Extending Single Input Charger to Dual Input Applications

Mao Ye
PMP - Portable Power

ABSTRACT

This application report extends a single input charger IC to dual input (AC adapter and USB) applications. First, a low-cost linear charger IC (bq24080) example is presented, and a CFE (charger front-end) protection IC (bq243xx) is used to provide Li-ion battery safety protection from charging-system failures. Second, the bq24100 is given as another example for high-voltage, switch-mode charger applications. Finally, the bq24100 with power-path selection is presented for high-current application.

Today, many portable products such as cell phones, MP3 players, and PDAs (personal digital assistant), etc., use a single-cell Li-ion battery as their primary power source. In the past, only an AC adapter was used as the power source for charging the battery. This scenario remained unchanged until recently.

The USB (universal serial bus) is now becoming the most popular interface to connect peripherals to personal computers (PC). The USB not only can transfer data between portable devices and the host PC, but it also allows power transmission over the USB cable. As a result, it is feasible for a handheld product to charge its battery while it is connected to a host PC through the USB cable. Most of today's portable products can be powered from an AC adapter, a USB cable, or a Li-ion battery.

For dual input applications, charger integrated circuits (IC) that support dual inputs are the first choice for system designers and are now available with many unique features. However, for those charger ICs that only support a single input, a small auxiliary circuit can be added to extend these charger ICs to support dual input applications. This can save cost, printed-circuit board space, and engineering design time.

Among the single input charger ICs from Texas Instruments, the bq24080 and bq24081 are highly integrated and flexible Li-ion linear charge devices targeted at low-cost, space-limited charger applications. These devices act as stand-alone battery chargers up to a 1-A charge current and work in three phases: conditioning, constant current, and constant voltage. Charge is terminated based on minimum current. An internal timer provides a backup safety for charge termination.

Figure 1 shows a minimum component solution by using the bq24080 as a Li-ion battery charger. In this case, only four components including the bq24080 are required. The fast-charge current is set by a resistor on the ISET pin, while precharge current and termination current are 1/10th of the fast-charge current. The total charge timer typically is set to 7 hours and the precharge timer to 30 minutes.

To extend this charger to a USB input application, designers must follow the USB specification, which defines load current limits that a USB device can draw from the host. Three operating modes are allowed. First is the suspend mode, wherein the USB devices stand by and draw less than 500 µA from the host. Second is the low-power mode, wherein the USB devices current can be up to 100 mA. Third is the high-power mode, wherein the current consumption can be as high as 500 mA.

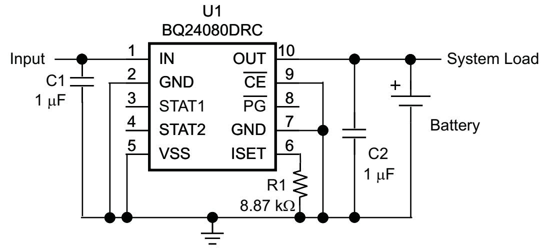


Figure 1. Minimum Component Count Li-Ion Battery Charger Using bq24080

The simplest and lowest cost solution to extend single input to dual inputs is adding two common-cathode Schottky diodes as shown in Figure 2(a). The two input voltages should not be presented at the same time. Otherwise, both diodes can be turned on and current is shared between two input terminals if the difference of two input voltages is less than the diode forward-voltage drop. When the difference is more than the diode forward-voltage drop, the higher voltage input powers the charger. The potential problem for this solution is the voltage drop across the Schottky diodes, which not only reduces system efficiency but also may cause battery charge problems when the USB bus voltage is too low. According to USB specification, the USB bus can be as low as 4.4 V, whereas the Schottky diode usually has a 0.2-V to 0.5-V forward-voltage drop for a 100-mA to 1-A range. Considering the charger IC internal dropout voltage, the voltage left for charging the battery may be lower than the voltage regulation set point, which is 4.2 V for most Li-ion batteries. As a result, in this situation, the battery cannot be fully charged.

To reduce the voltage drop across the Schottky diode, a P-channel MOSFET can be used to replace the Schottky diode as shown in Figure 2(b) and Figure 2(c). Figure 2(b) is a good trade-off between performance and cost. The body diode of the MOSFET acts as a Schottky diode initially to power the charger; then the proper FET is turned on to reduce the body diode forward-voltage drop and power dissipation. For example, in Figure 2(c), the gate of Q1 is connected to the adapter input and to ground by resistor R1. When the adapter is presented, the gate of Q1 is pulled high to turn off by adapter input voltage. When the adapter is not presented, the gate of Q1 is pulled to ground by resistor R1 to turn on Q1 if the USB is presented. Q2 and R2 perform the same function for adapter input. The gate resistor should be in the range 40 kΩ to 100 kΩ to meet the USB input impedance requirement.

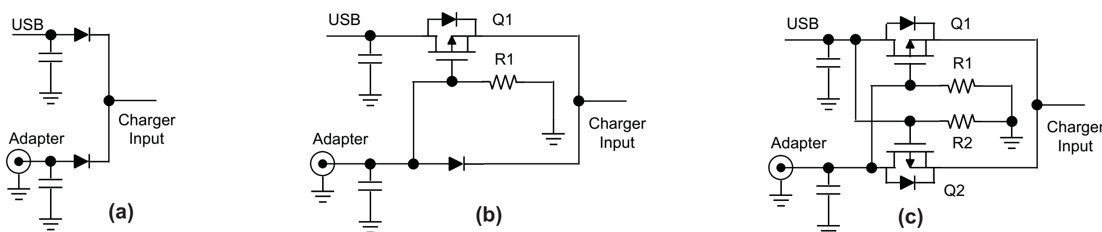


Figure 2. Typical Auxiliary Circuits for Dual Input Applications

The bq2408x charge IC has the current capability up to 1 A which is higher than USB 500-mA current limit. By adding some additional components to the ISET pin, the charger is capable of a higher charge rate from the AC adapter to a short fast-charge time.

Figure 3 shows an implementation of a dual input charger. Pulling up the $\overline{\text{CE}}$ pin to high disables the charger to meet the USB suspend-mode requirement. R1 gives a default USB low-power mode, 100-mA charge current. Turning on Q1A adjusts the ISET pin resistance to get the USB high-power mode, 500-mA charge current. Q1B turns on if the AC adapter is present and changes the fast-charge current to 800 mA.

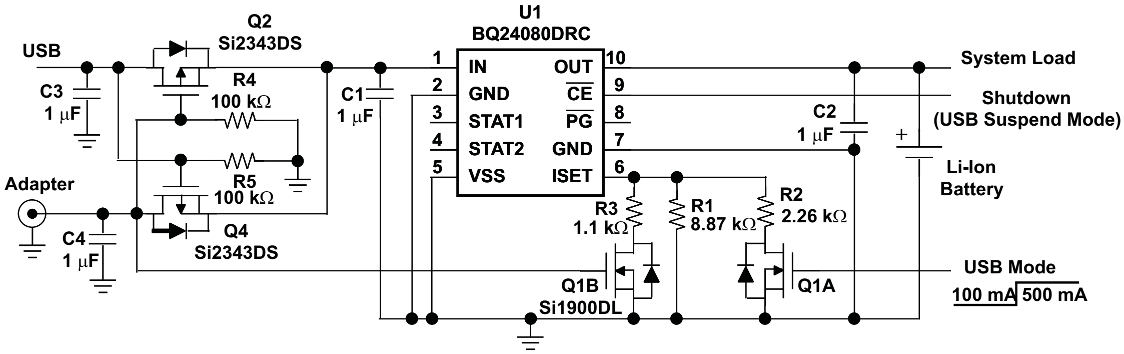
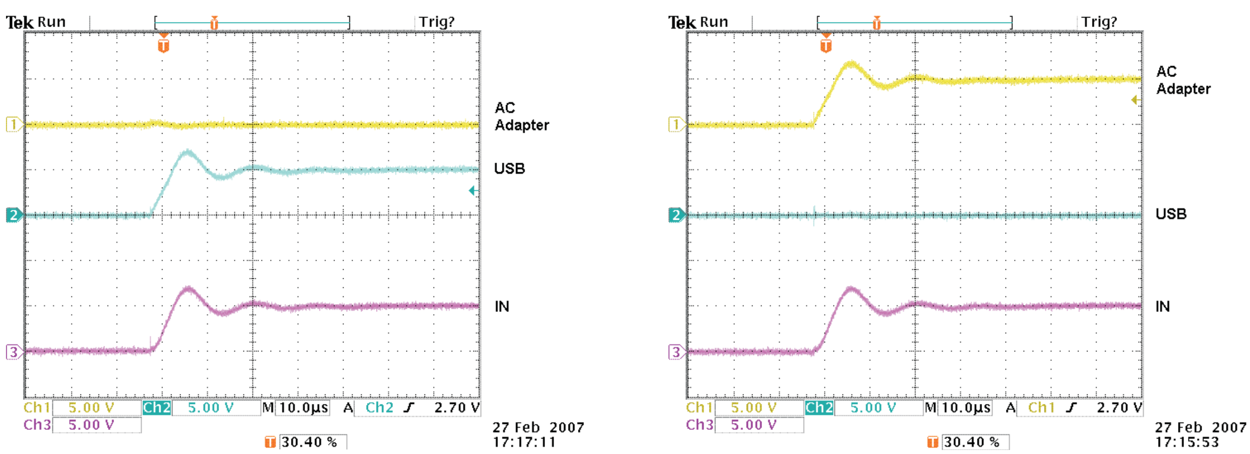


Figure 3. Dual Input Charger: 800 mA From AC Adapter or 100 mA/500 mA From USB

Figure 4 (a) and (b) shows USB and AC adapter hot plug-in waveforms, respectively. It is clear that the input voltage does not backfeed to either input source. Although the input voltage is set to 5 V, the parasitic inductor of cable resonance along with the input capacitor may cause a high-voltage spike on the input pin of the low-voltage rating charge IC. The bq24080's absolute maximum voltage rating of the input pin is only 7 V. Here the maximum input voltage spike is more than 7 V which may cause the charger IC to fail. If the charger IC fails, it may draw significant current through the USB cable and damage the host PC. The Li-ion battery also is in danger if an overcharge condition occurs.

To provide safety protection for the Li-ion battery from failures of a charging system, Texas Instruments now has many options for charger front-end protection for IC products. An IC of the bq243xx family continuously monitors the input voltage, the input current, and the battery voltage. In case of an input overvoltage condition, the IC immediately clamps the voltage at its output to a safe value. If the overvoltage condition persists for more than a few microseconds, the IC removes power from the charging circuit by turning off an internal switch. In the case of an overcurrent condition, it limits the system current at the threshold value, and if the overcurrent persists, switches the pass element off after a blanking period. Similarly, if the battery voltage rises to unsafe levels while charging, power is removed from the system and there is no output from bq243xx. Additionally, the IC also monitors its own die temperature and switches off if it becomes too hot.



(a) USB Hot Plug-in

(b) AC Adapter Hot Plug-in

Figure 4. Hot Plug-in Waveforms

The two types of CFE products are the bq2430x and bq2431x. The difference is that bq2430x has a fixed 300-mA current limit and fixed 10.5-V overvoltage protection while the output voltage is fixed to 5.5 V (bq24300) or 4.5 V (bq24304). The bq2431x current limit is resistor programmable, and the output voltage follows the input voltage. In this case, the overcurrent limit is set to 1 A. As a result, the bq24316 is selected as a CFE protection IC. Design of the bq24316 is simple. Figure 5 shows the dual input charger with a CFE protection IC. The 24.9-kΩ resistor connected to the ILIM pin gives a 1-A current limit set point. The 100-kΩ resistor between the VBAT pin and the battery positive terminal limits the current into the battery, if the CFE IC fails. The $\overline{FAULT}$ pin is in open-drain output status; when it is low, it indicates that the internal FET has been turned off due to input overvoltage, input overcurrent, or battery overvoltage.

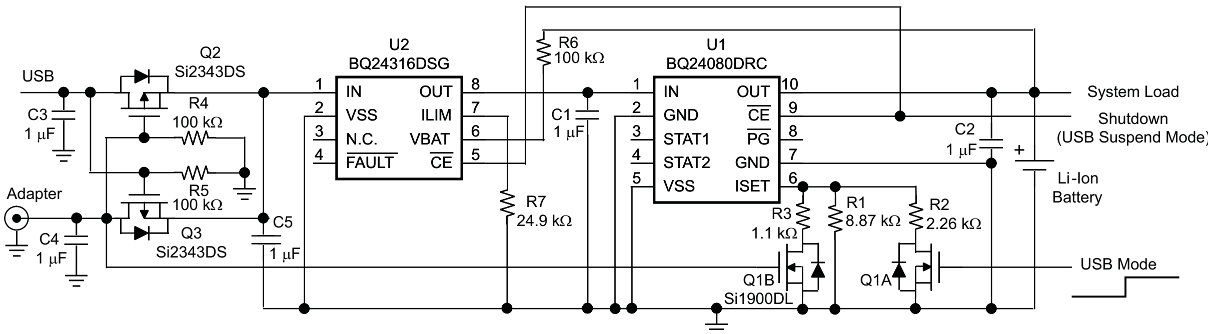
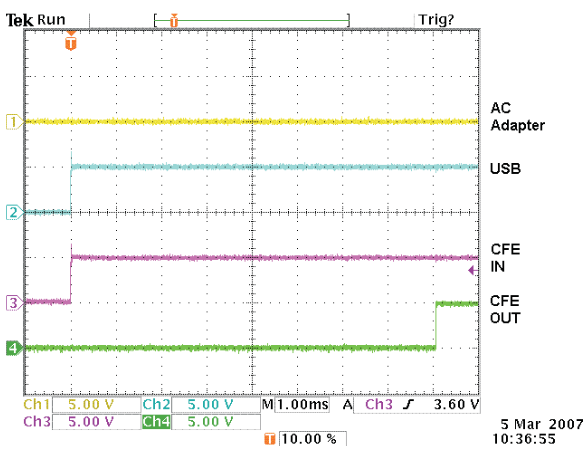
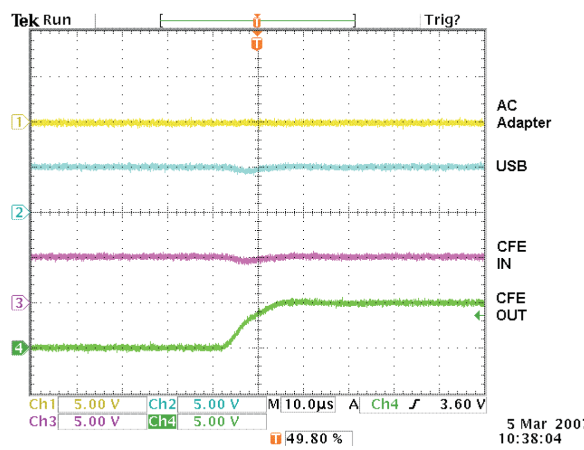


Figure 5. Dual Input Charger With CFE Protection IC

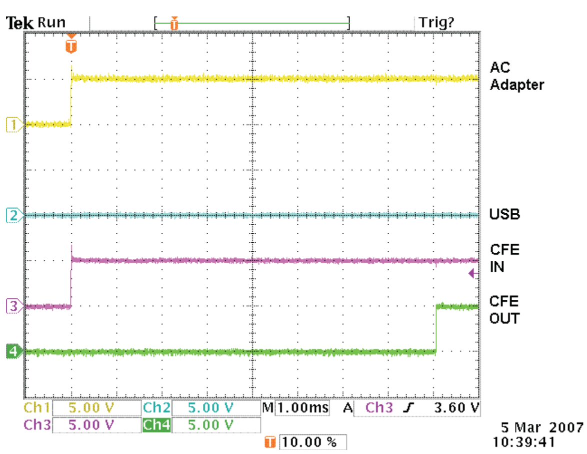
Figure 6 (a) and (c) shows USB and AC adapter hot plug-in waveforms, and (b) and (d) shows their zoom-in detail waveforms, respectively. The bq24316 has a 8-ms delay time to wait for input voltage stable. After 8 ms, the bq24316 turns on its internal FET to power up the charger IC. It is clear that the charger IC does not detect any overvoltage spike.



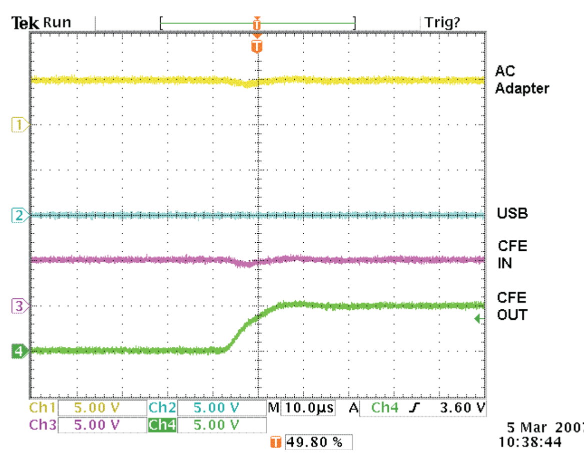
(a) USB Hot Plug-in



(b) USB Hot Plug-in Zoom-in



(c) AC Adapter Hot Plug-in



(d) AC Adapter Hot Plug-in Zoom-in

Figure 6. Hot Plug-in Waveforms With CFE Protection IC

For high-input voltage, high-current applications, the switch-mode charger solution is preferable due to its high efficiency. The Texas Instruments bqSWITCHER™ series (bq2410x/11x/12x) ICs are highly integrated, synchronous buck converters targeted at Li-ion and Li-polymer charger applications. The bq24100 is a stand-alone one-cell, 4.2-V charger suitable for a USB input voltage range.

Figure 7 shows an implementation of a dual input charger that works with a 9-V AC adapter input for 1-A charge current and a 5-V USB input for 500-mA charge current. USB suspend mode is supported by simply pulling up the $\overline{CE}$ pin of bq24100 to high.

Figure 8 shows a power-path selection solution for the bq24100. If an AC adapter is present, then D1 provides power to the system load. At the same time, D2 turns off Q4 and the body diode of Q4 is reverse-blocked by high adapter voltage. As a result, the system load is separated from the battery. When the USB is present, D1 and D2 are turned off. R10 pulls the gate of Q4 to ground to turn on Q4. As result, the system load is connected by Q4 to the battery.

For other power-path selection solutions, see the Texas Instruments application report *Implementations of Battery Charger and Power-Path Management System Using bq2410x/11x/12x (bqSWITCHER™)* (SLUA376).

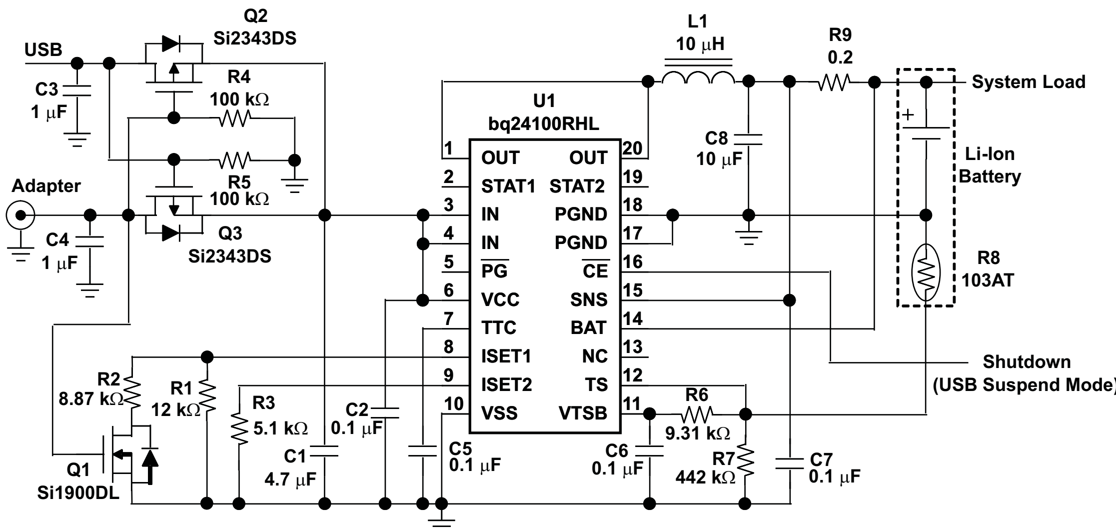


Figure 7. Dual Input Charger: 1 A From 9-V AC Adapter or 500 mA From USB

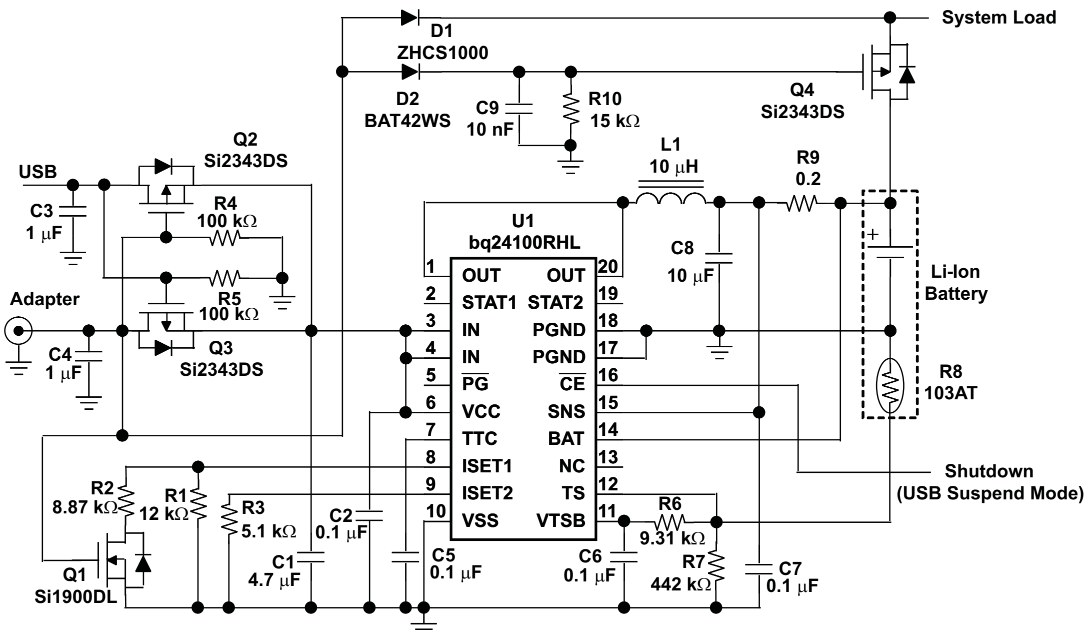


Figure 8. Dual Input Charger With Power Path Selection Solution