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EEET2610 – ENGINEERING DESIGN 3

Project Final Report

Design And Control of a Quadcopter

Lecturer: Dr. Dinh-Son Vu

Group G_ Tutorial 2: Thursday 14:30 – 16:00

Nguyen Bao Tuan s3713061

Duong Hoang Dang Khoi s3879524

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School of Science, Engineering, and Technology

What's next...

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1. Abstract

The primary goal of this project is to design, build, and deploy an autonomous drone quadcopter system that will revolutionize environmental monitoring and surveillance. The quadcopter's sophisticated sensors, cameras, and machine learning algorithms allow it to make wise decisions in situations that arise in real time. The main goal of the project is to develop a flexible and effective drone system that can gather sensor data and take high-resolution photos while navigating a variety of surroundings on its own. Modern technologies like computer vision and deep learning are integrated to improve the surveillance capabilities of drones by making it easier to monitor, identify anomalies, and recognize objects. The drone's environmental monitoring capabilities also involve gathering information on temperature, vegetation health, and air quality. This information is essential for determining the state of the environment, identifying possible risks, and supporting disaster relief efforts. The project also tackles issues with navigation accuracy and battery life, putting energy-efficient algorithms and precise control mechanisms into practice to maximize the drone's performance. Additionally, the system has the ability to monitor and manage remotely via an intuitive interface, giving operators the ability to adjust mission parameters and intervene as needed. The autonomous drone quadcopter project seeks to improve surveillance, environmental monitoring, and disaster response by using an interdisciplinary approach. The results of this study might improve environmental awareness, public safety, and the general effectiveness of monitoring efforts across a range of fields.

2. Introduction

The integration of unmanned aerial vehicles (UAVs) has emerged as a disruptive force across numerous sectors in an era marked by fast technical breakthroughs. Among them, drone quadcopters have become more well-known because of their adaptability, agility, and possible uses in environmental monitoring and surveillance. This project sets out to utilize autonomous drone quadcopters and combines state-of-the-art technologies to tackle important problems related to disaster relief, data collecting, and surveillance. The increasing need for effective and intelligent surveillance systems necessitates creative solutions that can navigate challenging surroundings and deliver real-time insights. Environmental monitoring has grown more and more important at the same time for understanding and reducing the effects of natural catastrophes and climate change. By creating an autonomous drone quadcopter system outfitted with cutting-edge sensors, cameras, and clever algorithms, this project aims to meet these objectives. Our project is driven by the goal of developing an advanced yet approachable drone system that can carry out surveillance tasks and collect essential environmental data on its own. The quadcopter seeks to go beyond simple data collecting by actively identifying and reacting to objects, abnormalities, and possible dangers in its operating environment by utilizing computer vision and deep learning algorithms. The project tackles issues with energy efficiency, precise navigation, and remote control interfaces to guarantee practical usability. The use of cutting-edge technology not only improves the functionality of the drone but also lays the groundwork for future developments in environmental sustainability, disaster response, and public safety. Hopefully to contribute to the developing field of unmanned aerial vehicle (UAV) applications as we explore the complexities of this research. Our findings might have an impact on a variety of industries, including environmental science, disaster management, security, and surveillance. The methods, design factors, and expected results of our project are explained in the next sections.

3. Literature Review

Drones in Modern Applications: Drones and unmanned aerial vehicles (UAVs) have become increasingly popular in a number of industries, including military, agricultural, and surveillance. Drone delivery services for the final mile present a potential application that tackles the issue of closing the gap between service providers and consumers [1]. As the need for drone technology increases, educational institutions are introducing more practical projects to provide students a thorough grasp of the operation and difficulties of these unmanned aerial vehicles.

Overview of the Engineering Design 3 (ED3) Project:

The Engineering Design 3 (ED3) project, which focuses on the foundational elements of quadcopter design and control, is an excellent undertaking in this educational setting. Through this project, students learn about key parts of a quadcopter's propulsion system, like propellers and Brushless DC (BLDC) motors. The Skywalker Quadcopter serves as an example of an inverted pendulum mechanism, which is the focus of this project's particular design attention [2].

Work Packages and Project Structure:

The ED3 project is structured into three distinct work packages (WPs): Project Proposal, Design of the Drone (WP1), Unit Testing (WP2), and Control and Validation of the Drone (WP3). The emphasis on spending significant time on the initial stages (project proposal, WP1, and WP2) before delving into the more challenging aspects of control and integration (WP3) showcases a systematic and scaffolded approach to learning [3].

In the WP1, students are entrusted with the careful design of the drone during the first part of the Engineering Design 3 (ED3) project. To do this, use advanced Computer-Aided Design (CAD) programs like SolidWorks or Fusion 360 to produce a detailed model. The objective is to explore the complexities of the drone's assembly as well as to envision the actual structure. One of the main goals is to impart knowledge about the dimensions, structural subtleties, and the minute details of the bill of materials of the drone. Technical drawings are not required, but it is strongly advised to include them since they give more information about important dimensions and help turn the virtual model into a tangible object [3]. Students can also interact with important design concerns throughout the CAD modeling phase. As they work on the drone's digital model, they are urged to examine the model's structural soundness, consider how to make it better, and learn about the bill of materials—a crucial document that will be used in later stages of the project. This stage lays the groundwork for the students' exploration of the complex field of drone design, guaranteeing that they understand both the theoretical ideas and their real-world applications in an engineering setting.

Unit Testing - Ensuring Component Functionality is Work Package 2 (WP2). The emphasis of the project changes as it moves on to the second work package (WP2) to ensure the distinct functioning of every component. Before integration, this stage is vital to ensure that all of the drone's components—including the driving unit, sensors, and remote controller—work flawlessly together. Functionality is not the only focus; a scientific methodology incorporating data collection and critical thinking is also highlighted. A joystick for pitch and roll control, push buttons for yaw rate changes, and a potentiometer for thrust control are all integrated into the design of the remote controller, which is a crucial component in controlling the drone. To enable connection between two ESP32 microcontrollers, the wireless communication protocol, espnow, is introduced, demonstrating how cutting-edge technology is included into the project [3]. This work package emphasizes how important it is to do thorough testing, prohibiting the simple act of copying code without providing empirical data to support component functionality.

The integration of the many parts into a functioning drone is the third and most difficult work package (WP3). PID (Proportional-Integral-Derivative) controllers are a crucial component of the project, and students learn about its intricacies, especially in relation to pitch and roll. Students must create a table of PID parameters in order to fully comprehend the tuning process, which turns the PID controller tuning into an experimental project. However, integration has its own set of difficulties, such as locating and fixing wiring mistakes and making adjustments for the physical differences between the real drone and its computer-aided design (CAD) model. Because propellers may be dangerous, safety measures like emergency stop mechanisms become critical. The focus shifts to testing thrust and yaw control to make sure the drone can operate autonomously and safely in various degrees of freedom [3]. WP3 prepares students for the complexities of drone control and validation in a real-world scenario by encapsulating the sum of theoretical knowledge, practical skills, and problem-solving abilities.

4. Project Task Description

The project task is divided into three work packages and presents the achievements of the final drone from the proposal milestones.

4.1. Work package 1: Design of the drone

The three deliverable objectives in WP1 of the drone's design are crucial for its functionality and performance. The first objective is CAD modeling, the 3D printed parts will be designed and measured carefully to fit with the drone’s frame. The second objective is the wiring diagram and PCB design, the electronics component will need to be carefully compared with their datasheet for correct pinouts. Correct wiring will allow the electronics component to work safely and normally. Finally, the objective is a step-by-step assembly guide to ensure correct component installation and PCB soldering.

4.1.1. CAD modeling

The first step to develop a drone is CAD modeling, the 3D model created on SolidWorks will be used to visualize the final drone in real life. The design of the drone model will affect the dynamic of the drone while flying or balancing, so it is important to finalize the design before working on other tasks.

4.1.1.a. Drone Frame

Figure 1. True-X drone frame [1]

There are many different types of drone frames and each type of frame suits different needs. For example, the H frame will have more space to install electronics components but due to the high moment of inertia design, the movement of the drone will be less flexible. After considering many different frame types, the team decided to use the True-X frame which means that the distance between each motor will be the same and the distance from the motors to the center of the drone will also be the same [4]. This design will be the most suitable for the time constraints of the project because it will ensure the centroid of the drone is in the center and the precision of the data from the IMU, as well as simplify the process of calibrating the PID controller.

4.1.1.b. Motor mount

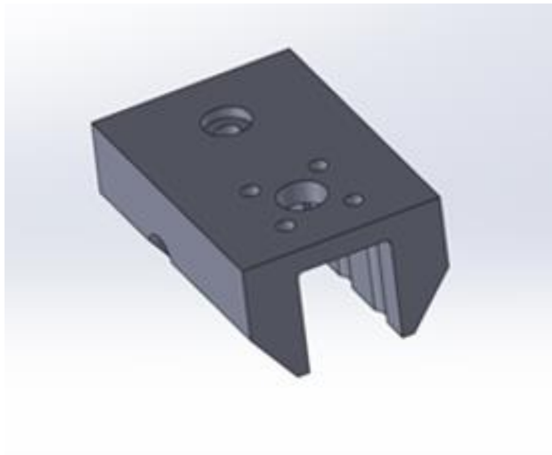


Figure 2. Motor mount CAD model

The fundamental design requirement of the project is the mounts for four brushless motors. The motor mount is the 3D-printed part used as a secure and stable platform for mounting the brushless motor onto the wood beam. The CAD design of the motor mount can hold the motor by using four small bolts and attaching them to the drone's beam without any swaying. Moreover, it fits the beam with a small tolerance. For these reasons, the design has successfully achieved the WP1 objectives.

4.1.1.c. Landing Gear

Figure 3. Landing gear CAD model

Drone legs, also known as landing gear, are used to give the drone a softer landing and protect the components on the drone from impact. It also elevates the drone from the ground to avoid damage if the drone takes off in an unbalanced position. The landing gear design is an enhancement outside of the initial scope of the WP1.

4.1.1.d. Controller CAD modeling

Another achievement from the proposed WP1 is the controller CAD model. The idea of a case for the controller comes up from the question of how to handle the controller's modules with ease and protect the wire connections while using it. The controller modules to control the drone are three buttons, a potentiometer, and a joystick. Each module has its own functionality, and the CAD model is designed to give better access and protection for these components.

- **Top case design:** The top case design included extruded cut holes for three red buttons, one potentiometer, one joystick, and one power supply for the ESP32. Each extruded cut hole is customized for its functionality. The joystick's hole is round, and the size is big enough for the joystick to move freely in all directions. Furthermore, the potentiometer's hole is designed into a round end rectangle to fit with its shape. In addition, the square holes for three red buttons are implemented so it does not obstruct when pressing the buttons. Finally, a power supply hold is used for a USB cable to connect with the ESP32 inside the controller.

Figure 4. Controller top case CAD model

- **Bottom case design:** The bottom case is designed to be a flat plate with four bolt holes in four corners and an extruded rectangle to mount the joystick. It will cover the components inside the controller case and protect them from external forces. This part is made with precise dimensions to fit with the top case.

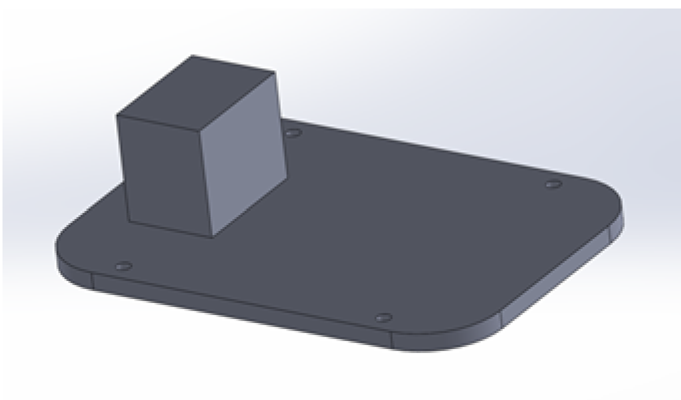


Figure 5. Controller bottom case CAD model

4.1.2 System Wiring and PCB design.

Printed Circuit Boards (PCB) are platforms for the assembly of electronic components, customized to fit the design requirements. PCB is important for drone systems because it provides efficient connection between components and compact design for the performance of the done. Most importantly, PCBs are designed to ensure signal integrity by reducing electromagnetic interference and maintaining a reliable connection.

4.1.2.a. Drone schematic system

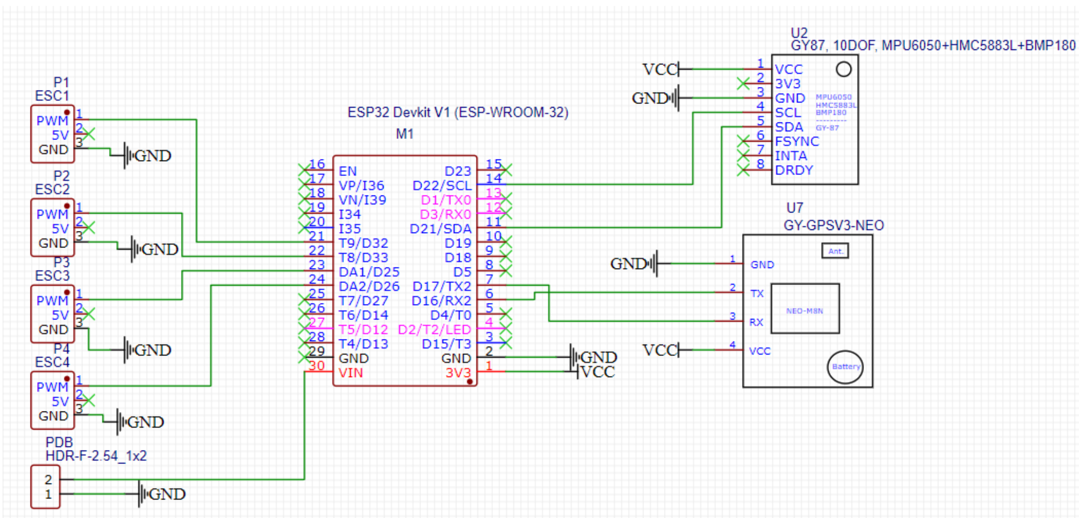


Figure 6. Schematic diagram of the drone's PCB

According to the WP1 objectives of wiring diagram and PCB design, the first deliverable is read the components datasheets and decide the correct footprint. In this project, the team has successfully researched and corrected wiring following each module pinouts. Using the information from datasheet, the wiring diagram for the drone can be created. The Power Distribution Board plays a role in distributing voltage from Lipo battery to four ESCs and provides a regulated 5.0 +/- 0.1VDC output voltage to the ESP32 through the VIN pin. Next, the four brushless Electronic Speed Controllers control the speed of the drone's motor, the Pulse Width Modulation pin of ESCs will connect to ESP32 digital pins T9/D32, T8/D33, DA1/D25, DA2/D26. This connection allows the ESP32 microcontroller to send a PWM signal to the ESC microcontroller. Additionally, the sensor MPU6050 can measure angle velocity and acceleration, it works on 3.3V power supply voltage so it VCC pin connects to the ESP32 3V3 pin [5] The MPU 6050 uses pin SCL for the clock and SDA for data transmission information, so they are connected with pin D22/SCL and D21/SDA of the ESP32 respectively. Finally, the GPS NEO8M can determine the drone's actual location based on satellite signal, it also works on 3.3V power supply and connect its VCC pin to the ESP32 3V3 pin. The pin connection between GPS NEO8M and the ESP32 is a bit non-intuitive, the GPS's RX pin is connected to pin D17/TX2 of the ESP32, and the GPS's TX pin is connected to pin D16/RX2 of the ESP32.

4.1.2.b. Drone's PCB

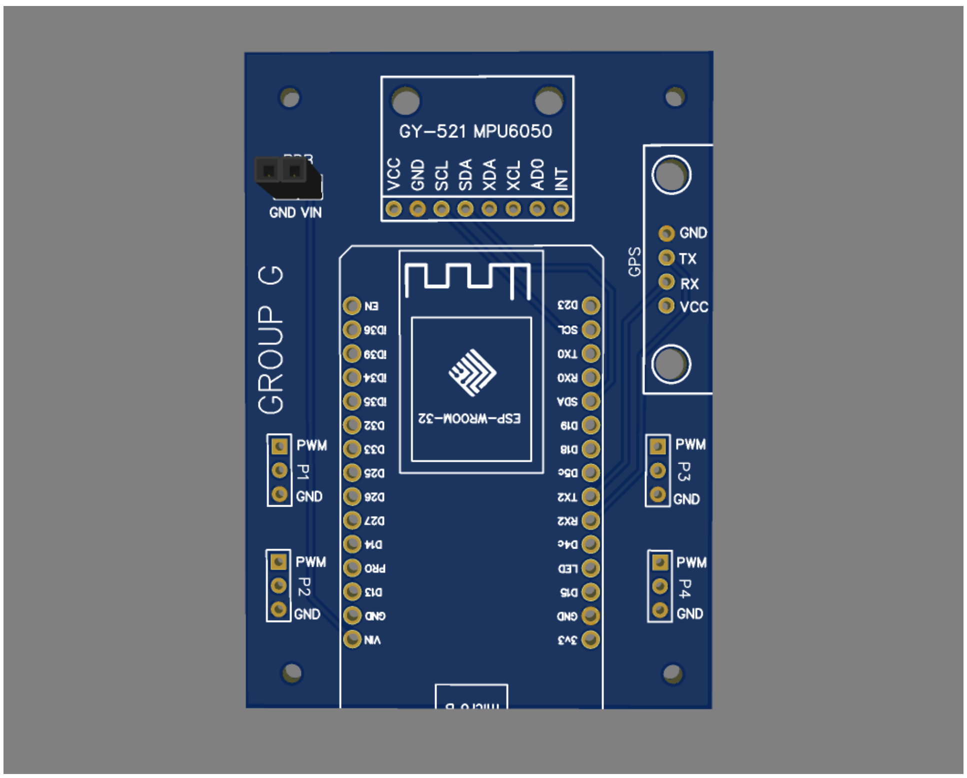


Figure 7. 3D rendering of the drone's PCB design

In the WP1 proposal, the PCB will be designed using easyEDA and design-appropriate routing. For the drone PCB, the team has completed the requirements for PCB design, but the footprint for the IMU is incorrect, so the team decided to solder the modules onto a prototype board. The achievements in the PCB design of the team are accordingly. First, the position of each module is placed with a specific purpose and keeps the design as symmetrical as possible. For instance, the MPU is designed to be placed at the center of the drone. At this position, the 3-axis gyroscope and the 3-axis accelerometer inside it can avoid uneven data of orientation measurement in all directions. Additionally, four ESCs are placed on both sides of the ESP32 to keep the design symmetrical and connect wiring according to coding pins. Secondly, the drone PCB needs to be small to reduce its weight and trace length, which will decrease the effects of signal degradation, noise, or interference. The ESP32 is positioned in the middle of the PCB to minimize its trace length to other modules with the USP port facing outward to make it easier for coding. In addition, the GPS orientation needs to be flat and facing upward to the sky, because the antenna is on the top side of the GPS and this orientation will help the GPS to pick up satellite signal. The power supply 5V from the PDB is kept close to the ESP32 to minimize the risk of voltage drops. Lastly, the copper area under the modules helps maintain signal integrity between modules and ESP32.

4.1.3. Detailed step-by-step assembly guide

From the proposal WP1 deliverables, the drone frame has been put together according to the CAD assembly model. However, one drawback is the components cannot be soldered onto the PCB because the footprint of the IMU is incorrect. So, the group decided to solder the modules onto the prototype board.

4.1.3.a. Drone frame assembly

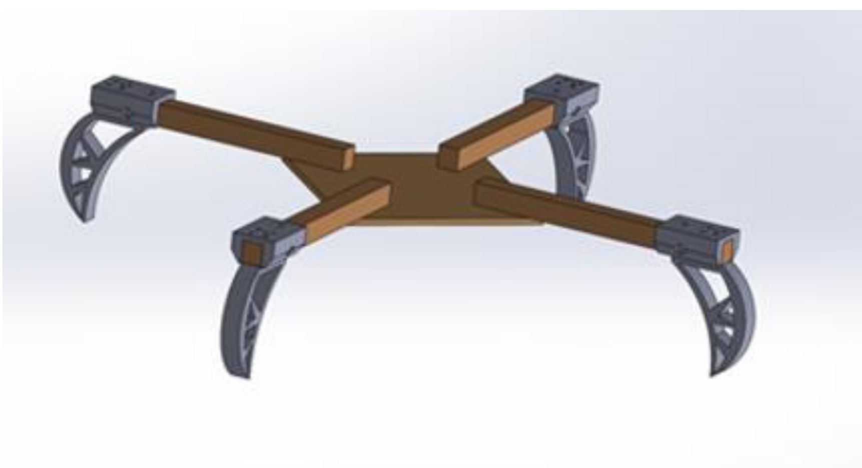


Figure 8. CAD assembly model of the drone’s frame

This is the CAD model of the drone frame and the 3D-printed parts after the assembly process. It consists of a wood plate, a Mica plate, four wood beams, four motor mounts, and four landing gears. The drone wood frame will be assembled with two M4X20mm wood screws for each wood beam and the position of four beams will be carefully placed according to the True-X frame design. Then, each landing gear will be attached at the end of each beam bottom by using two wood screws, and each motor mount will be mounted on top of each beam end with one wood screw on top and one wood screw to the side. The improvement from the initial design is the Mica plate, used as a top plate for the drone frame. The clear Mica plate will provide a better vision to observe the inside components, making it easier to repair.

4.1.3.b. Controller assembly

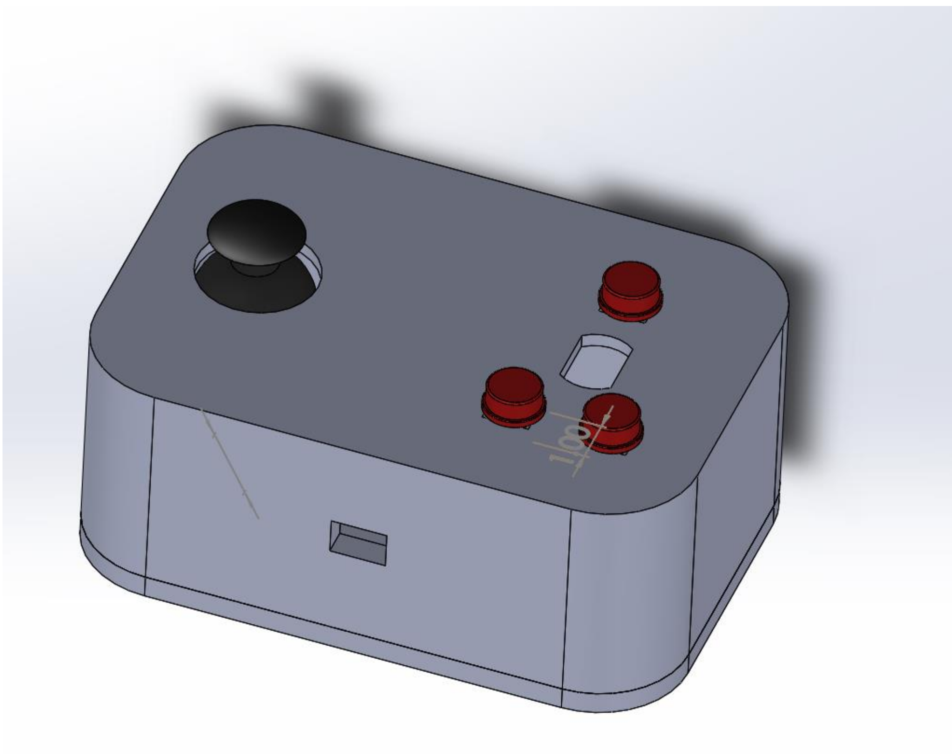


Figure 9. CAD assembly model of the controller

This is the assembled CAD model of the remote controller. The assembly process includes gluing the potentiometer and buttons onto their designed holes, then the joystick will be glued to the extruded rectangle inside the bottom case. Then, connect the wiring inside with the EPS32 on the prototype board and cover it with the bottom case where four bolts are used to fix the top case to the bottom case at corner holes.

4.1.3.c. PCB soldering

For the soldering on the prototype board, it follows a step-by-step process. First, the female connectors are soldered onto the board according to the footprint placement. Then, solder all connections following the module's correct pinouts with wires. And lastly, the modules can be attached and removed easily through the female connectors without soldering their pins into the board.

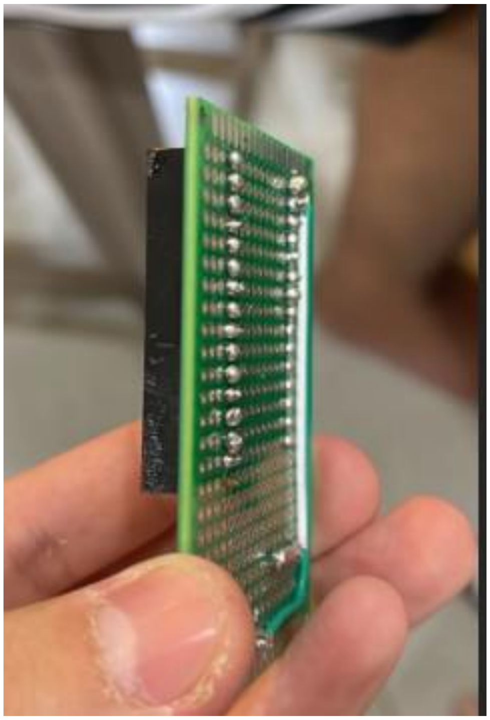


Figure 10. Soldered female connectors and wires on prototype board

4.2. Work package 2: Unit testing

4.2.1. Objectives

The three main goals of Work Package 2 (WP2) are the focus of attention. First of all, the remote control system's design is carefully thought out to guarantee smooth and effective functioning. This entails giving functional features and user interface components considerable thought.

Second, the driving unit's calibration and operation are highlighted, highlighting accuracy and dependability in its operation. Strict validation and testing protocols are put in place to ensure peak operation. Last but not least, the sensors are carefully tested and validated, with independent evaluations conducted on each part prior to integration. By following a methodical approach, all components are guaranteed to fulfill their assigned requirements, resulting in a well-functioning and unified system.

4.2.2. Design of the remote controller for the drone

4.2.2.a. Components knowledge researching

Before implementing the WP2 process, gaining a well-prepared information is extremely significant. The architecture of the drone includes all of the necessary parts that are needed for it to function flawlessly. The user interface is the remote controller, which has a potentiometer, push button, and joystick for accurate and user-friendly operation. The drone's power and maneuverability are provided by the driving unit, which consists of a motor, propeller, ESC, and battery. Ensuring proper operation of each component requires meticulous testing on an individual basis. Furthermore, the sensors which include a GPS and an inertial measurement unit (IMU) - are essential for stability and navigation. Extensive testing of these sensors guarantees precise gathering of data. The integration procedure doesn't start until all the separate assessments are finished, which guarantees a harmonious synergy between all the components for the drone's overall performance and efficiency.

To control the drone's roll and pitch, the remote controller is based on a joystick (type PS2) and for controlling the velocity two buttons are utilized. In addition, there is a potentiometer (MTS-103) for controlling the thrust of the drone.

4.2.2.b. Design of the remote controller

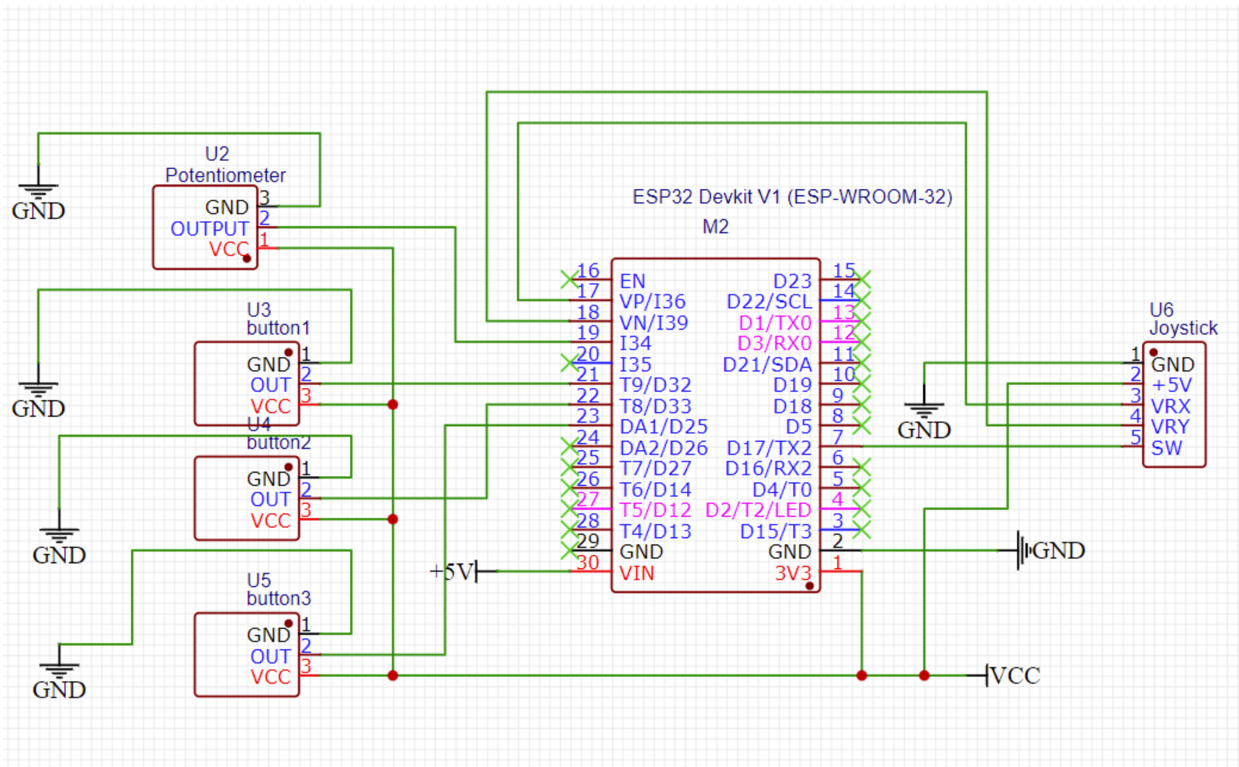


Figure 11. PCB remote controller schematic

The ESP32 must have all four components—three buttons, a joystick, a potentiometer, and a precise connection to the right pins—wired to a PCB. First, find out what pins are on your ESP32 development board. GPIO, 3.3V, GND, and analog pins are usually on the pinout. To ensure stability, connect the buttons to the GPIO pins using pull-up or pull-down resistors. Attach the button to a digital GPIO pin on the joystick and link the X and Y outputs to different analog pins. In a similar manner, connect the potentiometer to an ESP32 analog pin. Make that the 3.3V and GND pins on the ESP32 are connected to the power source correctly. Make sure voltage levels meet ESP32 standards and design the wiring to reduce interference.

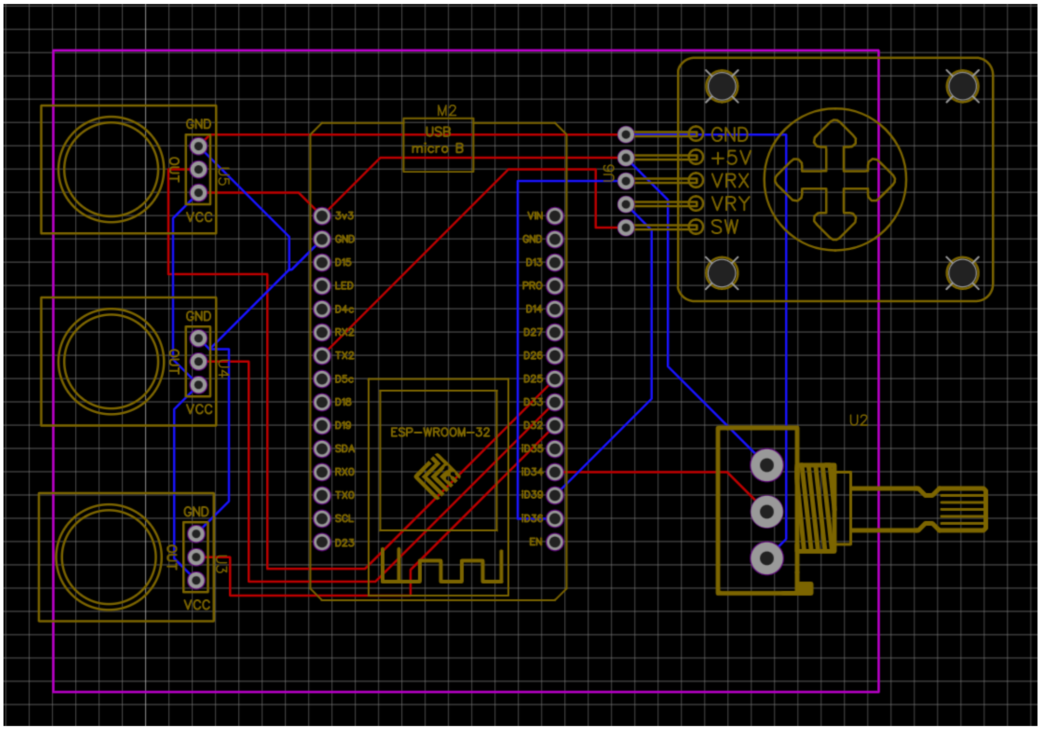


Figure 12. PCB remote control 3D sketch

4.2.3. Calibration and functioning of the driving unit

In the intricate system that propels the drone, the manipulation of propellers for directional control is orchestrated by motors. The speed of these motors is finely tuned using an electronic component known as an Electronic Speed Controller (ESC). The ESC acts as a crucial intermediary, connecting the battery and the microcontroller. The microcontroller, responsible for transmitting speed commands to the ESC, plays a pivotal role in directing the drone's movements. However, before integration into the broader drone framework, it is imperative that the ESC undergoes a meticulous calibration process. This calibration ensures that the ESC operates within its entire range of functionality, laying the foundation for precise motor control. As part of their learning journey, students are tasked with mastering the control of a single driving unit, comprising a propeller, motor, ESC, and battery, before progressing to the complex orchestration of four such units in unison for the comprehensive control of the drone. This stepwise approach ensures a solid understanding and proficiency in handling individual components before tackling the intricacies of the complete drone system.

4.3. Work package 3: Control and validation of the drone

WP3 is divided into three objectives. The first objective is PID tuning of the drone's pitch and roll, the objective is to control the speed of each motor by implementing the PID controller. The second objective is safety implementation for the drone emergency stop, the implementation will help with safety in case the drone loses control. Finally, establishing a reliable remote control of the drone will allow the user to wirelessly control the drone's movement. Unfortunately, we did not work on the drone software so there will not be any code for PID controller setting or remote controller programming code.

4.3.1 PID tuning of the drone for the pitch and the roll

The PID controller is implemented into the data obtained from the IMU orientation. This will allow the PID controller to control brushless motor speeds. The goal here is to set the PID values so that the system will behave faster with less error when it tries to control the IMU data back to setpoint [6] The proportional (P), integral (I), and derivative (D) can be calibrated according to the desired step response, step response is the system's behavior with respect to time.

Parameter	Rise time	Overshoot	Settling time	Steady-state error	Stability
K_p	Decrease	Increase	Small change	Decrease	Degrade
K_i	Decrease	Increase	Increase	Eliminate	Degrade
K_d	Minor change	Decrease	Decrease	No effect in theory	Improve if K_d small

Figure 13. The effects of changing PID parameters to the step response [7]

The group's prototype drone PID did not work properly because the team used regular PID control instead of Cascade PID control which can help the system respond faster in rejecting disturbance [8].

4.3.2. Safety implementation for the drone emergency stop

The drone emergency stop has been implemented into the drone system and the controller. Both the switch on the drone and the emergency stop button on the controller can cut off the power supply from the battery to four motors.

Figure 14. The emergency switch on drone

4.3.3 Establish a reliable remote control of the drone

The drone's remote control has worked successfully. It can send a signal to the drone and control brushless motor speeds for roll, pitch and yaw movement of the drone. Moreover, the controller can control the drone's thrust with a potentiometer for drone elevation.

4.3.4 Visualize the PID through Matlab

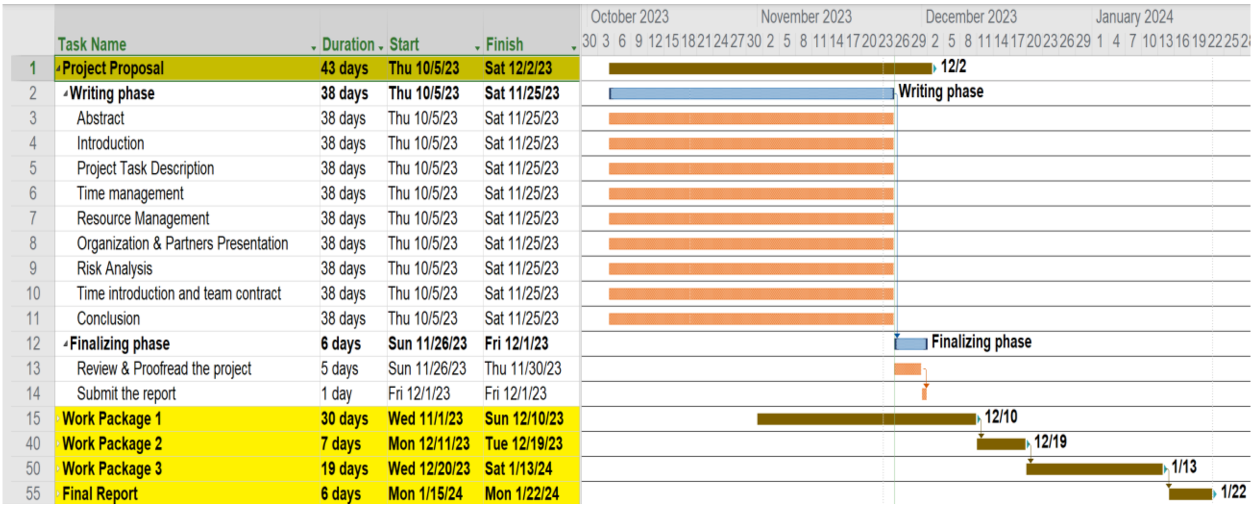
```
% Define PID Controller parameters
Kp = 1;    % The proportional gain
Ki = 0.1;  % The integral gain
Kd = 0.01; % Th derivative gain

% Write a PID controller code
pidController = pid(Kp, Ki, Kd);

% Define the system transfer function
numerator = 1;
denominator = [1, 2, 1]; % Example: s^2 + 2s + 1

% Create a transfer function for the system
system = tf(numerator, denominator);

% Connect the PID controller to the system
sysWithController = series(pidController, system);

% Create a feedback loop
closedLoopSys = feedback(sysWithController, 1);

% Plot the step response
step(closedLoopSys);
title('Step Response of System with PID Controller');
xlabel('Time');
ylabel('Amplitude');
grid on;
```

Figure 15. Matlab code for PID visualization

First of all, we must define the value of Proportional (Kp), Integral (Ki), and Derivative (Kd) gains for the PID controller. Then the given proportional, integral, and derivative gains are used to instantiate the PID controller object. After that, defining numerator and denominator is extremely significant. The plant's or system's transfer function is established in this section. The transfer function of the plant has a numerator of 1 and a denominator of [1, 2, 1], which suggests that the system is second-order. Finally, using command loop and the plot x and y for creating a close loop graph.

5. Time Management

5.1. The Project Proposal Stage



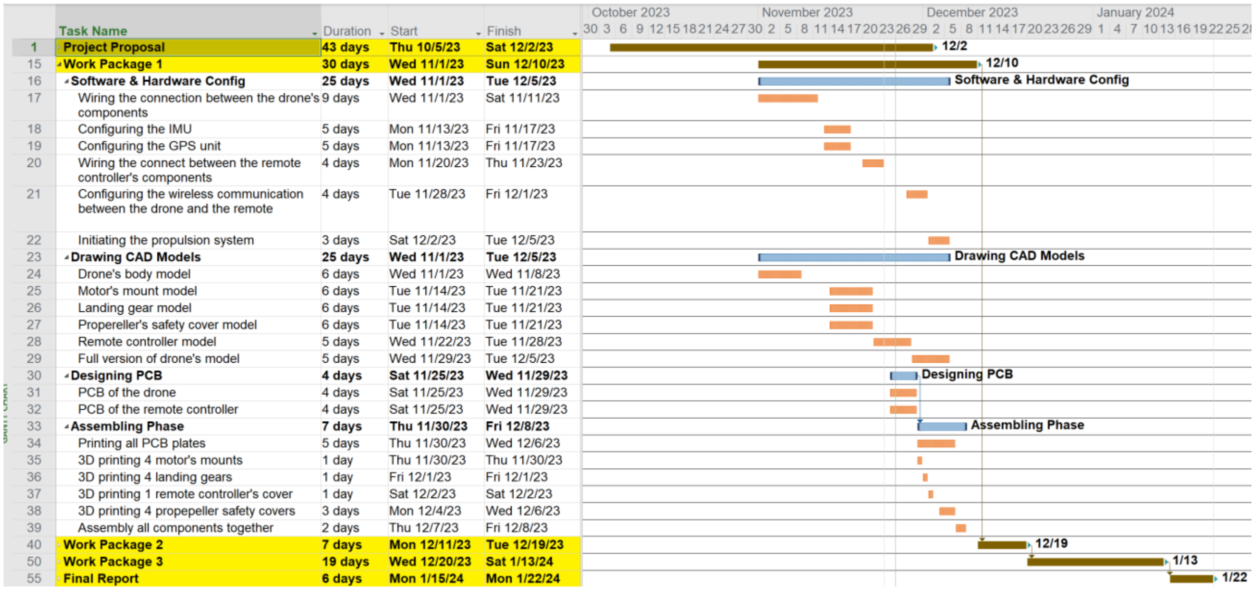
	Task Name	Duration	Start	Finish
1	Project Proposal	43 days	Thu 10/5/23	Sat 12/2/23
2	Writing phase	38 days	Thu 10/5/23	Sat 11/25/23
3	Abstract	38 days	Thu 10/5/23	Sat 11/25/23
4	Introduction	38 days	Thu 10/5/23	Sat 11/25/23
5	Project Task Description	38 days	Thu 10/5/23	Sat 11/25/23
6	Time management	38 days	Thu 10/5/23	Sat 11/25/23
7	Resource Management	38 days	Thu 10/5/23	Sat 11/25/23
8	Organization & Partners Presentation	38 days	Thu 10/5/23	Sat 11/25/23
9	Risk Analysis	38 days	Thu 10/5/23	Sat 11/25/23
10	Time introduction and team contract	38 days	Thu 10/5/23	Sat 11/25/23
11	Conclusion	38 days	Thu 10/5/23	Sat 11/25/23
12	Finalizing phase	6 days	Sun 11/26/23	Fri 12/1/23
13	Review & Proofread the project	5 days	Sun 11/26/23	Thu 11/30/23
14	Submit the report	1 day	Fri 12/1/23	Fri 12/1/23
15	Work Package 1	30 days	Wed 11/1/23	Sun 12/10/23
40	Work Package 2	7 days	Mon 12/11/23	Tue 12/19/23
50	Work Package 3	19 days	Wed 12/20/23	Sat 1/13/24
55	Final Report	6 days	Mon 1/15/24	Mon 1/22/24

The process of the Project Proposal begins at the start of the project on October 5th and is scheduled to last until December 2nd. However, our team aims to complete the writing phase by November 25th. Following the project description's release, we assigned all tasks related to the Proposal and all team members are expected to contribute to this process. The Project Proposal is divided into 9 distinct tasks, as illustrated in the Gantt chart above, and these tasks have been evenly distributed among the 6 group members.

The most significant parts of the Project Proposal are the Project Task Descriptions and Time Management. The project includes 3 Work Packages (WPs), with each pair of team members responsible for one. The Task Description's importance lies in its role in guiding our research and defining requirements clearly, which helps us gain a comprehensive understanding of the project. This understanding is crucial for effectively working on the 3 WPs after completing the Proposal. Time Management is another critical component, providing a timeline of tasks that helps readers and team members understand the workflow and adhere to deadlines.

Finally, we will enter the Finalizing phase, which spans 6 days from November 26th to December 1st. During this stage, we will hold an online meeting on November 30th to review and proofread the entire Project Proposal thoroughly before its submission on the following day.

5.2. The WP1 Stage



	Task Name	Duration	Start	Finish
1	**Project Proposal**	**43 days**	**Thu 10/5/23**	**Sat 12/2/23**
15	**Work Package 1**	**30 days**	**Wed 11/1/23**	**Sun 12/10/23**
16	**Software & Hardware Config**	**25 days**	**Wed 11/1/23**	**Tue 12/5/23**
17	Wiring the connection between the drone's components	9 days	Wed 11/1/23	Sat 11/11/23
18	Configuring the IMU	5 days	Mon 11/13/23	Fri 11/17/23
19	Configuring the GPS unit	5 days	Mon 11/13/23	Fri 11/17/23
20	Wiring the connect between the remote controller's components	4 days	Mon 11/20/23	Thu 11/23/23
21	Configuring the wireless communication between the drone and the remote	4 days	Tue 11/28/23	Fri 12/1/23
22	Initiating the propulsion system	3 days	Sat 12/2/23	Tue 12/5/23
23	**Drawing CAD Models**	**25 days**	**Wed 11/1/23**	**Tue 12/5/23**
24	Drone's body model	6 days	Wed 11/1/23	Wed 11/8/23
25	Motor's mount model	6 days	Tue 11/14/23	Tue 11/21/23
26	Landing gear model	6 days	Tue 11/14/23	Tue 11/21/23
27	Propereller's safety cover model	6 days	Tue 11/14/23	Tue 11/21/23
28	Remote controller model	5 days	Wed 11/22/23	Tue 11/28/23
29	Full version of drone's model	5 days	Wed 11/29/23	Tue 12/5/23
30	**Designing PCB**	**4 days**	**Sat 11/25/23**	**Wed 11/29/23**
31	PCB of the drone	4 days	Sat 11/25/23	Wed 11/29/23
32	PCB of the remote controller	4 days	Sat 11/25/23	Wed 11/29/23
33	**Assembling Phase**	**7 days**	**Thu 11/30/23**	**Fri 12/8/23**
34	Printing all PCB plates	5 days	Thu 11/30/23	Wed 12/6/23
35	3D printing 4 motor's mounts	1 day	Thu 11/30/23	Thu 11/30/23
36	3D printing 4 landing gears	1 day	Fri 12/1/23	Fri 12/1/23
37	3D printing 1 remote controller's cover	1 day	Sat 12/2/23	Sat 12/2/23
38	3D printing 4 propepeller safety covers	3 days	Mon 12/4/23	Wed 12/6/23
39	Assembly all components together	2 days	Thu 12/7/23	Fri 12/8/23
40	**Work Package 2**	**7 days**	**Mon 12/11/23**	**Tue 12/19/23**
50	**Work Package 3**	**19 days**	**Wed 12/20/23**	**Sat 1/13/24**
55	**Final Report**	**6 days**	**Mon 1/15/24**	**Mon 1/22/24**

Work package one, which consists of four smaller jobs (Software and Hardware Configuration, Drawing CAD, Designing PCB, and Assembling phase), begins during the proposal stage. By December 10th, all the subtasks need to be completed. We primarily concentrate on the hardware and software components of the first work package, which is divided to work with the microcontroller, sensors, and modules as shown below:

• Setting up the IMU.

• Setting up the GPS device.

• Setting up the drone and remote's wireless connectivity.

Hardware's task focuses on the following listed aspects:

• Connecting every component.

• Creating and sketching CAD models of the drone's body, motor mount, landing gear, remote control, and entire frame.

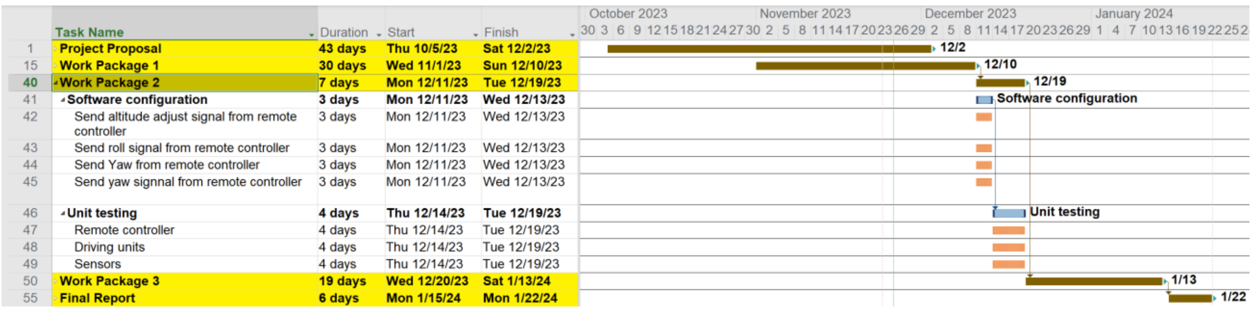
• Creating the controller and drone's PCB.

• Printing 3D objects

• The complete assembly of the parts.

The hardware and software duties are split up among personnel who have completed similar jobs in the past or who are capable of conducting the necessary research. Should any of the jobs exceed their scope, the remaining team members who have completed their duties already need to be prepared to tackle the issue as a whole.

5.3. The WP2 Stage



	Task Name	Duration	Start	Finish
1	Project Proposal	43 days	Thu 10/5/23	Sat 12/2/23
15	Work Package 1	30 days	Wed 11/1/23	Sun 12/10/23
40	Work Package 2	7 days	Mon 12/11/23	Tue 12/19/23
41	Software configuration	3 days	Mon 12/11/23	Wed 12/13/23
42	Send altitude adjust signal from remote controller	3 days	Mon 12/11/23	Wed 12/13/23
43	Send roll signal from remote controller	3 days	Mon 12/11/23	Wed 12/13/23
44	Send Yaw from remote controller	3 days	Mon 12/11/23	Wed 12/13/23
45	Send yaw signnal from remote controller	3 days	Mon 12/11/23	Wed 12/13/23
46	Unit testing	4 days	Thu 12/14/23	Tue 12/19/23
47	Remote controller	4 days	Thu 12/14/23	Tue 12/19/23
48	Driving units	4 days	Thu 12/14/23	Tue 12/19/23
49	Sensors	4 days	Thu 12/14/23	Tue 12/19/23
50	Work Package 3	19 days	Wed 12/20/23	Sat 1/13/24
55	Final Report	6 days	Mon 1/15/24	Mon 1/22/24

Work Package 2 (WP2) of our project is expected to begin following the completion of Work Package 1's last job. December 11, 2023, is when the WP2 starts, and it ends on December 19, 2023. The design of the remote control, the calibration and operation of the driving unit, and the testing and validation of the sensors are the three milestones that make up the stage. It is essential to reach each milestone before going on to the next. At this point, the work is split into hardware and software components.

Regarding the software side, we concentrate on receiving the data generated from the sensors and implementing the remote control's code. The software implementation has four primary goals:

• Using the remote control, send the attitude to change the signal.

• Using the remote control, transmit the roll angle signal.

• Using the remote control, send the yaw angle signal.

• Use the remote control to send the pitch angle signal.

Unit testing of each component prior to assembly is required after hardware setup. Three benchmarks will be completed for unit testing:

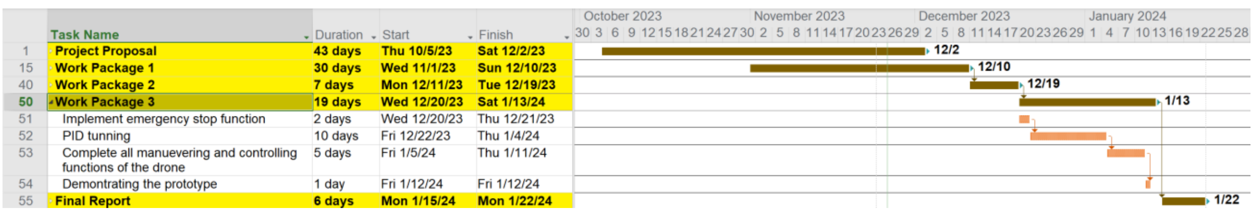
• Examine and confirm the remote control.

• Verify and test the driving unit.

• Verify and test the sensors.

Depending on their particular area of expertise and the demands of the jobs, certain individuals will be given specialized small assignments. The Task explanation section contains a full explanation of the task. This strategy makes use of the many experiences and backgrounds of our team to make sure that the best qualified people are in charge of every facet of WP2.

5.4. The WP3 Stage



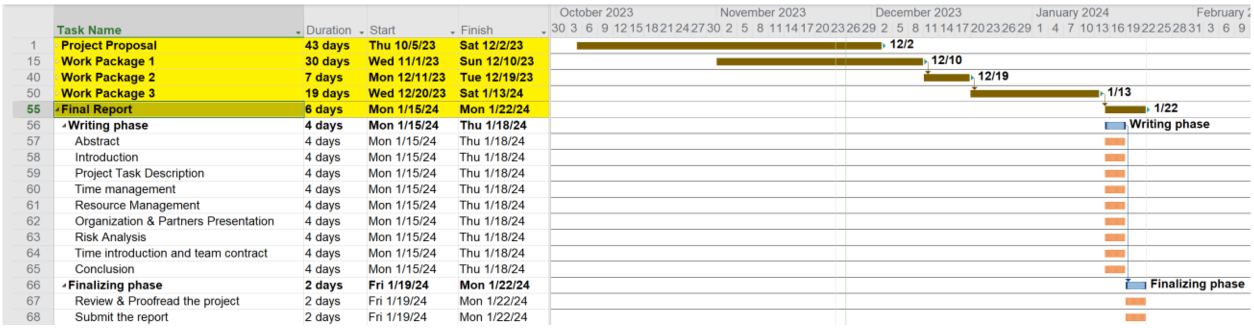
	Task Name	Duration	Start	Finish
1	Project Proposal	43 days	Thu 10/5/23	Sat 12/2/23
15	Work Package 1	30 days	Wed 11/1/23	Sun 12/10/23
40	Work Package 2	7 days	Mon 12/11/23	Tue 12/19/23
50	Work Package 3	19 days	Wed 12/20/23	Sat 1/13/24
51	Implement emergency stop function	2 days	Wed 12/20/23	Thu 12/21/23
52	PID tunning	10 days	Fri 12/22/23	Thu 1/4/24
53	Complete all manuevering and controlling functions of the drone	5 days	Fri 1/5/24	Thu 1/11/24
54	Demontrating the prototype	1 day	Fri 1/12/24	Fri 1/12/24
55	Final Report	6 days	Mon 1/15/24	Mon 1/22/24

In this project stage, we will be working on WP3, which is scheduled to start immediately on December 20 after the completion of WP2. The deadline for WP3 is set for January 13th, providing a total time duration of more than two weeks (19 days). This stage is divided into four key phases:

- Implementing the emergency stop function.
- Tuning the PID (Proportional-Integral-Derivative) controller.
- Completing all maneuvering and controlling functions of the drone.
- Demonstrating the prototype.

Work Package 3 is an important stage in this project, focusing primarily on drone control and validation. The primary goal is to successfully integrate individual components into the final drone design, addressing challenges such as PID tuning, wiring errors, and assembly adaptations. Among the key deliverables are a finely tuned PID controller, safety measures for emergency stops, and the capability to control the drone across various degrees of freedom for testing purposes.

5.5. The Final Report



	Task Name	Duration	Start	Finish
1	**Project Proposal**	**43 days**	**Thu 10/5/23**	**Sat 12/2/23**
15	**Work Package 1**	**30 days**	**Wed 11/1/23**	**Sun 12/10/23**
40	**Work Package 2**	**7 days**	**Mon 12/11/23**	**Tue 12/19/23**
50	**Work Package 3**	**19 days**	**Wed 12/20/23**	**Sat 1/13/24**
55	**Final Report**	**6 days**	**Mon 1/15/24**	**Mon 1/22/24**
56	**Writing phase**	**4 days**	**Mon 1/15/24**	**Thu 1/18/24**
57	Abstract	4 days	Mon 1/15/24	Thu 1/18/24
58	Introduction	4 days	Mon 1/15/24	Thu 1/18/24
59	Project Task Description	4 days	Mon 1/15/24	Thu 1/18/24
60	Time management	4 days	Mon 1/15/24	Thu 1/18/24
61	Resource Management	4 days	Mon 1/15/24	Thu 1/18/24
62	Organization & Partners Presentation	4 days	Mon 1/15/24	Thu 1/18/24
63	Risk Analysis	4 days	Mon 1/15/24	Thu 1/18/24
64	Time introduction and team contract	4 days	Mon 1/15/24	Thu 1/18/24
65	Conclusion	4 days	Mon 1/15/24	Thu 1/18/24
66	**Finalizing phase**	**2 days**	**Fri 1/19/24**	**Mon 1/22/24**
67	Review & Proofread the project	2 days	Fri 1/19/24	Mon 1/22/24
68	Submit the report	2 days	Fri 1/19/24	Mon 1/22/24

Although this last phase of the project is similar to the first (creating the proposal), it calls for more precise information and system specifications. The deadline for this phase is scheduled for January 21st, which is six days from January 15th. The Writing and Finalizing phases, which take four and two days, respectively, are the two milestones. Tasks in the Writing phase include parts like the Abstract, Introduction, Project Task Description, Time Management, Resource Management, Organization & Partners Presentation, Risk Analysis, and Conclusion, much like in the Proposal.

The report's objective is to gather and condense all project data. This level promotes the capacity to cooperatively design and construct a working product prototype and places an emphasis on efficient time management, both individually and as a team. By using their foundational engineering knowledge, participants are encouraged to consider both their technical and non-technical learning experiences. After that, the report is given to academics, industry experts, and peers, demonstrating the broad range of abilities developed during the project.

6. Resources Management

The WP1 Bill of Materials

Item Name	Description	Quantity	Total Price (VND)

ESP32	A flexible microcontroller and system-on-a-chip (SoC) made for Internet of Things applications is the ESP32. Due to its dual-core CPU, built-in Bluetooth and Wi-Fi, assortment of peripherals, low power consumption, and security features, it is well-liked for a variety of electrical projects. It is extensively used in applications like as industrial IoT and home automation, and is compatible with the Arduino IDE. It also receives good support.	2	158,000
Breadboard	A small breadboard to make the circuit.	1	20,000
Wood beams and plates	The frame of the drone	6	30,000
Mica plate 20 x 20cm	A transparent Mica top plate for drone	1	25,000
Lipo_Battery for Drone	The supplied power	1	473,000
Lipo_Battery for controller	The supplied power for remote control.	1	23,000
ESC	Electronic speed controllers, or ESCs, are essential parts of electronic control systems, especially when it comes to drones and remote-controlled cars. By modifying the electrical pulses delivered to electric motors, it controls their direction and speed. Brushless motors and ESCs are often used to regulate propulsion in various applications, including RC automobiles, aircraft, watercraft, and drones with quadcopters.	4	290,000
PDB	Power Distribution Boards, or PDBs, are crucial parts of electrical systems, especially those involving multirotor aircraft like drones. It effectively transfers power from the primary battery to a range of electrical parts, including attachments, flight controls, and	1	68,000

	motors. PDBs simplify system wiring and power management by including functions like voltage control, current monitoring, and occasionally built-in connections.		
Lipo Battery charger	Drone and controller battery charger.	1	359,000

Table 1. Bill of materials of the work package 1.

The bill of materials for WP1 have been added with a 20x20cm Mica plate to replace the top wood plate.

6.1. The WP2 Bill of Materials

Item Name	Description	Quantity	Total Price (VND)
PCB printing	The process of creating printed circuit boards, which are crucial parts of electronics, is known as PCB printing. It is the process of establishing conductive channels on a non-conductive substrate, which serves as the framework for different kinds of electronic circuits.	5	80,000
Red button	Using for adjusting the yaw rate angle.	2	16,000
Joystick	The joystick controls the roll and pitch rate of the drone.	1	17,000
Switch button	A basic electrical component used to regulate the passage of electricity via a circuit is a switch button. Usually, it is made out of a mechanism that, when pressed or toggled, opens or shuts the circuit. Switch buttons serve as a user-operated on/off switch and are frequently used in appliances and electronic gadgets to activate or inhibit particular functionalities.	2	8,000
PLA material for 3d printing	It is commonly used in 3D printing and is referred to as polylactic acid. It is an eco-friendly	1	310,000

	substance that provides the industry with excellent 3D printing.		
USB_C cable	Transmission wire between the ESP and laptop.	2	134,000
Brushless Motors	A brushless motor to be mounted on the drone's frame.	4	360,000
Potentiometer	Control the thrust level of the drone.	1	2,500
Propellers	The drone's propeller	4	38,000

Table 2. Bill of materials of the work package 2.

The PCB quantity is 5 because that is the minimum amount required for manufacturing.

6.2. The WP3 Bill of Materials

Item Name	Description	Quantity	Total Price (VND)
MPU6050	A single integrated circuit houses both an accelerometer and gyroscope in the MPU6050, a small motion-tracking gadget. It was created by InvenSense and is frequently used in electronic applications to detect and measure angular velocity, acceleration, and direction. Because of its tiny size, precision, and capacity to deliver real-time motion data, the MPU6050 is extensively used in a variety of applications, such as robots, drones, and motion-sensing devices.	1	27,500
Red button	A red button to stop the drone.	1	8,000
GPS NEO8M with ceramic antenna	The drone's altitude, longitude, and latitude are sent via the sensor.	1	242,000

Table 3. Bill of materials of the work package 3.

6.3. The Total Bill of Materials

No. Of Work Package	Items	Total cost (VND)
Work Package 1	9 items	1,446,000
Work Package 2	9 items	965,500
Work Package 3	3 items	277,500
All of Work Package	20 items	2,690,000

Table 4. Total cost of the project.

7. Risk Assessment

	Likelihood				
	1	2	3	4	5
Risk probability	Rare	Unlikely	Possible	Likely	Certain
Risk impact	Insignificant	Minor	Moderate	Major	Catastrophic

Overall Risk Scale		
Below 5	From 5 – 7	Over 8
Minor	Moderate	Require attention and risk mitigation

Internal Risks

Risk Description	Risk Probability	Risk Impact	Overall Score	Mitigation
Data Security and Privacy Concerns	2	3	6	Drones collecting and analyzing sensitive data during surveillance flights require strong encryption techniques and safe storage procedures to prevent internal attacks and guarantee data integrity.

Technical Challenges	4	4	16	Including the smooth integration of cameras, sensors, and algorithms, with a focus on subsystem coordination and communication to avert system malfunctions and guarantee steady flight performance.
User Interface and Remote Control Reliability	3	4	12	Software problems and interface issues, through rigorous testing, continuous observation, and iterative changes.
Testing and Calibration Issues	4	4	16	Including as software bugs, autonomous capability validation, and sensor calibration problems, therefore averting possible threats to safety and operation in real-world situations.
Complex Navigation Algorithms	3	2	6	Potential errors in the interpretation of sensor data and discrepancies in the execution of flight plans.
Battery life and power management	2	2	4	Power spikes, distribution problems, and battery deterioration, through extensive testing, ongoing monitoring, and iterative changes in order to ensure the reliability and success of a quadcopter drone project.

Table 5. Internal risks.

Data Security and Privacy Concerns:

Internal data security and privacy threats become critical when the drone gathers and analyzes sensitive data during surveillance flights. Confidential information may be made public by communication channel breaches, illegal access to stored data, or onboard software flaws. It is essential to have strong encryption procedures and safe data storage methods in place to reduce internal threats and maintain the accuracy of gathered data.

Technical Difficulties:

Developing a quadcopter drone requires a number of complex technical issues, such as integrating cameras, sensors, and advanced algorithms. Technical difficulties might include software defects, hardware malfunctions, and compatibility problems between different components. To avoid system failures and unexpected behavior during flight, it is imperative that the drone's subsystems coordinate and communicate with each other seamlessly.

User Interface and Remote Control Reliability:

The ability to remotely monitor and manage interfaces is essential for allowing users to customize mission parameters and intervene. Internal hazards like software bugs, slowness in communications, or UI design might make it more difficult for the operator to act quickly when things get urgent. Maintaining control over the drone is contingent upon the dependability and responsiveness of these interfaces, particularly in situations that are dynamic or urgent.

Enhancing the overall dependability, safety, and success of the quadcopter drone project requires addressing these internal risks throughout the development process through rigorous testing, ongoing observation, and iterative changes.

Testing and Calibration Issues:

In order to guarantee the drone's dependability and effectiveness in a variety of conditions, testing is essential. Internal hazards linked to insufficient testing include limited validation of the drone's autonomous capabilities, unidentified software faults, and inaccurate sensor calibration. If these problems are not found and fixed during testing, the drone's safety and efficacy might be jeopardized by unpredictable behavior during real operations.

Complex Navigation Algorithms:

Complex algorithms are used extensively in the quadcopter's autonomous navigation to plan its course, avoid obstacles, and maintain accurate control. Errors in the interpretation of sensor data, inaccurate positioning systems, and possible disparities in the execution of flight plans are some of the internal dangers connected with navigation algorithms. These problems could cause accidental crashes or unpredictable flying patterns, which might endanger the drone and its surroundings.

Battery life and power management:

Drone batteries have a limited energy capacity, which creates an ongoing internal danger. Optimizing the drone's flight duration and overall operating capability requires effective power management. The drone's capacity to finish missions may be jeopardized by internal variables that include unplanned power spikes, poor power distribution, or deteriorating batteries over time. This might result in dangerous landings or mid-flight shutdowns.

Enhancing the overall dependability, safety, and success of the quadcopter drone project requires addressing these internal risks throughout the development process through rigorous testing, ongoing observation, and iterative changes.

7.1. External Risk

Risk Description	Risk probability	Risk impact	Overall score	Mitigation
Weather and Environmental Conditions	3	4	12	Wind conditions, Altitude, Obstacles, and Terrain may significantly impact the drone testing process.
Regulatory Compliance and Legal Difficulties	3	3	9	Flight Restrictions, Data Protection, and Insurance Requirements must be included.
Interference and Communication Problems	3	2	6	Robust encryption and communication protocols must be implemented in order to mitigate the threat of external interference, which includes deliberate jamming and radio frequency congestion, to the drone's communication security and dependability.
Collisions and Airspace Congestion	3	3	9	Drone usage is increasing, which increases the potential of collisions with other aircraft and obstructions. To maintain drone and airspace safety, airspace congestion must be carefully considered, collision avoidance technologies must be put in place, rules must be followed, and real-time tracking is essential.

Security risks and illegal access	4	5	20	As drone usage increases, security risks become more prevalent. As a result, it's important to use best practices, software upgrades, and ongoing monitoring to guard against hacking attempts and unwanted access.
Public view and adoption	3	3	9	Negative public opinion or hostility to drone testing might affect public policy, limit usage, or damage outside people or buildings.

Table 6. External risks.

Weather and Environmental Conditions:

The quadcopter drone's functioning is significantly risked by the external environment, especially the weather. Unfavorable weather conditions, such as intense winds, precipitation, or high temperatures, might affect the drone's overall performance, stability, and sensor accuracy. The drone's capacity to carry out missions safely may be limited by unpredictable weather patterns; therefore, in order to reduce external risks, it is necessary to have strong backup plans and weather monitoring systems.

Regulatory Compliance and Legal Difficulties:

Adhering to changing regulatory frameworks is imperative while developing and utilizing autonomous drones for surveillance. Changes in privacy legislation, airspace limits, and municipal or national rules controlling drone operations can all pose external dangers. In order to avoid legal trouble, operational restrictions, or project delays, compliance with these standards is essential. As a result, ongoing oversight and adjustment to the legal environment are required.

Interference and Communication Problems:

The drone's communication systems may be interfered with by external electromagnetic interference from other devices or communication networks, making it impossible for it to send or receive important data or orders. External concerns that jeopardize the drone's communication channels' dependability and security include radio frequency congestion and deliberate interference. To reduce these external dangers, strong encryption and communication protocols must be implemented.

Collisions and Airspace Congestion:

As drone usage grows, there is a greater chance that they may collide with other drones, birds, or natural obstructions. To avoid mid-air collisions, external dangers like as airspace congestion and the presence of other drones or airplanes must be properly taken into account. The safety of the drone and the surrounding airspace depends on putting collision avoidance systems into place, following airspace rules, and adding real-time tracking capabilities.

Security risks and illegal access:

The increased use of drones has sparked worries about potential security risks, such as the possibility of hacking attempts or unauthorized access. Malicious external parties could try to take advantage of holes in the drone's software, communication protocols, or navigation systems. To prevent external assaults on the drone, cybersecurity risks must be continuously monitored, software upgrades must be performed on a regular basis, and security best practices must be used.

Public view and adoption:

The public's view and adoption of drone technology are also subject to external threats. Privacy issues, noise pollution, and possible abuse of monitoring powers might spark backlash from the public or even legal challenges. In order to promote favorable external connections and reduce reputational risks, it is imperative that the drone project incorporates privacy precautions, engages with the community, and transparently addresses concerns.

7.2. Safety Risk

Risk description	Risk probability	Risk impact	Overall score	Mitigation
Injuries when testing the drone with propellers	4	4	16	Disconnect the battery if the drone is malfunctioning, wear protective clothes.
Electrical hazards	3	4	12	Frequently checking wiring and components for damage, wear protective clothes.
Injured when working with tools	3	2	6	Wear protective equipment and check for tool malfunction.

Table 7. Safety risks

Injuries when testing the drone with propellers:

The quadcopter's propellers are tough and can spin at a fast speed during flight. This drone is a prototype of students so many things could go wrong when testing or flying. For this reason, a mitigation measurement to turn off the power of the drone such as a stop button on the controller or power switch on the drone will be implemented. Moreover, wearing protective clothes and staying covered in a safe place will reduce the risk impact.

Electrical hazards:

Electrical hazards include electrical shocks, overheating, electrical fires, etc. In order to minimize the risk and impact of electrical hazards, the drone system will need to be frequently checked for damage and wiring. In addition, wearing specialized personal protective equipment such as insulated gloves and electrical hazard-rated boots can protect yourself from electrical hazards.

Injured when working with power tools:

The drone assembly process requires working with various tools like drills, solder irons, screwdrivers, wrenches, etc. These tools can injure users with minor wounds, but the solder irons are very hot and can create great harm if someone touches the tip. Users can avoid big and minor injuries by wearing protective gloves while using hand tools and checking if the tool still functions normally.

8. Conclusion

The advancement of sensors and machine learning algorithms has paved the way for the capability and reliability of autonomous quadcopters. This project is a great opportunity for students from different engineering branch teamworking and apply technical skills for a practical problem. After 12 weeks working together, the team faced many challenges, and we had to adapt and overcome the obstacles. The achievements of the drone project not only show our technical skills but also our willingness to learn. Looking forward, there are still technical mistakes and soft skills need improvement, the feedback throughout the project will be a good direction for continuous self-improvement. In conclusion, the drone project fosters problem-solving skills, teamwork, and project management to prepare for future work in STEM professionals.

9. References

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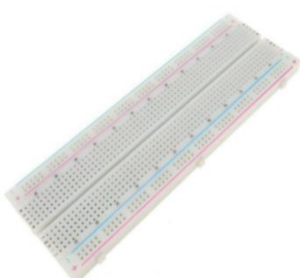
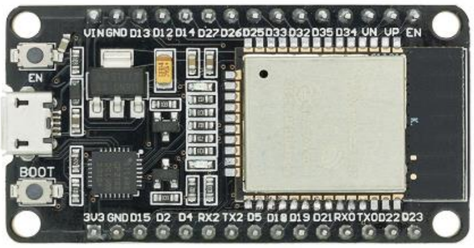
10. Appendixes



Appendix . Breadboard. Link

Appendix . Wood beams and plates. Link

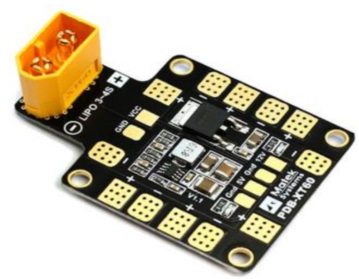

Appendix . ESP32. Link

Appendix . Power switch button. Link


Appendix . Joystick. Link


Appendix . Red button. Link

Appendix . ESC. Link



Appendix . PDB. Link

Appendix . Motors. Link

Appendix . Potentiometer. Link

Appendix . Propellers. [Link]

Appendix . Mica plate. [Link]