1.5MHz Switching Regulator in TSOT-23 Package Saves Board Space and Draws Only 20µA of Supply Current

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Introduction

The relentless drive to miniaturize portable electronics has driven a correspondingly strong demand for smaller components, including switching regulators. One tactic is to increase the switching frequency of the regulator, which allows for smaller inductors and capacitors in the circuit. Higher switching frequencies, though, make for a less efficient circuit. The new LTC3405 can maintain very high efficiencies even while running at a high frequency. While running at a very fast 1.5MHz, the LTC3405 consumes only 20µA of supply current (using Burst Mode® operation) at no load. The low supply current makes for outstanding efficiencies for load currents as low as 100µA while the high switching frequency allows the use of tiny inductors and tiny ceramic capacitors. Housed in a low profile TSOT-23 (1mm Thin SOT) package, the LTC3405 offers a very compact solution for portable electronics.

LTC3405 Features

The LTC3405 is a high efficiency monolithic synchronous buck regulator, which utilizes a constant frequency, current mode architecture. The on-chip power MOSFETs provide up to 300mA of continuous output current. The internal synchronous switch increases efficiency and eliminates the need for an external Schottky diode. Internal loop compensation eliminates additional external components that would require more PC board space.

The supply voltage ranges from 2.5V to 5.5V making the LTC3405 ideal for applications using a single Li-Ion battery or 3-cell NiCd and NiMH battery packs. The 100% duty cycle capability for low dropout allows maximum energy to be extracted from the battery. In dropout, the output voltage is fixed to the input voltage minus the voltage drop across the P-channel MOSFET and the voltage drop due to inductor resistance. The output voltage can be externally programmed with a resistive divider to any value above the 0.8V internal reference voltage. Fixed 1.5V and 1.8V output versions are also available. With the power saving Burst Mode operation enabled, the supply current is 20µA and reduces to less than 1µA in shutdown mode.

The LTC3405 includes protection against output overvoltage, output short-circuit and excessive power dissipation conditions. In the event of a forced overvoltage condition at the output (>6.25% above nominal), the top MOSFET is turned off until the fault is removed. If the output is shorted to ground, the frequency of the oscillator slows to 210kHz to prevent inductor-current runaway. The frequency returns to 1.5MHz when V_{FB} rises to 0.8V. Thermal shutdown is included, which limits junction temperature to 150°C.

Burst Mode Operation

Burst Mode operation is enabled by strapping the MODE pin to GND. With Burst Mode operation enabled, 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 19µA. At no load, the output capacitor discharges slowly through the feedback resistors resulting in very low frequency burst cycles that adds only a few microamps to the supply current.

To disable Burst Mode operation and enable PWM pulse skipping mode,

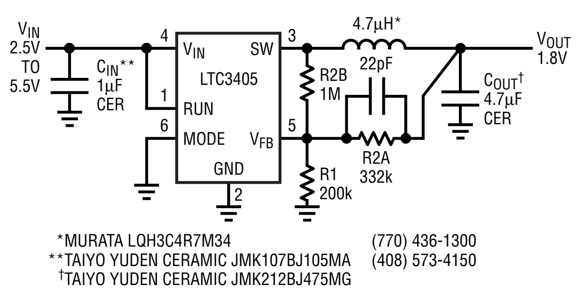

Figure 1. 1.8V/300mA step-down regulator using all ceramic capacitors

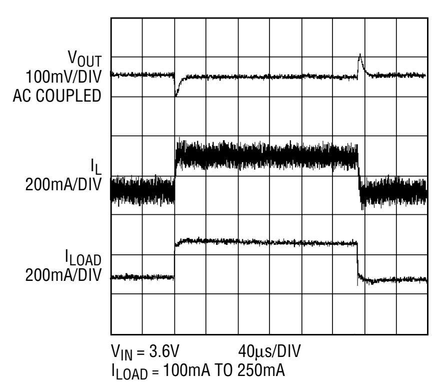

Figure 2. Transient response to a 100mA to 250mA load step

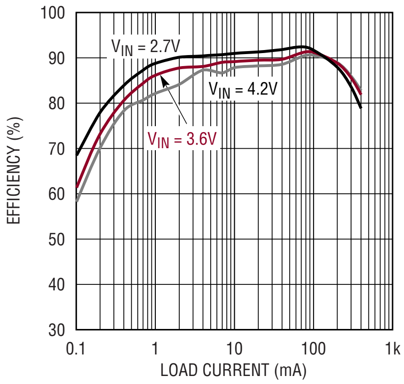

Figure 3. Efficiency vs load current for Figure 1's circuit (Burst Mode operation enabled)

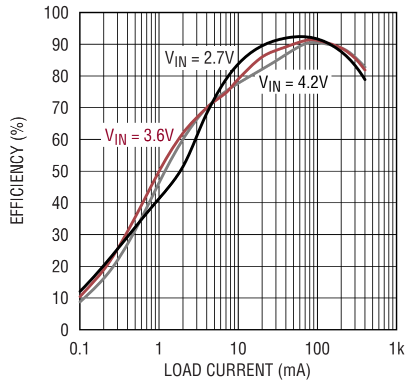

Figure 4. Efficiency vs load current for Figure 1's circuit (Burst Mode operation disabled)

connect the MODE pin to V_{IN} or drive it to a logic high (V_{MODE} > 2V). In this mode, constant-frequency operation is maintained at lower load currents resulting in lower output ripple. If the load current is low enough, cycle skipping will eventually occur to maintain regulation. In this mode, the efficiency will be lower at light loads, but becomes comparable to Burst Mode operation when the output load exceeds 25mA. Pulse Skipping Mode offers the advantage of reduced output ripple voltage and it maintains an easily filterable constant operating frequency spectrum.

1.8V/300mA Step-Down Regulator Using All Ceramic Capacitors

A typical application of the LTC3405 using all ceramic capacitors is shown in Figure 1. This design supplies a 300mA load at 1.8V with an input supply between 2.5V and 5.5V. Ceramic capacitors are used for their small size and low equivalent series resistance (ESR) producing very low ripple voltages at both the input and output. For a given package size or capacitance value, ceramic capacitors have lower ESR than other bulk, low ESR capacitor types (including tantalum, aluminum and organic electrolytics). However, when a ceramic capacitor is used at the output, its low ESR may not provide sufficient phase lag cancellation to stabilize the loop. The circuit shown in Figure 1 uses a large valued resistor, R2B, to inject a feedforward signal at V_{FB} that mimics the ripple voltage of a high ESR output capacitor. This technique provides stable operation similar to that obtained from a high ESR tantalum type capacitor. Figure 2 shows the transient response to a 100mA to 250mA load step. Note that R2B forms a parallel connection with R2A, so R2B must be accounted for when calculating the resistive network to set the output voltage, as follows:

$$R2 = R2A/R2B = R2A \bullet R2B/(R2A+R2B)$$
$$V_{OUT} = 0.8V(1+R2/R1)$$

Efficiency Considerations

The efficiency curves for the 1.8V/300mA regulator at various supply voltages are shown in Figure 3. Note the flatness of the curves over the upper three decades of load current, and that the efficiency remains high down to extremely light loads.

Efficiency at light loads requires low quiescent current. The curves are flat because all significant sources of loss except for the 20µA standby current—I^2R losses in the switch, internal gate charge losses (to turn on the switch) and burst cycle DC supply current losses—are identical during each burst cycle. The only variable is the rate at which the burst cycles occur. Since burst frequency is proportional to load, the loss as a percentage of load remains relatively constant.

Efficiency drops off as the load decreases below approximately 1mA, because the non-load-dependent 20µA standby current loss then constitutes a more significant percentage of the output power. This loss is proportional to V_{IN}, thus its effect is more pronounced at higher input voltages. Figure 4 shows the effect on efficiency when Burst Mode is disabled.

Conclusion

The LTC3405, housed in a tiny TSOT-23 package, is designed to meet the tightest space requirements without compromising the efficiency at very low load currents. Its high switching frequency and low quiescent current allow the use of tiny components while extending battery life in today's portable electronics.