Understanding Batteries and Chargers for RC Sailing

David Flakelar - Sydney

Introduction

The paper introduces simple electric circuits, batteries and chargers. It is for those new to the sport and who have only limited technical knowledge and may not wish to develop that further.

Additionally, reference is made to a separate paper *"Set-up of FlySky FS-i6 Transmitter (Tx) and FS-iA6B Receiver (Rx)."*

Electricity can be dangerous and an electric shock from faulty domestic wiring or appliances can kill - particularly around water. At low voltages of the magnitude encountered in RC sailing this is most unlikely, but the incorrect use and disposal of batteries can cause excessive heating and fire, so care is required, and manufacturer's advice should be followed.

Battery

A battery (sometimes called an accumulator) is a storage device. Using a charger, it takes electric energy, usually from mains, and stores this in the form of chemical energy for later discharge as electrical energy. A battery or battery pack is a collection of cells wired together, with housing, electrical connections, and possibly electronics for control and protection.

The fundamental unit is a voltaic cell, and a battery may comprise one or more cells connected in series or in parallel or both. Each cell comprises an anode, cathode and electrolyte. Convention has it that the anode is positive, cathode negative and current flows from the anode. The electrolyte may be either solid, a paste or liquid.

Cells are classified depending on whether they are rechargeable or not and are termed either a primary cell or a secondary (rechargeable) cell.

The discussion below is restricted to the recommended batteries used in RC sailing, and particularly the DF yachts.

The ONBO LiFe battery (or similar) often used in the FlySky receiver is rated 6.6v and comprises two cells in series and this is shown on the battery as 2S.

Primary Cells

The most common primary cells are labelled Alkaline which come in the following popular sizes AAA, AA, C, and D each with a rated voltage of 1.5 volts, so four batteries will deliver 6.0 volts. They are used in low power applications in portable devices that have a low current drain and are used intermittently. It should be noted that rechargeable batteries only have a 1.2 volt capacity, so four batteries will only produce 4.8 volts.

The popular FlySky onboard receiver requires a power source in the range 4.0-6.5V DC. While four 1.5V alkaline cells (AA) can be used, most serious sailors prefer a rechargeable battery such as LiFe (LiFePO4) 6.6 v 2S 850 mAh as a more sustainable and lower cost alternative. More of this battery below.

Primary cells cannot be reliably charged, and manufacturers recommend this not be attempted as rupture and leaking of hazardous liquids may result. As with all batteries they should be disposed of in the recommended way.

Secondary Cells

Batteries comprising secondary cells are rechargeable and may not have a full charge when supplied (i.e. they are delivered in "storage" mode). They are recharged by a charger by applying an electric current to the anode and cathode terminals which reverses the chemical reaction that occurs when discharging.

A Guide to Understanding Battery Specifications

These two references provide excellent additional information on batteries

- MIT Guide to battery basics http://web.mit.edu/evt/summary_battery_specifications.pdf)
- Electropaedia https://www.mpoweruk.com/performance.htm

What the Numbers Mean

Most batteries will be labelled with the following numbers:

- Voltage in volts (v) e.g., 6.6 v
- Capacity: amp-hours or usually shown in milli amp-hours (mAh) e.g., 850 mAh
- C-Rate: A charge rate multiplier shown as nC e.g., 25C

There may be other numbers that relate to battery physical size and shape.

Battery Types and Sizes

A comprehensive list of battery types and sizes is provided at
https://en.wikipedia.org/wiki/List_of_battery_sizes

Li-ion Batteries (not to be confused with LiFe)

These are a large group of rechargeable batteries that include LiFe and LiPo batteries. All are based on the use of a lithium compound as the cathode such as lithium ferrite phosphate (LiFePO4, sometimes shortened to LiFe, and lithium-ion polymer (LiPo).

Battery Capacity

A battery's capacity is a measure of the amount of electrical energy that it can store and safely discharge but does not indicate the rate this energy transfer can take place. See C-Rate below. Capacity is a function of the chemical energy stored which in turn is determined by the physical battery size, the chemical properties of anode, cathode and electrolyte, its thermal characteristics i.e., internal resistance and its ability to disperse heat, its state of discharge and its age - counted in number of cycles.

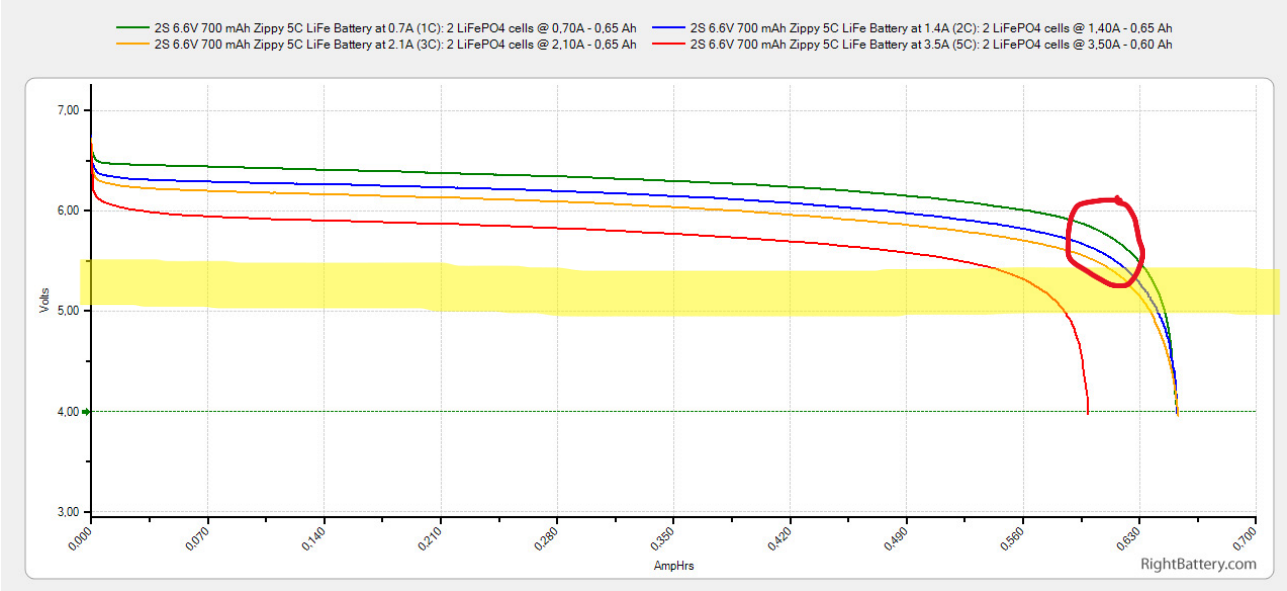
Capacity is measured in ampere-hours and in RC applications is usually shown as mAh (milli amp hours). The capacity may also be shown in real energy terms such as watts or milli watts hours (mWh).

A battery rated 1 Ah could theoretically store and deliver 1 amp for one hour, or 0.5 amp for 2 hours or 2 amp for 0.5 hours or and so on.

Capacity measured in (Ah) is only approximate and in some instances misleading because whilst 1Ah cell could deliver 1mA for 1,000 hours (0.001 x 1,000 = 1,000 mAh) it certainly could not deliver 100 amps for 0.01 hours (36 seconds). The heat generated by 100 amps would probably cause a fire.

The current delivered by a battery in use is determined by its voltage and the connected load. There is no known National or International Standard for measuring battery capacity.

This is the typical discharge chart for a LiFe battery. If the transmitter has an alarm function, a warning should be set at around 5.2 volts, so you have enough time to finish a race and get the boat back to shore.



C-Rate

This is the *maximum* rate at which a battery is charged/discharged relative to its maximum capacity.

The label on batteries can show a C-Rate from 0.2C to 100C. If not specified on the battery or in data sheets a rate of 1C is normally assumed. 1C means that theoretically the battery can be charged/discharged in 1 hour.

C-Rate in Perspective

Since the C-Rate is a measure of the rate at which a battery can be charged and discharged, a large C-Rate suggests the battery can be *charged* at a high rate (i.e., a large

current for a short charge time) and equally *discharge* a large current for a short period of time.
.
The value of the C-Rate is a measure assigned by the battery manufacturer and there appears to be no National or International Standard by which C-Rate is or should be measured. Hence whilst a large C-rate is seen to be a desirable battery attribute it is not necessarily a reliable guide to battery performance.

The physical size of the ONBO 850 mAh battery is about that of a matchbox. A C-Rate of 25C appears to be grossly exaggerated in that if charged or discharged at a rate of 21 amps for over 2 minutes (see calculation above) it would cook very quickly, probably ignite and trip the household circuit breaker. To get this current in perspective, a domestic 240v 800W bar radiator (electric fire) would draw about 3 amps.

A LiFe battery can be permanently damage if discharged below a critical voltage. If using the FlySky-i6 Transmitter/Receiver combination, the user is advised to set the receiver battery alarm voltage to 5.2v and to prevent battery under-volt damage the battery disconnect voltage should be set to 4.9v.

Chargers and Charging

After discharge, all batteries comprising secondary cell/s require a battery charger to restore the battery to a fully charged state. The individual cells in a battery pack vary and there may be small differences in their capacity and so, over time may have a different capacity in each cell These variations in capacity are due to manufacturing variances, assembly variances (e.g., cells from one production run mixed with others), cell aging, and impurities.
The FlySky receiver battery has two cells in series. Balancing these during charging helps to maximise capacity and service life of the pack by maintaining the state-of-charge in each cell. Balancing is only necessary for packs that contain more than one cell in series.

Self-Discharge
There are ongoing internal chemical reactions in any cell, and these reduce the stored charge and thus decrease the capacity of the battery over time. This phenomenon is called self-discharge. The battery shelf life is defined as the longest time a battery can be stored before its capacity falls below 80% of its nominal capacity.

Battery Memory
Battery memory describes the situation in which NiCd batteries gradually lose their maximum energy capacity if they are repeatedly recharged after being only partially discharged. The battery appears to "remember" the smaller capacity. A good charger should automatically fully discharge the battery before the charging process starts.

Available Battery Chargers

The charger will usually include a) a power supply to transform 240v AC to the charger nominal output AC voltage, b) a rectifier and smoothing filters to convert AC to DC and c) a battery management system (BMS) to measure battery state and provide the optimum charging current and voltage at the battery terminal for the time required. If the cells are

arranged in series the charger will provide additional cabling to monitor the state of individual cells and provide a balanced charge.

Each battery type and size has a particular set of constraints and requires specific charging regimes. For example, NiCd batteries should be nearly completely discharged before charging and this may be provided by the battery management system.

Typically, a battery charger designed for one battery type cannot be used for another type. The chargers recommended below can be set up to charge multiple battery types.

Optimum Charge Rate
Depending on the charger, the user can set the charge rate, often in amps. **S**low or trickle charging is deemed to be better because the thermal heat build-up is less. Temperature extremes, hot or cold, are never good for batteries. There is a lower risk of over-charging which can reduce battery cycle life.

A general rule of thumb is never charge faster than the mAh rating. So, an 850 mAh battery should not be charged at more than 0.8 amps… and preferably at 0.4 amps.

Battery Requirements for FlySky FS-i6 and Joysway J4C05 Transmitters:

- four 1.5v AA Alkaline cells, or preferably b) Rechargeable cells, say four 1.2v NiMH (Nickel Metal Hydride) AA cells. Or
- four 1.5v Li/FeS2 (Lithium Iron/Disulfide) AA cells. Both transmitters provide a housing to accept four AA cells.

Battery Requirements for FlySky or Joysway Receivers

- four 1.5v AA cells mounted on a snap-in tray under main hatch, or
- a single 2S 6.6v battery like ONBO 850mAh (or similar) mounted with Velcro on the keel box inside the hull and accessed from the forward hatch on a DF65. (An extension lead will be required for this recommended option).

Transmitter: Panasonic BQ-CC51 Battery Charger:

The Panasonic shown here accepts 4 x 1.2v NiMH cells. There are three flat pins on the back to allow it to be plugged directly into a 240v AC outlet. Green LEDs glow when charged. A number of other brands are available.
Features: Very simple to use and provides a constant current charge. Some brands provide capability to charge both AA and AAA cells at the one time.
Price: AUD 50
Available from: Various sources. Search using “NiMH charger”

Warning
Before purchase, always check the power supply of charger is compatible with your domestic power supply, suitable for the battery you wish to charge and all cables including the black JS/Futaba battery connectors are provided.

Receiver: SKYRC e430 Battery Charger
Features: Accepts 2, 3 and 4 cells for balanced charging of LiFe and LiPo cells. Very simple to use but very limited functionality. Does not accept AA batteries.
Price: AUD 29 and includes 240v power supply
Available from: Online shopping sites - Banggood, eBay Amazon, AliExpress etc. B6 mini shown below is favoured. Take care to avoid knock off copies with similar names.
Link to manufacturer site:
https:https://www.skyrc.com/Charger/e430_Charger
Link to site for manual:
https://www.manualslib.com/manual/1386587/Skyrc-E430.html

Receiver: SKYRC iMax B6 mini-Battery Charger

Features: Accepts 2, 3 and 4 cells for balanced charging for a range of secondary batteries including LiFe, LiPo, NiCd and NiMH. This is an upgraded version of the well-known IMAX B6 and is claimed to be more accurate and stable and has new automatic charging features. Refer manual. Does not accept AA batteries
Approximate Price: A$60, Power supply A$25
Available from: Online shopping sites
Link to manufacturer site: https //www.skyrc.com/iMAX_B6mini_Charger
Link to manual:

https://www.manualslib.com/manual/889362/Skyrc-Imax-B6-Mini.html
.

Receiver: G.T Power Battery Charger

Features from site: Accepts 2, 3 and 4 cells for balanced charging, auto detection of current rate and capacity of individual cells, identifying cell count automatically, automatic cut-off for safety temperature protection function and adjusts the charge power automatically when overheating. Does not accept AA batteries
Approx Price: A$60
Available from: online shopping sites
Link to manual: Not found

Multimeter

Multimeters are available from electronics stores such as Jaycar (Australia) and hardware chains (Bunnings) or online. A multimeter is an invaluable tool for fault finding particularly the following conditions and most modern digital types can show negative voltage and thus are suitable for checking polarity:

- battery voltage condition: select V (DC)
- open circuit by selecting resistance (ohms or Ω): should show very large reading
- short circuit by selecting resistance (ohms or Ω): should show zero reading
- polarity: should show negative value if wrong polarity

YouTube have a number of good sites. Search on “Use of multimeter”.

Disposal of Batteries

All unserviceable batteries should be held in a container (an empty PET bottle serves) and at infrequent intervals taken to a waste disposal agency or a battery retailer, such as Bunnings and Battery World, for safe disposal. Batteries in landfill are an environmental hazard.

David Flakelar BE MEngSc
dfflakelar@tpg.com.au
+61 404 829 414