TERMINATOR

Did you ever wish you had a drone that could do everything you dreamed about?

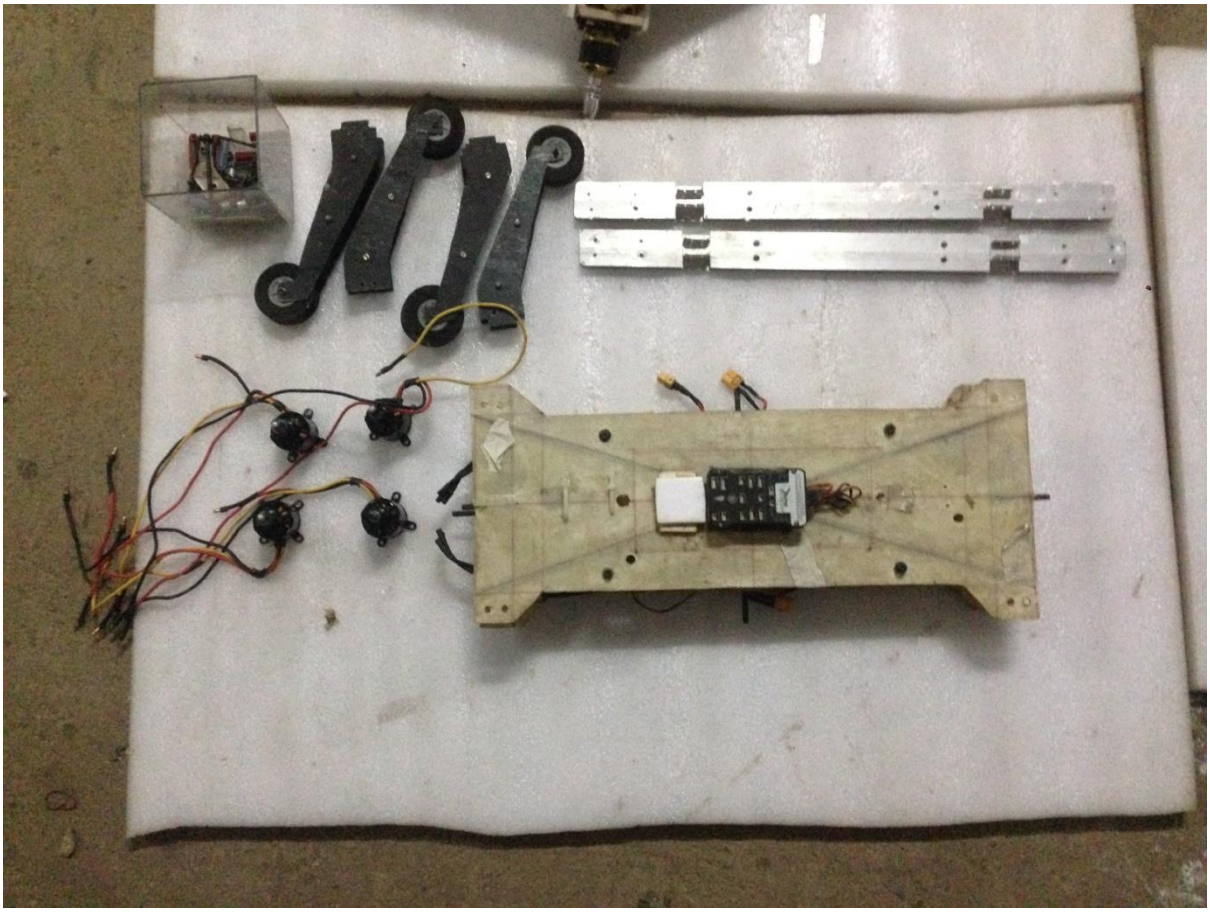
This quad can do all those things and much more!!!

It can travel the way you want it to, admire scenery from above as you wish it to, or give you a disco lighting system from 30 feet above ground and much more!!!

In this instructables, you will be able to build a quad from scratch which can

Do all these things !

Parts, Specifications and Price List



- **3DR Pixhawk Autopilot Flight Controller** (http://www.ebay.in/itm/171952103958?aff_source=Sok-Goog)
- **3d printed Pixhawk universal damping mount** (http://www.ebay.in/itm/262188719579?aff_source=Sok-Goog)
- **433Mhz Radio Telemetry Wireless Transmission Module with Antenna** (http://www.amazon.in/GoolRC-Telemetry-Transmission-Quadcopter-Multirotor/dp/B018XK8MKS/ref=sr_1_9?s=toys&ie=UTF8&qid=1473835147&sr=1-9&keywords=telemetry)
- **FlySky FS-T6 2.4ghz Digital Proportional 6 Channel Transmitter and Receiver** (http://www.amazon.in/Digital-Proportional-Channel-Transmitter-Receiver/dp/B012W6HJHG)
- **3DR uBlox GPS with Compass Kit** (https://store.3dr.com/products/3dr-gps-ublox-with-compass)
- **Sunny Sky v2814-10 800Kv Brushless Motors(4) including Motor plate to mount the Motor** (http://www.buddyrc.com/sunnysky-v2814-10-800kv-brushless-motor.html)
- **Flightline 40A ESC (4 in number)** (http://www.rcdhamaka.com/index.php?main_page=product_info&products_id=1833)

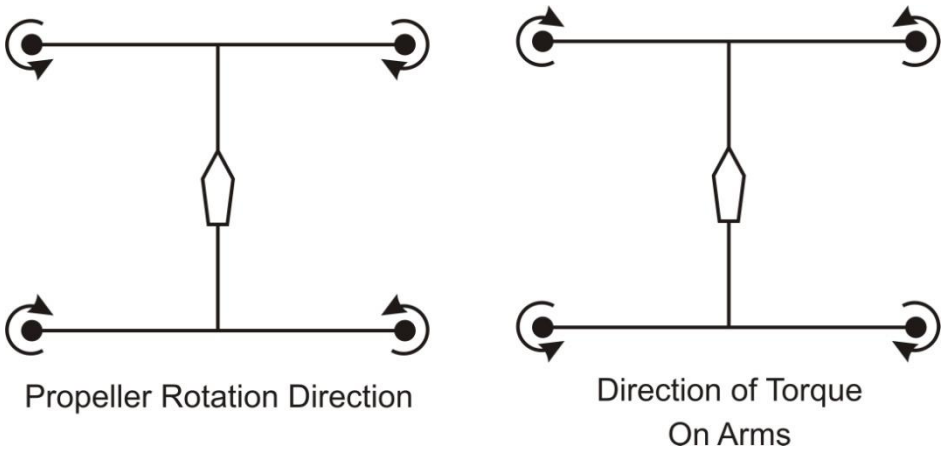
- **Tattu 16000mAH 14.8v 10C Battery** (http://www.ebay.com/itm/Tattu-LiPo-Battery-Pack-16000mAh-15C-4S1P-14-8V-for-OnyxStar-FOX-C8-HD-Gryphon-/262454841966)
- **Turnigy 5200mAH 2S 30C Battery** (https://www.amazon.com/Turnigy-5200mAh-Hard-Case-Lipo-APPROVED/dp/B00E70RZ4I, http://www.hobbyking.com/hobbyking/store/__21002__Turnigy_5200mAh_2S_30C_Hard_Case_Car_Lipo_Pack_ROAR_APPROVED_.html)
- **15X4.5 inch Propeller with different diameter Prop adapters (4 in number)** (http://www.helibatics.com/pair-15x4-1540-carbon-fiber-propeller-cw-ccw-for-tri-quad-hex-octo-multi-copter-42/)
- **FPV BGC 171g 2 axis brushless gimbal with controller for dji phantom gopro 3** (http://www.banggood.com/FPV-2-Axis-Brushless-Gimbal-With-Controller-For-DJI-Phantom-GoPro-3-p-908068.html)
- **XL-MaxSonar-EZ4** (http://www.maxbotix.com/Ultrasonic_Sensors/MB1240.htm)
- **Frame manufacture**
    - **Carbon Fibre sheets (250 gsm)** (http://www.ebay.com/bhp/carbon-fiber-cloth, https://www.aliexpress.com/store/product/Carbon-Glass-Fiber-Hybrid-Fabic-Plain-Weave-Hollow-Square-Cloth-250gsm-Fiberglass-3k-Carbon-Fiber/1884013_32541570718.html)
    - **Glass Fibre sheets (200 gsm)** (http://dir.indiamart.com/impcat/fiberglass-cloth.html, http://www.easycomposites.co.uk/#!/fabric-and-reinforcement/glass-fibre-reinforcement/woven-glass-fabric/light-weight-200g-woven-glass-fabric.html)
    - **A grade Balsa, 5mm thick** (http://www.ebay.com/sch/i.html?_from=R40&_trksid=m570.l1313&_nkw=5mm+balsa&_sacat=0)
    - **Hardener**
    - **Resin**
    - **Dye**
    - **Hollow Carbon Rods, 5mm diameter** (http://www.hobbyking.com/hobbyking/store/__6724__Carbon_Fiber_Tube_hollow_5x750mm.html, http://www.ebay.com/bhp/carbon-fiber-rod)
    - **Hex and Round Spacers** (https://www.aliexpress.com/popular/quadcopter-spacers-35mm.html)
    - **Aluminium I section Beam**
    - **Wheels**

Basic Design of the Quad

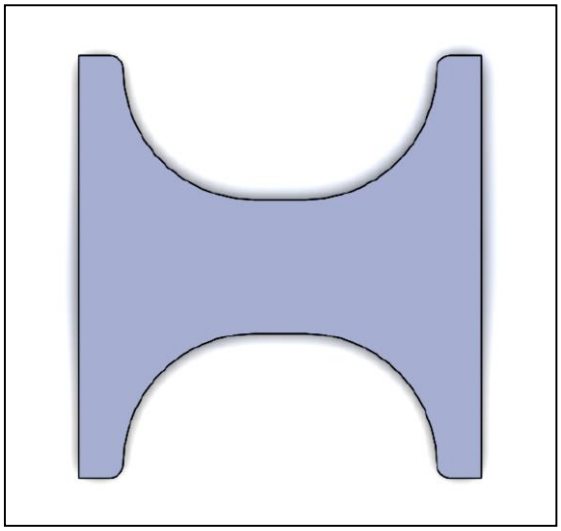
First, the basic design of the frame with dimensions needs to be done with at most precision. Frame is one of the major components which dictates the stability of a quad. When designing a frame, lot of parameters like centre of gravity, moment of inertia, torque experienced on arms, stress on frame, shock loads on legs etc... must be considered.

This is an H quad. It has two Arms at its ends and a mid-frame which houses all the equipment. An H quad is preferred as it provides a lot of space in the middle to hold different components for different functions even though balancing the quad is difficult.

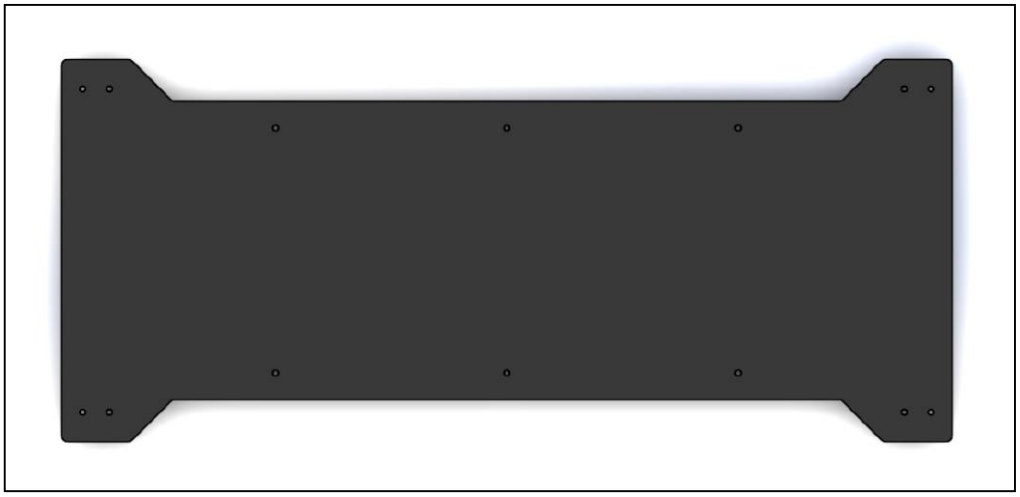
As the components are mounted in the mid portion of the quad, length of quad must be more than its width. Motors are placed at the ends of the two arms, hence arms need not be wide, but their joints with the mid frame must be extremely strong so that it doesn't bend due to the torque produce by the motors.



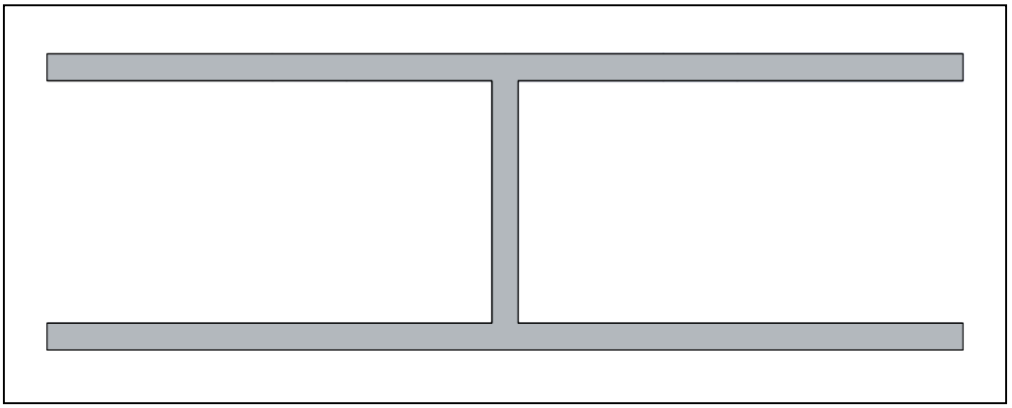
The mid-frame consists of Pixhawk, Telemetry, Receiver and GPS on the top frame; Battery and four ESC's are housed in between the top and bottom frame; Gimbal and sonar are on the bottom frame. Length and Width of the frame must be decided first. It must be sufficient to hold all the required components without increasing weight of the quad, and there must be enough clearance between two adjacent propellers so that they do not cause interference between themselves.



This design of the mid frame was done keeping in mind the joint strength necessary between arms and the mid frame that can withstand the torque produced, and stress developed throughout the frame. The frame is so designed to have sufficient strength against the stress produced from motors due to lift generation. With the main challenge of reducing weight while retaining stability parameters led to the following optimized design.

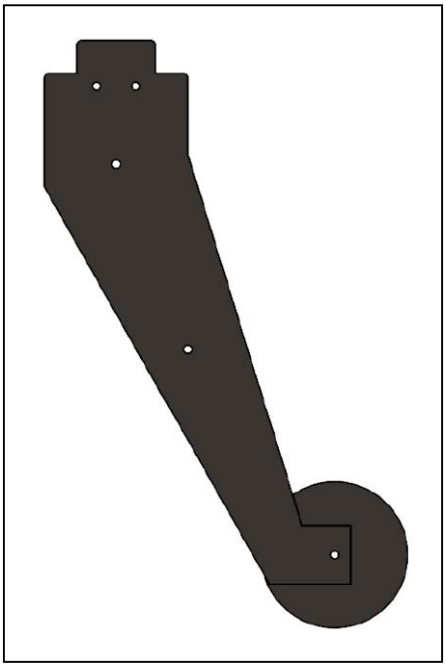


The arm was initially chosen to be a metal rod of square cross section, despite providing good strength it increases weight. So an I section rod was chosen for Arm. This gives the same strength but with much less material and hence reduced weight.



Design of the leg is very crucial as it must withold the total weight of the quad and should also withstand the impacts due to uncontrolled landing/crash. The clearance from ground must be enough to mount gimbal and other gear. Most importantly, it must withstand sufficient shock loads.

This was the first design of the leg, It had enough room below the quad for gimbal mount and also could bear the weight of the quad but it couldn't take shock loads. So an alternate design was done.



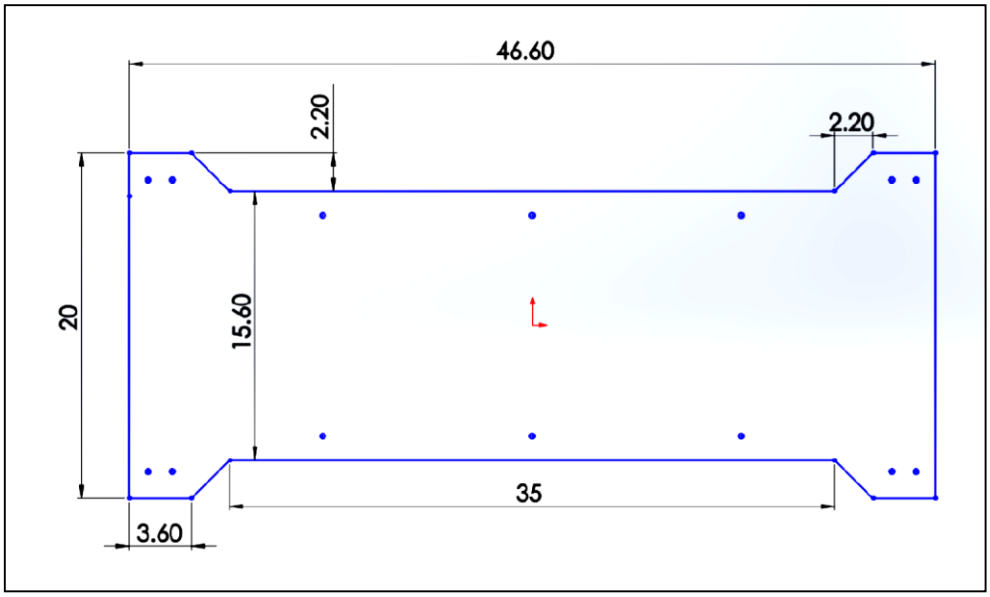
In this design, Leg has an angled shape to bear loads and wheel at its end which acts as cushion when quad does angled or extreme landing.

The entire design of quad frame is completed once the dimensions are assigned. For that a few small calculations need to done depending on the size of components, wire space that needs to be given and clearance of propellers.

Dimensioning of the Design

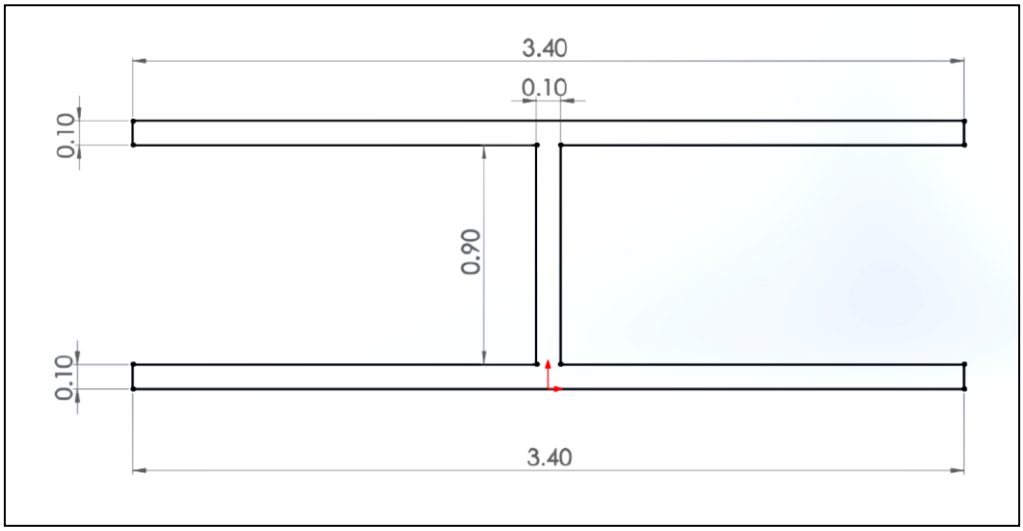
First the dimensions of top and bottom plate are done. So let us consider the propeller dimensions and clearance that needs to given for them. Length of the propeller used is 15 inches and clearance of around two inches is needed in between the two ends of adjacent propellers along the width, i.e on adjacent arms. So, the length from centre of one motor to the other, hence the length of quad is 15*2.54+2*2.54=43.18cm. Total length is 43.18+1.7+1.7=46.58 which is approximately 46.6cm.

Clearance needed for propeller is again taken into consideration to calculate the width of quad. Clearance of 1 inch is given between the two propellers. So width (from the centres of two motors) = 15*2.54+2.54=41cm. So total width taken = 49cm.

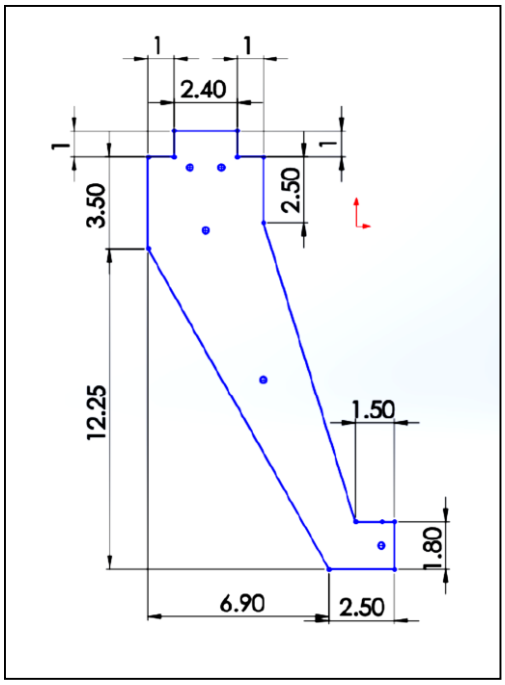


Dimensions of top and bottom plate of the frame are done.

Next, dimensions of I section of Arm must be done. Flange length is taken to be 3.4cm and web length as 0.9 cm. Thickness of flange and web is taken to be 1mm. So the dimensions of I section is done and hence dimensions of entire arm is done.



Dimensions of Leg needs to be done next. Its height must be sufficient to mount gimbal at the bottom of the quad and must be angled having enough strength to withstand shock loads. After few deductions using the dimensions of gimbal and trials, this dimension of leg was found to be most effective.



Frame Manufacture

So, designs and dimensions of the entire frame of the quad is done. Fabrication of all these parts and assembling them is the next major step in building of this quad.

Materials needed for fabrication of composites:

- Carbon Fibre
- Glass Fibre
- Carbon Rod
- Resin
- Hardener
- PVA (Poly Vinyl Alcohol)
- Dye (any preferred colour)

These are the common points followed while doing a Composite:

- Amount of resin (By Weight) =
    - Total weight of composite, (Carbon Fibre + Glass Fibre) if it's a Carbon Fibre - Glass Fibre Composite
    - 1.5 times the total weight of composite, (Balsa + Glass Fibre) if it's a Balsa - Glass Fibre Composite
    - Total weight of composite,(Carbon Fibre + Carbon Fibre) if it's a Carbon Fibre - Carbon Fibre Composite
- Ratio of resin : hardener = 10 : 1 by weight.
- A drop of dye of the preferred colour is added to Resin - Hardener mixture to get the desired colour.
- There are two ways of aligning Glass/Carbon Fibre sheets-
    - Parallel (All fibres are parallel to each other and also to the edge/side of the sheet)
    - Diagonal (All fibres are parallel to each other but make an angle of 45^0 to the edge/side of the sheet)
    - First layer laid is always parallel and then a diagonal layer is laid and consecutively layers are alternated.

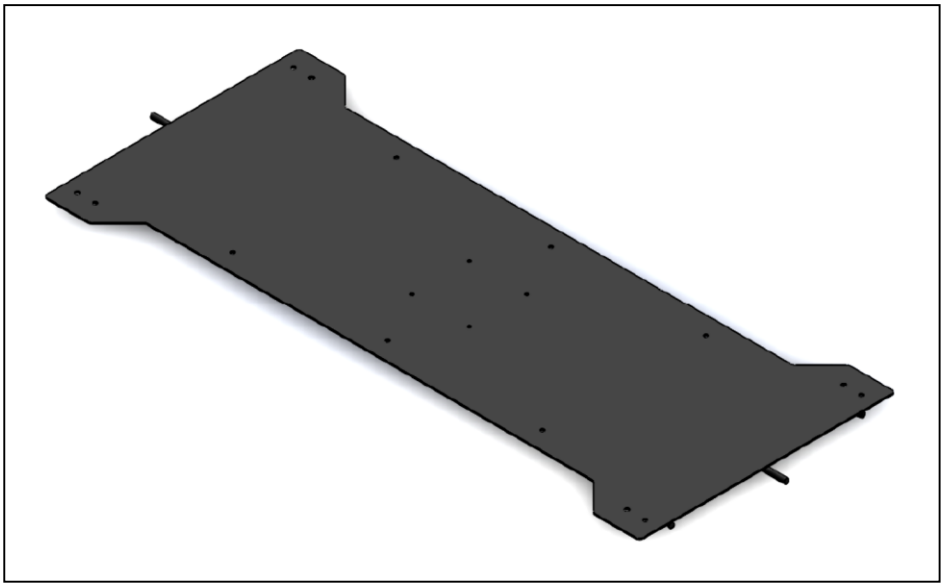
Precautionary measures:

- Glass and Carbon Fibre fabrics are very light and strong. They have infinite yarns/threads. Each Fibre is very thin and very strong. So care must be taken that gloves are always worn whenever working with these Fabrics. Surgical gloves are preferred.
- A dedicated sharp fibre scissors must be kept separate for the cutting these fabrics and must not be used for any other purposes.
- Care must be taken that skin never comes in contact with these Fabrics. These small Fibres cut into skin and are very tiny. Over a long run, this proves to be a major problem as micro cuts prove dangerous.

- Contact with these Fibres causes itching , further stimulating the itchy feeling more by hands is to be avoided.
- When cutting these Fabrics, make sure it's not a windy place. As tiny Fibres which are not visible to the naked eye may enter our body.
- Also, when cutting a Fabric, it is safer to wear a mask so that no Fibres enter our respiratory system which causes respiratory issues.
- Epoxy resins and hardeners, by their nature contain toxic compounds. However, if these products are to be used, do so with appropriate care and control. Avoid skin contact, inhalation or ingestion.
- Epoxy resins are also known to be skin sensitizers. The hardener is usually classed as a corrosive when in contact with the skin or by inhalation. Once fully cured an epoxy system is essentially inert and non-hazardous.

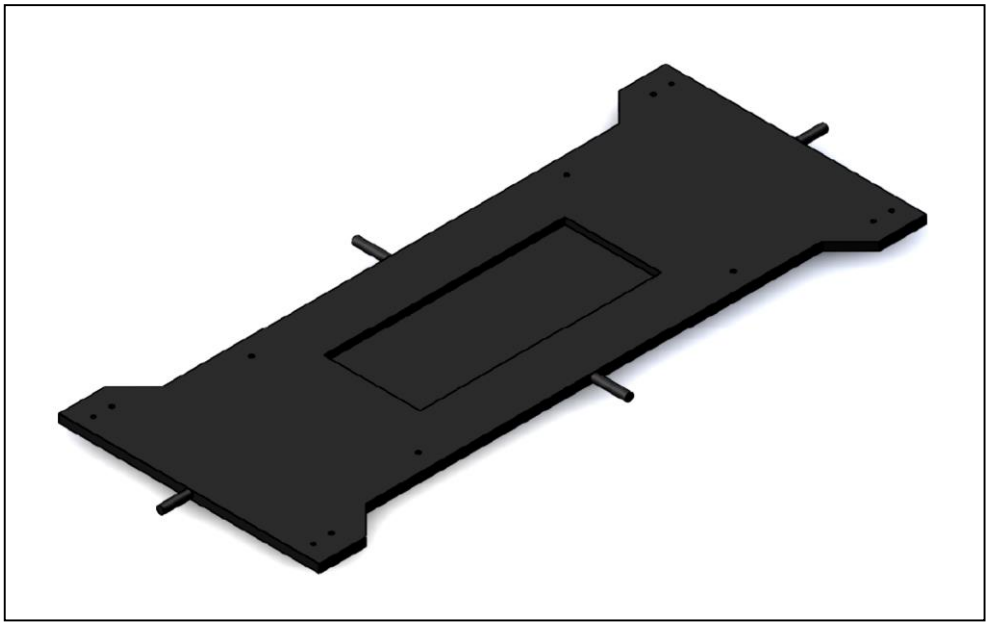
Composite Making

Top Plate



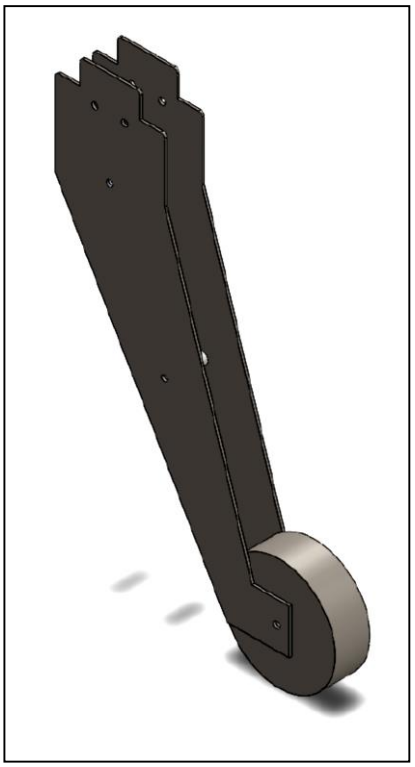
The top plate of the mid frame is made of glass fibre - carbon rod composite. First a layer of PVA is applied on a tile/smooth surface which gives a smooth finish on the finished composite. Total of six sheets of glass fibre are cut in the required shape. One sheet is placed on PVA layer such that there are no wrinkles on it. Now, a thin coat of Resin - Hardener mixture is applied on it uniformly. Second layer of glass fibre is placed and again Resin - Hardener mixture is applied uniformly. Similarly, a third layer of glass fibre is also done. Now, Carbon rods are placed such that it forms two diagonals and also two rods are placed along its length and breadth passing through the centre. The two rods along its length and breadth passing through the centre are given a total of around 5cm extra length. This extra length is provided so that if balancing of Centre of gravity of the quad becomes a problem in the later stages, appropriate weights are attached to these extra lengths of rods thus balancing centre of gravity. But ideally speaking, it mustn't come to that. Again, a thin layer of Resin - Hardener is applied uniformly and a glass fibre sheet is placed. Similarly, a total of three such glass fibre sheets are placed on the carbon rods. A thin layer of PVA is applied on another tile/smooth surface. This tile is placed on the present tile (containing the layered composite) and weights are kept on it. Once the above tile is kept, it must not be disturbed. It is allowed to set for one whole day. By next day, upon removing the upper tile, strong and stiff Glass Fibre - Carbon Rod composite is ready to be used.

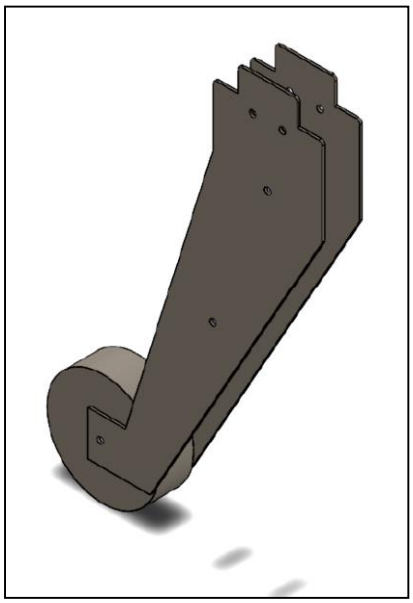
Bottom Plate



The Bottom plate of the mid frame is made of Glass Fibre - Balsa wood - Carbon rod composite. All the necessary/common steps are followed similar to the Top plate. First two layers are of Glass Fibre and then third layer consists of Balsa wood with impregnated Carbon Rods. Fourth and fifth layer are again made of Glass Fibre. So, the thickness of Bottom plate is more than that of Top plate as it bears much more load than that of Top plate. Hence, it must be stronger than the Top plate.

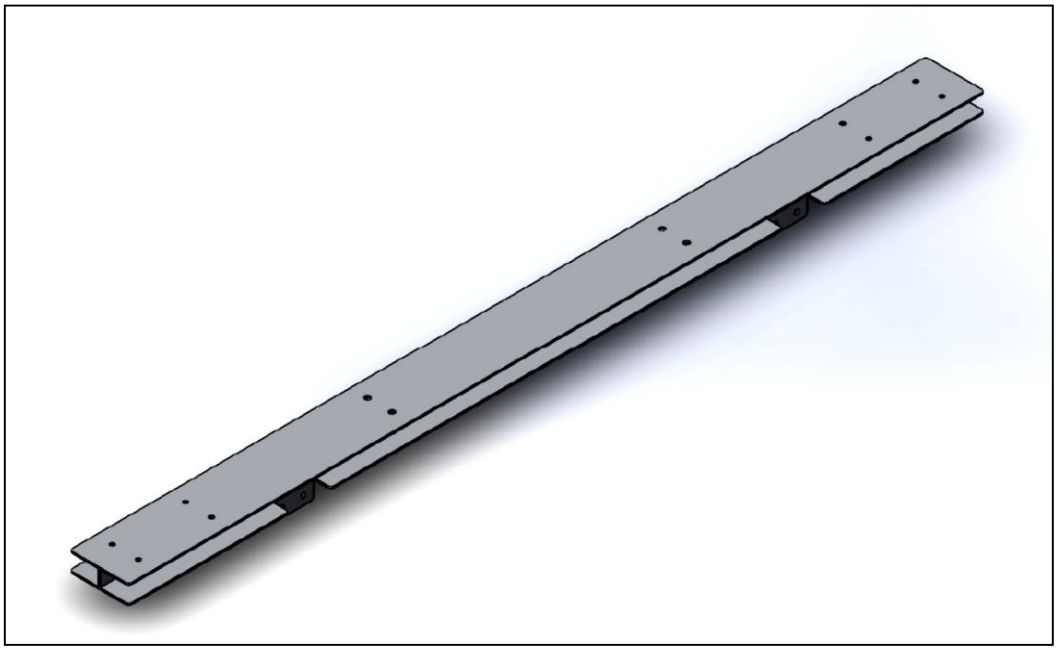
Leg/Landing Gear





Leg/Landing gear is made of carbon fibre-glass fibre composite. All the necessary/common steps are followed as before. First a layer of Carbon Fibre is laid, then two Glass Fibre layers and Carbon Fibre layer is again laid at the end. Two such composite sheets are done for single Landing Gear.

Arm



Arm is an I section beam. An aluminium I section beam of required dimensions is cut and used for the arms of the quad.

Thus, all the parts of the frame are manufactured and ready to be assembled to build the Quad.

Frame Assembly

In order to make the entire assembly of the quad, Joints are to be done between different components of the frame. For the purpose of joining two parts of the frame: Nylon screws, Lock Nuts, spacers and bushes were used.

Joints are to be done between:

- Arms and Top plate of the mid frame
- Arms and Bottom plate of the mid frame
- Two Landing gear composite sheets and a wheel
- Arms and Legs/Landing Gears
- Spacers between Top and Bottom plate of the mid frame.

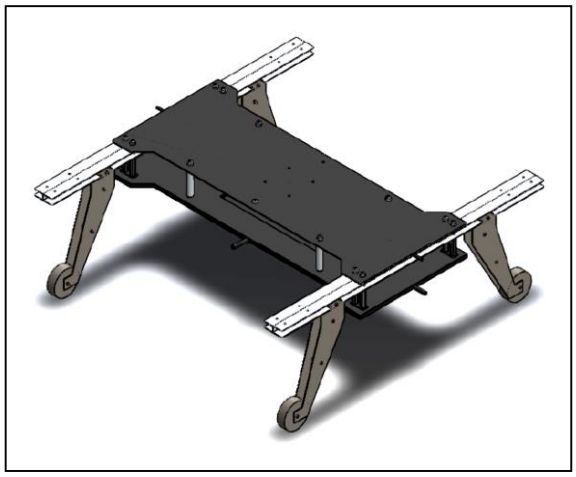
Holes are drilled at the appropriate places on Top plate, Bottom plate, Arm and Landing Gear.

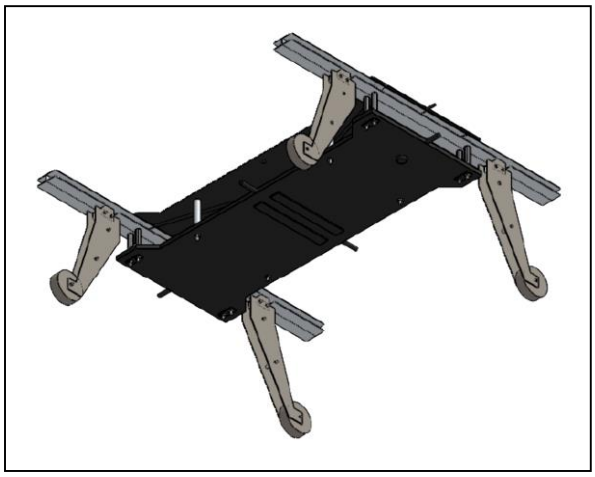
Arm - Top plate and Arm - Bottom plates are joined using long Nylon screws and adding spacers along its length to provide space between Top and Bottom plate of the mid frame. Likewise spacers are added in between the Top and Bottom plates also, to provide extra support and strength to the mid frame. A total of 12 Spacers and Nylon Screws are attached between the Top and Bottom Plates of the Mid Frame. 8 are attached in between Arms and Bottom Plate and 4 are in between Top and Bottom Plate. 4 Screws are attached in between the mid frame so that the frame does not sag in the middle. It must be sturdy and even when components are mounted on it, must not sag. The 8 screws which hold the arms and Bottom Plate in place are divided as 4 screws on one Arm and other 4 on the other Arm. Both Arms have two screws on one side of centre line and the other two on opposite side of the centre line. The two screws each are adjacent to each other. Two screws are needed and just one screw is not sufficient as there will be axial movement of the mid frame between the Top and Bottom plate. OR, in simple terms, there will be relative motion between the Top and Bottom plates along their lengths.

The two composite sheets of Landing Gears are joined together by using a medium length Nylon screws and spacers. A total of 4 screws connect the two composite layers. And at its end wheels are attached using a similar medium length Nylon screw. So, Landing Gear is ready to be attached to the Arm. It is done so by using small screws and nuts.

Lock Nuts are attached to Nylon screws wherever necessary. Bushes are added at all joints. Bushes and Nylon screws are used as they dampen the vibrations caused by the rotation of motors. This increases the overall stability of the quad to a great extent.

Thus, the entire Frame of the quad is built and ready to mount all its components.





Choosing the Right Product and Electrical Calculations

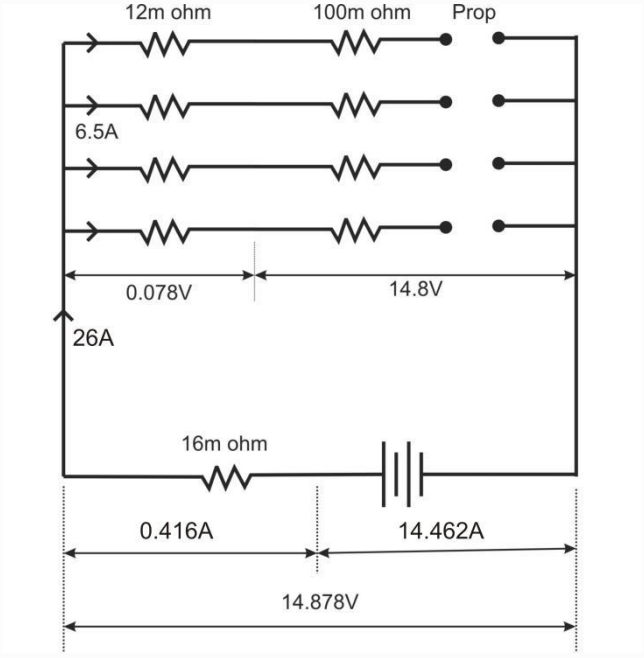
To choose the type and version of component which has to be bought. First current, voltage, Power and other relevant values need to be calculated. For this purpose, circuit is first analysed taking all the necessary precautions and following few common steps.

So, first these simple connections need to be done:

- +ve and -ve terminals of the battery must be connected to +ve and -ve terminals of all the four ESCs, so these four ESCs must be connected in parallel to the Battery.Hence use of Positive connectors like the XT-60 are recommended.
- Each ESC must be connected to one motor (containing a propeller).
- The three wires of a ESC are connected to the three wires of motor irrespective of order of connection. To change the direction of rotation of a propeller, simply interchange any two wires out of the three which are connected. This changes the direction of rotation of motor as these are 3 Phase motors.
- Signal wire from each ESC is connected to pixhawk and all the necessary connections to Pixhawk are done.
- Pixhawk connections include, Telemetry, Receiver, GPS, Buzzer, Switch, Gimbal and Sonar and any other extra connections if needed.

Based on the calculated values and appropriate fluctuations accounted for, we need to select the brand and type of Motor, Esc and Battery needed. So by approximation, we can assess the weight of the complete quadcopter based on the components used.

The completed Quad weighs around 3kg. So, each motor with a propeller must generate a minimum thrust of 750g.



This is the circuit of Motor, ESC and Battery. Motor, ESC and Battery all have their own internal resistances which has to be taken into consideration while calculating the amount of voltage and current flowing through the circuit.

Minimum of 750g thrust must be generated by a motor and its propeller. Keeping this in mind, SunnySky v2814-10 800kv motor was chosen which gives 870g of thrust with 15X4 propeller at 50% thrust capacity. This is perfect for our needs and so, this was chosen. To give 870g of thrust, it needs 96.2W of power and 6.5A of current and it has an internal resistance of 100m ohms.

For the required performance, voltage drop across the motor is 96.2/6.5 = 14.8v. Current flowing through this circuit is 6.5A. So, we need an ESC which can handle this much current. For this purpose Flightline 40A ESC was chosen. It has an internal resistance of 12m ohms. So, voltage drop across it is 0.078v.

Now, total current flowing through battery is 6.5*4 = 26A. And its voltage rating must be 0.078 + 14.8 = 14.878v. So 4S Tattu battery of 16000mAH 10C was chosen. Its internal resistance is 16m ohms.

Finally, the amount of current flowing through the circuit is 26A and nominal voltage of battery needed is 14.5v.

Amount of current drawn by the electrical components is continuously changing as current drawn by motor is not constant and this current is high enough to induce magnetic fields around it. This magnetic field interferes with other electronic components present on the Quad. So this interference must be removed. It is not possible to remove the magnetic fields but it is possible to block them. For this purpose all the wires connecting Electrical components and ESCs are given aluminium shielding which blocks the magnetic field generated by them.

Component Placement

Positioning of all the Electrical and Electronic components on a quad is very important. Care must be taken that centre of gravity of the quad is at the exact centre of the frame (where imaginary diagonals of the frame meet).

The four motors (including their spinners), four propellers and four ESC's are placed exactly opposite to each other and hence centre of gravity does not shift due to these components. These components balance each other. So, they are excluded while determining the position of other components.

Now, position of Battery, Pixhawk, Receiver, Telemetry, Gimbal, GPS and Sonar needs to be assigned. So, let's note down all their weights and accordingly their positions will be assigned with respect to the position of each one of their centre of masses.

Main Battery - 1250g

Pixhawk - 38g

Receiver - 25g

Telemetry - 22g

Gimbal - 230g

Battery for Gimbal - 300g

Sonar - 5.9g

GPS - 38g

Buzzer - 30g

Planning the placement of each component is important and needs to be done following the given methodical approach. So, to begin with all the light components must be placed on Top Plate. Here Pixhawk, Receiver, Telemetry, Buzzer and GPS Module are placed on Top Plate. Now, coming to the middle section between Top and Bottom Plate, Heavy components must be placed here, as Bottom Plate is thicker and stronger with the ability to carry more loads. So, Main Battery and the four ESC's are placed on the Bottom Plate. There are a few restrictions on placing of few components. GPS Module has to placed such that there are no obstructions directly above it. Sonar and Gimbal have to be placed at the bottom of the Quad facing the ground. So, Sonar and Gimbal along with its powering battery have to be placed below the Bottom Plate of the Quad.

Now, centre of mass must be balanced at each plane of the Quad.

Here, when the Quad is facing forward, imagine X-Y co-ordinate system with origin at the centre of the Quad.

We are setting only the Y axis positions as all the components are on the Y axis, X axis position need not be done as these are already balanced.

Starting with the top section (above the Top Plate):

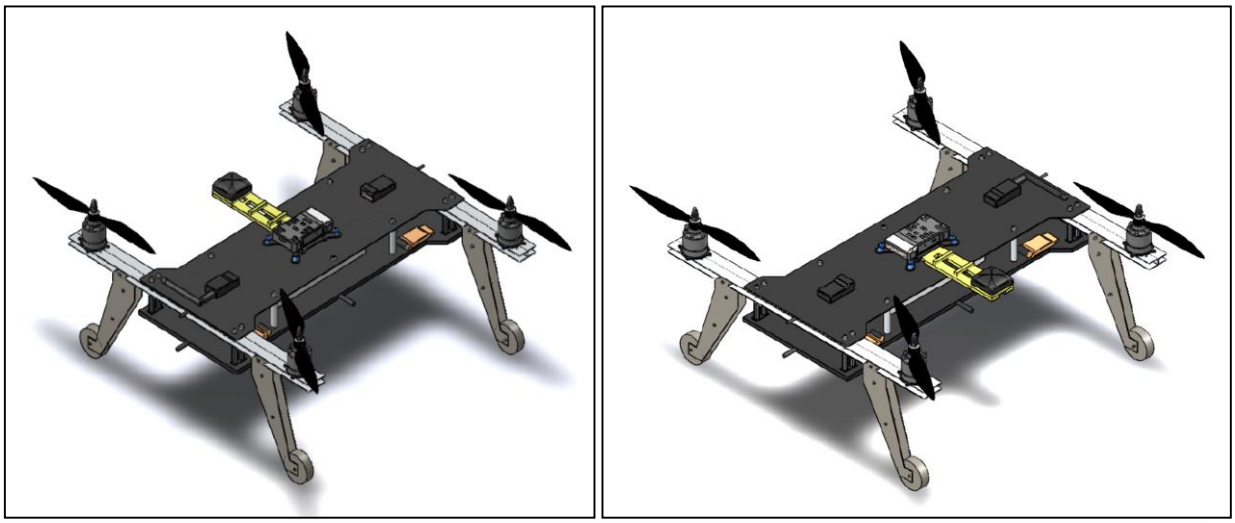
- Pixhawk is the main controlling unit of the Quad. It must always be placed at the centre of the Quad as it measures various parameters like Gyro, Altitude, Tilt of the Quad etc. It must be placed facing forward direction of the Quad. It is directionally oriented. So, as it is already at the centre of the Quad, Centre of mass is balanced.
- Next is the positioning of Receiver and Telemetry. As both have nearly the same mass, they are placed on opposite sides of Pixhawk. So, let us fix position of telemetry. Always, the component with lower mass must be fixed first, as the position of higher mass will be closer to the centre of mass, than the position of lower mass. If position of higher mass is fixed, there is possibility that position of lower mass may exceed than that of frame size and calculations must be done all over again. So, let us fix the position of telemetry to be 16.5cm from the centre of the Quad. So, applying Lever Rule, 16.5*22 = x*25.
  So, position of receiver is 14.5cm to the other side of Quad.
- Positioning of GPS must be done such that there are no other components near it, as if it is placed near other components, its readings are affected by the interference from other components. So, it is placed on +X axis at an appropriate distance. To balance this excess weight, buzzer is placed on its opposite end on -X axis.

Then considering the mid portion (Between Top and Bottom Plate):

- Main Battery is extremely heavy when compared to all the other components of the Quad. So, it must be necessarily placed at the centre of the Quad. Any shift in its position will alter the position of Centre of Mass of the entire Quad by a great amount.
- The four ESC's are placed at the four corners of the Frame. They are placed at a distance of 16.9cm from X axis and at a distance of 6.5cm from Y axis in all the four quadrants. These dimensions are chosen as it ensures that ESC's are placed at the very edge of the Quad along its width and near the Arm of the frame along its length. So, length of wire needed to connect ESCs and motors are reduced.

Finally taking the bottom section (Below the Bottom Plate):

- It consists of Sonar, Gimbal and its Battery. Gimbal and its Battery are extremely heavy when compared to sonar. Weight of Gimbal and Sonar together does not equal the weight of the battery. So ideally speaking Sonar and Gimbal must be on one side of X axis and Battery on the other. But, at all times, Sonar must have unrestricted line of sight with the ground as it continuously calculates the distance between the ground and Quad and sends feedback to Pixhawk based upon which Pixhawk balances the Quad. Gimbal is mainly used for aerial photography. So, it rotates in both X and Y axis directions. So, while rotating, there is a possibility that it may mask sonar. Even if Sonar is masked for fraction of second, it might prove very disastrous. So instead, Gimbal is mounted on one side of X axis and Sonar along with Battery on the other. Their positions are altered such that Centre of mass of the Quad is balanced.
- So, first positions of Sonar and Gimbal are fixed at appropriate positions which are most convenient. So, position of Sonar was fixed as 19cm in -Y axis and Gimbal was fixed as 16cm in +Y axis. Now, position of Battery was calculated. (19*5.9) + (x*300) = (16*230).So, x = 12cm. Hence Battery was positioned at 12cm from origin in -Y axis.

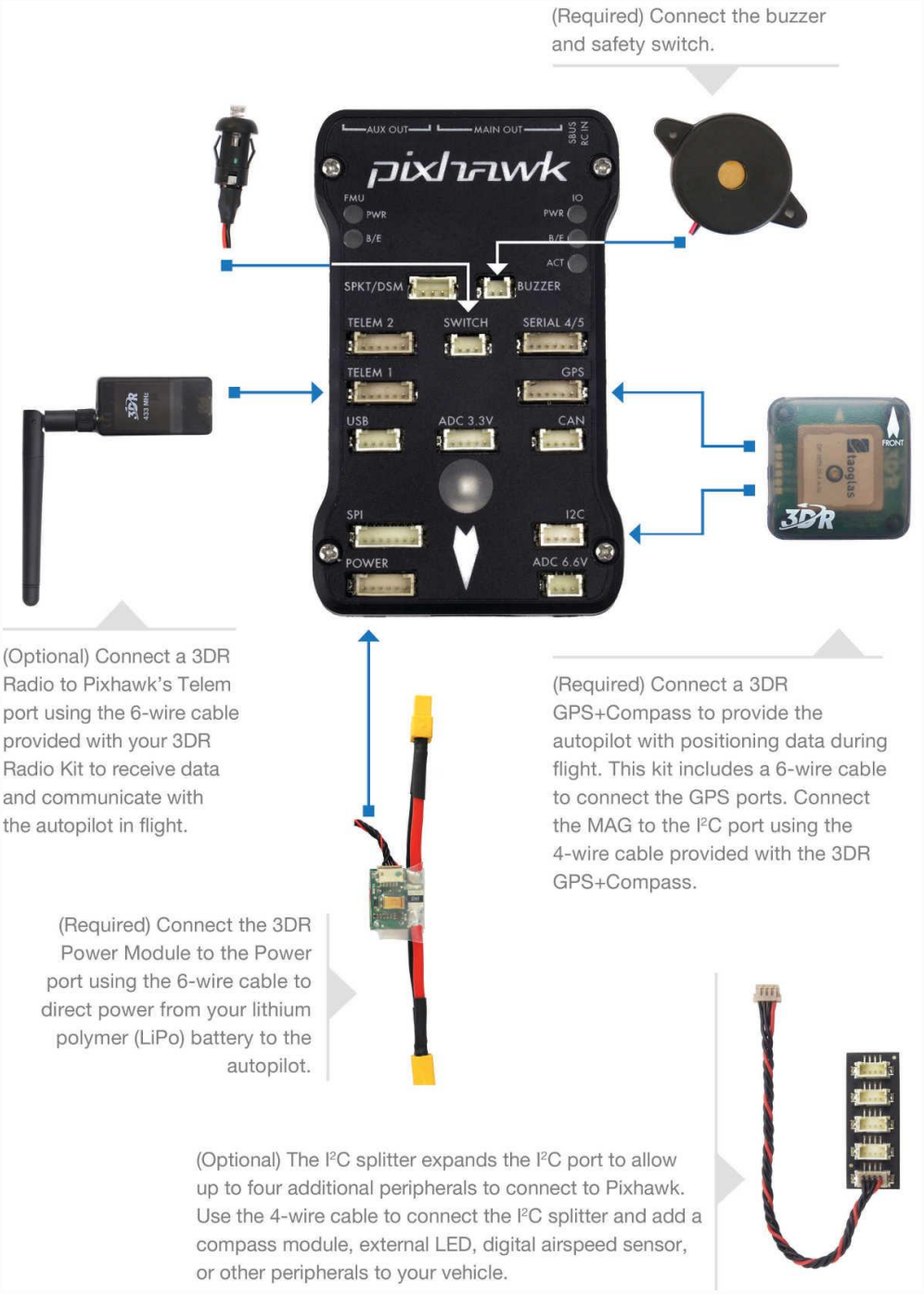


Pixhawk Wiring

Precautions:

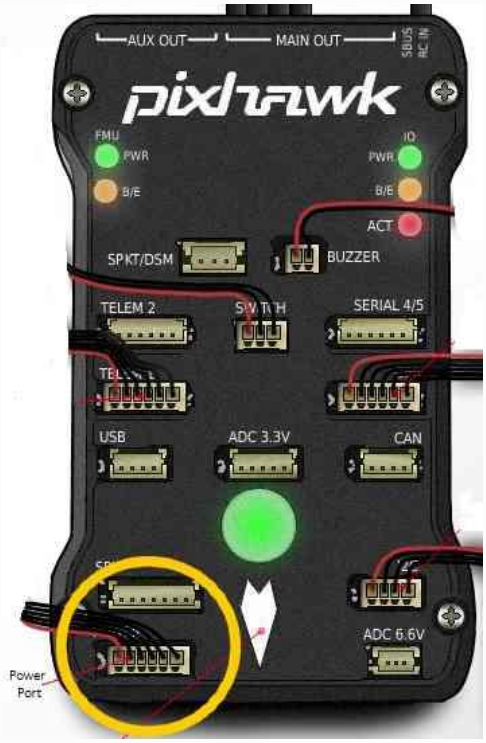
- Servos or any other devices must not be connected to the PWM outputs of the receiver. The RCIN port on the Pixhawk is designed only for low power devices, and a servo or relay draws a lot of current from the receiver. If servo is connected directly onto the receiver while the receiver is powered from the RCIN port of the Pixhawk, there is probability of Pixhawk getting damaged.
- Mount the beeper at least 5cm away from the flight controller or the noise may upset the accelerometers.

Pixhawk Wiring Chart:



Powering a Pixhawk:

Pixhawk is typically powered via its “power” port. The power port simultaneously powers Pixhawk and reads voltage and current analog values, produced by an optional power module.

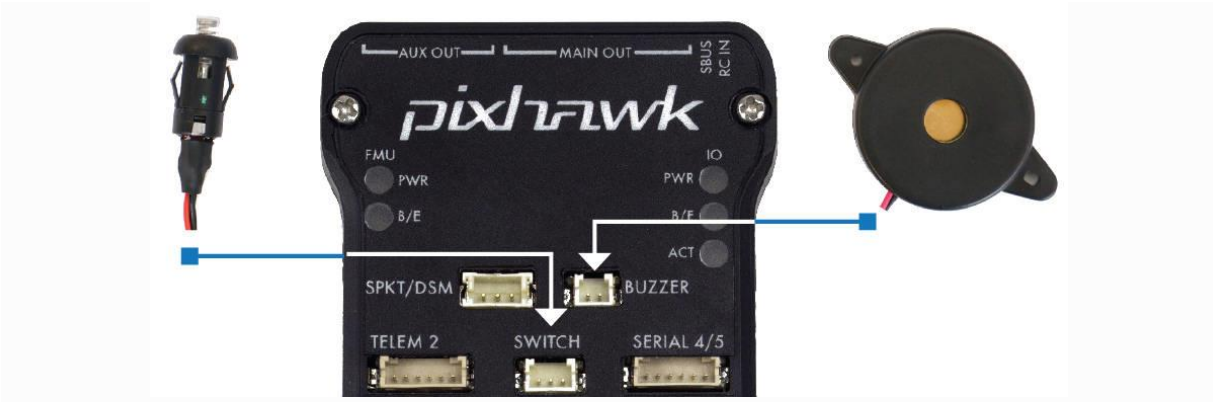


Connect remote control inputs:

Pixhawk is compatible with PPM remote control (RC) receivers, Futaba S.Bus receivers, and Spektrum DSM,DSM2, and DSM-X Satellite receivers. For traditional single-wire-per-channel (PWM) receivers a PPM encoder can be used to convert the receiver outputs to PPM-SUM.

Connect buzzer and safety switch:

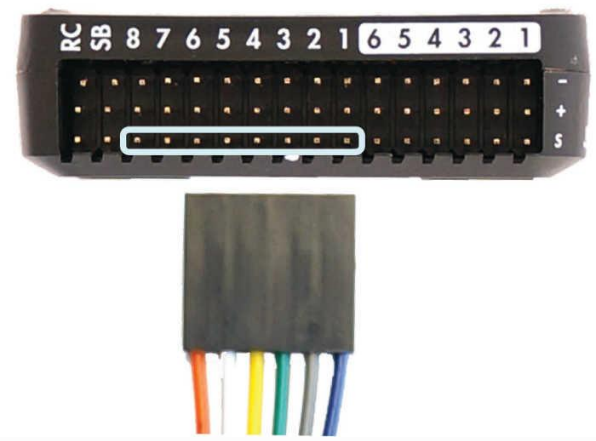
The buzzer and safety switch button are mandatory for Pixhawk.



3DR GPS+Compass:

The 3DR UBlox GPS + Compass Module is the recommended GPS for Pixhawk on ArduPilot. The GPS ports are connected with the six-position DF13 cable, and the MAG port is connected to the I2C port with the four-position DF13 cable.

Connect Motors:



In overview, for copters connect each signal wire from the PDB to the main output signal (S) pins by motor number:

- Pin 1 = Motor 1 - - Pin 5 = Motor 5
- Pin 2 = Motor 2 - - Pin 6 = Motor 6
- Pin 3 = Motor 3 - - Pin 7 = Motor 7
- Pin 4 = Motor 4 - - Pin 8 = Motor 8

For further detail on connections of different components, visit this link (http://ardupilot.org/ardupilot/index.html)

Thus, after the completion of all necessary connections, additional tuning and Pixhawk calibration is done. These calibration sequences vary for each and every Quad. It is also necessary to employ different methods of tuning. The calibration values obtained would thus be of little use, and must be aptly calculated for the final quad by testing rigorously. With the existence of unprecedented errors, balancing stability of the quad varies. Then the common steps of Transmitter Programming are done. Once these steps are followed and done accordingly, Quad is ready to be flown. But before flying, extensive test flights are to be carried out for further precision in tuning.

QUAD IS READY TO SOAR HIGH IN SKY!!!