DRONE THEORY

College Name

→SRM Institute of Science and Technology.

Club Name

→SRM UAV.

Domain

→Electronics.

Introduction

Unmanned aerial vehicle technology covers everything from the aerodynamics of the drone, materials in the manufacture of the physical UAV, to the circuit boards, chipset and software, which are the brains of the drone.

One of the most popular drones on the market is the DJI Phantom series. These drones are very popular with professional aerial cinematographers.

This Phantom UAVs are ideal to explain drone technology because they have everything in one package. It includes the UAV, gimbal and camera. They also have some of the top drone technology on the market today.

In the past few months, newer and highly advanced drones such as the DJI Mavic Mini, Mavic 2, Mavic Air 2, Phantom 4 Pro V2.0, Yuneec Typhoon H3 and Autel Evo 2 have come to the market.

Working principle

In this report, I'll be focusing on quadcopters but a lot of what I explain here applies to other flying devices with more than four propellers. Now, unlike the traditional helicopter, the quad relies on its four rotors to generate uplifting thrust by working together. Every single rotor lift around a quarter of the overall weight, which allows us to use smaller and less expensive motors. You basically control the movement of the quad by changing the amount of power each motor delivers to its propellers.

The motors are positioned in every corner of an imaginary square. On one diagonal, you have two motors that rotate in a clockwise direction, while the remaining two, on the opposite diagonal, rotate counter clockwise. If this wasn't the case, the quad would only spin around like a traditional helicopter when the tail rotor dies.

Before I explain how a quadcopter or any multi-rotator works there are some important concepts that we need to define – pitch, yaw and roll. These terms refer to the three dimensions that an aircraft in flight is free to move it.

- Pitch – Pitch refers to the nose of the aircraft going up or down. You could think of it as climbing or diving
- Yaw – Yaw on the other hand refers to the nose of the aircraft turning left or right. You could simply think of this as turning.
- Roll – To understand roll think of an axis running from the front to the back of the aircraft. When an aircraft rolls it is turning on this access. You can also think of roll as a tilt.

Quadcopters make use of 4 Motors. Two of these motor spin clockwise while the other two spin counter clockwise. Motors on the same axis spin in the same direction, as illustrated here.

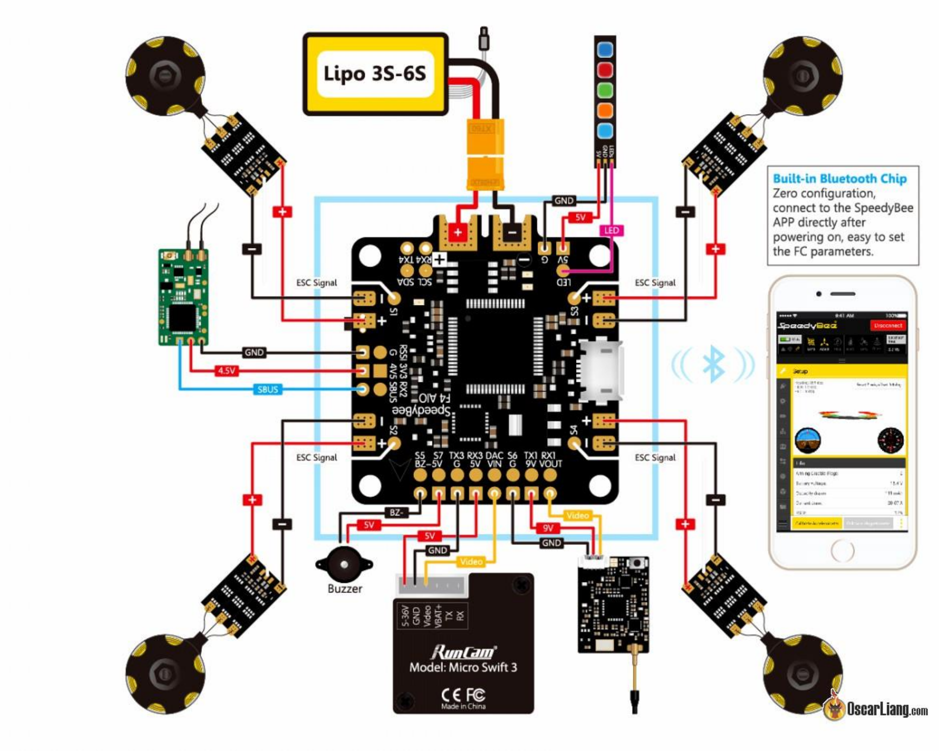
Altitude is a term that you're probably familiar with – it simply describes going up or down. A quadcopter can either hover or adjust its altitude by applying equal thrust to all four rotors.

To adjust its Yaw, or make it turn left or right, the quadcopter applies more thrust to one set of motors. For example, a quadcopter may apply more thrust to the two motors that spin clockwise to make a turn.

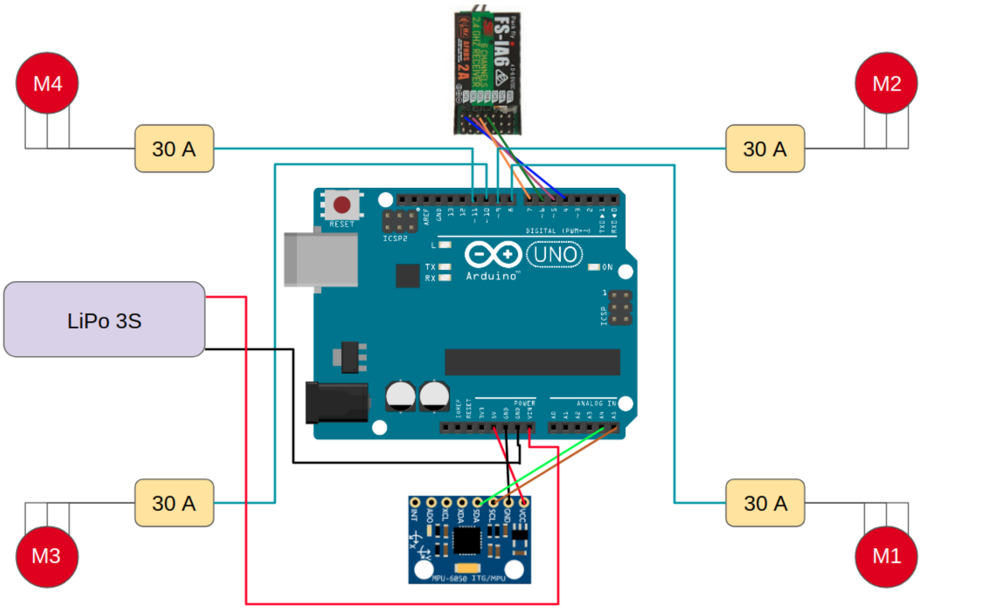
Pitch and roll on the other hand are adjusted by apply more thrust on one rotor and less to the other opposing rotor. For example, the quadcopter can adjust its pitch by applying more thrust to the clockwise spinning motor in the front and less thrust to the clockwise spinning motor directly opposite in the back.

One thing that makes quadcopters easy to fly is that you don’t actually have to adjust the motor speeds manually as this is where the controller and electronics come in. I’ll discuss the electronics in a moment but first let’s examine the motors.

Schematic diagram



Schematic diagram of quadcopter with flight controller



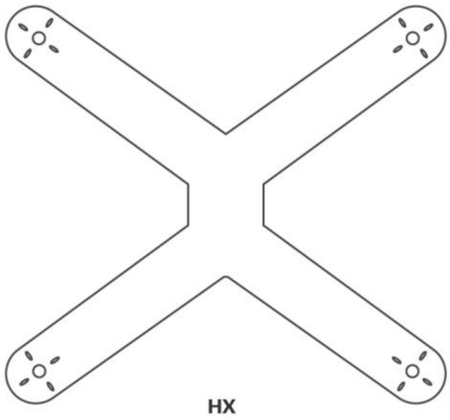
Schematic diagram of quadcopter with Arduino UNO

Components

Every quad will have to include the elements listed below in order to fly. Here is a short summation of each of the various parts of a quad, and we will cover these in more detail as the article goes on:

Frame

The “backbone” of the quadcopter. The frame is what keeps all the parts of the helicopter together. It has to be sturdy, but on the other hand, it also has to be light so that the motors and the batteries don’t struggle to keep it in the air. The frame can be made of aluminum, carbon fiber or wood but the material that is mostly used for the arms is aluminum. More precisely, the square hollow rails of the arms are made of aluminum. They are relatively lightweight, rigid and cheap. But, since they are not known as great compensators for the motor vibrations like carbon fiber ones are, they can confuse the sensors.



The size of the frame will determine what size props you will use (or vice versa), in turn the size of the props will determine the size of the motors, which will specify the current rating of your ESC's.

Motors

The thrust that allows the quadcopter to get airborne is provided by Brushless DC motors and each of them is separately controlled by an electronic speed controller or ESC. BRUSHLESS MOTORS

These motors are almost the same thing as traditional DC motors, but the shaft on them doesn't come with a brush, which is there to change the direction of the power that goes through the coils. When buying these motors, you need to check their technical data.

ESCs

Electronic Speed Controller is like a nerve that delivers the movement information from the brain (flight controller) to the arm or leg muscles (motors). It regulates how much power the motors get, which determines the speed and direction changes of the quad.

The ESC will have three sets of wires. There are three heavy-gauge wires that connect to the three wires on your brushless motor. Two other heavy-gauge wires connect to your power distribution board, this supplies voltage to the ESC and motors. There will also be three smaller wires that connect to your flight controller.

The ESC must be rated to handle the maximum current that your motor consumes. It is always wise to choose an ESC that is rated higher than the motor's maximum current.

Propellers

Depending on the type of a quad you build, you can use 9 to 10 or 11-inch props (for stable, aerial photography flights), or 5-inch racing props for less thrust but more speed. Propellers are standardized, and here are the most used ones for quads:

- → 5 pitch, 8 diameter – Small quads
- → 8 pitch, 9 diameter – Small quads
- → 5 pitch, 10 diameter – Medium-sized quads
- → 7 pitch, 10 diameter – Medium-sized quads
- → 5 pitch, 12 diameter– Provide plenty of thrusts and are great for quads that are larger

Battery

Depending on your setup maximum voltage level, you can choose from 2S, 3S, 4S, or even 5S batteries. But, for a standard for a quad that is planned to be used for aerial filming or photography (just an example), you will need a 11.4 V 3S battery. You could go with the 22.8 V 4S if you are building a racing quad and you want the motors to spin a lot faster.

The most popular version among the drone hobbyists is known as the 3SP1 battery, which comes with three cells and provides 11.1V.

Arduino board

We can either choose to use a controller board that's only purpose is to control a quadcopter, or you can choose an Arduino UNO. This is a general-purpose microcontroller that allows us to build your own flight controller by buying the parts you want to install, and assembling the controller on our own.

It comes with:

⟶ 14 digital input/output pins (6 of them can be used as outputs for PWM)

⟶ 6 analog inputs

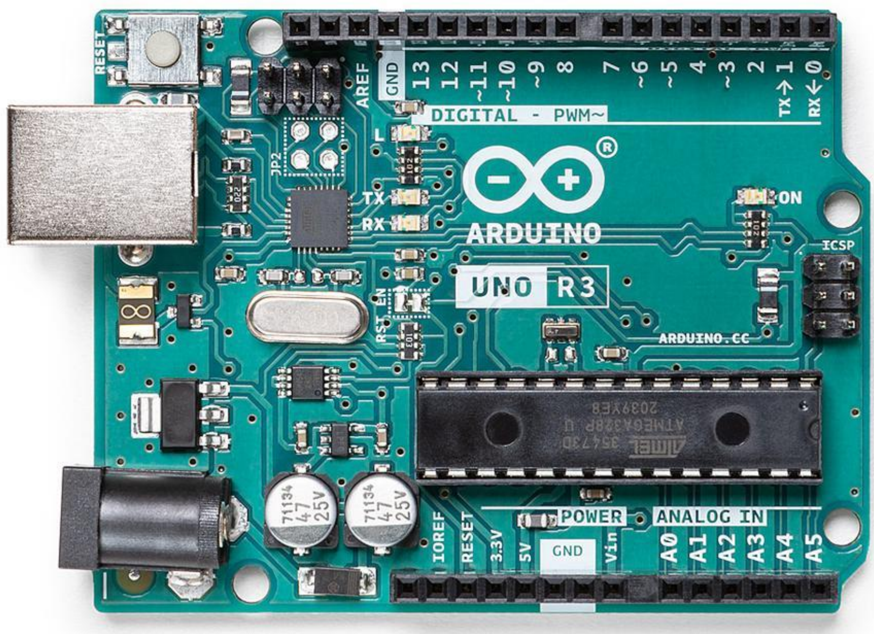
⟶ a 16 MHz quartz crystal

⟶ a USB connector

→ a power jack

→ an ICSP header

→ a reset button



OR

The Flight Controller

It is the brains of your quadcopter. This is the device that controls the speed of your motors by sending signals to your ESCs.

Advanced flight controllers have more features and are coupled with sensors such as gyros, accelerometers, sonar, GPS and magnetometers. Simple flight controllers contain only gyros and these are quite sufficient for most beginners.

Most of the wiring on your quad will be focussed around the FC. It needs to have the RX (receiver) connected, so it can be told what the pilot wants the craft to do. Each of the ESC signal and ground wires need to be connected for the FC commands to be carried out by the motors. With the introduction of BetaFlight OSD (On Screen Display), even the video feed from the FPV camera goes via the FC to the VTX (Video Transmitter).

IMU

A board that is basically (depending on your choice) a sum of various sensors that help your quad know where it is and how to level itself. This unit is in charge of measuring the quad's orientation, velocity, and the force of gravity.

This allows the electronics to control the amount of power sent to motors, in order to adjust the motors' speeds. The unit comes equipped with a 3-axis gyroscope, and a 3-axis accelerometer. This combination is known as the 6DOF IMU.

The gyroscope is there to read the values of angular velocity, while the accelerometer is in charge of measuring acceleration and force, meaning that it can feel the downwards gravity. Since it comes with three-axis sensors, it can sense the orientation of the quad.

RC Controller

The choice of the transmitter depends on the choice of the protocol you are going to use and the signal receiver that is onboard the drone.

This comes in handy for those who want to perform aerial stunts, because tilting the drone a bit is possible, and after the release of the sticks, the quad keeps the position.

It's not a good mode for beginners because it is quite difficult to control your quad in this mode. Basically, the more skill you have at controlling the drone, the less help we will likely want with stability.

SENSORS

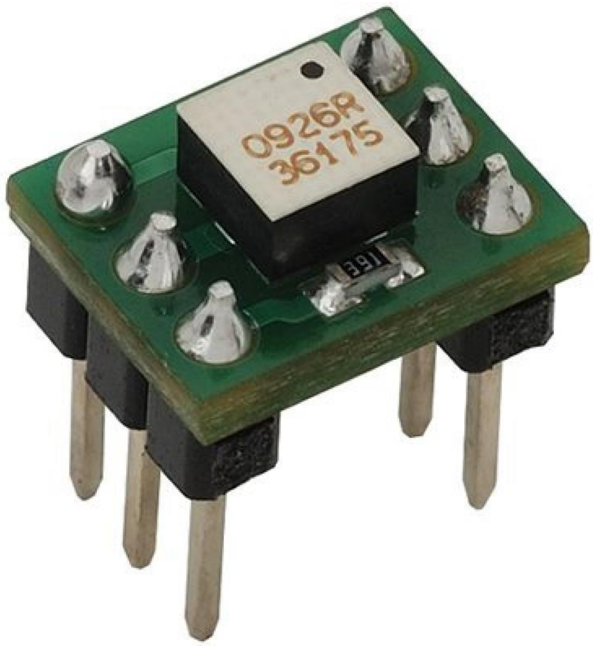
Accelerometers

Accelerometers are used to determine position and orientation of the drone in flight. Like your Nintendo Wii controller or your iPhone screen position, these small silicon-based sensors play a key role in maintaining flight control. MEMS accelerometers sense movement in several ways.

One type of technology senses the micro movement of very small structures embedded in a small integrated circuit. The movement of these small 'diving boards' changes the amount of electrical current moving through the structure, indicating a change of position relative to gravity.

Tilt Sensors

Tilt sensors, combined with gyros and accelerometers, provide input to the flight-control system in order to maintain level flight. This is extremely important for applications where stability is paramount, from surveillance to delivery of fragile goods.



These types of sensors combine accelerometers with gyroscopes, allowing the detection of small variations of movement. It is the gyroscope compensation that allows these tilt sensors to be used in moving applications like motor vehicles or drones.

Current Sensors

In drones, power consumption and use are important. Current sensors can be used to monitor and optimize power drain, safe charging of internal batteries, and detect fault conditions with motors or other areas of the system.

Current sensors work by measuring electrical current (bi-directional) and ideally provide electrical isolation to reduce power loss and eliminate the opportunity for electrical shock or damage to the user or systems. Sensors with fast response time and high accuracy optimize battery life and performance of drones.

Engine Intake Flow Sensors

Flow sensors can be used to effectively monitor air flow into small gas engines used to power some drone varieties. These help the engine CPU determine the proper fuel-to-air ratio at a specified engine speed, which results in improved power and efficiency, and reduced emissions.

Many gas engine mass-flow sensors employ a calorimetric principal utilizing a heated element and at least one temperature sensor to quantify mass flow. MEMS thermal mass air flow sensors also utilize the calorimetric principal, but in a micro scale, making it highly suitable for applications where reduced weight is critical.

Reference

[How does a Quadcopter Work? | DroneBot Workshop]