
Lithium battery charging

How to charge to extend battery life?

Why Lithium? Compared with the traditional battery, lithium-ion battery charge faster, last longer, and have a higher power density for more battery life in a lighter package. When you know a little about how they work, they can work that much better for you.

Lithium-ion battery cycle charge and discharge will lead to internal corrosion and electrolyte and electrode degradation deterioration. The Li ion charger is a voltage-limiting system that has similarities to the lead acid system. the difference with Li-ion lie in a higher voltage per cell, tighter voltage tolerances and the absence of trickle or float charge at full charge., While lead acid offers some flexibility in terms of voltage cut off. Lithium-ion battery manufacturers are very strict on the correct setting, because lithium-ion battery cannot accept over-voltage. The so-called miracle charger that promises to prolong battery life and gain extra capacity with pulses and other gimmicks does not exist. Li-ion is a “clean” system.

Charging Lithium cobalt oxide battery

Li-ion with the traditional cathode materials of cobalt, nickel, manganese and aluminum typically charge to 4.20V/cell. The tolerance is $\pm 50\text{mV/cell}$. Some nickel electrode batteries charge up to 4.1V, and high capacity lithium batteries may go to 4.3V and higher. Figure 1 shows the voltage and current signature as lithium-ion passes through the stages for constant current and topping charge. Full charge is reached when the current decreases to between 3 and 5 percent of the Ah rating.

ITECH ITS5300 battery test system can perform battery constant voltage, constant current, shelved, working conditions simulation and other charge and discharge step according to battery characteristics or the customer's requirements, which is suitable for all kinds of battery aging,

cycle life test applications.

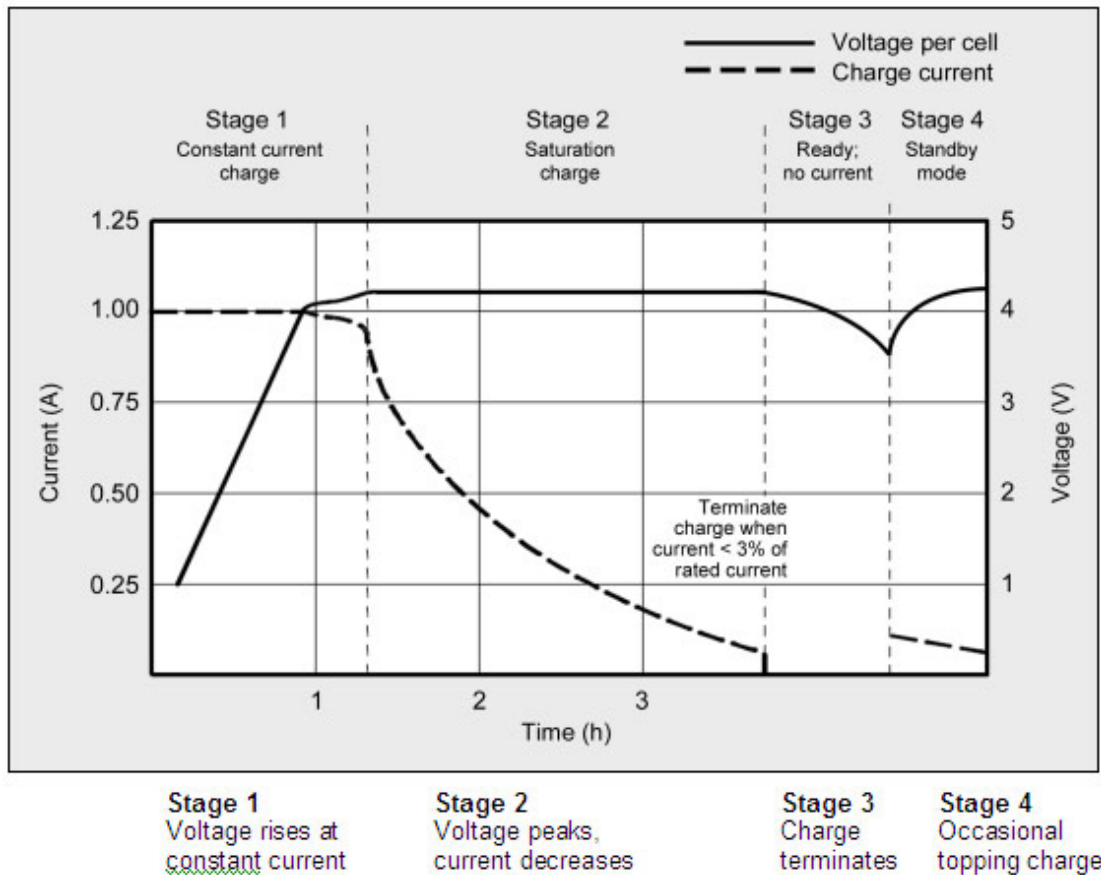


Figure 1. Lithium ion battery charging stages

The advised charge rate of an Energy Cell is between 0.5C and 1C like 18650; the complete charge time is about 2–3 hours. Battery manufacturers recommend charging at 0.8C or lower rate to extend battery life. Manufacturers of these cells recommend charging at 0.8C or less to prolong battery life; However, most Power Cells can take a higher charge C-rate with little stress. Some Li-ion packs may experience a temperature rise of about 5°C (9°F) when reaching full charge. This could be due to the protection circuit and/or elevated internal resistance. Discontinue using the battery or charger if the temperature rises more than 10°C (18°F) under moderate charging speeds.

The ITS5300 battery test system can monitor and record the temperature of hundreds of battery cells in real time during charging and discharging, and has the function of over temperature alarm and automatic protection to avoid the cost and unreliability of manual monitoring.

Increasing the charge current does not hasten the full-charge state by much. The battery can reach the voltage peak more quickly, but the saturation charge will take longer accordingly. With higher current, Stage 1 is shorter but the saturation during Stage 2 will take longer. A high current charge will, however, quickly fill the battery to about 70 percent. For example, Apple lithium-ion battery uses fast charging to quickly reach 80% of its capacity, then switches to



slower trickle charging. This hybrid charging mode not only can quickly charge, but also extends the lifespan of your battery.

Lithium batteries do not need to be completely filled like lead-acid batteries. In fact, it is best not to be fully charged, because the high voltage will cause pressure on the battery. Choosing a lower cut-off voltage or reducing the saturation charge process can extend battery life but reduce standby time, and the consumer market charger can only fill the battery to its maximum capacity, which is less important than battery life.

Some low-cost lithium battery 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. State-of-charge at this point is about 85 percent, a level that may be sufficient for many users.

Certain industrial chargers set the charge voltage 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
	60%	120 min	~65%
	70%	135 min	~75%
	75%	150 min	~80%
	80%	165 min	~90%
	85%	180 min	100%

Table 2. **Typical charge characteristics of lithium-ion.**

As shown in Figure 3, when the battery is first put on charge, the voltage shoots up quickly. This behavior can be compared to lifting a weight with a rubber band, causing a lag. The capacity will eventually catch up when the battery is almost fully charged. This charge characteristic is typical of all batteries. The higher the charge current is, the larger the rubber-band effect will be. Cold temperatures or charging a cell with high internal resistance amplifies the effect.

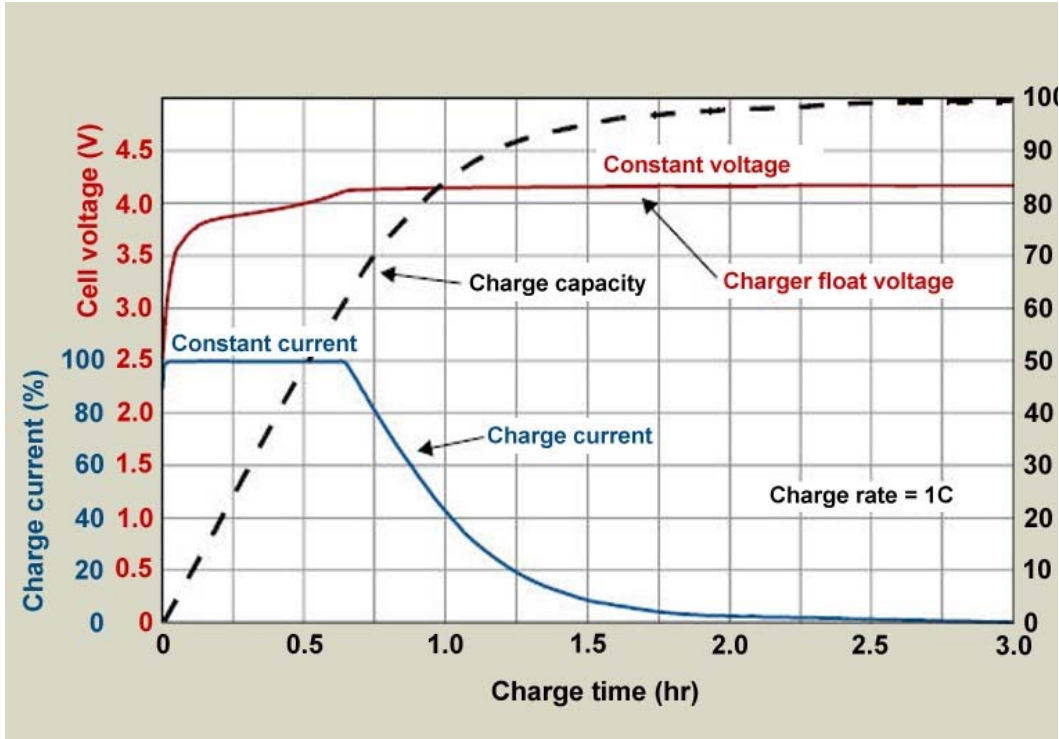


Figure 3: Volts/capacity vs. time when charging lithium-ion.

The ITS5300 charging and discharging process can detect the change of charging voltage, current and capacity, and can extract and analyze the parameters and automatically draw the relation graph between the parameters (figure 4).

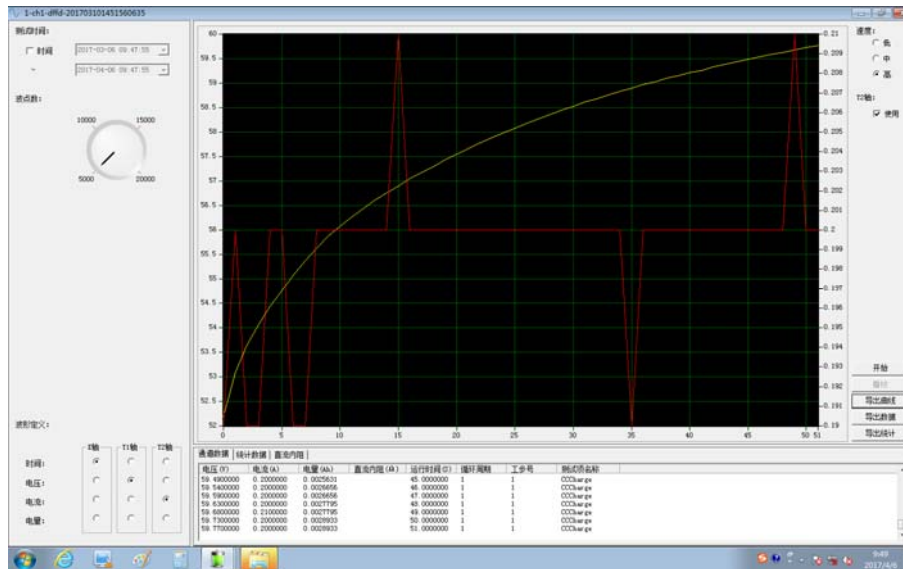


Figure 4. ITS5300 Battery test system data analysis

Estimating SoC by reading the voltage of a charging battery is impractical; measuring the open circuit voltage (OCV) after the battery has rested for a few hours is a better indicator. As with all batteries, temperature affects the OCV, so does the active material of Li-ion. However, the SoC of smart phones, laptops and other portable electronic devices is estimated by coulomb counting.



Li-ion that offer high coulombic efficiency and low self-discharge. Improvements have been made by also taking aging and temperature-based self-discharge into consideration but periodic calibration is still recommended to bring the “digital battery” in harmony with the “chemical battery.” The ITS5300 battery system can test and record the battery charge and discharge capacity during battery cycle charging and discharging to help customers build the battery model quickly.

Lithium ions cannot absorb overcharge, when full charged, the charge current must be cut off. A continuous trickle charge would cause plating of metallic lithium and compromise safety. To minimize stress, keep the lithium-ion battery at the peak cut-off as short as possible. As can be seen from Fig. 3, for example, when the core voltage of an unsaturated charge is at 3.7V-3.9V, the time remaining at the high voltage is much shorter than the time of the saturation charge.

A portable device should be turned off during charge. This allows the battery to reach the set voltage threshold and current saturation point unhindered. A parasitic load confuses the charger by depressing the battery voltage and preventing the current in the saturation stage to drop low enough by drawing a leakage current. A battery may be fully charged, but the prevailing conditions will prompt a continued charge, causing stress.

Overcharging Lithium-ion

While the traditional lithium-ion has a nominal cell voltage of 3.60V, Li-phosphate (LiFePO) makes an exception with a nominal cell voltage of 3.20V and charging to 3.65V. Relatively new is the Li-titanate (LTO) with a nominal cell voltage of 2.40V and charging to 2.85V. 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 on a Li-ion designed for 4.20V/cell will plate metallic lithium on the anode. The cathode material becomes an oxidizing agent, loses stability and produces carbon dioxide (CO₂). The cell pressure rises and if the charge is allowed to continue, the current interrupt device (CID) responsible for cell safety disconnects at 1,000–1,380kPa (145–200psi). Should the pressure rise further, the safety membrane on some Li-ion bursts open at about 3,450kPa (500psi) and the cell might eventually vent with flame.

A fully charged battery has a lower thermal runaway temperature and will vent sooner than one that is partially charged. All lithium-based batteries are safer at a lower charge, and this is why authorities will mandate air shipment of Li-ion at 30 percent state-of-charge rather than at full charge.

ITS5300 test system can set the charge and discharge arbitrary cut-off voltage, cut-off capacity and cut-off time, which is suitable for battery shipping and pre-charge.

In addition to internal cell safeguards, an external electronic protection circuit prevents any cell from exceeding 4.30V on charge. In addition, a fuse cuts the current if the skin temperature of any cell approaches 90°C (194°F). To prevent the battery from over-discharging, a control circuit cuts off the current path at about 2.20V/cell.

Each cell in a string needs independent voltage monitoring. The higher the cell count, the more complex the protection circuit becomes. ITS5300 can detect up to two hundred batteries



voltage, AC resistance and temperature at the same time, you can quickly find the voltage imbalance between the batteries, and are fully charged are charged, set the cut-off voltage to prevent the battery overcharge and over discharge

Summary

Simple Guidelines for Charging Lithium-based Batteries

- Turn off the device or disconnect the load on charge to allow the current to drop unhindered during saturation.
- Charge at a moderate temperature. Do not charge at freezing temperature.
- Lithium-ion does not need to be fully charged; a partial charge is better.
- Discontinue using charger or battery if the battery gets excessively warm.
- Apply some charge to an empty battery before storing (40–50 percent SoC is ideal).

Simple Guidelines for Discharging Batteries

- Heat increases battery performance but shortens life by a factor of two for every 10°C increase above 25–30°C (18°F above 77–86°F). Always keep the battery cool.
- Prevent over-discharging. Cell reversal can cause an electrical short.
- On high load and repetitive full discharges, reduce stress by using a larger battery.
- A battery exhibits capacitor-like characteristics when discharging at high frequency. This allows higher peak currents than is possible with a DC load.
- Nickel- and lithium-based batteries have a fast chemical reaction; lead acid is sluggish and requires a few seconds to recover between heavy loads.

Lithium-ion is not the only battery that poses a safety hazard if overcharged. Lead- and nickel-based batteries are also known to melt down and cause fire if improperly handled. Properly designed charging equipment is paramount for all battery systems and temperature sensing is a reliable watchman. The ITS5300 battery test system has been favored by many international companies, which can be customized according to customer needs. Applied to almost all battery systems, the comprehensive protection design including temperature sensing can work for a long time, with power protection and data analysis capabilities, and is a trustworthy testing system for users.