AN971

# USB Port-Powered Li-Ion/Li-Polymer Battery Charging

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## INTRODUCTION

The Universal Serial Bus (USB) allows many computer peripherals to be easily swapped without having to turn off the computer. Today, a variety of handheld, battery-operated peripherals provide USB ports to facilitate data transfer to and from a host computer. With the introduction of the new USB 2.0 specification, CD/DVD players, MP3 players, cameras, personal data assistants and even cell phones can transfer data at rates up to 480 Mbps.

These peripherals are, in some instances, self-powered. As a result, many of these peripherals do not take full advantage of the USB port. Often overshadowed by the data interface is the power capability that a USB port provides. Microchip's MCP73853/55 and MCP73861 advanced, fully-integrated, single-cell Li-Ion/Li-Polymer charge-management devices allow these peripherals to utilize the full “power” of the USB port.

## USB-POWERED, SINGLE-CELL, LI-ION BATTERY CHARGER

Many of the self-powered peripherals use a separate power supply for battery charging even while connected to a USB port. With the MCP73853/55, harnessing the power of the USB port for battery charging becomes extremely simple.

A USB port transfers signal and power over a four-conductor cable, depicted in Figure 1. Each USB port provides a limited amount of power over the cable. The amount of current provided from a USB port is defined in terms of unit loads, where one unit load is defined as 100 mA. The number of unit loads that a port can supply is an absolute maximum, not an average over time. A port may be configured as either low-power (at one unit load) or high-power (providing up to five unit loads). All ports default to low-power. The transition to high-power is under the software’s control. It is the responsibility of the host software to ensure that adequate power is available before allowing peripherals to consume high power.

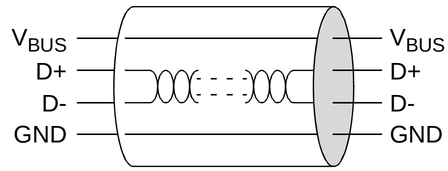


***FIGURE 1:*** *USB Cable.*

The USB high-power port is specified for a maximum current of five unit loads (or 500 mA), with a voltage of 5V, ±5%. The USB specification allows for voltage drops in the USB connectors and cables of up to 350 mV when delivering 500 mA. The maximum cable length is specified as 16 feet. Shorter cables will introduce less voltage drop. The minimum voltage seen at the peripheral device will be 4.4V.

Limiting the current draw to 400 mA produces an absolute minimum voltage of 4.47V, providing 0.27V of headroom to fully charge a single-cell, Li-Ion battery. The extremely low dropout voltage (200 mV at 400 mA) of the MCP73853/55 makes them an attractive and simple approach for a USB Li-Ion/Li-Polymer battery charger.

Figure 2 and Figure 3 illustrate USB-powered, single-cell Li-Ion/Li-Polymer battery chargers. The USB controller communicates with the host to determine if the peripheral is connected to either a low-power or high-power port. The controller then sets the appropriate charge current setting. The MCP73853/55 employs typical charge current settings of 85 mA and 400 mA for low-power and high-power, respectively. These settings ensure that the absolute maximum rating of the USB port is not exceeded. Optionally, the high-power charge current setting can be adjusted lower by placing a resistor between the MCP73853/55 and the USB controller. The appropriate value resistor can be determined from the formula:

$$R_{PROG} = \frac{13.2 - 33.3 \times I_{REG}}{14.1 \times I_{REG} - 1.2}$$

Where:

$I_{REG}$ is the desired high-power charge current setting in amps

$R_{PROG}$ is in kilo-ohms

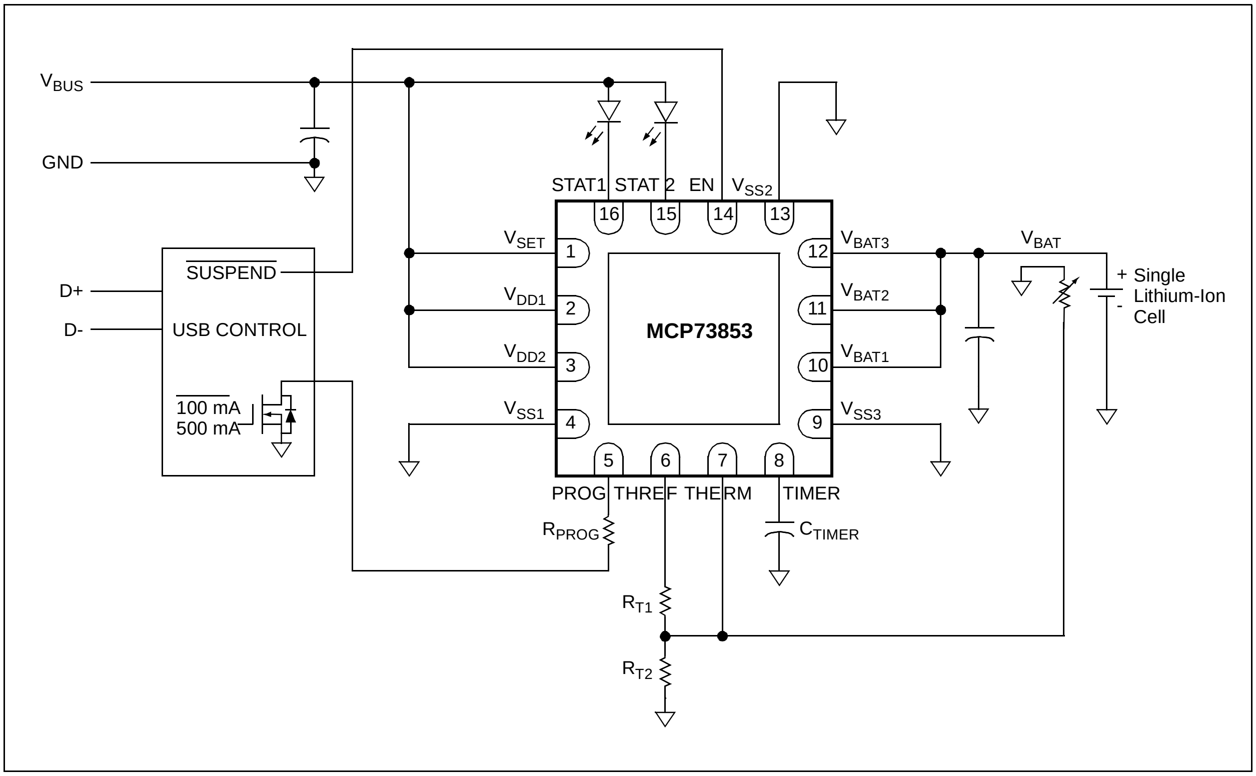


***FIGURE 2:*** *USB-powered, Single-cell, Li-Ion/Li-Polymer Battery Charger with Cell Temperature Monitoring.*

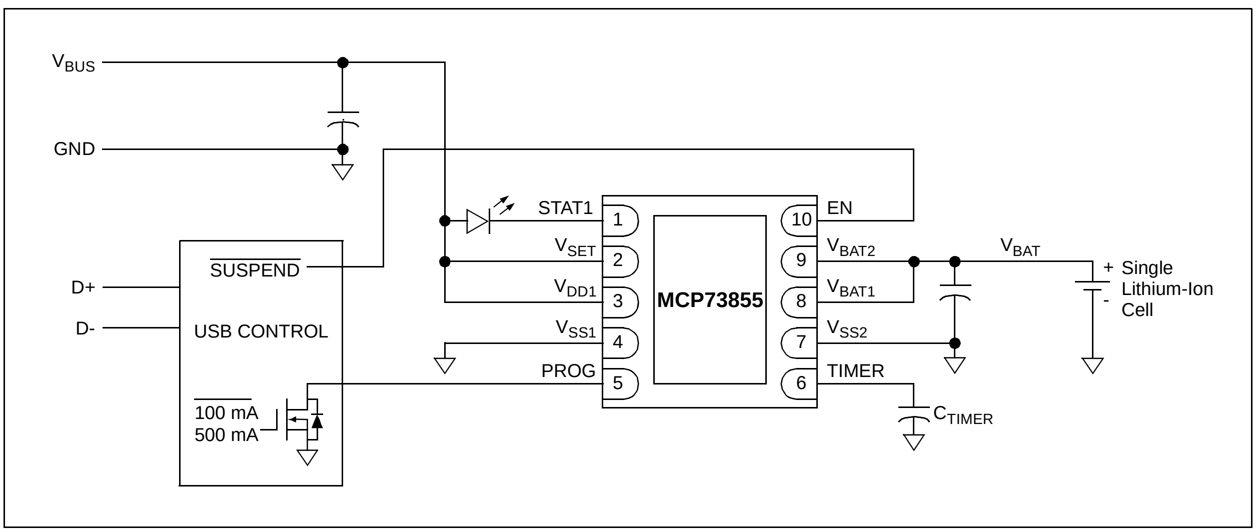


***FIGURE 3:*** *Small PCB Area USB-powered, Single-cell, Li-Ion/Li-Polymer Battery Charger*

## ADDITIONAL USB SUPPORTED FEATURES

In addition to the maximum permissible current draw on the USB power port, additional considerations must be adhered to as well. Any peripheral connected to a USB port must support a Suspend state as defined by the USB specification. A peripheral can enter the Suspend state from either power state (low power or high power). The allowed Suspend current is a function of unit load allocation. Ports operating in the Low-power mode are limited to 500 µA of Suspend current. Ports operating in the High-power mode are limited to 2.5 mA.

In the circuits of Figures 1 and 2, the peripheral device's system power, including the USB controller, is derived directly from the battery. In this manner, the MCP73853/55 controls the charging of the battery, while maintaining the current draw from the USB port below the specification limits. The Suspend state is entered when the USB controller pulls the enable pin of the MCP73853/55 low. Disabled, the MCP73853/55 consumes less than 1 µA of current. The peripheral Suspend current can be computed as the current from $V_{BUS}$ through the bus pull-up and pull-down termination resistors plus 1 µA.

In-rush current must also be considered whenever a peripheral is connected to a USB port. The $V_{BUS}$ power lines at the port are bypassed with a minimum low-ESR capacitance of 120 µF. The maximum load of the peripheral device is limited to 44Ω, in parallel with 10 µF of capacitance. This ensures that the $V_{BUS}$ voltage does not get pulled below its minimum operating voltage when a peripheral is connected to the port. The maximum droop allowed on $V_{BUS}$ is 330 mV.

The MCP73853/55 requires a minimum input capacitance of 1 µF, although 4.7 µF is recommended. This is well below the maximum USB specification. In addition, the MCP73853/55 controls the slew rate of the charge current when transitioning from preconditioning to fast charge, and when a new charge current setting is requested (i.e., from low-power to high-power). These unique features prevent large slugs of current from flowing to the charger output capacitor and battery, causing the $V_{BUS}$ voltage to droop excessively.

Another important specification to consider when connecting to the USB power bus is that no peripheral shall supply (source) current on $V_{BUS}$ at any time. The MCP73853/55 employs integrated reverse discharge circuitry that prevents current to flow from the battery onto $V_{BUS}$.

## FASTER CHARGE CYCLE TIMES WITH WALL ADAPTER

The USB high-power port is specified for a maximum current of five unit loads, or 500 mA. Utilizing Microchip's MCP73861, charge currents up to 1.2A can be realized from an alternate power source (such as a wall cube).

Figure 4 depicts the MCP73861 in a system that accepts input power from a USB port or alternate power source. This solution requires only a handful of external components, in addition to the MCP73861.

In this manner, charge currents up to 1.2A can be realized when the alternate power source is present. When only USB power is present, the P-channel MOSFET is supplying power to the charger from $V_{BUS}$. In this case, the programming resistor is not optional. A minimum resistance of 2.2 kΩ must be placed between the USB controller and the MCP73861 PROG input. The 2.2 kΩ programming resistor sets the typical high-power charge current to 420 mA. The high-power charge current setting can be adjusted lower by utilizing a higher value resistor. The appropriate value resistor can be determined from the formula:

$$R_{PROG} = \frac{13.2 - 11 \times I_{REG}}{12 \times I_{REG} - 1.2}$$

Where:

$I_{REG}$ is the desired high-power charge current setting in amps

$R_{PROG}$ is in kilo-ohms

When an alternate power source is connected, the P-channel MOSFET is turned off. Input power is supplied to the charger from the alternate power source through the Schottky diode. The P-channel MOSFET prevents current from being supplied on $V_{BUS}$. The alternate power source must provide a voltage greater than the maximum $V_{BUS}$ specification, minus the difference between the forward voltage drop of the MOSFET body diode and the forward voltage drop of the Schottky diode. An absolute minimum voltage of 5V is recommended for the alternate power source. The MCP73861 is rated for a maximum input voltage of 12V, so higher voltages can be utilized.

The maximum charge current is increased to 1.2A by pulling the MCP73861 PROG input to ground. The additional N-channel MOSFET is turned on when the alternate power source is present. Increasing the charge current significantly decreases the charge cycle time.

Figure 5 depicts complete charge cycles utilizing the MCP73861 with a high-power USB port and an alternate power source. The charge cycles depicted were performed on a 1400 mAh Li-Ion battery pack. Initial conditions were near full discharge.

While charging from the USB port, it takes approximately one hour longer until the end of charge is reached. The MCP73861 scales the charge termination current proportionately with the fast charge current. The result is an increase of 40% in charge time with the benefit of a 2% gain in capacity and reduced power dissipation. The change in termination current results in an increase in final capacity from ~98% to ~100%. The system designer has to make a trade-off between charge time, power dissipation and available capacity.

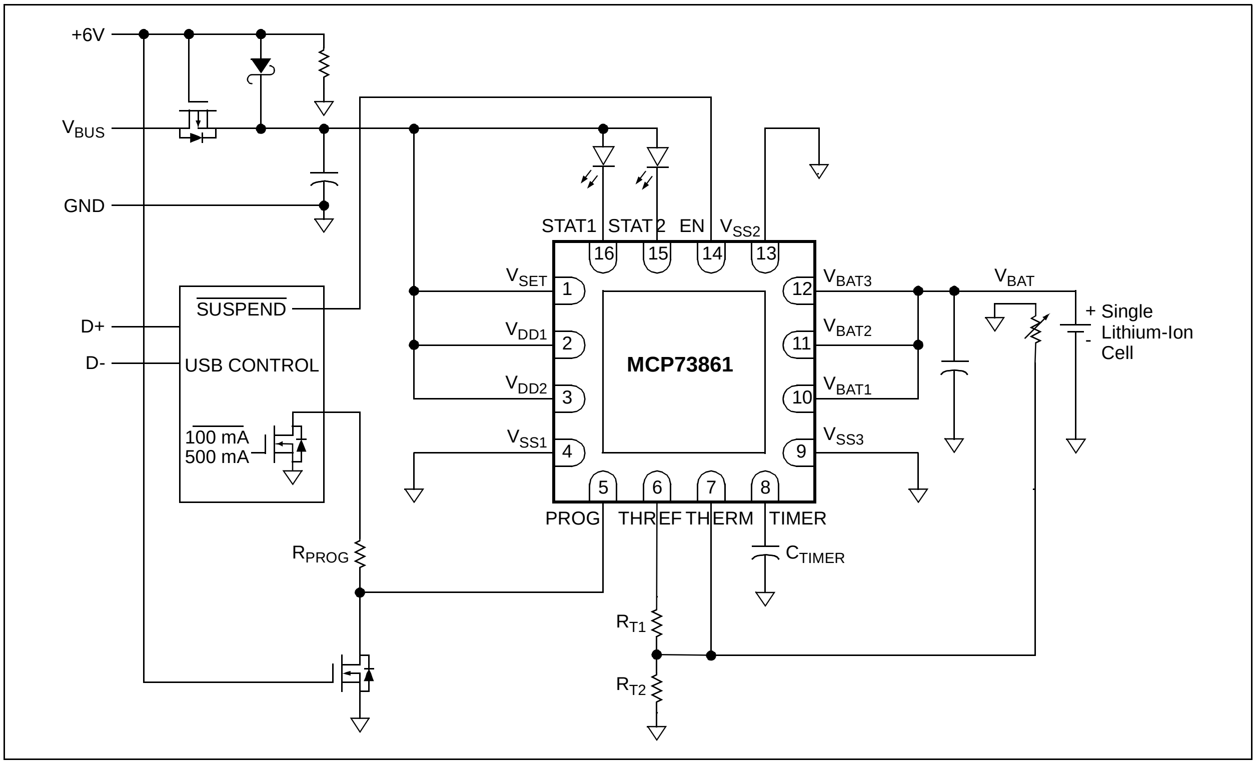


*FIGURE 4:* *USB-powered or Externally-powered, Single-Cell, Li-Ion/Li-Polymer Battery Charger with Cell Temperature Monitoring.*

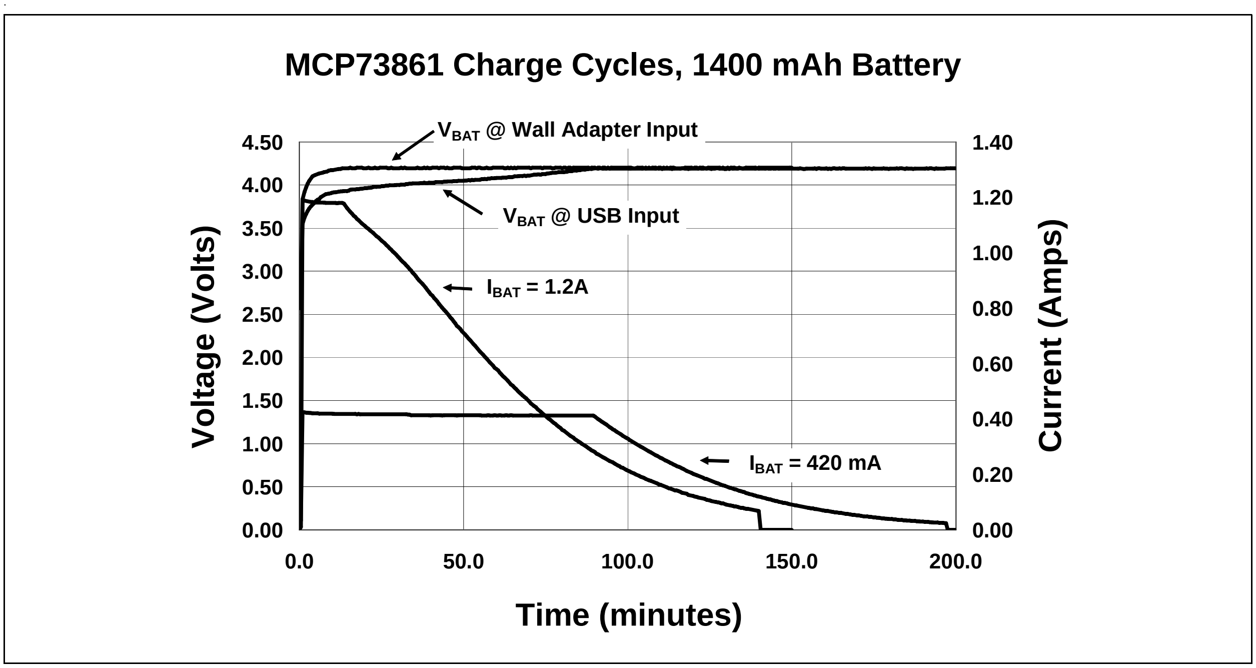


*FIGURE 5:* *MCP73861 Charge Cycle Waveforms.*

## CONCLUSION

When utilizing Microchip's MCP73853/55 or MCP73861, harnessing the power of the USB port for battery charging becomes extremely simple. The devices adhere to all the specifications governing the USB power bus.

Three stand-alone linear charging solutions for Li-Ion/ Li-Polymer batteries were presented. The guidelines and considerations presented in this application note should be taken into account whenever the power of a USB port is interfaced.

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