Testing to find the cyclic Life of Lithium Polymer Batteries.

This is the second part of a two-part article dealing with the cyclic life of lithium polymer batteries. Part 1 dealt with the general specification of LiPos and their performance, and with the testing equipment I have available to carry out cyclic testing of them. Part 2 will cover the test procedure and the results of testing a series of packs.

Test procedure.

The equipment I detailed in Part 1 operates to the following pattern. I try to start all of the tests at the same point in the charge/discharge cycle and although this could be anywhere I try to begin with an empty pack since this is easy to eastablish by checking the pack/cell voltage under load (nominally 3 cells at 3 volts each). The first stage in the cycle is then a normal balanced charge using the recommended pattern of a 1C constant current up to 4.2 volts per cell followed by constant voltage as the charge current reduces down to 10% of the 1C value. This normally takes around 70 minutes and is followed by a 10 minute pause or dwell to allow the pack to stabilise. The discharge follows at a rate which is normally the manufacturers' maxmum recommended value e.g. 20C, and the discharge is stopped when the poorest cell in the pack reaches 3 volts. This is again followed by a 10 minute dwell before the whole cycle begins again. You can see a pictorial representation of this single cycle in graph1. The equipment is designed so that this cycle is automatically controlled and repeats as long as needed to reach the required number of cycles. The data produced by each cycle in terms of the pack voltage, elapsed time, discharge capacity, and pack temperature is recorded by data logger and periodically downloaded to a computer.The set-up I am using with the logger gives me around 27 hours of recorded data with each cycle taking about 1 hour 40 mins so I get 16 or so cycles in each batch which means six days for the 100 cycle test.

One of the problems associated with this type of long term testing is the vast amount of numerical data you produce and I am only able to include examples of the data in the form of a typical HiBox plot and a set of temperature/time figures. Even here you can see that the HiBox plot of only 20 cycles is crammed to the point where it is difficult to interpret the data visually. Remember that the temperature data is a dual purpose record since it also provides a back-up discharge capacity. Since the discharge is at constant current the product of that value in amps and the time period of discharge in hours is the discharge capacity in Ah. In the event, the main recording system via the HiBox proved to be sufficiently reliable that no back-up was needed.

Data Interpretation.

The basic intention of the whole programme was to determine the loss of capacity suffered by the test packs over the 100 charge/discharge cycles. Of the two traces on the plot, the blue voltage values are basically a check that the process is proceeding as intended and that the maximum charge voltage does not exceed 4.2 volts per cell, and that the minimum discharge voltage did not drop below 3 volts per cell. The values on the chart are for a 3 cell pack so are 12.6 and 9 volts respectively. The balancer built into the equipment did control the discharge cut-off on the basis of the worst cell, i.e discharge was ended when the lowest voltage cell dropped to 3 volts.

The second green trace is for the discharge capacity and is accumulative, i.e. each step in the trace is the discharge magnitude for that particular cycle in Ah but the scale reading is the total of all the discharges since the test commenced. Over multiple cycles the vertical scale would be difficult to interpolate accurately but the HiBox software has a floating cursor which gives the reading of any point on the trace to two decimal places (10 mAh).

Once a hundred cycle test is complete, each of the discharge capacities is measured and a graph plotted of this capacity against cycle number. There is, of course, a fair amount of variation in these values which arises partially from experimental deviations and partially from timing and other minor errors. In spite of this there is clearly a downward trend in the plot which indicates a loss in capacity. If a mean line is plotted through the fluctuations (which are only some tens of mAh in value) then, in all of my results to date, this produces a straight line with a negative (reducing) slope. This implies that the capacity of a LiPo battery degrades with use, that the rate of degradation is constant and cumulative, and that the quality of battery can be assessed by the magnitude of the degradation.

Test Results.

The data I have gathered could be used in several different ways to measure the performance of the packs but in this article I am only referring to the loss in capacity over 100 full charge/discharge cycles. You could start with the manufacturer's specified capacity but this is usually measured at a very low rate of discharge and I have tested the packs at a much higher rate. All batteries produce a lower capacity if they are discharged under high loads so it would be unfair to base the assessment on the capacity on the lable. The figures in the table are therefore calculated by taking the the capacity of the mean line at 100 cycles and subracting this from the capacity of the mean line at 1 cycle and expressing this as a percentage of latter value. In graph 2 you will see that the indicated values are 2.08 Ah at 1 cycle and 1.92 Ah at 100 cycles giving a loss of 0.16/2.08 x 100 = 7.7%. In terms of the use of these packs it is obvious that we want this value to be as low as possible.

The table of test results presented here has been compiled from two sets of batteries. I had already completed the tests on several packs before I was invited to write this article, and in addition the editor contacted a number of manufacturers/retailers to submit packs for testing specifically for the article. The combination of makes is now fairly broad but remember that new makes of LiPo batteries seem to be hitting the UK market on what seems like a monthly pattern, so there are still some gaps. There are also some slight anomalies with the discharge rates. Although the majority of the packs are 2100 to 2400 mAh packs rated at 20C discharge, some are of different capacities and ratings. I attempted to be as consistent as possible with the 20C test and used this value even if the labelled rate was higher, but it would have been unfair to use it where a pack was rated at less than 20C and in this case the specified maximum was used. In all cases the packs survived the test regime although some were producing very low readings by completion.

Analysis.

There are several points to make about the results.

1) In terms of the cyclic life the results are probably better than I expected. All of the packs lost capacity but some lost very little and some a significant amount. Although the losses appeared to be linear over this 100 cycle span, I suspect that they would become progressive (at an accelerating rate) if the testing had been extended, especially with the poorer performing packs.
2) There are also large differences in the comparison between the rated capacity (the value on the label), and the initial test capacity (cycle 1) at maximum loading. Remember that the percentage loss over 100 cycles is based on the latter value rather than the former, but it is equally important to know how much you will get from a pack under load when it is new. It is clearly not always possible to rely on the value on the label.
3) There is absolutely no indication that LiPo packs should be bedded in by slow charge/discharge cycles when first used (as we were advised to do with NiCd and NiMH packs).
4) I hope that the data provided in this article is of use to the modellers reading it, but I have to add a word of caution. I believe my equipment and procedures are sound and reliable, but they are not up to the standards of a commercial testing laboratory in areas such as calibration. In addition to this, I am reporting on the results of testing a single sample of each pack type and statistically this is obviously not ideal. I am repeating the results I obtained from my tests and I hope you have found it interesting.

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Photographs etc.

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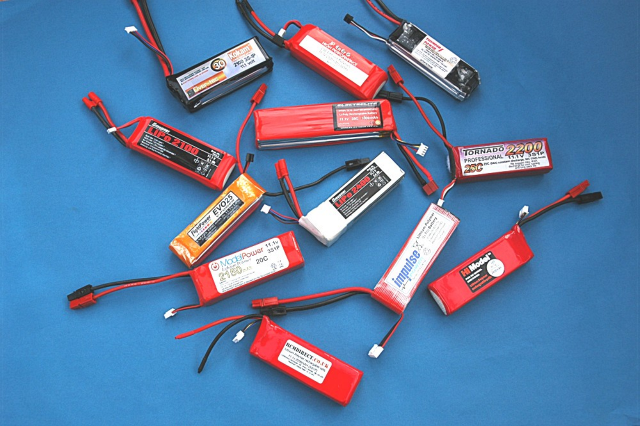
Page 1 -	**An assortment of the packs tested.**
Page 2 -	**Graph 1**
Page 3 -	**Graph 2**
Page 4 -	**Typical Temperature/Time data record**
Page 5 -	**Typical HiBox plot of cyclic voltage and capacity.**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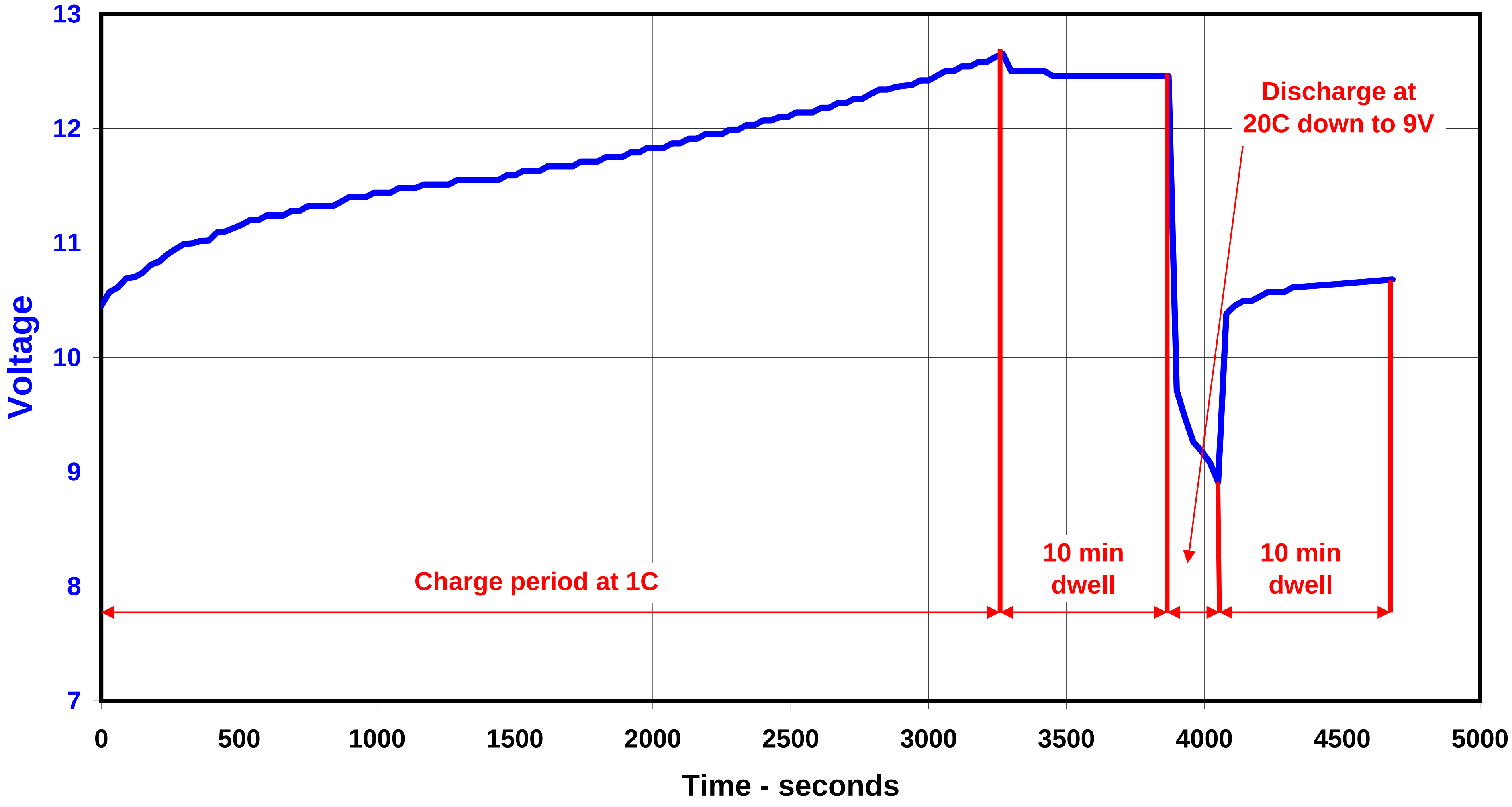
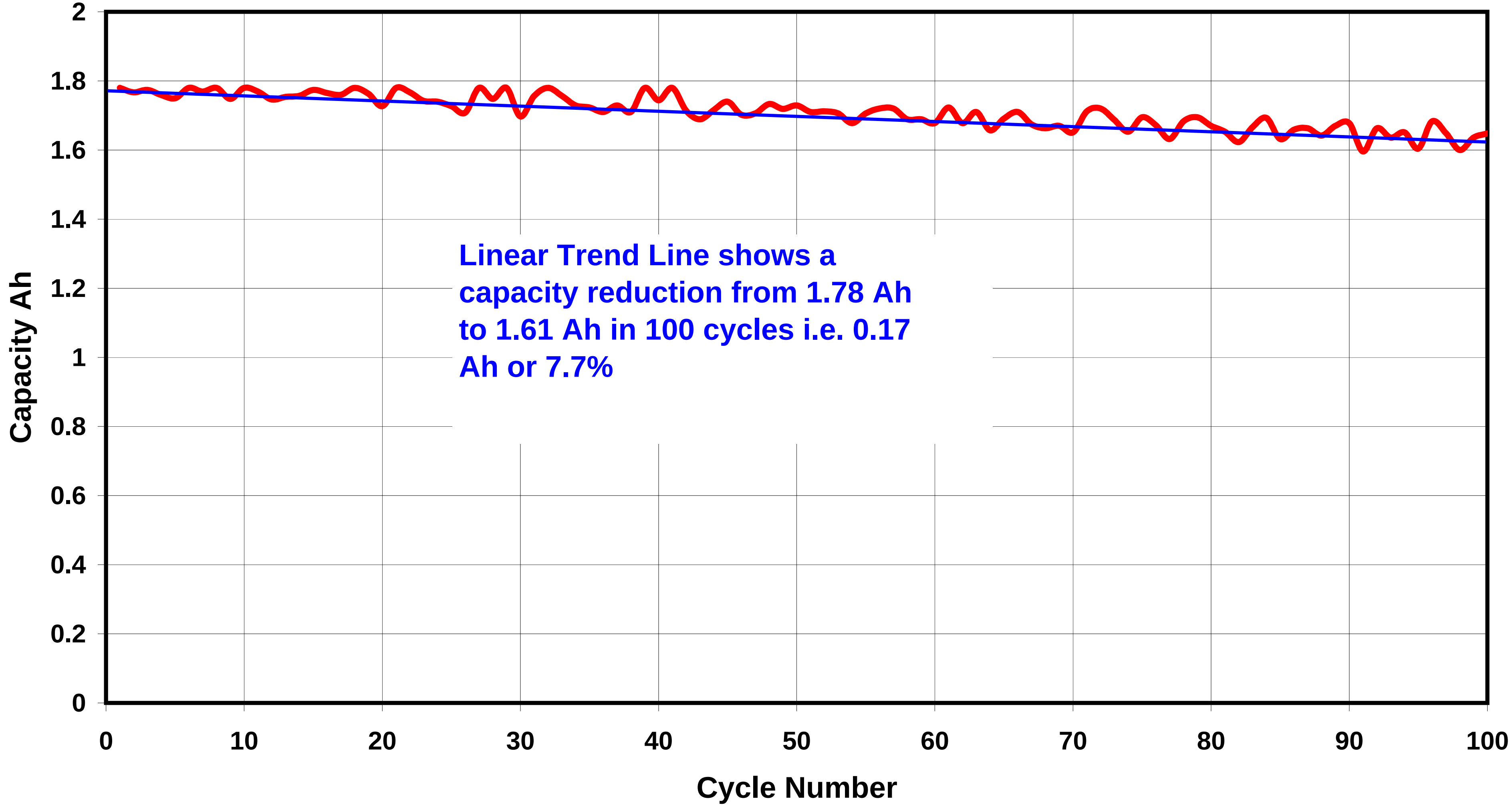
30
2100 3S-1P
11.1 volt
LiPo 2100
TORNADO 2200
PROFESSIONAL
11.1V 3S1P
25C
FlightPower
EVO25
LiPo 2400
ModelPower
11.1v
3S1P
20C
2150
impulse
HiModel
RCMDIRECT.CO.UK

Graph 1 - Example of a Single Cycle.



Graph 2 - Cyclic Capacity - HiModel 2200mAh 3S discharged at 44 amps (20C)



List

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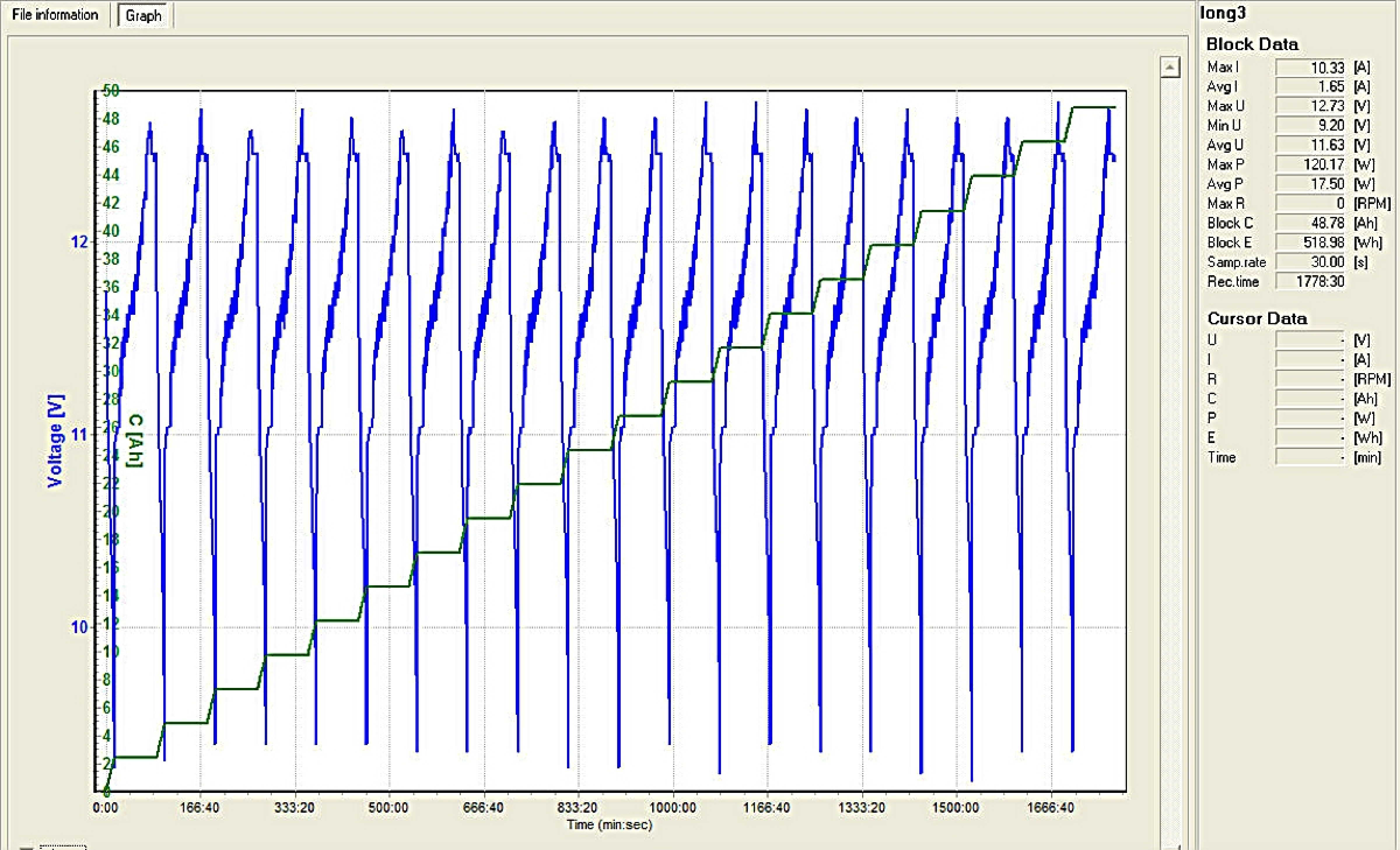
1	35.34 C	03/01 14:37:21
2	36.45 C	03/01 15:09:59
3	36.35 C	03/01 15:20:26
4	28 C	03/01 15:43:14
5	36.85 C	03/01 15:53:15
6	36.95 C	03/01 17:09:11
7	37.05 C	03/01 17:19:11
8	26.99 C	03/01 17:42:06
9	36.75 C	03/01 17:52:06
10	36.65 C	03/01 17:58:19
11	36.65 C	03/01 17:59:11
12	36.95 C	03/01 19:08:59
13	36.95 C	03/01 19:23:00
14	33.64 C	03/01 19:28:29
15	38.05 C	03/01 19:38:29
16	36.65 C	03/01 20:53:51
17	36.65 C	03/01 21:07:52
18	32.83 C	03/01 21:13:20
19	37.65 C	03/01 21:23:20
20	36.55 C	03/01 22:38:36
21	36.55 C	03/01 22:48:37
22	32.73 C	03/01 22:54:05
23	37.25 C	03/01 23:08:06
24	36.75 C	03/02 00:23:20
25	36.65 C	03/02 00:37:21
26	32.83 C	03/02 00:42:49
27	37.35 C	03/02 00:56:49
28	36.75 C	03/02 02:12:01
29	36.65 C	03/02 02:22:01
30	32.53 C	03/02 02:27:29
31	37.65 C	03/02 02:37:30
32	36.85 C	03/02 03:52:29
33	36.85 C	03/02 04:02:30
34	32.13 C	03/02 04:07:57
35	37.65 C	03/02 04:17:57
36	36.65 C	03/02 05:32:51
37	36.55 C	03/02 05:42:52
38	31.43 C	03/02 05:48:19
39	37.55 C	03/02 05:58:19
40	36.55 C	03/02 07:13:07
41	36.55 C	03/02 07:23:08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Avg I 1.65 [A]
Max U 12.73 [V]
Min U 9.20 [V]
Avg U 11.63 [V]
Max P 120.17 [W]
Avg P 17.50 [W]
Max R 0 [RPM]
Block C 48.78 [Ah]
Block E 518.98 [Wh]
Samp.rate 30.00 [s]
Rec.time 1778:30
Cursor Data
U - [V]
I - [A]
R - [RPM]
C - [Ah]
P - [W]
E - [Wh]
Time - [min]
Voltage [V]
C [Ah]
Time (min:sec)
0:00
166:40
333:20
500:00
666:40
833:20
1000:00
1166:40
1333:20
1500:00
1666:40
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11
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0
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Supplier	Battery (all 3S)	Weight grams	Rated Maximum Continuous Discharge	Actual Discharge current Amps	Initial Capacity mAh (Cycle 1)	Final Capacity mAh (Cycle 100)	% Loss in Capacity over 100 Cycles
Ripmax	Impulse 2100 mAh	159	16C	34 (16C)	1920	1780	**7.2**
Puffin Models	SharkPower 3700 mAh	367	20C	74 (20C)	3580	3450	**3.7**
Over-tec	Tornado Pro 2200 mAh	186	25C	44 (20C)	2190	2120	**3.0**
BRC Hobbies	FlightpowerEVO25 1800 mAh	151	25C	36 (20C)	1810	1590	**12.0**
Model Power	2150 mAh	192	20C	43 (20C)	1700	1510	**9.0**
W.London Mods	Thunderpower Extreme 2200 mAh	176	25C	44 (20C)	1970	1850	**6.3**
BRC Hobbies	HiModel 2200 mAh	185	20C	44 (20C)	1780	1610	**7.7**
RCM Direct	2200 mAh	181	20C	44 (20C)	1900	1740	**8.5**
Over-tec	Kokam 2100 mAh	200	30C	42 (20C)	1980	1920	**2.8**
J Perkins Dist.	EnErG Pro 2100 mAh	178	20C	42 (20C)	1880	1750	**7.1**
Electrolite	2500 mAh	227	20C	50 (20C)	2300	2180	**4.8**
Graupner	2100 mAh	177	25C	42 (20C)	2020	1930	**4.2**
Graupner	2400 mAh	213	30C	48 (20C)	2290	2200	**3.9**