

Batteries and Charging

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THERE are a number of types of batteries in use for flying models, and there are a lot of buzzwords, numbers and distorted facts around. This article will try to demystify battery technology and especially discuss how to charge your batteries to give them the best chance of a long and healthy life.

Battery Types

The first common rechargeable batteries were Lead-Acid (referred to as Pb) types and car batteries still are today. These are really heavy and contain liquid acid, so could not be flown in models. Sealed and Gel based lead acid batteries can now be found which don't have to be kept dead level, but are rarely used in model flying except maybe as the storage in a flying site power pack.



12V sealed lead acid battery often used in flight boxes

The next generation was NiCad (Nickel Cadmium). These are lighter than Lead Acid batteries and have a higher power density (i.e. stored energy per unit weight). Although they were the main type of small rechargeable battery for quite a few years, there are a few major problems with them - mainly that they don't hold a charge for very long (losing about 2% per day even when not in use) and if you don't fully discharge them before charging them up again then they can suffer from a 'memory effect' which means they will only discharge to that half-charged point in future. NiCad batteries come in the same sizes as conventional non-rechargeable batteries - AAA, AA, C etc. as well as some specialist sizes such as sub-C and 1/3 AA which are often used to fit into the unusually sized spaces available in models. Note that 'NiCad' is actually a trademark that gets used generically (like Hoover), so sometimes the actual chemical symbols 'Ni'(Nickel) and 'Cd'(Cadmium) are used instead to make 'NiCd'.

The most common type of rechargeable battery now is the NiMH (Nickel Metal Hydride) which is available in the same sizes (with generally larger capacities) as NiCd batteries. They don't have a significant memory effect, but they do lose their charge quicker than NiCds do - the worst lose up to 10% a day. There are new types of NiMH batteries now coming on to the market which are claimed to retain 70% of their charge after a whole year, which will be much better for those of us who like to always have a model and radio 'ready to fly' at a moment's notice.



Latest generation 4-cell NiMH battery pack



A 3-cell lithium polymer battery pack with balancing connector

The latest and greatest battery technology, and one which has revolutionised electric flight, is the LiPo (Lithium Polymer). These come as flat plastic-wrapped cells, usually with wires to a power connector and a set of smaller wires to a 'balancing connector' which is used during charging. Variants of LiPo such as Lithium-Ion and LiFePo are used in other applications such as electric bicycles or mobile phones, but LiPo is the only one commonly used in modelling.

For all these types of battery, a single cell only gives a set voltage out - for example NiCd gives 1.25V (Volts), NiMH 1.2V and LiPo 3.7V per cell. Although the voltage stays the same, the capacity tends to vary with physical size - for example an AA size NiMH will typically have over twice the energy capacity of a smaller AAA size battery.

By the way, when I say 'a set voltage', I'm lying to you. Most of the numbers in the world of batteries are 'nominal' - they are about right, but will vary somewhat depending on the state of charge of the battery, how quickly you are draining current from it, or even the temperature. The figures I've given above are the usual nominal values for each type. Battery capacities are also only nominal - they vary with the age of the cell, how it has been treated in the past, and especially with how quickly you are taking power from it. If you drain it quickly you may get as little as half the total energy from it that you would have got if you drained it slowly.

To get the voltages or capacities required for models, cells are combined into packs with a number of cells electrically connected in series (end to end) which increases the voltage, or in parallel (side by side) which increases the capacity. This is why battery packs come in odd steps like 4.8V, 6V, 7.2V - these are 4, 5 or 6 cell (in series) packs. Packs are often described as '3S' (three cells in series), '2P' (two cells in parallel) or even '3S2P' (three cells in series, in parallel with another three in series). A 3S2P pack, for instance, has three times the voltage and twice the capacity of a single cell, and contains 6 actual physical cells, usually spot welded together.

Amps and Volts

When talking about electricity, current is measured in Amps, voltage is measured in Volts. An amp is quite a large unit when you're talking about the amount used by models, so units of milliamps (thousandths of an Amp) are often used instead.

If you think of electricity like water in a pipe, voltage is the pressure and current is the flow. You can have a small pipe with lots of pressure, a big pipe with low pressure and anywhere in between. Model electronics tend to be at the low pressure, high flow end - typically 5-20 volts and from 100mA up to 50 Amps or more.

C

'C' is the symbol used to talk about the capacity of a battery pack - e.g. for a 2200mAh battery C is 2200. C is often used when specifying maximum charge and discharge rates. A '10C' discharge for that 2200mAh battery would be a current of 22000 milliamps - or 22 Amps.

mAh

You'll often see 'mAh' used when talking about batteries - this is the abbreviation for 'milliamp-hours'. A 1000mAh battery can give you 1000milliAmps for one hour or 250 mA for four hours. That's the nominal figures anyway - in practice if you drain the battery up to a rate of about 1C (1000mA for this battery) you should get that, but if you drain it much faster than that you will get significantly less. At 10C (a 10A drain) you might only get 600mAh out of it.

Charging

Now we get to the area that causes the most trouble, and that started me writing this article, charging. When you buy many rechargeable items with NiCd or NiMH batteries, even some radio equipment and low end models, a charger is supplied with them. This is usually of the 'wall-wart' type, as the Americans call them - a box that plugs into the wall with a thin cable coming out with a plug on the end.

These chargers are known as 'slow chargers' - they supply a very small charging current and are intended to charge batteries over a period of 10-14 hours. At these very low charge rates (typically 1/10 C or less, so under 100 mA for a 1000 mAh battery pack) batteries are very tolerant of poor charging, such as charging for much too long, or using varying voltages or currents. They do an adequate job but it can be very frustrating waiting overnight to fly your precious model when you find the batteries empty.

Fast chargers are the main topic of this section. You can fast charge all types of batteries, but the limits of how fast you can charge them and the way to tell when they are fully charged vary between the different types, so you need to be careful to set the charger to the correct settings. There are a lot of Fast Chargers on the market, but by necessity they all do basically the same thing, and have the same options. Many chargers can charge a number of types of batteries - most of the chargers on the market now, including the many almost identical chargers coming from the Far East via sites like EBay, can handle at least NiCd, NiMH and LiPo.



Fast charger capable of charging lead-acid, Ni Cd, NiMH and lithium polymer batteries

Incidentally, in some places (such as RC cars) you'll actually see the term 'fast charger' used for a charger which takes 4-6 hours to fully charge a battery pack, and 'quick charger' for 1-2 hour chargers.

Charging NiCad batteries

NiCd and NiMH batteries both require constant-current charging - i.e. the charger needs to control the current it feeds into the battery and it measures the voltage the

cell is currently producing throughout this process. The voltage will rise slowly throughout the charging process, but when the battery becomes fully charged it actually dips slightly. A fast charger will detect this dip (often referred to as '-dV' or 'negative delta V', the mathematical expression for 'the change in voltage') and stop charging. Adding more after this point will just overcharge the battery and will not add any more energy to it. The size of the dip varies slightly with the size of the cell, but for the sort of sizes used for models, a peak voltage sensitivity of 12mV is fine, and will safely detect the fully charged point.

The voltage values you'll see are actually per cell - i.e. for a 4 cell pack the actual sensitivity will be 48mV, but all the chargers I've seen set it as a 'per cell' value and multiply it up by the number of cells the pack has automatically.

NiCd batteries are best charged at a rate of about 1C - e.g. 1.0A for a 1000mAh battery. They will get warm (but not hot) as they approach the fully charged point, which will usually take about 80 minutes at 1C due to inefficiencies in the chemical charging process.

Many chargers will show you the voltage they are reading back from the pack and the amount of charge they have put in so far - usually in mA, a figure which will typically be in the hundreds or thousands as you approach the fully charged state. Fully charged NiCd cells will typically show about 1.45V, which will drop to about 1.3V after a small amount of use and stay around there until shortly before it runs out, when the voltage drops rapidly.

If you charge at low rates, say under 0.5C, then the voltage peak may not happen (it is caused by chemistry changes and at low rates may be much less pronounced). This is true for NiMH cells as well.

Charging NiMH batteries

NiMH batteries are charged in a similar way to NiCd, but the voltage peak when fully charged is much smaller. If you use a NiCd charger it may well miss the dip and overcharge the battery. The sensitivity should be set to 6mV (per cell). NiMH battery packs should also be charged at a rate of 1C for best effect.

Some chargers don't switch off when they reach fully charged but instead go into 'trickle charge' mode where they apply a very low charge current that can be used indefinitely - just enough to cancel out the self-discharge that NiMH and NiCd batteries all suffer from. The required trickle charge rates for NiMH are much lower than for NiCd - another reason not to use a NiCd charger for NiMH batteries.

Fast chargers usually have a 'safety cutoff' which limits time, charge or both. I usually set a 2 hour and 2C cutoff, so that if the delta-V peak is missed the batteries won't be damaged by major overcharging. Note that using '2C' as the cutoff actually means you need to change it for different batteries. Since most of my glider receiver packs are of similar capacity (1600-2100mAh) I just set the capacity limit to 3200mAh and the 2100mAh packs will definitely be safe, while still having enough slack in the system to fully charge them.

Some manufacturers now supply the batteries 'unfinished' from the factory - this means they have mixed the chemicals and filled the battery, but they have never been charged. The first few charges are crucial to the capacity and lifetime of the battery, as the molecular structure of the battery is aligned during them. For best effect, the first few charges should be quite slow, around 1/10 C and hence taking 12 hours or so. Many chargers have a 'charge-discharge' cycle you can select, which automatically charges the battery, waits a while, discharges it, waits etc. You can set the number of cycles and charge/discharge rates to suit, but on several chargers I've used, it isn't obvious how to set the rates - it actually uses the rates set for the charge and discharge modes, so set them up first before starting the cycle.

Charging LiPo batteries

LiPo batteries need to be charged correctly. Overcharging can do more damage to them than it would to NiCd or NiMH - they can even catch fire if badly treated or damaged.

LiPo batteries should be charged at around 0.6C to 1.0C. Charging them too slowly can cause problems with the chemistry - the innards are actually semi-liquid and metal salts can form if they are charged too slowly, which will drastically reduce their lifespan. Charging at greater than 1C can make them heat up and swell - continuing to charge them after they start to swell will cause a very hot chemical fire which will continue to burn, even underwater.

For the same reason, any LiPos which have swollen or been deformed through crash damage or over charging/discharging should not be used again. After a crash which damages the batteries, you should keep the batteries well away from anything else (but still where you can keep an eye on them) for at least an hour - chemical reactions can occur some time after the crash, causing the same nasty fire.

I don't want to give the impression that LiPos are horribly dangerous - when charged correctly and monitored for damage, they are fine - it's just that the potential consequences are quite severe. Some people use 'battery vaults' or 'battery bags' for safety - boxes or bags made of very fireproof material and sealed up so that if the worst does happen the damage should be localised. I just charge mine on the patio a few feet from the house...

Back to charging... one new thing which crops up with LiPos is 'balancing'. Multi-cell packs of LiPos have the usual +/- power wires coming from them, but also a small multi-pin connector, with as many pins as there are cells in the pack, plus one. This connector is used by LiPo chargers to measure the voltage across each individual cell in the pack - and is also used to feed a small extra bit of charge into a single cell, so any that are charging slower than others will be topped up and 'balanced' - i.e. every cell in the pack will be at exactly the same voltage by the end of the charge. Balance charging is quite a bit slower than standard charging, so usually I'd only do it every four or five charges.

Another option you may have is just 'Balance', not 'Balance Charge' - this just discharges individual cells so they all match, rather than topping them up.

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There are a few different types of balancing connector - chargers often come with small converter boards so you can balance packs with various connectors on. Chargers will also have a range of pack sizes (e.g. 1-6 cells) they can accommodate, and a range of balancing connectors to suit, with the appropriate (cells+1) number of pins.

LiPo cells have no memory effect, so can be charged from any point -there is no need to discharge them first. The charger will stop when they are fully charged, and will show the amount of charge it managed to squeeze into them, in milliamps. This lets you know how much your last flight took out of it so you know how much further you can push it next time! There is no 'delta-V' voltage dip with LiPo, so the charger has to monitor the cell voltages - the balance connector is used for this, so many chargers insist that the balance connector is plugged in while charging, even if you aren't explicitly balancing the cells.

LiPo cells give a nominal 3.7V each. They should never be discharged below 3.0V per cell, or (again!) there is a risk of fire. In most cases LiPos are used with Electronic Speed Controllers (ESCs) or Battery Eliminator Circuits (BECs) which have a programmable cut-off level, usually factory set to 3.3V, so that should avoid any problems with undervolting them. When that cut-off voltage is reached, the receiver is still powered but the motor is either cut off or only given access to say 20% power - just enough to get it landed safely.

LiPos are fully charged at 4.2V/cell, and should never be charged above 4.25V/cell or else - guess what? - FIRE! (potentially anyway - certainly swelling and pack damage). That's why you must use a specialist LiPo charger - nothing else will do.

Another figure used with LiPos is the confusing 'C rating' - this tells you the maximum discharge rate a pack can deliver - 20C is common (i.e. 20 Amps for a 1000mAh pack). Some newer packs even have a normal and 'burst' C rating, of say 35C - they can deliver more for a very short time than they can for a long run - these are typically used for things like electric gliders that need to use most of the power in a few short but intense bursts.

Some older and cheaper packs may have C ratings as low as 10C - these are best avoided really, as most well sized power setups for aircraft need more than that.

The final thing to watch out for is storage - the actual capacity of a LiPo cell is very dependent on temperature. If you fully charge the pack when the weather is cold, then leave it in the car on a sunny day, it can actually become overcharged, and you know what that means...

For that reason, it is recommended to store packs at about 60% charge - that will be safe with almost any likely temperature rise, while still being unlikely to self discharge to a dangerous level... LiPos discharge much slower than NiCd or NiMH cells, so stored LiPos only need topping back up to the storage voltage of 3.8-4.0V every six months or so. Many LiPo chargers have a 'Storage' setting which charges or discharges the cells as required to reach the correct storage charge level.

Summary

So, out of all that what do you actually need to know?

Well, you need to use the right type of charger for the type of battery you have - usually this is just better for the battery, but with LiPos especially it can actually be dangerous to use the wrong charger.

Charger settings - usually they will have sensible default settings, but if you have to set them, this is what I recommend:

NiCd:

- charge rate 1C
- discharge to min 1.0V/cell
- set the dV sensitivity to 12mV/cell

NiMH:

- charge rate 1C
- discharge to min 1.0V/cell
- set the dV sensitivity to 6mV/cell

LiPo:

- charge rate 1C
- discharge to min 3.3V/cell
- charge to 4.2V/cell
- DO NOT EXCEED 4.25V/cell

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