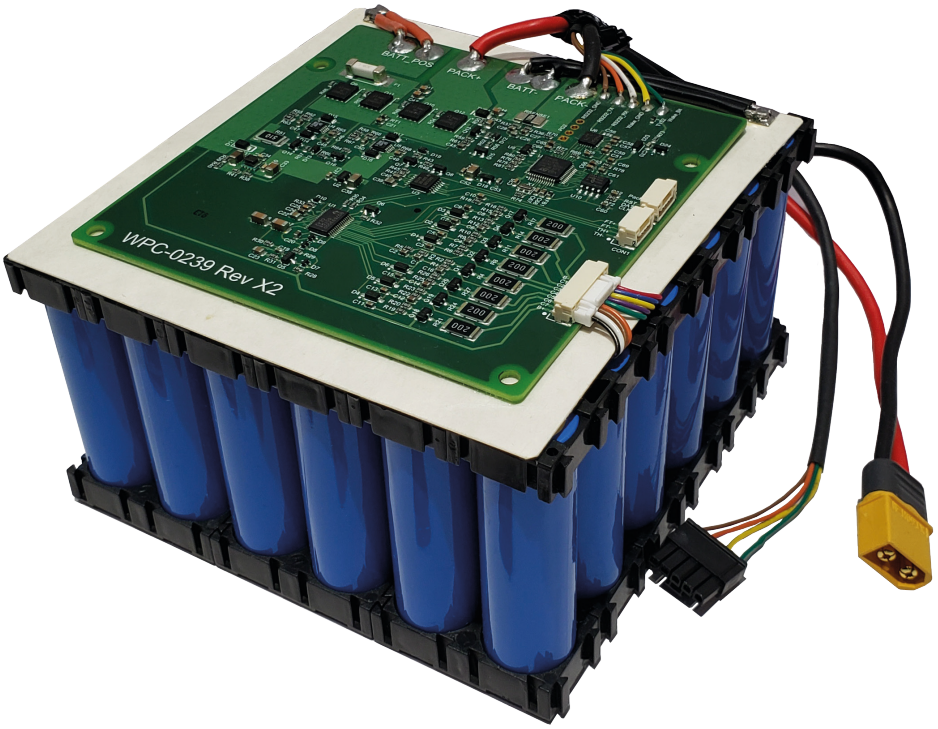
Custom Power

WHITE PAPER: LITHIUM BATTERY CHARGING



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Most product developers do not take charging into account at the beginning of the product design requirement process; usually it is an afterthought.

Proper charging of Lithium cells (Li-Ion) is an extremely important function and cannot be taken lightly. Most Lithium cells require a precisely controlled process that must follow the cell manufacturer recommendations closely.

This white paper looks at the essential elements to consider when working with Lithium batteries and the factors which will optimize charging for improved performance and life span. It explores charge voltage, current and the cell skin temperature.

Charging Li-Ion Cells
Li-Ion cells require a constant current, constant voltage (CC/CV) type of charger.

Charge current flows into the cell at constant rate of 0.5C to 1C rate until the cell voltage reaches 4.20 volts. At this point, the charger switches to constant voltage mode, sometimes referred to as CC to CV point.

At this point, the charger must hold the voltage extremely accurately while the charge current drops to C/10 or C/20. Once the current drops to that level the charger should disconnect and prevent any further current flow into the cell.

It is critical that the charge voltage control is accurate, even a 1% over voltage charging can result in cell failure. Cell charge under voltage can result in reduced capacity. Therefore, it is best to design for CC/CV transition voltage to be a bit below the maximum specified by the cell manufacturer.

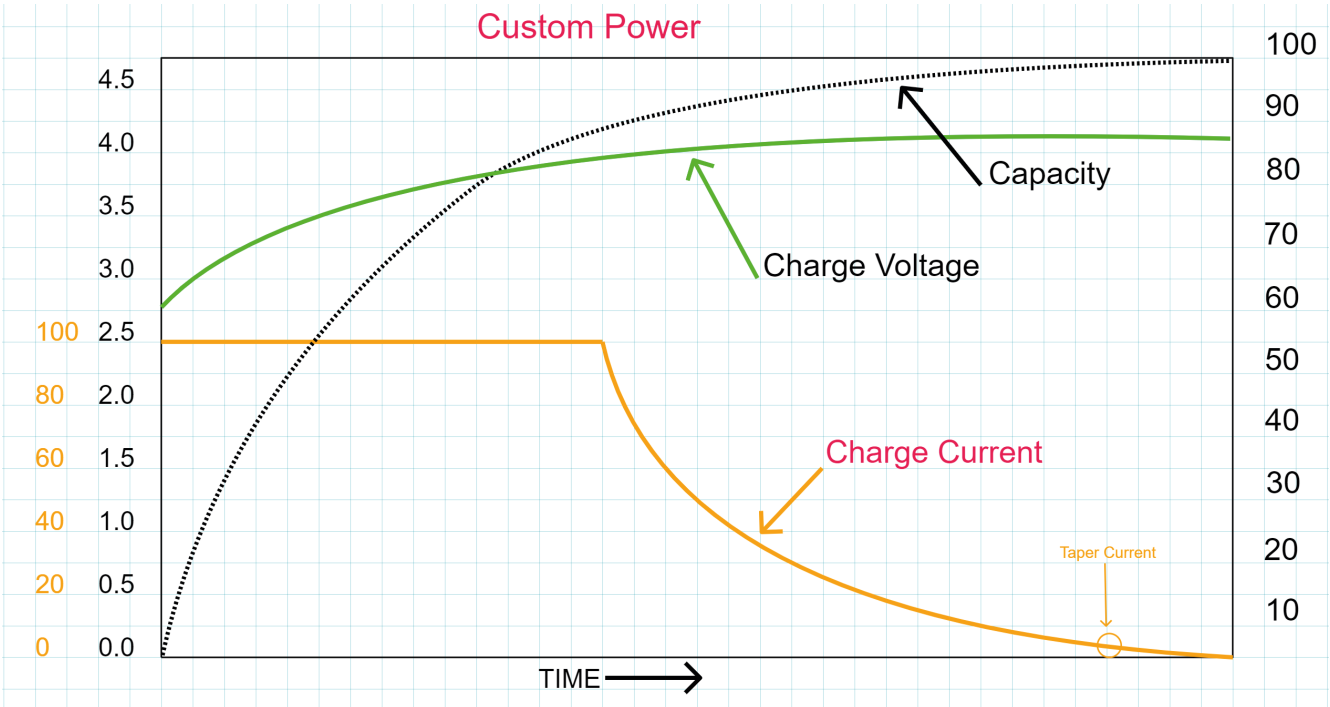


Figure 1: Lithium Ion charging profile using constant-current method until battery voltage reaches 4.2V, followed by top-off using constant-voltage until the charge current drops down to C/10 or C/20.

Figure 1 shows the typical charge profile of a Lithium cell. If the cell voltage is below 2.6-2.8-volt threshold, it should be charged at a low charge rate (~0.1C) until the cell voltage reaches approximately 3 volts.

Once the cell voltage is above 3 volts the charge rate can be increased to 0.5C to 1C. As the cell voltage approaches 4.2-volt charge transitions to constant voltage mode and the charge current starts to drop until it reaches 0.1C this is referred to as Taper current set point, at this point the charger should turn off and no more current should be allowed to flow into the battery pack..

Lithium Plating

Over voltage charging can lead Lithium plating, even a slight increase (above 4.20 volt) in CC/CV point can cause Lithium plating to occur which can cause internal cell short.

During the charge process, Lithium ions from cathode are transferred to anode material (Figure 2) normally a porous carbon structure. During this process if the charge voltage is above 4.20 volts, or the charge current is much higher than 1C rate or the cell temperature is low, Lithium plating takes place.

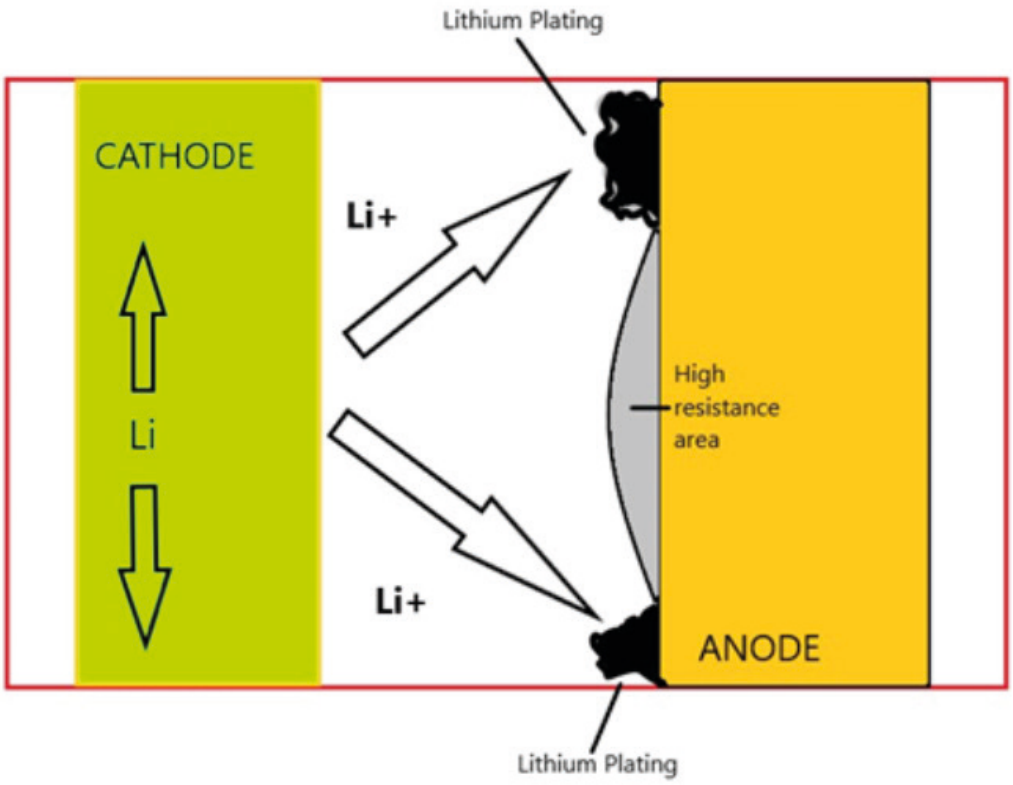


Figure 2: Minor physical nonconformities in the stack or jelly roll can lead to lithium plating also

Charging and Temperature

It is important to observe once the charger is shut off that no current flows into the battery pack, even a small leakage current over a few hours can create an unsafe condition. A poorly designed charger can lead to cell failure if the user leaves the battery pack connected to the charge over an extended period.

Figure 3: Charging vs. temperature

Smart chargers are designed to compensate for cell skin temperature. A typical industrial charger will allow normal charging between (Figure 3) 8°C to 35°C, above 35°C and below 8°C charging voltage and current is reduced to add safety margins. As mentioned above, charging at low temperatures is unsafe and should be avoided, it is best not to allow charging below 5°C, when it is necessary to charge below 5°C the CC/CV voltage should be lowered to 4 volts and charge current no more than 250mA.

Charging Safely

Below is a charge profile (Figure 4) used for a handheld portable device that is used on long shifts. Safety is paramount in these applications and safe charging is vital to good customer experience.

Charging is disabled below 5°C and above 45°C.

By reducing the charge current and voltage below 10°C Lithium plating will not occur.

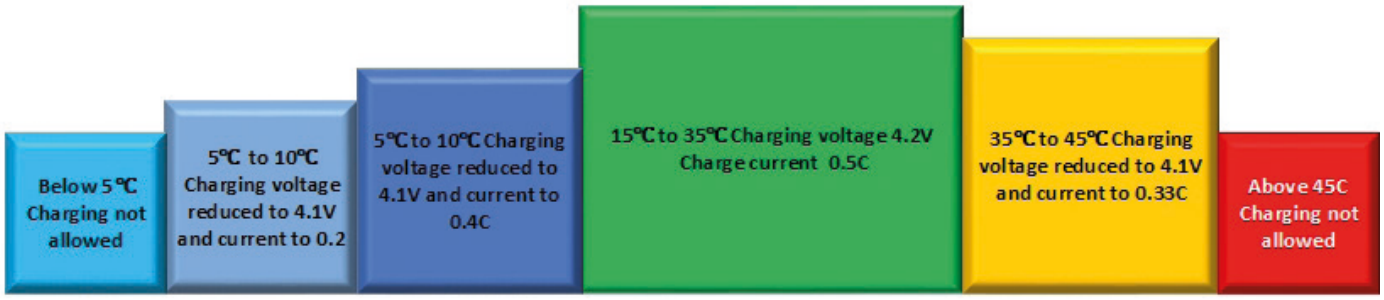


Figure 4: Recommended charge profile for handheld product with safety as the highest priority

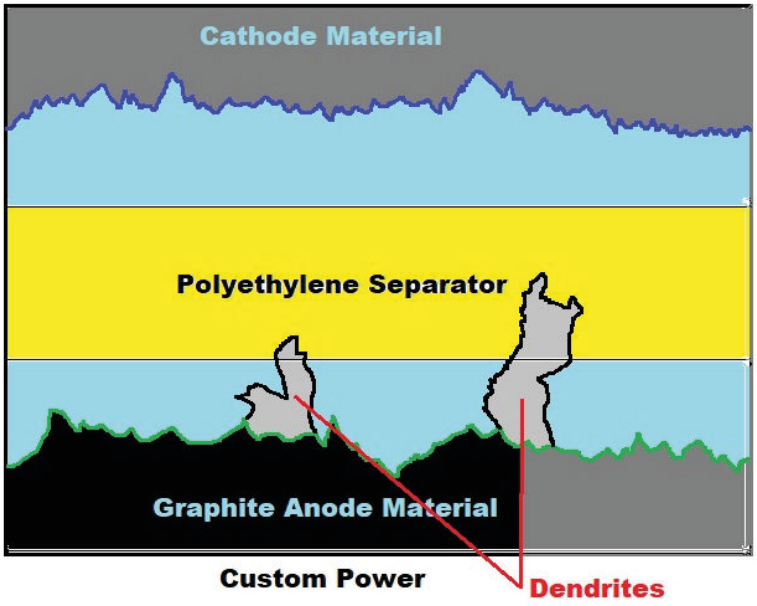


Figure 5: Anode to cathode shorting caused by lithium dendrite.

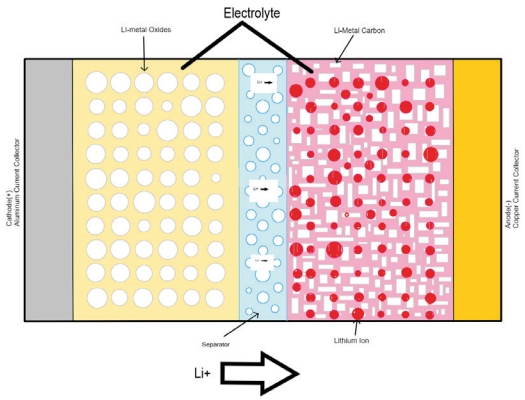


Figure 6: Charge

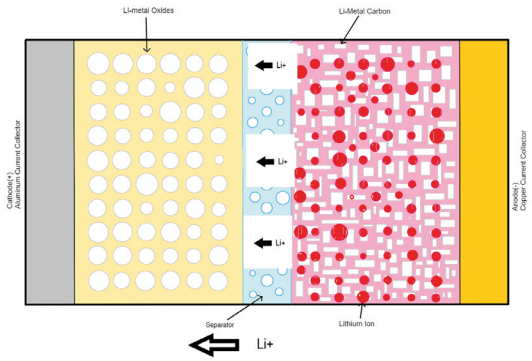


Figure 7: Discharge

Internal working of typical Lithium cell, active materials are physically separated from each other by a very important thin, porous membrane that physically keeps the Anode and Cathode separate but allows the Lithium Ions Li+ to travel back and forth.

Abusive charging, high temperature operation and physical abuse can damage this separator and allow the Anode and Cathode to encounter each other. When that happens (Figure 6), a cell will surely go into thermal run away.

Modern Lithium cells pack substantial amounts of energy when fully charged, for example LG INR18650MJ1 is rated at 3500mAh capacity and when fully charged its terminal voltage is 3.7 volts.

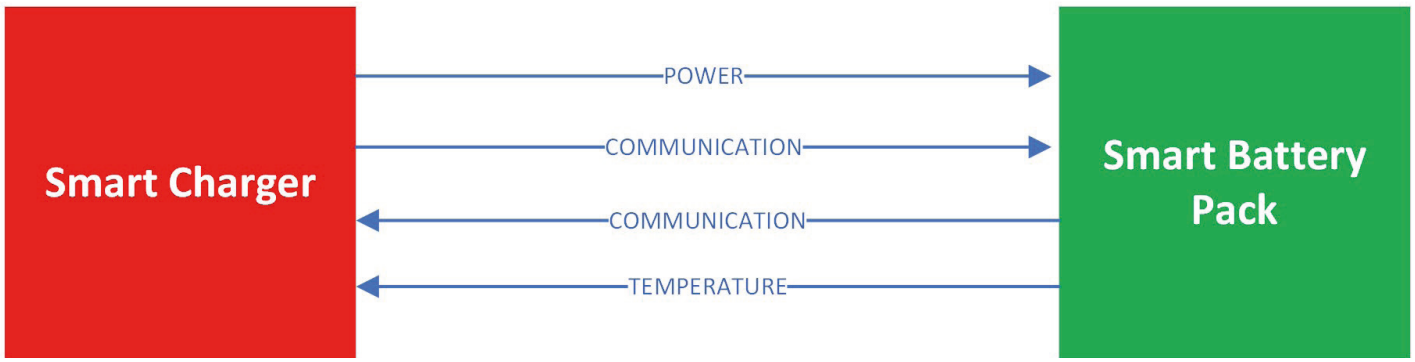
Energy [J] = Voltage [V] x Current [A] x Time [s]

Energy contained in a fully charged 18650 cell is approximately 46620J =3.7V x 3.5A x 3600s

In case of an internal failure all that energy will cause thermal runaway which will in turn be released in a few seconds. The energy number above does not include the energy released during thermal runaway caused by the chemical reaction of anode, cathode, and electrolyte materials. A typical 18650 cell can release 11-15 liters of gas during failure mode.

The Charging Process
The heart of a lithium battery's efficiency lies in its Battery Management System (BMS). This intelligent system communicates with the charger, sending signals about the battery's current state. The charger, in turn, processes these signals and delivers the precise current needed. This intricate communication ensures your battery charges optimally, maintaining both performance and longevity.

The Dangers of 'Non-Smart Charging'
Using a mismatched charger can lead to unsafe conditions, where the charger cannot properly identify the precise battery charge parameters. This can result in overcharging or undercharging; this diminishes the battery's life cycle and can pose safety hazards. In extreme cases, it might even lead to battery failure or fires.



Information retrieved by charger from the battery pack:
- Charge voltage and current requirements
- Core pack temperature (may be multiple locations)
- Individual cell voltages
- Voltage and current as measured by fuel guage (calibrated values)
- Serial number
- State of charge
- Vital fuel guage flags
- State of health
- Number of charge / discharge cycles

Custom Power multi cell chargers are designed to seamlessly work together with battery packs designed by Custom Power, charger design considers the specific electrical characteristics and safety features. Using advanced communication between the pack the charger ensures a safe and optimized charging regime. Using a charger and battery from different brands is very risky, not understanding the detailed design parameters of the battery and charger may not deliver the best customer experience.

Custom Power Battery Charger Benefits
If you need a reliable battery charger to keep the power flowing for your industrial, defense, medical, aerospace, or other application, Custom Power offers several benefits:

We work with tier one cell suppliers such as Panasonic, LG, Samsung, Saft and Molicel.

Our team is constantly learning more about chargers and the latest technologies to bring you best-in-class battery chargers.

We offer some of the most comprehensive solutions on the market: in addition to chargers, we bring you battery packs, custom battery packs, and battery supplies.

At Custom Power, we focus on knowledge, experience, and partnership and treat every project as unique - because it is. Many industries rely on our batteries and chargers, which keep power flowing in hospitals, at defense installations, in aerospace facilities, and in other high-stakes environments.

Contact our solution development team to see how we can optimize your power systems.

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