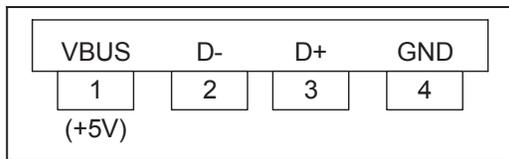


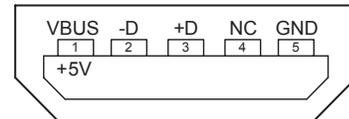
## Automatic Charge Reduction (CHR) Function Solves Issues with Lithium-Ion Battery Charging from USB Ports

### Introduction

The convenience of charging single-cell Lithium-ion (Li-Ion) battery-powered portable products is a desirable feature that many designer engineers will incorporate into their new devices. Highly integrated portable products—such as cell phones, PDAs, MP3 players, and digital still cameras—are powered by single-cell Li-Ion batteries and use a computer's Universal Serial Bus (USB) port to transfer data files. A USB port provides bi-directional data transfer, as well as power and ground, from the host system. Using a USB port as a charging power source allows a user to simultaneously download or update files and recharge the battery for their portable product. Figures 1 and 2 show examples of commonly-used USB port receptacles.

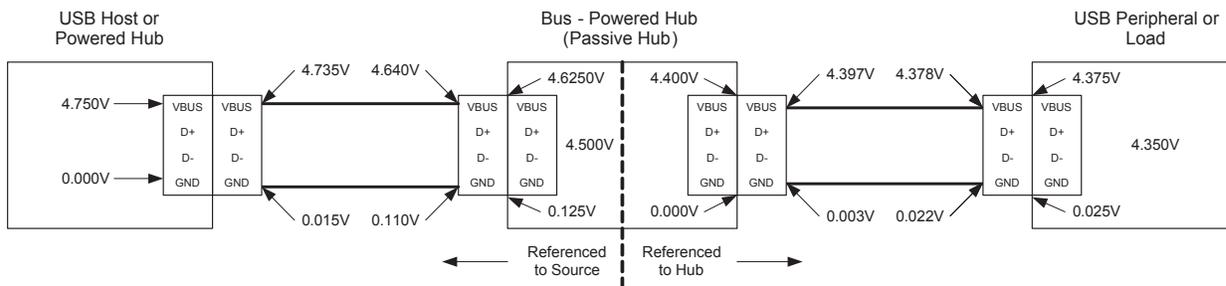


**Figure 1: Type A USB Connector.**



**Figure 2: Type B Mini USB Connector.**

Designers who intend to utilize the USB port as a battery charging source must contend with several challenging variables. First, not all USB ports adhere to the USB standard; and, even when a USB port is truly compliant, the port has power sourcing limitations. Figure 3 shows the minimum specified voltage levels for a USB port, as stated in the USB 2.0 specification<sup>1</sup>.



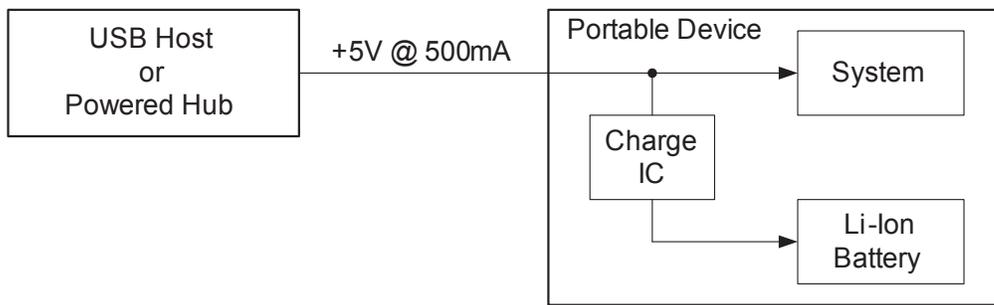
**Figure 3: Worst Case Voltage Drop Topology for a USB Port.**

1. To obtain additional information regarding USB power distribution standards, reference Section 7.2 of the Universal Serial Bus Specification, Revision 2.0.

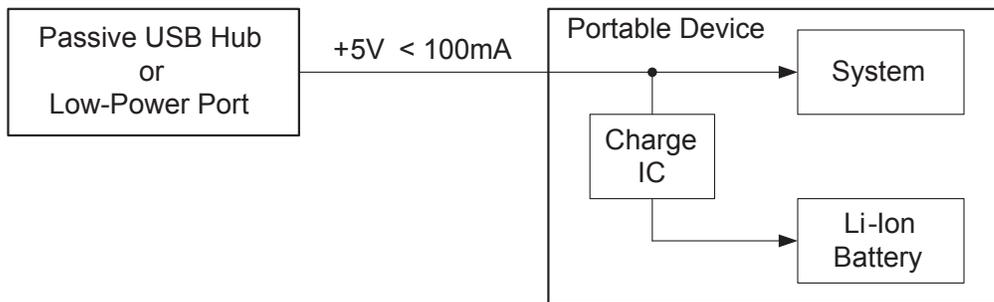
A valid USB host source is limited to supply no more than 500mA. USB ports must provide a current limit protection function that can be set as high as 5.0A, but can also be set as low as 500mA in the case of a host or self-powered hub (a port can be set as low as 100mA in the case of a bus or low-power hub). When using a USB port to charge a battery and possibly power the system within the peripheral, one must make sure to not draw more current than can be delivered by the host USB port. If the load current demand exceeds what the port can deliver, the port will be shut down by its internal current limit protection circuit and the battery charge cycle will be halted. Mechanisms to assure a USB port will not be overloaded must be built into a peripheral product to assure reliability with the system and USB charging function.

Due to the wide variation in available voltage and current that can be drawn from a USB port, it is difficult to design a system that incorporates USB charging. An additional complication can arise when a design permits the system to function simultaneously with the battery charging operation. In this case, the charging function must share the available USB port power with the operating system. Figures 4 and 5 show a typical system block for a USB-powered portable product.

AnalogicTech's AAT3685, AAT3686, and AAT3688 battery chargers can be manually controlled for USB charging functions. These devices also provide a unique automatic charge reduction (CHR) feature to simplify the task of managing the power available from any given USB port source supply.



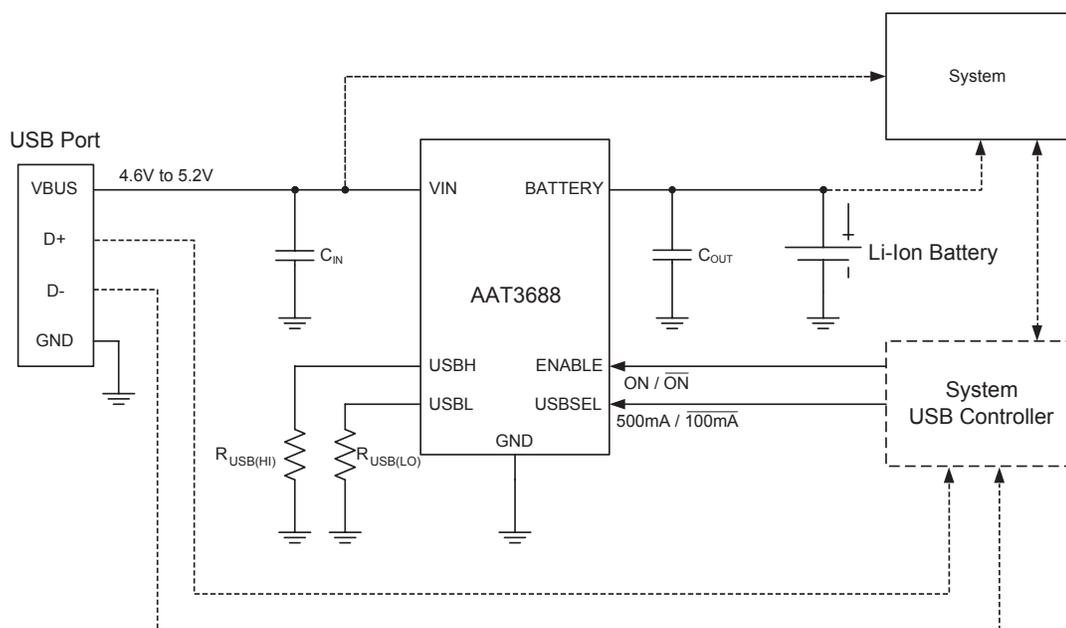
**Figure 4: System Powered by a USB Host Supply.**



**Figure 5: System Powered by a Passive Hub or Low-Powered Port Supply.**

## USB Li-Ion Battery Charging Solutions

In the past, system designers have either omitted the USB charging function altogether from a product or they have contended with complicated hardware and firmware solutions. As port supply capabilities or system load demands change, the constant current charge level for battery charging must be adjusted in order to maintain USB port operation. The AAT3685/86/88 devices provide the ability to set two different constant current charging levels and have an input control to manually toggle either the higher or lower level. In most portable systems that transfer data via the USB port, a system ID is read by the internal USB controller and the system microcontroller adjusts the charge current level based on the USB port type. Figure 6 shows a typical Li-Ion charger IC under control from the system microcontroller and USB interface.



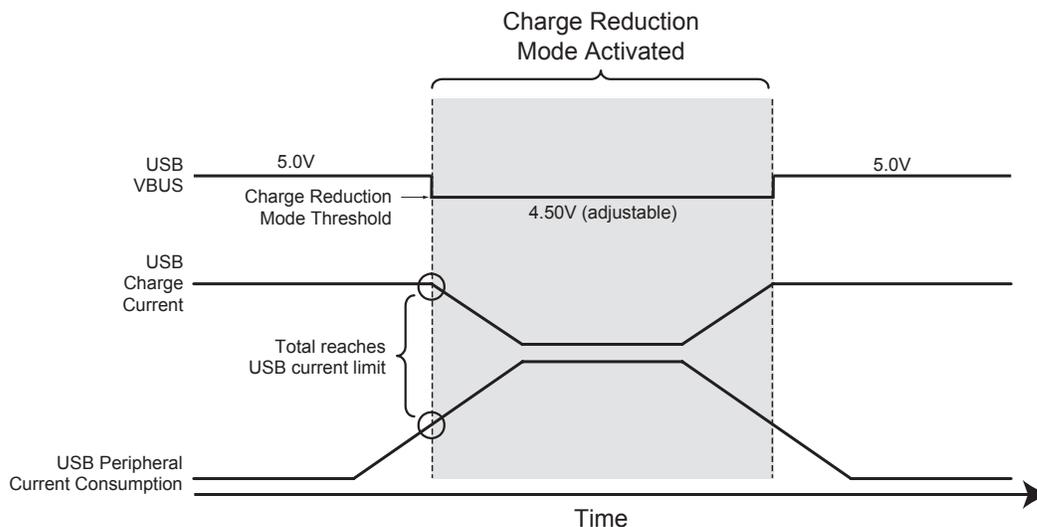
**Figure 6: Typical USB Charging System.**

The system of reading a port ID and setting a high or low charge level works and is reliable, yet still has two drawbacks. First, not all portable devices have the ability to read a host USB port ID. Second, a system is bound to two discrete charge levels: the high level, which is typically set at 500mA, will obviously charge the Li-Ion battery in the fastest possible time; while the low level, typically set to 100mA, will force an extended time to fully charge a battery. If the system is connected to a fully capable 500mA host USB port, but the device requires some current to operate while the battery is charging, the charge control will be forced to the lower charge level, unnecessarily extending the battery charge time.

## Automatic USB Charge Reduction

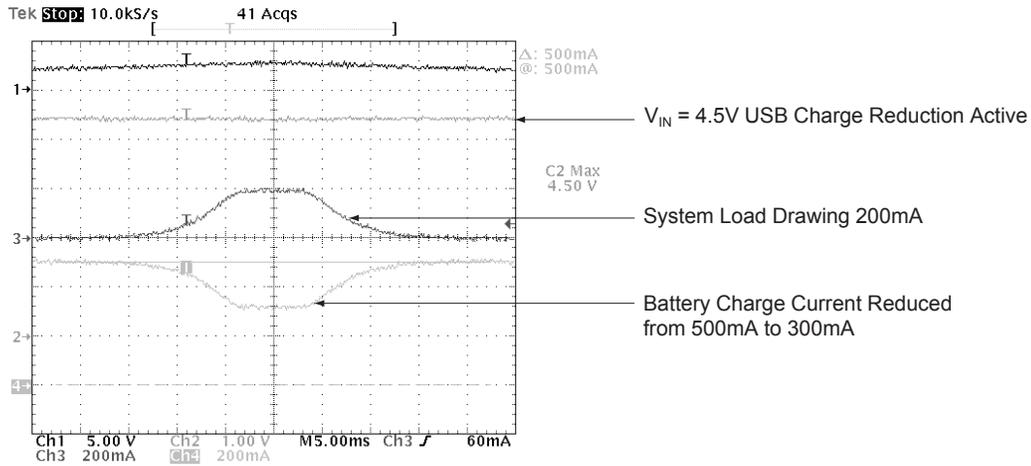
The automatic USB charge reduction control built into the AAT3685/86/88 will allow the system to leave the charge control IC set at a high charge level and will automatically reduce the constant current charge level to maintain a valid USB port voltage level. In this manner, the maximum possible current will be delivered to a battery cell under charge, allowing the fastest possible charging time.

The charge reduction mode operates with either the high or low constant current charge setting. The system is controlled by the voltage seen on the charger input pin and will not allow the charge current to force a voltage drop below the preset CHR threshold. This "intelligent" approach to charging avoids a shutdown of the USB port and ensures that the battery will be charged at the maximum rate possible at all times throughout the charging cycle. This, in turn, maximizes charge cycle efficiency and reduces it to the shortest time period possible. Figure 7 shows the basic operation of the USB CHR system.



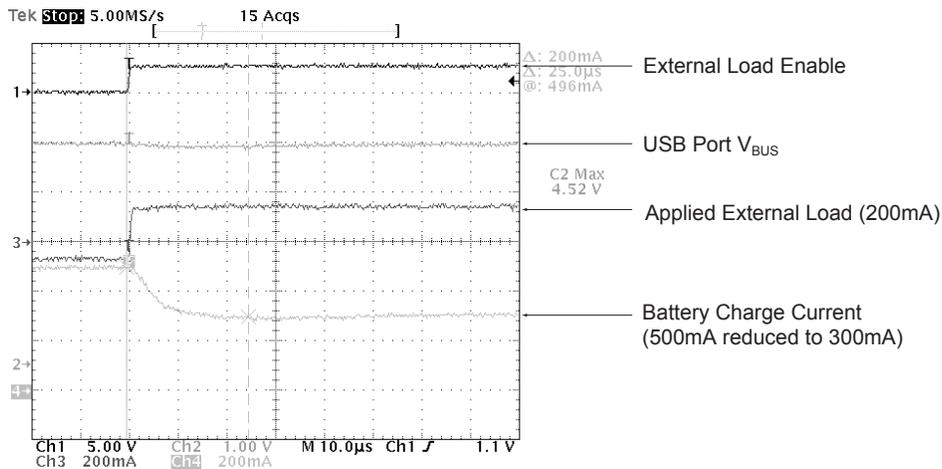
**Figure 7: USB Charge Reduction (CHR) Mode Operation.**

For example, a portable device is connected to a 500mA USB host supply and draws 200mA to operate the system, so 300mA remains available to charge the battery. In the case of a conventional USB charger IC, the charge level to the battery would be reduced to 100mA and the remaining 200mA would go unused. With automatic USB charge reduction, the charge control IC senses the voltage level supplied by the USB port. When the port's current sourcing capability is exceeded—as in the case of attempting to draw 200mA to power a system and draw 500mA to charge the battery—the port will current limit, resulting in a drop in port voltage. The AAT3685/86/88 is preset to activate the USB charge reduction when the port voltage drops below charge reduction threshold of 4.5V. The AAT3685/86/88 also allow the user to custom program the charge reduction threshold to a higher or lower level, if desired. Please refer to the AAT3685/86/88 product datasheets for details regarding CHR threshold programming. Figure 8 shows the actual measured response for a system attempting to charge a battery at 500mA from a 500mA USB host port, with a 200mA load current demand switched on and off.

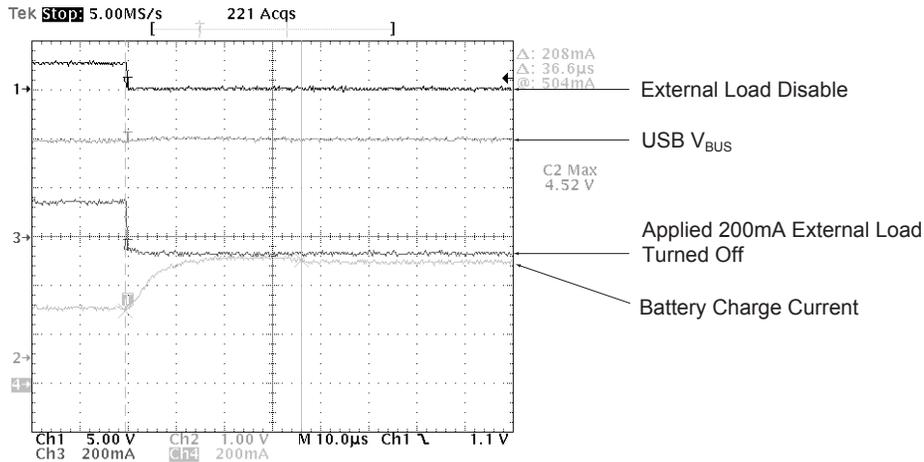


**Figure 8: Measured USB CHR for a 5V, 500mA Limited Supply;  $I_{CHARGE}$  is Automatically Reduced from 500mA to 300mA in Response to a 200mA System Load Demand.**

Designers may be concerned with the speed in which the USB charge reduction system will react when an over-current situation arises at the USB port. The automatic charge reduction function responds and settles in less than  $10\mu s$ . This reaction time is so fast that the over-current event will not be detected by the host USB port over-current protection circuit. With such a rapid circuit response time, there is little or no need for additional capacitance on the input to the charger IC to dampen a potential power surge. Once the system current demand terminates, the charge reduction control will turn off and allow the constant current charge to resume at the maximum level. Refer to Figures 9 and 10 for CHR mode turn-on and turn-off timing.

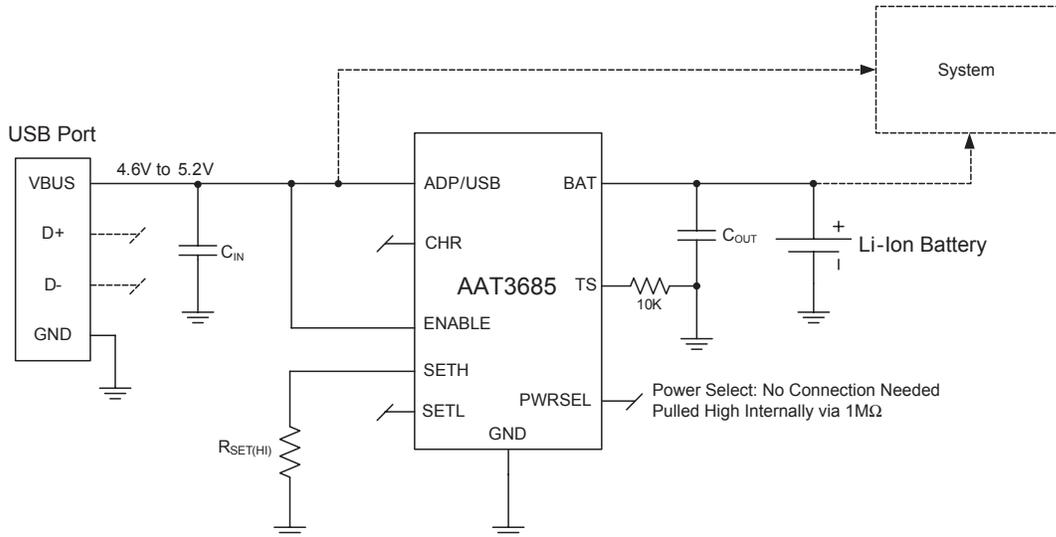


**Figure 9: Charge Reduction Activation Turn-On Response Time  $\approx 10\mu s$ .**



**Figure 10: Charge Reduction Turn-Off Recovery Response Time  $\approx 20\mu\text{s}$ .**

Some products lack the ability to read the USB port ID and have the system microcontroller set the appropriate charge level. In this case, a designer can set the battery charging constant current to a fixed high level and rely on the automatic charge reduction function to set the best possible charge current regardless of the type of port encountered as a power source (see Figure 11).



**Figure 11: Simple USB Charging Circuit Using the AAT3685.**

Finally, for system designers concerned about USB port reliability, the AAT3685/86/88 CHR function will protect both the host USB port and the product under charge. The possibility exists for a USB host to have an ID that will tell the peripheral system that it has a 500mA high current capability, yet the port power source could be defective. This is common in the case of host USB ports that utilize poly fuse protection circuits. The peripheral will set a high current to charge and the defective port voltage will collapse under the applied load. The USB charge reduction feature will prevent inadvertent port collapse and will charge the battery in the peripheral with the available power for the given condition.

## Conclusion

As the popularity of portable consumer electronic devices powered by single-cell Li-Ion batteries continues to climb, more and more designers will incorporate the USB port as a charging source. The ubiquitous USB port can vary in type and capability when used as a source supply for Li-Ion battery charging. The intelligent USB charge reduction feature offered by the AAT3685, AAT3686, and AAT3688 battery charger ICs allows system designers to integrate USB charging features into portable products with minimum risk and maximum reliability.

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