Adjustable Low-Battery Threshold Detector Extends Battery Runtime

by Brendan Whelan

The LTC1998 is the first Lithium-Ion low-battery detector that guarantees 1% accuracy even when using inexpensive 1% programming resistors. This device facilitates more reliable battery capacity management; it extends battery runtime and improves prediction of remaining battery charge. The LTC1998 achieves this performance by combining an accurate internal reference and a proprietary comparison circuit. Other features include:

- ❑ Low supply current, 2.5µA typical
- ❑ Adjustable low-battery threshold, 2.5V to 3.25V
- ❑ Adjustable hysteresis, 10mV to 750mV
- ❑ Rail-to-rail push-pull output eliminates pullup resistor
- ❑ Dedicated output supply pin ensures compatibility with microprocessors
- ❑ Small ThinSOT™ 6-lead SOT-23 Package

The LTC1998, in the SOT-23 package, compares the voltage of a single Lithium-Ion cell to an internal reference voltage. When the battery voltage falls below a predetermined low-battery threshold, the output pin ($\overline{BATTLO}$) changes state to indicate a low-battery condition. The low-battery threshold voltage is adjustable from 2.5V to 3.25V via the threshold adjust pin. The threshold voltage is guaranteed to be within 1% of the programmed voltage as long as the threshold-adjust pin voltage is programmed with a resistor divider composed of 1% or better resistors. The $\overline{BATTLO}$ output of the LTC1998 can be used by a microprocessor or microcontroller in a battery-powered system to ensure that the battery has sufficient remaining capacity to allow proper operation or ensure that stored settings are not lost. The high accuracy of the LTC1998 improves the ability of the system to predict the remaining battery capacity. The LTC1998 can provide a longer runtime than a system using a less accurate threshold detector since it requires a smaller guardband for detector error. The LTC1998 can also be used to protect a battery from damage from overdischarge. *In addition, the 2.5µA typical supply current is less than the effective self-discharge current of most Li-Ion cells.*

In many applications, the system reduces the battery load current during a low-battery condition, thus allowing the battery voltage to recover over time. The large adjustable hysteresis of the LTC1998 allows it to ignore this voltage change so that the output does not change state to indicate a false recharged battery condition. The hysteresis is programmable via the hysteresis-adjust pin.

Programmable Thresholds

An accurate internal reference and internal divider set the low-battery threshold level at which the $\overline{BATTLO}$ signal changes from high to low. The threshold can be adjusted via the threshold-adjust pin ($V_{TH.A}$), as in Figure 1. A proprietary threshold adjustment circuit maintains a highly accurate threshold voltage even when using 1% external resistors to set the threshold voltage. This gives the LTC1998 the accuracy of a trimmed fixed-threshold device as well as the flexibility of an adjustable threshold.

Hysteresis is programmable via the hysteresis-adjust pin $V_{H.A}$). This pin works in exactly the same way as the low-battery threshold adjust pin, except that it controls the threshold at which the $\overline{BATTLO}$ signal changes state from low to high, indicating a charged battery condition. Both the low-battery threshold voltage and the hysteresis-threshold voltage may be programmed to be between 2.5V and 3.25V; the hysteresis is the difference between these two thresholds. The hysteresis may be as large as 750mV. This large hysteresis prevents false state changes at the output due to transients or battery recovery. The

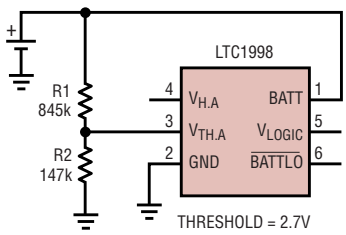

Figure 1. Threshold adjustment with resistor divider

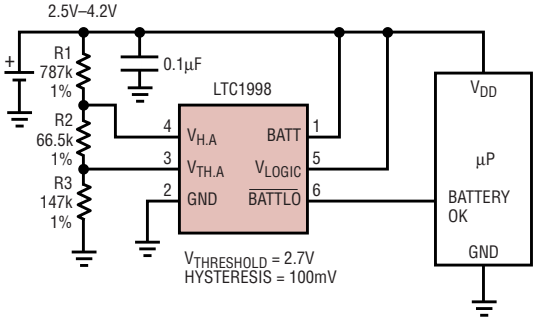

Figure 2. Single resistor divider sets both thresholds

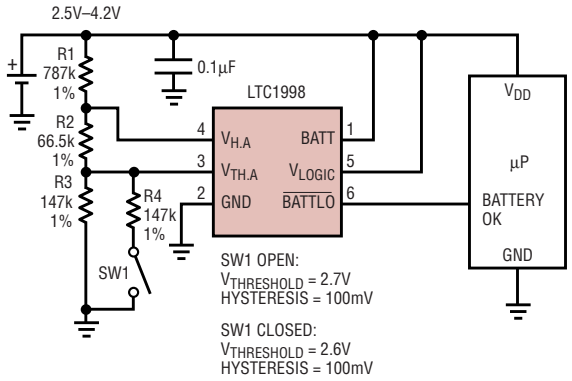

Figure 3. Dual low-battery threshold circuit

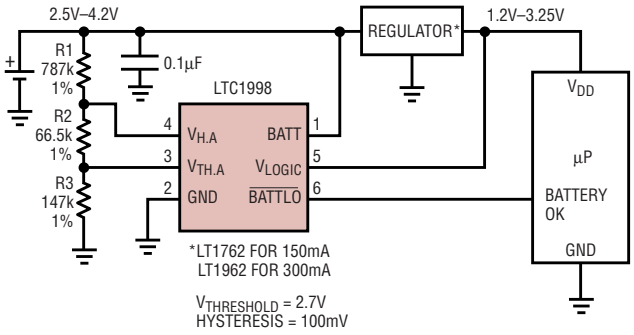

Figure 4. V_{LOGIC} pin ensures compatibility with processor logic level

system may then be designed to automatically reduce the battery load current when a battery-low signal is received. If the battery voltage recovers under this reduced load, the output of the LTC1998 will maintain a low output state. Both thresholds may be programmed using just three external resistors, as shown in Figure 2, minimizing component count. The threshold-adjust and hysteresis-adjust pins exhibit very high input impedance, which allows the use of large external program resistors to reduce the battery drain current.

The threshold-adjust function is continuous; threshold voltages can be adjusted at any time and changes take effect instantaneously, without the use of a clock or reset. This allows simple switched resistors to change thresholds. Figure 3 illustrates how a system can be designed with multiple low-battery threshold levels. In such an application, the load current can be reduced when a low-battery signal is produced. For example, the application can change the low-battery threshold to a lower voltage with S1 and continue to run in a low power mode, keeping system parameters stored safely in memory. When the battery voltage finally drops below the new low-battery threshold, the system can be shut down completely in order to protect the battery from damage due to overdischarging.

Versatile Output Stage

The LTC1998's $\overline{\text{BATTLO}}$ output is a rail-to-rail push-pull CMOS output driver with a dedicated driver supply pin, V_{LOGIC}. A break-before-make circuit prevents power supply cross-conduction currents during switching to reduce battery load transients. The V_{LOGIC} pin may be wired to BATT or driven by a lower supply voltage to allow compatibility with low voltage microprocessors (Figure 4). The $\overline{\text{BATTLO}}$ pin will drive a high output signal to the voltage set by the V_{LOGIC} pin. The V_{LOGIC} pin can be any voltage between 1V and V_{BATT}. This feature helps to protect a low voltage microprocessor or microcontroller from overvoltage stress at its battery-threshold detect input pin. The V_{LOGIC} pin can also be driven from a separate supply so that output drive current is not taken from the battery, further increasing battery life. The $\overline{\text{BATTLO}}$ output can drive a voltage that is a higher potential than the BATT pin, provided that a resistor is connected from the V_{LOGIC} pin to the required supply, as in Figure 5.

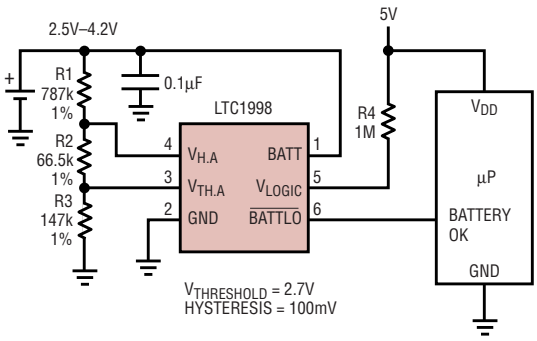

Figure 5. Simple pull-up resistor increases compatible logic range

Conclusion

The LTC1998 low-battery threshold detector provides a small (SOT-23-6), accurate, low power solution to capacity management problems in Lithium-Ion battery applications. It can improve useful battery life and is flexible enough to work in many different applications. Low cost 1% resistors can be used to configure thresholds while maintaining 1% threshold accuracy. Its ultralow power consumption minimizes battery drain current.

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