What Is a LiPo Battery?

Lithium Polymer batteries (henceforth referred to as “LiPo” batteries), are a newer type of battery now used in many consumer electronics devices. They have been gaining in popularity in the radio control industry over the last few years, and are now the most popular choice for anyone looking for long run times and high power.

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

1. LiPo batteries are much lighter weight, and can be made in almost any size or shape.
2. LiPo batteries offer much higher capacities, allowing them to hold much more power.
3. 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.

1. LiPo batteries have a shorter life span than NiMH/NiCd batteries. They average only 300 – 400 cycles if treated properly.
2. The sensitive nature and chemistry of the batteries can lead to fire should the battery get punctured and vent into the air.
3. LiPos need specialized care in the way they are charged, discharged, and stored. The equipment can be price-prohibitive.

In short, LiPo batteries offer a wide array of benefits. But each user must decide if the benefits outweigh the drawbacks. For more and more people, they do. In my personal opinion, there is nothing to fear from LiPo batteries, so long as you follow the rules and treat the batteries with the respect they deserve.

What Do All The Numbers Mean?

They way we define any battery is through a ratings system. This allows us to compare the properties of a battery and help us determine which battery pack is suitable for the need at hand. There are three main ratings to be aware of on a LiPo battery.

The ratings are:

A. Voltage
B. Capacity
C. Discharge Rating

So what does it all mean? Let's break it down and explain each one.
Voltage

A LiPo cell has a standard 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 Series. So a two-cell (2S) pack is 7.4V, a three-cell (3S) pack is 11.1V, and so on.

The voltage of a battery pack is essentially going to determine how fast your vehicle is going to go. Voltage directly influences the RPM of the electric motor (brushless motors are rated by kV, which means 'RPM per Volt'). So if you have a brushless motor with a rating of 3,500kV, that motor will spin 3,500 RPM for every volt you apply to it. On a 2S LiPo battery, that motor will spin around 25,900 RPM. On a 3S, it will spin a whopping 38,850 RPM. So the more voltage you have, the faster you're going to go.

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:

\[
1000\text{mAh} = 1\text{ Amp (1A)}
\]

The capacity of the battery above is 5000mAh. This means that a load of 5000mAh (or 5A) would drain the battery completely in one hour. We use this information on charging as well, because it works in the opposite way as well. If we charge the above battery at 5 Amps, it will be completely charged in about an hour. Physics is a bit fickle, and there is energy lost along the way, so it won't be an hour on the dot, but it's a good ballpark time.

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. 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.

Discharge Rating ("C" Rating)

The last two specs 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 make 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 Capacity). 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:

\[
20C = 20 \times \text{Capacity (in Amps)}
\]

\[
20 \times 5 = 100\text{A}
\]
The resulting number is the maximum sustained load you can safely put on the battery. Going higher than that will result in the battery becoming, at best, unusable. At worst, it could burst into flames. So our example battery above can handle a maximum continuous load of 100A.

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 straightaway. The Burst Rating is almost always higher than the Continuous Rating. Batteries are usually compared using the Continuous Rating, not the Burst Rating.

Our example battery has a Burst Rating of 30C. That means it can handle a load of 150A, but only for 10 seconds or less.

There are 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 assume that our example customer is purchasing a Slash VXL R/C truck. That motor, according to the available information online, has a maximum continuous current draw of 65A and a burst draw of 100A. Now that I know that, I can safely say that our example battery will be sufficient, and 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 that 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.

For most applications, a 20C or 25C battery should be fine. But if you're driving a heavy truck, or you're geared up for racing, you should probably start around a 40C battery pack. But since there is no easy way to figure this out, I encourage you to talk to your local hobby shop to have them help determine which battery pack is right for your application.

**Proper Care and Treatment**

I said before that LiPo batteries require specialized care. In this segment, we'll break down the charging, discharging, and storage techniques & equipment that are essential for maintaining a healthy battery.

**Charging**

LiPo batteries must be charged using a LiPo-compatible charger. There are two main reasons for this.

First, LiPos charge using a system called CC/CV charging. It stands for Constant Current / Constant Voltage. Basically, the charger will keep the current, or charge rate, constant until the battery reaches its peak voltage (8.4v for a 2S 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 next section.

While there are stand-alone balancers on the market (the AstroFlight Blinky being probably the most notable), I recommend purchasing a charger with built-in balancing capabilities. 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, there are few reasons you would not
want to simplify your charging set up.

At the time of this writing, I consider the Hitec X1 AC to be one of the best values on the market. It's a multi-chemistry charger, which means it can charge NiMH, NiCd, and Lead Acid batteries as well as LiPo batteries. It can even charge the newest LiFe batteries that some use for receiver packs in airplanes and cars. It has a built-in balancer that handles up to 6S LiPo batteries, and can charge up to six amps. Priced around $70, it's a great charger especially for that price.

If you need to charge multiple batteries at the same time, the Hitec X4 charger is probably the best bet. It has all the capabilities of the X1, but with four independent charge ports. This means you can charge up to four batteries at one time! The X4 is the charger we use every day at the store, and we love it.

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 \(1000\text{mAh} = 1\text{A}\). 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.

Due to the potential for fire when using LiPo batteries, regardless of the likelihood, certain precautions should be taken. Always have a fire extinguisher nearby; it won't put out a LiPo fire (as I will further explain below, LiPo fires are chemical reactions and are very hard to put out). But a fire extinguisher will contain the fire and stop it from spreading. I prefer a CO\(_2\) extinguisher - it helps to remove oxygen from the burn site, and will also cool down the battery and surrounding items. Another safety precaution is to charge the LiPo in a fire-resistant container. Most people opt toward the LiPo Bags on the market today. They are a bit pricy, but are more portable than other solutions. Finally, **never** charge your LiPo batteries unattended! If something does happen, you need to be around to react quickly. While you don't have to always be in the same room, you shouldn't leave the house, or go mow the lawn, or anything else that will prevent you from taking action should the battery catch fire.

Since we established that the capacity of a battery is a measure of the drain it would take to deplete the battery in one hour, it follows that, by charging at the 1C rate, it will take approximately one hour to charge the battery. However, since we should be balancing our battery while it charges, it can take up to an extra half-hour to complete the entire process. So, the average charge time of a LiPo battery is around 1 to 1.5 hours. Keep in mind that if you are using a charger that is slower than the 1C rate of the battery, it will take longer than this to charge, since you aren't filling the battery pack as fast.

So now that our LiPo is charged, it's time to have some fun with it! Let's talk about the proper equipment, dangers present, and precautions you should take while discharging your LiPo batteries.
Discharging / Using the Battery

LiPo batteries offer plenty of power and runtime for us radio control enthusiasts. But that power and runtime comes at a price. LiPo batteries are capable of catching fire if not used properly - they are much more delicate than the older NiMH/NiCd batteries. The problem comes from the chemistry of the battery itself.

Lithium-Polymer batteries contain, quite obviously, lithium. Lithium is an alkali metal, meaning it reacts with water and combusts. Lithium also combusts when reacting with oxygen but only when heated. The process of using the battery, in the sometimes extreme ways that we do in the R/C world, causes there to be excess atoms of Oxygen and excess atoms of Lithium on either end (cathode or anode) of the battery. This can and does cause Lithium Oxide ($\text{Li}_2\text{O}$) to build up on the anode or cathode. Lithium oxide is basically corrosion, albeit of the lithium kind; not iron oxide, which is otherwise known as "rust". The $\text{Li}_2\text{O}$ causes the internal resistance of the battery to increase. Internal resistance is best described as the measure of opposition that a circuit presents to the passage of current.

The practical result of higher internal resistance is that the battery will heat up more during use.

Heat causes the excess oxygen to build up more and more. Eventually the LiPo pack begins to swell (due to the oxygen gas build up). This is a good time to stop using the battery - its trying to tell you that it has come (prematurely or not) to the end of its life. Further use can, and probably will, be dangerous. After the pack has swollen, continued use can cause even more heat to be generated. At this point, a process called Thermal Runaway occurs.

Thermal Runaway is a self-sustaining reaction that is accelerated by increased temperature, in turn releasing energy that further increases temperature. Basically, when this reaction starts, it creates heat. This heat leads to a product that increases resistance (more $\text{Li}_2\text{O}$), which causes more heat, and the process continues until the battery bursts open from the pressure. At this point, the combination of heat, oxygen, and the humidity in the air all react with the lithium, resulting in a very hot and dangerous fire.

However, even if you stop using the battery when it swells, you still have to render it safe (a process I'll get into later on). If you puncture a LiPo that has swollen and still has a charge, it can still catch fire. This is because the unstable bonds that exist in a charged battery are in search of a more stable state of existence. That's how a battery works; you destroy a stable chemical bond to create an unstable chemical bond. Unstable bonds are more apt to release their energy in the pursuit of a more stable bond.

When a LiPo is punctured, the lithium reacts with the humidity in the atmosphere and heats up the battery. This heat excites the unstable bonds, which break, releasing energy in the form of heat. The Thermal Runaway starts and you again get a very hot and dangerous fire.

The entire process of building up that lithium oxide usually takes around 300-400 charge/discharge cycles to reach a tipping point. That's a typical lifetime of a LiPo battery. But when we heat the batteries up during a run, or discharge them lower than 3.0 volts per cell, or physically damage them in any way, or allow water to enter the batteries (and I mean inside the foil wrapping), it reduces the life of the battery, and hastens the build up of $\text{Li}_2\text{O}$.

In light of this, most manufacturers have taken to putting a Low Voltage Cutoff (LVC) on their speed controls. The LVC detects the voltage of the battery, and divides that voltage by the cell count of the battery. So it would see a fully charged 2S LiPo as 8.4V, or 4.2V per cell.
This is where the advantage of balancing comes in. Because the speed control does not read off the balance tap, it cannot know the exact voltages of each cell within the battery. The speed control can only assume that the cells of the battery are all equal. This is important because, as I mentioned above, discharging a LiPo cell lower than 3.0V causes a usually permanent degradation of the cell's ability to absorb and retain a charge.

The LVC works to cut-off the motor of the vehicle (or in some cases, pulse the motor) to alert you to a nearly-depleted battery pack. It uses the total voltage of the battery as its reference. Most LVCs cut off around 3.2V per cell. For our two-cell example battery, that would be 6.4V. But if our battery isn't balanced, it's possible for the total voltage to be above the cutoff threshold, yet still have a cell below the 3.0V danger zone. One cell could be 3.9V, while the other could be a 2.8V. That's a total of 6.7V, which means the cut-off would not engage. The vehicle would continue to operate, allowing you to further degrade the battery. That is why balancing is so important.

So when running your LiPo, make sure you have the Low Voltage Cutoff enabled, set up correctly, and for the sake of all that is Holy, don't continue to run it after the LVC has kicked in! It may be a slight nuisance, but it's worth enduring so that your LiPo batteries remain in good health.

**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.

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 in as little as a week. 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.
LiPo Battery Disposal

So you have a bad LiPo battery? No one really wants to keep them around (fire hazards that they are). So what is the process to get rid of a bad LiPo battery safely? Let's go through it.

1. **Discharge the LiPo battery as far down as you safely can.**
   You can do this a number of ways. Most computerized LiPo chargers have a discharge feature in them. If you don't have a charger with a discharge feature, you can run down the battery in your vehicle - keep in mind that you risk a fire and potentially damaging your vehicle doing this, so take care to have the necessary safety equipment around. Alternatively, you can build your own discharge rig with a taillight bulb and some wire. Simply solder a male connector of your choosing to the tabs on a taillight bulb, and plug the battery in. Make sure to have the battery in a fireproof container while doing this.

2. **Place the LiPo in a salt water bath.**
   Mix table salt into some warm (not hot) water. Keep adding salt until it will no longer dissolve in the water. Ensure that the wires are all entirely submerged. The salt water is very conductive, and it will essentially short out the battery, further discharging it. Leave the battery in the salt water bath for at least 24 hours.

3. **Check the voltage of the LiPo.**
   If the voltage of the battery is 0.0V, great move onto the next step. Otherwise, put it back in the salt water bath for another 24 hours. Continue doing this until the battery reaches 0.0V.

4. **Dispose of the battery in the trash.**
   That's right - unlike NiMH and NiCd batteries, LiPos are not hazardous to the environment. They can be thrown in the garbage with no problem.

Alternatively, if you don't feel like going through this process yourself, you can bring the battery in to us and we will dispose of it for you at no cost. If you're not in our area, check with your local hobby shop to see if they offer a similar service.

### Outfitting Your LiPo with a Proper Connector

LiPo batteries have all sorts of power just waiting to be unleashed, and we want as much of that power to reach the motor as possible. But all too frequently, I have customers come in with a great LiPo battery attached to a terrible connector. Bad connectors increase resistance and prevent all that power from being used efficiently. So while it's not superficially about LiPo batteries, let's talk about connectors a little.

#### Traxxas Connectors

Traxxas' High Current Connectors have been gaining in popularity over the last few years. These are seen mostly on R/C cars and trucks, though some airplane enthusiasts have switched over to them as well. The main appeal of these connectors is the ease of assembly. The terminals are separate from the plastic housing, making them easier for novices to solder. They don't require heat shrink, as the plastic housing shrouds the terminals completely. They are polarity protected, so they can't be plugged in backward. Finally, they have the most surface area of any of the high current connectors, and are probably the easiest connectors to slide together and apart.
Deans Connectors

Deans Connectors are really the king of connectors. They've been around seemingly forever, and have been the top choice for the discerning R/C enthusiast for quite some time now. They are somewhat difficult to solder, especially for novice users. Deans connectors slide together smoothly, and are very well designed. Like almost every modern connector, they are polarity protected. Currently, they are neck-and-neck with Traxxas connectors for the title of most popular connector - Traxxas has the edge in the R/C surface category, but Deans dominates in the air.

EC3 Connectors

EC3 connectors came onto the scene because Horizon Hobby was looking for a connector to replace the Tamiya connector as its standard plug. So the story goes, Horizon approached Deans with the intent to license the connectors and obtain them at a bulk rate (so they could install them on their batteries at the factory). Deans refused to be "reasonable" in negotiations, so Horizon was left to come up with an alternative. They found the EC3 and licensed that connector. From there, it's no surprise that the EC3 spread like wildfire. While they aren't much fun to assemble, they have a sizeable foothold in the R/C airplane market.

Tamiya Connectors

Only through the sheer force of Tamiya's market share did these connectors take on their name. Originally called a 'Molex' connector, these connectors were the de facto standard of the hobby industry for years. Popularized by Tamiya in their bazillion R/C cars, these connectors came on every vehicle until very, very recently. Even today, some R/C manufacturers still use the Tamiya connector on their vehicles (Axial, I'm looking at you). This is a terrible connector with lots of resistance. You are more likely to melt these connectors than anything else. If you have a LiPo that has a Tamiya connector on it, cut it off and solder on one of the above connectors.

Venom Connectors

Venom's offering to the connector world sounded really great on paper. When they were announced, I was quite excited about the idea of having a connector that would interface with the four most popular connectors on the market. However, when they came out and I got to see them in person... Let's just say that we pretty much always cut off the Venom connectors to solder on the connector that our customer is actually using. The Venom connectors come with adapters to interface with Traxxas, Tamiya, Deans, and EC3 plugs. None of these adapters work particularly well in my experience. The only reason I bring them up is because they come standard on all Venom's batteries.
Anderson Power Poles

These connectors were wide-spread in the early days of radio control. As most of our stuff is borrowed from other industries, Anderson Power Poles are no different. Originally designed by the ham radio industry for their 12V DC standard connector, they were quickly adopted in the radio control community. Power Poles are the only plug on this list that is hermaphroditic, meaning that the plug is neither male nor female. They are all the same - so no worrying about which gender plug goes on the battery or the speed control. They’re much rarer in the R/C world today, but they are probably my favorite plug. They do take up a lot of room, though, and as such, may not be useful in many applications.

These are the most common connectors today. Other connectors have come out in recent years, but their adoption rate is minimal. Some gained a bit of popularity (the XT60 comes to mind), but have seen their use fall off a bit as people come back to the old standards. Of the above connectors, the only ones you want to avoid are the Tamiya and Venom connectors. Other than that, go with whatever connector makes sense for what you're doing - if Bind-N-Fly Parkzone airplanes are your thing, it makes sense to use all EC3 connectors, as that is what all those airplanes come with. If you run Traxxas trucks, well, Traxxas connectors are an obvious fit. Most of the above plugs have similar specs, so go with what your vehicles come with. Don't make it more complicated than it has to be!

Now let's talk about balancing plugs. There are many different plugs here as well, but there are only two main plugs.

**JST-XH Plugs**

This plug is as close to an industry standard as we will ever have in a balance plug. It comes on almost all the major brands, from Traxxas and Venom to E-Flite and Duratrax. Most of the cheap battery places out of China use this plug as well. While it's not quite as nice as the Thunder Power plug below, it's ubiquitous, and that makes it the logical choice for these brands. There are very few manufacturers that don't use the JST-XH plug for their balance lead. Just make sure to unplug it by grasping the plastic housing. Pulling on the wires will almost certainly pull the wires out of the housing, potentially shorting the battery out.

**Thunder Power (TP) Plugs**

I bemoaned Thunder Power's choice of balance connector for years. Thunder Power makes some of the nicest (and most expensive) LiPo packs in the industry, but their connector is not compatible with 95% of the chargers on the market, at least out of the box (most chargers will require an adapter from the more common JST-XH to the TP connector). That having been said, it's a nicer design, with a little clip on the top of the plug, allowing the user to unplug the connector much more easily. It's hard for me to recommend this connector, as it's only used on Thunder Power and Flite Power battery packs. But I'll begrudgingly admit it's a better plug than the JST-XH.
So there you have it - now you know most of what you need to know about LiPo batteries. I make no claims that this article teaches you everything there is to know about LiPos, but hopefully it helps give you some insight into how they work. LiPo batteries have the potential to overtake NiMH batteries in general use in the next few years, quicker than any battery in history. It is certainly an exciting time for the hobby, and things are changing on a frequent basis. Just remember to have fun, and ask questions! The only dumb question is the one you don't ask!

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