Drone Building GUIDE

Learn to build a quadopter drone in simple, easy steps

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Building and choosing parts

Picking the drone body/frame

The frame or body is what holds everything together. They are generally designed to be strong and lightweight and consist of a center plate where the main flight controller chip and sensors are mounted and arms where the motors are mounted. It is most often made of carbon fiber, titanium, fiberglass, aluminum, balsa wood or steel. Some cheaper, smaller models also use plastic.

Carbon fiber is the most ideal material for a quadcopter frame. They're very strong, stiff, durable and light. If you are building your own frame however, know that carbon fiber is toxic to breathe!

The second most commonly used material is the fiberglass. They are however, softer and less durable than carbon fiber. They are also relatively heavier. However, they're pretty cheap!

If you are looking to build your own frame, we suggest you use balsa wood or plastic to begin with. Though they are not the most ideal in terms of sturdiness or weight, they are easier to acquire and build on.

With some creative thinking, you can even build frames out of PVC or duct tapes!

As of pre-made frames, they come in varieties for different multirotor types: Tricopter, quadcopter, hexacopter, octocopter. It also varies on different builds, especially if you are building a quadcopter. The X-frame is the most popular and is used on most quadcotpers , the I-frame (mainly used on racing drones) and the V-tail frame.

You should also consider the size of frame. Different sized frames will be capable of swinging different sized props. And as we'll see in the next section, larger multirotors are usually used to fly high altitudes and in rougher wind conditions while smaller multirotors are more capable of agility.

In conclusion, consider the following before picking a frame for your multirotor:

- Do you want to build one on your own or buy a pre-existing one? If you want to build one, consider using materials such as plastic, balsa wood, PVC or even duct tape! If you want to buy a pre-existing frame, we recommend you start with either fiberglass or carbon fiber.
- Consider the size of the multirotor you want to build and choose the frame size accordingly. Larger multirotors are ideal for flying high altitudes and in tough weather and for carrying payloads for photography, videography and thermal imagining while smaller ones are agile, maneuverable flyers (think indoor flying and drone racing).
- This is related to the above point, but consider the size of the propeller you want the drone to rotate. You do not want your frame to be so small that the propeller would clip into the frame while swinging. At the same time, you want your frame to be small and light enough for your chosen propeller size to generate enough thrust to generate lift. We'll see this in the next section.
- Choose if you want to build a tricopter, quadcopter, hexacopter or octocopter.

- Pick the type of frame: X-frame and I-frame are the most common types of frames if you are building a quadcopter. X is the most stable with perfect centre of gravity while I frame is suitable if you need room to add stuff ON the quadcopter, for example, FPV equipment for drone racing.

Picking the motors and propellers

The motivation behind using motors is to turn the propellers, which is responsible for providing thrust for countering gravity and drag. Every rotor ought to be controlled separately by a speed controller. Motors are the primary force behind how quadcopters fly.

They are somewhat like typical DC motors in the sense that coils and magnets are utilized to drive the shaft. The brushless motors do not have a brush on the shaft that deals with iterating the power in the coils, hence, the 'brushless' reference.

The brushless motors have 3 coils on the inside center of the motor, which is settled to the mounting. On the external side, it contains multiple magnets mounted to the cylindrical structure that is appended to the turning shaft.

Hence, the coils are fixed and there is no need for brushless. Brushless motors turn a lot quicker and utilize less power at the same speed relative to DC motors. Unlike DC motors, they don't lose power in the brush-transition, so it is a lot more vitality productive.

The Kv (kilovolts) – rating in a motor demonstrates how various RPMs (Revolutions each moment) the motor will do per volt. The higher the kV rating is, quicker the motor rotates at a steady voltage.

Having a basic idea about brushless motors and the ability to understand different configurations and specifications will go a long way if you want to tweak and build your multirotors.

Though the specifics behind the inner workings of these motors are beyond the scope of this post, we will cover enough for you to be choosing motors and propellers that are right for your craft.

KV rating

The first thing you need to understand is the KV rating. Here, it stands for the number of rotations the motor makes per minute for every volt applied to it. Higher the KV, the faster it rotates per volt.

Most motors come with the KV rating printed on it. If you are unsure, you can use a tachometer to get a rough idea of the RPM (Divide the RPM on the tachometer with the number of volts the battery you connect to has)

Generally speaking, high KV ratings are found on smaller motors and these are used to drive smaller propellers. These motors tend to be thinner. Larger motors with lower KV drive larger props. These motors tend to be wide and short.

The choice should be on whether you want speed and acrobatics or the ability to carry heavy loads and fly high (typically for aerial photography). For speed, you typically want a high KV – small prop setup. For carrying heavier loads, you want larger propellers and motors capable of such propellers.

Voltage, Power (Watts) and Thrust

The voltage specification on your motor determines how much voltage can be applied to it. This generally comes as a function of propeller size. As the amount of voltage applied on the motor increases, it is recommended that the prop size be reduced. Most manufacturers will have a recommended propeller size.

Power (Watts) is Voltage x Current. Generally, higher the Watt rating of the motor, the higher will be the power of the motor itself.

This is maximum potential horsepower your motor can produce, without being damaged.

Thrust is roughly the measure of how much the motor is capable of producing a propulsive force. Most manufacturers will print the thrust rating of motors on the motor itself. If you are unsure, you can use an online calculator. It is still recommended to contact your manufacturer to make sure.

So that's it for motors. Hopefully by now you have an idea about the KV, voltage and thrust ratings of motors and what it means. We will be using this information very soon.

Propellers

Understanding propellers and knowing how to choose the right ones is important as it typically goes hand in hand with the choice you make with the motors. While you can use this information to decide what propeller to choose, never go overboard and always stay within the prop size ranges recommended for the motor.

Propeller diameter and pitch

When you go to purchase propellers, the specifications on it are defined in terms of diameter and pitch (D x P). For example, a 9 x 4 propeller has a diameter of 9 and a pitch of 4.

The **diameter** is the end to end length (in inches) of the propeller. It determines how much surface area of the prop is in contact with air around it at all times. Note that slight variations in propeller sizes can drastically change the responsiveness and efficiency of your craft.

Larger props swinging at lower RPMs are paired with lower KV rated motors and are more efficient relative to smaller props paired with higher KV rated motors.

Larger props are used in scenarios where there are heavy loads (like a camera) attached to the craft and are ideal for aerial photography and videography. Smaller props are ideal for speedy crafts ready to take on acrobatic maneuverers.

The '**pitch**' of a propeller can be defined as the distance (in inches) travelled per revolution. Higher the pitch of a prop, the speedier your craft gets. This comes with a price – higher pitched props produce turbulence and are not as energy efficient.

Lower pitched propellers, like the longer ones are ideal for flight efficiency, hence used for aerial photography and videography while higher pitched propellers are picked for speed and acrobatics.

When picking the right propeller, it is important to consider both the diameter and pitch. Finding the balance between both is one of the key factors to building an amazing craft.

Material used

Propellers are built with different materials including plastic, carbon fiber and wood. The material that the prop is built with can make a difference in flight times and efficiency. Generally, carbon fiber props tend to be lighter and can add to flight times.

As a general rule of thumb, quality matters more than the specific material used and can make a world of difference in your flying experience including reduced vibrations and increased responsiveness and stability.

Rotation

It is very important to purchase both clockwise and counter clockwise propellers while building or tweaking your craft. Both should be purchased in the same amount. It would be simply impossible for your quadcopter to hover and fly around if all of the props rotate in the same direction.

Putting it together

Now that we have shed some light into the basics of motors and propellers, it is time to put that knowledge to use to build or tweak our craft.

First, we need to consider the weight our craft. While measuring the weight, it is important to consider everything including any cameras or loads that maybe attached to it. Next, we have to take into consideration the **thrust to weight ratio** of the multirotor. This is the most important element.

We want our craft to be able to hover at about half (50%) throttle. This is to ensure that we have ample headroom for speeding and gaining altitude when necessary. To get this, it is generally recommended to **aim for a thrust to weight ratio of 2:1**.

However, we should aim for a little bit more than that to account for any inefficiency with the motors and/or propellers. Hence, a **2.5:1** thrust to weight ratio would be ideal. For example, if our craft weighs 500 grams, we should then aim for a total thrust of 1250 grams.

Note that when we measure the thrust, it is the **total** thrust. Hence, while picking motors, we divide the total thrust by the amount of motors. Hence, for quadcopters, we divide the thrust by 4. In our previous example, thrust per motor would be 1250/4 or about 312 grams. For tricopters, we divide total thrust required by 3 and so on.

After you have picked your motor, it now boils down to picking the right propeller to go along with it. As mentioned before, stick to using propellers near what is recommended for the motor for any particular cell count.

We have already covered the basic things that you need to know about propellers. Remember that larger propellers with lower pitch ratings are more efficient than smaller propellers with higher pitch ratings. Higher KV ratings on the motor aren't everything for every scenario. Remember – balance is key and you may need to play around a little bit before you find the perfect combination for your specific purposes.

Other important things to consider –

- **Make sure your motors can handle the voltages of the battery.**
- **Make sure the propellers come within recommended range**.

Picking ESCs

Motors spin, but in order to fully understand how quadcopters work, we need to understand how the motor is controlled. The electronic speed controller or (ESC) is what tells the motor how to spin. It is responsible for controlling the rate at which the motor it is connected to, spins. Since the multirotor motors are supposed to spin at variable speeds, depending on control inputs, ESCs are crucial. In a multirotor, each motor will have an associated ESC connected to it.

The ESCs are connected to the batteries via the power distribution board within the multirotor's frame. Most ESCs come with a battery eliminator circuit (BEC) which acts as a voltage regulator, allowing other electronic components like the flight controller and receiver to power up without connecting them directly to a battery. If your ESCs do not come with an in built BEC, make sure to get a compatible BEC!

It is important the measure the current draw of the motors to make sure that the ESCs can support it. Never load the ESCs with motors that draw more than the current rating of the ESC.

Suppose our motors have a current draw rate of 10 Amps, it is important to make sure that the ESCs have a current rating of at least + 30% to allow for some headroom in case of unforeseen circumstances. In this example, we will be picking at least 13A ESCs.

Picking flight controller

The flight controller is the mind or 'brain' of the multirotor. This board is what sits at the center, controlling the firmware within the ESCs, consequently controlling the spin rate of the motors. This is how a quadcopter flies.

Essentially, it takes the inputs from the receiver (Throttle, Elevator, Rudder and Aileron) and adjusts the motor RPM accordingly, via ESC.

Flight control systems house additional sensors to enhance control and stability of the craft. The controller usually contains gyroscope, accelerometer and barometer. GPS can also be added onto the flight controller to feed coordinate information and altitude information of the multirotor.

The following is the sequence of how quadcopters work: Flight controller -> EScs -> Motors.

To figure out what is the best flight controller for your craft, you must first figure out WHAT EXACTLY you are trying to accomplish. Are you a beginner trying to build that first quadcopter/multirotor? Do you want toA 5C charge rate on a 1000 mAh battery would allow you to charge it completely in 60 minutes/5 = 12 minutes.

build a fast, racing style multirotor? Or are you a tech savvy cinematographer looking to build a multirotor to add to your photography and videography repertoire?

Of course, depending on what you want to accomplish, the price will vary. A flight controller like the KK2.X for a beginner or a Naze32 (which is typically popular on racing quads), would be way cheaper than a flight controller capable of autonomous flight and videography. Racing quads are often equipped with flight controllers that are on the cheaper end of the scale (mainly because they are prone to crashing).

Ease of setup and firmware

I don't know about you, but to us, a flight controller that is a pain to setup is less valuable than one that is easy to get going with. Some boards are compatible with configurator software packages such as CleanFlight and OpenPilot, which are very easy to setup. CC3D and Naze 32 are examples.

Other boards like the KK 2.X models, come with an on-board UI that makes tuning (PID, for instance) very easy, without having to go back to your PC all the time. Many boards come with their own configurator package and firmware.

Fly-ability

Not all flight controllers fly the same. Some flight controllers are better than others at handling and balancing. The KK 2.X model's handling capabilities for example, is far inferior to the Eagle tree vector.

Quick note: Please make sure to update your flight controller firmware before even setting it up and taking it out for flying. Many boards have reported to have significantly improved their fly-ability from their initial firmware release (including the KK 2.Xs).

Supported sensors and capabilities

Last but not in any way the least, you must consider the capabilities that the said flight controller supports. The following is a list of sensors and features that you must check whether or not the flight controller supports, depending on your needs:

- Microcontroller bit size (8bit vs 32 bit): 32 bit flight controllers are far superior to 8 bit ones in terms of handling the craft
- Gyroscope and accelerometers : All flight controllers have these
- Barometer : Holding altitudes (A requirement for most cinematography based multicopters)
- Magnetometer : Useful for detecting direction (head holding)
- GPS : Useful for autonomous flights
- Whether or not the flight controller supports the kind of craft you want to build: (quadcopter, hexacopter, tricopter, octocopter and so on and so forth)

In Summary, consider the following before making a purchase:

- What do you want to build with the flight controller? A 250 style quad? An autonomous flying machine? A cinematography capable drone?
- Supported sensors and other capabilities
- Open source vs. closed source?

- Is the said flight controller new or is it tested thoroughly and battle hardened over the years?

Picking Transmitters and Receivers

The radio transmitter and receiver is used to control the quadcopter. In order for a quadcopter to work, four channels (throttle, elevator, aileron rudder) are required. Getting a transmitter with 6 or 8 channels is recommended for additional functionalities.

Quadcopters can be programmed and controlled in totally different ways. However the most common ones are in either rate (acrobatic) or stable mode. In rate mode, only the gyroscope is used to control the quadcopter balanced, it does not self-level.

If switched to stable mode, the accelerometer gets activated, helping to stabilize the quadcopter. The speed of the 4 motors can be adjusted automatically and perpetually to keep the quadcopter balanced.

A transmitter may also have an FPV screen on which a camera mounted on the multirotor beams video in real time. This gives the pilot a unique experience of flying by seeing what the multirotor sees.

Budget

Before you go about looking for the best RC transmitter for your RC quad, heli or plane, you should first set a budget. RC transmitters can range from $50 to all the way up to $1000! Now of course, this will depend on how committed to flying you are. If you are a beginner, it is recommended that you get a cheap (but good quality) transmitter.

However, if you plan on flying for years to come, we recommend you invest in a higher end, higher quality transmitter that you can use for multiple, different crafts that you would purchase or build on your own.

Number of channels

This is more or less tied to the budget. Typically, the higher the number of channels the transmitter supports, the higher the price. RC transmitters for quadcopters, planes and helicopters range from 4 channel to all the way up to 10 channels and beyond.

- The basic 4 channel transmitter offers the following functionalities on its 4 different channels –
- Throttle
- Yaw
- Pitch
- Roll

The additional channels on the transmitters are typically used for changing flight modes or changing control to a camera gimbal by 'switching'. For example, on a quadcopter, you could use the additional channel switches to change from 'Acro' mode to self-level mode.

For a beginner, a 6 channel transmitter like the **Spectrum DX-6i** would be a great long term investment. A transmitter like this would allow you to have all the basic functionalities plus the ability to change flight modes.

If you are more advanced, an 8 channel transmitter like the **Futaba T8J** or a 9 channel model like the **Hi-Tec Aurora 9** is a great buy. Another GREAT transmitter you should check out is the

FrSky Taranis X9D. It is reasonably priced and supports over 14 channels!

Memory

Model memory is another consideration that must be taken into account, especially if you plan on flying multiple different crafts including different quadcopters, helicopters or planes. Needless to say, the ability to store settings for your different crafts should not be underestimated.

The basic models like the **Spektrum DX-6i** has a model memory of 10, which should be more than enough for a beginner. On the other hand, some models like the **Spektrum DX9**, can store up to 250 models!

Features and build quality

The amount of features your transmitter has is yet another consideration. Having a backlight in the display screen can seem trivial but can make a big difference in your usability experience. Other things to consider are:

- Build quality and how the gimbals and the sticks feel

- Buddy training support
- Programmable firmware

Bind and fly models

This is something that cannot be stressed enough. If you plan on purchasing a transmitter for a bind and fly quadcopter, plane or helicopter, make sure that it is going to be compatible with the model or you'll be wasting your money.

Modes

Note that there are 4 different modes transmitters come in. The most common mode that you would see is mode 2. Make sure to check that your transmitter supports the correct mode you are used to flying in.

The ability to use with a simulator

We recommend that you do not overlook this. Especially if you are a beginner, you might want to train plenty on a flight simulator. The OrangeRX T-SIX for example, is a cheap, 6 channel transmitter for beginners and it works well with flight simulators, so we consider it as a great buy.

Flight simulators are a great way to train if you are a beginner. They are also an excellent tool to maintain your skills during harsh winter conditions since you probably wouldn't be able to head out much!

Picking batteries

Lithium Polymer (LiPo) batteries are the most famous power source for controlling multirotors (or 'drones') today. Without going a lot into detail, the principle explanation behind this is on the grounds that they are rechargeable and ordinarily have expansive limits.

LiPo batteries can have discharge rates sufficiently expansive to control even probably the most taxing multirotors. This settles on them the favoured decision over different choices, for example, the

Nickel Cadmium (NiCd) battery. This is likewise the essential reason they can be a genuine fuel source for multirotors.

Capacity

Higher the capacity for your battery, the longer flight times you can expect. There is an important caveat here however – batteries tend to get really large and heavy at larger capacities and so you cannot simply scale this indefinitely.

Weight is an important factor to consider when selecting your LiPo batteries. Even if you get a battery with the largest capacity on the planet, it may not give you the flight times you'd expect.

Remember that the heavier the craft gets, the harder it is on your motors and propellers. This means more power drawn and that defeats the purpose of going for a larger battery in the first place! And if you go too heavy, your craft may not fly at all. Remember the thrust to weight ratio!

Go for the highest C (discharge) rating possible

If budget permits, go for the highest C rating possible on any given capacity. If you get too frugal here, you could damage your motors and ESCs! Not to mention you would be completely limited in your ability to do all the cool moves with your RC craft!

When you are out LiPo shopping in your local hobby store, it is better to pick one solid, highly dischargeable battery than 2 or 3 batteries with low C rating.

Voltage

When you pick your LiPo, make sure it meets the voltage requirements of your motors! For example, if your motors require 10 volts, make sure your batteries have a reading of at least 10 volts!

This means that the amount of required cells in your battery (The 'S' rating) would vary from motor to motor!

Like discharge rate, if you go too low, it will damage your motors!

Picking a drone kit

Kits are the easiest way for a beginner to learn how to assemble a multirotor drone. It comes with all the basic parts you'll need and every part is designed to work with one another.

The other advantage of a quadcopter kit is that it is cheaper. A similarly powerful RTF quad would be much more expensive.

You could of course buy all the parts needed separately and build a custom quad instead of getting a quadcopter kit, but we discourage you from doing that if you are new to this. Quadcopter kits come with all the necessary parts in configurations that **work well with each other**. You don't have to calculate and experiment.

Quadcopter size

Before you go about choosing the best quadcopter kit, you should decide the size of the quadcopter you want to build. The 450 quad is fit to carry heavier batteries and other payload. They are also faster and stable, especially in windy conditions. That being said, the 250 style quad is more maneuverable.

Glass fiber vs. Carbon fiber for the body

Most kits come with a body that has a glass fiber body while others have a carbon fiber body. What you need to know is that carbon fiber is lighter and more rigid but glass fiber is much more "flexible", making it less prone to breaking. Cost wise, glass fiber is much cheaper.

Here is a list of quadcopter kits that we usually recommend to beginners. We try to keep the article updated as much as possible!

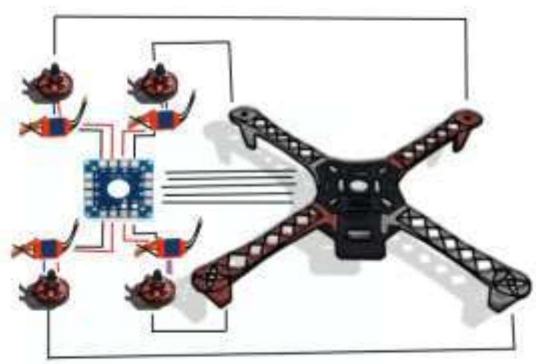
Putting it all together (Building a simple multirotor)

Mount the power distribution board onto center of the frame

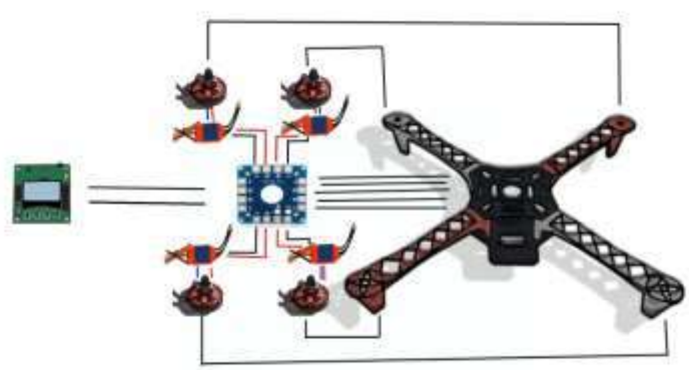
Connect the ESCs onto the power distribution board, zip tie them onto the frame under each arm.

Connect the motors to the ESCs (use bullet connectors)

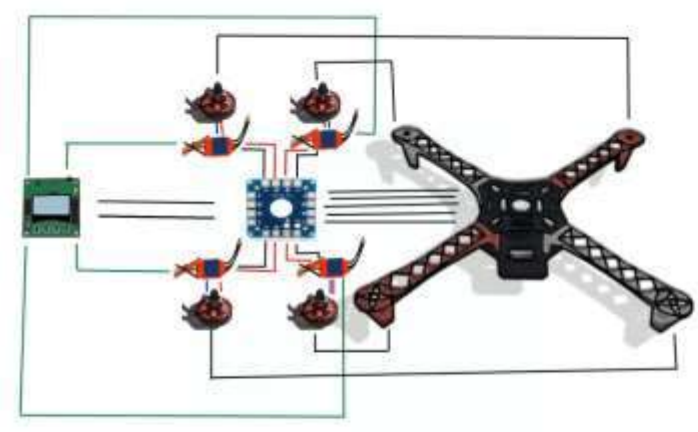
Screw the motors onto the frame.



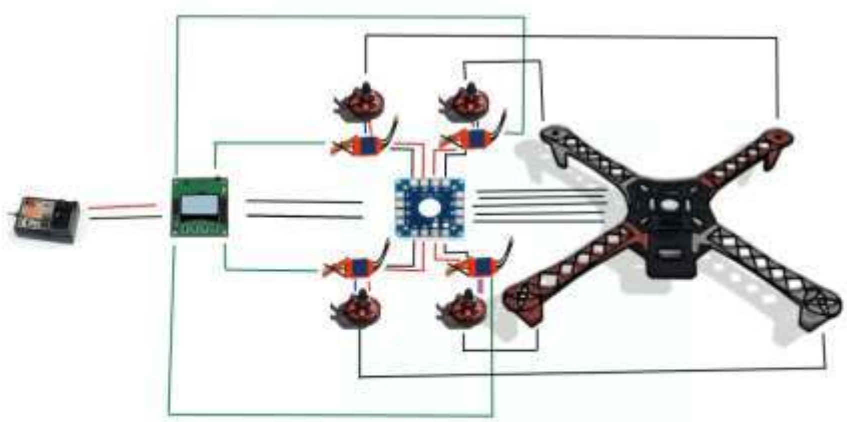
Mount the flight controller onto the center of the frame, above the power distribution board. Note that the flight controller will not be directly connected to a power source. The power will be delivered via the ESCs



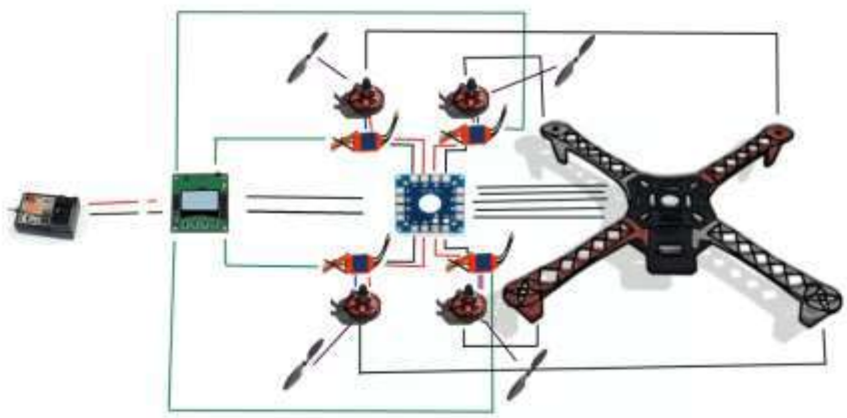
Connect the ESCs to the flight controller



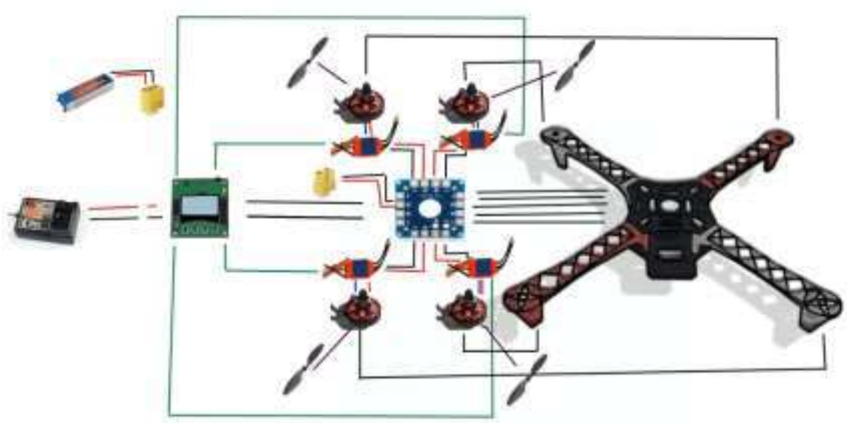
Connect the flight controller to the receiver



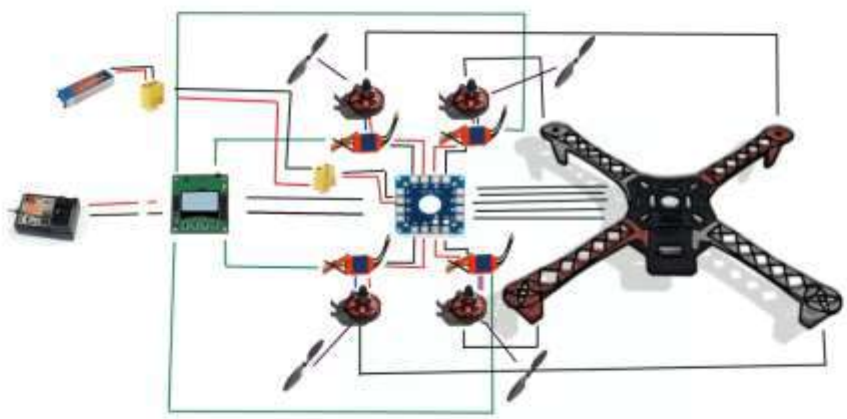
Mount the propellers onto the motors. Note: You may want to skip this step and leave it till the end if you want to test the motor orientation. If the rotation of any motor is not correct, simply switch the ESC -> motor wires for that particular motor.



Connect the battery and solder wires onto the power distribution board onto complimentary connectors so they can be connected.



Connect the battery. Your multirotor should now power up. Time to test it out!



Free resources you should check out

- Resources to build an Arduino Quadcopter: http://www.droneybee.com/arduino-quadcopter-guide/
- Picking your flight controller: http://www.droneybee.com/best-flight-controller-quadcopter/
- Taking care of your LiPo batteries: http://www.droneybee.com/lipo-battery-tutorial/
- Building an FPV quadcopter Part 1: https://www.youtube.com/watch?v=EYAW6kVoxHc
- Building an FPV quadcopter Part 2: https://www.youtube.com/watch?v=J3CtoXy53Cw
- DIY Mini quadcopter: https://www.youtube.com/watch?v=R9cpGJ3Sw90
- Make quadcopter from plastic box: https://www.youtube.com/watch?v=NHBxqRLjEos
- How to build a quadcopter (ELECTROHUB build): https://www.youtube.com/watch?v=c5yXm_PJxK0