

Lithium Polymer Batteries and Brushless Systems

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April 7, 2010

Lipoly batteries come in many varieties but two types are very popular for radio control use. The most popular is called "LiPo" but its actually short for Lithium Polymer which all cells of this type of chemistry and style are classified under. The active ingredient in a LiPo is Cobalt but that is not apparent in the generic name of the cell. Another cell type is called LiFe. LiFe cells have been made popular by a brand called A123 and can be found in two forms; flat and round cells. The active ingredient in LiFe cells is Iron Phosphite.

Q: What is the difference and how do I use them for radio control applications?

The main difference between the two cell types is made apparent in their voltage. The LiPo cell nominal voltage is 3.7 Volts per cell (Vpc) while the LiFe cell is 3.3Vpc.

The difference in the peak voltage will make it very clear why a LiPo cell is preferred over a LiFe cell for performance applications.

LiPo – 3.7 V per cell Nominal Voltage / 4.2V per cell Peak Voltage

LiFe – 3.3 V per cell Nominal Voltage / 3.6V per cell Peak Voltage

Lipo cells have a higher performance capability and are ideal for powering vehicles that demand higher power levels as well as standard operational needs.

LiFe cells are perfect for applications such as transmitters and receiver packs due to their chemical stability and lower voltage. LiPo batteries can be used for the same application but caution should be taken because the voltage is higher and can require the use of a voltage regulator depending on the RC equipment used. Some newer equipment is designed to handle direct LiPo power.

LiPo cells are slightly more delicate than LiFe cells for one basic reason, chemistry. The LiFe cell is more stable in the long run and will retain more of its performance in comparison to LiPo cell chemistry. LiPo chemistry is the second most powerful and as such it has a shorter service life.

LiFe cells can be used as the main power source for a vehicle but their lower voltage means the application will require more cells to reach a desired peak voltage. The added weight of the extra cells will offset or begin to offset the potential performance gains commonly found with LiPo use.

Q: How do LiPo cells compare to NiMh?

LiPo cells are much lighter than NiMh round cells by as much as ~33%.

LiPo cells maintain a much higher voltage under operational load which means greater performance for the model.

LiPo's usually have lower operational temperatures under normal operating conditions.

All things being equal the single most significant performance gain an electric model can receive is more voltage. A LiPo pack will not only provide more voltage under load it will be lighter than a NiMh pack of the same capacity. If you add back the ~33% weight reduction in extra capacity you gain more runtime for the same weight and more performance due to the increase in pack capacity. This is especially significant in RC car applications which typically use NiMh battery packs.

More power, more runtime and less weight??? Inconceivable! Nope it's true!!

Q: What is C Rating?

The C Rating of a cell/pack is the manufacturers' performance value of the cell/pack.

The value suggests or implies the battery packs continuous discharge capability. This number will help you determine the applications of the battery pack and if it is a good match for your application.

There is a simple formula to figure out what the battery pack is capable of which is expressed in Amps.

Pack capacity Divided by 1000 then Multiplied by the C Rating.

For example; 20C 2500mah battery pack

$$2500/1000 = 2.5$$

$$2.5 \times 20C = 50$$

50A Continuous Discharge

Q: What is Burst Current?

Burst current is the battery packs ability to provide more power than the standard C rating and it is expressed as an additional C rating.

For example; 20C/30C Burst

Use the standard C formula to determine the Burst current of the pack.

Typically the Burst current is a value that is only meant to be interpreted as an instantaneous release of power and not the continuous discharge rating. The Burst current value is only meant to be good for a few seconds of “overdrive”. The duration is not always disclosed by the manufacturer so it’s safe to assume its less than 10 seconds.

The Burst current of a pack will only be useful to know if you have an onboard data logger or telemetry so you can observe the requirements of the model under load. The typical application in a model when this figure could be of importance is in racing cars, 3D helicopters and 3D aerobatics. These models typically require fast throttle inputs and surges of power. A graphical read out of the power consumed will show amp spikes where the load was very high for an instant. These peak values will reveal a packs Burst current capability.

Q: What is Continuous Discharge and how do I apply that?

Continuous Discharge is simply the packs ability to deliver its rated current from start to finish for its full capacity.

How it is applied can vary from just the knowledge that if you call on it the pack could deliver that power to needing to know the peak RPM of your motor for a speed run.

Knowing this figure will help you balance your models power system needs and help prevent you from asking too much of any one component i.e. Battery, ESC, Motor.

Q: What is the operating temperature of a LiPo pack?

Opinions vary on this but here are some solid truths about how LiPo's like to be used in RC vehicles from our extensive testing in all weather conditions locally.

1. Max safe operating temp under load in a vehicle – 120F
2. Max temp– 140F
3. Min temperature – 60F
4. Best starting operational temp – 95F (cold day use, preheat the pack before use)

Q: What is Heat Soak?

Heat soaking is a phenomenon that occurs with all things that achieve an excited state and then are allowed to relax. The chemistry in a LiPo cell will be very excited during use and an Operational Temperature will be reached. There will be an exchange of heat on the surface and the pack will reach a state of relative temperature stability. Once the battery pack is allowed to rest the molecules within the cells will remain at an excited state for a period of time. This period is called a heat soak period and will last for up to about 5 minutes.

The significance of this is knowing at what point your packs operational temperature peaked and when the heat soak period began. You can expect the battery pack to increase in temperature as much as 15 to 20 degrees extra over the operational peak temperature.

So in other words *how hot was the pack when you turned the power off from the battery pack to the ESC?*

This takes us back to the previous subject, operational temperature and safety.

A LiPo pack's chemistry becomes unstable at temperatures above 140F. If you operate a pack up to 140F and then it heat soaks there is a very real risk of a thermal run away reaction within the pack or an individual cell. At this point one or more cells will "balloon" and the pack will be very hot, 150F and above. The best thing to do is to remove the pack from the model and immediate area. Place it on a cement slab or on sand/dirt or any nonflammable cool surface. Observe the pack for 15 minutes. More on this in another section covering pack disposal.

Q: What is Low Voltage Cut Off (LVCO) and how do I apply this?

LVCO is very important to operating your vehicle especially if it flies. This is the minimum operating voltage of the cell or pack. It is usually expressed in voltage per cell.

Typical LVCO of a single LiPo cell – 3.0Vpc

Min voltage before damaging the cell – 2.8Vpc

This is equivalent to your fuel tank gauge and lets you know how much power you have in the battery pack. Most ESC's (electronic speed controls) today have preset and or selectable LVCO's to choose from. The settings can range from 2.6V to 3.2Vpc. How this setting is used is very important because it is also tied into the operating temperature of the battery pack. The lower a LiPo cell is allowed to drop in voltage under load the more it will stress to deliver power. More stress = more temperature. A good base set up is 3Vpc. A high power application requiring quick throttle changes will stress a battery pack with instantaneous high amp peaks. During this spike the voltage will drop. Later in the pack the average voltage will be lower and the demands may be the same. In this condition the packs average voltage will reach the LVCO preset by the ESC. Once the LVCO is reached and sustained for short period of time the ESC will alert you by reducing the throttle setting and slowing the model or interrupting power momentarily.

In the high power model example if you have adequate cooling for the pack and know your equipment very well you can lower the LVCO to 2.6Vpc. At this point you are taking full advantage of the Burst C rating of the battery pack. This is a very advanced set

up and is not recommended for average applications or anyone without proper experience or guidance.

The LVCO can be used to help you tune the temperature of your set up, maintain a safe operating temperature, and help you extend the life of your investment in batteries.

Note: In general, for LiPo's, sustained conditions are more dangerous than momentary ones during operation.

Q: What is cell balancing and do I have to do this all the time?

In a battery pack of 2 cells or more it is important that the pack begins service in a "balanced condition". What this means is that the voltage of each cell is nearly identical to within 0.001 Volts. During operation the pack will see high temperatures and the individual cells will begin to vary in voltage. Over time the pack will be considered to be out of balance. The significance of this becomes clear when you consider the LVCO of and ESC. The LVCO reads the average voltage of the pack and not the individual cells, typically. So for example Mr. X never balanced a LiPo pack and one day it comes out of the plane with one cell ballooned...so what happened? Let's say it was a 3 cell pack.

Cell 1 = 3.0V

Cell 2 = 3.15V

Cell 3 = 2.6V

Average 3.0V

Cell 3 with some heat and a low voltage will probably balloon and ruin this battery pack or at least make it a 2 cell pack now if it's safe to disassemble.

Your best bet is to make a habit of balancing the battery pack once every 3-5 cycles depending on service style. If your application is a high stress and high power set up then

balance your packs more frequently for best results. If you're set up is more conservative then balancing the pack every 5 cycles is just fine.

During a cell balance charge cycle the battery pack will take longer to charge, this is normal. There is a very accurate charge cycle going on and unlike NiMh cells there is no "overflow" during a charge. Try filling 5 tea cups at the same time from 3 feet away without spilling a drop!

Q: How do I charge a LiPo and can I speed it up?

Charging a LiPo battery requires the use of a charger specifically designed for this chemistry and or the individual chemistry of the Lithium Polymer battery type. A LiFe pack cannot be charged on a LiPo charger/profile. So LiFe with LiFe and LiPo with LiPo and so on. Select the correct cell type before charging a pack.

LiPo cells should always be charged following a 1C rule unless otherwise specified by the manufacturer.

1C means the C rating of the cell or battery pack X 1

For example; 5000mah / 1000 X 1 = 5A charge rate

Insider note; even if a pack is specified to be capable of a 5C charge rate it is not advisable because it will harm the pack and reduce the service life. If you must speed charge a pack do not exceed 3C. The charger should also be capable of high charge rates.

Most LiPo packs will take about 50min to fully charge in normal charge mode.

There is no appreciable temperature change during a charge cycle under normal conditions. If the pack is getting hotter than ambient temperature there is a problem. Stop the charge and review your settings and connections.

Q: What are the battery pack designations and what do they mean?

LiPo battery packs can be constructed in a couple of ways. The goal is to create more voltage or capacity by assembling the cells in parallel or series circuitry, or both parallel and series circuits to make a larger power source with more than one battery pack.

For example a 3S2P designation tells me there are 6 cells total and the voltage is 11.1V.

Series (S) = multiple cells in series increases the voltage of a pack

Parallel (P) = multiple assemblies of cells in parallel increase the capacity of a pack

So 10S4P = 40 cells total, 37V (nominal voltage not peak)

But 5S8P = 40 cells total, 18.5V

Same cell count but different voltage and total capacity

How does this apply to capacity?

3S2P 5000mah pack = 6 cells total, 11.1V

3 X 2500mah cells X 2 sets of cells

3S1P 5000mah is simply 3 X 5000mah cells in Series

Double that and you get 6S1P 5000mah = more voltage

Or place them in parallel = 3S2P = 10000mah, more capacity

There are many ways to combine packs and cells to create the power required by any application.

NOTE: Remember the C Rating is always constant regardless of the pack configuration. With increased capacity comes an increase in Amp performance from the larger assembly of packs.

Common problems with larger pack configurations;

1. High cell count in Parallel = increases the chance of excess heat and cell failure
2. Long charging times due to excessive cell count
3. Difficulty in balancing packs
4. Higher likelihood of cell imbalance due to heat and excess circuitry
5. Less reliable capacity accuracy with higher P cell count

The best course to take with larger pack configurations is to use more single cells in series and fewer cells in parallel. The benefits are;

1. lower operating temperatures
2. easier to balance the packs
3. fewer points of failure
4. more reliable capacity accuracy
5. more robust system

CAUTION: These assemblies must use the same cells of the same capacity and C rating. Do not mix and match different cells.

Proper Disposal of Lithium Polymer cells

In case of a ballooned pack/cell

1. Allow the pack to cool off for 1hr minimum on a nonflammable surface/area or in a nonflammable container and in a well ventilated space, like outdoors.
2. Once it is safe to handle the pack discharge the remaining voltage at 1C if possible to 2.6Vpc.
3. Place the pack in a large pale of salt water over night.
4. Check the cell voltage. If the pack voltage is 0.0V it is safe to dispose of the pack in the trash.
5. Continue to soak the pack in salt water until there is no voltage left.

In case of fire

There are a couple options here and a level head and quick action will be the best way to handle the event.

First – this is a chemical fire. If the protective laminate film of the cell is breached the chemicals inside will react to OXYGEN in the air. **DO NOT USE WATER!!!**

Water will act like an oxidizer and increase the volume and intensity of the fire.

Option 1

Snuff the fire out with sand or baking soda

Use a chemical fire extinguisher, Class BC or D

Option 2

Allow the battery pack to burn but control the surrounding area to keep the fire from spreading like in a field or similar situation.

During a charge cycle and depending on location and situation;

1. disconnect the power to the charger first
2. use a Class BC or D fire extinguisher or sand to snuff the fire out if possible
3. call 911

Required Safety Items for the proper handling of Lithium Polymer cells;

1. a charger made specifically for the cell chemistry you intend to use
2. a nonflammable container i.e. LiPo Sac, Ammo Box, Steel Utility Box, Ceramic Jar
3. Class BC or D Fire extinguisher for metal/chemical fires
4. 5gal metal bucket of regular playground sand
5. 5gal metal bucket of salt water

Suggestions for Charger set up and operation

1. Increase the wire length of the charging wires to a minimum distance of 18 inches from battery to charger.
2. Do not place the battery or charger between you and the charger's power supply. In case of a failure you cannot reach the power supply to turn off the charger without putting yourself in harm's way.
3. **DO NOT CHARGE THE BATTERY PACK INSIDE YOUR MODEL**
4. **DO NOT CHARGE ANY BATTERY PACK UNSUPERVISED**
5. Always use a nonflammable container to charge a battery pack to help contain the failure of a battery pack of any chemistry type.

Q: Why are LiPo packs more dangerous than any other battery types?

This is categorically not true. LiPo packs have been made to appear more dangerous by people who don't understand the technology and have mishandled them. The fact is that they are no more dangerous to handle than any other battery in our industry and hobby. In some cases you could argue that at least they give you a warning by ballooning prior to catastrophic failure. Other cells contained in steel cans like NiMh & NiCad do not provide much of a warning and can explode like a grenade sending sharp fragments flying and then cause a fire.

Early on people posted videos of LiPo's going up in flames and since the technology was new to RC it made headlines and false impressions. Today, this period in hobby history is no different than 20 years ago when the industry ushered in NiMh battery technology to replace NiCad batteries. People had to learn how to use them as well and today it is no different.

As long as you take the time to understand LiPo's and their operating practices you will enjoy the awesome potential these batteries provide.

Q: How do I select a power system for my model airplane?

There are a few basic bits of information you need to know before you think about selecting components to power an electric plane or to convert a nitro/gasoline powered plane. We are going to assume for the benefit of this exercise that the information available today is not there or is difficult to acquire.

1. What is the model type? Scale, Aerobatic, Sport, Glider
2. How do you intend to fly it? Fast, Scale, Slow
3. Is it a draggy or sleek airframe? Biplane, monoplane, retracts, fixed gear, what is the basic aerodynamic characteristic of this plane?
4. How heavy is it? If you don't know because you have no experience with it then go by the suggested finished weight or All Up Weight (AUW) the manufacturer specified. Also ask other pilots who have experience with their own for their AUW.
5. Are you doing an electric conversion to a fuel model? If so what was the recommended engine for the model?

Generally an electric model will give you the specific power system requirements so there is no guess work but now you know some critical information about your model project if you don't otherwise have any guidance.

You now know type, intent, weight and comparable power requirement.

Start with Horse Power (hp) for example.

1hp is equal to 746 Watts of electric horse power

Let's say your model is a 60 size sport aerobatic plane you want to be Sunday flier, low wing tail dragger and weighs about 9.5lbs AUW.

A typical 60 size engine will produce about 1.65hp lets say.

$1.65\text{hp} \times 746\text{W}/\text{hp} = 1230.9\text{W}$ This is your equivalent power figure, electric to nitro.

Now you have an equivalent power target to compare power systems to.

Now let's apply that to the weight of the model. Divide the power figure by the models weight to find Watts per Pound. It's just like horse power per ton or thrust to weight, it's a relative ratio of performance.

$1230.9\text{W} / 9.5\text{lbs} = 129.5\text{W}/\text{lb}$

Here is a generally accepted table of model types and power guidelines.

0-80 watts/lb. indoor to park flier models

80-100 watts/lb. Trainer and slow flying aerobatic models.

100-120 watts/lb. Sport aerobatic and fast flying scale models.

120-140 watts/lb. advanced aerobatic and high speed models

140-160 watts/lb. lightly loaded 3D models and ducted fans.

160-200+ watts/lb. unlimited performance, 3D models, ducted fans

According to the table your model will fall into the 120-140W/lb advanced aerobatic class as expected, it's a 60 size plane after all. These guides will become second nature the more you work with electric power in aircraft.

ESC/Motor/Battery pack selection and the power triangle.

The three basic components to a brushless power system are;

1. the electronic speed control otherwise known as an ESC
2. the battery pack
3. the brushless motor

In order to understand the next section you have to understand one basic principle, the power triangle.

AMPS/WATTS/VOLTS

Power systems for today's models are going to refer to Watts as a basic form of comparison. It's like saying horse power among car guys, same thing.

Knowing Watts gives you 3 important bits of information that will help you understand just about all there is to know about a model's characteristics. From there you can find out what the ESC capability is, what the battery pack configuration is and what the performance of the model is like.

Amps X Volts = Watts

25 A X 12.6V = 315Watts

Divide or multiply these factors as needed to dissect the power system of a model.

For example;

5.5Kw power and a 12S LiPo pack so how many amps does the ESC have to be rated at?

$5500W / 50.4V = 109.12A$ (in this example I'm using peak cell voltage, 4.2Vpc)

Now you know this plane needs a 110 -120Amp ESC and 12 cells rated to handle 110A. The battery is probably a 25C 5000mah pack minimum (125A) to be safe.

ESC information – the basics

ESC's today are rated in Amps for the peak continuous current capability. They are also rated in Watts for total power output. Finally all ESC's will specify how many cells and what type of batteries you can use. Some still have recommendations for NiMh and they will specify total number of cells.

Different brands will offer different features but you must read and understand each feature and function the ESC your going to use has so you don't accidentally cause a problem and potentially lose your model the first time out.

Generally the name brands in ESC's will plug and play with the name brands in motors. There are a few adjustments you can make within an ESC like timing, brake and frequency that can fine tune the pair for optimum performance.

Some ESC's are more limited than others so it is very important to know what you're dealing with prior to purchase and during assembly and preflight.

The power figure you have figured out previously will now come into play. Our 60 size Sunday flier still needs an ESC, we need to cover 1230.9W now.

1230.9W can be broken down with some information. Doing some research on ESC's you will see what models can handle the power you need. It's not a good practice to get an ESC that is exactly the same as your requirement because this does not provide any margin for error, future expansion, or if nothing else a safety margin. I suggest a common practice of covering an application with at least 10A of extra capacity; I call it "**head room**".

With a little investigation you will find that 1230.9W falls into the 60A capacity of many ESC's. Next you will be able to estimate the battery voltage.

$$1230.9W / 60A = 20.5V$$

The ESC of choice would be a 60A unit but you can consider up to a 70A unit. Depending on brand they might not offer an ESC that meets your requirement so it's a good idea to select the next higher unit, within reason of course. For now let's continue with a 60A unit.

Battery information – the basics on choosing a pack

LiPo Battery voltage standards to know are as follows;

- LiPo Nominal Voltage – 3.7V
- LiPo Peak Voltage – 4.2V
- LiPo Minimum Voltage – 2.8V

In practice LiPo cells have been known to hold about 3.5-3.7Vpc under load.

The requirement for our Sunday flier is about 20.5V under load. This figure is pretty easy to arrive at using the Nominal Voltage to figure out the number cells the battery pack will need to be.

$20.5V / 3.7V = 5.5$ cells, so in this case it would be safe to say round up to 6 cells.

A 6 cell pack is equal to **22.2V Nominal Voltage** and **25.2V Peak Voltage** – remember these figures for later.

The battery pack required for the Sunday Flier will be determined by a couple factors.

1. the size of the battery compartment
2. the power requirement of the ESC & Motor

The practical application of the C rating of a LiPo pack

A battery pack can be chosen based on the C rating, Capacity and Voltage. Because of the wide selection of packs there may be several choices for the same application and the final determining factor might be simply physical dimensions.

For example;

3S 10C 2000mah pack = 20A Cont. Discharge and 252W = more run time

3S 20C 1000mah pack = 20A Cont. Discharge and 252W = less run time

3S 40C 500mah pack = 20A Cont. Discharge and 252W = less run time

A higher C rating will allow a lower capacity pack to produce the same amount of power but for a shorter amount of time. Also the higher C rated pack will typically be lighter than its equivalent pack in a lower C rating.

For our Sunday Flier we can look at the following packs as potential candidates;

$$1230.9W / 22.2V = 55A$$

Rounded up to 60A you need to find Battery packs capable of 60A or more continuous current. For example; $3600mah / 1000 \times 20C = 72A$ Cont. = safe battery choice

1. 6S 22.2V 20C 3600mah
2. 6S 22.2V 20C 3400mah
3. 6S 22.2V 20C 3000mah
4. 6S 22.2V 25C 2400mah
5. 6S 22.2V 30C 2000mah

The actual fit will determine which pack is the best to use. Also once you find a pack size that fits you can also look for more battery packs in the same size but with more capacity to extend your flight time.

Now you know the ESC and the Battery Pack required so what motor do you need?

Motor information – the basics on choosing a brushless motor

There are two types of motors for models in common use today. The most recognizable type is called an in-runner motor. This is a conventional motor, the magnet is located on the shaft and the shaft spins inside the motor case. This motor type is known for its very high RPM and compact size.

The second type is called an out-runner motor. This type is interesting because the magnets and outer case revolve around the center which is stationary. There is a shaft that goes through the center supported by ball bearings. This shaft is assembled to the outer case with the magnets. These motors are known for their tremendous torque and efficiency.

All brushless motors have one very important rating in common called KV.

KV is the number of revolutions the motor will turn for one volt of electricity.

$500KV = 500RPM/Volt$

You must know this figure and one other in order to figure out if the motor will be a good match.

The next rating you must know is Watts. How much power (W) can this motor handle? 1500W? Or 150W? What do you need to cover for the Sunday Flier to fly? We need 1230.9W to go flying.

Today motor manufacturers have made it far easier to choose a motor than even just a couple years ago. They have done certain things like cross reference nitro engines in the name of the motor or description. An Eflight (Horizon Hobby) Power 60 motor is equal to a 60 size nitro engine for example. Model Motors aka AXI (Hobby Lobby) has model weights and classes included in the motor description.

If you didn't have this info you can proceed as follows.

Your Watt requirement is 1230.9W so you need to research which motors qualify.

You have to decide in-runner (IR) or out-runner (OR). This is made simple by the fact that our example model is a sport aerobatic plane and you want torque not RPM. The best choice will be an OR motor. An IR motor will require a gearbox to develop torque which is expensive and adds complexity to an otherwise simple solution. An OR motor is pretty simple and they tend to include a motor mount or it is easy to source. With some experience it will become obvious which motor to consider and why.

You are looking for an OR motor that can handle 1230.9W. The motor specs say 5-7cell LiPo, the KV rating is 515KV and the ESC they suggest is 70A max.

All the info you need to know is there. Use the maximum known values to determine if this motor qualifies. More motor is better than less and the extra Watts a motor can handle beyond your needs is a safety margin that you want to know ahead of time.

$7 \text{ cell LiPo} = 7 \times 4.2\text{V} = 29.4\text{V Peak Voltage}$ or $7 \times 3.7\text{V} = 25.9\text{V Nominal Voltage}$

70A ESC

$70 \times 29.4\text{V} = 2058\text{W}$ Or $70 \times 25.9\text{V} = 1813\text{W}$ your requirement is 1230.9W

According to this you can see this motor will provide plenty of performance and a good margin of safety. Also you might consider a lower specification motor or consider the possibility that you might like the extra power. This is a judgment call that can be made during the research phase of determining the power set up of your particular model. You can go back and review the potential Watt per Pound to help make this call. Remember your set up calls for 6 cells not 7 cells and you have to consider any space constraints the model may have. Knowing what the motor is capable of you can proceed to plan your set up. You can repeat the step above as needed per motor until you're satisfied with a motor candidate.

Q: what about the KV rating and how do I use that info?

KV is also an indication of the motors Torque capability. If a motor has a higher KV number like 5400KV then it's assumed that it has low torque and high RPM. If a motor has a KV of 515KV then it's assumed it has a lot of torque and lower RPM.

The KV of this motor example is 515KV. We know the Peak and Nominal Voltage of our LiPo pack so the RPM of the motor is known.

$22.2V \times 515KV = 11433RPM$ under Nominal Voltage

$25.2V \times 515KV = 12978RPM$ under Peak Voltage

Here we have the theoretical RPM of the prop and motor at maximum and nominal voltage. This is not a true representation of what is going to happen because this assumes 100% efficiency and that has yet to be achieved. In reality you can assume brushless systems operate at about 80% efficiency as a realistic figure to work with. This also allows for a bit of losses from the propeller. This has become my personal defacto formula over the past 6 years to subtract 20% from the peak values. In practice this has proven to predict performance to within a few percent of actual field data.

Furthermore when it comes to aircraft my target practical prop RPM is 10000RPM. Most of the time we use APC E electric props and unless your racing or doing something special 10K peak RPM is plenty of RPM to work with for most models. Combined with pitch and diameter you can achieve anything you need for your plane.

$12978RPM - 20\% = 10382.4 RPM$ estimated max RPM under full load

Lets review the set up this far.

ESC = 60A - Why? Because under load we can see $1230.9W / 6S 22.2V = 55A$

Reasons to consider a 70A ESC

1. installation – is there enough ventilation?
2. performance – am I going to push this set up to the limit all the time?

3. safety – can I count on this set up? There are ways to adjust it with prop selection

Motor = power available 1554W on 6S under load ($70A \times 22.2V = 1554W$)

power required 1230.9W

Battery pack – 6S 22.2V 20C 3600mah LiPo pack - Why? Good choice with head room

You have now completed the **Power Triangle**.

With practice you will be able to determine any models power needs based on minimal information, your experience and personal taste.

Motor Design basics and how they apply

Out-runner motors develop torque from their diameter. It's a simple matter of leverage based on the motor diameter multiplied by the length and thickness of the magnets. Other factors related to their power are the number of Magnetic Poles and Stators and the style of wire wind.

Change any of these characteristics and the performance of the motor will change.

OR motors are great for models of all sizes and performance from peanut scale to IMAC, Ducted Fans to full size gliders! OR motors are truly remarkable for their high power, quiet operation and generally lower cost.

In-runner motors are best known for their high RPM. They typically have small diameter magnets but in an effort to produce more torque designers will lengthen the magnet and stator section. These motors tend to be less efficient and run hotter requiring very good ventilation and heat sinks especially when installed in an EDF unit (Electric Ducted Fan). In an effort to generate more torque an external planetary gearbox can be mounted to the

motor face plate. This is especially useful in applications with very narrow fuselages and for high speed propeller driven models.

One thing all brushless (BL) motors have in common is a linear feel and instant torque. The feeling of power is very obvious and immediate, depending on the model, but in general it's pretty impressive. Once you experience it you will have a hard time resisting its appeal, ease of use and cleanliness.

One simple fact is that today the speed records held by many nitro/gas powered vehicles are falling to electric power. Just a couple years ago gas powered boats just broke the 100mph barrier while electric boats are pushing past 120mph on a regular basis. There are many more examples but electric power is growing and here to stay.

Table of preferred brands for BL power systems

- www.venom-group.com batteries – great performance, best warranty, good price
- <http://www.horizonhobby.com/> good model selection, simple power set ups
- <http://www.hobby-lobby.com/> good selection, distributes Model Motors AXI OR motors
- <http://www.modelmotors.cz/> AXI motors home site in English
- <http://www.castlecreations.com/> ESC's, sold through Horizon Hobby
- <http://www.maxxprod.com/> Himax motors, lower cost good performance, good quality
- <http://www.neumotors.com/Site/Welcome.html> Neu Motors made in the USA, best US made motors you can buy

Forums for all subjects in RC modeling

- <http://www.rcuniverse.com/> RCU Forums very large community online
- <http://www.rcgroups.com/forums/index.php> RCGroups very international community, lots of info, great support

Happy modeling!

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