Lipo Battery Performance Measurement

Aim:

- To measure the difference between Lithium Polymer batteries with various C ratings
- To compare the performance to Nimh batteries
- To measure the performance loss of Lipo batteries with use

Background:

Lithium Polymer (Li-Po) batteries are released with a C rating, which is a measure of the current draw that the battery is 'rated' to.
Current Rating (A) = C Rating x Battery Capacity (Amp.hours)

Higher C rating batteries provide noticeably greater power on the track. It was anticipated that the key difference for higher C rated batteries was a reduced voltage drop under current draw. Basic electric motor theory shows that torque (acceleration) is proportional to current, and RPM (top speed) is proportional to voltage. A battery that can maintain a higher voltage under load will allow taller gearing to be used and have higher top speed AND greater acceleration.

The objective of this exercise is to understand the actual difference between batteries of different C rating.

4 batteries are compared in this report:

- IB 3800 25C (95A rating) (new and used)
- IB 4200 30C+ Saddle Pack (126A rating) (new)
- IB 5000 40C (200A rating) (new)
- IB 4600 Nimh battery (no C rating) (new)

Note: The 3800 battery used for this test has ~40 cycles. This battery was compared to the 4600 mAh battery during a test in 2008 when both were <5 cycles. These results are compared in this report also.

Summary:

- Using the Novak Sentry data logger, a linear relationship between voltage drop and current draw was observed. The slope of this line is the Internal Resistance (IR)of the battery.
- The internal resistance of the batteries was measured as follows:
  - IB 3800 25C (new) = 0.0135 ohm
  - IB 3800 25C (~ 40 cycles) = 0.0184 ohm
  - IB 4200 30C Saddle = 0.0161 ohm
  - IB 5000 40C = 0.0110 ohm
  - IB 4600 Nimh = 0.0197 ohm
- The voltage of the Lipo batteries gradually decreases over the discharge cycle. The Nimh has a rapid initial voltage drop, then has a steady voltage (higher than Lipo at 10A discharge)
- The 10A discharge voltage of the different Lipo batteries (when new) is similar.
- Around the track, the current regularly exceeds 50A in modified. Along the straight, the current draw starts at ~70A and finishes at ~ 40A.
- Using the 10A discharge voltage and the measured IR, the battery voltage under 50A load was calculated.
  - The 5000 40C battery has significantly higher voltage (~0.2V) than all other batteries in this condition (see Figure 1). At higher am draw, the difference will be greater.
- After 40 cycles, the IB 3800 battery has dropped by ~0.1V, the IR increased by 36% and the 50A voltage has dropped by ~0.3V.

Conclusion:

- The key difference between battery performance is due to the reduced internal resistance of the Higher C rated Lipo batteries.
  - Higher C rating = Reduced Internal Resistance = More Voltage under Load

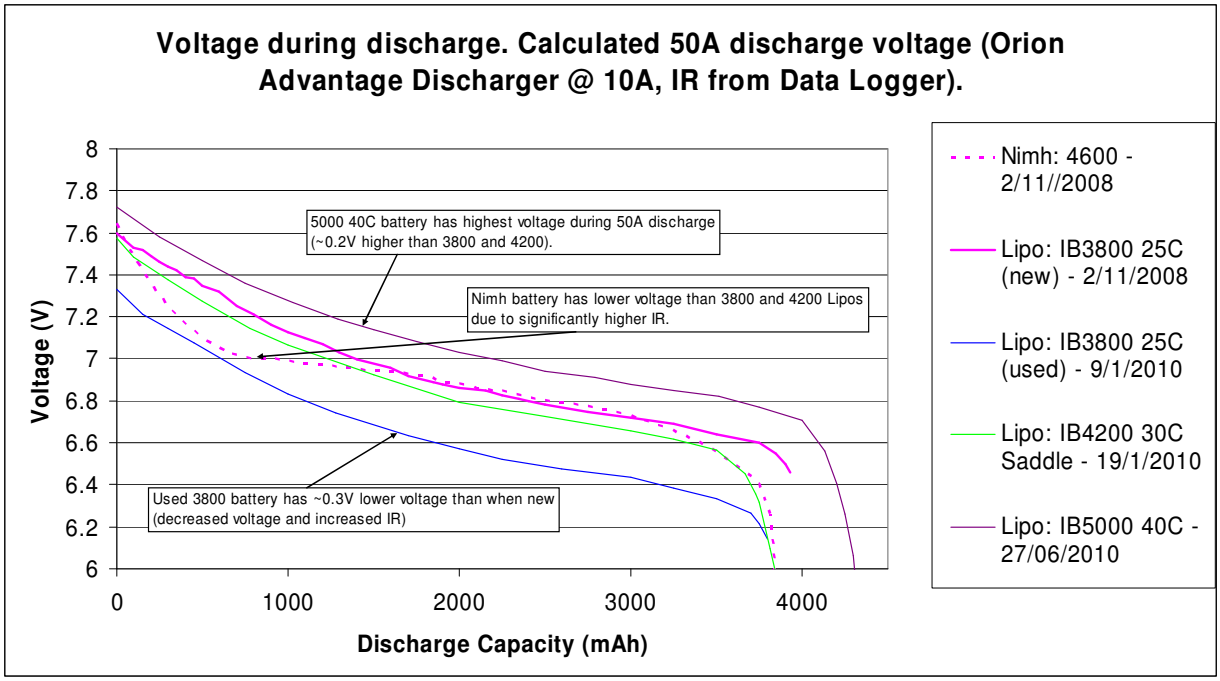

Figure 1 - Battery Voltage @ 50A Discharge Rate

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1. Method:

1.1. IR Measurement (on vehicle)

A Novak Sentry data logger was installed in an AE T4 (1/10 Stadium Truck). The truck was tested on tarmac under repeated hard acceleration / braking. Each battery was tested on the same day (i.e. same temperature).

The following data was recorded vs. Time:

- Throttle Position
- Battery voltage
- Battery current
- RPM
- Longitudinal G force / Lateral G force

The data was downloaded to laptop and converted to an xls file. A plot of voltage vs. current draw was used to measure the Internal Resistance of the battery (IR = slope of voltage drop vs. current draw).

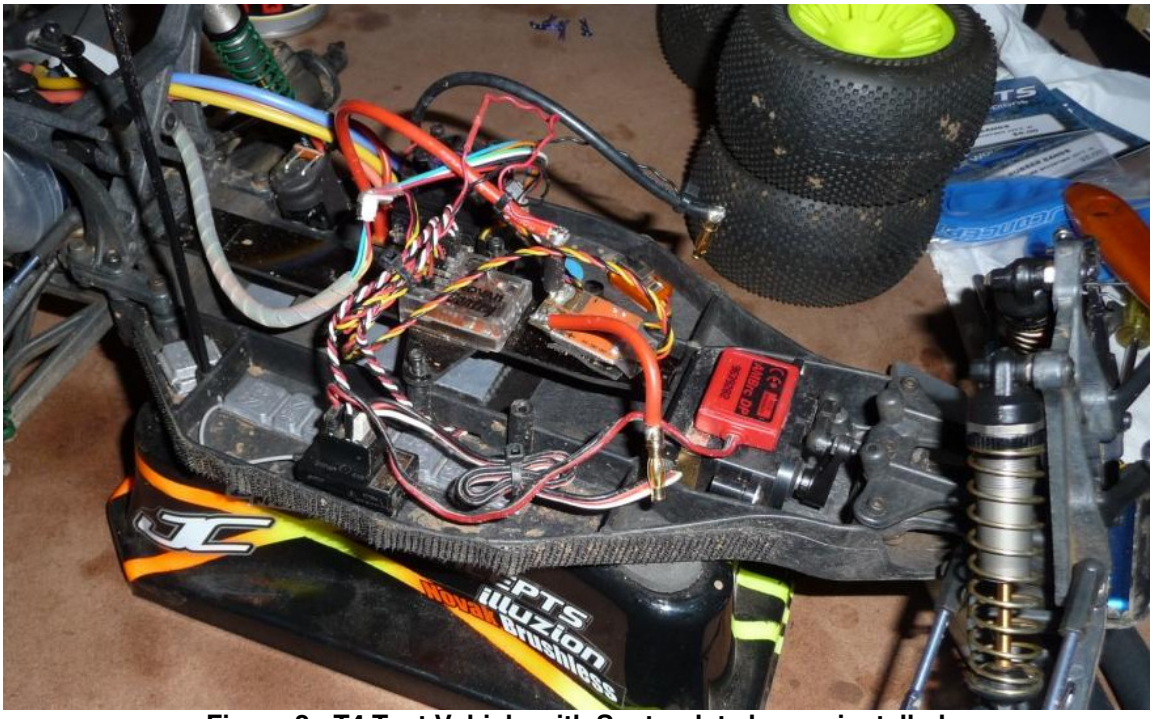

Figure 2 - T4 Test Vehicle with Sentry data logger installed

1.2. Voltage Measurement (Discharger)

An Orion Advantage Charger/ Discharger was used to measure the voltage vs. mAh during a 10A discharge. Each battery was charged ~ 1C using an Orion SBS balancer, left for ~ 30 minutes and then discharged to 6.0V. The voltage and capacity were read off the screen.

2. Vehicle Setup:

2.1. Test 2: T4 Test, March 2010

Vehicle:	Team Associated T4 Factory Team 1/10 Stadium Truck. JC Bar Code tyres, 99mm diameter (at rest).
Date:	28 March 2010
Battery:	1) Intellect 5000mAh 40C Li-Po battery (<5 cycles) 2) Intellect 4200mAh 30C+ Saddle Pack Li-Po battery (<5 cycles) 3) Intellect 3800 mAh 25C Li-Po battery (~40 cycles)
ESC:	Team Novak Havoc Pro, EXPO-1, 1% minimum drive, 2% deadband, 9% drag brake, 3 kHz brake freq, 14 Gauge wires.
Motor:	Novak 6.5 Light, 12.3mm sintered rotor, timing as set by factory.
Gearing:	13.31:1 (17/87)

2.2. Test 1: T4 Test, October 2008

Vehicle:	Team Associated B4 Factory Team 1/10 Buggy.
Date:	22 October 2008
Battery:	1) Intellect 4600 Nimh battery (<5 cycles) 2) Intellect 3800 mAh 25C Li-Po battery (<5 cycles)
ESC:	Team Novak GTB
Motor:	Novak 7.5 Light, 12.3mm sintered rotor, timing as set by factory.
Gearing:	8.78:1 (24/78)

3. Results

3.1. Acceleration Testing

3.1.1. Acceleration Testing Typical Results:

Typical results from a straight line acceleration test on tarmac are shown in Figure 3. Note that battery voltage drops under high current draw.

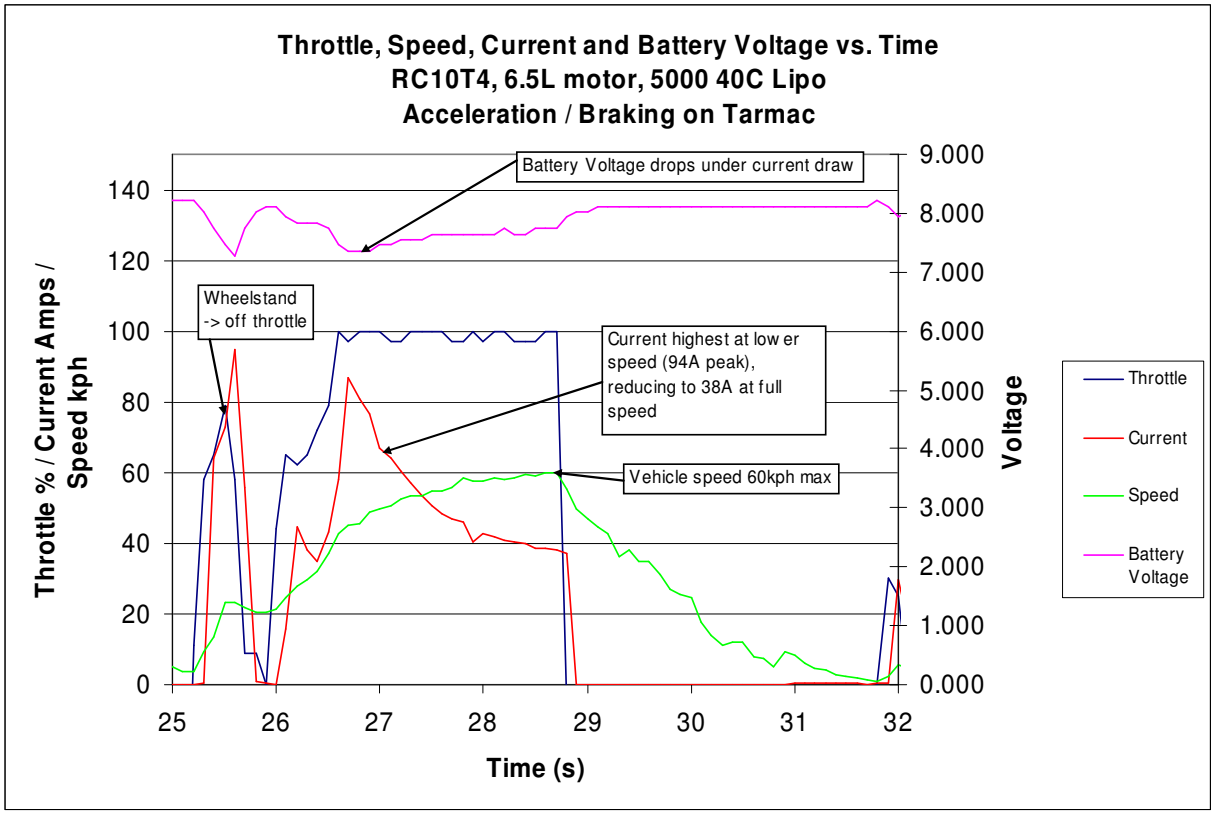

Figure 3 - Typical Acceleration Data

Note: An aim of this project was to compare the acceleration power of the different batteries. This was not possible with a 2wd stadium truck as the vehicle would wheel stand under full throttle and therefore consistent acceleration was not possible. As the stick batteries could not be mounted in the author's 4wd buggy, this test was abandoned.

3.1.2. Voltage drop vs. Current Draw results

Figure 4 and Figure 5 show battery voltage vs. current draw for straight line acceleration tests. The result is a linear voltage drop as current increases. A line of best fit has been calculated for each data set. The slope of this line is the Internal Resistance of the battery in ohms.

These results show that the batteries with the highest C ratings have the least IR (voltage drop). Lipo batteries also have significantly less IR than brand new Nimh batteries.

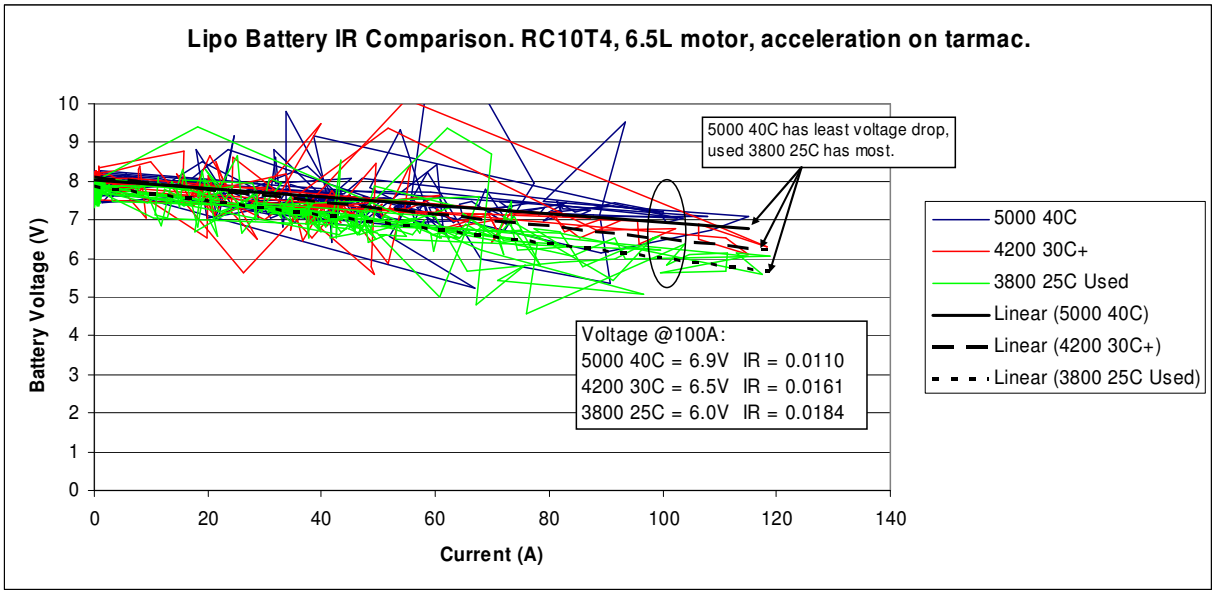

Figure 4 – Voltage vs. Current Draw (new 5000C Lipo, new 4200 Lipo, and used 3800 Lipo)

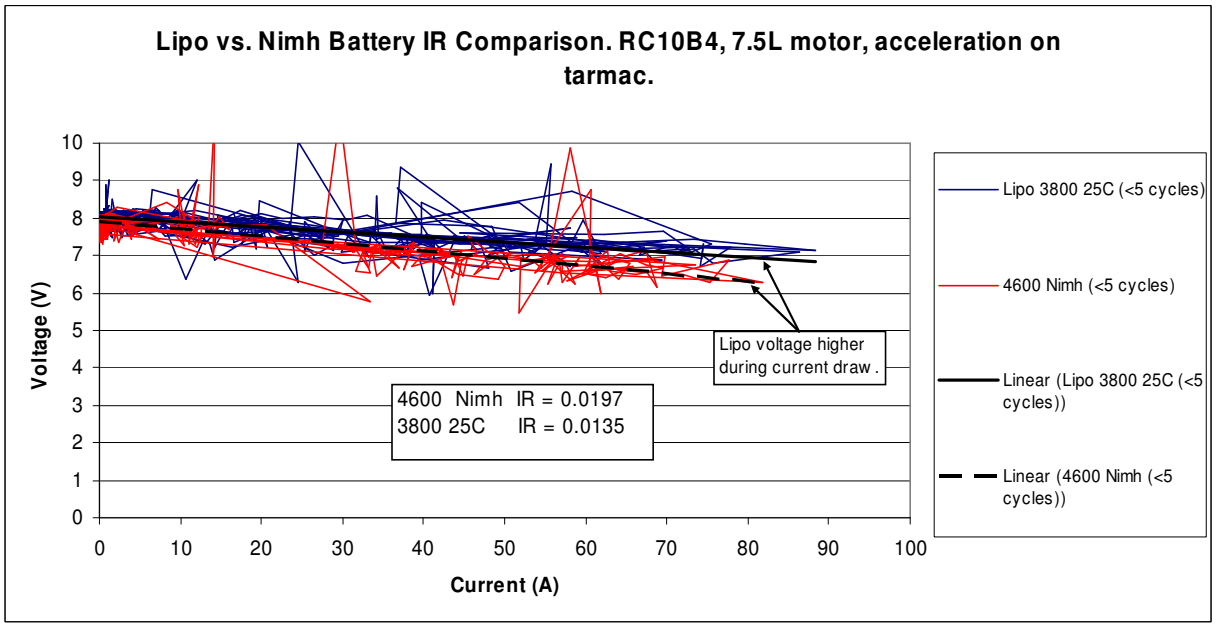

Figure 5 - Voltage vs. Current Draw (new 3800 Lipo and new 4600 Nimh)

These results are summarised in Figure 7 and Figure 6 below.

	Battery	IR (ohms)	Voltage Drop @ 100A
Lipo	5000 40C (new)	0.011	1.1
	4200 30C+ Saddle	0.0161	1.61
	3800 25C (new)	0.0135	1.35
	3800 25C (used)	0.0184	1.84
Nimh	4600 Nimh (new)	0.0197	1.97

Figure 6 - IR results

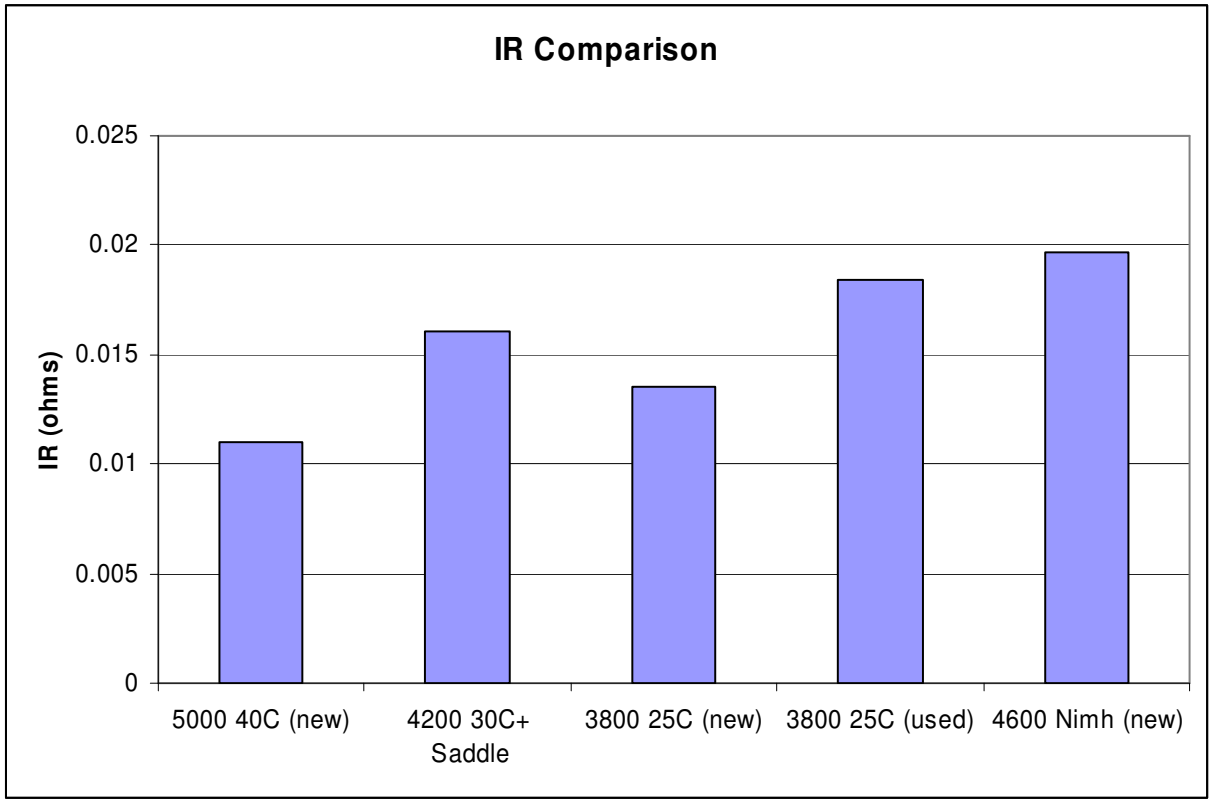

Figure 7- IR Comparison

Straight line Acceleration IR Measurement Conclusions:

- Lipo batteries have significantly less IR than Nimh
- Lipo batteries with higher C ratings tend to have less IR
- IR increases as batteries are used (3800 has ~36% higher IR after ~40 cycles).

3.2. Voltage vs. Discharge Results

3.2.1. 10A Discharge (Measured)

Figure 8 shows the measured battery voltage during a 10A discharge.

Main points:
- The Nimh battery has the highest voltage during most of the discharge cycle.
- The Nimh battery has a rapid initial voltage drop, then a very flat curve through the majority of the discharge.
- Lipo batteries have a constant voltage drop throughout the discharge.
- The voltage of the 5000 40C Lipo is slightly higher than the other Lipo batteries (~0.02V)
- The used 3800 25C has lost ~0.1V compared to new
- The actual capacity of the Nimh, Lipo 5000 and Lipo 4200 are well below rated capacity

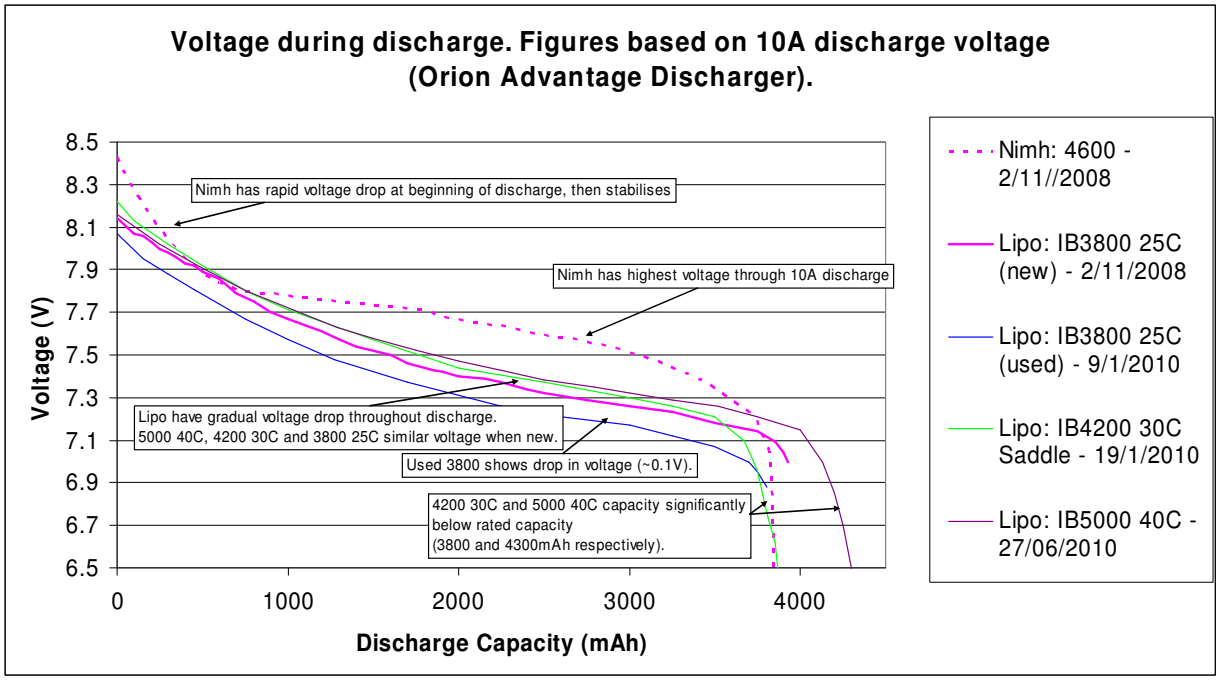

Figure 8 - Battery Voltage vs. mAh (10A Discharge)

3.2.2. Track Data

The previous graph showed a comparison of battery voltage at 10A discharge. However, on the track the current draw is often much higher. Figure 9 and Figure 10 show some data from track testing of a Truck and 4wd respectively (data taken by Novak Sentry).

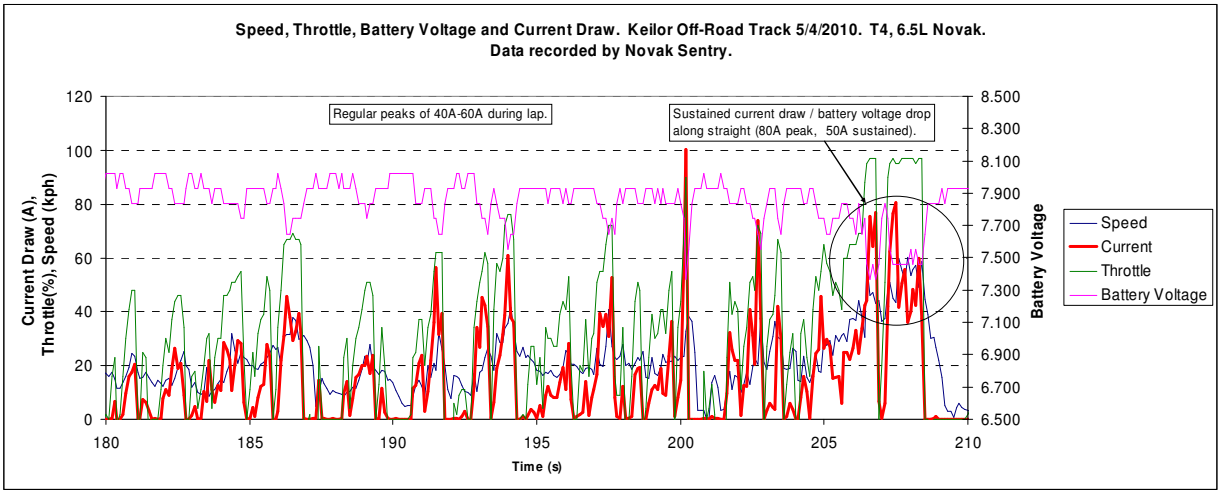

Figure 9 – Sentry Data from track testing (Truck Open)

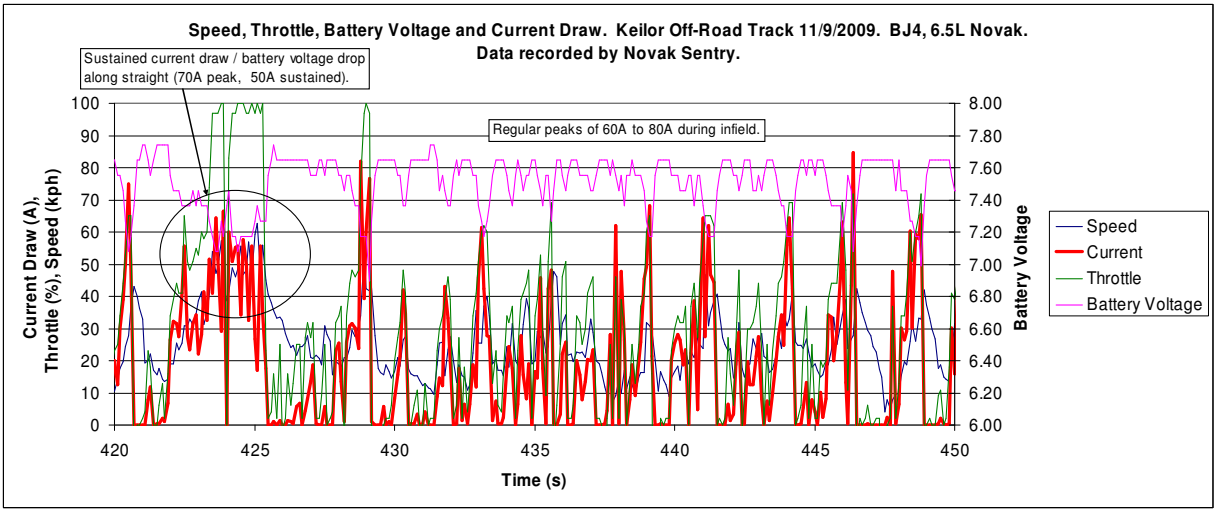

Figure 10 – Sentry Data from track testing (4wd Open)

This data indicates that the voltage in the 40-60A range is important during the lap during corner-corner acceleration and for top speed along the straight.

3.2.3. 50A Discharge (Calculated)

To give a comparison of performance under actual usage conditions (as shown in Figure 10), the battery voltage at 50A discharge was calculated using the 10A measured voltage minus the voltage drop due to internal resistance. A higher voltage under load means more acceleration power at higher speeds.

Note that this is a calculation - it relies on the assumption that IR does not change throughout the discharge cycle.

The results are shown in Figure 11 below.

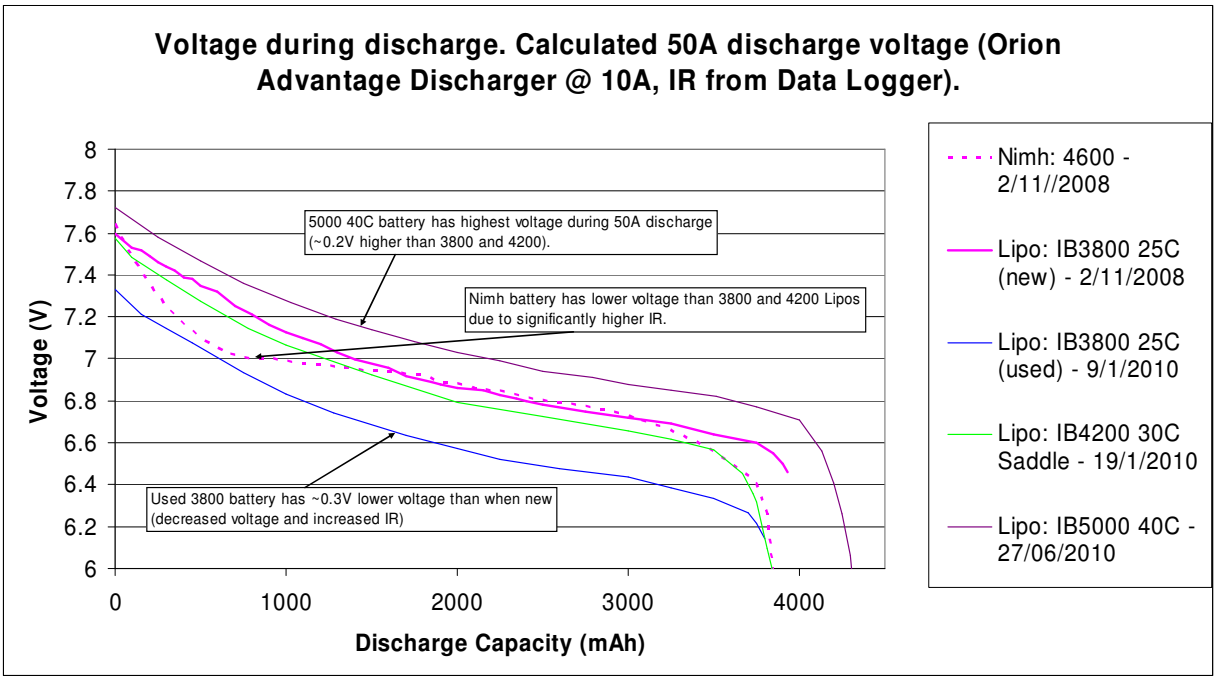

Figure 11 - Calculated Voltage at 50A Discharge

These results show that under heavy current draw, the voltage of the 5000 40C battery is much higher than the other batteries. The 4200 30C and 3800 25C batteries have more voltage than the new Nimh batteries for the first 1000 mAh, then have a similar 50A voltage for the remainder of the discharge.

Battery Voltage Conclusions:

- Lipo batteries have a constant drop of voltage over the discharge cycle. Nimh batteries have a rapid initial drop followed by a steady voltage.
- Lipo batteries with higher C ratings (eg 5000 40C) have similar voltage at low load, but maintain a much higher voltage under normal current draw. At 50A, the voltage of the 40C battery is ~0.2V higher than for the Nimh and 25/30C rated batteries.
- Older Lipo packs suffer from reduced voltage and increased IR, therefore their voltage under load is very low.
- **Lower Internal Resistance is the primary reason for high C rated batteries feeling more powerful than lower C rated batteries.**