N.B. The information below is my best shot based on my personal experience. This article may be corrected or updated at any time so if you find a mistake or a better way of doing any of this please let me know.

This article aims to complement the article “Choosing And Using A LiPo Battery Charger” for pilots who might wish to look at more technical detail. There is some duplication.

Cells and Batteries

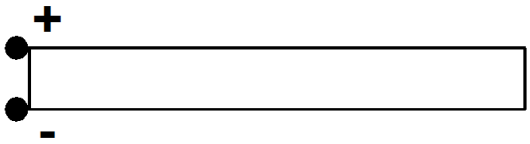
Understanding the difference between a cell and a battery is crucial! When most people talk about an “AA battery” they actually mean an AA cell. A battery is two or more cells put together so that their voltages add to make a higher voltage.

Charging Criteria

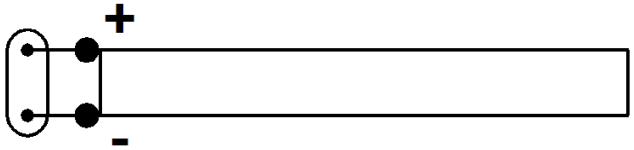
There is some debate about the criteria for a fully charged battery. A general guide I came across stated that a LiPo battery full voltage should be 4.2V +/- 0.03V per cell with cells balanced within a 20mV spread. However I would hope that with most chargers the voltage of any cell will not exceed 4.21 volts. A bit of a grey area.

The single (1S) LiPo cell

The cells in most LiPo batteries we use are rectangular and flat. Viewed side on they look a bit like this:



There are two connections at one end, one positive (+) and one negative (-) shown as black blobs in the diagram. On a 1S LiPo these will be wired to a connector of some sort.



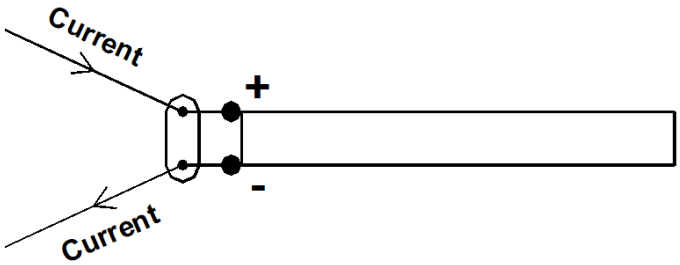
We can measure the cell voltage across this connector which gives us a good indication of the approximate state of charge of the cell.

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Charge	Voltage	
%	V	
100	4.2	Full
90	4.1	
80	4.0	
40	3.8	Storage
10	3.7	
0	3.3	Empty

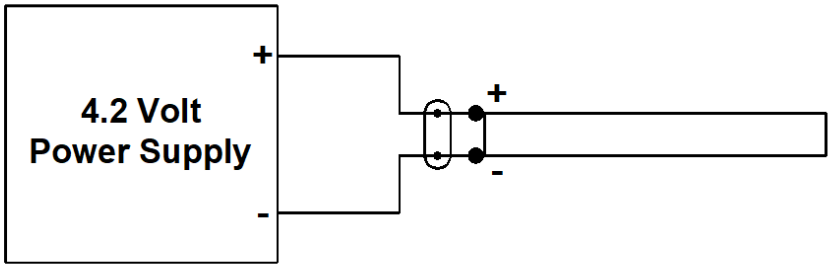
These voltages are for cells which have no load on them. i.e. The battery is not driving the motor in our model or other significant load. Cells are normally charged to 4.2 volts (100% charge), and we would not normally want the voltage to fall below 3.7 volts (10%). We normally store them at about 3.8 volts (40%).

To charge a cell we have to make a current flow through it. Current is electricity flowing through a conductor, usually a wire. Current flowing into the plus connection of our cell and out of the minus connection will charge the cell.



This will make the voltage rise in accordance with the chart above. The current going in to the cell will be exactly the same as the current coming out. We measure current in amps “A” or sometimes in milliamps “mA” which are thousandths of an amp. When we discharge the cell (using it to run our motor) the current will flow in the other direction.

We can easily charge a single cell by connecting it to a power supply of 4.2 volts.

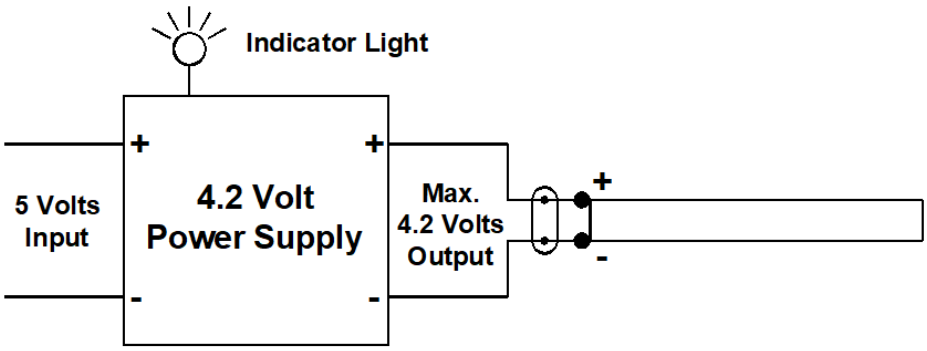


This will work OK as long as the power supply current is limited (controlled) otherwise things could get very hot! A current limiter in the power supply will not allow more than a preset current to flow into the cell. The result is that the cell voltage will rise slowly until it reaches 4.2 volts when the current falls to zero.

There are chips made specially for this purpose in which the current limit can be

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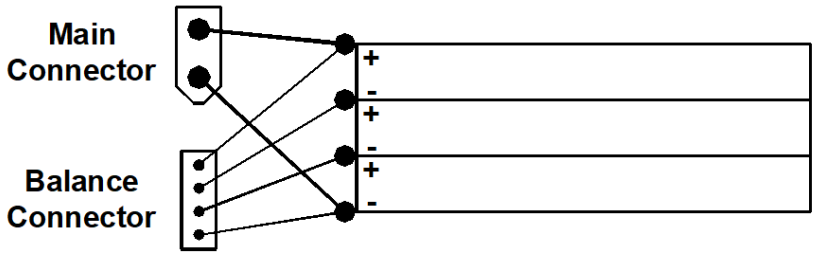
adjusted. We will normally set this to a maximum of 1C, the load (motor) current which would empty the cell from full in 1 hour. These chips sometimes incorporate a detector which can be used to switch indicator lights on or off to show whether the cell is charging or full. They are also usually made so the cell will not discharge back through the power supply if the input power fails.



This shows a typical circuit with a 5 volt input such as could be obtained from a USB supply.

The LiPo Battery

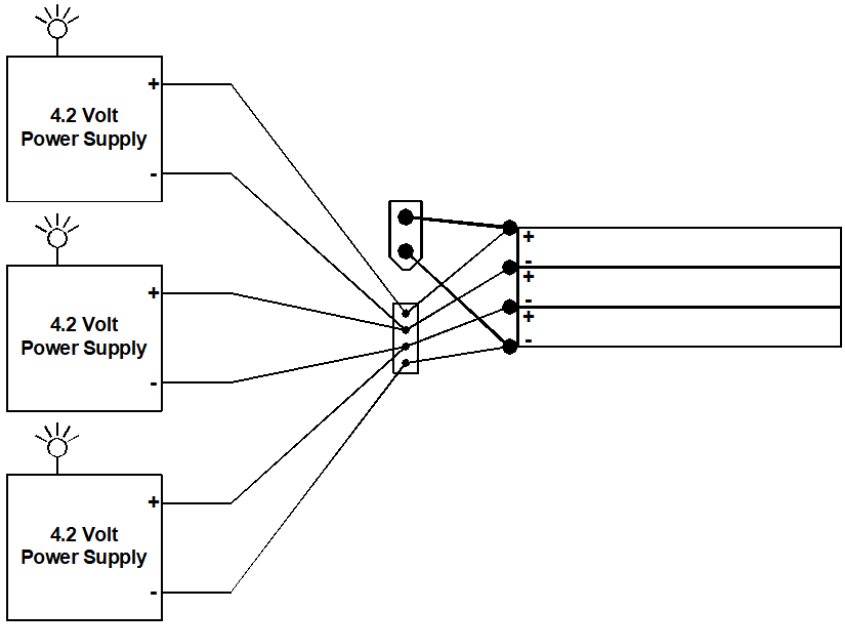
Our battery might look a bit like this:



3 single cells are stacked together with the positive tab of each cell connected to the negative tab of the adjacent cell to make a 3S battery. This adds the voltages of each cell together and the ends are connected with substantial wires to the main connector. Additionally there is a balance connector which has 4 pins. One pin is connected to each plus/minus connection between pairs of cells and one to each end of the stack.

In this way each individual cell is accessible through the balance connector. The simplest way to safely charge the battery is to charge each cell individually like this:

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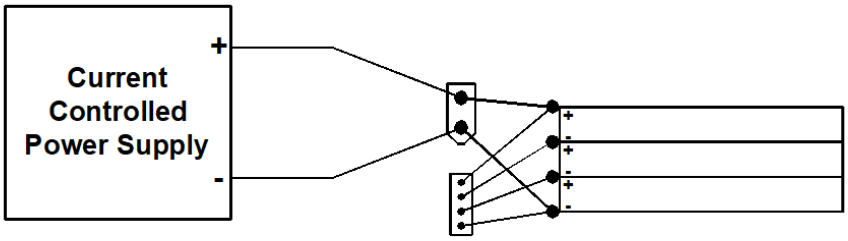


Each 4.2 volt power supply charges one cell and the battery is charged when each of the indicators changes colour. Some commercial chargers work in this way.

Computer controlled charging

For more controlled and flexible charging we can use a microprocessor controlled charger.

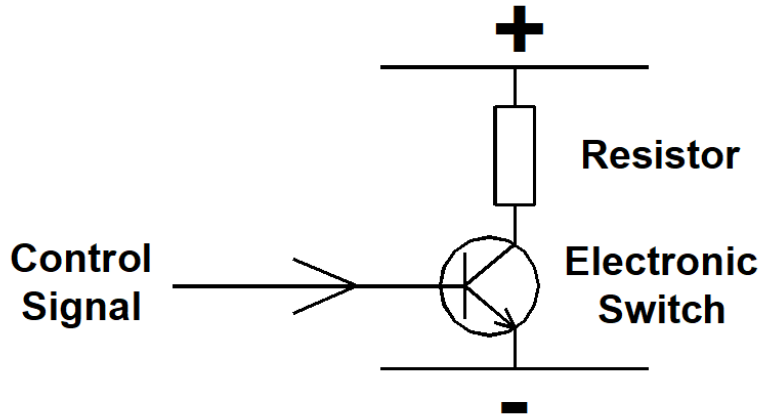
The charge current is supplied directly to the main battery connector.



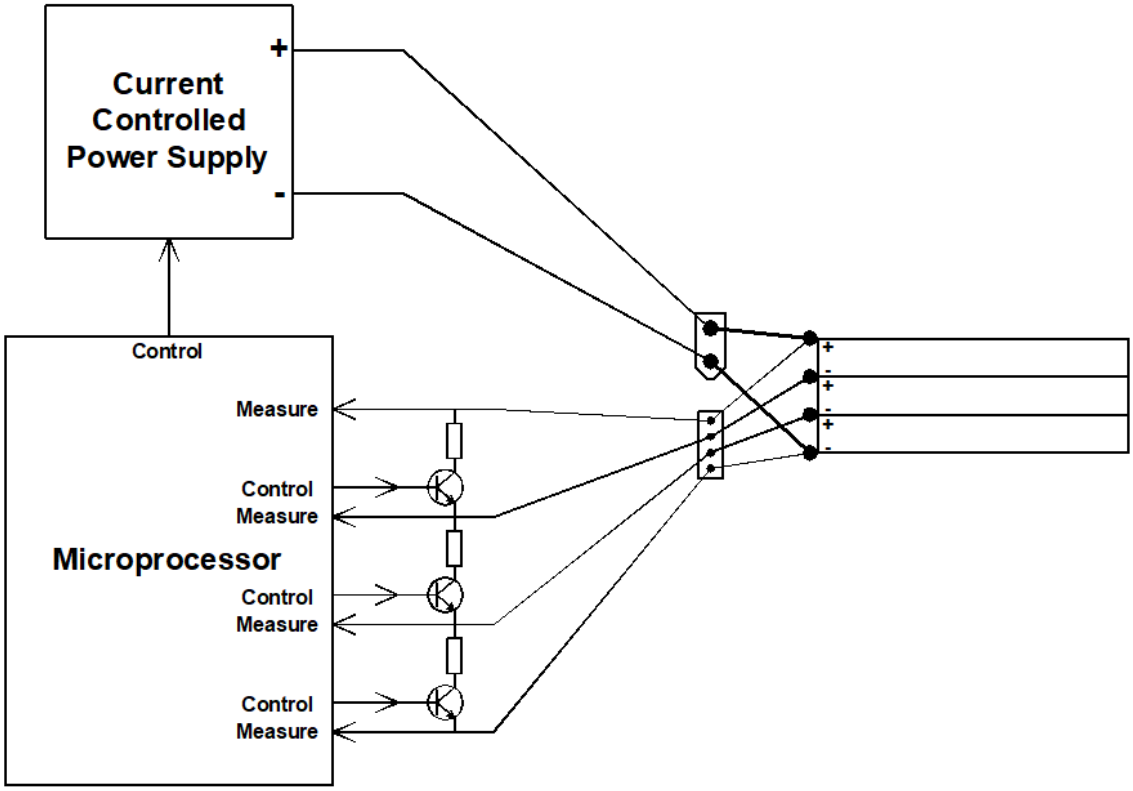
The power supply current is set by the operator, controlled by the microprocessor and goes through each cell in turn. This will charge the battery but will not correct (balance) differences in the voltages of individual cells. We need something to correct these differences.

The simplest way is to switch a resistor across the cell or cells with the highest voltages. A resistor is simply a small electric heater. Switched across a cell it will “steal” or “bypass” some of its charging current. The switch will be a transistor of some kind operated by a control signal from the microprocessor.

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We need one of these bypass circuits for each cell. The microprocessor also needs to measure the voltage on each cell so it knows when to switch the bypass resistor on and off.



Things are starting to look a bit complicated, but with the addition of a signal allowing the microprocessor to control the main charge current supply we have the main workings of a balancing charger. Of course if we want to select a charge current etc. we have to have control buttons and a display panel too, but the above is all that is necessary to actually charge a battery.

With this basic setup there can be any number of variations of circuit and programming. Chargers can have two bypassing resistors and switches for each cell enabling different bypass currents to be selected. Bypass resistor switching can also be pulsed by the microprocessor to reduce the average bypass current.

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Exactly how the charging and balancing is controlled is down to the microprocessor's program. It might be a bit like this:

The operator selected charge current is applied by the current controlled power supply. The computer measures the voltage of each cell and switches in the balancing resistors to the cells with highest voltages.

As the first cell reaches 4.2 volts the charge current is gradually reduced to keep it from exceeding 4.2 volts while the other cell voltages “catch up”.

Eventually all the cells will be at 4.2 volts and the charge current will continue falling. When the charge current falls below a certain threshold, perhaps around a tenth or twentieth of the set charge current, the charge is considered complete and the charge current is cut off.

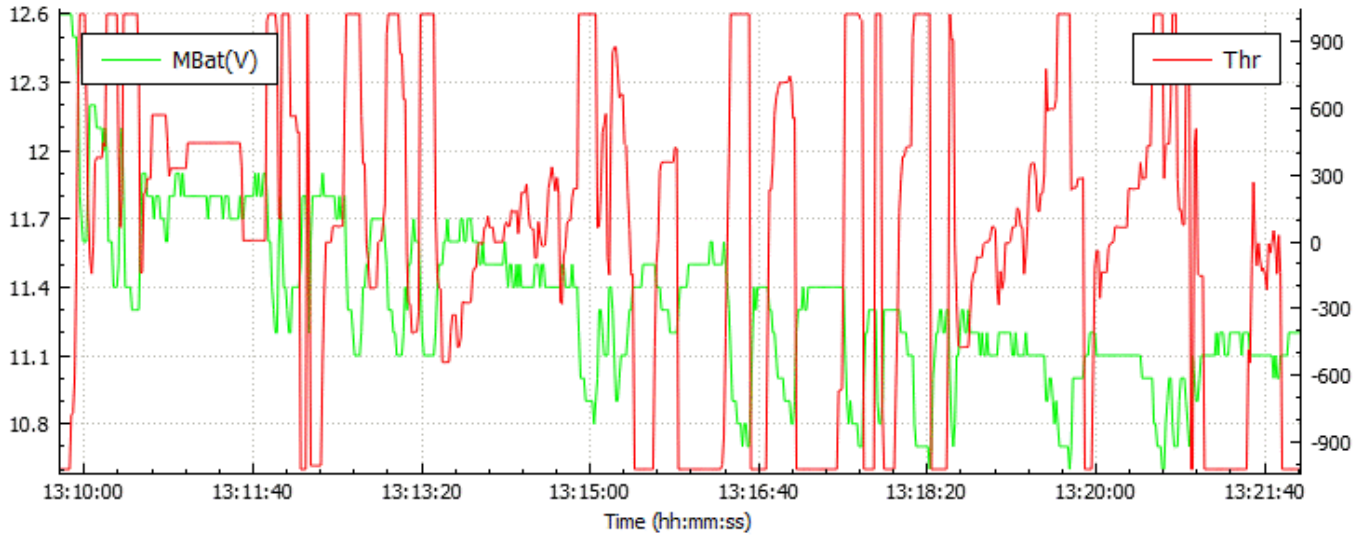
Note that cutting the charge current will cause the cell voltages to drop slightly. How much will depend on the charge current at the time and the condition of the cells. The cell voltages may drop further over a period of some minutes as the cells “slump” a bit.

As stated earlier the exact behaviour of a charger will depend on its controlling program as well as its circuitry. The manufacturer will have made compromises necessary to make a practical charger.

LiPo Batteries In Flight

Below is a telemetry trace from a flight of a trainer model doing some aerobatics.

The red trace shows the throttle stick position and the green trace the 3S battery voltage.



Note that in general the battery voltage drops as the throttle is opened and

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increases as the throttle is closed. This is mainly due to the internal resistance of the cells. This resistance is not an actual resistor, it is a consequence of the chemistry of the cell.

Note also that as the flight progresses the battery voltage gradually falls as it discharges.

Some chargers can measure and show the internal resistance of each cell while charging. Internal resistance will increase as a battery ages. The end of the useful life of a battery will usually be when the internal resistance of one cell increases significantly compared to the rest.

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