Oyster Cellular
Battery Test Summary

Revision 1.0 – 29 June 2017

1. INTRODUCTION

The Oyster Cellular tracking unit uses 3 x "AA" cell batteries. The circuitry is designed to handle battery cell voltages from 1.5V to 1.8V, suitable for use with Li/FeS_2 batteries such as the Energizer Ultimate Lithium (L91). It can also operate briefly on regular Alkaline batteries.

Predicting the battery life is quite difficult, due to the wide range of operating conditions. The battery life is affected by:

- The type and quality of batteries used
- The type of modem (2G, 3G, LTE), and the average signal strength
- The average GPS signal strength available when installed
- The average temperature of operation
- The operating mode (periodic, GPS based tracking, accelerometer based tracking)
- The particular configuration of that mode
- The level of asset activity (trip quantity and length, loading / unloading jostling)

To help inform the battery life prediction and evaluation process, many discharge tests have been performed, and approximate battery cost constants extracted.

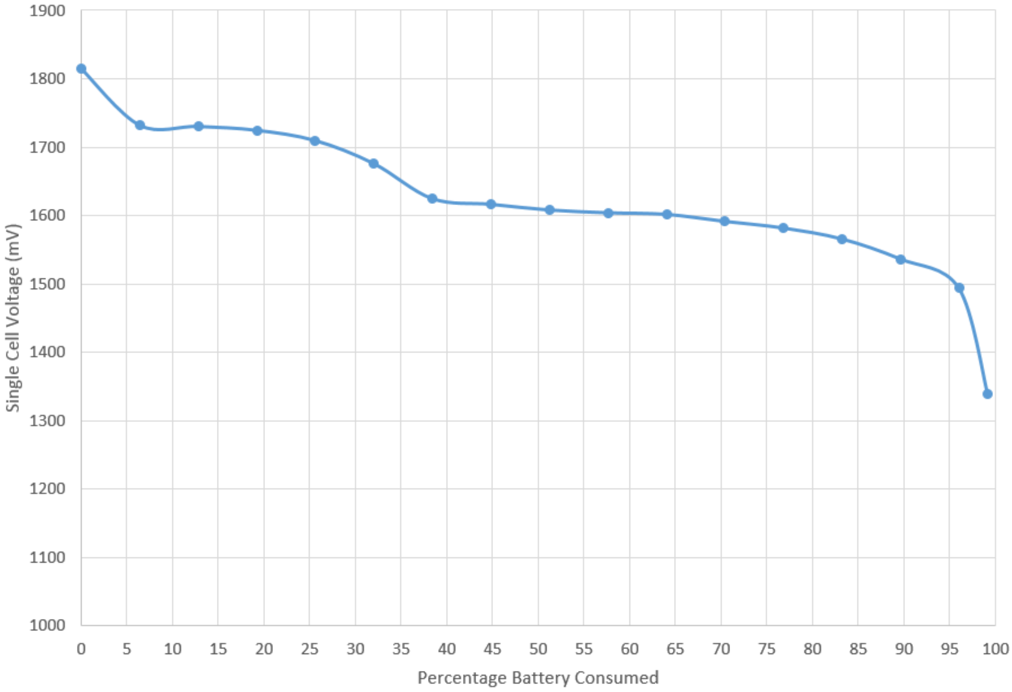
2. TEST DESCRIPTION

In our standard discharge tests, a unit is configured to repeatedly connect to our management server and upload its battery levels. There is only a 90 second rest period between connections, so this constitutes a fairly high load on the batteries compared to regular use. Every 256 connections, the unit sleeps for 3 hours to allow the battery chemistry to recover enough for an open-circuit voltage measurement. The tests were done at room temperature, in a refrigerator, and in a freezer, all with moderate cellular signal.

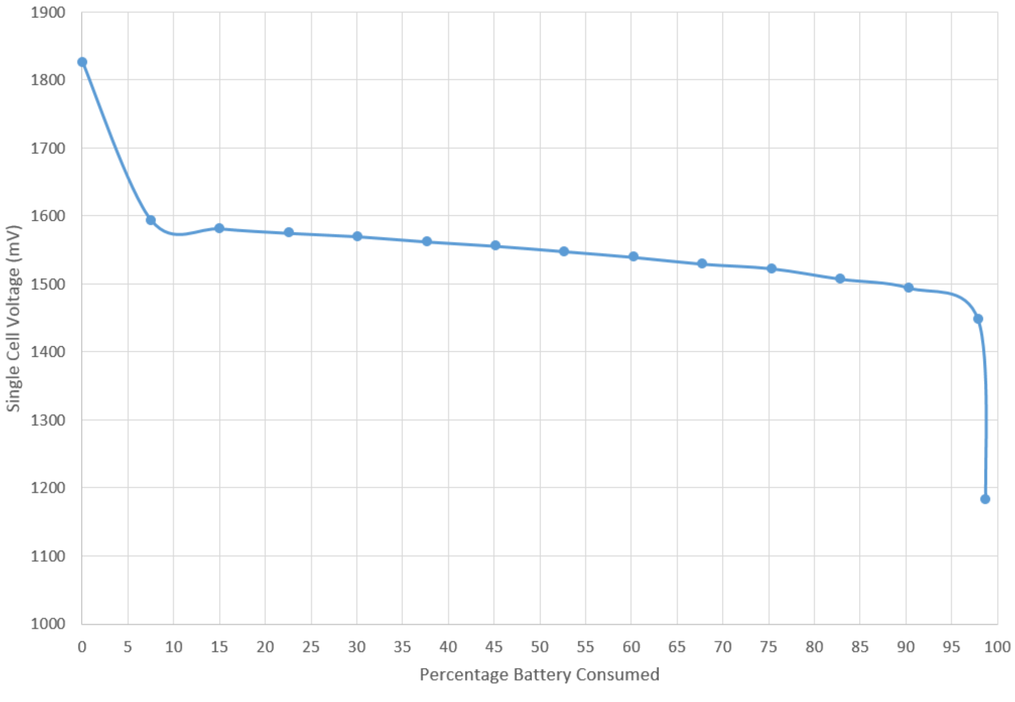
3. SAMPLE TEST RESULTS

Each test discharge produced a discharge graph similar to this sample:

At room temperature, the open circuit battery voltages (sampled after the 3 hour sleep) produce graphs similar to:



At lower temperatures (< 10), the voltage is not able to recover, and the graph becomes temperature and duty-cycle dependent. This graph was captured at roughly 5° C:



In the field, the Oyster Cellular reports the maximum voltage sampled in the last 36 hours. If temperatures are moderate or hot, and the Oyster is not in continuous operation, the state of charge can be estimated from the room temperature graph.

At lower temperatures, or in the absence of sufficient sleep time, the voltage cannot be converted to a capacity reliably. The temperature and duty cycle dependence is an unfortunate feature of the Li/FeS_2 battery chemistry. In these circumstances, the battery capacity must be estimated from the Oyster's upload count and GPS on-time. Work on automating this estimation is on-going.

4. SUMMARY OF UPLOAD ONLY TESTS

The average uploads achieved were similar at both room and refrigerator temperatures. These tests represent the current consumption of the microprocessor and modem only:

Batteries	Capacity	Modem	Cell Signal	Temperature	Uploads
3x Energizer	3500 mAh	2G	Strong	25° C	6600
3x Energizer	3500 mAh	2G	Strong	5° C	5800
3x Energizer	3500 mAh	2G	Strong	-20° C	5200
3x Ansmann	2800 mAh	3G	Strong	25° C	4000
3x Ansmann	2800 mAh	3G	Moderate	5° C	3400
3x Ansmann	2800 mAh	3G	Moderate	-20° C	3000

5. FURTHER CHARACTERISATION

Similar tests were run with GPS fix time included, and current measurements were performed on the microprocessor, GPS, and modems. Comparing these result sets and solving for the average current consumptions and battery capacity, we arrived at the following approximate constants:

Effective Battery Capacity (3x Lithium)	3.5	Ah
Cost per connection	620	µAh
Cost per data record	4.2	µAh
Cost per second of GPS time	7.5	µAh

Further characterisation is pending using real-world field data. All Oyster Cellulars report detailed breakdowns of their battery usage on a regular basis, allowing for continued monitoring and refinement of battery life predictions.

6. TRIP TRACKING PERFORMANCE

While the maximum possible uploads and the current consumption breakdown are important to know, they don't answer the question '*How long will the battery last on my asset?*'. The short answer is *2,000 to 5,000 uploads* and *2,000 to 20,000 positions*, depending heavily on your particular application. Empirical testing is the best way to determine battery life, but for a rough estimate, you can use:

$$Weeks\ of\ operation = \frac{Battery\ mAh/Trips\ per\ Week}{\left(2+\frac{Trip\ Length}{In\ Trip\ Upload\ Period}\right)\times 0.62+\left(2+\frac{Trip\ Length}{In\ Trip\ Logging\ Period}\right)\times\left(0.0042+0.0075\times(Fix\ Time)\right)+\frac{2}{Trips\ per\ Week}}$$

For instance, with an average fix time of 5s (good GPS signal and repeated fixes), 14 trips per week, of 180 minutes each, with 2 minute logging and 30 minute uploads:

$$\frac{3500/14}{\left(2+\frac{180}{30}\right)\times 0.62+\left(2+\frac{180}{2}\right)\times\left(0.0042+0.0075\times(5)\right)+\frac{2}{14}} = 28\ weeks$$

For a heartbeat-only application there are no begin-trip or end-trip uploads, so the equation changes to:

$$Weeks\ of\ operation = \frac{Battery\ mAh}{(Heartbeats\ per\ Week)\times\big(0.62 + 0.0042 + 0.0075\times(Fix\ Time)\big) + 2}$$

For instance, with an average fix time of 30s (fair GPS, single fix), and 14 heartbeats per week:

$$\frac{3500}{(14)\times\big(0.62 + 0.0042 + 0.0075\times(30)\big) + 2} = 252\ weeks$$

The 2 in the denominator accounts for a 3% per annum battery self-discharge, so the 5 years calculated above is plausible. However, batteries can be expected to fail in the field if left in operation for too long, regardless of the low self-discharge of lithium batteries. Any life-time projections of longer than 5 years should therefore be viewed with suspicion.