Battery Management Systems: How Battery Chemistry Affects Battery Charger IC Selection

Battery-powered devices are integral to modern technology, and have revolutionized our ability to take devices with us anywhere and everywhere. Medical devices such as glucose meters and pacemakers allow people to thrive with minimal inconvenience, and devices such as portable power tools and radios can be used to coordinate efforts for disaster relief. In our day-to-day lives, we use battery-powered devices such as smartphones and laptops, which help us work effectively and connect with the world.

This article will discuss the benefits and challenges of four battery chemistries (Li-ion, LFP, Li-polymer, and NiMH) in battery applications under 30V. It will also introduce battery charger ICs that can be used to optimize battery performance, runtime, and lifespan for these battery types in applications.

Battery charger ICs play a crucial role in the battery management system (BMS) by ensuring safe charging. They can also work with fuel gauges and battery monitors and protectors to help protect the battery, monitor the battery's health, and communicate with the BMS if there are any issues.

Lithium-Ion (Li-Ion) Batteries

Li-ion batteries are commonly used in devices such as laptops, e-bikes, electric vehicles (EVs), and smartphones. These batteries provide higher energy density, longer lifespan, and have low discharge rates to further improve longevity between charges.

When Li-ion batteries are charged, the lithium ions flow from the cathode to the anode (see Figure 1). The cathode is the battery's positive electrode, made of a lithium compound, while the anode is the battery's negative electrode, and is typically made of carbon. When these batteries discharge while powering devices, the opposite occurs, and lithium ions flow from the anode to the cathode.

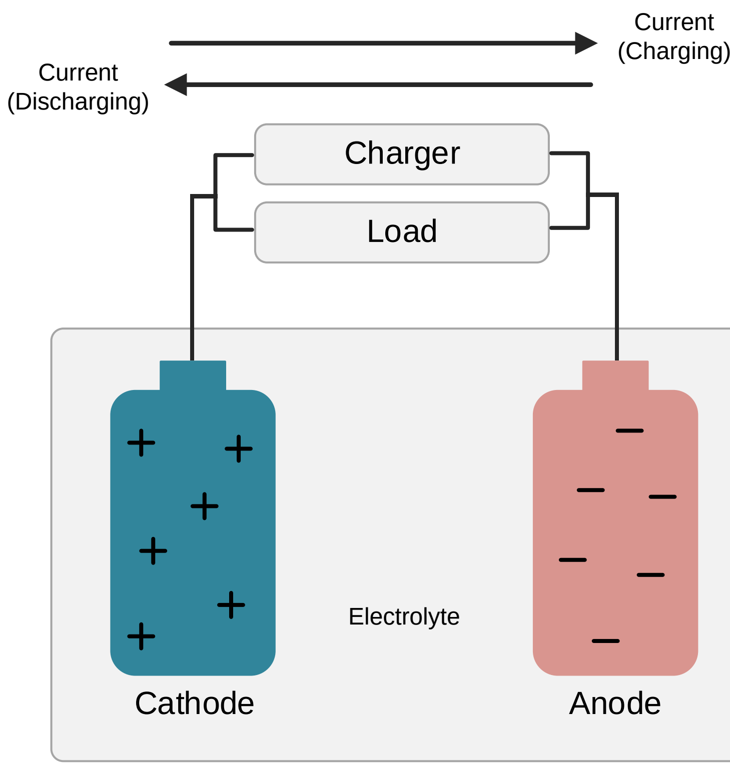

Figure 1: Simplified Battery Charging/Discharging Diagram

There are a few drawbacks to using Li-ion batteries. If they are overcharged or overly discharged, they can have reduced performance. Under extreme temperature conditions, they are potentially dangerous and can explode or catch fire.

Li-Ion Battery Chargers

Li-ion battery charger ICs are designed to charge Li-ion batteries and allow them to be reused. Li-ion chargers can monitor the current, voltage, and temperature to regulate the charging process. Li-ion battery charger ICs have multiple charging phases, including:

1. Trickle charge: This stage is typically used when the battery voltage (V_{BATT}) is low, such as when the battery is deeply discharged or disconnected. During trickle charge, the charger IC sources a small current to charge the battery pack's capacitance.
2. Pre-charge: In this stage, the charger IC begins to slowly charge the battery so that V_{BATT} slowly rises at a safe speed.
3. Constant-current (CC) charge: CC charge, also called fast charging, is when the battery can safely handle larger currents. This stage continues until V_{BATT} reaches its full or floating voltage.
4. Constant-voltage (CV) charge: This stage guarantees safe operation. The charger IC monitors V_{BATT} during CC charging, then switches to CV charging once V_{BATT} exceeds the battery cell voltage in the pack.
5. Charge termination: Charge termination denotes when charging is complete, and V_{BATT} begins to decay.

Figure 2 shows the charging profile for battery chargers.

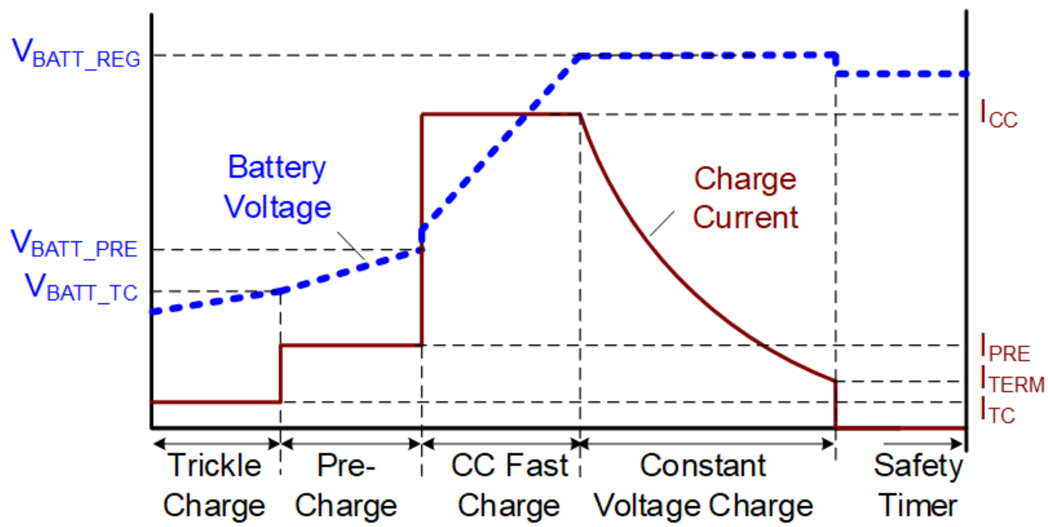

Figure 2: Battery Charging Profile

This charging profile can also be implemented for other battery types, including all of the battery chemistries and battery charger ICs listed in this article.

Li-ion charger ICs and other Li-related chargers can often incorporate protection features such as over-voltage protection (OVP), short-circuit protection (SCP), and battery voltage protections. In addition, they may have configurable protection thresholds, limits, and values, which allow them to accommodate a wide array of BMS applications.

Consider the MP2770, a 1-cell switching charger that can be used in portable applications such as smartwatches, gaming controllers, drones, and mobile point-of-sale systems (POS). When an input is present, the MP2770 operates in charge mode and uses V_{BATT} to charge in one of three modes: pre-charge, CC charge, and CV charge. When the input is absent, the MP2770 can operate in boost mode and be powered from the battery.

The MP2770 integrates an 8-bit analog-to-digital converter (ADC) that can monitor the input voltage (V_{IN}), V_{BATT}, system voltage (V_{SYS}), and battery current (I_{BATT}), among others. Additional parameters — such as the input current limit (I_{IN_LIMIT}), boost voltage (V_{BST}), and protection thresholds — can be configured for flexible use.

The MP2770 is available in a space-saving QFN-18 (3mmx4mm) package, and provides system power path management to complete a highly integrated battery management system solution (see Figure 3).

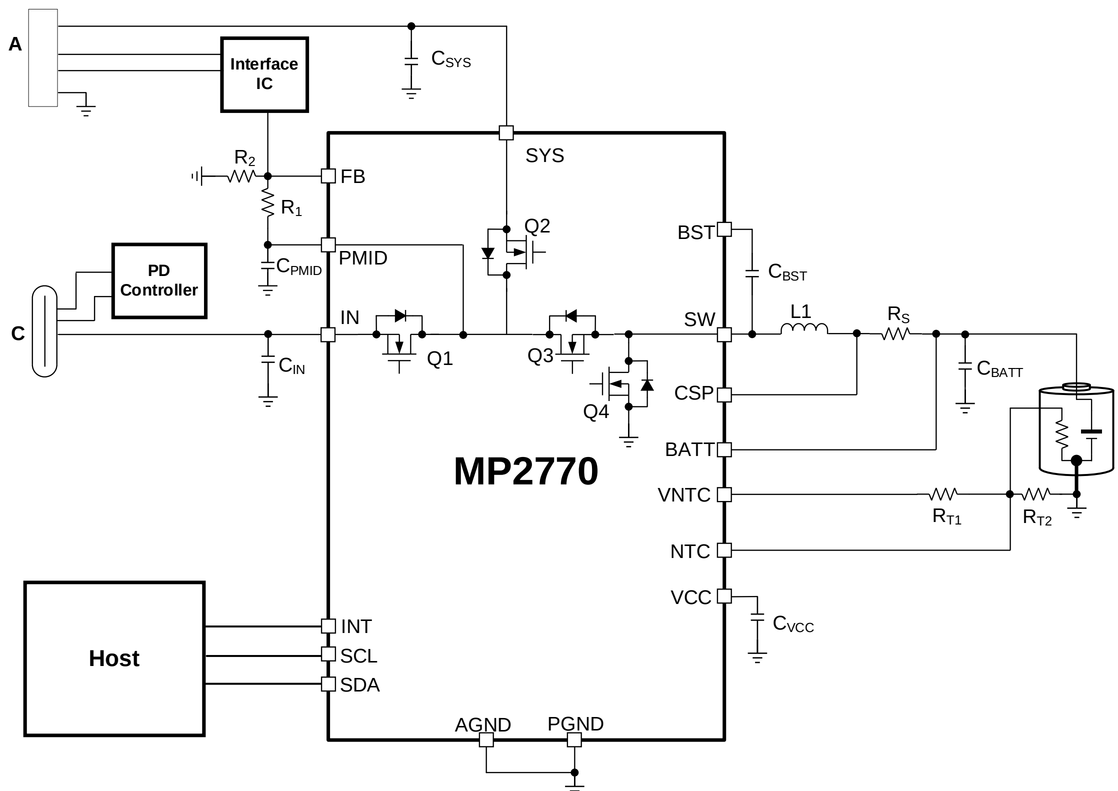

Figure 3: MP2770 Typical Application Circuit

In addition to battery charger ICs, Li-ion and other lithium-related batteries can be part of battery packs, which include multiple connected batteries within one system. In this scenario, battery packs and their battery management system can benefit from fuel gauges and battery protectors and monitors.

When fuel gauges (such as the MPF42791 and MPF42793) work with battery monitors (such as the MP2790 and MP2797), they can prolong the lifespan of batteries by optimizing charging and integrating other necessary components of a BMS, including current-sense resistors, cell-balancing between individual cells, and state-of-charge (SOC) monitoring to communicate when the battery is charged.

Lithium Iron Phosphate (LFP) Batteries

LFP batteries are a variation of Li-ion batteries, in which the cathode material consists of iron-phosphate instead of nickel-manganese-cobalt (NMC) or nickel-cadmium (Ni-Cd). LFP batteries have lower energy density and lower power density than Li-ion batteries, which is typically at a premium for space-constrained applications. For this reason, they are much less commonly found in power tools, e-bikes, laptops, and other low-voltage battery applications. Furthermore, LFP batteries produce a lower output voltage (V_{OUT}), which can complicate the power design or require more cells connected in series than Li-ion batteries to reach the minimum voltage requirements.

There are also distinct advantages for LFP batteries. They are lower cost, are stable across a wide range of temperatures to ensure safety, and they provide a longer lifecycle than other battery types, meaning they can withstand more charge and discharge cycles. With these advantages and steady improvements in their performance, LFP will likely grow in popularity for low-voltage applications.

LFP Chargers

LFP charger ICs follow a similar set of stages to Li-ion chargers, including CC charging, CV charging, and charge termination. These charger ICs can simplify the implementation of LFP batteries in a battery management system as they often regulate the voltage, which allows batteries to be powered from USB ports or even solar panels.

The MP2652 is a buck-boost charger recommended for power tool applications, and it is designed for 2-cell to 5-cell in series batteries (see Figure 4). To guarantee a safe voltage, the MP2652 has a V_{IN} limit that prevents overloading at the input power (P_{IN}) source. In addition, the integrated 10-bit analog-to-digital converter (ADC) provides monitoring during charge mode and source mode.

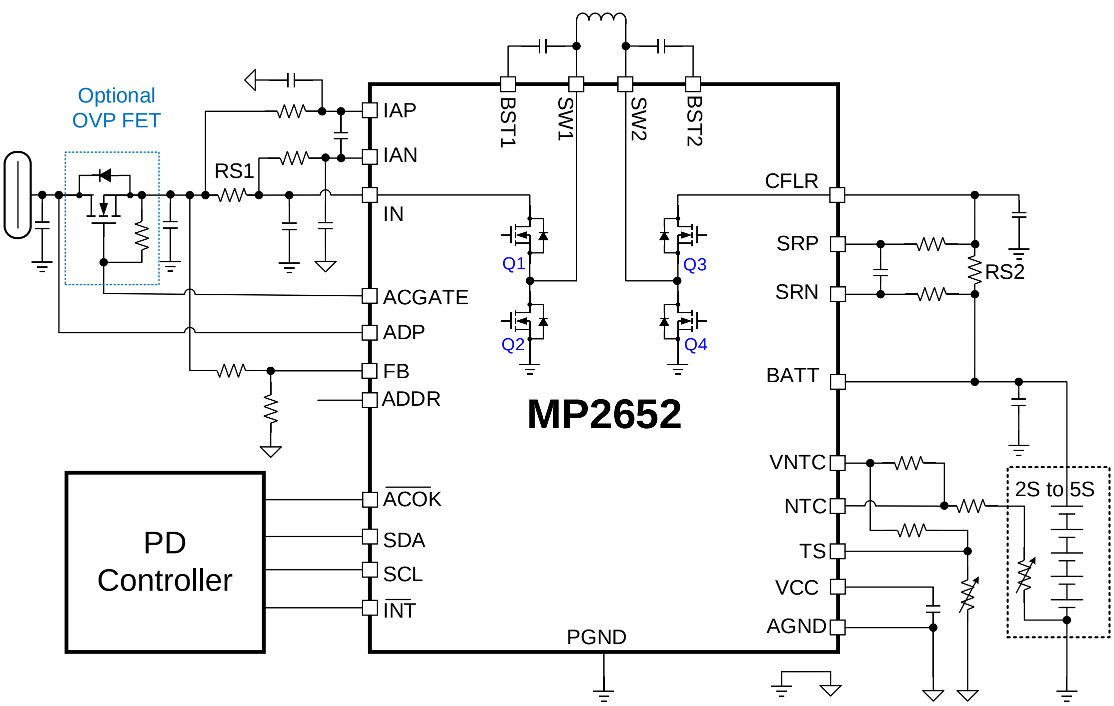

Figure 4: MP2652 Typical Application Circuit

The MP2759 is another buck-boost charger that can be used in industrial medical equipment. It is designed for battery packs with 1-cell to 6-cell in series, operates from a maximum 36V DC V_{IN}, and features OR power path management to reliably charge the battery using external switches (see Figure 5).

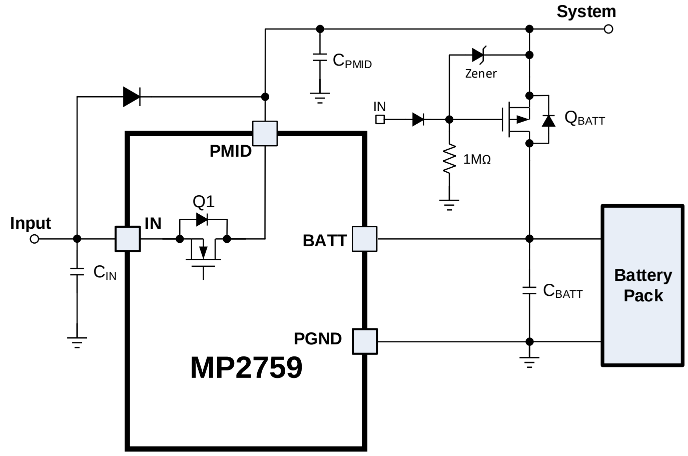

Figure 5: The MP2759 with OR Power Path Management

When an input power supply is present, the MP2759 charges the battery with four phases: trickle charge, pre-charge, CC charge, and CV charge. Protections include battery OVP, thermal shutdown, and a charging safety timer. Its status pins indicate the power source and operation status for added visibility. The MP2759A is similar to the MP2759, but it provides a narrow negative temperature coefficient (NTC) window.

Li-Polymer

Li-polymer batteries are typically used in portable devices such as smartphones, tablets, and wearable gadgets. They are thin, lightweight, and come in a wide range of shapes and sizes to fit different applications.

The anode and cathode for Li-polymer batteries are similar to Li-ion batteries; however, the electrolyte, which allows for lithium ions to flow between the anode and cathode, is different. Li-polymer batteries utilize a solid polymer electrolyte, which enables flexibility and contributes to their light weight.

Li-ion polymer batteries have lower self-discharge rates and higher energy density, meaning they can maintain stored energy and provide a longer battery life. However, any physical damage or overcharging or discharging these batteries can cause the battery to swell or even catch fire. They are also not highly standardized, which means that Li-polymer batteries cannot always be used across different devices.

Li-Polymer Chargers

Li-polymer charger ICs function similarly to both Li-ion and LFP charger ICs. Not only do they follow the same charging profile, but they also provide benefits such as voltage and current regulation, safety protections, and smart charging algorithms to prevent overcharging and overheating. These functions maximize the Li-polymer battery's lifespan.

Chargers that are compatible with Li-ion batteries are also compatible with Li-polymer batteries, including the MP2770, MP2652, and MP2759.

Nickel-Metal Hydride (NiMH) Batteries

NiMH batteries tend to be used in digital cameras and portable power tools. Unlike standard batteries that you might put into a portable device, use, and then throw away, NiMH batteries can be recharged and reused.

NiMH batteries have a cathode that is nickel-based, and their anodes are typically an alloy that absorbs hydrogen. They also use an alkaline electrolyte to facilitate ion flow between the anode and cathode.

NiMH batteries offer high energy density and have a low self-discharge rate, so they can retain their charge over longer periods of inactivity. However, they supply a voltage of 1.2V/cell, which means they can only be used in a limited number of applications, and incomplete charging or discharging cycles can negatively impact their ability to charge and discharge optimally.

NiMH Chargers

Although NiMH batteries have an entirely different battery chemistry from their Li-related counterparts, their charger ICs follow the fundamental rules of all chargers; that is, they provide numerous protections for the battery and battery charger, and implement parameter monitoring and configurations. NiMH chargers also track the change in V_{BATT} to regulate the charging process.

The MP270x series (including the MP2700, MP2702, and MP2703) is a family of linear battery chargers that can work with 2-cell to 6-cell NiMH batteries. Each charger has up to 26V of sustainable voltage and can charge the battery in four phases: trickle charge, pre-charge, CC fast charge, and CV charge.

Depending on application needs, the charger can be selected for the application, such as P_{IN} monitoring (the MP2702 and MP2703), charge status indication (the MP270x family) and an enable (EN) pin to enable the entire chip (MP2702). Memory selections can be used to configure parameters such as the input current limit (I_{IN_LIM}), minimum V_{IN} limit, and battery-full voltage. Figure 6 shows the typical application circuit for the MP2702.

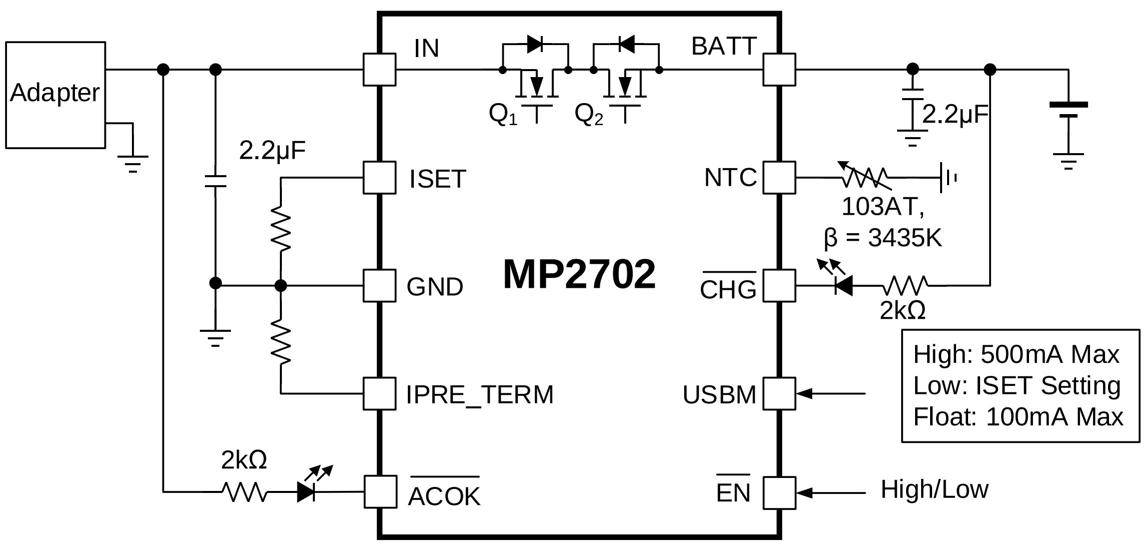

Figure 6: MP2702 Typical Application Circuit

Conclusion

Battery-powered devices have changed the way we interact with the world, and the ways in which they charge are integral to their functions and lasting use. This article explored battery chemistries and the ways that these chemistries can impact the battery management system (BMS) for low-voltage systems.

Although batteries follow a common charging profile, their individual chemistries can change their typical applications, and require compatible chargers to ensure safety and efficiency. Even battery chargers that charge the same battery chemistry may be better suited for different applications, such as the MP2652, which is ideal for power tools, and the MP2759A, which is well-suited for medical equipment.

MPS offers an extensive portfolio of battery charger ICs — including linear battery chargers and 3+ series chargers — that can be implemented in almost any application. For batteries in a battery pack, fuel gauges and battery protectors and monitors provide additional protections and features to optimize the overall BMS.