

PROTECTING RECHARGEABLE LITHIUM BATTERIES

As battery technology and form factors for electronic devices expand beyond traditional cylindrical cells, Lithium based batteries are in increased demand due to their high energy density, small form factors and design flexibility. Although some Li-ion cylindrical cells contain a PTC as a basic protection against current surges, popular Lithium polymer (Pouch and Prismatic type) cells do not contain PTCs, and as such, additional consideration must be applied in order to prevent premature failure caused by misuse and or improper handling.

NEED FOR BATTERY PROTECTION

Battery packs containing Li-ion cells require a mandatory protection circuit or CID (Circuit Interrupt Device) to assure safety. In addition to cell level safeguards, an external protection circuit or what is commonly known as PCM (Protection Circuit Module) is often implemented to battery packs to prevent thermal runaway resulting either from Over-charge, Over-discharge, Over-voltage, Over-current, and Short-circuit condition. Since Lithium based batteries contain very high specific energy per volume, an unprotected cell or battery pack can potentially result in costly and irreversible damage.

OVER-CHARGE CONDITIONS

Various battery chemistries require specific charging profiles to optimize performance and prevent safety issues during charge. Generally, most Li-ion cells operate in constant current and constant voltage charging algorithm where charging current is dependent on the rated capacity at the cell/pack level while the charging voltage must be kept at 4.20V/cell to prevent over-charge condition. Since Li-ion cells contain high potential energy compared to other rechargeable batteries it is particularly important to avoid exposing them to over-charge conditions as it can lead to damaging the internal structure.

A cell/battery pack over-charge condition is often caused by:

- Faulty charger: Charger fails to stop or limit the supply current once it is fully charged
- Improper Use: Cell or battery is charged using non-compatible charger

OVER-CURRENT CONDITIONS (CHARGE OR DISCHARGE)

Over-current condition occurs when a Li-ion cell or battery pack is charged or discharged at a much higher current than set by its cell design manufacturer. For example, if the manufacturer states a Li-ion 18650 cell is only rated for 2.0A maximum continuous discharge current but the user decides to neglect this warning and applies a continuous load of 4.0A. The cell has now gone into what is known as



over-current condition which cause internal temperature to rise from chemical reaction and may lead to swelling or rupturing of cells and risk damaging the battery. To help prevent this condition the end-user must always adhere to manufacturer's cell or battery specification.

SHORT-CIRCUIT CONDITIONS

Accidental short-circuits can occur when exposed positive and negative terminals come into contact with metal objects such as a key or keychain, which will lead to rapid rise in cell internal temperature and result in performance degradation as well as swelling of cells. Test results on unprotected lithium cell from testing laboratories such as UL and Intertek has shown that temperatures can reach in excess of 600°C or 1112°F during this type of event and may lead to venting of toxic and highly flammable gases. Once ignited, it can propagate to other cells or flammable objects and lead to irreversible damage.

Short-circuit condition is often caused by:

- Exposed positive and negative terminals that come into contact with metal objects
- Reversed polarity
- Poor manufacturing or assembly



Before thermal runaway



After thermal runaway

OVER-DISCHARGE CONDITIONS

Typical rechargeable lithium cells can safely operate down to 2.75V/cell. However, when an unprotected lithium cell is discharged past the minimum voltage level you run the risk of damaging the cell and ultimately lead to degraded cycle-life, unstable voltage characteristics and swelling of cells from internal chemical reaction. Generally, a protection circuit is designed with some extra buffer capabilities and sets the discharge protection slightly higher, usually in the +0.25~0.40V range from the cell manufacturer's minimum voltage for protection and longevity.

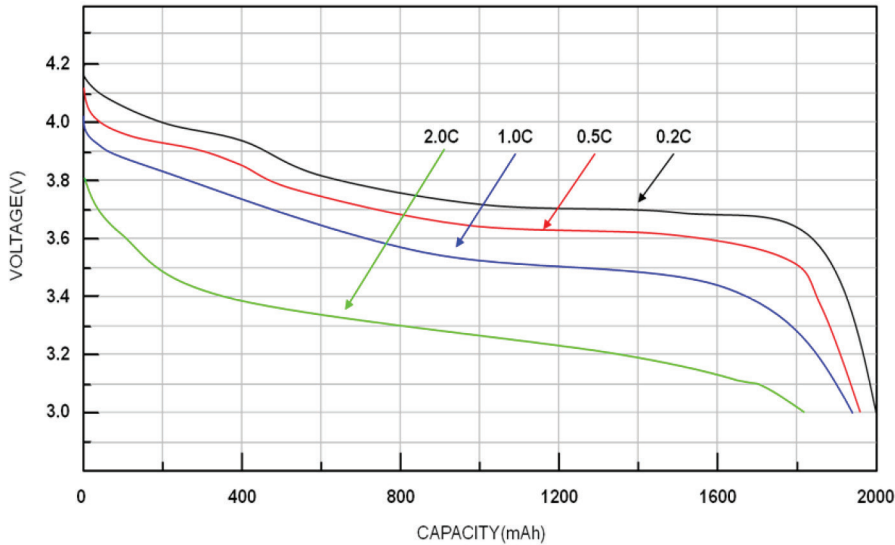




Common causes of over-discharge conditions include:

- Host device minimum operating voltage is below cell's discharge cut-off Voltage
- Improperly set discharge cut-off Voltage
- Poorly implemented Protection Circuit Module

Voltage Characteristics on various loads. Cut-off Voltage = 3.0V

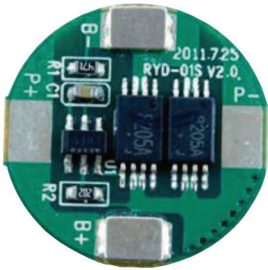


KEY ELEMENTS OF PROTECTION CIRCUIT MODULE

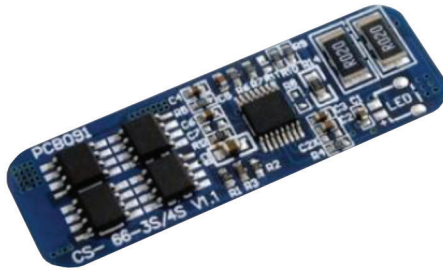
- Over-charge: Protects against over-charge condition
- Over-current: Protects against over-current condition
- Short-circuit: Protects against external short-circuit condition
- Over-discharge: Protects against over-discharge condition

- Temperature: Protects against overly high cell temperature
- Cell balancing: Balancing of cells in battery pack containing multiple cells in series

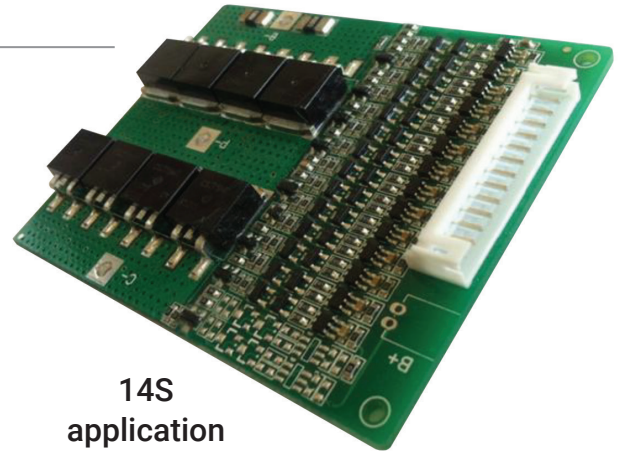
Various types of PCMs



PCM for
1S configuration



3S/4S
application



14S
application

COMMON SIGNS OF DAMAGED LITHIUM-ION/POLYMER CELLS

- Visible swelling or deformation
- Unstable Voltage characteristic during charge/discharge
- Significantly diminished run time
- Electrolyte leakage
- Fire from thermal runaway

SUMMARY

Various considerations must be given prior to designing a device requiring rechargeable Lithium-ion batteries. Following cell manufacturer's specific electrical parameters such as maximum discharge/charge current, operating Voltage, as well as operating temperature is some of the most important design elements to ensure battery safety, performance, longevity and return on investment.

AUTHOR: Kevin Oh - Application Engineer at ZEUS Battery Products, www.zeusbatteryproducts.com