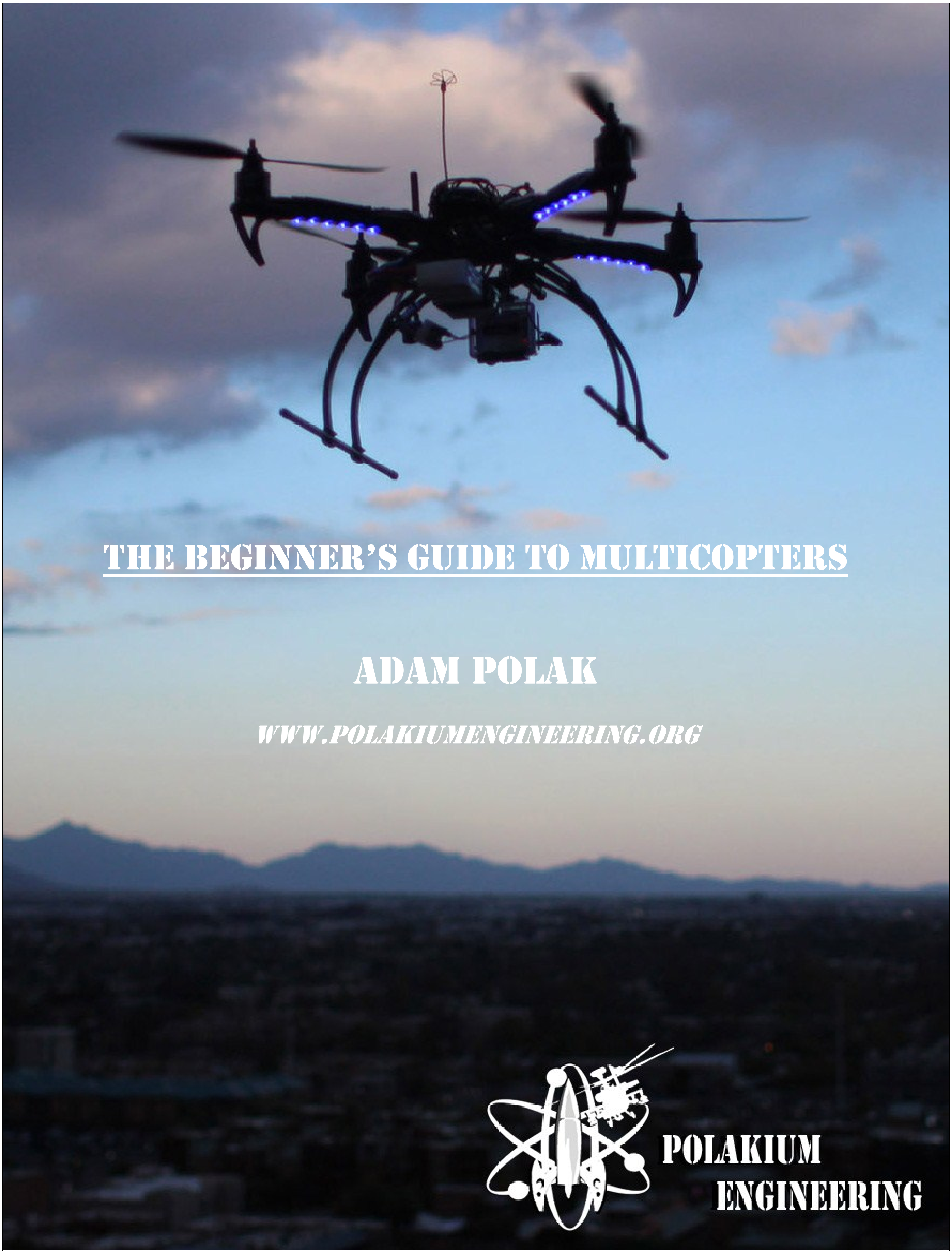

THE BEGINNER'S GUIDE TO MULTICOPTERS

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This guide is intended to be used by those that have little experience with multicopters and remote control equipment. It has been written to provide the basic information for building an entry level multicopter. Flight controller hardware and software documentation is not covered in this guide and can often be found online. The parts listed within this guide as well as all the information provided are intended to be used as guidelines for building various multicopters. Components with similar ratings can often be interchanged. As always, use caution when working with harmful tools, chemicals or electronics.

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I. BASIC EQUIPMENT

Before beginning to build your first multicopter, it is important to have all of the necessary tools and skills. One of the most essential skills for building a multicopter is having the ability to solder. Many of the components of your multicopter must be properly soldered into place. Due to the multitude of variations of multicopter sizes and shapes, the wiring and power distribution always require special attention, as they vary by design. With good soldering skills, you will have no problem assembling the components to your frame. Although multicopter frames can be purchased and pre-assembled, they are often most cost effective to build from readily available materials such as wood and sheet metal. These materials can be purchased from any local hardware or crafts store and they can be easily repaired or replaced if damaged in a crash.

A. COMMON TOOLS AND SUPPLIES

CA Glue (Cyanoacrylate) – Lightweight and good for bonding many materials. CA Glue is available in various thicknesses for use with foam, joining of small parts and filling large gaps.

Hot Glue

Cable Ties – A strong, inexpensive and replaceable part for securing components and wires.

Solder and Soldering Flux

Soldering Iron

Heat Shrink Tubing – Essential for protecting exposed wires and components.

Heat Gun or Butane Torch – Necessary for shrinking heat shrink tubing.

Micro Screw Driver Set

Needle Nose Pliers

Wire Cutter and Stripper

Alan Wrenches / Hex Keys

Hobby Knife

Hand Drill

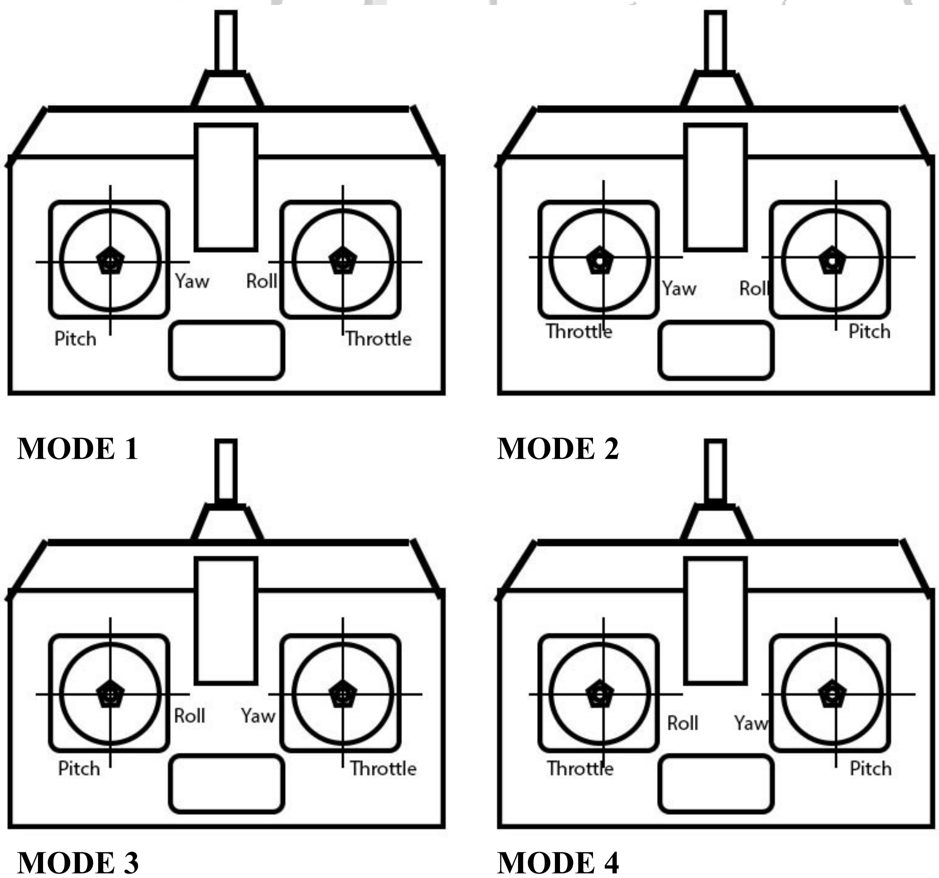
Balance Charger

Multimeter

B. RADIO EQUIPMENT

In order to control any remote control model, it is absolutely necessary to have a radio controller. Most controllers consist of a handheld transmitter and a small receiver. These can range in price from $30 up to several thousand dollars. Many inexpensive radios can be purchased for less than $100; however, they may sometimes require technical modifications and maintenance to achieve the desired performance. These radios are not always as reliable as more expensive radios, but they are great for budget multicopters.

Radios come in a variety of different bandwidths and channels. 2.4GHz radios are most commonly used because they are inexpensive and do not require any crystals to be swapped when flying in the presence of other 2.4GHz radios. Although their range may be shorter than similar radios of lower frequency, most still have a range of about 1000 meters. For multicopters a radio must have a minimum of four channels, although six channels are recommended. The four primary channels are used to control pitch, roll, throttle and yaw, while any additional channels can be used to change flight modes or trigger electronics. Radios are also available in different modes according to the function of each axis on the gimbals. The most common mode is mode 2.



C. BATTERIES

The most common battery used for multicopters is the lithium polymer battery or LiPo. These batteries are preferred for their high energy density, allowing them to output large amounts of power while keeping very lightweight and compact. However, LiPo batteries can be extremely dangerous if not handled properly. These batteries are very volatile and hazardous if handled improperly. Here are some common precautions to take with LiPo batteries:

- Never exceed the recommended maximum charge rate.
- Never puncture or deform the cells.
- Never discharge below 3.0 volts per cell or charge beyond 4.2 volts per cell.
- Never overheat or expose the battery to a flame.
- Never reverse or cross the positive and negative battery leads.
- If a cell becomes inflated, disconnected, unbalanced from the remaining cells or any of the above have occurred, you should properly dispose of the battery immediately.
- Always charge the battery on a concrete surface several meters away from any flammable materials.

It is also important to understand the ratings of a LiPo battery. LiPo batteries consist of cells, each with a nominal voltage of 3.7 volts, 4.2 volts when fully charged. These cells can be arranged in either series or parallel to form a LiPo battery pack. They will most commonly be arranged in series to produce the needed voltage; for example, 3 cells in series are commonly known as a "3S" pack producing a nominal voltage of 11.1 volts. LiPo batteries are also rated by their capacity in milliamp hours. A 5000mAh LiPo (5 amp hours) should last an hour at a constant current draw of 5A. If you are flying a multicopter that consistently draws 25 amps, then a 2500mAh battery should last close to 6 minutes. Finally, the C rating of a battery determines its discharge rate. LiPos are often given a rating for continuous discharge and maximum or burst discharge (for up to about 10 seconds). The current draw from a battery back can be calculated using the formula:

I = C * Capacity (Ah)

*For example, a 5000mAh 20C LiPo would produce 100 amps (100A = 20C * 5Ah).*

LiPo batteries greater then 1S require a balance charger. Balance chargers come in many variations; some are capable of rapid charging (if supported by the LiPo), charging multiple batteries, storing and discharging. A 50W balance charger is sufficient for charging most batteries one at a time within about an hour. If your LiPos support rapid charging, then a 100-200W balance charger can be used to charge multiple LiPos simultaneously or a single LiPo at an increased charge rate. Most balance chargers also support LiPo storage. This mode charges / discharges the battery to 3.8 volts in order to maintain chemical equilibrium within the cells and prolong battery life. This is recommended to be used with batteries that are not frequently cycled. LiPos should not be stored for long periods of time while fully charged or discharged.

Common battery sizes for use with various multicopters:

1000mAh	Micro size multirotors (3-4 motors)
2200mAh	Medium size multirotors (3-4 motors)
5000mAh+	Large, heavy lift multirotors (4+ motors)

D. MOTORS AND SPEED CONTROLLERS

Selecting the correct motors and speed controllers can be quite complicated without knowledge of the rating systems assigned to each component. I will begin by introducing a few common motor ratings. These include power (watts), current draw (amps), speed (kv) and thrust.

First, you must decide what the multicopter's primary use will be, whether it is casual flying, aerobatics or heavy lifting. Start by estimating the amount of weight you plan to lift including the airframe and any heavy components such as batteries or cameras and gimbals. Since you want your multicopter to hover at 50% throttle, a good way to estimate the thrust for your prop and motor combination is to double your weight. For aerobatic multicopters it may be good idea to choose lightweight, yet overpowered components that can supply more than twice the weight in thrust. Once you know your estimated thrust you can use a *thrust calculator* to determine the best ratings for your components. To use a thrust calculator you will need to know the diameter and pitch of the props, the battery voltage and the speed of your motor. In order to determine the nominal rpm for your props, multiply the kv of your motor by the voltage of your battery. Without getting too technical with the reasons for different prop sizes and their rotational speeds, the bottom line is that you want to use larger and slower props with heavy lift multicopters and smaller faster props for micros and aerobatic multicopters.

	MICRO	STANDARD OR AEROBATIC	HEAVY LIFT
SIZE	10 - 15"	15 - 20"	20" +
WEIGHT	200 – 500 GRAMS	500 – 1200 GRAMS	1.2KG +
THRUST	0.5 – 1KG	1- 2.5KG	2.5KG +
PROP SIZE	5 – 7"	8 – 10"	11 – 15"
SPEED	3000 – 1800KV	1800 – 1000KV	1000 – 500KV
CURRENT	5 - 10A	10 – 20A	20 – 60A
BATTERY SIZE	2 – 3S (7.4 – 11.1V)	3S (11.1V)	4 – 6S (14.8 – 22.2V)
POWER	50 – 100W	100 – 200W	200 – 800 W

Note: The estimations above are intended to be used as guidelines for quadcopters. Heavy lift hexacopters and octocopters may sometimes use smaller props and motors because some heavy lift frames may not support the spacing necessary for larger props.

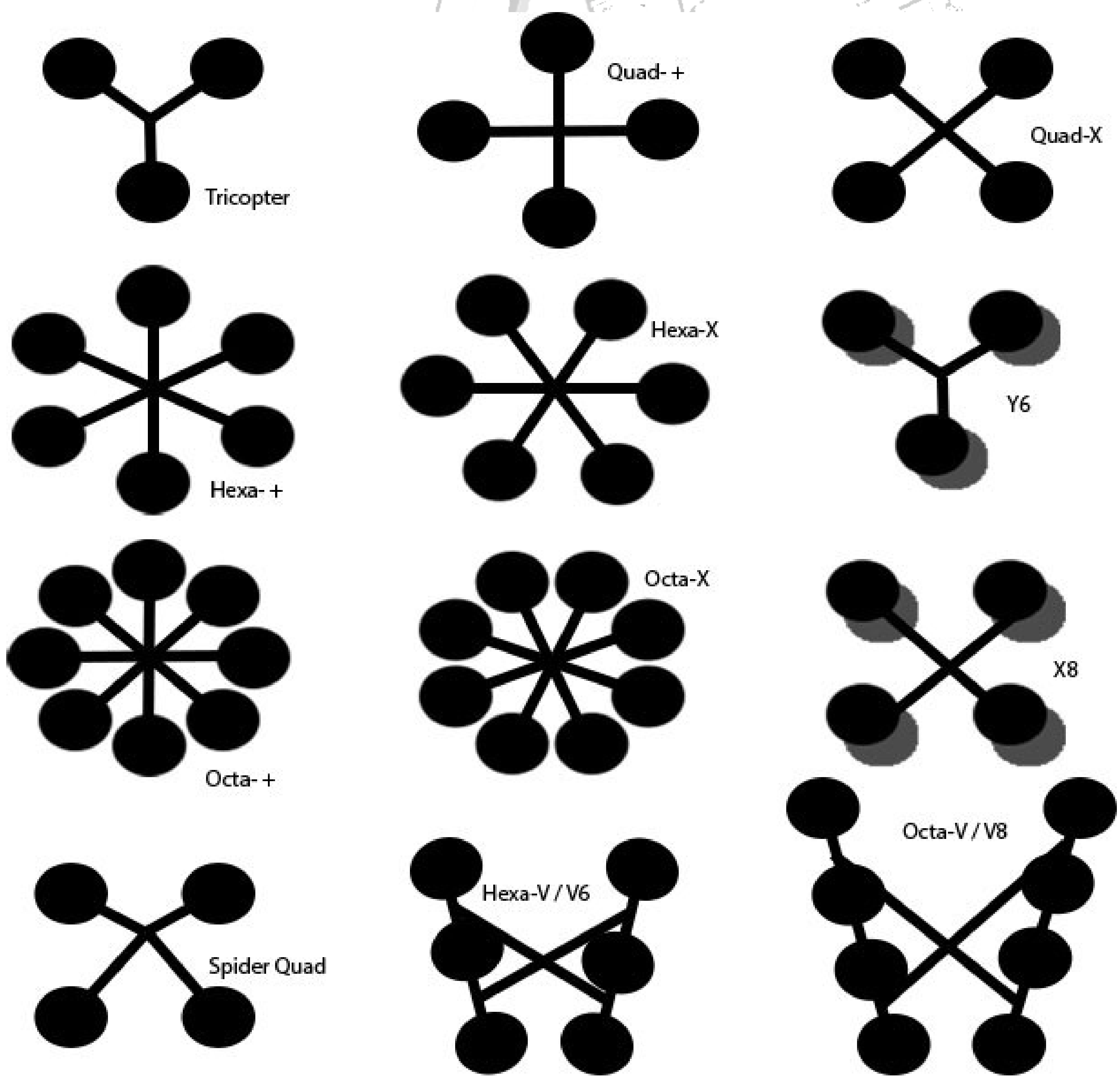
II. MULTICOPTER FRAMES

When designing a multicopter, there are many different frame designs and configurations to consider with some having advantages over others. The most common multicopter frame is probably the quadcopter. Other common configurations include the tricopter, hexacopter, Y6, octocopter and X8. These configurations relate to the number of motors, but with several configurations the frame orientation can also be modified to either +, X, spider or V.

By changing the number of motors, the most significant and obvious difference between each configuration is the increase in available thrust as the number of motors increases. Strapping high power motors to a quadcopter may achieve similar thrust to an octocopter; however, doing so would require large, slow-spinning props that are likely to induce low frequency oscillations into the platform due to slower response times from the increased momentum of each prop. The Y6, octocopter, X8 and V8 configurations not only offer increased thrust, but also motor redundancy that often enables the aircraft to continue flight with a damaged motor. With more motors the stability of the aircraft in the wind will increase, but generally overall stability is more affected by the flight controller than the number of motors. Y6 and X8 frames are the most redundant, having a top and bottom motor and prop, but they are less efficient if the prop sizes are not properly configured.

Frame orientation can be altered for purely aesthetic reasons, but they are most often changed to accommodate a camera. While the standard + configuration helps for beginners to point which direction is forward, an X configuration removes the front motor from the camera's field of view, allowing for an unobstructed view. Furthermore, the frame can be altered such that the central mounting plate where the legs are joined is moved forward, increasing the angle between the front motors while leaving the flight controller at the center of gravity just as with a standard + or X frame. This is known as a spider style frame. It still flies using the same mixes as an X configuration, but the camera's field of view can be increased even further without obstruction. Finally, a V frame can provide the greatest field of view and also allow the camera to be mounted above the frame. This helps to protect the equipment and it shifts the center of gravity above the lowest point of the landing gear; helpful for preventing top-heavy tips upon landing when flying fpv.

With multicopters, it is common to have an even number of motors without the use of a servo. This balances the rotation of the multicopter while in flight. With a tricopter, a servo is used to direct rotational force from the rear motor. With all other multicopters, every other motor spins opposite the direction of the motor beside it. When configuring your frame and electronics, it is important to reference the documentation for the flight controller in order to determine the proper rotation of each rotor. To reverse the rotation of a brushless motor, any two of the three leads from the esc may be swapped. Always remove the props from each motor when testing its rotation.



III. FLIGHT CONTROLLERS

The most important part of the multicopter is the flight controller. The flight controller is responsible for mixing the control inputs through a control system in order to command each motor to perform the desired operation. It enables the pilot to control the multicopter without having to manually alter the rpm of each motor. Flight controllers come in many different configurations ranging from a most basic flight controller to GPS-navigated autopilot systems, each having their own advantages and disadvantages.

A. BASIC CONTROLLERS

The most basic flight controller is the gyroscope-only controller. This controller's sensors are limited to only a 3-axis gyroscope. A gyro helps to feed angular velocity back to the flight controller, but it cannot be used to determine the multicopter's acceleration or exact angle of orientation. This allows for basic balancing of the platform by counteracting any measurable rotation and holding the desired angle. Gyro-based flight controllers are the most simple and cost-effective controller. They are also preferred for flying aerobatics. The disadvantages of a basic flight controller such as these are their reduced stability when compared to an auto-leveling controller and their lack of support for camera stabilization with a gimbal. Some controllers use piezoelectric gyroscopes which can be sensitive to IR radiation; therefore, they should be shaded from direct sunlight. These flight controllers are best suited for a low budget, aerobatic or sometimes fpv builds.

B. AUTO-LEVEL CONTROLLERS

Auto-level controllers are nearly identical to a basic gyroscope-only flight controller, but with the addition of a 3-axis accelerometer. Adding an accelerometer allows the control system to interpret acceleration due to gravity into angular data. Auto-level controllers have come to be very common and inexpensive for amateur aerial photography, fpv and casual flying. They also have the ability to be used for stabilizing the pitch and roll of a gimbal-mounted camera. Auto-level controllers are the easiest and most forgiving to fly. These controllers commonly have the ability to disable the accelerometer if the multicopter is to be used for aerobatic flight. Although these controllers can level the aircraft, they do not help much to compensate for wind drift.

C. AUTOPILOT CONTROLLERS

The most advanced flight control systems are autopilot systems. Autopilot systems commonly support GPS navigation or some other form of relative positioning data. These controllers have a combination of many different sensors, often including a gyroscope, accelerometer, barometric pressure sensor, magnetometer and a GPS receiver. In addition to having the same functions as an auto-leveling controller, an autopilot system can control altitude using a barometric pressure sensor and magnetic heading using a magnetometer. Magnetometers also allow for carefree operation or intelligent orientation control. This mode will update the aircraft's heading relative to the location of the pilot; the front of the aircraft will always face away regardless of orientation. The use of GPS also allows for position holding, navigation of waypoint and compensation for wind drift. Autopilot controllers are suited for more advanced projects or professional aerial photography. Autopilot controllers often have a failsafe that allows for automatic return to launch and landing of the aircraft, a helpful feature for protecting expensive aerial photography equipment.

Common Sensors

Gyroscope – Measures angular velocity allowing for relative angle holding.

Accelerometer – Measures acceleration allowing for auto-leveling.

Magnetometer – Measures magnetic heading allowing for orientation control.

Barometric Pressure – Measures altitude for holding within approximately 1-2 m.

Ultrasonic – Measures altitude for object avoidance and holding within approximately 1-2cm. (Range = 4m)

Optical Flow – Measures optical displacement for position holding and optical navigation.

GPS – Receives and processes global positioning data for position holding and waypoint navigation.

IV. MULTICOPTER FLIGHT BASICS

Before jumping into aerial photography and aerobatics, it is important to understand how to fly a multicopter. For those who are familiar with remote control aircraft, specifically helicopters, flying a multicopter is not much different. As with any remote control vehicle, maintaining orientation while navigating from a 3rd person perspective can be quite difficult, but it develops with practice.

The first step to start with flying a multicopter is to learn how to maintain a stable hover. Many multicopters have an arming feature to prevent accidental power up of the motors while the props are installed. Consult your flight controller's documentation to learn the correct arming and disarming procedure. Once the controller is armed, try hovering the multicopter just above the ground. Assuming the correct components were chosen, the multicopter should lift off and hover at around 50% throttle. Flying the multicopter about a meter above the ground helps to avoid ground effect disturbances caused by the prop turbulence. Adjusting the throttle of a multicopter can be very sensitive. If it begins to drop, lightly raise the throttle; if it begins to climb, lightly drop the throttle. Avoid large inputs of throttle on the control stick. Movements of ±5% should be adequate for maintaining a stable hover. In the event that the multicopter is out of control, cut the throttle to zero and attempt to disarm the motors. If you can manage to stop the props from spinning before it hits the ground, you will minimize the damage to your components. For initial flight tests it may be helpful to tether the frame to the ground using yarn, shoe laces or rope. If possible, tether each arm individually to minimize tipping, but make sure not to leave enough slack in the tethers to get caught up in the props.

After mastering how to hover the multicopter, try to fly using cyclic inputs (pitch and roll). It is good practice to try navigating to various places while walking behind the multicopter as you fly. This helps to familiarize you with movement and turns. It also helps to eliminate orientation problems while you begin learning to fly. Try this exercise at different altitudes to help improve orientation control.

Finally, you are ready to start developing good control over the aircraft regardless of orientation. Begin flying circuits and figure eights with the multicopter. It is possible to do so while always keeping the aircraft pointed away from you; however, it is important that you develop proper control of the aircraft no matter which direction it is pointing. Practice coordinated turns using pitch, roll and yaw while flying perpendicular and towards you. When you are ready for more aggressive maneuvers, try increasing the rates and expos on your transmitter.

V. ADVANCED SETUP

A. PID TUNING

PID tuning can be one of the most difficult parts of tuning a multicopter. The methods of PID tuning are quite similar with each flight controller, but their values differ depending on the unique hardware and control algorithms of each multicopter. A PID loop is the control algorithm responsible for maintaining stability and control of the aircraft while in flight. It uses a feedback loop that mixes your control inputs with sensor data and accumulated error in order to determine how to properly modulate the velocity of each motor. It is important to understand the meaning of each value in a PID controller.

P (Proportional) – Force of correction to current errors

I (Integral) – Accumulation of previous errors

D (Derivative) – Prediction of future errors

The P term of the control loop is responsible for proportionally counteracting present error. In most multicopters, it is the speed with which the pitch and roll will return or lock into to their desired positions. The P term should be the first value to tune. While tuning the P term it is important to begin by zeroing the I and D terms. A high P term for rate control will cause the multicopter to feel forcefully locked into position, while for level it will cause the multicopter to rapidly rotate back to a level position. A low P term will result in little balance or auto-leveling corrections. Oscillations may be induced if the P term is too high. Increase the P term until you begin to experience oscillations, and then back off to a comfortable position.

The I term of the control loop is responsible for accumulation of error from previous operations. For example, under windy conditions the multicopter may hover at a non-level angle to prevent drift. The I term will measure this accumulation in error and adjust for it accordingly. Increasing the position I term of an autopilot navigation system may help to combat wind drift. Additionally, increasing the I term of rate will help to hold a desired angle and increasing the I term of level will help decrease oscillations during rapid ascents or descents. Just as with the P term, the I term can induce oscillations if not properly tuned.

The D term is responsible for dampening oscillations by attempting to predict the error in an operation. It generally magnifies control inputs in an effort to accelerate reaching the desired output. The D term is last to tune because it can also magnify any oscillation present after tuning the P and I terms.

B. CUSTOM ESC FIRMWARE

Another method of improving flight performance and stability is by flashing SimonK firmware to standard inexpensive speed controllers. This firmware increases the refresh rate of the speed controllers allowing the motors to more rapidly react to input commands. This can reduce rpm error and overshoots exhibited during flight. Flashing the firmware of a speed controller requires access to an ISP programmer and compatible speed controllers. The speed controller must have an Atmel MCU and accessible programming pads. A list of compatible speed controllers can be found *here*. More information regarding the process of flashing a speed controller can be found *here* or at *this article*.

VI. AERIAL PHOTOGRAPY AND FPV

Another very common use for multirotor aircraft is aerial photography and first-person view flying. Many heavy lift platforms are more than capable of lifting complex and expensive video production equipment, while even smaller aircraft can be capable of lifting fpv equipment and lightweight cameras. The following are some of the primary components of AP and FPV multirotors:

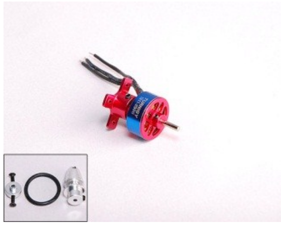
Gimbal -	A camera gimbal attempts to isolate the movements of the frame from the camera, always keeping the camera level. This is accomplished by moving the camera platform using servos that are constantly being adjusted by angular data interpreted by the flight controller or a separate gimbal controller.
Transmitter -	The video transmitter is responsible for transmitting back the camera's video signal to a ground station.
Receiver -	The video receiver captures the transmitter's video signal and outputs an analog or digital signal that can display the real-time video data on a monitor or a set of video goggles.
Diversity Receiver -	A diversity receiver processes the signals from multiple video receivers in order to relay the strongest signal back to the monitoring device. Diversity receivers are very useful when using specialized antennas with various gains and signal patterns. They greatly help to reduce signal drop out.
Dipole -	Dipole antennas are common low gain antennas. They have limited range and can often drop signal if oriented at a 45-degree angle to the paired antenna.
Circular Polarized -	Circular polarized antennas also have a relatively low gain, but an improved range over dipole antennas. Circular polarized antennas are designed to reduce multipathing that is common with higher frequency transmitters in congested areas.
Helical -	Helical antennas are another form of circular polarized antenna with a relatively high gain. They are intended for directional use at long range.
Patch -	Patch antennas are another high gain antenna intended for directional use at long range.
Yagi -	Yagi antennas are very high gain antennas intended for directional use at very long range.

When selecting wireless video equipment, it is important to check local regulation for restrictions on certain bandwidths. Lower bandwidths are more capable of broadcasting over long distances and penetrating objects, while higher bandwidths can handle a greater flow of data. Video transmitters can interfere with wireless radios and telemetry so they should each operate on different bandwidths. Although increasing the power of a transmitter will increase range, using a high gain antenna is much more effective at receiving long range signals even at low power.

VII. PARTS LISTS

A. THE MICRO MULTICOPTER

2900KV BRUSHLESS OUTRUNNER



HK 6A ESC OR **PLUSH 6A ESC *(FAST PWM)***

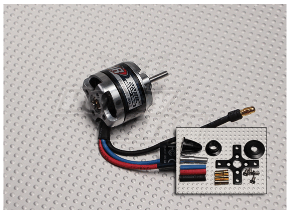
1000MAH 2S LIPO OR **1800MAH 2S LIPO** OR **2200MAH 2S LIPO**

5030/R PROPS OR **[5030X3 PROPS** AND **5030X3/R PROPS]**

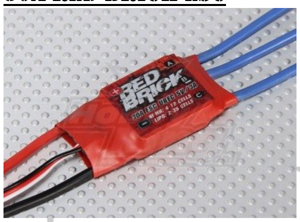
20AWG SILICONE WIRE

B. THE BUDGET MULTICOPTER

1200KV BRUSHLESS OUTRUNNER OR **1320KV BRUSHLESS OUTRUNNER**



30A RED BRICK ESC



2200MAH 3S LIPO OR **3300MAH 3S LIPO** OR **5000MAH 3S LIPO**

8X4.5/R PROPS OR **9X4.7/R PROPS** OR **10X4.5/R PROPS**

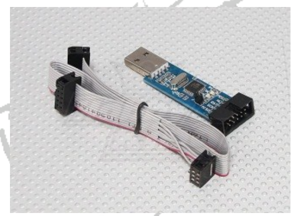
[3.5MM BULLET CONNECTORS AND **16AWG SILICONE WIRE]**

C. FLIGHT CONTROLLERS

[HK CONTROLLER AND USBASP PROGRAMMER]

- ATMEGA 328PA
- 3-Axis Piezo Gyroscope

MWC CRIUS CONTROLLER OR [KK2 CONTROLLER AND USBASP PROGRAMMER]



- ATMEGA 328P
- 3-Axis Gyroscope
- 3-Axis Accelerometer
- 3-Axis Magnetometer
- Barometric Pressure
- FTDI Programmer

- ATMEGA 324PA
- LCD Screen
- 3-Axis Gyroscope
- 3-Axis Accelerometer

ARDUPILOT 2.0 CONTROLLER

- ATMEGA 2560
- 3-Axis Gyroscope
- 3-Axis Accelerometer
- 3-Axis Magnetometer
- High Resolution Barometric Pressure
- 10Hz GPS
- Micro SD Card Data Logging

D. ACCESSORIES

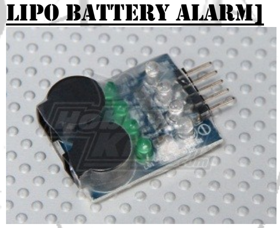
[50W 5A BALANCE CHARGER AND 60W POWER SUPPLY AND XT60 BATTERY PLUGS]


2.4GHZ 6CH TX & RX OR 2.4GHZ 9CH TX & RX

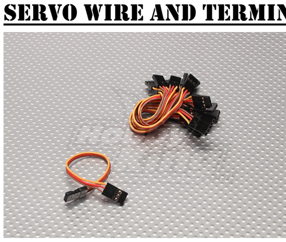
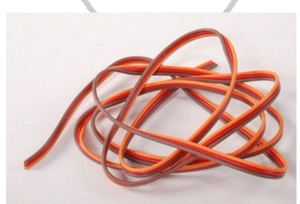

MEDIUM CA GLUE

CABLE TIES

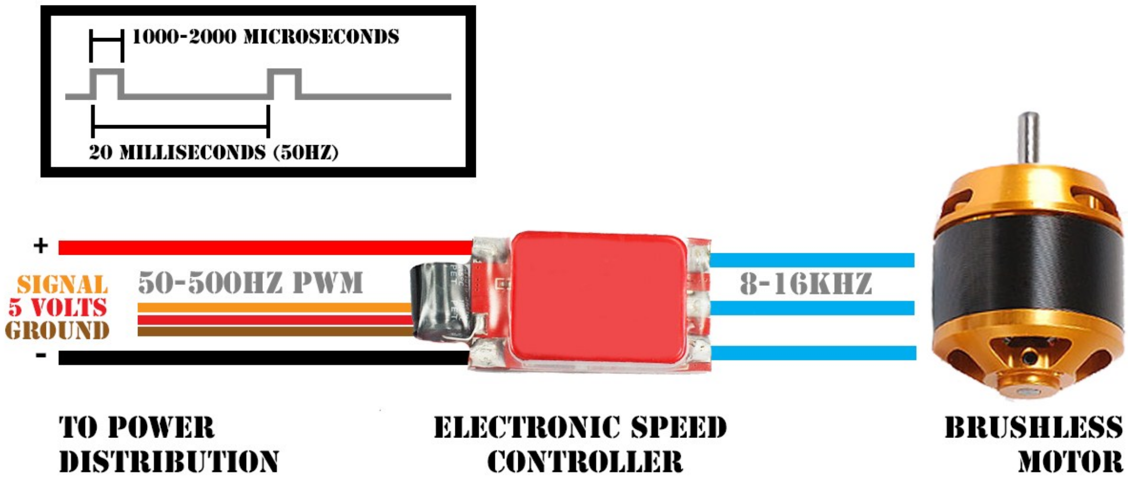

[LIPO BATTERY MONITOR AND LIPO BATTERY ALARM]

SERVO WIRE AND TERMINALS


VIII. WIRING



1. Begin by flashing any custom firmware to each electronic speed controller (*optional*).
2. Using either bullet connectors or a direct solder connection, wire each motor to the proper speed controller. Ensure that the appropriate motors have been properly reversed; this can be done by switching any two of the three wires between the ESC and the motor.
3. If you have an ESC with a built in BEC (Battery Elimination Circuit) that uses a switching regulator, remove the red wire from the 3 wire signal cable on all but one ESC. Most flight controllers will support connection of all 5 volt lines of the three pin signal cable only if the ESC uses a linear regulator.
4. Solder all of the primary positive and negative leads from the speed controllers to a power distribution board or power spider. Include a battery connection and any additional auxiliary power connections on your power distribution. Be sure to properly shield the connections from any shorts by using electrical tape or heat shrink tubing.
5. Check for the correct polarity of all connections. Also check that there is no continuity or shorts between the positive and negative leads of the battery connector using a multimeter.
6. Secure all electronics to the airframe and properly connect each of the signal cables from the ESCs to the flight controller. Consult your flight controller's documentation for the proper placement of each cable.
7. Connect the radio receiver to the flight controller using a set of male to male 3 pin signal cables. Provided that one of the connections is powering the receiver, the remaining channels need only be wired with a single signal cable.
8. If your ESCs do not have a built in BEC, you will need to wire an independent BEC from your power distribution to the flight controller. This will power your flight controller and receiver with the necessary 5 volts power. This can also be helpful for providing a cleaner, less noisy power supply to the electronics or video transmitter.

IX. TIPS AND TROUBLESHOOTING

- Random uncontrollable twitches and oscillations may be caused by vibrations reaching the flight controller. Reduce vibrations at the source. Apply vinyl electrical tape to properly balance props and motors. Using neoprene washers at bolted motor connections can also help to reduce vibrations. Try to mount the flight controller on top of thick vibration dampening foam or tape.

- If your multicopter won't turn on make sure that the controller is armed. Check that all of the speed controllers are properly connected according to their polarity. Ensure that the transmitter has been properly bound to the receiver. Be sure to perform stick centering and calibration of the transmitter with the flight controller.

- Individually calibrate the throttle range of each speed controller using the following procedure:
  1) Connect the signal wire to the throttle channel of the receiver.
  2) Power on the TX and set the throttle to max.
  3) Connect the ESC to a power source and wait for the confirmation beep.
  4) Reduce the TX throttle to zero and wait for the confirmation beep.
  5) Unplug the ESC and repeat these steps for each speed controller.

- If the props spin but the multicopter won't hover, check for the correct installment and rotation of each prop.

- Sudden flips immediately after takeoff may indicate that a motor has been incorrectly reversed. Check each of the three motor leads of each motor to ensure the connections are correct; use your flight controller's documentation as a reference.

- If the multicopter spins out of control after takeoff, check that the motors are correctly reversed. If they are all backwards then reverse the yaw direction of the flight controller or rewire each motor.

- If black smoke is released from an ESC then it is probably wired backwards or underpowered and it needs to be replaced.

- If you have isolated all vibrations and the multicopter still oscillates or twitches, try adjusting you PIDs according to the PID tuning section of this guide. If resonating vibrations are still reaching the fight controller, enable your gyro's low pass vibration filter if available.

X. ADDITONAL LINKS

Forums:
http://www.rcgroups.com/multi-rotor-helis-659/

http://www.multiwii.com/forum/index.php

Flight Controllers:
http://store.diydrones.com/

http://www.hobbyking.com/

http://www.dji-innovations.com/

http://www.hoverflytech.com/

http://www.openpilot.org/

http://xaircraftusa.com/

Parts Suppliers:
http://www.hobbyking.com/

http://www.goodluckbuy.com/

http://store.diydrones.com/

http://www.hobbypartz.com/

http://www.sparkfun.com/

Control Software:
http://code.google.com/p/multiwii/

http://code.google.com/p/aeroquad/

http://code.google.com/p/arducopter/

http://code.google.com/p/megapirateng/

Other:
https://www.google.com/

http://www.wikipedia.org/

http://polakiumengineering.org/

I recommend using PayPal when placing international orders. Although I have never had problems with Hobbyking orders, goodluckbuy is notorious for lengthy processing times. PayPal provides buyer protection in the event of complications.