Lithium Ion Battery Assembly Challenges

Marko Dimitrijevic, Applications Engineer, International Components Corporation

Advances in lithium-ion battery technology have created new opportunities for the development of portable devices. Contemporary lithium-ion cells offer energy densities that are significantly higher than legacy battery chemistries such as nickel cadmium (NiCd), nickel metal hydride (NiMh) and lead acid (LA). The smaller form factors and lighter weight of lithium-ion cells enable the development of compact, feature-rich portable devices with long run times. When developing an advanced battery pack, design engineers should consider the required levels of protection, redundancy, compensation for excessive load transients, protection settings and special mechanical challenges. Development of advanced lithium-ion battery packs requires expertise and experience in order to balance system load demands with reliability and safety.

Advantages of Lithium-ion Chemistry
One of the primary benefits of lithium-ion cells is their energy density. The common method of evaluating energy density is to consider the amount of Watt-hours per kilogram (Wh/kg). State of the art AA nickel metal hydride (NiMH) cells, commonly used in portable devices, offer approximately 100 Wh/kg. Latest lithium-ion cells, however, yield more than 240 Wh/kg, providing significantly longer run times.

In addition to energy density benefits, lithium-ion cells provide a standard nominal voltage of 3.7V/cell and a potential voltage of 4.2V/cell as compared to only 1.2V/cell available in NiMH cells. As many as three NiMH cells would therefore be required to meet the nominal voltage of a single lithium-ion cell. The additional cells not only add cost and weight to a battery pack, but also increases pack complexity.

Cycle life is another benefit to lithium-ion cells. As the table in figure-1 indicates, cycle life exhibited by lithium-based cells exceeds that of standard legacy chemistries. Battery pack construction and related safety and monitoring circuits play a crucial role in realizing extended cycle life. The end benefit of increased cycle life is a battery pack with a longer lifespan.

	Lead Acid	Nickel Cadmium	Nickel Metal Hydride	Lithium Cobalt	Lithium Manganese	Lithium Iron Phosphate
Capacity	0.5	1.2	1.8	2.6->2.9AH	2.2-2.45AH	1.3-1.6AH
Voltage	2V	1.2V	1.2V	3.7V	3.7V	3.V
Energy Density(W/Kg)	35	45	70	167	110	100
Cycle Life	400	500	500	>500	>500	>1000
Life (Yrs) @ one charge/day	1	2	2	2	2	3
Charging Time	8 hrs	1.5 hrs	4 hrs	2-4 hrs	2-4 hrs	1-2 hrs
Self Discharge Rate (%/mo)	20%	30%	35%	10%	10%	8%
Safety	Good	Good	Good	Poor	Average	Good
High Temp Performance	Good	Good	Good	Average	Poor	Good
Cold Temp (0°F) Charge	Good	Fair	Fair	Fails	Fails	Fails
Cold Temp (0°F) Discharge	Good	Good	Poor	Poor	Good	Good

Figure 1. Cell Chemistry Comparison.

Lithium-based cells can also be charged much faster than legacy chemistries. More precisely, proper lithium-ion charging techniques and advanced termination and transition algorithms can accelerate the charging process significantly and enable a pack to reach more than 75% of its Relative State of Charge within a much shorter period of time. This can be achieved without impact to cycle life. Although Nickel and Lead-based batteries can be charged quickly, such actions impact their overall lifespan.

Safety

Due to their volatile nature, lithium-ion cells cannot be used on a stand-alone basis and require additional layers of safety. Before proceeding, it should be noted that there is a significant difference between a cell and a battery pack. A cell is considered the basic component that stores and releases charge. Nickel cadmium (NiCd), NiMh and LA cells can be used without additional levels of safety as they are generally non-volatile. Their stand-alone, unprotected use has contributed to those cells being referred to as “batteries.” Lithium-ion cells, however, need safety components and circuits to monitor and manage the charge/discharge cycles and prevent inadvertent application and mishandling. Only after those circuits are added are such systems be considered “batteries.” That is why development of lithium-ion battery packs is often much more complex than construction and assembly of standard batteries.

Figure 2. Prismatic li-ion cell with PTC

One level of protection to an advanced lithium-ion battery pack is the PTC, or positive thermal coefficient device. It reacts to high current discharge levels to increase output impedance. The increased impedance controls output current and the PTC can disconnect the output path if the discharge levels exceed safe limits. Most contemporary high energy cylindrical lithium-ion cells incorporate a PTC, eliminating the need, cost and complexity of adding such a component.

The charge/discharge monitoring cutoff circuit is another, more active safety level. Controlled by protection IC's, this circuit monitors charge/discharge levels and activates/deactivates the relative transistors (switches) to allow or inhibit current flow. This works in combination with the PTC to prevent unwanted side effects of overload or short circuits. Cutoff circuits often utilize a thermal sensor to monitor individual cell temperatures and also trigger accordingly.

Individual cell monitoring circuits provide an additional level of protection. These circuits respond to cell imbalance conditions in packs with multiple series connections. The absence of individual cell monitoring circuits can lead to cell imbalance, which can result in uneven or excessive charging and discharging of individual cells. If any of the cells connected in series exhibits levels significantly different from other series cells, the monitoring circuit triggers the cutoff process.

Chemical fuses are also utilized to provide permanent circuit interruption, if it ever becomes necessary. These fuses are controlled by the cell monitoring and cutoff circuits that respond to extreme events during pack exploitation and automatically open to permanently disable the battery pack. Although such actions seem extraordinary and will render the pack unusable, this protection is necessary in applications where high levels of safety and reliability are required.

Protection circuit reaction time is determined by parameter settings in the control IC firmware. Design engineers have options of not only setting the critical thresholds, but also time constants for reaction time. A protection circuit could be made to react faster or slower to a transient event by varying the time constants. Transient events do not always have to be excessively high transient spikes. Momentary loads can induce temporary cell voltage dips to below minimal values. Although this is not desirable, it is permissible for brief periods.

In addition to thresholds, engineers can modify the firmware settings to control the hysteresis of a particular circuit. Hysteresis could be viewed as the desired lag between an initial trigger event and the point at which the circuit resets. By adjusting the protection threshold hysteresis appropriately, designers can ensure that a battery pack will not enter an undesirable oscillation mode between a fault condition and subsequent relaxation.

Battery Assembly Challenges
Once the proper protection parameters are determined, the challenge of battery pack assembly emerges. This is especially true in cases where the pack faces extreme clearance requirements or needs to meet specific standards for robustness. Aspects such as enclosure wall thickness, the plastic material used, the effects of color tints and joint methods need to be considered. Designers also have to pay attention to the intended and unintended uses of the pack, especially if it will be handled by consumers. A well designed battery pack must be able to withstand use and abuse without any adverse side effects.

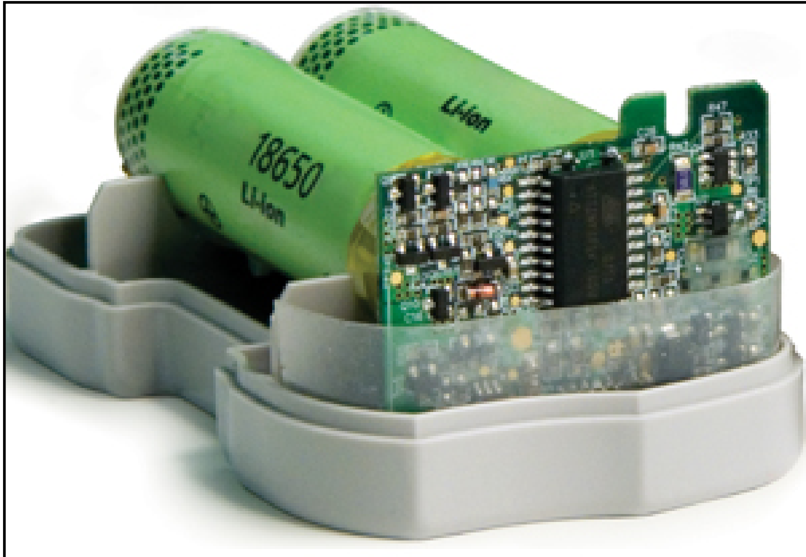

Figure 3. Ultrasonic welded battery pack.

If the battery pack utilizes any form of a living hinge, proper design methods and studies need to be implemented in order to ensure adequate cycle life of the component. Sonic or laser welding may also need to be applied and proper joints need to be engineered in cases where a tight product envelope is needed. Internal structures and proper printed circuit board (PCB) and contact retention need to be carefully considered. Application of proper contact materials could add years to the battery lifespan, but also significant cost to the pack. Such materials have to be carefully considered to satisfy both the quality and financial aspects of the product.

Advantages of Battery Development Partners
Although lithium battery technology offers multiple advantages over other commonly available chemistries, their properties require much more development

expertise. There are many off-the-shelf products specifically designed for lithium-ion battery pack protection and fuel gauging, but proper application and pack configuration is complex and hard to achieve.

Since product development timeframes and budgets are shrinking at an alarming pace, it is often advantageous to partner with a reputable lithium-ion battery pack developer. Not only are such partners able to provide a custom-tailored solution rapidly, but they often provide overall cost advantages as well. Companies, such as International Components Corporation work closely with their clients to analyze all aspects of the system and develop battery pack solutions precisely configured for the end application. This encompasses all levels of safety, protection thresholds, fuel gauge precision, system communication, and mechanical rigidity requirements.

In addition to solving critical engineering challenges, an expert battery pack developer can manage the entire agency certification process. Contemporary standards for battery technology often involve elaborate and lengthy certification processes with nuances that can add months to development time if all agency parameters are not properly considered during initial design phases. Battery pack integrators provide the necessary expertise on such requirements as a primary service.

Conclusion
Lithium-ion technology is at the forefront of advanced battery design. Device manufacturers are transitioning from legacy chemistries to take advantage of the many benefits lithium-ion has to offer. Additional hardware and software must be applied to lithium-ion cells to ensure safe and reliable battery pack operation. This article outlined the various levels of protection, reviewed firmware setting options and discussed mechanical considerations, all necessary elements for an advanced lithium-ion battery pack design.

Based on the complexity of today’s battery pack design, OEMs will find it advantageous to partner with an expert in battery pack development. Companies such as International Components Corporation provide device makers with state of the art battery pack design that meet today’s design challenges.