How to Prolong Lithium-based Batteries using the APTUS CASE:

You just bought your APTUS CASE. Congratulations on your fantastic purchase. You can use your case to improve the life of your phone battery but now allowing it to discharge fully. Always keep your Aptus Case charged and keep your phone charged. By not allowing your phone battery to discharge to zero level, you can significantly improve the life of your battery. See the below research on the li-Ion and li-polymer batteries from various industry sources.

The lithium-ion battery or lithium polymer battery works on ion movement between the positive and negative electrodes. In theory such a mechanism should work forever, but cycling, elevated temperature and aging decrease the performance over time. Since batteries are used in demanding environmental conditions, manufacturers take a conservative approach and specify the life of most Li-ion between 300 and 500 discharge/charge cycles.
Counting cycles is not conclusive because a discharge may vary in depth and there are no clearly defined standards of what constitutes a cycle. A battery may fail within the allotted time due to heavy use or unfavorable temperature conditions, but most quality packs will last considerably longer than what the stamp indicates.
The performance of a battery is measured in capacity, a leading health indicator. Internal resistance and self-discharge also play a role but with modern Li-ion these carry lower significance in predicting the end-of-battery-life.
Figure 1 illustrates the capacity drop of 11 Li-polymer batteries that have been cycled at a Cadex laboratory. The 1500mAh pouch cells for smartphones were first charged at a current of 1500mA (1C) to 4.20V/cell and allowed to saturate to 0.05C (75mA) as part of the full charge procedure. The batteries were then discharged at 1500mA to 3.0V/cell, and the cycle was repeated.

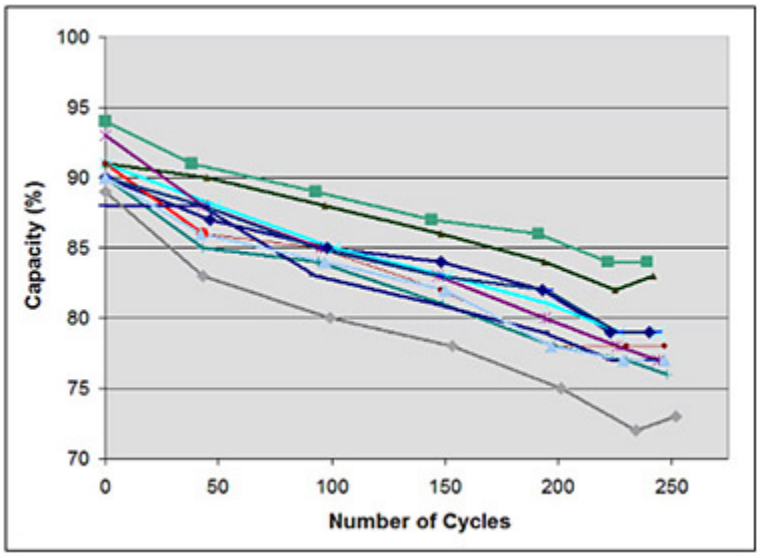


Figure 1: Capacity drop as part of cycling
A pool of new 1500mAh Li-Polymer batteries for smartphones is tested on a Cadex C7400 battery analyzer. All 11 pouch packs show a starting capacity of 88–94 percent and decrease in capacity to 73–84 percent after 250 full discharge cycles (2010). Courtesy of Cadex

Although a battery should deliver 100 percent capacity during the first year of service, it is common to see lower than specified capacities, and shelf life may have contributed to this loss. In addition, manufacturers tend to overrate their batteries; knowing that very few customers would complain. In our test, the expected capacity loss of Li-ion batteries was uniform over the 250 cycles and the batteries performed as expected.
Similar to a mechanical device that wears out faster with heavy use, so also does the depth of discharge (DoD) determine the cycle count. **The shorter the discharge (low DoD), the longer the battery will last. If at all possible, avoid** full discharges and charge the battery more often between uses. Partial discharge on Li-ion is fine; there is no memory and the battery does not need periodic full discharge cycles to prolong life.

Table 2 compares the number of discharge/charge cycles Li-ion can deliver at various DoD levels before the battery capacity drops to 70 percent. The number of discharge cycles depends on many conditions and includes charge voltage, temperature and load currents. Not all Li-ion systems behave the same.

Depth of discharge	Discharge cycles	**Table 2: Cycle life as a function of depth of discharge** A partial discharge reduces stress and prolongs battery life. Elevated temperature and high currents also affect cycle life.
100% DoD 50% DoD 25% DoD 10% DoD	300 – 500 1,200 – 1,500 2,000 – 2,500 3,750 – 4,700	

Lithium-ion suffers from stress when exposed to heat, so does keeping a cell at a high charge voltage. A battery dwelling above 30°C (86°F) is considered *elevated temperature* and for most Li-ion, a voltage above 4.10V/cell is deemed as *high voltage*. Exposing the battery to high temperature and dwelling in a full state-of-charge for an extended time can be more stressful than cycling. Table 3 demonstrates capacity loss as a function of temperature and SoC.

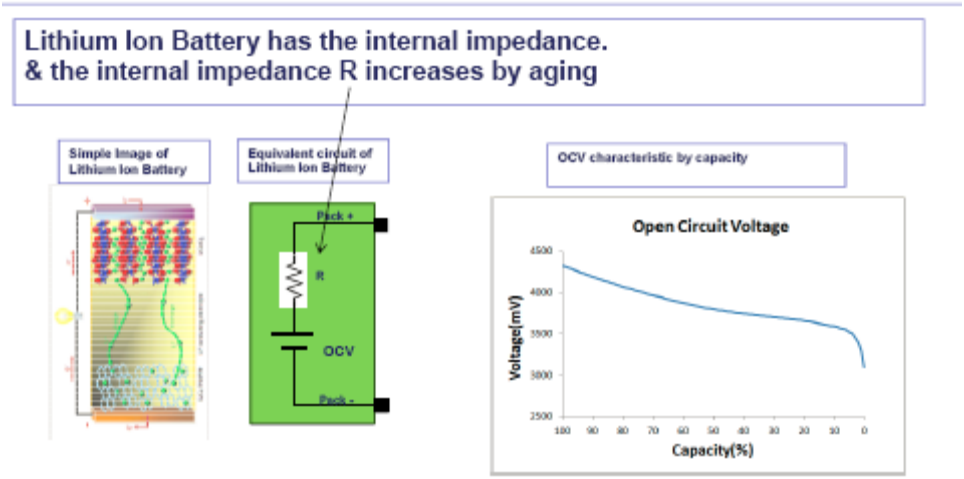
Temperature	40% charge	100% charge	**Table 3: Estimated recoverable capacity when storing Li-ion for one year at various temperatures** Elevated temperature hastens capacity loss. The capacity cannot be restored. Not all Li-ion systems behave the same.
0°C 25°C 40°C 60°C	98% 96% 85% 75%	94% 80% 65% 60% (after 3 months)	

Most Li-ions are charged to 4.20V/cell and every reduction of 0.10V/cell is said to double cycle life. For example, a lithium-ion cell charged to 4.20V/cell typically delivers 300–500 cycles. If charged to only 4.10V/cell, the life can be prolonged to 600–1,000 cycles; 4.00V/cell should deliver 1,200–2,000 and 3.90V/cell 2,400–4,000 cycles. Table 4 summarizes these results. The values are estimate and depend on the type of li-ion-ion battery.

Charge level(V/cell)	Discharge cycles	Capacity at full charge	**Table 4: Discharge cycles and capacity as a function of charge** Every 0.10V drop below 4.20V/cell doubles the cycle; the retained capacity drops accordingly. Raising the voltage above 4.20V/cell stresses the battery and compromises safety.

[4.30]	[150 – 250]	~[110%]	
4.20	**300 – 500**	**100%**	
4.10	600 – 1,000	~90%	
4.00	1,200 – 2,000	~80%	
3.92	2,400 – 4,000	~75%	

For safety reasons, lithium-ion cannot exceed 4.20V/cell. While a higher voltage would boost capacity, over-voltage shortens service life and compromises safety. Figure 5 demonstrates cycle count as a function of charge voltage. At 4.35V, the cycle count is cut in half.



Li- Ion battery capacity loses with each cycle as the internal impedance increases. The temperature has a huge negative impact on the Rds of the Li-Ion and can increase exponentially. Don't charge your APTUS Case in very high temperature. It is detrimental to your case battery as well as the phone battery if the phone is in the case.

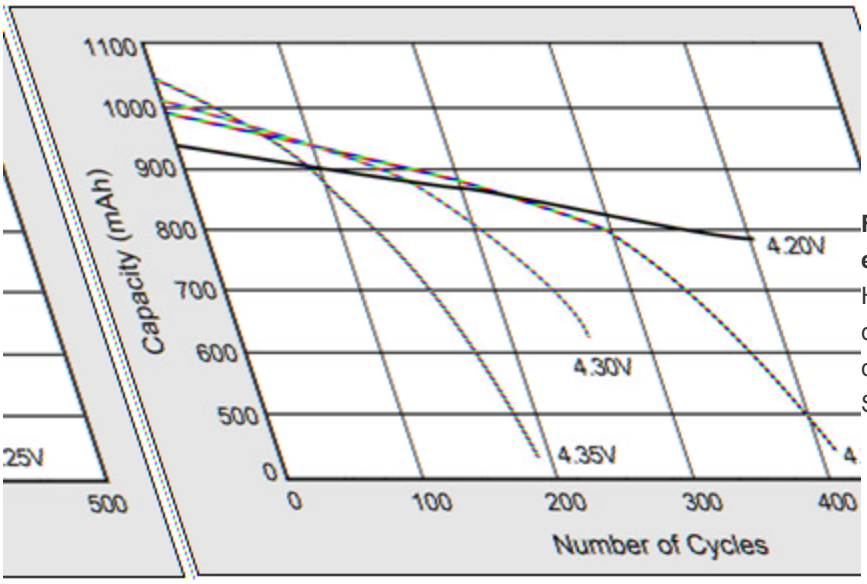


Figure 5: Effects on cycle life at elevated charge voltages
Higher charge voltages boost capacity but lowers cycle life and compromises safety.
Source: Choi et al. (2002)

Aptus Case the Li-ion battery to 4.20V/cell. This allows maximum capacity, because the consumer wants nothing less than optimal runtime. Industry, on the other hand, is more concerned about longevity and may choose lower voltage thresholds. Satellites and electric vehicles are examples where longevity is more important than capacity.