DRONE BATTERY MAINTENANCE AND BUILDING

DRONEYBEE

Contents

Introduction and disclaimer

Let's face it: While drones can be powered by solar panels, hydrogen cells, combustion engines and a myriad of other different ways to get longer flight times, batteries are going to be the cheapest and most popular in the foreseeable future.

If you know how to manage and construct custom batteries for your drones, you will be far ahead of the competition in terms of knowing how to get the most flight times and avoiding battery hazards.

If you are looking for knowledge on how to properly take care of your drone batteries (we shall see why drone batteries are not like your regular lithium batteries and why it requires extra care), get extra flight times and plan your own custom battery setup for your DIY drone projects, you have picked up the right manual!

We shall cover how to make sense of battery ratings, how to pick the right battery for your drone and how to charge, balance, discharge, store, revive and increase the life cycle of your batteries. You will also learn how to pick from different battery brands (as of 2017) and the different types of battery connectors. Lastly, you

will learn how to combine battery packs in series and parallel and set it up in a way to get maximum flight times.

Disclaimer: LiPo batteries (the type of battery used in drones) can be hazardous if you do not take proper care. These batteries contain a large amount of energy and are specifically designed to discharge the stored energy very quickly. Always be safe and never leave your batteries charging unattended. This book is meant to be guidance only. Please do not attempt to experiment with your batteries if you are unsure. Seek help from someone with experience!

Types of lithium batteries and why LiPo

There are a ton of different lithium batteries out there based on lithium ion (Li – manganese, li- co, NMC, NCR, LiFePO and LiPo). For drone batteries though, we use LiPo (lithium polymer) batteries.

The original term referred to a type of cell that used to have a dry electrolyte made of polymer instead of liquid or gelled electrolyte between the anode and cathode of the batteries. However, that type of battery is unimportant for us because it is neither used to power drones nor did it make it out of the laboratory into commercial markets for any other use.

The "LiPo" that we see in the market today are technically lithium-ion in that they function by the transfer of lithium ions back and forth through an electrolyte. The term LiPo, short for lithium polymer became popular after manufacturers started calling pouch cells (which is just the shape of the cell and says nothing about the internal chemistry) that use micro porous electrolyte as lithium polymer batteries.

LiPo batteries are essentially high power Li-co (chemistry based on cobalt) batteries that are capable of releasing a large amount of current. In the RC and drone industry, the ability to draw large amounts of current and hence generate enough power is needed to drive the vehicles and aircrafts.

On the other hand, LiPos are also the most dangerous and volatile among all the different types. They also have the shortest life cycle (typically around 150-200) among the different types. For these reasons, LiPo batteries require special care and management and this is what this manual is mostly about.

Battery ratings, wires and connectors

A typical LiPo battery, regardless of cell number should have two main connectors – one being the main connector (also the thicker one) and the other being the balance connector.

The main connector can be used for charging the battery quickly at the cost of cell voltage balance in multi-cell batteries. It is also the connector that is directly plugged to your actual RC electronics. Typically, the red wire connecting to the connector is positive while the black wire is negative.

The balance connector is the one with the thinner wires. This connector is plugged in to a battery charger to get a balance charge, keeping the voltages of the cells in the battery near equal. More about charging is covered in the how to charge section.

For beginners, it can be really daunting to see all the different numbers printed on a LiPo battery. Worry not, the readings are actually simpler than it seems. Really, it boils down to five different things – Voltage, cell count, capacity, discharge rate and charge rate.

Voltage

As you may already know, voltage is the direct measure of the electromotive force (or potential difference) within a cell. What does that mean for you and your RC craft? Well it is what determines how fast the motors on your RC craft spins.

Brushless motors come with a kV rating. For every volt you apply on such a motor, it will spin at that particular RPM (rotations per minute). For example, if you apply 1 Volt on a 1000 kV motor, it would spin at 1000 RPM. 2 Volts would mean a 2000 RPM spin.

Note that the voltage reading on the battery is usually the **total voltage** from all the cells in the battery pack. Each cell within a LiPo pack has a nominal voltage of **3.7 V**. However, when a cell is fully charged, it can go up to **4.2 V.** This is not ideal for longevity, but more on that later.

Cell Count (S rating)

The 'S' (short for series) is the total number of cells that are in your battery pack. A 1S battery is a single celled battery, while a 3S battery has 3 cells in it (connected in series). You may rarely come across with batteries that also have a 'P' rating along with the S rating.

This is just a reading of the number of batteries that are connected in parallel. For example, a 3S2P battery has 3 cells connected in series and 2 cells connected in parallel.

Capacity

The capacity is the amount of 'fuel' your battery has in reserve. The larger the capacity, the longer the run time before it is time to recharge again. This is measured in milliamp hours (mAh) load (1 amps (A) = 1000 mAh). **It actually is a time measurement than the actual amount of current in it.**

For example, a 1000 mAh (or 1 A) battery would be completely discharged in 1 hour if you put a continuous draw of 1 A (1000 mAh) current on it.

A 5000 mAh (or 5A) battery would discharge completely in 5 hours if you put that same load on it. If you double the load to 2A (2000 mAh), it would discharge in 2.5 hours.

Obviously what this means for you is that the higher the capacity for your battery, the longer flight times you can expect. There is an important caveat here however – batteries tend to get really large and heavy at larger capacities and so you cannot simply scale this indefinitely.

Discharge rate

Discharge rate ('C' rating) is directly tied to the capacity reading. This is the measure of how much of the capacity of the battery can be pulled off at a time.

To give you a concrete example, if you pick a battery with a capacity of 1000 (mAh) and a 10 C discharge rating, you could potentially pull 1000 * 10 = 10000 mAh (10 A) power off that battery continuously, without damaging it.

Now of course, at a 10A current draw you cannot expect that battery to last for an hour. We already know that at a 1A draw it would last an hour (or 60 minutes). At a 10A draw it would last 60 minutes/10 = 10 minutes. This is a reasonable flight time for a lot of RC crafts, especially multirotors.

Some battery packs show a 'burst' C rating. This is the capacity for discharge at a higher rating than usual for short periods of time. This is useful in situations like steeply climbing altitudes or performing flight acrobatics.

Charge rate

The charge ('C' rating) is the rate at which you can safely charge the battery. For example a 1C charge rate on a 1000 mAh battery allows you to charge your battery at 1000 mAh. Therefore, it would take about an hour to charge it!

A 5C charge rate on a 1000 mAh battery would allow you to charge it completely in 60 minutes/5 = 12 minutes.

If this measurement is not explicitly given in your battery pack, stay safe and charge at 1C.

How to select a LiPo battery: Some important factors to consider

Now that we have LiPo batteries explained, how do we go about selecting one to suit our needs? What are some of the most important factors that we must consider? Let us arm our new found knowledge in this section of the LiPo battery guide!

Go for the highest C rating possible

If budget permits, go for the highest C rating possible on any given capacity. If you get too frugal here, you could damage your motors and ESCs! Not to mention you would be completely limited in your ability to do all the cool moves with your RC craft!

When you are out LiPo shopping in your local hobby store, it is better to pick one solid, highly dischargeable battery than 2 or 3 batteries with low C rating.

Make sure it doesn't get too heavy

Weight is an important factor to consider when selecting your LiPo batteries. Even if you get a battery with the largest capacity on the planet, it may not give you the flight times you'd expect.

Remember that the heavier the craft gets, the harder it is on your motors and propellers. This means more power drawn and that defeats the purpose of going for a larger battery in the first place! And if you go too heavy, your craft may not fly at all!

Voltage!

When you pick your LiPo, make sure it meets the voltage requirements of your motors! For example, if your motors require 10 volts, make sure your batteries have a reading of at least 10 volts!

This means that the amount of required cells in your battery (The 'S' rating) would vary from motor to motor!

Like discharge rate, if you go too low, it will damage your motors. Even if the motors and ESCs have predetermined LVCs (low voltage cut-offs) that are below the functioning voltage, it might be difficult to find what their actual LVCs are. Also, for motors to

last longer and for your drones to perform optimally at all times, you must ensure that the battery meets the minimum voltage requirement.

Battery care, Safety and extending lifecycle

How to charge a LiPo battery

Properly charging your LiPo battery is of paramount importance not only for longevity, but also for safety. The MOST important thing to remember is to **only charge your LiPo using a LiPo battery charger!** Charging it with any other charger can cause some serious damage.

Most LiPo chargers available in the market today come with an inbuilt balancing capability that will level the voltages in the cells in your battery. If possible, get your hands on one of these and does a balance charge whenever possible. This may take longer, but it'll help with longevity!

It is also important to remember to pick a charger that can accommodate the appropriate cell count (S rating) for your LiPo. For example, never charge a 3S battery using a charger meant for a 2S battery!

Charging rate

We've already covered what a charge rate (C) is. Most batteries come with a charge rate of 1C and this is the safest to go for, if you are unsure of your battery's capabilities.

Even if the battery comes with a potential for higher charge rate, it is recommended that you charge it at 1C to minimize damage and to ensure maximum longevity, especially if you aren't in a hurry to head out with your RC craft.

Regardless of the specifications on your battery, constantly charging it over 1C will definitely have an impact on its overall life. Patience vs. life? You decide!

Avoid overly charging or discharging

Like we discussed earlier on in this post, a LiPo battery can go up to 4.2V when fully charged with a LiPo battery charger. This is the absolute maximum you must charge your battery to. Anything above this and you significantly reduce the life expectancy of your battery!

4.2V is still not ideal if you want maximum longevity off your battery. For this, charging your battery till it hits around 90% charge rate is ideal. This means getting it up to about 4.15 to 4.17 V range. Of course, this comes with a cost of reduced one time flight time!

Over charging is not the only way you can damage or reduce the life expectancy of your batteries. The absolute minimum you should discharge your battery to is to about 3 – 3.2V. Beyond that, you again run the risk of damaging the battery and/or reducing its life expectancy.

This is an important thing to remember when you head out to fly your RC craft. Never fly till your battery charge hits rock bottom if you want longevity. Land when your battery charge goes down to about 20% instead of an absolute 0. This will do more than just protect your craft from a crash landing!

Other safety considerations

This is arguably the most important section of this LiPo battery guide. If you do not expend some thought energy to actually care for safety of your LiPo battery, you open up the possibility for causing some serious damage to yourself and your surroundings. This cannot be stressed enough. Life is unpredictable enough, so do not overlook this!

The first thing to remember is to absolutely not go out for a party if your LiPos are charging unless you want to witness your house burnt down when you return. Sure, the odds maybe slim but why take chances?

Always make sure that you are in proximity of a charging LiPo battery because if and when things go wrong, you must be there to react to it! Make sure that charging your LiPos is done in isolation, away from easily flammable objects and material in your household.

In most cases, LiPos catch on fire if they are charged or discharged at a high rate immediately after a flight. It is important to remember that the battery get heated up during the flight. It is hence wise to let it cool off before you charge or discharge it.

If you can get your hands on a LiPo bag, please go ahead and do so. It is essentially a fire resistant container that can contain a LiPo battery burn if things head south. Do note that most of these bags tend to be of low quality so it is important to pick one that has good reviews!

How to balance a LiPo battery

What is balancing and why you need to do it

In this section of the LiPo battery guide, we'll first cover what exactly is the process of battery balancing. We've already covered what a cell count is. In batteries with multiple cells, balancing is simply the process of making the voltages of the cells in the battery pack equivalent.

Why do we need to do this and what would happen if the cells go unbalanced? For example, in a 2S battery that is charged, if one of the cells has a voltage of 4.1V and the other has a voltage of 4.2V, it is the unbalanced.

To put it simply, unbalanced cells in a LiPo battery significantly reduces its life expectancy. Not only this, it will also give you lower flight times than usual. Balancing is very easy to do, so why throw away the battery for nothing?

How to check if your battery is balanced

The first obvious thing you'll need to do is to check if the cells in your LiPo battery are actually unbalanced. If you can, go ahead and buy a battery meter. Most of these battery meters can do more than just check the voltages of your battery.

Some of them can act as a discharger, check the capacity of the battery (in case you tear the front sticker of your battery) and also check the internal resistance of your battery.

To ensure that you get the most out of your batteries, it is necessary to regularly check the voltages of your battery and see if it is balanced. Battery meters are in my opinion a great investment!

Using a battery meter is usually as simple as plugging in the balance plug into the meter. From then on, it is easy to check the individual voltages of the cells to check if it is balanced or not. If you want more about balancing, here is a decent article on it.

How to balance a LiPo battery

Okay, now onto actual balancing of the battery. It is easier than you think it is. All you need is a charger capable of doing a balance charge. Most LiPo chargers these days have this feature.

It is as simple as plugging in the balance connector (from the smaller wire) into the balance charger, setting up the appropriate voltage, capacity and settings on your balance charger and voila! You are done!

How to store a LiPo battery

How to discharge a LiPo battery for storage and why

In this section of the LiPo battery guide, we'll cover how to discharge LiPos for storage and next, we'll learn where to store them. The very first thing you need to know about LiPo storage is that you must **never** store a LiPo battery fully charged. Why? The cells in the batteries function from chemical reactions.

Keeping it stored fully charged for long periods of time will degrade the cell from these increased chemical reactions, causing it to puff and/or have reduced efficiency at the bare minimum when you use it again.

On the flipside, discharging your cell below 3V will damage our cell as well. Storing it at anything below 3.5V per cell voltage will increase the chances that your battery loses its efficiency and life expectancy.

What is the ideal voltage then? Well, the very ideal voltage range for storage is 3.7V per cell. This is about 50% of the charge.

Anything from 40% charge to 60 % charge should work well, however.

Discharging a LiPo battery for storage is pretty easy, much like charging it. All you need to do is to plug in your battery into a balance charger or a multipurpose battery charger or meter and set it to discharge for storage. If your charger doesn't have the automatic function, just discharge all the cells till it reaches close to 3.7V.

Where to store LiPo batteries?

Now that we have voltages out of the way, where do you actually store the batteries? The ideal place for storage is in a cool room with no inflammable or magnetic objects around it.

Storing it in a really hot place can entice a chemical reaction and damage the cells. If you have an ammo box or a LiPo bag, store the battery in it.

Storing LiPo batteries in a fridge is not unheard of. If you go this route, make sure you put it in a LiPo bag or an ammo box before putting it in the fridge!

We DO NOT recommend doing this because if not done correctly, like emptying the air from the container (typically a plastic bag), it can cause condensation and therefore damage your batteries. I'd rather just store them in a relatively cool place.

How to revive a LiPo battery

So what if you made the mistake of over discharging your LiPo battery cells (below 3V or even 3.2V in some cases) and your charger refuses to charge the battery? For maximum safety, you dispose it. Do not attempt to revive a dead LiPo battery if you aren't sure what you are doing!

I'd only recommend attempting to revive it if you are absolutely positive that it is not supposed to be dead (no puffing or deforming of the battery for example) and if you have taken necessary safety precautions. You do not want a **LiPo fire**!

Spending a couple of bucks to buy a new battery is always better than risking your safety especially if your battery is old. That being said is recovery possible? Absolutely! It is not guaranteed, however.

Also, do not expect a recovered battery to be like a brand new one. 9 times out of 10, it will be weaker than ever before and give you much less flight times. All the more reason to get a new battery pack!

Here are a couple of ways you can go about restoring a LiPo battery (Note that we DO NOT recommend any of these methods. Do it at your own risk, do not blame this LiPo battery guide if anything goes wrong.

Using a Nickel Metal Hydride battery mode on the charger

Connect your dead LiPo battery to the charger and use the Nickel Metal Hydride setting. Set it to the lowest charge rate and charge the battery for about 10 – 15 minutes. Now, plug in the balance plug into the charger and change the setting to LiPo and check the individual voltages of the cells.

If the LiPo cells have a voltage higher than 3V, then disconnect the main charger and let the charger do a full balance charge to 4.2V. This procedure should recover your dead LiPo battery and get it to functioning again.

Connecting the dead battery to a live one for a minute

This is a much riskier method and the chance for short circuit and a LiPo fire is higher. Nevertheless, this method may come in handy if you do not have a smart charger. You must have another LiPo with the same amount of cells, however.

Connect the dead LiPo to a live one using external wires. A jumper wire with protection should do, but ideally get a thicker wire. Make sure you connect the positive end of the dead battery to the positive end of the still working one and the negative end to the negative one.

Leave the batteries connected for about a minute. Check the voltage of the dead LiPo battery and if everything went well, you should now see a positive reading. If not, I wouldn't try repeating the procedure.

Safety considerations

Put the battery in a LiPo bag in to contain a LiPo fire if things go wrong during either of the recovery procedure. Also remember to keep a fire extinguisher nearby and absolutely positively DO NOT WALK AWAY FROM THE battery when you have kept it for a recovery.

Do the procedure on a concrete floor and away from any other object. There is a lot of risk involved so please do not overlook these simple safety measures!

How long do LiPo batteries last? When and how do you dispose it?

The lifeline of your LiPo batteries will depend on how well you take care of it. If all is good, it should last about 300 cycles. Constantly exposing the cells to high temperatures and not regularly balancing it can exponentially reduce how long it will last.

To squeeze out maximum lifetime out of the LiPos before you throw it away, you should take care of it properly – Keep the cells balanced, make sure you do not charge it over 80% (about 4.1V) and do not discharge the cells below 3.4V.

How to tell if a LiPo battery is bad

You can tell if a LiPo battery is bad and needs to be disposed by the following:

- It is best to consider a LiPo dead if you attempted recovering the battery once in the revival techniques we covered above. Do not try to recharge a dead battery too much for safety reasons. Remember – No LiPo fire!
- If you managed to successfully recover the battery and find that the discharge rate is too pathetic for any practical use, time to throw it away.
- If the battery cells discharges too unequally every time, time to throw it away. For example, after flights session on a fully charged 3S battery, if the battery cells read something like 3.3, 3.3 and 3.5, your battery is bad.
- A sure way to tell if your LiPo battery has to be disposed is if your LiPo battery gets puffed. Never keep using a puffed battery even if it works. It is a risky endeavor and you risk fire/explosion.

How to dispose of a LiPo battery

The first thing you want to check is if the battery pack is physically damaged or not. If so, you should go right ahead and submerge the battery in salt water. If could discharge it first, but be careful and let it discharge at a very low rate (below 1 C).

If the pack is not physically damaged (puffing, for example), you should first discharge the cells of the battery. DO NOT discharge when it is hot, wait for it to cool down if it is hot. Make sure you put the LiPo in a fire proof container like an ammo box during the discharge.

If you do not own an ammo box, fill up a thick plastic container with sand in it and submerge the LiPo in the sand during the discharge. Connect the LiPo to a discharger and set it to the lowest possible voltage and let it drain completely.

For safety, discharge it in 1C. To discharge, you can connect the battery to a mini light bulb, a mini motor or a power resistor and let the voltage of the pack go all the way down to 1V per cell. Note that you may not be able to measure the voltage using a battery meter or a smart charger at low voltages so you may have to use a volt meter or a multimeter.

After you have done that, fill up at least a gallon of salt water in a plastic container. I'd recommend adding around half a cup of salt to the water. Submerge the LiPo battery inside the container and leave it be for 2 weeks. **IMPORTANT –** Keep the container with

the submerged battery away from anything that is flammable, pets and children. It is also imperative that you close the lid of the container.

After the 2 weeks of submersion is done, you can now safely dispose it away in the trash.

If you do not want to go through all the steps, the **absolute best thing** you can do is to take it to your local waste disposal center or to a hobby shop. They will typically dispose them properly. DO NOT however, throw your LiPos in the garbage can without properly discharging it.

Choosing LiPo brands

Price

First and foremost, how much are you ready to pay? Some brands are more expensive than others. While the adage "you get what you pay for" is generally useful, we ask you to hold on before deciding to purchase the most expensive LiPos out there just because they are expensive. Though we don't endorse buying cheap Chinese knockoffs off eBay, don't fall for the "appeal to wealth" fallacy. From our research and experience with different LiPo brands, it is hardly useful.

Durability

This is an important consideration. How long will the battery last before puffing out and becoming absolutely useless? (This is assuming you have taken care of your LiPos well of course) We've found out that some battery brands tend to last longer than others. This is true in terms of number of cycles and also when used in rough conditions like putting them through large power draws.

Availability in different configurations

Another thing to note is that not all battery brands manufacture the exact same configuration you are looking for. If you are looking for a specific battery with a specific capacity and C rating, you may have to sacrifice your freedom of buying from a specific brand.

However, if you are tad bit more flexible with your builds, most manufacturers offer batteries that fall under similar categories anyway, with slight differences.

The most important difference you may encounter with different brands is the type of connector. If you can't connect the battery, what's the point? X-T60 and deans are some of the most common types of connectors that come with LiPo batteries these days.

It is possible to work around this problem by making your own connectors. Cutting and soldering the type of connector you want to any battery brand is a good solution. Nevertheless, it can be a pain. Choose a LiPo brand that can get you up and running with minimum hassle.

Performance

Performance? Yes! Different brands may manufacture batteries with the exact same configuration and yet, the batteries may

perform different. What does "performance" mean in this context? Let's be specific:

- How much flight time or run time the battery will offer, with each charge?
- How much power the battery is capable of generating? Two batteries from different brands may have the same C rating, but you would often notice that your craft performs better on one instead of the other.

Some LiPo brands

Please note that your experience may differ. We are also not affiliated to any of the brands listed below.

Gens Ace

In terms of durability and performance, these ought to be the best batteries out there, based on our experience. It is not just us, most people in the community have mostly positive things to say about this brand.

They come in almost all variations and last pretty long. These come with a dean's connector. Note that they are not the cheapest of the lot though, so if you want something cheaper, read on.

Turnigy

Next up, we have the Turnigy batteries. In terms of durability and performance, we think it is pretty close to the Gens Ace. Overall life cycle of the battery though, is not be as good as the Gens Ace. Nevertheless these are awesome, especially considering you can get them for cheaper.

One major benefit we found with the Turnigy is that the brand manufactures pretty good battery chargers and other battery related accessories. So if you want to pick a brand that offers everything LiPo battery related and stay with it for consistency, we recommend Turnigy!

ThunderPower

ThunderPower batteries deserve a spot here because we think that it may be the best in terms of performance. It is probably the most popular among competitive RC enthusiasts. We found it to fall short when it comes to durability, however.

Do note that these are some of the most expensive batteries out there so if you think might will crash a lot, it might not be worth getting these.

Zippy

Zippy batteries are great, especially when it comes down to value for money and best when it comes to price vs. performance ratio. It is one of the cheapest and will get the job done. Though not as great as the brands listed above, they are good at delivering good performance and are pretty durable too, for the price.

We'd recommend zippy batteries to newbies just getting into drones or those who want to build a cheap craft on their own.

Choosing LiPo battery chargers

Selection criteria and what to consider

Budget

LiPo chargers come at a really wide range of different prices – from about $10 all the way up to $200 and above. If you want the cheapest, easiest solution, we recommend you go with something like the **Tenergy 1-4 Cells**. It doesn't give you very

many options like the ability to discharge, but it should be enough for most hobbyists.

However, in order to get the best LiPo battery charger, it is always recommended that you invest a little bit more. Spend a couple more dollars, and you will have a really good charger at your disposal that can be used for years instead of needing to purchase a new one in case the cheap one dies out (which will be more likely, if it is cheap) or you happen to need the additional functionalities that the really cheap ones don't have.

Multi-Chemistry capability

The next thing you MAY want to consider, especially if you are looking to charge different types of batteries including the NiCd and NiMh. This may not be as important if you plan on ONLY using LiPo batteries. Still, even if you are not really into the RC hobby, we recommend you purchase multi-chemistry chargers. The best LiPo battery chargers in the market, except the very cheapest ones have this sort of flexibility.

Charging speed

Like we mentioned previously, if you want additional functionalities like fast charge, you may want to purchase a LiPo charger that has this feature. The cheapest LiPo battery chargers generally do not have a user interface for different settings. By default, most of these chargers do a balance charge. The best LiPo battery charger for us will be one that will have a user interface and customization.

User Interface, multi modes and ease of use

If the battery charger is too complicated to use, then it is probably going to be a pain in the neck. The ones we have picked here are easy to use and come with easy to understand manuals.

However, it may also be important to you that the best LiPo battery charger for you has different modes including discharge mode and the ability to set different charge rates.

Parallel charging capability – dual LiPo chargers

Parallel charging multiple batteries at the same time can be handy especially if you are looking to head out with longer potential flight times. Charging 3 or 4 batteries one after the other can take quite a while! Some of the more expensive chargers (we have listed one below) have this functionality. Alternatively, you can also use **parallel charging board**. However, this method will only allow you to charge batteries of the same chemistry and 'S' rating.

Cooling capacity and sensors

This is very important for safety. If you are using a charger that is poor at cooling and unable to detect when the batteries are overheating, you are increasing the odds of a fire disaster. Always remember – safety first.

Power

This is the maximum amount of power (in Watts) the charger can charge your battery at. It is the product of voltage and current so

essentially the higher the power, the more capable your charger is at supplying the adequate amount of current that your battery needs to charge at.

Brand

Last but not least, the brand you purchase from is something you must consider if you want the best LiPo battery charger for the money. Quality is especially important with charging a LiPo battery. Buy a charger from a cheap/fake brand and you increase the odds of a disaster.

Battery Connectors

XT-60

A bullet connector that is probably the biggest RC hobby favorite, the XT-30, 60, 90s are probably easiest to solder relative to other types of connectors. They also come pretty cheap and are easy to

connect and disconnect. It is also difficult to connect them the wrong way unless you force and jam them in.

Be cautious while soldering them though. These connectors are known to melt if they get too hot. There are two versions of the XT-60s, one being more heat resistant. Here is a video that discusses this matter:

One way to circumvent this to an extent is to mate the other connector before soldering, so the heat doesn't warp and melt the connector.

Deans

Many batteries come with dean's connector but many more recent ones have dropped them for something else. Designed in a way that it cannot be connected in the wrong way, these come with flat ends making it difficult to solder. They are also pretty difficult to connect and disconnect in comparison to the XT-60 like connector. Ideal wire length to be used with the deans is about 12-

13 awg. These are not built to handle high powered systems running on 4S or 6S LiPos.

EC2, EC3, EC5

Although not as popular, ECXs are great connectors, right up there with the XTXs. The plastic may even be more resilient to heat while soldering, relative to the newer XT-60 type connectors. Soldering is easy and the housings are properly shielded. They are

a tad bit pricier than the XTX type connectors, but the main bonus is that they work well together! **If you need a connector for high current draw systems, we'd say that EC5s are the way to go**.

TRX

A deans like connector that comes with a flat surface, we found that these are just as difficult to solder. These connectors come with Traxxas RTR vehicles and are generally better than the deans in terms of quality. Buy them if you want them as a prefect replacement for your Traxxas ground vehicles. They are expensive connectors so you may also wish to swap them off for something else like the EC3s or XTXs.

HXT (most commonly come in 3.5 and 4mm)

The HXT connectors are essentially bullet connectors with housing. Easy to solder and to work with but be careful because there is only type of housing that you can use with both the source (battery) and the device (your craft), unlike other bullet connectors like the EC3 and XTXs. Since this is possible, you may think you can connect two batteries in series but DO NOT DO THIS!

Wires and connector size for overall use

So how do you pick a wire and connector to connect to your battery wires and connector? Generally speaking, you want less wire and a smaller connector size to minimize the weight of your craft. You do not have to follow the wire thickness of your LiPo battery pack. The better you optimize this, the better the performance will be. It'll also cost less. Remember: thicker wires and bigger connectors are pricier than their thinner/smaller counterparts. Optimize on the wire thickness when you can.

But that's not enough to consider because on the other hand, the thinner the wire is, the smaller the connector you can attach to it, less current can pass through it. This is not ideal if you are using a large quadcopter for example, that handles a 4S to a 6S battery. You'll need larger wires, and therefore bigger connectors to go with it.

A word of caution: If the amp draw is less than what the motors and ESCs require, then this can cause damage to them permanently. So, if you are unsure of the size of the wire you need, then you should go with the larger wire. A good rule of thumb is to follow the wire size of the ESCs because the wires attached to them are typically the size that allows for the correct amount of current draw.

Major considerations

- Never cut both wires together at the same time, unless you want to cause a spark and destroy your battery.
- Before soldering a wire to a connector, make sure you insert the heat shrinks/insulators and get it ready for post soldering
- Make sure you insulate the connections after connecting. Failing to do so increases the chances of an electrical short circuit 10x. Heat it up with a lighter so it stays firm.
- When soldering wire gauges, especially thick ones, do not simply place the ends of the wires next to each other, solder them and expect the connection to be solid. Instead, push the ends to each other so that the strands of both of the ends are inside of each other (some of the strands may pop out). Use a thin wire strand and wrap it around the joint. Solder this joint after for a strong, connection!

Customizing and stacking battery packs

Now that you know how to pick LiPo batteries, their chargers and connectors and how to maintain those batteries, it is time to dive into building custom battery packs from existing packs to give you additional capacity, voltage, current etc.

Unlike other batteries, it is not recommended that you work on building packs from individual cells in the case of LiPos unless you absolutely know what you are doing. Here we'll only look at stacking batteries in series and parallel and how to determine what batteries and how many you will need to stack for maximum efficiency.

Parallel connections

In order to connect two batteries in parallel, you must connect the positive end of the first battery to the positive end of the second battery and negative end of the second battery to the negative end of the second battery. You can do the same with any number of batteries. Connecting batteries in parallel will give your batteries more capacity while keeping the voltage constant.

Important note: Make sure that the voltages of the batteries that you connect in parallel are at least nearly identical. Failing to do so will result in a "voltage dump" from the higher voltage pack to the lower voltage pack, damaging the cell or potentially causing a fire hazard.

In order to calculate the total capacity of the battery packs that are connected in parallel, you simply add the capacities of the battery packs. Voltage will remain the same.

Series connections

In order to connect two batteries in series, the positive end of the first battery is connected to the negative end of the second battery. Connecting the batteries in series will give your batteries more voltage while keeping the capacity constant.

Important note: SHOULD NOT connect the other positive and negative ends – doing so will cause a short circuit, causing a thermal runway, potentially causing an explosion. Be EXTREMELY careful with making series connections!

In order to find the total voltage of the final battery pack, you simply multiple the number of battery cells in all packs that you have connected by the nominal voltage of each cell (3.7 V).

Remember that each cell can be charged upto 4.2V and discharged to about 2.5V. So as an example, if we have motors

that require at least 30V to operate optimally, then we will need to connect enough cells in series so that the motor functions even near 0% capacity of the battery pack (2.5V each cell).

Connecting packs so that there are 10 cells in series, though it will give us a maximum voltage of 42 and a nominal voltage of 37 and 30V if we discharge it to 3.0V each cell. If we discharge beyond that, the motors will cease to function because of the lack of voltage leaving the rest of the battery capacity wasted. Connecting 12 cells in series will be ideal because it will enable the motors to use the full capacity.

Connecting in both parallel and series

What if you want to build a custom pack by simultaneously increasing the capacity and voltage? Answer: Connect batteries in parallel, and then connect those groups of parallel connected packs in series.

Whenever possible make the parallel connections first, before making the series connections for maximum safety.

Tools

You can of course, solder your own wires to make the parallel and series connections, but there is an easier and safer way. You can

get pre-made parallel and series connector cables in the market on Amazon and on various hobby shops. Following are examples:

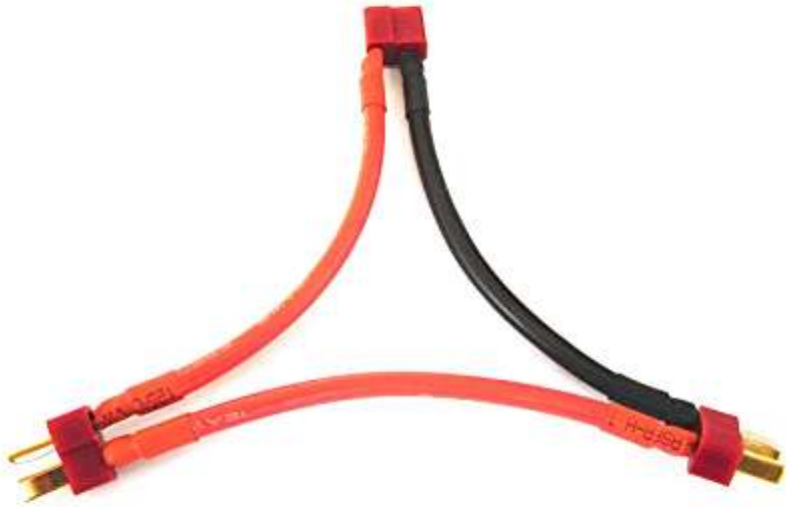

Illustration: Series connector

Illustration: Parallel connector

Designing the battery stack

In order to determine what battery spec and how many you will need, you will need to know the required voltage, capacity and maximum continuous current that you will need for your drone. Most of your battery stack design will depend on compromise and tuning between these factors. These factors in turn, are related to the weight to thrust ratio that you get from the motors and propellers that we saw in an earlier section.

Voltage

We've already covered that in order for brushless motors and ESCs to function optimally and last longer, they must function at their ideal voltage requirement, even if they have an LVC that is below the requirement.

Also, for drones, it is important to make sure that the performance remains stable and does not slow down toward the end of the battery life for maximum safety.

Therefore, in order to determine how many battery packs you need to connect in series, you need to determine much voltage your motors need and meet that requirement. For higher voltages, the in-built BEC within the ESCs will step it down to meet the motor requirement (which is why it is crucial to match ESCs with motors!)

Capacity

You might think that the more capacity of your battery, the longer the flight times. But it is not always that simple. First, if you connect multiple cells in parallel to increase capacity, then the weight of your drone will go up lowering flight times or worse, rendering the motors unable to lift the craft.

Second, the total energy of batteries is not only dependent on the capacity, but also on the voltage. Usually, battery capacities are measured in terms of mAh or Ah. But if you want a more accurate measurement, then you will have to use Wh (watt hours) which is calculated by multiplying the voltage of the battery by Ah.

Therefore, if you take two batteries with the same capacity, say 4 Ah or 4000 mAh, and if the first battery is rated at 10V and the

second battery at 20V, the second battery will have more total energy.

If you want to deep dive into how much capacity your drone build will need to get any number of flight time, it is again, important to think in terms of watt hours. It will also be important to know the current that your motors draw continuously. For this, you will have to check the specifications

For now, let's hypothetically say that your drone motors drain 8A of current continuously and takes 11V. Let's say that you want 2 hours of flight time on your drone. In order to calculate the capacity of battery that you will need in this scenario, you will first need to calculate the power (watts).

Watts = volts * amps. In this scenario, power = 11 * 8 = 88W of power is continuously being drained.

Now, we have to calculate the total energy in watt hours (Wh) that will take place in 2 hours of flight time.

Watt hours (Wh) = power * time. In this scenario, Wh = 88 * 2 = 176 Wh. Therefore, in order for the drone to power for 2 hours, you will need a battery that can supply Wh of power. To convert this measurement into Ah, we simply divide the watt hours by voltage. In this case, the capacity in Ah = 176/ 11 = 16 Ah or 16000 mAh!

An average 10000 mAh pack weighs around 800 grams which is quite heavy in itself. Total weight of the battery alone will then reach more than 1200 grams! How can you build a drone with such a battery, then?

Either you will have to reduce your expectations and go for smaller capacities or you will have to think of ways to reduce your drone's weight or the motors might not be able to support your drone's weight. An example would be to build the drone with a duct tape or thin, plastic frame. You might have to compromise on payload capacity.

Going for bigger motors to support your drone might not cut it because it will require higher current and voltage draw, which in turn will require higher power output and hence, higher capacity from the battery!

Ultimately, it is up to you to decide what you want your drone to do and how much flight times you expect from it from your builds. Out of the box semiprofessional drones to professional drones can fly for anywhere about 20-30 minutes. Hobby grade drones can fly for about 8-10 minutes on average.

Current discharge rate

In order to make our discussion complete, it is also important to understand current. We already know what a C rating of a

battery is at this point and this is where you'll see why you should go for the highest C rating when possible.

In order to calculate the maximum current discharge rate of a battery, we multiple the capacity of the battery (Ah) by the C rating. Therefore, if a battery has 2.5 Ah capacities and has a C rating of 2, then the current discharge rate would be 2.5 * 2 or 5A.

In the engineering world, it is advised to consider something called the "factor of safety". The factor of safety is simply the maximum allowable load divided by the actual load.

So, if the battery has a maximum allowable load of 5A and the motors place an actual load of 3A, then the factor of safety would be 5/ 3 = 1.6. It is generally advised to have a factor of safety of at least 1.5 when designing your drones and the batteries that go along with it.

The main reason for this is because as the cell capacity drains, so does its discharge. Therefore, if you had a battery which had a maximum allowable load of 3A and a load of 3A by the motors, although it would technically be still meeting the specifications, it is highly likely that the batteries will start supplying lower current as it depletes. This is not ideal and should be avoided for both longevity of the electronic components of your drone and generally safety.

In closing

If you are a UAV or RC owner or enthusiast, it is imperative that you understand at least the basics of LiPos to not only be informed and responsible in terms of properly taking care, storing and disposing them but to thoroughly enjoy operating the machine that the battery powers.

A properly maintained, healthy LiPo battery is not only LiPo fire and healthy proof, but also stronger in terms of providing the necessary power you require.