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Batteries Must Perform in Extreme Temperatures

Dr. Robin Sarah Tichy, Technical Marketing Manager
Micro Power Electronics

Consumer electronics have remarkably short product lifecycles and innovative features are rapidly integrated into portable, battery powered consumer products. Almost everyone has a cell phone; most of the phones are equipped with some degree of multimedia capability; you can spontaneously take a picture and send it along with an appropriate sound bite. Products in other portable markets are far slower to integrate new technology, but the expectation of every end user is changing due to the widespread use of cell phones, laptops and MP3 players. Users are demanding increased functionality in ever lighter and smaller packages, but industrial and military equipment is often exposed to more extreme temperatures than consumer electronics, and in addition, the battery functioning at these temperatures is not just an expectation; it is a requirement. Rechargeable battery packs for ruggedized portable devices must operate in both extreme hot and cold environments, but much like humans, temperature affects a battery's performance during both rest and work.

What's Available

Sealed lead acid (SLA) batteries have been around since the 1850's and are the oldest type of rechargeable battery, but they are still ubiquitous. This is partly because they are so cheap, but also because they function when exposed to extreme environments and a wide operating temperature, ranging from -40°C to 70ºC. Unfortunately, SLA batteries have poor energy density and aren't appropriate for handheld applications.

Nickel Metal Hydride (NiMH) cells demonstrate a great improvement in energy density, but they operate effectively between -20°C and 60ºC, and self-discharge rates are about 30 percent per month.

Lithium Ion (Li-ion) technology was introduced commercially in 1991, and with it's operating voltage that is 3 times that of NiMH, Li-ion's energy density is the best available today. It is the chemistry of choice for handheld devices. Li-ion cells operate effectively between -20°C and 60ºC. Of all the chemistries listed above, Li-ion requires the greatest degree of protection, including a thermal shut down separator and exhaust vents (within each cell) to vent internal pressure, an external safety circuit that prevents over-voltage during charge and under-voltage during discharge and a thermal sensor that prevents thermal runaway. However, with the appropriate level of safety designed into a Li-ion pack, Li-ion offers the most attractive cell chemistry even in extreme temperature environments.

When Temperatures Soar

Extremely high temperature operation provides equal challenges for cells based on lithium chemistry. As mentioned earlier, the upper range of safe operation for Li-ion cells is 60°C. Cells provide energy through the electrochemical shuttling of lithium ions between the anode and the cathode materials. However, at high discharge rates this chemical reaction generates heat, and so high drain rate applications must be designed with extra caution. The affects of the generated heat is compounded when numerous cells are assembled into a multi-cell pack.

High storage temperature can affect the subsequent performance of Li-ion cells, so storage conditions are a concern, as well. Under optimal storage conditions of 20ºC, a fully charged Li-ion cell has a natural self-discharge of 1 percent per month. However, with an elevated storage temperature of 60ºC for a twelve month period, the capacity naturally discharges down to 40 percent of the original capacity. This drastic self-discharge substantially limits the run time of the cells performance after storage. Additionally, after storage, this fully charged cell would only have a recoverable capacity of 70 percent of the original capacity. A cell stored at 60ºC for 12 months at 50 percent state-of-charge would have a recoverable capacity of 90 percent.

Batteries for handheld surgical tools are exposed to a temperature extremes far beyond the cell manufacturer's recommendation. The tools and battery packs must be autoclaved, and withstand temperatures up to 137°C and are impermeable to 30 psi of superheated steam and they must have a battery that allows the surgeon enough run time and power to complete major orthopedic procedures. A surgical tool battery pack is specially designed to survive the extreme conditions of an autoclave with minimal deterioration in performance. For this application NiMH cells are used. The plastic housing is a glass blend that will help it to withstand the heat and the pieces are sealed together with a gasket and screws. A valve allows the pack to vent. Throughout the pack the materials selected must withstand the elevated temperatures, so even the interior glue and thermistor must be specified for high temperature use. Designs like this allow medical battery packs to be used in sterile surgical environments bringing ease of use and efficiency.

And When the Temperature Drops

Performance of rechargeable Li-ion chemistry starts to suffer as the temperature drops below freezing. As the temperature drops below 0°C, the internal impedance of the battery increases. Cell capacity is also reduced during the lower temperatures.

The military requires the manufactures of is equipment to meet Military Standard 810, which requires low temperature operation down to -40°C. The manufacturers of military radios need them to be light for handheld use and to cut down on the soldier's overall pack weight. Some new widely available li-ion formulations can operate at temperatures close to -40°C, but their performance is severely degraded. For true low temperature operation more obscure cells must be used. One manufacturer has changed the battery active material and electrolyte so that -40°C operation can be achieved, but the cells are large bulky and a price premium is certainly paid.

Advancements in both the cell's chemistry and the battery pack's construction are allowing rechargeable batteries to be used in a wider variety of environments, from surgical tools to military radios. Surgeons and soldiers are now benefiting from the same new technologies as consumers.

Contact Micro Power Electronics at www.micro-power.com.

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7355 E. Orchard Rd., Ste. 100, Greenwood Village, CO 80111 USA • Phone 720-528-3770 • Fax 720-528-3771 • www.infowebcom.com