EEET2610– ENGINEERING DESIGN 3

Individual - Detailed Work Report

Tutorial Session 2

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School/Department/Area of Science, Engineering, and Technology

What's next...

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ABSTRACT

This report is the individual work report of the student Truong Tan Gia Huy, student ID s3806881 for the course EEET2610 – Engineering Design 3 (ED3), from group F. The main focus of the course project to the design and control of a quadcopter, with a frame made of wood, spanning approximately 60cm in diameter. The flight controller for the drone is based on a microcontroller, specifically model ESP32, which communicates wirelessly with another ESP32 via WiFi connection, connected via USB cable using a protocol called ESPNOW. The student Gia Huy's work is summarized as follows: initially, being the group's leader, the workload is assigned for other team members, with CAD and PCB design is personally handled. With assistance and cooperation from another student, Mina Jeon (student ID s3764040), CAD models of the motor's holder with controller and PCB design for the EPS32 is finalized and components are fabricated.

1. INTRODUCTION

A quadcopter is a flying system that utilizes four brushless motors, known as BLDC (brushless direct current) motors, with propellers to generate lift and propulsion. These motors are equipped with propellers that rotate to generate thrust and enable the mechanism to fly. While other actuator technologies such as DC motors or combustion engines, are also available, BLDC motors are the most commonly used in small to medium-scale drones due to their superior efficiency, high thrust-to-weight ratio, and quiet operation.

Apart from the given main components of the drone by the lecturer, students are required to design one CAD model to attach motors to the drone's arms, another model for the controller, which will attach a joystick, a potentiometer and two buttons that particularly control the drone pitch, yaw and roll behaviour. Solidworks or Autodesk Fusion 360 software could be used for CAD design. PCB design is also recommended, however it is optional. Students could manually solder the components such as ESP32, GPS module or IMU on a multipurpose PCB instead of printing a PCB. The university does not support printing PCB as well, so students must take consideration and get PCB fabricated outside campus. EasyEDA software could be used for PCB design and manufacture. All the drone's components are carefully measured and understood by students Huy and Mina for further development and design for CAD models and PCB in order to perfectly fit in the components' dimensions and meet the technical requirements.

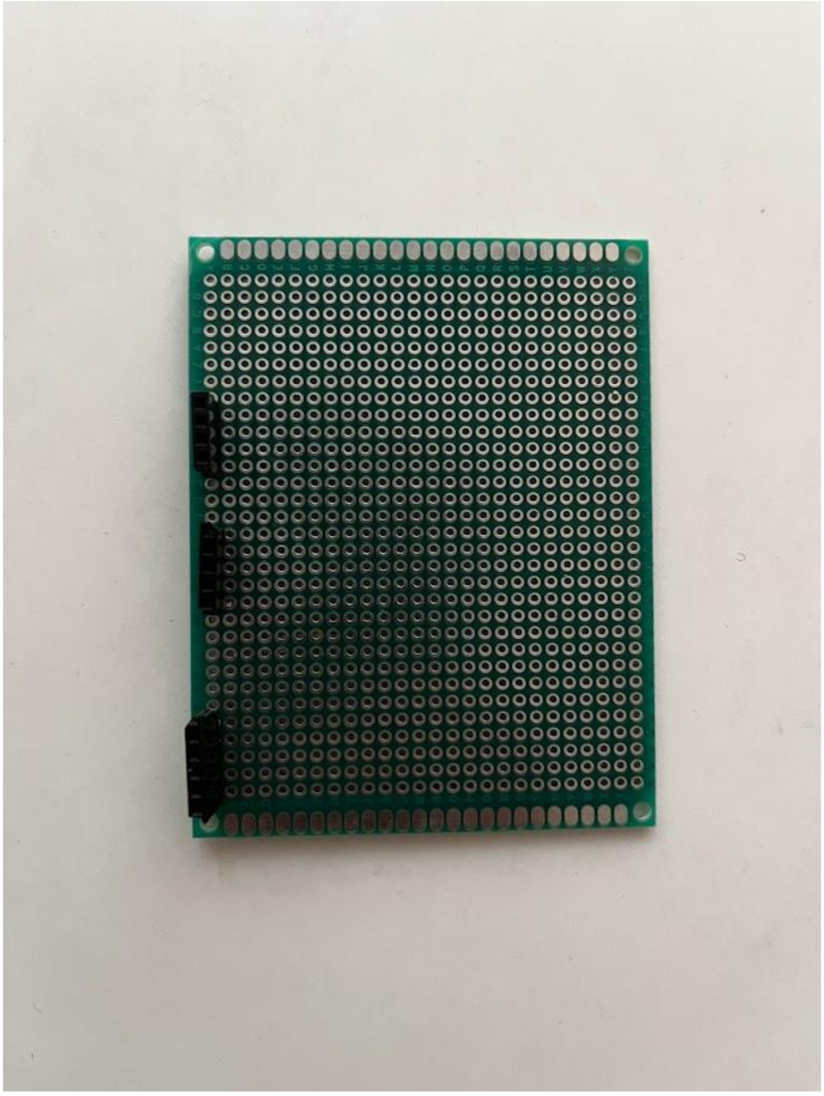

Figure 1: Multipurpose PCB

When CAD models and PCB are finished and collected, all components are assembled and the drone is tested. The experimental testing of the drone mainly focuses on its stabilization behaviour. Without human intervention, the drone is fixed on a tripod platform, as it should stabilize without falling, be able to correct itself under external factors such as wind or a slight touch that makes the drone lean and under full control of the operator, such as being able to increase its pitch, roll or yaw side to side. When fully stabilization is confirmed, a flight test could be performed. All of the processed is done with all the members cooperation. Specifically, the mechanical assembly is done by two team members, Son - s3818468 and Nhan - s3810151 as they both have some experience in mechanical tasks such as drilling or wire soldering. When all components are ready, the code is developed by three students, Duy - s3924701 with Long - s3879366 and Tu - s3957386 and uploaded to the two ESP32. The code includes all control procedures, protocol of the drone, safety feature when the lean angle is too high, as well as PID modifications that helps with the drone’s self-balance.

2. CAD MODELLING OF THE SYSTEM

There are two CAD models designed, one model as motor holders, one model as controller frame. After finalizing the CAD design, STL files are generated and sent to the lecturer for fabrication.

2.1 Motor holders CAD model

The overall shape and size of the model is minimally designed that just meet the fitting requirement, as the more complex the design is, the greater risk could occur when printing out. This also minimizes the extra weight, reduces manufacture cost, printing time while strong enough to hold the motors firmly to the drone's arm.

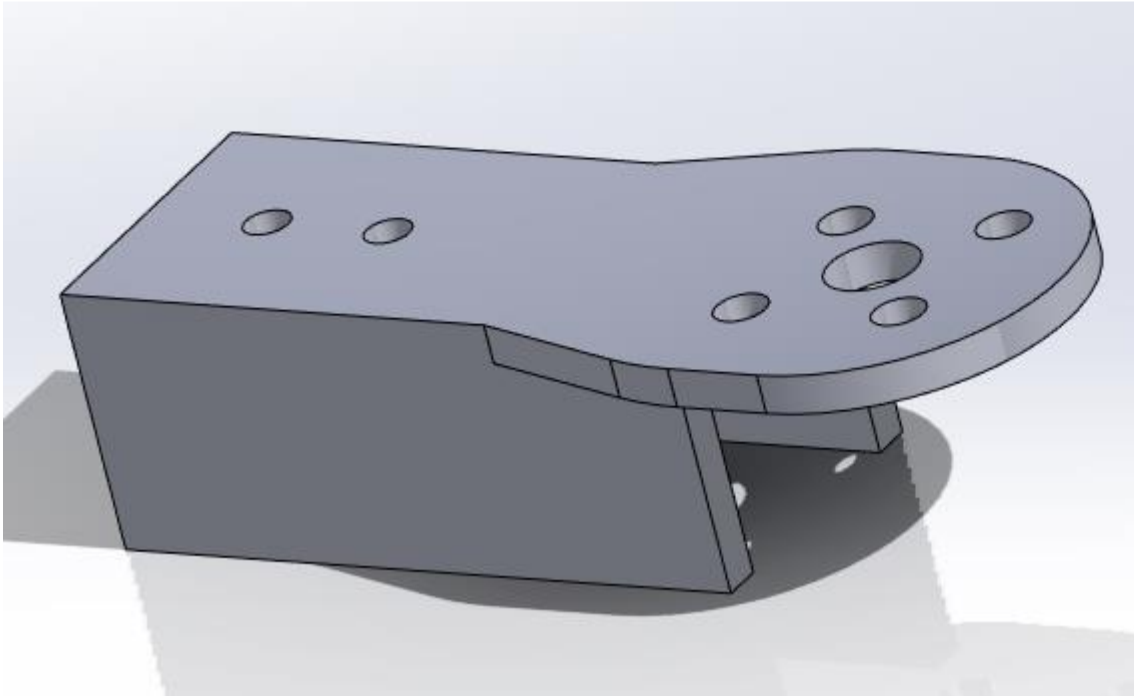

Figure 2: Motor holder CAD model in Solidworks

All the dimensions on this model is based on hand-measurement from students using rulers, identify the sizes of several parameters such as screws and motor's screws diameter, width of the drone's arm as precise as possible. In case of model tolerance when the part is 3D printeded, every dimension in the model is designed to be 1mm larger than measurement, ensure every component will fit in perfectly.

For the thickness of the model, especially the front round part where the motors are attached to, it is designed so that the part is thick and strong enough to withstand the stress, while it is thin enough so the motor's screws can properly tighten in the motors because these screws are not really long.

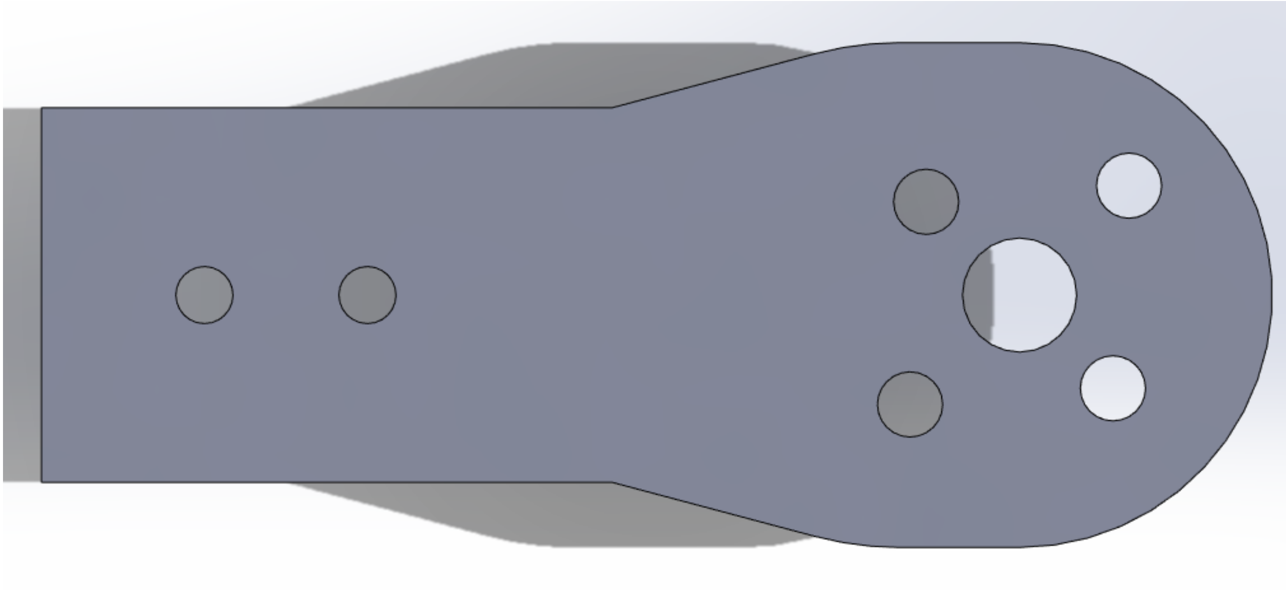

Figure 3: Top view of the model

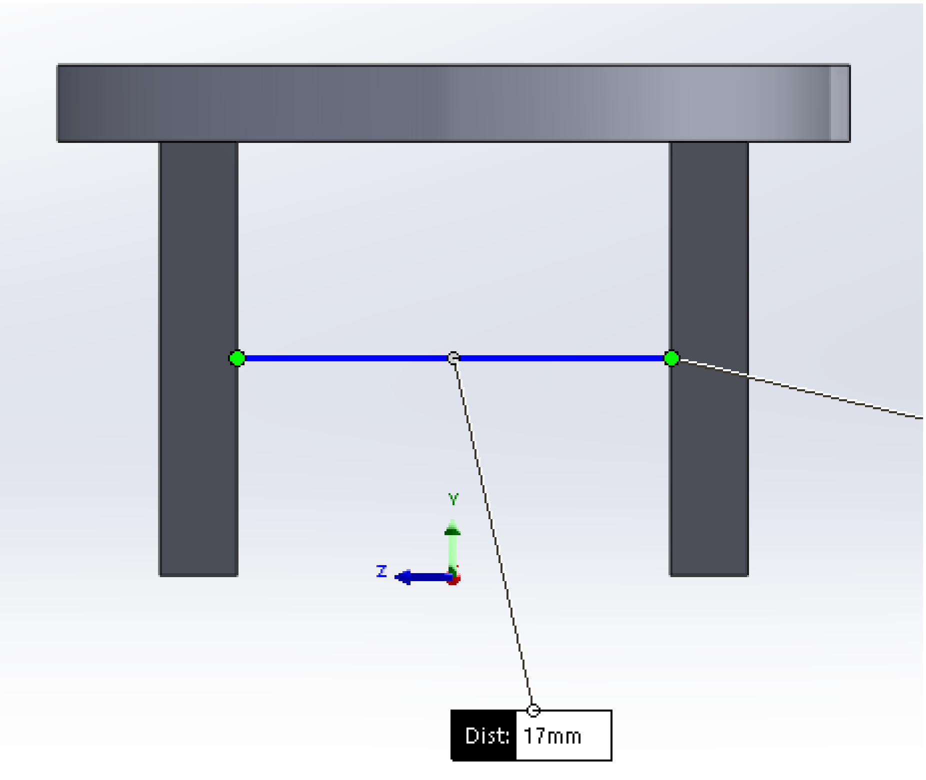

Figure 4: Front view of the model shows width of the gap

After the models are printed, they are attached to the drone's arm and the motors are fixed, which could be seen in the Figures below, where they fit perfectly while the motors can spin smoothly without resistance:

Figure 5: Motor is fixed on the 3D printed part

Figure 6: 3D printed part fits in the drone's arm

2.2 Controller CAD model

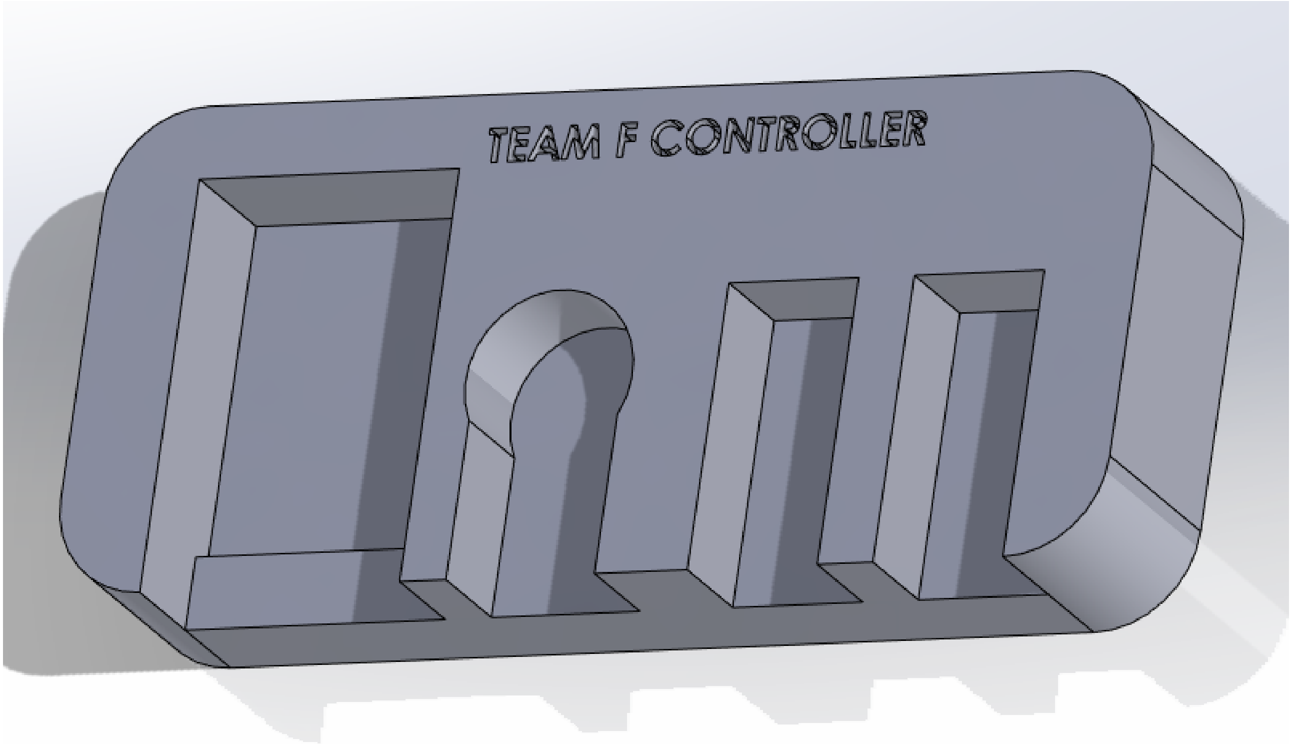

Figure 7: Controller CAD model in Solidworks

Similarly, the dimensions of the joystick, potentiometer and buttons are hand-measured as precise as possible, every dimension in the design is 1mm larger in case of tolerance, ensure all components will fit. Foam, double-sided tape or glue will be used to firmly fixed the components into the frame.

Nevertheless, by the time this report is written, the 3D printed part for the controller is not ready, so no experiement and testing is performed yet.

3. DESIGN OF THE PCB OF THE DRONE

Although PCB is not compulsory for this project, students can develop their own PCB design for optimizing the space and convenience when attaching components on the drone's frame. Two PCBs are developed, one for the drone and the other for the controller, however, only PCB for the drone is printed. Since the components of the controller could be connected on a breadboard, PCB is not necessary as it would require greater effort and investment.

3.1 PCB of the drone

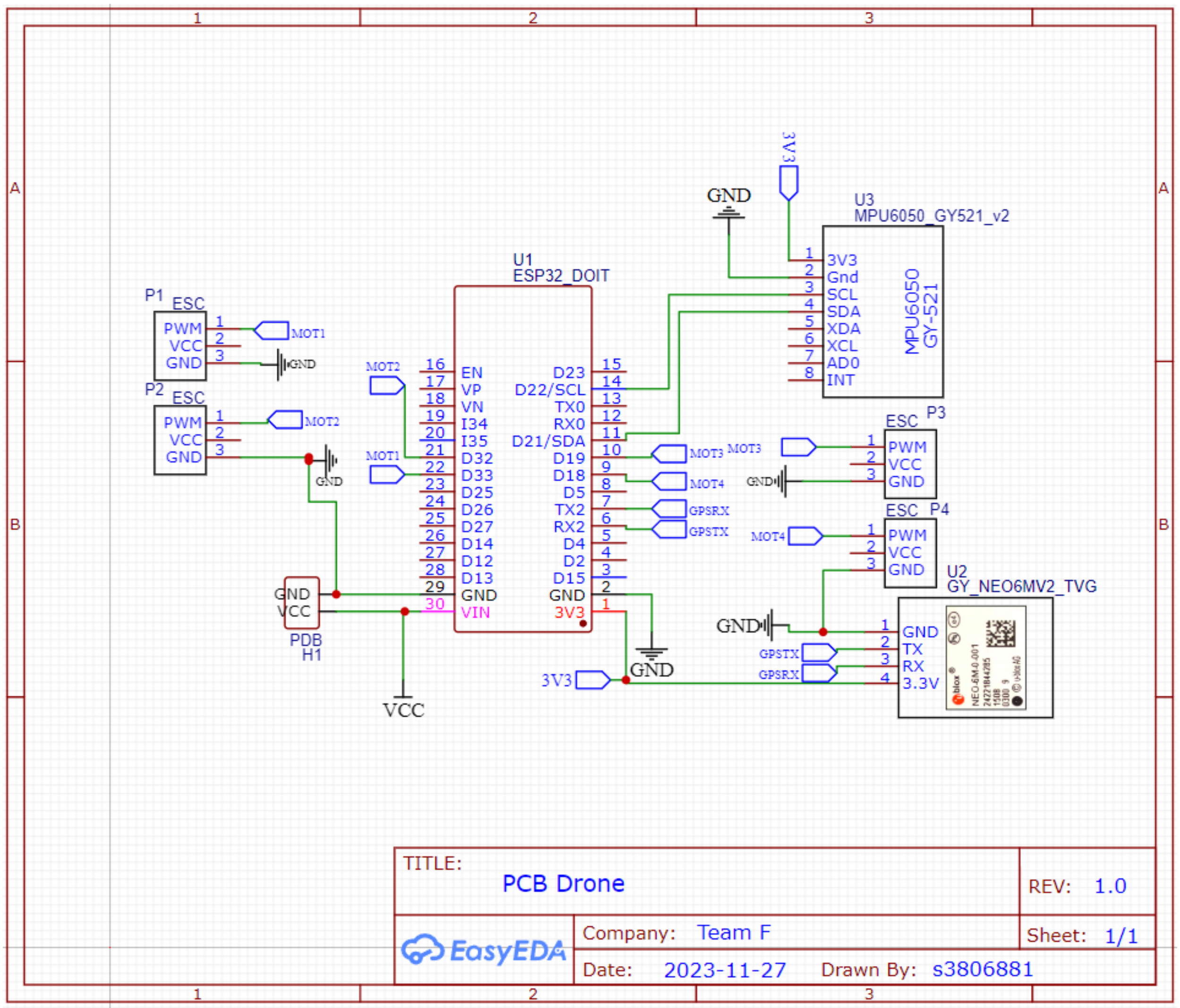

Figure 8: Wiring schematic of the drone PCB

The MPU and GPS modules in the schematic above are different from the models used in real life because the exact models cannot be found on EasyEDA library, however, their pin layouts are quite similar.

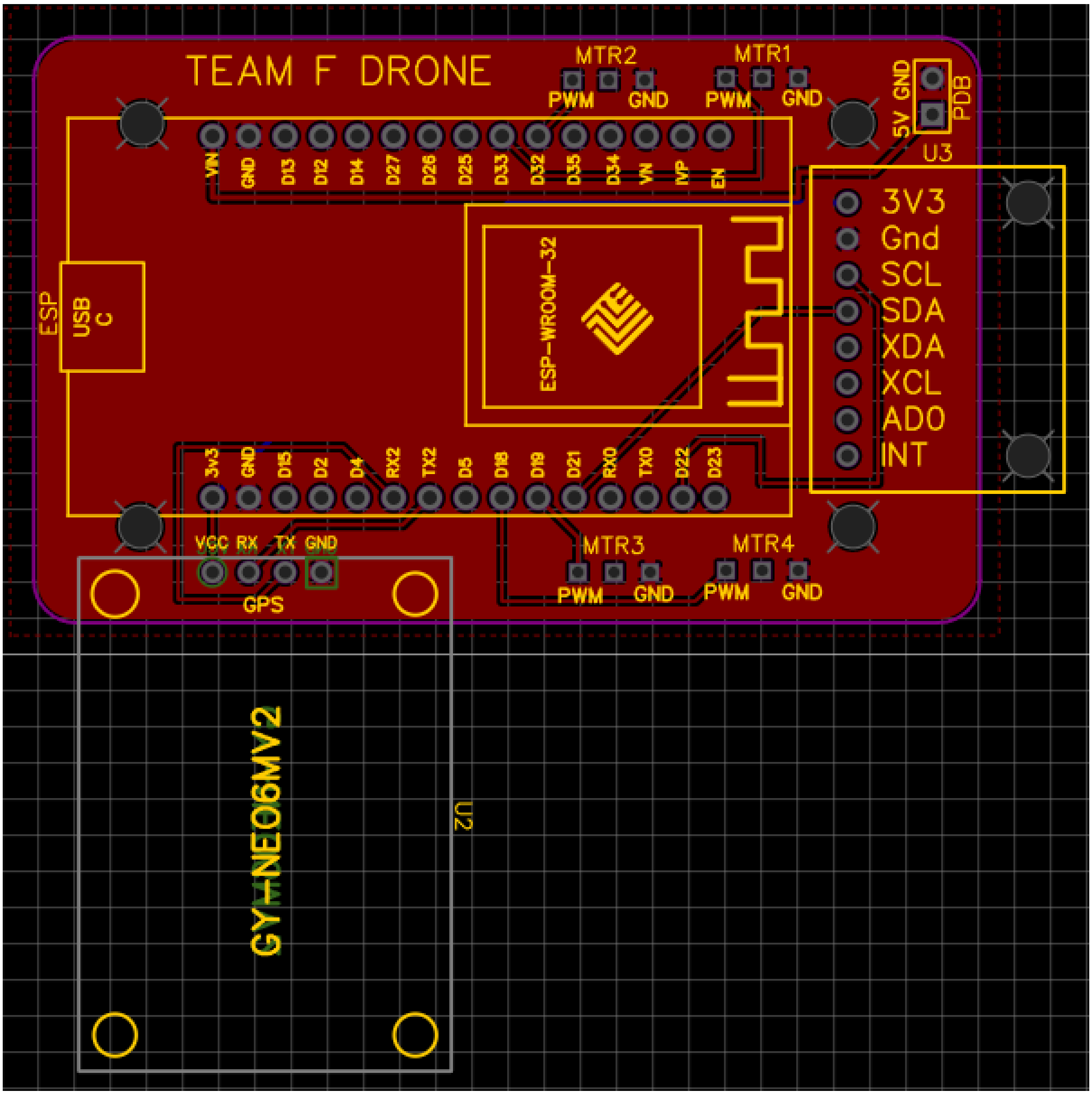

Figure 9: Wiring layout of the drone PCB

Most of the traces width are set by default in EasyEDA software, which is 0.254mm, except for the trace lines that connect 5V from PDB to VIN pin of the ESP32 and from 3V3 of ESP32 to 3V3 pin of the MPU, which is 0.4mm wide. The reason for this is these lines carry the highest voltage and current in the whole system. The wider the trace width, the less resistance it has to the current, and less heat it accumulates, which will help increase PCB durability [1]. A copper layer is laid out to connect all grounds instead of manually connect them pin by pin.

All the modules and pins positions are carefully decided in order to optimize the space usage of the PCB, and minimize the size of the printed PCB, as there is limited gap between the drone's arm where the PCB will be put in the middle.

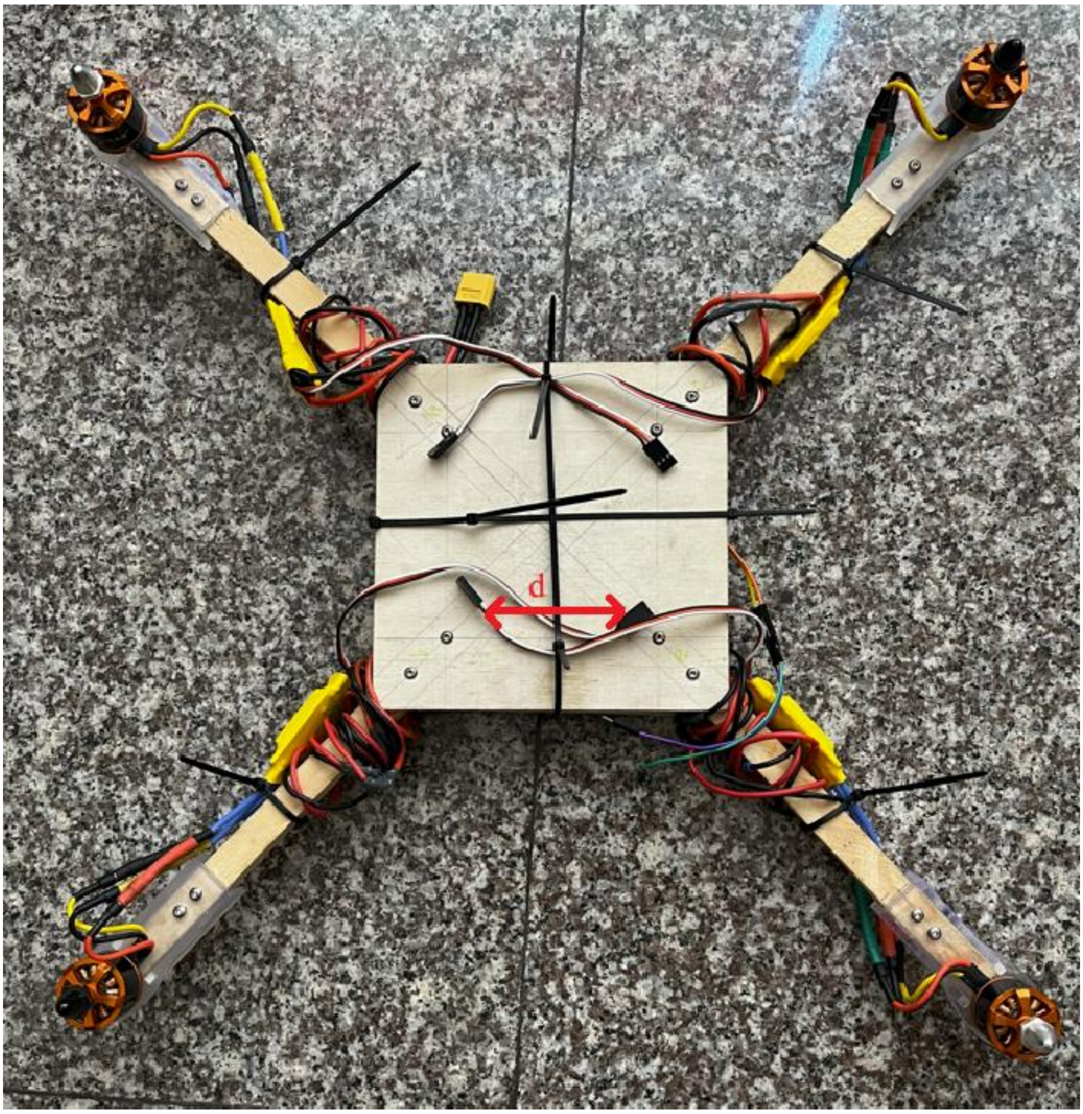

Figure 10: Limited gap d between the arms to fit in the PCB

After Design Rule Checking (DRC) is completed, a Gerber file is extracted and sent to JLCPCB for fabrication. 5 PCBs are the minium quantity for printing, having 2 layers because the trace lines is put on 2 layers of the PCB design, can be shown in Figure 3.

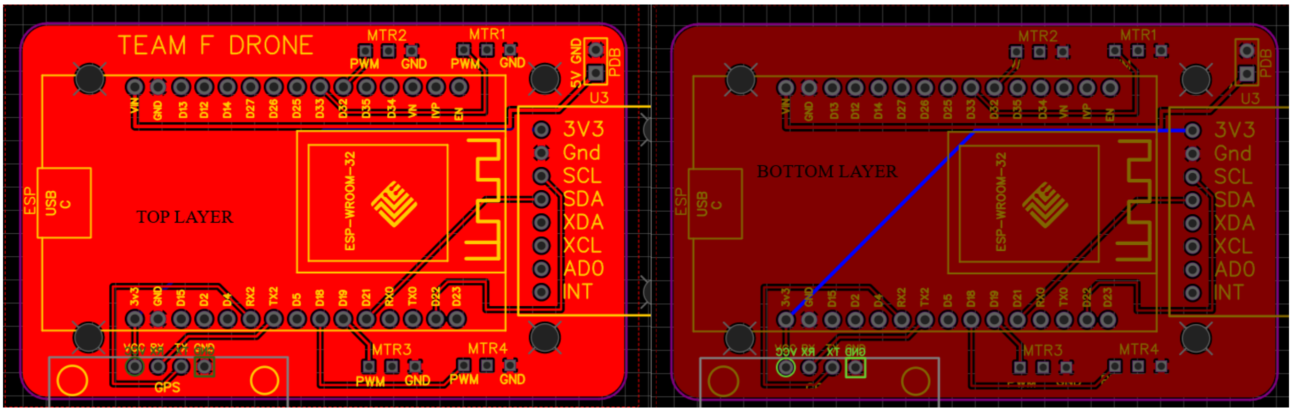

Figure 11: PCB top and bottom layer wiring

The screw holes are 3mm in diameter as in this project, M3 size screw is used to tighten and fix all the components into the drone's frame. The figure below is the drone PCB after fabrication by JLCPCB. Male and female pins will be soldered accordingly to the PCB to install all the modules.

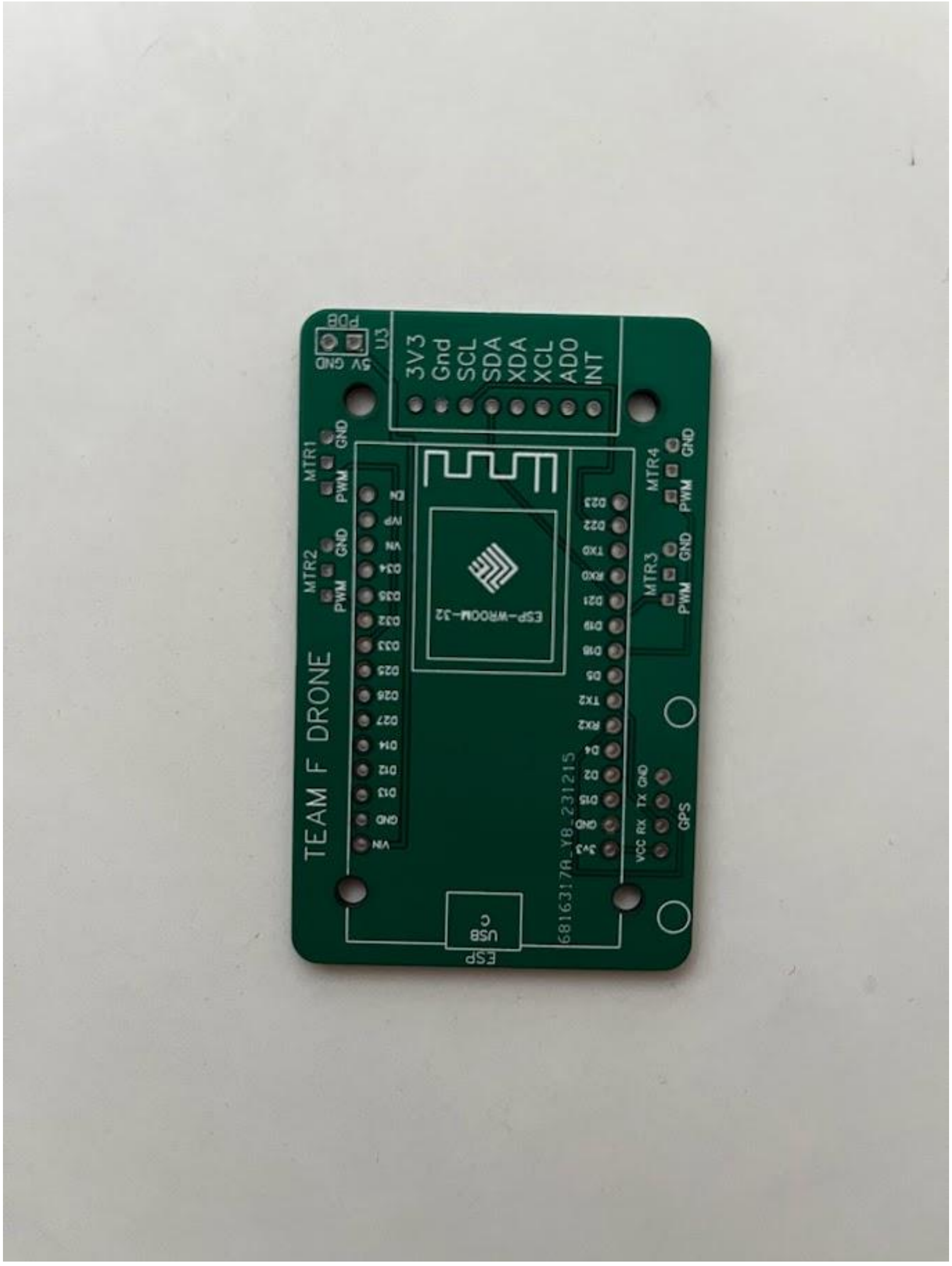

Figure 12: Drone PCB

3.2 PCB of the controller

Team F decided to ultilize the breadboard to connect all components for the drone controller. Although this is not compulsory, a brief design of the controller PCB is developed for initial consideration and reference.

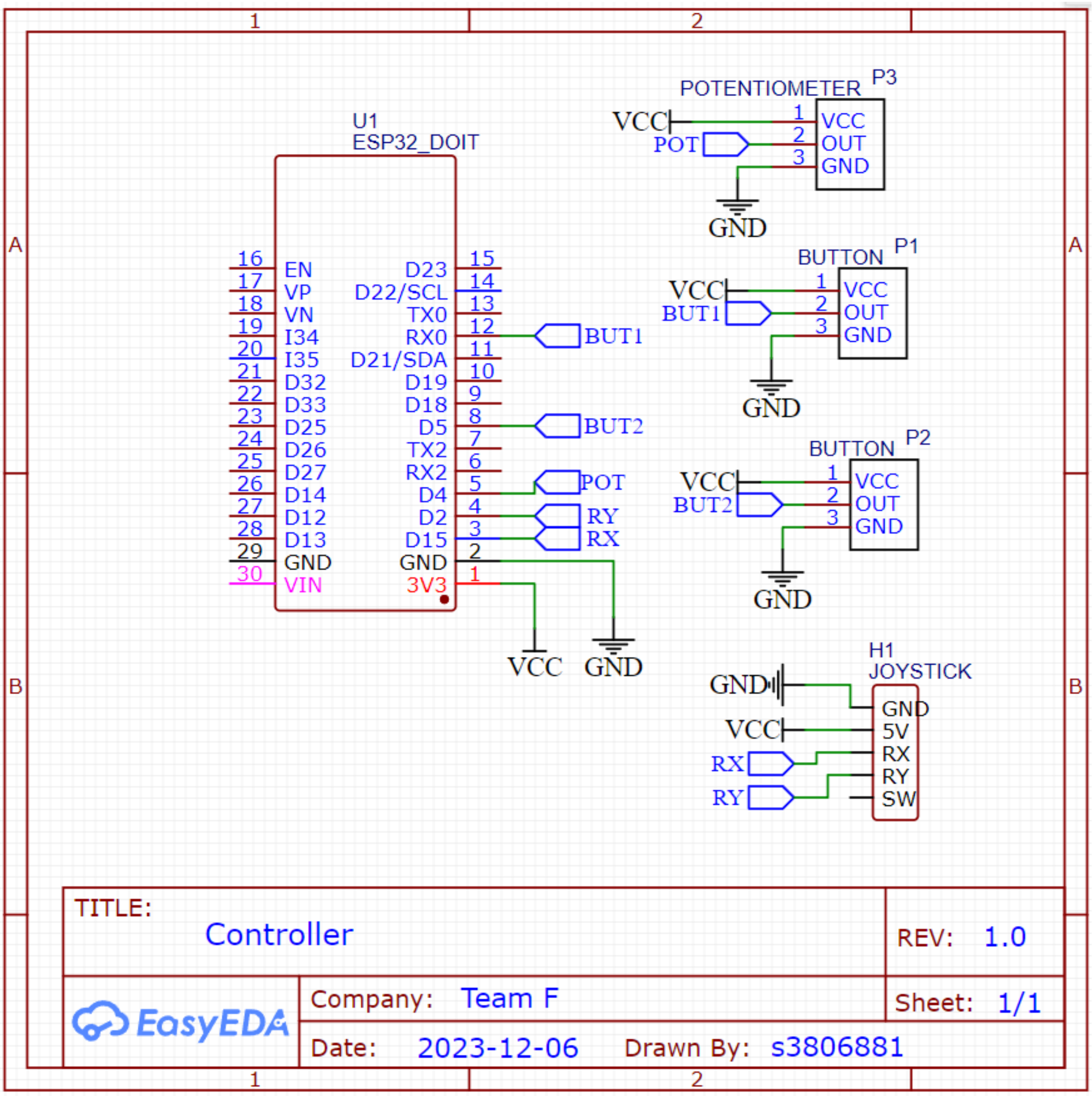

Figure 13: Wiring schematic of controller PCB

The controller power will be supplied by USB-C cable connect directly to the ESP32 via the operator's laptop.

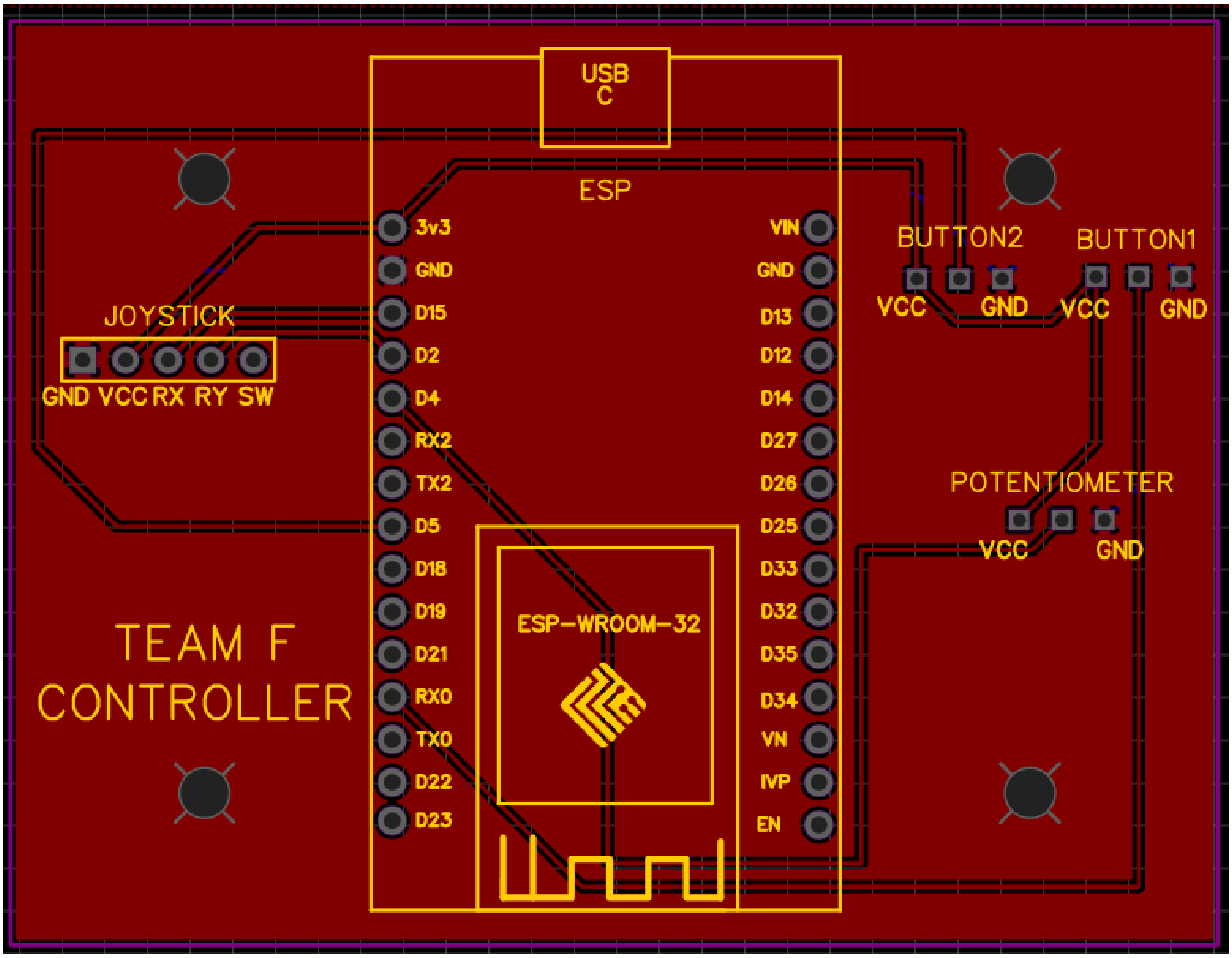

Figure 14: Wiring layout of controller PCB

Traces width or screw holes dimensions have similar principles with the design of the drone PCB. The controller circuit is typically simpler than the drone PCB, so the pins and wiring layout is also simpler, which only one wiring layer is required.

4. DISCUSSION

The final design of both CAD models and PCB is a success overall. They all serve their requirement and work perfectly fine when integrating into the drone. After performing various experiments, there are a few problems that could be solved in order to enhance their working cap

CAD models design

Although the CAD model design of the motor holder serves its purpose, some more innovations could be done for better performace. For instance, about the motor holder model,, the side bar could be extended further to serve as the landing gear of the drone. With the current design, when the drone is put flat on the ground, its bottom wooden plank will make contact with the floor, therefore, it is better if the drone itself has a landing gear system.

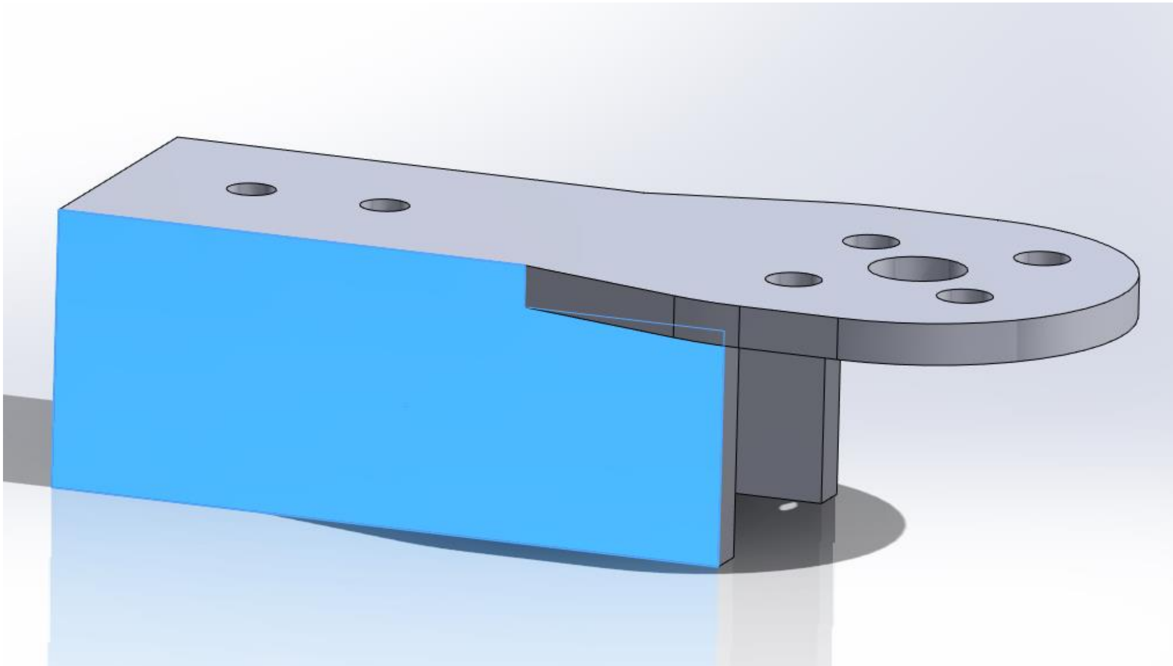

Figure 15: Motor holder CAD model, the side bar is highlighted blue

Furthermore, the rounded front part of the model, where the motor will be fixed onto, could be designed an extend part which it would reach to the bottom, align with the side bars as shown in Figure below. Since there was an accident when the student Gia Huy accidentally dropped the 3D printeded part from table height, the part was broken in half at the front part. Consequently, the student asked the lecturer for another model being printed.

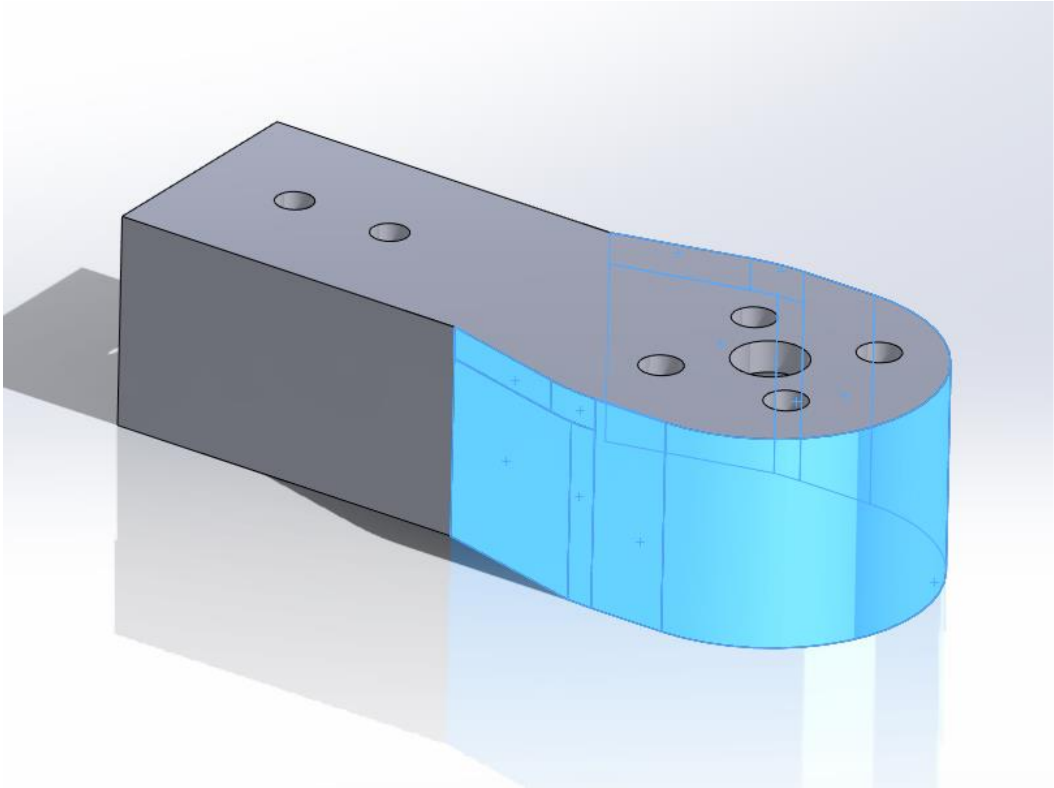

Figure 16: Innovated motor holder CAD model, the front part is highlighted blue

Conclusion: From the beginning, the initial model could be redesigned and innovated for optimizing its strength and firmness from external factors, so that components damage could have been prevented.

About the controller, the model should hold everything in place as intented, however, there is one flaw in the design, specifically at the joystick position.

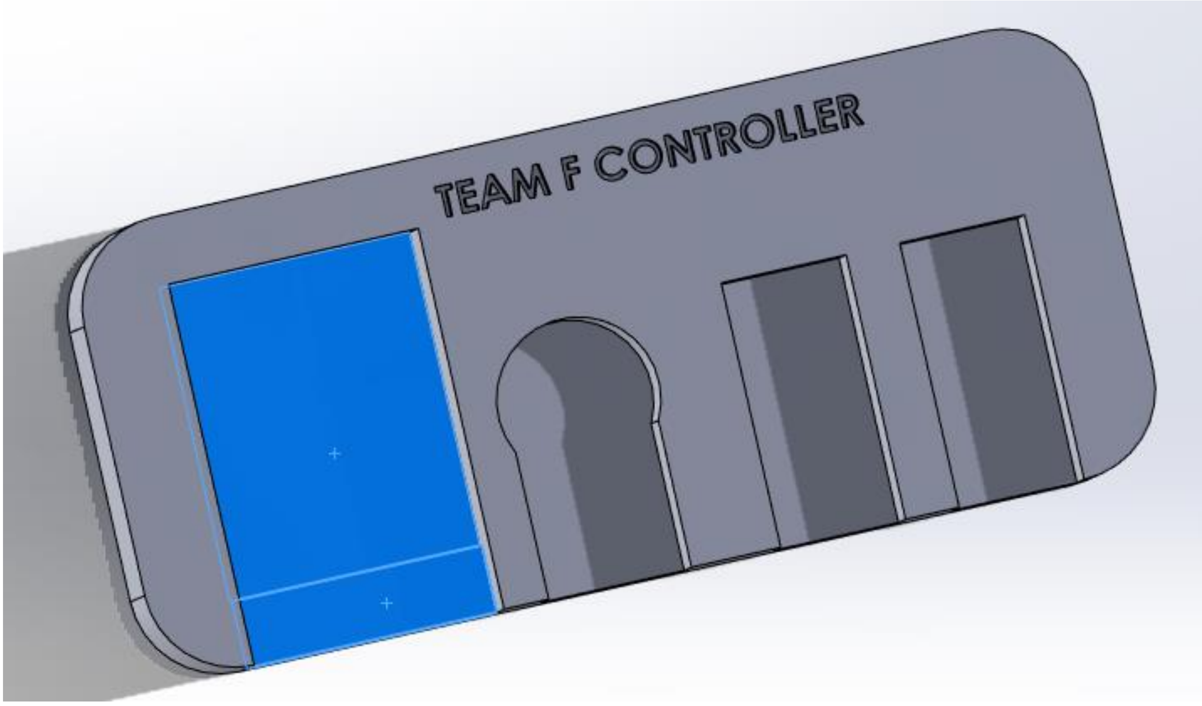

Figure 17: Controller CAD model, joystick position is highlighted blue

The reason for this mistake both from subjective and objective issues. During the CAD design, the student Gia Huy was not informed that the joystick operational principle is different from expectation. The student Gia Huy expected the joystick control principle is in vertical direction, while the correct control principle is in horizontal direction. The control principle of the joystick is illustrated in Figure below:

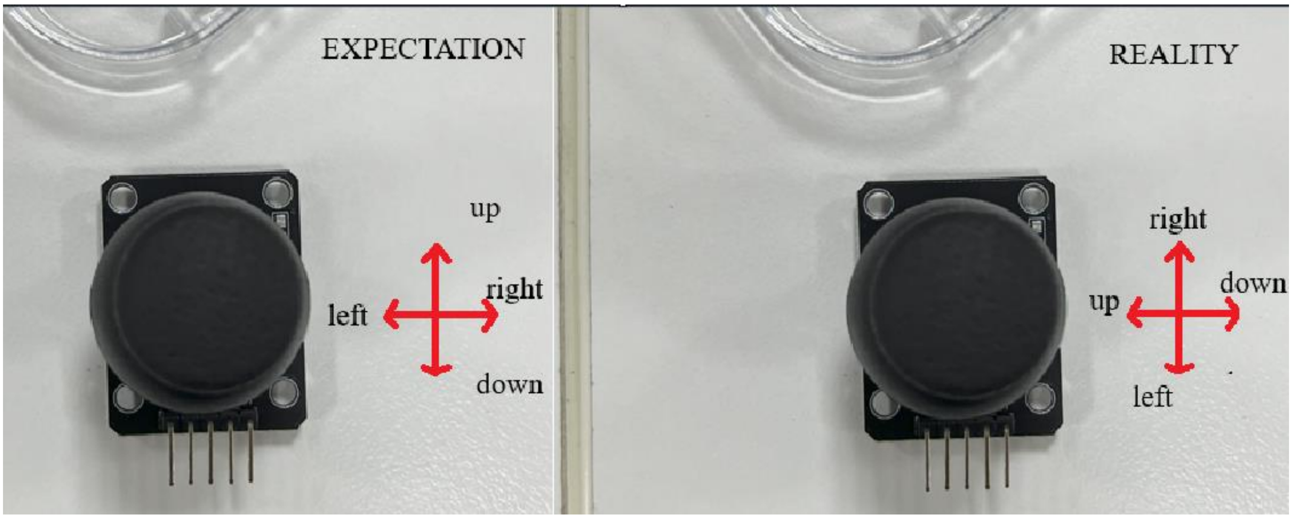

Figure 18: Joystick control principle of controlling the drone behaviour

To deal with this, the operator must adapt to control the joystick accordingly when it is attached to the CAD model.

PCB Design

There is one big flaw with the design of the PCB for the drone, particularly the MPU model used in the schematic. This issue was not detected after the PCB was printed and the modules were installed. As mentioned from the report description above, the MPU model used in design the PCB in EasyEDA software is not the same as the one used in real life, so its pin layout is also wrong, and incorrect wiring was done without noticing.

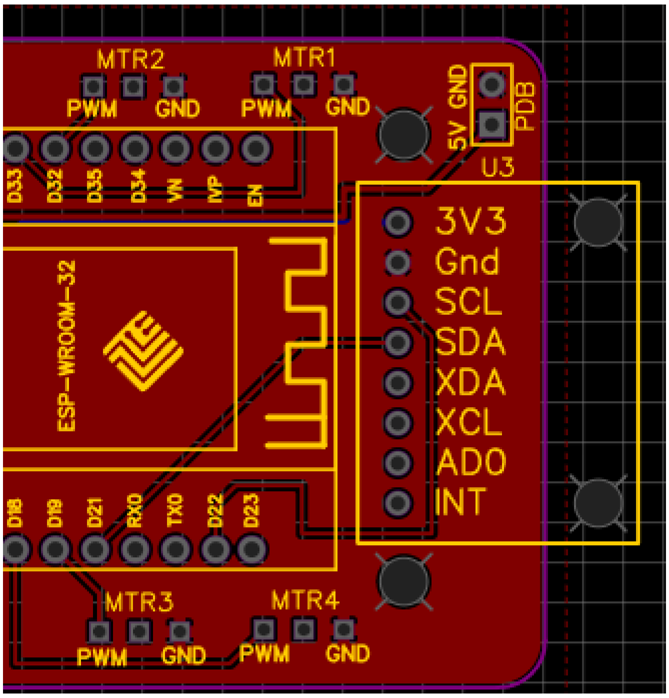

Figure 19: MPU module pin layout is incorrect

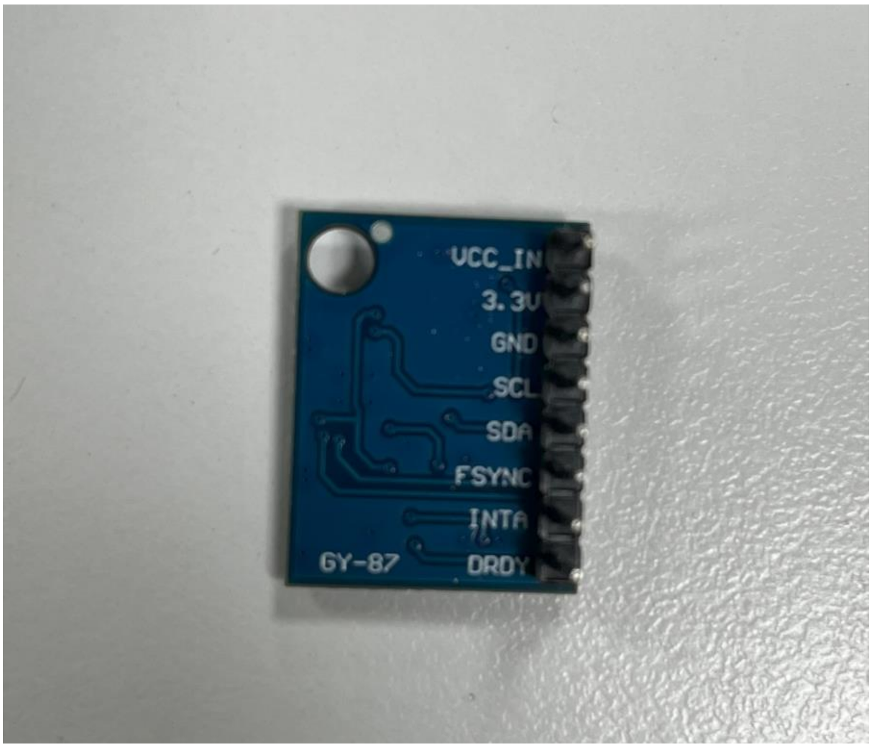

Figure 20: MPU used in real life

The reason for this mistake both from subjective and objective issues. During the design of the PCB process, the student Gia Huy believed that all MPU models would have the same pin layout without any doubt, moreover, the students who were working on the code were keeping the MPU for testing, therefore, the students designing the PCB could not acknowledge the correct pin layout for the MPU, leading to this mistake. Technically, the needed operational pins of MPU when plugging in the system are 3.3V, GND, SCL and SDA pins, comparing to the model used in EasyEDA, these pins are above one pin comparing to the MPU in real life. The PCBs are already printed, redesign of the PCB and fabrication would be more costly and time-consuming. Therefore, the only solution is to plug the MPU in the PCB one pin next to, which is illustrated as Figure below.

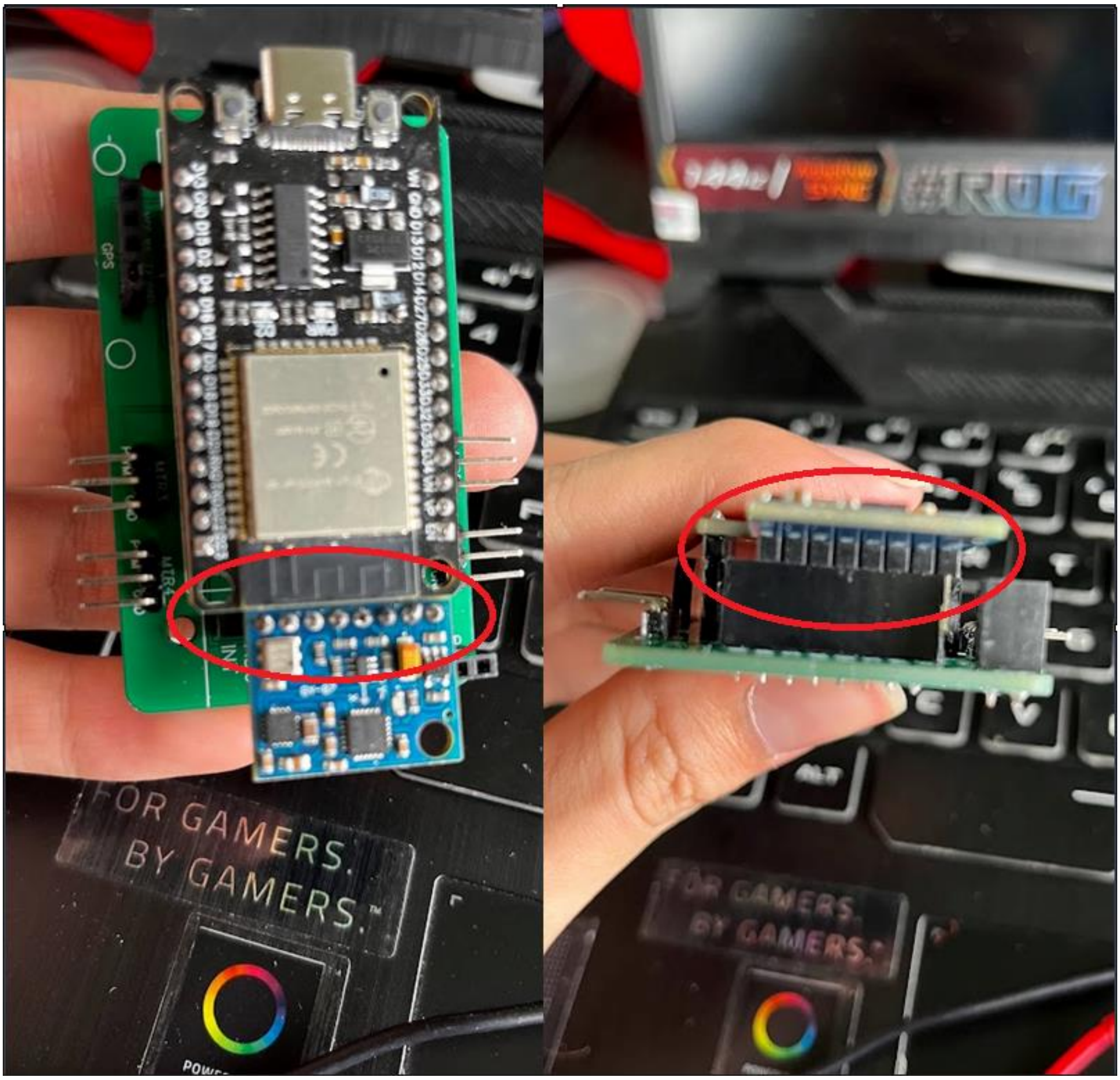

Figure 21: MPU attachment on PCB after change

Another small problem with the PCB design is the silkscreen printing on the top silk layer. Although the students included the legends on the silk layer for pin identifications. However, these legends are put too close the the pins themselves, leading to coverage when the male and female pins are soldered on the PCB, which arise some difficulties when reading these legends.

Conclusion: Students should have been well-informed with all the parameters of the components so as to prevent error PCB printing, as well as better legends spacing for better readings.

5. CONCLUSION

In conclusion, the design process of the quadcopter was a challenging yet rewarding endeavor. The project was started with a comprehensive study of the principles of aerodynamics, control systems, and electronics, which formed the theoretical foundation for the quadcopter. The drone's design is a combination of advanced technologies such as GPS for navigation, gyroscopes for stability, and BLDC motors for propulsion. The quadcopter was meticulously designed and calibrated to ensure it self-balance capability, maneuverability, and efficiency. The final product would be a robust and versatile quadcopter that is capable of performing a variety of tasks, including aerial photography to environmental monitoring.

The future of quadcopter design holds much promise and excitement. With greater advancements in technology, we can expect quadcopters to become increasingly autonomous, capable of performing complex tasks such as delivery of goods, search and rescue missions, or even passenger transportation. Furthermore, improvements in battery technology and materials science are likely to result in longer operation time and more durable design, therefore further expanding the capabilities of these versatile vehicle.

Overall, the process of designing this quadcopter has been a testament to the power of engineering and innovation. It has unlocked a wide range of possibilities and set the stage for the exciting future of unmanned aerial vehicles.

6. REFERENCE

[1] “Best Guide To PCB Traces: Width, Thickness And Design Fix Recommendations,” Jhdpcb, 2024. [Online]. Available: https://jhdpcb.com/blog/best-guide-to-pcb-traces/. [Accessed: Jan. 7, 2024].