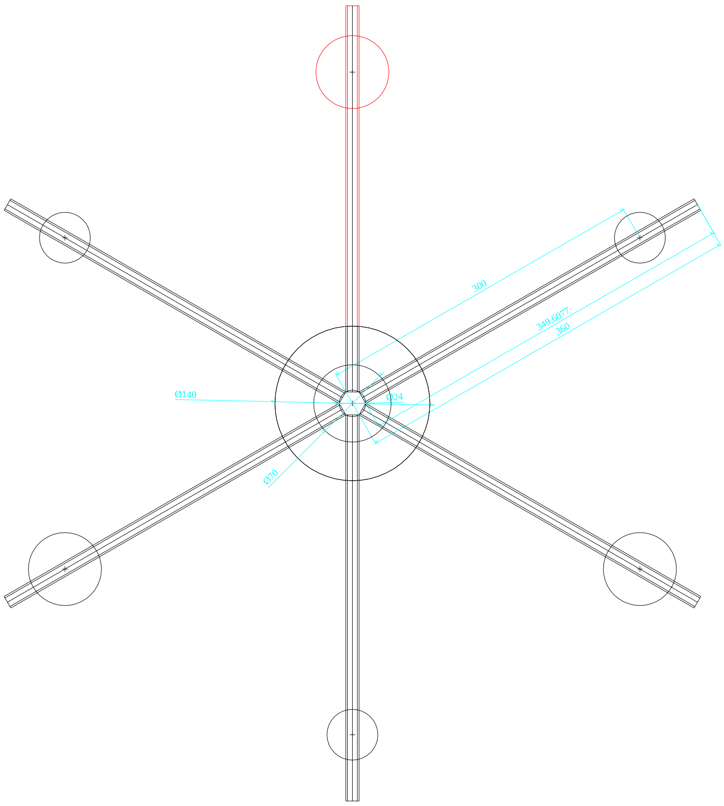
A Six Rotor Multicopter

Designed and built by Fran Oakey

The sketch below shows the airframe layout for a Multicopter having six lift motors, usually referred to as a Hexacopter.



The arms that support the motors for this machine are spaced at 60degs to each other with the motors mounted on a 600mm PCD. As with my previous machines, the Tricopter and Quadracopter, the control system uses standard, “off the shelf” RC components, gyros and mixers, on this machine four gyros and two Cyclock CCPM mixers are used.

The two onboard CCPM mixers are available and manufactured by CSM. The claimed resolution for these units is better than 0.05% and the calculations are completed in about 1mS. The units are programmable, so they can be adjusted to compensate for any irregularities that might show up on a machine with 6 motors. The yaw control is accomplished by differential speed control of the motors.

The Components

Motors and Propellers

Suitable motors for this machine are those with a Kv of 1000 to 1200, a power rating in the order of 100watts and capable of operating from a 3S1P Lipo. The Komodo 2208-8 with a Kv of 1050 and the Himodel CF2822 with a Kv of 1200 have both worked fine with APC 10 x 3.8 and 11 x 3.8 slow fly props on the Tricopter and Quadracopter.

ESCs

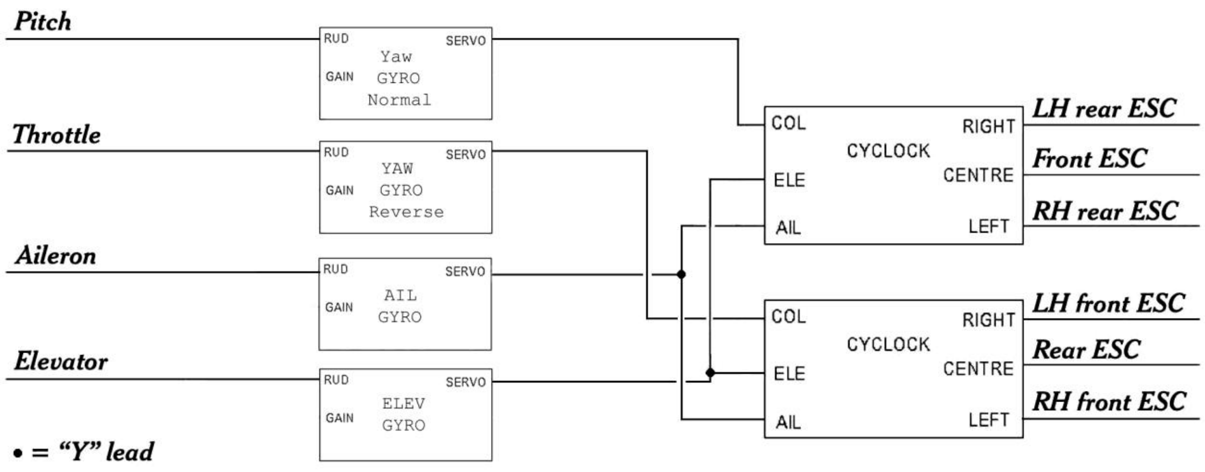
The motors draw in order of 3.5 to 4amps to lift about 300grms each, so 18amp ESCs are more than adequate, both the Robotbirds Basic and Turnigy Plush work well.

Batteries

Battery weight is an issue with any Multicopter so the only option is to use Lipos. Six 3S1Ps each with a capacity of 1000 to 1200mAhr are suitable and have a weight of about 95grms each, they will give a run time of 15 to 20 minutes.

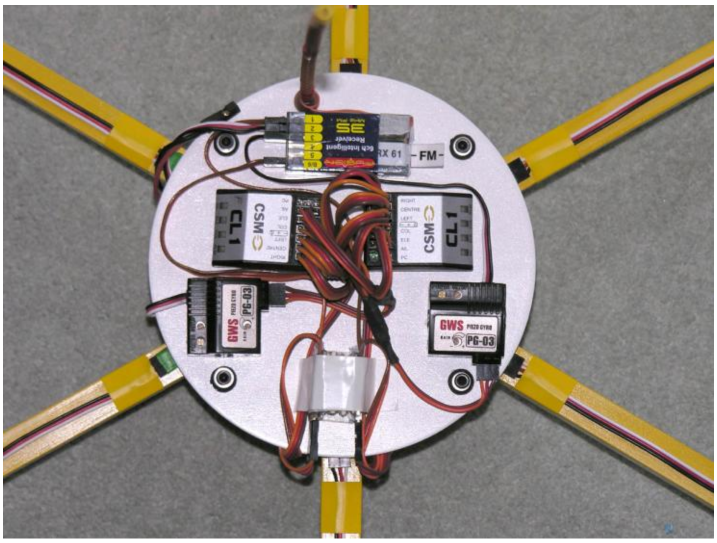
The batteries and ESCs are mounted below the motor/prop assemblies, a little more about this later.

Block diagram for the gyros and mixers



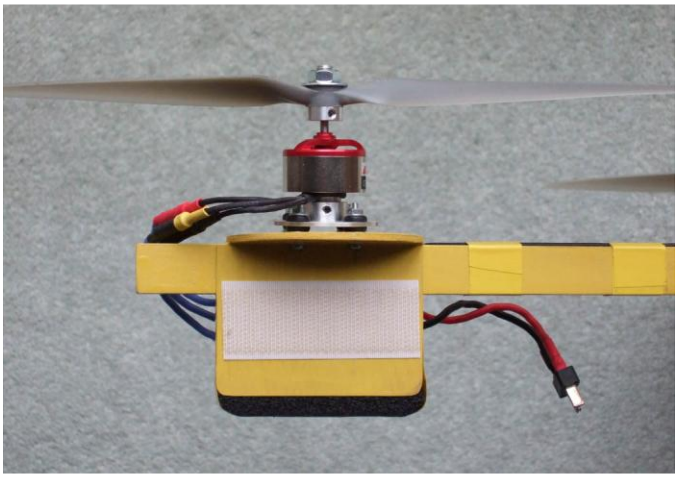
Testing the control system

First, one of the Cyclock (CCPM mixer) units was powered up and the parameters adjusted whilst measuring the output pulses with a servo tester, (the servo tester has pulse width measuring capability). This was done to understand how the scaling within the Cyclock mixer functions. It was established that the throttle and pitch travel in the Tx had to be set to 130% to give an output pulse width at the Cyclock's servo outputs of 1.1 to 1.9mS for the six speed controllers. The parameters for the Cyclock 's three servo outputs were then set, collective gain to 100%, elevator gain to 50% and aileron gain to 87%. At this stage both Cyclock mixers were connected to six servos instead of ESCs and motors to check and correct the mixer's output sense. Philosophy, first get it working then make the changes to get the control logic correct. The yaw on this machine is accomplished using differential speed control of the motors, three have pusher props fitted and three have tractor props. Then to achieve the yaw control the rudder channel is mixed with the pitch, normal and reverse with the throttle, these are mixed in the Tx. Both throttle and pitch O/Ps must have a gyro with the sense of one of the gyros reversed. See the block diagram.



The photo left is a photo of the radio control components, they have been mounted on a separate board which can be moved from model to model, it's painted white. The leads to the ESCs from the mixers have been fed through a hole in the centre of the board in an attempt to keep the assembly reasonably tidy. The radio board is mounted on the airframe using rubber grommets to isolate it and the components from any possible vibration.

The ESC parameters were configured first using a programming card and then calibrated for full and low throttle. The machine was then powered up and the control sense of the sticks and gyros checked, all was found to be correct the advantage in setting up using servos initially.



To the left is a photo of one of the arms with its motor, showing the motor mounting arrangement. The Velcro to which the battery is attached can also be seen in this shot, in flight the batteries are secured with elastic bands.

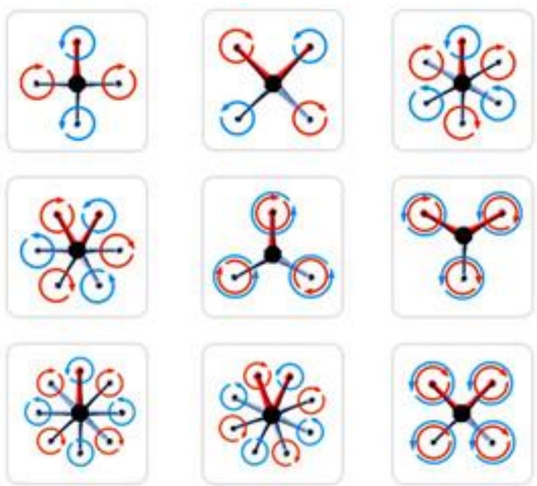
The reason for placing the battery and ESC near to the motor are many. Power and motor leads are kept as short as possible and being well away from the Rx reduces the possibility for radio interference. Finally putting the weight at the end of the arms gives inertia to the pitch, the roll and yaw, which was found necessary to give the machine its stability. This arrangement also reduces the possibility of damage where the arms are joined at the centre of the machine in the event of a heavy landing, as there is virtually no weight at the centre.

The first flight was fairly lively, a result of too much control input. The transmitter "travel adjust" for the pitch and roll was reduced to 70% and the machine felt a lot better not as twitchy. As with the second Quad the yaw, using differential motor speed control, is very soft. This first flight was with the JR 388 TX, which does not have the ability to increase the rudder slope in exponential mode. However the JR 3810 does have the ability to set the exponential rate plus or minus and this has been set at -70% in readiness for the next test flight.

Model up grade

The time has come to progress to a computer controlled stabilization system. The system chosen for this part of the project is the DJI Naza-M V2. This system has a micro processor to do all the calculations from the GPS sensor, compass, barometric pressure sensor, three axis gyro, three axis accelerometer and three PID controllers.

The Naza-M V2 controller is a very complete package it comes with everything needed to control the model, which includes the MC (Main Controller), a PMU (Power Management Unit), GPS/compass puck, LED indicator unit, leads to connect the receiver to the main controller and a USB lead to connect to a PC but no instruction manual. The manual has to be downloaded from the DJI web site, as does the assistant.exe program and device drivers. Also on the DJI web site are tutorial videos which help when setting up the transmitter, calibrating the compass and so on, a well put together package with good support. The system covers nine configurations of multicopter, shown left, and all use differential motor speed control for the yaw function, so using the Naza-M V2 controller for the Pentacopter or Tricopter is out of the question.

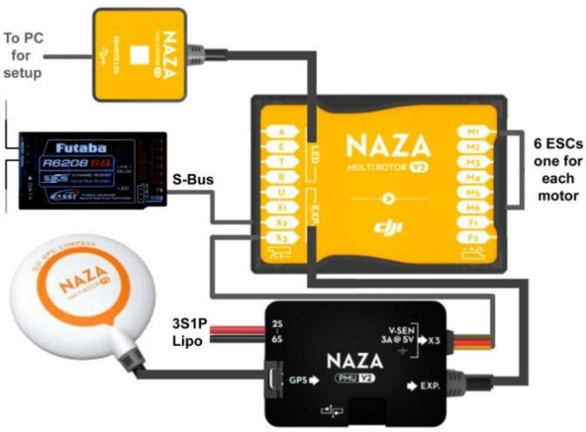


Airframe rework

The same motors, props and ESCs have been used on the reworked machine but the positions of the ESCs have changed from the original. These are now placed part way along each arm, instead of being positioned below the motor, this means that the power lead will not have to be extended to reach the battery which is now at the centre of the machine. The ESC signal leads are long enough to reach the Naza Main Controller so they will be OK only requiring the positive lead to be lifted from their plugs and isolated.

The machine now has one 5 Amphr battery to power it instead of the six 1100mAhr batteries that were used on the original Hexacopter, one for each motor and a 4.8volt battery for the receiver. Having one battery to power the six motors requires a power distribution board. It was made from a piece of double sided PCB with the positive connections soldered on one side of the board and the negative on the other. The distribution board is fixed to the underside of the machine with four screws and spacers. The board has one input for the battery and seven outputs one for each motor and one output for the PMU (Power Management Unit) which has a BEC (Battery Eliminator Circuit) to supply 5volts for all the electronics. The last part of the rework was to fit a 1.6mm hard plywood disc on four 25mm spacers at the centre of the machine on which to mount the battery and GPS puck.

The first task was to download the manual, the programming software and the device drivers, then install them. The tutorial videos on the DJI web site were played several times. The most useful clip was one spoken in a Chinese tongue with subtitles in English.



The reworked airframe was populated with the Naza–M control system, the components and their connections are shown to the left. The Naza controller is designed to work with the traditional 1msec – 2msec pulse system (that's the system mostly used for our models), S-Bus or PPM transmissions. S-Bus was chosen because only one lead is required to connect the receiver to the Naza controller. This one lead carries the data for all channels plus the 5volts to power the receiver.

Having connected the components of the on board system it is not possible to just switch on and go, as is done with say, a model boat. The transmitter has to be programmed and then calibrated to match the controller set up parameters and channel allocation. After programming the transmitter calibration is performed using the Assistant.exe software of which there is eleven pages to go through, including the update page. The channel order for the Futaba transmitter is different to that of the JR, Futaba use channel 1 for the aileron, 2 for elevator, 3 for throttle, 4 for rudder, 5 for gear and 6 for collective pitch, which they call VPP (Variable Pitch Propeller). The Naza system requires the throttle to be on channel 3 when using S-Bus which suggests that it was designed around Futaba's configuration.

With the transmitter and Naza controller calibrated on the bench there was just one more calibration to do at the flying site and that's the compass, this is the equivalent to calibrating the compass on a boat, referred to as "swinging the compass". The Control Mode Switch is toggled more than 5 times between GPS and Atti, the LED turns to yellow indicating that the machine is ready to start the calibration. Rotate the machine as in fig 1, when complete the LED turns green ready for the next part of the calibration fig 2, if calibration is successful the LED goes out.

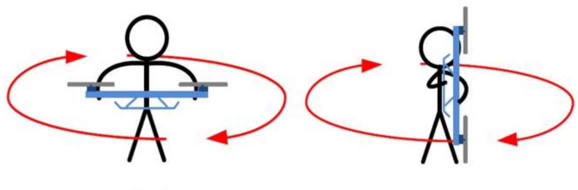


Fig.1 Fig.2

With all of the calibration procedures complete the machine was ready to take to the air. So with trouser clips on, the transmitter and machine switched on, then a 30sec or so wait for the GPS to acquire its six satellite signals, this is complete when the LED shows green, it's ready to go.

The photo left is of the model flying on one of its test flights. Control of the model was very good as was the model's stability. However, the flight characteristics were improved with a little tweaking of the controller's basic and attitude gains.