IGEN 330 Final Report

Helmet HUD, Team 303

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Jackson Mills - 44003176
Chanel Robertson - 30228381
Jared Good - 30304810
Kenny Wakaba - 91378315
Felipe Nunes - 76672831
Felipe Diaz - 63602809

1. Executive Summary

Helmet HUD provides users with real-time race metrics presented in a Heads-Up Display (HUD) format. The HUD is a mountable piece of technology that attaches externally to a Formula helmet and is currently designed in conjunction with UBC Formula Electric to be used in a race application.
The system consists of three major subsystems, being the Electronic-Box, Near-Eye Display, and Quick Disconnect System. When fully assembled, the system provides the driver with an effective, reliable, and safe HUD for general use. The HUD displays distance travelled, power output, and state of charge without infringing on safety rules and regulations. The system works by collecting data from the car through CAN Bus, then translates the data in the software and displays it on the screen.

2. Summary of Project

The aim of our project is to seamlessly convey live information about the vehicle to the driver in order to improve race performance. Our system is composed of 3 sub-systems: Quick Disconnect System (QDS), the Electronics-Box (E-Box), and Near Eye Display (NED) Module, working in series to accomplish our goal.

Our requirements were outlined through Stakeholder consultations with motorcycle riders and the Formula E captains and drivers. After careful consideration, the team opted to create a custom HUD.

The QDS is a waterproof 3D-printed enclosure with 3 magnetic connectors between the vehicle and E-box. This system enables the driver to exit the vehicle quickly with 14.71 N of force (1.5kg) while providing a solid electrical and mechanical connection to the vehicle's CAN bus.

The E-Box is a waterproof 3D printed enclosure containing a custom PCB, 9V battery, rotary switch, and power switch. The CAN messages are decoded and translated in the E-Box which is then transmitted to the NED module.

The NED module attaches to the driver's helmet externally to display an image with race metrics. It contains an OLED, screen, reflector, and a bi-convex lens with a focal distance of 35mm. The lensing system increases the user's depth perception by 300mm, reducing the effort required to focus on the information.

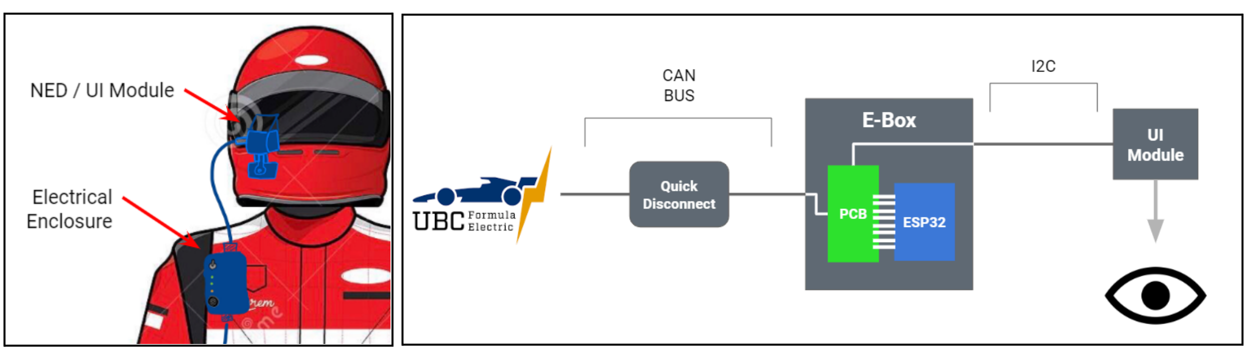


Figure 1: System Layout of our components and connections for the Helmet HUD.

2.1 Problem Definition Updates

Through our design work we've had to update our problem definition in terms of distractibility. Specifically, We've identified a problem focusing on both the display and the surroundings. A potential solution to this issue involves the development of a lensing system that allows the user to perceive the information a distance further away than the current design, thus lessening the strain associated with switching focus between the background and the display.

To achieve this, we first met with two opticians from EssilorLuxotica who recommended a trial-and-error approach given the high tolerances required in lens making. Next, we consulted an IGEN 430 project group working on binoculars to take inspiration from their testing rig. We observed a sensitive relationship between the focal distance and the size of the image, suggesting the need for another magnifying lens. Adding lenses helped our distance problem but distorted the image. We were not sure whether we could accommodate the precision required to produce a clear image.

The opticians explained that the eye-to-NED module and eye-to-road ratio is large which makes changing the focal distance without distorting the image a complex task. They've suggested we look into existing solutions such as Google Lens. The Google Lens design was far too expensive and complex for us to undertake. Instead, we met with an optical professor during his office hours who explained that our task was ambitious. We used our testing rig with a lens he lent us. We tested user response times with the lens at various distances to quantify the decrease in the time it took to change focus. Overall, we were able to increase the focal distance by 38mm and decrease the time to focus by about 400 ms.

Another aspect of the project that required an update to the problem definition was the mounting system. Course instructors indicated their concerns regarding the safety implications of an externally mounted system, specifically:

- Reduced shock absorption: The presence of a hard object on the outside of a helmet could reduce the helmet's ability to absorb shock and distribute the impact force, as the energy from the collision may be concentrated in the area where the object is attached.
- Increased risk of rotational injuries: Adding a hard object on the outside of a helmet can increase the risk of rotational injuries, as the object can catch on a surface during a collision, causing the helmet to twist or rotate.

To address these concerns, the problem definition was updated to include requirements that specify how, and at what load the mounting system should fail at.

3. Design and Implementation

3.1. Quick Disconnect System (QDS)

The Quick Disconnect System's goal is to pass the CAN signals and ground without degrading the signal integrity and interfering with the Formula SAE standards that Formula E must follow. The main structure is a 3D-printed enclosure containing 6 magnets wrapped in copper.

The first prototypes were rectangular and used an asymmetrical placement of magnet polarities to ensure the wires cannot get mixed up. Later prototypes focused on the asymmetry of the enclosure since there were problems with the magnets interfering with each other when similar poles were nearby.

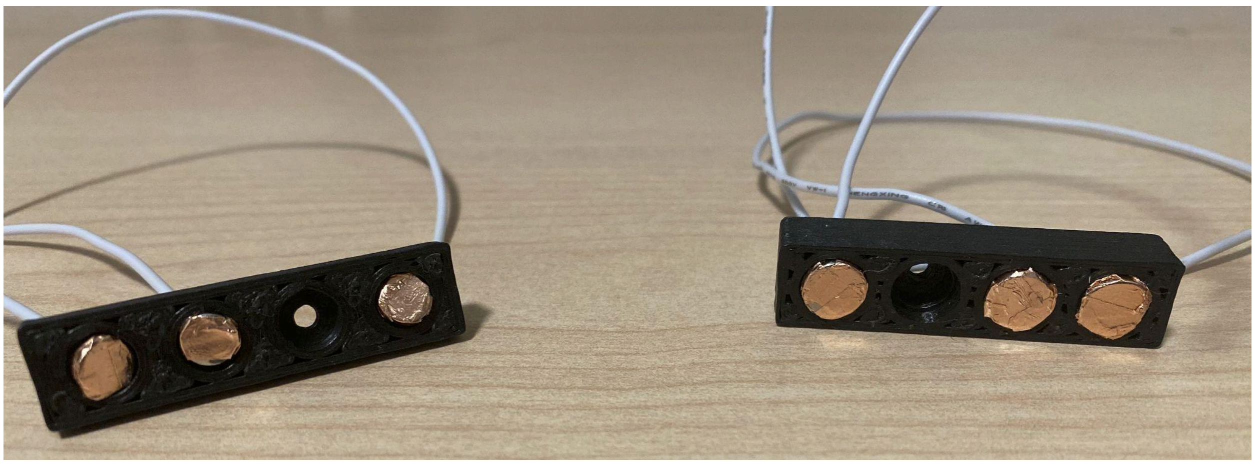


Figure 2. Third Rectangular Prototype of the QDS.

Additionally, stranded core wires were used to reduce noise for our signal channels. The wires were soldered onto neodymium magnets to ensure a strong connection. Given neodymium's strong magnetic pull but long conductivity, the magnet's were wrapped in copper tape.

The final iteration features a circular arrangement of magnets, minimising the size of the enclosure and improving water-proofness by minimising the area. A tap and hole on the two enclosures prevents the wires from mixing. Stronger magnets were used since the soldering greatly reduced the magnet's pull.

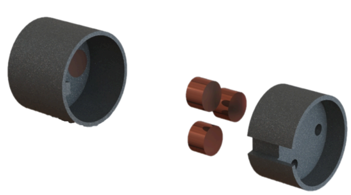


Figure 3. Isometric view of final QDS design.

The reliability of the system was first tested with a prototype with 3 magnets per connection which did not prove to be reliable at the frequencies we were operating at. The next iteration featured 2 magnets.

We wanted to test the signal response through the QDS to ensure the signal could pass with minimal noise. To do this, we attached the probe of the oscilloscope to one end and the two probes from a function generator to another end. The function generator was set to output square waves with a range of frequencies from 500kHz to 1MHz. Our oscilloscope probed a large circuit, having to go through long wires and two magnets. The signal output was downloaded through a USB, we observed significant noise at the edges, and the signal became noisier as the frequency increased. Additionally, we measured the resistance of the QDS by probing both ends of the QDS connections using a multimeter. The resistance was calculated as around 1.4 to 2.26 ohms. All in all, the second prototype successfully passed square waves of 500kHz to 1Mhz with a reasonable amount of noise and a reasonable amount of resistance.

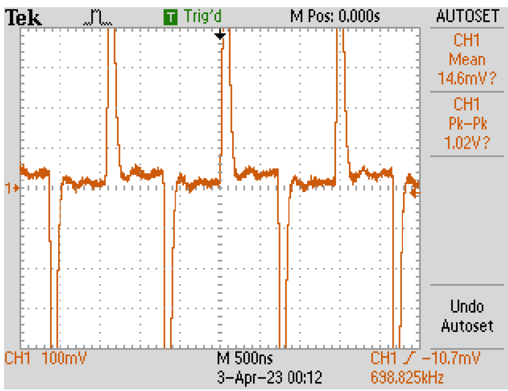


Figure 4: Output given a square-wave input of 698.825kHz of the left wire.

3.2 Electronics Box (E-Box)

The E-box serves as an enclosure for the 9V battery, power switch, rotary switch, and our custom PCB. It is designed to be waterproof with IP-67 rated components to meet the stakeholder's need of driving in the rain in an exposed vehicle. The specific layout and completed list of included parts can be found in the appendix.

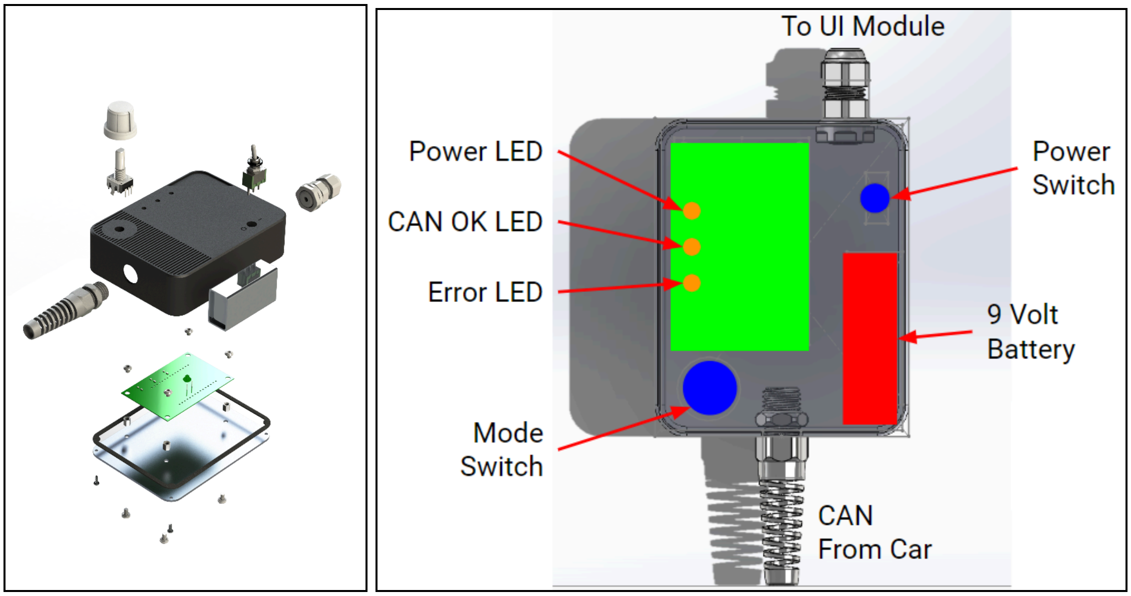


Figure 5: E-Box and its complementary components.

<u>9V Battery & Power Switch:</u>

One of the largest discussions for this project is the power system of the Helmet HUD. Through meetings with our stakeholders, we identified that the user is interested in operating the device for a long time. We researched possible power sources for our system and found two primary options:

1. 18650 Battery
2. Lithium 9V battery

The 18650 battery is widely used by hobbyists to power devices and would make an excellent choice as a battery. We initially liked this option due to its battery capacity of 2600mAh, wide availability, and well supported resources online. However, its voltage (3.6V) is not high enough to be fed directly to the V_{in} pin of ESP32. This is because the pin regulates the input voltage through AMS1117, the on-board linear regulator (LDO) with a required drop-out voltage of 1.1V, and 18650 is 0.8V short.

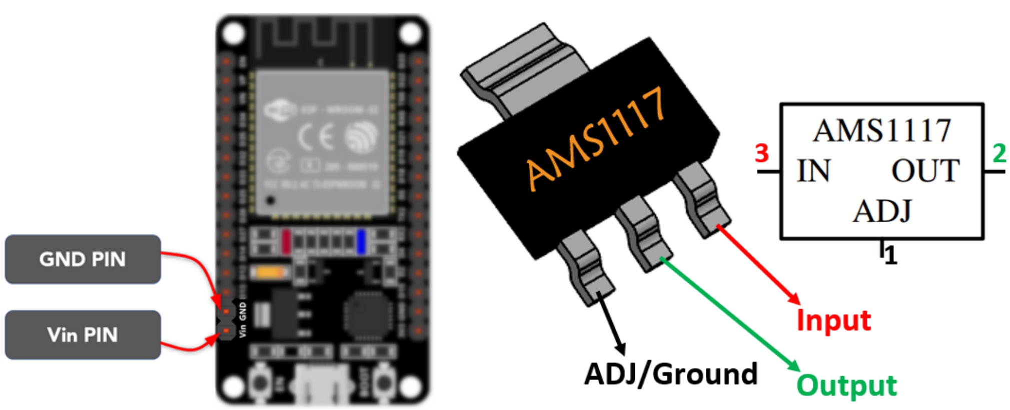


Figure 6: V_{in} & GND pin on ESP32 and AMS1117

While we can still use 18650 by first feeding it through an external LDO with lower drop-out voltage and to the 3.3V pin on ESP32 that does not regulate voltage further, we would not be taking advantage of its already existing regulator and increase the cost and complexity of our system. Furthermore, not only do we need to add an LDO, but we also need to build an undervoltage protection circuit. The circuit detects when the battery voltage is too low and cuts off the power to ESP32. It is necessary for our application as ESP32 does not operate correctly when powered with insufficient voltage, its behaviour becomes erratic and unreliable, this is known as undervoltage. Implementation of these circuits is fairly straightforward thanks to undervoltage protector ICs like MAX6399, however, our board size is already mechanically constrained and it might require us to make it bigger.

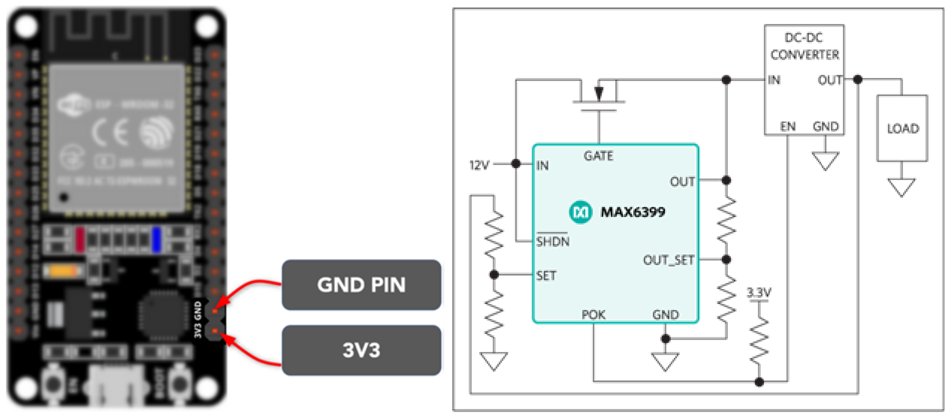


Figure 7: 3V3 & GND pin on ESP32 and MAX6399

On the other hand, a 9V battery has enough overhead for the on-board LDO so it is able to take advantage of the V_{in} pin while providing sufficient operating time. Therefore, it is able to reduce size, cost, and complexity of our board. Moreover, its mechanical profile is better than 18650 we're able to fit 2 of the 9V in the E-box. Due to the reduced size, we were able to integrate a power switch that allows users to turn off the device whenever they are not using it to conserve power easily.

Rotary Switch

The rotary switch allows the user to interface between different parameters of the vehicle by switching the display screen. The following schematic illustrates a three-position rotary switch, which conventionally controls four separate circuits (indicated by channels A, B, C, and D). For the team's purposes, only one of these channels was needed, channel A. The subsequent pins 1, 2, and 3 were connected with the digital GPIO pins on the ESP32.

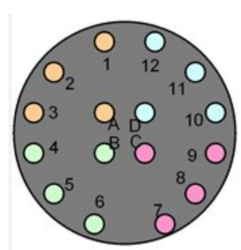


Figure 8: Rotary Switch Bottom View

Rather than crowding the OLED display with various information, we found that it is less distracting to occupy the whole screen with the most important parameter according to the race event. The switch directs the MCU to look out for a specific CAN address which indicates the electrical control unit (ECU) of interest on the bus.

PCB:

Due to the exposure to large vibrations and the stakeholder's need for a small device, a PCB was designed. The PCB contains CAN transceiver (TJA1050), controller (MCP2515), microcontroller (ESP32), and LEDs.

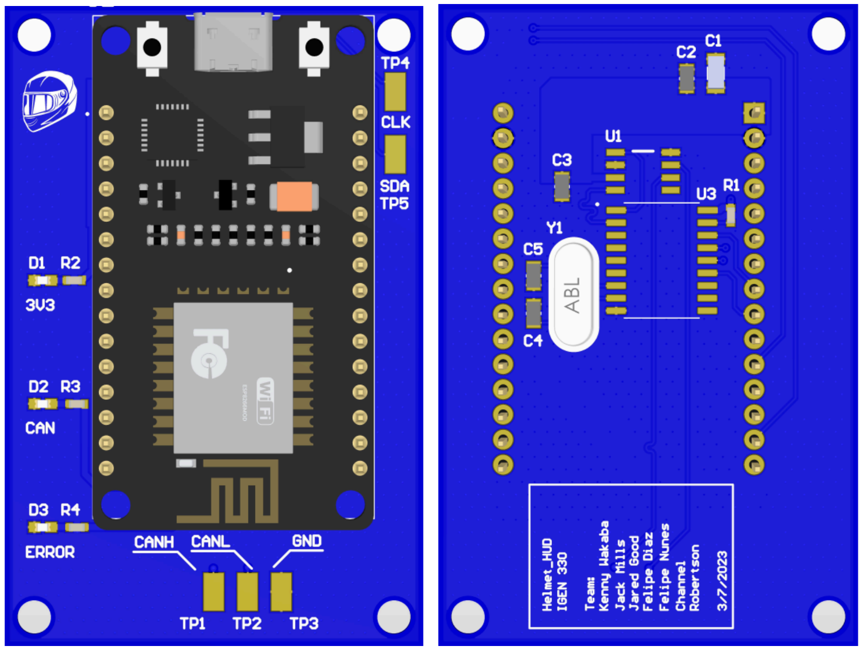


Figure 9: Top (Right) and Bottom (Left) Layer of the PCB.

TJA1050 and MCP2515 were selected for this application since they are widely available as their own packages and are ESP32 compatible modules which allows us to accelerate firmware development. TJA1050 is necessary for transceiving CAN messages by providing ESD protection, common mode noise rejection, and converting differential signals to common mode signals so the voltages are levelled with other devices. TJA1050 translates the differential ended signals of CAN into a single ended one.

Figure 10: Input and output of TJA1050.

MCP2515 then translates CAN to serial peripheral interface (SPI) consisting of SCLK, CS, MOSI and MISO so ESP32 can understand the messages being sent from the vehicle.

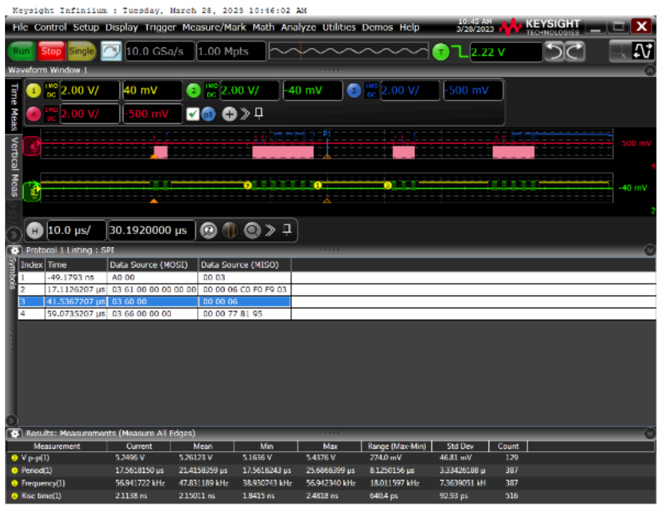


Figure 11: Output of MCP2515 taking the previous output of TJA1050 as input.

The two ICs and the MCU work in conjunction to receive and translate the CAN data into something that can be outputted to the OLED display in the NED. However, if there is a CAN communication error, the onboard LED will light up to indicate a failure. There are also power checks, and boot up LEDs for easy troubleshooting.

3.3 Near Eye Display (NED)

The Near Eye Display (NED), is composed of three different parts: the NED mount, the User Interface Module, and the Optical System. Together, these components form the module that displays live information to the driver. The mechanical drawing, along with all the parts that make this module can be found in the appendix.

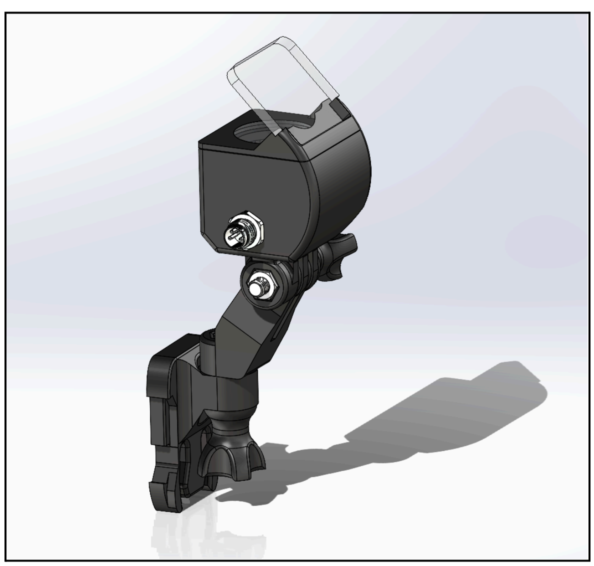


Figure 12: Near Eye Display Module

NED Mount:
The NED module's housing mounts onto the helmet through commercially available adhesive GoPro mounts. Attached to this are custom and modular, 3D printed PLA parts. The NED mount features two degrees of freedom, allowing the user to adjust the display according to their preferences and proportions. By reducing the tension on the custom knobs, the user is able to quickly adjust the NED's location to best suit their needs. Furthermore, this method mounts the NED without destructively modifying the helmet, adhering to Formula SAE rules.

Figure 13: Exploded View of the NED mounting system.

Throughout the course of this project, the mounting system evolved considerably. Initial prototypes were considered overly bulky, and lacked the degrees of freedom required to successfully adjust the NED screen. Furthermore, improvements were made to the tensioning system, such a s the inclusion of nyloc nuts to prevent losing during vibrations. An exploded view of this system, along with the various parts that make it can be found in the mechanical drawing within the appendix.

The mounting system was designed with stress concentrations, such that it would break when subject to any considerable load. The 'ROTATION CONNECTOR' part (seen within the appendix) was designed and printed such that when a force was applied to the NED body, the most likely place to be impacted, it would shear at the base. Once broken, the only remaining part of the system attached to the Helmet is the base, which protrudes at most 3 cm from the helmet.

User Interface Module:
The User Interface (UI) Module contains the OLED display and reflects the image to the user. The image is reflected through a lens and waterjet-cut reflector with a 3D printed base. Furthermore, the reflectivity of the acrylic is enhanced through the addition of a reflective film; this minimises the amount of ambient light from behind the driver that gets reflected. This system allows the user to see both the reflected image as well as the surroundings.

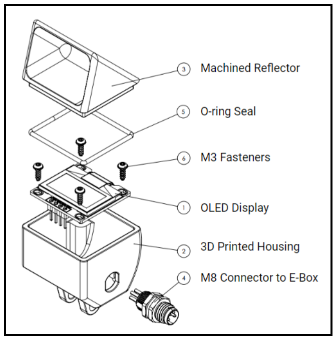


Figure 14: Exploded View of the UI Module.

Optical System:

As its name implies, the Near Eye Display (NED) is positioned very close to the driver's eye. However, this proximity makes it challenging and time-consuming for the driver to shift their focus from the NED to the track ahead during a race. This highlights the importance of developing an optical system to address this issue.

Our team engaged with numerous experts, constructed several testing rigs, and performed rigorous evaluations before arriving at a final design for our optical system. Ultimately, we opted for a bi-convex lens with a 35mm focal length, considering a range of factors that needed to be carefully balanced in order to meet all the stakeholder's needs.

Our main objective was to increase the depth perception of the NED display to facilitate the transition between focusing on the display and the track. However, increasing the depth perception also resulted in the magnification of the display, which meant that a smaller percentage of the screen could be utilized. Furthermore, the size, focal length, and lens-to-OLED distance influenced the overall size of the User Interface Module, which we aimed to minimize. In addition, we had to consider the budget allotted for the lensing system. All of these factors were taken into account before making our final decision.

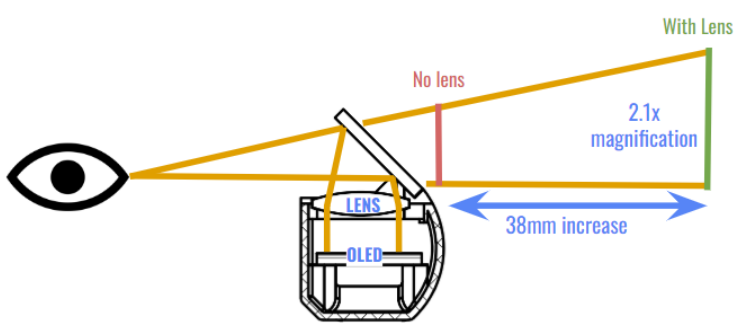


Figure 15: Diagram depicting the optical system

After conducting both qualitative and quantitative tests, as well as making informed predictions, we arrived at a final design that would improve depth perception by 38mm while also reducing the time required for the driver to shift their focus by about 400ms. The resulting User Interface Module increased in height by approximately 15mm, while the screen was magnified by a factor of 2.1.

3.4 CAN Simulation

Since the system relies on data through Formula E's CAN bus for the output display, a simulated version of the vehicle was necessary to demonstrate the working principles of the HUD during Design and Innovation Day. This is accomplished by sending potentiometer values deciphered by an Arduino Nano through the bus to the ESP32 in the E-Box.

The potentiometer provides the user with a way to change the output to the three display selections without being tethered to Formula E's CAN bus. Since the project calls for three different displays, there are three corresponding potentiometers to control each one respectively. Further, in order to maintain the aesthetics of the project, the electronics are enclosed in a model Formula E car, with the potentiometers protruding outside the body of the car. To power the sub-system, a 9-volt battery and power switch were implemented into the design of the model car.

Figure 16: Model Formula E car

The CAN cable routes from the back of the vehicle and is hooked up to a female DB9 connector since the current CAN connector on the Formula E vehicle is of the same connector type. This allows for CAN to be fully modular and also allows for a more portable system when showcasing the project.

3.5 Display

It is of utmost priority for the driver that the information provided does not obstruct their vision. Keeping this in mind, the team designed three output displays to visualise the information that Formula E requires.

Figure 17/18: Display 2 - Distance Travelled and Battery

Of note, the power output screen only displays a numerical value and a power bar, which was hard-coded into the software, so there is no image corresponding to it.

4. Validation and Verification

4.1. Validation

Optical system:

Prior to investing our budget into the development of an optical system, we sought advice from two experts - an optometrist and an optics professor - to determine its feasibility. Based on their feedback and utilizing the lens equation as well as a range of online simulators (as shown in Figure 19), we formulated a comprehensive testing plan.

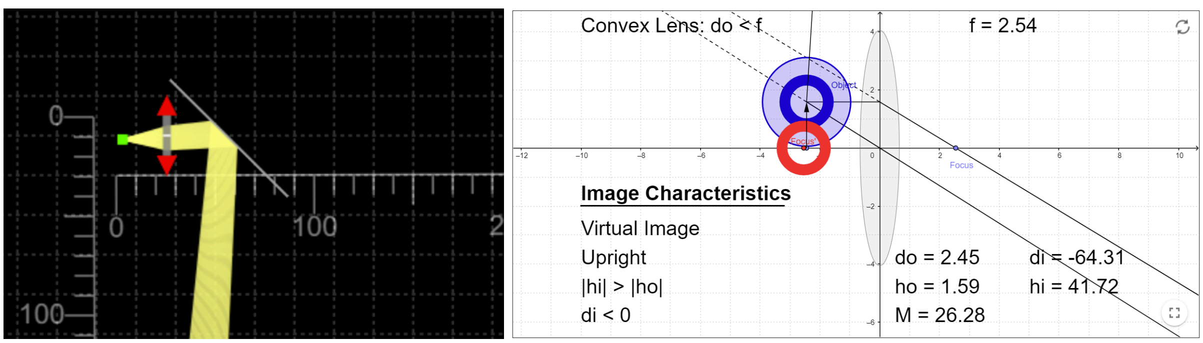


Figure 19: Simulation of Testing Procedure (units for left image in mm, right image in cm)

We were granted permission by the optics professor to showcase our testing procedure, which utilised a 3D-printed testing rig (as seen in Figure 20), at his lab.

Figure 20: Optical 3D-printed testing rig. Left image one can see the reflector, the lens mount and the OLED mount in order. Right image one can see the testing lens.

By providing us with a worn-out lens to use and keep, the optics professor enabled us to confirm the accuracy of our previous calculations in a real-world application. While we had intended to test with a range of lenses, this experience still proved to be extremely valuable in informing our next steps.

Following our successful testing and additional simulations, we ultimately decided to order a bi-convex lens with a 35mm focal length. We modified our testing rig and conducted tests with three different team members to determine the optimal distance between the lens and the OLED, as well as the overall effectiveness of the lens.

During these tests, one team member would read a one-syllable number on the NED, followed by a different number displayed on a large projector positioned 5 metres away to simulate the track ahead. Once both numbers had been read out, a second team member would press a button to record the time interval. The processed data is depicted in Figure 21.

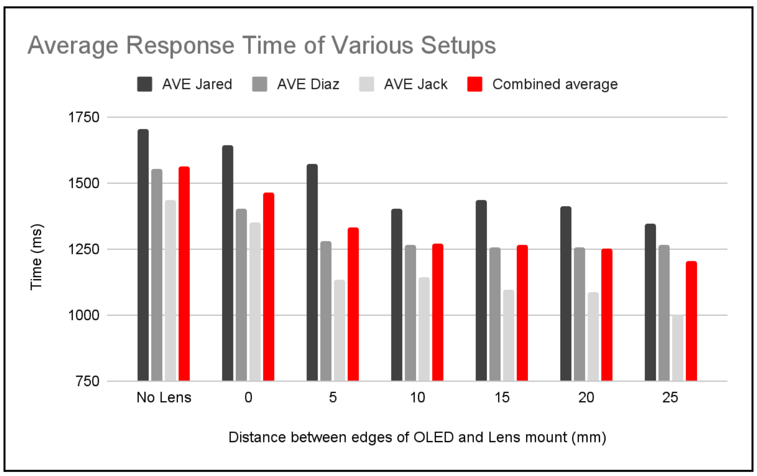


Figure 21: Average response time of participants

Analysing the data in Figure 21, we observed a noticeable decrease in response time until a distance of 10mm was reached, after which the response time remained relatively consistent. Given that we needed to find a balance between response time, magnification, and the size of the NED module, we decided to opt for a distance of 10mm, as the difference in response time at this point was minimal. It is worth noting that, compared to having no lens at all, the addition of the lens resulted in an impressive 400 ms decrease in response time.

QDS Signal Integrity:

QDS is a custom cable that has an unknown effect on the signal passing through, hence we must quantify the signal degradation and validate it to meet the data rate specifications that Formula E provides. The CAN bus communicates at a baud rate of 500 kbps which is equivalent to 1 MHz of switching frequency. This frequency range may pose a problem since the magnets will introduce an impedance mismatch where reflection may occur. Furthermore, QDS employs long cables to allow the driver to connect to the vehicle while being seated. This long stranded conductor will increase inductance which will cause ringing during any sharp rising and falling edges of the signal.

The system detaches readily with 17.7 N of force (1.5kg*9.81m/s^2), it can withstand lower forces and detaches at higher forces. We've assumed the driver's 5 second exit from the vehicle as being forceful enough to detach the system. Finally, the system's CAN High and CAN low wires are attached to a male DB9 connector which can be plugged directly into the side of the Formula E car. The QDS allows our Helmet HUD to be integrated seamlessly with Formula E's car.

Power system:

Our stakeholder needs the device to run for a prolonged period of time, they have specified it to last for the whole duration of the race and practice. We aimed for 7-8 hours of continuous usage as the device is typically only used during racing which is nowhere near the 7 hours target we set, giving it plenty of time for the racer to use. The integration of the power switch is an additional way for the user to conserve the power further, theoretically, this will extend the lifetime of the device to days. In addition, replacement of the battery can be done with ease thanks to the simple connection type of the 9V battery. This solution for the battery life was presented and approved by Formula E as they believe it will be sufficient for their application.

4.2. Verification

Optical system:
After modifying the NED module based on our ideal combination of lens and distance between the OLED and lens, we conducted qualitative tests to ensure the accuracy and readability of the information displayed.
First, we tested for legibility under various circumstances and found that all types of users were able to read the information accurately, although some gave feedback that the display was harder to read than expected.
Second, we tested the module's function under simulated driving conditions with vibrations, and found that under heavy vibrations, there were difficulties in quickly and reliably reading the information, but under light vibrations, the issues were minimal.

Unfortunately, we were unable to test the device under real racing conditions due to other priorities, such as the perfection of subsystems for display at Design and Innovation day. However, we believe that our rigorous testing process has resulted in a highly functional and effective NED module.

QDS Signal Integrity:
Using a function generator, we fed square waves of frequency ranging from 500 kHz to 1 MHz to one end of the QDS, and attached a load to the other end to complete the circuit. We then probed the output of the cable to check the effect of the signal degradation.

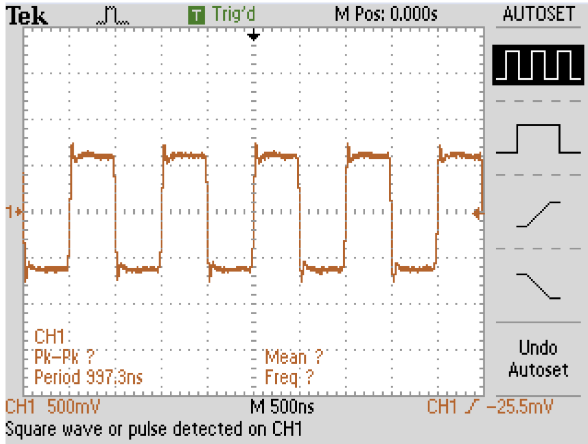


Figure X: 1 MHz signal at the output of the cable

As shown, we can observe ringings at the edges of the square wave but nothing significant like reflection. Considering CAN signals are low voltage digital signals, such ringings do not pose any issues to our application.

<u>Power system:</u>
We have initially calculated the approximated battery life by reading the datasheet of the battery and estimate the current consumption of the system. The formula for battery life is as follows:

$$B \div I_C = T_B$$

Where B = battery capacity in mAh (milliamp hour unit), I_C = current consumption in mA, and T_B = battery life in hour. The battery capacity of the lithium 9V battery we specced out is 1200mAh. We have approximated that our device will be consuming at most 150mA (30mA from LEDs + 50mA from TCJ 1050 CAN transceiver + 5mA from MCP2515 CAN controller + 65mA from ESP32) and that yields 8 hours of battery life. Although this calculation assumes ideal conditions, the current consumption is also heavily overestimated to ensure we hit our target battery life. This calculation was later verified by conducting a test to measure the amount of time it takes for the system to fail CAN communication. We ran the whole circuit on a breadboard until CAN failed, which was approximately 7.5 hours, successfully verifying the solution we built.

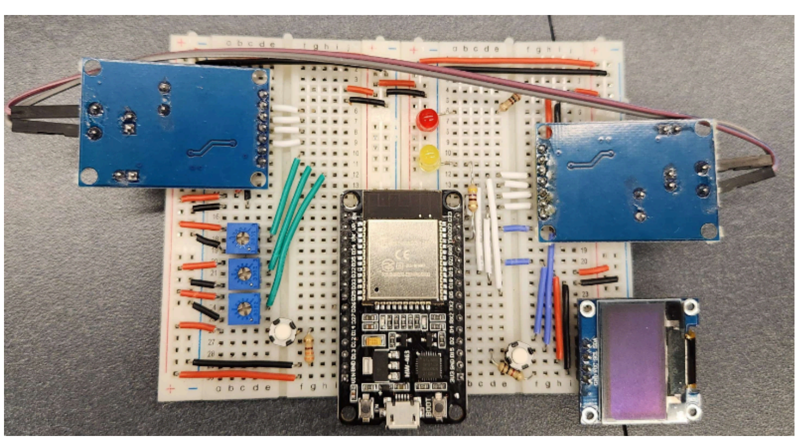


Figure 08: Simulated electrical system on breadboards

Mounting system:

The mounting system allows for the user to customise the location of the reflective screen. During live demonstrations in class and during DIAD, many different people were able to successfully adjust the mount to best suit their needs. Additionally, the entire system can be quickly removed and reattached, with the only permanent fixture being the GoPro base section. While no specific tests were performed, the overall performance of this system during these live demonstrations was sufficient to verify that the needs and requirements outlined by the stakeholders regarding this system had been met.

5. Stakeholder Investigation

Throughout our project we have had close communication with our Stakeholder Formula E, as such, we have decided to perform an Assessment of Stakeholder Needs. Our team-initiated interviews with Formula E Captains helped us ensure that the project scope is relevant to their needs. To further engage the Captains, we intend to incorporate a survey that highlights their needs and ask if they have been met. In addition, a track day to test the HUD will be used to see if the driver can benefit from our project and thus eventually use it in their competition.

The following needs were identified early in the design process:

- **Displays Information**: The helmet's display must convey real-time information to the user.
- **Information is Relevant**: The information displayed by the helmet is directly relevant to the user and does not distract from the user's operation of the vehicle.
- **Safety**: The helmet must adhere to the current safety requirements attributed by the SNELL, DOT, or ECE certifications to meet Formula SAE regulations. More specifically, the helmet must be unaltered and the attachment must break off easily.
- **Weather Proof**: Electronics must be sufficiently insulated from the environment to ensure that the helmet is functional in all weather conditions including rain.
- **Comfort**: The device is non-intrusive and has minimal effect on the overall comfort and weight of the helmet.
- **Long Battery Life**: The device should have a sufficient battery life of 8 hours or an alternate power supply, for an extended period of use.
- **Detaches quickly:** The device must not impede the driver's ability to get out of the vehicle within 5 seconds.
- **Does not impede head motion:** The device should have no noticeable effect on the driver's head motion.

We conducted in-depth analysis of Formula E's relevant needs, and we translated them into requirements to navigate our team's design decisions. In addition, we have performed a multitude of tests to fully verify the workings of our subsystems with Formula E's car.

6. Budget and Project Work Summary

Date	Company	Item	Item Cost	Shipping + Tax	Total
12/01/2022	Amazon	CAN Bus Module	$23.99	$2.88	$26.87
01/17/2023	Amazon	OLED Display	$21.90	$0	$21.90
01/24/2023	Amazon	HUD film reflector	$18.90	$0	$18.90
01/28/2023	Amazon	DB9 Connector	$11.58	$1.29	$12.87
01/30/2023	Lee's Electronics	2mm Magnets	$20.00	$0 + $2.40	$22.40
02/22/2023	Lee's Electronics	Copper Tape	$2	$0 + $0.24	$2.24
01/27/2023	Facebook Marketplace	Helmet	$40	$0 + $0	$40.00
03/15/2023	JLCPCB	PCB	$9.14 USD	$19.64 USD	$51.91 CAD
03/03/2023	Home Hardware	0.3in Magnets	14.49	$0 + $1.73	$16.22
03/14/2023	McMaster-Carr Parts	Various components	$51.00	$3.15	$54.15
03/21/2023	Digikey	Various components	$100.71	$12.09	$112.80
03/20/2023	Amazon	ESP32	$15.60	$1.87	$17.47
03/21/2023	Thorlabs	F35 lens	$27.64 USD	$27.75 USD	$78.06 CAD ($55.39 USD)
04/06/2023	Lee's Electronics	Electrical items	$23.00	$0+$2.00	$25.00
04/10/2023	Staples	Poster Board	$1.29	$0 + $0.15	$1.44

Total = $502.23

Project Work Summary:

Each task in the project will be defined by their definition and the initials of the members who contributed.

Jackson Mills: JM
Chanel Robertson: CR
Jared Good: JG
Felipe Nunes: FN
Felipe Diaz: FD
Kenny Wakaba: KW

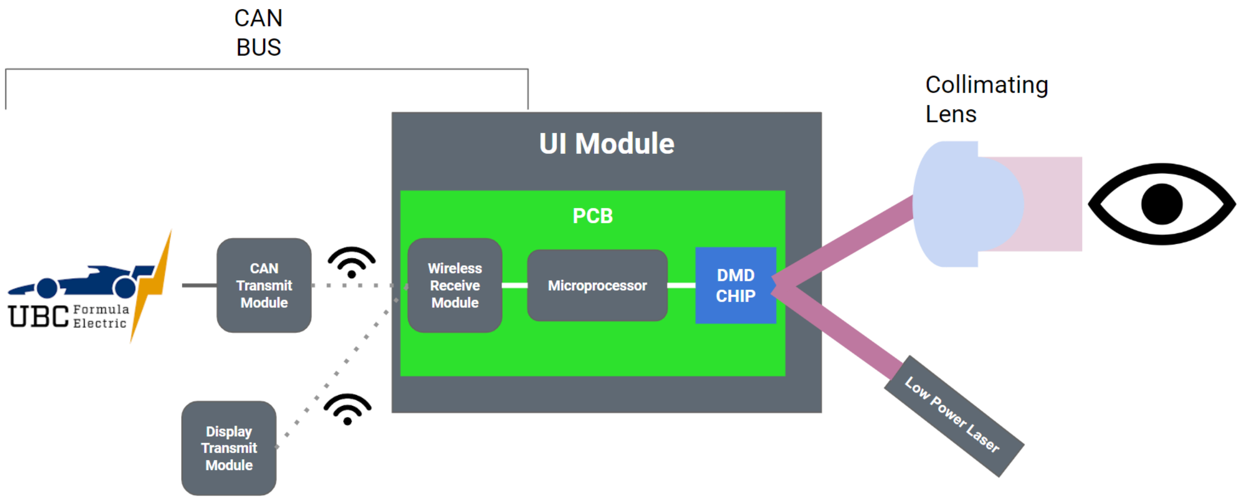
1. Development of project scope and definition of problem **(Sept - Nov)**
    a. Stakeholder interviews (all)
    b. Definition of problem (all)
    c. Initial research of safety systems and current NEDs (CR, FD)
2. Development of project prototypes **(Nov - Feb)**
    a. In depth project requirements (all)
    b. Electrical architecture (KW)
    c. Mounting System (JM)
    d. Lens / optics prototype (FD)
    e. Reflector prototypes (JG, FD)
    f. Mechanical / System architecture (JG)
    g. QDS prototype (CR)
    h. CAN Messaging (KW, FN)
    i. Display prototyping (FN, JM)
3. Refinement of final design **(Feb - Apr)**
    a. E-Box design (JG)
    b. UI Module / NED design (JG)
    c. PCB Design (KW)
    d. NED mount design (JM)
    e. QDS design (CR)
    f. Firmware for display and electronics (FN)
    g. Optical testing (JG, FD, JM)
    h. Manufacturing NED mount (JM)
    i. Manufacturing UI module (FD, JG, JM)
    j. Manufacturing E-Box (FN, JG, JM, KW)
    k. Manufacturing QDS (CR)

7. Recommendations

Though the HUD met the project objectives and performed well for an initial prototype, the project would benefit from future iterations. The optical system especially was by far the most challenging part of this project and would greatly benefit from future refinement, but many other systems would benefit as well. In continuation of this project a new set of project requirements should be outlined. Mainly the addition of wireless communication with UBC Formula Electric's car as well as an improved focus range on the lens should be set as hard requirements. In this section, we will cover a part by part list of recommendations on each sub-system for the project in its entirety to meet the new set of requirements listed previously.

1. Removal of QDS through the implementation of wireless communication such as bluetooth. Though the QDS did meet project requirements, having wired communication is inherently heavier and more dangerous. Wireless communication may increase complexity, but removing the weight and hassle of a wired system would simplify the overall mechanical architecture and cost.
2. Implementation of wireless controller for changing display modes instead of a rotary switch on the E-Box. Moving the rotary switch to an external module would allow the user more flexibility and allow display modes to be changed without taking hands off the wheel. As well, changing the hardware used for the rotary switch to provide one with better tactile feedback and more positions would improve the mushy feeling and limited display modes.
3. Combination of E-Box and UI Module through the development of high density PCB. With the implementation of a wireless system, many of the electronics could be simplified to one PCB that would fit into the UI Module and remove the wires mounted on the helmet. These wires were heavy and added significant costs to the project as well as reduced driver mobility.
4. Improving lensing system to provide an improved focal length and larger display. Users expressed that they sometimes struggled to see the smaller text and focus on the display even with the addition of our current lens. Instead of using fixed focal length lens, an optical collimating lens could be used like are currently used in aircraft HUDs. To achieve this, a perfect parabolic mirror could be used or a combination as seen below . Providing a smaller display would mean the lens could greatly reduce in size.
5. Remove ESP in favour of a microcontroller or System on Module. Removing the ESP32 would greatly reduce the size and power of the electronics as you can specially choose the processor and electronics to match the need exactly. Having large header pins on the ESP is nice for prototyping but does not belong in the long term project.
6. Change the OLED to a DMD or similar display type. A DMD chip works by rotating small mirrors on a silicon chip which greatly improves compactness as well as allowing for a point source to use a greater variety of optical lenses to achieve a near infinite focal length. DMD chips are readily available as they are used in projectors, but require an external light source such as a laser to provide light. As well, there are LCD on silicon displays that would achieve the same results without the need for a laser but are much harder to find at our price point.
7. For all subcomponents, it would be useful to conduct real life testing of the device in use. Having this experience would expose potential flaws that come with constant user use. From here various iterations would likely occur to end with a successful finalised product that meets all requirements exceptionally.

In combination with all of these factors, the new system architecture can be seen below.



8. Project Wrap-Up

Further Demonstrations:

As outlined in our Stakeholder Investigation, we plan on showing our Helmet HUD system to Formula E to discuss further iterations. As of now, the project served its proof-of-concept purposes, and given the steps we took in making this project modular, fully implementing the HUD with Formula E will solely be a question of software, since the last step is to integrate with Formula E's CAN bus.

Final Proposed Location

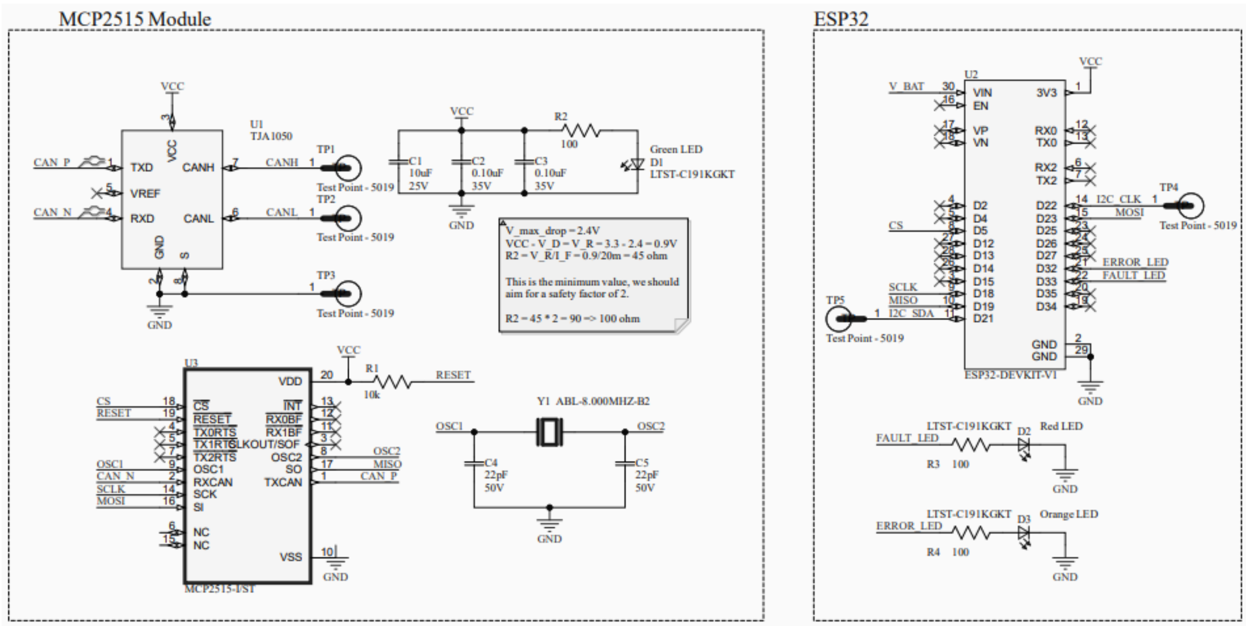
Currently, the assembled prototype is stored in the IGEN Clubroom in a team member's personal locker. In terms of part recovery, the final assembly consists entirely of components purchased for the project specifically. Currently, there are no specific plans for further development, however the team has agreed to keep the prototype assembled in the event this changes.

Reimbursement

Team member Felipe Diaz has kindly agreed to be responsible for completing the expense reimbursement on behalf of the team.

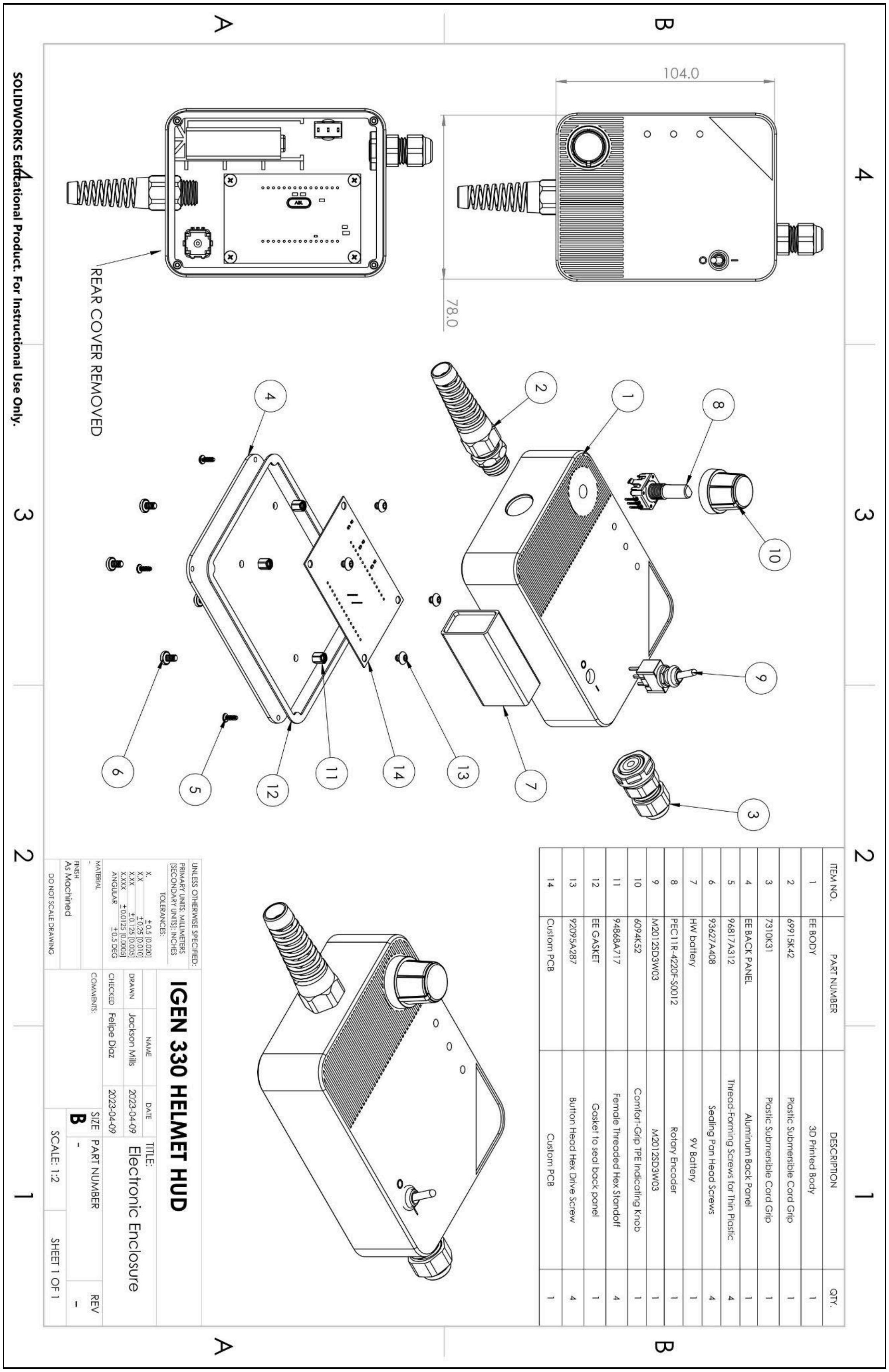
10. Appendices and References

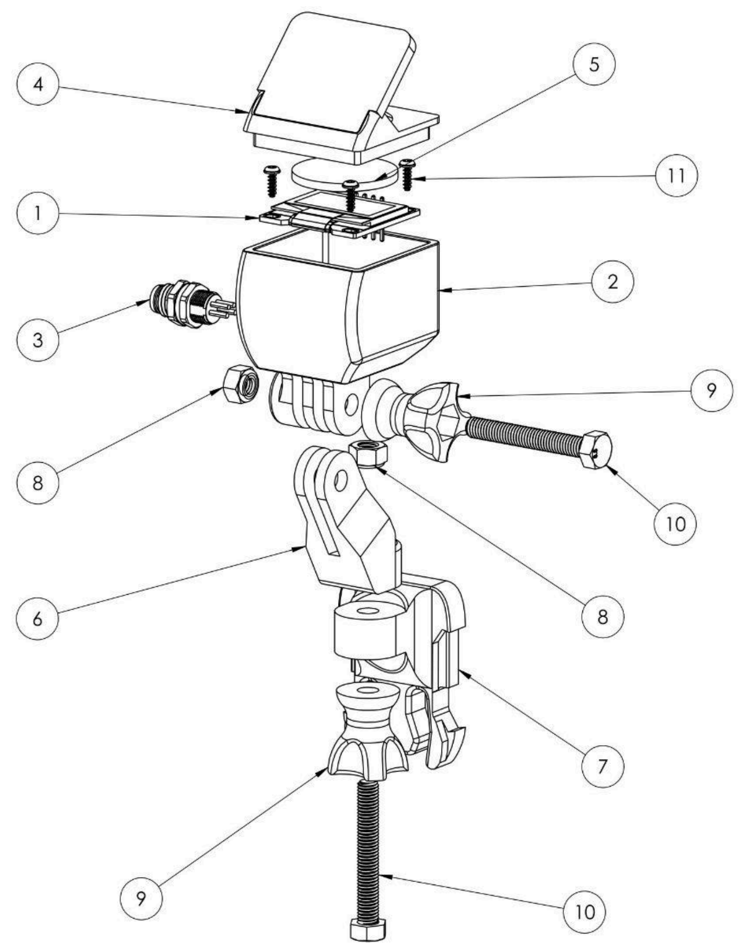
Schematic of the PCB:



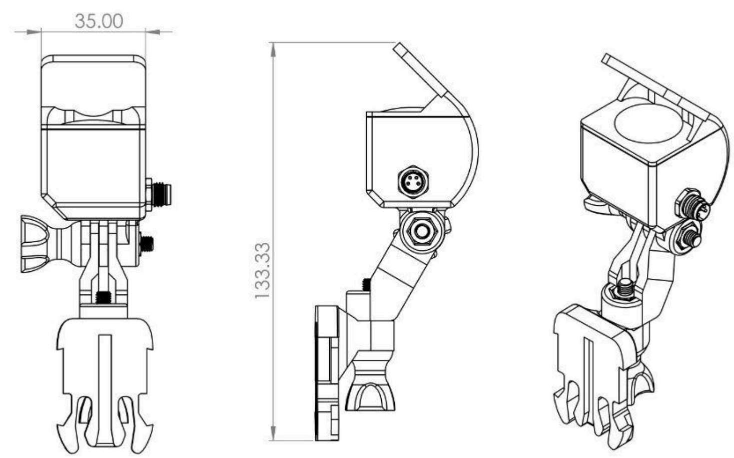
[GitHub Repository]

Electronic enclosure and NED System Drawings:





ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Pantalla OLED 0.96_ 128x64 [Edit]	OLED Screen	1
2	NED BODY	3D Printed Body	1
3	c-t4072014041-001-a-3d.stp	4 pin Connector	1
4	NED REFLECTOR FLAT PANEL	Acrylic Reflector	1
5	LB1027-Solidworks	35mm Lens	1
6	ROTATION CONNECTOR	Connector	1
7	NED GOPROMOUNT REV 3	3D Printed Base	1
8	90576A104	Medium-Strength Steel Nylon-Insert Locknut	2
9	KNOB SMALL	Provieds Tension	2
10	91280A057	8.8 Steel Hex Head Screw	2
11	96817A312	Thread-Forming Screws	4



UNLESS OTHERWISE SPECIFIED:
PRIMARY UNITS: MILLIMETERS
[SECONDARY UNITS]: INCHES
TOLERANCES:
X. ±0.5 [0.020]
X.X ±0.25 [0.010]
X.XX ±0.125 [0.005]
X.XXX ±0.0125 [0.0005]
ANGULAR ±0.5 DEG
DO NOT SCALE DRAWING

IGEN 330 Helmet HUD

	NAME	DATE
DRAWN	JACKSON MILLS	2023-04-04
CHECKED	CHANEL ROBERTSON	2023-04-09

COMMENTS:
BEST IGEN TEAM

TITLE:
NED Display Module and Mount

SIZE B | PART NUMBER - | REV A

SCALE: 1:2 | SHEET 1 OF 1