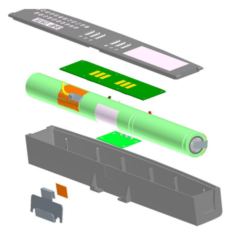
Upgrading from Older Battery Technologies to Lithium Ion (Li-Ion) Systems

MICRO POWER

Battery systems are no longer simply a collection of isolated components, but a complete electro-mechanical structure that plays an integral role in the function of a portable device. Yesterday's "dumb" battery system typically consisted of the battery cells, safety components, and a physical enclosure. Today, more sophisticated and advanced power systems are available. The term "Smart" battery systems are in common use.

The main components of a smart battery pack include:



1. Cells providing the primary energy source
2. A printed circuit board providing the intelligence of the system for advanced functions such as fuel gauge calculations to determine remaining cell capacity, protection circuitry, thermal sensors used to monitor internal pack temperature, LEDs that indicate battery status, and a serial data communications bus that communicates to the host device or charger
3. A custom plastic enclosure typically produced in an injection mold
4. External contacts providing a physical electrical interface with the host device
5. Insulation used to absorb external shock and retain the positioning of internal components
6 .Some smart battery designs also include on-board charging capabilities

What are some of the Critical Performance Factors used for battery system selections?

The total battery system integration involves a host of considerations. Paramount among these:

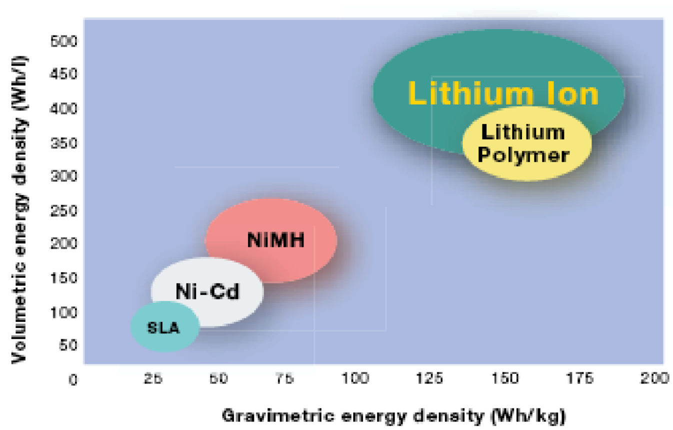
1. Cell selection (including chemistry, cell type and vendor considerations)
2. Pack characteristics (the number of cells in a pack and location of the pack in the unit)
3. Operating requirements (how, when and where the device will be used)
4. Battery safety and management (seeing the pack as an integrated system with cells, board, management and, in some cases, charging units)
5. Correct calibration and learn cycle (to ensure the design functions properly)

What are the differences between Lithium Ion (Li-Ion) and other battery types such as Nickel Cadmium (Ni-Cad) and Nickel Metal Hydride (Ni-MH)?

Li-Ion cells represent the latest in rechargeable performance options deployed in the commercial/industrial market. Functionally, they are totally unlike other chemistries in capacity, storage, charging and flexibility of any of the more traditional technologies. In addition, because the cells go beyond traditional sizes and form factors, there is more design flexibility; cells are available in cylindrical (traditional Ni-Cad and Ni-MH shapes), Prismatic (flat, thinner box-like profiles) and Polymer (very flat, softer foil packaging). All Li-Ion cells have a nominal voltage of 3.6V or 3.7V versus Ni-Cad or Ni-MH cells of 1.2V or 1.25V per cell. This means that one Li-Ion cell can replace 3 nickel cells. In addition and unlike nickel cells, the chemical make-up of the cells lend themselves to effective use of combinations of both in series and in parallel cell packs that yield a much greater delivery of overall power to the system.

What are the benefits of Li-Ion versus my older technology?

Li-Ion cells and batteries provide for greater rechargeable energy storage capacity, at a lighter weight and smaller size than previous technologies. In the combination of series and parallel cell strings, the overall delivered voltage and capacity can be used to support multiple application requirements that previously were impractical and/or cost prohibitive. In addition, since no heavy metals are used in the chemical compound of the technology, Li-Ion cells are more environmentally "friendly" than Sealed Lead Acid, Ni-Cad or Ni-MH rechargeable technologies. Today, with advancements in technology and demand, virtual price parity per Watt Hour now exists between Ni-MH and Li-Ion batteries.



How long will Li-Ion batteries last? What are the number of charges and discharges?

Battery life is typically measured in numbers of cycles. A cycle is defined as one complete discharge and recharge of the battery. Industry expectations are that batteries, when properly used, will last between 300 and 500 cycles. While this is a broad range, there is enough variability in the utility of the battery and the specific design of the battery that this range is appropriate. Ultimately, the end of life occurs when a battery is no longer capable of reaching 80% of its initial or rated capacity. With Li-Ion batteries, the battery does not have to be completely discharged (called shallow discharge) prior to recharging and this capability can result in the appearance of prolonging the overall functional life of the battery. In addition, unlike other chemistries and with a well-designed charger and battery control circuit, shallow discharging and repeated recharging does not damage the battery or cause the battery to require premature replacement.

Is it always possible to upgrade to Li-Ion from other battery types?

No. Li-Ion batteries are significantly more complex electronically than other technologies. Li-Ion batteries typically include circuits than provide for power management, charging and safety. Many Li-Ion batteries are classified as "Smart" batteries that have various levels of intelligence that can provide for anything from fuel gauging to cell balancing. Finally, Li-Ion batteries use a different way of charging and charge cut-off control than previous chemistries. Not all host devices are designed with the flexibility to upgrade from nickel-based batteries to Li-Ion.

Can I use my old battery charger? (External vs. internal chargers)

No. Li-Ion chemistries use a different charging algorithm than other rechargeable technologies and these are not compatible with each other. For that reason, when systems are upgraded from Nickel (Ni-Cad or Ni-MH) to Li-Ion, batteries are designed so that mechanically they will not be able to be used in the existing chargers.

What about battery storage conditions?

Li-Ion batteries should be stored in a well-ventilated location, with ambient temperatures between 20ºC to 40ºC and at 40% state of charge or lower. Prolonged storage at elevated temperatures and high state of charge will result in the permanent loss of performance of up to 40% per year. Batteries stored in cold environments will have to be stabilized within normal temperature ranges prior to recharging and use. In addition, it is important to understand that the different chemistries will temporarily lose their state of charge while stored but at different rates. When stored under optimal conditions, Li-Ion temporary state of charge loss is the best with <1% per month and Ni-MH performs the poorest with losses of >50% within 30 days. It is a good idea that whenever possible, after a lengthy storage period, all batteries should be recharged prior to being placed back into service or use.

Do I have to worry about "memory" with Li-Ion?

No. Nickel chemistries frequently had problems due to continuous shallow discharge and repeated over charge. With Ni-Cad batteries, this was called "Memory Effect" or sometimes, premature voltage depression. To a lesser extend, this problem has been experienced in Ni-MH batteries as well. With either chemistry, this would lead to the need to frequently recondition or replace batteries earlier than expected. Li-Ion exhibits none of these tendencies and, in fact, with a properly designed charger, shallow discharge patterns make the batteries appear to last significantly longer than otherwise expected. As a caution, less sophisticated fuel gauges often do not compensate for battery aging and therefore do not accurately reflect the deliverable capacity of the battery. This, however, should not be confused with "Memory Effect."

Reconditioning Li-Ion – when and why would I need to?

While there are some manufacturers that have recommended reconditioning Li-Ion, Micro Power has determined that there is little benefit to this other than being able to measure the remaining charged energy capability of the battery. In fact, whatever immediately apparent benefit in improved capacity of the battery is typically temporary and not sustainable after putting the battery back into service. Conditioning or cycling of Li-Ion batteries serves more to indicate to the user the capability of the battery than to restore lost but recoverable energy.

What can I do to maximize my battery's life?

Both nickel-based and Li-Ion rechargeable technologies will maximize their potential if used within the recommended environment; are designed correctly for the application; are stored correctly; and used in a charger designed to meet the specific battery operational requirement. For Li-ion this means operating environments from 0° to 60°C with good air circulation and in host devices where thermal considerations of the other components do not create "hot spots" that could cause premature degradation of the cells or electronics within the battery. Unless designed for it, batteries do not function well if used for several hours in extreme temperatures (either hot or cold) and do not provide the run time expected in these conditions. While most batteries are designed for the ruggedness required of the system, physical abuse of batteries can result in the batteries being damaged and they will have to be replaced.

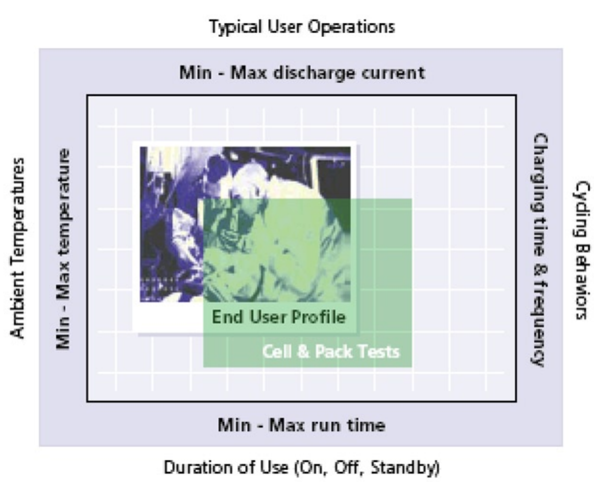
In addition, Li-Ion battery design frequently uses sophisticated Power Management Systems to improve or optimize the overall functionality of the energy delivery system. The basic functions of the power management circuits are:

- Control of energy flow into and out of the battery
- Prevention of abusive conditions so that user safety comes first
- Monitoring critical parameters and communicating that information to the system

How will cold effect my battery? What about heat?

An important point to consider is that for these measurements, the temperatures referenced are for the internal temperature of the battery so that devices operating in cold or hot temperatures – but sheltered by something like a coat (cold) or fan (hot) – are not likely to be exposed long enough to be impacted by these temperature extremes. Users experience this more at cold temperature operations than at hot environments. Ni-Cad batteries perform much better at the lower temperature ranges than either Ni-MH or Li-Ion. Ni-Cad batteries will achieve approximately 40% of rated capacity at -30°C while standard application Li-Ion batteries are not rated to work below -20°C. In fact, Li-Ion electrolyte begins to freeze at -30°C.

Evaluate which cells work best



What if I have an extreme operating condition that requires battery support?

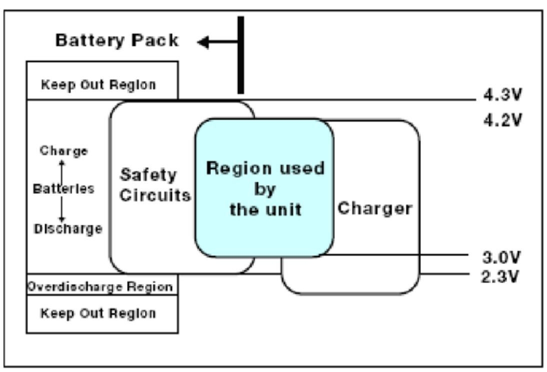
The cell manufacturers recognize that there are operating conditions that demand a variety of extreme uses. In today's marketplace, there are many new demands for portable devices and therefore needing batteries. Conditions where high and prolonged power (power tools), and high or cold temperature applications (desert or near arctic operations) are becoming more common product needs. Cells and battery packs for use in these applications are being developed, and some are now available that are designed specifically for each of these needs. As these needs are identified prior to or during the system development, then the battery packs can be designed accordingly.

When should I replace my batteries and why?

The battery industry recommends that batteries no longer capable of holding 80% of their original capacity should be replaced. Judging this can be difficult since not everyone has a measuring device, and therefore users should consider how frequently a battery is recharged. Daily use typically results in 200 to 250 charges per year and this use should result in batteries lasting 18 – 24 months. If the batteries are used 24/7 and recharged every other shift, then annual replacement is recommended. If the batteries are used less frequently, stored for periods of time or are used in a back-up role, then batteries may last three or more years before being replaced.

What should I look for in making sure my Li-Ion batteries are safe?

As mentioned earlier, Li-Ion batteries are more complex electronically than batteries of any other chemistry. The battery industry uses more efficient and effective electronics to make sure that the Li-Ion batteries being designed and manufactured today are as safe as possible. In addition, since most of the risk occurs during charging, charger design has become more and more recognized as a critical component in the overall system safety matrix. The battery safety circuits used today provide protection for overvoltage, undervoltage, overcurrent, and for excess thermal conditions. Some of these circuits will provide for re-settable uses but most designs also include components that will permanently disable the battery in extreme conditions. Key to product safety is to use only those batteries designed for the original product by the original manufacturer. These batteries are thoroughly tested and qualified for the devices in which they are used. This provides the end user the best assurance of both the safe and optimal performance of the system.



Here is an example of a typical implementation of a Li-ion safety circuit.

Do I have to worry about overcharging Li-Ion batteries?

Overcharging batteries can be a problem with any battery chemistry. A well-designed Li-Ion battery system will include a power management circuit than can accurately detect when the battery charge cycle is completed and will terminate the charge. With Li-Ion batteries, a method called "Constant Current/Constant Voltage" (CCCV) shut-off helps assure users of not risking overcharge concerns.

How do I dispose of my old Ni-MH and Li-Ion batteries?

Disposal of used batteries is subject to local regulations and guidelines. Requirements vary significantly around the world. In most locations, there are facilities and companies set up for receipt of old batteries. It is recommended that all customers comply with these regulations and use those facilities. The distributor can provide the guidance of how they regulations and services should best be followed.

What is next in batteries?

Over the last 25 years, there have been a number of advancements in rechargeable technology, with the widest uses moving from Ni-Cad to Ni-MH and in the mid-1990s to the various Li-Ion configurations and formulas now available. As the demand for portable energy continues to out pace current capabilities, the energy industry continues to experiment and drive new technologies. Several new technologies are constantly being evaluated and tested, and these processes can take from 5–10 years to go from the lab to the manufacturing line. Several of these such as super capacitors, fuel cells, several polymer chemistries, etc. have excited interest, but have not reached a point of general deployment in this industry. In response to this, cell manufacturers are working with new formulations of the basic chemistries of the cells to expand the theoretical limits of the cells now in use.

Conclusion

Today's sophisticated portable electronic systems have created new challenges for battery system designers. The mobile world is demanding higher performance, lower weight, longer effective usage times, and absolute consistent reliability from applications as diverse as emergency medical instruments, test and measuring equipment and portable data collection devices. These systems rely on increasingly sophisticated battery packs for their power requirements. A good design will take all of these factors and more into consideration, particularly focusing on those related to power, safety and accuracy.

The choice of battery chemistry is critical for performance, reliability and cost issues. For these reasons, more designers are turning to advanced formulations, such as Li-Ion and Li-Polymer. These chemistries deliver high energy densities and competitive cost-per-output for their weight. Characterizing and validating cells to fit their usage profile define chemistry choice and circuitry further.

Advanced battery chemistries demand extra attention for safety considerations. Voltages must be kept within strict operating limits. Safety circuits are mandatory to protect against hazards caused by external stresses. The design and placement of Printed Circuit Assemblies (PCAs) is a more critical safety issue in Smart battery systems as well.

Additionally, Smart battery systems require extra attention to highly accurate fuel gauging. Inaccurate fuel gauges may fail to optimize all of a cell's available power, as well as cause inefficient charging. By recognizing and considering these design challenges, battery system designers can avoid or minimize problems early on. Moreover, they can maximize performance, durability, reliability and safety.

Micro Power Electronics provided the information presented above. The contributing writers include Jeff VanZwol, Dr. Robin Tichy, Dr. Rory Pynenburg and Bill Stout.

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