Versatile Over-The-Top Precision Comparator is Ideal for Status Monitoring

by Jon Munson

Introduction

The LT1716 is a micropower, precision rail-to-rail comparator that operates on single or split supply voltages that total anywhere between 2.7V and 44V. The part is unique in that the input threshold range is from V_{EE} up to 44V above V_{EE}, regardless of the V_{CC} voltage being used. This means that operation at low logic levels no longer restricts the range of input levels that can be compared. In addition to the Over-The-Top® feature, the LT1716 will tolerate overdrive of up to –5V with respect to V_{EE} on an individual input without phase inversion. Besides offering robust input voltage swings, precision performance is retained; typical input offset is less than 500µV.

The LT1716 also has some unique output characteristics. When driving high-impedance loads, the output swings close to the rails without need for external components, thanks to an active pull-up current-source. While able to eliminate an external pull-up resistor in many applications, the LT1716 topology also includes an integrated Schottky diode configuration that provides support for traditional "open-collector" operation up to 44V above V_{EE} when load-switching or level-translation is desired.

The LT1716 is offered in the popular SOT-23 5-lead package and typically draws a "micropower" supply current of 35µA. Refer to Table 1 for a summary of the major performance characteristics of the LT1716.

Table 1. Summary of LT1716 performance characteristics (V_{CC} = 5V, V_{EE} = 0V)

Parameter	Value	Condition
Input Voltage Range	–5V to +44V with respect to V_{EE}	Independent of V_{CC}
Input Offset Voltage	<500µV typical	0.5V to 44V above V_{EE}
Supply Voltage Range	2.7V to 44V	V_{CC} – V_{EE}
Supply Quiescent Current	35µA typical	V_O = High
Propagation Delay	3µs typical	$V_{OVERDRIVE}$ = 100mV R_L = 10kΩ
Output Sink Current	10mA minimum	$V_{OVERDRIVE}$ > 30mV
Output Source Current	85µA typical	$V_{OVERDRIVE}$ = 5mV
Output Leakage Current	0.5µA typical	V_{OH} = V_{CC} to 44V above V_{EE}

How Does It Work?

Input Architecture

The LT1716 achieves its unique input capabilities by the use of a sophisticated input structure. The topology is completely symmetric differentially and each input signal is processed in four distinctly different ways that vary as a function of the applied voltage. The left-hand portion of the simplified schematic, Figure 1, shows the input

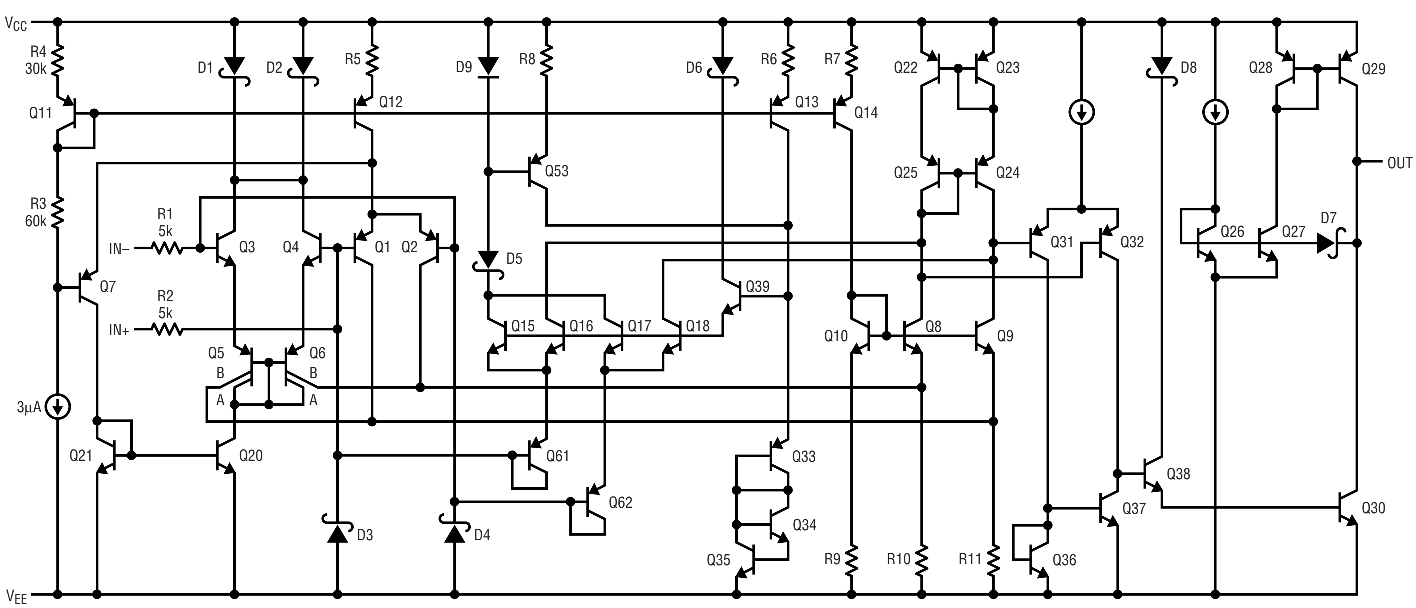

Figure 1. LT1716 simplified schematic

circuitry. The inputs are coupled to the bases of a PNP differential pair (Q1, Q2) and an NPN differential pair (Q3, Q4), as well as the emitters of a secondary NPN differential pair (Q18, Q16) via diodes formed by Q62 and Q61. Q5 and Q6 form a current-mirror biasing stage for the main NPN input pair.

The PNP stage is active when either of the inputs are in the range of about V_{EE} + 0.3V to V_{CC} – 0.8V, delivering differential currents to loads R10 and R11. The biasing section steers current between the PNP stage and the main NPN stage depending on whether the PNP transistors go into cutoff. The NPN stage provides active gain for inputs in the range of about V_{CC} – 0.8V to V_{CC} + 0.3V. The NPN differential currents are passed by the Q5/Q6 pair, arriving at the R10/R11 loads, adding to any currents generated by the PNP stage.

As an input voltage goes above V_{CC} + 0.3V, the NPN gain drops to unity (becomes a diode) and the inputs effectively drive the emitters of Q5/Q6, which continue to mirror currents to the loads R10/R11. During Over-The-Top operation, Schottky diodes D1 and D2 prevent forward biasing of the NPN base/collector junctions, and the PNP stage is completely reverse-biased, effectively removing it from the circuit.

As input voltage falls below V_{EE} + 0.3V the PNP stage becomes saturated and the NPN stage remains off, but the emitter-coupled pair Q16/Q18 becomes active and comes into play to provide a continued differential sensing capability. Signals below V_{EE} – 0.3V are internally clamped by Schottky diodes D3 or D4 and voltage begins to develop across the 5k series input resistors R1 or R2 for voltages down to the rated limit of V_{EE} – 5V. So long as only one input goes under-the-bottom, the comparison function remains correct. Should both inputs drive their clamp diodes into conduction, then the signals look the same to the circuit and the LT1716 output becomes unpredictable, though no harm will come to the device. The differential pair Q8/Q9 serve to combine the R10/R11 signals with the Q16/Q18 outputs to maintain the proper output voltage state over the entire input voltage range.

Figures 2 and 3 show the resulting input current/voltage characteristics of the LT1716. For input comparisons within the rails, the bias currents are very small, in the few nanoamp range, while for Over-The-Top thresholds, a modest 8µA of bias may be required of the higher-potential input signal. For signal-swings below V_{EE}, the 5kΩ protection resistance limits the input current to about –1mA. If desired, external series resistance can be added to reduce the negative-going bias current or to extend the allowable signal swing below V_{EE} to beyond –5V.

Output Architecture

The LT1716 provides its versatile interfacing capability through the use of a specialized output structure. The right-hand portion of Figure 1 shows the output circuitry. Differential pair Q31/Q32 and emitter-follower Q38 provide the differential to single-ended drive for Q30, which is the main output device and provides the pull-down capability of the part. The pull-up feature is accomplished by current mirror Q28/Q29 that is slaved to mirror Q26/Q27. When the output is driven low, Schottky diode D7 conducts and turns off the current mirror stages. The interesting thing about this configuration is that in the high state, the output can be easily forced above V_{CC} by an Over-The-Top load return, reverse biasing D7 and the Q28/Q29 base-emitter junctions. This allows the LT1716 output to behave like an open collector for driving loads up to 10mA, yet providing rail-to-rail output for Hi-Z loading without the pull-up resistor that a traditional open-collector would require.

Some Interesting Design Solutions

Overcurrent Indicator

The LT1716 is well suited to monitoring current in power buses, since the inputs can operate well above the logic-level power supply. An important power bus monitoring function is one that produces a logic signal indicating when an overload condition is taking place. Figure 4 shows a circuit that performs that function using the LT1716.

In this circuit, the LT1716 is powered indirectly from the hot side of the sense resistor, via an LT1643-1.25 shunt reference. The reference permits an accurate offset to be developed (about 120mV) that represents the current-induced drop on the sense resistor at the desired trip point, assumed here to be about 20% over the maximum normal current. The 10MΩ positive-feedback resistor is used to prevent indication chatter at the threshold by producing a consistent 3mV of hysteresis over the range of bus voltages that can be monitored. The 10MΩ connected to the inverting input nominally matches the offset that is induced by the 10MΩ hysteresis resistor. The Schottky diode at the output is used to clamp the LT1716 output at about V_{LOGIC} + 0.3V, to prevent

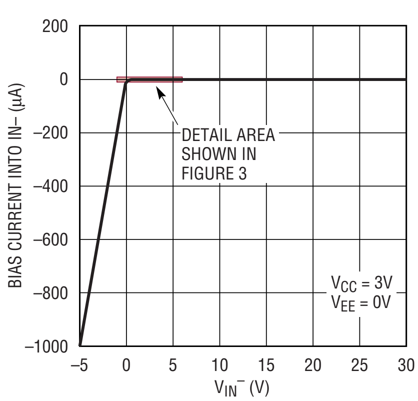

Figure 2. LT1716 input bias current

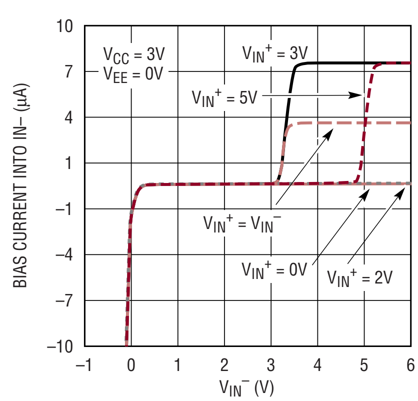

Figure 3. LT1716 input bias current (detail)

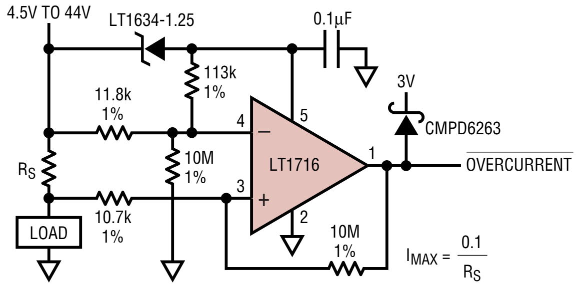

Figure 4. Overcurrent indicator

overvoltage at the logic load and to properly set the hysteresis.

Voltage-Sensing Relay Trigger

Figure 5 shows a circuit that creates a precision voltage-level actuated coil-drive trigger for a miniature relay (or large relay with an additional transistor). With an output capability of sinking more than 10mA, an LT1716 can directly drive low-coil-current relays and provide simple resistor programmable make or break thresholds. This basic circuit offers a convenient solution for providing alarm annunciation or load-protection switching related to DC bus voltage monitoring.

The threshold reference is established by the 1.25V drop of the LT1634-1.25, which is biased by the LT1716 supply current. The resistor divider at the non-inverting input sets the trip-point as a multiplier of the reference. The 10MΩ positive-feedback resistor sets the LT1716 input hysteresis at about 0.5% of the trip voltage for clean state changes and noise rejection. The relay should have guaranteed pull-in capability somewhat below the desired trip-on voltage to allow for the V_{OL} drop and thus ensure that the comparator has full control of the contact state. The Schottky diode at the output provides fast clamping of the relay turn-off transient. The entire circuit uses less than 0.1mA in the "off" state and adds less than 0.4mA to the "on" state current of the relay coil.

Lamp Integrity Monitor

Even with their limited lifetimes, incandescent lamps are still widely used as low-cost hi-level illumination in many products like automobiles and aircraft. With the trend in products to provide more self-diagnostic information, it is optimal to have a circuit that provides a full-time status of the lamp load, whether it is activated or not. Figure 6 shows a circuit using the LT1716 for monitoring a typical automotive lamp-load.

The LT1716 is shown powered from a logic-voltage supply of 3V, while it monitors a lamp powered from a battery system supply like 14V or 28V in vehicles. When the lamp is on, a voltage drop exists across the sense resistor that exceeds the bias-current induced drop on the 5.1kΩ resistor, thereby detecting that a suitable load current is flowing. When the lamp is off, the filament will pull-down through the 100kΩ and the low-leakage diode/1MΩ will cause a slight voltage rise across the 5.1kΩ, signifying to the comparator that the lamp load is intact.

Conclusion

The LT1716 provides the designer with the most flexible power supply and output interfacing options possible in that it has the unique ability to precisely monitor signals that may be completely unrelated to the logic voltage involved. This feature, plus its micropower performance and its easy-to-use SOT-23 footprint, make the LT1716 an ideal choice for integrated system monitoring applications.

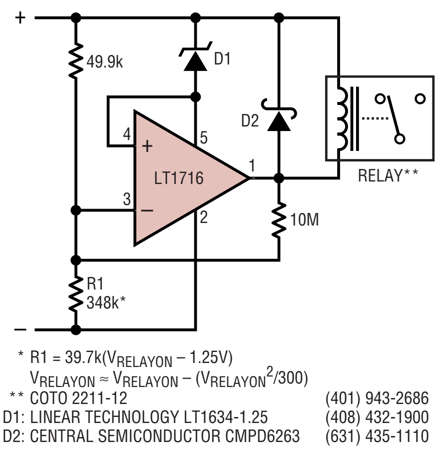

Figure 5. Voltage-sensing relay trigger

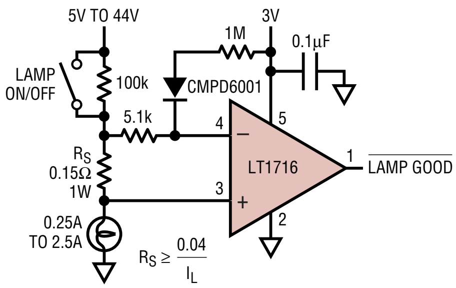

Figure 6. Lamp integrity monitor