# Bidirectional Power Manager Provides Efficient Charging and Automatic USB On-The-Go with a Single Inductor

by Sauparna Das

## Introduction

Imagine that your car won't start—the battery is dead, the kids are getting fussy, you're stranded in the middle of nowhere, and your cell phone won't turn on because you forgot to charge it. What do you do now? Fortunately, you remember that your new camera is in the car, and it has a fully charged battery. Even better, this camera supports USB On-The-Go using a bidirectional power manager. You connect a USB micro-AB cable between the cell phone and camera and instantly start charging your phone. The phone powers up and you're able to call for help.

The LTC4160 is a versatile, high efficiency power manager and battery charger that incorporates a bidirectional switching regulator, full featured battery charger, an ideal diode (with a controller for an optional external ideal diode), and an optional overvoltage protection circuit. The bidirectional switching regulator is able to power a portable system and charge its battery or provide a 5V output for USB On-The-Go using a single inductor (Figure 1). This reduces component count and board space, key attributes for a power management IC in today's feature rich portable devices. In shutdown, the part only draws 8µA of current, thus maximizing battery life.

## Bidirectional Switching Power Path for USB On-The-Go

The LTC4160 contains a bidirectional switching regulator between $V_{BUS}$ and $V_{OUT}$. When power is applied to $V_{BUS}$, the switching regulator acts as a step down converter and provides power to the application and battery charger (Figure 1). The switching regulator includes a precision average input current limit with multiple settings. Two of the settings correspond to the USB 100mA and 500mA limits.

***The bidirectional switching regulator is able to power a portable system and charge its battery or provide a 5V output for USB On-The-Go using a single inductor.***

The voltage on $V_{OUT}$ is approximately 300mV above the battery when the switcher is not in input current limit and the battery voltage is above 3.3V. This technique, known as Bat-Track output control, provides very efficient charging, which minimizes loss and heat and eases thermal constraints. For battery voltages below 3.3V, $V_{OUT}$ regulates to 3.6V when the switcher is not in input current limit. This instant-on feature provides power to the system even when the battery is completely discharged.

Power to the application is always prioritized over charging the battery. If the combined system load and charge current exceed the current available at the input, the battery charger reduces its charge current to maintain power to the application. If the load alone exceeds the input current limit, then additional current is supplied by the battery via the ideal diode(s).

For USB On-The-Go applications, the bidirectional switching regulator steps up the voltage on $V_{OUT}$ to produce 5V on $V_{BUS}$. In this mode the switching regulator is capable of delivering at least 500mA. Power to $V_{OUT}$ comes from the battery via the ideal diode(s). A precision output current limit circuit, similar to the one in step-down mode, prevents a load on $V_{BUS}$ from drawing more than 680 mA (Figure 1). The switching regulator also features true output disconnect which prevents body diode conduction of the PMOS switch. This allows $V_{BUS}$ to go to zero volts during a short circuit condition or while shut down, drawing zero current from the battery. When $V_{OUT}$ is ≥ 3.2V, the LTC4160 allows a portable

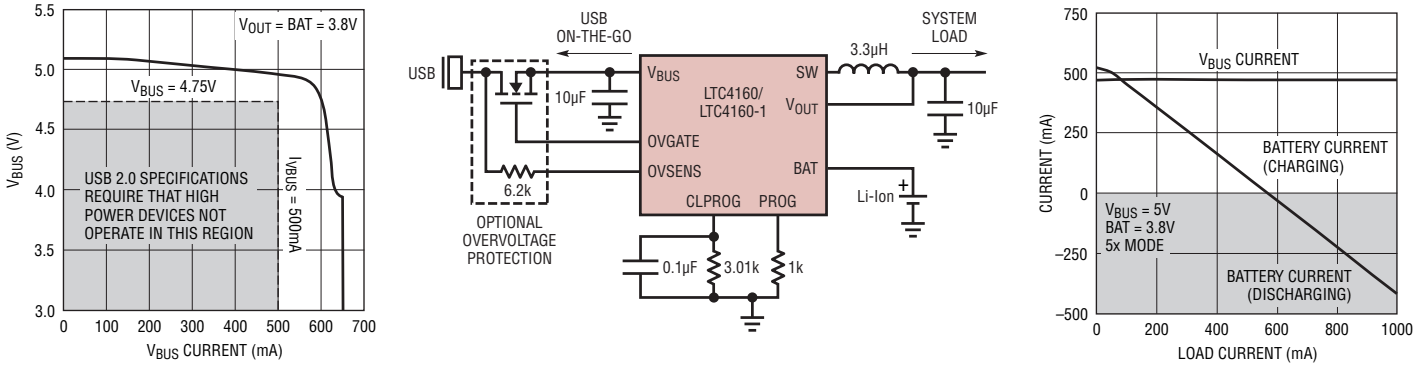


**Figure 1. The LTC4160 provides bidirectional power transfer. Left plot: $V_{BUS}$ voltage vs $V_{BUS}$ current in On-The-Go mode. Right plot: battery and $V_{BUS}$ currents vs load current when input power is available.**

product to meet the specification for a high power USB device by maintaining $V_{BUS}$ above 4.75V for currents up to 500mA.

## Automatic USB On-The-Go

When two On-The-Go devices are connected, one is the A-device and the other is the B-device, depending on the orientation of the cable, which has a micro-A and a micro-B plug. The A-device provides power to the B-device and starts as the host. Micro-A/micro-B cables include an ID pin in addition to the four standard pins ($V_{BUS}$, D–, D+, and GND)—the micro-A plug has its ID pin shorted to GND while on the micro-B plug the ID pin is floating. The impedance on the ID pin allows the USB power manager to determine whether it receives power from an external device or whether it should power up $V_{BUS}$ to provide power to an external device.

Step-up mode can be enabled by either the ENOTG pin or the ID pin. The ENOTG pin can be connected to a microcontroller. The ID pin, on the other hand, is designed to be connected directly to the ID pin of a micro-AB receptacle. The pin is active low and contains an internal 2.5µA pull up current source. When the ID pin is floating or a micro-B plug is connected to the AB receptacle, the internal current source pulls ID up to the max of $V_{BUS}$, $V_{OUT}$ and BAT. When a micro-A plug is connected to the receptacle, the short between ID and ground in the micro-A plug overrides the pull-up current source and pulls the ID pin on the LTC4160 down to ground. This activates the bidirectional switching regulator in step-up mode and powers up $V_{BUS}$. A complete application schematic is shown in Figure 2.

## Other Features

The LTC4160 also includes a battery charger featuring programmable charge current (1.2A max), cell preconditioning with bad cell detection and termination, CC-CV charging, C/10 end of charge detection, safety timer termination, automatic recharge and a thermistor signal conditioner for temperature qualified charging. For the LTC4160, the nominal float voltage is 4.2V. The LTC4160-1 provides a nominal float voltage of 4.1V.

The overvoltage protection circuit can be used to protect the low voltage USB/Wall adapter input from the inadvertent application of high voltage or a failed wall adapter. This circuit controls the gate of an external high voltage N-channel MOSFET, and in conjunction with an external 6.2k resistor, can provide protection up to 68V.

The LTC4160 includes an integrated ideal diode and a controller for an optional external ideal diode. This provides a low loss power path from the battery to $V_{OUT}$ when input power is limited or unavailable. When input power is removed, the ideal diode(s) prevent $V_{OUT}$ from collapsing, with only the output capacitor required for the switching regulator.

## Conclusion

The LTC4160 is a feature rich power manager that is especially suited for USB On-The-Go applications, enabling bidirectional USB power transfer between portable devices. The part can directly detect the impedance on the ID pin of a micro-AB receptacle to automatically tell the internal bidirectional switching regulator to provide a 5V output on $V_{BUS}$ for USB On-The-Go. The switching regulator can supply at least 500mA and comes with a current limit of 680mA. In addition, the LTC4160 can efficiently take power from 5V inputs (USB, Wall adapter, etc.) to power a portable application and charge its battery using a single inductor. Its unique switching architecture and Bat-Track output control provides fast and efficient charging. Furthermore, an optional overvoltage protection circuit can provide protection against voltages of up to 68V on the $V_{BUS}$ pin. The combination of bidirectional power transfer, automatic USB On-The-Go functionality and high voltage protection make the LTC4160 a must have for today's high end portable devices.

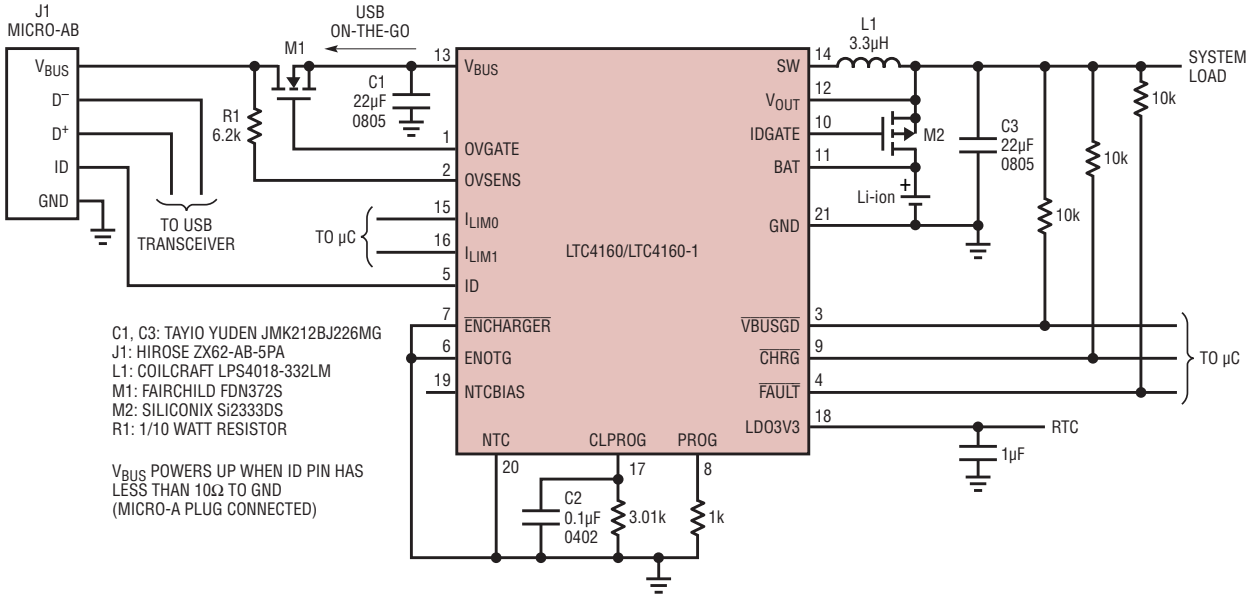


**Figure 2. LTC4160 with automatic USB On-The-Go**