Battery Talk for FDLAA builders group.

There are many different options for batteries used for RC flight. These include choices for electric power for motors and/or radio equipment. This talk will give an overview of the various types and their uses.

Radio equipment:

Transmitters, receivers, and servos are involved in all RC planes. Transmitter battery packs can be NiCd, NiMh, LiFe, or Lipo. The limiting factor is usually the physical size of the pack. Generally, you want the largest capacity pack that will fit. Transmitters have been powered by NiCd or NiMh packs for years and they have the advantage of being safe and usually the battery can be charged with a simple wall wart type charger while still in the transmitter.

LiFe packs are also manufactured to fit transmitters. The advantages of LiFe packs is they hold more energy for longer run times and have very low self discharge rates. The disadvantage is they have to be removed from the radio (or at least open the battery hatch) to charge with a balancing charger for LiFe batteries. Life batteries are considered much safer than Lipos but since you have to open the battery compartment anyway to access the balance taps, I always remove the battery to charge it. Always make sure the voltage of the pack matches your radio if you change battery types.

Lipos are sometimes used, especially for FPV flying to power the video receiver and/or headset. The high energy density of Lipos is important in this application. Lipos should never be charged in the radio due to the fire hazard.

Receiver power:

All RC vehicles require power for their receiver and servos. The most important thing to be sure of is that your battery pack can deliver adequate power under maximum load. Servos and electric retracts can place high loads for short periods of time. When 2.4 GHz systems came out, their receivers where much more sensitive to low voltage than analog 72 MHz systems. As a result, many unexplained losses of control where really the result of momentary low voltage causing the rebooting of the receiver (aka brown out.) Even though the pack may seem to have plenty of capacity, the important factor is whether can it maintain adequate voltage under high loads.

NiCd batteries have been used for many years and for good reason. They are robust and can deliver lots of current when called upon. They are relatively heavy for the power they hold.

NiMh batteries are often substituted for NiCds. They hold more power for the same size and weight. However, NiMh may not be a direct replacement of NiCd because they have a much lower peak current rate. This can result in a dangerous voltage sag under high loads.

LiFe prismatic (flat polymer cells like Lipos) and A123 (cylindrical, metal encased batteries used in power tools) batteries are being used more and more for receiver packs. They have better peak current rates and hold more power per weight than NiXX chemistries. They also have much lower self discharge and higher charging rates so you can be ready to fly faster. The disadvantage is that you need to remove the battery, or at least access the balance plug to charge. Life batteries have a very flat discharge curve so measuring the voltage doesn't tell you much about how much capacity you have left.

A two cell LiFe/A123 battery has a nominal voltage of 6.6V and a fully charged voltage of 7.2V. Many never receivers and servos can handle this higher voltage with no modifications. Some older systems can not! Just going from 6V to 7.2V can damage some servos and receivers so check first before going from a 5 cell NiXX to a 2 cell LiFe battery.

All battery types degrade over time. Most importantly, and hardest to detect, is that they start to lose their ability to deliver high current without a dangerous voltage sag. Newer radios are equipped with telemetry that allows you to monitor the receiver's power supply in real time. That is the best solution because you can measure what's happening under actual flight conditions. Alternatively, you can periodically test your packs on the bench by placing them under a known load (like a string of automotive light bulbs for instance) and measuring the voltage drop with a volt meter. This will give an idea of how good the pack is relative to other packs you may have or to how this pack was when it was new. There are some newer battery chargers with what's called "regenerative discharge" that can put significant loads on a battery pack (they essentially run in reverse; taking power out of the flight battery and putting it back into the charger's power source.) These chargers will allow you to set up a program to test your flight packs.

The other alternative to power your receiver and servos is to use a UBEC (universal battery eliminator circuit.) This is an electrical device that steps the voltage down from a battery to the voltage needed for the receiver. This is often used with electric powered aircraft because you have a large, high voltage battery on board anyway to power the motor. This saves the added weight of another battery for the receiver. This can also be used in an IC powered plane with a Lipo or higher voltage NiXX system to provide power at a lower voltage for the receiver. They are sometimes used with a small lipo as part of a back up receiver power system.

Another big advantage is that it provides constant voltage. As long as you don't overload the device and your power source has adequate voltage, the UBEC provides a constant voltage regardless of load. There are two types: Linear and Switched. Linear BECS are basically like a resistor. They step down the voltage by converting the excess to heat. Don't buy one! Switched UBECs don't waste power by turning excess voltage into heat and can handle a much larger voltage step down than a linear UBEC. They are sold by their amperage capacity and the maximum voltage they can handle.

Finally, there are back up or redundant power systems available for receiver power. These systems use two separate power sources for the receiver. They can be two batteries, two UBECs or a combination of the two. They range from simple DIY systems using diodes to isolate the two power sources to commercial systems that will log power usage as well. It's a good safety precaution for any plane that can carry the extra weight of the second power source.

Lipos for electric motor power

Lipos have pretty much completely replaced NiCds for electric motor power. You get twice the power per weight and a much higher discharge rate. But lipos have a whole set of new concerns. Lipos and to a lesser extent LiFe batteries suffer from the phenomenon of thermal runaway. When the internal temperature of the battery reaches a certain point, it keeps going up, leading to a fire. It takes a lot of heat to start a lipo fire. The thermal runaway temperature is around 300F so even a lipo that's too hot to hold is not in danger of thermal runaway. <u>Physical damage or a short circuit are the two most common causes of lipo fires.</u> It's important to inspect your batteries before charging and after use for any signs of damage. Modern balance chargers have multiple safety systems that shut down the charging process long before enough heat is generated to cause a thermal runaway. That said, Lipos should not be charged unattended and should either be charged on a non-flammable surface or in a fire proof container. A disused charcoal or gas grill makes a excellent charging station. Lipo sacks or a metal ammo case are good for transport. A cinder block cave or even clay flower pots have been used for storage or charging. Lipos are no more dangerous than a can of gasoline. As long as you know how to handle them safely, you'll be fine.

Note that LiFe (Lithium Ferrophosphate) batteries can also suffer thermal runaway but at a much higher temperature than Lipos. They are regarded as “safe” and are in many electronic devices and power tools.

Chargers

Lipos and LiFe batteries require sophisticated chargers to be used safely. Safe lipo chargers are “balance chargers” , they charge and monitor each cell individually in the pack. Even a basic charger will have balance charge, fast charge, discharge, and storage cycles.

Balance Charge: Charge each cell individually to 4.2V (3.6V for LiFe) Can take a long time for old batteries or batteries with mismatched cells. The charger drops the rate of charge as it nears 4.2V.

Fast Charge: Charges at high rate to about 4.1V/cell then skips the slower finish to full charge.

Discharge: Will discharge a battery to a set voltage and display the amount of energy used. (Look for “regenerative discharge” that can take the power from one battery and put it into another at higher rates.)

Storage Charge: Will charge or discharge each cell to 3.8V. Less expensive chargers only have a resistor to convert excess energy to heat and can take a long time to take a fully charged battery to storage voltage.

Other features on Lipo chargers.

Other chemistries. Many chargers can charge/discharge NiXX and lead acid batteries as well. This can be very useful because all but the cheapest chargers will show you how much energy was added to the battery to charge it. That can give you information about the condition of that battery. This can also be useful to determine how much energy was used by what you connected to that battery (like how much energy was consumed from your NiXX receiver battery.)

Multiple battery chargers: There is a whole class of chargers that will charge two or more batteries of different capacity and voltage at once. They are essentially several smaller chargers in the same box.

Internal resistance measurement: This gives you an idea of the condition of the battery. It relates to the true “C” rate of a battery. Unfortunately, the measurement is very temperature sensitive so great care must be taken is you wish to get numbers you can apply over time. Also, the resistance of the balance plug is another source of error. It is very useful for comparing cells in a given battery to each other. Batteries often go bad because one or more cells start to fail rather than the whole battery getting tired. Having even inaccurate IR measurements to compare cells is useful for detecting an ailing battery. You can relegate that battery to less demanding roles where it can continue to be useful.

Parallel charging boards: Not part of the charger per se but all chargers can use this type of board to charge several batteries at once. The batteries must all be the same voltage and should be the same capacity. They should be a similar states of charge. Since they are connected in parallel, current will flow between the batteries until they are equal. That current could be high enough to damage the balance plug if a fully charged battery was connected to a discharged one. The rate drops to whatever the charger can handle which is usually much slower than charging a single battery. Still very useful for charging up several batteries before a trip to the field.

Lipo Batteries

Lipo and LiFe batteries are typically made up of several cells in series. A “3S” or “6S” battery refers to how many cells are connected in series to make up the battery. Another number is the mAh rating (milliamp hour.) This refers to the size or power capacity of the cells. Finally there is the “C” rating with relates to the maximum current you can safely draw from the battery. A higher C rating means you can draw current from the battery at a higher rate without over heating the battery. (C ratings are notoriously inaccurate from manufacturer to manufacturer and almost always overstated. They can be useful to compare one battery to another from the same manufacturer.)

Example: 3S, 2200mAH, 20C battery is:

3S= 4.2V x 3 = 12.6V fully charged (LiFe would be 3.6V x 3 =10.8V)
2200 mAh = you could draw 2.2A (2200 mA) for an hour to completely drain the battery.
20C = This battery can theoretically safely deliver 44 amps (2.2 x 20) of current.

Lipos also shouldn't be allowed to discharge too low as that will damage them. There is no hard cutoff for these levels. The lower you go, the shorter the life. Some general guidelines are don't let your lipos discharge to below 3.0V under load. Most speed controls will allow you to set the LVC (low voltage cut off.) The lipo should not be below 3.3V/cell at the end of the flight. If you stay within those guidelines you should get good life from your lipos.

Lipos should be stored at 3.7-3.8V/cell. Most modern balance chargers will have a “storage charge” setting that will automatically charge or discharge each cell to 3.8V. Storing lipos either fully charged or discharged increases their internal resistance and increases the voltage sag they experience for a given amp current. How long can you go before you storage charge your lipos? There is no hard and fast answer but the sooner the better (hours, not weeks.) The good news is that once charged to storage voltage, they stay there for months or even a year.

The exception to this rule is LiFe batteries. LiFe batteries <u>can</u> be safety stored fully charged.

Using A123 cells as flight batteries.

A123 cells can be used as flight batteries. The advantage is that they are very safe, charge quickly, and are rated at 30C which is adequate for sport type flying. They also last a long time; hundreds of cycles. The disadvantages are that they are heavier than lipos (30% more for comparable packs), you have to build your own packs, and they cost more initially.

However, there are situations where A123 might make sense. For models that can handle the extra weight (usually large models) and/or you need extra weight to balance the plane. Some planes have no room for a lipo but because you have to build the packs, you can build them in whatever shape you need to fit. They are safe to charge in the plane so you can mount them more or less permanently and use extensions to charge the battery. For example, a WWI plane that would normally require lead in the cowl to balance. You could built a round pack with a hole in the center to clear the motor and fit it inside the cowl with the motor.

Pat's usage guidelines.

I got back into the RC hobby about 6 years ago and exclusively use electric power. I've made every mistake and fried many batteries. I don't claim to be an expert but this works for me. My philosophy is to run everything well within it's limits. I now get good life out of my batteries. This what I do.

1. Get a watt meter. Lipos can be damaged if overloaded. So I check each new setup to see what the motor/prop combination is actually drawing. I make sure none of the components are overloaded.
2. I use a timer or telemetry and fly to a resting voltage of 3.7 – 3.8V/cell. Storage voltage represents about 2/3-3/4 of a batteries useful capacity (remember, you can't fly them to 0V.) I never get near LVC (low voltage cutoff) and don't have to storage charge the batteries because they are already there. I still have plenty of reserve if I need it. Before I had telemetry, I would fly for longer and longer times, checking the voltage after each flight, until I got to my desired ending voltage. I fly shorter flights than possible but my batteries last longer.
3. I measure the cell voltages before and after each flight. I have a cheap voltage meter that plugs into the balance tap on the battery and it only takes a few seconds. I check that the battery is in fact, charged and I am also looking for imbalance among the cells. I check the battery again at the end of the flight to see if it needs to be storage charged and if the cells are imbalanced. I don't worry about a difference of <0.1V between cells. If it's more than that, I only use those batteries for less demanding aircraft. When they get really bad (>.3V difference) I'll still use them for a bench power supply for setting up planes etc. In that case, I charge it to storage voltage. If they get damaged or just old, discharge them completely with a light bulb to 0 V and recycle them.
4. I use “Fast Charge” a lot. I read somewhere that charging to 4.1 vs. 4.2V doubles the life of lipos. I don't now if that is applicable to the way we use lipos because they don't stay at 4.2V long before they get used. The batteries do charge much faster, especially older batteries that can take a long time to get to a balanced 4.2V/cell. I lose maybe 5%-10% of flying time but since I fly to storage voltage, I still have plenty of reserve for “go arounds”.
5. I store and transport lipos in “lipo sacks”. Theoretically, they can contain a lipo fire (I have my doubts) but they do protect the lipos from physical damage and shorts in my flight box. I have some ceramic tiles on the workbench when I charge at home but I often charge at the field. Fast charge of a battery from storage voltage takes only 20 minutes at 2C.

Lipos require some care to use safely and give long life but if you develop some simple habits they are safe and economical to use. I get over a hundred cycles from my batteries and have some that are three years old and still give good service.

Battery type	Nominal voltage	WH/kg	self discharge/month	Load/Peak load	Overcharge tolerance	Toxicity	safety	Store fully Charged?	Charge time
NiCd	1.2V	45-70	20%	1 / 20C	moderate	High	Thermally stable	Yes	1 hr
MiMh	1.2V	60-90	20% (LSD)	.0.5 / 5C	low	low	Thermally stable	Yes	2-4 hr
LiFe (prismatic)	3.3V	80-120	<10%	<10 / >30C	low	low	Circuit protection necessary	Yes	< 1 hr
A123 (Cylindrical)	3.3V	80-100	<10%	<10 / >30C	low	low	Circuit protection necessary	Yes	< 1 hr
Lipo (prismatic)	3.8V	100-150	<10%	<10 / >30C	none	low	Circuit protection necessary	No 3.7-3.8V/cell	< 1 hr

Notes:

NiCd: Heavy but can deliver fairly high amps, safe. Good for flight packs and Tx.

NiMh: Better energy density than NiCd but lower amps. Good for Tx and low amp flight packs.

LiFe/A123: High energy density, safe, fast charging, high amp rates. Good for flight packs but requires access to the balancing tap to charge. Can be used for electric power if you handle the weight.

Lipo: Best energy density, high amps, fast charging. Good for electric power. Requires extra care to use safely.