VISOR

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***Abstract* — Motorcycles are one of the most common forms of transportation seen in modern history. Despite their numerous advantages, safety has always hindered the image of motorcycles globally due to their high rates of injury and death. The purpose of this project is to help enhance the experience of the motorcyclist by creating a system in which safety is enhanced through the use of a Heads-Up Display (HUD) that provides useful information to the user. The main features of this project include smartphone application, GPS, Blind Spot Monitoring System, Gear Indicator, RPM Counter, and an emergency system that responds in the event that an accident has occurred. The advantage of using a HUD comes in its ability to eliminate the need for the motorcyclist to look down at the dials of the motorcycle to read the data. Displaying the information in front of their face, while not disturbing the user, makes for a much safer and pleasant experience.**

***Index Terms* — Bluetooth, , Hall effect, Microcontrollers, Optics, Printed circuits, Sonar.**

I. Introduction

Motorcycle riding is a popular hobby for a lot of people, but it is a dangerous hobby to pursue. The best way to protect oneself is by wearing the correct gear usually gloves, helmet, pants, jacket and boots. As time progresses many of these components get upgraded and have added functionality such as an airbag system inside jackets or boots with turn signals inside of them. However, the helmet has remained mostly unchanged over the course of many years.

Driving motor vehicles is known to be one of the most dangerous activities we perform during our daily lives. According to the National Highway Traffic Safety Administration (NHTSA), the fatality rate for motorcyclists are significantly higher than that of drivers in passenger cars. [1] Progression in safety equipment for motorcyclists have saved and continues to save numerous lives. The project aims to improve the functionality of helmets for those that already use them, and additionally encourage the use of helmets to those who do not utilize them enough.

The objective of this project is to design and prototype a user-friendly heads up display (HUD) for motorcyclists with an augmented reality display on the visor of their helmet. The focus of the project will be to enhance the safety of the user by developing a device that displays various sensor data, and navigation data onto their line of sight without obstructing the user's view of the road and their surroundings. By reducing the user's necessity of looking down to retrieve information from the built-in dashboard, the user will be able to maintain the vision of their path more consistently.

Many people who ride motorcycles already own a helmet, so the project aims to develop a modular solution that will offer our proposed safety and comfort features to the users. This device will be designed to easily adapt to almost any motorcycle helmet without the need of any modifications to the existing system.

To improve the user's experience, this device will be easy to use, lightweight, rechargeable with a typical phone charger, and most importantly Bluetooth compatible to connect to a mobile device.

This project is unique from other projects and current products in the marketplace is the full integration in to the helmet like Skully's concept, however rather than using glassware so close to the eyes of the user the display is projected directly on to the visor with the use of mirrors and optics. By using lenses to collimate and enlarge the images from the OLED display, the system will be able to focus the images at infinity. This allows the HUD to be in focus always for the driver. This helps from a safety perspective as well as adding additional challenge to the project regarding fitment and display.

The overall block diagram for the two major modules is shown below in Fig. 1, and Fig. 2. The modules are comprised of the microcontroller, sensors, Bluetooth Low Energy modules, and the power system. The components will be discussed more in detail in the subsequent sections.

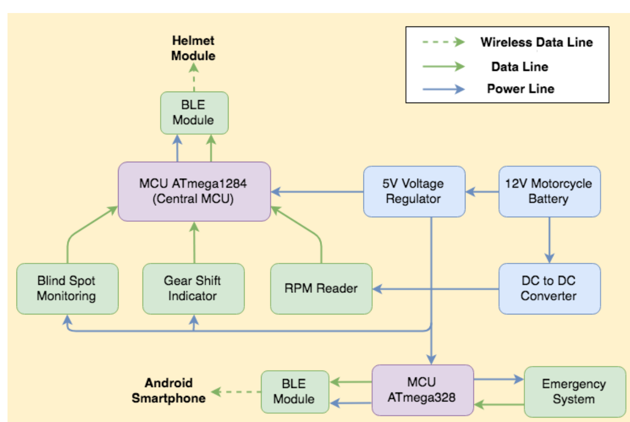

Fig. 1. Motorcycle Module Overall Block Diagram

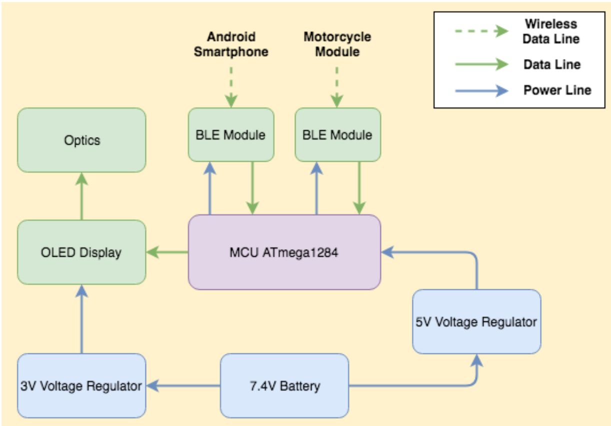

Fig. 2. Helmet Module Overall Block Diagram

II. Hardware Design Details

The following subsections describe in detail all of the main features of this project with respect to hardware. This includes, circuitry, power, and sensors that are mounted on the motorcycle.

A. Microcontrollers

The system uses three microcontrollers, two ATmega1284's and one ATmega328. The helmet mounted ATmega1284 takes input data from the motorcycle mounted module and the users phone and drives that information to the display. The 1284 mounted to the motorcycle module takes input data from varying sensors mounted on the motorcycle and transmits them to the helmet mounted module, the ATmega328 motorcycle mounted module is used to control the emergency system monitoring potential crash data. The chips were chosen based on the ease of programming as well as the requirements for increased RAM to drive the display on the helmet and do the necessary calculations on the motorcycle. The ATmega328 was chosen for its more than adequate clock speed and ability to interface easily with the emergency system chip.

B. Gear Sensors

To measure the current gear the user is in the US-5881 was used due to its ability to have a slightly higher release point at 25mT over its other competitors. This is useful since the location for the sensors is often near the stator cover of the motorcycle which can produce its own small electromagnetic field and interfere with the sensor getting the correct reading. The sensor measures a change in the electromagnetic field around them and can change the output pin to high or low depending on the field it is experiencing. This in turn will turn a pin high or low on the ATmega328 and that will indicate either an up or down shift depending on the active sensor.

C. Op-Amp

To take the input data from the motorcycle to measure RPM a multistage filter design is used to generate square waves which are more easily measured by the 1284.As seen in the image below, the raw data coming from the motorcycle does require some filtering to ease the microcontroller's ability to decipher the data.

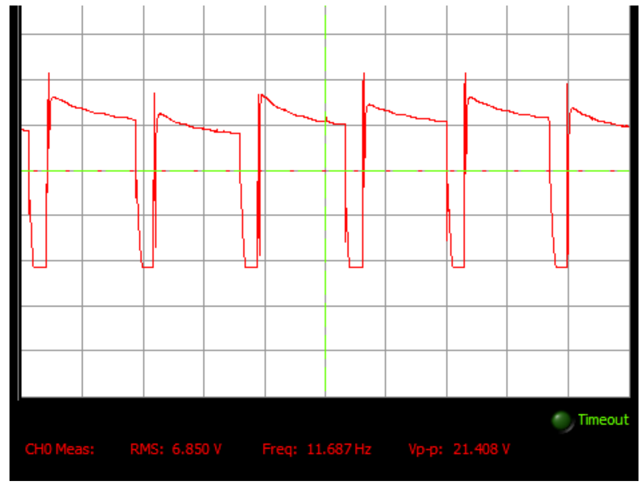

Fig. 3. Signal coming from spark plug wire to determine the RPM of the motorcycle. Frequencies range from 20Hz to 200Hz depending how the motorcycle is being used.

The TLV-0964 was used due to its ability to produce a rail-to-rail output, meaning if the positive and negative VCC are set to 5V the output will be able to reach that. Which is the voltage required to be able to measure a pulse on the ATmega1284.

D. DC-DC Converter

To be able to run the aforementioned Op-Amp a positive and negative 5V signal is required, this is made achievable by using the LTC1174. The primary reason this was chosen was its ability to output both a positive and a negative voltage from the same chip. This in turn allowed for less clutter on the PCB and decreases potential.

E. Emergency System

To measure whether a crash has occurred at GY-521 board is being used, on this board an MPU-6050 chip is mounted, the reason for using the board is the cost of the board is less than that of the chip and in addition to that the MPU-6050 only comes in QFN package making it very hard to solder. The board is capable of measuring lean angle and acceleration, both of these factors are considered to consider whether a crash has occurred. The primary reason for the selection of this chip was due to its easily accessible breakout board in addition to plenty of other projects involving this chip allowing for plenty of documentation and examples.

F. Power

For the VISOR project, it is important to consider the two separate power systems needed. Since there are two modules that communicate wirelessly, two unique power systems were created.

In the helmet module, it is required to have a power source that is rechargeable, compact in size, and able to support the helmet module for a minimum of 3 hours. It was then decided that a dual-cell lithium-ion battery with a capacity of at least 2000mAh would be appropriate for this application. A battery with these characteristics would be able to supply the sufficient voltage to operate all of the components and for several hours with a single charge. Upon further research, the Tenergy 7.4V lithium-ion battery met all of the requirements needed in order to appropriately power the helmet module.

Furthermore, the components in the helmet module all require 5.0V in order to operate except for the OLED display which will be running at 3.0V. It is necessary to step down the voltage from the battery for these components at their respective voltage levels in order to prevent damage to the components. Voltage regulators will be used to approach this issue in a simple and efficient manner. For the 5.0V voltage regulator, the dropout voltage is a major concern for the helmet module since a large dropout voltage would reduce the capability of the battery in this system. For this reason, the LM2940 voltage regulator by Texas Instruments was chosen due to its 0.5V voltage dropout which allows the system to fully drain the battery down to 6.0V. As for the 3.0V voltage regulator, dropout voltage is not much of a concern, however, the maximum output current is of concern since this voltage regulator would be supplying power to the OLED display which consumes a relatively high amount of current in the range of 160mA – 200mA. The REG102 3.0V voltage regulator was chosen for the main reason that it has a maximum output current of 250mA which would allow for the OLED display to be appropriately powered even under heavy loading conditions.

On the other hand, the motorcycle module will similarly be powered by using a battery. However, to simplify the power system, it was decided to simply use the lead-acid battery that is already installed on the motorcycle to supply power to the motorcycle module. In this module, all components and devices are operating at 5.0V. In this case, the LM2940 voltage regulator can be used once again since it capable of handling the input voltage of 12V from the motorcycle battery. One factor that needs to be considered for the motorcycle module is that it also contains the emergency system. Because this aspect of the project is so important for the safety of the user, it is necessary for this part of the system to be as robust as possible. For this reason, a separate power rail is created on the PCB that is to only be used by the emergency system. This requires another LM2940 voltage regulator to be in place that is fed from the same power source. This will reduce the possibility of the emergency system failing in the event that there is an issue involving all of the other peripherals on the motorcycle module.

Furthermore, there is active filter circuit on the motorcycle module as well. In order to appropriately power the operational amplifiers, a DC-DC converter is used to generate positive and negative power rails for the operational amplifiers to operate. The LTC1174 DC-DC converter was chosen as the best option for the purposes of this project. It can provide positive and negative power rails and also has a major advantage is that it can supply both power rails simultaneously.

G. Blind Spot Monitoring System

The main focus of this project is to enhance the safety of the motorcycle user. One key feature of the VISOR project is the blind spot monitoring system. This system is capable of alerting the user if there is another vehicle or other obstacle within the blind spot. This system works in almost any setting for it can alert the user if there is an obstacle in the blind spot regardless of the width of the car lane. The national highway standard for the width of a car lane is 12 feet and for this reason the blind spot monitoring system is set to notify the user for anything within that range.

There were several technologies that were taken into consideration for detection. One technology taken into consideration is infrared. The major concern that arose with using infrared is its ability to correctly detect vehicles in different weather conditions. In warmer climates, infrared sensors may face issues with detecting a vehicle due to a lot more interference. Although infrared sensors offer a very cost-efficient option, it was deemed as not a viable solution for the purposes of this project.

Moreover, another technology that was greatly taken into consideration was LIDAR. LIDAR offers great detection ability for it creates a map of its surroundings and also provides data about distances of each obstacle in its surrounding. However, LIDAR sensors are very expensive and are also rather unnecessary for the purpose of the blind spot monitoring system. This system only requires detecting an obstacle within a small region.

Finally, the best option for detection for the blind spot monitoring system was found to be with ultrasonic sensors. These sensors offer the best balance of price and quality. Active ultrasonic sensors emit a high frequency sound wave and wait for the echo to determine the amount of time it takes for the round trip of the sound wave. This round-trip time is then used to calculate the distance that the obstacle is from the sensor given the speed of sound. This technology, as you can see, is a lot less dependent on the environment it is in for it to work properly and also provides and fast and accurate method of detecting. With respect to price, ultrasonic sensors also offer a very good option for they range between $10 to $50 in price.

The ultrasonic sensor that was chosen for the blind spot monitoring system is the Maxbotix Ultrasonic sensor. This sensor is available for a fairly low price of $27 and most importantly has a great beam pattern that returns high quality measurements with a precision of up to 1 inch. This sensor has a range of up to 21 feet with an angle of roughly 15 degrees. This beam pattern is sufficient for detection of the blind spot region of the motorcycle. Once this sensor detects an object within the desired 12-foot range, then it will notify the user through the HUD This will be done by assigning the rightmost and leftmost regions of the OLED display to show a colored rectangle in the event that an object is detected in the blind spot.

H. Lenses

The optical design layout uses two positive lenses and an aperture in between them. The aperture acts as a field stop for the system as well as defining the entrance and exit pupils. The aperture is a circular iris that has a clear diameter equal to 20mm. The first lens of the system is a biconvex lens (lens 1) with a 25.4mm diameter and a 25.4mm focal length. The second lens is a plano-convex lens (lens 2) with a 25.4mm diameter and an 88.3mm focal length. Lens 1 has enough refractive power to bend most of the light emitted from the display and force the rays to converge quickly. Lens 2 is orientated to have the flat (plano) surface facing away from the display. This lens acts as a field lens and aides in focusing the image to have a sharp resolution.

Once the light rays emerge from the last surface, the image is then displayed onto the mirror. Using a mirror introduces no chromatic aberrations, this is important for displaying the entire color spectrum in focus. The image of the display will be placed at the focal point of the mirror; rays emerging from the focal point of a mirror will reflect parallel rays to the user. By having parallel rays imaged on the eye, the eye itself will cause the rays to converge on the retina; therefore, the user can accurately see the display. The user will be able to adjust the mirror to ensure that the HUD is in focus and in a location where it will no obstruct their vision from the road.

I. Display

There are a variety of different display options that can be used for the HUD. After conducting extensive research, the NHD OLED Display was selected primarily for its low power consumption. OLED displays in general offer a good option when it comes to power consumption compared to display output (brightness, resolution, and refresh rate). The NHD OLED display requires a low input voltage to operate with a range of 2.4V - 3.5V. Furthermore, the NHD OLED display will also only require between 200mA to 300mA of current to function properly.

The main appeal to use an OLED as the display for VISOR is the fine details and resolution that are achievable. Moreover, the part number we selected has a plethora of documentation available. The data that we strive to illustrate to the driver are RPMs, gear indication, blind spot monitoring, speed, navigation, and battery life. This set of data we wish to display stems from the general response of other motorcyclists' opinion on which data sets they would prefer to be displayed to them rather than looking down at the dashboard.

With the displays on hand, we will be loading the bootloaders to the ATmega1284. The display will be driven by that chip. To begin prototyping the display, the ATmega1284 will be loaded with preset images. These images will be determined as pure color images, like pictures of red, green, and blue colors. By having the ATmega1284 chip regulating the display and determining which information to show the user, we can mitigate where the point of failure stems from. Whether the information being displayed incorrect or missing, we can determine that the sensors are at fault. However, if the image is mostly visible, the display might have faulty pixels. Unfortunately, if the display contains dead pixels, the only remedy would be to purchase a replacement screen.

Given that the HUD will be consuming the most power out of any component in the helmet module, it is important to minimize its consumptions as much as possible to improve overall power management. These values, of course, could always be lower depending on the brightness and refresh rate that is used on the system. To help power management and improve the user's experience, the user will be able to adjust the brightness of the display to help improve battery life.

J. Simulation

To achieve a greater holistic understanding of the system, we used the program OpticStudio by Zemax. In the software, we created the ideal model for the optical system and the current model that will be implemented in the prototype. The figures below illustrate the optical design created for the HUD system of VISOR.

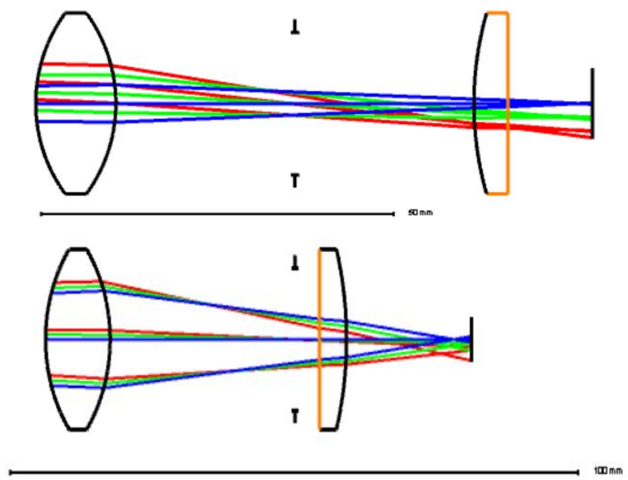

Fig. 4. (top) Optical layout design implemented in the HUD (bottom) ideal model for the optical design.

Shown from the figure above, there were multiple avenues to pursue to create the optical layout necessary to meet our needs of the HUD. The total optical path length from the two systems differ by only a few millimeters, however by having the field adjacent to lens 2 limits the field of view more, which in turn, provides a sharper image.

In addition to the perceived image quality one can visually inspect with the optical system, Zemax offers a quantitative analysis of the image.

III. SOFTWARE DESIGN DETAILS

The following subsections will discuss the software designed for this project. The two major categories for the software are the Arduino software designed for the helmet module and the motorcycle module, and the Android application that will be responsible for the turn-by-turn navigation.

A. Arduino

The helmet module and the motorcycle module are operated by the ATmega microcontrollers that handle the data involved in the system. The software used by the ATmega microcontrollers chosen for this project are written in the Arduino programming language that is built off of C.

The motorcycle module implements two microcontrollers. An ATmega1284P to gather data for the blind spot monitoring, RPM counter, and the gear shift indicator. An ATmega328P is utilized for the accelerometer and gyroscope for the emergency detection system. They each have an AT-09 BLE module attached to it that will be communicating to their respective modules. The BLE modules on the motorcycle module act as the slaves in the connection process and wait for connection to be initiated from their master devices. The program running on the main microcontroller will be polling data from each of the sensors to continually update the variables related to each of the subsystems.

The blind spot monitoring will be triggered when the sonar sensor detects an object closer than 12ft. The gear shift indicator will be triggered when an upshift or downshift is detected, and update the gear value. The RPM counter will continually monitor the rpm read from the motorcycle and continually update the value. The variables used in subsystems will be formatted into a single string and sent out via BLE to the helmet module to be displayed. The program running on the emergency system microcontroller will be gathering data related to the acceleration and the angle of the motorcycle. In the case that an accident is detected due to the sensor detecting an unusual angle, and no acceleration, it will send a signal via BLE to the Android smartphone that will then execute the emergency protocol.

The helmet module implements a single microcontroller, the ATmega1284P that is interfaced with 2 BLE modules, and the OLED display. The function of the helmet module is to receive the data from the smartphone, and the motorcycle via BLE, and to display the information onto the OLED display that will be projected onto the HUD. First the helmet module will initialize the OLED display and cover the screen with black pixels. The default setting is to display all the sensors, so it will initialize the text for the RPM counter, and the gear indicator.

Next, it will attempt to establish a BLE connection to the motorcycle module via commands sent to the BLE module. The connection to the smartphone will be initiated from the smartphone application. Once the connections have been established, it will wait to receive data that will then be displayed on to the OLED display. The data received for the blind spot monitoring will indicate whether there is an object detected in the blind spot of the user. The data received for the gear will indicate the current gear that the user is in. The data received for the RPM will indicate the current RPM value that the motorcycle engine is running at. When the RPM value exceeds the threshold set by the user through the Android application, the helmet module will display an indicator to the user to shift the gear up. Once a shift has been detected, and received by the helmet module, the indicator will be cleared. In the image below, there is a breakdown of how the data is organized onto the OLED display.

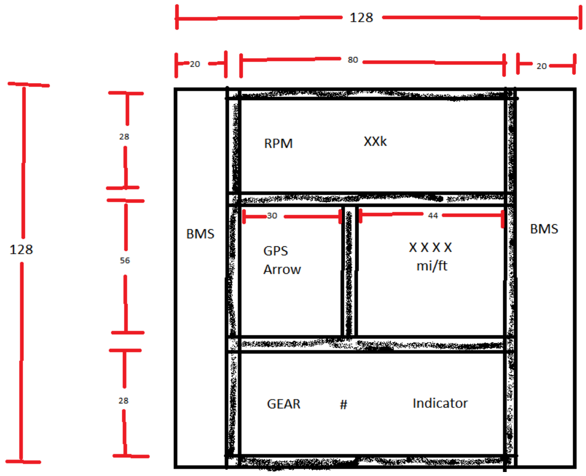

Fig. 5. Design layout for OLED Display

B. Android

Most Android smartphones support BLE connections, as well as GPS communication. Utilizing this technology, the application for VISOR has been developed. The core features of the application is to be able to initiate a navigation session, select the desired sensors to be displayed onto the heads up display, and to set the emergency contact for use with the emergency protocol.

When the application is started, it will attempt to connect to the helmet module, as well as the bike module via BLE. The application will initiate the connection and will indicate the status of the connection at the top portion of the application window. In the case that the connection is interrupted, a button is available for the user to initiate the connection again. If the devices are connected, the user can also select to disconnect them if they decide they do not need to utilize them.

The navigation portion of the application is implemented using the Mapbox Navigation Software Development Kit (SDK) for Android. The SDK is free to use for public/free applications. Currently, the user will be able to find their current location GPS coordinates with the touch of a button but will have to enter in their desired destination in the form of a GPS coordinate with the longitude and latitude. The information can be obtained from Google through its search function. Once the coordinates have been entered, and the phone is connected to the helmet module via BLE, when the navigation session is started, the instruction will be transmitted to the helmet module and displayed in the form of an arrow and distance. The Android application screenshot of a navigation instance is shown below in Fig. 6.

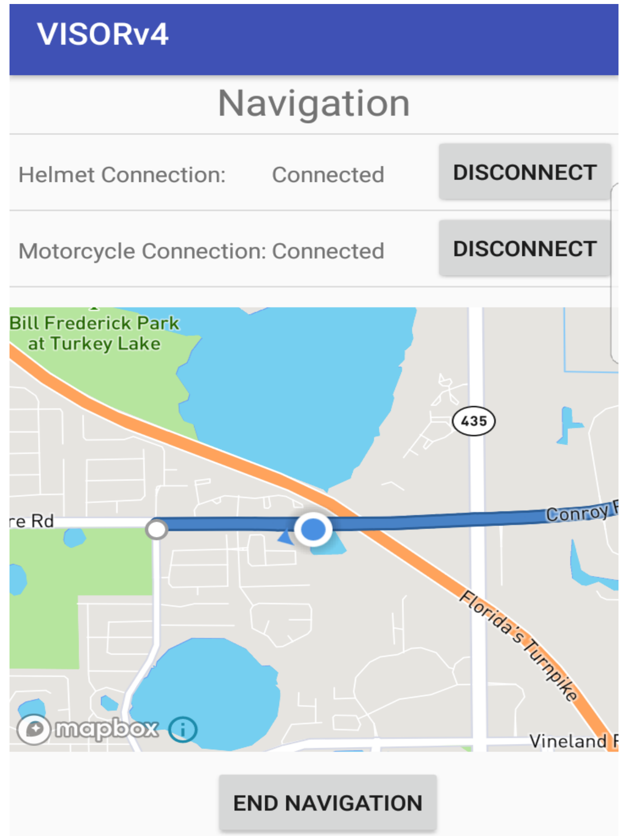

Fig. 6. VISOR Application Running Navigation

The user can also select the sensors to be displayed onto the heads-up display. The options include blind spot monitoring, rpm counter, and the gear shift indicator. The user can select any combination of the sensors that they would like to see, and once they press the update button, the information will be sent to the helmet module via BLE, and the helmet module will set the display accordingly. If the gear shift indicator is selected, the user will be able to enter in their desired RPM value that they would like to be notified of the need to shift gears. This is done due to the fact that motorcycles have different thresholds depending on their model.

The user will also be able to set their emergency contact that will be notified in the case of an emergency. The emergency protocol will be initiated once an accident has been detected. The type of notification will depend whether the phone is in sleep mode or is turned on. If the Android phone screen is turned on, a notification will be displayed on the center of the screen with the prompt. In the case that the phone is in sleep mode, a notification utilizing the Android notification bar will be displayed with the same message. First, the application will sound an alarm followed by a message that prompts the user whether they need assistance or not. In the case that the user decides they do not need assistance, the protocol will end there. In the case they do select that they need assistance, a call to emergency officials will be initiated, followed by a SMS message sent to their emergency contact notifying them of the situation. On the other hand, if the user is not able to respond to the notification, the user is assumed to be unconscious. The emergency contact will be sent a SMS message notifying them of the situation and the last known GPS coordinates of the user and will prompt them to contact emergency officials on behalf of the unconscious user.

IV. Board Design

Since there are two separate modules in this project, two different PCBs are created. All components on each PCB are surface mount components. Before committing to a PCB, prototyping and testing was conducted on breadboards using wires to facilitate the process until a final design was created.

The helmet module PCB faced a constraint with the dimensions that were allowed due to the helmet. With this in mind, the helmet module PCB was made to be as small as possible by not allowing it to be greater than the dimensions of the battery which are 71 x 37 mm.

To appropriately connect all of the peripherals of the helmet module PCB, several vias were created to install header pins in which the two Bluetooth modules, the OLED, and the lithium-ion battery can be connected. On the board itself, there are two voltage regulators to power the components as well as the ATmega1284 microcontroller unit which serves as the brain of this board. This board includes breakout pins for easy access to burn the bootloader and to program the board as seen below in Fig.7.

Assembly of the helmet module PCB was fairly simple due to its small number of components that are found on the board. All components were carefully chosen to have larger SMD packaging sizes to further facilitate the assembly process. All SMD components were ordered through Digikey due primarily to the short lead time that they offer.

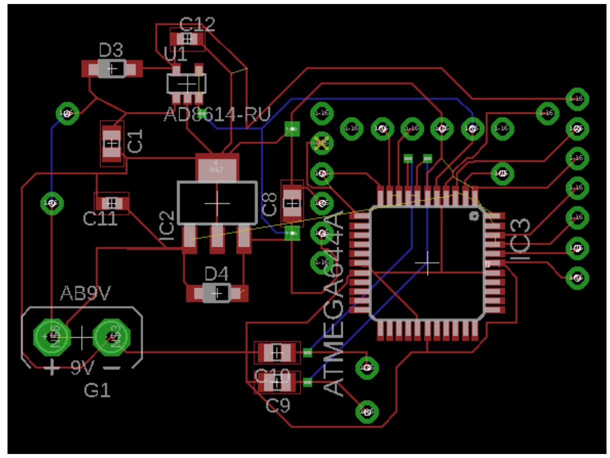

Fig. 7. Helmet Module PCB design from EAGLE.

Furthermore, the motorcycle module PCB is much more complex with respect to the helmet PCB. This board is similar in that it includes multiple vias to install all of the peripherals that relate to that system. Unlike the helmet module PCB, this board has no real constraints with respect to size.

On the board itself one can see that there are two microcontroller units along with two voltage regulators to power each of them to increase reliability of the system especially with the emergency system. For the RPM counter, there is a filtering circuit that uses operational amplifiers which can be found on the board as well. To power the operational amplifiers, there is also a DC-DC converter on the board to provide the positive and negative voltage rails. Fig. 8. below is the image for the final revision of the motorcycle module PCB as seen from EAGLE.

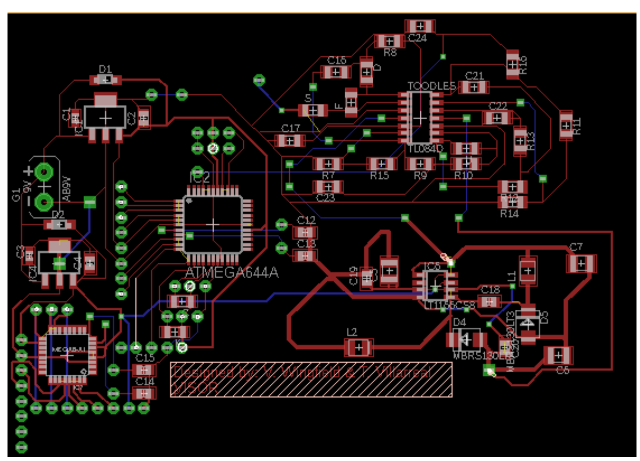

Fig. 8. Motorcycle Module PCB from EAGLE.

Both PCBs were created on EAGLE by Autodesk suing the libraries provided in the program as well as libraries found online to create the design for the PCB. Once the PCB was designed with the correct connections, the files were sent to then be manufactured with JLCPCB. Assembly of the PCBs was conducted on campus by the engineers involved in the project to help reduce cost and time.

V. Conclusion

All in all, the VISOR project is designed to provide motorcyclists with a new meaning of safety. With its various features aimed at the safety of the user, this project has the possibility of having serious implications on how the motorcycle is viewed. The technology that VISOR provides is capable of making motorcyclists or even potential motorcyclists more confident in using a motorcycle, allowing people to become more mobile with a more cost-efficient method of transportation. This project was created with keeping cost in mind, however, quality was always the most important factor in deciding the components and devices to be used to help ensure the lack of failure within the entire system.

Finally, this project provided all members with various new experiences. Some of the new challenges the group members were faced with were working with microcontrollers, Bluetooth, GPS, ultrasonic sensors and Hall Effect sensors. However, perhaps the most important thing that the group members learned was working as a group to completely develop a project from start to finish including research, design, and prototyping.

Acknowledgement

The group members would like to thank the University of Central Florida for providing us with a very high-quality education as well as providing numerous resources that helped with the development of this project.

Daniel Strien for providing a motorcycle helmet for testing and prototyping.

Brian Kim PhD for providing help with filter design of the RPM counter

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The Engineers

Manuel Navas is a 26 year-old Photonic Sciences and Engineering student at the University of Central Florida. After graduation, he aspires to become a certified professional engineer. Ultimately, he wishes to develop laser medical equipment for precision-based surgery. Manuel was primarily tasked with creating the optical design that will display the information from the OLED display for the user to see.

Tomas Villarreal is a 22 year-old Electrical Engineering student at the University of Central Florida. He aspires to work in the field of power systems as works towards acquiring his Fundamentals of Engineering certification and ultimately his Professional Engineer license. He was primarily tasked with creating the power system for the whole project as well as working on the Blind Spot Monitoring System.

Vincent Wingfield is a 23 year-old Electrical Engineering student at the University of Central Florida. His primary focus is on filter designs and embedded systems, and aims to use both of these focusses to be able to design systems for weapons and aircrafts for the US government. Primarily tasked with working on the RPM counter, Gear Shift Indicator, and the Emergency System as well as providing insight on the motorcycle and how to work with one.

Kyle Otsuka is a 23 year-old Computer Engineering student at the University of Central Florida. He continually seeks opportunities to improve his knowledge and experience working with computer software and hardware. Kyle was tasked with working primarily on the software including programs for the microcontrollers as well as the smartphone application.