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Designing for Telecommunications in China

New national mobile phone charging requirements in China drives design requirements

People's Republic of China has recently introduced a new Telecommunications Industry Standard for mobile telecommunication terminal equipment to reduce handset cost for consumers and to minimize electronic waste and help protect the environment. Designs for this market need to be adapted accordingly.

By Takashi Kanamori and George Paparrizos, Summit Microelectronics Inc.

Under the new standard, all compliant wall chargers need to provide a USB connector to ensure universal charging with all mobile phones. Furthermore, specific safety and performance requirements need to be met to make this standard effective. This article analyzes the new standard in detail, discusses its impact on wall charger and mobile phone designs, and introduces a variety of charging implementations that allow system designers to meet these new requirements.

Main Requirements

The new standard introduces a variety of electrical and mechanical requirements that ensure battery charging inter-compatibility and safety. New wall chargers are required to provide a connector that is compliant with the mini USB type A specification. This mechanical implementation allows the mobile phones to be connected to any dedicated wall charger or computing USB port for battery charging purposes. The output current capability of the new wall chargers needs to be at least 300mA and lower than 1.8A. This current range addresses both the low-cost and the high-performance product segment. Last but not least, the output voltage of the new compliant wall chargers needs to be 5V nominal with a ± 5% tolerance.

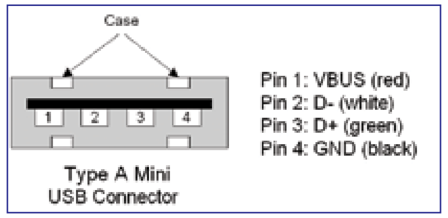

Figure 1: Typical mini USB type A connector and pin description.

Power Source Detection

One of the most critical sections in new mobile phone designs, that need to be compatible with the new directive, is the detection of the connected power source. This is critical because a USB port and a new wall charger will be identical from a mechanical point of view (both utilize USB type A connectors), however their power characteristics are drastically different. For example, when connected to a USB port, the mobile handset needs to fully comply with the USB2.0 specification. In this case, the charger IC needs to initially limit the current to less than 100mA and only allow a 500mA level once "hand-shaking" with the USB host/hub has found place. On the other hand, when connected to a wall charger, the charging algorithm can be initiated immediately and fast charge current level needs to be adjusted (usually higher) depending on the wall charger rating.

The new standard provides guidelines on detecting the power source type by reading the impedance between D+ and D-. More specifically, a compliant wall charger will have the D+ and D- shorted inside the charger, and the shorted node should be floating. This means that D+ and D- are shorted but not specifically connected to any part of the charger. The new Telecommunications Industry Standard doesn't provide further specifics on D+ and D- short-circuit detection mechanisms.

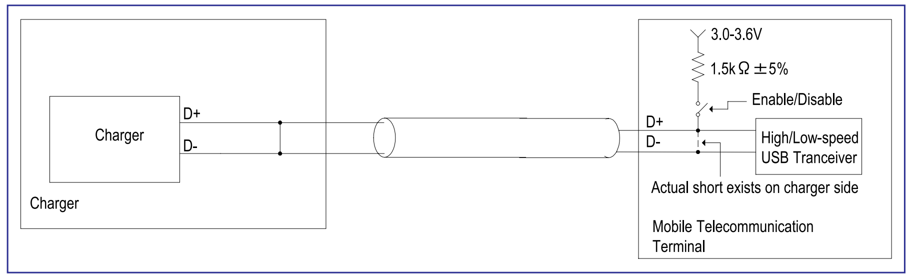

Figure 2: Power source detection implementation for compliant wall charger.

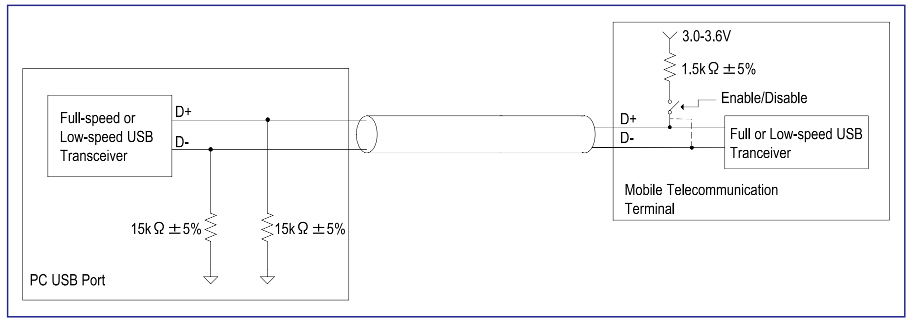

Figure 3: Power source detection implementation for USB port.

D+ and D- are the signal lines used in USB protocol. D+ and D- form a differential pair. D+ and D- line carry binary data from upstream port to downstream devices, or from downstream devices to upstream port. Since D+ and D- is a differential pair, the voltage level on one is greater than the other, except in SE0 state, SE1 state, or when a downstream device is not connected. SE0 is a state that both D+ and D- are low, and frequently asserted to signal an end of packet, and to signal a reset. SE1 is a state that both D+ and D- are high. SE1 is not an intended state, per Universal Serial Bus Specification Revision 2.0. Universal Serial Bus Specification Revision 2.0 specifies that 15kΩ ± 5% resistors connected to ground should terminate both D+ and D- lines at host or hub ports. At the mobile telecommunication terminals, 1.5kΩ ± 5% resistor connected to a voltage source between 3.0V and 3.6V must pull up either D+ for a full speed device or D- for a low speed device. This pull up resistor usually resides inside the USB physical layer (PHY), and gets connected or disconnected by a switch activated by a specific enable signal.

Figure 2 illustrates a simple way to detect whether the upstream port is a charger specified by the new Telecommunication Standard or not. If the upstream port is a wall charger, D+ and D- should be shorted together, and the shorted node should be floating as shown in Figure 2. Then the mobile telecommunication terminal asserts a specific enabling signal for the 1.5kΩ ± 5% pull up resistor inside the USB physical layer (PHY). In this case both D+ and D- should go high. See Figure 4 for the transition diagram. Since D+ and D- are shorted, it does not matter if the 1.5kΩ ± 5% is located on D+ side for full speed device, or on D- side for low speed device. Both D+ and D- will get pulled up simultaneously.

In the case in which the upstream port is not a wall charger specified by the new Telecommunication Standard, D+ and D- are not shorted. Since the connector for the upstream port is a USB standard Type A one, the upstream port is most likely to be a PC USB port. A PC USB port operates under USB protocol specified by Universal Serial Bus Specification Revision 2.0, hence, 15kΩ ± 5% pull down resistors are required on D+ and D- at the upstream port as shown in Figure 3. Then the mobile telecommunication terminal asserts a specific enabling signal for the 1.5kΩ ± 5% pull up resistor inside the USB physical layer. Note that the 1.5kΩ ± 5% pull up resistor is a much stronger pull up than 15kΩ ± 5% pull down resistor. This time, only one of the two signal lines, D+ or D-, should be pulled up high, while the other is pulled down by the 15kΩ ± 5% pull down resistor. Hence, only D+ should be pulled high for full speed device, and only D- should be pulled up high for low speed device. See Figure 4 for transition diagram.

These results are summarized in the truth table (Table 1) below.

If the mobile telecommunication terminal is not equipped with the USB physical layer (PHY) that can enable the 1.5kΩ ± 5% pull up resistor, an alternative detection method can be employed. One example is to apply current source on D+ pin and check its continuity on D- pin. See Universal Serial Bus Specification Revision 2.0, 7-1, for pull up and pull down resistors on D+ and D- lines, and signal timings.

Battery Charger Implementation

A typical charging solution that addresses the new standard is shown in Figure 5. In this example, the wall charger is rated at 500mA. The SMB135 switch-mode battery charger IC can operate from 4.35V to 6.5V and is therefore compatible with the 5V ± 5% adapter output voltage specified by the new Telecommunications Industry Standard. In addition, this charging IC solution incorporates an input over-voltage protection that suspends operation when the wall charger voltage goes above approximately 7V. Additional protection features, including battery over-voltage

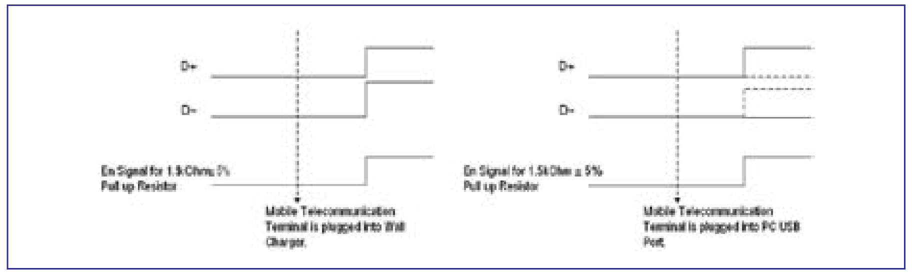

Figure 4: Transition diagrams for power source detection.

Table 1: Truth Table, Signals vs. Upstream Power Source.

Upstream Power Source Signals	Charger	PC USB Port
EN for the 1.5kΩ ± 5% pull up resistor	1	1
D+	1	1/0
D-	1	0/1

and over-current protection, are also available to meet the industry's strict requirement for secondary safety.

When the system detects a wall charger connection (i.e. D+ and D- shorted), the system microcontroller (or a discrete switch implementation) brings the USB500/100 input high, resulting in a fast charge current of 495mA or 525mA (selectable). When the system does not detect a short between the D+ and D- pins, it will assume that the mobile phone is connected to a USB port of a desktop or notebook computer. To be compliant with the USB2.0 Specification, the microcontroller can then enable the charger via the EN input pin and bring the USB500/100 input low. This will result in a fast charge current of 100mA or less (selectable). Once the system microcontroller has successful performed the USB enumeration process, the mobile phone, and therefore the charger IC, can draw as much as 500mA out of the USB port. This can be accomplished by bringing the USB500/100 input pin high. A simplified flowchart describing this operation is demonstrated in Figure 6.

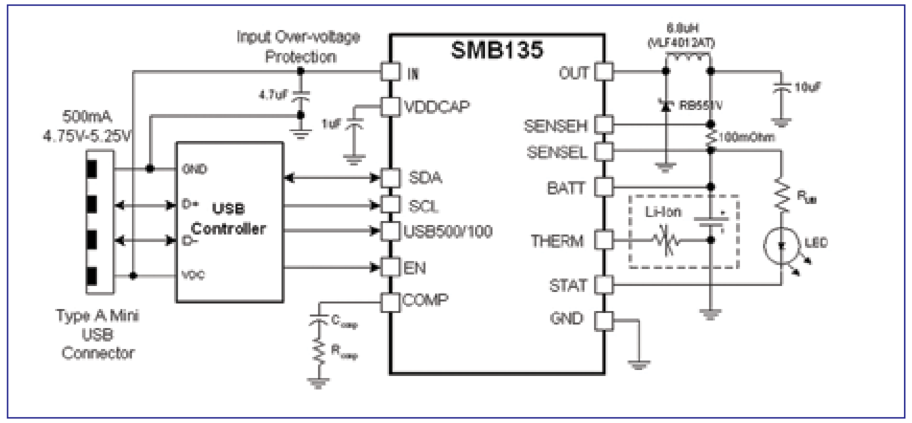

Figure 5: Typical charging application with single AC/USB input that meets the new standard.

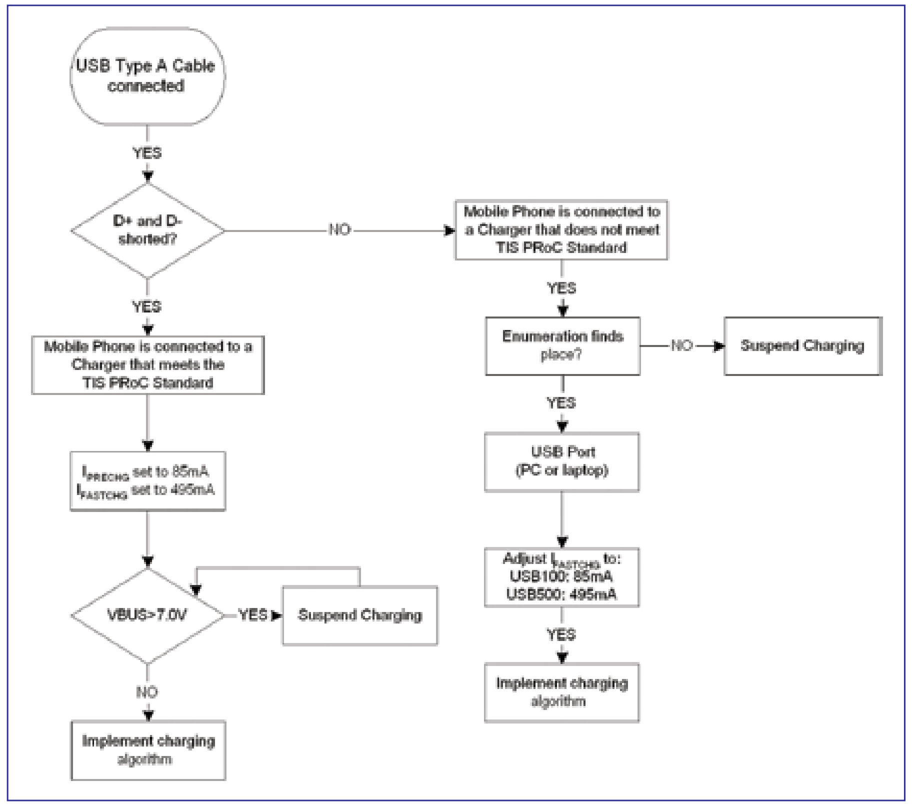

Figure 6: Simplified flow chart that describing a typical, 500mA battery charging implementation that meets the new standard.

In addition to providing full compliance with the new standard, the implementation shown in Figure 5 can provide additional value to the mobile phone design. Unlike traditional linear charging solutions, the basic operation of the SMB135's switch-mode architecture allows for an output (charge) current that can be significantly higher than the input current, resulting in shorter charging times and better consumer experience. This is very beneficial when a USB port is used as a power source (limited at 500mA) as well as with the introduction of the new, compliant wall chargers; many of the new chargers will be limited to low current levels (as low as 300mA) for reduced system cost and lower cost associated with the China Compulsory Certification (CCC). Such cost reduction measures will be necessary, since they will allow the wall charger manufacturers to provide solutions that are priced appropriately for the broad consumer market.

Summary

The new Telecommunications Industry Standard for mobile telecommunication terminal equipment in China is a major step towards universal battery charging. The main goal is to provide consumers a safe and easy way to charge their mobile phones, while reducing the environmental impact and cost associated with non-interoperability. Both wall charger and mobile phone designs need to take into account the new electrical and mechanical requirements and also to develop cost-effective implementations without compromising time-to-market and system safety.

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Frequency Compensation in Switching Regulator Design

Part 2: Feedback path compensation

In part one of this two-part series, the forward path of a switching converter was considered. In this second and final part, the feedback path is considered as the loop is closed and the overall circuit is compensated.

By Nigel Smith, Business Development Manager, Portable Power, Texas Instruments

Once the gain and phase response of the forward path is known, the error amplifier response can be designed. The main aims of frequency compensation are to ensure: (a) an adequate phase margin (typically >45°); and (b) an adequate gain margin (typically >10dB). In addition, the loop gain should pass through unity with a slope of -20dB/decade.

Before the frequency compensation can be designed, a suitable crossover frequency f_c must be chosen. Switching converters with high crossover frequencies respond more quickly to changing operating conditions, and are therefore generally preferred; however, sampling theory limits the maximum crossover frequency that can be used. In practice f_c typically lies between one tenth and one sixth f_{sw}, however, if the error amplifier's open-loop gain is insufficient at this frequency, f_c may have to be further reduced.

Having selected the desired crossover frequency, the gain, phase and slope of the forward path at f_c can be obtained from its Bode plot. The required gain, phase and slope of the compensated error amplifier at f_c can now easily be obtained by comparing the two.

Three types of compensation scheme are commonly-used, known as Type-I, Type-II and Type-III (see Figure 1). Type-I is not commonly used in switching regulator circuits and will not be discussed here.

Type-II compensation exhibits a pole at the origin (to achieve high DC gain) plus an additional zero and pole. The resulting frequency response contains a flat area between the zero and the pole. Type-II compensation is generally used in applications where the output filter exhibits a single-pole roll-off at the cross-over frequency. The desired -20dB/decade roll-off at fc is achieved by ensuring that cross-over occurs somewhere in the flat part of the error amplifier's response.

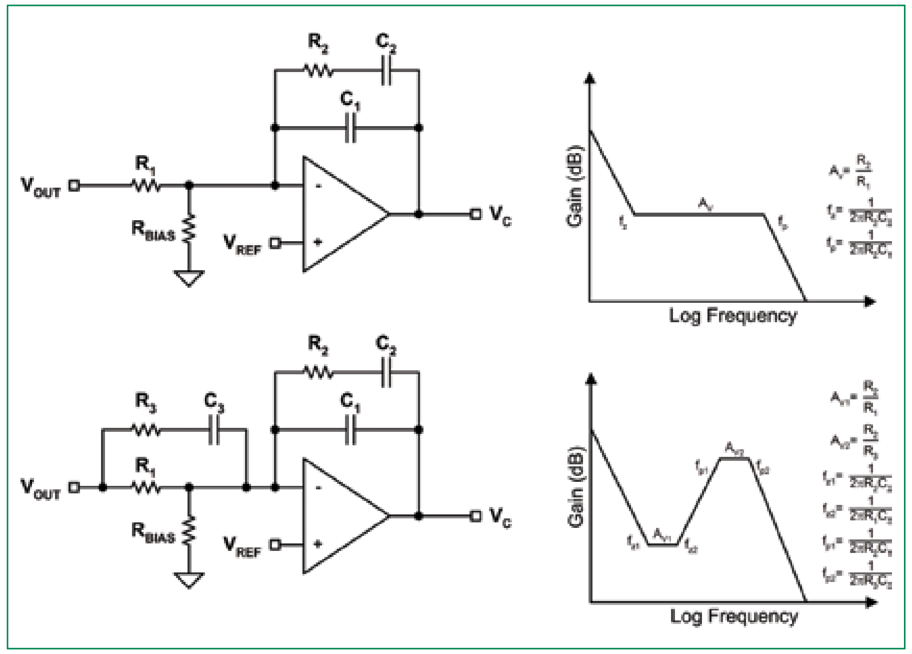

Figure 1. Commonly Used Compensation Circuits and Their Response.