How to build your own mini-drone with the STEVAL-DRONE02 and STEVAL-FCU001V2

Introduction

The STEVAL-DRONE02 mini drone companion kit features motors, propellers, plastic frame, and battery that you need to assemble your own mini-drone.

The flight controller unit is not included in this kit. To build a fully functional drone, or unmanned aircraft system (UAS), you need to use the STEVAL-FCU001V2 control board with the set of spare parts included in the STEVAL-DRONE02 kit. To complete the hardware and firmware aspects of the mini-drone kit, use the STSW-FCU001 firmware.

Figure 1. STEVAL-DRONE02 reference design kit

1 Safety considerations

A drone presents safety hazards for the person piloting the drone and others in the vicinity of the drone, so due care and attention must be applied when operating the drone.

You must ensure the drone has sufficient clearance from all objects and persons to fly safely.

Check the rules and regulations specified by your country's Civil Aviation Authority or similar authority, and ensure that your drone does not enter "no-fly" zones.

2 Overview

2.1 Features of the STEVAL-DRONE2 kit

- Four motors: 3.7 V, 85x20 mm coreless DC motors
- Two clockwise and two counterclockwise 65 mm propellers, plus a couple of spares
- LiPo 3.7 V/600 mAh battery with a maximum discharge current of 30 C
- 3D plastic mechanical frame including propeller guards for safety

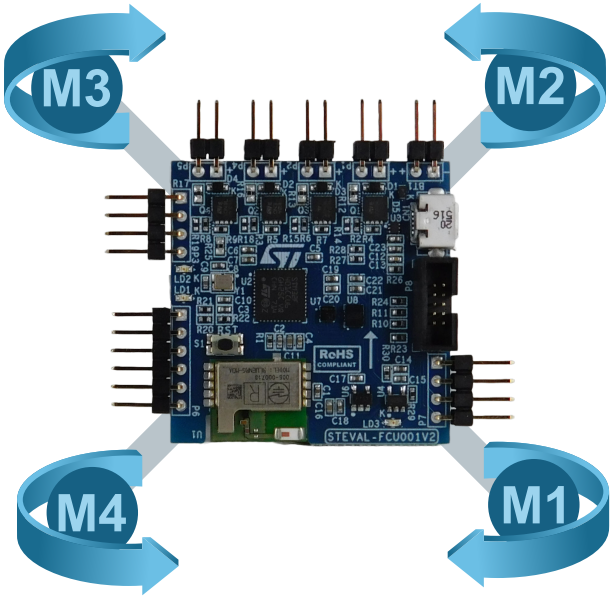
Note: The kit does not include the STEVAL-FCU001V2, which must be ordered separately.

2.2 Flight control dynamics

In the quadcopter configuration shown below, each motor spins in the same direction as its diagonal counterpart, and in the opposite direction of its horizontal and vertical counterparts. The rotors on each motor produce a thrust and a torque around their center of rotation.

It is important to note that the FCU has an arrow depicted on Top, since it is the reference to be used in the following section to indicate the front direction.

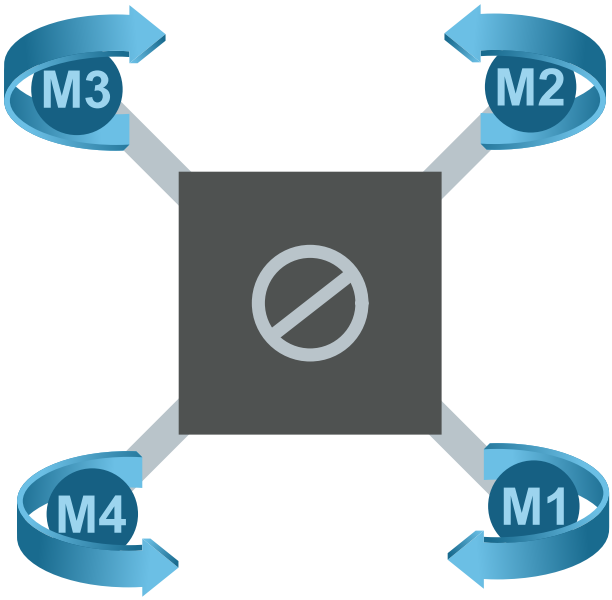
Figure 2. Motor rotation on a quadcopter



The direction (yaw), vertical inclination (pitch), horizontal inclination (roll), and altitude of the drone are all controlled by manipulating the velocity of the motors with respect to each other and to the force of gravity.

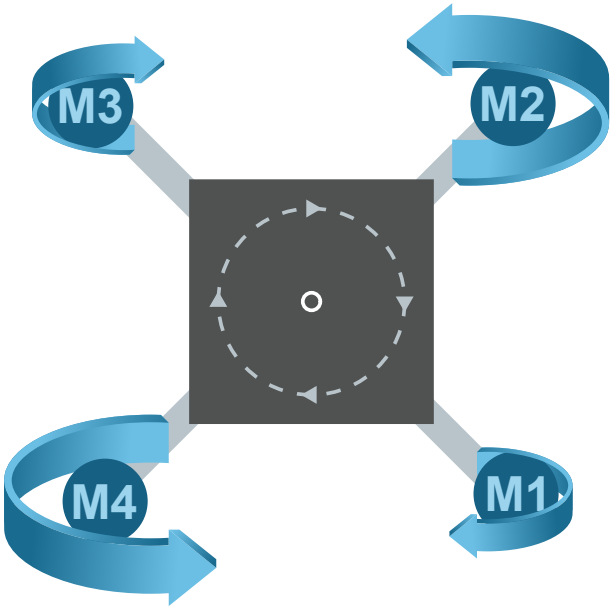
When all four motors rotate at the same speed, the drone can only move up or down, or simply hover (see Figure 3).

Figure 3. **Four motors rotating at the same speed**



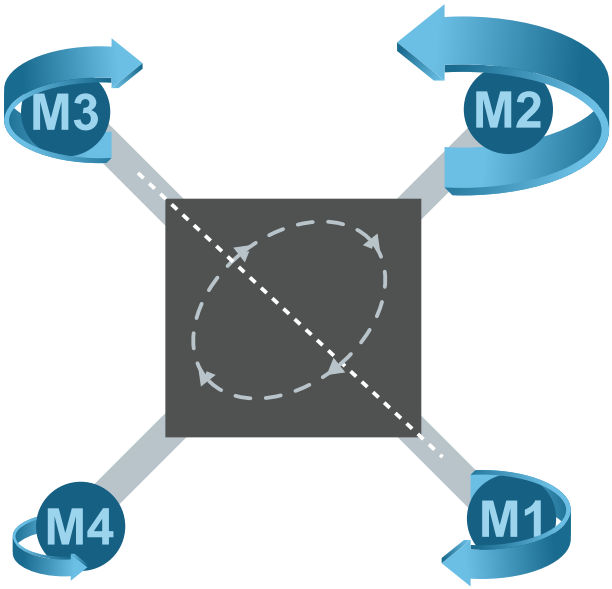
When two diagonal motors rotate more quickly than the other two motors, the drone rotates along its yaw axis. If the counterclockwise motors spin faster, the drone rotates in a clockwise direction (see Figure 4), and vice versa.

Figure 4. **Anticlockwise motors cause clockwise rotation**



When a motor is accelerated and its diagonally opposite motor is slowed down, the drone rotates along the other diagonal axis. This will cause the drone to either pitch in order to move forwards or backwards, or roll in order to move sideways (see Figure 5).

Figure 5. **Differentiating diagonal motor velocities adjust pitch and roll**

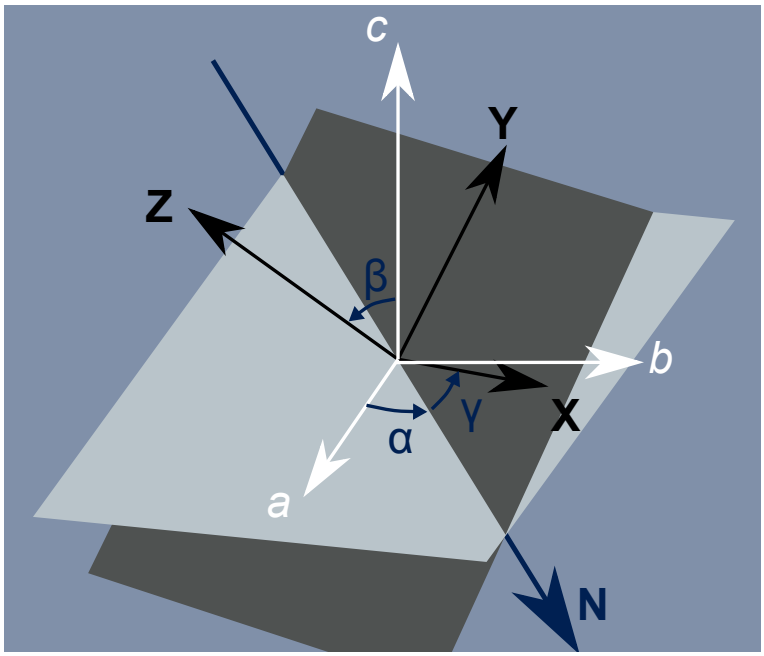


2.2.1 Euler angles

The flight control unit (FCU) uses Euler angles to determine the orientation of a drone and produce desired balance and movement. The FCU algorithm compares actual Euler alpha (α), beta (ß) and gamma (γ) angles with target angles to determine the necessary adjustments to the individual motor velocities.

Figure 6. **Reference axes for Euler angles**

abc: the fixed system
XYZ: the rotating system
N: the intersection line between the ab and XY planes
α: the angle between the x axis and N
ß: the angle between the z and Z axes
γ: the angle between N and the X axis



2.3 Frame of the drone kit

The frame included in the kit is built through a die casting process, however you can download the STL file from the STEVAL-DRONE02 product folder to build your own frames starting from our basic design. If you develop a new design for your frame, it is important that it retains the necessary size, weight, strength and symmetry characteristics for the drone to be able to fly.

To promote the air flow for clockwise and counterclockwise rotors, the three arms that hold the motors have an airfoil shape.

Figure 7. STEVAL-DRONE02 frame

3 How to mount the your own mini drone

Follow the instructions below to mount you own mini drone including the STEVAL-FCU001V2 flight control unit on the frame, in the following Steps have been considered to mount the FCU on the top of the frame, and the battery below it, this is to have an easy access to programming connector. Clearly, you can revert them.

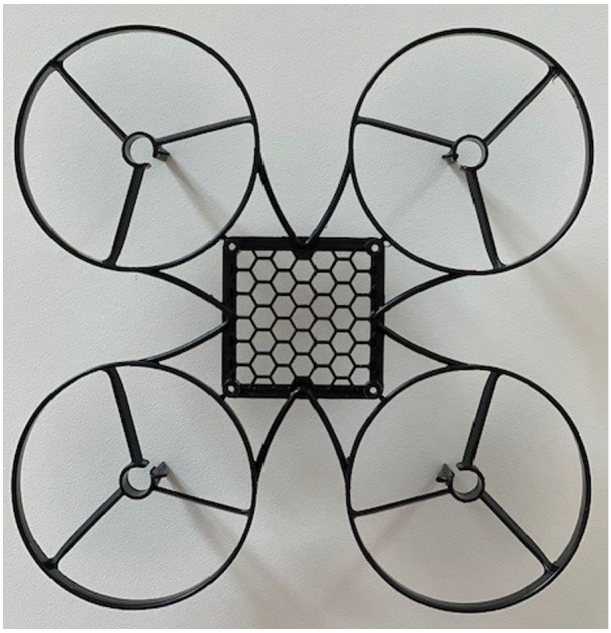
Step 1. Identify the frame orientation

As indicated in Section 2.2, the quadcopter configuration is shown in Figure 2. Since, by looking at the Flight Control Unit with the arrow in the up direction, as in Figure 2, and starting by top left angle we have:

- M3 Motor rotating in ClockWise direction, on top left side
- M2 Motor rotating in CounterClockWise direction, on top right side
- M4 Motor rotating in CounterClockWise direction, on bottom left side
- M1 Motor rotating in ClockWise direction, on bottom right side

Since the frame has to be oriented to respect this configuration maintaining the air blade to support these rotations, see Figure 8.

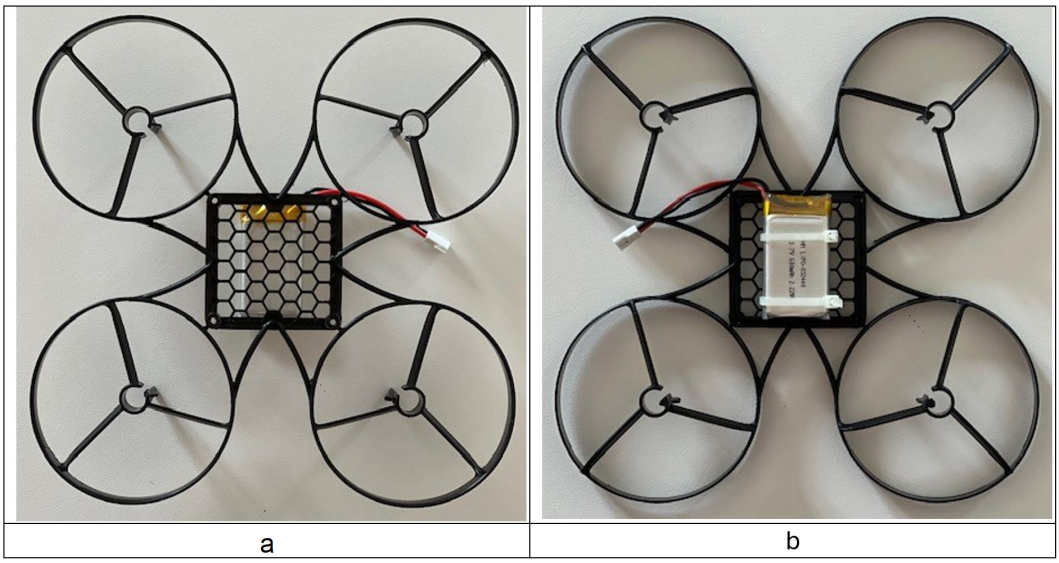
Figure 8. Correct frame orientation



Step 2. **Mount the battery on the frame**

Considering to mount the battery on the bottom of the frame, it has to be considered the position of the battery connector of the STEVAL-FCU001V2, represented in Figure. 9 of UM2958, in the top right corner of the board. Since, it is kindly suggested to position the battery as in Figure 9 (a) and ensured to the frame as in Figure 9 (b). The plastic ties are provided in the kit, however it is possible to use the 3M double tape.

Figure 9. Battery positioning, on (a) there is the top view and on (b) there is the bottom view where the battery has been ensured to the frame with the usage of the plastic ties



a b

Step 3. **Holes preparation**

Considering to mount the board on the top of the frame, its holes have to be prepared, see Figure 10, to host the screws. Since, by using the metal screw included in the Kit, you have to create the screw threads in the four holes, as in Figure 11, simply by screwing and unscrewing this metal screw in any hole.

Figure 10. Position of the four holes of the frame to be used to ensure the FCU board

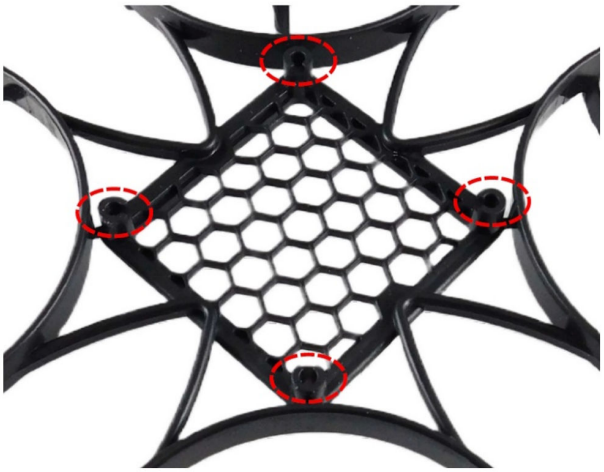


Figure 11. Use the metal screw to prepare the holes to host the plastic screws

Step 4. Starting by the position of the frame shown in Figure 8 and Figure 9 (a), the Flight Controller Unit has to be positioned on the top as in Figure 12, in fact on side of each hole there is a notch to host the board angles. Once, the board has been positioned, the four plastic screws with the washers have to be used, see Figure 13.

Figure 12. Board positioning on the frame by placing the battery connector on top right

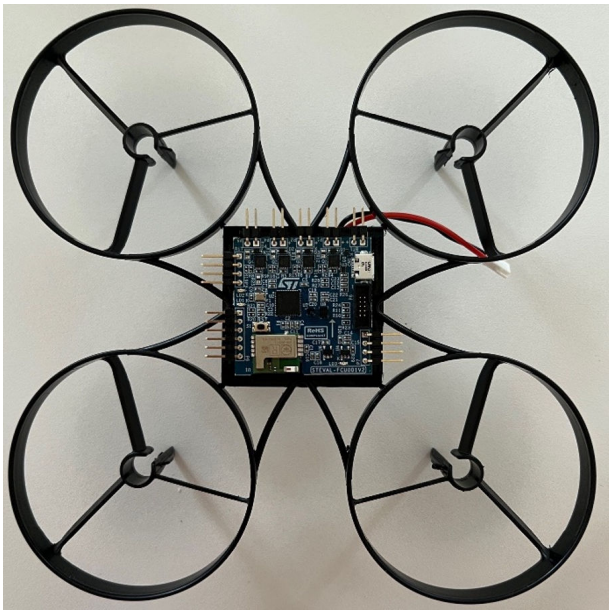
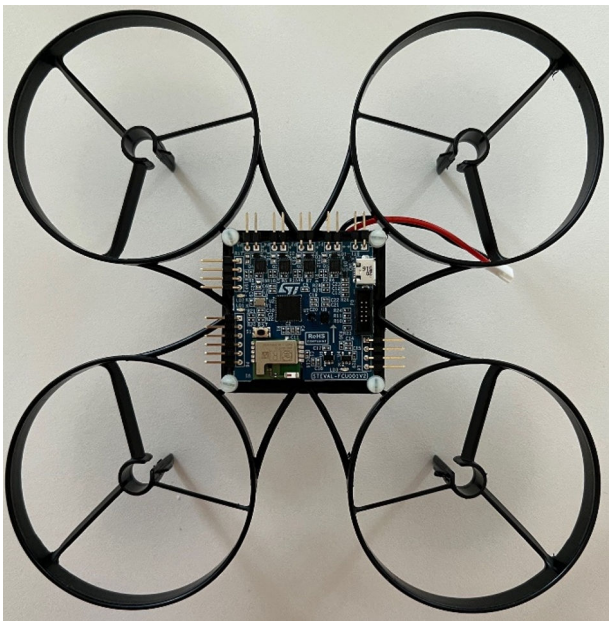


Figure 13. Mount the four plastic screws and the washers in the four corners



Step 5. **Identify motor orientations**

The four motors must be identified by the color of the wires:

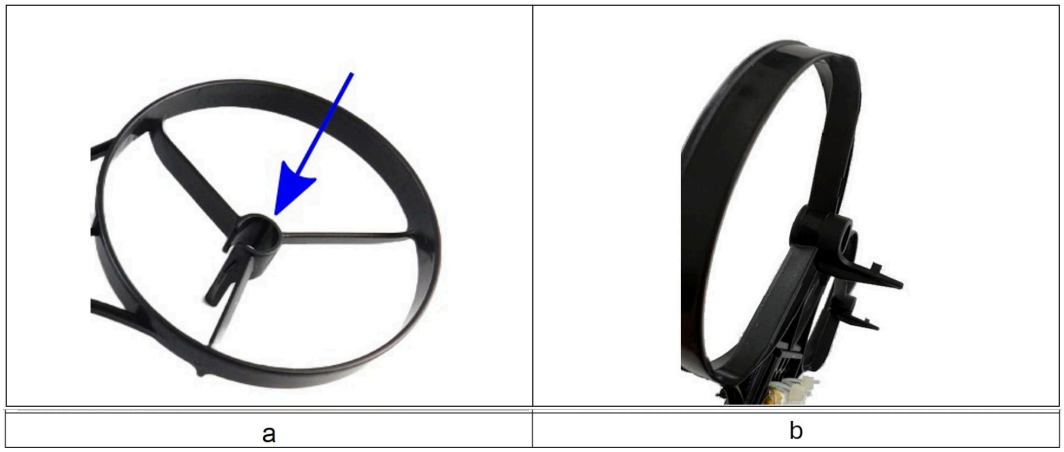
– The ClockWise motors have red (+) and blue (-) cables, and they have to be associated to M1 and M3

– The CounterClockWise motors have white (+) and black (-) cables, and they have to be associated to M2 and M4

Step 6. **Mount the motors on the frame**

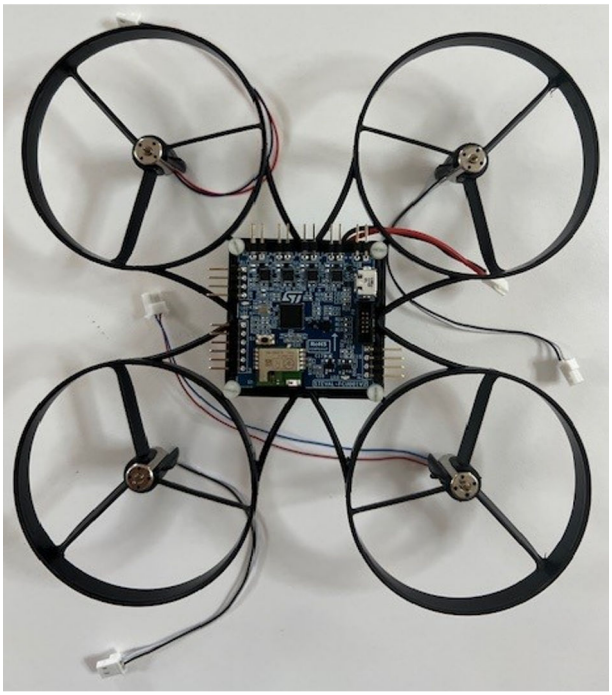
Insert the four motors in the sleeves, as shown in Figure 14 (a), from the top and pushing the motors until they reach the blocking point on the frame foot, see Figure 14 (b).

Figure 14. How to mount the motors on the frame



Place the four motors in the correct configuration with respect to the Figure 2, obtaining the configuration of Figure 15, where starting from top left there are CW (M3), CCW (M2), CCW (M4), CW (M1) motors.

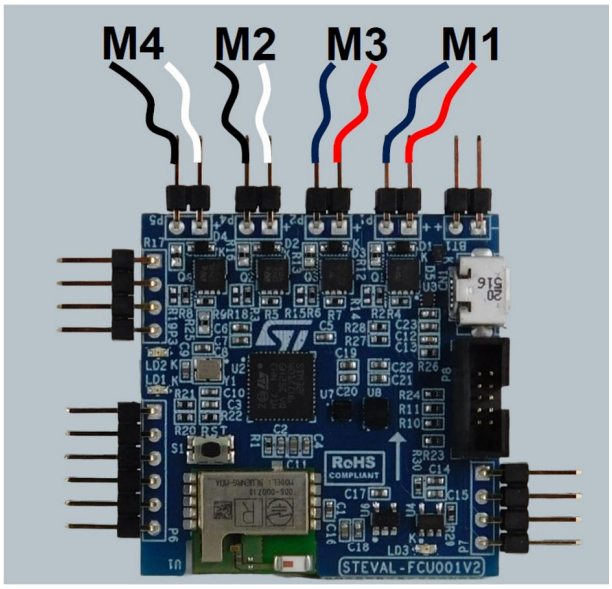
Figure 15. Correct configuration of the motors



Step 7. **Connect the motor cables to the supply pins on the FCU board**

The four motor cables have to be connected following the indication in Figure 16.

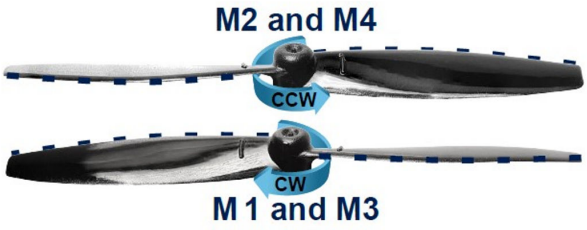
Figure 16. Motor supply connections on FCU board



Step 8. **Identify the propellers**

The correct propeller for clockwise and counterclockwise rotation has the leading edge raised in the respective direction of rotation, see Figure 17.

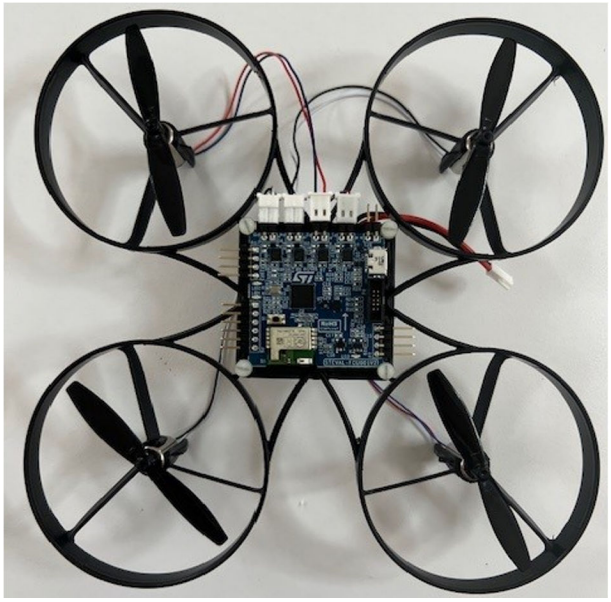
Figure 17. Propeller rotation directions



Step 9. **Mount the propellers on the motors**

Push and fit the propellers onto the motors.

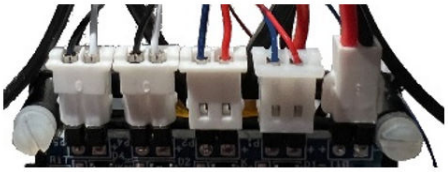
Figure 18. drone almost completed with the propellers mounted



Step 10. Battery connection

Connect the battery to connector BT1 on the STEVAL-FCU001V2 board, by ensuring the correct polarity, the black wire has to be on the right as per Figure 19 and Figure 20.

Figure 19. Battery connected

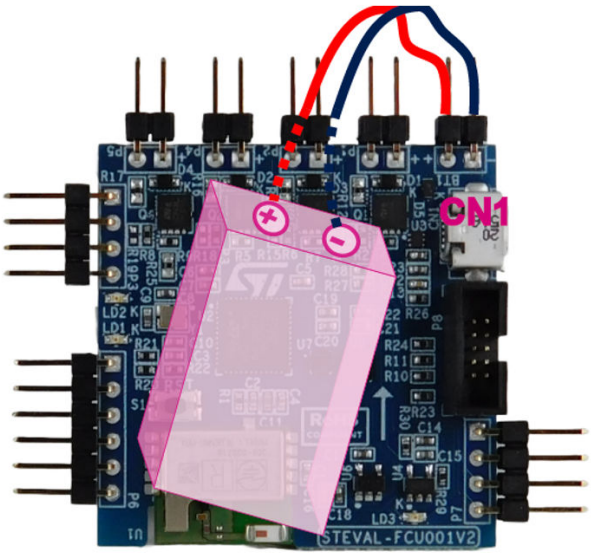


Note:
- *Reverse battery protection is not implemented on the FCU board.*
- *Carefully read the storage and handling recommendations provided by the battery manufacturer.*
- *Do not leave the battery connected when the drone is not in use.*

Danger: *LiPO batteries can be damaged and even explode if they are short-circuited or overcharged.*

Warning: *Do not allow the battery to discharge completely or this may permanently damage it.*

Figure 20. Battery Connection respect to CN1, the USB connector



4 How to fly the drone with the ST BLE Drone App for iOS

Before you fly the drone, make sure that you have:

1. updated the latest version of the STSW-FCU001 firmware
2. assembled the STEVAL-DRONE02 kit as described in the previous section
3. Considered enough space around the drone itself

Note: For Android phone see next Section.

Step 1. Download and install the ST BLE Drone app from Apple Store on your iPhone or iPad.

Step 2. Activate the Bluetooth® connection on your smartphone and enable ST_BLE_DRONE app to use it.

Step 3. Place the quadcopter on a flat surface and press the reset button on the board.

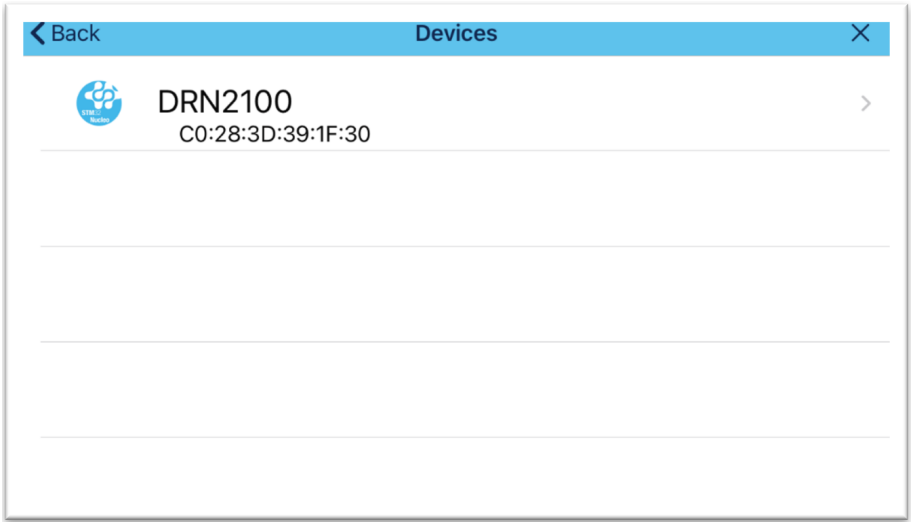
Step 4. Run the app, the screenshot in Figure 21 will appear.

Figure 21. ST BLE Drone App main Screen

Step 5. Tap on [Start discovering] and select the DRN2100 device from the list to connect the phone to the Flight Controller Unit, see Figure 22.

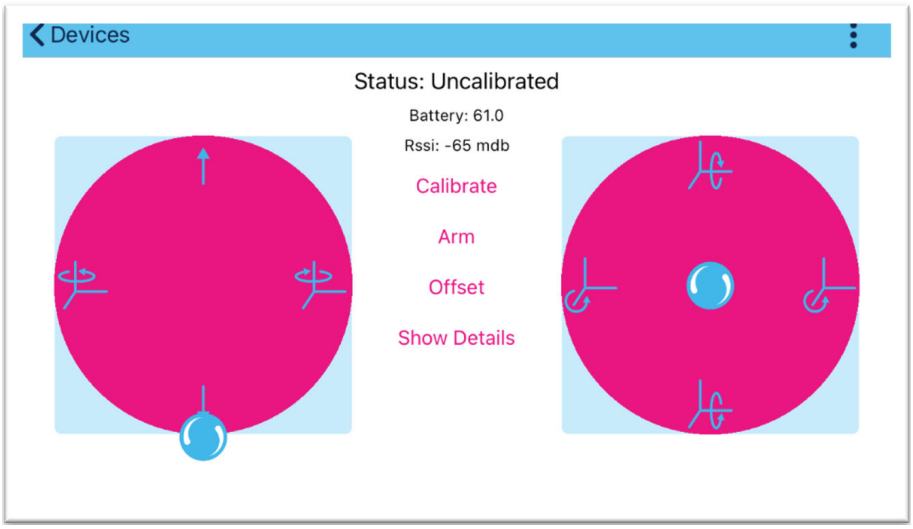
Note: To avoid issues, in case you are using different STEVAL-FCU001V2 evaluation boards in your operating space, you have to reprogram them to show a different name, otherwise you will be not able to distinguish between the different boards.

Figure 22. ST BLE Drone - Discovering devices



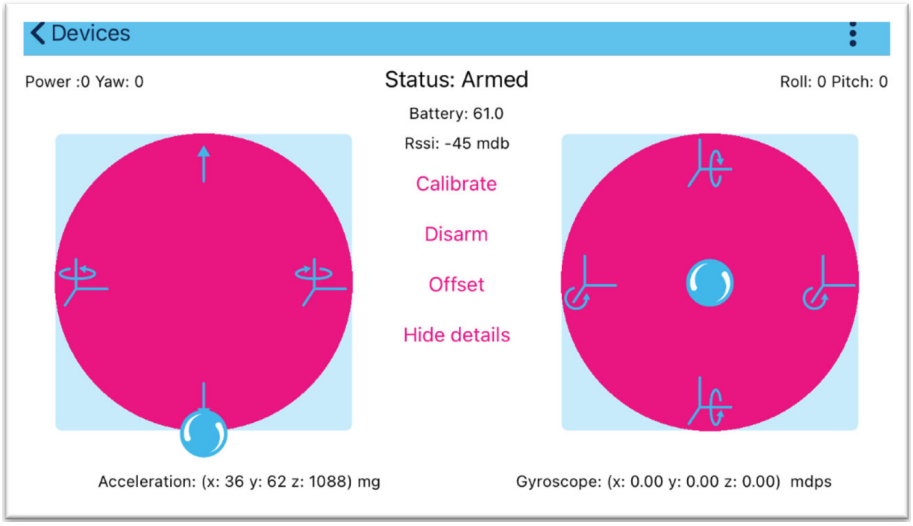
Step 6. Your remote control appears on the screen, see Figure 23, where you can observe the Battery level and the RSSI value of the Bluetooth communication channel. Then tap on [Calibrate] to start the sensor calibration, when this operation is completed the LD1 will turn on and the app will change the Status message in “Calibrated”.

Figure 23. Remote Control



Step 7. To allow flight, tap the button related to the arming procedure.

Figure 24. Armed Status



The Status message changes to "Armed" and LD2 turns on.

Step 8. Move the smartphone left lever up and down.
The voltage on M1, M2, M3 and M4 change according to the drone flight rules described in Section 2.

5 How to fly the drone with the ST BLE Drone app for Android

Before you fly the drone, make sure that you have:

1. updated the latest version of the STSW-FCU001 firmware
2. assembled the STEVAL-DRONE02 kit as described in the Section 4
3. considered enough space around the drone itself

Step 1. Download and install the ST BLE Drone app from Google Play on your smartphone or Tablet.

Step 2. Activate the Bluetooth® connection on your smartphone and enable ST_BLE_DRONE app to use it

Step 3. Place the quadcopter on a flat surface and press the reset button on the board.

Step 4. Run the app.

Figure 25. AppDrone app main screen

Step 5. Click [**Start Connection**] in the main app screen.
You will be prompted to enable Bluetooth on your device, and to select your Drone from the list.

Step 6. Place your drone on a flat, horizontal surface.
The surface represents a reference plane to determine any offsets for the AHRS Euler angles. Ensure the surface is reasonably horizontal or the offsets will be too high for reliable flight.

Step 7. Tap and hold the  icon to perform sensor calibration.
Hold your finger on the icon for a few seconds until it turns green.

Step 8. In the AppDrone app, tap on the  icon.

6 Arming procedure with external remote control

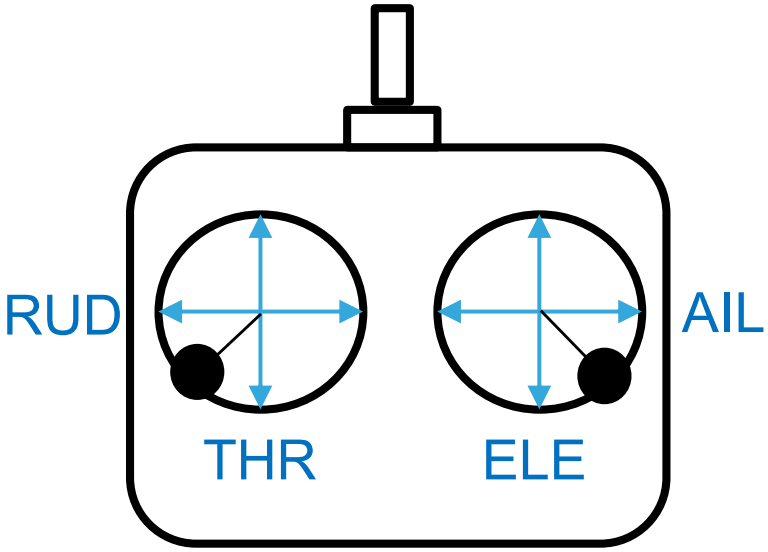
If you are using an external remote control unit:

Step 1. Connect a remote controller receiver to P6 of STEVAL-FCU001V1 (please refer to UM2311 for pinout details).

Step 2. Enable the Remote Controller in the firmware (refer to UM2329).

Step 3. On your remote control unit, move and hold the levers to the positions shown in the figure below:

Figure 26. Remote control lever positions to arm drone



7 Regulatory compliance information

Notice for USA

According to Federal Aviation Administration (FAA) rules, the drone built with the electronic control unit STEVAL-FCU001V2 plus the set of accessories included into the STEVAL-DRONE02 kit is intended for recreational flyers only, according 49 U.S. Code § 44809 - Exception for limited recreational operations of unmanned aircraft. The exception for recreational flyers only applies to flights that are purely for fun or personal enjoyment. A person may operate a small unmanned aircraft without specific certification or operating authority from the Federal Aviation Administration if the operation adheres to all of the following limitations:

(1) The aircraft is flown strictly for recreational purposes.

(2) The aircraft is operated in accordance with or within the programming of a community-based organization's set of safety guidelines that are developed in coordination with the Federal Aviation Administration.

(3) The aircraft is flown within the visual line of sight of the person operating the aircraft or a visual observer co-located and in direct communication with the operator.

(4) The aircraft is operated in a manner that does not interfere with and gives way to any manned aircraft.

(5) In Class B, Class C, or Class D airspace or within the lateral boundaries of the surface area of Class E airspace designated for an airport, the operator obtains prior authorization from the Administrator or designee before operating and complies with all airspace restrictions and prohibitions.

(6) In Class G airspace, the aircraft is flown from the surface to not more than 400 feet above ground level and complies with all airspace restrictions and prohibitions.

(7) The operator has passed an aeronautical knowledge and safety test described in subsection (g) and maintains proof of test passage to be made available to the Administrator or law enforcement upon request.

(8) The aircraft is registered and marked in accordance with chapter 441 of this title and proof of registration is made available to the Administrator or a designee of the Administrator or law enforcement upon request.

The statutory provision (P.L. 115-254, Section 350 p.117, as amended by P.L. 116 283, Section 10002) clarifies that education and research uses of drones for educational purposes can be operated under the rules for recreational flyers.

Notice for Canada

According to Transport Canada rules, the drone built with the electronic control unit STEVAL-FCU001V2 plus the set of accessories included into the STEVAL-DRONE02 kit weigh less than 250 grams (take-off weight less than 250g) and therfore falls into the category of microdrones. These are the precautions that the user must adopt according to this category of drone:

- Avoid emergency sites and restricted airspace (forest fires,first responder perimeters)
- Follow provincial, territorial or municipal rules that mayalso apply, including rules about privacy and trespassing: canada.ca/safe-legal-drones
- Keep the drone below 122 metres (400 feet) in the air—approximately a 30-storey building
- Keep the drone where it can be seen
- Avoid advertised events and airports.

Selon les règles de Transports Canada, le drone construit avec l'unité de contrôle électronique STEVAL-FCU001V2 plus l'ensemble d'accessoires inclus dans le kit STEVAL-DRONE02 pèse moins de 250 grammes (masse au décollage inférieure à 250g) et entre donc dans la catégorie des microdones. Voici les précautions que l'utilisateur doit adopter selon cette catégorie de drone:

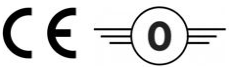
- Évitez les sites d'urgence et l'espace aérien restreint (feux de forêt, périmètres des premiers intervenants)
- Suivez les règles provinciales, territoriales ou municipales qui peuvent également s'appliquer, y compris les règles sur la vie privée et les intrusions: canada.ca/safe-legal-drones
- Gardez le drone en dessous de 122 mètres (400 pieds) dans les airs, soit environ un bâtiment de 30 étages
- Gardez le drone là où il peut être vu
- Évitez les événements annoncés et les aéroports.

Notice for the European Union

The UAS built with the electronic control unit STEVAL-FCU001V2 plus the set of accessories included into the STEVAL-DRONE02 kit is in conformity with the essential requirements of the Directive 2014/53/EU (RED), with the Directive 2015/863/EU (RoHS), with the Regulation (EU) 2019/945 and with the Regulation (EU) 2019/947.

According to EU 2019/947, the drone classification is: UAS of type “Open category” A1, Class C0. This implies that:

- the unmanned aircraft has a maximum take-off mass (MTOM) of less than 250 g, a maximum speed in level flight of 19 m/s, a maximum attainable height above the take-off point limited to 120 m;
- the unmanned aircraft is equipped with a follow-me mode and when this function is on, be in a range not exceeding 50 m from the remote pilot, and make it possible for the remote pilot to regain control of the UA;
- the remote pilot ensures that the unmanned aircraft is kept at a safe distance from people and that it is not flown over assemblies of people;
- the remote pilot keeps the unmanned aircraft in VLOS (“Visual Line of Sight”) at all times except when flying in follow-me mode or when using an unmanned aircraft observer;
- during flight, the unmanned aircraft is maintained within 120 metres from the closest point of the surface of the earth, except when overflying an obstacle;
- when flying an unmanned aircraft within a horizontal distance of 50 metres from an artificial obstacle taller than 105 metres, the maximum height of the UAS operation may be increased up to 15 metres above the height of the obstacle at the request of the entity responsible for the obstacle;
- the remote pilot shall be familiarised with the user's manual provided by the manufacturer of the UAS;
- the remote pilot shall be at least 16 years old;
- during flight, the unmanned aircraft does not carry dangerous goods and does not drop any material;
- it is strictly forbidden to install a camera on this drone.



Notice for the United Kingdom

The UAS built with the electronic control unit STEVAL-FCU001V2 plus the set of accessories included into the STEVAL-DRONE02 kit is in compliance with the UK Radio Equipment Regulations 2017 (UK SI 2017 No. 1206 and amendments), with the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Regulations 2012 (UK SI 2012 No. 3032 and amendments), with the UAS Implementing Regulation CAP 1789A and with the UAS Delegated Regulation CAP 1789B by the UK Civil Aviation Authority (CAA).

According to the UAS Delegated Regulation CAP 1789B, the drone classification is: UAS of type “Open category” A1, Class C0. This implies that:

- the unmanned aircraft has a maximum take-off mass (MTOM) of less than 250 g, a maximum speed in level flight of 19 m/s, a maximum attainable height above the take-off point limited to 120 m;
- the unmanned aircraft is equipped with a follow-me mode and when this function is on, be in a range not exceeding 50 m from the remote pilot, and make it possible for the remote pilot to regain control of the UA;
- the remote pilot ensures that the unmanned aircraft is kept at a safe distance from people and that it is not flown over assemblies of people;
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- the remote pilot shall be at least 16 years old;
- during flight, the unmanned aircraft does not carry dangerous goods and does not drop any material;
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Revision history

Table 1. **Document revision history**

Date	Revision	Changes
28-Aug-2023	1	Initial release.
13-Jun-2024	2	Updated Section 2: Overview, Section 3: How to mount the your own mini drone and Section 5: How to fly the drone with the ST BLE Drone app for Android. Added Section 4: How to fly the drone with the ST BLE Drone App for iOS.

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