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Project No.15

SMART HELMET WITH LIGHT INDICATORS FOR BRAKES & TURNS

by

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Abstract

In our project proposal, we are addressing the challenge of motorcycle safety by attempting to increase their visibility to other vehicles. This is done by incorporating turn and brake signals on helmets, which being required in many places by law, would be both physically as well as legally positioned to serve better than existing turn lights. We outline the usage of components required for this project, the wireless communication between light sensors and microcontrollers, as well as ethics and safety guidelines we are abiding by for our project.

Contents

1. Introduction

Motorcycle riders account for 14% of all traffic facilities, despite the fact only 3% of all registered vehicles are motorcycles, and “The number of motorcyclist fatalities in 2021 increased by 8 percent from 2020, from 5,506 to 5,932.” [1] According to the National Highway Traffic Safety Administration (NHTSA) of the United States Department of Transportation, “More than other vehicle drivers, motorcyclists must remain visible at all times, and anticipate what might happen.” We want to address this safety problem. Lane splitting is a common practice endorsed by American Motorcyclist Association, wherein a motorcycle’s narrow width can allow it to pass between lanes of stopped or slow-moving cars on roadways where the lanes are wide enough to offer an adequate gap.

We believe to address all the above, (visibility to other vehicles, aiding lane splitting and reducing fatality) it is essential to remove ambiguity about the motorcyclist’s path and make turn signals and braking more visible.

1.1 Problem

The biggest challenge faced by motorcyclists on roads is their visibility to other vehicles. Left turn crashes due to oncoming traffic being unable to assess their turn intention (turn signals are mostly situated on the back of motorcycles) are exceedingly common. In 2021, 42 percent (1,158) of motorcycles-vehicle collisions were due to the other vehicles turning left while the motorcycles were going straight, passing, or overtaking other vehicles [1]. Furthermore, many countries of the world are still using hand signals to communicate turn intention!

Another instance where turn signals are obviously critical involves the practice of lane splitting, which is legal in 17 US states. Lane splitting involves weaving in and out of traffic lanes to reduce the risk of cars running into the back of the motorcycle in stop-and-go traffic. More states are considering legalizing this practice, which, if carried out with proper training and safety, can help reduce crashes from the back. However, lack of turn signal/braking visibility can make this practice incredibly dangerous.

1.2 Solution

Our solution proposes to increase the visibility of motorcyclists by a simple, yet practical solution: by integrating turn and brake signals onto helmets using strong LED strips. 18 US states make it illegal to ride motorcycles without helmets, and many others require young riders to do so as well, making this a solution that would be enabled by law. As the lights will be visible on the sides as well as the back of the helmet, they will be a lot more difficult to miss or confuse. The helmet will be able to communicate wirelessly with the turn and brake signals in real time, and a combination of light sensors, microcontrollers with Bluetooth modules and LED lights will be used to complete this project.

1.3 Visual Aid

Figure 1: Expected LED placement on helmet.

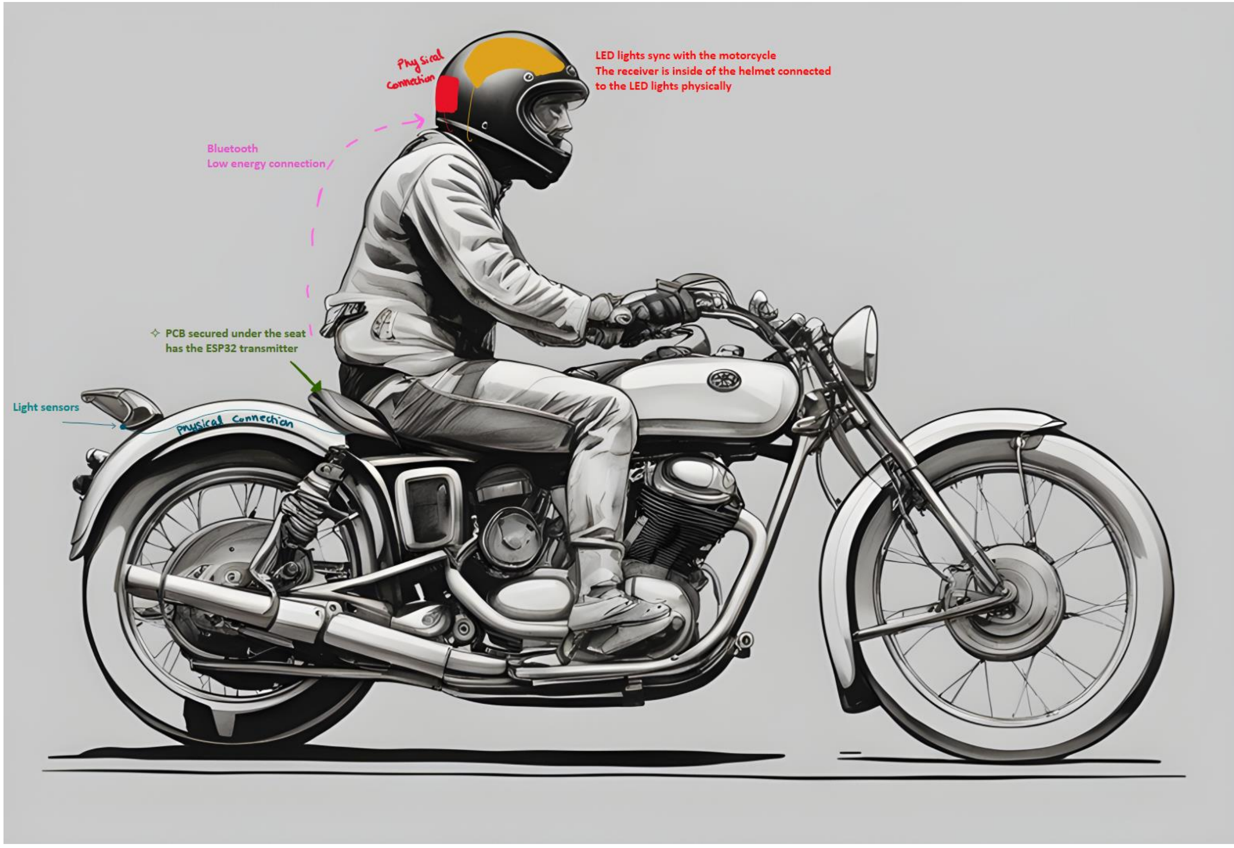


Figure 2: LED and circuitry placement relative to motorcycle.

1.4 High-level Requirements

We would expect our project to fulfill the following high-level requirements:

1. When the motorcycle’s right turn signal illuminates and blinks, the helmet's right LED should illuminate and blink. The same relationship should apply to the left LED.
2. When the motorcycle applies its brakes and its brake lights illuminate, the helmet’s brake light should illuminate. When the brakes are released, the LED should turn off.
3. Latency for the helmet LED lighting up, especially the brake, should be very low, ideally as low as possible to communicate in real time precisely the moment when brakes have been applied. Should not be above 3 seconds.
4. Battery should indicate when the battery is below 20%.

2 Design

2.1 Block Diagram

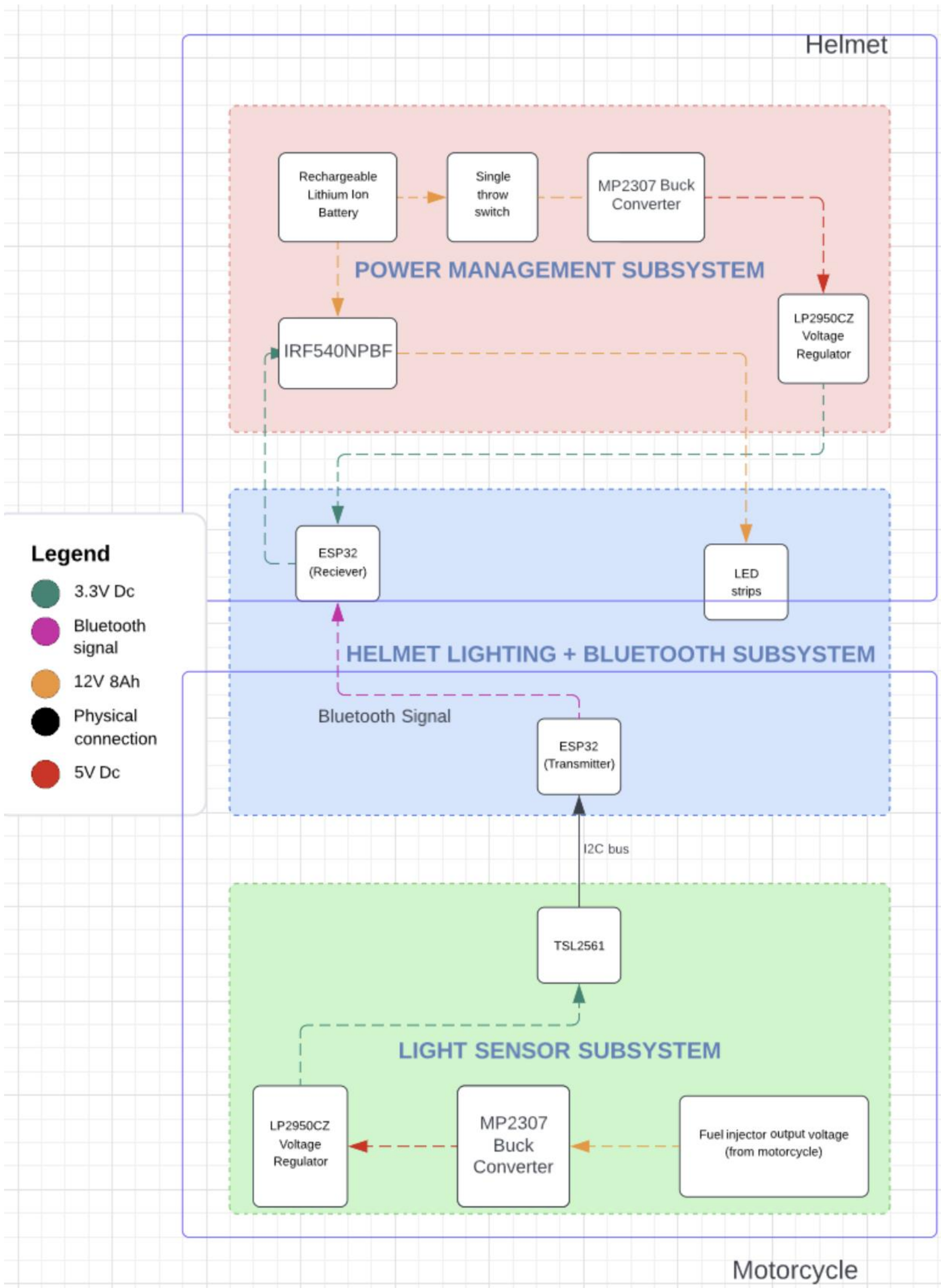


Figure 3: Block Diagram for the lighting system

The 3 main subsystems that make up our entire system consist of the Power Management Subsystem, the Helmet Lighting & Bluetooth Subsystem, and the Light Sensor Subsystem. The Power Management Subsystem is responsible for providing and regulating power to the LEDs and microcontrollers. The Light Sensor Subsystem is responsible for sending signals to the helmet of when the motorcycle's turn signals & brake lights illuminate and the Helmet Lighting and Bluetooth Subsystem is responsible for communicating with the motorcycle to illuminate the LEDs on the helmet.

2.2 Subsystem Overview

2.2.1 SUBSYSTEM 1: LIGHT SENSOR SUBSYSTEM

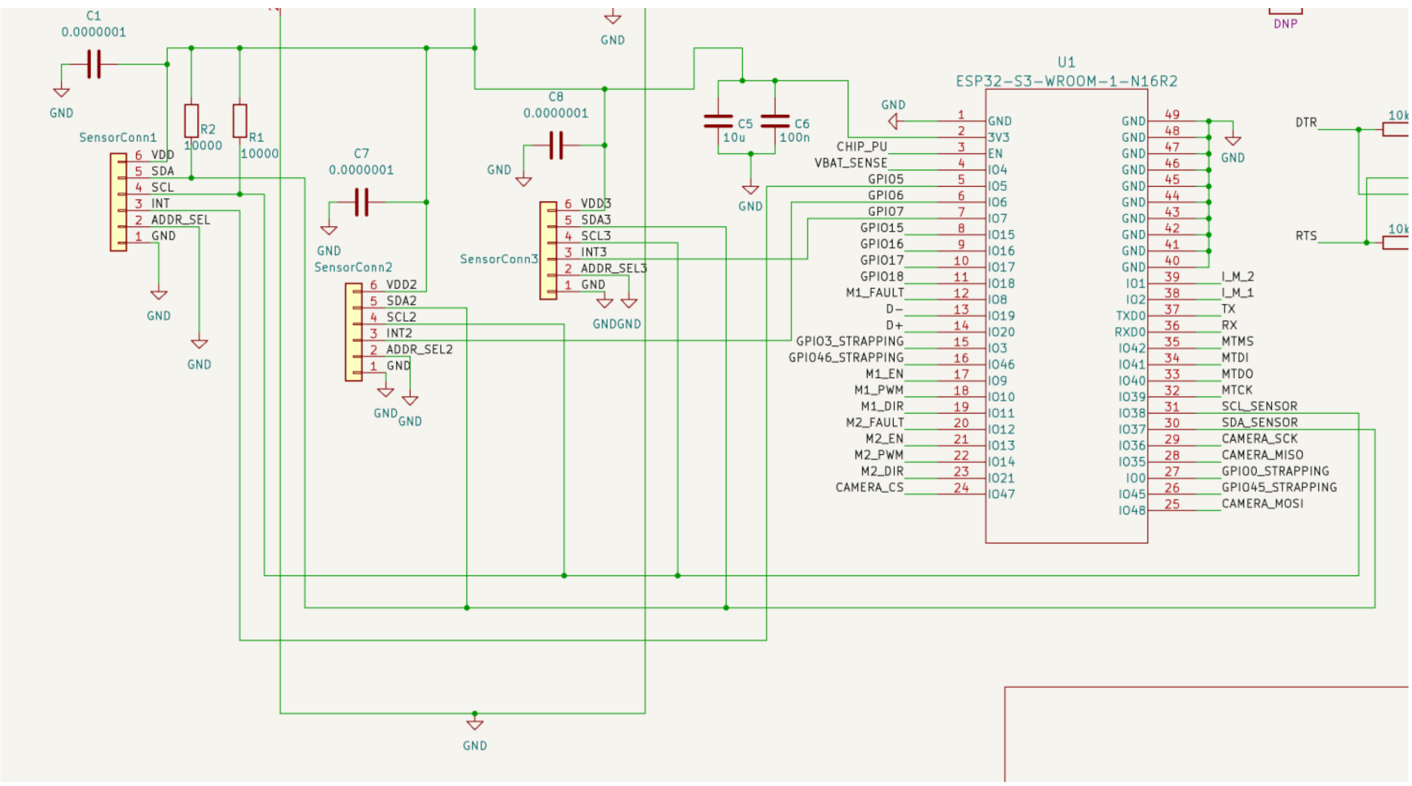


Figure 4: Light Sensor Subsystem – Motorcycle Schematic

- Light Sensor: Light-to-Digital Sensor TSL2561
- Microcontroller: ESP32
- External Pull-up resistors

The TSL2561 sensor will communicate via I2C (multi-master, multi-slave) bus with the ESP32, and will allow us to read the light intensity data from the turn signal. This will be affixed to our

PCB in the motorcycle itself (can be accommodated under the seat discreetly) and will receive 12 volts of power from the fuel injector on the motorcycle. This subsystem communicates with the Bluetooth subsystem to communicate sensor data as described in the next section.

2.2.2 SUBSYSTEM 2: BLUETOOTH SUBSYSTEM - HELMET & MOTORCYCLE COMMUNICATION

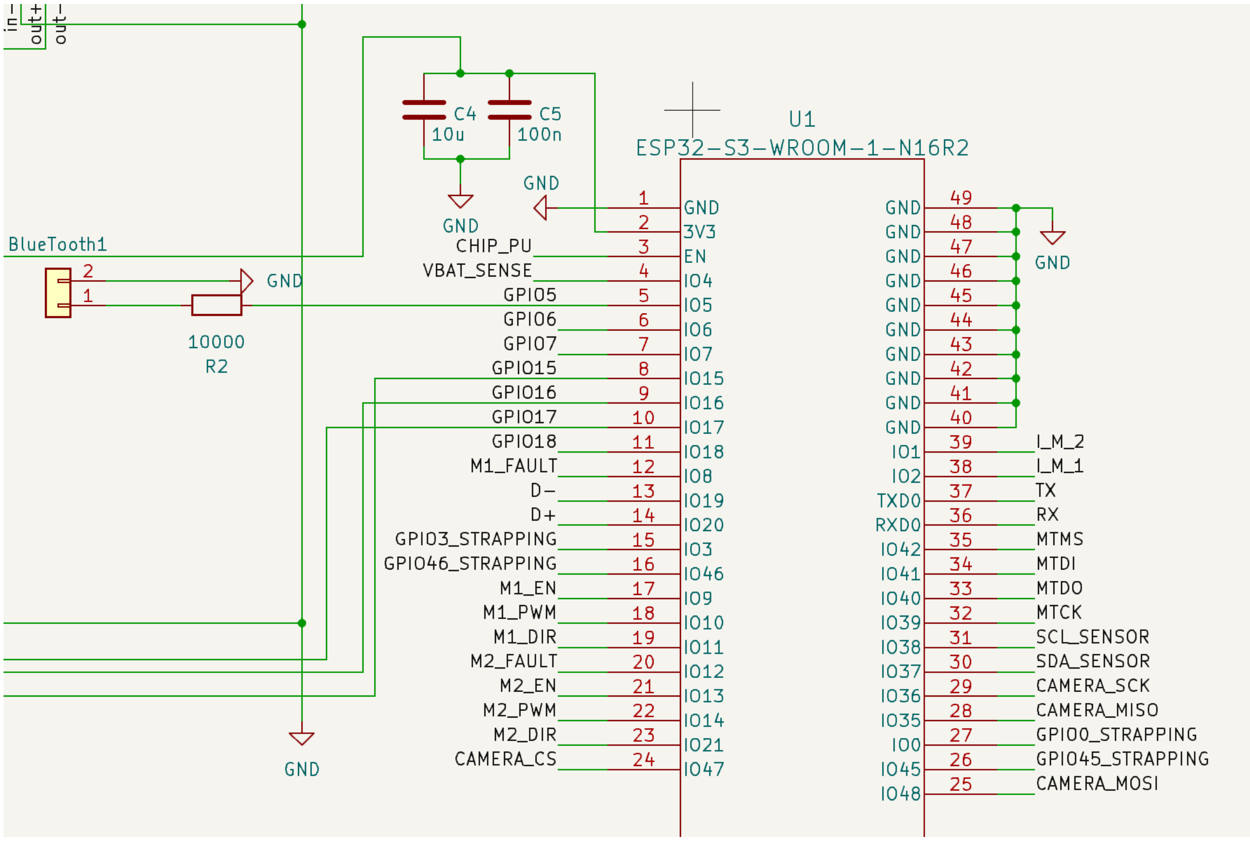


Figure 5: Bluetooth Subsystem – Receiver – Helmet Schematic

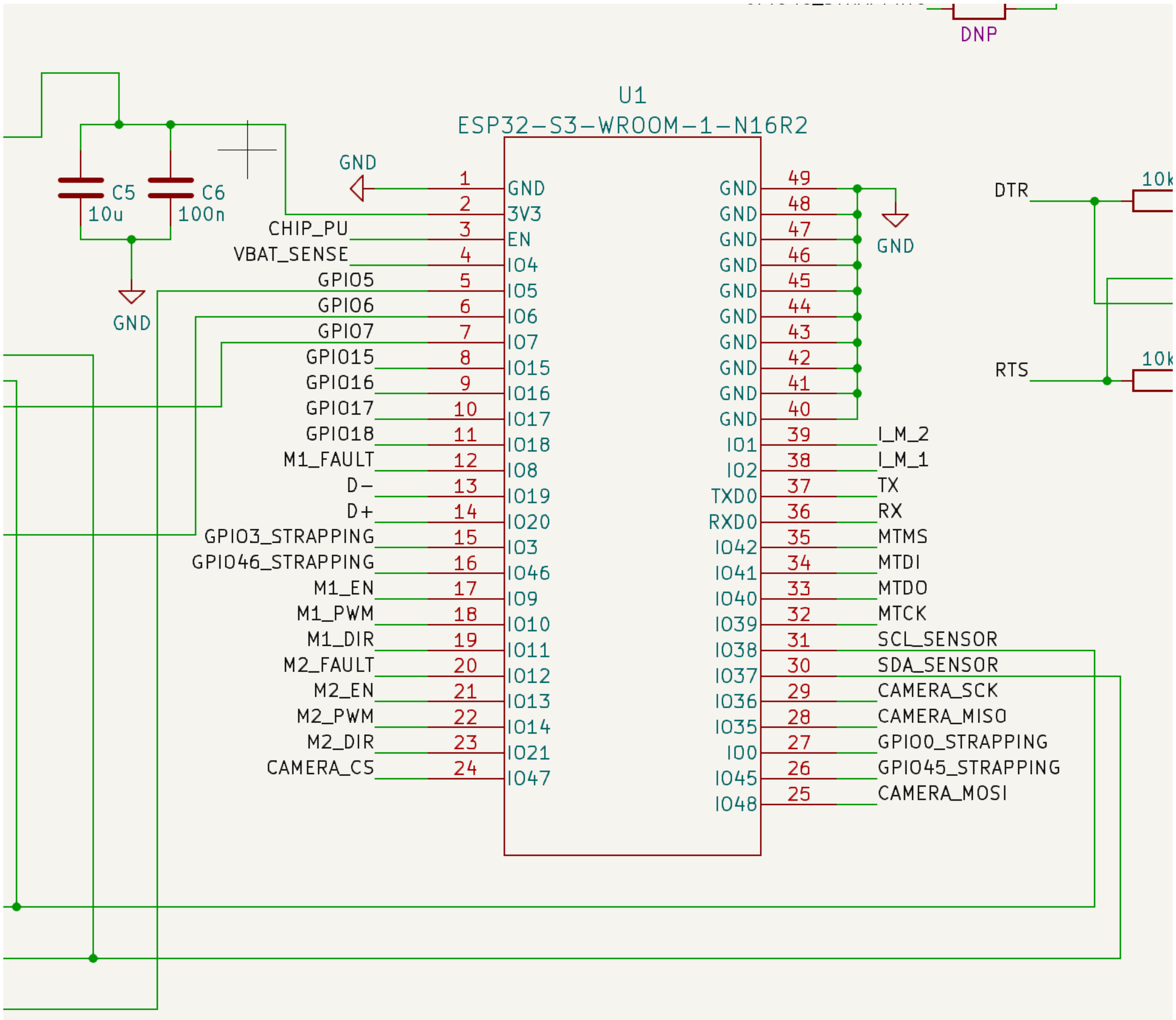


Figure 6: Bluetooth Subsystem – Transmitter – Motorcycle Schematic

We are using the ESP32 for its Bluetooth communication capabilities, which eliminates the need for an additional Bluetooth module. We plan to use BLE (Bluetooth Low Energy) to keep our power usage efficient. It will be used both as a transmitter (motorcycle) and a receiver (helmet). One will be affixed to our motorcycle PCB, and the other will be fixed to the helmet PCB to transmit light sensor data from the motorcycle to the helmet. On our chip, we have assigned our light sensors to use GPIO pins 5, 6, and 7 on our motorcycle PCB. On the helmet PCB, we have assigned GPIO pins 15, 16, and 17 to the corresponding LEDs which appear in the helmet lighting subsystem. We have assigned GPIO pin 5 on the helmet PCB to be used for the Bluetooth indicator LED, which will communicate Bluetooth connection status.

2.2.3 SUBSYSTEM 3: HELMET LIGHTING SUBSYSTEM

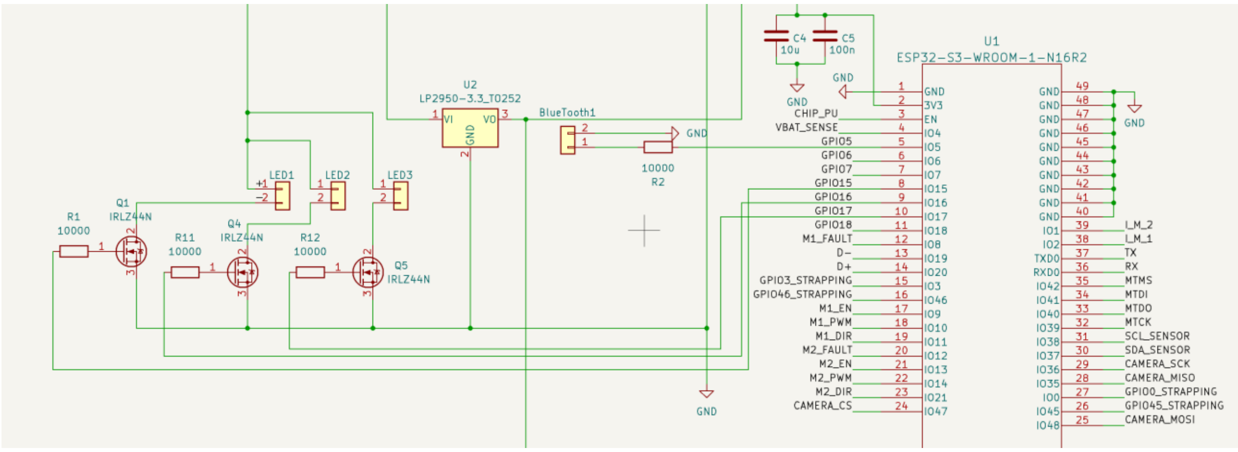


Figure 7: Helmet Lighting – Helmet Schematic

As a part of the Bluetooth subsystem, this subsystem receives the light sensor data that will be used on the helmet. The Helmet LEDs will be connected to the ESP32 in the helmet which will be acting as a receiver from the motorcycle PCB. The turn signal LEDs will be on the upper side of the helmet so that they don't obstruct the peripheral view of the rider. Most road accidents relating to lights on the motorcycle are due to left turns, so we made sure that the LED would be visible from the front as well. The brake light on the other hand only needs to be visible from the back. We will be using a larger-than-average helmet and will include extra padding so that the power system and Bluetooth system are not in direct contact with the rider's head white still maintaining a comfortably snug fit.

- LEDs: Red and amber LED strips will be affixed to the helmet, compliant with Illinois law. To avoid compromising the structural integrity of the helmet, we will be using strong adhesive strips.

2.2.4 SUBSYSTEM 4: POWER MANAGEMENT SUBSYSTEM

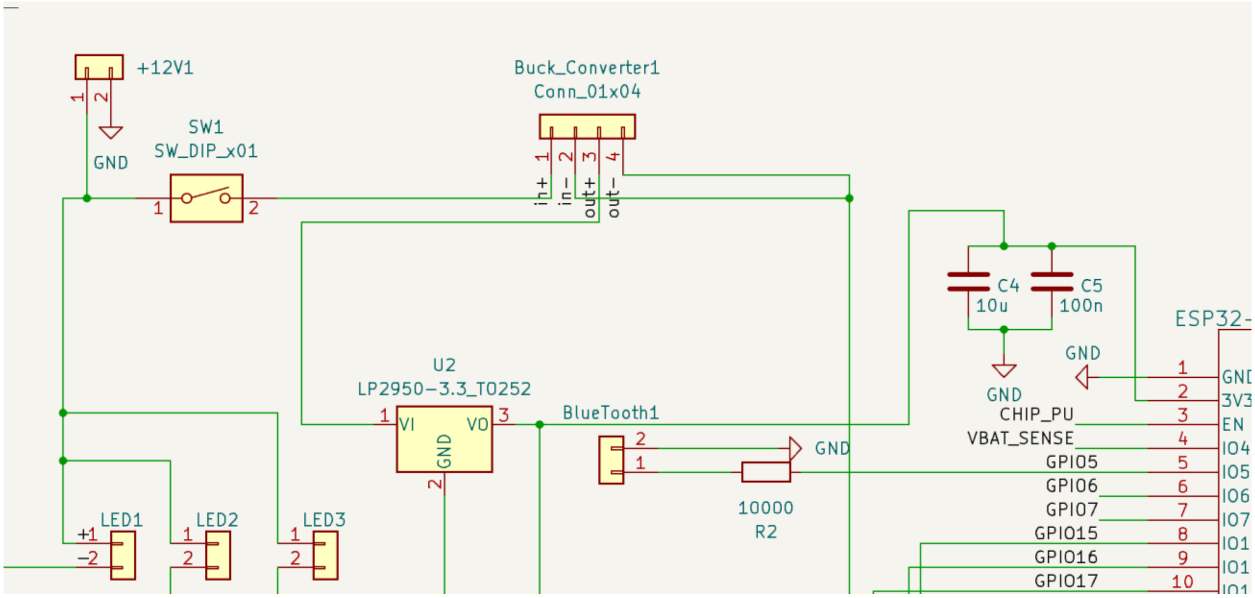


Figure 8: Power Management – Helmet Schematic

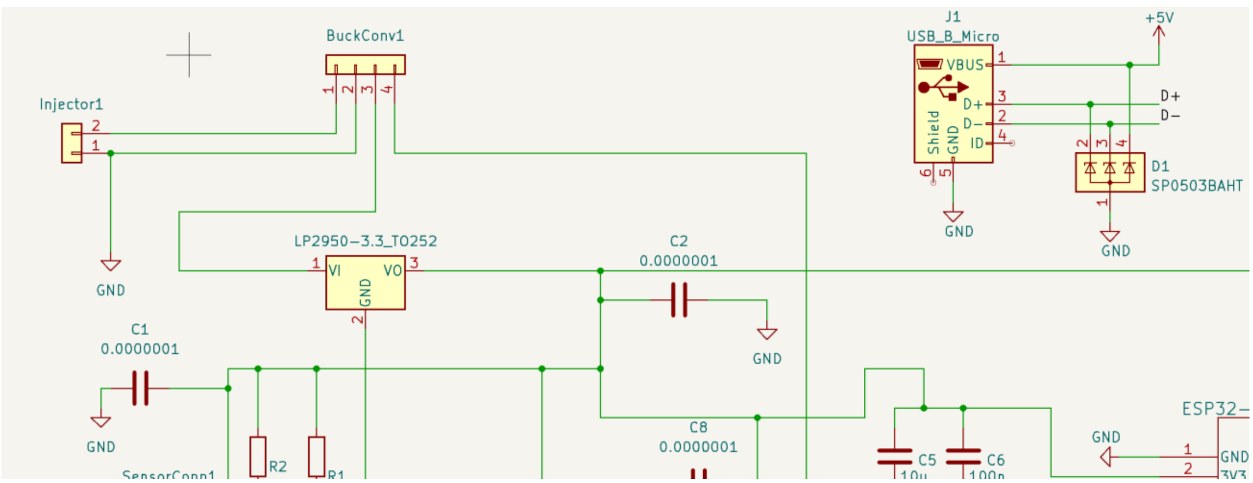


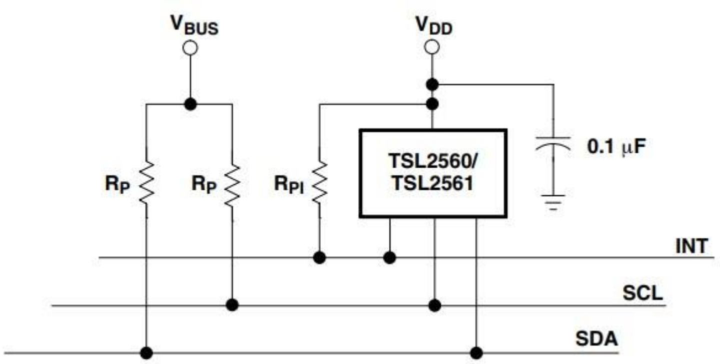
Figure 9: Power Management – Motorcycle Schematic

For the components connected to the motorcycle they will be connected to the Fuel Injector Output Voltage which only supplies power when the motorcycle is on, so the system should not drain the power when the motorcycle is not in use. (For simplicity purposes initially, we will be using a separate battery pack for the system connected to the motorcycle and this may be a stretch goal.) Rechargeable batteries will be present inside the helmet to power up the ESP and the LEDs.

Due to the possibility of the battery heating up and to maintain the safety of the helmet the battery pack will be in cased in flame retardant fiberglass bag https://www.amazon.com/Fireproof-Temperature-Resistant-Retardant-Explosion/dp/B0CF9KGNQ7 that would be stitched up to fit the battery pack.

2.3 Subsystem Requirements

2.3.1 SUBSYSTEM 1: LIGHT SENSOR SUBSYSTEM

Requirements	**Verification**
1. Hardware set-up requirements [2]: **1.1** The power supply lines must be decoupled with a 0.1 μF capacitor placed as close to the device package as possible. This bypass capacitor should have low effective series resistance (ESR) and low effective series inductance (ESI), such as the common ceramic types, which provide a low impedance path to ground at high frequencies to handle transient currents caused by internal logic switching. **1.2** Pull-up resistors are required for the SDAH and SCLH lines at a high level, and a separate pull up resistor between 10 kOhm and 100kOhm is required for the interrupt (INT) line.  	W will ensure that a 0.1 μF capacitor is placed as close as possible to the power supply pins of the TSL2561 to minimize noise and stabilize the power supply. We will physically inspect the PCB to confirm correct placement of the decoupling capacitor and pull-up resistors. We will use a multimeter to verify the correct resistor values and the continuity of the connections and ensure there are no short circuits between the power supply lines and ground. An oscilloscope can be used to check the integrity of the signals on the SDA, SCL, and INT lines (if there are sharp transitions without excessive ringing, indicating good decoupling and correct pull-up resistor values)
2. Sensitivity and Performance requirements: The sensor should be able to differentiate between ambient light conditions and the motorcycle's turn and brake lights. For this, the integration times and gain settings need to be correctly configured to optimize response for light intensity changes.	After setting up the sensor, we will perform tests under controlled light conditions to calibrate the sensor. We will adjust the integration times and gain settings until we can reliably detect the difference between ambient light and the lights of the motorcycle. By analyzing the ratio of visible to infrared light (using channel 0 and channel 1 readings), we will program the ESP32 to recognize light patterns emitted by the motorcycle's indicators. The tests will look as follows. We can see that the light reading value

<table>
<tr>
<td></td>
<td>changes from values like 324 -> 26 -> 1623 from ambient light conditions, to dim lighting, to bright light.

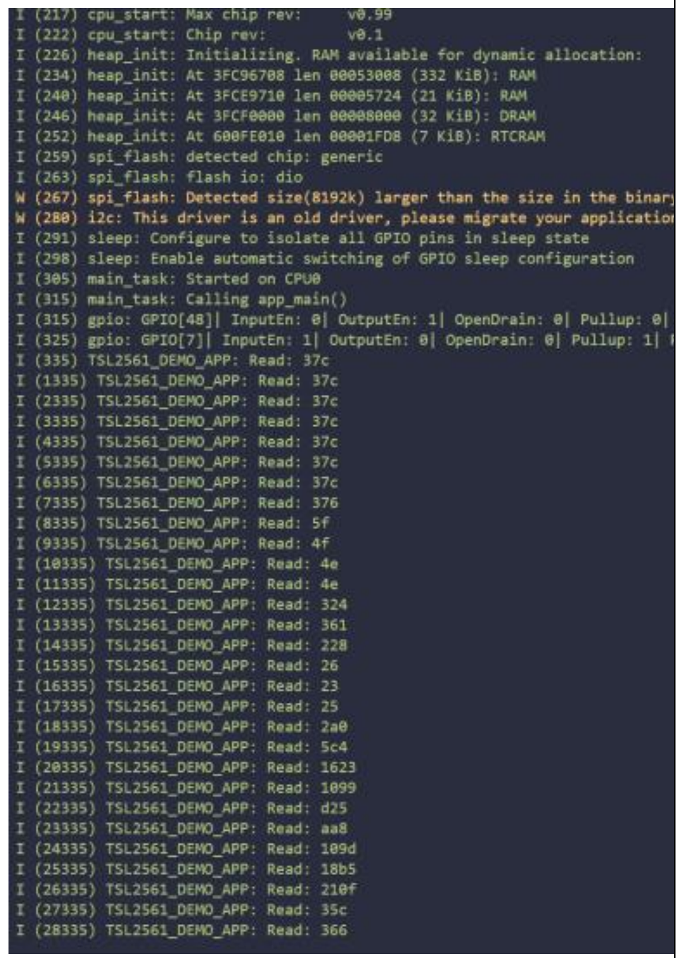


Figure 10: Example values for lux values while polling</td>
</tr>
<tr>
<td>3. Communication with ESP32:

The light sensor should be detected by the ESP32 and should periodically obtain a light reading from it, displaying it on the console. One TSL2561 device will be connected to two GPIOs on the ESP32 (I2C SDA and SCL).10 kOhm resistor from each GPIO to the 3.3V supply are connected to act as pull-up resistors.</td>
<td>The light sensor is directly connected to the ESP32 via GPIO pins. We will set upper and lower thresholds based on the expected light intensity values when the motorcycle indicators are on. These values are programmed into the TSL2561's interrupt threshold registers to trigger an interrupt when it detects light intensity from the indicators.</td>
</tr>
</table>

2.3.2 SUBSYSTEM 2: BLUETOOTH SUBSYSTEM - HELMET & MOTORCYCLE COMMUNICATION

Requirements	**Verification**
1. The ESP32 must establish a Bluetooth Low Energy connection between the helmet and the motorcycle.	We will use a blinking led indicator to signal whether Bluetooth connection was successful or not, as in standard Bluetooth devices.
2. The Bluetooth subsystem must reliably transfer light sensor data between the helmet and motorcycle.	This will be verified by a polling mechanism which polls at a fixed rate to receive light sensor information in varying brightness conditions.
3. The Bluetooth system should be able to remain connected during travel	We will send data messages between the devices to ensure an active connection. If a timeout occurs (no acknowledgement of the data message), it will attempt to reconnect.

Comprehensive testing scenarios should include pairing, connection initiation, reconnection after disconnection, and handling of potential connection errors or interruptions. Signal strength and range testing must be conducted to guarantee reliable communication under various environmental conditions, such as interference from other devices or obstacles between the motorcycle and the helmet.

Data integrity checks and error correction mechanisms should be implemented to detect and mitigate transmission errors that may occur due to noise or signal degradation.

Robust error handling mechanisms should be in place to handle situations where the light sensor data transmission fails or encounters errors, ensuring that the system can recover gracefully and maintain functionality.

2.3.3 SUBSYSTEM 3: HELMET LIGHTING SUBSYSTEM

Requirements	**Verification**
1. Turn signal LEDs must be visible from the front & back and the brake light LED must be visible from the back	An observer will perform a visibility test of the helmet at different angles and in different lighting conditions of the LEDs.
2. LEDs must be securely fixed to the helmet	Perform an adhesion test by applying a pulling force by hand to the LEDs. Perform test in a dry condition, after applying water, and while applying heat.
3. The LED light must not restrict the motorcyclist vision	While wearing the helmet, assess the helmet’s vision by identifying markers placed within view of the helmet at different angles.

4. Latency of motorcycle indicator turning on and helmet LED turning on should not exceed 3 seconds.	We will conduct tests to ensure that the latency remains below our fixed value using a timer when the motorcycle indicator lights are turned on. If the latency is above 3 seconds, we will revisit the polling mechanism.

The positioning of the turn signal LEDs on the upper side of the helmet, away from the rider's direct line of sight, prevents distraction and maintains the rider's focus on the road ahead. Similarly, ensuring that the brake light LED is visible from the back alerts following vehicles of the rider's intention to slow down or stop, reducing the risk of rear-end collisions.

The secure fixation of LEDs to the helmet is crucial to prevent detachment during normal riding conditions, which could pose a safety hazard to the rider and other road users. The use of strong adhesive strips provides a reliable method for affixing the LEDs to the helmet without compromising its structural integrity or compromising safety standards. We will perform physical tests to assess the durability and stability of the attachment mechanism under various environmental conditions, including exposure to vibrations, wind forces, and temperature fluctuations.

2.3.4 SUBSYSTEM 4: POWER MANAGEMENT SUBSYSTEM

Requirements	**Verification**
1. Components directly connected with the motorcycle must receive power from the fuel injector voltage output only when the motorcycle is on	Using a multimeter, measure 12 volts output from the fuel injector when the motorcycle is on and 0 volts when the motorcycle is off.
2. The system should only use/drain power when the motorcycle is on	Using a multimeter, connect the probes in series with the output of the MP2307 buck convert and measure 5 volts output when the motorcycle is on. Additionally, measure the output of LP2950CZ voltage regulator and measure 3.3 volts output when the motorcycle is on. When the motorcycle is off, our measurements should read 0 volts for both components.

2.4 Tolerance Analysis

1. For the light sensor TSL2561, the two main configurations that can be sources of errors are the style of interrupts chosen and the lux value outputted by the sensor.

1.1 Interrupt styles are determined by the INTR field in the Interrupt Register and the primary purpose is to detect a “meaningful” change in intensity. This can be defined both in terms of light intensity and time, or persistence, of that change in intensity. We can define a threshold above and below current light level or specify a number of conversion cycles for which a light intensity exceeding either interrupt threshold must persist before actually generating an interrupt. This can be used to prevent transient changes in light intensity from generating an unwanted interrupt. This value can range from 1 (interrupt occurs immediately whenever either threshold is exceeded) to 15 (15 consecutive conversions must result in values outside the interrupt window for an interrupt to be generated).

For e.g., if N is equal to 10 and the integration time is 402 ms, then an interrupt will not be generated unless the light level persists for more than 4 seconds outside the threshold. Using functions defined in a TSL2561 driver procured online [15], we are currently implementing a polling mechanism to detect light intensity values. We read the irradiance values, and we use predefined thresholds to restrict functionality of these sensors depending on external light conditions.

1.2 As mentioned in subsystem requirements, the integration time and gain settings directly impact the accuracy of light intensity reading. These are fixed using the TIMING register.
INTEG FIELD VALUE "00": Integration time is 13.7 ms with a scale factor of 0.034.
INTEG FIELD VALUE "01": Integration time is 101 ms with a scale factor of 0.252.
INTEG FIELD VALUE "10": Integration time is 402 ms with a scale factor of 1.
INTEG FIELD VALUE "11": Not applicable (N/A), as this setting is used for manual timing control and stops the integration cycle when writing a 0.
These settings allow for adjustment of the sensor's sensitivity and response time to changes in light intensity. The scale factor adjusts the sensitivity of the sensor to light, with a higher scale factor (closer to 1) providing greater sensitivity.

The gain setting (low gain at 1× or high gain at 16×) directly influences the sensor's light sensitivity. High gain settings can allow for better detection in low-light conditions but may lead to saturation under bright conditions. The chosen integration time and gain setting must be matched to the expected light levels for accurate light intensity measurements.

Motorcycle lights are generally between 35 and 90 lux [3], and for this range we will test with low gain (1x) first, especially in a moderately lit environment. If the sensor fails to differentiate light levels adequately at this setting, we will switch to high gain (16x).

2. In microcontrollers, floating point operations are often not supported, or have poor performance, so the lux calculation must be done without floating point operations. Since floating point has been removed, scaling must be performed prior to calculating illuminance if the integration time is not 402 ms and/or if the gain is not 16. This is explained in detail in the TSL2561 software integration portion of the datasheet.

3. **For the TSL2561 light sensor:**
   Supply Current: Active mode 0.24 to 0.6 mA, Power-down mode 3.2 to 15 μA.
   Voltage: Output low voltage at 3 mA sink current is 0 to 0.4 V and at 6 mA sink current is 0 to 0.6 V.
   Leakage Current: -5 to 5 μA.
   For the ESP32 microcontroller:
   Input Voltage (VIH/VIL): High-level input voltage is 0.75 times the supply voltage to the supply voltage plus 0.3 V. Low-level input voltage is -0.3 V to 0.25 times the supply voltage. [4]
   Output Voltage (VOH/VOL): High-level output voltage is 0.8 times the supply voltage. Low-level output voltage is up to 0.1 times the supply voltage. [4]
   Sink Current (IOL): Low-level sink current is up to 28 mA for output drive strength set to the maximum. [4]
4. The ESP32's VIH and VIL levels must match the TSL2561's logic levels for proper communication. Since TSL2561 operates with logic levels based on its supply voltage (2.7V to 3.6V), we will ensure that the ESP32's GPIO pins, when configured for I2C communication work with these levels.
5. Both the ESP32 and TSL2561 have specified operating temperature ranges. The devices' performance, including the accuracy of the TSL2561's (operates between 243 K to 343 K) light measurements and the ESP32's (operates between 233 K to 398 K) [4] processing capability, may vary with temperature.
6. **Heat tolerance analysis:** The main sources of heat dissipation in our project are:
   ESP32: The products sealed in moisture barrier bags (MBB) should be stored in a non-condensing atmospheric environment of < 40 °C and 90%RH. The module is rated at the moisture sensitivity level (MSL) of 3.
   After unpacking, the module must be soldered within 168 hours with the factory conditions 25 ± 5 °C and 60%RH. If the above conditions are not met, the module needs to be baked.

   Voltage Regulators: We will calculate the maximum power dissipation and thermal resistance as such:

$$Pdmax = (Vin – Vout) * Iout + Vin * Iq$$

Where P*dmax*: Maximum Power Dissipation, V*in*: Input Voltage, Vout: Output Voltage I*out*: Output Current, I*q*: Quiescent Current

We will calculate the thermal resistance (Rt) from the junction to ambient to ensure the junction temperature (Tj) does not exceed the maximum rated junction temperature (Tjmax) using:

Tj = Ta + Pd * Rt, where Ta is ambient temperature

LP2950 has a thermal resistance junction-to-ambient (Rt) of 180°C/W for the SOIC-8 package, and the maximum junction temperature (TJ) is +150°C.[11]

Buck Converter: We are using an MP2307 buck converter to step down our voltage from 12V to 5V. The operating input voltage should be between 4.75V to 23V, and the operating output voltage is between 0.925V to 20V. The device works in an operating temperature range of –40°C to +85°C

The switching frequency of the buck converter determines the performance of the converter. On a higher switching frequency, the capacitor and inductor needed are smaller.

The main power loss sources are switching loss, conduction loss and driver loss. [15]:

Switching Loss: Switching losses occur due to transition of the switch from an ON state to OFF state and vice versa. In a single cycle, power loss is:

$$E = 2 \times \int_0^{tcross} \frac{V(t)}{(t)} dt = Vdsmax * Idmax * tcross$$

Where Vdsmax is voltage across switch (when it is OFF)

Idmax is current through it when it is ON

Tcross is crossover time during turn on and turn off respectively

Power loss proportional to switching frequency is :

$$P = Vin \times Idmax \times tcross \times fsw$$

Where Vin is the input voltage and

fsw is switching frequency

Conduction Loss: Conduction losses occur in the power processing interval in the converter. These losses depend not on its frequency, but on its duty cycle:

$$P = Irms^2 \times Rds$$

Where Irms is the RMS switching current

And Rds is the on-resistance of the mosfet

Driver Loss: Driver loss occurs when the interelectrode capacitances charge and discharge. The controlling equation is:

$$P = Vdrive \times Qg \times fsw$$

Where Vdrive is the gate drive voltage

And Qg is the gate charge factor (proportional to the effective input capacitance and gate drive voltage)

Batteries: We are using the Turnigy Graphene Panther 4S 1300mAh 75C LiPo Battery. We will monitor the battery temperature to prevent heating over around 60°C (140°F) which is the maximum recommended temperature for LiPo batteries [14].

3 Cost & Schedule

3.1 Cost Analysis

3.1.1 Labor

$87,267 Average Salary = $41.96/Hour

$41.96/Hour x 2.5 x 45 Hours = $4720.5

$4720.5 * 3 Engineers = $14,161.5

3.1.2 Parts

Part	**Manufacturer**	**Quantity**	**Cost**
MP2307DN-LF-Z	Monolithic Power Systems Inc.	2	$3.83 MP2307DN-LF-Z
LP2950CZ-5.0/NOPB	Texas Instruments	2	$1.28 LP2950CZ-5.0/NOPB
101020030-TSL2561	Seeed Technology Co.	3	$10.90 101020030 - TSL2561
ESP32-S3-WROOM-1-N16R2	Espressif Systems	2	$3.62 ESP32-S3-WROOM-1-N16R2
10118194-0001LF	Amphenol (ICC)	2	$0.45 10118194-0001LF
IRF540NPBF	Infineon Technologies	3	$1.33 IRF540NPBF
Adafruit Flexible Silicone Neon-Like LED Strip	Adafruit Industries	3	$13.95 Flexible Silicone Neon-Like LED Strip
SP0503BAHTG	Littelfuse Inc.	2	$0.86 SP0503BAHTG
DS04-254-2L-01BK	CUI Devices	1	$0.66 DS04-254-2L-01BK
SS8050-G	Comchip Technology	4	$0.29 SS8050-G
B3S-1000	Omron Electronics	4	$0.66 B3S-1000
RC0805FR-0710KL	YAGEO	14	$0.10 RC0805FR-0710KL
RC0805FR-071KL	YAGEO	4	$0.10 RC0805FR-071KL

RC0805FR-07100KL	YAGEO	4	$0.10 RC0805FR-07100KL
C0805C104K9RAC7800	KEMET	6	$0.19 C0805C104K9RAC7800
C0805C106K9RAC7800	KEMET	2	$0.48 C0805C106K9RAC7800
C0805C105K9RAC7800	KEMET	4	$0.18 C0805C105K9RAC7800

3.1.3 Sum

Part Total Cost = $108.10

Labor Cost = $14,161.5

Total Sum = $108.10 + $14,161.5 = $14,269.60

3.2 Schedule

Week	Task	Will	Sanji	Jas
2/19	1. Complete Design Document 2. Retrieve Motorcycle Helmet	**1**	**1, 2**	**1**
2/26	1. Finalize Bill of Materials and Order Parts 2. Complete Draft of PCB for Review	**1, 2**	**2**	**1, 2**
3/4	1. Finalize PCB Design and Submit Order 2. Determine Hardware Configuration within Helmet and Deliver Helmet to Machine Shop 3. Program Microcontrollers 4. Perform Functionality Test using Breadboard Circuit and Sensors	**1, 2, 4**	**2, 3, 4**	**1, 3, 4**
3/11	Spring Break	Spring Break	Spring Break	Spring Break
3/18	1. Perform PCB Functionality Tests 2. Test Physical Layout of PCB within Helmet 3. Perform Bluetooth Connectivity Tests with Sensors	**1, 2**	**1, 3**	**1, 3**
3/25	1. Submit Final PCB Order 2. Perform Durability & Functionality Test on Helmet	**2**	**1**	**2**

4/1	1. Entire System Integration Testing with Motorcycle and Helmet 2. Conduct Test Drive	**1, 2**	**1, 2**	**1, 2**
4/8	1. Perform Final Debugging 2. Prepare Mock Demo	**1, 2**	**1, 2**	**1, 2**
4/15	1. Perform Mock Demo 2. Prepare for Final Demo	**1, 2**	**1, 2**	**1, 2**
4/22	1. Perform Final Demo 2. Finalize Final Paper 3. Prepare Final Presentation	**1, 2**	**1, 2**	**1, 2**
4/29	1. Perform Final Presentation	**1, 2**	**1, 2**	**1, 2**

4. Ethics and Safety

In developing the smart motorcycle helmet, we recognize that it is important to address ethical & safety considerations during the development and the lifecycle of the product, on and off the road. Throughout our time as students and soon as professional engineers, we will adhere to the ethical principles outlined in both the IEEE and ACM Codes of Ethics. These codes will be the basis of principles in our journey and will guide us through ethical decisions we face. By addressing the following, we are committed to designing and developing a motorcycle helmet that improves rider safety and upholds ethical principles.

4.1 Ethics

4.1.1 User Safety

Our biggest concern is the safety of the helmet user. Our commitment is to design a helmet that creates a safer environment for every motorcycle rider that uses it, without compromising ethical principles. As stated in the IEEE code, we must prioritize public safety in professional activities. Additionally, we also value transparency and will make certain that users are fully informed of all capabilities of the helmet.

4.1.2 Accessibility

Another focus of our agenda focuses on designing an inclusive project that can be used by all motorcycle riders, regardless of technological understanding or physical capabilities. As seen in the IEEE code, there is immense value in promoting diversity and accessibility in all engineering projects.

4.1.3 Professionalism

As a group, we will work to uphold the highest level of professionalism throughout our product's development. We will accurately and honestly communicate our product's capabilities, in line with the principles of integrity in professional practice outlined in the IEEE and ACM codes.

4.2 Safety

4.2.1 Regulation, Durability, & Integration

We will work to make sure the helmet complies with federal safety regulations as outlined by the United States Department of Transportation and with industry standards related to safety. This will involve materials testing and padding implementations to ensure the helmet provides proper protection in case of a crash. We will also adequately integrate the helmet with existing subsystems of the motorcycle to ensure compatibility and reliability of the product. This will culminate in real-world test rides performed by a licensed driver to verify performance.

4.2.2 Product Instruction

We will ensure comprehensive product training to users to ensure proper use of the helmet to mitigate safety concerns related to user error.

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