Adaptive Lean-Angle Headlights

Abheshek Kothary
Philip Davidar
Prithwi Roy

Final Report for ECE 445: Senior Design Spring 2016

TA: Vivian Hou

May 4, 2016

Group #21

Abstract

This report documents the motivation, design, and implementation of the adaptive lean angle headlight project for motorcycles. The adaptive lean angle headlight is an auxiliary light for safer motorcycle operation in dark environments, specifically while executing a turn. Furthermore, all safety and operation considerations as well cost analysis are outlined. This document is used as the final report for ECE 445 at the University of Illinois at Urbana Champaign.

Contents

1. Introduction....4
   1.1. Title....4
   1.2. Motivation....4
   1.3. Goals....4
   1.4. Functions and Features....4

2. Design.... 5
   2.1. Design Introduction.... 5
   2.2. Block Diagrams.... 5
   2.3. Description of Modules.... 6
   2.4. Circuit Schematic.... 13

3. Requirements and Verification.... 14
   3.1. High Level Requirements.... 14
   3.2. Modular R/V.... 14
   3.3. Tolerance Analysis.... 16
   3.4. Presentation of results....18

4. Cost.... 18
   4.1. Cost Analysis.... 18

5. Safety Statement.... 19

6. Conclusion.... 21

7. References.... 23

1. Introduction

1.1 Title

Adaptive Lean-Angle Headlights

1.2 Motivation

The Adaptive Lean-Angle Headlight is an important step in the evolution of motorcycle safety. As it stands, there are not many tools for keeping a motorcyclist safe. There are no seat belts or airbags and there are only electronic driver-aids on very new and high-end motorcycles. We chose this project because we want to improve the safety measures for a large demographic of motorists, who are very much unprotected. Every year motorcyclists are 5 times more likely to be seriously injured and 26 times more likely to be killed due to poor visibility.[1] We hope that with this device, we can greatly improve the visibility of motorcyclists while riding, especially at night, thus making it safer for them to ride. This device will enable these riders to see more clearly as they are making turns, allowing them to effectively avoid road hazards and stay on the tarmac, making the roads a safer place for everyone. With a low cost per unit, this device will have a high scalability factor, allowing many consumers to get their hands on it without burning a hole in their wallets.

1.3 Goals

The ultimate goal of this project is to sense tilt angle of motorcycle and illuminate in the direction of tilt to aid riders that are making turns and going around corners at night.

1.4 Functions and Features

- Increase beam width as tilt angle increases
- Keep height of beam under 0.5m to avoid blinding other motorists
- Light up 2.5m~3.0m of road on either side of motorcycle
- Lights should be bright enough to illuminate the path of travel, but not bright enough to blind oncoming traffic

2. Design

2.1 Design Introduction

To implement the above system, we intend on creating a modular unit, for both the left side and right side of the motorcycle. Both units will function in identical ways as the absolute value of the angle will determine the control of LED columns. The unit consists of an array of LEDs that are mounted on the sides of the gas tank via a pressure sensitive, multi-use adhesive that can be applied and removed via heat. The box itself will be shock absorbent to prevent the circuitry from moving around inside and protect the battery in the event of a crash. All the crevices are filled with a silicon polymer sealant to make it rain and snow proof. An Inclinometer senses the angle of tilt of a motorcycle from a user-calibrated initial rest position and communicates with the microcontroller in the logic unit which in turn determines which columns of LEDs need to turn on whilst the motorcycle is turning.

2.2 Block Diagram

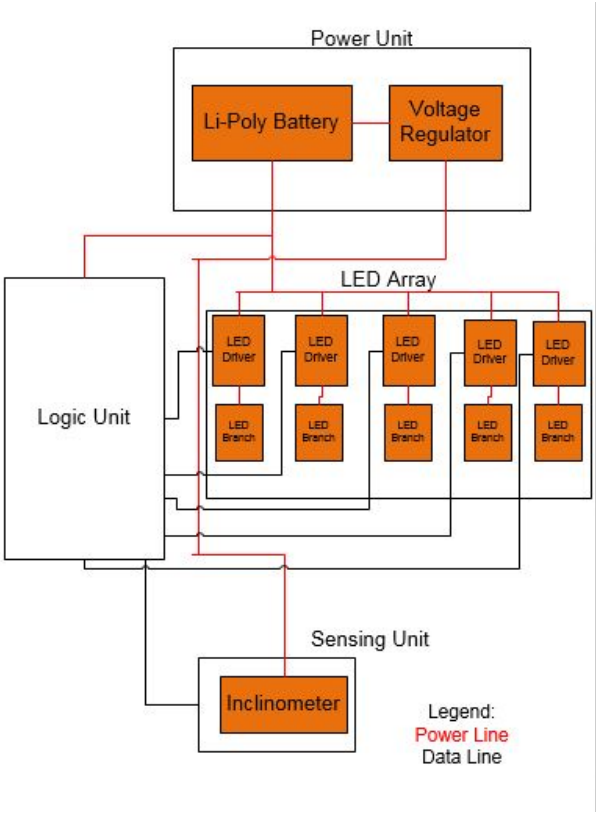


Figure 1: Block Diagram

2.3 Descriptions of Modules

LED Array

The LED array will consist of 5 columns and 2 rows of high power LED's (i.e 5 parallel columns of 2 LEDs in series) and 5 LED drivers in series. We refer to the column of 2 LED's and an LED driver as an " LED Branch" in the block diagram (figure 1). As detailed in the Tolerance analysis, we are choosing to use the LEDs with 400 mA. The array will be mounted diagonally on the side of the bike, specifically on the gas tank. The array will output specific configurations of columns of LEDs based on inputs from the Logic Unit, such that the road is illuminated optimally based on motorcycle tilt angle. We have defined optimal lighting as 2.5 m of light on either side of the motorcycle because we do not want to illuminate too far into neighboring lanes. An interstate highway has a width of 3.7m so we believe that lighting 2.5m on either side of the motorcycle is reasonable, accounting for the fact that the rider might not be in the center of the lane.

In regards to the actual array, we chose LEDs over other light sources for a couple of reasons. Firstly it is power efficient. It does not suck up a huge amount of power and has a long lifespan (4.32W per LED bulb). This will keep the overall power usage of our device low, thus reducing heat dissipation as well as making the device long lasting. Furthermore, LEDs have a high Lumens to Watts efficiency ratio (30-90 lm/W) versus some of the other standard lights used such as halogen (16-24lm/W). Our bulb outputs 227 lumens at recommended operating current of 1 A, giving it a efficacy ratio of 90 lm/W, placing it on the higher end of the efficacy ratio.

We also decided to use 10 LEDs in 5 columns of 2 each (each column represents a different angle of tilt) because the LEDs will provide high luminous output. This was a threshold we wanted to keep so that the lights are not blinding for other motorists. The pin layout of each LED bulb can be seen in figure 2.

Pin Out	
Pad	Function
1	Anode
2	Cathode
3	Cathode
4	Anode
5[2]	Thermal

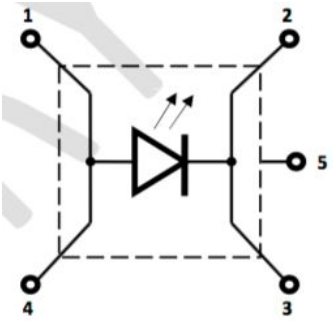


Figure 2: Pinout of LED, taken from Data sheet for LZ1-00CW02[2]

Each LED driver was identical. Figure 3 details the LED driver circuit. It consists of an 8 V voltage regulator, and an output of a 5 Ω resistor, an nmos FET, and the LED column. There are also coupling capacitors at the input and output of the regulator. The FET functions as the switch, which has input from the Logic unit. The FET was the ideal switch, since it is voltage driven, so it is easier to power form the Logic unit than a BJT would be. We used an NMOS due to better power handling. In order to determine the current over the LED, we used a current limiting resistor. We experimentally measured the voltage over the unit to be 6 V. The calculations are shown in figure 4. We get a 5 Ω, 1 W power resistor.

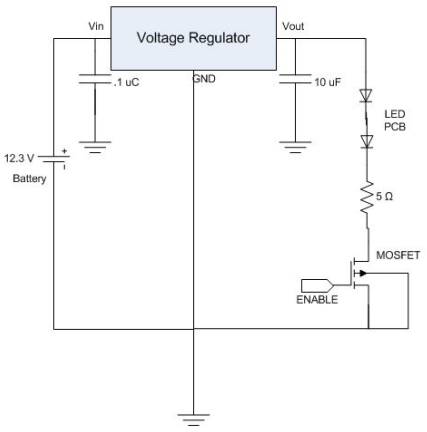


Figure 3: LED Driver circuit

$$V_{reg} - V_{led} = IR$$
$$8V - 6V = 400\text{mA} \times R$$
$$\Rightarrow R = 5\Omega$$
$$P = I^2R = (0.4)^2 \times 5 = 0.8\text{W}$$
$$\text{Resistor rated for 1W} \rightarrow \text{OK}$$

Figure 4: LED Driver calculation

Originally, we had intended to use a Buck Regulator to drive the LEDs. We designed the PCB according to the datasheet, and placed the LEDs on the same PCBs. When we did this, we encountered several issues. For one, we were unable to drive any current through the LEDs. Additionally, on the PCB copper, we observed areas of random voltage. Since this didn't work, we decided to rework it, separating the LEDs onto a separate PCB, and creating the driver on another.

Logic Unit

For the Logic Unit, we are using the AtMega328 chip using a SPI interface to communicate with the sensing unit. This is, in large part, due to the familiarity of our team with programming the Arduino[3], which cut down on development time. Additionally, the Arduino is able to handle the functions of the Logic Unit, such as controlling the LED Array, receiving the inputs, and handling the algorithm. The AtMega chip has 32 kb of memory, which will be sufficient size for the main program. The Logic Unit needs to be able to control the LED array based on the inputs from the Sensing Unit. It will uses an algorithm we developed over the course of the project to accurately turn on the correct LEDs based on inputs from the sensing unit.

To communicate with the the inclinometers internal memory, it was necessary to create a read function called "readRegister". SPI works by specifying a data frame in which the peripheral receives instructions. A read is carried out by sending a command to the inclinometer and then sending two bytes of garbage data to read the incoming byte in the next instruction cycle. The Algorithm is outlined in further detail in figure 5 below.

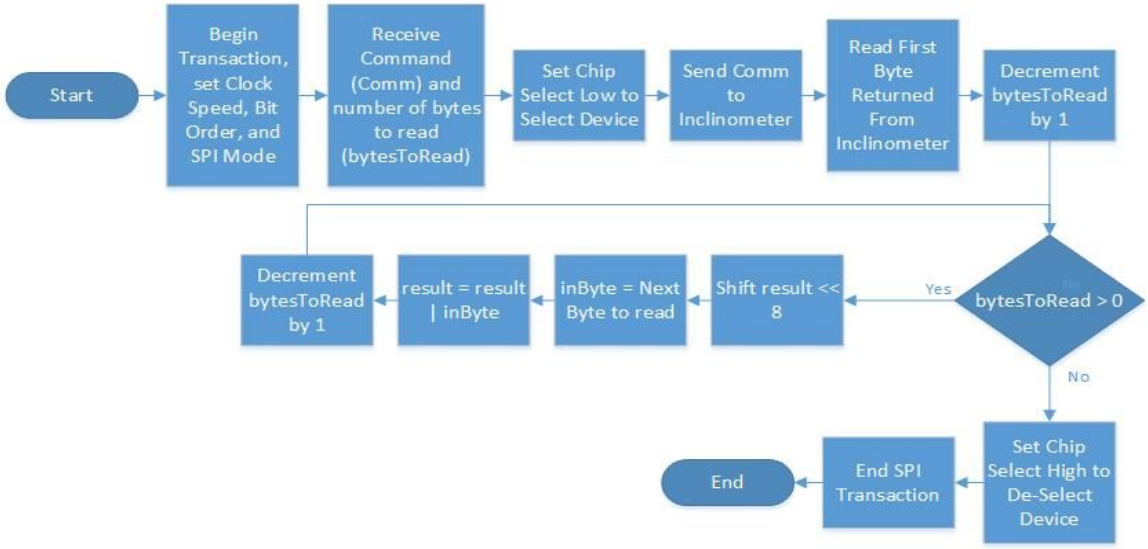


Figure 5: readRegister Function Flowchart

The data is read in 11 bit digital format. This data word must then be mapped to a readable angle in the form of a double. A simple formula shown below is used to transform the 11 bit word to an angle in degrees. The absolute value of the angle is used such that the unit can be installed on either the left or right side of the motorcycle while using the same logic design.

$$angle = arcsin(\frac{(data - 1024)}{1638}) \times \frac{180}{\pi}$$

Once an angle is successfully read from the inclinometer and in double format, it can be used to enable the correct LED columns. The LED columns are enabled from the digital output pins of the arduino, one pin for each column. As the angle increases, more columns are enabled. The logic is outlined in detail in figure 6 below.

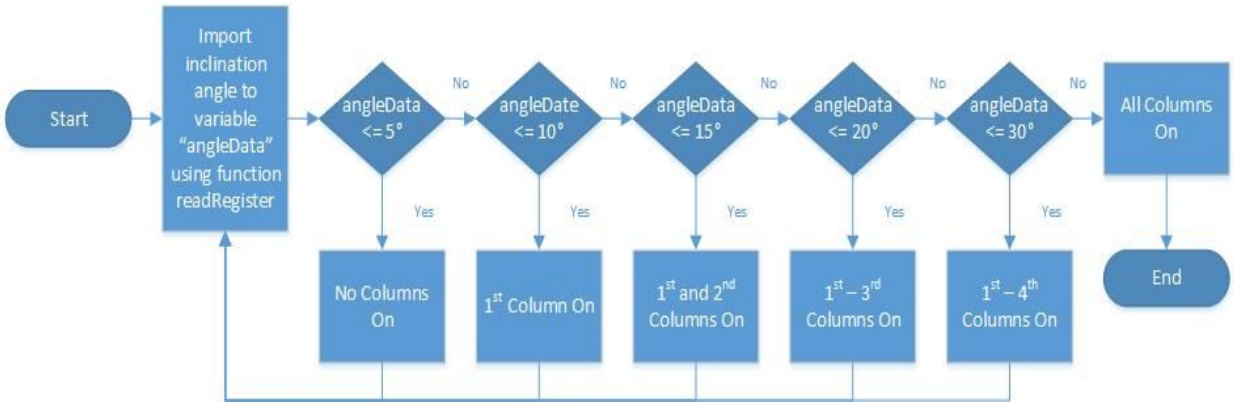


Figure 6: LED Column Flowchart

It is important to note that calibration is done via software. When the program is started, an initial angle is read. For all subsequent reads, the initial angle is subtracted from the current angles, effectively re-defining the zero angle of the inclinometer.

In a previous design, we used the ADIS16203[4] by Analog Devices as our inclinometer. This chip had a very complicated instruction set that made communication very difficult to comprehend. There were also more complications chip, which we outline in the Sensing Unit block description. With all of these factors and limited time, we abandoned the ADIS16203 and instead we used the Murata SCA61T[5] . This chip was much easier to solder, accepted 5V for the data lines, and the instruction set was much easier to comprehend.

For future models of this project, we would code a hysteresis function to filter out any flickering of columns near the borders column decision statements. An example of how this would be beneficial would be if a motorcycle is leaning at exactly 10 degrees and the engine vibrations cause the inclinometer to change the angle between 9.99 degrees and 10.01 degrees at a very quick rate. Without a hysteresis function, the first second column would flicker on and off very quickly as well, which could be distracting to the motorcyclist and other road users as well.

Power Unit

To power our device, we have chosen to use a 11.1V, 5200mAh, 58Wh Li-Po battery. A Li-Po battery is a rechargeable battery of lithium ion technology in a package, which we chose for a couple of reasons. First, it packs enough power in its package to power entire

device and its components, and provide enough amperage to run the LED array. Secondly, it is rechargeable for the user so that he would not need to replace standard batteries every time they fully discharge (which for the purposes of this project was not powerful enough to drive the circuit, nor would it have lasted long enough even if we had put in a dozen of them). In testing our battery, we noticed that it outputted 12.3V.

LiPo batteries require additional safety instructions to use. If they are overcharged, damaged, or get too hot, LiPo batteries are liable to explode. In order to handle these batteries, we took the *Safe Practice for Lead Acid and Lithium Batteries* course, and followed all corresponding instructions, such as charging in the LiPo sack, and safe handling requirements.

The logic unit requires 7V~12V to power the ATMega328. We achieved this by connecting resistors in series with the output of the batter to drop the 12.3 voltage to a desirable range for the device.

The LED unit uses 12V to drive each column (which is internally regulated down to 8V, as mentioned above). Each column of LEDs uses 400mA when both of the LEDs are switched on. In order to compute the maximum run time for the LEDs, we assumed all 5 columns were on. Calculations for all 5 columns can be seen in the calculation below.

$$I_{1Column} = 400\text{mA}$$
$$I_{5Columns} = 400\text{mA} \times 5 = 2A$$
$$\text{Run time} = \frac{5.2Ah}{2A} = 2.6\text{h}$$

Sensing Unit

The sensing unit we used was a Murata Inclinometer, part number SCA61T. This unit had a 5 V operating voltage, and has an internal sensitivity of 4 V/g. This is an important metric for comparing inclinometers and this particular model compares relatively well with most other affordable inclinometers . Additionally, the Inclinometer has a range of ±30 degrees, at a sensitivity of 0.0025°.

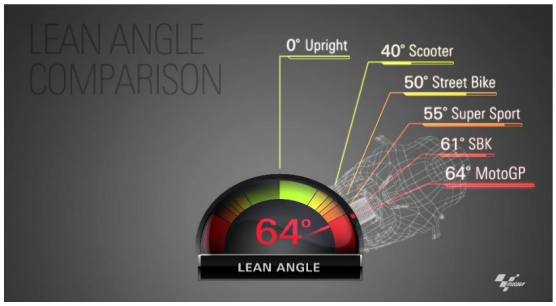


Figure 7: Lean Angle Comparison of Various Styles of Motorcycles [6]

As seen in figure 7, a standard motorcycle generally tilts up to 45 degrees on normal road conditions while a racing motorcycle tilts up to 65 degrees in full blown racing conditions. Generally, the tilt angle of the motorcycle can be calculated as follows:

$$\tan\theta = \frac{v^2}{rg},$$
$$\text{where : v} = \text{speed of motorcycle, r} = \text{radius of turn, } \theta = \text{lean angle}$$

This says that the faster one turns, the more more the lean angle and the tight the turn (smaller r), the more the lean angle. Considering only static friction forces for standard non-sliding tires, the friction is proportional to the normal force.

$$F_{friction-max} = \mu_s N$$

Equating the frictional force with the centripetal force,

$$\frac{v^2}{r} = \mu_s g \rightarrow \tan\theta = \mu_s$$

Here μ_s is the static friction coefficient, which ranges between 0 and 1 typically. Hence we can see that the maximum tilt angle for a standard motorcycle is:

$$\theta_{max} = \arctan(1) = 45 \text{ degrees}$$

Due to these reasons and limitations, we have chosen to break up the degree of tilt into 5 'levels' that will correspond to various columns of the LED array lighting up.

The inclinometer we used outputs digital signals to an Arduino, with which it is interfacing using SPI, about the degree of tilt, which we printed onto a console log and subsequently verified with protractors.

As mentioned in the Logic Unit, we started with the ADIS16203. This device was very difficult to use as the package size was very small and it didn't have pins. Instead, there were pads underneath the chip. This made soldering very difficult and we didn't know if a connection was made with the chip. Furthermore, we did not use a 5V to 3.3V voltage leveler for for the SPI lines on the chip, which might have rendered the chip useless. Finally, this chip had a very complicated instruction set that made communication very difficult to comprehend. With the change to the SCA61T, however, communication was a lot easier and implementation was a lot easier to debug. We did lose significant range in angle sensing, but we did gain a fair amount of granular resolution. The loss in sensitivity did not affect us too much because, as mentioned, motorcycles do not generally tilt more than 45 degrees, that too at very high speeds.

Housing Unit

The housing unit is the overall package in which the various modules will be housed. The unit is designed to withstand certain conditions such as rain, wind and snow. We also have a strong industry-standard adhesive on the rear of our design package so that it sticks to the body of the motorcycle and not become loose, even at high speeds. The sealant used to cover the holes through which the LED wires run and all other crevices is water-and-snow-proof and can tolerate temperatures ranging from -55°C to 300°C. The image on the left in figure 8 below shows the finished product in its housing, with the LED columns tilted and varying angles on the top of the package.

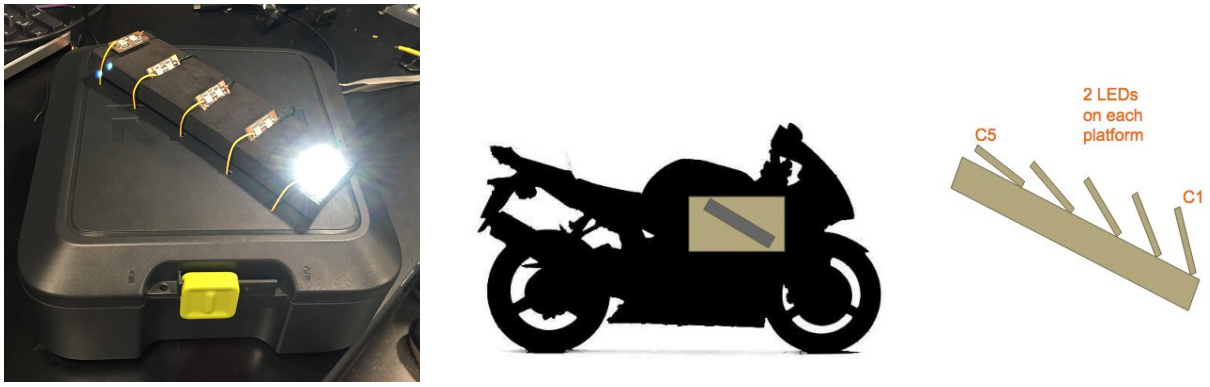


Figure 8: Finished Product in Housing and Placement of Product on Motorcycle

The image in the middle of figure 8 below shows the side profile placement of the housing unit on the motorcycle gas tank itself. The image on the right in the same figure shows the angling of each column of LEDs on the side of the motorcycle, with C1 being the most tilted and C5 being the least tilted so that the beam is always directly below waist height, as per our requirements.

Future considerations of the housing unit will be to make it slightly flexible so that it can fit on various motorcycles that have different shaped gas tanks or fairings (these are the plastic or metal trim bits of a motorcycle). In order to do this, we are going to have a backing that is made of a silicon material that is semi-flexible so that it will fit onto various motorcycle makes. Just inside the cover, we will use aluminium reflectors to direct the light such that the light beams don't shine too high (vertically) and will be more directed towards the road in general. Another possible inclusion is the use of apertures to further control the light emission. Furthermore, we would add an external power switch and charging port on the housing unit so that the system can be activated and charged without having to handle the battery terminals. The battery is very powerful and untrained consumers should not be expected to handle the battery directly.

2.4 Circuit Schematic

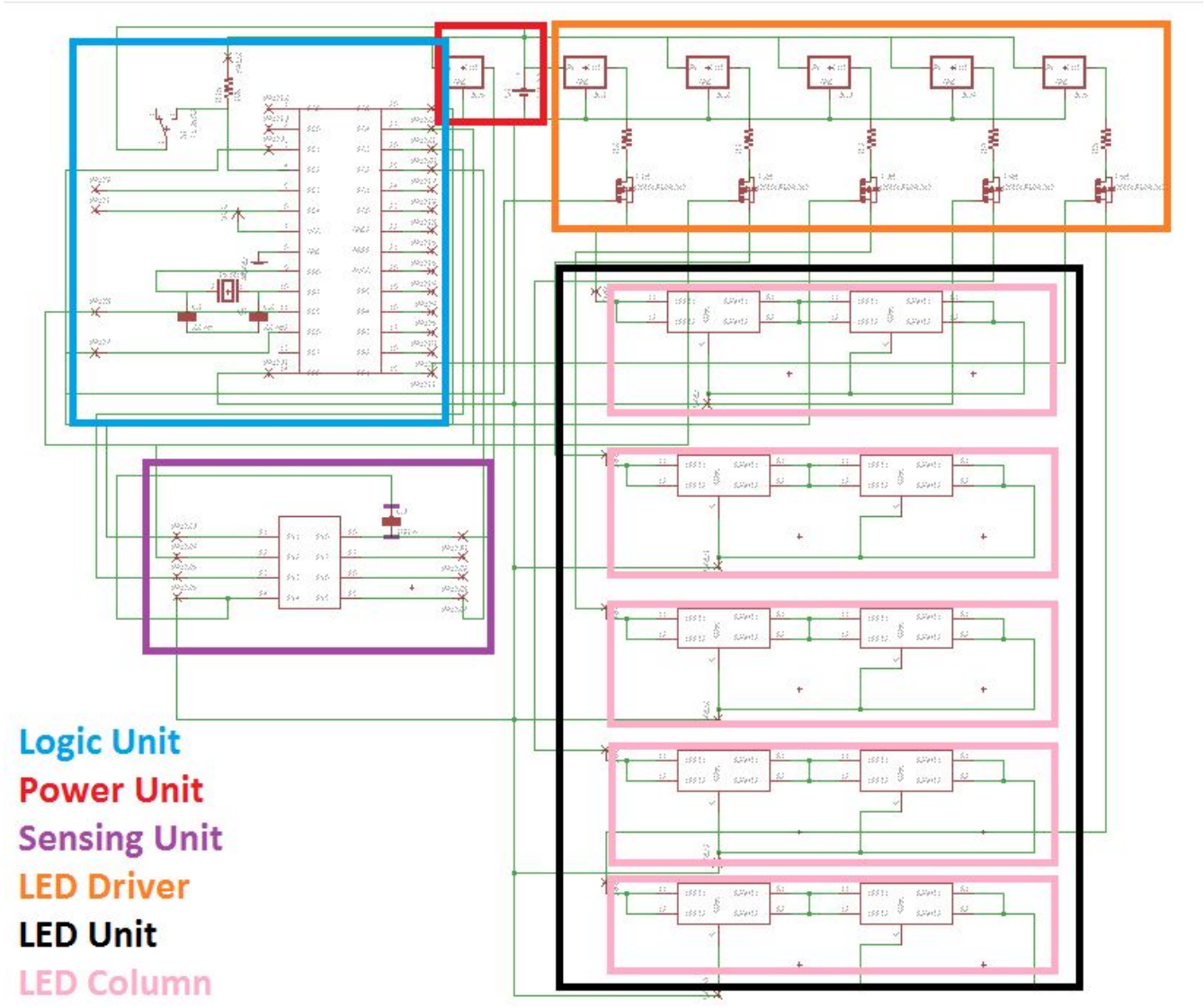


Figure 9: Overall Circuit Schematic of System

3. Requirements and Verification

3.1 High Level Requirements

Table 1: High Level Requirements and Points Allocated

Module Name	High Level Requirement	Points
LED Array	● The LED array will light up to about 2.5 m in the direction of the lean and illuminate in a forwards position ● The LED array will provide a sufficient amount of light such for safe operation	20
Logic Unit	● More columns of LED's on the array are illuminated as tilt angle of the motorcycle is increased, and in the direction of tilt	10
Power Unit	● Battery needs to supply enough power to drive the LED array within acceptable tolerances, as well as supply the sensing and logic units.	0
Sensing Unit	● Position sensor senses motorcycle tilt from 0 to 30 deg with accuracy of plus or minus 1 deg	15
Housing Unit	● Device's housing unit should withstand operating conditions on the road as well as various climate settings.	5

3.2 Modular Requirements and Verification

LED Array

Table 2: Requirements and Verifications for LED Array

Requirements (20 Points)	Verification
1. Voltage delivered to LED's should be 3.7±0.5V and current must not exceed 1A (4) 2. Illumination must not exceed 2.5m on either side of the motorcycle. (8) 3. Max luminous flux must not exceed 3000 Lumens (headlight brightness). At 227 lumens per LED, we plan to use 10 LEDs to achieve maximum brightness with all of them on. (8)	1. A digital multimeter will be used to measure the voltage and current flowing into the array of LEDs (in each column) while the tilt sensor is active. 2. Lean system from 0 deg to 30 deg at height of motorcycle tank a. Check that beam width is kept under 2.5m ahead throughout swing of tilt 3. Visually inspect lights from a distance, ensuring not brighter than headlights. a. Point LED and headlight in same direction and position b. Walk away from LED and headlight to around 100 ft. c. Compare brightness of two lights

Logic Unit

Table 3: Requirements and Verifications for Logic Unit

Requirements (10 Points)	Verification
1. Consecutive columns of LEDs turn on as the motorcycle tilt angle increases (3) a. C1 for 5 $\leq$ 10 degrees b. C2 for 10 $\leq$ 15 degrees c. C3 for 15 $\leq$ 20 degrees d. C4 for 20 $\leq$ 30 degrees e. C5 for $\geq$ 30 degrees 2. Delay between tilt sensing and LED turn on must be less than 100ms (faster than human reaction time) (3) 3. User should be able to calibrate tilt-sensor accurately (define null position based on placement of device). (3) 4. Recommended Input Voltage: 9V ± 0.5 V (1)	1. For accurate lighting logic - a. Plug ATmega data logger to output to screen b. Send software signals of varying levels of tilt c. Inspect that correct lights turn on 2. Set time delay via arduino code 3. Place Tilt sensor on level surface and calibrate a. Tilt sensor to the right in 2 degree increments b. Verify tilt from data logging console with protractor c. Hit reset button d. Measure tilt from calibrated e. Position and ensure correct lights still turn on 4. Use multimeter at input to ensure voltage requirements are met

Power Unit

Table 4: Requirements and Verifications for Power Unit

Requirements (0 Points)	Verification
1. Battery will supply 3.6V ± 0.5V to the LED module 2. Battery will supply 7 ± 0.5V to the Logic Unit to power microcontroller (ATMega328) and logic gates	1. Set up multi-meters and probes across module and monitor that 3.2 to 4.2 volts are achieved across the module 2. Measure voltage drop across respective modular units in the same manner as step 1

Sensing Unit

Table 5: Requirements and Verifications for Sensing Unit

Requirements (15 Points)	Verification
1. Inclinometer to sense tilt angle accurately (plus or minus 2 deg) from 0 to 30 deg such that the appropriate LED columns will be lit Eg. (5) a. C1 for 5 <= 10 degrees b. C2 for 10 $\leq$ 15 degrees c. C3 for 15 $\leq$ 20 degrees d. C4 for 20 $\leq$ 30 degrees e. C5 for $\geq$ 30 degrees 2. Data from sensors can be transferred to ATMega328 via SPI wire. (10)	1. Place Tilt sensor on level surface and calibrate (5) a. Tilt sensor to the right in 2 degree increments b. Verify tilt from data logging console with protractor c. Repeat steps in left hand direction 2. Hook up sensors to SPI ports and print tilt-angle onto control log window. (10)

Housing Unit

Table 6: Requirements and Verifications for Housing Unit

Requirements (5 points)	Verification
1. Cold weather proof down to -18°C (Freezer Temperature) (1) 2. Enclosure should not allow penetration of water that would damage circuitry. (2) 3. Strong Adhesive on underside of housing. (2)	1. Put housing unit in freezer overnight a. visibly inspect housing unit for any cracks or imperfections that may have formed 2. Put a piece of liquid-indicating paper inside the housing a. Place housing in shower and ensure paper not moist. 3. Drive the motorcycle at 40-50 mph with the housing attached to ensure it doesn't become loose.

3.3 Tolerance Analysis

Critical Component - LED Array

Acceptable Tolerance

The tolerance for our LED array is contingent on the brightness to the human eye. The headlight should be bright enough to be visible at night and illuminate the turning path, but if it is too bright, nearby motorists or pedestrians will be blinded. With the LED unit running at 1A capacity, we observed smoking on the PCB, largely due to the high current.

Taking these considerations into mind, we decided to halve the brightness, from 227 lumens to 113.5 lumens. From figure 10, we can see the current for 50% light output would be 400 mA. An allowable range for the light output would be 40% to 60%, which would be 320 mA to 500 mA LED current. If all 10 LEDs are on at the same time, we will have 1135 lumens. We are allowed a max of 300 lumens, which is the standard for a HiD headlight. According to the datasheet, the operating voltage of an LED is 3.6 V, with a minimum tolerance of 3.2 V. We observed 3 V in practice.

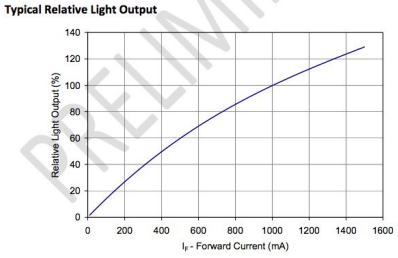


Figure 10: Light Output vs Forward Current of LED, taken from Data sheet for LZ1-00CW02[2]

Test Procedure

In order to test this project, we modularly tested each component, as well as tested how they integrate with each other. In order to test each LED column, we used our test breadboarded driver to drive the LED. This circuit used lab bench power. We measured the voltage over the resistor in order to determine both the voltage over the LED column, as well as the current through the branch. In order to test each LED driver, we saw whether each driver was capable of powering an LED unit.

In order to test the sensing unit, we hooked it up to a Arduino Uno board, and ran a test program that prints to screen the current angle. We tilted the sensing unit, and confirmed that it is indeed the correct angle using a protractor. When we tested the Logic Unit, we tested the algorithm by hooking up the Logic Unit to the sensing unit, and connecting basic low amp, through hole LEDs across the terminals. We ensured that the columns turned on in this order, for different angles of tilt:

- Column 1 for $5 \leq 10$ degrees
- Column 2 for $10 \leq 15$ degrees
- Column 3 for $15 \leq 20$ degrees
- Column 4 for $20 \leq 30$ degrees
- Column 5 for ≥ 30 degrees

After this, we tested the power unit by hooking up its leads to the battery terminals, and ensuring that the correct voltage outputs were present. After this step, we moved into system integration tests. These consisted of piecing together the different units, and running them as a whole. As mentioned previously, the system integration between LED Column and LED Driver was complete, as was the integration between Sensing Unit and Logic Unit. The next system integration task was between the Logic Unit and LEDs plus LED Driver, in which we drove the output as high and low in test programs. With that complete, we next tested integration by adding the sensing unit to the mix, and loading our program algorithm. Lastly, to test full system integration, we added the power module, and replaced the lab bench supply with it. This concluded system integration, and we were free to move on to the last step, housing the entire the project.

3.4 Presentation of Results

As shown in figure 11, the final product allows for ample luminosity and an appropriate beam width for a lane.



Figure 11: Left: Photo to Show Product Mounting Position on Motorcycle

Top RIght: Photo to Show Rider Perspective of Illuminated Directivity

Bottom RIght: Photo to Show Front Perspective of Illuminated Directivity

4. Cost

4.1 Cost Analysis

Table 7: Cost Labour Analysis

Name	Hourly Rate	Total Hours Invested	Total = Hourly Rate x 2.5 x Hours Invested
Philip Davidar	$35.00	150	$13,125
Abheshek Kothary	$35.00	150	$13,125
Prithwi Roy	$35.00	150	$13,125
Total	$105.00	450	$39,375

Table 8: Cost Parts Analysis

Part	Part Number	Unit Cost	Total
LED	LZ1-00CW02-0055	4.13	41.65
Atmega328 chip	Atmega328	1.95	1.95
Li-Poly Battery	LCH4P2S3R1WR	69.95	69.95
Inclinometer	SCA61TFAHH1G	52.05	52.05
Housing	N/A	10	10
Smart Charger	CH-L1118	29.95	29.95
.2 Ohm SMD Resistor	652-CRM2512FXR200ELF	.353	3.53
22 nF Capacitor	80-C0402C223J3R	.27	.54
10 k Ohm Resistor	588-AS08J1002ET	.05	.05
4.7 uF Capacitor	80-C0402C475M9P	.288	2.88
Schoktky diodes	630-HSMS-2800-TR1G	.496	2.48
Switch	540-DC1C-A1RB	7.35	7.35
16 MHz Crystal Oscillator	774-CB3LV-3C-16M0	1.35	1.35
Total			223.73

5. Safety Statement

Safety Gear

The rider of the motorcycle will wear gloves, jacket, pants that cover from waist to ankle, boots, and a DOT approved helmet at all times when operating the motorcycle.

Motorcycle Maintenance

The rider will make sure that the following motorcycle components are functional before every time the motorcycle will be used:

- Low beam headlight
- High beam headlight
- Turn signals
- Horn
- Front brake
- Rear brake
- Brake light

The rider will make sure that the tires have enough tread such that there is proper traction

While operating the motorcycle:

The rider will be stop the testing on the motorcycle if:

- A chemical or burning odor is sensed
- The motorcycle becomes uncomfortably hot
- Any liquids are leaking from the motorcycle
- The gears are slipping or not shifting smoothly
- The clutch is not engaging properly
- The throttle is not acting linearly (“bucking”, jerky delivery of power)
- Smoke is coming from anywhere on the motorcycle
- Steering is compromised by tension in the steering rack

Circuit Safety

We are using high current components for our project, so general lab safety will be followed as well as some extra precautions. We made sure that power sources will not be punctured, as we used a Li-Poly battery. Li-Poly batteries explode if they are punctured. Also we made sure that extreme care was taken while soldering components, as soldering irons are very hot. We also made sure that our circuit is isolated from any water or high humidity. If the lighting housing is emitted any smoke or hissing noises, or if the housing was found to be inflating or very hot, we stop cut power and stopped testing immediately. Once the package stops smoking, hissing, inflating, or converges to room temperature, we would disassemble the housing and assess what components must be thrown out and re-designed such that no more problems occur. Furthermore, we followed the following procedure to protect ourselves, our equipment, and the people around us.

- Group members will not work alone in case of emergency
- Group members will always keep one hand in their pocket when using any high voltage or high current system
- Group members will wear rubber-bottom shoes or sneakers
- Group members will wear eye protection
- Group members will not wear any jewelry or hanging pieces of clothing that may come in contact with circuitry
- Group members will have a fire extinguisher at the ready during builds
- Group members will power off all electrical components before soldering

LED Safety

The LED’s we are planning to use are very powerful. They output around 227 Lumens Each when operating under suggested forward voltage and current. Therefore, we will take extreme care so that we do not blind ourselves when using these LED’s. We will wore polarized sunglasses or tinted lab goggles when testing the LED’s. We also made

sure that no other students are in close proximity when testing the LED's. Even with eye protection, we ensured that we did not look directly at the LED's while they were powered.

6. Conclusions

Accomplishments

We were able to complete the entire project during the course of this semester with successes in most aspects of our initial requirements. Our final project will be able to effectively increase the safety of motorcyclists, especially when turning.

Uncertainties

All of our uncertainties have to do with the packaging of the final project. Due to the size of the final product, we were uncertain if we could mount it onto the motorcycle without it falling off, so we didn't do any highway testing. Additionally, we were unsure if the internal circuitry of our final product would withstand the vibrations from the motorcycle engine and the uneven surfaces of the road.

Future Work/ Alternatives

For future work, we would like to make the adaptive lean angle headlight into a consumer product, specifically as an aftermarket addition to motorcycles. This means applying for several patents, starting with the provisional. Apart from this, in order to sell this product, we need to make additional technical design amendments. One issue we would have to prepare for is that motorcycles with higher displacement engines vibrate a lot more than motorcycles with small engines. In order to account for this, we will need to implement Hysteresis or filtering into the software such that the vibrations do not cause flickering of the LED's near angles that are on the border of enabling a column. Additionally, we would want to design this product to be compatible cheaper battery, as the battery is a major cost limitation for this product. Furthermore, if we were to use off-the-shelf batteries, it would be a cost on the consumer, rather than a part of the system cost, in turn lowering the initial cost of the product. As mentioned in the technical overview, we will shrink the size of the PCB by consolidating several units into one, neatly planned PCB. We will also order a custom housing to better arrange the internal circuitry, which will also lower the overall product footprint . In order for the user to calibrate, we would have an external on/off switch. In our current project, we need to connect the terminals of the battery manually to supply power. Since the ATMega calibrates the inclinometer on start, we have to open the housing every time we want to start or

calibrate the inclinometer. This is dangerous as and untrained user should not be handling such a strong battery and it also causes errors in calibration, since the housing moves around a lot while connecting battery terminals. Lastly, in order to charge the battery, we will have an external port, again so that the user does not have to handle a dangerous LiPo battery

Ethical Considerations

Motorcycle Fair Use

We intend to test our project on a motorcycle. The motorcycle we intend to use is a red 2013 Honda CBR500r. The owner of the motorcycle is Prithwi Roy (one of our group members). Prithwi Roy accepts full liability of all damages to the motorcycle should anything happen to it, and accepts that his safety and well-being is in his own hands, and the University of Illinois will not be at fault should anything happen to Prithwi or his motorcycle. The purpose of this clause is to adhere to the point numbers [1] and [2] of the IEEE Code of Ethics[7].

Rider State

Prithwi will not operate the motorcycle if he hasn't received enough sleep or had any substances that would alter his mental and physical state (cough medication, alcohol, pain medication). Furthermore, Prithwi will not operate the motorcycle if he is injured in a way that would affect the safe operation of the motorcycle (eg. broken limb that hinders mobility). The purpose of this clause is to adhere to the point number [9] of the IEEE Code of Ethics[7].

Testing Environment

The testing on a motorcycle will not be done on public roads, as the the lights have not been reviewed for legality. Therefore we will test the motorcycle in a parking lot with very few cars. We will only test in parking lots that we have been given permission to use. The purpose of this clause is to adhere to the point number [9] of the IEEE Code of Ethics[7].

Signature:  Date: 3/1/2016

7. References

[1] Caranddriver.com, "Texting While Driving: How Dangerous is it? - Feature", 2016. [Online]. Available: http://www.caranddriver.com/features/texting-while-driving-how-dangerous-is-it-the-results-page-2. [Accessed: 10- Feb- 2016].

[2] LZ1-00CW02, 1st ed. LED Engin, 2016, p. 11

[3] Arduino.cc, "Arduino - Memory", 2016. [Online]. Available: https://www.arduino.cc/en/Tutorial/Memory. [Accessed: 10- Feb- 2016].

[4] Analog Devices, "Programmable 360° Inclinometer", 2006. [Online]. Available : http://www.mouser.com/ProductDetail/Analog-Devices-Inc/ADIS16203CCCZ/?qs=%2fha2pyFaduh6FfAyl6pvBdpsbyIrWsP3tgNYaP8TzzsevMOKfWk74g%3d%3d. [Accessed 10-Feb-2016].

[5]"THE SCA61T INCLINOMETER SERIES", Murata.com, 2016. [Online]. Available: http://www.murata.com/~/media/webrenewal/products/sensor/gyro/selectionguide/sca61t_inclinometer.ashx. [Accessed: 05- May- 2016].

[6]D. Sports, "The Lean Angle Experience", Motogp.com, 2016. [Online]. Available: http://www.motogp.com/en/videos/2013/09/26/the-lean-angle-experience/125254. [Accessed: 01- Mar- 2016].

[7]"IEEE IEEE Code of Ethics", Ieee.org, 2016. [Online]. Available: http://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 07- Mar- 2016].