LiPo Battery Pack Primer V1.1

This document provides a guide for the management and safe handling of LiPo battery packs used in model aircraft, helicopters and multi rotors.

The Average Lifespan of a LiPo Battery Pack

A LiPo battery pack, should have an average lifespan of around 300–500 cycles according to leading LiPo battery pack manufacturers.
Of course this also depends largely on factors such as how much “abuse” you put your LiPo battery packs through, and how you handle them on a daily basis.
But even if you have charged and discharge your battery over 500 times, you can still use it as long as you are happy with its performance and there is no visible damage.
One of the biggest issues with heavily used LiPo battery packs is the increase in cell internal resistance (I.R). This is an indicator of a reduction in a LiPo battery pack performance

Check Internal Resistance

Internal Resistance (I.R.) is the most useful LiPo battery pack health indicator.
The **I.R**. of the cells in a LiPo battery pack determines how effectively a battery can deliver current.
Higher **I.R.** means lower performance, and more energy is wasted as heat.
When the **I.R**. is too high, the battery can overheat during charging and go into thermal runaway.

The internal resistance **(I.R.)** of a battery pack cell is measured in ohms Ω.
It’s difficult to say what **I.R.** value is considered good without mentioning the size as of the cells.
Bigger cells tend to have a lower **I.R**.
For a typical 3000mAh to 6000mAh LiPo battery pack, I would consider cell **I.R**:

- Under 10mΩ to be in excellent condition, good for highest current loads (100A +)
- 10mΩ to 12mΩ to be OK, for high current loads (<80A)
- 12mΩ to 15mΩ OK for medium current loads (<30A)
- Over 15m Ω - time to retire the pack from flying or use it in low current applications.

It’s always a good idea to document the **I.R.** of any new LiPo battery packs that you buy so you can see how **I.R.** changes over time and decide if you should retire the pack. This could be written directly onto the pack with a felt marker along with the date purchased.

Also, if one of the cells in your battery pack has noticeably higher **I.R.** than the rest (e.g. 100% higher), it’s a good idea to retire the battery because that problematic cell will supply less current and heat up more than it should during usage and may drop the output voltage below the cutoff levels of ESC and receiver.

How to Measure I.R.?

Most modern LiPo battery chargers these days can measure **I.R**. - for example the TookitRC M6 (which I use).

Fig. 1

The **I.R.** of each cell is displayed on the screen while you are charging the battery pack.

If you are buying a charger I strongly recommend getting one with I.R. measurement.

When measuring I.R, you should try to keep all conditions constant, because several factors can affect your IR readings, such as:

- Capacity of the battery
- Quality of the cells
- Chemical properties
- Age (number of discharge cycles)
- Temperature
- Voltage of the LiPo
- Discharge rating

I.R. depends on the size of the cells (i.e. capacity). Larger cells have inherently lower **I.R**.
For example, when you parallel charge, the **I.R.** will appear lower than when you charge those batteries individually. Note that **I.R.** increases at lower temperature, that's why LiPo battery packs don't perform as well in the winter. Also the state of charge affects **I.R.** reading, i.e. when the pack is empty the **I.R.** tends to be higher than when it's fully charged.

Why do LiPo Battery Packs get WARM or HOT?

Using Ohm's Law you can calculate the heat (wasted energy) that is being generated internally by the **I.R.** of the LiPo battery pack under load.

P (Power in Watts) = Current Load **(Amps)^2** x Resistance **(Ohms)**

Using the **6S** example in the M6D charger (Fig.1) above and using **50A** current draw
(Power) ***P*** = *(Current in Amps)****I^2*** × *(sum of cell internal resistance)****R***
= (50 amps)^2 × (.004+.003+.002+.002+.003+.003) Ohms
= 2500 x 0.017 = **42.5 Watts**

Now let's use a LiPo battery pack with 15m(.015) Ohms per cell= 6 x .015 = 0.09 Ohms
= (50 amps)^2 × (0.09) Ohms
= 2500 x 0.09 = **225 Watts**

Increasing the current to **100A** load using the 6S M6D charger **(Fig.1)** example above
= (100 amps)^2 × (.004+.003+.002+.002+.003+.003) Ohms
= 10000 x 0.017 = **170 Watts**

Now let's use the LiPo battery pack with *15m(.015) Ohms per cell = 6 x .015 = 0.09 Ohms*
= (100 amps)^2 × (.09) Ohms
= 10000 x 0.09 = **900 Watts**
This would likely permanently damage (puff) the LiPo Pack and possibly catch fire

C (Current) Rating

The C rating of a LiPo battery pack refers to the amount of energy the battery can safely supply when fully charged, represented as a multiple of its overall capacity in mAh.
The higher the C rating,the more current (Amps) that can be supplied by the pack.

A 50C 5000mAh battery pack can deliver 1C (1 x 5000mA=5000mA) 5A for 1hour
A 50C 5000mAh battery pack can deliver 10C (10 x 5000mA=50000mA) 50A for 1/10 hour (6 min)
A 50C 5000mAh battery pack can deliver 50C (50 x 5000mA=250000mA) 250A for 1/50 hour (1.2min).

*It is not recommended to exceed the **C** rating load of a LiPo battery pack as this would cause the pack to overheat and likely cause permanent damage or worse, thermal runaway and catch fire*

Physical Condition

A visual examination of your LiPo battery pack can help determine if it should be retired.
LiPo battery packs can easily become deformed in a crash since they are exposed on the outside.
It's not safe to use a deformed battery pack; it should be disposed of safely. (see Below)
Your batteries can also become *"puffed"* if over charged, over discharged, or when they are getting old.
You can't fix a "puffed" battery pack; it should be disposed of safely. (see Below)

How to avoid a "puffed" LiPo Battery Packs

- Proper charging - charge at 1C or less to reduce the chance of battery getting overheated.
- A battery charged at 1C will usually charge in less the 1 hour depending on the initial charge % level.
- Avoid over-discharge: Make sure you land before the voltage drops below the minimum cut-off voltage.
- Batteries don't like heat: If the LiPo battery pack is still warm after flying, let it cool down first before charging/discharging it again.
- Don't abuse your battery: Ideally you never want to go below 3.4v per cell to maintain a healthy battery. 2.9v per cell and lower is likely to cause permanent damage.
- Always discharge or charge your LiPo battery packs from 3.8V to 3.85V per cell when not in use.
- LiPo battery packs don't like the cold just as much as they don't like the heat.
- Store your LiPo battery packs in a lockable metal box, LiPo Battery Bags or a metal Ammo Box
- I recommend charging your LiPo battery packs at home to monitor them closely during charging and also to reduce discharging the battery banks at the field, particularly on cloudy days.

Causes of puffed LiPo Battery Packs

Gas generation in LiPo batteries is normal, even if you don't abuse them.
Normal use of your LiPo battery packs will generate gas through a process called electrolyte decomposition. The *electrolyte decomposition* occurs faster if you over-discharge a battery or overcharge a battery.

What is electrolyte decomposition?

Simply put, a battery is made of three things: the anode, the cathode and the electrolyte.
The cathode and the anode are the positive and negative terminals on your battery.
The electrolyte is a chemical inside the battery that allows charged ions to flow from the anode to the cathode during discharge (and the other way during charging).
Electrolyte decomposition is what happens when that electrolyte chemically breaks down.
In a LiPo battery, as the electrolyte breaks down you end up with lithium and oxygen. This forms lithium oxide on the anode and cathode (depending whether you are charging or discharging).
But what you also end up with is excess oxygen that doesn't adhere to the anode or cathode.
This excess oxygen is part of what causes a battery swell ***and*** oxygen boosts combustion.
Puffy battery packs are getting toward the end of their life and should be monitored closely.

Unbalanced Cell Voltages

It's pretty normal that the cell voltages are slightly different after a flight, e.g. 3.55V, 3.59V, 3.61V. The point being, they should all be within reasonable range. When the I.R. of a particular cellis much higher than the other, the voltage always end up unbalanced after flight and it will put more stress on the other cells. Higher I.R. cells also generate more heat during usage.

Pay attention to Performance

Battery performance decreases when they get older:

- Not holding charge, voltage drops after charging, and reduced flight time.
- Voltage sag (the LiPo battery pack voltage drops under load) is noticeably worse

Another thing to keep in mind is the temperature of the LiPo after a flight.
If a battery pack is getting way hotter (can't hold it in your hand for more than 10 seconds) than others, it's also a sign of an aged LiPo battery pack.

Check Temperature While Charging

LiPo battery packs should not get noticeably warm when charging at 1C. If your LiPo battery pack is getting noticeably warm during charging it is a sign that your battery pack may have a problem.
You should stop charging it immediately and physically check the pack and the **I.R.** of each cell.

"Is My LiPo Battery Pack still safe to Use?"

If you ever ask yourself this question, the answer is probably **NO**.
If you handle a healthy battery properly, it should never catch on fire.
When you have a battery with a dented corner or one of the cells with unusually high **I.R.** the risk of it catching fire increases exponentially.

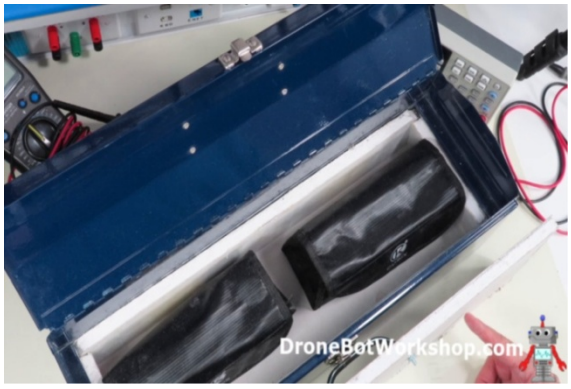
Would you risk your house over a suspect LiPo battery Pack?

LiPo battery packs damaged at the field

If a LiPo battery pack is damaged at the field and you are worried about taking a battery home in your car you should submerge the battery in a bucket of water and leave it outside of the sheds to discharge. It is essential that you remove the battery the following week and dispose of it properly as outlined below**.**

LiPo battery pack storage

LiPo battery packs should be stored at room temperature between 3.8V and 3.85V per cell when not being used. This is considered to be the best storage voltage range to prolong the life of LiPo battery packs.You should store your LiPo battery packs in LiPo Fireproof/Explosion Proof Bags or a Metal Box, Metal Toolbox or a metal Ammo Box preferably lined with plasterboard (which is relatively fire resistant) or other fire resistant material.



Early Warning

Due to the chemical reaction you cannot put out a LiPo battery pack fire once it starts!

A smoke alarm, a fire blanket and fire extinguisher close by (to put out any spot fires) in the area where you store and charge your LiPo battery packs are essential. (*see Annexure 1*)

Methods of LiPo Battery Pack discharge and disposal

When disposing of LiPo battery packs, it's important to discharge them completely to reduce the risk of fire. This means bringing the voltage down to 0 volts.

Never leave a pack that is being completely discharged unattended and always monitor the pack temperature regularly. If the pack is getting very warm stop discharging immediately, wait for it to cool down and then continue discharging it.

1. Halogen Downlight Bulbs

Discharging LiPo batteries with Halogen downlight bulbs is an affordable and speedy option.
I recommendusing 50W 12V MR16 Halogen downlight bulbs (*available at Bunnings*).
Use 2 bulbs wired in series for 2S, 3S, 4S, 5S and 6S packs.
Don't use12V LED bulbs as theyare much lower wattage and due to their forward voltage drop, would stop discharging around 0.5V and as a result there will be a small amount of charge left in the battery.

2. Salt Water

Salt water discharges the battery slowly over time, but it might not completely discharge the battery. Corrosion also takes place where the exposed metal of the connectors/wires will have a layer of chemical insulation building up in salt water. This might eventually stop the discharging entirely. However, many people still favour using salt water over other methods because it's much safer as the battery is entirely immersed in water and dissipates any heat from the pack.

To discharge LiPo battery pack with salty water:

1. Get a plastic bucket and fill it with cold water
2. Mix in salt until it dissolves completely. Use about 30g of salt per litre of water.
3. Cut the power connector (XT60 etc) off the power leads (+ and -) and remove about 20mm of the insulation of both leads **and keep them separate** (so they don't touch).
4. Put the battery in the salty water, and leave it somewhere fireproof for two weeks or longer, depending on the original charge. Check regularly - clean the corrosion off the power leads, check the voltage with a multimeter and place back in the salt water if not 0V
5. Finally dry it, cut off the power leads and dispose of it at an authorized battery disposal facility.

My Recommendation

I normally use halogen downlight bulbs to completely discharge the LiPo battery pack.
The advantage of this method is you get a visual indication that the pack is close to 0V when there is no longer any light from the downlight bulbs.

Use a multimeter to check to pack voltage to ensure it is close to 0V.
Cut the power connector(XT60 etc), off the power leads (+ and -) and remove about 20mm of the insulation of both power leads (+ and -).
Twist the power leads together to ensure there is no charge left in the pack. You might get a small spark when the wires first touch, the pack might even get warm, but it shouldn't be an issue if the battery is close to 0V. Leave the power leads twisted for 30mins checking the pack is no longer getting warm.
Finally cut the powers leads off and then dispose of the packat an authorized battery disposal facility.
These can be found at some Bunnings, Officeworks and other battery stores eg. Battery World.

Annexure 1 - A note from Rod Slavik our resident fire safety expert on LiPo Battery Packs

"I have two smoke detectors screwed onto the shelf above where I charge, with another on the ceiling and one fire blanket on either side of the charging station, with long BBQ tongs nearby and 2 small fire extinguishers handy in the laundry!
It's all cheap enough and easy enough to do.
I've seen way too many sorry faces at work over the years not to take these easy steps to avoid a life changing disaster.
Batteries will thermal runaway if they are damaged, crushed, pierced and during recharging - where the exothermic reaction (flame, sparks, smoke) will be more violent/longer in duration due to the battery being at greater capacity.
You cannot put out the fire once it starts!
The fire smoke and sparks are a by-product of a chemical reaction which must exhaust itself before the flame/smoke dies out. All you can do is to protect exposures (walls, shelves, curtains, carpets, furniture) from catching alight, until the chemicals reaction has exhausted and stop flaming.
Make sure you have a clear safe exit route to outside - in case things turn bad...
A fire blanket or two thrown over the top of the battery should help keep the flame/sparks contained, and from flying all over the room. A fire extinguisher should be used to put out 'spot fires' in the surrounding area.
Keep calm, keep out of the smoke - which is toxic, and evacuate if the situation is untenable.
Call 000 – *NSW Fire and Rescue* as we have Thermal Imaging Cameras to ensure there are no hidden fires and the temperatures are down. We will also want details for our (*NSW Fire and Rescue*) Lithium Battery statistics."

This a living document - If you have suggestions and ideas, please let me know so we can update this document.

Ron Irving

Sources:
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