Monolithic Buck Regulator Operates Down to 1.6V Input

by Gregg Castellucci

Introduction

The LTC3549 is a monolithic synchronous step-down regulator designed specifically to save space, improve battery life and simplify the design of 2-cell alkaline, NiCd and NiMh powered applications. It is similar to the LTC3409, but it is smaller, without synchronization capability and has a 250mA maximum output current. It operates from a wide input voltage range, 1.6V to 5.5V, without the complexity and accompanying loss of efficiency of competing devices that require boost circuitry for generating internal voltages greater than V_{IN}. Space-saving features include a 2mm × 3mm DFN package and a fixed 2.25MHz operating frequency, which allows the use of small surface mount capacitors and inductors. To extend battery life, two operating modes exist to improve light load efficiency, including Burst Mode operation, which consumes only 50µA of supply current at no load, and pulse skipping mode, which offers low ripple currents for noise-sensitive applications. The device consumes less than 1µA quiescent current in shutdown. The LTC3549 also provides soft start which limits inrush current at start-up.

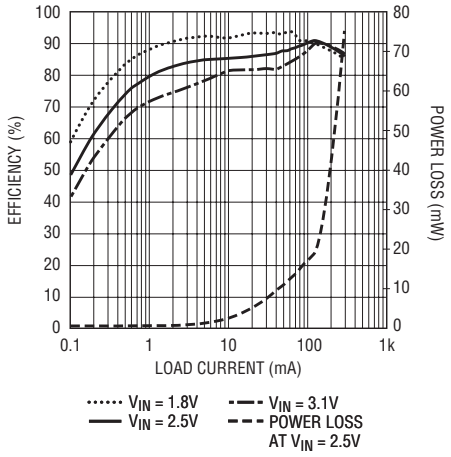

Figure 1. Efficiency vs load current for the LTC3549 in Burst Mode operation

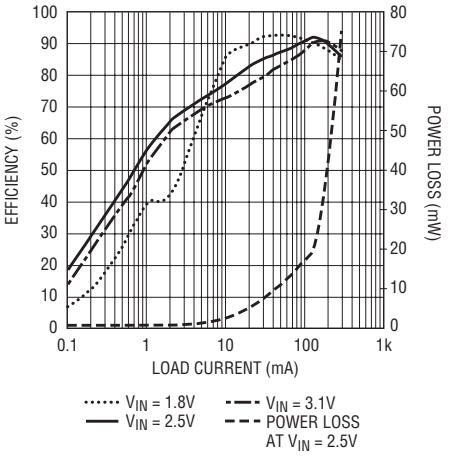

Figure 2. Efficiency vs load current for the LTC3549 in pulse skip mode

Features

Soft-Start

The LTC3549's soft-start function reduces inrush currents at start-up by linearly ramping up the output voltage in about 1ms. For instance, the average output current required during soft-start to charge a 10µF output capacitor to 1.8V in 1ms is 18mA. The total output current is the sum of the output capacitor charging current and the current delivered to the load as V_{OUT} ramps up. Without soft-start, the average current during startup could be as high as I_{limit}, which is around 500mA.

Efficiency-Improving Operating Modes

The Mode pin has two states corresponding to two operating modes that improve efficiency at light loads: tied high for pulse skip mode, and tied low for Burst Mode operation. The choice between the two is a matter of weighing low output voltage ripple against light load efficiency. In pulse skipping mode, constant frequency operation is maintained at lower load currents to decrease the output voltage ripple, and therefore reduce the chance of interference with audio circuitry. If the load current is low enough, cycle skipping eventually occurs to maintain regulation. Pulse skipping mode is not quite as efficient as Burst Mode operation at light loads, but comparable when the output load exceeds 50mA (see Figures 1 and 2).

In Burst Mode operation, the internal power MOSFETs operate intermittently based on load demand. Short burst cycles of normal switching are followed by longer idle periods where the load current is supplied by the output capacitor. During the idle period, the power MOSFETs and any unneeded circuitry are turned off, reducing the quiescent current to 50µA. With no load, the output capacitor discharges slowly through the feedback resistors resulting in very low frequency burst cycles that add only a few microamps to the supply current. Burst Mode operation offers higher efficiency at low output currents than pulse skip mode, but when activated Burst Mode operation produces

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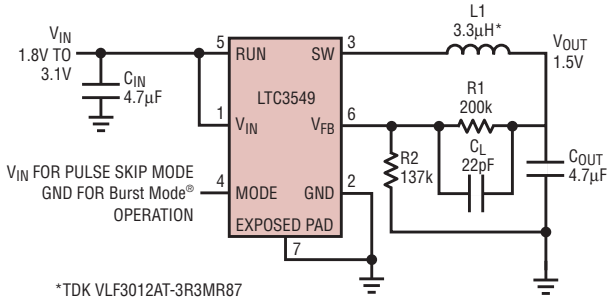

Figure 3. A 1.5V/250mA step down regulator

pendently of the output common mode voltage. These input characteristics often eliminate the need for an input transformer and/or AC-coupling capacitors. This allows DC-coupled operation for applications that have frequency ranges including DC. At the outputs, the common mode voltage is set via the V_{OCM} pin, allowing the LT6402 to drive ADCs directly. V_{OCM} is a high impedance input, capable of setting the output common mode voltage anywhere in a range from 1.1V to 3.6V.

The topology of the LT6402 is closed-loop and incorporates three internal amplifiers. Two of the amplifiers are identical and drive the differential outputs. The third amplifier sets the output common mode voltage. Gain and input impedance are determined by the resistors in the internal feedback network. The low output impedance is based on the inherent output impedance of each feedback amplifier.

The LT6402 includes built-in single-pole output filtering. The user has the choice of using the unfiltered outputs, the filtered outputs (75MHz –3dB lowpass), or modifying the filtered outputs to alter the frequency response with additional components. Numerous lowpass and bandpass filter configurations are easily implemented with just one or two additional components.

The LT6402 operates on a single 5V supply and consumes only 30mA. When 2.0V or greater is applied to the ENABLE pin, the supply current reduces to 250µA. It comes in a compact 16-lead 3mm × 3mm QFN package. The DC954 demo board has been created for stand-alone evaluation of the LT6402 amplifier. Contact LTC applications for demo boards that combine the LT6402 with one of LTC's high-performance ADCs.

1.6V, 1µA Precision Rail-to-Rail Input andOutput Op Amps

The LT6003/LT6004/LT6005 are single/dual/quad op amps designed to maximize battery life and performance for portable applications. These amplifiers operate on supplies as low as 1.6V and are fully specified and guaranteed over temperature on 1.8V, 5V and ±8V

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higher output ripple than pulse skip mode. Burst Mode ripple can be 10 to 20 times larger than pulse skip ripple for a given set of conditions.

Output Voltage Programmability

The LTC3549 output voltage is externally programmed via a simple resistive divider to any value above the 0.611V internal reference voltage, and is capable of 100% duty cycle. In dropout, the output voltage is determined by the input voltage minus the voltage drop across the internal P-channel MOSFET and the inductor resistance.

Fault Protection

The LTC3549 protects against output overvoltage, output short circuit and excessive power dissipation conditions. When an overvoltage condition at the output (>10% above nominal) is sensed, the top MOSFET is turned off until the fault is removed.

If the output is shorted to ground, reverse current in the synchronous switch is monitored to prevent inductor-current runaway. If the synchronous switch current is too high, the top MOSFET remains off until the synchronous switch current falls to a normal level.

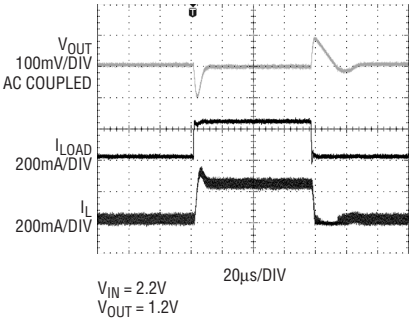

Figure 4. The LTC3549's transient response to a 20mA-to-250mA load step, pulse skip mode.

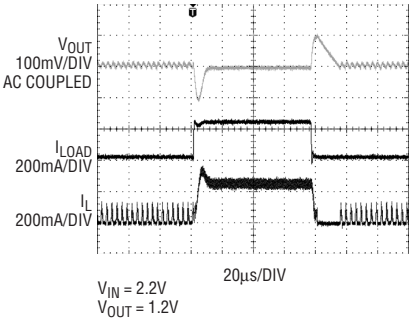

Figure 5. The LTC3549's transient response to a 20mA-to-250mA load step, Burst Mode operation.

When the junction temperature reaches approximately 160°C, the thermal protection circuit turns off the power MOSFETs allowing the part to cool. Normal operation resumes when the die temperature drops to 150°C.

Applications

1.5V/600mA Step-Down Regulator Using Ceramic Capacitors

Figure 3 shows an application of the LTC3549 using ceramic capacitors. This particular design supplies up to a 250mA load at 1.5V with an input supply between 1.8V and 3.1V. Ceramic capacitors have the advantages of small size and low equivalent series resistance (ESR), allowing very low ripple voltages at both the input and output. Because the LTC3549's control loop does not depend on the output capacitor's ESR for stable operation, ceramic capacitors can be used to achieve very low output ripple and small circuit size. Figures 4 and 5 show the transient response to a 20mA to 250mA load step for the LTC3549 in pulse skip mode, and Burst Mode operation.

Conclusion

The LTC3549's wide 1.6V to 5.5V V_{IN} range allows it to operate from various power sources that range from a 5V AC wall adapter to two series alkaline batteries. Features such as soft-start, Burst Mode operation/pulse skip mode selection and overvoltage protection add application flexibility to this 2mm × 3mm device.