# The TPS61042 as a Standard Boost Converter

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## ABSTRACT

Although designed to be a white light LED driver, the TPS61042 can be configured as a hysteretically controlled boost converter operating in discontinuous mode.

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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. As an example, Figure 1 below shows the TPS61042 configured to provide:

$$V_O = V_{ref} = \left(\frac{R1}{R2} + 1\right) = 0.25\text{ V}\left(\frac{1.21\text{M}}{19.1\text{k}} + 1\right) = 16.2\text{ V}$$

and $I_O$ = 30 mA from $V_I$ 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.

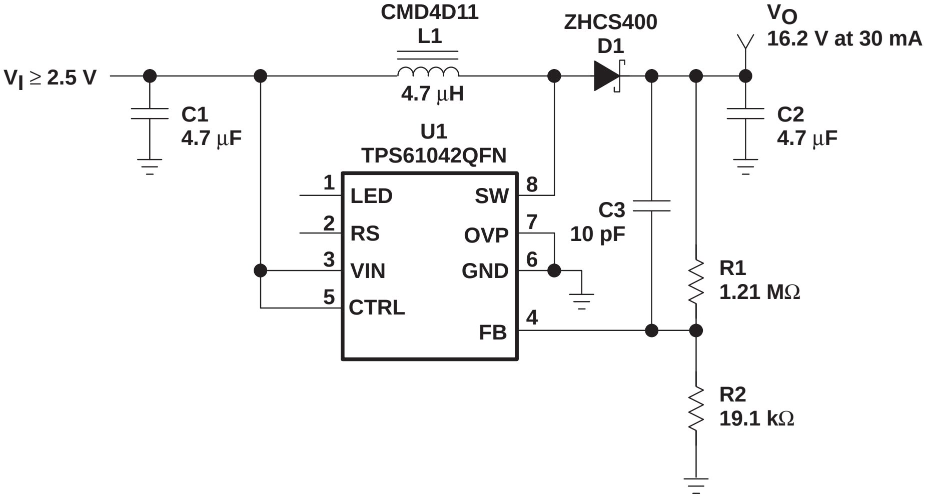


Figure 1. TPS61042 in a Boost Configuration

## Operation

As a boost converter, the TPS61042 operates with an input voltage range of 1.8 V to 6 V and can generate output voltages 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, and with a switching frequency up to 1 MHz, the device enables the use of very small external components.

The converter monitors the output voltage, and as soon as the feedback voltage falls below the reference voltage of typically 0.25 V, the internal switch turns on and the current ramps up. The switch turns off as soon as the inductor current reaches the internally set peak current of typically 500 mA. Refer to the section *peak current control* for more information. The second criteria that turns off the switch is the maximum on-time of 6 µs (typical). This is just to limit the maximum on-time of the converter to cover for extreme conditions. As the switch is turned off the external Schottky diode is forward biased delivering the current to the output. The switch remains off for a minimum of 400 ns (typical), or until the feedback voltage drops below the reference voltage again. Using this PFM peak current control scheme the converter operates in discontinuous conduction mode (DCM) where the switching frequency depends on the output current, which results in very high efficiency over the entire load current range. This regulation scheme is inherently stable, allowing a wide selection range for the inductor and output capacitor.

## Peak-Current Control

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

$$I_P = I_{LIM} + \frac{V_I}{L} \times 100\text{ ns}$$

$$I_P = 500\text{ mA} + \frac{V_I}{L} \times 100\text{ ns}$$

$I_P$ needs to be considered when selecting an inductor with an appropriate current rating.

## Softstart

All inductive step-up converters exhibit high inrush current during start-up if no special precaution is made. This can cause voltage drops at the input rail during start-up and may result in an unwanted or early system shutdown.

The TPS61042 limits this inrush current by increasing the current limit in two steps starting from $\frac{I_{LIM}}{4}$ for 256 cycles to $\frac{I_{LIM}}{2}$ for the next 256 cycles, and then full current limit.

## Inductor Selection, Maximum Load Current

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

$$L_{max} = \frac{V_I \times 6\ \mu s}{I_P}$$

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

$$L_{min} = \frac{2 \times I_{Omax} \times (V_O - V_{Imin} + V_d)}{I_P^2 \times f_{smax}}$$

where:

$I_P$ = Peak current as described in the previous *peak current control* section

$I_{Omax}$ = Maximum load current

$V_d$ = Maximum rectifier diode forward voltage (typically 0.3 V)

$f_{smax}$ = 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 then be estimated as follows:

$$I_{Omax} = \eta \frac{V_I \times I_P}{2 \times V_O}$$

where:

$\eta$ = Expected converter efficiency. Typically 85%

## Output Capacitor Selection

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

The output voltage ripple can be calculated as:

$$\Delta V_O = \frac{I_{Onom}}{C_O} \times \left(\frac{1}{f_S(I_{Onom})} - \frac{I_P \times L}{V_O + V_d - V_I}\right) + I_P \times ESR$$

where:

$I_P$ = Peak current as described in the previous *peak current control* section

L = Selected inductor value

$I_{Onom}$ = Nominal load current

$f_S(I_{Onom})$ = Switching frequency at the nominal load current as computed below

$$f_S(I_{Onom}) = \frac{2 \times I_{Onom} \times ((V_O - V_I) + V_d)}{{I_P}^2 \times L}$$

$V_d$ = Rectifier diode forward voltage (typically 0.3 V)

$C_O$ = Selected output capacitor

ESR = Output capacitor ESR value

Refer to Table 1−1 for choosing the output capacitor.

**Table 1−1. Recommended Input and Output Capacitors**

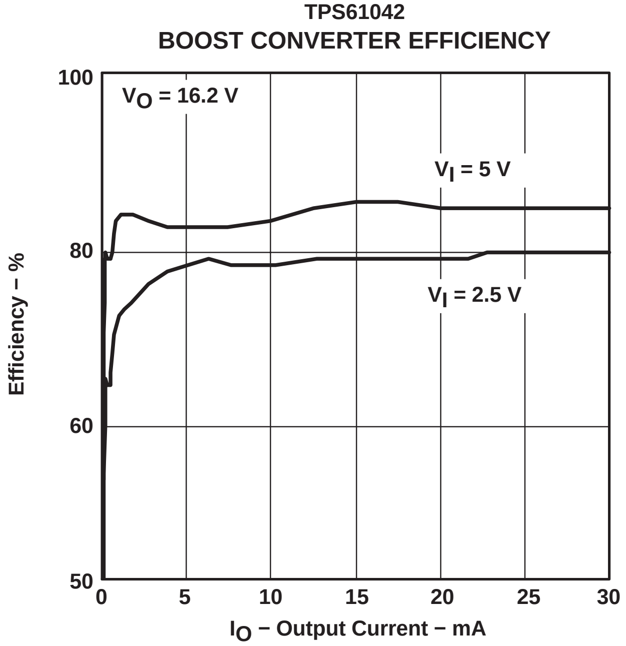
| DEVICE | CAPACITOR | VOLTAGE RATING | COMPONENT SUPPLIER | COMMENTS |
|---|---|---|---|---|
| TPS61042 | 4.7 µF/X5R/0805 | 6.3 V | Tayo Yuden JMK212BY475MG | $C_I/C_O$ |
| | 10 µF/X5R/0805 | 6.3 V | Tayo Yuden JMK212BJ106MG | $C_I/C_O$ |
| | 1.0 µF/X7R/1206 | 25 V | Tayo Yuden TMK316BJ105KL | $C_O$ |
| | 1.0 µF/X5R/1206 | 35 V | Tayo Yuden GMK316BJ105KL | $C_O$ |
| | 4.7 µF/X5R/1210 | 25 V | Tayo Yuden TMK325BJ475MG | $C_O$ |

## 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 of the applications. For better input voltage filtering this value can be increased. Refer to Table 1−1 for input capacitor recommendations.

## Efficiency

As shown in the typical efficiency curves below, in a boost configuration, the TPS61042 efficiency ranges from mid 70% to 86%.



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

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