Charging with APTUS Case:

Charging and discharging batteries is a chemical reaction, but Li- Batteries is claimed as an exception. Here, battery scientists talk about energies flowing in and out as part of ion movement between anode and cathode. This claim has merits, but if the scientists were totally right then the battery would live forever, and this is wishful thinking. The experts blame capacity fade on ions getting trapped. For simplicity, we consider aging a corrosion that affects all battery systems.

The Li- Batteries charger is a voltage-limiting device that is similar to the lead acid system. The difference lies in a higher voltage per cell, tighter voltage tolerance and the absence of trickle or float charge at full charge. While lead acid offers some flexibility in terms of voltage cut-off, manufacturers of Li- Batteries cells are very strict on the correct setting because Li- Batteries cannot accept overcharge. The so-called miracle charger that promises to prolong battery life and methods that pump extra capacity into the cell do not exist here. Li- Batteries is a “clean” system and only takes what it can absorb. Anything extra causes stress.

Most cells charge to 4.20V/cell with a tolerance of +/–50mV/cell. Higher voltages could increase the capacity, but the resulting cell oxidation would reduce service life. More important is the safety concern if charging beyond 4.20V/cell. Figure 1 shows the voltage and current signature as lithium-ion passes through the stages for constant current and topping charge.

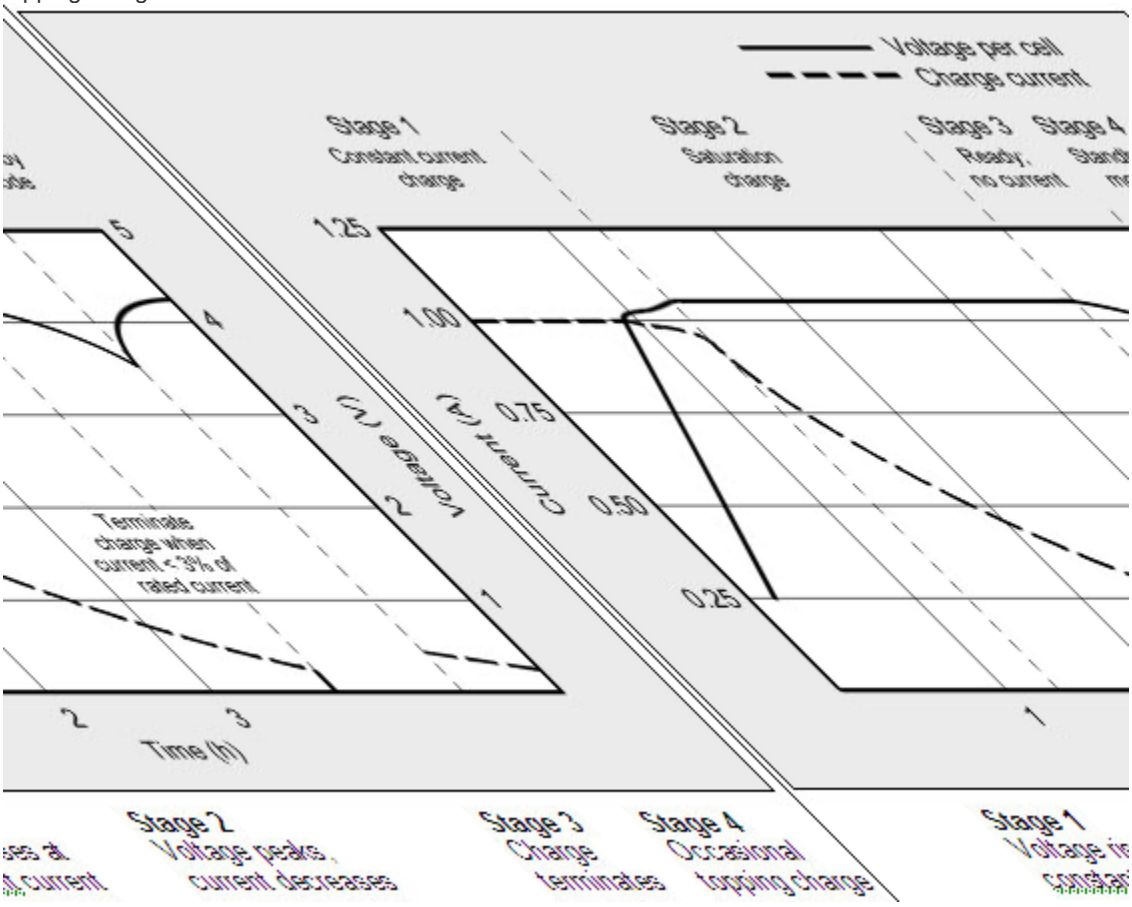

Figure 1: Charge stages of lithium-ion. Li- Batteries is fully charged when the current drops to a predetermined level or levels out at the end of Stage 2. In lieu of trickle charge, some chargers apply a topping charge when the voltage drops to 4.05V/cell (Stage 4).

Courtesy of Cadex

The charge rate of a typical consumer Li- Batteries battery is between 0.5 and 1C in Stage 1, and the charge time is about three hours. Manufacturers recommend charging the Li-batteries cell at 0.8C or less. Charge efficiency is 97 to 99 percent and the cell remains cool during charge. Some Li- Batteries packs may experience a temperature rise of about 5ºC (9ºF) when reaching full charge. This could be due to the protection circuit and/or elevated internal resistance. Full charge occurs when the battery reaches the voltage threshold and the current drops to three percent of the rated current. A battery is also considered fully charged if the current levels off and cannot go down further. Elevated self-discharge might be the cause of this condition.

Increasing the charge current does not hasten the full-charge state by much. Although the battery reaches the voltage peak quicker with a fast charge, the saturation charge will take longer accordingly. The amount of charge current applied simply alters the time required for each stage; Stage 1 will be shorter but the saturation Stage 2 will take longer. A high current charge will, however, quickly fill the battery to about 70 percent.

Li- Batteries does not need to be fully charged, as is the case with lead acid, nor is it desirable to do so. In fact, it is better not to fully charge, because high voltages stresses the battery. Choosing a lower voltage threshold, or eliminating the saturation charge altogether, prolongs battery life but this reduces the runtime. Since the consumer market promotes maximum runtime, Aptus case chargers go for maximum capacity rather than extended service life. Some lower-cost consumer chargers may use the simplified “charge-and-run” method that charges a lithium-ion battery in one hour or less without going to the Stage 2 saturation charge. “Ready” appears when the battery reaches the voltage threshold at Stage 1. Since the state-of-charge (SoC) at this point is only about 85 percent, the user may complain of short runtime, not knowing that the charger is to blame. Many warranty batteries are being replaced for this reason, and this phenomenon is especially common in the cellular industry.

Avoiding full charge has benefits, and some manufacturers set the charge threshold lower on purpose to prolong battery life. Table 2 illustrates the estimated capacities when charged to different voltage thresholds with and without saturation charge.

Charge V/cell	Capacity at cut-off voltage	Charge time	Capacity with full saturation
3.80	60%	120 min	~65%
3.90	70%	135 min	~75%
4.00	75%	150 min	~80%
4.10	80%	165 min	~90%
4.20	85%	180 min	100%

Table 2: Typical charge characteristics of lithium-ion. Adding full saturation at the set voltage boosts the capacity by about 10 percent but adds stress due to high voltage.

When the battery is first put on charge, the voltage shoots up quickly. This behavior can be compared to lifting a heavy weight with an elastic band. The lifting arm moves up quickly but the weight lags behind. The voltage of the charging battery will only catch up when the battery is almost fully charged (see Figure 3. This charge characteristic is typical of all batteries.

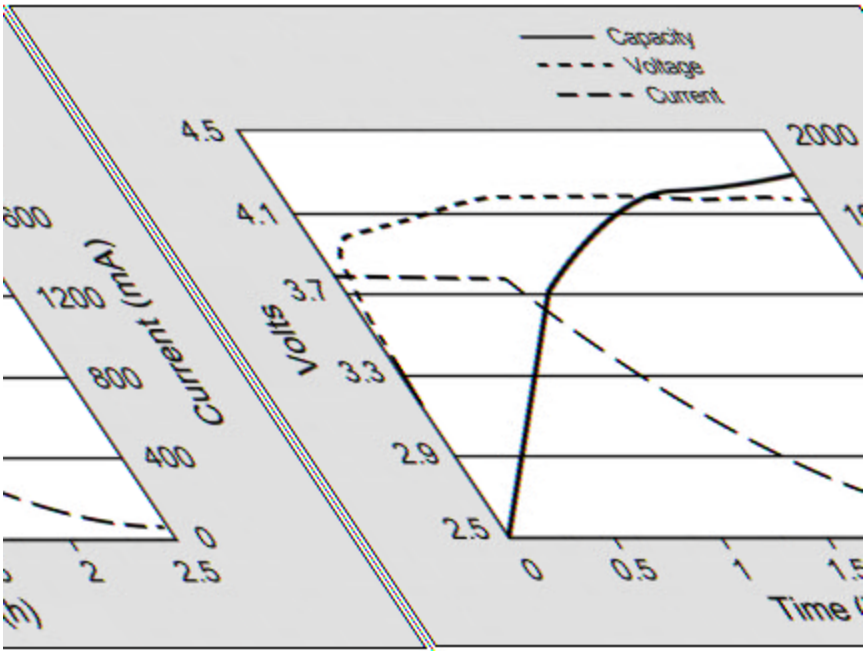

Figure 3: Capacity as a function of charge voltage on a lithium-ion battery
The capacity trails the charge voltage, like lifting a heavy weight with an elastic band. Courtesy of Cadex

Relying on the *closed circuit voltage (CCV)* to read the available capacity during charge is impractical. The *open circuit voltage (OCT)* can, however, be used to predict state-of-charge after the battery has rested for a few hours. The rest period calms the agitated battery to regain equilibrium. Similar to all batteries, temperature affects the OCV.

Li- Batteries cannot absorb overcharge, and when fully charged the charge current must be cut off. A continuous trickle charge would cause plating of metallic lithium, and this could compromise safety. To minimize stress, keep the lithium-ion battery at the 4.20V/cell peak voltage as short a time as possible. Aptus charger with its advance microprocessor based technology and protection circuit will protect the any overcharging of the case and phone battery.
Once the charge is terminated, the battery voltage begins to drop, and this eases the voltage stress. Over time, the open-circuit voltage will settle to between 3.60 and 3.90V/cell. Note that a Li- Batteries battery that received a fully saturated charge will keep the higher voltage longer than one that was fast-charged and terminated at the voltage threshold without a saturation charge.
If a lithium-ion battery must be left in the charger for operational readiness, some chargers apply a brief topping charge to compensate for the small self-discharge the battery and its protective circuit consume. The charger may kick in when the open-circuit voltage drops to 4.05V/cell and turn off again at a high 4.20V/cell. Chargers made for operational readiness, or standby mode, often let the battery voltage drop to 4.00V/cell and recharge to only 4.05V/cell instead of the full 4.20V/cell. This reduces voltage-related stress and prolongs battery life.

Overcharging Lithium-ion

Lithium-ion operates safely within the designated operating voltages; however, the battery becomes unstable if inadvertently charged to a higher than specified voltage. Prolonged charging above 4.30V forms plating of metallic lithium on the anode, while the cathode material becomes an oxidizing agent, loses stability and produces carbon dioxide (CO_2). The cell pressure rises, and if charging is allowed to continue the current interrupt device (CID) responsible for cell safety disconnects the current at 1,380kPa (200psi). Aptus Case will protected the overcharging of the battery

Over-discharging Lithium-ion

Li- Batteries should never be discharged too low, and there are several safeguards to prevent this from happening. The equipment cuts off when the battery discharges to about 3.0V/cell, stopping the current flow. If the discharge continues to about 2.70V/cell or lower, the battery's protection circuit puts the battery into a sleep mode. This renders the pack unserviceable and a recharge with most chargers is not possible. To prevent a battery from falling asleep, apply a partial charge before a long storage period.

Battery manufacturers ship batteries with a 40 percent charge. The low charge state reduces aging-related stress while allowing some self-discharge during storage. To minimize the current flow for the protection circuit before the battery is sold, advanced Li- Batteries packs feature a sleep mode that disables the protection circuit until activated by a brief charge or discharge. Once engaged, the battery remains operational and the on state can no longer be switched back to the standby mode.

Do not recharge lithium-ion if a cell has stayed at or below 1.5V for more than a week. Copper shunts may have formed inside the cells that can lead to a partial or total electrical short. If recharged, the cells might become unstable, causing excessive heat or showing other anomalies. Li- Batteries packs that have been under stress are more sensitive to mechanical abuse, such as vibration, dropping and exposure to heat.

Charging Lithium-ion Polymer

Charging Li- Batteries polymer, also referred as Li-polymer, is very similar to a regular lithium-ion battery and no changes in algorithm are necessary. Most users won't even know if their battery is Li- Batteries or Li-polymer. The word "polymer" has been used as promotional hype and does not reflect special attributes other than to know that the battery is built in a different way to a standard Li- Batteries.

Most polymer batteries are based on a hybrid architecture that is a cross between Li- Batteries and Li-polymer. There are many variations within the polymer family, and the true dry polymer battery for the consumer market is still years away.

Simple Guidelines for Charging with your Aptus Case:

- Charge at a moderate temperature. Do not charge below freezing.
- Aptus case can charge your battery to full charge but Lithium-based batteries does not need to be fully charged; a partial charge is better.
- Discontinue using Aptus Case if the battery or Aptus Case gets excessively warm.
- Before prolonged storage, apply some charge to bring the Case to about half charge.

- Over-discharged batteries can be “boosted” to life again. Aptus case can charge the battery that is over discharged and can raise the voltage of the battery. But if the voltage does not rise after some time discard the Case after few attempts. .