The Smart Battery Survival Guide Series:

Intelligent Design for Portable Applications

Foreword

Planning for the battery system early in the design process maximizes performance, durability, reliability and safety.

Fueled by industry and consumers, marketplace demand is skyrocketing for high-power portable instruments and equipment. In the healthcare and field-service industries, for example, companies hope to increase productivity, competitiveness and customer service by implementing the use of portable electronic devices into many daily business operations.

To address this rising demand, electronics manufacturers are leveraging faster processors, enhanced color displays and backlighting, wireless networking, as well as voice and multimedia capabilities for next-generation portable devices. But the transition to highly sophisticated, power-hungry portable electronic systems in smaller, lighter, more ergonomic packages is creating new battery system-design challenges.

It is now crucial that battery system engineers avoid design problems and device failures by effectively planning, developing and implementing smart battery system solutions into their portable applications. Yet designing a power-management system for high-performance portable electronics applications can be difficult, even for the most experienced design engineer. Underestimating the complexity of the battery system and the interrelationship between battery and device circuitries can lead to setbacks during product development. Worse, the entire system may fail in the field.

These kinds of problems indicate that many original equipment manufacturers (OEMs) are facing battery-system design issues that they may not have the tools or internal expertise to solve. Fortunately, planning for the battery system early enough in the design process, along with proper implementation, can minimize or eliminate the possibility of battery problems.

This “Smart Battery Survival Guide” series helps battery system designers recognize and avoid challenges inherent in the battery system design process. It also helps designers develop intelligent designs that contribute significantly to the value of a product and its success in the marketplace.

SMART BATTERY SYSTEMS: THE PERFORMANCE ADVANTAGE

Smart battery systems are the preferred choice in mission-critical applications, such as the medical and field-service markets. These markets require ultra-dependable, high-power battery packs designed to withstand rough handling while providing reliability even under the most extreme environmental conditions.

Medical and industrial battery systems must also meet a wide variety of size and functional requirements, generally offering voltages ranging from 3 volt (V) to 14.8V and a typical range of 10 to 80 Watts (W).

A valuable smart battery pack feature to users of mission-critical applications is the pack's ability to monitor its status, accurately predict its remaining run time, and communicate its operational status to the host device. These features allow the end-user to intelligently manage device use and avoid unexpected failures or shutdowns.

A smart battery pack, when programmed to the end-user's unique discharge profile or characteristics, will be better able to deliver a much higher percentage of available power over the operational lifetime of the battery pack. A smart battery pack can also give feedback on its usage history, which is convenient for traceability and warranty issues.

Additionally, battery systems for medical and industrial applications must also incorporate redundant safety systems and reliable protection circuitry. Clearly, the value and performance of a portable electronic device is directly influenced by the quality and reliability of its battery system. Even minor problems tend to influence how users perceive the value of a portable device. For example, any battery problem that occurs during field use can cause an increase in the number of service calls, warranty costs and downtime, wasting the customer's time and money.

Only a smart battery system can meet all the requirements of today's portable electronic devices. It provides a solution that promises high-performance, maximum durability, long-term reliability and safety.

SMART BATTERY SYSTEMS: STANDARD OR CUSTOM SOLUTION?

Contrary to popular belief, a battery system is no longer simply an isolated collection of components. It is 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. However, today's smart battery system offers the addition of a fuel gauge and battery management components that enable communication with the host device.

Smart battery systems are complex and sophisticated systems. Their capacity, reliability and durability are determined by a wide-range of critical factors, including the cell chemistry, cell supplier, battery gauge accuracy, discharge rates, environmental temperatures and self-heating. These factors can determine the success or failure of the battery system in terms of capacity loss, service-life reduction and safety.

In view of this complexity, engineers can take a couple of different approaches to solving smart battery system-development challenges. One is the selection of a "standard" or off-the-shelf battery pack. A standard battery pack is designed to offer a general solution for a wide range of applications and provides a pre-determined set of performance characteristics and packaging alternatives. The advantage of such a solution for the OEM is that there is limited research and development or non-reoccurring expense (NRE) costs to contend with, and time-to market is short.

However, repeated experience has shown that a reliance on standard battery pack resources often proves to be a shortsighted approach. Although it is attractive to select off-the-shelf standard battery packs for design projects subject to severe time-to-market and cost limitations, these standardized solutions do not typically meet the majority of unique design specifications or the demands of a custom application.

When utilizing a standard battery system, the designer has little or no control over the physical configuration of the pack. The vast majority of standard battery packs are not user-programmable or configurable, and the design engineer utilizing a standard pack solution has very little opportunity to enhance or optimize any aspect of the pack's performance. Some examples include:

- the pack's operational protocol (i.e. SMBus or One Wire) and battery ID nomenclature operating voltages or charging regime
- alarm limits and optimal fuel gauge settings
- display characteristics
- issues relating to quality and reliability that require constant oversight and attention

Typical examples of which the end-user should be aware are:

- the workmanship and quality standards of the supplier
- the choice of cell manufacturer or cell/pack capacity
- influence or control over how the pack is calibrated and tested
- the packaging and labeling of the product

Finally, the cells and integrated circuits (ICs) used to make the standard packs tend to vary by manufacturer. One "standard" pack may not perform the same as another, or even operate in an OEM's application.

Engineers who believe that they must use a standard battery pack solution may find themselves dealing with battery-related deficiencies that compromise the full potential of their designs. In extreme cases, the critical or competitive performance features of their product may not be fully realized, negating market differentiation. More often than not, the consumer perceives performance issues as being related to battery life, reliability, durability and safety.

With a few exceptions, custom battery solutions provide the best source of power management for any application. Increasingly, designers are turning to custom development and manufacturing vendors for their smart battery systems. In addition to meeting the exact performance and packaging specifications required by a portable device, a custom battery system gives them the added benefit of aftermarket profits. Because batteries do not last forever, batteries are sold by OEMs as an accessory item with good profit margins. Custom batteries direct the benefits of accessory sales to the OEM rather than to aftermarket vendors.

DESIGNING AND MANUFACTURING A SMART BATTERY SYSTEM

When designing a smart battery system that offers optimal performance characteristics in the target application, engineers must approach the problem holistically. A complete front-to-back development process that emphasizes early design characterization, optimization and validation will provide the maximum battery power, reliability and safety for field-service applications.

Application characterization of the battery cells in the pack configuration desired is crucial to the development of high-performance battery systems. This involves a series of test, measurement and analysis functions such as creating a predictive performance model, running reliability tests and establishing accurate calibration procedures at expected operating temperatures. Because battery chemistries differ in performance, and recipes among cell manufacturers vary, it is extremely difficult to develop a fixed model or algorithm that would fit all applications and battery cells.

Considering the impact that high currents and temperature extremes can have on a battery system's performance, safety and reliability, it is critical to validate the battery system using realistic usage patterns and operating conditions. This process requires sophisticated, programmable test equipment. It is difficult to accurately predict a battery system's performance based on a manufacturer's published specifications.

Without access to precision verification equipment, less sophisticated calculations are often employed, which can be time-consuming and result in system unreliability.

By validating the battery system against the specifications set by the application at each stage of the process, the designer will be able to ensure that the battery system will perform as expected. This early involvement helps to certify that the battery system has been optimized to deliver the maximum runtime, reliability and manufacturability.

Implementing early design characterization, optimization and validation while taking the battery system from initial specification to volume production can uncover potential design problems early in the development process. The knowledge gained from these procedures can be used as a test bench platform during the manufacturing process.

Another design method to achieve higher system reliability and greater manufacturing efficiency is to minimize the number of components used in the battery system by leveraging common components whenever possible. It is important that designers look for opportunities to leverage existing modules, or building blocks, to reduce the development time and cut costs.

In today's competitive marketplace, however, it is no longer enough to have the most exceptional design created from advanced characterization and validation procedures.

Modern smart battery systems must also be cost-effective and easy to build. Designers should adhere to design-for-manufacturability principles by working closely from the start of development with the manufacturing staff to ensure the battery systems will be easy and cost-effective to manufacture and test.

BATTERY SYSTEM DESIGN CHALLENGES

The need for smaller battery systems is making design for manufacturability increasingly important. As form factors shrink, design and manufacturing challenges grow. Diminishing real estate in portable applications has made it more difficult to fit the required components into the available space. As component congestion increases, so does the risk for accidentally pinching or shorting wires and contacts.

Component layout also becomes important in battery systems, as a poor layout can complicate the assembly process or create hot spots inside the pack. Although venting is less crucial with Lithium-ion (Li-ion) than with Nickel Metal Hydride (Ni-MH), ensuring that heating is even throughout the pack enables the safety devices to trip when needed.

Furthermore, the designer must be careful to ensure that vital contacts are not placed too closely together to avoid shorting that may occur if the device is dropped or subjected to vibration. The designer also must ensure that contacts are recessed to prevent external short circuits.

Another design challenge associated with smaller battery systems is the mechanical fit. With smaller tolerances, the contact points, energy director (for ultrasonic welding) and locking mechanism must be designed and manufactured with greater precision and care. Smaller packs usually utilize thin-walled plastic (.060" thick) that can be difficult to ultrasonically weld without cracking and must be tested to ensure adherence to drop test requirements.

Soldering, resistance welding and ultrasonic welding can also be challenging processes. It takes many years of experience to be able to create high-quality joints consistently. Poor solder and weld joints are the greatest source of industry defects. Without effective training, controlled processes, high-quality equipment and rigorous inspection procedures, it is possible to create weak weld and solder joints that may not be discovered until something goes wrong with the portable unit in the field.

Major causes of battery pack field defects are cold, fractured, or missing solder joints. These flaws can create an electrical connection that manages to pass a functional test, but breaks in the field due to vibration or heat. Occasionally, failures are intermittent, making the problem more difficult to diagnose.

Solder balls, which are tiny drops of solder that remain in the battery system after careless production procedures, are also a source of defects. When vibration or thermal stress causes these conductive balls to break free inside the battery system, they can short and damage the battery system.

Resistance welding is particularly difficult to master with Li-ion chemistries. Because they have thinner outer walls, Li-ion cells are more delicate than Ni-MH and Ni-Cd cells, and the welding process must be more precise and consistent. If excessive energy is applied during the welding process, the heat burns a hole in the cell wall, thus destroying it. If there is too little energy, a weak joint is created. Resistance welding must be done in a unique window of pull strength, and the industry standard is 2 kilograms (Kg) (1 weld hit) to 3Kg (2 weld hit) minimum. Additionally, Li-ion can be less forgiving than other cell chemistries. For example, Ni-based cells, with their thicker cans, can usually sustain multiple welding attempts, while Li-ion will not.

Soldering and welding not only are core processes, but they also are critical success factors in the development of a reliable battery system. To ensure consistent, high-quality welds, it is important to use only state-of-the-art, computer-controlled welding equipment; perform window studies on every cell; use statistical process-control methods; and perform rigorous pull tests to ensure the highest levels of reliability.

CONCLUSION

More than ever, sophisticated portable applications demand equally advanced power solutions. Increasingly, OEMs are turning to smart battery systems to meet the needs of their mission-critical equipment for high-performance, maximum durability, greater reliability and safety.

The best design teams are starting to demand the benefits not only of smart battery systems, but also of custom power solutions. Custom battery solutions offer the best fit for the real-world performance and packaging specifications of a portable device. Additionally, custom battery packs provide the OEM with aftermarket profit opportunities.

Since smart battery design and fabrication take more work, designers must take a comprehensive development approach, placing emphasis on early design characterization, optimization and validation. Care and expertise are called for in the manufacturing process as well. But the effort more than pays for itself with a system that provides maximum power, reliability and safety. These customer, smart battery solutions an lead to fewer callbacks, higher customer satisfaction and even greater profits.

REQUIRED CAPABILITIES FOR TODAY'S SMART BATTERY MANUFACTURERS

The rise in industry battery defects is directly related to a competency gap between the capabilities of battery assemblers and the skills required to produce the next generation of high-performance battery systems.

Technical competence is a key requirement for designers of high-performance battery systems. A battery system supplier that does not possess the technical skills and application experience needed to understand the requirements of the application, interpret the specifications or speak intelligently about the latest battery cells and battery management technologies is likely to fail.

Driven by the requirements of the marketplace and today's portable applications, manufacturers must:

- develop a unique, systems-focused development approach
- possess extensive application knowledge and expertise
- provide lean, flexible and state-of-the-art manufacturing capabilities
- maintain close relationships with technology leaders, including the top-tier cell vendors
- offer exceptional customer service through quality, delivery, responsiveness and flexibility

High-performance battery systems require greater levels of sophistication and talent to develop than yesterday's battery packs, which were simple enough for anyone with a soldering iron, a garage and a few developers. Today's manufacturers must offer advanced technical skills, tightly controlled development processes, complex testing and manufacturing equipment, as well as many years of experience in the development of battery systems. These are capabilities that most battery pack assemblers currently lack.

ABOUT MICRO POWER ELECTRONICS INCORPORATED

With a proven track record of technical excellence, quality solutions and award-winning service, Micro Power Electronics Incorporated has become the fastest growing supplier of custom battery systems in North America.

Micro Power is an ISO 9001 certified and FDA-registered supplier of custom battery systems for the portable healthcare, field-service and handheld computing markets. As a pioneer in the development of Lithium battery systems and smart battery packs, Micro Power is capable of meeting the most challenging power requirements. We have more than 15 years experience developing battery solutions for the world's most demanding customers.

Offering state-of-the-art cell chemistries, accurate fuel gauging technologies and the latest in smart battery options, Micro Power battery systems are optimized to deliver maximum performance in the customer's application. And our battery systems are verified extensively to perform reliably and safely in challenging work environments.

Micro Power's mission is to develop the world's most dependable power sources for portable equipment. Our solutions enable manufacturers to free their technologies from the power sockets that confine them—making them mobile and more accessible to people who critically need them.

For more information on Micro Power, call 800-576-6177, email experts@micro-power.com or visit the web site, www. micro-power.com.