# A123/LiFe Monitoring

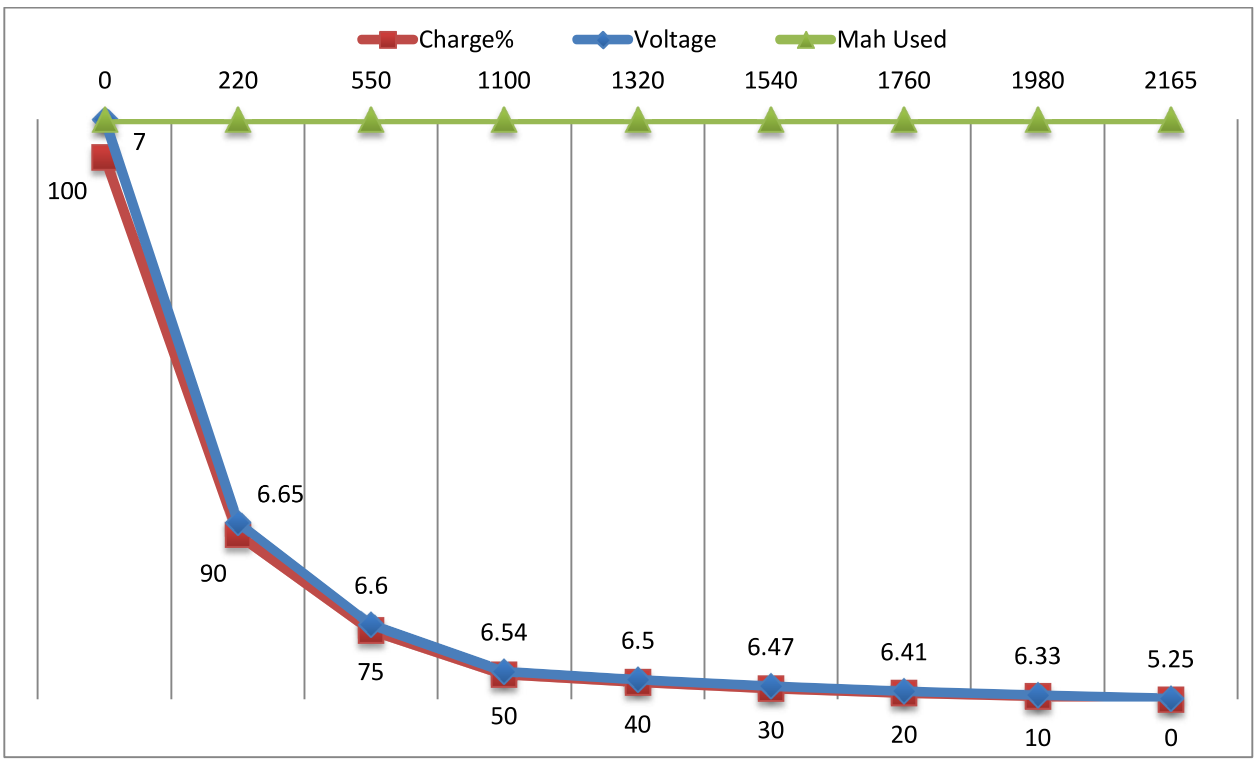
Written 11/25/2012 by Jack Sallade (Web Site: www.flyrc.info Email: jack@flyrc.info)

I have been using A123 battery packs to run my onboard electronics in my fuel powered RC aircraft for a couple years now. A123 Systems makes, in my opinion, the best LiFe chemistry batteries on the market and LiFes in general are almost ideal for use in our larger fuel power aircraft. As a result I have gotten somewhat complacent when it comes to on board batteries as they have proven to be extremely reliable. My two largest planes (both 50cc class… a Mustang and a Slick 540) each carry 2 2300mah 2 cell packs that power everything on board from receiver to servos and ignition. I typically charge them after each flying session but rarely even check them when I get to the field if I've charged since the last trip. I can do this because LiFes have the characteristic of very low drain whilst being stored… on the order of 2-3% a month! That means after a year on the shelf at room temperatures, 2/3rds of the capacity is still available!!! One of the great things about LiFe batteries is that they have a very flat discharge curve. That means that through a vast majority of the time they are in use from just a few minutes after they are taken off charge until they are very nearly drained, they put out the same voltage. That range is between 6.5 and 6 volts over about 90% of their available capacity. That means our on board electronics see a very constant voltage during every flight. LiFes also are capable of massive current delivery… on the order of 15C (15 times the 1 hour discharge rate of the pack) with little sag in voltage so short bouts of high load maneuvering doesn't cause an issue either. Even then, voltage seems to stay above 5 Volts so all onboard systems continue to run flawlessly.

A few other folks have adopted LiFe use in their airplanes and one of them approached me with a question that started me to doing some thinking. It went something like this. "My battery is showing 6.42 volts. I should be OK for another flight, right?" It would soon be dark and even a quick charge would have likely ruled out another flight. I so rarely check my battery voltage these days that I was not immediately sure how to respond. Of course it would be easy to say to play it safe and charge but was it really necessary?

In the past, most users of LiFe batteries didn't look at voltage output of an LiFe pack as the measure of whether to fly. Aficionados of the LiFE batteries have all been taught to charge and fly a couple flights and then calculate our usage per flight. Repeat this a few times and then get an average mah used per flight and divide into the pack capacity and you have an idea how many times you can fly without running low on battery power. It's sort of like running your car without a working gas gauge. You know you can go 200 miles on half a tank so you make sure to fill up every 300 at least… 200 if you're the cautious type. We adopted this method with LiFe batteries because of the aforementioned characteristics of these batteries. The range of usable output voltages is very constant and putting a load on the battery… even if it's mostly dead… does not help make the test any more accurate. LiFes simply don't sag any more under load at 90% depleted then they do at 10%!!

Looking for answers, I started researching on the web as well as running some test on my own and here is what I discovered. Firstly, a loaded volt meter (the very thing we need for NiCad and NiMH cells) is the <u>wrong</u> tool in this case. The load applied by the meter is too small to be useful in the LiFe world… putting virtually no strain on the battery… but could cause an issue because every connection in the system can show a small voltage drop when enough current is pulled through it (extension leads, switches, etc…) which may throw off the accuracy of the reading. This might also result in different readings depending on where in the system the measurement was taken… at the charge jack, balance lead, etc… Add to this that there is no standard for exactly how much load such a meter places. I've seen 250ma, 500ma, 1A, and even 5A loads placed by these devices and the resulting readings would be all over the board. The only consistent reading seems to be an "at rest" or "no load" reading that imposes little or no draw on the batteries. This reading will not vary significantly no matter where the measurement is taken, within reason. With that in mind I have found references to and then did my own tests of no load voltage readings of a LiFe 2 cell pack. Here is what I found:




First I drained my pack to 2.5V per cell… a conservative low voltage cutoff for LiFes which will not harm them in any way. Some chargers use 2.0Volts. (I used a different charger to run this whole procedure with the cutoff set to 2 Volts and the results are almost identical… the last .5V drop happens very quickly and is well outside any usable charge level of the pack) I then fully charged and noted the capacity. My 2300 pack showed a capacity of just over 2200mah. I then set my charger to discharge the pack at a rate of 2.3A. This is a 1C rate and is near what I believe my 30% Slick draws, on average, during flight. This is based on some past observations. (On a repeat test using a similar pack I used 1A and found similar results so I don't believe the rate of discharge is particularly relevant to the at rest voltage measurements.) I then went through a procedure of discharging the pack, pausing at various times and measuring the packs at rest voltage with a standard Digital Multi-Meter. DMMs are designed to place very little load on the circuit under test and therefore do not affect the readings significantly. They are also very inexpensive. I also did these measurements with varying times at rest before making the measurement and found that the battery will recover very slightly over time giving a slightly higher reading. This change is very small and likely not a concern so 1 minute or 10 minutes after the flight appears to be largely irrelevant.

As can be observed, the pack dropped markedly in the first 220ma/10% (90% capacity remaining)... from 7 to 6.65V but then levels off quickly and is only down to 6.33V at 10% remaining. I.E. Approximately the same voltage drop from 90-10% of capacity as we got in the first 10%! So, if I were to draw a green/yellow/red scale as many of the old loaded/expanded scale meters did… it would probably look something like this:

**<u>Jack's Expanded Scale Volt meter for LiFe batteries</u>**

**7-------------------------6.5-----6.4-----------------------------5**

**SAFE CAUTION NO-FLY!**

Based on past recharge experience in the plane I know that the receiver and servos draws 100-250ma per 10 minute flight and the ignition may draw another 80ma. Let's round up to a worst case scenario of 350ma per flight. That means at the 40% remaining line (1320 mah used) I have 2-3 flights left over on a single 2300mah pack and have already flown almost 4 full flights. Now consider that I have 2 packs on board and I actually have 8 flights accomplished and perhaps 5 in reserve. So my green – safe to fly – zone would be from 7V to 6.5V. To be safe I would say my yellow line starts at 6.5V with a good reserve and extends down to 6.4V. My red line would be at the 6.4V level with just under 20% remaining. I would not fly this aircraft below that level. This allows for 10 full flights and a reserve of 2 with a small buffer.

I will test this with some real flying in the spring but expect that this whole calculation will turn out to be overly conservative, and wouldn't be surprised to get 10-12 full flights without dipping down past the 6.5V level. I rarely actually fly 10 minutes and my maneuvers do not include a lot of demanding 3D maneuvers. I will attempt to report back with more real world measurement at that time.

So what would my answer have been to my friend? Considering he is flying a much smaller plane that likely draws far less power per flight and being a glow aircraft there is no ignition to account for… I would have told him to fly with confidence and simply monitor his batter after every flight since he was already below 6.5V and has a single LiFe pack.

So in conclusion I believe that a voltage measurement, if done correctly and backed up by experience with the aircraft in question, can be a useful tool for monitoring your LiFe battery packs. All it takes is a bit of know-how and practical experience to stay safe using this new battery technology.

It should be noted that this test was using true A123 brand batteries and has not yet been verified using other brands of LiFes. I do not expect significant differences would occur. A123s are just more capable of high rate charging and discharging than other brands but that is largely irrelevant to the data presented here. Voltage levels are constant across brands in my experience so the above presented measurements and calculations are still valid with other manufacturers.

One last note: In order to keep LiFes in good working order you want to use an appropriate charger with balancing capabilities. Keeping your batteries in good condition and having access to the proper connections can be a challenge, but is doable with the right equipment and no-how. I will attempt to address this and other "care and feeding" issues regarding LiFes in a future article.