Low Voltage PowerPath Driver
Switches from a 3.3V or 5V Supply to Battery Backup

by Peter Guan and Tim Skovmand

The LTC1473L solves the problem of seamless power switching between 3.3V or 5V supplies and backup battery packs (3- or 4-cell NiMH) at high current levels. By driving two sets of back-to-back N-channel MOSFET switches, the LTC1473L routes power to the input of a low voltage (3.3V to 10V) system efficiently and inexpensively. An internal micropower boost regulator is included to fully enhance the external NMOS switches, even at low operating voltages. An external 1mH inductor and 1μF capacitor charge VGG to approximately 8.5V above V+, providing ample drive for the external MOSFETs. The LTC1473L includes inrush-current limiting during supply switchover to produce smooth transitions between the DC supply and the battery backup and to ensure that the load capacitors are always charged and discharged in a controlled fashion.

During start-up or under abnormal operating conditions, when voltages are varying, current can still pass to the output load from the higher input source if the Diode pin is enabled. Enabling the Diode pin essentially converts the two external MOSFETs into diodes. This “2-diode mode” is defeated when V+ drops below 2.5V.

Continuous short-circuit protection is also provided by a programmable timer that limits the amount of time the switches are allowed to be in current limit. When the time limit is reached, the LTC1473L removes the gate drive and then retries the offending switch, with a very small duty cycle, until the short circuit is removed, thus limiting all power dissipation to safe levels. The LTC1473L is housed in a space-efficient 16-pin narrow SSOP package and drives a wide range of N-channel MOSFET switches.

Figure 1 is a schematic diagram of an automatic PowerPath™ switch for 3.3V applications. The LTC1442 micropower, low voltage, dual comparator monitors the DC supply rail with its internal 1.182V reference and an external resistor divider. As soon as the supply falls below 3V, the two comparator outputs change state and invert the two logic inputs (IN1 and IN2) of the LTC1473L. This action smoothly switches the load from the DC supply to the backup battery pack. For hysteresis on the comparator’s trip point, an additional resistor divider can be added between the REF (6), HYST (5), and V– (2) pins of the LTC1442 (refer to the LTC1442 data sheet for details).

Figure 2 is a schematic showing the LTC1473L switch controller in conjunction with an LT1512 battery charger. In this application, the 4-cell NiMH battery is fully charged by the 3.3VDC supply through the LT1512 buck-boost converter to ensure that it is always “topped off” and ready to provide backup power. R3 is set at 1Ω to charge the NiMH battery pack at a constant 100mA rate.

In both applications, the value of CTIMER determines the amount of time continued on page 37
In the circuit described, the amount of hysteresis for the circuit is calculated to be 92mV. Hence, VBATT must climb back above 3.092V before the battery is connected.

Hysteresis = \( \frac{V_B' \cdot R_1}{R_2} + V_B - V_t \)

where \( V_B' = \left( V_{OMAX} - I \cdot R_4 \right) \cdot \frac{R_4}{R_5} + V_{REF} + I \cdot R_4 \)

\( V_t \) = lockout voltage

\( V_{OMAX} \) = maximum output swing (high) of \( U_1 \)

The formula for maximum output swing is:

\( V_{OMAX} = \left( V_{OMAX} - I \cdot R_4 \right) \cdot \frac{R_4}{R_5} + V_{REF} + I \cdot R_4 \)

The battery manufacturer should be consulted regarding the maximum ESR at maximum recommended discharge current. Multiply the two values to get the minimum hysteresis required.

**Being Precise**

The worst-case voltage-monitor accuracy is better than 0.4%. Interestingly, the battery's longevity and capacity are directly related to the depth of discharge. More cycles can be obtained by partially rather than fully discharging the Li-Ion battery, and, conversely, more use time can be obtained by fully discharging a Li-Ion battery. Cutting off the load at the perfect end-of-discharge voltage would ideally result in the best of both cases. To perform this task requires an accurate overall system. For example, if the optimum lockout voltage is to be set at 3.1V, a 5% overall accurate system would yield ±155mV, cutting off at either at 2.945V or at 3.255V. At a lockout voltage of 3.255V, maximum capacity is not obtained. In addition, the operating range is reduced, with the fully charged battery voltage being 4.1V. For a 0.4% overall accurate system, the lockout voltage would be at 3.088V or at 3.112V, more than twelve times better accuracy and optimally achieving the highest capacity. Furthermore, the load is kept disconnected with only 4.5mA to the protection circuit. Thus, the protection circuit works by preventing deep discharge of the battery.

**Conclusion**

There need not be a trade-off between performance and current consumption. The LT1389 nanopower precision shunt voltage reference and the LT1495 1.5mA precision rail-to-rail input/output op amp deliver the highest performance with virtually zero current consumption.

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**Figure 2. Battery-backup circuit with LT1512 battery charger**

In the circuit described, the external NMOS switches are allowed to be in current limit, and the value of RSENSE determines the inrush current limit, which is set at 2x to 3x of the maximum required output current.

When \( V^+ \) falls below 2.5V, the LTC1473L's undervoltage lockout circuit turns off both switches. With a built-in hysteresis of 100mV, the LTC1473L becomes active again when \( V^+ \) rises above 2.6V. Therefore, for 3.3V systems, small Schottky diodes are used to power \( V^+ \) from both DCIN and BAT1 so that the undervoltage lockout circuit will not be falsely tripped. Since the LTC1473L has an \( I_D \) of less than 100µA at 3.3V, the drop across the Schottky diode is less than 0.4V, leaving enough room for a typical ±5% supply tolerance.

Glitch-free and seamless transition of power is crucial for maintaining normal operation in low voltage electronic equipment. The LTC1473L makes the transition transparent and trouble free. (For systems using supply voltages between 6V and 28V, refer to the LTC1473 data sheet.)

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