Lithium-ion Batteries

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When it comes to lithium-ion batteries, safety takes the pole position.

Recently, rechargeable lithium-ion batteries used in consumer applications have received attention because some have melted or even exploded. But, contrary to sensational news reports, lithium-ion batteries remain safe and engineers will continue to design them into portable equipment. The defective batteries featured in news reports came from one manufacturer and resulted from a production defect. Of the billions of lithium-ion cells manufactured in 2006, few had problems.

The nature of the lithium-ion chemistries produces high amounts of electricity with light-weight materials, so lithium-ion batteries generally provide the best power sources for portable electronic devices. And, continuing research into lithium-ion and lithium-polymer chemistries and materials will increase the capabilities of these batteries for some time.

But, do not expect to find "bare" lithium-ion cells on your distributor's shelf. Reputable cell manufacturers sell only to qualified and authorized companies that place these cells in battery packs. Those packs include electronics that protect users and batteries. When a design calls for a lithium-ion battery, plan to work with an authorized company that can tailor a battery pack to your requirements.

"Usually customers come to us with specific current, voltage and mechanical requirements," said Ralph Wise, Director of Technology, at Ultralife Batteries. "So, we can determine if we have battery technologies that will help them. We might slightly modify a current battery-pack design to create something similar. We also help customers determine whether a lithium-ion battery pack makes economic sense."

"We always ask customers about a battery's operating conditions," said Wise. "Suppose engineers plan to put a battery in a medical device users must autoclave. A lithium-ion battery pack cannot take high-temperature shocks, so in this case, we might recommend a nickel-cadmium battery." One battery type or chemistry cannot always suit every application.

Engineers also must examine safety and regulatory requirements established by the Underwriters Laboratories (UL), Federal Aviation Administration (FAA), Department of Transportation (DOT), Food and Drug Administration (FDA) and other groups and agencies. Often, lithium-ion battery-pack suppliers have experience with regulations and can help engineers anticipate and meet them. Wise noted, "You do not want to get a product ready to manufacture and have an engineer say, 'Gosh, we need to be certified to UL-2054 [a standard for household and commercial batteries].'"

Saft starts customers with a Product Study Request form that asks for specific application information. After Saft engineers have basic data, they can elicit more application information from customers. Or, customers may make lab measurements and come back with additional details. "We ask about operating conditions, too," said Dr. Graham Archdale, commercial manager of lithium-ion products at Saft. "We must know if someone needs a battery pack to operate at -40°C. We may have to design the battery pack with more cells in parallel to provide power at that temperature." Archdale noted Saft has a proprietary battery chemistry that will work between about -40°C and 60°C.

But, Archdale cautions customers to not overspecify battery requirements. The more stringent the battery operating conditions, the more the battery will cost.

"We would like people to come to us as early as possible so we can start to test cells," said Dr. Robin Tichy, technical marketing manager at Micro Power Electronics. "Cells can have similar published specifications; typically slow discharge and charge rates at room temperature. But as you deviate from that situation - say you have transient currents or slightly higher or lower temperatures - you find a cell may not behave as you would expect."

"Here is an example," explained Tichy. "Typically, you do not want a battery with high internal impedance. But in a cold environment, a higher resistance will help warm the cell and increase its energy output as you draw current from it. So, a cell that may seem to perform worse than others at room temperature could perform better at colder temperatures. We can start to test for that kind of characteristic as soon as we know a customer's requirements."

Safety First and Always

Safety looms large in the realm of lithium-ion batteries, so battery-pack suppliers include internal circuits to control how the batteries charge and discharge and to monitor operating conditions. (See: "Charge Batteries with Care.")

Lithium-ion battery packs include internal positive-temperature-coefficient (PTC) devices, thermal fuses and electronic circuits that ensure the packs operate only under specific conditions. "If a customer wants to charge a battery pack at 35°C, we may design it so charging can occur up to 45°C," said Ralph Wise at Ultralife Batteries. "We add a thermal sensor so if the pack's temperature exceeds 45°C, charging stops until the temperature drops."

Most of the electronic safety circuits keep a battery pack's voltage and current within design limits. If the pack experiences a voltage surge due to a bad charger, the internal circuit disconnects the charger from the battery pack. "We design our products so they safely cease operating if abuse occurs," explained Wise. "If a battery fails because it experiences a forbidden condition - say someone tried to

charge at too high a temperature <md> circuits ensure the pack no longer operates. We do not want a customer to use that pack again."

"Every bit of current the cells deliver goes through the safety circuit," said Dr. Graham Archdale of Saft. "So, we need to know the maximum current the pack must deliver. Even if a device demands only a 100-msec high-current pulse to start a motor, the circuit must not detect this pulse as a short circuit. We need a lot of details about a pack's intended use so we can deliver one that will work under all the customer's operating conditions."

Safety circuits assume people will do something wrong, such as try to over charge a pack or connect it to the wrong charger. In these cases, the safety circuits can stop the charge, temporarily reset the charger or blow a fuse to stop charging completely and prevent anyone from using the battery pack again.

Panasonic provides lithium-ion cells only to authorized assembly companies that produce battery packs for customers. Even though that process removes the company one step from end users, Panasonic continually stresses safety. "We ensure the assemblers provide safety circuitry to the end customer," said Dennis Malec, a senior applications engineer at Panasonic. "We are strict. If a pack assembler does not understand our position and it will not put the safety components in a pack, they will not get batteries from us."

Sometimes, Malec finds engineers who view safety circuits as redundant and expensive. "They want to build the safety circuits onto their main circuit board instead of have it in the battery pack. We do not want that to happen because our assemblers lose control of pack safety. We require that every pack an assembler produces leave their facility with the safety circuit in the pack and 100 percent functional."

Safety circuits on a main board may not undergo thorough testing for overvoltage, undervoltage, and overcurrent. And safety components on the board become easy targets for cost reduction. "Someone may see a safety circuit and think the charger circuit provides the same controls," noted Malec. "It might, but we prefer redundant levels of safety in the battery pack and in the charger. If you put safety circuits only in the charger and it fails, the pack has no safety backup."

Stay Safe and Well Informed

A battery pack's internal circuits can offer more than safety. The same circuits can monitor the pack's "health" and status. "Most designers do not think of a battery pack as something they can use to differentiate their product," explained Dr. Robin Tichy of Micro Power Electronics. "Engineers might choose, for example, to hot-swap a battery, so their product can run from one battery pack, charge another pack and switch between them without losing power. Intelligence in the pack helps

implement that sort of function."

Because lithium-ion batteries are still fairly new, semiconductor companies continue to develop innovative battery-monitor ICs. Fuel-gauge ICs, for example, can determine the amount of energy left in a battery. These ICs also can monitor current flow, number of charge cycles, temperature extremes, lifetime characteristics, and other variables. Smart ICs, such as the Texas Instruments bq20z90-V110 chip, comply with the Smart Battery Specification and communicate with a host controller over the System Management Bus (SMBus), a two-wire interface. These "smart battery" capabilities let engineers customize battery packs for an application and differentiate their application from others. Smart batteries can provide warranty and pack-abuse information, too.

The TI chip (and others) incorporates a security feature that employs the Secure Hash Algorithm (SHA-1) that ensures the authenticity of an attached battery pack. According to Tichy, after-market lithium-ion batteries cause the biggest problem in the industry. So, assemblers may put a security function in their packs so users can determine they have an authentic rather than a counterfeit pack in their equipment.

Lithium-Polymer Goes Thin

Engineers might consider lithium-polymer batteries as a separate class of batteries, but they are members of the lithium-ion-battery family and deserve attention when a design pinches space for a power source.

Engineers always need a lot of power but they leave only a small space for a battery, noted Julia Palu of VARTA Microbattery, which manufactures lithium-ion and lithium-polymer batteries. "We produce a thin polymer electrolyte, so we can manufacture a battery only 0.7 mm thick. That type of battery can go in a product against a hard cover or shell."

Unfortunately, engineers may associate "flexible" with "thin" and think they can fold a lithium-polymer battery to squeeze it into a small space. But they cannot. This type of battery must adhere to a rigid surface, so designers must protect a lithium-polymer battery to ensure it does not bend.

Like its lithium-ion cousins, a lithium-polymer battery also requires protection circuitry; but instead of assembling the circuits within a battery pack, they can go into the sealing space around the battery's perimeter. That packaging technique saves space and keeps lithium-polymer batteries thin. And because lithium-polymer batteries use solid materials, they do not leak.

According to Palu, technical manager/national sales manager new technologies OEM at VARTA, the polymer is intrinsically safe and it can withstand overcharge at a voltage as high as 4.8V, at which a regular lithium-ion battery would go into a "runaway" state.

The company's lithium-polymer batteries undergo only slight swelling. (Swelling occurs in all lithium-ion batteries due to the chemistry and physics of their charge/discharge processes.) "When engineers design small portable products such as cell phones and MP-3 players, we must fight for tenths of a millimeter," said Palu. "That is when swelling becomes an issue." VARTA specifies a maximum 0.2 mm increase in battery dimensions for the life of a battery at room temperature. Thus, engineers must leave space for battery swelling within a product's battery compartment. The battery also will operate at down to about -20°C,

According to Palu, lithium-polymer batteries have the best chance to increase the energy capacity and density of lithium batteries. That increase can amount to eight to 10 percent every six to nine months.

For further reading

Dietz, Ken, "Battery Authentication for Portable Power Supplies," *Power Electronics Technology*, April 2006. www.powerelectronics.com [1].

The Battery University at www.batteryuniversity.com [2] provides a wealth of information about batteries of all types.

The System Management Interface Forum provides information about power management and system technologies: powersig.org. The group also maintains the SMbus standard: smbus.org.

<Image>ec74cs100b.eps</Image><cap>Manufacturers of lithium-ion cells deliver several package types to authorized companies that produce complete battery packs for OEMs. Courtesy of Panasonic. </cap>

<Image>ec74cs100c.eps</Image><cap>This image shows two unconnected lithium-ion cells, two shrink-wrapped cells with electronics, and additional cells within the cut-away housing. Cell packagers can supply standard assemblies as well as custom configurations. Courtesy of Saft. </cap>

<Image>ec74cs100d.eps</Image><cap>Companies authorized to purchase and package lithium-ion cells can configure battery packs for specific applications, connectors, voltages, and other design needs. Courtesy of Micro Power Electronics. </cap>

<Image>ec74cs100e.eps</Image><cap>A diagram of a battery pack shows the placement of protection circuitry within the package housing. Customers can add additional circuitry to monitor operating conditions and battery health. Courtesy of Micro Power Electronics. </cap>

<Image>ec74cs100f.eps</Image><cap>This large lithium-polymer battery includes protection and monitoring circuitry on a small PCB mounted within the packaging material between the two battery connectors. Two smaller rectangular battery packs include protection circuits on the smallest surface. Courtesy of Ultralife Batteries. </cap>

Links:
[1] http://www.powerelectronics.com/
[2] http://www.batteryuniversity.com/