How to Choose the Perfect Battery

Demand for smaller, sleeker portable communications devices, is pushing the wireless industry harder than ever to reduce the size of rechargeable batteries.

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Driven by increased consumer demand for smaller, sleeker portable communications devices, the wireless industry is pushing harder than ever to reduce the size of rechargeable batteries to help stimulate a stagnant market. This market trend has increased the popularity of ultra-thin lithium polymer and polymer-type batteries.

Today's designers are faced with more choices than ever when it comes to power sources. With the availability of Nickel-Metal Hydride (Ni-MH) batteries, Lithium-ion (Li-ion) batteries, Lithium Polymer batteries (PLB) and Advanced Lithium batteries (ALB), design engineers have a myriad of options to choose from when designing energy solutions for portable and wireless communications devices. How do they determine which solution is best for their application?

No single chemistry is a silver bullet to all portable needs, but each presents distinct advantages that must be carefully considered when making this critical decision. Every market segment has unique battery requirements, and the pack designer's &quotchecklist&quot should include several essential items: form factor, voltage, energy density, temperature performance, drain rate, and cycle life.

The Notebook Market

Run time is the perpetual mantra of notebook computer designers. Higher temperatures, faster processors, CD-ROM and DVD technology, resulting in increased power demands in the notebook environment, have nearly eliminated Ni-MH as a viable power source for these applications. The highest energy density cell commercially available today, the Li-ion 18650 (18 mm in diameter &#215 65.0 mm long), is also one of the most economical, making it the choice for most notebooks. With the growing popularity of ultra-thin notebooks and sub-notebooks, prismatic Li-ion cells, with their low-profile form factor, have recently made inroads in computing designs.

The number of even thinner battery technologies, has enabled many designers to begin investigating more creative mechanical solutions. PLBs and ALBs have a thickness of only 3 mm and can be produced as thin as 1 mm, thus providing the optimal solution for low profile devices. For example, a PLB or ALB could be embedded between a liquid crystal display (LCD) and the computer's outer casing, where it may be used either as the main power source in a smaller product or as an additional battery to supplement the main battery in a larger, higher-end system. Since many leading battery producers also manufacturer LCD panels, the convergence of these technologies could create more synergy in the marketplace, enabling assemblers to purchase finished LCD, battery and top cover units from a single source.

The Cellular Market

Historically, pricing pressures in the cellular market have led most wireless phone manufacturers toward Ni-MH solutions in order to keep costs down. In recent years, however, mobile phones have become a fashion statement, with removable, personalized faceplates and sleek designs quickly becoming the norm.

As phone form factors began shrinking, the Ni-MH standard evolved from AA to AAA and long-AAA. Subsequently, prismatic Ni-MH cells were designed into low-end and mid-tier phones, while many of the high-end products offered prismatic Li-ion cells. As Li-ion cells became available at much lower price points, they quickly became the standard in mid-tier, and even some so-called &quotgive away&quot phones.

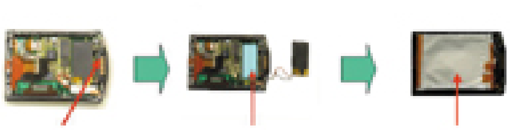

Figure 1. The thin form factor of the ALB and PLB technologies can save board real estate in a PDA which can be used to enhance the phones' features.

The same progression is now occurring with ALB and PLB technologies. Standard Li-ion cells range in thickness from 4.8 mm to 14.0 mm, meeting the requirements for most phone models currently available. However, the newer ultra-slim designs and phones incorporating Bluetooth&#153 and/or MPEG-4 type technologies, require additional board space, prompting the need for these products to adopt the thinner ALB and PLB cells (see Figure 1). These cells, while offering energy densities equivalent to prismatic Li-ion cells (see Figure 2), currently have a thickness of only about 3 mm.

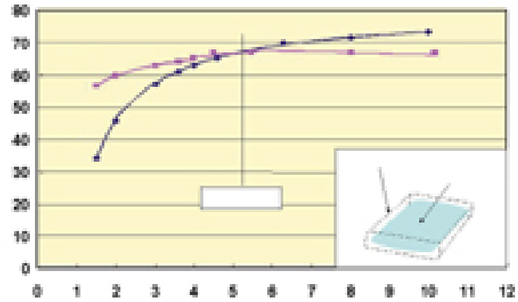

Figure 2. This diagram shows the cell thickness versus effective volume within the cell. based on current ALB technology, applications which are using cells thicker than 5.2 mm are better suited by LIB technology.

As cellular phones evolve into &quotcommunication tools,&quot incorporating email, photo, video, and wireless data transfer capabilities, battery selection will become even more critical, since such features increase drain rates and thus reduce battery life. Shortened battery life is an unacceptable trade-off for most consumers, so mobile phone designers must aggressively seek ways to optimize battery capacity.

The Personal Digital Assistant (PDA) Market

PDAs offer designers an even greater challenge due to the variety of form factors and power sources available to them. Designers must wrestle with a number of issues: Will the device fit into a shirt pocket? Will it have Internet capability? Will it have cellular functionality? What kind of operating system will it employ? These are all questions that must be carefully considered when the designer begins looking at the various battery options.

The first question is whether the battery should be rechargeable or non-rechargeable? For entry-level models without cellular or Internet capabilities, the answer is simply a matter of economics, leaving alkaline as the obvious choice. Meeting a magical, at times mythical price point for the PDA becomes the designer's primary objective. If a rechargeable battery is designed in to the device, it is reflected in the point-of-sale cost. On the other hand, a non-rechargeable battery, or &quotbatteries not included&quot option, allows manufacturers to pass the responsibility and liability of battery procurement to the consumer, who in many cases may not consider costs beyond the sale price when purchasing a PDA.

Some of the more complex PDAs currently on the market have Internet, phone, MPEG, Bluetooth, and MP3 capabilities that can rapidly drain battery life. By placing a non-rechargeable battery in these devices, the average consumer is forced to become a battery &quotjunkie&quot&#151 constantly having to replace batteries to keep the habit going. In addition, non-rechargeable batteries deter the consumer from using the device's wireless capabilities for fear of draining battery life. PDA manufacturers ultimately want to encourage their customers to use these capabilities to help offset the cost of the units via wireless contracts, much as cellular manufacturers do. Once this occurs, the line between cellular phones and PDAs begins to blur.

Most multi-functional PDAs now incorporate Li-ion batteries as well as ALB and PLB technologies. For slim designs that can fit into a shirt pocket, ALB and PLB are the chemistries of choice. ALB and PLB allow PDA designers to form fit a cell under the plastic case, thus maximizing available space, while adding only 3 mm to the overall thickness.

Power Tools

Due to the unique drain rate requirements of power tools, the operating environment is far different from that of other devices. Power tools can drain batteries at rates of 50 amps (A), while mobile phone applications drain 500 milliamps per hour (mAh). Newer chemistries available in today's market, such as Li-ion, PLB and ALB, are unable to withstand this level of current drain, making Nickel-Cadmium (Ni-Cd) the standard for such devices. In recent years, Ni-MH has made significant progress toward achieving the types of drain rates required, but cycle life, with 500 cycles for Ni-MH versus 1000 cycles for Ni-Cd, is still an obstacle for many power tool manufacturers.

With the pricing of Ni-MH 30 to 50 percent higher than equivalent Ni-Cd cells, the feasibility of Ni-MH is limited primarily to high-end applications. High volume power tools, such as screwdrivers and drills, are extremely price competitive, and the average user is not seeking the additional run time which Ni-MH would provide. Professional tools, on the other hand, have started to adopt Ni-MH, enabling construction workers and other professional craftsmen to work longer between charges.

Scanners and Other Wireless Devices

Other portable markets are highly segmented and use a variety of battery chemistries depending on the targeted customer. Portable scanners, for example, use everything from Ni-Cd cells to PLB. Scanners designed for operation in warehouses and shipping services typically use the higher energy density Li-ion cells, similar to those found in notebook computers. In-store scanners may employ a lower cost Ni-MH or Ni-Cd solution, since they are typically not used for extended periods of time between recharging.

Other wireless devices range from wearable PCs, in which form factors and weight are critical, to military radio charging base stations which can incorporate 40 to 50 cells in a pack. Wearable PCs, Internet appliances and eBooks are all rapidly expanding market segments that tend to be on the cutting edge of technology. Depending on the form factor of the system, most use Li-ion, ALB or PLB technologies. Larger systems, such as charging stations and land mobile radios typically choose the highest energy density cell in the market, the Li-ion 18650. On the other end of the spectrum, wireless Bluetooth devices, such as wireless headsets, may incorporate Li-ion coin cell technologies along with PLB and ALB chemistries.

Having looked at each market segment, let's invert the equation and examine the strengths and weaknesses of each battery chemistry.

Nickel Cadmium (Ni-Cd)

Ni-Cd has been in mass production longer than any of the other rechargeable battery solutions listed in this article, so it makes sense that it would be the most robust. At 1.2 volts (V) per cell, most applications require multiple cells in a series and parallel to meet a product's energy requirements. Memory affect has always been a concern with Ni-Cd technology, and thus is a severe limitation for high-end applications.

Recycling and environmental issues reduce the feasibility of Ni-Cd for other applications. Compared to other chemistries, Ni-Cd cells have an excellent drain rate capability, cycle life and good performance at extreme temperatures. Although Ni-Cd is an economical solution, the savings comes at the expense of energy capacity. Ni-Cd offers approximately half the run time of its evolutionary partner, Ni-MH, making most Ni-Cd solutions bulky and heavy.

Nickel Metal Hydride (Ni-MH)

Although Ni-MH lacks the robust characteristics of Ni-Cd, and the energy density of a lithium-based technology, it does offer a performance advantage over Ni-Cd at a competitive price. Ni-MH operates at the same voltage as Ni-Cd, 1.2 V per cell. With the major battery market segments (notebook and cellular) moving to lithium-based chemistries, RD efforts have slowed and theoretical capacity limits are drawing near. As a result, efforts are being made to increase cell robustness in order to accommodate other market segments, such as power tools and hybrid electric vehicles.

Lithium-Ion (Li-ion)

Li-ion has been in commercial production for almost 10 years. As the chemistry has matured, Li-ion cells have become more robust and less expensive. A single Li-ion cell has a voltage of 3.7 V, equal to three Ni-Cd or Ni-MH cells. High energy density and low self-discharge have always been key to the Li-ion's success in the market, and now other cell characteristics are being developed to further enhance the chemistry. For example, manufacturers are now working to develop cells, which will no longer require protection circuitry in order to further reduce the power solution cost.

Li-ion cells are divided into two mechanical categories, cylindrical and prismatic.

Cylindrical batteries offer the highest energy density of any commercially available rechargeable cell. Cylindrical Li-ion cells are typically between 17 mm to 18 mm in diameter and 50 mm to 67 mm long. These batteries continue to push the technology envelope, spurred on by notebook manufacturers who are accustomed to a technology that accelerates at a speed relative to that of semiconductors. Over the past two years, the energy capacity of the 18650 Li-ion cell has evolved from 1350 mAh to 1600 mAh to 1800 mAh, to today's 1950 mAh. In 2002, the bar will be raised again to more than 2150 mAh.

Prismatic Li-ion cells offer a thinner profile with an energy density slightly less than that of their cylindrical counterparts. Slim-line notebooks and mobile phones have created the demand for these cells. Prismatic Li-ion batteries come in a variety of form factors, ranging in thickness from 4.8 mm to 14 mm, in lengths ranging from 40 mm to 67 mm, and widths ranging from 30 mm to 34 mm. With prismatic cells, smaller the size, the lower the energy density.

Advanced Lithium Ion (ALB)

ALB cells offer the voltage (3.7 V) and energy density of a prismatic Li-ion batteries, but are encased in an ultra-thin aluminum laminate foil package. ALB is safer than standard Li-ion as it contains nonflammable electrolytes and has increased stability under abusive conditions.

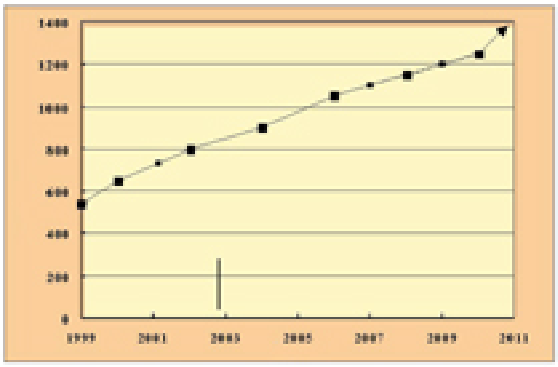

Figure 3. Capacity for ALB/PLB cells can reach over 1400 mAh.

The primary advantage of ALB over Li-ion is its thin design. Advanced lithium cells can be manufactured in form factors as thin as 1 mm and can offer capacities up to 1500 mAh (see Figure 3). Compared to PLB and even prismatic Li-ion, the ALB chemistry offers reduced swelling (less than 0.1 mm under severe conditions) and superior low-temperature performance. For example, ALB maintains over 50 percent residual capacity at -20 degrees Celsius (C).

Mass production of ALB began during the last 12 months, so the chemistry still carries a price premium over its Li-ion cousin. However, as yield rates and manufacturing capacities increase, pricing should continue to decrease, matching and possibly eclipsing that of prismatic Li-ion. Since this technology is still fairly new to the market, the energy density of the ALB is expected to continue its rapid increase.

Lithium Polymer (PLB)

With the exception of its electrolyte, PLB technology is nearly identical to ALB technology. The PLB electrolyte, which is polymer-based, provides an additional level of safety, as it will not leak the liquid electrolyte of ALB. However, unlike ALB, PLB is still somewhat limited in its low temperature and swelling performance, although it will continue to grow more robust in time as development efforts continue.

PLB offers the same thin form factor, aluminum laminate foil package as ALB and similar capacities as ALB. Many applications use both PLB and ALB as dual power sources for the same application.

Lithium Ion Coin Cell (IVR)

With the increasing number of small wireless applications expected to emerge during the next three to five years, the IVR could become a popular choice for very small portable devices, such as wireless headsets and communicator-type watches. The IVR technology is essentially a Li-ion cell compressed inside a coin-sized package.

A coin cell's capacity is limited (140 to 150 mAh in a 3.2 mm by 30 mm cell), but it could be just enough energy to power these small devices. Although the technology itself has been around for a number of years, battery manufacturers are just now beginning to look at large scale production, due to strong forecasted demand.

Future Technologies

For decades, the battery industry advanced slowly, offering Ni-Cd and sealed lead acid as the only sources of rechargeable energy. Now, within the span of nearly a decade, we have made the leap from Ni-MH to Li-ion, then to PLB and ALB. The most common question asked is, &quotWhat's next for batteries?&quot

The wireless world we live in is not slowing down. Heightened pressure is being placed on battery manufacturers to power future portable products. The current expectation for growth in battery capacity is 5 to 10 times greater than the 10 to 30 percent increases now being achieved.

Many believe the future for batteries will come in the form of fuel cells. Although still in the early stages of development, fuel cells may provide the kind of capacity advances which manufacturers are looking for. Fuel cells will enable consumers to instantly &quotrecharge&quot their portable devices without having to be near a power source, simply by plugging in a cartridge of fuel, such as methanol.

By combining a fuel cell with a Li-ion, ALB or PLB battery, the consumer would be able to recharge when near a power source and &quotfill up&quot when on a plane, in the woods or on the beach, without the concern of the dreaded &quotlow battery alert.&quot Depending on technical and manufacturing obstacles, fuel cells could enter the market as early as 2004. In parallel, there are ongoing developmental activities with a variety of other technologies, such as advanced solar cells and motion activated batteries, which could change the face of the rechargeable battery market.

Conclusion

Choosing a power solution has become more complicated than ever before. With continuous advancements being made and new technologies becoming available, it will only become more difficult in the future. There is still no single power source that covers the needs of every portable device, but understanding each chemistry's benefits and limitations can determine the success or failure of a new product. As product designs become thinner, smaller and lighter, the variety of cell chemistries and form factors will ultimately enable a more customized power solution approach. Battery development, although not known as a &quotsexy&quot technology is quickly picking up steam as we move into a wireless tomorrow.

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