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Li-Ion/Poly batteries drive high growth of battery management ICs from headsets to electric vehicles, says Petrov Group

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The requirement for power-efficient and high performance solutions in Li-Ion/Poly battery-powered devices and equipment continues to open profitable growth opportunities for existing IC vendors as well as for numerous start-up entrants. The profitability aspect is best illustrated by the fact that Linear Technology, a profit-driven company, is a major participant. Linear Technology offers 78 core products - three standalone fuel gauge ICs and 75 core battery charger ICs. In comparison, the start-up AnalogicTech offers only single function standalone charger ICs targeted at mass market applications featuring a single cell Li-Ion/Pol battery and USB 2.0 compliant power source.

Four major market forces impact battery management IC attributes: end-equipment system trends, battery technology trends, battery charging trends, and industrial design and marketing (end-user) trends. Battery management ICs are application-specific and analog-intensive mixed-signal ICs used in numerous end-systems and their battery packs. The complexity and variety of battery management ICs are driven by end-equipment types, battery types, and battery management architectures. This drives the need for customization of battery management ICs in order to meet the specific needs of the target end-equipment system, battery, and power sources.

Battery management ICs include products that are typically used on an end-equipment system board or inside a battery pack. In addition, some are designed for use in battery charging cradles. Battery management ICs are not used in adapters (also commonly referred to as "chargers") providing power to an on-board charger IC.

Battery management ICs link an end-equipment system's power architecture with the front-end power sources (typically an AC adapter and USB port) and the back-end battery pack system; they are an integral part of the overall end-equipment system's power architecture. The need for customization is especially strong for ICs integrated into battery packs (such as fuel gauges) where there is a tight relationship between a battery's chemistry and the associated electronics.

Battery power management architecture is typically specific to an end-equipment device and drives battery management IC implementation strategies. Key system level trends include:

(1) System level approach to battery power management featuring increasingly closer relationship among charging, fuel gauging, protection, and system host functions.
(2) (2)Increasing number of power sources and relevant standardization trends. Power sources include adapters (AC/DC, DC/DC) and USB/USB-OTG ports, each featuring a range of operating standards that must be managed by the charging IC.
(3) Increasing use of smart battery system architecture compliant with SBS1.0 (Intel/Duracell) specifications beyond traditional notebook applications.
(4) In-system use of standalone fuel gauges enabling a higher degree of battery standardization and low battery cost. Increasing charger requirements for managing system power delivery (powerpath management).
(5) Increasing use of one- and two-wire communications interfaces for battery status/data report, control, and charging parameter programming.

The product classification and market segmentation of this fast changing over US$3 billion standalone battery management IC market in 2009 are best validated by a bottom-up analysis of products and vendors and various battery charger, fuel gauge, protection, and authentication ICs. The Petrov Group analyzed more than 600 core products of twenty vendors and eleven end-systems, stated Boris Petrov, managing director of The Petrov Group. These core products constitute about 3,000+ standard products.

Standalone charger ICs alone accounted for about 1.9 billion units and US$1.4 billion revenues in 2009, while standalone fuel gauge ICs accounted for about 1.6 billion units and US$1.4 billion in revenues. Texas Instruments, Maxim, and Linear Technology accounted for nearly one-third of the standard IC products. About half of the standalone battery management ICs are custom rather than standard ICs.

Analysis of 20 IC vendors and 622 battery management core IC products reveal that the top-seven vendors represent about 85% of total products. TI alone represents about 39% of the analyzed 622 products. As a result, TI is the dominant supplier of battery management ICs. Charger ICs and fuel gauge ICs are the two major product categories representing 76% and 14% of total products, respectively. Six hundred twenty-two core products translate to about 3,000 generic products and at least 10,000 catalog (variant) battery management IC products.

Battery management IC categories include charger ICs − single function and multifunction, fuel gauge ICs − standalone and monitor, protection ICs − charger front-end (FE), fuel gauge analog front-end (AFE), and level-2 protection ICs, and authentication ICs. The authentication function is typically integrated into other battery management ICs, hence, a relatively small number of offered devices.

Standalone charger ICs feature an on-chip charge control algorithm execution engine (typically a state machine). This type of charger IC is usually referred to as a standalone device because it can operate autonomously without any assistance from a system host (host processor, battery pack, or system based fuel gauge). However, variations of this type of charger IC could include products featuring a degree of control over the execution of the charging algorithm. IC vendors typically offer these products as part of a product family that includes the core standalone product and its host controlled variations.

Single function ("discrete") charger ICs represent about 87% of the total of 471 analyzed charger IC products used in a broad range of end-equipment applications. The standalone type dominates 86% of 352 analyzed products: Linear topology chargers represent about 61% of products and are mainly targeted at 1-cell Li-Ion/Pol battery applications; about 52% of those products are USB 2.0 power source compliant. Switching topology chargers represent the remaining 39% of products and are mainly targeted at multi-cell Li-Ion/Pol battery applications.

Multifunction (integrated) charger ICs (PWMICs) are mainly used in mobile phone applications as power management companion ICs for the system's main processor. They represent about 13% of the 471 analyzed charger IC products and are typically sold in high volumes, yielding relatively high revenues per product.

The level of functional integration varies widely from a charger IC with an added on-chip DC/DC converter (Bluetooth devices application) to highly integrated SoC type devices used in mobile phone applications. The Petrov Group estimates that about 50% of PWMICs feature an on-chip charger function. These products typically use linear topology chargers for 1-cell Li-Ion/Pol batteries and usually feature a USB 2.0 compliant power input (50 of 63 analyzed PWMICs). They feature standalone and host controlled operation.

The Petrov Group classified battery charger ICs into a five-level hierarchy by integration, topology, algorithm execution, input power sources, and application attributes, said Boris Petrov. Fuel gauge ICs are classified by algorithm execution (intelligence), integration, battery chemistry, cell configuration, and protection and monitoring features. End-equipment power is segmented into three main power levels; energy harvesting devices and electric vehicles are separate emerging segments.

Enabled by microelectronics technologies Li-Ion batteries are displacing other battery systems. The demand for increasing performance battery management ICs is driven by two major forces: (1) maximum utilization of a battery's available capacity and (2) full-proof protection from safety hazards.

Battery management ICs have to deliver high precision, high power (voltage and current) capability, and ultra-low power consumption. Bipolar is a must process technology for battery management ICs − hence the use of BiCMOS and BCD dominates. The trend toward universal adapters ("chargers") requires an added degree of protection and favors increasing use of BCD technology.

The 2009 market for charger ICs and fuel gauge ICs was about 2.3 billion units and 1.6 billion units, respectively. About 82% of portable end-equipment units feature standalone charging capability (or about 1.9 billion units). At a volume ASP of US$0.75, this amounts to about US$1.4 billion. Standalone charger ICs includes single function ("discrete") and multifunction (integrated) charger ICs. Standalone fuel gauge ICs represent about 1.6 billion units (1.1 billion units plus 50% current replacement rate, hence 1.6 billion units) and US$1.4 billion at a current volume ASP of US$0.85. The CAGR (2009 to 2012) for both product categories is about 12%.

Front-end charger IC protection is becoming increasingly critical due to the emergence of universal AC adapters ("battery chargers"). Increasing and mandated use of universal AC adapters in mobile phones in China and in Europe/North America (there are two "universal" adapter standards) is increasing the protection requirements of front-end charger IC protection. In an environment of standardized adapters produced by a range of third-party vendors, charger ICs might be exposed to high voltages and currents.

This requires an added degree of front-end protection either via a separate protection IC or an on-chip protection capability of a charger IC. In both cases use of BCD process technology is mandatory. This trend is illustrated by recent PWMIC introductions, e.g., the Power IC chipset for Intel's Atom Z6xx processor. At Computex 2010 Freescale introduced a highly integrated chipset, including charger functionality, using its 130nm BCD SmartMOS-10 platform. Maxim and Renesas PWMICs for Atom Z6xx processor will likely use 180nm BCD process technology. The new adapter standards promote use of USB connectors − USB type-A for the China standard and micro-USB connector for the USB-IF standard (Europe and North America).

"Dumb" battery packs feature at minimum a protection IC with power MOSFETs and a thermistor. In addition, it could include a monitor IC to acquire battery data required by an external fuel gauge for processing. "Smart" battery packs feature an in-pack fuel gauge compliant with the SBS1.1 specification. In addition, the battery pack typically contains a protection IC with power MOSFETs. This leads to a 4- or 5-pin battery pack vs. 3-pin in the case of a "dumb" battery. A "smart" battery can act as the master of a smart battery system (SBS) where the charger IC acts as a slave (a so-called Level-2 charger).

The most versatile battery management architecture is based on the smart battery system specification (SBS 1.1) initially created by Intel and Duracell primarily for use in notebook applications, according to the Petrov Group. The smart battery system architecture uses SMBus for communication between a smart battery, smart charger, and system host.

Smart batteries feature an integrated fuel gauge which communicates the condition of the battery and requests a charge (voltage and current) over the SMBus. Charge requests are met by the smart battery charger, which applies the requested voltage and current to the battery terminals. The charger does not need to know the battery chemistry because the fuel gauge maintains the charge algorithms. As a result, any smart battery charger can charge any smart battery. The SBS 1.1 specification provides for two major modes of operation (1) the smart battery is the system master (level-2 system), and (2) any device other than the smart battery can be the master (level-3 system). In this architecture, any smart battery and smart charger form a closed loop charge system that does not require host processor intervention.

Energy harvesting technologies could be segmented into two major categories. (1) Macro-scale harvesting using renewable energy sources (such as solar and wind). A key attribute of these technologies is that they provide off-grid power sources and can feed the electric power grid; hence, their ultimate goal is to reduce oil dependency. (2) Micro-scale harvesting using energy from the environment (such as vibration, body heat, and light). A key attribute of these technologies is to power ultra-low power devices; hence, their ultimate goal is to enable perpetual devices.

A significant near-term business opportunity for standalone battery charger ICs is in solar single panel applications less than four square feet in area producing up to 25-30W of power. Typical end-equipment applications include high-end consumer, automotive, industrial, roadside, and marine and military segments − both portable and non-portable. Linear Technology and TI have recently accelerated product introductions in this area as well other energy harvesting applications.

Electric transportation is not only relevant to cars but already in use in many millions of simple task-oriented vehicles around the world. The systems are more basic compared to those on the hybrid and electric car side but consist of the same functional blocks. Representative examples include e-bike, scooter, golf cart, forklift, and other small task-oriented vehicles (STOVs)

The hybrid and electric vehicle system is built of several modules to form the drive train and energy storage system. The battery block is typically Li-Ion chemistry in the range of 400V. It is managed and monitored by the battery management system (BMS) and charged via an on-board AC/DC converter module ("adapter") with voltages ranging from 110V single phase to 380V three-phase systems. A battery management system (BMS) is integrated into the battery pack.

The battery management system (BMS) is a key element in the overall electric vehicle architecture. It represents a highly safety-critical function − therefore the associated analog and digital components (microcontroller) need to meet specific safety requirements. The battery pack must be carefully monitored during operation and charging in order to maximize energy usage and prolong battery life. This is accomplished with advanced battery monitoring ICs typically managed by a host controller, according to the Petrov Group.

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