EEET2610 – ENGINEERING DESIGN 3

Final Project Report

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21st January, 2024

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What's next...

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1. Abstract

In the final report, we present a comprehensive exploration of the design, testing, and integration of unmanned aerial vehicles (UAVs), specifically focusing on the quadcopter. The flexible devices have garnered widespread applications in delivery services, agriculture, and military operations, showcasing their potential to revolutionize various facets of daily life. Despite their prevalent use, certain fundamental aspects of drone design, including motor efficiency, power consumption, and control system balancing, necessitate continuous enhancement. The project spanned 12 weeks and was structured into three well-defined work packages (WPs).

WP1 was primarily focused on the initial design phase of the drone, which included Printed Circuit Board (PCB) design, Computer aided design (CAD) modeling, and assembly guide development. Special attention was given to understanding and improving the lecturer-provided design. WP2 involved unit testing, where components such as the Inertial Measurement Unit (IMU), Global Positioning System (GPS), and a remote controller were meticulously validated. The motor’s calibration and testing were also part of this phase.

The most challenging part of the project, WP3, centered around controlling and validating the drone's functionality. During this phase, it was necessary to integrate the various units, fine-tuning the PID controllers, implement safety features, and ensure the remote control work flawlessly. The project concluded with a dynamic presentation, showcasing PID testing without propellers, drone balancing on a tripod, robustness to disturbances, real-time data display using MATLAB, and a flight test to validate the system's safety and stable behavior.

In summary, this comprehensive project provided students with hands-on experience in the complete life cycle of designing, building, and controlling a quadcopter. The collaborative nature of the project fostered teamwork, problem-solving, and practical skills among students. Additionally, by giving students insightful knowledge that will be invaluable for their future engineering careers, the initiative helped advance drone technology by improving motor efficiency and control system precision.

2. Introduction

In the field of unmanned aerial vehicles, the quadcopter emerges as a remarkable and adaptable invention that is revolutionizing a number of industries. According to [1], A quadcopter, or quad-rotor, is a type of helicopter featuring four rotors arranged in a square formation at an equal distance from the center of mass. Control of the quadcopter is achieved by manipulating the angular velocities of the rotors, which are powered by electric motors. Due to its uncomplicated structure, the quadcopter is a common design for small unmanned aerial vehicles (UAVs). These UAVs find applications in various fields such as surveillance, search and rescue operations, construction inspections, and numerous other scenarios.

This is the DJI Mavic 3 Pro, a drone that sets new standards in imaging performance. This drone, which has a triple camera system that is state-of-the-art, is a major advancement in the field of UAVs with cameras. Three sensors and lenses with varying focal lengths are included into the Mavic 3 Pro's innovative design, a technological marvel that enhances the camera's capabilities to previously unprecedented levels. The Hasselblad camera and two telephoto lenses form the basis of the Mavic 3 Pro's remarkable camera array, which distinguish the Mavic 3 Pro as a pioneering triple-camera drone. This unique configuration not only enhances image quality but also expands creative possibilities for users. With the ability to capture scenes from various perspectives, the Mavic 3 Pro give users to the freedom to explore new dimensions of creative expression. Unlocking a realm of creative freedom, the Mavic 3 Pro enables users to capture breathtaking scenery, delve into captivating photographic storytelling, and craft cinematic masterpieces. Its advanced camera system, denoted by the reference [2], which demonstrates the drone's adaptability and its ability to be a powerful tool for translating artistic visions into reality.

Figure 1: DJI Mavic 3 Pro in flight

2.1. Literature Review

According to [3], a quadcopter, a type of drone, comprises several essential components that work harmoniously to facilitate its flight and functionality. At its core is the flight controller, acting as the brain of the drone, receiving inputs from sensors and the remote control and directing outputs to the Electronic Speed Controller (ESC). The four motors, arranged in pairs with clockwise and counterclockwise rotations, enable the quadcopter to lift, turn, pitch, and yaw. Attached to these motors are propellers that push air downward, providing lift. The camera, mounted on the drone, captures photos and videos, while antennas transmit and receive signals from the remote control. Other critical elements include the ESC, responsible for motor control, flight LEDs that indicate the drone's orientation, a GPS module for location tracking, and sensors for height calculation and obstacle avoidance. The 3 Axis Gimbal ensures camera stabilization, and various boards manage power distribution, camera information, joystick inputs, and remote-control signals. Together, these components form the intricate system that defines the functionality of a quadcopter. However, for the specific focus of this project, we have selectively utilized key components including the drone flight controller, drone motors, drone propellers, electronic speed controller (ESC), the GPS module, ESP32 microcontroller, joystick, and Li-Po battery.

At the core of a drone's structure lies its frame, a fundamental element designed for maximum lightness. The classification of drone frame construction predominantly hinges on the number of arms, each arm accommodating a motor. This categorization leads to a diverse range of drones, including bicopters with two motors, tricopters featuring three motors, quadrocopters incorporating four motors, hexacopters with six motors, and octocopters equipped with eight motors. The number of arms and motors directly influences the drone's stability during flight, with the consensus acknowledging that a construction with more arms tends to result in a more stable and controlled aerial performance [4].

Figure 2: Bicopters

Figure 3: Tricopters

Figure 4: Quadcopters

Figure 5: Hexacopters

Figure 6: Octocopters

As referenced in [5], a quadcopter employs four propellers configured either in a cross or plus format to generate thrust, allowing for vertical take-off and landing. This vertical take-off capability offers a significant advantage by reducing the need for an elaborate landing platform. Additionally, it enables the quadcopter to maintain stable hovering, preventing potential crashes in adverse weather conditions or due to external forces like wind. The quadcopter utilizes two sets of fixed-pitched propellers, with two rotating clockwise (CW) and two counter-clockwise (CCW). Variations in RPM control lift and torque, facilitating precise control over the vehicle's motion. By adjusting the rotation rate of one or more rotor discs, the quadcopter can modify its torque load and lift characteristics. Notably, the front and rear propellers rotate counter-clockwise, while the left and right ones turn clockwise, eliminating the need for a tail rotor, as observed in standard helicopter structures. This unique configuration enhances stability and maneuverability, contributing to the quadcopter's versatility and adaptability in various applications.

The primary driving force behind the aerial mobility of multirotors is the utilization of brushless motors, each equipped with three wires that play a pivotal role in controlling the three-phase motor. As elucidated in [6], the connection of these wires to the Electronic Speed Control (ESC) determines the motor's rotational direction, allowing for clockwise (CW) or counterclockwise (CCW) movement. This technology is particularly prevalent in Quadcopters, as discussed in [7], owing to the brushless

DC motors' superior thrust-to-weight ratios compared to their brushed counterparts. Brushless DC motors also stand out due to their integrated commutators within the speed controller, contributing to enhanced speed versus torque characteristics, high efficiency, noiseless operation, and an extensive speed range, all while ensuring prolonged motor life. Commands in the form of Pulse Width Modulation (PWM) signals dictate the motor speed, with individual ESCs translating these signals into appropriate motor speeds. The ESC, aside from regulating motor speed, serves a dual role by acting as a Battery Elimination Circuit (BEC), enabling a single battery to power both motors and the receiver. Lithium Polymer (LiPo) rechargeable batteries are the preferred choice for quadcopters, providing high specific energy and lightweight properties. These batteries supply electric power to both the motors and electronic components. Quadcopters achieve lifting thrust through propellers, which come in various sizes and materials, measured by diameter and pitch. The propeller selection is crucial to achieving the appropriate thrust for lift without overheating the motors. Notably, each Brushless DC (BLDC) motor is associated with a specific propeller, and the four propellers exhibit unique tilts – the front and back propellers tilt to the right, while the left and right propellers tilt to the left. This intricate combination of components ensures the efficient and controlled flight of the quadcopter.

The PID (Proportional-Integral-Derivative) controller plays a crucial role in achieving system precision through feedback, as elucidated in [5]. Comprising three components – Proportional, Integrative, and Derivative – it responds to the current error value, accumulates previous error values, and predicts future errors based on the rate of change. These controls can be applied individually or in combination, depending on the desired plant response. The PID system, relying solely on measurable process variables, finds widespread application. Tuning the PID controller involves adjusting three model parameters (Kp, Ki, Kd gain) to meet specific process requirements. However, the PID algorithm does not guarantee optimal control or system stability. Tuning involves iterative adjustments of Kp, Ki, and Kd, optimizing the system's response in terms of rise time, overshoot, and oscillation. In the context of this balance control system, angle PID control is implemented for each axis of the quadcopter. This involves maintaining a fixed setpoint angle for balanced positioning, and the PID control output influences motor speed, as described in [5]. This motor speed, determined by the PID output, is then utilized in the kinematic formula of the quadcopter to ensure balance. Feedback on tilt angles is provided by the IMU sensor mounted on the flight controller.

2.2. Problem Statement

The propulsion system of a quadcopter, consisting of four motors and propellers, is the most critical component of the drone. To ensure proper operation, the control systems must be thoroughly researched and developed to allow for high precision and minimal errors. The drone needs to be able to balance itself when it is fixed stationary on the tripod and performs basic maneuvers such as increasing or decreasing pitch, turning and rolling, which requires complicated control algorithms and fast response time.

Balancing is the most crucial aspect of design a quadcopter. Maintaining the drone's stability and control requires meticulous weight distribution of all components and precise motor speed control. The IMU position should be placed at the center of the drone to ensure the most accurate measurement, therefore simplify the PID calibration. Proper assembly of the components such as the drone's arms and motors also relatively affects the drone propulsion and aerodynamics. A slight error of any of these elements could negatively cause imbalance or unstable hovering. Subsequently, designing and building a perfect quadcopter is a complicated process which demands profound understanding and deep research on aerodynamics principles, electronics knowledge, control system design as well as accurate mechanical skills.

2.3. Contribution

The project is structured into three primary work packages (WPs), each with a distinct set of objectives and deliverables. WP1 is delivered within the first few weeks of the semester for the drone's design, followed by WP2 focuses on unit testing. Finally, WP3 for control and validation of the drone, ensuring all fundamental functions ready for demonstration:

1. **WP1 – Design of the drone:** Some basic components including wooden frame, ESC, motors, potentiometer, battery and wires are provided for the first-step testing, where students will be taught to do ESC calibration and drone assembly. The team will also learn and implement wiring diagrams, CAD model and PCB design. Although a design is already available, students are required to understand and improve the initial design.
2. **WP2 - Unit testing:** More components are provided such as remote controller (including joystick, push buttons and an extra ESP32), driving unit (including propellers, extra motors and ESCs) and sensors (including IMU and GPS module) are provided. Students must have detailed research and critical thinkings of the components' operating principles, then perform individual testing before a total implementation. A brief design of the controller should be made, components are tested and calibrated, finally test and validation of the sensors, along with data acquisition to support.
3. **WP3 – Control and validation of the drone:** This is the most challenging part of the project. All components will be integrated and further troubleshooting will proceed. The drone is put to various testings to observe its behaviors. During this stage, PID controller is carefully tuned. PID tuning is by far the most time-consuming process of this stage. A safety mechanism should be deployed in case of emergency. It could be done in terms of hardware or software. All the wires and cable management should be cautiously focused and

accommodated in order to prevent avoidable mistakes such as short circuit or loose wire, as well as improve the drone's appearance. After careful testing and experiment, ensuring all components are intact and no error occurs, the drone is ready for demonstration.

2.4. Report Structure

This final report presents a comprehensive plan consisting of three work packages, each addressing crucial aspects of the project. The report has a brief introduction, followed by a detailed description of the process involved in the drone's design and implementation, as well as the methods used to address any potential issues that may arise during the project. The project also includes an in-depth evaluation of the test results of the drone's systems and behaviors, listing all occurrences during the drone's development, providing insights into the students' achievement and experience, and offers recommendations for future improvement and innovation.

3. Project task description

Clear task description is essential for effective project management, particularly when working with multiple team members and stakeholders. To facilitate smooth progress and ensure all tasks are completed successfully, the project is divided into distinct and measurable milestones based on the project description provided by the lecturer. Three work packages will serve as checkpoints for monitoring work progress and ensuring each task is finished before moving on to the next one. Each stage will have a set of objectives that must be accomplished before advancing to the next stage. These objectives help the team members understand what their final result should achieve, therefore providing a clear direction for their work. By employing this approach, the project should be kept on track and team members are well informed of the progress. This will ultimately lead to a successful completion of the project as well as a better understanding of the tasks involved and their respective importance. In this final report, the students will evaluate their work done, what they have achievement and the limitations met.

3.1. Work package 1: Design of the drone

The beginning of the project is a crucial process where students get know to the fundamental working principles of the basic components and make up an initial plan to outline the overal design of the drone. As this may significantly affect the drone's performance, and overall appearance of the drone should be finalized since there will not be likely sufficient time to make changes in the next stages.

3.1.1. WP1 - Objectives

The initial package will primarily focus on the conceptual phase of the drone, which involves several key steps:

- Creating a detailed list of components required to build the drone.
- Designing and constructing the drone's frame, with a wingspan approximately 50cm in diameter.
- Develop detailed wiring diagrams and PCB designs.
- Carefully place the components on the drone's frame to ensure proper balance and stability during flight.

Throughout these steps, the package aims to provide a comprehensive foundation for the development and assembly of the drone, facilitating the successful progression of the project.

3.1.2. WP1 - Task breakdown and milestones

The tasks involve in this work package includes deep understanding of the project description, 3D CAD models for the motors holder and controller of the drone, wiring diagram and PCB design to connect all electronic modules and drone assembly.

Table 1: Work package 1 tasks

No.	Action	Deliverable	Member	Priority
0	Read the work package description	Understand the objectives of work package 1	Everyone	High
Milestone 1: CAD modeling				
1	Create and check bill of material with the lecturer for all of the components and adjust if needed	Have a list of all the necessary components to start working on the project	Everyone	High
2	Gather the components	Acquire all the components	Everyone	High
3	Measure all components	Have precise measurements of all components	Mina	High
4	Draw the components in Fusion360 or SolidWorks	Have a CAD file for each component	Mina, Huy	Medium
5	Decide the placement for the beams in Fusion360 or SolidWorks	The beam placement should result in a wingspan of 50cm	Mina, Huy	High

6	Translating the beams' placement onto the physical frame and attaching them	All the beams are attached, and the wingspan is approximately 50cm	Huy, Nhan, Son	High
7	Design the 3D model to hold the motors and print them	Have both the files and the attachment piece	Mina, Huy	Medium
8	Load test the beams with given components and adjust if necessary	The beams do not break when loaded with motors and their attachment pieces	Huy, Nhan, Son	Low
9	Decide the placement for the electrical components in Fusion360 or SolidWorks	All of the delicate components must fit in the frame, the battery can rest on top of the drone	Everyone	Medium
10	Mark the placement for each component on the wooden plate	A precise marking map for where each component will be attached	Son, Nhan	Low
Milestone 2: Wiring diagram and PCB design				
1	Measure the space available for PCB	Have the maximum potential space for PCB	Son, Nhan	Medium
2	Design the conceptual wiring schematic for electrical components and clarify with the lecturer	Know how each component is going to connect in the system	Everyone	High
3	Learn to use EasyEDA	Learned the basics of EasyEDA	Mina, Huy, Nhan	High
4	Find or draw the electrical components in EasyEDA	Have the parts ready for the wiring design	Mina, Huy, Nhan	High
5	Design the PCB wiring diagram and check with the lecturer	A complete wiring plan for PCB	Mina, Huy	Medium
6	Finalize and print the PCB	Have the PCB ready to connect to other electrical components	Huy	Medium
7	Mark PCB placement on the frame	Have a clear idea of where PCB will be placed	Nhan	Low
Milestone 3: Assembly				

1	Using the placement map, design the attachment system used to attach components to the frame	Decided which part can be attached by screw and bolt or can be zip-tied to the frame	Son, Nhan	Low
2	Drill the holes used to attach components	Have the frame drilled and ready to attach components	Son, Huy	Medium
3	Solder the electrical components	Soldered all the electrical components	Nhan, Son	Medium
4	Attach all components to the frame	Have the drone assembled	Nhan, Son	Medium

3.1.3. WP1 - Achievements and work done

For WP1, we managed to fully achieve the objectives set by the instructor as well as our milestones from the initial project proposal. Below are some pictures of the drone frame and components fully attached. Unfortunately, we neglected the task of taking step-by-step assembly pictures due to time constraints during the tutorial lab sessions, so there are not many detailed pictures of the inner layer of the drone. Additionally, detailed pictures of the process of CAD modeling for each component will not be included as they would add unnecessary bulk to the report and the CAD models are primarily representative of the given components. However, the pictures for 3D printed parts will still be included.

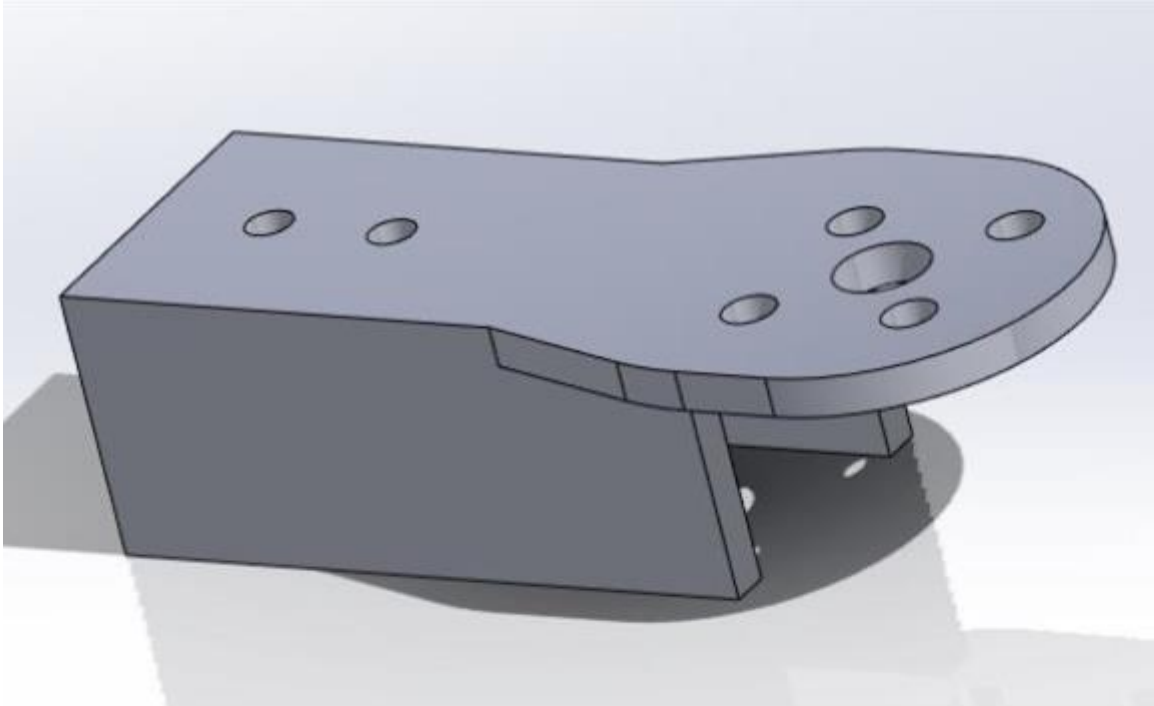


Figure 7: CAD model for 3D print manufacturing

Figure 8: 3D printed part in real life

Figure 9: 3D printed part fits in the components

The model's shape and size have been designed to be simple and compact to reduce risks of printing errors, save manufacturing costs, time and weight, while still providing sufficient support for the motors. All dimensions are carefully noticed and designed in case of tolerance. As a result, it can be observed that all components could fit in the 3D printed part without obstruction. Notwithstanding, strong external force could break the 3D printed part in half, which the team did encountered a few times during testing. Correspondingly, the team had to ask the lecturer for additional printed parts.

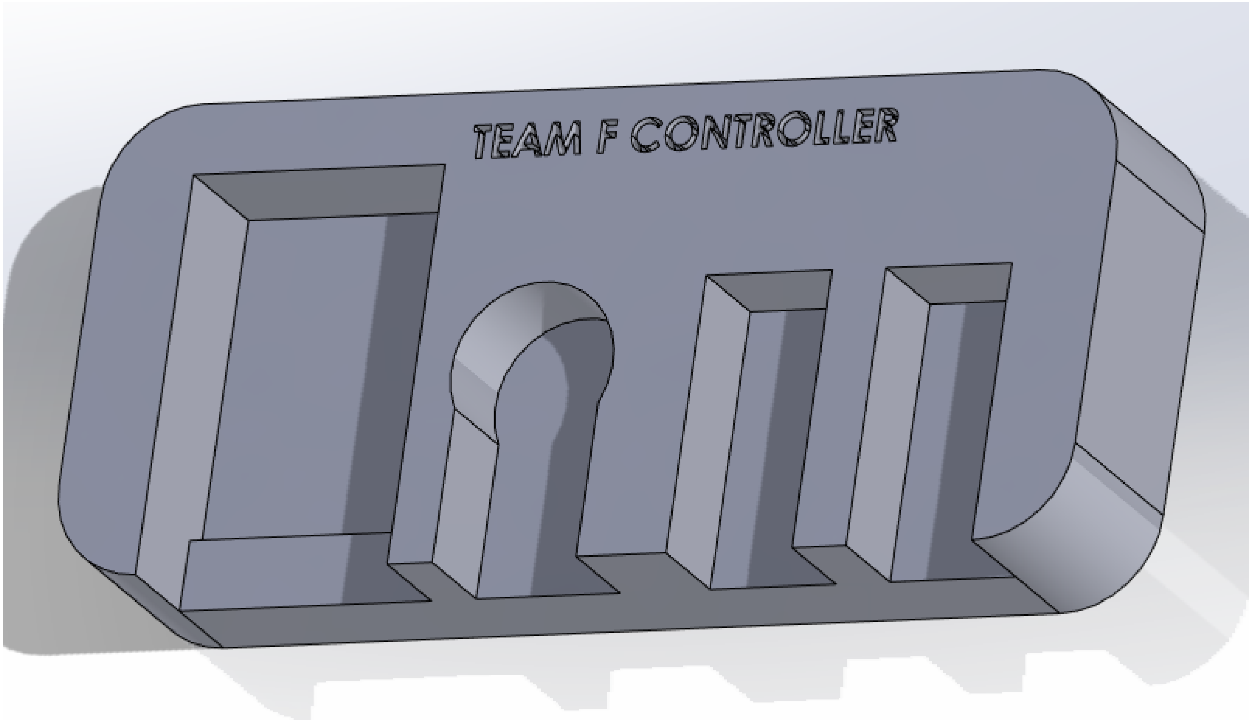


Figure 10: CAD model of the controller

Similarly, the dimensions of the controller for all features are carefully considered, in terms of sizes and tolerance. The controller model is only printed after careful consideration and was printed during work package 3.

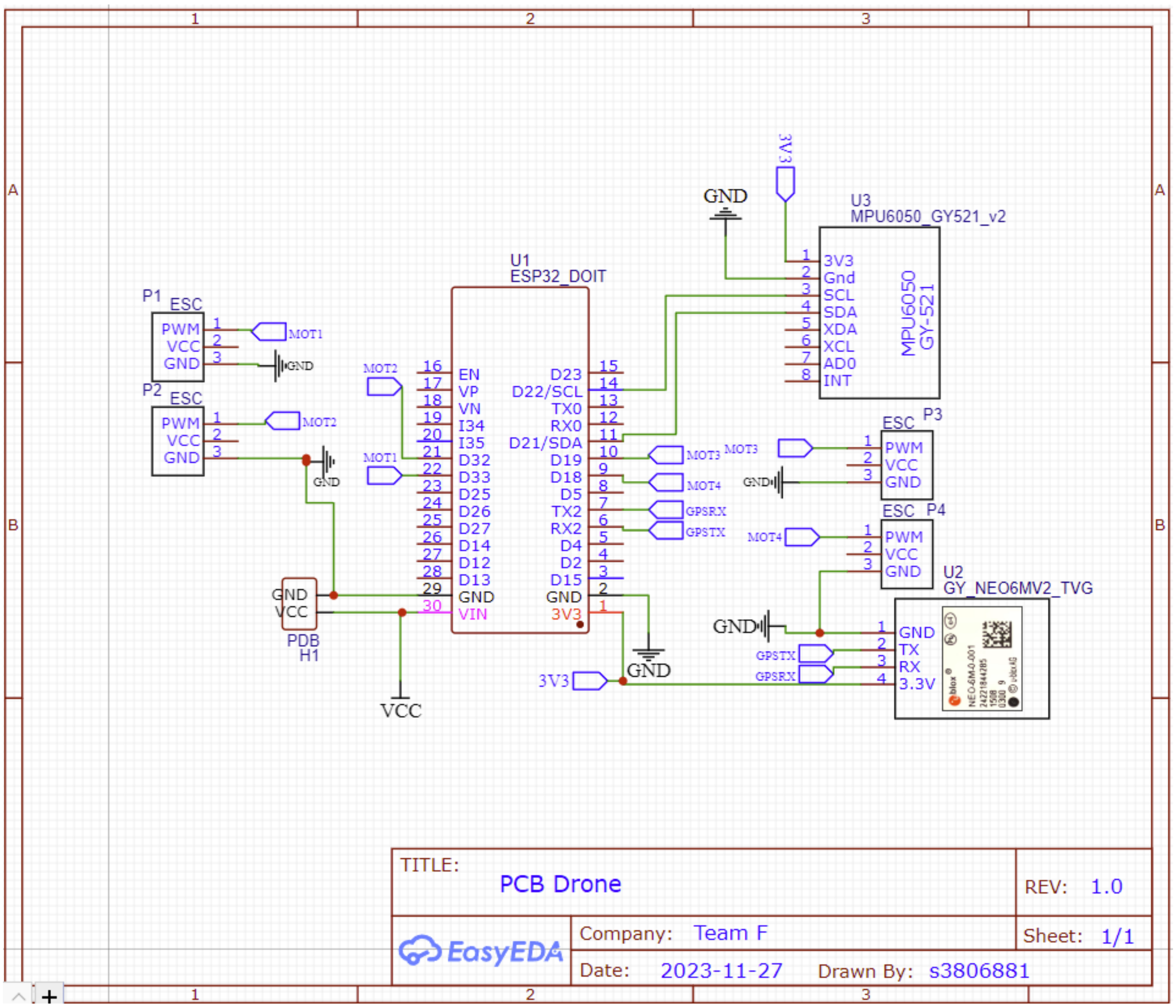


Figure 11: Wiring schematic of the drone PCB

Although PCB is not compulsory for this project, the team decided to fabricate one for convenient purpose to attach all the modules, reducing soldering time and saving space inside the drone's compartment.

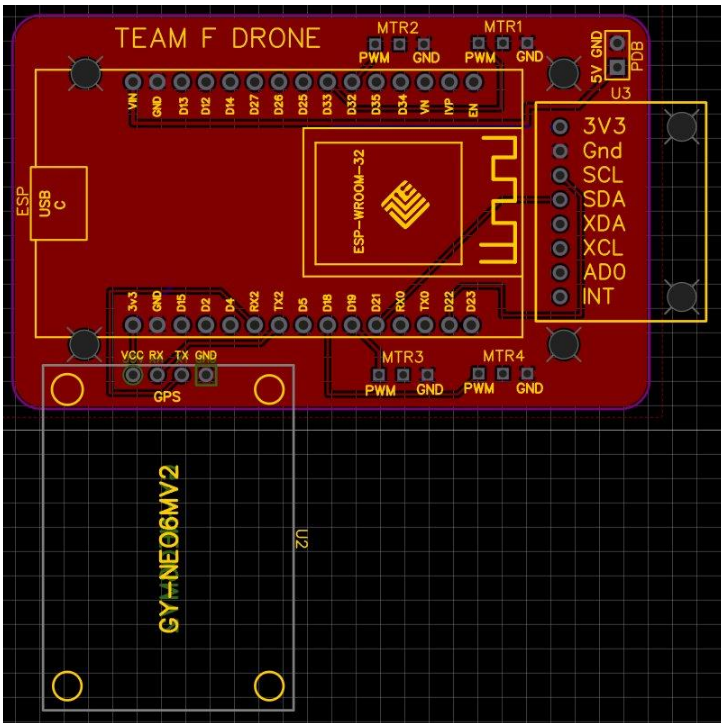


Figure 12: PCB diagrams in EasyEDA software

The modules' placement has been carefully planned to make the most efficient use of available space, minimizing its size. This is crucial since there is limited space in the drone compartment.

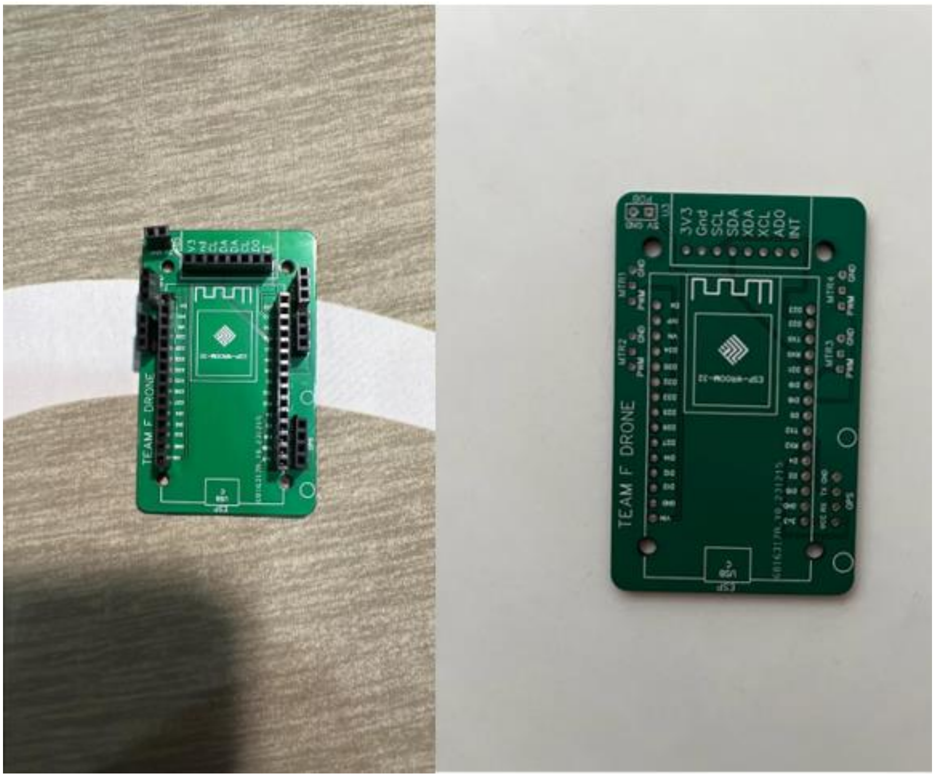


Figure 13: PCB in real life and female connectors are soldered

The PCB is well-manufactured with clear legends and details. After the female connectors are soldered, all other modules could be attached firmly without interaction. In the beginning, the holes for the motors and PDB connections are soldered with female connectors, however, they are changed to male pins to optimize the wiring and spacing inside the drone compartment.

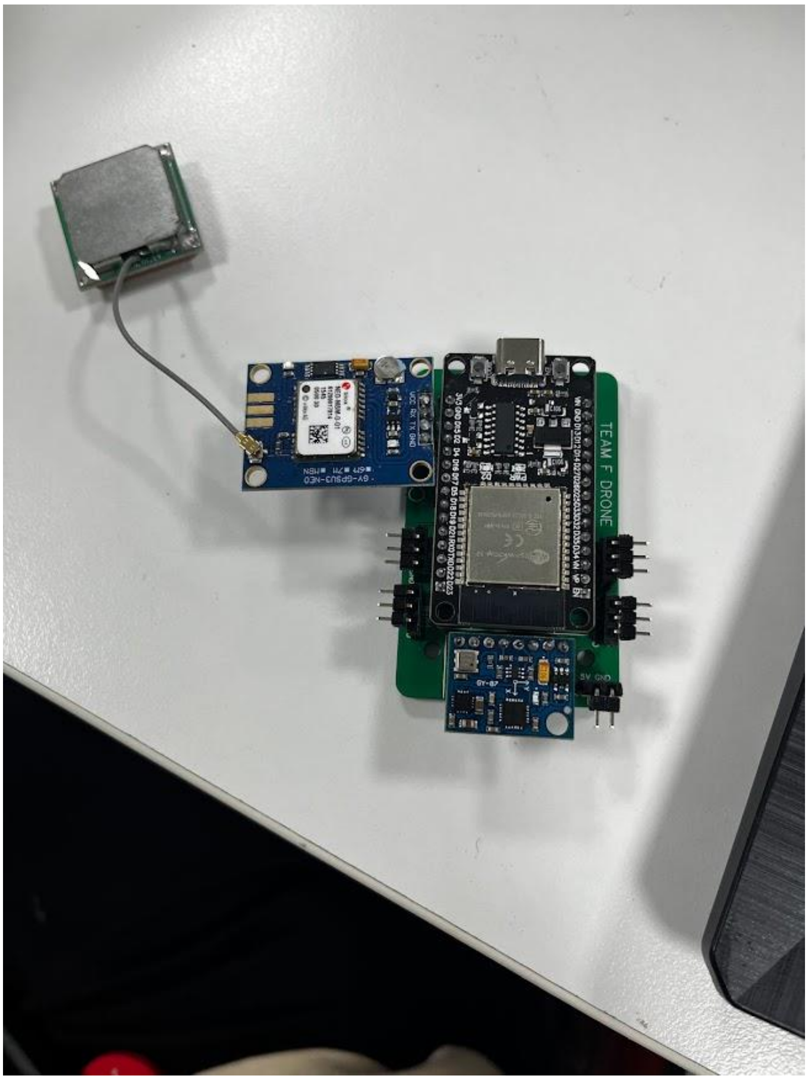


Figure 14: PCB after modules are attached

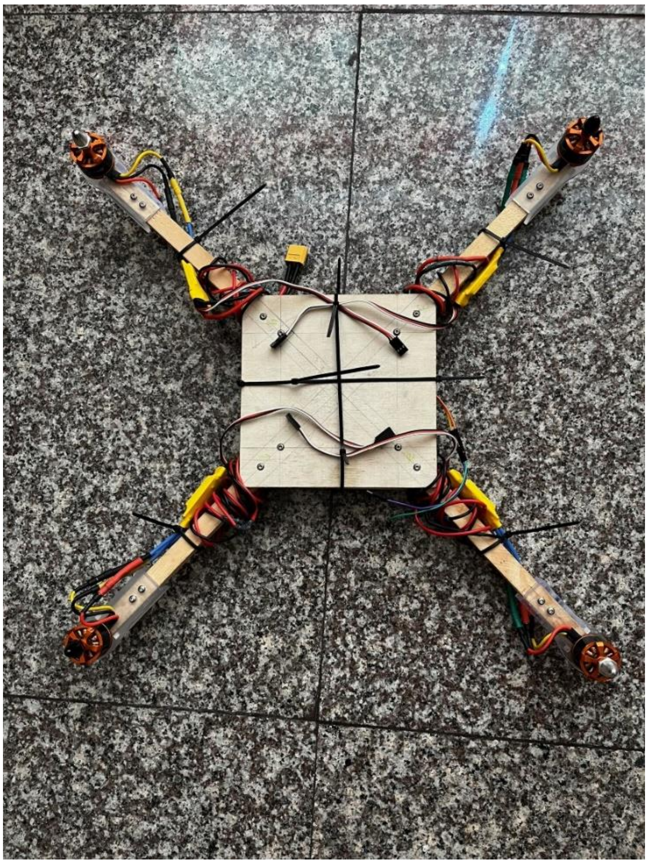


Figure 15: Assembled drone with most components

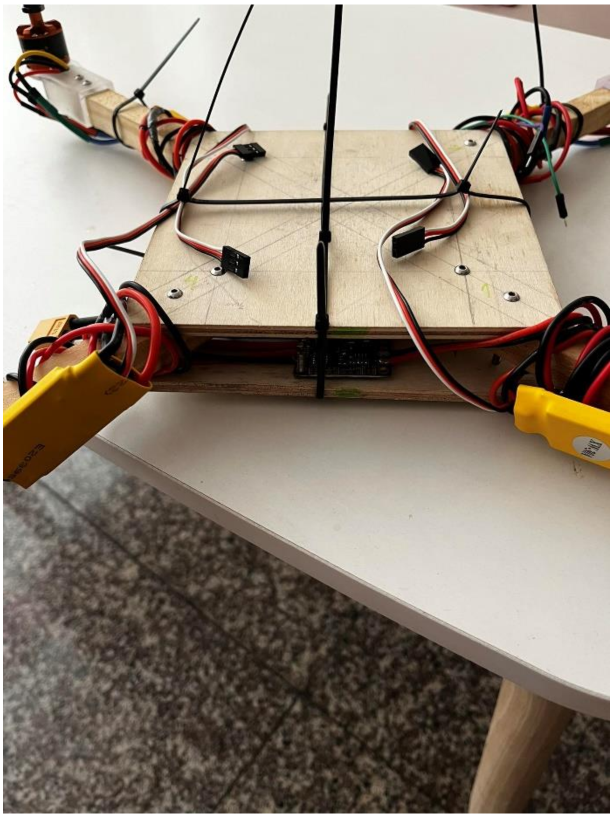


Figure 16: Rear view of the drone, showing the PDB inside

As the project continued to progress beyond the initial plan, it was discovered that certain tasks could have been removed to save time or were overly complex. Based on these findings, some tasks have been identified that could be eliminated or simplified to enhance the project's efficiency. The following table will display the tasks that have either been removed or are recommended for removal in future iterations:

Table 2: Tasks can be improved

No.	Action	Reasonings
Milestone 1: CAD modeling		
4	Design the components in Fusion360 or SolidWorks	It can be considered cutting this task if task 5 and 9 is decided to be removed, but the team did finish the CAD models to make the attachment planning phase easier.
5	Decide the placement for the beams in Fusion360 or SolidWorks	These tasks could be done directly on the drone's body plate with a bit of additional effort and caution. Drilling holes should not be initiated until the wingspan calculations are finalized.
6	Translating the beams' placement onto the physical frame and attaching them	
9	Decide the placement for the electrical components in Fusion360 or SolidWorks	Can also be summarized similarly to tasks 5 and 6.
10	Mark the placement for each component on the wooden plate	

Problems encounter:

In comparison to other groups performance, the team's drone lacked the necessary landing gears mechanism to land without causing damage or shattering of the body and other components. This could be considered a failure to enhance the original design.

Another major issue arises from the initial design is about the PCB implementation. There are two serious problems with the PCB design. Firstly, the team underestimated the remaining gap when the two plates are assembled. When female connectors are soldered and modules like ESP32 are attached, they significantly increase the total thickness of the whole PCB, causing the gap between the plates to be too small to accommodate the four arms, resulting in the arms not being able to be fully tightened. Even though no technical issue occurs, the components are not fully secure and risks still exists. The figure below will illustrate the mention issue:

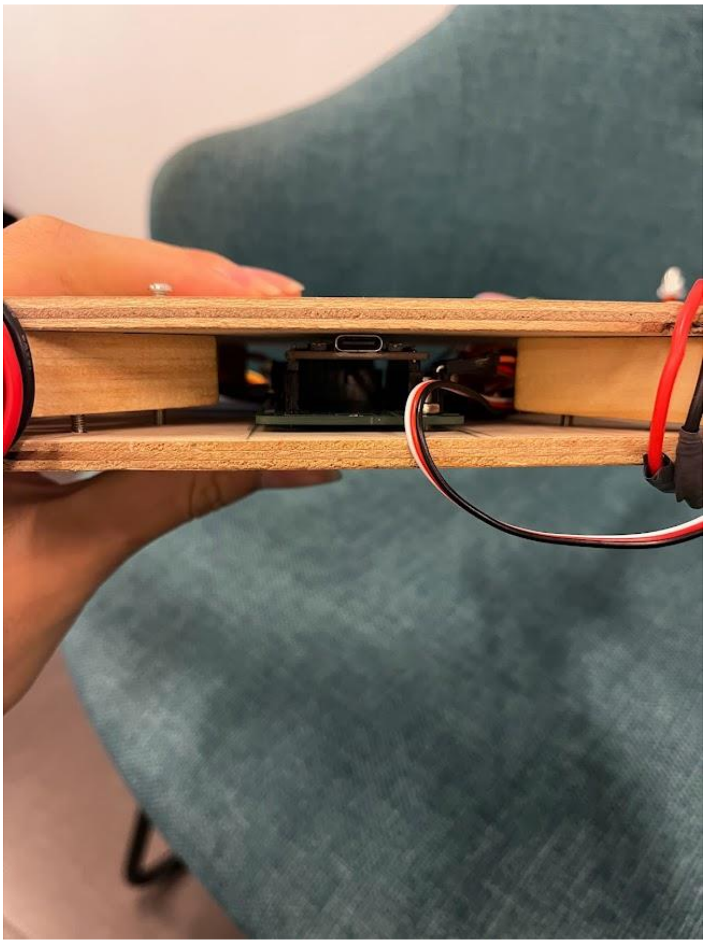


Figure 17: Problem with the thickness of PCB module during assembly

Secondly, the pin layout of MPU module is incorrect. The team did not have effective communication to inform the actual pin layout of the MPU used in real life. In EasyEDA software, the student used a different MPU model with different pin layout. This problem was only noticed until the PCB is fabricated. Technically, the required operational pins are 3.3V, GND, SCL and SDA, the difference between the two models are not significant. Therefore, the only viable option is to connect the MPU in the PCB one pin next to its initial place, as shown in the figures below:

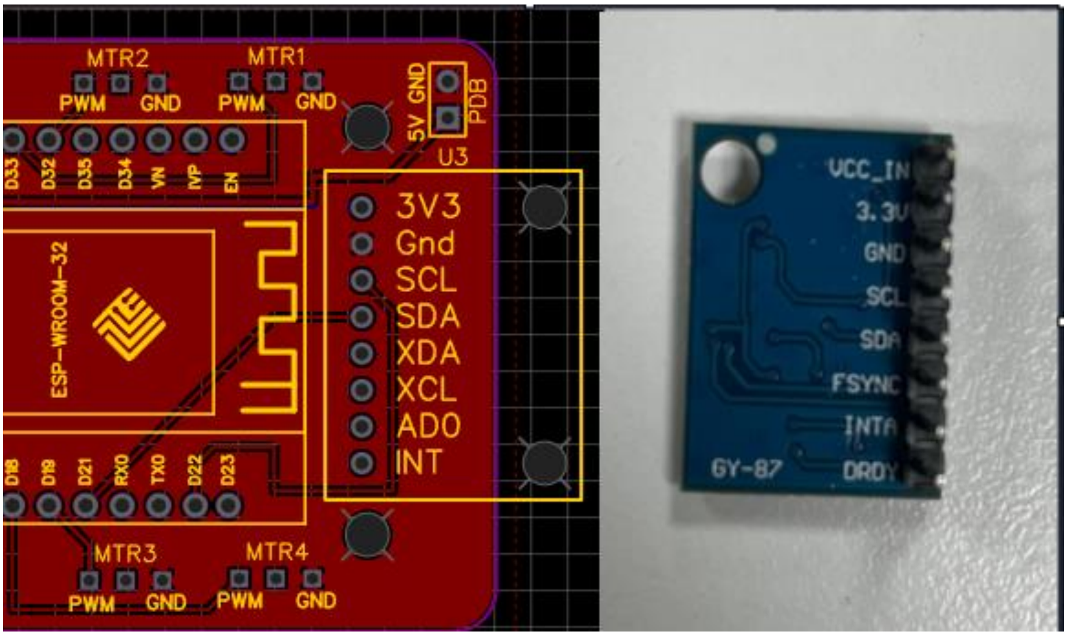


Figure 18: PCB in design and in real life'

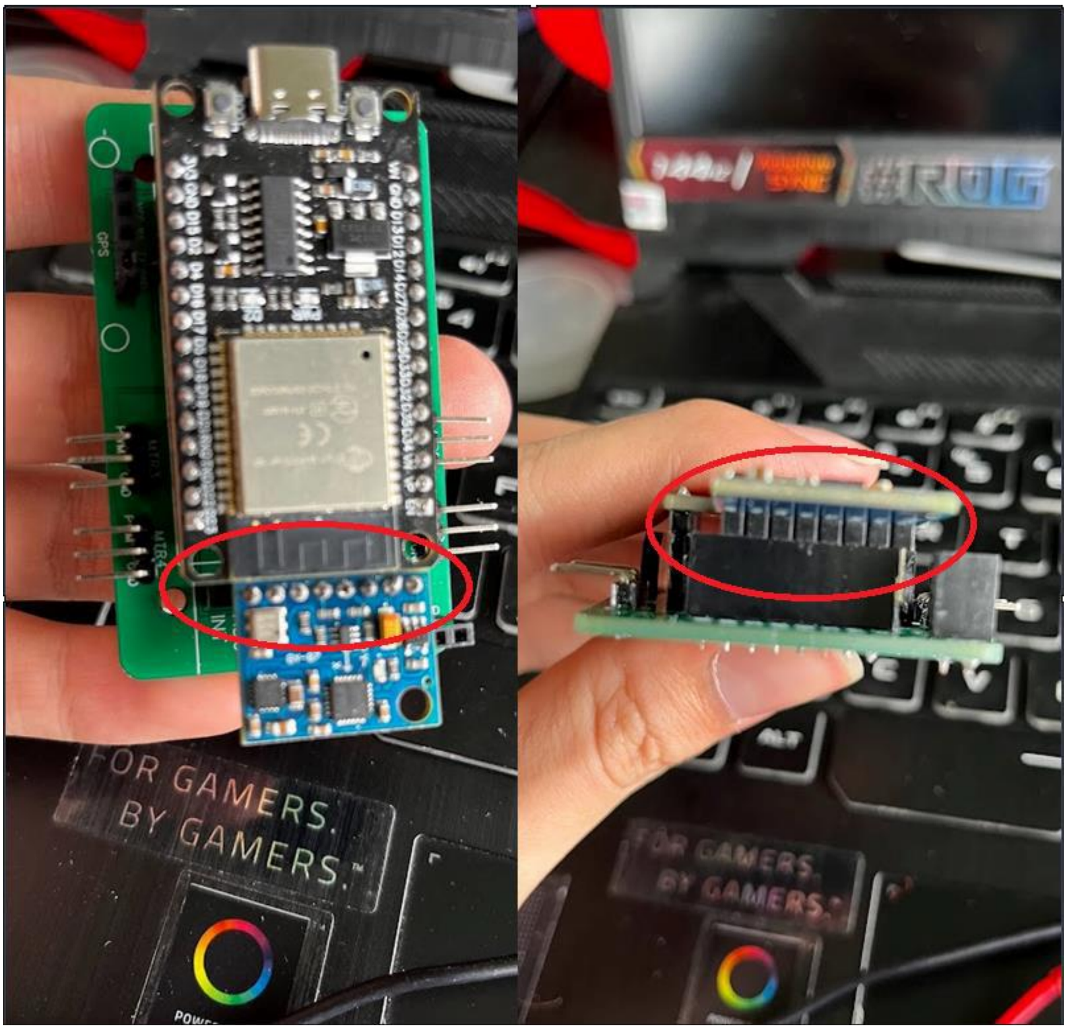


Figure 19: MPU attachment on PCB after adjustment

3.2. Work package 2: Unit testing

This process is the following stage, where students must ensure all electronic modules are fully researched and tested individually before integrating them together. It includes design of the remote controller how all components are connected, calibration and functioning of the driving unit (including combination of ESCs, motors, battery and coding), make sure all motors can spin simultaneously, and testing of all sensors.

3.2.1. WP2 - Objectives

Within this work package, tasks can be done simultaneously or intermittently across each milestone, with a recommended approach to maximize time efficiency. The primary objectives of this work package involve:

- Developing and creating a prototype for a functional remote controller equipped with a joystick for managing the drone's pitch and roll behavior, 2 push buttons for yaw control, and a potentiometer for thrust controller – which adjust the motors' speed.
- Building and programming the drone's driving units using ESCs, a battery, 4 motors and propellers, and collecting data on the generated lift force to enable smooth drone control in the future.
- Acquiring skills to operate the IMU and GPS, collecting data from these devices and subsequently using this data to control the drone.

3.2.2. WP2 - Task breakdown and milestones

The tasks involve in this work package includes deep understanding of the electronic modules, remote controller design, code implementation into microcontrollers, components calibration, and sensors analysis and validations. All of these ensure proper operation of the drone, thence further balancing tests could be performed.

Table 3: Work package 2 tasks

No.	Action	Deliverable	Member	Priority
0	Read the work package description	Understand the objectives of work package 2	Everyone	High
Milestone 1: Design of the remote controller				
1	Research about System-on-Chip (SoC) microcontroller, potentiometer, and wireless	Understand the basic requirements and how to use them	Duy, Long, Tu	High

	communication through the ***ESPNOW*** protocol			
2	Setup the hardware required for the SoC microcontroller	Have the equipment ready to run	Duy, Long, Tu	High
3	Setup the potentiometer, a joystick and 2 buttons for the controller	Have the equipment ready to run	Duy, Long, Tu	Medium
4	Design and implement code to receive input from the controller.	The outputs can be read in the terminal	Duy, Long, Tu	Medium
5	Design and implement code for the SoC microcontroller to receive input signal	The inputs can be read by the SoC controller	Duy, Long, Tu	Medium
6	Design and implement code for wireless communication between the controller and ESP32 microcontroller	The inputs from the controller are received by the SoC microcontroller	Duy, Long, Tu	Medium
Milestone 2: Calibration and functioning of the driving unit				
1	Research about propeller, motor, ESC, battery	Understand the basic requirements and how to use them	Huy, Long	High
2	Design and connect the wiring between the battery, ESC and motor	All components are connected and powered	Huy, Long	High
3	Design and implement code to make a single motor spin	Have the motor spin	Huy, Long	Medium
4	Measure the motor's RPM and compare it to the input code	Know whether the motor spins at the correct RPM	Huy, Long	Medium
5	Designing and connecting the wiring for 1 PBD and 4 ESC	All components are connected and powered	Son, Nhan	Medium
6	Design and implement code to make multiple motors spin simultaneously	Have the motors spin simultaneously without any motor stopping	Huy, Long	High

7	Measure all motors' RPM and compare them to input code	Know whether all motors spin at the correct RPM	Huy, Long	Medium
8	Analyze the results and optimize the system	Using the measured RPM to adjust the code if needed	Everyone	Medium
Milestone 3: Testing and validation of the sensors				
1	Research about IMU and GPS	Understand the basic requirements and how to use them	Duy, Long, Tu	High
2	Setup the hardware required for IMU and GPS	All components are connected and powered	Duy, Long, Tu	High
3	Design and implement code to receive data from IMU and GPS	Data sent from both IMU and GPS can be read on the terminal	Duy, Long, Tu	Medium
4	Perform test runs to confirm the data	Data obtained from the terminal should match the one from the tests performed	Duy, Long, Tu	Medium
5	Collect and analyze the data received from the IMU and GPS	Understand the gathered data and how they can be used to later control the drone	Duy, Long, Tu	Medium

3.2.3. WP2 - Achievements and Work done

GPS

Before working on the GPS module and assembling it to the drone, it is crucial to understand the workings of the GPS. For proper operation, it needs to be soldered with a single Male Pin Header, which was purchased from Shopee based on the lecturer's advice. Once soldered, the antenna should be connected to the GPS board and positioned facing upward. The GPS is then wired to the PCB by connecting VCC to 5v, TX to pin 16, RX to pin 17 and GND with GND. After that, the code is uploaded, successfully generating an output that can be viewed in the terminal. As a result, an output from the terminal is obtained:

Location: 10.730295,106.695224 Altitude: 3m Date/Time: 1/7/2024 08:09

Putting these coordinates into Google Maps, it will display RMIT University Saigon South campus location on the map.

Problems Encounter:

Due to hardware constraints, the signal cannot be received when inside the building. Initially, it was suspected to be a code issue as the term "INVALID" continuously printed for every output variable. Therefore, a significant amount of time was spent trying to find the solution. Fortunately, with the assisstance from the lecturer, it was the GPS module staying inside the building, blocking all of the signal. Another limitation of the GPS module is that its timezone is always located in London, which is 8 hour earlier than in Vietnam.

Remote Controller (ESPNOW)

Before working on the setup and activating the espnow for two ESP32s, it is important to understand the establishment wireless communication via the espnow protocol with another ESP32 connected to the computer through a USB cable and comprehending the drone's roll, pitch, and yaw motion to ensure the compatibility with components such as the joystick, buttons and potentiometer.

The first step involves identifying the MAC addresses of the two ESP32s to ensure they can communicate with each other. Next, the data to be transmitted must be determined, keeping in mind that the size limit is 250 bytes, approximately equivalent to 62 floating-point numbers. Following this, the pins corresponding to various components such as the joystick, buttons, and potentiometer need to be specified. Specifically, PIN 34 and 35 are allocated for two push buttons, PIN 39 for the potentiometer, PIN 32 for the X-axis of the joystick, and PIN 33 for the Y-axis. Although these pin assignments may seem unconventional, they align with the ESP32 pinout diagram provided by the lecturer, ensuring appropriateness and safety. Additionally, considering the ESP32 board's 8-bit resolution, we aim to transmit the maximum values for all components. Consequently, the joystick transmits values ranging from 0 to 255, with the default centered value set at 114. Moreover, the two buttons convey only 0 or 1 through the terminal, while the potentiometer is fixed at a value of 180, as desired configuration.

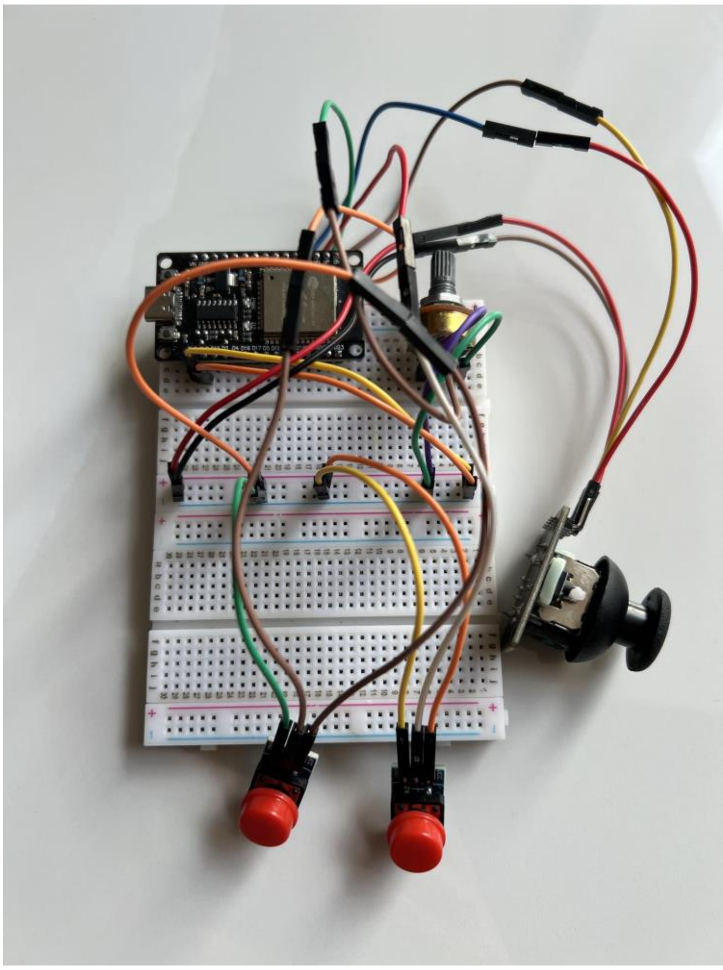
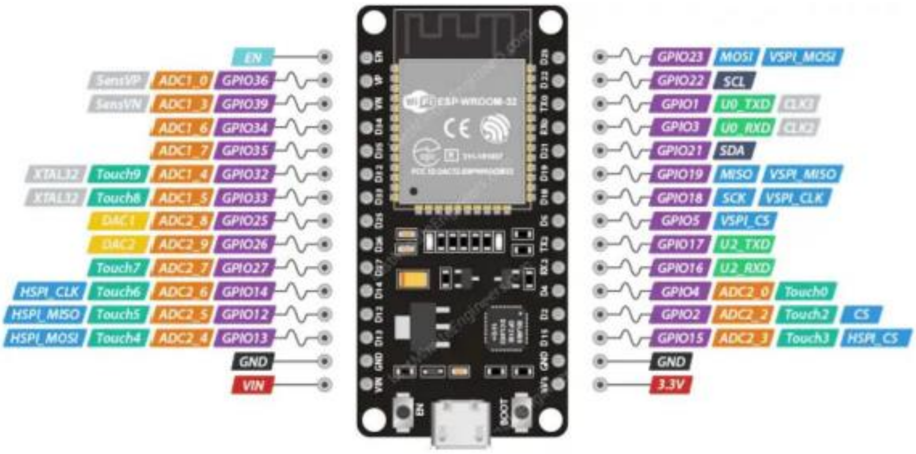


Figure 20: Remote Controller

As a result, the data is successfully transmitted via the serial monitor at a baud rate of 115200. However, the completion of this stage did not occur rapidly; it merely progressed sufficiently to proceed to subsequent stages. The challenges faced during this process will be outlined in the following section.

Problems encounter:



Label	GPIO	Safe to use?	Reason
D0	0	!	must be HIGH during boot and LOW for programming
TX0	1	✗	Tx pin, used for flashing and debugging
D2	2	!	must be LOW during boot and also connected to the on-board LED
RX0	3	✗	Rx pin, used for flashing and debugging
D4	4	✓	
D5	5	!	must be HIGH during boot
D6	6	✗	Connected to Flash memory
D7	7	✗	Connected to Flash memory
D8	8	✗	Connected to Flash memory
D9	9	✗	Connected to Flash memory
D10	10	✗	Connected to Flash memory
D11	11	✗	Connected to Flash memory
D12	12	!	must be LOW during boot
D13	13	✓	
D14	14	✓	
D15	15	!	must be HIGH during boot, prevents startup log if pulled LOW
D15	15	!	must be HIGH during boot, prevents startup log if pulled LOW
RX2	16	✓	
TX2	17	✓	
D18	18	✓	
D19	19	✓	
D21	21	✓	
D22	22	✓	
D23	23	✓	
D25	25	✓	
D26	26	✓	
D27	27	✓	
D32	32	✓	
D33	33	✓	
D34	34	!	Input only GPIO, cannot be configured as output
D35	35	!	Input only GPIO, cannot be configured as output
VP	36	!	Input only GPIO, cannot be configured as output
VN	39	!	Input only GPIO, cannot be configured as output

Figure 21: ESP32 Pinout

Initially, a challenge arose with the joystick pins, initially set to 12 and 15. These pins, as indicated by the pinout diagram, come with a warning to be "HIGH/LOW during boot, preventing boot logs if pulled LOW ". It was an oversight on our part not to test this configuration initially, resulting in unstable data transmission with continuous value fluctuations. When attempting to resolve this, pins to 26 and 27 were changed, but an Espnow error that hindered the connection between the two ESP32s occurred. Regrettably, the chosen pins were plugged into a socket affecting the ESP32's Wi-Fi functionality. Ultimately, the appropriated pins are selected as mentioned earlier. The challenges encountered with the controller likely stemmed from technical issues such as wiring and pin configurations.

PID Tuning

Before working on the setup and tuning of the PID, it is imperative to thoroughly discuss the PID control mechanism and the significance of each P, I, and D parameter. This discussion will be facilitated through video and document resources that have been provided by the lecturer.

PID Setup:

Each motor in our system is governed by an individual PID controller. The input for each PID is derived from the roll angle readings obtained from the MPU. Setting the target point (setpoint) for each PID to zero aligns with our objective of maintaining a vertical balance in the system. The PID calculation results are then mapped to a range of -127 to 127.

PID Tuning:

In the PID tuning process, various tuning parameters, including the proportional (P), integral (I), and derivative (D) parameters, play a crucial role. These parameters are associated with individual PID controllers, each dedicated to specific aspects such as roll, pitch, roll rate, and pitch rate control.

During the initial phase, the proportional (P), integral (I), and derivative (D) parameters are set for all PID controllers to 1, 0, 0, respectively. This preliminary configuration aimed to evaluate the responsiveness of the motors when the drone was tilted in different directions. For example, tilting the drone forward should lead to a correct increase in the speed of the two front motors based on the PID output. Similarly, tilting left or right should appropriately adjust the speed of the respective motors on the left or right side, and tilting downward should increase the speed of the two downward motors. These initial parameters of 1, 0, 0 served as a starting point, with the intention of refining these values as we progressed to the phase of balancing the drone on a tripod

The choice of values 1, 0, 0 for the PID parameters stemmed from their ability, during experimentation, to yield PID results that closely approached zero.

However, the initial response of the drone did not meet expectations due to changes in the motor PIN configuration during the quadcopter assembly process, deviating from our original plan. Consequently, in the initial run, the speed of motors 1 and 3, as well as motors 2 and 4, changed inconsistently when the drone was tilted. Following additional experiments and clarification of the correct PIN assignments for the motors, we successfully modified the code. This adjustment ensures that each motor appropriately adds or subtracts the PID result based on the direction in which the drone is tilted, effectively rectifying the initial discrepancy.

Result:

As a result, PID tuning of the drone is achieved for the pitch and the roll, enabling each motor on the quadcopter to respond appropriately based on the direction in which the drone is tilted. However, despite great efforts, there are several challenges in the drone's self-balancing capability.

Throughout the testing and assembly process, various components such as the 3D motor holder and ESC were damaged or burnt, leading to delays for waiting for the replacement of these components. This setback prevented the team from reaching the self-balancing stage in a timely manner and addressing potential adjustments in our control system code to facilitate autonomous balancing on the tripod.

The following video serves as evidence of our successful PID tuning for both pitch and roll, showcasing the precise response of the four motors according to the drone's leaning direction. However, it is important to note that in the video, the drone appears notably shaky and is unable to achieve self-balancing on the tripod. To view the video demonstrating the motor responses and the drone's stability challenges, please follow this link.

3.3. Work package 3:

This stage is the final process of completing an operational drone, including fine tuning of PID controller to ensure the drone’s self-balancing capability, designing and building a safety mechanisim to toggle the battery’s power and evaluate the drone’s behaviors under maneuver controls.

3.3.1. Objectives

This work package should be done after completing the two previous work packages, as it relies on the integration of all components from those packages. Similar to the preceding stages, this consists of three objectives that can be carried out simultaneously:

- Optimizing the PID controller to improve control over the drone maneuvers.
- Implementing safety measures for emergency situations where the drone needs to make an abrupt stop.
- Controlling the drone’s thrust to change the drone’s altitude and yaw to make it spin while staying still.

3.3.2. Task breakdown and milestones

The tasks involve in this work package includes deeper PID tuning to ensure the drone’s self-balance capability, safety mechanism implementation for emergency stop, and the drone’s maneuvers performance evaluation and optimization.

Table 4: Work package 3 tasks

No.	Action	Deliverable	Member	Priority
0	Read the work package description	Understand the objectives of work package 3	Everyone	High
Milestone 1: PID tuning of the drone for the pitch and the roll				
1	Read the PID manual to understand and get the default value provided	Understand how to access and use the necessary parameters	Huy, Duy, Mina, Long	High
2	Design and implement code to let the controller receive input from the joystick and send it to the SoC microcontroller	The inputs can be received by the SoC microcontroller	Duy, Long	High
3	Test to see if the SoC microcontroller receives the correct value sent from the controller	All output values should match the inputs'	Huy, Duy, Long	Medium
4	Perform Proportional (P), Integral (I) and Derivative (D) tuning by gradually changing the default value	• Drone is responsive after P tuning • Drone does less overshooting after I tuning • Drone is stable after D tuning	Huy, Duy, Long	Medium
5	Perform controlled testing after each tuning	Drone satisfies the wanted outcome of each PID tuning	Huy, Duy, Long, Tu	Medium
6	Perform indoor testing	The drone can perform basic maneuvers when firmly fixed on a tripod	Everyone	High
7	Collect and analyze data from the tuning process	Understand the data and see if the drone needs further tuning	Everyone	Medium

8	Optimize and fine-tuning	Drone is fine-tuned and now performs with the best possible performance	Everyone	High
Milestone 2: Safety implementation for the drone emergency stop				
1	Research about automatic stopping for motors when having too much resistance	Understand how to stop the motors automatically	Son, Nhan, Huy	High
2	Design, implement and perform tests on mechanical safety features to protect delicate components	Components must not suffer irreversible damages	Son, Nhan	High
3	Take risk analysis, design prevention and protection against propellers before attaching	Fully understand risks involved with propellers and ensure prevention and protection methods are ready	Mina, Son, Nhan	High
Milestone 3: Remote control of the drone				
1	Setup value range for the thrust and yaw	The values setup must not let the drone fly too high or over spin and each value increment must be within a reasonable range of the previous one	Tu, Long, Duy	High
2	Design and implement code to get input for thrust from the potentiometer and yaw from the 2 buttons	The potentiometer can change thrust value and the buttons can change yaw value	Tu, Long, Duy	High
3	Test to see if the SoC microcontroller receives the correct inputs	The output values should match the inputs'	Tu, Long, Duy	High
4	Perform controlled test	The motors' speed can be adjusted, and drone's maneuvers are not too violence	Huy, Duy, Long, Tu	High

6	Collect and analyze data	Understand the data and see if the drone needs further tuning	Huy, Duy, Long, Tu	High
7	Optimize and fine-tuning	Drone is fine-tuned and now performs with the best possible performance	Huy, Duy, Long, Tu	High
9	MATLAB Visualization	Drone control signals from joystick, potentiometer, motor speeds or PID value are developed for better data observation.	Tu	High

3.3.3. WP3 – Achievements and Work done

MATLAB Visualization

In order to show graph from Drone's raw data, the drone needs to be connected to laptop to connect MATLAB through terminal. So basically, it will display all the data that is currently printed to the Serial Monitor. After successfully connected to the serial monitor of the drone, X and Y output of the joystick can finally be printed out, as well as pitch, roll output and rate, potentiometer, and all four motor output.

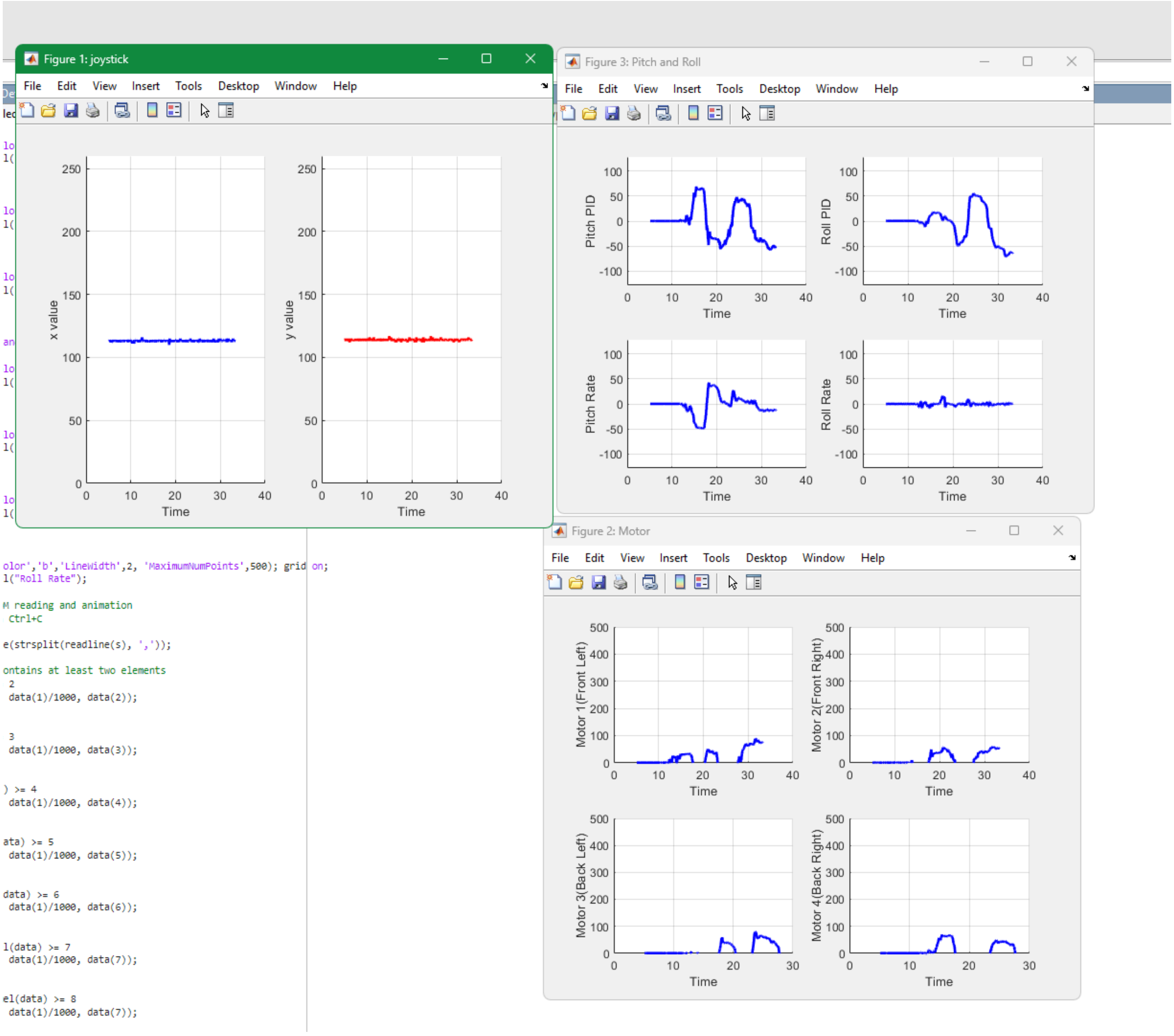


Figure 22: MATLAB Visualization

Problems Encounter:

This part presents an opportunity to apply MATLAB knowledge acquired from OENG1207 – Digital Fundamentals Course. It poses numerous challenges as it is a solo task and most team members are unfamiliar with MATLAB. Therefore, a review of MATLAB is necessary to create a digital graph showing raw data from the drone and controller. Initially, the starting point was clear. Extensive research was conducted on how to connect MATLAB with the drone, but it was unsuccessful until advice was received from the lecturer. A solution was found on the lecturer's GitHub to connect the drone and MATLAB through Serial Monitor. As more features were added to MATLAB, the code became increasingly unoptimized, causing updates to take around 5 to 10 seconds, leading to the removal of some features and reoptimization of the code. The drone's motors responsed to basic maneuvers such as increasing pitch, roll and yaw when the joystick and buttons are adjusted accordingly.

Problems encounter:

Safety feature was not implemented. Two team members are assigned to design and build a safety switch around 1 week before the demonstration day. However, the exact port to connect the battery was not found at the time, and it was too late for any improvization. The figure 23 below is a safety feature built by the lecturer, make an example of how a simple safety mechanism should look like, where the power and ground wires are connected via a PCT Spring Lever connector. This helps to extend the length of the wire connecting the battery, increase the distance from the operator and the drone for safety, as well as the wires could be easily unplugged when emergency occurs. As a result, the team needs to borrow the safety switch from the lecturer for the demonstration.

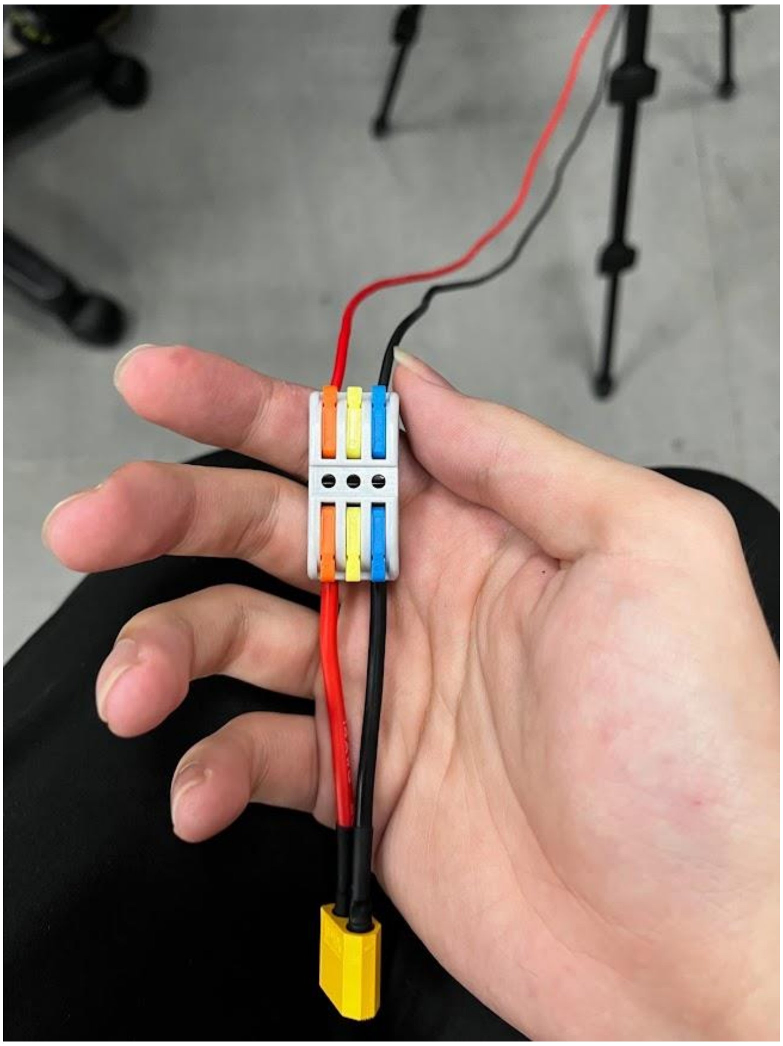


Figure 23: Safety feature to connect and disconnect the battery at a safe distance

Another serious issue occurred during the drone testing is the drone controller connection integrity.

After finish testing the drone's motors behavior, the propellers are installed to test the PID tuning. Everything went well until the motors suddenly span incredibly fast, making the drone unstable and collapsed. This accident was not expected by any of the member, and it caused quite severe injury to the lecture as the propellers cut the lecturer's finger. The reason for this accident is believed to be loose wire connection of the controller, specifically the potentiometer wiring. All of the wires used for connection of the controller are jumper wires, without any further reinforcement. While the test was being performed and the potentiometer was slowly increased, the GND or the signal pin of the potentiometer got loose, leading to the microcontroller to received the maximum value of the potentiometer, and the motors span at maximum power. Luckily, the student managed to turn off the battery right after the abnormal accident happened, so no further injury occurs. However, this results in two 3D printed parts and one propeller broken, and the lecturer urgently printed two extra parts and provided one propeller to compensate.

Figure 24: Serious accident occurred, causing 2 motor holders breakdown

4. Time management

Effective time management constitutes an integral aspect of any project, aiding the team in adhering to schedules and meeting deadlines essential for producing the project's final deliverable. Implementing a well-thought-out strategy for allocating time to each task not only conserves resources but also enhances overall project productivity by identifying and addressing issues or risks early in the process.

One valuable tool for visually depicting the project schedule is the Gantt chart. This chart typically includes the following details:

- **Timeline:** A sequence of milestones that outlines the time required to complete the project, represented by the project's start and end dates.
- **Task:** Specific activities or units of work assigned to each team member, are essential for project completion.
- **Assignee:** The individual responsible for completing a task, tasked with taking necessary actions, meeting deadlines, and ensuring task performance.
- **Progress:** Presented as a percentage, indicating the completion status of each task and estimated based on the allocated time.
- **Allocated time:** The designated time assigned to a specific task, providing a structured framework that allows team members flexibility in handling their tasks while ensuring the availability of the right resources when needed.

4.1. General Gantt chart

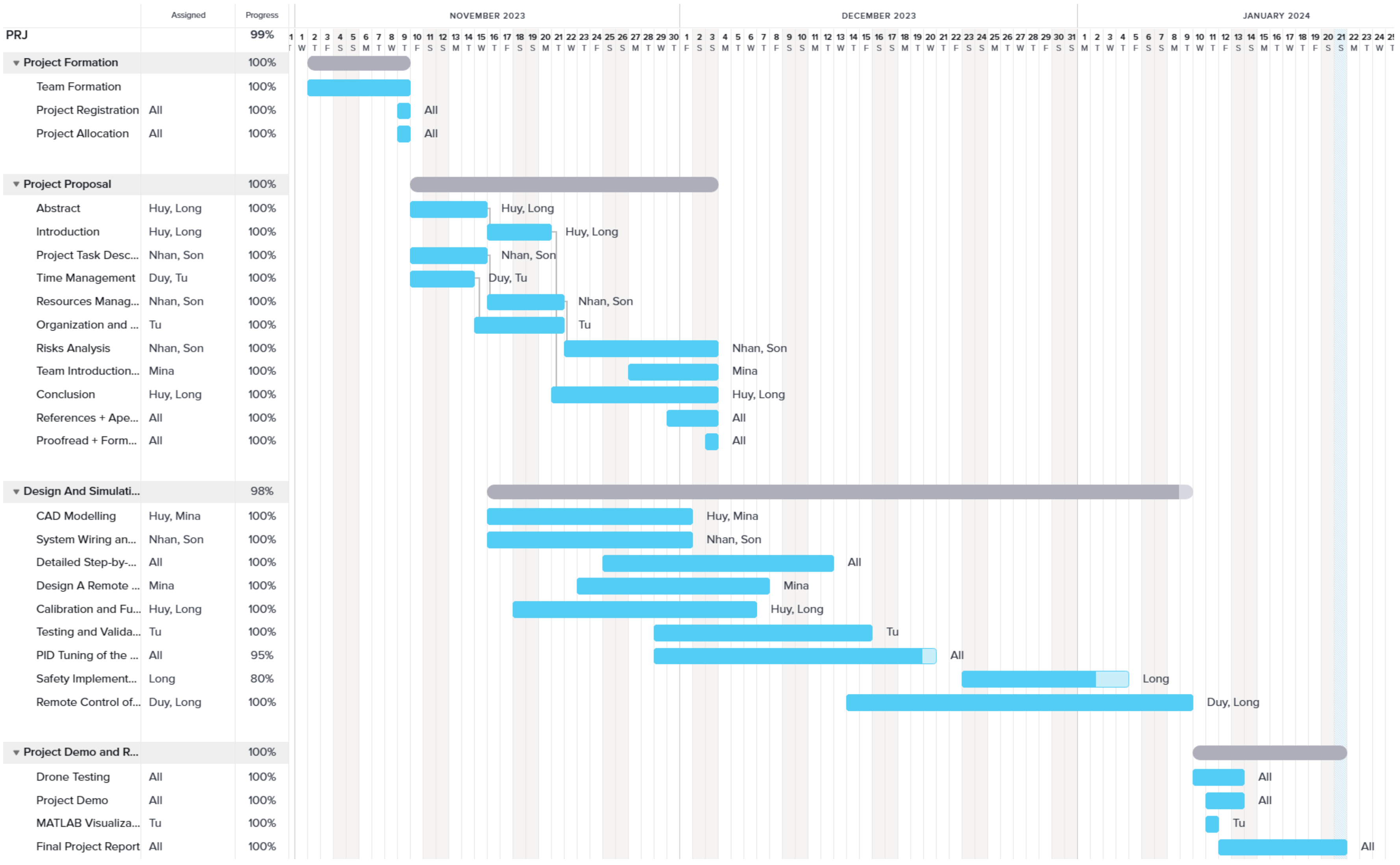


Figure 25: Gantt chart for the entire project

The project is being operated within 12 weeks. The project is divided into 4 stages Project Formation, Project Proposal, Design and Simulation, Project demo and Report. In terms of Design and Simulation, it is broken down into 3 smaller projects called work packages (WP1, WP2 and WP3) as mentioned above.

On top of that, the red lines in the Gantt chart display the correct time the user opens the application.

The general Gantt Chart includes the following:

- **Timeline:** 12 weeks, starting from Dec 10, 2023, to Jan 19, 2023. The end of the project is the submission of the Final Project Report.
- **Task:** Tasks are feasibly categorized and arranged according to each stage in the first column.
- **Assignee:** Assignee is shown in the second column "Assigned to" which could be a specific person, a group of members or all members.
- **Progress:** Progress presents the performance of each task in percentage. It is adjusted depending on the allocated time bar.
- **Allocated time:** The estimated duration for completing a specific stage is illustrated by the dark grey bar, while the light grey bars indicate the time already expended on individual tasks. In contrast, the purple bar visually represents the remaining time required to complete the respective task.

4.2. The Project Formation

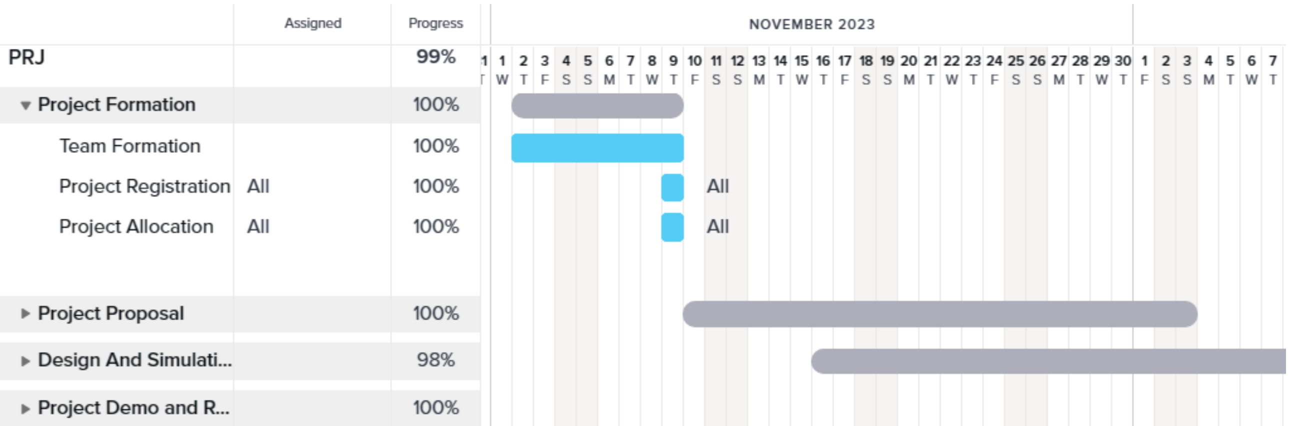


Figure 26: Gantt chart for team formation and project allocation process

The duration required to assemble a project team depends on members' voluntary participation or may be dictated by the lecturer. Typically, this stage spans around one week, facilitating team establishment and acquaintanceship among peers.

4.3. The Project Proposal stage

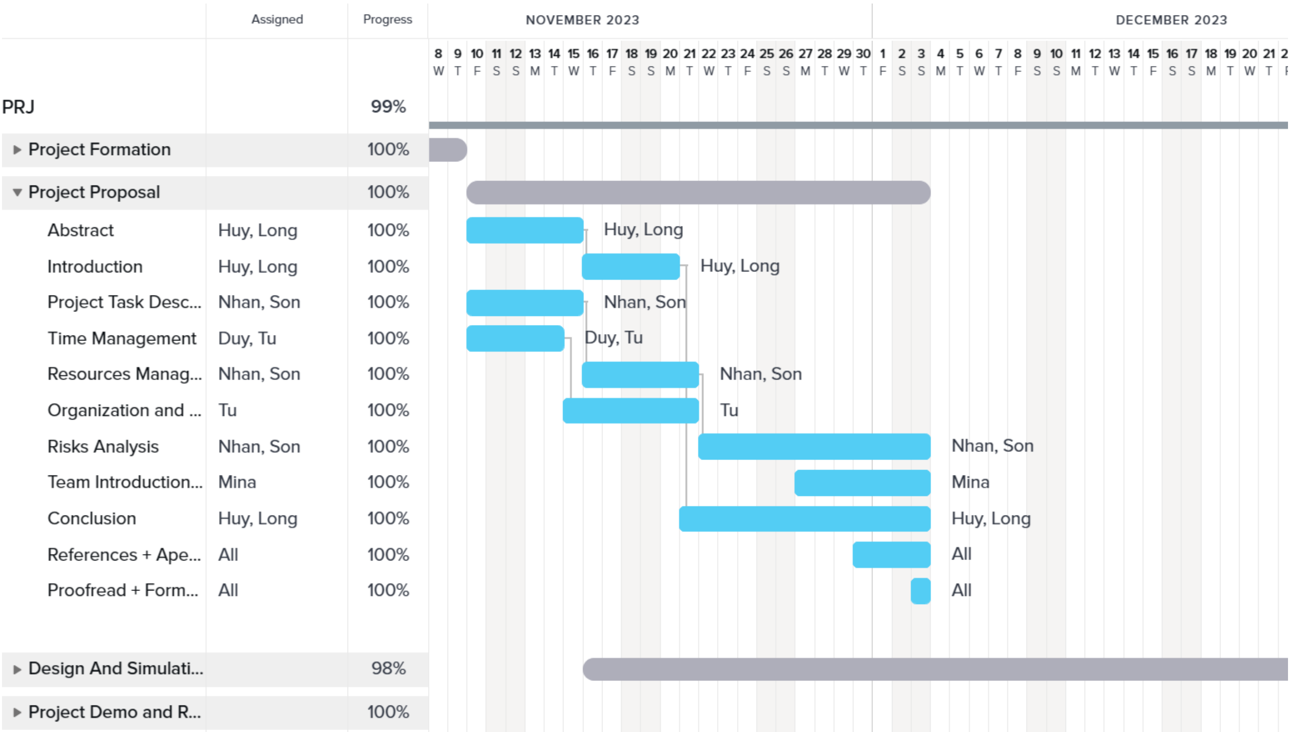


Figure 27: Gantt chart for Project proposal process

Presenting the project proposal to the instructors serves the purpose of providing a comprehensive overview and offering a glimpse into the project for everyone involved. Starting on November 10 and spanning over three weeks, this phase requires the submission of the project proposal by December 3.

The Gantt chart outlines all primary tasks, each requiring the participation of the entire team. There is a possibility that the project proposal may run concurrently with the Design and Simulation stages, ensuring a clear understanding of the necessary content for the proposal and optimizing time efficiency for subsequent phases. The variation in allocated time for tasks is noticeable. In response, we have opted to allocate additional time for individuals handling challenging tasks or those who might be burdened with their projects. As illustrated in Figure 26, where Risk Analysis and Conclusion are assigned to Son and Nhan, and Huy and Long respectively, the duration for their tasks has been extended to accommodate the time needed to meet their respective deadlines. Furthermore, to ensure the quality of the project proposal, we have decided to allocate 3 to 4 days before the deadline for a thorough review and correction of any errors in the proposal.

4.4. The Design and Simulation stage

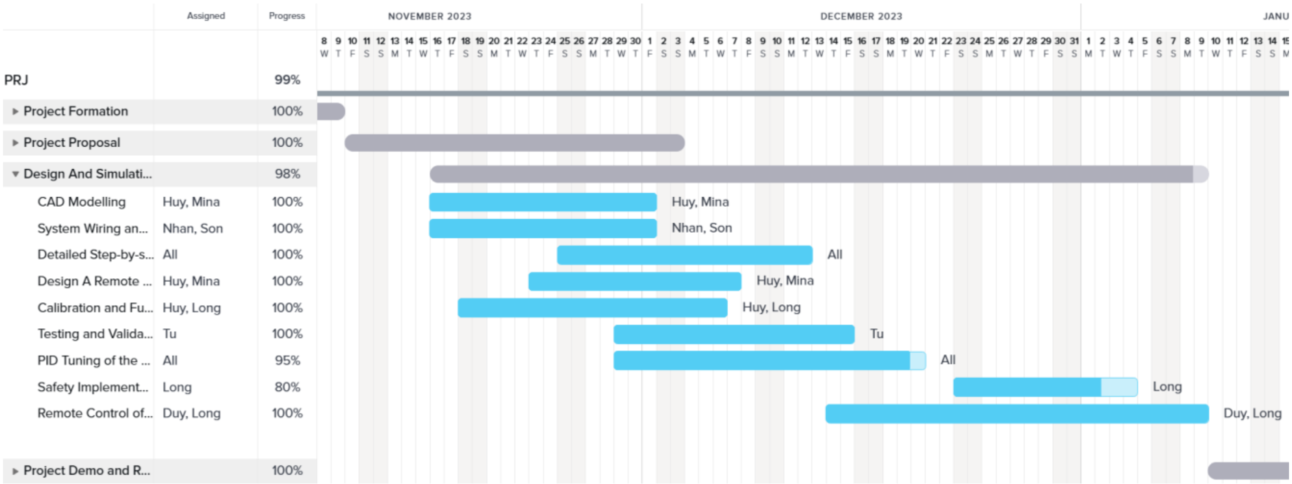


Figure 28: Gantt Chart for Design and Simulation process

Initiating the Design and Simulation phase promptly is imperative, prompting us to integrate this stage starting on November 16, running concurrently with the project proposal phase. The deadline for completion is set for January 9, slightly over a week before the report submission deadline, spanning a total duration of approximately 6-7 weeks.

In more detailed terms, we have divided this phase into three distinct work packages, as specified in the project task description.

Work Package 1, spanning 3 weeks from November 16 to December 12, focuses on the Design of the Drone. It contains three main tasks: CAD Modeling, System Wiring and PCB Design, and the creation of a Detailed Step-by-Step Assembly Guide. Collaboration among all team members is expected during this phase, with specific minor responsibilities delegated to individuals based on their expertise and task requirements. For instance, Huy and Mina, responsible for CAD and PCB Design, have assigned tasks to Son and Nhan.

Work Package 2, also a 3-week duration from November 23 to December 15, is centered around Unit Testing. This segment is further broken down into three primary tasks: Design of the remote controller, Calibration and functioning of the driving unit, and Testing and validation of the sensors. With most essential components provided, Duy, Huy, Long, and Tu are tasked with ensuring these components operate without errors.

However, Work Package 3, spanning 5 weeks from November 29 to January 9, revolves around the Control and validation of the drone. In this phase, Long and Tu focus on working with the IMU and GPS to display accurate data on the terminal. Following that, Duy is responsible for the remote controller setup, connecting buttons and joysticks to manage the drone. This phase also serves as preparation for the successful completion of the entire stage.

For a more detailed explanation of each task, please refer to the task description section.

4.5. Project Demo and Report

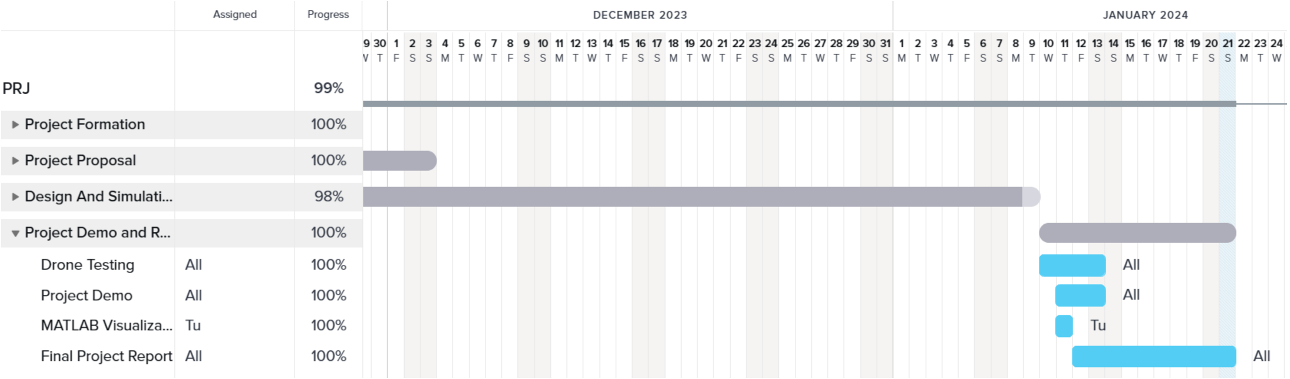


Figure 29: Gantt chart for Project demo and report process

In terms of the project demo and report, MATHLAB visualization has been added to our project and we have to conduct the Drone Test on January 11 to confirm that it works well. Next, we will spend more than a week on the Project Demo and submit the Final Project Report before January 22.

Adjusting the project timeline by approximately one week is expected to yield improved outcomes for the team, considering that our achievements currently stand at 95%, 80% for PID Tuning, and Safety Implementation for the Drone, respectively. Extending the project by more than one week would allow the team to allocate additional resources to enhance the remote controller, drone frame, and refine PID operation further. It is worth noting that, at this point, the progress of the final report has reached 100% near the deadline, which is somewhat slower than anticipated due to each team member having multiple deadlines to meet.

5. Resources Management

This section of the proposal outlines the theoretical components required to build the quadcopter drone, as specified by the team members. The bill of materials (BOM) table lists all the components, both provided by the lecturer and purchased by the team, excluding backup or replacement components. As the project progresses, additional components may be needed to complete the drone, including parts provided by the lecturer in the future or adaptations made by the team to improve the design. The BOM will be combined from Work Packages 1 and 2 for easier management and replication. The team will source components from various e-commerce platforms, local electronics shops, and remote-controlled vehicle hobby shops. Once the drone is constructed, the final documentation of the building process will be published, and the BOM will be updated accordingly.

Table 5: Project Bill of Material

Name	Specification	Description	Quantity	Price of 1 unit in VND
Wooden Board	Dimensions: 15x15x5mm	Serve as the base of the drone's frame	2	Provided by lecturer, estimated 50.000
Wooden Bar	Dimensions: 20x1.5x1.5mm	Serve as the drone's arms to attach the motors	4	Provided by lecturer, estimated 10.000
Propeller Pair	Length: 1045 mm	A pair of clockwise and counterclockwise propellers.	2	Provided by lecturer, estimated 32.000
Motors	Motor Himodel XXD A2212-1400kV Brushless	Spin the propellers to create lift	4	Provided by lecturer, estimated 125.000
ESC	Model: XW-30A	Serve as power regulator and speed controllers of the motors	4	95.000
Drone's Battery	- Battery type: Lithium Polymer	Ovonic 1550mAh 4S 100C 14.8V LiPo Battery XT60	1	380.000

	rechargeable battery - Output power: 14.8V - Capacity: 1550mAh - Size: 76x40x32mm			
GPS Module	Model: GPS NEO8M	For navigation and positioning	1	125.000
IMU Module	Model: MPU6050	Include accelerometer and gyroscope that measure force, angular velocity and attitude to balance the drone	1	34.000
SoC Microcontroller	Model: ESP32-WROOM-32	Integrated with Wifi and dual-mode Bluetooth	1	150.000
Potentiometer	Resistance: 1kΩ	Integrate into the controller to change the drone's motor speed	1	30.000
Connectors	A pair of ESC-Motor 4mm jack	Soldered on to ESCs and motors' wire for connection	12	12.000
Jumper Wires	Male-male, Male-Female, Female-Female, A pack of 25 wires	Connect all circuit boards	1	28.000
Heat shrink tube	A pack of 164	Cover the open wires and connectors to isolate them, and prevent short circuit	1	25.000

Breadboard	Size: 8.5x5.5cm, 400 holes	For testing the motors and ESC circuit before the PCB is printed	1	16.000
3D Printed Model	Size: 50.5x31x20mm	4 parts serve as the motor holder to attach the motors to the drone's arms; 1 part serve as the frame of the controller	4 to attach propellers, 1 for controller	Estimated 120.000
PDB	Model: Matek XT-60 PDB	Power Distribution Board that distributes power from the battery to other components through an XT-60 port.	1	120.000
PCB	Will be designed by team members	Serve as a circuit board to attach other modules for the drone.	1	20.000
Press button	Arduino press button	For controlling the drone yaw	2	10.000
Joystick	Black Arduino thumbstick	Maneuver the drone	1	10.000
Zip tie	A pack of 100	Used to tie any loose parts if needed	1	10.000
Electrical wires	1 meter of 18AWG electrical wire	Used to extend the ESC wires	1 of red, 1 of black	10.000
Male header pin	A row 1x40 of gold-plated male header pins	Used to solder onto the GPS module	1	1.900
Total cost in VND	3.297.900			

During the Bill of Materials (BOM) creation process, the prices of certain items were difficult to determine due to significant price variations between suppliers, so some of the components' prices are estimated. For 3D printed parts and PCBs, the pricing of manufacturers offering similar products was used as a basis to determine the estimations.

The selection of certain resources for the project was based on a deliberate and thoughtful process, taking into account various factors to ensure their suitability and effectiveness. Some of the reasons behind these choices include:

1. Wooden boards and bars for the frame: these are more accessible to access than a fully 3D printed frame, which is lighter and more durable than the 3D printed material the university-provided resin materials. This allows easier parts' replacement when they are damaged during testing.
2. PDB model: Matek PDB XT-60 model is chosen as it already comes with the XT-60 port that matches the battery's port, making it easier to connect the two rather without needing to solder them.
3. Male header pins: these can be either gold or brass plated. The gold ones are chosen because of better conductivity and the price difference is minimal,, approximately around 400đ each.

The BOM table above provides a brief list of necessary components and the estimated total cost of the drone, however, there are a few complications, making the total estimated cost not 100% accurate. Firstly, as being mentioned above, the team has burnt and broken a few components such as two 3D printed parts and a few PDBs. Therefore, a quite greater amount of money was spent to get the replaced components, as PDB is one of the most expensive components of the drone. Secondly, the team only need one PCB for the drone. However, the manufacturer minium number of PCB for fabrication is 5 PCBs, therefore, the team has to accept and receive 5 PCBs. Still, this is fine as the team has multiple backup PCBs in case of breakdowns, as well as the PCBs are relatively cheap, including the discounts at the time of order.

6. Risk Assessment

To yield the desired results, a thoughtfully planned risk assessment and mitigation plan is imperative. It is crucial for every team member to deeply comprehend the potential hazards that could arise during the drone construction process and testing in order to ensure their safety and minimize the damage to the equipment.

Table 6: Risk impact and probability

Risk table			
	Impact (Low to High)		
Probability (High to Low)	Moderate	High	Critical
	Low	Moderate	High
	Extremely low	Low	Moderate

There are some potential risks in the project work. These risks are categorized based on their likelihood of occurance and potential impact on the project. The probability of each risk occurring ranges from Low (unlikely to occur), Medium (possibly to occur), and High (likely to occur). By recognizing and evaluating these risks, effective strategies can be developed to mitigate or manage them, ultimately leading to a successful completion of the project.

Table 7: Risks analysis table

Task name	Risk description	Risk probability	Risk Impact	Overall score
Project planning				
Weekly meeting	Meeting is not available / Meeting is not sustained	*Low*	*Low*	*Extremely low*
Punctuality	Being late for a project deadline	*Low*	*High*	*Moderate*
Milestone: modeling	Draft model (hardware): without inspection	*Medium*	*Medium*	*Moderate*
Milestone: coding	Draft model (software): without inspection	*Medium*	*Medium*	*Moderate*
Manufacturing				
Hardware (CAD&PCB)	Faults in technology (hardware)	*Medium*	*High*	*High*

Software (coding)	Faults in technology (software)	*Medium*	*High*	*High*
Injuries	Get injuries when manufacturing the model	*Medium*	*Low*	*Low*
Damaged components	Get some damage on the components when powered on	Medium	High	High
		Testing		
Injuries	Get injuries cause by components due to technical or human errors	*Medium*	*High*	*High*
Connection	During the test, suddenly have mechanical connection issue	*Medium*	*Medium*	Moderate
Code	During the test, suddenly have coding issue	*Low*	*Medium*	Low
Lost	Lose components after testing	*Low*	*Medium*	Low
		General		
Injuries	Get any injuries caused by components	*Medium*	*Medium*	*Moderate*
Material preparation	Lack of materials	*Medium*	*Medium*	*Moderate*
Breaking components	Whenever break the components	*Medium*	*Medium*	*Moderate*
Lack of communication	Cause the misunderstanding by lack of communications in the project group	*Low*	*Medium*	*Low*

After 11 weeks of development, the team faced with several unexpected incidents, arising some more risks that affect both the drone integrity and people's wellbeing. Indeed, severe accident during testing process was not expected, leading to certain injuries to team member and the lecturer as mentioned above in work package 3.

7. Conclusion

In general, UAVs widespread adoption has been becoming increasingly inevitable. This project aims to delve into the design, fabrication and testing of a quadcopter drone, with the primary objective of evaluating its stability and maneuverability. By gaining a comprehensive understanding of each component of the drone and integrating them within a closed system, students will be able to ensure optimal operation and self-balancing capability under various scenarios and environmental factors. After 12 weeks of hard-working effort, the students managed to apply all knowledge on ensuring the understanding of all electronic components as well as required technical skills to complete build of the drone. Basically, the drone did performed its fundamental maneuvers such as reacting to roll, pitch and yaw from the controller, as well as motors' reaction to PID controller when the drone is lean during testing, but the drone could not balance itself on the tripod without human interaction. However, this development represents a significant accomplishment for the team involved in this project, as it embodies a formidable challenge that has been met with remarkable success.

With all experience gain from this project during the development process, students could improved themselves to successfully design and built a complete operational quadcopter, with proper behaviors, self-balancing capability and perfect maneuverability. This also provides the students with the opportunity to advance their skills in teamwork and collaboration as well as technical skills and knowledge. The success of this project has leid the background for even more ambitious projects in the future, as students have gained the knowledge and expertize necessary to deal with increasingly complicated challenges with confidence and efficiency.

8. References

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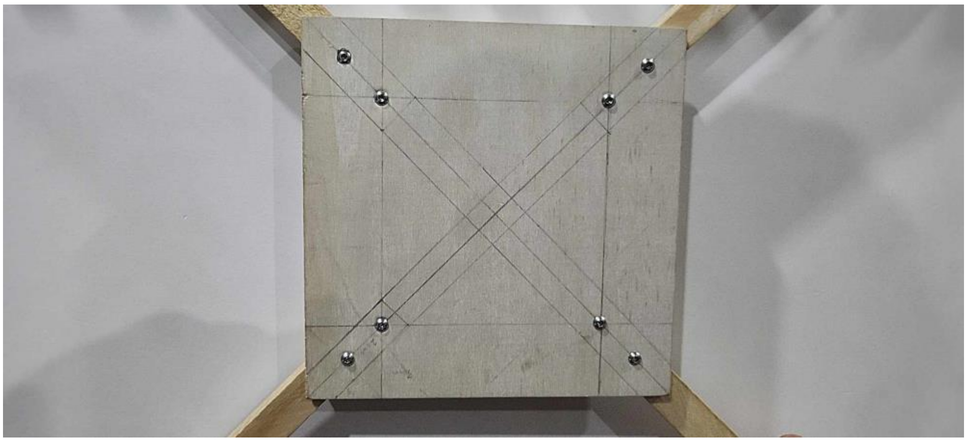
9. Appendix

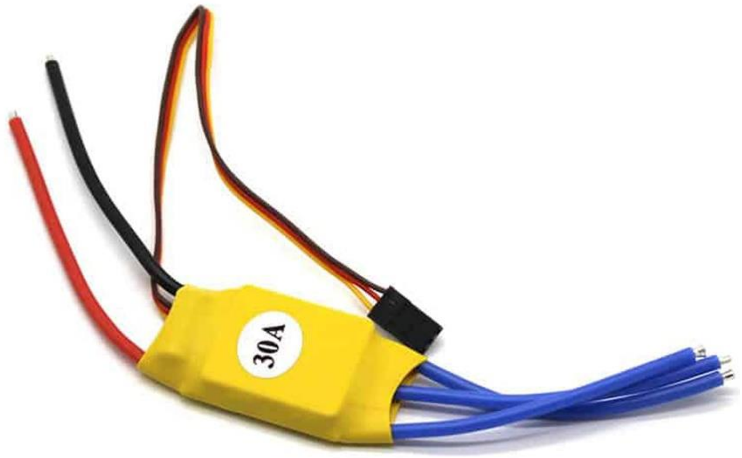


Appendix 1: Wooden Board

Appendix 2: Wooden Bar

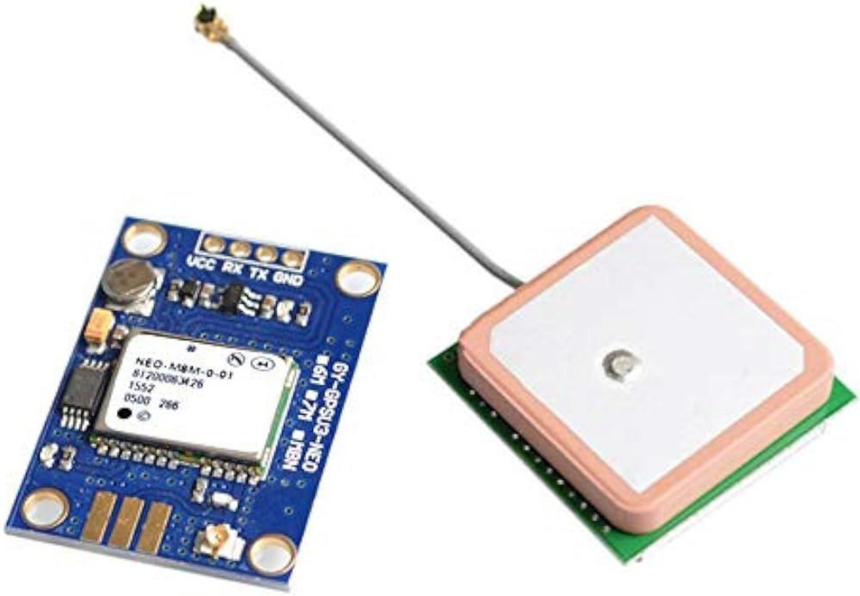
Appendix 3: Propellers

Appendix 4: BLDC Motors

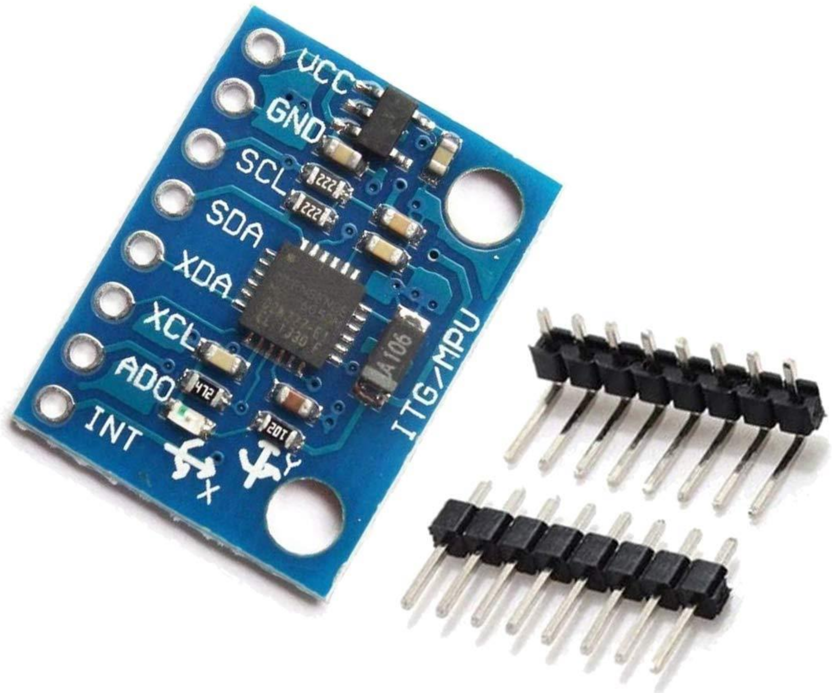


Appendix 5: ESC

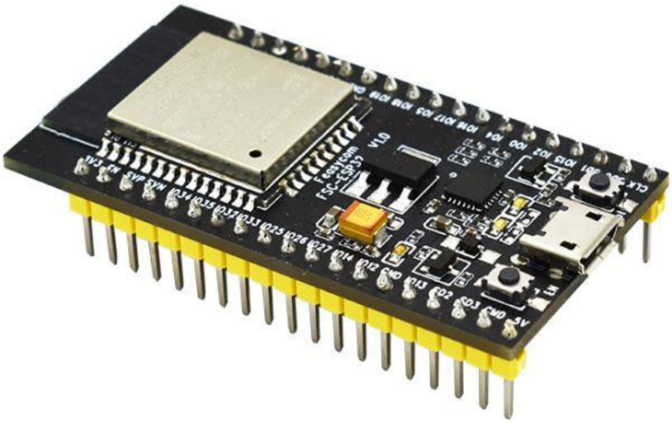
Appendix 6: LiPo Battery



Appendix 7: GPS Module



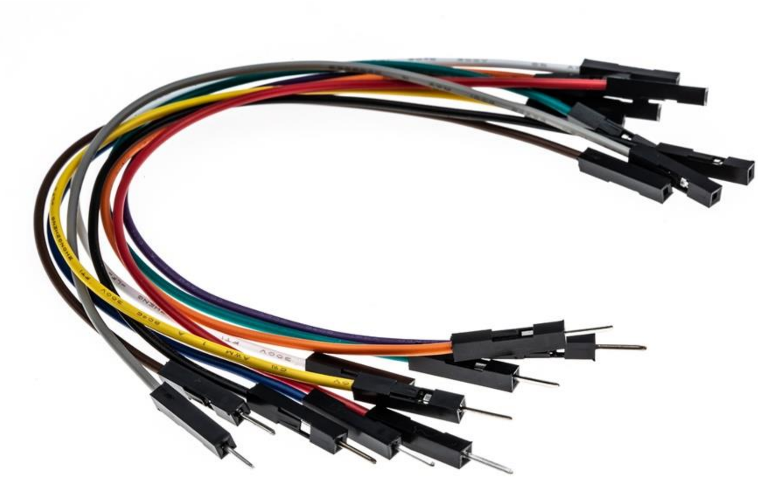
Appendix 8: IMU Module



Appendix 9: SoC ESP32-WROOM-32

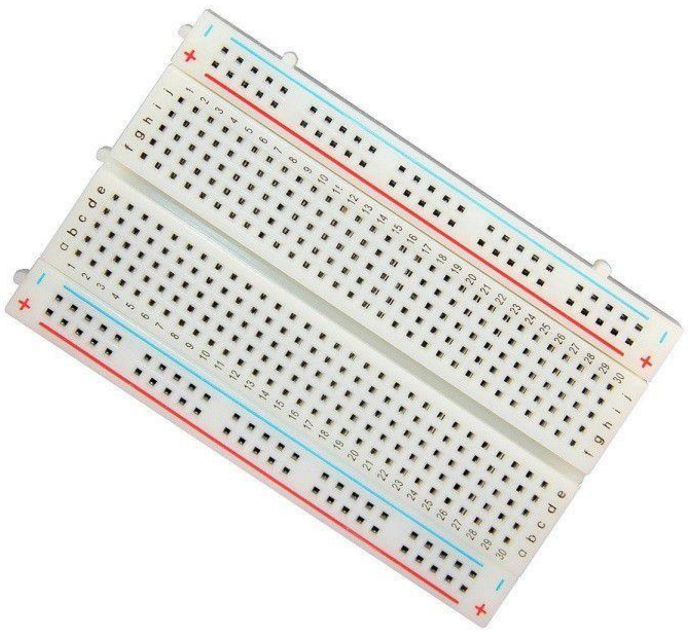
Appendix 10: Potentiometer

Appendix 11: 4mm Male-Female jacks



Appendix 12: Jumper wires

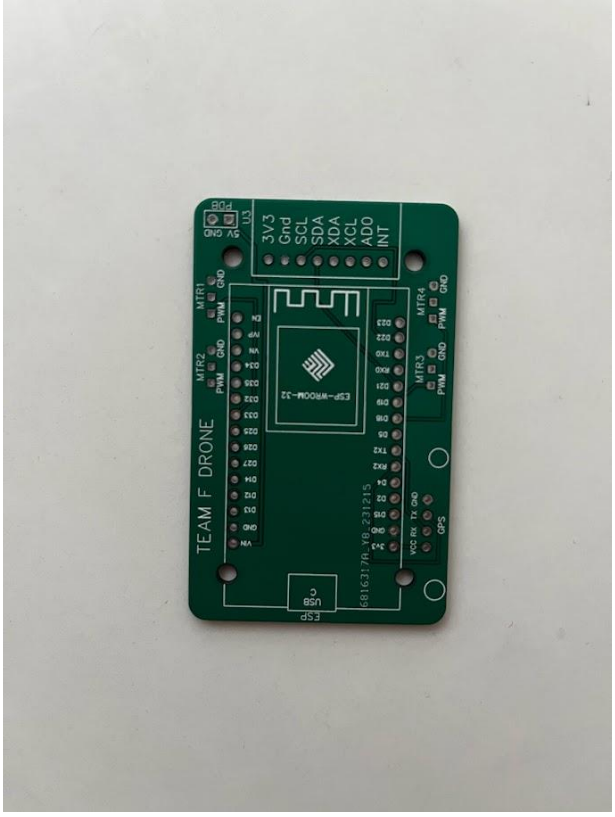
Appendix 13: Heat shrink tubes



Appendix 14: Breadboard

Appendix 15: 3D Printed Parts

Appendix 16: PDB



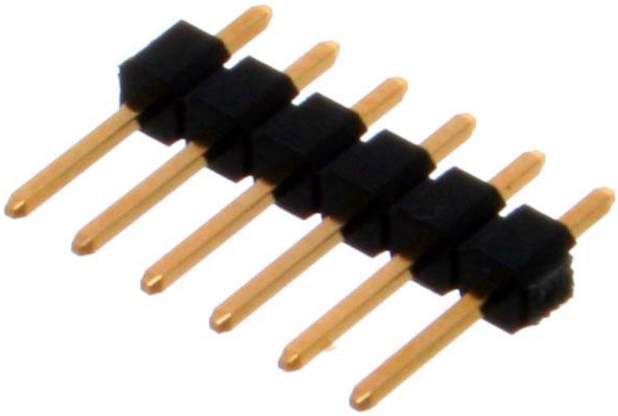
Appendix 17: PCB

Appendix 18: Arduino push button

Appendix 19: Arduino joystick

Appendix 20: Zip ties

Appendix 21: Electrical wires



Appendix 22: Male header pins