Selecting Cell Chemistries for Your Portable Battery System

MICRO POWER

Introduction

Three cell chemistries currently dominate the growing portable application market: Nickel-Metal Hydride (NiMH), Lithium Ion (Li-Ion), and Lithium Polymer (Li-polymer). While all of these chemistries can address the high power demands of portable applications—handheld scanners, medical life-saving equipment, and consumer electronic devices—each has unique characteristics that make it appropriate, or inappropriate, for a particular portable device.

Choosing the optimal cell can contribute to the success or failure of a product in the field and requires extensive knowledge of the performance profile of cells under consideration, as well as an understanding of the 'real world usage profile' for the device. This profile includes temperature ranges, discharge profiles, charging regimens, expected shelf life, and transportation requirements.

Knowing the specific characteristics of each cell chemistry in terms of voltage, cycles, load current, energy density, charge time, and discharge rates is the first step in selecting a cell for a portable application. The following discussion gives a short overview of the characteristics, strengths, and weaknesses of each of the three cell chemistries.

Nickel-Metal Hydride (NiMH)

Characteristics of NiMH batteries include a nominal voltage of 1.25 V, 500 duty cycles per lifetime, less than 0.5C optimal load current, an average energy density of 100 Wh/kg, less than four-hour charge time, typical discharge rate of approximately 30 percent per month when in storage, and a rigid form factor. NiMH Battery systems excel when lower voltage requirements or price sensitivity are primary considerations in cell selection. NiMH Systems can be configured with up to ten cells in a series to increase voltage, resulting in a maximum aggregate voltage of 12.5 V.

Lithium Ion (Li-Ion)

Li-ion battery characteristics include a nominal voltage of 3.6 V, 1000 duty cycles per lifetime, less than 1C optimal load current, an average energy density of 160 Wh/kg, a less-than-four-hour charge time, typical discharge rate of approximately ten percent per month when in storage, and a rigid form factor. These characteristics make Li-Ion battery systems a good option when requirements specify lower weight, higher energy density or aggregate voltage, a greater number of duty cycles, or when price sensitivity is not a consideration. Li-Ion battery systems can be configured up to seven cells in series to increase voltage, resulting in a maximum aggregate voltage of 25.2 V.

Lithium Polymer (Li-polymer)

Li-polymer cells have similar performance characteristics when compared with Li-Ion cells, but have the advantage of being packaged in a slightly flexible form. However, this flexibility is often misleading, as Li-polymer cells should remain flat when installed in a device, not even bending for installation in the battery system. Characteristics of Li-polymer cells include a nominal voltage of 3.6 V, 500 duty cycles per lifetime, less than 1C optimal load current, an average energy density of 160 Wh/kg, less than four-hour charge time, typical discharge rate of less than ten percent per month when in storage, and a semi-rigid form factor. Li-Ion cells can be configured up to seven cells in series to increase voltage, resulting in a maximum aggregate voltage of 25.2 V.

Today, industrial applications, such as medical devices, handheld scanners, and ruggedized radios, are migrating from NiMH to Li-Ion battery systems due to the reduced price sensitivity of the applications combined with higher voltage requirements. In contrast, portable consumer products are continuing to operate on a wide range of batteries, from alkaline to Li-polymer.

But determining the right cell chemistry for a particular application is more complicated than simple price and voltage considerations. For a product to be successful in the field, engineers must analyze the different chemistries based on a 'real world usage profile' that goes beyond the performance and profile information listed on manufacturers' specification sheets. There are five factors that comprise this profile:

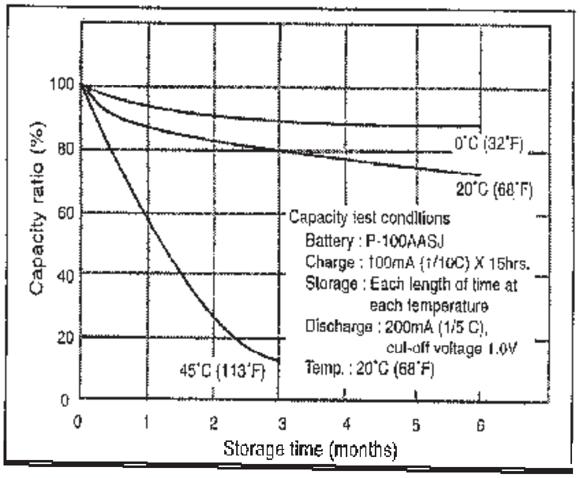
Temperature Ranges: Both external and internal operating temperatures are important considerations in selecting the optimal cell for a portable application. First, manufacturers typically specify cell performance at an ideal C/5 constant current and +20 C degrees external temperature, a.k.a., ‘room temperature. However, most portable applications do not operate in this ‘ideal’ environment very often — if ever. Rather, portable devices are expected to operate in a range from -40 C to +60 C degrees. These temperature extremes can cause similarly rated cells from different manufacturers to demonstrate widely varying a performance results, such as voltage output and run-times. In fact, a cell capacity variation of 65 percent has been demonstrated between cells tested at +5 C and +45 C degrees.

Another commonly overlooked temperature consideration is heat radiating from cells during charging and discharging. If the battery system is located next to temperature sensitive electronics, the combined battery system and equipment enclosure will have a maximum temperature threshold.

Discharge Rates: A non-uniform pulse discharge causes the cells to generate substantially more heat — up to an incremental 10 C degrees — compared to a constant drain. Additionally, a large pulse discharge degrades cell capacity faster than a uniform discharge profile. The larger the pulse current, the greater the heat generation, and the greater the chance for cell degradation.

Charging Regimens: Charging regimens affect heat radiated from cells and should be factored into battery system designs. When considering the temperature effect of a constant-current, constant-voltage charge method, a typical NiMH cell will increase by +20 to +25 degrees and a Li-Ion cell will increase by +6 to +10 degrees at a 1C rate charge. This temperature increase will vary by cell manufacturer but should always be factored into the heat tolerance of the portable device.

Expected Shelf Life: Shelf life plays a critical role in the selection of the appropriate cell chemistries. If the battery system is expected to be stored for months, or possibly over a year, the self-discharge rate of the cell chemistry may be the determining factor in selection the optimal chemistry. NiMH Cells will self discharge about 30 % per month. A NiMH cell could be fully discharged within a half year Li-Ion cells self-discharge at a rate of 10 % per month, and Lithium-polymer cells self-discharge at a similar rate.



Discharge Profile for NiCD Cell at Different Temperatures

Transportation Guidelines: Beyond technical considerations, design engineers must design battery systems with stringent Department of Transportation (DoT) and United Nations (UN) regulations in mind. These guidelines state that a battery system exceeding eight grams of equivalent lithium content must be shipped as Class 9 hazardous material. Shipping guidelines for Class 9 materials impose additional fees and regulations on the device manufacturer. For example, a portable device with a substantial power requirement—such as portable defibrillator—may require that two independent battery systems comply with DoT regulations, even though, from a technical perspective, one battery system may be more efficient. This restriction can cause design engineers to consider alternate cell chemistries. On the other hand, a carefully designed system may allow the device manufacturer to comply with the DoT shipping guidelines.

In summary, it is important to use a combination of cell specifications and information about the real-world usage of the portable device in selecting the optimal cell chemistry for the device. In all cases, cells — and cell manufacturers — should be qualified by the device manufacturer or an independent battery system manufacturer, such as Micro Power Electronics, to ensure the selected cells are a good match for the device’s usage profile.