LiPo Packs versus NiMH Batteries

LiPo batteries offer three main advantages over the common Nickel-Metal Hydride (NiMH) or Nickel Cadmium (NiCd) batteries:

- LiPo batteries are much lighter weight, and can be made in almost any size or shape.
- LiPo batteries offer much higher capacities, allowing them to hold much more power.
- LiPo batteries offer much higher discharge rates, meaning they pack more punch.

But, just as a coin has two sides, there are some drawbacks to LiPo batteries as well.

- LiPo batteries have a shorter lifespan than NiMH/NiCd batteries. LiPos average only 300–400 cycles.
- The sensitive chemistry of the batteries can lead to fire if the battery gets punctured and vents into the air.
- LiPo batteries need special care in the way they are charged, discharged, and stored. The required equipment can be expensive.
- **Voltage / Cell Count**
- A LiPo cell has a nominal voltage of 3.7V. For the 7.4V battery above, that means that there are two cells in series (which means the voltage gets added together). This is sometimes why you will hear people talk about a "2S" battery pack - it means that there are **2** cells in **S**eries. So a two-cell (2S) pack is 7.4V, a three-cell (3S) pack is 11.1V, and so on.
- About Nominal Voltages
- I thought (mistakenly) that this was common knowledge, but after a handful of emails on the topic, it was clear I needed to clarify what nominal voltage is.
- Nominal voltage is the default, resting voltage of a battery pack. This is how the battery industry has decided to discuss and compare batteries. It is not, however, the full charge voltage of the cell. LiPo batteries are fully charged when they reach 4.2v/cell, and their minimum safe charge, as we will discuss in detail later, is 3.0v/cell. 3.7v is pretty much in the middle, and *that* is the nominal charge of the cell.

In the early days of LiPo batteries, you might have seen a battery pack described as "2S2P". This meant that there were actually four cells in the battery; two cells wired in series, and two more wired into the first two batteries in parallel (parallel meaning the capacities get added together). This terminology is not used much nowadays; modern technology allows us to have the individual cells hold much more energy than they could only a few years ago. Even so, it can be handy to know the older terms, just in case you run into something with a few years on it.

Capacity

The capacity of a battery is basically a measure of how much power the battery can hold. Think of it as the size of your fuel tank. The unit of measure here is milliamp hours (mAh). This is saying how much drain can be put on the battery to discharge it in one hour. Since we usually discuss the drain of a motor system in amps (A), here is the conversion:

1000mAh = 1 Amp Hour (1Ah)

I said that the capacity of the battery is like the fuel tank - which means the capacity determines how long you can run before you have to recharge. The higher the number, the longer the run time. Airplanes and helicopters don't really have a standard capacity, because they come in many different sizes, but for R/C cars and trucks, the average is 5000mAh - that is our most popular battery here in the store. But there are companies that make batteries with larger capacities. Traxxas even has one that is over 12000mAh! That's huge, but there is a downside to large capacities as well. The bigger the capacity, the bigger the physical size and weight of the battery. Another consideration is heat build up in the motor and speed control over such a long run. Unless periodically checked, you can easily burn up a motor if it isn't given enough time to cool down, and most people don't stop during a run to check their motor temps. Keep that in mind when picking up a battery with a large capacity.

Q: Why do we use voltage, and not capacity, to determine how charged a battery is?

A: The reason we use voltage, and not capacity to determine how charged a battery is stems from our *difficulty* in measuring capacity. Voltage is simple to measure — if you've ever used a voltmeter to measure an AA battery, you understand how trivial it is to measure voltage.

Capacity, however, is nearly impossible to measure accurately. We can measure how much energy is going into a battery (at least somewhat accurately), but we can't measure how much is actually *in* the battery.

Think of it like beakers of water. For voltage, the beaker is transparent, and we can easily see the amount of water in the beaker in the same way we can measure voltage whenever we like. On the other hand, we have the beaker representing capacity, and it's opaque — we can't see through it, and so the only way to know how much is inside is to empty it and measure the water (energy) as it's leaving the beaker (battery).

Because amperage and voltage are intertwined, as we will discuss later in detail, the voltage of a battery does correlate, approximately, to the capacity left in the battery, and while there are times when the voltage can deceive you, in general, it's okay to rely on voltage as our primary measure of how full a battery is.

Discharge Rating ("C" Rating)

Voltage and Capacity had a direct impact on certain aspects of the vehicle, whether it's speed or run time. This makes them easy to understand. The Discharge Rating (I'll be referring to it as the C Rating from now on) is a bit harder to understand, and this has lead to it being the most over-hyped and misunderstood aspects of LiPo batteries.

The C Rating is simply a measure of how fast the battery can be discharged safely and without harming the battery. One of the things that makes it complicated is that it's not a stand-alone number; it requires you to also know the capacity of the battery to ultimately figure out the safe amp draw (the "C" in C Rating actually stands for **C**apacity). Once you know the capacity, it's pretty much a plug-and-play math problem. Using the above battery, here's the way you find out the maximum safe continuous amp draw:

50C = 50 x Capacity (in Amps)
Calculating the C-Rating of our example battery: 50 x 5 = 250A

The resulting number is the maximum sustained load you can safely put on the battery. Going higher than that will result in, at best, the degradation of the battery at a faster than normal pace. At worst, it could burst into flames. So our example battery can handle a maximum continuous load of 250A.

Most batteries today have two C Ratings: a Continuous Rating (which we've been discussing), and a Burst Rating. The Burst rating works the same way, except it is only applicable in 10-second bursts, not continuously. For example, the Burst Rating would come into play when accelerating a vehicle, but not when at a steady speed on a straight-away. The Burst Rating is almost always higher than the Continuous Rating. Batteries are usually compared using the Continuous Rating, not the Burst Rating.

There is a lot of vitriolic comments on the Internet about what C Rating is best. Is it best to get the highest you can? Or should you get a C Rating that's just enough to cover your need? There isn't a simple answer. All I can give you is my take on the issue. When I set up a customer with a LiPo battery, I first find out what the maximum current his or her application will draw. Let's look at how that works.

Let's assume that our example customer is purchasing a Slash VXL R/C truck. That motor, according to Traxxas, has a maximum continuous current draw of 65A and a burst draw of 100A. Knowing that, I can safely say that a **2S 5000mAh 20C LiPo** will be sufficient, and will in fact have more power than we need. Remember, it has a maximum safe continuous discharge rating of 100A, more than enough to handle the 65A the Velineon motor will draw. Similarly, the Burst Rate of 150A easily covers the 100A the motor could draw.

However, the ratings on the motor aren't the whole picture. The way the truck is geared, the terrain the truck is driving on, the size of the tires, the weight of the truck... all of these things have an impact on the final draw on the battery. It's very possible that the final draw on the battery is higher than the maximum motor draw. So having that little bit of overhead is crucial, because you can't easily figure out a hard number that the truck will never go over.

nternal Resistance: The Mystery Number

There is one very important rating we haven't talked about yet: Internal Resistance (or IR). Problem is, you won't find the IR rating anywhere on the battery. That's because the internal resistance of a battery changes over time, and sometimes because of the temperature. However, just because you can't read the rating on the battery doesn't mean it isn't important. In a way, the internal resistance is one of the most important ratings for a battery.

To understand why the IR is important, we have to understand what it is. In simple terms, **Internal Resistance** is a measure of the difficulty a battery has delivering its energy to your motor and speed control (or whatever else you have a battery hooked up to). The higher the number, the harder it is for the energy to reach its preferred destination. The energy that doesn't "go all the way" is lost as heat. So the internal resistance is kind of a measure of the efficiency of the battery.

Internal Resistance is measured in milliohms (mΩ).
1,000 milliohms is equal to 1 Ohm (Ω)

Measuring the IR of your battery requires a special toolset. You either need a charger that will measure it for you or a tool that specifically measures internal resistance. Given that the only tool I have found for this (at least in the hobby world) is almost as expensive as a charger that does this for you, I'd go with a charger for this process. Some chargers measure each cell's IR separately, and some measure the entire battery pack as a whole. Since internal resistance is a cumulative effect, and the cells are wires in series, if you have a charger that does each cell independently, you need to add up the IR values of each cell, like this:

Suppose we have a 3S (3-cell) LiPo battery, and the measuring the cells independently yields these results.

Cell 1: 3 mΩ   Cell 2: 5 mΩ   Cell 3: 4 mΩ

To find the total internal resistance for the battery pack, we would add up the values for the three cells.

3Ω + 5Ω + 4Ω = 12 mΩ

For a charger that measures the pack as a whole, all you would see is the 12 mΩ - the rest would be done for you - behind the scenes, as it were. Either way, the goal is to have the IR for the entire pack.

The first reason internal resistance is important has to do with your battery's health. As a LiPo battery is used, a build of up Li_2O forms on the inside terminals of the battery (we'll go more in depth on this later in the Discharging section). As that build up occurs, the IR goes up, making the battery less efficient. After many, many uses, the battery will simply wear out and be unable to hold on to any energy you put in during charging - most of it will be lost as heat. If you've ever seen a supposed fully charged battery discharge almost instantly, a high IR is probably to blame.

Proper Care & Treatment: Charging

It's important to use a LiPo compatible charger for LiPos. As I said in the Introduction, LiPo batteries require specialized care. They charge using a system called CC/CV charging. It stands for **C**onstant **C**urrent / **C**onstant **V**oltage. Basically, the charger will keep the current, or charge rate, constant until the battery reaches its peak voltage (4.2v per cell in a battery pack). Then it will maintain that voltage, while reducing the current. On the other hand, NiMH and NiCd batteries charge best using a pulse charging method. Charging a LiPo battery in this way can have damaging effects, so it's important to have a LiPo-compatible charger.

The second reason that you need a LiPo-compatible charger is balancing. Balancing is a term we use to describe the act of equalizing the voltage of each cell in a battery pack. We balance LiPo batteries to ensure each cell discharges the same amount. This helps with the performance of the battery. It is also crucial for safety reasons - but I'll get to that in the section on discharging.

While there are stand-alone balancers on the market, I recommend purchasing a charger with built-in balancing capabilities, using a balance board like the one pictured to the right. This simplifies the process of balancing, and requires one less thing to be purchased. And with the price of chargers with built-in balancers coming down to very reasonable levels, I can't think of a reason you would not want to simplify your charging set up. We'll talk more about chargers in the next section.

Most LiPo batteries need to be charged rather slowly, compared to NiMH or NiCd batteries. While we would routinely charge a 3000mAh NiMH battery at four or five amps, a LiPo battery of the same capacity should be charged at no more than three amps. Just as the C Rating of a battery determines what the safe continuous discharge of the battery is, there is a C Rating for charging as well. For the vast majority of LiPos, the Charge Rate is **1C**. The equation works the same way as the previous discharge rating, where 1000mAh = 1A. So, for a 3000mAh battery, we would want to charge at 3A, for a 5000mAh LiPo, we should set the charger at 5A, and for a 4500mAh pack, 4.5A is the correct charge rate.

The safest charge rate for most LiPo batteries is *1C*, or 1 x capacity of battery in Amps.

However, more and more LiPo batteries are coming out these days that advertise faster charging capabilities, like the example battery we had above. On the battery, the label says it has a "3C Charge Rate". Given that the battery's capacity is 5000mAh, or 5 Amps, that means the battery can be safely charged at a maximum of 15 Amps! While it's best to default at a 1C charge rate, always defer to the battery's labeling itself to determine the maximum safe charge rate.

Please, *please*, don't use parallel charging cords. There is no safe way to use these. Parallel charging simply tempts fate. You will be able to find thousands of successful attempts to parallel charge batteries around the web. These are simply people that have not yet managed to burn their home down. **Every battery expert I have talked to agrees on this**. the **absolute *best* way** to charge multiple batteries at the same time is to have a **multi-port charger**, like the Dynamite Prophet Sport Quad mentioned above. If you find yourself needing to charge many batteries at once, do the smart thing and purchase a charger (or chargers) that will fit your needs.

Proper Care & Treatment: Storage

In the old days, we used to run our cars or airplanes until the batteries died, then just set the batteries on the shelf at home, waiting for the next time we could use them. We just stored them dead. But you should not do that with LiPo batteries. Nor should LiPo batteries be stored at full charge, either. For the longest life of the batteries, LiPos should be stored at room temperature at 3.8V per cell. Most modern computerized chargers have a LiPo Storage function that will either charge the batteries up to that voltage, or discharge them down to that voltage, whichever is necessary.

Proper LiPo Storage Voltage = 3.8V per cell

I recommend to our customers that they put their LiPo batteries in storage mode after every run. This isn't necessary per se, but it does build up good habits. If you do it every time, you don't have to worry about whether or not you remembered to put it in storage. I have had many customers come to me with batteries that died because they charged it up, intending to use it, but life got in the way and they never remembered to put it back to storage voltage. **Lithium-Polymer batteries can be damaged by sitting fully charged for as little as a week**. This doesn't mean they *will* get damaged every time you leave them for over a week. It just means they can, and I've seen it happen. So don't forget to put your LiPos at storage voltage when you're done using them.

They should also be stored in a fireproof container of some sort. As I mentioned above, most people tend toward leaving their LiPos in a LiPo bag, as they are portable and protect your workshop from catching fire should the LiPo combust. I have also seen people use empty ammo boxes, fireproof safes, and ceramic flower pots. Whatever you have (or can buy) that will prevent any fire from spreading will be worth it in the unlikely event that anything untoward should happen.

I feel the need to reiterate: **the most common problem people have with LiPo batteries is a direct result of *improper storage***. When a LiPo battery sits for a long period of time (and not at proper storage voltage), it tends to discharge itself. If it drops below 3.0V per cell, the vast majority of

LiPo chargers *will not charge it*. Sometimes, batteries with this problem can be rehabilitated, but just as often, they are a lost cause. So again: if you take a 'laissez-faire' approach to the storage of your LiPo batteries, it's entirely likely that you will be purchasing new batteries sooner than you think.

** This LiPo information comes from Brian Schneider of Roger's Hobby Center

https://rogershobbycenter.com/lipoguide/

LiFePo – Lithium Iron Phosphate Battery

LiFePo batteries are my chosen battery based on the current technology available. They hit the sweet spot of lightness vs performance. For the same capacity they are half the weight of SLAB (sealed lead acid batteries) which is pretty significant if you have to walk any distance to your operating location.

LiPo batteries offer similar performance, but with quite a major drawback, they're quite prone to catching fire while charging! LiFePo batteries are a lot safer in this regard while offering the same level of performance.

Here are the advantages I've found:

- Light – Half the weight of SLAB batteries of the same capacity
- Supply 13.2v – This is enough to power my rigs at their full output where a 12v battery wouldn't be man enough
- Slow Discharge Curve – The high voltage is maintained almost until the battery is depleted, certainly not the case for SLAB's!
- Fast Charge – My 4200mAh LifePo4 battery takes less than 1 hour to charge
- Stamina – I've yet to deplete one of these batteries in one session, indeed I ran a pileup for 4 hours on one EA8 SOTA summit and it was still fine running my KX3 at 10 watts.

I own two of these LiFePo batteries:

- Zippy 4200mAh LiFePo4 4S2P (around £35 from hobbyking.co.uk)
- Zippy 8400mAh LiFePo4 4S2P (around £63 from hobbyking.co.uk)

- The *4200mAh battery* is the one I use most often for SOTA activations and any QRP operation. This must have had over 75 outings to date and is holding up well with no discernible decrease in performance.
- I use the *8400mAh battery* less often for shorter QRO operations with my Yaesu 897, once again I haven't had any issues with this battery:

Charging

A quick word on charging these LiFePo batteries. You will require a special balanced charger for these batteries. I use the Turnigy Accucell 6 Charger/Balancer (around £25 from hobbyking.co.uk) which can charge a multitude of battery types including Lead Acid, NiCD, NiMH, LiPo and of course LiFePo.

Balance charging is important to keep each cell healthy and evenly charged. LiFePo batteries have a separate balancing cable which you connect to the charger to help with this.

Conclusion

LiFePo batteries are justifiably popular with a lot of serious portable operators and seem to be the defacto choice by a lot of SOTA operators. From my point of view their weight to performance ratio is fantastic compared to the other options currently available. They do cost more but this is repaid by better performance.

** Above info on LiFePo batteries comes from here:

http://www.hamblog.co.uk/batteries-for-portable-amateur-radio-use/

U.S. source for LiFePo batteries and chargers:

https://www.bioennopower.com/collections/12v-series-lifepo4-batteries