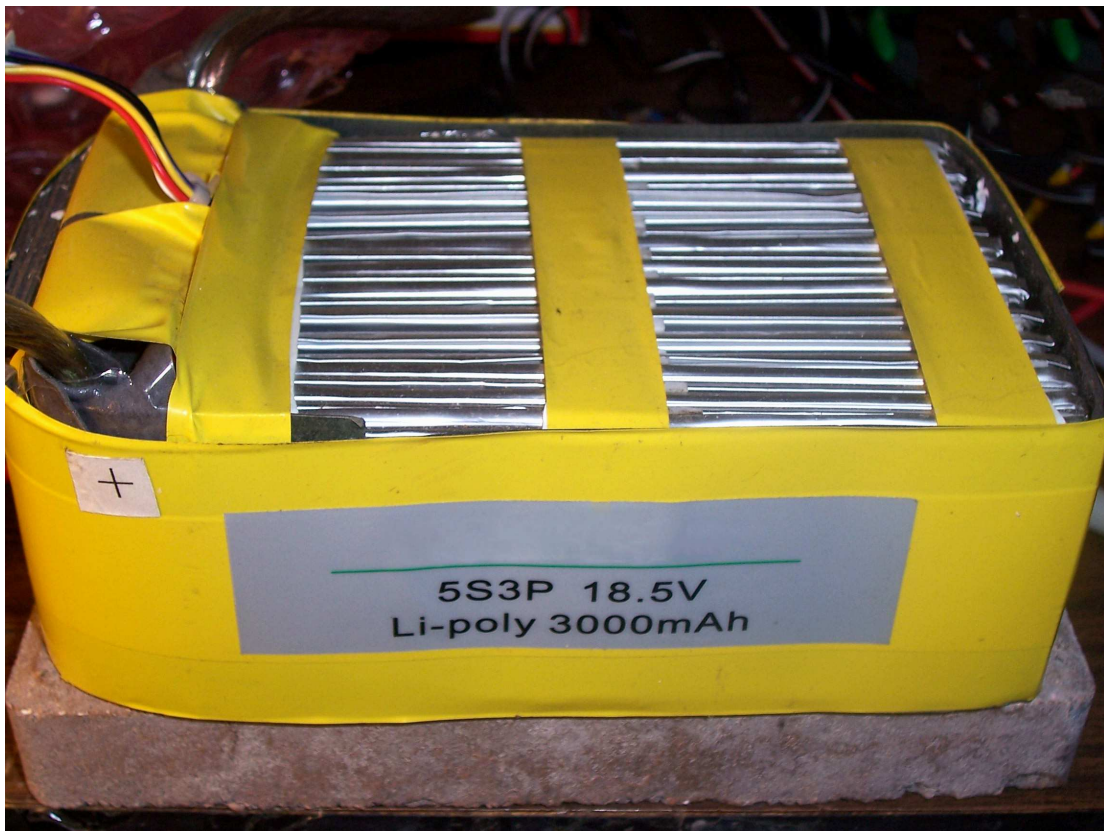


“The TRUTH About Rechargeable Lithium Batteries”

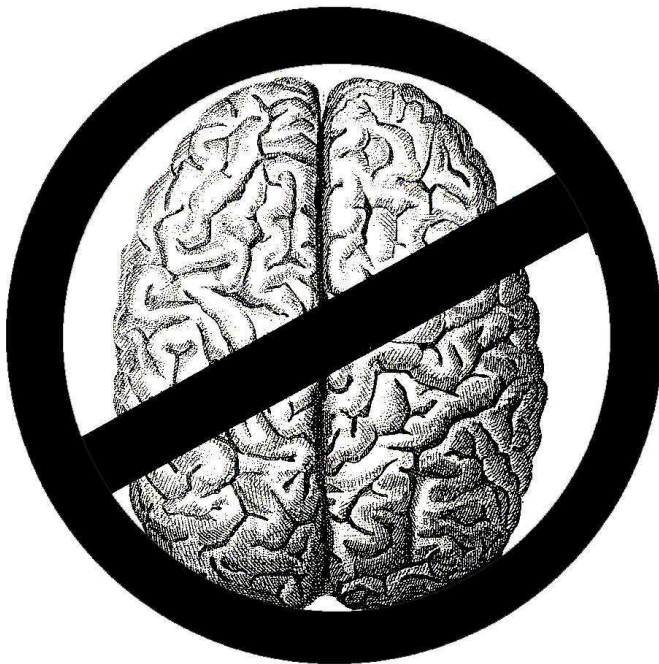
Money Saving Tips to extend the life of Lithium Batteries



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Other than the standard safety things that everyone knows about, like; don't drop, puncture, overcharge or short lithium batteries, there are some subtle but significant ways we can extend the life of these fragile but amazing cells. The following tips are not well known, but understanding them can save you a lot of money if you read and follow them closely.

1. Lithium batteries have NO MEMORY so they do not need, nor do they like to be fully discharged like Nickle batteries do. Even though RC speed controllers, your cell phone and your laptop have circuitry to protect and shut down the main load when the low cutoff voltage is reached, if you leave the battery physically connected to the protection circuitry after cutoff, the battery will continue to discharge very slowly and gracefully die. Many times this is irreversible if left to go too long.

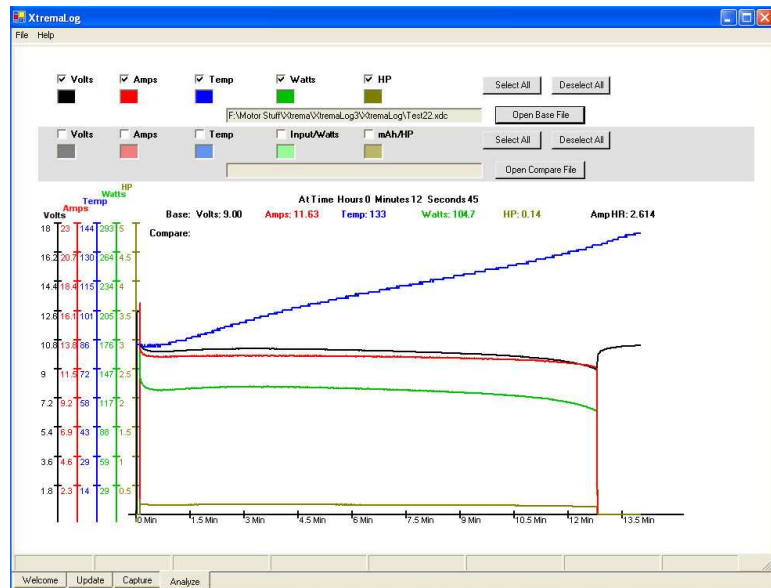


Why does this happen? Because ALL low voltage detect circuits need a tiny bit of energy to do their job! It may not be much, but these circuits will continue to slowly drain your battery even though they have shut down the "main" power load of the battery. It may be months in a cell phone or hours in an RC Speed Controller but it WILL happen if you don't charge or remove the pack. What makes it worse is that most good chargers will **NOT** charge a battery that has gone below the cutoff. So make it a habit to charge up or unplug your pack from all circuits when your device shuts off when it gets down

to the safe cutoff voltage (usually 2.7 to 3V per cell)

2. Lithium batteries live longest with shallow discharges.

This is similar to tip number 1 above but goes more further in terms of being conservative. In RC application we want long run times and often run down the batteries to cutoff. This works reasonably well but it does take its toll on the number of cycles you will get from your batteries had you not discharged them so low. It is better to have timed battery runs and count on shutting down your rc aircraft or land



vehicles power plant before you get to the end of the charge. In the same way it is better to charge your cell phone or laptop every day even if you only had a few hours of use. Unlike Nickle batteries the shallower you run them the better off you are. Therefore you have to unlearn what you learned about Nickle Batteries.

Think of it this way. Say you somehow know that your lithium battery was going to last you exactly 250 full cycles. Each cycle means a full discharge from fully charged to the low cutoff point. If you discharge them to the 50% charge point, it takes two 50% discharges to equal a 100% cycle. Therefore you get twice as many uses of your pack by discharging only half way. Also the closer you get to the cutoff point other bad things begin to happen so you may get even more uses than the simple example above.

The only place and time you would ever want to fully discharge a lithium battery down to cutoff is occasionally in a laptop application. Say once a month or so. Why? Well because a laptop has a self calibrating digital battery meter. A digital “fuel gauge” if you will. Over time this meter needs to know the actual run time of your battery while running the laptop in order to give you an accurate battery gauge.

So if your laptops battery gauge seems to be showing a percentage of battery life that doesn't quite seem right, then allow your laptop to run down the battery to “shut off” once or twice so that it can calculate a better gauge display for your battery. Try to be nearby when the laptop shuts off so you can recharge it immediately. Remember that tiny monitoring circuit will still be zapping away a little bit of energy so you don't want to forget and get back to it a month later only to find a ruined pack.

3. The biggest enemy of your lithium batteries is HEAT!

It doesn't matter if the batteries are running or not, heat alone will diminish the capacity (run time) of your batteries in a slow but permanent fashion. Temperatures above a mere 40°C (104°F) will cause a noticeable deterioration after only a year.

Therefore it is best if you store your batteries in a refrigerator or even a household freezer double wrapped in an air tight plastic bag (to prevent condensation while warming up) when not in use for long periods. Note that you never want to actually freeze the lithium in the battery. This occurs at -40°C (-40°F), way below the capabilities of a household freezer. Now, that said, these batteries don't run very efficiently if operated when cold, so you do need to heat them up to room temperature before you use them to get the full power and run time out of the cells.



In an RC vehicle or aircraft or any time you run batteries hard in a custom installation, you want to make sure there is plenty of air circulation around your batteries. In poor setups the inner cells of a multi-cell pack will run hotter than the outside ones and deteriorate faster eventually leading to out of balance capacities. This will turn into balance problems that never seem to go away. Generally a good multi-cell lithium pack should hold its balance surprisingly well. If it doesn't, it may have already experienced harm or be defective from the factory.

If your laptop has a tendency to run hot and you typically run it off the wall AC, then you may want to remove the battery pack while you use it plugged in. This constant heat can keep your battery over 40°C (104°F) and shorten your battery life. If your laptop stays cool to the touch, then there is little need to remove the pack during prolonged desk use since the charger will stop as soon as the battery is fully charged. However be warned that if you are working on a document in a public place or anywhere that

you, or someone, can trip over the cord to your laptop causing it to become unplugged, you will lose all your work without the protection of the battery.

4. The next biggest enemy of your lithium batteries is how you store them.

We mentioned above that the best way to store them was in a cool place. However if you store them fully charged the rate of deterioration is faster than if stored at 40% charge. That means either discharging or charging up to 3.7V to 3.8 volts for normal Lithium Polymer batteries. Generally it is a little better if your battery can be set to **charge up** to the storage voltage rather than you simply **waste** a half a cycle running it down. Remember every cycle counts against your allotment.



5. The last big enemy to lithium batteries is time!

No matter how you baby your batteries, Lithium batteries start to deteriorate from the day they are first manufactured. Even though we expect to get 200 to 500 cycles out of

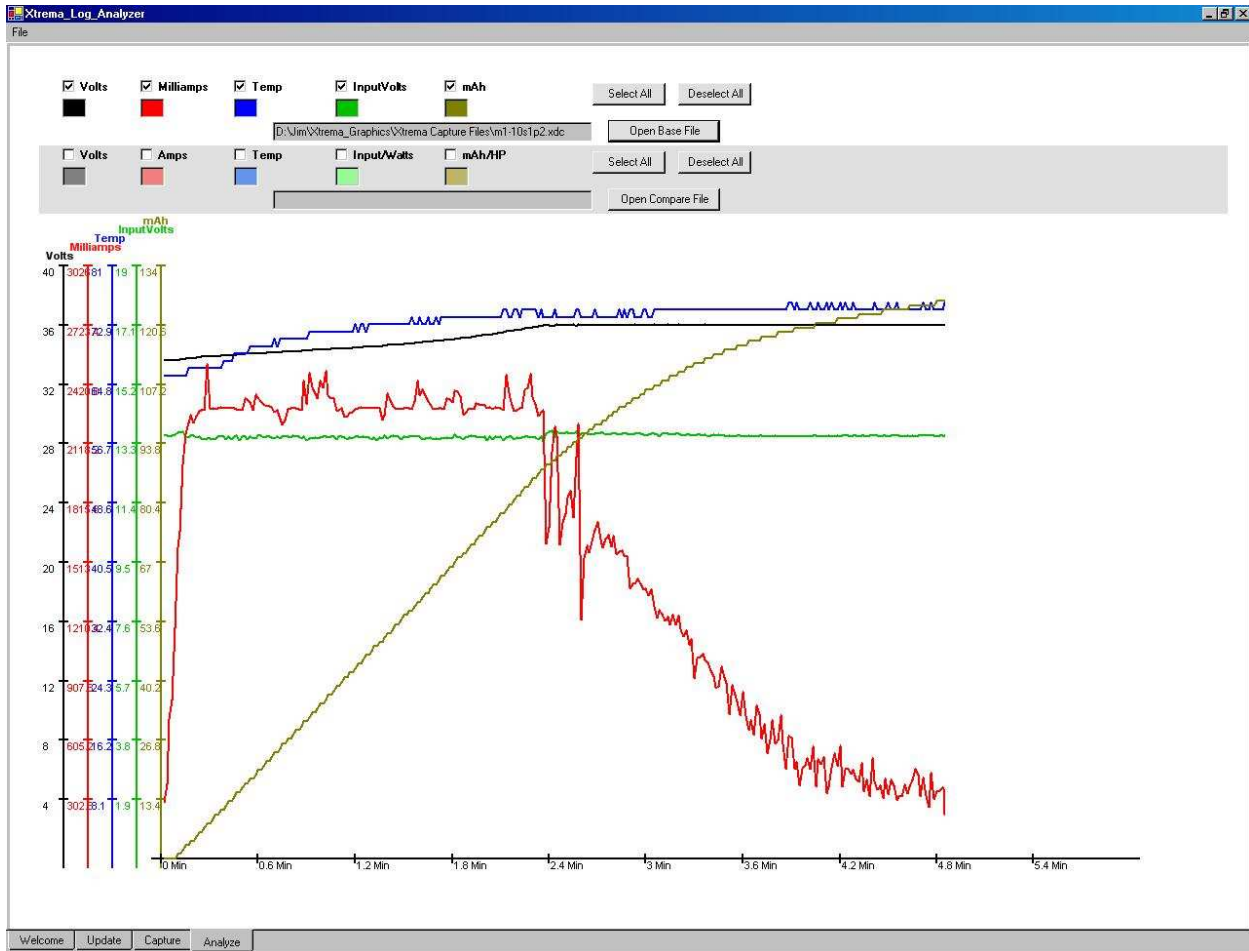


a lithium battery, if we take years to put those cycles on the battery we lose a bunch of them. Yep, we can't get away from this one, however keeping them cool as in tip #3 will slow down the effects of time. The bottom line is that the chemicals used in making lithium cells deteriorate over time. Avoid buying spare lithium batteries for later use. Spares are best if you plan to swap them out frequently. If you do have a spare keep it in the refrigerator until you need it to maximize its service time. Don't buy old unused stock.

The chart below shows how temperature and cell charge affect the batteries capacity over time:

| Temperature | Capacity Loss at 40% charge (recommended storage charge level) | Capacity Loss at 100% charge (typical user charge level) |
|--------------------|--|---|
| 0°C (32°F) | 2% loss after 1 year | 6% loss after 1 year |
| 25°C (77°F) | 4% loss after 1 year | 20% loss after 1 year |
| 40°C (104°F) | 15% loss after 1 year | 35% loss after 1 year |
| 60°C (140°F) | 25% loss after 1 year | 40% loss after 3 months |

6. Keep the charge rate LOW! If you are charging your batteries on a charger that allows you to vary the charge rate, keep the rate low. Preferably at or below 1C for maximum life. (1C means you set the charge current to be the same as the battery capacity. Ex: If your battery capacity is 500 mah then a 1C charge rate is 500 Milliamps. Many manufacturers are claiming you can charge at 2C and 3C rates without harm. While this may be true, studies have shown that you will get many more cycles



7. The lower the discharge rate the longer they last. Say your pack is rated to be able to discharge continuously at 30C. That means max discharge is 30 times its capacity. So if you had a 1 Amp hour battery you should be able to discharge it at 30 amps without hurting it. Well if you discharge it at 20C it will last much longer (more cycles). And if you discharge at 10 C it will last even longer and so on. So from a practical viewpoint when you are buying lithium batteries for high powered applications you are better off getting the highest C rating you can even if it exceeds your power requirement.



8. Make sure the max charge voltage is less than 4.2 Volts per cell?

Not only is 4.2 volts the maximum safe voltage to charge individual lithium cells but studies have shown that those that get away with charging cells up to 4.35 volts, to get extra capacity (run time) from their batteries, severely compromise the cycle life. Yes it is possible to get 1250 mah out of a 1000 mah battery. However the number of life cycles drops to about 1/3 as many cycles when charging to 4.35 volts rather than 4.2 volts. (you don't get something for nothing) Our experience has shown that you can actually extend the cycle life a little more by charging to 4.15 or 4.1 volts per cell while compromising with a lower capacity (run time)



9. Re-purpose your lithium batteries when they age to extend their life.

As lithium batteries age you will see a gradual degradation in their capacity. They typically don't just stop working one day but instead they simply will not hold up as long as they did when they were young. The cause of this degradation is an increase in the cells internal resistance. What this means is that as you try to draw high power out of the battery the output voltage will sag and the safety cutoff in your device will shut down early having been fooled by the lower voltage. This effect, caused by a high internal resistance, is more pronounced in high current applications like laptops, RC power systems and cordless tools. This resistance problem is much less noticeable in low power devices like cell phones, mp3 players, clocks etc. So when your high powered batteries begin to lose their capacity with age, re-purpose them as maybe a portable pack to power radios, gps, mp3's and other low power devices. A 3 cell pack makes an excellent 12 volt source for many devices even though the nominal voltage is only 11.1V. You will be surprised how well the packs will hold their voltage when you are not forcing them to work so hard.



Summary:

The worst thing you can do to the long term life of lithium batteries, for example, is leaving a fully charged spare cell phone battery stored in a hot car. Your RC batteries stored fully charged in a hot garage in the summer. Or a hot running laptop that has a fully charged battery that is often used plugged in like a desktop. Be conservative in min and max charge voltage, min charge current, and max discharge currents for the longest life. Of course if you race RC cars you will want to break all of these rules above because your only goal is to win the race! Long life is not a concern. :)

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