V for Vengeance (oops! Sorry, I mean Voltage).

By Bob Smith

How's that for a Freudian slip? As I started to write this I was reminded of an occasion when I was due to receive a prize at school speechday (very rare, believe me). The prizewinners were given book tokens and sent out to the local WH Smith to choose a suitable textbook. I got diverted into the fiction section and started to read the Dennis Wheatley novel "V for Vengeance". This was a just a few years after WW2 and I got so interested in the story that I exchanged the token for this book instead of the expected text on Geometry. The Headmaster was much put out by my lack of academic responsibility but it was too late to change things so I inadvertently struck the first of what later became a series of protests against authority.

Back to voltage then. When we were all running Nickel based batteries and brushed motors it was amperage that was king, the more amps you could pull then the better your plane flew, or so it seemed at the time. Now that we are all brushless and into LiPos, the emphasis has changed to voltage, though in a more subtle way.

Firstly there is the cell voltage. 3.7 volts per cell is a big jump from 1.2 volts per cell and we generally now work with smaller cell numbers but higher voltages. The second area, and the one which is the basis for this article, is the change in cell voltage as we discharge them. When we used Nickel cells we knew that they were so robust that we did not need to worry about voltage levels. The voltages could be increased to 1.5 volts/cell in fast charging and down to very low values (0.5 volts/cell) both during and at the end of discharge. We did not realise how lucky we were with these cells and when LiPos appeared it took us a while to appreciate that we had to be much more careful. LiPos have to be kept within a band of voltage throughout their usage, nominally 3.0 volts minimum to 4.2 volts maximum, and this is for every individual cell in the pack, not just the pack as a whole. If we look at this more closely, then we are concerned about several separate stages in our use of the batteries.

Charging LiPos.

This part is the easiest part to control. If you have a good charger then those clever electronic/computer engineers have sorted it all out for us. The algorithms programmed into the unit means that the charging rate can be maintained at the recommended 1C over the first stage until the pack voltage reaches the product of the cell count and 4.2 volts. Once this point is reached the charger holds the voltage constant and allows the current to fall away until it is down to around 10% of 1C. The problems of ensuring that each cell follows an identical charge pattern are covered by the use of a balancer, either built-in to the charger or as a separate unit, and that, basically, is it for charging.

Discharging LiPos.

Although we sometimes need to discharge our packs under controlled bench testing conditions, the vast majority of our discharges take the form of a flight with a model. The fact that the load on the pack can vary during this process is not important and we can look at the situation as if the discharge was at constant current. The voltage is critical in three forms. Firstly as a result of the magnitude of the load (i.e. of the current drawn). As this increases the voltage of the pack and the cells decreases. The specification of the pack will include a recommended maximum discharge (e.g. 20C), but like all specifications, this is not an optimum value. The pack voltage can easily be dragged down to below the critical value at high loads and it follows that they will perform much better at lower load rates which allows the voltage to be maintained at a higher level.

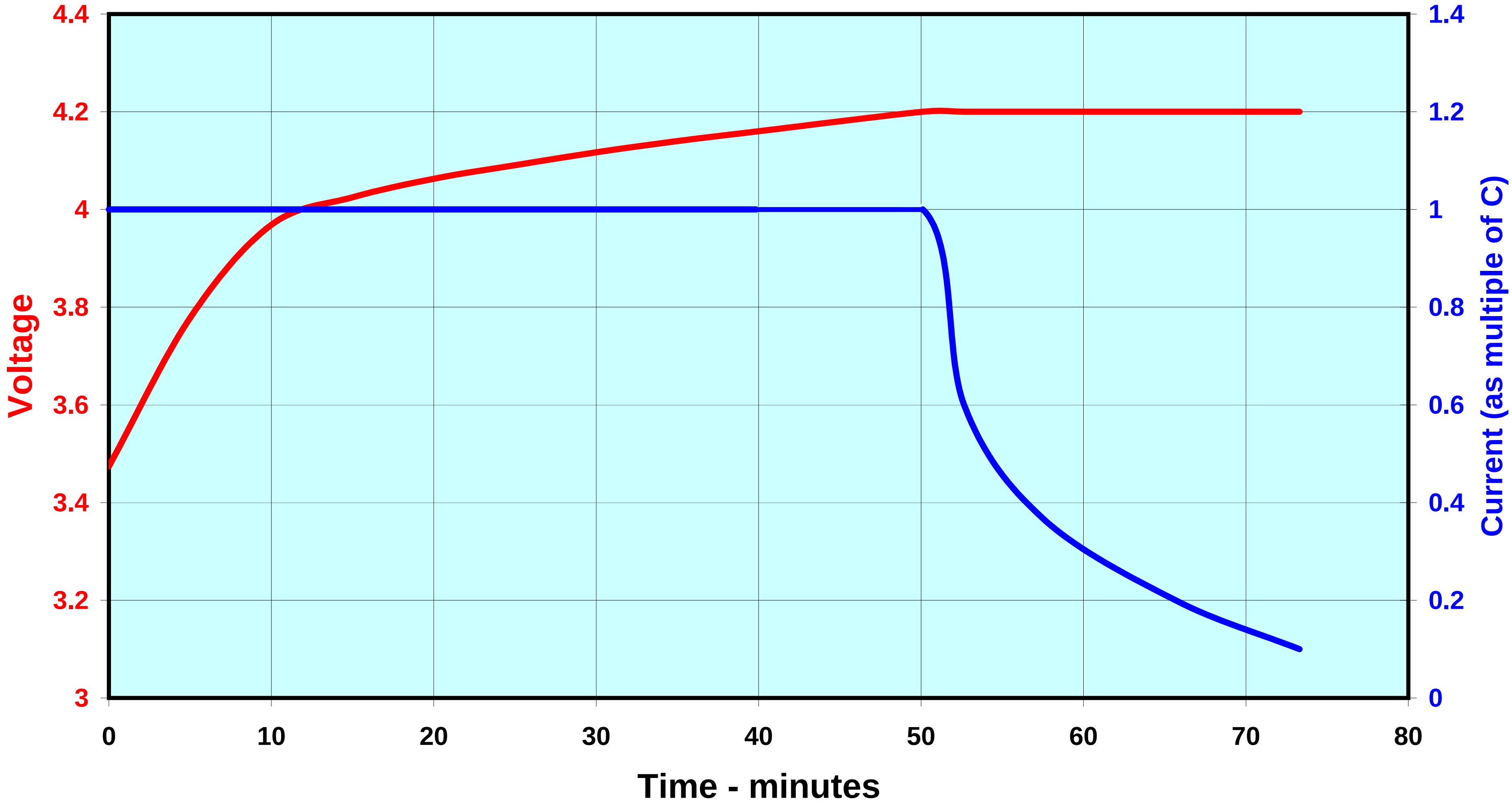
The second feature affecting voltage is temperature. As the pack gets hotter the internal resistance reduces and the voltage rises. This can be a secondary reaction to higher current draw as this causes the pack to heat up and this can show up as discharge proceeds. The secret is to take advantage of the effect but not to excess, as the pack will begin to deteriorate if the temperature gets too high. If you are not trying for the ultimate performance then it might be wise to prefer the safety and longer life of a pack kept cool throughout the discharge.

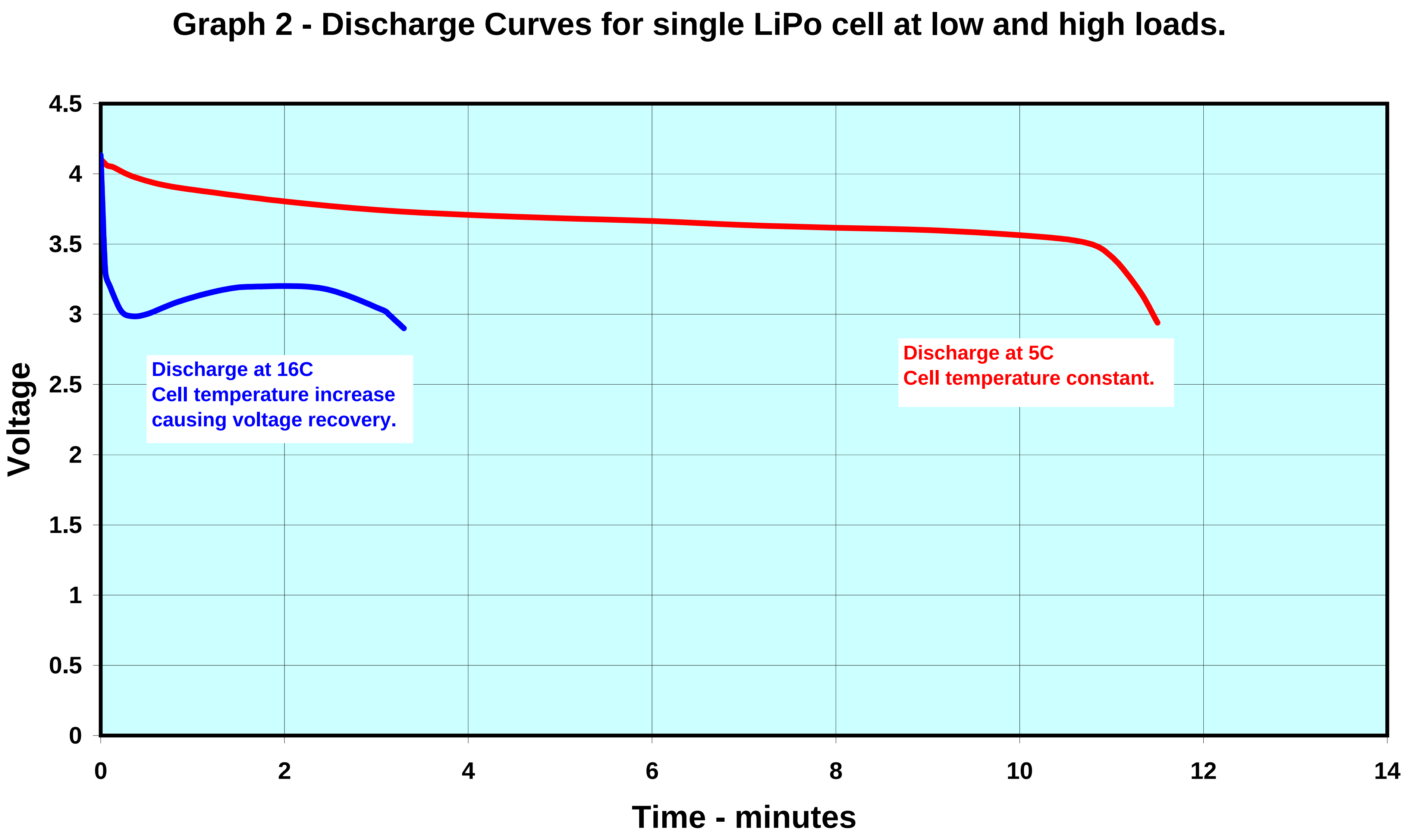
The third aspect of voltage to concern us is the voltage of the cells at the very end of discharge. In this area, say the last 10% of the discharge, cell voltages begin to drop more rapidly and can quickly drop below the critical value. Since all this is happening during a flight it is difficult to check but there are ways. There are a number of "discharge protection" units (such as the Leton, the FMA, the Schulze and the Dimension Engineering units) available, which fit between the ESC, the receiver, and the pack balancing lead. The best of these allow you to set the minimum individual cell voltage so that when any cell reaches that value the power supply is reduced or cut-off. This then prevents any cell damage although it does not give you information as to which cell (or cells) is the problem and by how much. What we need is a protection module which is also a data logger and records the cell voltage reduction values for every cell during the flight. There is a Custom Electronics logger which records the individual cell voltages but does not have a safety cut-out function so we need someone to combine these features into a single bit of kit.

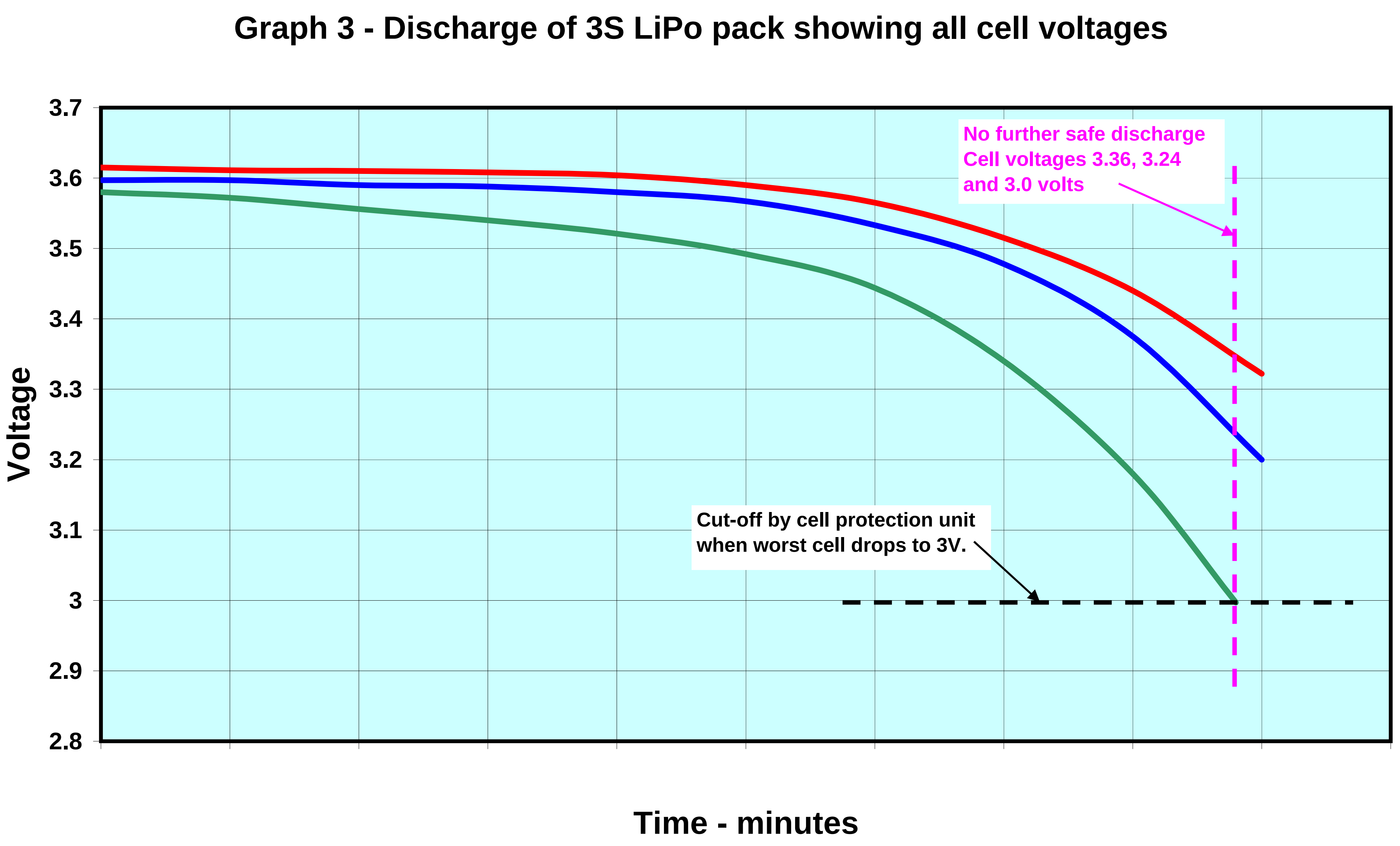
Voltage Graphs.

Just to help illustrate why voltage readings are so important to the use of LiPos, I have drawn some graphs of the critical features. I hope you will be able to see from these that it is voltage which counts with LiPo batteries, and that the well-being of your packs depends on controlling the voltages of the cells during both charging and discharging. To paraphrase it, "look after your volts and your volts will look after you!".

Graph 1 - Typical Charge Curve for single LiPo cell.




Graph 2 - Discharge Curves for single LiPo cell at low and high loads.
Voltage
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
2
4
6
8
10
12
14
Time - minutes
Discharge at 16C
Cell temperature increase
causing voltage recovery.
Discharge at 5C
Cell temperature constant.


Graph 3 - Discharge of 3S LiPo pack showing all cell voltages
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3
2.9
2.8
Voltage
Time - minutes
No further safe discharge
Cell voltages 3.36, 3.24
and 3.0 volts
Cut-off by cell protection unit
when worst cell drops to 3V.