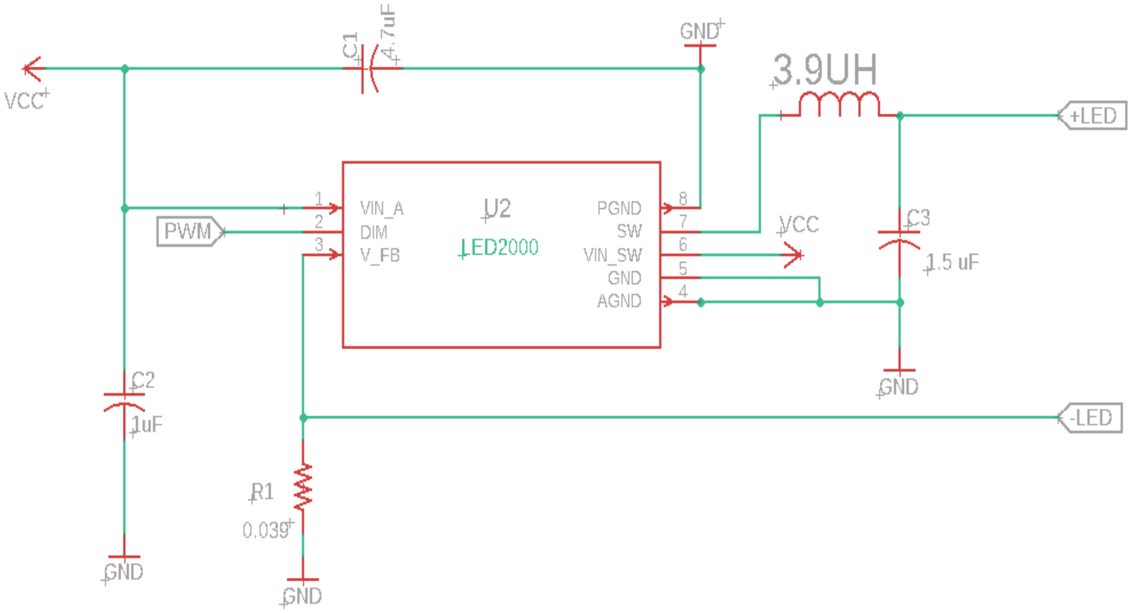


Figure 32. Schematic of the LED2000 current driver (rev)

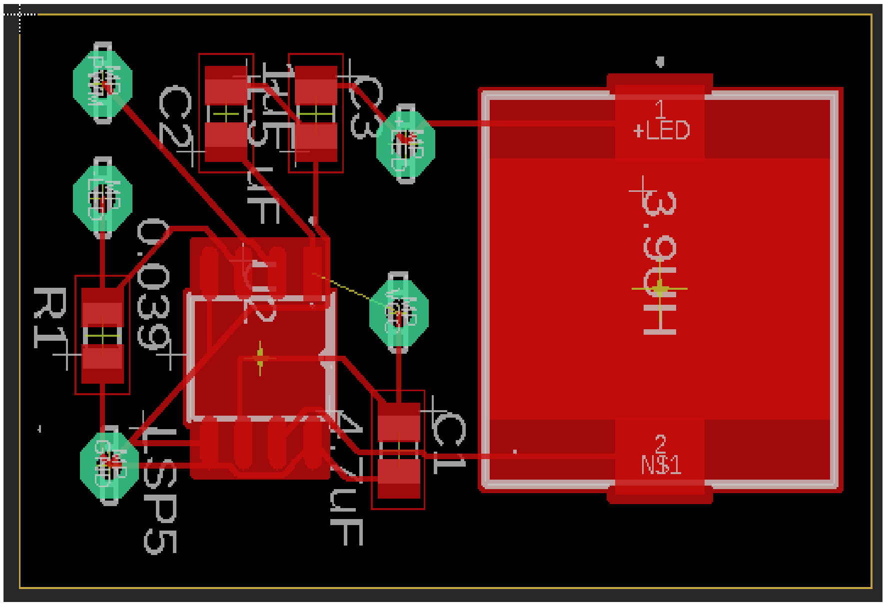


Figure 33. Approximate layout of the LED2000 current driver (rev1)

5.3.4 TPS56339DDCR LED driver design

For the design of the TPS56339DDCR constant voltage driver we used the WEBENCH Power designer by Texas instruments to aid us in the component selection process. The TPS56339DDCR is a constant voltage driver instead of the A6211 and LED2000 that are constant current driver. However, they both function in a similar way using a buck converter topology. The IC is also similar in the way it regulates the voltage to the other chips. It uses a feedback pin (FB) and a set of two resisters to set the desired voltage using equation$R2 = \frac{Vout - Vref\ volts}{Vref} R3 = 0.04\Omega$ in which R3 is set to 10k and . In figure 35 we can see the approximate PCB layout that measures approximately 18.8 mm * 21.1 mm = 397 mm^2 so size wise it is relatively the smallest of the previous LED drivers we have looked at.

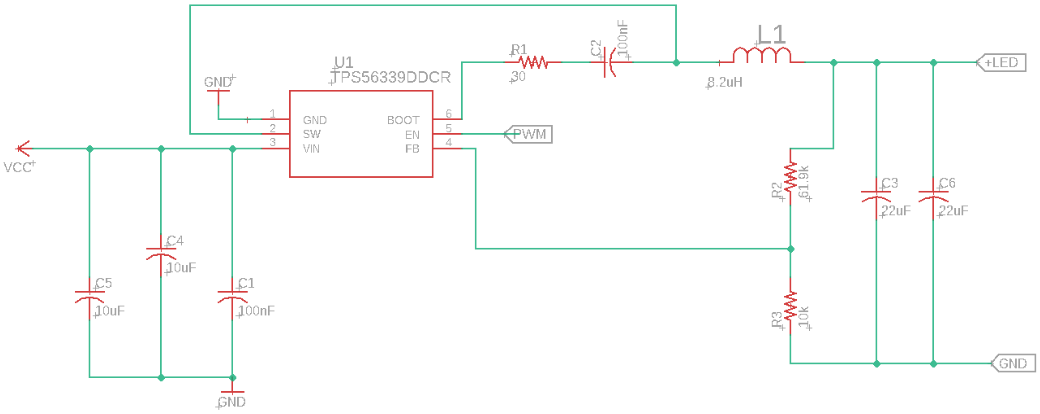


Figure 34. Schematic of the TPS56339DDCR LED driver

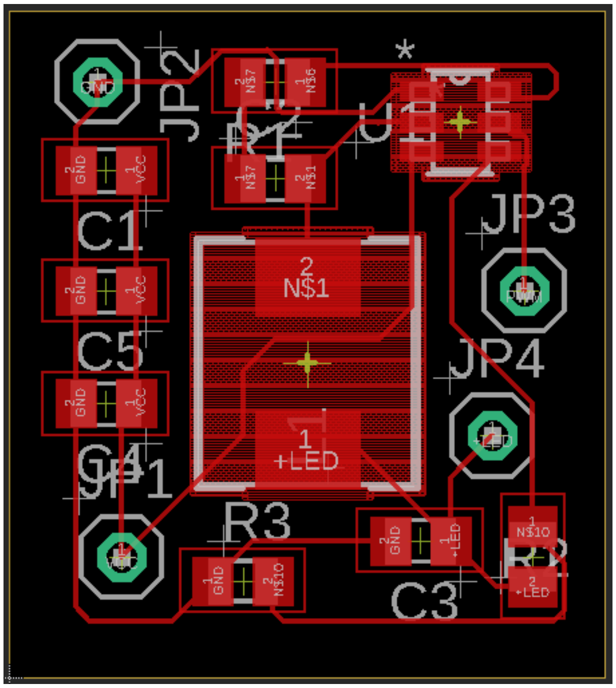


Figure 35. Approximate PCB layout of the TPS56339DDCR LED driver

5.3.5 Microcontroller and Sensor power supply

For the low power components, we will be using a switching DC to DC converter. From our research the switching converters are reliable and efficient. They however take more space do to the need for an inductor. We are still waiting on further research to finalize at exactly what voltage will the microcontroller unit, water sensor and light sensor.

5.4 PCB AND CIRCUIT DESIGN

Designing and fabricating a custom PCB is a requirement for this course and an essential part of our design. There are two main sub systems that need to be integrated into the design. The power subsystem for the LEDs and the microcontroller subsystem. Depending on the size of the PCB it would be more economical to make two separate boards on that handles the microcontroller and anther that supplies the power to the system and then connecting the two boards using ribbon cables. This idea would also be beneficial in case if one board fails, we can swap a new one in instead of having to redo the whole system.

5.4.1 PCB DESIGN SOFTWARE

There are various PCB design tools available for free, for example NI Ultiboard, Eagle and Altium. For this project we will be using Eagle since it offers a wide range of features, it is free for students to use up to 2 layers and most manufactures lots of footprints available and there.

5.4.2 FABRICATION AND ASSEMBLY

For the PCB used in this project we will limit the number of layers to two mainly because the complexity of the design can be easily achieved with 2 layers and financially for some manufactures a single layer PCB cost the same as a two layer one or sometimes even more. Also having two layers you have the easier it will be to trace out our connections. There are some factors that need to be taken into consideration in our design such trace widths which depends on the amount of current flowing through the trance, additionally the thickness of cooper. Additionally, we have not yet decided on a method of connecting the all the components. Either placing all of the components (microcontroller, dc-dc converters and LED drivers) into one single PCB board or each component work separately then connected by using jumper cables.

Once we have ordered all of our components and have the PCBs, we must solder the components onto the board. Some of the components are really small so special care must be taken. There are different component sizes for resistors and capacitor, generally we will try to use components 0805 or greater since having components smaller than that can be challenging to work with without the proper tools. There are different soldering methods such as using hot air station, soldering iron and a hot plate. Since we are trying to save on cost, we will be using the school soldering iron stations. When you order a PCB there is generally an option get a stencil, which are outlines of the soldering pads. Using the stencil, you can simply place soldering paste on the outlined pads, place the components in the proper orientation and then heat the solder to attach the components.

5.5 MICROCONTROLLER PROGRAMING

The microcontroller will be programed to compute the image processing as well as dictate which LEDs will be turned on at which times by reading data from the sensors. This means that it will need to have pins assigned to each output as well as each input. The next two charts display each input/output and which pin will correspond to them.

Input	Pin Number
Light Sensor	4
Camera	5 & 14
Water Sensor	6

Table 10. Pin layout

Output	Pin Number
Fog Light	7
LED 1	8
LED 2	9
LED 3	10
LED 4	11
LED 5	12
High Beam LEDs	13

Table 11. Pin layout

In the program, the code will be constantly looking to update a variable called "state". This variable will be used to determine the state of the output LEDs. If you would like to see how the state affects the headlights, see section 4.4.2.

5.5.1 LANGUAGE

The programming langue we will be using is C. The language is simple to use and there is no need for anything faster or more complicated. Everything was made as simple as possible in order to process data more efficiently.

5.5.2 CONTROLLING HEADLIGHTS

The headlights being on, dimmed, or off will be controlled by the microcontroller. Once the conditions are met for a light being in a certain state, the microcontroller will act accordingly.

The inputs are Camera, Light Sensor, and Water Sensor. The microcontroller will process an image from the camera. If there is no other head light detected on the road, all the camera bits will be 1. Camera has 6 bits, bits 0-4 are used to control each low beam LED. The bit 5 (so the 6th bit) will control if the high beams come on. Our project will also have a Light Sensor in addition to the image processing so that we have some form of "fail safe" in case the image processing doesn't work correctly. This Light Sensor input will be stored as a 1 or 0. 1 means that it is safe to turn all the lights on.

The Water Sensor input will detect when there is rain present so that the fog lights will be turned on. For this sensor, 1 means that the fog lights need to be turned on because rain has been detected, 0 means no rain detected and the light will be off. Putting all these inputs together into 1 "state" variable is how we've decided to implement controlling the LEDs. Once we have all the separate inputs, the state variable can be made by masking the inputs and then "and-ing" them with the mask then “or-ing” them together. The format will be as follows, Camera will be bits 0-5, Light will be bit 6 and Water will be bit 7.

Sensor	Bit(s) Controlled
Water	10000000 – bit 7
Light	01000000 – bit 6
Camera	00111111 – bits 5-0

Table 12. Bit layout

In order to get the state variable, we did the following operations.

state = (water << 7) **|** (light << 6) | (camera & 63);

This will set our state variable to the desired setup so that when we pass it to our function as an argument, we will get the desired LEDs being on. Here is a picture that shows which sensors affect which bits in our state variable.

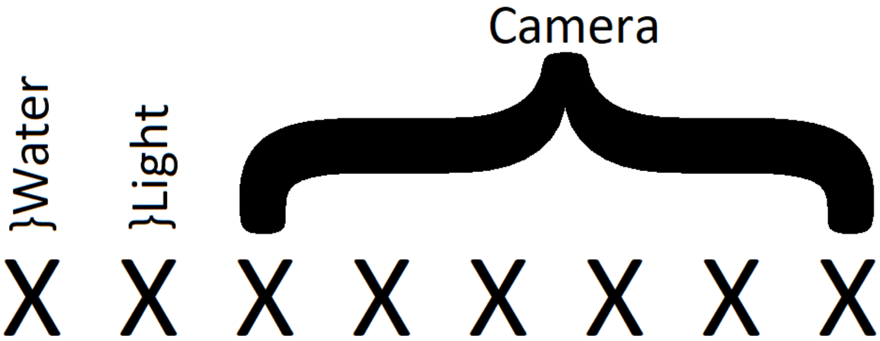


Figure 36. Below is a table of how each input of the microcontroller affects each output. 1 means on, 0 means off, X means it is not affecting that specific LED.

Output	Camera Input	Light Sensor Input	Water Sensor Input	State
High Beam LEDs	111111	1	0	01111111
LED 0	XXXXX1	X	X	XXXXXXX1
LED 1	XXXX1X	X	X	XXXXXX1X
LED 2	XXX1XX	X	X	XXXXX1XX
LED 3	XX1XXX	X	X	XXXX1XXX
LED 4	X1XXXX	X	X	XXX1XXXX

FOG LED	111111	1	1	11111111

Table 13. Logic table

As you can see in the figure, for the high beams to be on, the camera has to show no headlights and the light sensor has to see no excess light coming in.

5.6 IMAGE PROCESSING PROGRAMMING

When you think of image processing, you think of taking an image and looking to see if another image is inside of it. This is not what we will be doing in our system. We will be looking not for a shape but a color. Since our pictures are in black and white, the only thing we need to look for to see if there is any light is if a pixel has a stored value higher than the threshold we set in our code. We could go even deeper in depth here by once we've seen a pixel with a high enough value, we could do a localized search around that pixel to find out if it was just a stray bright pixel or not. Depending on how quickly our computer can process every single pixel in the picture depends on if we need to implement a selective processing pattern. Instead of every pixel we could process every other pixel. This could help reduce the processing our device would do by half. We could do this until just before our headlight is not reliable enough to detect a light consistently.

Another way to implement a selective pattern would be to process a pattern from the image. Here are some patterns that would work well. The top part is what will determine the high beams being on and each rectangle on the bottom will determine which LEDs will be dimmed/off.

This pattern is like the previously mentioned pattern of just decreasing the number of pixels we check because it is uniform. This would work if most of the light the camera sees does not come from any specific area in its vision.

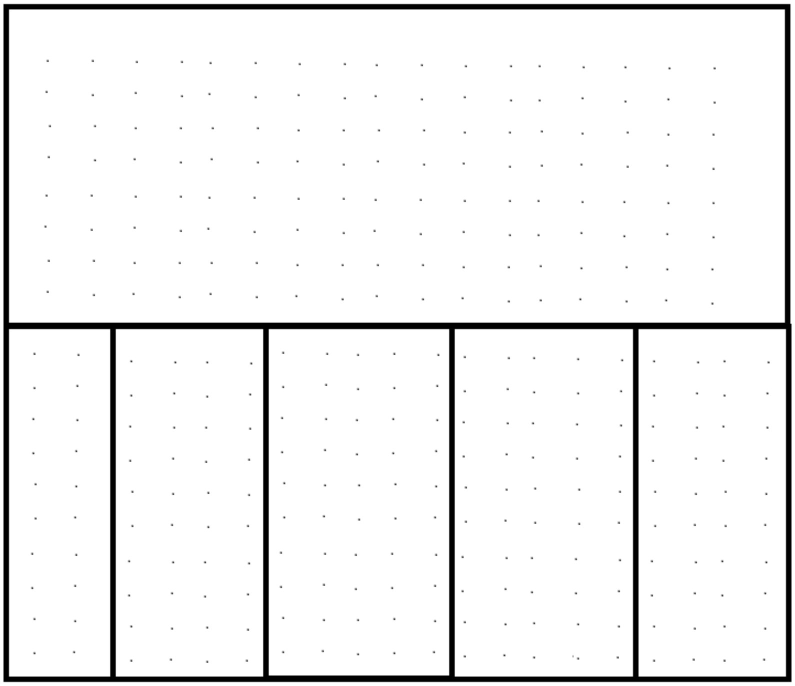


Figure 37. Analysis pattern

This next pattern does not work very well but it shows what a pattern would look like if we knew where our lights would be concentrated around. The MC wouldn't process the whole circle. It would process around the perimeter.

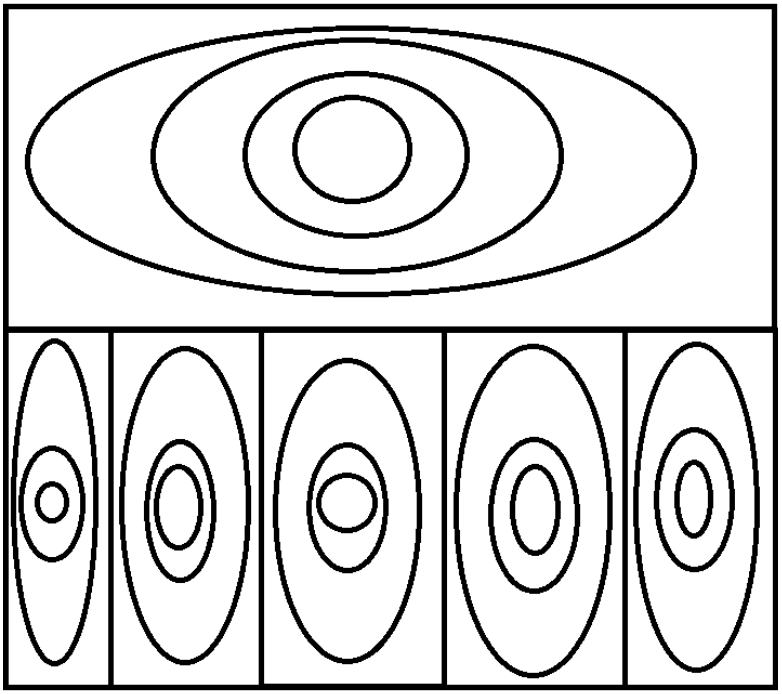


Figure 38. Analysis pattern

We want to go with the 1st idea of processing every pixel to see if there is enough light to trigger that area. This is what our MC would see if we were able to process the image correctly. Everything in the red field is what would trigger the High Beams to be off (as well as anything in green fields would turn the high beams off). The green parts are for each of the controllable LEDs. From right to left they are LED0, LED1, LED2, LED3, and LED4. In this case, all of the LEDs would be on except LED2 and the high beams.

Figure 39. Camera FOV breakdown

5.7 LEDS

The LEDs listed below are the chosen parts for the headlight for the low beam and high beams, respectively. Below the table each LED will be discussed in further detail.

#	1	2
LED Part Number	XHP50A-00-0000-0D0HH250G	MKRAWT-00-0000-0B0HG440F
Manufacturer	Cree	
Price	4.60	5.90

Lumens	970	840
Voltage (V)	6 or 12	
Max Junction Temperature (ºC)	150	
Viewing Angle (º)	120	
Color	White White	Warm White

Table 14. LED Specification

LED 1 and 2 are Cree XLamp MK-R series LED. These LEDs are comprised of a 2x2 array and offer an optimized directional lighting solution. As for color the LED can come in colors ranging from 2700 K to 5000 K. The chosen color for this LED 1 was a cooler white at 3500 K, and LED 2 was a warmer white around 5700 K. The design of the LED can be seen below in Figure 40.

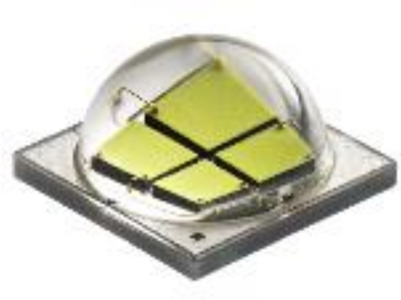


Figure 40. The design of the Cree XLamp MK-R series LEDS as a 2x2 array with a diffusive dome of water clear lens.

LED 1 was chosen as the LED for the high beams due to the higher lumen output. With our high beams we wanted a higher brightness to increase the illumination at larger distances. The main use for our high beams is to see beyond the range of our low beams. LED 1 is able to be driven at 6 V with 1.4 A or at 12 V with 700 mA. The maximum current of the device is 2.5 A. Since this is a high current device, it generates a large amount of heat. The device has a thermal resistance of 1.2 ºC/W. The full width half max viewing angle is 120. Each LED's brightness is 970 lumens. When the LED is run at 6 V with a current of 2 A the Luminous flux of the device is approximately 135% when the junction temperature is at 85 ºC. The luminous flux of the device as a function of the forward current can be observed below in Figure 2.

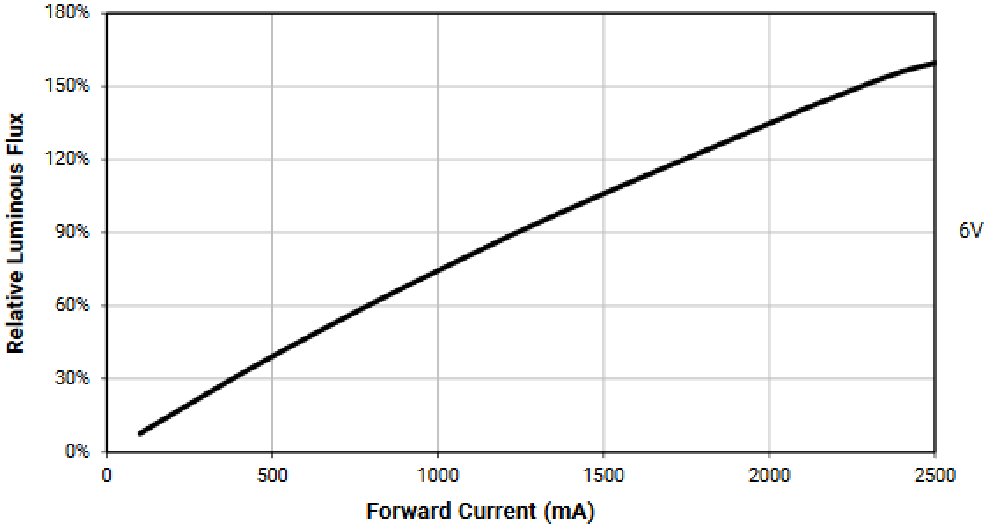


Figure 41. The Luminous flux of the LED's as a function of the forward current of the device with forward voltage of 6 V, and a junction temperature of 85 ºC.

LED 2 is also from the same series as LED with similar specifications. It differs in purpose though, whereas LED 1 is going to be used for the high beams of the headlight LED 2 is going to be used for the low beams. The design of LED 2 is the same as LED 1. The focus of the low beam LEDs is to illuminate the area in front of the car within 200- 300 ft and angle the beams down on the road. The brightness of LED 2 is 870 lumens. The full width half max viewing angle of LED 2 is also 120º. This LED is able to be driven at 6 V or 12 V as well and has a max current of 2.5 A. Luminous flux as a function of the forward current is the same as LED 1, at 2 A the luminous flux is around 135%. LED 2 has a different thermal resistance of 1.7 ºC/W.

Since both LEDs being used are high current and power devices pulling around 0.5 to 2 A, there is a large amount of heat generated by the devices. At higher temperatures the luminous flux of each device changes. In order to stabilize the headlight and provide a constant temperature a heatsink will be used along with a housing for the LEDs. As seen below in Figure 3 the relative luminous flux decreases as the temperature of the device increases. The max temperature of the devices is 150 ºC.

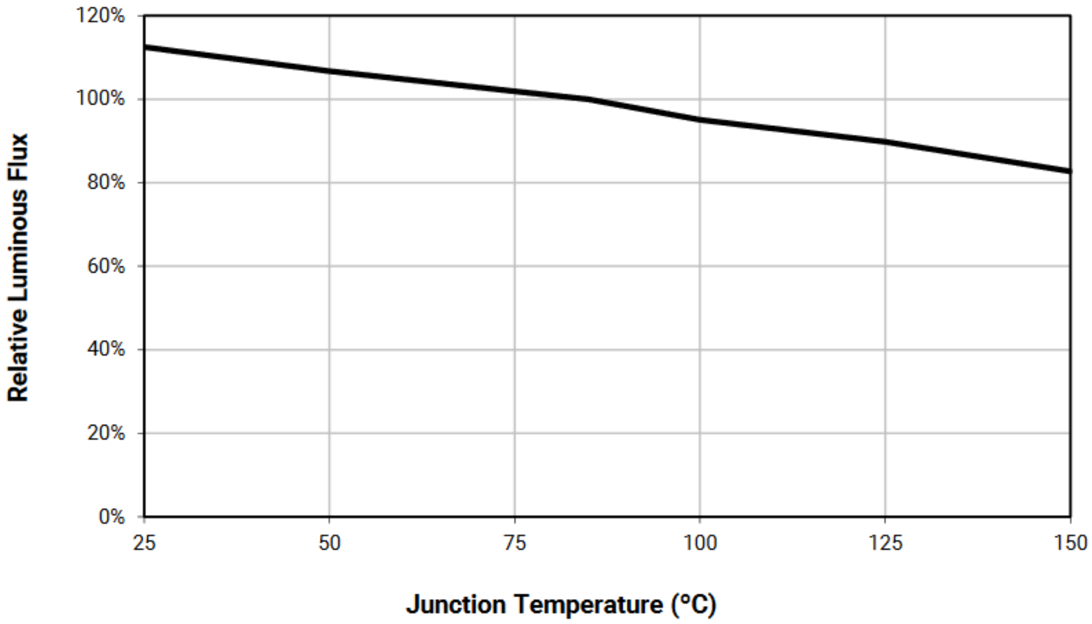


Figure 42. The relative luminous flux is inversely related to junction temperature. The max junction of temperature of the LED is 150 ºC.

In order to regulate the temperature of the device an aluminum housing and heatsink will be used. Aluminum is the desired material due to its easy machinability, and low cost. The heat sink will be attached to the back of the PCB. This will allow for the temperature of the LEDs to remain at a lower operating temperature.

5.8 LENSES

In order to image and collimate the LED's so that we have a wide field of view and a smooth beam pattern a reflector and lens system is needed. Each LED is comprised of a 2x2 matrix that emits light inside a 120º field of view. Since we will be making a 5x1 array of the LED's each one only needs to be in a small field of view with little overlap from adjacent LED's. For this to be achieved each LED will be collimated using a lens and reflector housing.

For the lenses there are many different types that could be used. However, we will be mainly looking at Plano-convex lenses with a small focal length on the order of 25 mm, with a diameter around 10 mm. The Plano convex lenses are positive singlet lenses. Any chromatic aberrations are not cared about for out set up so none of the lenses will be achromatic. Our light sources emit white light so our lenses should work over a broad spectrum, from 300nm to around 900nm which requires an uncoated lens. Since we will also be attaching these lenses to a reflector mount, it would be preferred an unmounted lens for ease of implementation.

Model	Diameter (mm)	Focal Length (mm)	Back Focal Length (mm)	Radius of Curvature (mm)	Diopter	Manufacturer	Price
LA1576	9	12	9.7	6.2	+83.3	Thorlabs	22.94
LA1472	9	20	18.3	10.3	+50	Thorlabs	20.56
LA1540	12.7	15	11.6	7.7	+66.7	Thorlabs	22.94
KPX334	10	55	53.4	28.53	-	Newport	5.00
-	10	7	-	-	-	Wholesale LED lens	.50
-	34	40	-	-	-	CN	0.17

Table 15. Lens specification table

Thorlabs LA1576 lens is made with BK7 glass and is unmounted with a refractive index of 1.5. We want an unmounted lens so that it can fit into a reflector housing that would surround the LED. The lens has a 9 mm diameter which is within the range of sizes we want. The focal length is also 12 mm, with a back focal plane of 9.7 mm. The lens also has a radius of curvature of 6.2 mm and an optical power of +83.3 D. This provides us with a small sized lens that can fit compactly within our setup. Since out set up will be compact and the size of our LEDs that are being tested range from 5 mm to 9 mm. The price of this lens at $22.94 is cheap relative to other lenses. For a single lens system, it would be ideal and fit our criteria for lenses. However, our system is going to be comprised of an array of 5 LEDs so 5 lenses would be needed in order to collimate each LED. This puts a constraint on our budget.

LA1472 lens made by Thorlabs is also made of BK7 glass and is unmounted with a refractive index of 1.5. The lens being unmounted suits our needs so that it can fit in to a reflector housing on the LEDs. The diameter of the lens is also 9 mm. The focal length of the lens is larger at 20 mm, with a back focal length of 18.3 mm. The radius of curvature is 10.3 mm, and an optical power of the lens at +50 D. This lens falls within our ideal criteria for lenses, but it is expensive being $20.56 per lens and about 5 lenses will be needed for the whole design.

LA1540 lens made by Thorlabs is another BK7 glass unmounted lens with a refractive index of 1.5. It has a diameter of 12.7 mm, which is slightly larger than our preferred size of 10 mm. However, it allows our system to have a higher numerical aperture which allows for our system to capture more light and focus more of it on the road. The focal length of the lens is 15 mm, and the back focal length is 11.6 mm. The radius of curvature of the lens is 7.7 mm. This gives us a thinner lens than the LA1472, but larger than the LA1576 lens. Our ideal lens is thinner and with a diameter closer to 10 mm since our LEDs are no bigger than 9 mm. The optical power of the LA1540 lens is +66.7 D. This lens costs $22.94 per unit. Since our design requires 5 lenses to properly image and focus the LEDs, this lens constrains our budget costing approximately $100 to develop a single headlight.

The next lens we researched is the Newport KPX334, and it is made of BK7 glass with a refractive index of 1.5. The diameter of this lens is 10 mm and is exactly at the benchmark we are looking for. The focal length of the lens is 55 mm and the back focal plane is 53.4 mm. The radius of curvature is 28.53 mm. The lens has a price of $5.00 per unit. The price is what we are looking for, but the focal length is large compared to what we want. Since each LED is comprised of a 2x2 matrix we don’t want the lens to be at the focal plane from the LED. Since that would just image the matrix, we want the LED to be slightly out of focus so that we have a smooth beam pattern.

The wholesale LED lens manufacturer lens are good lenses for cheap. Since one of the biggest constraints so far has been the price of the lenses. Since the lenses from Thorlabs and Newport were made of uncoated BK7 glass, the price was going to be higher since its higher quality materials. However, for this project functionality and low cost is more important than quality. These lenses are made of acrylic and offer a cheaper cost. The diameter of the lenses is 10 mm with a focal length of 7 mm. Since the lenses are an ideal size of 10 mm which is larger than our LEDs, and with a small focal length that will image the LEDs out of focus these lenses are ideal for our given constraints.

The lenses from CN are also acrylic and provide a cheap alternative to the BK7 uncoated glass. While we get a cheaper per unit cost using acrylic, we have to buy in bulk from the manufacturer, which provides its on constraint. The diameter of these lenses is 34 mm. With a focal length of 40 mm. Since these lenses are cheap and around the size, we need they are a god candidate. But since the must be bought in bulk of 1000 pieces, they are not suitable to be used for our project due to waste of resources and impractical number of lenses.

While we have researched and found lenses multiple lenses that can work in our system, further research before picking a lens is required. Since we are still in the development stage of our setup, we do not exactly know what requirements we need for a lens to meet. We have general parameters so that preliminary research can be done to expedite the process. To image the LEDs, we know that we want it to be slightly out of focus in order to accommodate a smooth beam pattern at any distance. The LEDs we have chosen to use are comprised of a 2x2 matrix. When the LED is placed at the focal plane of the lens then we image the pattern of the matrix on the LED chip. The pattern is not suitable for the headlight while driving. In order to prevent this, we will have the LED chip be slightly out of focus to not prevent any illegal beam patterns.

5.9 REFLECTORS

In order to image the LEDs our imaging system is going to be composed of a lens and a reflector. The lens component of the system has been discussed in the previous section. In this section the reflector will be discussed and what the criteria for selecting a reflector will be.

A reflector is needed in order to use more of the light generated by the LEDs. Since they emit light in a 1220-degree field of view, a large portion of the light is not going to be used. But with the implementation of a reflector surrounding the LED chip we can effectively focus the light into our lens and use more of the light generated by the LED. This will raise our electrical to optical power efficiency. The field of view from the reflector is important because it limits where we can focus the light and how far the light can be transmitted in the horizontal axis. The main concern of the reflector is be able to provide small sections of overlap at large distances of about 500 ft. When we have a large overlap in the field of view the effect of toggling off certain LEDs is diminished. While we do not want to prevent any light from reaching observers in oncoming cars, we want to effectively sim our headlight and be able to maintain constant driving of the high beams so that we maintain maximum illumination of adjacent areas.

Our ideal reflector will be able to accommodate a 9 mm x 9 mm LED chip, and have a viewing angle less than 65 degrees. It would ideally be made from metal due to its high reflectivity of light within the visible range of 400 to 700 nm. Metal also has the benefit of having a higher specific heat, due to the high electrical and optical powers of the LEDs that are being tested generate a large amount of heat. The reflectors need to be robust in not changing shape due to heat. The price per unit should be low and not cost more than $5 per unit due to the volume of units needed for the overall design.

Model	Manufacturer	Material	Viewing Angle	Diameter	Height	Price
OPC-12COL	Dialight	Metal	26	9.7 mm	3.8 mm	$2.28
CX11524_ LAURA-R-W	Ledil	Metal	68	12.9 mm x21.6 mm	21.6 mm	$3.99
CX12983_ LAURA-R-xW	Ledil	Metal	71	12.9 mm x21.6 mm	21.6 mm	$3.37

Table 16. Reflector options

The Dialight OPC-12COL round reflectors are a good candidate reflector for our headlight. Since some of our LED chips are 9 mm by 9 mm the diameter of 9.7 mm of the reflector fits the size of our LED. Metal has a high reflectivity for the entire visible spectrum of 400 nm to 700 nm. Since metal has a high reflectivity over this range of wavelengths it helps to increase the efficiency of our system. The viewing angle of 26 degrees is on the smaller side of reflectors. While we want to limit the field of view to be small with little overlap at large distances this can allow for us to achieve that design goal. The height of the reflector is 3.8 mm, which is compact for our design constraints. Most headlights are compact in design which places a constraint on the size of our device. The cost per unit is approximately $2.28. The low cost of this reflector makes it a suitable choice to incorporate into our design since it is affordable.

The Ledil CX11524_LAURA-R-W square reflector has dimension of 12.9mm x 21.6mm x 21.6 mm. The square design of the reflector benefits from the design of the LED chip. Since both are square, they can fit tightly, as opposed to a round opening. However, since the length of the reflector is larger than that of our LED chips, a proper fitting can be of concern. Also, the termination style of this reflector is adhesive. The LED chips we have been testing since they operate at a high electrical power, and emit a large optical power there is a large amount of heat generation. The metal material like the previous reflector has a good reflectivity over the visible range of 400 nm to 700 nm. This reflector has a larger viewing angle at 56 degrees. The larger viewing angle gives us a larger overlap with the other LEDs in the matrix allowing for less control over how dim the headlight can be when each LED is toggled on or off. While having a larger field of view can also benefit since it will allow for residual light to be spread out across a larger area with a greater overlap of the beams. The size of the reflector is bigger than that of the previous one, but it is still a compact design and able to fit within out headlight design constraint. The price of the reflector is $3.99 per unit. While approximately 5- 10 of the reflectors would be needed, costing about $40. This reflector has a higher cost but offers a larger field of view and a suitable base shape for our square LED chips. This reflector is a viable component of our design scheme.

The Ledil CX12983_LAURA-R-XW is a square reflector with the dimension of 12.9 mm x 21.6 mm x 21.6 mm. Since the reflector is a square design benefits from the design of the base of the LED chips which allows for a closer fit. Similar to the previously mentioned reflector the length is longer than that of our researched and testing LED chips. Just like the previous reflector the termination method is by adhesive which may cause concerns with the heat of the LEDs. The viewing angle is larger than the CX11524_LAURA-R-W, which had a viewing angle of 68 degrees. The CX12983_LAURA-R-XW has a viewing angle of 71 degrees. The larger viewing angle can provide a larger overlap in the bema pattern, but it also prevents precise control of the entire beam from the headlight. In order to properly block out certain cars we would ideally want a smaller field of view so that we have a small overlap between each LED, and a tighter focus from the reflector and lens. The cost per unit of this reflector is within our ideal specification of being below $5.

Each reflector is $3.37, making the total cost if 10 LEDs were used, for the low and high beams, about $34.

Most of the reflectors compared in this section satisfy our constraints on size and reflectivity. Some of the fields of view are larger than our constraints but that is a looser constraint. We can have a larger field of view from the reflector due to the need for slight overlapping at large distances so that some residual light can be perceived by oncoming drivers, and our headlight will appear dimmed to the observer. While we have not decided on any reflector to use or manufacturer. We are doing preliminary research to decide on which component to use later. LEDs are stilling being researched and tested. A few of the LEDs being tested are different sizes in width and length. In order to decide and finalize a decision on a reflector design the main headlight component must be designed and finalized. The spacing and determined fields of view are still being researched and designed.

For our reflectors used in our final design they were hand made and designed. The reflectors used for our high beams and fog lights are different and more suited to what the purpose of each part of the headlight is deigned to do.

The reflector for the high beams were designed to have a large image size to maximize the illumination of the road and surrounding areas. In order to accomplish this a reflector bucket was designed with a parabolic back and a rectangular aperture. The high beams are going to be imaged by having the LEDs aimed into the reflector and allow for the beam to diverge be reflected out onto the road. Below in Figure 42 is a drawing of our final agreed design of the reflector for the high beams.

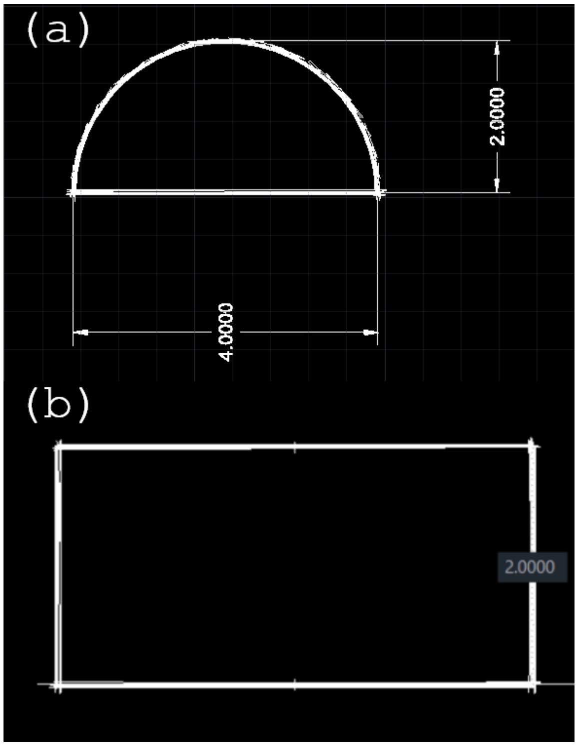


Figure 43. (a) Top (X -Z) view of the reflector. (b) Front (X - Y) view of the reflector. (All units are in inches)

The Fog light reflector design we went with was for a more cylindrical reflector so that our beam spot would be circular in shape. We wanted a circular design for the fog lights since it will be low to the ground and we can have a larger beam divergence. The design for the reflector is symmetric in both the x and y axis and is parabolic in the z plane as seen below in Figure 43.

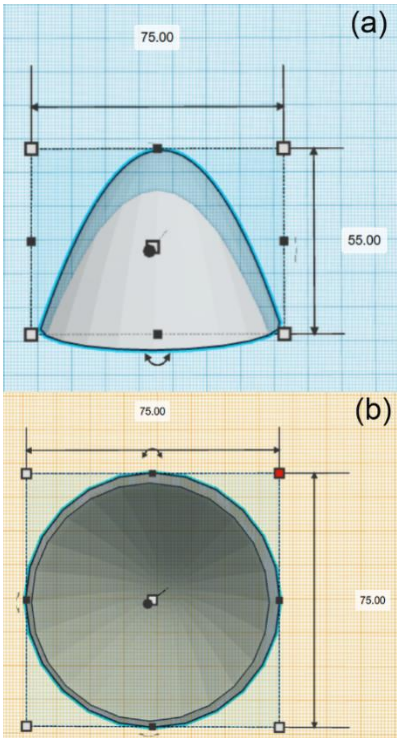


Figure 44. (a) X – Z plane view. (b) X – Y plane view. (All units are in millimeters)

Due to recent world events with the COVID-19 pandemic, we were unable to 3D print or machine our reflector designs. In place we made a makeshift reflector out of aluminum cans to show the proof of concept.

The final design of our low beam ended up using a projector style headlight that allowed us to collimate a square beam. The LED module we used had an emission region in the pattern of 4 square in a 2 x 2 order. By making the assembly such that the LED board is just inside of the focal length of the lens we were able to defocus the beam such that the output pattern was square and the defocus pattern was smooth and even in light distribution.

5.10 DESIGN SUMMARY

The user should be able to easily turn on the headlight unit. This will be done with a switch. The headlight unit will be powered by a 12V car battery because when it is inside of a car working, that will be the power source. The circuits will be made of printed circuit board. The sensors and camera will be hooked up to the micro controller. The microcontroller will be taking input from the sensors and giving output based on the readings. The readings from the camera will be processed by the micro controller and the processed image's data will be stored in the memory. Once the micro controller has all the data from the sensors and processed camera image, it will dim or light up the correct LEDs. The LEDs will take input from the micro controller and that will control how bright each light should be given the data. Each LED will have a lens attached to it so that the light will be dispersed or focused. They will also have a reflector so that the light from the LEDs can be focused into a certain direction. The focused beams are there to be dimmed as to not shine direct light on any light sources. The dispersed light will be for seeing in the dark when the focused beams are dimmed.

6 PROJECT PROTOTYPE

In this section we will discuss our methodology for testing the major components, our observations and our conclusion. We will try to find which component works best for our needs and expectations. In this section we will show our testing procedure and the things we were testing for.

6.1 HARDWARE TESTING

In this section we will test the physical components that are going to be used in the final design. These components include the LEDs, the LED drivers, DC converters and the microcontroller. We will outline our testing procedures and describe our results.

6.1.1 LED TESTING

Testing intensity and color of each LED chip in order to decided witch color light would be best of the eyes depending on if it is the high beams, low beam or fog lights.

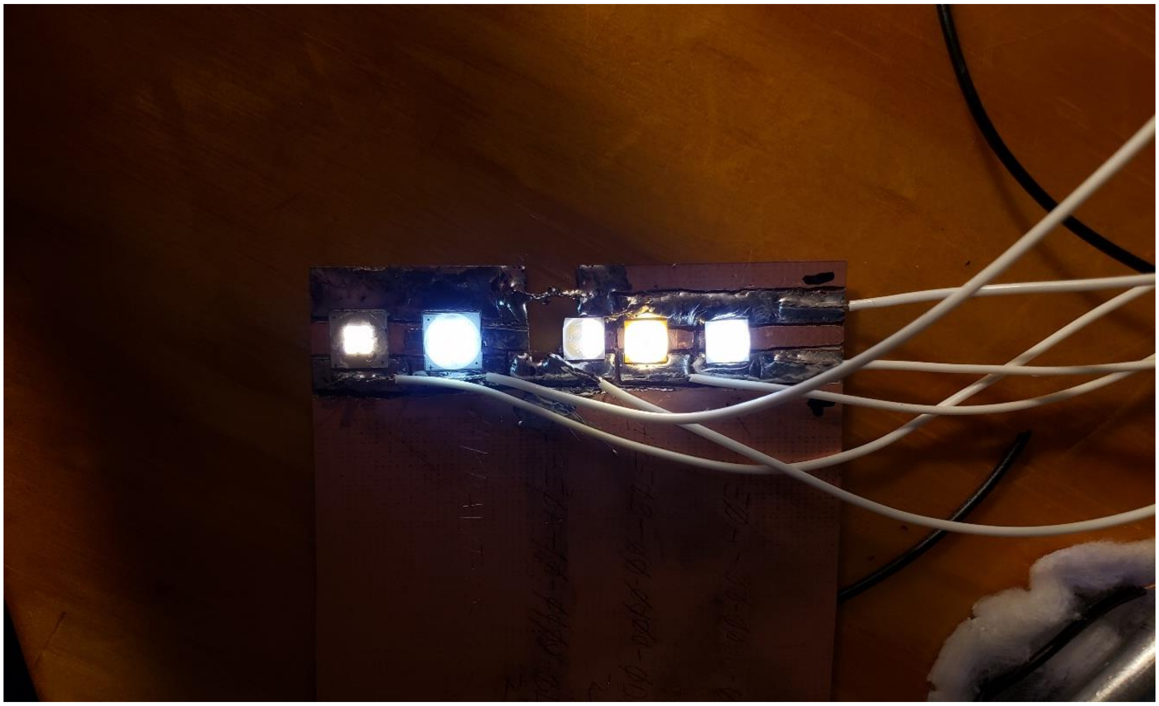


Figure 45. From left to right we have a warm white and cool white 7mm x 7mm LED the next three are 5mm x 5mm neutral white, warm white and cool white.

Cree LED testing		
Test	Test description	Result
1	Power and test color of XHP50B-00-0000-0D0HH230G	Not going to use
2	Power and test color of XHP50A-00-0000-0D0HH240G	Not going to use
3	Power and test color of MKRAWT-00-0000-0B00H440F	Not going to use
4	Power and test color of XHP50A-00-0000-0D0HH250G	Using for the Low beams
5	Power and test color of MKRAWT-00-0000-0B0HG40E2	Using for the High beams

Table 17. Cree LED testing

Test Procedure

First, we mounted all of the LEDs onto a board and inscribed the part number on the board. After the LEDs were mounted, we connected them to individual wires so that each LED could be turned on and tested separately. We connected them to a DC power supply set to 6 V and then varied by current. The LEDs were tested at a range of .50 mA up to 1.5 A. The brightness of each LED was qualitatively observed. While the brightness of each LED was being observed, the color component of the LEDs was also being observed and tested. All of the LEDs are white, but they varied in the colors of white. Some of the LEDs were a warmer white, which has a reddish tint and is similar to Halogen or Incandescent bulbs. Neutral white was also tested which is similar to natural light from the sun without any blue or red tints to it. The last color tested was a cool white, which is characterized by a slight blue shift, these lights are more of the typical LED headlights on the road that have the bright blue tint.

This testing was done qualitatively and mainly served as the purpose of picking the color of the headlights. A color for the headlights was decided and will be discussed further in the Test Conclusion section. Another more quantitative test is planned at a later date once a light meter is acquired. The quantitative test is necessary in order to determine the lumens per unit area, or lux of the LEDs. We also plan to further test the field of view and determine the lumens per degree and find the candelas, or lumens per steradian.

Test Conclusion

During our preliminary tests of the LEDs it was concluded that more quantitative tests were needed for the brightness of the LEDs. All of the LEDs tested had a high observable brightness at a close proximity and need a cover to block and diffuse most of the light emitted.

Testing of the color of the LEDs yielded results. Two different colors were chosen for the headlight. A warm white was chosen for the low beams and a neutral white which had a higher advertised brightness was chosen for the high beams. Both of the LEDs were illuminated in tandem to observe the color mixing of the two LEDs. When mixed the LEDs produce a more neutral colored white. Both colors of the LEDs are legal colors for automotive headlights that produce a gradient intensity output when out of focus. When the LED is set near the focal point the beam becomes more evenly distributed and confined in a 2 x 2 square with a defined space between each square. This effect is due to the LED being a small matrix of LEDs, to counteract this we will adjust our collimating lens to be slightly out of focus so that the beam is still more square with softer edges and no dimming within the beam caused by the board layout.

The reason the warm LED was chosen for the low beams was due to the harshness of the light on the eye. It was found that the warm LED while having a high brightness it was less harsh on the eyes to view, then the cool or neutral lights. The warmer LEDs with the red tint to them are not as harsh on the eyes due to our photoreceptors in the eye. Our eyes are less sensitive to red than they are to blue. Due to the high energy of blue light it creates a brighter image in the retina than the lower energy of red light. Since blue light has a shorter wavelength than red light, the energy of the photons is different. Also, because of the higher energy required to produce blue light the devices used in order to produce them have a shorter lifetime. With all of these factors taken into account the warm LEDs were the best option to use for the low beams.

The LEDs that were decided to be used for the high beams were a neutral white and had a higher. The neutral white had a perceived higher brightness than the cool white or warm white LEDs. While the tested neutral white LEDs were 7mm x 7mm and had a higher stated brightness from the manufacturer. The main reason the neutral whites were picked for the high beams was for the higher perceived brightness while also not being harsh to perceive. When the neutral and warm white LEDs were illuminated alongside each other, the resultant color was a strong neutral white with some red tones. The combination of the two LEDs provided a larger perceived brightness.

6.1.2 Low Beam Testing

The final design of our low beam ended up using a projector style headlight that allowed us to collimate a square beam. The LED module we used had an emission region in the pattern of 4 square in a 2 x 2 order. By making the assembly such that the LED board is just inside of the focal length of the lens we were able to defocus the beam such that the output pattern was square and the defocus pattern was smooth and even in light distribution. We needed to measure the beam quality of the low beam pod.

The first beam quality we wished to test was the beam shape as we were aiming for a diverging square beam such that we have a defined region illuminated that also allowed for the physical beam overlap with other pods in the system to provide a some light to the regions that might be dimmed on purpose. For this we needed to have a diverging beam. The physical measurement of the beam divergence consisted of measuring the beam diameter at several distances to average out the rate of divergence. In table 19 below are the physical measurements of one of the pods.

Low Beam Divergence			
Position	Distance (cm)	Diameter (cm)	Divergence (rad)
1	5	5	-
2	8	6.8	0.583
3	10	8.4	0.761
4	13	11	0.818
Average			0.720

Table 18. Low Beam divergence testing

The rate of divergence was 41.25 degrees this show that the beam is able to cover more than the fifth of the total field of view meaning that there will be overlap of illumination from pod to pod. This is the effect we were aiming for such that when one pod is turned off the amount of illumination is significantly reduced but still has some illumination for safety.

The next beam characteristic we wished to document was the illumination pattern. We aimed for a concise square beam pattern with minimal out of pattern light that might create unwanted points of excess illumination. As we can see in figure 45 the beam is square with chamfered edges. The secondary ring of illumination is due to limited tooling available so rather than a smooth transition a step bit was used to machine the housing resulting in the reflection ring. Although not planned as part of our original beam pattern it is well below the intensity of the central illumination. Therefore, this ring pattern is not of concern and can be acceptable within the total beam shape.

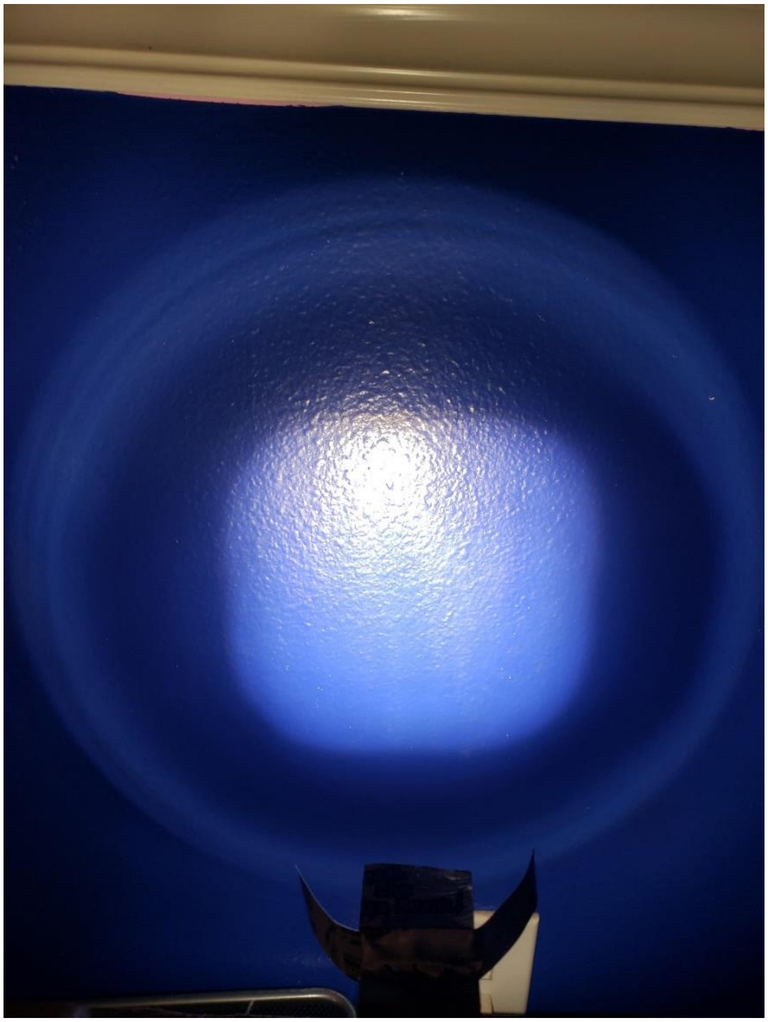


Figure 46. Here we can see the beam is projected in a very symmetrical square that decreases intensity near the edge with very little excess illumination present.

For the fact of reliability, we wanted to ensure these headlights can run for an ample amount of time without overheating. This concern is a serious one as these lights are very power demanding and produces a lot of heat as To ensure this we turned on the headlights at our testing current and P.W.M. frequency and ran them for three hours in which the temperature was kept stable without any failure. Through entire system testing the low beam pods accumulated eight plus hours of run time without failure of beam quality, output intensity or any issues maintaining a reasonable temperature.

6.1.3 High Beam and Fog Light Testing

The high beams for the system needed to be a bright white color such that it appears brighter to our eyes and also have a wider spread than an individual pod. We selected for our high beams a cool white rather than the warm white we used for the low beam. This choice came as the cool white had a higher output of 970 lm compared to the warm white 840 lm output. As white light is the combination of all visible light, we can state both color temperatures are broadband while the cool white has more of a peak in the blue region compared to the warm white that has more in the red region. The human eye responds best to green followed by res and then blue. With the peak intensity of the cool white being bluer shifted there is inherently more green light as well. This makes our perception of the light present to be brighter even though the same intensity of light is present with a warm white LED. To test the beam quality, we can see in the following figure 46 the high beam is much brighter than the low beam pods. This demonstrates how the high beam can allow the driver a farther line of sight.

Figure 47. Here we can see on the left that the high beam covers a larger region and has a greater physical output of light when compared to that of the low beam on the right.

Hard to see in the image due to the blue wall the output is truly more of a blue tint. This is seen very clearly in the demo video. The benefits of the bluer color temperature is that not only do our eyes respond better but most reflective signs tend to reflect much better with colors that are not red. There are few signs that are red most tend to be green or even white. The white reflects all light back so if a spectrum more attuned to a human’s eye response hits the sign the more visible spectrum is reflected back at the driver making for ease of sight. Green signs reflect green light and yellow reflect the yellow portion of the spectrum. The blue shifted LED tends to emit more light in the middle of the visible spectrum meaning there is more green and yellow light present making again for ease of sight for reflective surfaces.

In conclusion for the high beam testing we achieved a selection for the LED and housing design such that the output is brighter than that of the low beam while giving more of a flood pattern to illuminate far and wide. The hue of the LED also gave off more of the visible spectrum that is more common with reflectors as well as better aligning with the spectral response of the human eye.

For the fog light we ended up having a lot of similarities in the physical construction as the high beam except we were to use the same LED as the low beam so that we were just adding more light down on the lower part of the road. We used the same 2 x 2 matric layout as the high beam with adjustable aluminum reflectors to steer the path of propagation to be narrow in the y-axis and wide in the x-axis. The result was a fog light assembly that added an extra 1600 lm in the lower region of the forward FOV of the driver. This extra light was kept low to the ground such that it illuminates the road and other indicators and hazards that lay ahead while being low enough not to cause a large amount of back scatter that could cause issues with the drivers vision.

6.1.4 Light Sensor Testing

The main purpose of the light sensor is to detect the ambient amount of light to trigger the high beams. This sensor is needed to allow for maximum illumination when outside of well-lit areas such as cities, or when there is no oncoming cars. Our sensor was programmed to turn off the high beams when it reached a certain threshold of light. For the light sensor we used a photoresistor.

When the photoresistor was programmed and connected to a its own self-contained circuit it was successful in turning on and off the high beams. The circuit consisted of the 1 kΩ - 10 kΩ and a 2.2 kΩ resistor to provide a voltage divider circuit that varies with light to make a proper light sensor. The physical circuit can be seen in the figure below. When the sensor was triggered high it turned off a test light to simulate turning off the high beams, and then turned on the test light to simulate turning the high beams on when in the absence of light. The testing of our photoresistor circuit was successful.

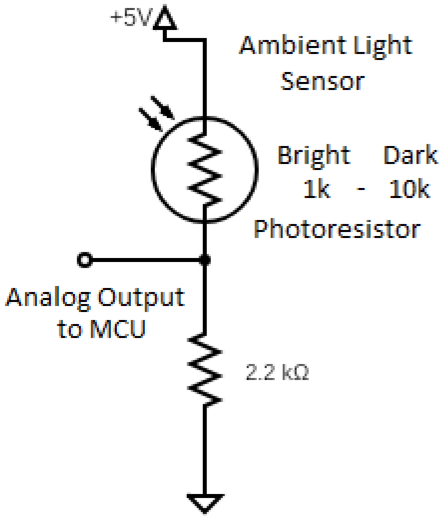


Figure 48. Breakdown of the ambient light sensor assembly.

When the light sensor was implemented into the headlight assembly, it worked as it did during preliminary tests. During operational tests of our headlight we used a flashlight in order to simulate daylight. While running the headlight in a controlled environment, the flashlight was able to successfully trip the light sensor to turn off the high beams when the flashlight was put over the light sensor. When the flashlight was moved off the light sensor it turned the high beams on again. The testing was successful for tripping both day and night states of the headlight operation.

6.1.5 Rain Sensor Testing

Our rain sensor is composed of three optical components, a laser diode, photodetector, and a transmissive medium (acrylic). Initial testing of each component was successful. The laser diode was able to be coupled into the acrylic and able to escape through the interface when water was on the transistion plane. The phototransistor was able to generate a signal when in the presence of the laser light.

Next, we needed to test the responsivity of the photodetector with the laser diode. When the laser diode was aligned with the photodetector and passed through the acrylic the photodetector was able to generate a signal distinguishable from the noise. This is due to the high intensity and direct path into the phototransistor. This test was successful in showing that our transmissive medium was able to transmit the wavelength of our laser diode and the attenuation of the acrylic was minimal. It also proved that our photodetector was responsive to the wavelength of our laser diode.

In order to create our rain sensor, we had to find the incident angle of our laser onto the acrylic in order to achieve the critical angle so that total internal reflection is achieved. With the acrylic facet cut to achieve the appropriate incident angle, the beam path while totally internally reflected was traced and the photodetector was placed accordingly. The resulting signal from produced by the laser diode on the phototransistor proved that we had total internal reflection and a steady signal at the detector plane. Below we can see the circuit diagram for the rainsensor composed of only four components.

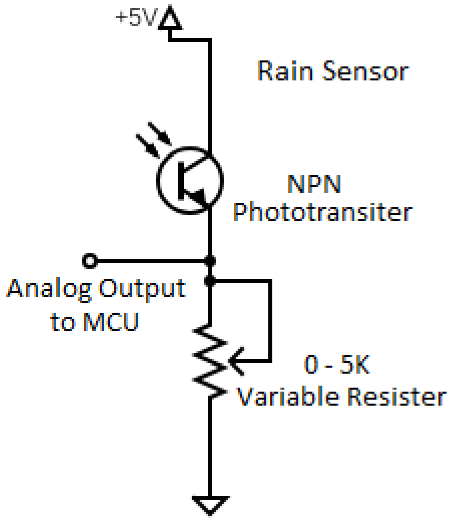


Figure 49. Breakdown of the rain sensor assembly.

Finally, for the rain sensor to work appropriately it needed to be sensitive enough to detect a loss of power when there was water on the surface of the acrylic, which changes the critical angle and lets some light escape the system. When a drop of water was placed on the face of the acrylic the resulting signal dropped at the detector drastically from 4.85 V to 0.35 V. The overall senstivity was very high as we were able to sustain a 50% drop in signal voltage from the moisture of a breath causing condensation on the acrylic surface.

6.1.6 Camera Testing

We bought 2 cameras from our research sections. We should only have bought one but the extra camera we bought was only $5 so it wasn’t much of a loss and could be a good investment to practice with. This is the $5 C&W camera.

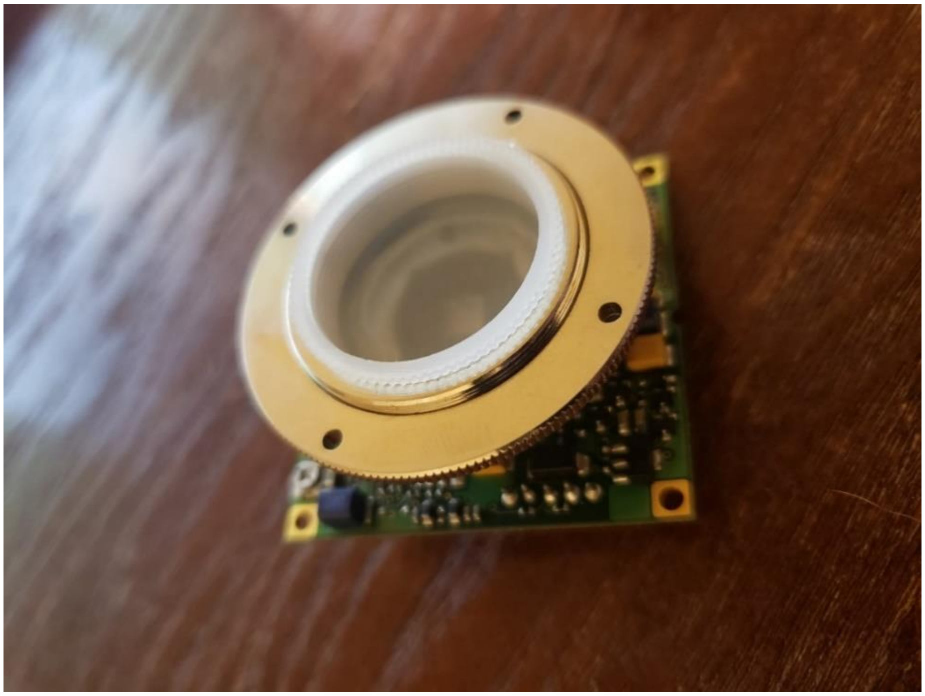


Figure 50a. C&W camera.

The next picture is the TLL serial Camera.

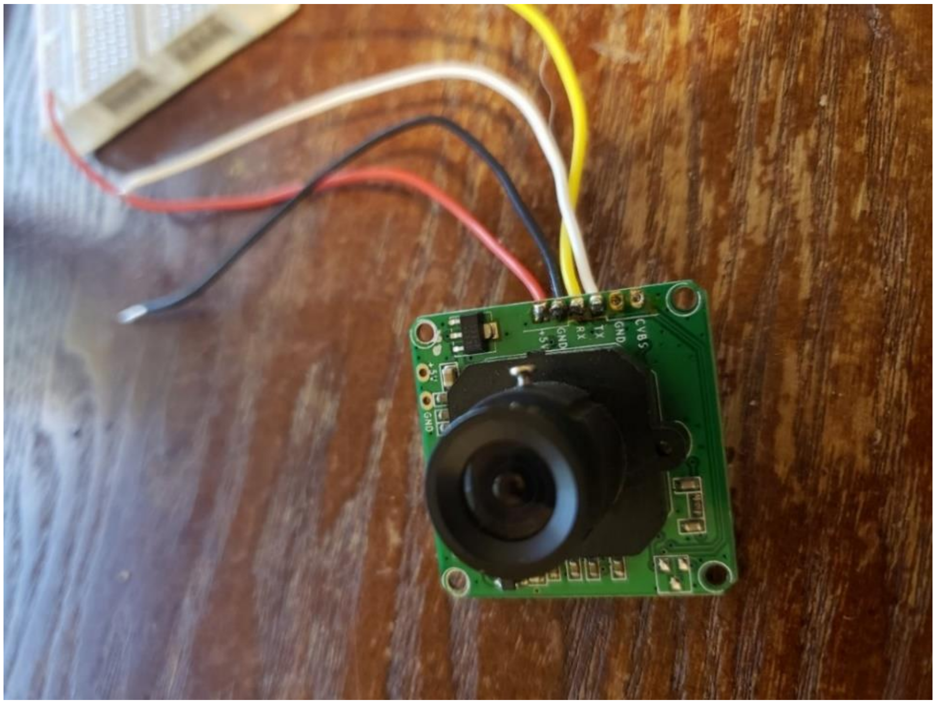


Figure 50b. TTL camera.

We were able to hook the camera up to an Arduino that has an SD card attachment so that we know the camera works. The focus is really off but we don't care too much about focus as long as it is not too far out.

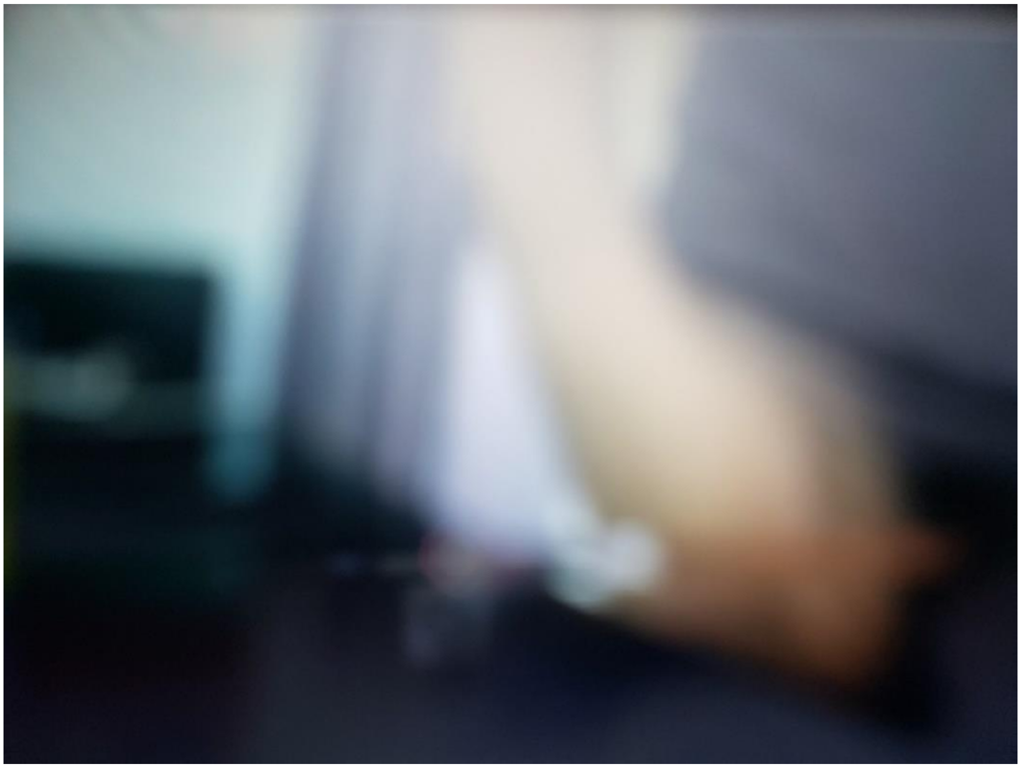


Figure 51. Picture captured by the TTL camera.

The next picture is of the board we used in order to get this picture. We used this board because we wanted to save the picture on an SD card so that we could show it in the report. This board still used the Arduino Uno and that is what we did a lot of our testing on.

The way that this board worked is the camera was attached to it with the read only pin and the tx pin. The micro controller had an ultra-sonic sensor attached to it as to trigger when it sensed anything in the area. The camera was pointed in the direction that the sensor was observing. Once we powered the device on, we triggered the ultra-sonic sensor and the micro controller started reading the data coming from the camera. This specific camera gives the picture in a JPEG format. So the micro controller read that data and stored it as a JPEG into the SD card seen in the top of the board.

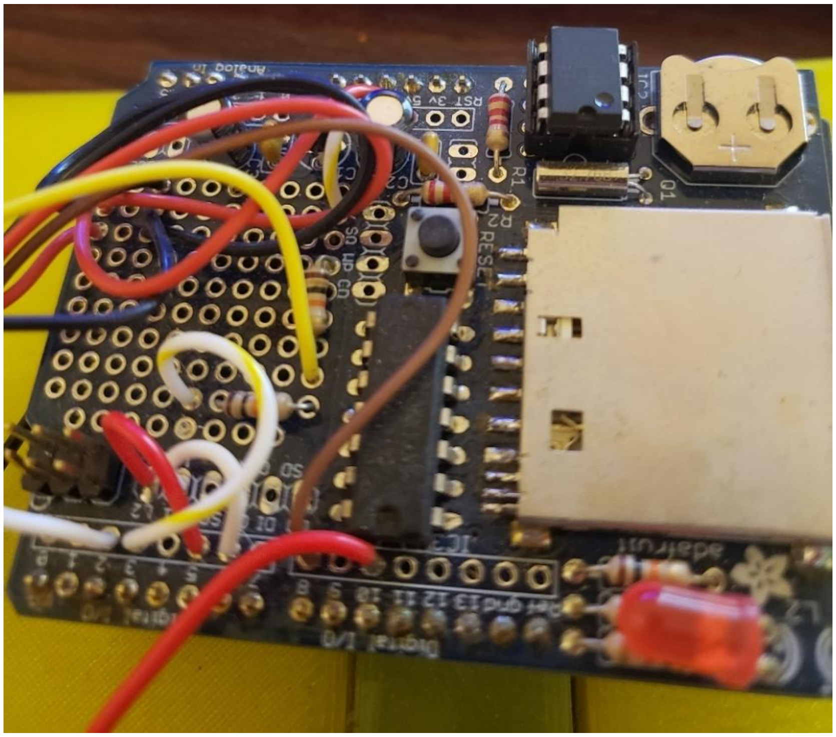


Figure 52. Camera storage circuit to SD card

Here is a table with the process of testing this camera

Test	Test description	Result
1	Connect the camera to the board.	Pins connected fine
2	Connect power to board and camera	Success
3	Power on board and trigger picture taking	Success
4	Extract picture from SD card	Success

Table 19. Testing process

6.1.7 POWER SUPPLY TESTING

There are two main types of systems that need to be powered, the high current LEDs and the low voltage devices such as a microcontroller and external sensors. The most important and with relative difficulty thing we have to get right is the LED driver. So, for that reason we will be testing three different LEDs drives

6.1.7.1 A6211GLJTR-T (A6211)

Using the schematic for A6211 we will test the circuit as shown below in figure 37. We preformed the test shown in table 18 in order to make sure our LED driver able to meet our requirements. The circuit for this IC was constructed as planned. However, there were several issues with this IC, it would not power on. The IC did not become warm or hot and the power supply unit never indicated there was a short in the system. We tried different input voltages, and nothing would work. Additionally, I thought it could be an issue with the enable signal, so we tried making the enable signal high different voltages within the rated range. Then we tried using PWM with varying duty cycles and there was still no change. Lastly, we tried and new IC chip but the problem still persisted.

A6211GLJTR-T Constant driver Test		
Test	Test description	Result
1	Powered on using Keithley 2230-30-1 l Power Supply	FAILED
2	Turns CREE LED on	FAILED
3	Output current greater than .5 amps	FAILED
4	Maintains output greater .5 amps for over a minute	FAILED
5	Controllable using Microcontroller	FAILED

Table 20. A6211 LED driver testing procedure

6.1.7.2 LED2000DR (LED2000)

Using the schematic for LED2000 we will test the circuit as shown below in figure 38. We preformed the test shown in Table 19 in order to make sure our LED driver able to meet our requirements.

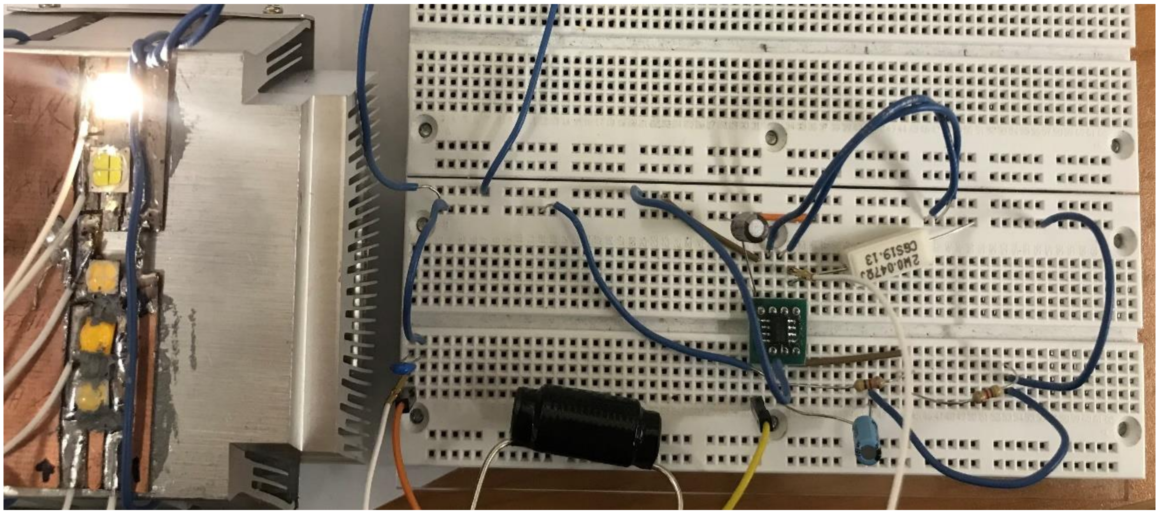


Figure 53. bread board testing of the LED2000 constant current LED driver

LED2000DR Constant Current driver Test		
Test	Test description	Result
1	Powered on using Keithley 2230-30-1 l Power Supply	PASSED
2	Turns CREE LED on	PASSED
3	Output current greater than .5 amps	PASSED
4	Maintains output greater .5 amps for over a minute	PASSED
5	Controllable using Microcontroller	PASSED

Table 21. LED2000DR LED driver testing procedure

6.1.7.3 TPS56339DDCR (TPS56339)

Using the schematic for TPS56339we will test the circuit as shown below in figure 39. We preformed the test shown in Table 22 in order to make sure our LED driver able to meet our requirements. We constructed the constant voltage source and were able to meet our testing criteria. The only downside is that this is a constant voltage source so the voltage can vary from driver to driver.

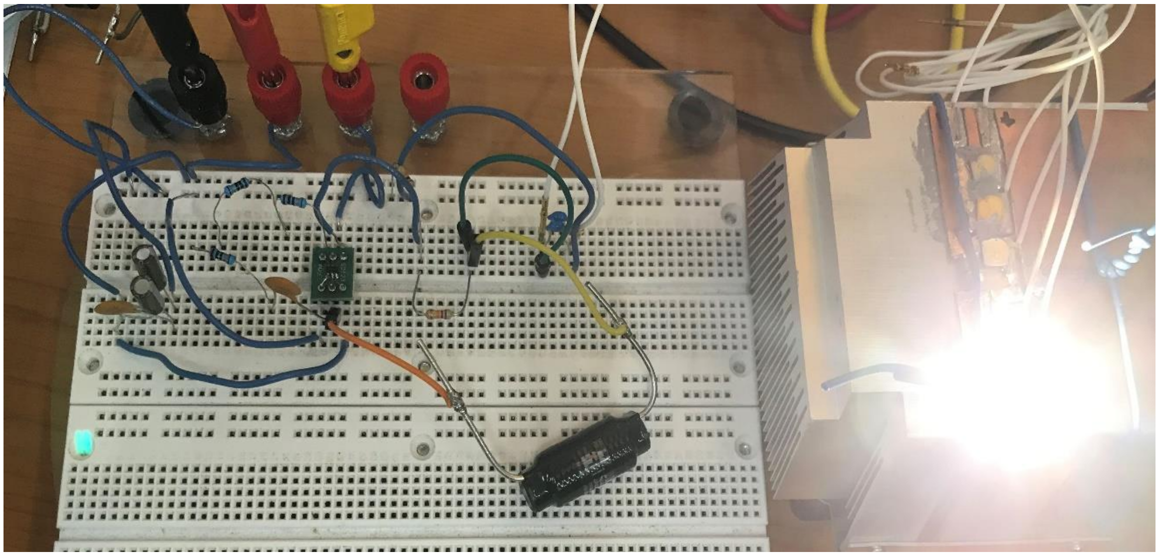


Figure 54. Bread board testing of the TPS56339constant current LED driver

TPS56339DDCR Constant Voltage driver Test		
Test	Test description	Result
1	Powered on using Keithley 2230-30-1 l Power Supply	PASSED
2	Turns CREE LED on	PASSED
3	Output current greater than 1 amp	PASSED
4	Maintains output greater 1 amp for over a minute	PASSED
5	Controllable using Microcontroller	PASSED

Table 22. TPS56339LED driver testing procedure

6.1.8 AFTERIMAGE REDUCTION

To increase the safety of oncoming drivers we need to reduce the impact of afterimage caused by intense light. To address this the low beam is highly adaptable in the sense that the beam propagation path is divided into five segments that can be dimmed or shut off to limit the amount of light making it to oncoming drivers therefore decreasing the afterimage that may occur to other drivers when passing by. To further the afterimage reduction the mistake of driving with high beams with an oncoming car present would no longer happen as the system designates when high beams should be on vs when they should be off and automatically selects the lighting necessary for the condition at hand.

6.2 SOFTWARE TESTING

The testing we did was on an Arduino Uno because it was readily available and coding on any MCU would be identical. We coded in C and what we needed to test was if our states idea was going to work. The next table shows how to get each state from our software.

Expected states per environmental condition.

	Day	Night	Rain	Fog	Smoke	Day On coming	Night oncoming
Light sensor	True	False	True or False	True or False	True or False	True	False
Water sensor	False	False	True	False	False	True or False	True or False
Back scatter detection	False	False	True or False	True	True	False	False
High beam	False	True	False	False	False	False	False
Low beam	False	True	True	True	True	True	True
Modifying low beam	False	False	False	False	False	False	True
Fog light	False	False	False	True	True	False	False

Table 23. Logic table for software to interpret for each component and condition

6.3 SOFTWARE FLOW DIAGRAM

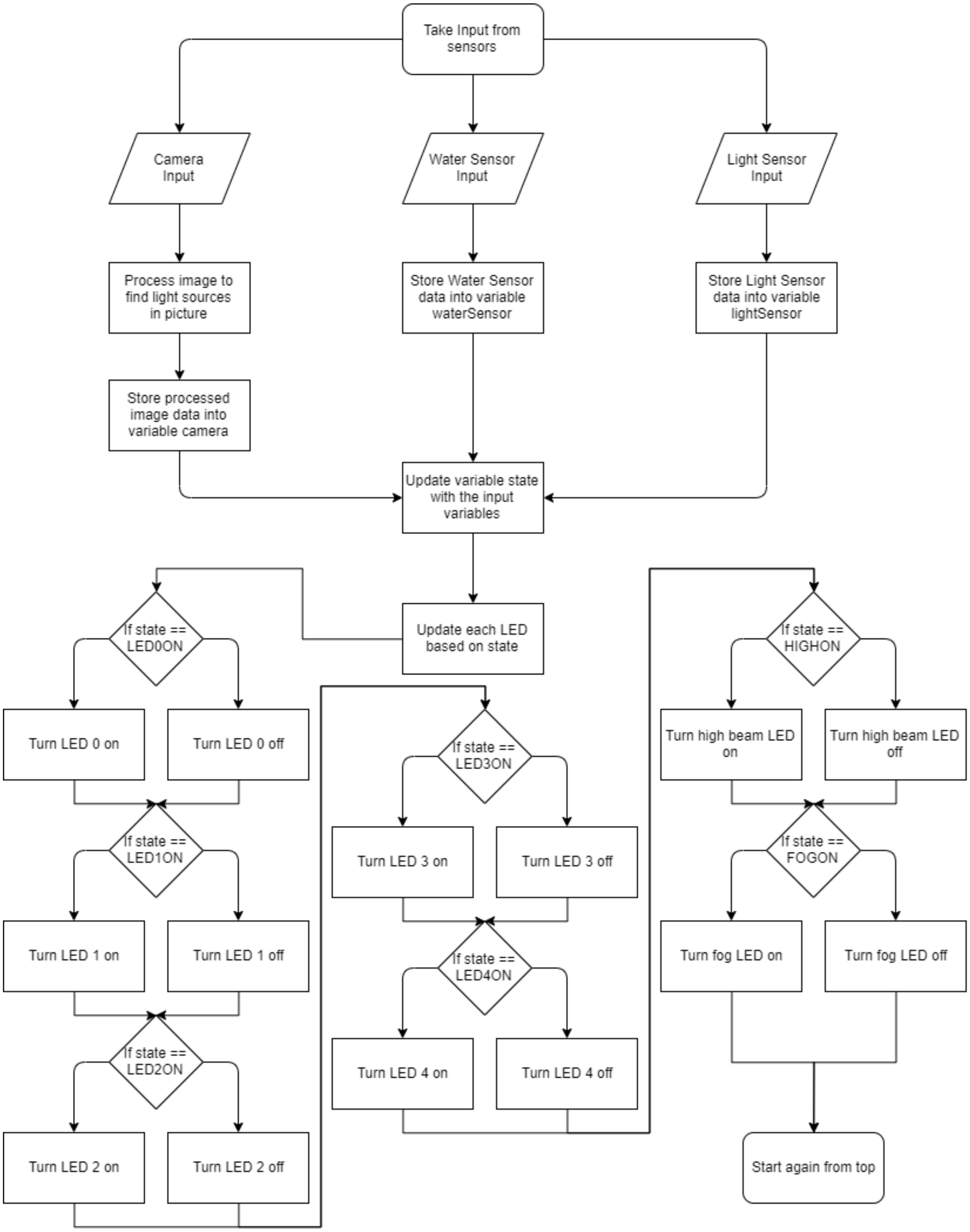


Figure 55a. Flow diagram.

The flow diagram shows how the microcontroller should work under normal conditions. The part that says process image to find light source in picture can be expanded into a larger part here.

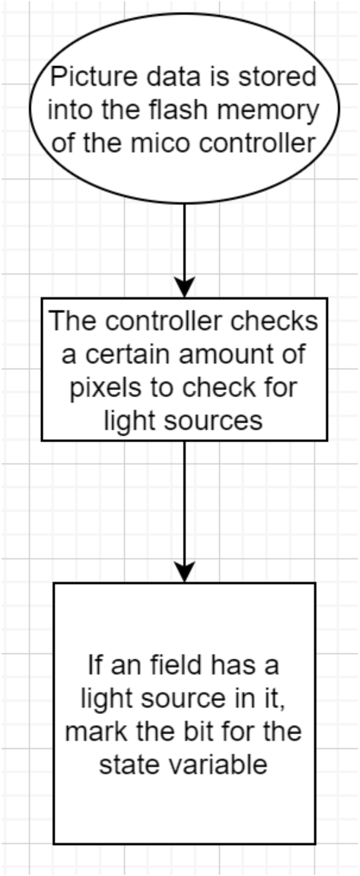


Figure 55b. Flow diagram.

If this part of the flow chart were in the previous page’s the chart would be too big to be able to read very well. Once you look at it as a whole, it should be very easy to understand.

6.4 OVERALL SCHEMATIC

The overall schematic show in figure 51 consist of 3 main components. The 5 volt DC regulator used to power the microcontroller and sensors, the microcontroller itself, and lastly the LED driver.

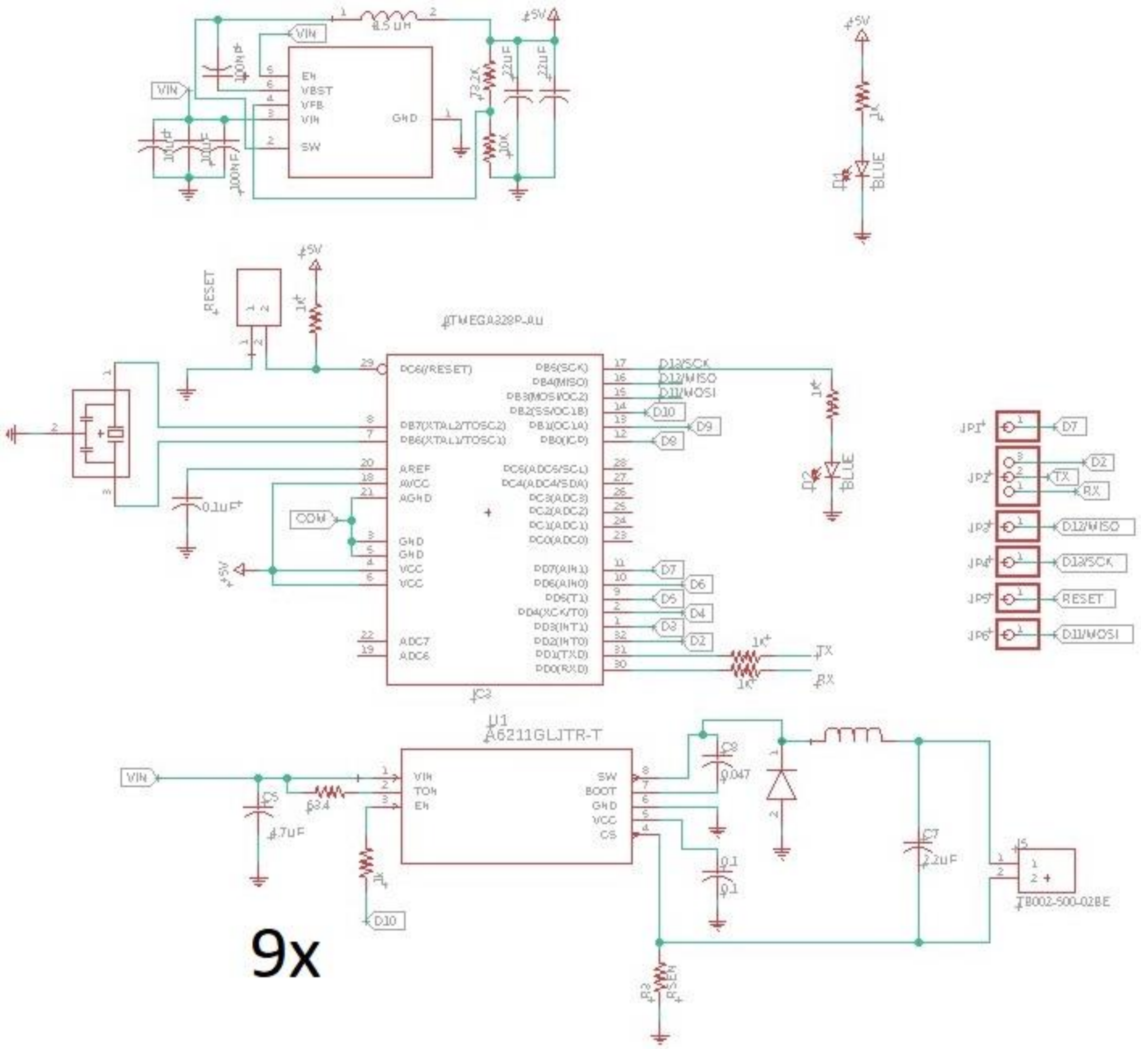


Figure 56. Complete electrical schematic.

6.4.1 PCB LAYOUT

The first PCB we made show in figure 52 was used to test 7 LED drivers and one 5-volt DC regulator. We did this because our initial results were not as promising as where expecting, mainly due to the fact we were using breakout boards for the IC's and through hole components which resulted in issues, since there wasn't enough time in senior design 1 to order and assemble a PCB. The Rev. 1 PCB was meant to adequality test our designs to see if they worked properly and which one worked best. So, that when we found what worked best, we could create Rev. 2, our final PCB.

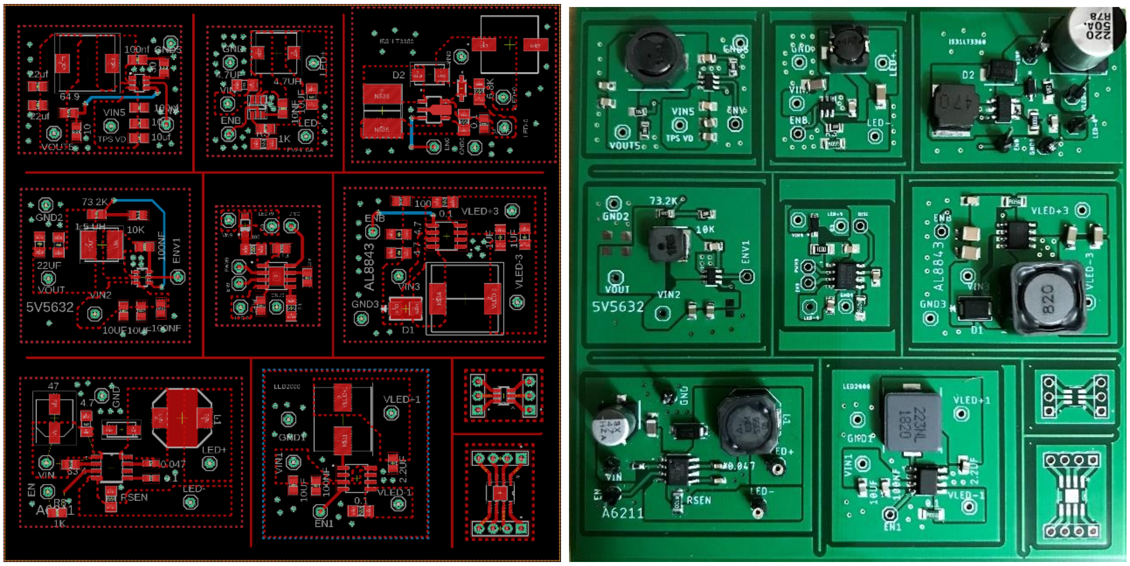


Figure 57. PCB Rev. 1 layout (100 mm x 100 mm)

Testing of the PCB drivers

From figure 29 we can see that our PCB houses most of our electronic components. Figure 53 shows the PCB design for this project, in this PCB we find 9 A6211 LED drivers with control signals from the MCU and some block terminals to easily connect the LED lights. The 5-volt regulator for the MCU and some sockets for the sensors. Lastly the MCU board with a 16 MHz crystal, reset button, sensor pins and programing pins. Prior to putting all the components, we checked to see if they were individually working to not waste time and components. Lastly, we included a power indicator and programing indicator to ensure all components were working properly.

For design this PCB we used Eagle since it offers a wide range of features, it is free to use, widely used and user friendly. The board is almost square measuring at 76 mm by 77 mm. The board itself has 2 layers and inexpensive at around 3 dollars per board. The methods for PCB design was to have neighboring components as close as possible. We did this to reduce the total board size. The LED driver where put on the outside of the board for connecting the power leads easier to the LEDS. The 5-volt regulator was place close to the MCU in the middle to further save space and to avoid having long traces. Lastly a power and programming SMD LED was used to show to the state of the device and for easier trouble shooting.

We added thicker traces were possible to ensure good conductivity current flow and heat dissipation, since thinner traces can be damaged easier. Polygon traces were used in places were multiple components were spread out the a having thick traces would help with current flow and reduce resistance. Having a thicker piece of copper is good for several reasons such as heat dissipation, less resistance and noise for the signals and a stronger build. Generally having a thicker piece cooper greatly increase the cost back for our purposes 1oz copper board was all we needed.

The soldering process was straightforward. Some of the components are small (603 and 805) so special care must be taken not to break the component by applying too much heat. However, using a Hot Air Rework Station and 63/37 No Clean Leaded Solder Paste made the job much easier.

When you first get the Atmega328p-AU chip it is not programmed to do anything. To program the MCU on the PCB various methods were tried. Eventually we found the Pocket AVR Programmer. The In-System Programming (ISP) pins were used to program the board using the Arduino IDE.

The board successfully worked

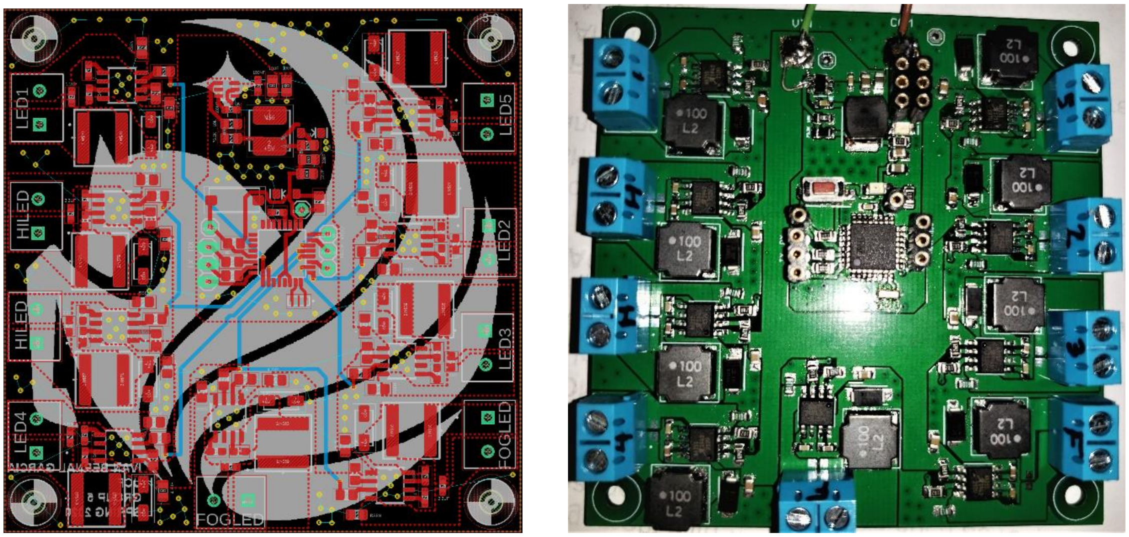


Figure 58. PCB Rev. 2 layout (76 mm x 77 mm) Testing our boards

6.4.2 PCB COST ESTIMATES

Different places charge different amounts. The Cheapest you could get these boards would be around $3.00 for an average quality PCB. We only will buy a few so that increases the price a few dollars so we are looking at around $5.00 each. This is only if we buy them from China though. The shipping costs will be a lot because it is coming from so far away. So, the price range we are looking at for a Printed circuit board from China is going to be around $20. This might not be the best though because the board would take a relatively long time to get to us.

In table 24 we have summarized the approximate cost estimates based on the submitted Gerber files. Having a thicker piece of copper is good for several reasons such as heat dissipation, less resistance and noise for the signals and a stronger build. Generally having a thicker piece cooper greatly increase the cost. The oshpark option is on the higher end, which is not really needed. The best priced option is jlcpcb, however the estimated shipping times for these company is around 2 weeks which is not ideal given our time frame. Pcbway seems like the best option given the price and shipping takes less than a week and the company is well know.

Manufactures	oshpark.com	jlcpcb.com	pcbway.com
Cost per board for 5 boards	$124.70	$2	$5
Shipping	$0	$5.77	$17
Copper thickness	2 oz	1 oz	1 oz

Table 24. PCB costs per supplier and specification

7 ADMINISTRATIVE CONTENT

In order to keep track of spending and deadlines we must organize ourselves. In this section each group members roles will be outlined, along with their respective areas of research. The timeline of the project from research to construction of the prototype will also be discussed. Finally, the budget and estimated cost of each component will be reviewed.

7.1 MILESTONES

Table 25 breaks down the key points in our project based on timeframes dictated by the class for assignments. The milestones are dated as the point of completion to mark key steps that outline the main components for the system.

	Deliverable	Research	Testing	Implement/Due
SD1	Divide & Conq	--	--	9/20/19
SD1	Divide & Conq V2	--	--	10/4/19
SD1	Standards	--	--	10/25/19
SD1	60-page draft	--	--	11/1/19
SD1	LED Selection	X	X	11/9/19
SD1	Current Drivers	X	X	11/14/19
SD1	100 pg. submission	--	--	11/15/19
SD1	Camera Operation Test	X	X	11/26/19
SD1	Final 120 pg. Document	--	--	12/2/19
SD2	Critical Design Review	--	--	1/30/20
SD2	LED Boards Designed and Soldered	X	X	2/2/20
SD2	PCB Redesign for Final Circuits	X	--	2/24/20
SD2	LED Pods constructed	--	X	3/6/20
SD2	Software Testing	--	X	3/19/20
SD2	Mid Point Demo	--	--	3/20/20
SD2	Confrence Paper	--	--	4/3/20
SD2	Rain and Light Sensors	X	X	4/5/20
SD2	Final assembly and testing of all components	--	X	4/11/20

SD2	Final Presentation and Demo	--	--	4/15/20

Table 25. Milestones and due dates

In table 26 we breakdown the personal deadlines for each member and their tasks for senior design 1.

	Deliverable	Research	Testing	Implement/Due
All	Solidify Design	9/20/19	10/1/19	10/8/19
Owle	MCU	10/1/19	10/8/19	10/15/19
Owle	Image Processing	11/4/19	11/11/19	11/18/19
Zeiher	LED Array / Mounting	10/1/19	10/8/19	10/15/19
Zeiher & Kleier	Reflector	10/8/19	10/15/19	10/22/19
Zeiher & Kleier	Housing Unit	11/11/19	11/18/19	11/25/19
Garcia	PSU for everything	10/15/19	10/22/19	10/29/19
Kleier	Rain Sensor	10/8/19	10/15/19	10/22/19
Kleier	Lenses	10/1/19	10/8/19	10/15/19
Owle & Garcia	MCU + Power	11/11/19	11/18/19	11/25/19
Winter Break	--	--	--	--
All	Implement Sensors with MCU	1/10/20	1/17/20	1/24/20
Owle	PCB Design	1/24/20	1/31/20	2/7/20
Owle	PCB Order	--	--	2/7/20
All	Encasing Everything into Housing Unit	1/10/20	1/17/20	1/24/20

Table 26. Senior desing one schedule

In table 27 we discuss the approximate timeline of senior design 2 in order to give an idea of the time frame we have to work with to avoid stress and procrastination. With all now complete we can align our dates with our milestones to see if the dates were truly met.

ALL	SD2 Deliverables	duration	Due Data
SD2	Finalize design/Order parts	1-2 weeks	1/28/20
SD2	Construct prototype	6-8 weeks	3/24/20
SD2	Testing	1 week	3/31/20
SD2	Refine prototype	1 week	4/7/20
SD2	Write final paper	1 week	4/21/20
SD2	Final presentation	1week	4/15/20

Table 27. Senior design two schedule

7.2 BUDGET

Projects like these can become very expensive quicky. Since, this project is self-funded and the total cost will be evenly split up among the 4 team members, we aim to reduce the total costs of this project since it is not sponsored. These prices are general estimates and do not take into consideration shipping costs. Additionally, some of the items listed below are already owned by some of the team members and will be loaned out to help with the project.

7.2.1 MAJOR COMPONENTS PARTS LIST

In table 28 we talk about different parts that we need to have tested in order to prove that in theory our ideas to complete our design is possible. This is our more concise budget. The full research and design expenditure can be found in section 7.3.1 where all the purchase orders and receipts are collected.

Vendor	Part Number	Description	Cost	Order status	Tested
Mouser	XHP50B-00-0000-0D0HH230G	LED	4.22	Received	Yes
Mouser	XHP50A-00-0000-0D0HH240G	LED	4.68	Received	Yes
Mouser	XHP50A-00-0000-0D0HH250G	LED	4.60	Received	Yes
Mouser	MKRAWT-00-0000-0B00H40E2	LED	5.90	Received	Yes

Mouser	MKRAWT-00-0000-0B0HG440F	LED	5.90	Received	Yes
Digikey	A6211GLJTR-T	LED driver	0.99	Received	Yes
Digikey	TPS56339DDCR	LED driver	2.56	Received	Yes
Digikey	LED2000DR	LED driver	2.04	Received	Yes
Digikey	LMZ12010TZE	LED driver	15.7	Received	Yes
Digikey	TPS561201DDCR	DC-DC converter	0.87	Received	Yes
N/A	ATMEGA328PB-AUR	Microcontroller	1.42	Received	Yes
Adafruit	Product ID: 397	Camera	$25.00	Received	Yes

Table 28. List of major components

7.2.2 BILL OF MATERIALS

Estimated cost per our initial design is found below in table 29. Upon further reasearch and implementation of the end products the true bill of materials are found in table 30.

Items	Quantity	Estimated Cost $
MCU (or microprocessor)	1	$50
Custom PCB	3-4	$50
Medium intensity LED chip	14	$20
High intensity LED chip	8	$30
Light sensor/low resolution camera	2	$20
Water sensor	2	$20
Headlight encloser	2	$60
SMD Passive components (resistors, switches, capacitors and inductors)	>50	$10
SMD active components (MOSFET, Op-amp, buck converters)	>20	$15
Car battery	1	$70

Car battery charger	1	$30
Miscellaneous (wires, LED power indicator, heat sinks)		$30
Through hole components for prototype	>70	$25
Lenses	14	$100
Refractor	12	$40
Total		$570

Table 29. Estimated project budget

In table 30. We can see our final bill of materials for the final project. To note the comparision from table 29 to table 30, we can see that we overestimated our final per unit build cost. Most of the cost reduction was from being able to machine our own structural components and thourough research on the electrical side to find reduce cost circuitry and ordering PCBs early from cheaper sources that had longer lead times for delivery. The last massive cost reduction was the use of a “no-name” plastic lens set that cost a twentieth of what was originally projected.

	Items	Part number	Vendor	Qty:	Cost	End Cost
1	LED Lighting XLamp® MK-R White, Cool 5700K	MKRAWT-00-0000-0B00H40E2	Mouser	2	$ 5.90	$ 11.80
2	LED Lighting XLamp® MK-R White, Neutral 4000K	MKRAWT-00-0000-0B0HG440F	Mouser	7	$ 5.90	$ 41.30
3	IC LED DRIVER RGLTR DIM 3A 8SO	620-1477-1-ND	Mouser	10	$ 0.88	$ 8.81
4	Laser Diode Red <1mW 3-6 VDC	-	Skycraft	1	$ 2.95	$ 2.95
5	TTL Serial JPEG Camera with NTSC Video	PTC08 JPEG compression module	Adafruit	1	$ 39.95	$ 39.95
6	Microcontroller	ATmega328P	Digi-Key	1	$ 2.08	$ 2.08
7	20 mm convex lens	N/A	Ebay	5	$ 1.00	$ 5.00
8	Housing/ Cardboard	11 x 8 x 4	-	1	$ 0.00	$ 0.00
9	PCB	-	JLCPCB	2	$ 0.40	$ 0.80
10	Photocell 1k-10kΩ		Adafruit	1	$ 0.95	$ 0.95

11	Acrylic	1227T619	McMaster Carr	1	$ 12.82	$ 12.82
12	Phototransistor	BPW76A	Mouser	1	$ 3.45	$ 3.45
13	Aluminum bar stock 1”x1”x24”	9008K14	McMaster Carr	1	$ 15.46	$ 15.46
14	Basic electronic components	-	-	-	-	$ 125.09
					Total:	$ 270.46

Table 30. Final bill of materials

7.3 RECEIPTS AND PURCHASE ORDERS

Within this section we will show all purchases and budget allowance expenditures. We will break down the costs in three subsections one for our initial spending for component testing this is our research and development stage. From those components we will move only the ones we use on the final build to the second section of which will be the cost of the unit as a whole this is a continuation of the development and transition to a production stage. To be more specific this will be the budget in which we only account for the components used for the end build. Lastly, there will be a final cost sheet in which we will account for all expenditures from senior design one and two combined. This will be the cost of research, development and production.

7.3.1 RESEARCH AND DEVELOPMENT EXPENDITURES

Below are the parts we have ordered received and are using for our initial research of our senior design project. Of which we will consider as our research and development expenses. This list will is a brief summary of the many items tested and considered.

	Items	Part number	Vendor	Qty:	Cost	End Cost
1	LED Lighting XLamp® XHP50.2 White, Warm 3000K	XHP50B-00-0000-0D0HH230G	Mouser	1	$ 4.22	$ 4.22
2	LED Lighting Xlamp® XHP50 White, Neutral 4000K	XHP50A-00-0000-0D0HH250G	Mouser	1	$ 4.68	$ 4.68
3	LED Lighting Xlamp® XHP50 White, Cool 5000K	XHP50A-00-0000-0D0HH250G	Mouser	1	$ 4.60	$ 4.60
4	LED Lighting XLamp® MK-R White, Cool 5700K	MKRAWT-00-0000-0B00H40E2	Mouser	1	$ 5.90	$ 5.90

5	LED Lighting XLamp® MK-R White, Neutral 4000K	MKRAWT-00-0000-0B0HG440F	Mouser	1	$ 5.90	$ 5.90
6	IC LED DRIVER RGLTR DIM 3A 8SOIC	620-1477-1-ND	Digi-Key	1	$ 0.99	$ 0.99
7	20 mm LED convex lens 5 piece	-	Amazon	1	$ 5.00	$ 5.00
8	TTL Serial JPEG Camera with NTSC Video	PTC08 JPEG compression module	Adafruit	1	$ 39.95	$ 39.95
9	Phototransistors Phototransistors TO-18 450-1080nm +/-40 deg	BPW76A	Digi-Key	1	$ 2.38	$ 2.38
10	Sparkfun Pocket AVR Programmer	-	Sparkfun	1	$ 20.57	$ 20.57
11	Laser Diode Red >1mW 3-6 VDC	-	Skycraft	1	$ 2.95	$ 2.95
12	PCBs		JLCPCB	8	$ 0.40	$ 3.20
13	Basic electronic components	-	-	-	-	$ 110.03
14	Miscellaneous	-	-	-	-	$ 58.30
15	Taxes, tarriffs and shipping	-	-	-	-	$ 84.08
					Total:	$ 352.75

Table 31. Complete cost for research and developmental testing

7.3.2 COST FOR UNIT

The table below outlines the major components and their costs. The subcomponents such as small IC's and resistors are summed up as one complete cost.

	Items	Part number	Vendor	Qty:	Cost	End Cost
1	LED Lighting XLamp® MK-R White, Cool 5700K	MKRAWT-00-0000-0B00H40E2	Mouser	2	$ 5.90	$ 11.80
2	LED Lighting XLamp® MK-R White, Neutral 4000K	MKRAWT-00-0000-0B0HG440F	Mouser	7	$ 5.90	$ 41.30
3	IC LED DRIVER RGLTR DIM 3A 8SO	620-1477-1-ND	Mouser	10	$ 0.88	$ 8.81
4	Laser Diode Red <1mW 3-6 VDC	-	Skycraft	1	$ 2.95	$ 2.95

5	TTL Serial JPEG Camera with NTSC Video	PTC08 JPEG compression module	Adafruit	1	$ 39.95	$ 39.95
6	Microcontroller	ATmega328P	Digi-Key	1	$ 2.08	$ 2.08
7	20 mm convex lens	N/A	Ebay	5	$ 1.00	$ 5.00
8	Housing/ Cardboard	11 x 8 x 4	-	1	$ 0.00	$ 0.00
9	PCB	-	JLCPCB	2	$ 0.40	$ 0.80
10	Photocell 1k-10kΩ		Adafruit	1	$ 0.95	$ 0.95
11	Acrylic	1227T619	McMaster Carr	1	$ 12.82	$ 12.82
12	Phototransistor	BPW76A	Mouser	1	$ 3.45	$ 3.45
13	Aluminum bar stock 1”x1”x24”	9008K14	McMaster Carr	1	$ 15.46	$ 15.46
14	Basic electronic components	-	-	-	-	$ 125.09
					Total:	$ 270.46

Table 32. Cost for one unit

7.3.3 COMPLETE COST OF R&D AND FIRST UNIT BUILD

This sectionfully addresses the cost of senior design one and two for the entire cost of the system between research and development to the final product and any spare items ordered to ensure there would be minimal faults with the end project. Below we can find the all the key elements that were necessary for our research phase and for final build and testing.

	Items	Part number	Vendor	Qty:	Cost	End Cost
1	LED Lighting XLamp® XHP50.2 White, Warm 3000K	XHP50B-00-0000-0D0HH230G	Mouser	1	$ 4.22	$ 4.22
2	LED Lighting Xlamp® XHP50 White, Neutral 4000K	XHP50A-00-0000-0D0HH240G	Mouser	1	$ 4.68	$ 4.68
3	LED Lighting Xlamp® XHP50 White, Cool 5000K	XHP50A-00-0000-0D0HH250G	Mouser	1	$ 4.60	$ 4.60
4	LED Lighting XLamp® MK-R White, Cool 5700K	MKRAWT-00-0000-0B00H40E2	Mouser	4	$ 5.90	$ 23.60

5	LED Lighting XLamp® MK-R White, Neutral 4000K	MKRAWT-00-0000-0B0HG440F	Mouser	11	$ 5.90	$ 64.90
6	IC LED DRIVER RGLTR DIM 3A 8SOIC	620-1477-1-ND	Digi-Key	14	$ 0.99	$ 13.86
7	SOCKET ADAPTER SOIC TO 8DIP	LCQT-SOIC8-8	Digi-Key	1	$ 2.57	$ 2.57
8	IC LED DRIVER RGLTR DIM 3A 8SOIC	A6211GLJTR-T	Digi-Key	2	$ 1.98	$ 3.96
9	SOCKET ADAPTER SOIC TO 8DIP	LCQT-SOIC8-8	Digi-Key	1	$ 2.57	$ 2.57
10	PWR MGMT SPECIALIZED REGULATOR	TPS56339DDCR	Digi-Key	2	$ 2.56	$ 5.12
11	SOCKET ADAPTER SOT-23 TO 6DIP	LCQT-SOT23-6	Digi-Key	1	$ 2.38	$ 2.38
12	IC REG BUCK ADJ 1A TSOT23-6	TPS561201DDCR	Digi-Key	2	$ 1.22	$ 2.44
13	SOCKET ADAPTER SOT-23 TO 6DIP	LCQT-SOT23-6	Digi-Key	1	$ 2.38	$ 2.38
14	Tariff and sales tax	-	-		-	$ 134.36
15	Copper cladding	-	Skycraft	1	$ 3.50	$ 3.50
16	Thermal Grease	-	Skycraft	1	$ 5.95	$ 5.95
17	Laser Diode Red >1mW 3-6 VDC	-	Skycraft	1	$ 2.95	$ 2.95
18	TTL Serial JPEG Camera with NTSC Video	PTC08 JPEG compression module	Adafruit	1	$ 39.95	$ 39.95
19	Microcontroller	ATmega328P	Digi-Key	1	$ 2.08	$ 2.08
20	20 mm convex lens	N/A	Amazon	5	$ 1.00	$ 5.00
21	Housing	11” x 8” x 4”	-	1	$ 0.00	$ 0.00
22	PCB	-	JLCPCB	10	$ 0.40	$ 4.00
23	Acrylic	BL20050404	McMaster Carr	1	$ 12.82	$ 12.82
24	Phototransistor	BPW76A	Mouser	1	$ 3.45	$ 3.45

25	Basic electronic components	-	-	-	-	$ 248.93
26	Miscellaneous	-	-		-	$ 22.94
					Total:	$ 623.21

Table 33. Complete cost of R&D with the first unit produced

7.4 GROUP MEMBER RESPONSIBILITIES

Group Responsibilities			
Ivan Bernal Garcia	Justin Kleier	Justin Owle	Michael Zeiher
DC Converters	Testing of Laser diode for Rain Sensor	Design of Camera system	Design of LED Array
PCB Design/ Assembly	Design of Rain Sensor	Interfacing Camera with Microcontroller	Design of Collimating Optics
Designing of drivers for LED array	Optics Design of Lens to Image on Camera sensor	Programming to detect vehicles	Graphical Ray Tracing of Headlights
Designing dimmable circuit for individual LED	Determining resolution of Camera module	Creating masks based off detected vehicles	Testing of LED P-I curve
Interfacing with microcontroller	Determining of resolution of system	Tracking of vehicles and controlling LED array	Designing of Beam pattern for headlight

Table 34. Group member responsibilities

8 CONCLUSION

Our project is about making a headlight in a car that is bright but will not blind other drivers on the road. The goal for this project was to design this project to be as low cost as possible and still have it be just as effective if not better than current headlight designs. Our motivation for this project was that we needed to build something for senior design and with having two Photonics Engineers in our group we needed to ensure there was a large portion to sustain enough work for them as well as enough electrical and software based tasks for the E.E. and the C.E. student. So, with the motivation of trying to make sure all of our course requirements are met we also wanted to do something that truly does increase the public safety for all. We really had one idea that stuck out since most UCF students commute, we wanted to find a way to increase the safety for those that commute while also adding any comforts we could. As well as our desired goal of increasing public safety and comfort of driving experience for as many people commuting long distances in the dark hours of the day. As per section 2.3 requirement specifications, we have designed our project so that it meets all our specifications as well as all legal specifications.

There have been many systems like ours implemented in Europe and Canada. From the research we have done, we found several companies that have produced relevant research on the subject. The reason there has not been much research done is because it is excruciatingly hard to get a headlight approved by the Department of Transportation. Since approval of any new technology to be included in cars must be done by the Department of Transportation, a few car manufacturers have been lobbying for research to be conducted on adaptive driving beam headlights within the US. Research of existing products in use in Canada and Europe was done to understand different devices methods to achieve the same results as well as the benefits of each system.

At the end of December, we were well into the research and development phase of this project. We had researched several components for every aspect of the project so that we can select the best fit item that works with our constraints and standards. The selection of major components such as the LEDs, camera and power sources were completed and we had demonstrated functionality of each component selected thus far. As we had shown functionality of many of the components, we needed to start integrating the components into the system such that they can work as a whole. This allowed us time to work out any issues well in advance of the deadline. The components we selected have been researched based on the theory and functionality of the system as discussed and at that point and were projected to function together and meet all relevant constraints and standards at this time. Along with primary component selection we had researched components like those selected so that we have a backup incase things did not go as planned while assembling the headlight.

We continued to research components for our project as we have some minor components that needed to be selected such as photodiodes and printed circuit board types. As we continued forward, we tested the system thoroughly as we combine each aspect to chase out any issues. The major optical components had been selected, an enclosure and mounting structures were mocked up so that we could assess the specifications for the lens and reflectors in order to fit the assembly within the defined dimensional constraints. Along with the need to meet the constraints we assessed how our beam shaping methods work out in the actual layout. Our final designs and actual reflectors used were different due to the closures caused by COVID-19. This caused us to mockup general reflectors to show the basic concept of our mocked-up designs.

The constraints and specifications of dimensions, legal and environmental concerns have been met. We were able to stay within the major constraints throughout the project. The theoretical function and adaptive systems are planned out such that we meet the legal standards. Overall, our project merged seamlessly to meet all functions required by law and be able to meet all constraints we have assessed as needed for the project. To recap we are abiding by all state laws for headlights while trying to prove a viable solution to the beam brightness and distribution that is standardized on the federal level. The federal law has maximum and minimum brightness points which are set to reduce glare on oncoming drivers and to provide enough light for visibility of hazardous conditions. Our beam intensity is able to meet and exceed federal standards so our solution was that we can adjust the beam pattern to be able to limit the intensity of the light towards the oncoming drivers while providing more light to illuminate hazards farther away more clearly. This improves the safety for the driver, other motorists, and pedestrians due to the increased illumination of the road and environment.

APPENDIX

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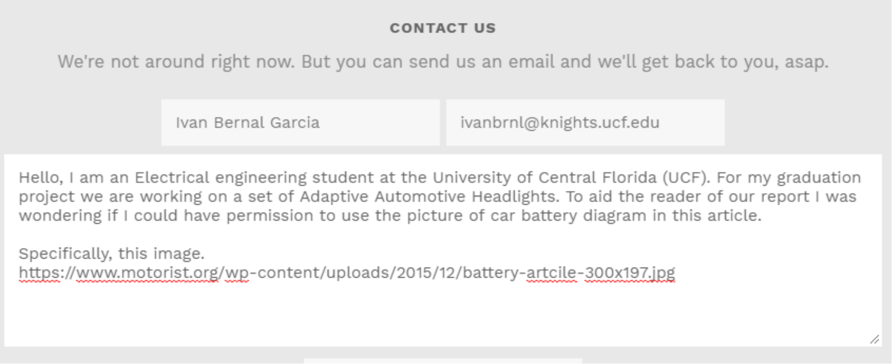


We're not around right now. But you can send us an email and we'll get back to you, asap.

Ivan Bernal Garcia

ivanbrnl@knights.ucf.edu

Hello, I am an Electrical engineering student at the University of Central Florida (UCF). For my graduation project we are working on a set of Adaptive Automotive Headlights. To aid the reader of our report I was wondering if I could have permission to use the picture of car battery diagram in this article.

Specifically, this image.
https://www.motorist.org/wp-content/uploads/2015/12/battery-artcile-300x197.jpg

draw.io support <support@draw.io>
Tue 10/29/2019 3:52 AM
Ivan Bernal Garcia

Hi Ivan,

Thanks for contacting us.

Draw.io online and Desktop app are totally free to use for any purpose, including commercially.
This info you can find here https://about.draw.io/pricing/ so feel free to use draw.io without worrying :)

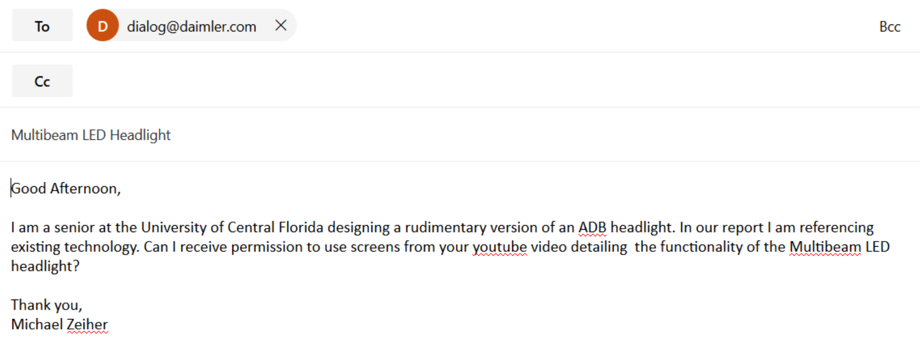
Good luck with your project!

Kind regards,
Marija
draw.io support

Ticket: https://desk.draw.io/helpdesk/tickets/35586

On Tue, 29 Oct at 3:05 AM , Ivan Bernal Garcia <ivanbrnl@knights.ucf.edu> wrote:
Hello, I am an Electrical engineering student at the University of Central Florida (UCF). For my graduation project we are working on a set of Adaptive Automotive Headlights. To aid the reader of our report I was wondering if I could have permission to use your draw.io software to make a diagram to use in our report.
The diagram being used is the attached file.

Ivan Bernal Garcia
ivanbrnl@knights.ucf.edu



To: dialog@daimler.com

Multibeam LED Headlight

Good Afternoon,

I am a senior at the University of Central Florida designing a rudimentary version of an ADB headlight. In our report I am referencing existing technology. Can I receive permission to use screens from your youtube video detailing the functionality of the Multibeam LED headlight?

Thank you,
Michael Zeiher

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