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Matching battery charging solutions to system designs

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The popularity of such applications among consumers has set new requirements in terms of usage time, weight, size, environmental friendliness and functionality, making Lithium-based re-chargeable batteries the number one power source choice. While Li-Ion and Li-Polymer, the two most popular variations of this battery technology, offer great advantages in terms of energy density, they also introduce some new requirements in terms of handling and charging. Understanding these requirements and the system design goals are key for optimising the battery charging circuit of new product developments.

The relatively flexible battery charging profile of a Li-Ion battery, and the wide variety of available batteries and battery charger ICs on the market, makes the design even more challenging—especially if battery management is a new task for the engineer. The goal of this article is to provide some key understandings of the trade-offs in battery charging designs, thereby allowing for a more sophisticated and structured decision process.

Battery selection

One of the most critical components in finalising the battery charging design is the battery itself. Over the last few years the industrial design has become very influential in choosing the battery. The reason is that form factor, usability and overall appearance of the electronic device are considered key elements in consumers' purchase decision process. From a system design stand point this translates to a battery capacity that might be lower than desired, making the task of long usable life a very difficult one.

In addition to understanding the industrial design requirements at the start of the design process, it is good practice to also conduct an analysis of the average system power, board space and cost requirements. Since in most cases these requirements do not go well together, trade-offs have to be made on a case-by-case basis. It is extremely important for design trade-offs to take place early in the development process; last-minute changes can impact the entire power management sub-system as well as other application specifications.

The average power requirements of the application, in combination with an acceptable usable battery life will determine the necessary battery capacity. Obviously, in cases in which the industrial design (weight, size and form factor) imposes a lower-than-desired capacity, more effort has to be put into power conservation. Choosing a specific battery capacity and form factor can result in significantly lower cost if the same battery type is widely adopted in high-volume portable applications. As we will discuss in the following paragraphs, higher battery capacity can also translate to a longer charging time, unless this is proactively addressed in the system power design.

Once the battery type (Li+ technology), make and model are selected, the recommended charging algorithm is available from the battery manufacturer (battery datasheet). Deviation from the datasheet specifications is not recommended, since it could lead to early battery degradation. Even though the charging profile of Li-Ion batteries is well defined, certain charging parameters can be adjusted based on system needs (see Figure 1). For example, charging current needs to be below a certain level for reliability (usually 0.5C to 1C,) however the system might not be able to provide this current level because of power dissipation or other design constraints. The termination current threshold is another parameter that can differ from one design to the next, since delaying the charge termination from a certain point onwards does maximise battery capacity but results in a significantly longer charge cycle. Hence, system requirements need to be carefully analysed before finalising the power conversion and battery management architecture.

Charging topology

The selected battery capacity and target charge cycle times also determine the charging IC architecture to be used for a specific design. For small battery capacities, a linear-mode charging solution is ideal because of low cost and complexity. As the required charge current levels increase, a switch-mode topology becomes inevitable. The significantly higher efficiency of a switch-mode battery charger IC allows for higher charge current levels (i.e. shorter charging times), and at the same time minimises hot spots—a key issue in compact designs.

A switch-mode charger IC is also more desirable in systems that use unregulated or simply higher-voltage wall-adapters, since their power dissipation is not a direct function of input (adapter) to output (battery) voltage differential. New linear charger IC offerings do incorporate current fold-back. This allows the charge current to be reduced as the charger IC die temperature increases, thereby protecting the IC itself. The downside of this operational mode is longer charging times that are the result of the thermally-reduced charge current.

An example of a switch-mode charging solution is shown in Figure 2. This implementation allows for continuous charge currents of up to 1.25A, thereby supporting 1C charge rates for higher-capacity batteries. Furthermore, by utilising TurboCharge™ technology, the SMB138 is able to provide a charge current that is higher than the input current. This current "multiplication" is extremely important with an increasing number of applications relying on charging from current limited USB port and AC adapters, and with new-generation processors requiring a higher current level for system wake-up.

Charging IC features

System philosophy will define the necessary secondary protection features for a specific design. The primary protection features (over-voltage, under-voltage, over-current, etc.) are always integrated into the battery pack, and are the responsibility of the cell itself, as well as the battery protection circuitry in the pack. However, given the "sensitivity" of Li-Ion battery chemistry and consumer perception (as a result of the few but significant accident reports), a lot of applications incorporate additional protection in their designs. This becomes especially important when certain standards need to be met, like the recently introduced IEEE 1725™ from the IEEE Power Engineering Society.

One of the most popular safety features in hand-held system designs is the monitoring of cell temperature. High temperature levels are the main source of Li-Ion instability, therefore battery packs incorporate a thermistor element that can monitor temperature levels and provide this information to the "outside" world. In response to this, many of the charging ICs have the ability to "read" this thermistor output and suspend charging when the cell temperature is outside a battery manufacturer's specified range (usually 0?C to +45?C).

Another very important protection feature is the monitoring of the battery voltage level. Protecting the battery from an over-voltage condition is one of the main functions of the protection IC located inside the battery pack. Having secondary protection allows for higher system reliability and meets the most stringent safety requirements in the industry. Input over-voltage protection is also a desirable feature in many new designs. It prevents the charging IC from charging when the input voltage is higher than a specific voltage threshold. This feature is extremely important when companies are concerned with their devices being connected to "non-compliant" wall-adapters.

Additionally, safety (also called charge) timers are used frequently in battery charging applications. These timers provide protection against defective battery cells by suspending charging when the duration of the charging process exceeds the time expected under normal charge (and operating) conditions. This is a parameter that is adjustable in most charging ICs, since it needs to allow some design flexibility associated with charge current levels, and therefore normal charging duration.

Charging IC parameters

The most critical parameters to look after when selecting a battery charging solution are input voltage, float voltage, input current and charge current. Input voltage seems trivial, since everyone knows that it defines the voltage that the charging IC solution can accept from a wall adapter. However, in many cases a wider (i.e. higher) input voltage operating range can have a positive effect on total system cost, since is eliminates the need for a well-regulated wall adapter.

Float voltage level and accuracy are two of the most important parameters when charging a battery. A higher than expected float voltage degrades the life of the battery and could allow the battery pack to enter an over-voltage condition, resulting in charge suspension. On the other hand, a lower than expected float voltage leaves the battery cell under-charged, thereby reducing the battery's usable operating life. In addition to float voltage accuracy, system designers need to start taking into account short-term transitions to new battery technologies with higher or lower float voltage levels. The high majority of today's charging ICs provide a 4.2V float voltage, and only very few solutions exist that are able to address the new, higher or lower, float-voltage requirements.

The increasing use of computers' USB ports as the primary power source for charging, together with the newly-defined wall adapters by the USB Implementers Forum (USB-IF), has resulted in the input current accuracy becoming a critical parameter. The USB2.0 specification limits the USB port's current to 100mA before enumeration has completed, and to 500mA after "hand-shaking" has found place. This means that, for USB2.0-compliant designs, it is critical to provide as much current as possible for system power and battery charging, and in the same time limit the current below the 100mA/500mA levels. Implementing input current limit and offering accurate current measurement can address both these challenges.

As mentioned earlier, the battery pack datasheets provide recommendations on charge current levels that ensure safety and reliability. While the charger IC should ideally provide the maximum current provided by the battery manufacturer in order to achieve the shortest charging times, in reality there are many system parameters that affect the "real" charge current level. It is recommended that power dissipation under worst-case system conditions be analysed to ensure that "advertised" charge current for a specific charger IC is feasible. Charge current accuracy is also very critical, since the more precise the current setting the less design headroom is required for the system. For example, in USB-powered charging applications, the host device needs to draw less than 500mA to meet the USB2.0 specification, but at the same time draw a current level that is as close to 500mA as possible to accelerate the charging process.

Summary

Li+ based rechargeable batteries have become the default power source for the increasing number of portable consumer devices. This trend has resulted in the development of a high number of battery charging ICs by various manufacturers. While this wide product offering allows for great design flexibility, it can also delay or complicate the selection process.

It is critical to understand the key topologies, parameters and features of modern battery charging solutions to better analyse the system design trade offs and define a more sophisticated decision process. The goal is to ensure a positive consumer experience with a reliable system design, while keeping the cost at acceptable levels.

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