Nano-Power Battery Monitoring in Personal Electronics

Chuck Sins, Analog Signal Chain

Introduction

The need for under-voltage detection in battery-powered personal electronics is obvious but how a system engineer provides such detection varies according to the resources available in the system. The most common solution for detecting when a battery voltage gets too low is to use a 5-pin comparator in conjunction with some sort of voltage reference. The solution looks something similar to Figure 1.

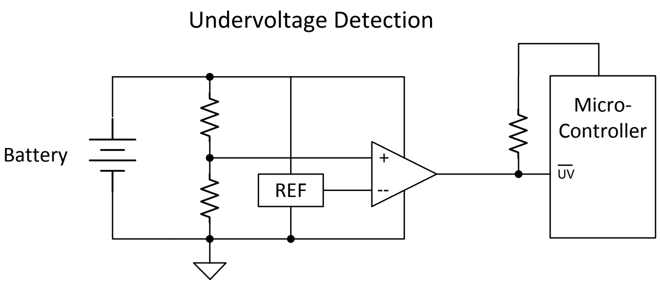

Figure 1. Under-Voltage Detection with a 5-pin Comparator

Under-Voltage Detection with a 5-Pin Comparator

Typically the comparator and voltage reference are directly powered by the battery if their operating voltage range extends high enough to include the maximum battery voltage. The battery voltage is then reduced with a resistor divider such that the battery voltage will cross the threshold of the voltage reference when the battery reaches a critically low voltage level. Frequently, the output of the comparator is used to alert a microcontroller in the system that the battery level is low. Another option that is commonly exercised is to light an LED in order to provide a visible indication that the battery level is low.

Depending on the usage case, the output level of the comparator may need to be level shifted in order to communicate with a microcontroller or to control a shutdown pin on a DC/DC converter. Level shifting is necessary when the comparator is powered directly from a battery and the device that is monitoring the output of the comparator is operating at a different voltage level. For these applications, a comparator with an open-drain output stage is required, as shown in Figure 1. Comparators with open-drain output stages require a pull-up resistor on their output. When the non-inverting input to the comparator is more positive than the inverting input, the output of the comparator enters a state of high impedance. The pull-up resistor now provides the logic high output level for the comparator. Likewise, when the non-inverting input to the comparator is more negative than the inverting input, the output of the comparator creates a low impedance path to ground and sinks current through the pull-up resistor. A low output state in Figure 1 alerts the microcontroller that a low battery voltage has been detected.

Alternative Solution with a 4-Pin Comparator

As shown in Figure 1, a traditional 5-pin comparator is frequently selected to monitor a battery voltage. However, there are alternative solutions available that serve the same function, take up less physical board space, and possess a unique ability of having their input driven even when the operating voltage is zero. One such device is Texas Instrument's TLV7081 which is a 4-pin comparator.

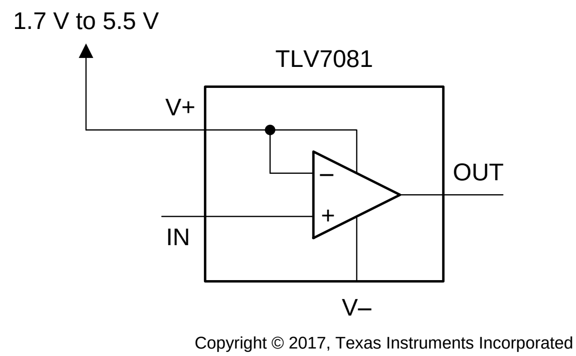

Figure 2. TLV7081 Block Diagram

As shown in Figure 2, one pin is eliminated by internally connecting the inverting input of the comparator to the positive supply pin. The application of the TLV7081 for an under-voltage detection circuit is shown in Figure 3.

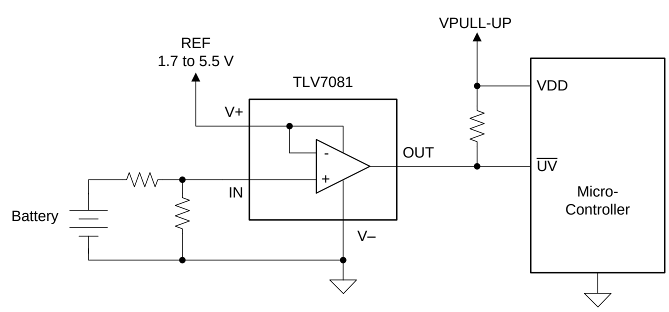

Figure 3. TLV7081 Under-Voltage Detection

Instead of being powered directly from the battery, the nano-power comparator is powered directly from a voltage reference that exists in the system. The input to the comparator is allowed to operate above and below the reference voltage due to the unique analog front end of the TLV7081. When the battery voltage is above the reference threshold, the output of the comparator is high and when the battery drops below the threshold of the reference, the output of the comparator goes low (see Figure 4 for details). For simplicity, the integrated hysteresis of the comparator is not shown in the timing diagram. Integrated hysteresis is helpful in avoiding glitches at the comparator output when operating in noisy environments or when the input voltage changes thresholds very slowly. An open-drain output configuration allows the output logic level of the comparator to be level-shifted to match the logic level of the receiving device.

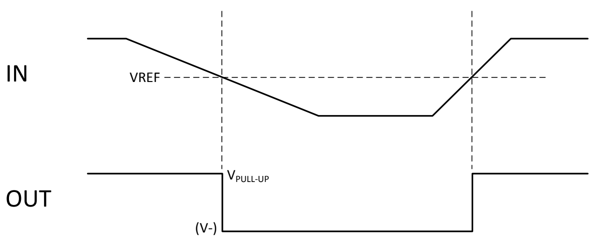

Figure 4. Timing Diagram

Advantages of a 4-PIN Comparator

In addition to saving board space, the 4-pin comparator has other circuit advantages. First, the battery input can be connected to the input of the comparator even if the reference voltage is not powered. Most comparators have ESD protection diodes on the input that prevent the input from being driven when the supply to the comparator is disabled. This is possible in the TLV7081 because the comparator's input stage is designed to accept voltage levels independent of the operating voltage applied to the supply pins. Being able to leave an input voltage such as a battery connected to the input of the comparator even when the comparator is powered down eliminates any power supply sequencing concerns. Moreover, it provides a secondary means for saving power. Comparators such as the TLV7081 are nano-powered but for applications such as energy harvesting applications where total power consumption needs to drop below 100nA when a battery voltage drops to dangerously low levels, devices such as the TLV7081 can be power cycled by a microcontroller GPIO pin or a nanotimer device. In Figure 5, a GPIO pin of the microcontroller is used as the supply voltage for the comparator. Since the input stage's input voltage range is independent of the supply voltage, the battery voltage can remain connected to the comparator input without any negative impact to the circuit.

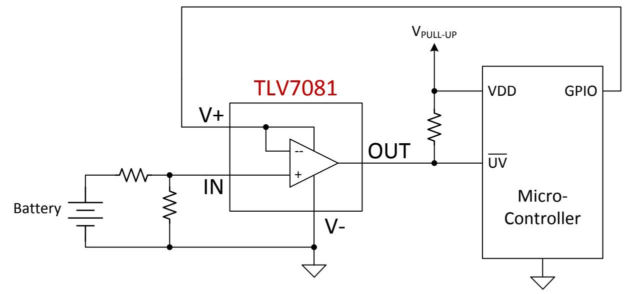

Figure 5. Power Cycling Under-Voltage Detector

A second advantage to the 4-pin comparator is the performance improvement that results powered directly from a reference. Since the reference voltage is well regulated, there will be little or no comparator offset change due to the operating voltage changing (there will be no noticeable PSRR error contribution). In the case of the 5-pin comparator configuration, the comparator is directly powered by the battery that will sag over time. The sagging of the battery will have an impact on the threshold voltage of the comparator due to a finite power supply rejection ratio.

Conclusion

For battery powered systems requiring under-voltage detection, 4-pin comparators such as the TLV7081 offer several advantages over the traditional 5-pin options. The smaller PCB footprint, removal of power supply sequencing concerns, low-power consumption, and improved threshold accuracy due to operating directly from a reference make 4-pin comparators a logical choice for systems requiring under-voltage detection.

Table 1. Low Power, Micro-Package Comparator Family

Family	Package Information	Quiescent Current	Propagation Delay	Output Configuration
TLV7081	4-pin WCSP (0.7 x 0.7 mm^2)	370 nA	4 usec	Open-Drain
TLV7011	5-pin X2SON (0.8 x 0.8 mm^2), SC70	5 uA	260 ns	Push-Pull
TLV7021	5-pin X2SON (0.8 x 0.8 mm^2), SC70	5 uA	260 ns	Open-Drain
TLV7031	5-pin X2SON (0.8 x 0.8 mm^2), SC70	335 nA	3 usec	Push-Pull
TLV7041	5-pin X2SON (0.8 x 0.8 mm^2), SC70	335 nA	3 usec	Open-Drain
TLV3691	6-pin X2SON (1 x 1 mm^2), SC70	75 nA	24 usec	Push-Pull

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