UNDERSTANDING THE TECHNOLOGY USED IN FPV DRONES

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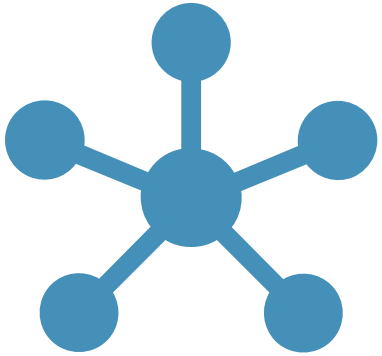
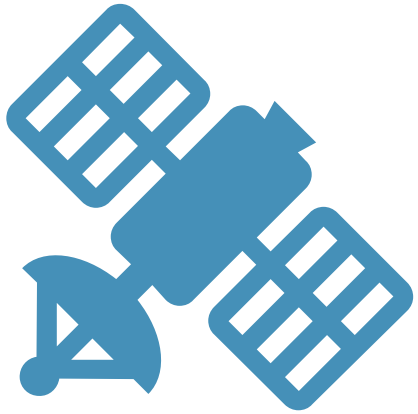
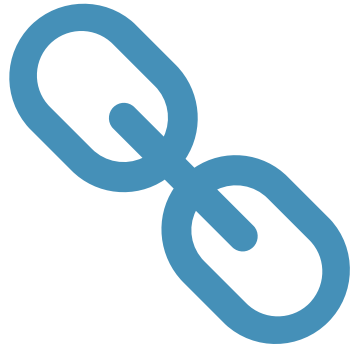
MAJOR PARTS OF REVIEW



Components



Communication



Assembly

COMPONENTS

FRAME

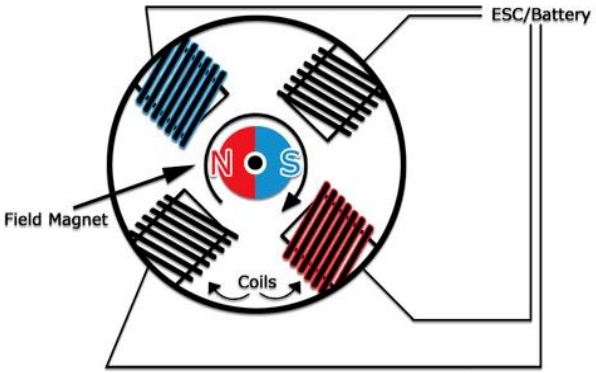
The frame is the mounting point of all the other parts of a drone. All drones have some kind of frame, small or big. Frames need to be strong but also light, carbon fibre is the ideal material which is used in almost all drones including the one I built. The frame I used was the Anniversary Special Edition Martian 215 due to the fact that it is a larger frame for its relatively low price

The reason why carbon fibre is so strong is due to the up to 4 strong covalent bonds which they can make with other carbon atoms giving them much greater stiffness and rigidity as well as heat resistance seen as it is said to melt at over 3500° which is however a little extreme for our purposes.

Although one thing to be wary of is the process of fibre splitting which happens at the edges of the frame where the fibres separate out. This can be easily prevented by sanding the edges with 400 grit paper to prevent this

MOTORS

The motors of an FPV drone are responsible for delivering the thrust which is required for movement.
After receiving the motors I saw that there were some copper wires in the inside of them which after a little research are actually coils of wires inside the brushless motors which are required for this use case as brushless offer greater longevity and power for the same weight. These coils are electromagnets which are energized resulting in a magnetic field being induced causing the permanent magnets in the middle of the motor ,which is a little difficult to see without opening the motor assembly itself, to rotate. This is depicted by rightmost image.



ELECTRONIC SPEED CONTROLLER (ESC)

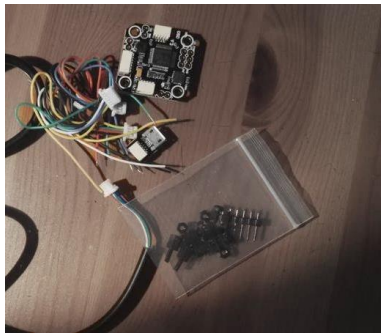
The ESC is just like a gear box in a car, the gear box tells the wheels at which speed it must rotate, in the same way an ESC controls the speed at which the motor must rotate for the throttle applied. This throttle signal is provided by the flight controller(Next slide) to the ESC spinning the motor. I went for the Eachine Blheli_S Brushless ESC.

As seen in the name the ESC runs the BLHeli firmware. It uses 8 bit processors, and has simpler interface as compared to previous generations. They also deliver a smoother response curve thanks to the hardware pwm(pulse width modulation). It also has small step resolution varying between 512 and 2048 steps. It has a signal response delay of 1-2ms. 4 were needed in total for each motor.

FLIGHT CONTROLLER

A flight controller (FC) is a small circuit board of varying complexity. Its function is to direct the RPM of each motor in response to input. A command from the pilot for the multi-rotor to move forward is fed into the flight controller, which determines how to manipulate the motors accordingly.

The majority of flight controllers also employ sensors to supplement their calculations. These range from simple gyroscopes for orientation to barometers for automatically holding altitudes. GPS can also be used for auto-pilot or fail-safe purposes. Such as disarming when connection to the controller is lost.

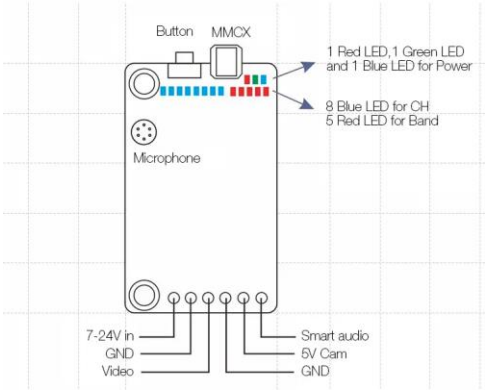


The flight controller which I am using runs the BetaFlight firmware which is a piece of software used to configure the drone and how it works, for example it can change the direction in which the motors spin(which is important for the drone to fly). The software is open source and free to use. The start page of BetaFlight shows various information regarding the drone once it is plugged in via a micro-USB cable connected from the circuit-board to the computer. The flight controller is also the hub of all connections as it connects to the VTX.

VIDEO TRANSMITTER(VTX)

The VTX transmits the live video feed and communicates with the goggles (more on this in the communication section) so that the pilot can see exactly what the drone sees in real time. This is especially useful as it allows pilots to fly the drone whilst it is out of their sight greatly extending the capabilities of the drone.

As you can see here the VTX consists of a circuit board with two separate parts coming out of it, one side is the antenna which is used to send the video feed wirelessly to the goggles which receive it, and one is to connect it to the flight controller. The camera's feed is sent through the flight controller to the VTX where it is sent to the goggles, I will explain more about how the electrical signal from the camera is converted into radio waves and then received by the goggles in the communication section.



This picture shows a simplified schematic for the circuit board which is used showing the MMCX connection which his used to connect the antenna and then the wires are simply soldered on to the holes at the bottom which is then wired up to the corresponding points on the FC.

CAMERA

This is a CMOS nano camera, CMOS stands for complementary metal-oxide semiconductor which is used instead of a CCD(charged coupled device) camera

Although CMOS cameras often suffer from far greater distortion than CCD cameras they need roughly 100 times less power than a CCD camera, making it a much better choice for drones as keeping power consumption of parts other than the motors down is vital to the flight time.

Each types of imagers convert light into electric charge and process it into electronic signals. In a CMOS sensor, each pixel has its own charge-to-voltage conversion, and the sensor often also includes amplifiers, noise-correction, and other circuits, so that the chip outputs digital bits. These other functions increase the design complexity and reduce the area available for light capture. With each pixel doing its own conversion, uniformity is lower, but it is also massively parallel, allowing high total bandwidth for high speed. In a CCD sensor, every pixel's charge is transferred through a very limited number of output nodes to be converted to voltage, buffered, and then sent as an analogue signal. All of the pixel can be used to capture light, and the output's uniformity (a key factor in image quality) is high.

BATTERY

The power source for the FPV drone, this battery contains 1500Mah which is a measure of capacity to show how much power can be held before the battery must be recharged. The type of battery used in almost all FPV drones are called LiPo(lithium-ion polymer battery) the benefits of this type over others is

- Lighter and can be made to any size, reducing the overall weight of the drone which increases its speed
- Higher capacity allowing a longer flight before the battery must be recharged.
- Faster discharge rate shown by the discharge rating giving the drone greater torque which makes acceleration much greater especially at lower speeds since the torque is constant.

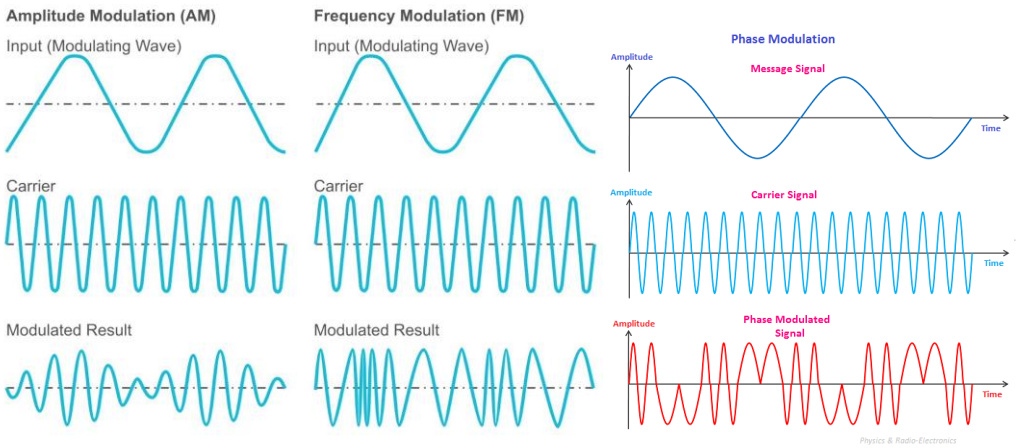
But LiPo batteries have their flaws which include

- Shorter lifespan so only can last up to 150-250 cycles meaning after around 200 times flying and recharging you are going to need new batteries which actually may not be so bad if you only fly once a week as 200 cycles will last you around 4 years.
- Sensitive chemistry can lead to fires.
- Additionally they require special charging procedures which require a special charger (which I purchased alongside the battery)

COMMUNICATION

COMMUNICATION - TRANSMITTER

Modulation is a process of mixing a signal with a sine wave to produce a new signal. Mixing of low frequency signal with high frequency carrier signal is called modulation. The information can be added to the carrier in several different ways, in different types of transmitters. In a amplitude modulation (AM) transmitter, the information is added to the radio waves signal by varying its amplitude. In a frequency modulation(FM) transmitter, information is added to the radio waves by adjusting the frequency of the waves slightly to illustrate the information. There is another way called phase modulation which is where the phase(more commonly known as period) of the carrier signal is changed according to the low frequency of the message signal is known as phase modulation.



The picture shows the way in which the carrier waves are affected by the inputs in both AM and FM and also phase modulation.
Note that in AM only the peaks and troughs of the graph change and the points where the graph intersects the line are the same as before. Then see that in FM the peaks and troughs are always on the same point but the points where the graph intersects the axis has changed significantly, and in phase modulation both peaks and troughs are still at the same and the intersections are at the same spots at times but you can see sometimes it doesn't intersect so this is where the period is being extended.

COMMUNICATION-RECEPTION

After the data is sent via modulation(see previous slide) it needs to be received by the goggles and viewed as video. First the goggles (which I didn't mention in the components section since they are simply a receiver and a display also I didn't mention the controller which simply sends data to the drone in the opposite way), need to be on the same band as the drones VTX, inside these bands are more finer channels which can be changed both on the VTX and the goggles, also the bands can be changed on the VTX and goggles as well.

Bands is a unique set of frequencies(peaks and troughs) which is used to send the data in waves.

The bands can be seen as A-F and there are 8 more precise channels in between them

Band	Frequency Ch1	Frequency Ch2	Frequency Ch3	Frequency Ch4	Frequency Ch5	Frequency Ch6	Frequency Ch7	Frequency Ch8
A	5865	5845	5825	5805	5785	5765	5745	4725
B	5733	5752	5771	5790	5809	5828	5847	5866
C	5705	5685	5665	5645	5885	5905	5925	5945
F	5740	5760	5780	5800	5820	5840	5860	5880

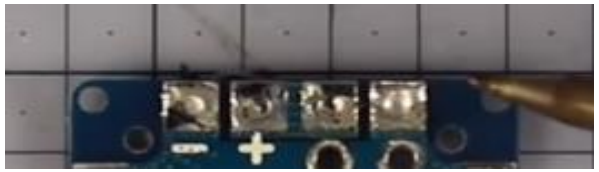
Although this process has been greatly simplified with auto-connect features where goggles will toggle though all the channels and find one where there is a video feed and automatically connect to that one which prevents you from needing to remember the exact channel you are using

ASSEMBLY

SOLDERING

After spending some time on the internet I learned that the best way to create strong bonds which would be reliable and not come apart after some flying was to go for pre-solder method.
This method involves adding solder to the point where you want to connect first and the other part then connect the wire and with heat and fuse the two together. This creates a very strong bond which is very difficult to break.
Also using something to hold the wires in place such as a piece of blue-tac can make the process much easier.

Only solder is being added, the connection is not being made this is the pre-solder which will give a strong bond

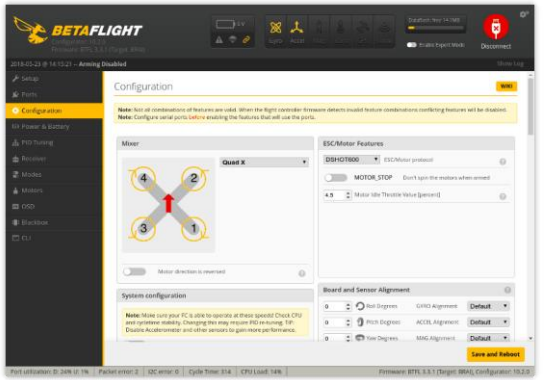


The same should be done to the circuit board where you want to make the connection.

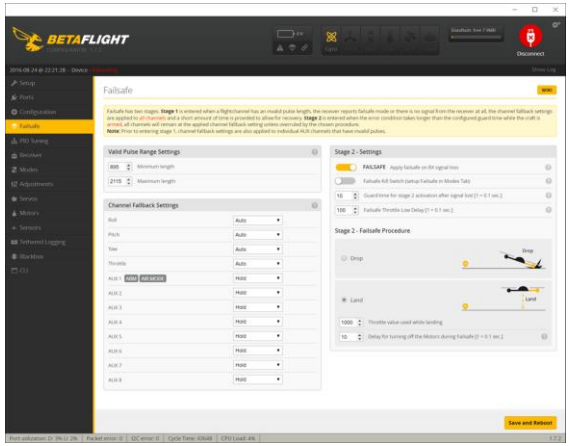
The result is a strong bond

BETAFLIGHT SETUP

BetaFlight is open-source software which is used to configure the electronic parts of the drone to ensure that the drone functions properly some key things.



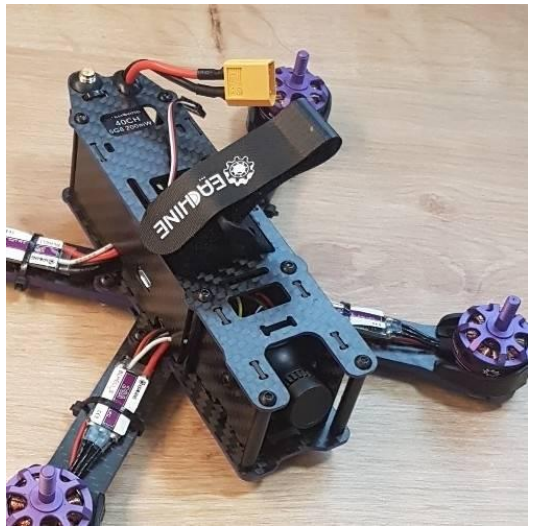
One of the things which must be properly configured is the yaw/pitch/roll sensor alignment to ensure that if the electronics are mounted in alternate directions then the flight controller is aware of this so that it can make the necessary calculations to ensure that the drone fly's normally. Other settings can also be configured throughout the software such as the flight modes, and other checks can be carried out such as on the receiver tab and motor tab



Additionally another very important area to make sure is configured correctly is the failsafe, this is to ensure that if the drone loses connection or some other event the drone will automatically slowly descend and land safely which prevents what is known as a fly away from occurring which is when the drone continues and flys away into the distance.

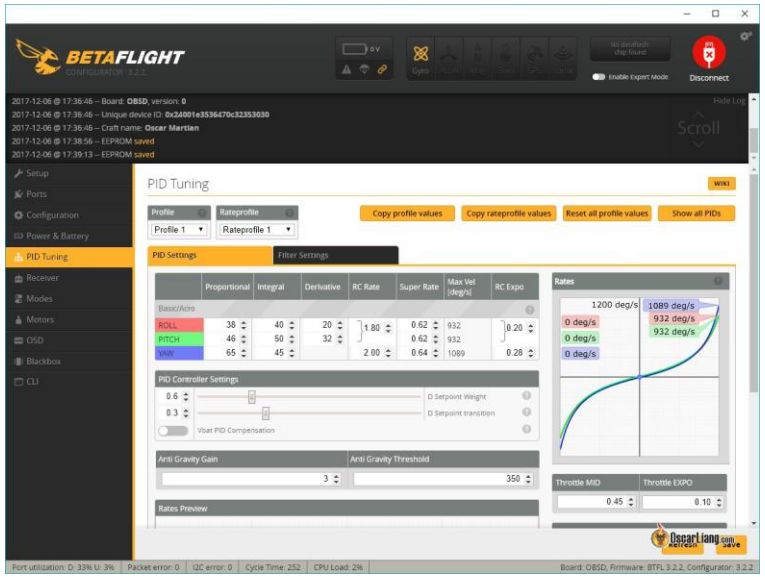
OVERALL ASSEMBLY

Unfortunately I didn't film myself completing the final assembly but I do have an image of the finished product



Unfortunately I found out that you are required by law to register your drone and take theory tests which makes it illegal for me to fly my drone outside so I have refrained from doing so in the time being.

With the propellers off and the battery charging



I first worked on making the base frame, then worked on the motors putting them onto the frame and soldering them together and added a few zip ties I soldered the ESC's onto the FC, then connected the battery attached the strap as seen as well as the camera for which I had to undo a lot of my work because I forgot to put it in earlier, but finally when I connected it to my computer and loaded up BetaFlight I adjusted some settings such as roll pitch and yaw as well as making sure that the front two propellers were spinning inwards and the back outwards

THANK YOU

FOR GIVING ME THIS OPPORTUNITY- ASHLEY TYAGI