Using the TPS61042 white-light LED driver as a boost converter

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Applications, Portable Power

Introduction

Although designed to be a white-light LED driver, the TPS61042 can be configured as a discontinuous, hysteretically controlled boost converter with a 500-mA peak switch current. For example, Figure 1 shows the TPS61042 configured to provide V_{OUT} = 16.2 V and I_{OUT} = 30 mA, from V_{IN} down to 2.5 V. The LED driver circuitry is either left unconnected (pins 1 and 2) or grounded (pin 7); and pin 5, CTRL, is used as enable.

Operation

As a boost converter, the TPS61042 operates with an input voltage range of 1.8 to 6 V and can generate output voltages of up to 28 V. The device operates in a pulse-frequency modulation (PFM) scheme with constant peak-current control. This control scheme maintains high efficiency over the entire load-current range. With a switching frequency of up to 1 MHz, the device enables the use of very small external components.

The converter monitors the output voltage. When the feedback voltage falls below the reference voltage (typically 0.25 V), the internal switch turns on and the current ramps up. The switch turns off when the inductor current reaches the internally set peak current of 500 mA (typ). Refer to the following paragraph, entitled "Peak-current control," for more information. The second criterion that turns off the switch is the maximum on-time of 6 µs (typ). This limits the maximum on-time of the converter in extreme conditions. As the switch turns off, the external Schottky diode is forward-biased, delivering the current to the output. The switch remains off for a minimum of 400 ns (typ), or until the feedback voltage drops below the reference voltage. Using this peak-current control scheme, the converter operates in discontinuous conduction mode (DCM) where the switching frequency depends on the output current. This results in very high efficiency over the entire load-current range. Inherently stable, this regulation scheme allows a wide selection range for the inductor and output capacitor.

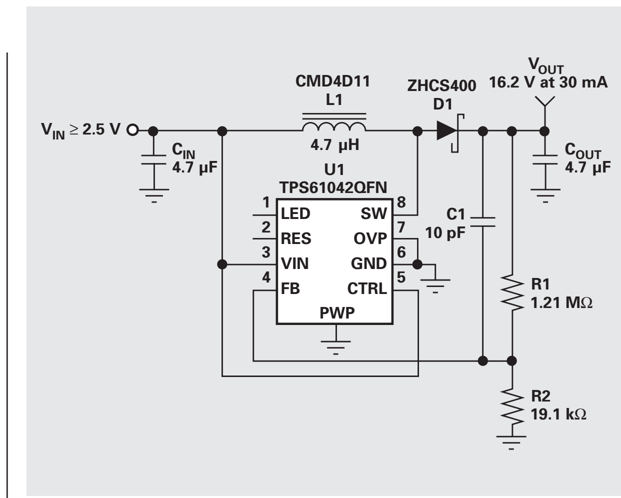
Peak-current control

The internal switch turns on until the inductor current reaches the typical dc current limit (I_{LIM}) of 500 mA. Due to the 100-ns (typ) internal propagation delay, the actual current exceeds the dc current-limit threshold by a small amount. The typical peak-current limit can be calculated by

$$I_P(\text{typ}) = I_{LIM} + \frac{V_{IN}}{L} \times 100\text{ ns} \quad \text{and}$$

$$I_P(\text{typ}) = 500\text{ mA} + \frac{V_{IN}}{L} \times 100\text{ ns.}$$

Figure 1. TPS61042 in a boost configuration



Soft start

All inductive step-up converters exhibit high in-rush current during startup if no special precaution is taken. This can cause voltage drops at the input rail during startup and may result in unwanted or early system shutdown. The TPS61042 limits this in-rush current by increasing the current limit in two steps, starting from $I_{LIM}/4$ for 256 cycles, then up to $I_{LIM}/2$ for the next 256 cycles, and ending with the full current limit.

Inductor selection, maximum load current

Since the PFM peak-current control scheme is inherently stable, the inductor value does not affect regulator stability. The selection of the inductor, together with the nominal load current and the application's input and output voltage, determines the converter's switching frequency. Depending on the application, inductor values between 2.2 to 47 µH are recommended. The maximum inductor value, L_{MAX}, is determined by the maximum on-time of the switch, 6 µs (typ). The peak-current limit must be reached within this 6-µs period for proper operation. L_{MAX} is calculated as

$$L_{MAX} = \frac{V_{IN}(\text{min}) \times 6\,\mu\text{s}}{I_P}.$$

DEVICE	CAPACITOR	VOLTAGE RATING (V)	COMPONENT SUPPLIER	COMMENTS
TPS61042	4.7 µF/X5R/0805	6.3	Tayo Yuden JMK212BY475MG	C_{IN}/C_{OUT}
	10 µF/X5R/0805	6.3	Tayo Yuden JMK212BJ106MG	C_{IN}/C_{OUT}
	1.0 µF/X7R/1206	25	Tayo Yuden TMK316BJ105KL	C_{OUT}
	1.0 µF/X5R/1206	35	Tayo Yuden GMK316BJ105KL	C_{OUT}
	4.7 µF/X5R/1210	25	Tayo Yuden TMK325BJ475MG	C_{OUT}

The minimum inductor value, L_{MIN}, is a function of the output voltage, load current, and switching frequency and is calculated as

$$L_{MIN} = \frac{2 \times I_{LOAD} \times [V_{OUT} - V_{IN}(min) + V_D]}{I_P^2 \times f_{SMAX}},$$

where I_P is the peak current as previously described under "Peak-current control," I_{LOAD} is the maximum load current, V_D is the maximum rectifier diode forward voltage (0.3 V typ), and f_{SMAX} is the maximum switching frequency (1 MHz).

A smaller inductor value gives a higher converter switching frequency but lowers the efficiency.

The best way to calculate the maximum available load current under certain operating conditions is to estimate the expected converter efficiency at the maximum load current. The maximum load current can be estimated by

$$L_{LOAD}(max) = \eta \frac{V_{IN}(min) \times I_P}{2 \times V_{OUT}},$$

where η is the expected converter efficiency (typically 85%).

Output capacitor selection

For the best output-voltage filtering, a low-ESR output capacitor is recommended. Ceramic capacitors have a low ESR value; but tantalum capacitors can also be used, depending on the application.

Assuming that the converter does not show double pulses or pulse bursts on the switch node (SW), the output voltage ripple can be calculated as

$$\Delta V_{OUT} = \frac{I_{OUT}}{C_{OUT}} \times \left(\frac{1}{f_S \times I_{OUT}} - \frac{I_P \times L}{V_{OUT} + V_D - V_{IN}} \right) + I_P \times ESR,$$

where I_P is the peak current as previously described under "Peak-current control," L is the selected inductor value, I_{OUT} is the nominal load current, f_S (I_{OUT}) is the switching frequency at the nominal load current as previously calculated, V_D is the rectifier diode forward voltage (0.3 V typ), C_{OUT} is the selected output capacitor, and ESR is the output capacitor ESR value.

Refer to Table 1 for recommended output capacitors.

Input capacitor selection

For good input-voltage filtering, low-ESR ceramic capacitors are recommended. A 4.7-µF ceramic input capacitor is sufficient for most applications. Increasing this value provides better input-voltage filtering. Refer to Table 1 for recommended input capacitors.

Efficiency

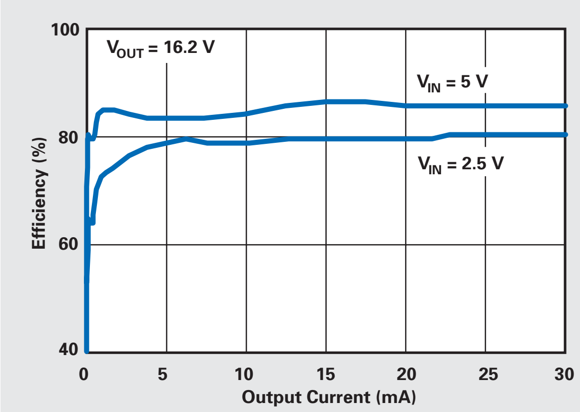
As shown in Figure 2, the TPS61042's efficiency ranges from about 70% to 86% in a boost configuration.

The inductor and diode in Figure 1 were selected to minimize the overall area. A larger inductor and/or diode can improve efficiency.

Related Web sites

analog.ti.com
www.ti.com/sc/device/TPS61042

Figure 2. TPS61042 boost-converter efficiency



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