Compact Solution Uses USB Power to Run a Device and Simultaneously Charge its Battery

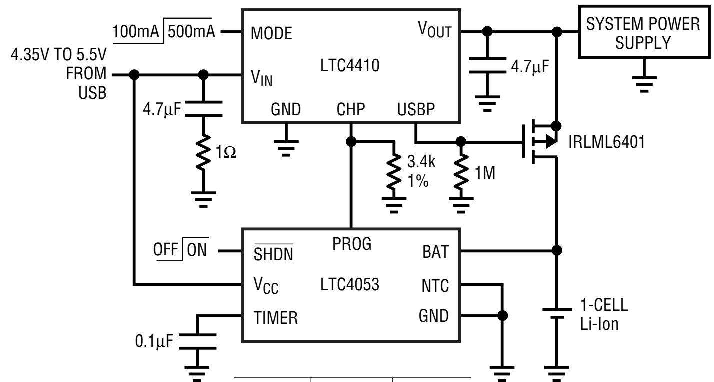
by George Humphrey

Introduction

Increasing numbers of portable devices are tapping into the Universal Serial Bus (USB) to charge their batteries. USB power supplied by the host allows batteries to be recharged at the same time data transfer is occurring, and in some cases, eliminates the need for a bulky wall adapter. The challenge is to provide battery charging and device operation simultaneously in the most efficient manner, while not exceeding either 100mA or 500mA as required by the USB specification.

USB Power Manager and Battery Charger

Figure 1 shows a circuit that allows simultaneous battery charging and device operation using USB power. The LTC4410 USB power manager is a PowerPath™ controller that controls the current that the LTC4053 Li-Ion charger uses to charge the battery. The circuit reduces the battery charging current as the system load current increases, and likewise increases the battery charging current as the system load decreases. This helps to keep the total current within USB spec (assuming the powered device never tries to draw more than the USB spec allows).



USB MODE	LTC4410 MODE	LTC4053 SHDN
500mA	1	1
100mA	0	1
SUSPEND	1	0

Figure 1. USB power manager and battery charger

The battery charge current is set externally with a 3.4kΩ resistor on the PROG pin of the LTC4053, where:

$$I_{BATT} = \frac{V_{PROG}}{R_{PROG}} \bullet 1000 = \frac{1.5V}{3.4k\Omega} \bullet 1000$$

$$= 441mA$$

This is within the 500mA limit imposed by the USB spec. The USB device operating load (I_{LOAD}) is powered through the LTC4410's low voltage drop P-Channel MOSFET switch. The CHP pin produces a replica of the load current equal to $I_{LOAD}/1000$. This current flows to the PROG pin of the LTC4053 where it alters the charge current by the following:

$$I_{BATT} = \left[\left(\frac{1.5V}{3.4k\Omega}\right) - \left(\frac{I_{LOAD}}{1000}\right)\right] \bullet 1000$$

As I_{LOAD} current increases, the battery charging current decreases, to keep the total to less than 500mA. This allows the device to be used even while the battery is charging. The LTC4410 guarantees that the charger current is

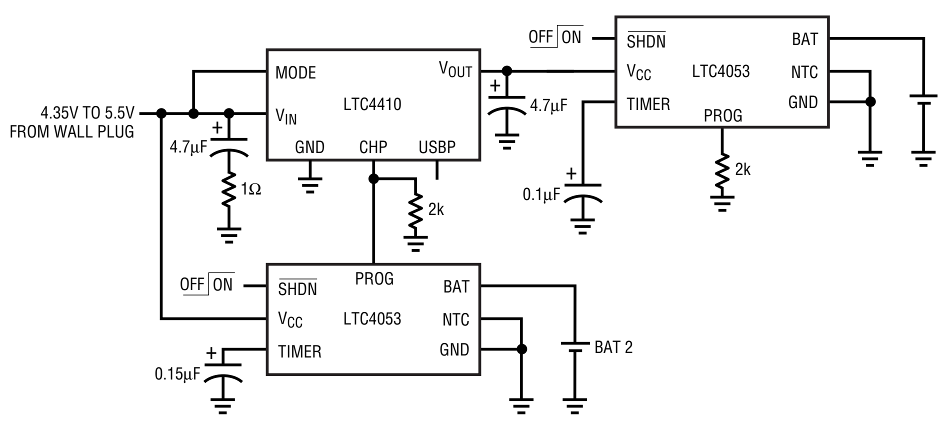


Figure 2. Priority dual battery charging with a wall adapter

reduced to zero when I_{LOAD} = 500mA, or 100mA, depending on the specific USB mode of operation. Note that the LTC4410 can lower the charger current to zero, but it will not limit I_{LOAD}. It is assumed that the load device circuitry draws no more than 500mA, or 100mA, from the USB host.

The LTC4410 MODE pin provides the decoding for the LTC4053 to make it compatible with the different USB modes (100mA, 500mA and Suspend, which are required by the USB specification 1.0 and 2.0 power requirements). When an external controller drives the MODE pin low, an internal circuit sources an additional offset current out of the CHP pin, reducing the battery charge current to under 100mA. When the MODE pin is driven high, this offset current source is disabled (for 500mA and suspend mode). For suspend mode it is the system's responsibility not to exceed 500µA or 2.5mA depending on the specific USB mode.

An important feature of this design is that it fits into the tight spaces required by handhelds. The LTC4410 is offered in the ThinSOT 6-pin package, and the LTC4053 is housed in a thermally enhanced 10-pin MSOP package. Neither part requires a reverse current blocking diode, and the system requires very few external components.

The LTC4410 USB present comparator output (USBP) drives the gate of an external P-channel MOSFET to disconnect the battery from the USB system when a valid USB voltage is present. This enables device operation when connected to the USB port regardless of the state of the battery (even a dead battery). When the USB cable is unplugged, the system reverts to operating off the battery.

Battery Charging with Priority

The LTC4410 is also useful in non-USB applications. A typical example is a wall-adapter powered cell phone charging cradle that has two slots, one for the phone and one for a spare battery. The challenge here is to charge two batteries as fast as possible, while giving charging priority to one of the batteries. When the phone and spare battery are both in the charging cradle, the battery in the phone is charged faster, utilizing all the available current from the wall adapter. As the battery in the phone approaches full charge and its current demand decreases, the spare battery starts charging.

Figure 2 shows a circuit that meets this challenge. The current for the priority charger flows through the LTC4410. A replica current equal to the (priority charger current)/1000 flows from the LTC4410 CHP pin in to the battery charger 2 PROG pin, which reduces the nonpriority charger current to zero. As BAT 1 approaches full charge, the priority charger reduces the current to the battery, which reduces the current out of the CHP pin allowing for the second battery to charge. See Figure 3 for full battery charger cycle.

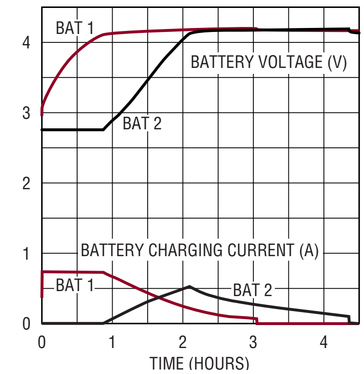


Figure 3. Battery charging cycle with the priority dual battery charger shown in Figure 2

The R_{PROG} resistor for each charger is 2kΩ, equating to 750mA of battery charge current, which is the rated current for the wall adapter. The MODE and USBP pins are not used on the LTC4410. The MODE pin is tied high, disabling its function while the USBP pin is left open. The timer capacitors on the LTC4053 are selected so that the timer for BAT 1 is 3 hours and for BAT 2 is 4.5 hours.

Conclusion

The LTC4410 and LTC4053 provide a complete and compact solution for charging batteries from a USB cable, or for charging two batteries with priority from a standard wall adapter.