

Power Management IC Combines USB On-The-Go and USB Charging in Compact Easy-to-Use Solution

by George H. Barbehenn and Sauparna Das

Introduction

The USB interface was originally designed so that the device providing power (an “A” device) would act as the host and the device receiving power (a “B” device) was the peripheral. The A plug of the USB cable would always connect to the host device and the B plug would connect to the peripheral. The USB On-The-Go (OTG) standard, however, removes that restriction, so that the B device can now become a host and the A device can act as a peripheral.

In the USB specification, standard hosts and hubs are limited to providing 500mA to each downstream device, but if a device is designated as a USB charger, it can supply up to 1.5A. USB chargers come in two flavors. A “dedicated charger” is a charger that is not capable of data communication with the attached B device. A “host/hub charger” is a charger that is capable of data communications with attached B devices.

When USB OTG functionality is combined with a USB battery charger in an end-user product, power can flow in both directions, with relatively complicated logic and handshaking steering the flow. To implement a robust solution, an integrated USB battery charger and power manager is a necessity. This article shows how to use the LTC3576 USB power management IC to easily combine USB On-The-Go functionality and battery charger capability into a single portable product.

Overview of the LTC3576

The LTC3576 provides the power resources needed to implement a portable device with USB OTG and USB battery charger detection capabilities (see block diagram in Figure 1). The USB input block contains a bidirectional

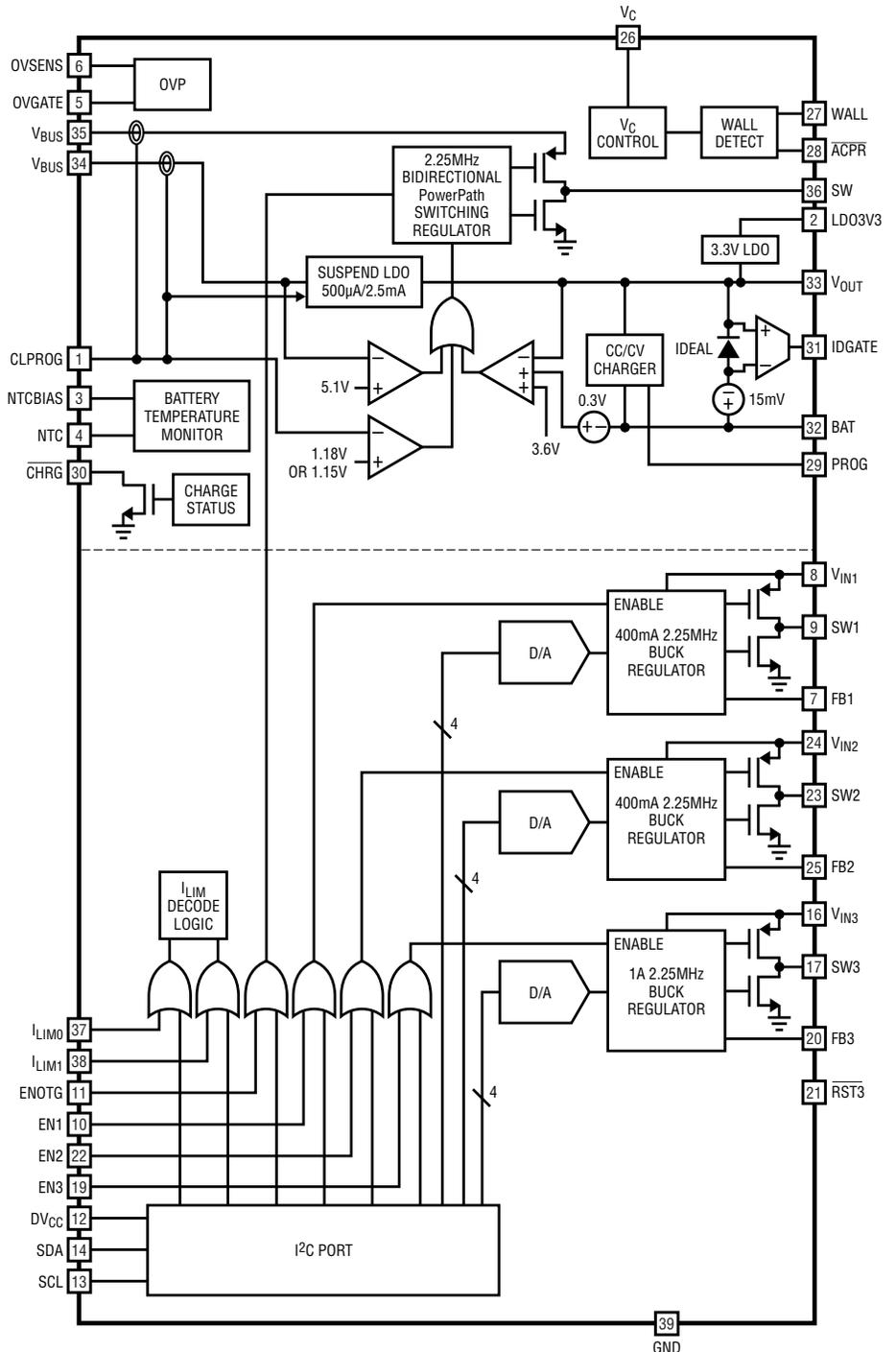


Figure 1. The LTC3576 combines USB charging and USB On-The-Go by using bidirectional DC/DC conversion from V_{BUS} to V_{OUT}

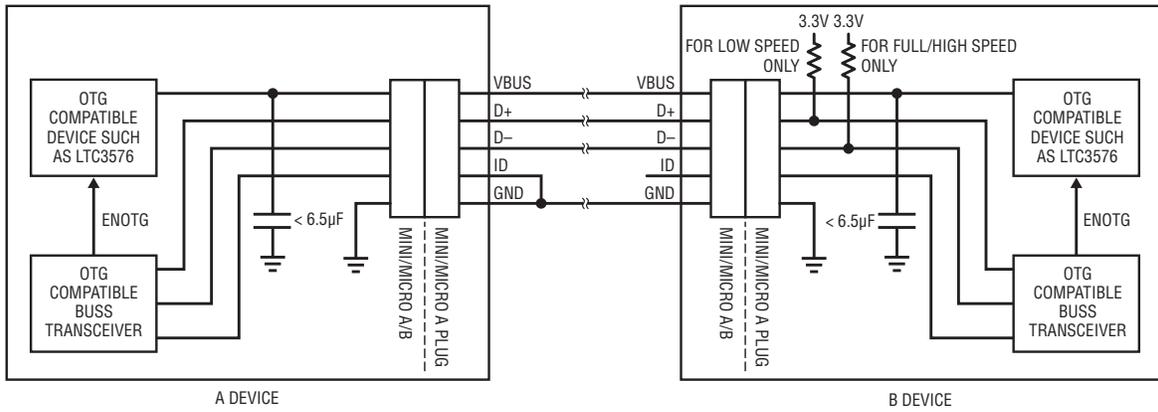


Figure 2. USB On-The-Go system diagram

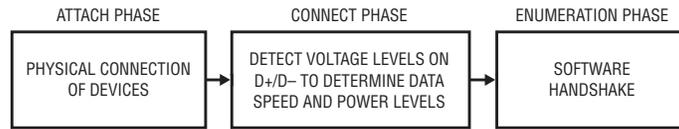


Figure 3. USB sequence of events at start-up

tional switching regulator between V_{BUS} and V_{OUT} . When power is coming from the USB input, this regulator operates as a step-down converter. Using the Bat-Track™ charging technique, the switching regulator sets the voltage at V_{OUT} to $V_{BAT} + 0.3V$, providing a very efficient charging solution. When operating as an OTG A device, the regulator acts as a step-up converter by taking power from V_{OUT} to produce 5V on V_{BUS} .

The LTC3576 also has overvoltage protection and can be used with an external HV Buck regulator to provide V_{OUT} . In OTG mode, the bidirectional switching regulator can take power from the HV buck regulator to supply power to the USB connection.

In addition, the LTC3576 provides two 400mA and one 1A step-down

switching regulators for generating three independent voltage rails for the portable device. The LTC3576 allows all three step-down switching regulator output voltages to be enabled/disabled and adjusted over a 2:1 range via I²C. All three step-down regulators feature pulse-skipping mode, Burst Mode® operation and LDO mode, which can also be adjusted on-the-fly via I²C.

Mode Detection

The USB specification allows for a number of different modes of operation for products supporting both the USB OTG specification¹ and the battery charger specification². Figure 2 shows a typical OTG system and Figure 3 shows the sequence of events that occur when the USB cable is plugged in. The product can be a B device

and can draw up to 100mA, 500mA, 900mA or 1.5A, depending on the type of A device powering V_{BUS} , as shown in the Table 1.

When an OTG device has a micro/mini-A plug connected to its micro/mini-AB connector, the OTG device becomes the A device and starts off as the host. The OTG A device supplies power to V_{BUS} , as any other host A device would, when requested by an attached peripheral or OTG B Device. As an A device, the LTC3576 can supply up to 500mA

The USB OTG specification provides two means for a B device to signal to the A device that it wants power. The B device may drive the V_{BUS} line above 2.1V, momentarily, or it may signal by driving the D+ or D- signal lines. The D+/D- signaling method could be

Table 1. Load power signaling during Attach and Connect

	Host/Hub $I_{BUS} < 500mA$	Dedicated Charger $I_{BUS} < 1.5A$	Host/Hub Charger $I_{BUS} < (LS,FS < 1.5A/HS < 0.9A)$
Voltage on D- with VDAT_SRC on D+ during Attach	0V	0.5V–0.7V	0.5V–0.7V
1.5kΩ to 3.3V on D- during Connect for Low Speed, measure voltage on D+	—	> 2V	< 0.8V
1.5kΩ to 3.3V on D+ during Connect for Full/High Speed, measure voltage on D-	—	> 2V	< 0.8V

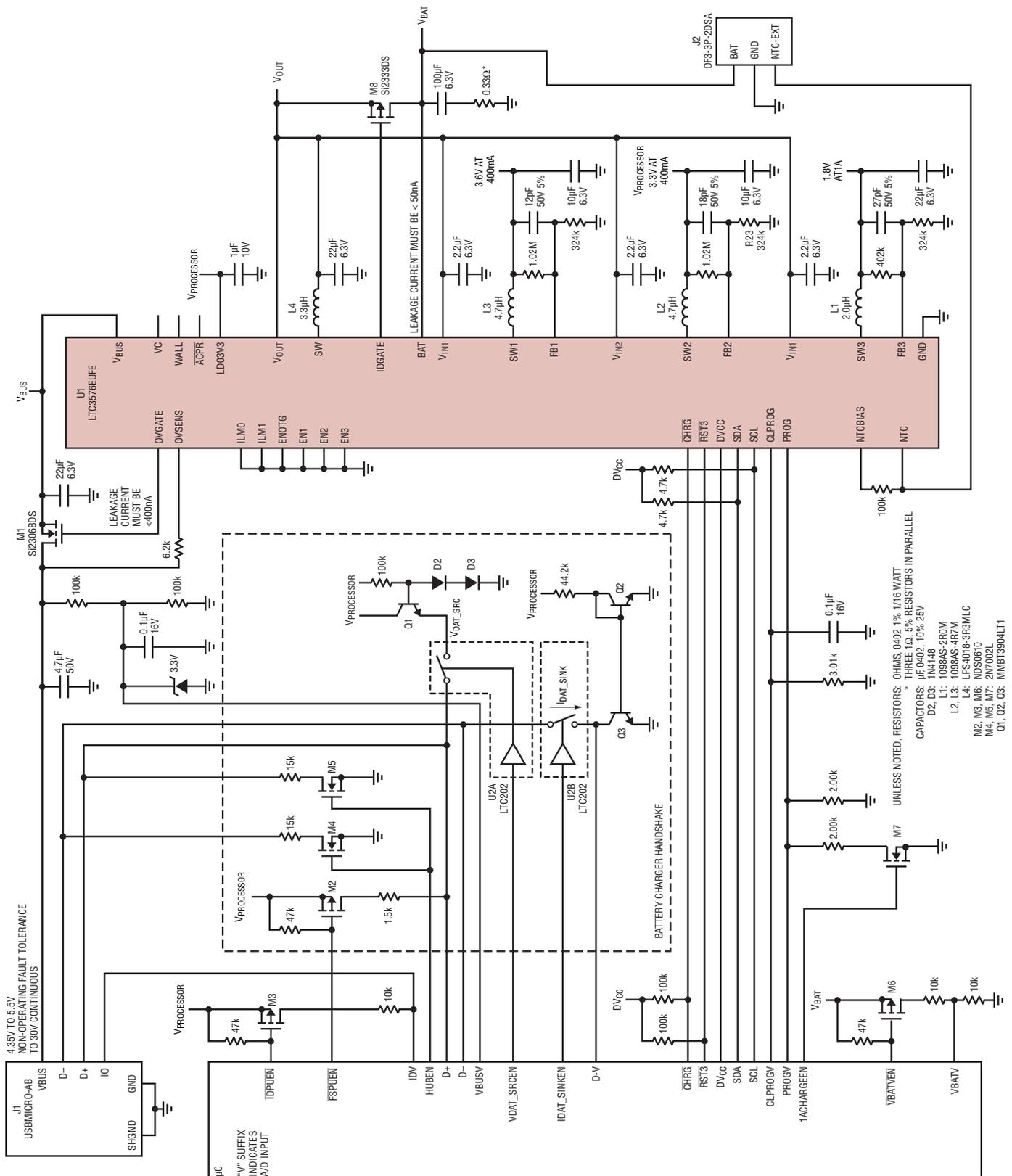


Figure 4. Portable system with OTG and battery charger support

detected by an OTG compatible USB module on the system microcontroller (μC). The V_{BUS} signaling method could be detected via an A/D on the μC . The LTC3576 bidirectional switching regulator is then enabled as a step-up converter (OTG mode) by setting the appropriate bit in the control registers via I²C.

Implementing a System for USB OTG and Battery Charging

Figure 4 shows an application for a portable device that supports both USB battery charging and USB OTG.

When $\overline{\text{IDPUEN}}$ is low, the ID pin is pulled up via R5, and if IDV is $> 3\text{V}$ then it is configured to be a B device. If IDV is $< 0.5\text{V}$ then it is configured to be an A device. The components enclosed in the box labeled “battery charger handshake” enable communication of the power capabilities depending on whether the portable device is configured as an A device or a B device. During the Attach phase, if the portable device is a B device, it can apply $V_{\text{DAT_SRC}}$ (0.5V~0.7V) to the D+ line, load the D- line with $I_{\text{DAT_SINK}}$ (50 μA ~150 μA), and measure the resultant voltage on D- via D-V. If the voltage is 0, the A device is a Host/Hub, if the voltage is $V_{\text{DAT_SRC}}$ then the A device is a USB Charger.

During the Connect phase, $\overline{\text{FSPUEN}}$ is pulled low to apply 3.3V to D+, indicating a full/high speed device. At the same time the voltage on the D- line is read again via D-V. If it is less than 0.8V, then the A device is a Host/Hub Charger. If the voltage on D-V is above 2V, then the A device is a Dedicated Charger.

For OTG functionality, if the portable device is configured as an A device, then it must drive V_{BUS} from V_{OUT} , which in this case is powered from the battery. Since the LTC3576 is capable of supplying 500mA as an A device, the μC asserts HUBEN to indicate it is a Host/Hub. The bidirectional switching regulator in the LTC3576 is enabled by setting the appropriate bit in the control registers via the I²C port. If the B device drawing current from the V_{BUS} line goes idle, then the OTG A device may turn off the V_{BUS} voltage to conserve the battery. When the B device needs the V_{BUS} voltage to be present at some later time, it can request that the A device again drive V_{BUS} by turning the bidirectional switching regulator back on. It can do this by signaling on the D+ or D- lines or by driving the V_{BUS} line to $> 2.1\text{V}$ (see Figure 5).

The Host A device only needs to respond to one of two SRP signaling methods. However, since not all USB engines respond to the D+/D- signaling, the V_{BUS} line is sensed to check if it is higher than 2.1V via the VBUSV A/D input.

When the portable device's μC detects that the B device is requesting power on V_{BUS} , either by sensing the D+/D- signaling or by sensing that V_{BUS} has been driven higher than 2.1V, it should again turn on the OTG step-up converter in the LTC3576.

The PROG (PROGV) and BAT (VBATV) pins allow a Coulomb counter to be implemented in the μC . Reading the BAT voltage requires that the sensing divider be enabled by setting $\overline{\text{VBATVEN}}$ low. This ensures that the sense divider network does not dis-

charge the battery when the battery voltage isn't being measured.

The default battery charge current has been set to 500mA, but can be increased to 1A by asserting the IChargeEN signal. This turns on M7, halving the PROG resistance and increasing the charge current. The input current limit will need to be set to 10X mode (1A) using the I²C port.

The optional network of C14 and R27/R28/R29 suppresses ripple on the BAT pin (and consequently on the V_{BUS} pin) if there is no battery present. This ripple can be in the tens of mV. While this will not damage anything, it may be desirable to suppress this signal.

The CLPROG (CLPROGV) and $\overline{\text{CHRG}}$ signals are often useful for housekeeping tasks in the μC .

The LTC3576 has an overvoltage protection function that controls M1, and protects the system from excessive voltages on the USB (J1) connector. Because the A/D is configured to monitor V_{BUS} , it must also be protected by D1 from excessive voltages.

The LDO3V3 regulator is configured to power the μC in low power mode ($< 20\text{mA}$). When the μC needs to leave low power mode it first enables Buck Regulator 2, which will provide up to 400mA.

Conclusion

The LTC3576 is a versatile PMIC consisting of a bidirectional power manager, overvoltage protection, three step-down switching regulators and a controller for an external high voltage step-down switching regulator. In conjunction with a few support components, the LTC3576 allows the implementation of a complete power management system for portable devices that support both USB OTG and USB battery charging. 

Bibliography

- ¹ “On-The-Go Supplement to the USB Specification”, Revision 1.3
- ² “Battery Charging Specification”, Revision 1.0
- ³ www.usb.org/developers/docs

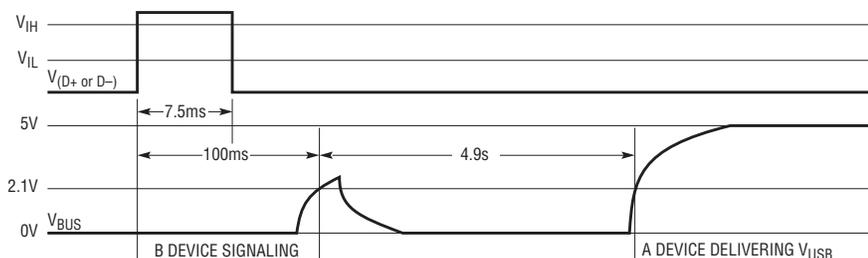


Figure 5. Session Request Protocol timing reference¹