3µA Quiescent Current LDO Improves Efficiency for Low Power Circuits in Industrial, Automotive and Battery-Powered Systems

by Sam Rankin

Introduction

Many electronic systems spend much of their time in an idle state, waiting for something to happen. Industrial remote monitoring systems and keep-alive circuits are but two examples. Many of these systems depend on battery power, so a high efficiency power supply is paramount to preserve battery life. Efficiency during quiescent state is of particular importance since active operation may draw milliamps while quiescent operation only microamps. Small size and reverse output and input protection capabilities are also desirable features in a power supply. This is a demanding combination of power supply requirements, but there is an easy way to satisfy them with one device.

Ultralow Quiescent Current PNP LDO

Figure 1 shows a typical application for the LT3009, a 3µA quiescent current low dropout linear regulator in tiny 2mm × 2mm DFN and 8-lead SC70 packages. Its ultralow 3µA quiescent current is well controlled—it does not rise excessively in dropout as happens with many regulators. Quiescent current is less than 5% of output current at 20mA I_{OUT}, even in dropout (Figure 2).

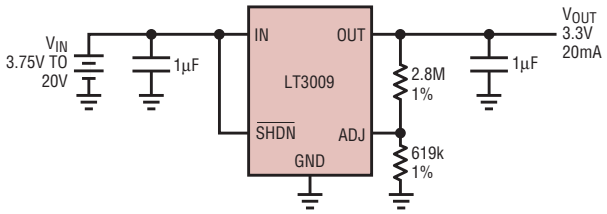

Figure 1. New 3µA quiescent current low dropout regulator

The LT3009 can supply up to 20mA from input supplies ranging from 1.6V to 20V to output voltages ranging from 0.6V to 19.5V. Dropout voltage on the LT3009 is only 280mV while delivering up to 20mA of output current. It can be put into a low power shutdown state by pulling the $\overline{SHDN}$ pin low. In shutdown state, the already low quiescent current is reduced to the leakage currents of the internal transistors. This leakage, typically a few nA at room temperature, stays below 1µA over the entire operating temperature range. Low quiescent current and tiny package size does not translate into poor performance in the LT3009. The LT3009 features industry leading load, line, and temperature regulation (see Figures 3, 4 and 5)

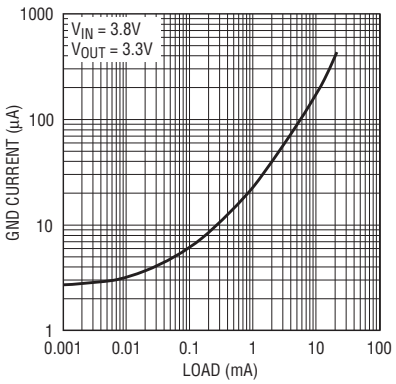

Figure 2. GND Pin current vs I_{LOAD}

Aside from the output voltage setting resistors, the only external components required are input and output bypass capacitors. Internal frequency compensation in the LT3009 stabilizes the output for a wide range of capacitors. A minimum of 1µF of

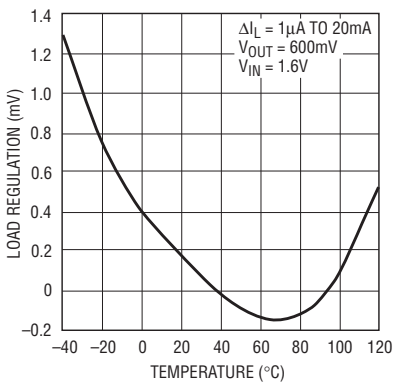

Figure 3. Load regulation vs temperature

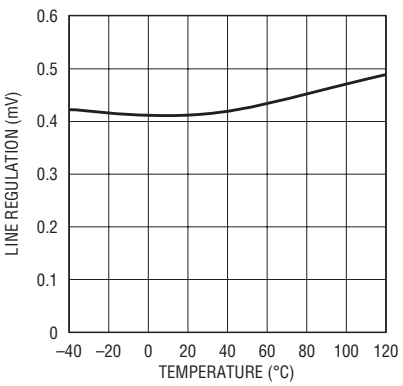

Figure 4. Line regulation vs temperature

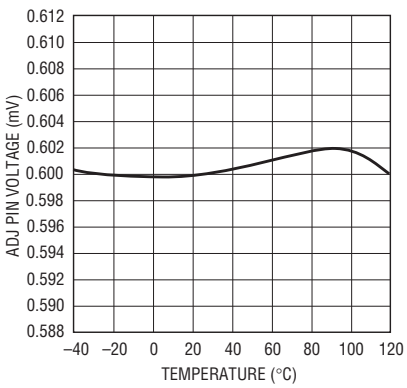

Figure 5. Output voltage vs temperature

output capacitance is required for stability, and almost any type of output capacitor can be used. Even small ceramic capacitors with low ESR can be used without the additional series resistance commonly required with other regulators. The combination of small package size and the ability to use small ceramic capacitors enable the LT3009 to fit almost anywhere.

The LT3009 has a number of protection features to safeguard itself and sensitive load circuits. Should the input voltage become reversed (due to a battery inserted backwards or a fault on the line, for example), current flow from the IN pin is limited by a 100k resistance and no negative voltage is seen at the load. No external protection diodes are necessary when using the LT3009. With a reverse voltage from output to input, the LT3009 acts as though it has a 500k limiting resistor in series with two diodes from output to input to limit reverse current flow. For dual-supply applications where the regulator load is returned to a negative supply, the OUT and ADJ pins can be pulled below ground (by up to a 20V input-to-output differential) while still allowing the device to start and operate. The LT3009 also includes protection features found standard on linear regulators such as current and thermal limiting.

The Ideal Solution for Remote Monitoring

The LT3009 provides an optimum solution for remote monitoring applications. The duty cycle of many of these applications is very short—they spend most of their time in shutdown, waking briefly to take and communicate measurements, then returning immediately to shutdown. Aside from the typical supply regulation requirements required by sensitive analog circuitry (tight supply regulation, quiet supply, load protection, etc.), the principle supply requirement is low quiescent power consumption. With its 3µA quiescent current coupled with industry leading supply regulation capability and myriad of protection features, the LT3009 fits the bill.

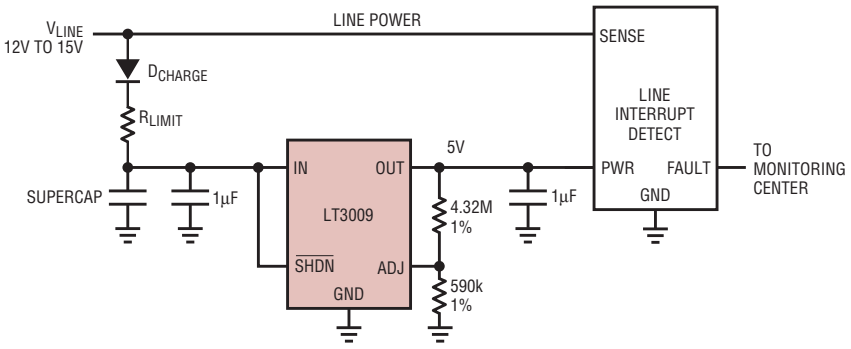

Figure 6. Typical last-gasp circuit

A typical remote monitoring application used frequently in utility meters is a "last-gasp" circuit, shown in Figure 6. In this application, a 12V to 15V supply derived from line power charges a large capacitor (SuperCap) through a diode and a current limiting resistor. This stored voltage on the SuperCap provides input voltage for the LT3009. The LT3009 provides a quiet, well-regulated 5V supply to the analog fault detection circuits as well as a digital communication module used to send distress signals to the remote monitoring center. The fault detection circuitry is typically active for only a few hundred milliseconds every 15-minute detection cycle. In the event of a line failure, the ultralow quiescent current of the LT3009 enables the SuperCap to provide enough power to the fault detection and communications circuitry for several detection cycles.

The 3µA quiescent current of the LT3009 reduces the required size and cost of the SuperCap while simultaneously extending the life of the detection and communications circuits after line failure. Additionally, with its output regulation of ±2% over load line and temperature, the LT3009 can do double duty as a highly accurate voltage reference for the fault detection circuits.

An Excellent Choice for Keep-Alive Power Supplies

Switching power supplies provide robust local low voltage/high current power from high voltage rails, but switching power supplies are overly complex for the low power keep-alive circuits that typically run only a few milliamps of current. There are many such low current applications in industrial, monitoring, security systems, smoke detectors, and other always-on circuits. For many of these applications, the LT3009 provides a relatively simple and inexpensive solution.

A typical keep-alive application is shown in Figure 7. A 12V rail powers a keep-alive circuit for monitoring or other purposes. Low quiescent current is critical here to reduce battery drain. A battery backup keeps the output alive when a fault on the input occurs. Should a fault on the 12V rail occur, the battery backup takes over. The internal protection of the LT3009 limits current flow from the output back to the input, removing the need for protection diodes.

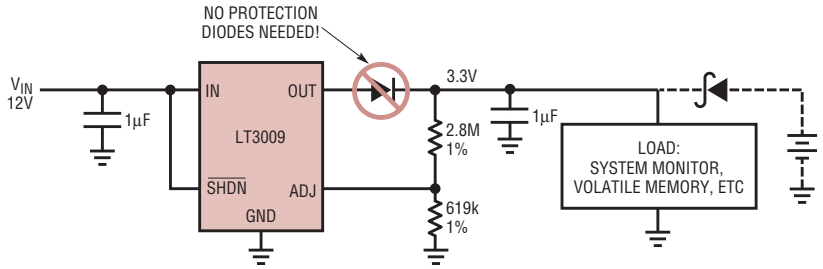

Figure 7. Typical keep-alive power supply

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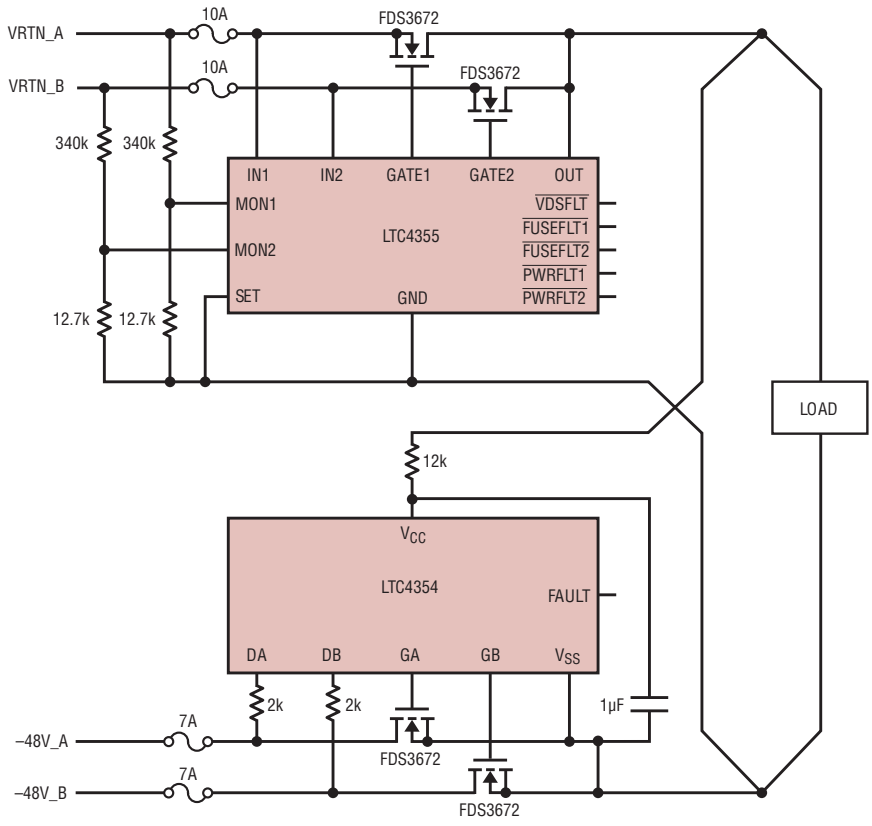

Figure 3. –48V/5.5A positive and negative supply diode-ORing for telecom systems.

Large supply variations and transients are easily accommodated by the wide operating voltage ranges of these two parts, 4.5V to 80V for the LTC4354 and 9V to 80V (100V absolute maximum) for the LTC4355.

This circuit combines all fault indicators to drive one optoisolator. If an input supply falls to less than 36V or the forward voltage drop across one of the positive-side MOSFETs exceeds 0.25V, the LTC4355's $\overline{\text{PWRFLT1}}$ or $\overline{\text{PWRFLT2}}$ pin pulls low to signal the fault. If a positive-side fuse blows open, the LTC4355 indicates a fault by pulling the $\overline{\text{FUSEFLT1}}$ or $\overline{\text{FUSEFLT2}}$ pin low. Finally, if the forward voltage across a low side MOSFET exceeds 0.26V, the LTC4354's FAULT pin drives an NPN that turns off the same optoisolator driven by the LTC4355's pins.

Because the high side fuses have lower current ratings than the return fuses, the high side fuses blow first under most fault conditions. With the return fuses intact, system potentials tend to settle near ground after a fuse blows open.

The $\overline{\text{VDSFLT}}$ pin is not shown in this schematic. Since the $\overline{\text{PWRFLT1}}$ or $\overline{\text{PWRFLT2}}$ pin pulls low when the $\overline{\text{VDSFLT}}$ pin pulls low, $\overline{\text{VDSFLT}}$ is redundant in this application. Furthermore, this schematic is capable of accommodating not just the smaller DFN-14 package, but also the larger SO-16 package. While the SO-16 lacks a $\overline{\text{VDSFLT}}$ pin, it features the wider pin spacing sometimes desirable in higher voltage applications.

–48V/5.5A High side and Low Side Diode-ORs for Telecom

Many –48V telecom systems, including those that conform to the new AdvancedTCA specification, require ORing circuits on both the high and low side of the redundant power feeds. A few simple modifications convert the +48V solution in Figure 2 to the –48V solution in Figure 3. The +48V supply input becomes the return feed, VRTN, and the returns in the +48V system now serve as the –48V input feeds. The 10A and 7A fuses have been swapped, placing the 10A fuse in the high side return path. As a result, most fault conditions cause the high side 7A fuse to blow before the low side 10A fuse. Consequently, system potentials generally settle near VRTN after a fuse blows. The minimal circuit in Figure 3 does not connect the fault pins. If desired, faults can be monitored with a circuit similar to that in Figure 2.

Conclusion

The LTC4355 frees up PCB area by reducing power dissipation and the size of associated heat sinks in applications that require supply ORing. Its wide 9V to 80V supply operating range and 100V absolute maximum rating accommodate a broad range of input supply voltages with ample margin for supply variations and transients. In addition, the ability to provide system health monitoring functions makes it especially well suited to high-availability applications. Those systems that require both high side and low side ORing can combine the LTC4355 with the LTC4354 to form a complete solution.

LT3009, continued from page 9

Conclusion

The LT3009 offers ultralow quiescent current, a shutdown mode, and wide input and output voltage ranges in tiny 2mm × 2mm DFN and SC70 packages without sacrificing performance or reliability. A stable output is available with a wide range of output capacitors, including small ceramics. Internal protection circuitry in the LT3009 eliminates the need for external protections diodes, further saving space and lowering cost. Competing devices can't come close to the performance and advantages that the LT3009 offers in the world of ultralow quiescent current regulators.