Maximum Performance with LiPo Batteries
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When you think about getting the most out of your LiPo battery pack what are you thinking about? Do you think about keeping the battery pack cool while wringing out your model? Or do you consider pulling high amps and just running for a few minutes your best result?
What if you could get the highest amps, optimum operating temperature and maximum runtime all at the same time? Well you can and there are some things to consider before pushing the limits of your power system.
There are so many applications in the radio control hobby for LiPo batteries but they all have a basic common thread, tune-ability. You have the choice to make adjustments and figure out how to best operate your model. This is the key to understanding and unlocking your models potential.
Another common thread between all electric radio control models is the electronic speed control (ESC), the motor and the battery pack. We can call this a Power Triangle. When the Power Triangle is in balance and no one component is demanding too much of the others the system operates at an optimum efficiency and delivers all that it can without fail.
How to achieve that balance goes further than just the electronic components themselves it extends to the model they are powering as well. You must understand the various ***adjustments*** that can be made either mechanically or aerodynamically, or both, that will directly affect the power system. For example in a car it's the gear ratio and tire compound, in a plane it's the weight and the propeller, for a boat it's the propeller and the trim, and with a helicopter it's the rotor blades length and weight.
If we assume for a moment that the ESC, motor and battery pack are adequate to power a basic RC car and in its ready to run (RTR) form it works adequately as advertised then that would be the end of the story. But what if you're interested in more speed from that same model? How do you go about it, what is required to go faster? What if you want to get longer runtime with higher speed how would you go about that?
Let's start with some basic understanding of the RC car before we get into the power system. In all RC cars and especially within the last 10 years they have an adjustable gear ratio transmission. This means that you can change at least the pinion gear and the spur gear to achieve a different gear ratio which in turn changes the speed or acceleration of the car. The pinion gear is always assembled on to the motor shaft and the spur gear is always assembled to the transmission no matter how simple the car is. In this example let's say the car is 2WD direct drive on-road car for carpet, a pan car. There are two gears, a pinion gear and a spur gear and the spur gear is coupled to a ball differential and live axle similar to a GoKart you would ride in. If you change the gear ratio for more top speed by increasing the pinion gear tooth count the car will have a higher top speed but the acceleration would be slower in general. Usually this has another side effect which is more heat due to higher stress for the motor, battery pack and ESC. Normally this would not be an issue as long as the change is small. When considering larger changes there has to be some compensation so the power system can handle the load and deliver the performance you're looking for. When considering these larger changes the factors are;

1. Amps
2. Motor KV
3. Battery pack C Rate and Capacity
4. Temperature

Taking each factor one at a time lest see why they are important.

Amps, or current, is directly related to temperature and the maximum rated capability of the ESC (electronic speed control). If the gearing adjustment is too aggressive then the load will be greater than the system will handle. If the car in use is demanding 100A and the ESC is rated to 80A then the

ESC is not capable of sustaining this load. This will cause an immediate rise in temperature and eventually the system will fail.

Motor KV is the number of revolutions the motor shaft will turn for every volt applied. If a motor has a KV rating of 3000KV then at 6V the RPM should be 18000RPM. If the KV is very high, like 5500KV, and the gear ratio is set up for top speed then the motor will labor to provide enough torque to accelerate the car. A high KV motor in an RC car is like starting a real car from a stop in 3rd gear. If the motor is not matched to the application within reason then it will over heat and also demand higher current which can damage the ESC or battery as well.

Battery Pack C Rate and Capacity are two very important bits of information you will want to understand. Battery pack capacity is pretty straight forward it's simply the total expected power delivery the battery pack is capable of. It's expressed in Milliamps and depending on where you're from you may see it expressed as Amp Hours. We call it capacity as a general term but it's a very important figure.
C Rate is the manufacturers rating of the battery packs capability to perform or in other words its maximum potential.
When you combine the C Rate with the Capacity you get a number which represents the maximum potential in Amps the battery pack is capable of delivering continuously, for example;
Maximum Continuous Current = Battery Capacity divided by 1000 then multiplied by the C Rate value.
5000mah divided by 1000 = 5
5x 20C = 100A continuous load.
A 20C 5000mah LiPo Battery pack will deliver 100A continuously under load until it is discharged.

Temperature is very critical to the whole operation and safety of an electric RC vehicle. Different components have different temperature ranges and how they are used and installed varies wildly across the hobby spectrum. The best advice here is to know your application very well and keep certain temperature figures in mind when installing the power system and when it's in use. Never assume it will be OK as is, you should always know the models temperatures. Motors generally should not be operated above 180F. The magnets and the wire coatings will begin to fail above 180F unless the manufacturer specifically has rated the motor for high temperature operation.
ESC's are generally not to be operated above 140F. These are delicate precision electronics and they cannot withstand high temperatures without some help from high speed air flow, an incorporated fan or water cooling.
LiPo battery packs have a safe operating range of 70F to 120F. Above 120F the battery pack begins to have an internal chemical reaction that creates gases. This is normal to all chemical reactions that take place inside of all batteries but it is critical to your safety to control the peak operational temperature of the battery pack in any application.

So now we understand that the models inherent adjustments are important and that there are several things to consider when making changes or adjustments to a power system.
Taking the Pan Car example a step further let's put the car on a track to explain further how these factors and adjustments can be applied.
On a track you can measure the total performance of any vehicle because you have a controlled environment and repeatable distance to cover each lap. Here you can see the effects of the changes within minutes or laps and you can determine what the best combination is for the session.
When the car is racing the goal of the power system set up should be able to deliver the most power and runtime to finish the race set time or distance and nothing more. Let's say the race time is 5minutes. How do you select your battery pack in this case? You need just enough capacity to reach the end of the race and you need enough C Rate to have competitive performance. If you use a data logging device or telemetry you can monitor the total power performance of the car on the track and

review the data. If not you can make an estimate based on how much capacity the battery pack took to recharge. However with a data logger you can see peak amps, voltage under load and other data points that will give you a clear picture of what's going on with your car. In any case if you're seeing that you consistently have way too much capacity left over in the battery pack after a race then you can choose a smaller capacity high C Rate pack that will be ***lighter*** and still provided the power the car needs. One guideline is to have used no more than 70%-80% of the capacity by the end of the race. The extra 20% or so of capacity may seem like a waste but that gives you flexibility to make adjustments or to make the distance on larger tracks.

In any electric radio control power system the single greatest increase in performance will come from more voltage. In racing where a class is set to run a specific battery pack voltage the detail you need to look to is voltage under load sometimes called voltage sag. This is best seen in the data read out from a data logging device. Comparing different battery packs and running the same set up will provide a clear picture as to the battery packs capability. The pack with the highest voltage per cell under load is your best pack.

Having selected the best battery pack the next item to look at is the motor. Typically in a race class there is either a set motor specification or it's open to your liking, typically in the upper pro modified classes that is the case. When the motor specification is set then it's very important to tune the peak performance by temperature at a bare minimum. If the speed of the car is good and you know you can make the distance then there is a possibility you might be able to make an adjustment to the gearing to see if you gain or lose speed, time, temperature or maybe how easy the car is to drive at the limit. Sometimes too much power is just too much and can be risky during a race especially with today's high power brushless systems. Detuning becomes another strategy and having power in reserve is not a bad thing when the moment calls for it to be used.

In an open class where the motor limit is unlimited the choice of motor comes down to personal taste and the track itself. Generally you will have far more power on hand than the track can handle. You need a new strategy so experience, chassis set up, driving skill and some luck will be more important than all out power.

With cars the body provides an aerodynamic shape and the underside is open around the chassis. There is a lot of turbulence under the body and as a result the ESC battery pack and motor receive inconsistent airflow for cooling. It's very important when building a competition car to consider this situation.

When the car is pulled off of the track the temperature of the battery pack should be less than 120F. Here are 4 performance targets you can monitor to gage the cars performance;

1. Temperature – Motor 180F or less/ESC 140-150F/Battery Pack 120F or less
2. Battery pack charge capacity – 20% remaining
3. Making the race distance with enough power to be competitive the whole race distance
4. Top speed on the straight – correct gearing to reach a competitive top speed by the end of the longest straight

With all that in mind if you can achieve the performance targets and drive competitively you will be force to be reckoned with on the track. Its takes some practice and experience to learn what is more important and when to apply these techniques but having this knowledge will add to your tool box of tricks!