BY TAKASHI KANAMORI AND GEORGE PAPARRIZOS • SUMMIT MICROELECTRONICS

USB battery-charger designs meet new industry standards

USB IS NOT JUST FOR DATA TRANSFER ANY MORE; THERE ARE TOO MANY GOOD REASONS TO USE IT IN SUCH APPLICATIONS AS CHARGING HANDHELD-DEVICE BATTERIES. NEW STANDARDS ADDRESS SUCH USES, AND NEW CONNECTORS AND ICs CAN MAKE SHORT WORK OF YOUR DESIGNS.

The USB (Universal Serial Bus) has become the industry's most pervasive connectivity technology, especially in portable, consumer devices. The broad adoption of this standard has initiated several follow-up efforts that respond to handheld devices' continuing need to have USB perform more functions than just USB 2.0-compliant data transfer. The industry has seen a growing trend toward using USB's power capabilities to charge batteries. In addition, increasing numbers of applications now take advantage of the USB OTG (On-The-Go) supplement, which allows device-to-device connectivity without the need for a PC host. Moreover, the increasing dominance of industrial design in system design calls for space-saving, low-profile PCBs (printed-circuit boards) and components that require new, slimmer interconnection technologies. To provide industry-standard approaches to these challenges and maintain USB's high level of consumer satisfaction, the USB-IF (USB Implementers Forum) has developed several new specifications (**references 1** and **2**).

In addition to these specifications, other initiatives have found ways to address similar challenges. The most influential of these initiatives has been China's new Telecommunications Industry Standard for mobile-telecommunication-terminal equipment (**Reference 3**). This standard aims to reduce consumers' handset costs, to provide interoperability of ac/dc-charging adapters, and to protect the environment by minimizing electronic waste. Under the new standard, compliant wall-mounted chargers provide a USB connector to ensure universal charging with all mobile phones. The standard also specifies safety and performance requirements that chargers and phones must meet.

BENEFITS OF USB CHARGING

Most of today's computers and peripherals, including flash cards, digital cameras, cellular phones, printers, mice, and keyboards, use a USB port for data transfer. The USB 2.0 specification has expanded market opportunities by enabling data transfer at rates as high as 480 Mbps and maintaining attractive plug-and-play characteristics (**Reference 4**). In addition, the USB port's power capabilities make it a useful power source for millions of consumers.

One of the most popular applications of the USB port's power capabilities is charging of single-cell lithium-ion- and lithium-polymer-battery packs. Many users spend hours each day in front of a PC and therefore have USB charging at their finger tips—a great convenience. According to the USB specifications, a USB port can deliver a theoretical maximum of 500 mA at 5V±10%. By taking full advantage of USB's power capabilities as well as the need for high-speed computer access, some applications have been able to eliminate the need for an ac adapter and its associated cost. A great example is the MP3 player: A typical user connects an MP3 player to a computer to create or update the device's music list, so a USB port and cable are already in use for data transfer. Using the same setup for battery charging is a logical next step. Digital still cameras, portable GPS (global-positioning-system) devices, and smartphones further exemplify applications that require PC access for data uploads, such as pictures and contacts, and thus can benefit significantly from USB charging.

NEW USB-CHARGING STANDARDS

The new Chinese standard introduces a variety of electrical and mechanical requirements that ensure battery-charging intercompatibility and safety. The standard requires new wall chargers to provide a connector that complies with the USB Type A specification (**Figure 1**). This mechanical implementation allows connection of mobile phones to any dedicated wall charger or computing USB port for battery charging. The

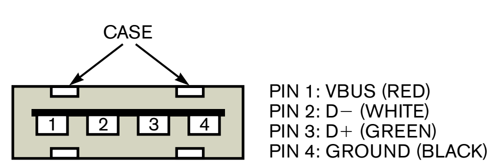

Figure 1 USB Type A connectors have four pins. The original function of pins 2 and 3 was data transmission. Newer standards also use these pins to enable communication between power controllers and power sources to establish such characteristics as maximum output current.

new wall chargers must be able to supply at least 300 mA but not more than 1.8A. This current range addresses both the low-cost and the high-performance product segments. The Chinese-government mandate also refers to a wall-charger-detection scheme, which requires detecting a short circuit between the D+ and D− terminals. Last, the new wall chargers' output voltage must be 5V±5%.

The new USB-IF battery-charging-specification revision 1.0, published in April 2007, introduces a provision that allows charging of a dead battery with 100 mA when the system is asleep until the system is awake, contrary to the original specification's 2.5-mA limitation. This higher current reduces wake-up time and eliminates the need for consumers to wait until the battery charges above the system-active level. This provision also introduces and defines three types of power sources for battery charging: a wall charger, a PC USB charger, and a host charger. These power sources look the same and have a USB mechanical connection. Therefore, the standard introduces a well-defined methodology for allowing the portable-device application to distinguish among them and take appropriate system actions.

In January 2007, the USB-IF also released the micro-USB specification for a next-generation USB connector (**Figure 2**). The development of this connector has enabled portable-system applications to further reduce space and profile without any performance or reliability compromises. Furthermore, the micro-USB-connector specification supports the current USB OTG supplement, which allows communication among portable devices without going through a host. Integrating OTG in new designs does, however, require use of the new connector, because micro-USB connectors don't support OTG. The first mobile phones with this new interconnect technology were announced in the second quarter of 2007, and industry leaders expect that, within a few years, the micro-USB technology will become the connectivity standard for portable devices.

POWER-SOURCE DETECTION

One of the most critical aspects of mobile-phone designs that must be compatible with the new standards is detection of the connected power source. Detection is critical because the new wall charger and USB ports will be mechanically identical to the older versions—that is, they both use USB Type A connectors—even though their power characteristics drastically differ. For example, when you connect a mobile handset to a USB port, the handset must fully comply with the USB 2.0 specification. In this case, the charger IC needs to initially limit the current to less than 100 mA and allow a 500-mA

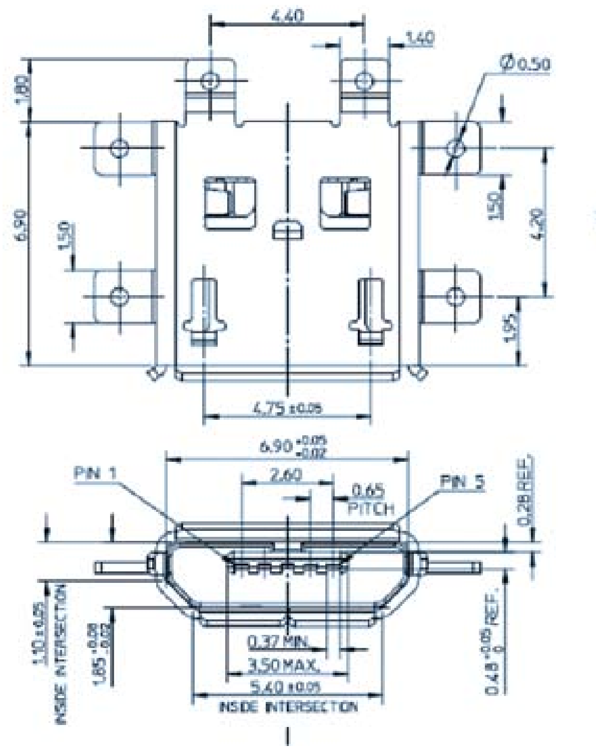

Figure 2 The new low-profile micro-USB connector allows cell phones to use computer-USB ports as well as dedicated chargers for both data interchange and battery charging (courtesy Molex Corp).

level only after completion of handshaking with the USB host or hub. On the other hand, when you connect a handset to a wall charger, charging can start immediately, and you should adjust the fast-charge current to a usually higher value that depends on the wall-charger rating.

Both the new Chinese and USB-IF standards provide guidelines for detecting the power-source type by reading the impedance between D+ and D−. More specifically, a compliant wall charger internally short-circuits D+ and D− and leaves the shorted node floating. Therefore, D+ and D− short together but do not connect to any part of the charger. The new Chinese standard doesn't specify short-circuit-detection mechanisms, whereas the USB-IF battery-charging specification 1.0 sets forth two alternative methods.

The USB protocol uses the D+ and D− signal lines to form

Figure 3 To control charging current, a new spec from the USB Implementers Forum calls for wall-mounted battery chargers to implement this design, which connects the USB connector's D+ and D− pins but does not otherwise connect them.

Figure 4 If you use a PC's USB port for battery charging, the D+ and D− pins do not short together as they do in the wall-mounted charger. In addition, a 15-kΩ resistor connects each of the pins to ground.

a differential pair. D+ and D− carry binary data from an upstream port to downstream devices or from downstream devices to an upstream port. The USB 2.0 specification requires that 15-kΩ±5% resistors that connect to ground should terminate the D+ and D− lines at host or hub ports. A simple circuit detects whether the upstream port is a charger that the new standards specify (**Figure 3**). If the upstream port is a wall charger, D+ and D− should short together, and the shorted node should float.

When the upstream port is not a wall charger that one of the new standards specifies, D+ and D− do not short. Because the upstream-port connector is a USB-standard Type A device, the port is most likely a PC's USB port, which operates under a protocol that USB 2.0 specifies. Hence, D+ and D− require 15-kΩ±5% pulldown resistors at the upstream port (**Figure 4**).

CURRENT LIMIT

Although the D+ and D− short-circuit-detection scheme can effectively identify a wall charger, the mobile device's charging-control circuit should determine the charger's current-carrying capability so that charging complies with safety standards. For instance, if the mobile's charging-control circuit tries to sink more current than the wall charger can furnish, an overcurrent condition results and activates overcurrent protection, which typically clamps the charger's output voltage, although some chargers may behave differently.

The Chinese standard specifies the maximum charger-output current as 300 to 1800 mA, whereas the new USB-IF battery-charging specification specifies a current range of 500 to 1800 mA. Therefore, the charger-current limit should lie between 300 or 500 mA and 1800 mA. To safely optimize charge current versus charge time, the charging-control circuit must identify the charger's current limit. Summit Microelectronics (www.summitmicro.com) has pending patent applications for making and applying this determination.

If you can't establish the optimum current, a safe design practice is to set the maximum-charge current to 300 mA, ensuring that the mobile phone operates safely with all compliant chargers whose current ratings lie between 300 and 1800 mA. A drawback is that such low charge currents yield long charging times, which negatively affect consumer perception. So, both standards require that wall chargers carry labels with relevant information, such as input and output current and voltage. It is therefore feasible to optimize the charge current for mobile-phone designs and to recommend the use of chargers with specific output-current ratings. For instance, setting the mobile device's sinking current at 800 mA for an 800-mAhr battery pack (1C rate) and recommending the use of chargers with no less than 800-mA output-current capability are effective ways to ensure sat-

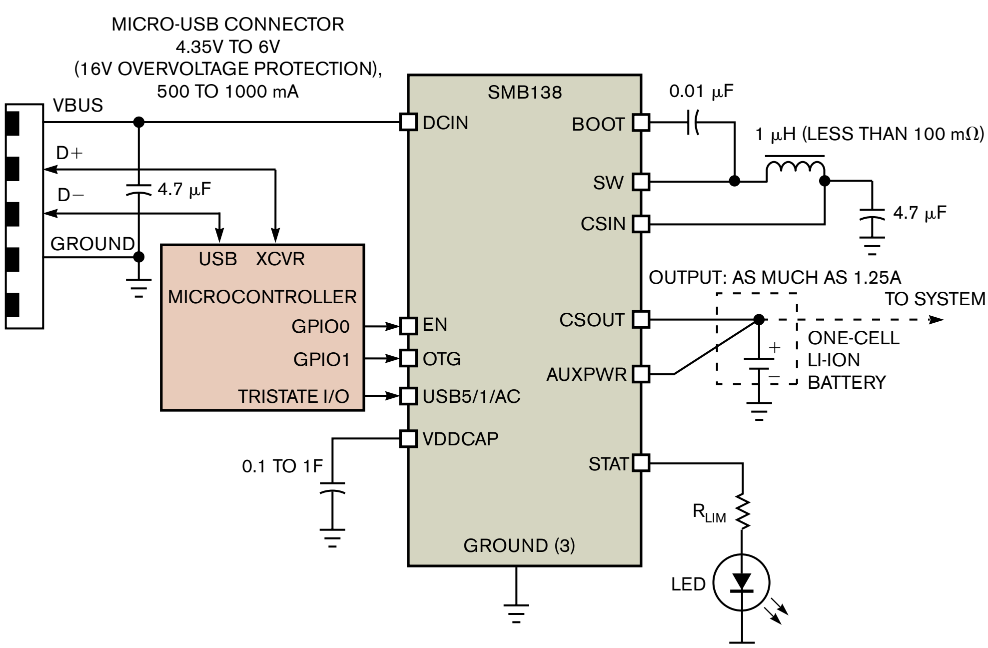

Figure 5 You need only one IC to meet the requirements of USB data transfer and charging control. This device also implements features that increase charging speed and ensure the application's safety.

isfactorily rapid charging. (The "1C rate" is the rate that will theoretically charge a battery to its capacity in one hour.)

SAMPLE BATTERY-CHARGER IMPLEMENTATION

A typical charging approach is compatible with the several new standards (**Figure 5**). Summit Microelectronics' SMB138 switch-mode-battery-charger IC operates from 4.35 to 6V and is therefore compatible with the 5V±5% adapter-output voltage that the Chinese standard and the USB-power specifications specify (**Reference 5**). In addition, this charging IC incorporates input overvoltage protection that suspends operation when the charger voltage exceeds approximately 6.2V. Additional protection features, including battery-overvoltage and -overcurrent protection, meet the industry's strict secondary-safety requirements.

When the system detects a wall-charger connection with D+ and D− shorted, the system microcontroller or a discrete-switch implementation leaves the USB5/1/AC input floating, thereby allowing a programmable input current of 550 to 1250 mA. This operation allows for maximum-charge current and thereby minimum charging time in the fast-charge mode. If the system does not detect a short circuit between D+ and D−, it assumes that the mobile phone is connected to a desktop or notebook computer's USB port. To comply with USB 2.0, the microcontroller brings the USB5/1/AC input low, thereby limiting input current to less than 100 mA. Once the microcontroller has successfully performed the USB-enumeration procedure, the mobile phone, and therefore the charger IC, can draw as much as 500 mA from the USB port. To accomplish the current increase, the controller can bring the USB5/1/AC input pin high.

In addition to providing full compliance with the new standards, **Figure 5**'s implementation can provide additional value to the mobile-phone design. Unlike traditional linear-charging approaches, the basic operation of the SMB138's switch-mode architecture allows for an output charging current that can be significantly higher than the input current, resulting in shorter charging and a better consumer experience. This feature is beneficial when you use a USB port as a 500-mA-maximum power source. In addition, many of the new, compliant wall chargers are limited to current levels as low as 300 mA for reduced system cost and the lower cost associated with CCC (China Compulsory Certification). Such cost-reduction measures will be necessary to enable charger manufacturers to provide appropriately priced products for the broad consumer market.

When not in charging mode, the SMB138 can also provide the output voltage of 5V and current of more than 100 mA required for powering an OTG-compliant peripheral that connects to a mobile phone or digital camera. Integrating this capability eliminates the need for additional components, thereby reducing system cost and board space. Equipment designers can configure the SMB138 to operate in many modes and adapt it to many charging profiles. This versatility allows the use

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of one type of IC in multiple products, even those with widely different system designs, battery types, and capacities. In addition, the advanced protection features provide primary and secondary protection and simplify compliance with strict safety standards, such as IEEE 1725.

USB's increasing popularity has resulted in several industry initiatives that respond to handheld devices' growing need for expanded USB capabilities. New battery-charging specifications introduce conditions and limits for allowing devices to draw current greater than what USB 2.0 specifies. The strengthening of supplemental specifications simplifies the use of USB without the need for a host. Requirements for slimmer industrial designs have resulted in the definition of new USB connectors that are poised to establish a new industry standard. All of these initiatives aim at maximizing consumer satisfaction by reducing cost, enhancing compatibility, and minimizing electronic waste.EDN

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AUTHORS' BIOGRAPHIES

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