Lithium Ion Technology in the Radio Control Application.

See the Lithium-polymer safety comments at the end of this document.

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April 2002

As opposed to crying wolf here, lets take a look at what the Li-Ion technology really is. I spoke at length recently on this list regarding 7.2V LG Chem 18650 Li-Ion 7.2V packs looking for interest from you the (narrow or specialty-market) consumer. I have in hand ~100 of the LG Chem cells, through industrial testing on a contract I managed. Recently a company has introduced Li-Ion to the modeling public offering various tapped voltages. I suspect that others will make their presence known shortly most likely using the manufacturers I have mentioned here and previously.

All pack builders who legitimately acquire Li-Ion or Li-polymer cells are obliged to install protection circuitry that matches the cells characteristics. Depending on the pack builder and their reputation, this may be required in writing! The two main reasons for this are cell integrity, and safety. One could argue which is more important, but it is really academic.

Given the nature of our application, and the inevitable risks associated with supplying Li-Ion packs with or without protection circuitry, is a double-edged sword. For me to supply packs to you without protection circuitry, means I would make each and every one of my customers legally sign off to hold me harmless. I personally would have it no other way. In the world of legalities though, this STILL may not save my butt if something untoward were to occur. I think my reasoning will become evident as I continue. To supply packs WITH onboard protection circuitry, requires you the consumer to understand that it is not such a bad deal. For starters, all issues regarding overcharge, switches left on, and over-current that would cause problems anyways, are no longer an issue. The over-current thing will be discussed further down (phew...sooo much writing ahead).

There are lots of quality battery pack builders across the continent. However there are very few who are willing (and competent enough) to supply current technologies with higher than average current delivery abilities. One has to keep in mind the intended market (which is HUGE) for these relatively new technologies; cellphone/pagers, laptops, PDA's, PCS's, and a host of other new enduser technology. These systems, although relatively power hungry, do not have current demands on the order of what WE are making them do! One look at the nominal specs will confirm this. Anyways, I was lucky enough in my investigations to find such a company, and I think you will find the following information I absorbed interesting:

Lets talk about Li-Ion cells, specifically the 18650 series that I proposed a while back for our use. These are cylindrical, and weigh ~43g each. There would be 2 parallel packs, wired in series to create 7.2V nominal. For the record, I would not have suggested these cells if I did not believe they would work in even our most demanding scenario to date. For starters, every 18650 regardless of manufacturer has a PTC (Positive Temperature Coefficient) installed under the + button during cell manufacture. This is not removable without destroying the cell. A PTC reacts to temperature elevation by reducing current flow and can be chemically altered (during manufacture of the component itself) to trigger at different temperatures. However, this is not an exact science, and as a result there is a relatively wide window as far as tolerance goes on these devices (I have used these in circuits and can attest to this I assure you).

In essence, a PTC can reach a specified undesirable temperature and begin to reduce or stop current flow in an attempt to reduce temperature. Known as polyfuses (remember the last time I mentioned these??), these devices will literally stop current flow (to uA anyways), and require removal of the load and must allowed to cool down in order for them to properly reset, to again allow initial specified current flow. Kinda like a self-resetting fuse if you will. This is is an undesirable characteristic when it comes to batteries in general, and specifically our situation.

To get around this, the battery manufacturers install PTC's so that they are compressed or "squished", altering their chemistry and therefore their function. What this does is limit the current flow, but does not stop current flow. The degree to which they are compressed will have a great bearing on HOW much (maximum) current will flow at a given temperature. Now, given that there will always be minor inconsistencies from cell to cell as they come off the assembly line, requires a warm body to test samples out of each batch to determine that indeed the PTC, amongst other things, will operate between a set range of values. In other words, one cells maximum current delivery will be slightly different then another! No biggie, but chew on it for a moment.

Then there is the fact that cells are paralleled, then these 2 are connected in series with another 2, to come up with a nominal 7.4V. No matter HOW precise cells are manufactured, and no matter HOW linear one cell is to its brother, there ARE inconsistencies! What this equates to is as the pack ages, individual cell performance will not be linear compared to it's counterparts within the pack. We have already seen how this can adversly effect pack performance if some sort of measures are not taken to monitor/tune up each and every individual cell periodically. Sounds bad...doesn't it? There is no cell-mathcing going on that I am aware of that would minimize this. Then again, cell matching might not initially show actual cell performance to the degree that enhances consistency! Welll, maybe by the time this type of inconsistency rears it's ugly head, the pack will be near or at EOL (end of life). Something else to chew on. Li-Ion is dangerous as someone else has pointed out. The risk of fire or explosion is real (remember what I said about getting you the consumer to sign off for me?). If for some reason a cell reaches ~130C, it tends to go into thermal runaway. That is, it no longer requires current flow to prevent the internals from turning cherry-red and either catching fire or exploding. The last defense to prevent this is what are called shut-down separators that are strategically placed between the anode and cathode (reactive materials - one in this case Lithium). The shut-down
separators are made of a plastic-like material which is normally porous, allowing ionic flow (ion flow is the process by which the battery allows us to charge and discharge - supplying us with the energy to fly our aerobats). This material literally melts, sealing off it's porous structure, hopefully preventing ionic flow and stopping catastrophic failure. No ionic flow inside the battery, no electron flow outside the battery. Don't chew on this one too hard, your might burn your mouth.

As a side note, prizmatic (rectangular form-factor) cells do not have the PTC internally installed, but are still required to be welded externally during the pack building process. The prizmatics can NOT supply the same power as the 18650's.

Incidentally, I was talking to our supplier and asked if indeed the LG was the best out there. One of their engineers really enjoys his job, and as a result is infinitely more knowledgeable than I will ever be. As opposed to adhering to the cell manufacturer's recommendations religiously, he has (with their blessings) moved into no-man's land and really "exercised" these technologies. Things like controlled shorting to see what current IS available with and without the PTC in place. A
couple of cells stood out over even the LG Chem. The Samsung and Moli's demonstrated excellent comparative internal resistance against the LG cells. In the real world though, the cells we will get will

have the PTC. These two marques also demonstrated better performance WITH the PTC. Then again, if during production the PTC had been squished too tight, this could account for the extra current handling abilities. Needless to say, the target is always moving as cell manufacturers are coming up with better ways to lower internal resistance, which in turn will allow greater current flow, which will in turn minimize the amount of protection circuitry required in the first place! Which brings up the next topic.

The statement I have heard (even from the "experts") most often is "I would much rather have the pack kill itself and allow me to land my aircraft, than have it shut off on it's own accord". I propose with properly designed onboard pack protection circuitry, the point at which the pack would die is slightly below the point at which the circuitry would shut down. However, given some variables, we can only get part way there (I would be writing till the cows came home if I go down this path). Then again, one needs to look at just what would be gained by having a pack kill itself in order to "save" an aircraft. That in itself is a topic worthy of REAL discussion! The concept of a pack sacrificing itself to allow a successful landing, would be speculative at best. However a nice conversation exploring onboard circuitry I suspect would result in a thought change that would make it a viable and acceptable component to compliment exotic(?) battery technologies. The empathy bridge has already been crossed on a number of other fronts, most recently NiMH cells, matchboxes, onboard power distribution busses, regulators, electronic RX switches, microprocessor-driven TX's, servos, and ignition systems, autopilots...the list goes on.

The onboard circuitry their engineer and I are working with (their in-house offerings) will allow the following (using LG Chem 18650's):

-4Ah, 7.4V nominal, 8.4V max, 5.6V min. -6A continuous, 12A peak with an RC constant that can be extended depending on application. -~200g (7oz) total weight

The above scenario uses 2 protection circuits per pack to get the minimum current demand I proposed. Onboard smarts does more than just limit max current (I). The canned circuitry also monitors charge V, low V cutoff, continuous I, instantaneous short protection, and max current that has an adjustable time constant to allow I peaks of selectable duration to address unique load needs. He has worked with another manufacturer's onboard circuitry that will allow even larger constant/peak current demands, but would cost more. All the circuits are "very" reliable, consisting of controlling 2 or more high-current FETS (Field Effect Transistors). The reliability is as much a non-issue as it is with our TX, RX's, servos, etc.

At this point, for me, what makes the system (sorta) viable on large aircraft is the idea of 2 of the above mentioned packs, with protection circuitry, operating in parallel, feeding 4 pigtails from 2 packs into 2 Rx's. That equates to 8Ahrs, 20A+ on demand, with single drop-out redundancy to 12A, which you would probably notice during flight, for total mass of around 400g (14oz).

Now for the fun stuff. Due to the relatively high internal resistance associated with Li-Ion, under load the voltage O/P drops significantly. This is sorta OK, as it occurs with all other cell technologies we are using (NiCD offering the lowest internal resistance therefore lowest V-drop - which is better for our needs as current demands change drastically). It is possible to have the onboard circuitry get messed up though. A pack that is reaching EOL, if asked to deliver a large amount of current, may exhibit V-drop to the degree that the onboard circuitry (OBC from now on!) will think the pack has reached it's discharged state and temporarily turn off, or stay off. Thing is, if you are running that close to the bottom on that aged a pack, maybe you deserve what you get! How do you decipher adequately EOL to avoid this. No one has done testing to the degree that will make Joe modeler comfortable I believe. But these are just the types of things that someone as a retailer/supplier has no

control over. Using these types of technology can be equated to giving your dad (who has driven an Olds all his life)
an F-1 car as a daily driver. It ain't goin' to last long.

Which brings up my next point. Although I relish new technology, it has to serve a viable purpose by demonstrating that it is indeed a better mousetrap than the one I am using now. Frankly, from a CPV (computer's point of view - I use this term often to demonstrate the idea of a non-emotional, purely logical decision-making process) no new battery technology has demonstrated enough of a change over what we are using right now (which in itself continues to demonstrate performance gains on par OR BETTER than all other battery technologies) to warrant switching. The only area where current technologies has an advantage in our arena is mass. Which brings up my next point.

Although I find the issue of mass to be inconsequential on large aerobats, there is some weird marketing thing that makes it the selling point, and quite possibly lucrative. Lets face facts, a blind test to determine if an "expert" pilot could determine even 6 times out of ten that aircraft "A" or "B" had 1.0Lb difference due to battery mass is beyond reason. Anyways, it's beyond me.

Finally, I think Li-Ion would market well on the "regular" model aircraft front, the major obstacle being "if it ain't broke, why fix it mindset" as it relates to Nickel Cadmium technology. I mean really, current technologies still have a long way to go to beat the all-round performance of today's NiCD offerings. In my electrics, modern NiCD's are supplying in excess of 100 amps and can climb vertically out of site in a few seconds. NiMH as a changing technology is coming close, but it's internal resistance is going to keep it in second place until it matches NiCD. At that point, NiCD's will probably become obsolete.

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4/17/02
p.s. I have posted this site before, but it seems appropriate to point
people to it again: http://battery.rnd.lgchem.co.kr/english/doc/main.asp

Lithium Safety – by Fred Marks (as posted on RCU - Battery Charger forum).

In order to present as clear a picture as possible and to guide in the safe use of Li pos, no matter the manufacturer, you will find at www.fmadirect.com under the Support section the Kokam Battery Systems Ap Note, Ap Note # 2 in pdf to download.

The following is a brief supplement to the Charging and safety sections of the Ap Note. The principal things to remember: Li Ion and Li Poly cells have Lithium in them and that is why they have five times the energy density of other chemistries. Powdered Lithium, if heated sufficiently, can ignite and burn. Understand: we can test, report, educate, add in any kind of safety device but, as long as Li is present there may be some way that it might be ignited. In the ultimate, suppose a lightning strike hits your model! The only thing to do in all this is to charge the packs in such a way that, if they do ignite, no harm is done.

Please do take time to read the following and download the information in the Ap Note.

All high energy density batteries including Ni Cd, Ni MH, Li Po, and LI Ions and the chargers used require common sense and caution. If any are overcharged or shorted, great heat and pressure result. Ni Cd and Ni Mh cells have a mechanism to vent excess gas pressure, as do Li Ion cells. These cells all have in common, a thin metal can enclosure. I have experienced explosion of Ni Cd cells when the vent did not function properly. One such occurred at 1 AM in a deathly quiet shop as I worked on an Army radio system in 1984. That was behind me and about 15 ft away. You probably never saw a 55-year-old, 225 lb guy clear a 4 ft workbench flatfooted! I didn't even bother sending the 4AH cells back to Sanyo since it was a charger malfunction that caused the event.

Li Ion cells truly can explode as they are sealed in a metal can. They too have vents. However, Lithium is a metal that, as a powered material can burn if ignited. This is true of several metals, not just Li. Magnesium burns readily even in solid form. Thermite is powdered iron that, when ignited, has been used to weld steel. Finely powered aluminum is the "fuel" for almost all solid rocket motors. Some solid rocket motors are made of extruded nitrocellulose, an organic material. Organic materials burn when ignited, just like paper. Powdered, sintered nickel takes a very high temperature to ignite.

Li Po cells also can vent if charged at too high a voltage. There is a narrow range of choice of the electrolyte for use in Lithium Ion cells. Remember that Li Po cells are a form of Li Ion; they derive their name from the fact that Li Po cells are housed in a plastic (polymer) envelope. If the envelope has a small Vee cut in the join line, that serves as a vent. The major difference with Li Po is that the envelope can swell when pressure builds to form the infamous "silver sausage".
Any cell is ruined when pressure that causes venting is experienced.

If a Li Ion cell suffers ignition, the vent cannot act quickly enough to prevent rapid pressure build up. When this happens, the can fails instantly and catastrophically just as it can in a Ni Cd/Ni MH if the vent does not function properly. The pressure release is, therefore, explosive just like popping a balloon only with massively more force. This is why all Li Ion cells used in OEM applications such as cell phones have a protective circuit on them.

The failure mode that leads to explosion in a Li Ion leads to an event called "venting with flames" in a Li Po cell. The basic phenomenon is called thermal runaway. If, say, a Li Po cell is charged at six to seven volts, well above the nominal 4.2 V limit, the electrolyte can begin to "boil" and develop voids as temperature rises above about 180 degrees F. If this abuse continues for, say, ½ hour, the electrolyte, being organic, can eventually ignite. As we said earlier, it takes a lot of heat to igniter Lithium. In a solid rocket motor, ignition is initiated essentially by a high explosive blasting against the propellant.

If the thermal energy release of the electrolyte used is high enough, the Lithium can be ignited. In tests I have conducted, the electrolyte burns at about the intensity of burning paper when it has a heat gun blasting it. When I light the fireplace I winter, I wad up newspaper in softball size wads and put in a layer before I put wood on the grate. If I have light, dry kindling, just igniting the paper with a lighter lights the fire. Last winter was so nasty that we ran out of kindling. I found that the thermal output of the wadded paper could be increased sufficiently to ignite reasonably dry maple logs by blasting the paper with my Monokote iron. The point: Subtle but significant changes can affect ignition. Not every overcharge event causes ignition.

If the lithium ignites, it burns with an intensity and gas generation that can cause "venting with flames" that is the gasses exit the envelope with a swoosh, not a blast. If you have the pack in your airplane when this happens, your airplane is going to be damaged. If you have the pack on a highly flammable car seat, the seat is likely to catch fire.

Does this happen often? Not really; we have about a dozen such events reported in the past 18 months out of perhaps 100K cells in the field and, probably, a million or more charges. In all instances, analysis of the event has shown that the cell/pack was charged at too high a voltage and/or there was a fault in pack assembly.

Methods that are as stress-free as possible that permit one to use Li P cells in a completely safe way are outlined in Ap Note 2 located at www.fmadirect.com. Open the home page, click on Support then scroll to Ap Notes to open or download the pdf file for Kokam Li Po battery Systems.

It is a simple matter to operate safely. Just as you are asked to avoid smoking while handling an open can of glow fuel, keep your hand out of the prop, don’t whittle toward yourself, and don’t fly while drinking, it is suggested that the simple warnings posted at our web site be followed. Remember, safety is a matter of discipline. Remember also, that we take care to educate the user about these things.

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11/30/03