Lithium battery life chart

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Battery research is focusing on lithium chemistries so much that one could imagine that the battery future lies solely in lithium. There are good reasons to be optimistic as lithium-ion is, in many ways, superior to other chemistries. Applications are growing and are encroaching into markets that previously were solidly held by lead acid, such as standby and load leveling. Many satellites are also powered by Li-ion.

Lithium-ion has not yet fully matured and is still improving. Notable advancements have been made in longevity and safety while the capacity is increasing incrementally. Today, Li-ion meets the expectations of most consumer devices but applications for the EV need further development before this power source will become the accepted norm. BU-104c: The Octagon Battery - What makes a Battery a Battery, describes the stringent requirements a battery must meet.

As battery care-giver, you have choices in how to prolong battery life. Each battery system has unique needs in terms of charging speed, depth of discharge, loading and exposure to adverse temperature. Check what causes capacity loss, how does rising internal resistance affect performance, what does elevated self-discharge do and how low can a battery be discharged? You may also be interested in the fundamentals of battery testing.

The lithium-ion 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. Manufacturers take a conservative approach and specify the life of Li-ion in most consumer products as being between 300 and 500 discharge/charge cycles.

In 2020, small wearable batteries deliver about 300 cycles whereas modern smartphones have a cycle life requirement is 800 cycles and more. The largest advancements are made in EV batteries with talk about the one-million-mile battery representing 5,000 cycles.

Evaluating battery life on counting cycles is not conclusive because a discharge may vary in depth and there are no clearly defined standards of what constitutes a cycle(See BU-501: Basics About Discharging). In lieu of cycle count, some device manufacturers suggest battery replacement on a date stamp, but this method does not take usage into account. A battery may fail within the allotted time due to heavy use or unfavorable temperature conditions; however, most packs 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 roles, but these are less significant in predicting the end of battery life with modern Li-ion.

Figure 1 illustrates the capacity drop of 11 Li-polymer batteries that have been cycled at a Cadex laboratory.

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The 1,500mAh pouch cells for mobile phones were first charged at a current of 1,500mA (1C) to 4.20V/cell and then allowed to saturate to 0.05C (75mA) as part of the full charge saturation. The batteries were then discharged at 1,500mA to 3.0V/cell, and the cycle was repeated. The expected capacity loss of Li-ion batteries was uniform over the delivered 250 cycles and the batteries performed as expected.

Eleven new Li-ion were tested on a Cadex C7400 battery analyzer. All packs started at a capacity of 88-94% and decreased to 73-84% after 250 full discharge cycles. The 1500mAh pouch packs are used in mobile phones.

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 contribute to this loss. In addition, manufacturers tend to overrate their batteries, knowing that very few users will do spot-checks and complain if low. Not having to match single cells in mobile phones and tablets, as is required in multi-cell packs, opens the floodgates for a much broader performance acceptance. Cells with lower capacities may slip through cracks without the consumer knowing.

Similar to a mechanical device that wears out faster with heavy use, the depth of discharge (DoD) determines the cycle count of the battery. The smaller 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. The exception may be a periodic calibration of the fuel gauge on a smart battery or intelligent device(See BU-603: How to Calibrate a "Smart" Battery)

The following tables indicate stress related capacity losses on cobalt-based lithium-ion. The voltages of lithium iron phosphate and lithium titanate are lower and do not apply to the voltage references given.