Nanopower Buck Converter Runs on 720nA, Easily Fits into Energy Harvesting and Other Low Power Applications

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The LTC3388-1/LTC3388-3 integrated synchronous step-down regulator provides a regulated output while consuming a mere 720nA of quiescent current. It accepts inputs up to 20V and can deliver up to 50mA of load current. Eight pin-selectable output voltages are offered: 1.2V, 1.5V, 1.8V, and 2.5V on the LTC3388-1 and 2.8V, 3.0V, 3.3V, and 5.0V on the LTC3388-3. The extremely low quiescent current prolongs battery life for keep-alive circuits in portable electronics and makes it a good fit for energy harvesting applications.

The LTC3388-1/LTC3388-3 (Figure 1) achieves its low quiescent current by entering a sleep state once the output is in regulation. In the sleep state, load current is provided by the output capacitor while the output voltage is monitored. When the output falls below a fixed hysteresis window, the converter wakes up and refreshes the capacitor.

This hysteretic method of providing a regulated output minimizes losses associated with FET switching and makes it possible to efficiently regulate at very light loads. The total quiescent current at V_{IN} in the sleep state is 720nA when V_{IN} is 4V and increases to only 820nA when V_{IN} is 20V. At light loads, the time the buck is active is miniscule relative to the time it sleeps, so the average quiescent current required to maintain regulation approaches the DC sleep quiescent current.

ENABLE AND STANDBY

Two pins, EN and STBY, control enable and standby functions on the LTC3388-1/LTC3388-3. When EN is low, the buck is turned off and only 520nA of quiescent current appears at V_{IN}. When EN is high, the STBY pin places the LTC3388-1/LTC3388-3 in standby. In this mode the buck is prevented from switching, resulting in a quiet supply. The PGOOD pin, which is high when the output is in regulation, remains active while in standby. PGOOD transitioning low can serve as an indicator that the output has fallen and that the LTC3388-1/LTC3388-3 should leave standby mode to refresh the output.

HIGH EFFICIENCY AT LIGHT LOADS

The extremely low quiescent current of the LTC3388-1/LTC3388-3 allows for high efficiency at loads as low as 10µA. This is especially useful for low power systems that spend a long time idling and only periodically wake up to perform a task. Figure 2 shows typical efficiency of the LTC3388-1 for the 1.8V output, which is suitable for powering low power microprocessors.

SUPPORTS ENERGY HARVESTING APPLICATIONS

The LTC3388-1/LTC3388-3 is especially well suited for energy harvesting applications where only low amounts of energy are available. Figure 3 shows the LTC3588-1 piezoelectric energy harvesting power supply harvesting ambient vibration energy with a piezoelectric transducer and producing a 3.3V output. The LTC3388-3 is powered from this output and is configured to provide a –3.3V rail, producing a low power dual output supply. The LTC3388-3's low quiescent current, combined with the LTC3588-1's

(continued on page 43)

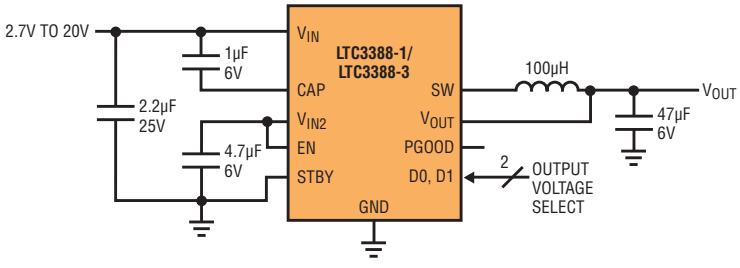

Figure 1: Low quiescent current buck converter

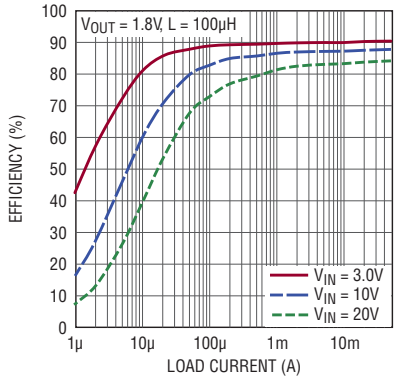

Figure 2: LTC3388-1 Efficiency vs load current for the 1.8V output

The LTC3787 is a high power 2-phase single output synchronous step-up DC/DC controller, which replaces the boost diodes with high efficiency N-channel MOSFETs. This solution eliminates the heat sink normally required in medium to high power boost converters. The LTC3787 can produce a 24V at 10A output from a 12V input at up to 97% efficiency.

bursts, when the circuitry is powered up to take measurements and transmit data.

The LTC3105 offers an auxiliary LDO that delivers up to 6mA of output current to power external microcontrollers and sensors while the main output is charging. Once fully charged, the main output can deliver voltages as high as 5.25V with up to 100mA of output current. It can also regulate V_{OUT} even when V_{IN} is greater than or equal to V_{OUT}, offering further design flexibility. In shutdown, the LTC3105 offers output disconnect, isolating V_{IN} from V_{OUT}, requiring only 10µA of quiescent current.

The combination of the LT3105's 3mm × 3mm DFN package (or MSOP-12) and very small external components offers a very compact solution for energy harvesting applications.

HIGH POWER POLYPHASE SYNCHRONOUS BOOST CONTROLLER ELIMINATES HEAT SINK WITH 97% EFFICIENCY

The LTC3787 is a high power 2-phase single output synchronous step-up DC/DC controller, which replaces the boost diodes with high efficiency N-channel MOSFETs. This solution eliminates the heat sink normally required in medium to high power boost converters. The LTC3787 can produce a 24V at 10A output from a 12V input at up to 97% efficiency. The LTC3787's 135µA standby quiescent current when configured for Burst Mode operation makes it ideal for high power automotive audio amplifiers, as well as industrial and medical applications where a step-up DC/DC converter must deliver high power in a small solution size.

The LTC3787 operates from an input voltage ranging from 4.5V to 38V during start-up, maintains operation down to 2.5V after start-up and can regulate an output voltage as high as 60V. The powerful 1.2Ω onboard N-channel MOSFET gate drivers are capable of slewing large MOSFET gates quickly. The device's current mode architecture, clock output and phase modulation enables easy paralleling of multiple devices for up to 12-phase operation. The LTC3787 has a phase-lockable frequency from 75kHz to 850kHz or a selectable fixed frequency from 50kHz to 900kHz. In applications where the input voltage exceeds the regulated output voltage, the LTC3787 keeps the synchronous MOSFET on continuously so that the output voltage follows the input voltage with minimal power loss. In addition, this device features adjustable cycle-by-cycle current limit and can use a sense resistor or monitor the voltage drop across the inductor (DCR) for current sensing. Furthermore, the LTC3787 has adjustable soft-start, a power good output and maintains ±1% reference voltage accuracy over an operating junction temperature range of –40°C to 125°C. ■

(LTC3388-1/LTC3388-3, continued from page 41)

own low quiescent current results in a complete solution that draws only 1600nA with no load at both outputs.

CONCLUSION

The LTC3388-1/LTC3388-3 monolithic buck converter's extremely low quiescent current makes it ideal for low power applications. A quiescent current of less than a microamp prolongs battery life for keep-alive circuits in portable electronics and enables a new generation of energy harvesting applications. ■

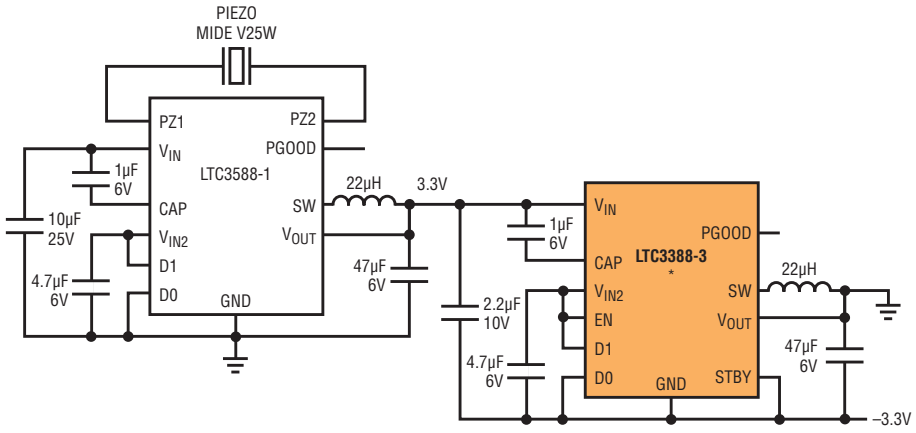

Figure 3: Piezoelectric energy harvester with dual ±3.3V outputs

* EXPOSED PAD MUST BE ELECTRICALLY ISOLATED FROM SYSTEM GROUND AND CONNECTED TO THE –3.3V RAIL.