LED Driver PR4404

Low Voltage Boost Driver PR4404
for 0.5 W / 1 W Power LEDs

The PR4404 is a step-up converter for white LEDs, operating with single battery cell supply (1.2 /1 .5 V) at up to 150 mA LED current or dual cell supply (2.4 / 3.0 V) at up to 300 mA LED current.
A minimum part count allows compact and cost-efficient solutions.
The converter can be switched on and off with a logic signal, which is useful e.g. for PWM control, timer circuits etc.

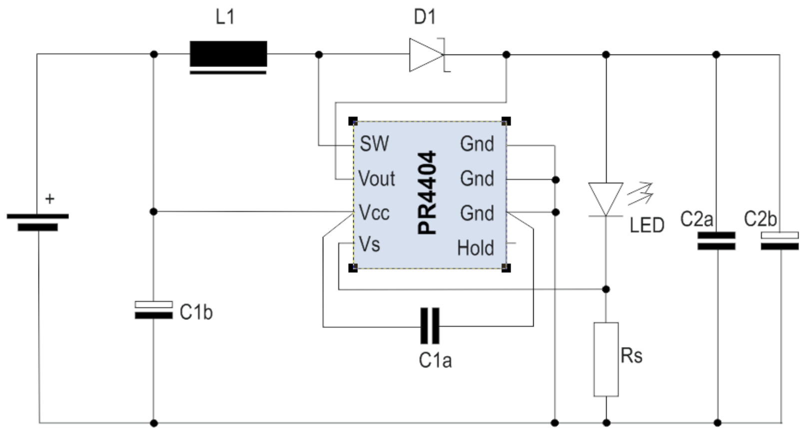
FEATURES

- minimum startup voltage 1.0 V
- supply by one or two battery cells
- low number of external components
- battery deep discharge protection

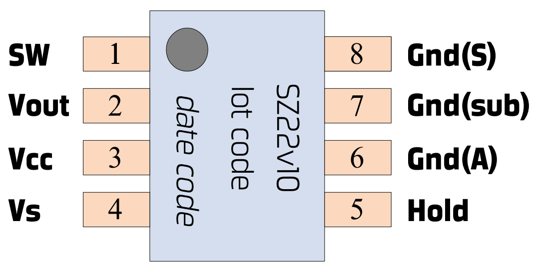
APPLICATIONS

- LED torches
- LCD panel backlighting
- home lighting
- toys

TYPICAL APPLICATION CIRCUIT



PIN DESCRIPTION



* Pins 6, 7, 8 must all be connected.

Pin No	Pin Name	Pin Function Description
1	SW	driver output
2	Vout	output voltage, rectified
3	Vcc	battery supply input
4	Vs	LED cathode / current sense resistor
5	Hold	shutdown
6	Gnd (A)	ground (analog)*
7	Gnd (sub)	ground (substrate)*
8	Gnd (S)	ground (power)*

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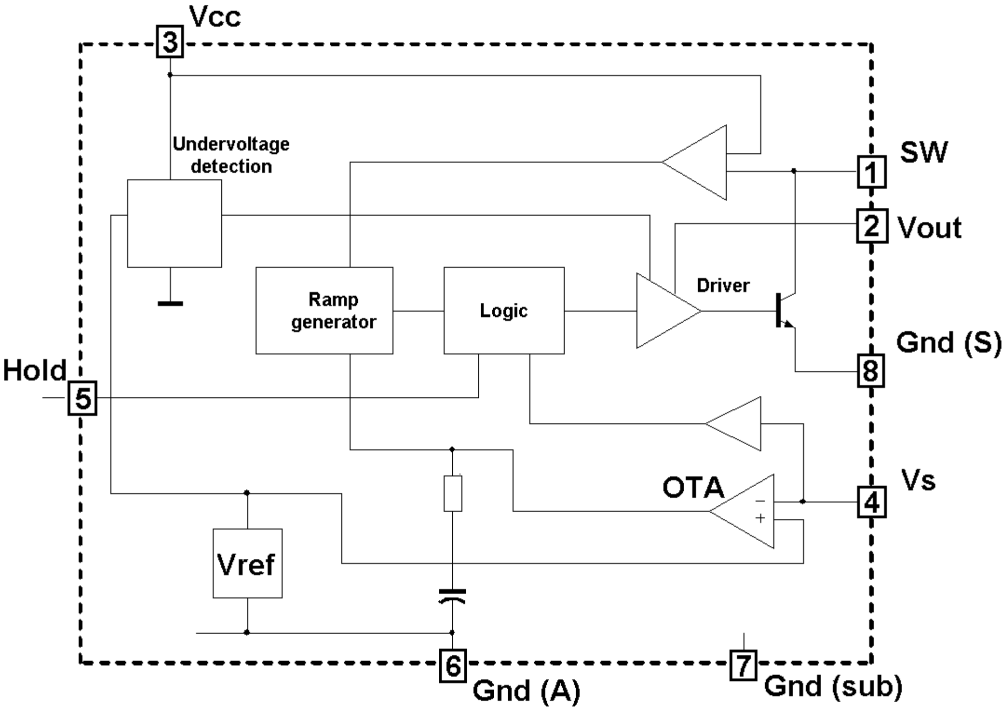
Properties

BLOCK DIAGRAM



ELECTRICAL CHARACTERISTICS

Ta = 25°C, unless otherwise noted.

Symbol	Parameter	Conditions	Min	Typ	Max	Units
V_{cc}	Supply Voltage: min. operating min. startup max. operating		0.89	 1.00	 1.05 5.0*	[V] [V] [V]
V_{sat}	SW output transistor saturation	1.0 A			0.4	[V]
f_{sw}	Switching Frequency		300		700	[kHz]
V_{FB}	Feedback voltage threshold at Vs			200		[mV]
	Quiescent supply current	Hold = LOW Vcc > 850 mV		 2.0	 3.0	 [mA]
Icc	Supply current	Hold = open Vcc > 850 mV		 2.0	 3.0	 [mA]
$V_{SW\ Clamp}$	SW output clamping voltage		14			[V]
Θ_{JA}	Thermal resistance junction - ambient	no air convection		160		[K/W]

* but Vcc must be less than the Forward Voltage of the LED

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Characteristic Performance Curves

PROPERTIES OF UTILIZED LEDs

This datasheet presents characteristics for different typical applications:

A   Supply voltage 1...2 V
    Target current **100 mA** - one LED

B   Supply voltage 1...2 V
    Target current **150 mA** - one LED

C   Supply voltage **1.5...3 V**
    Target current **300 mA** - one LED

D   Supply voltage 2...5 V
    Target current 200 mA - **two LEDs** in series

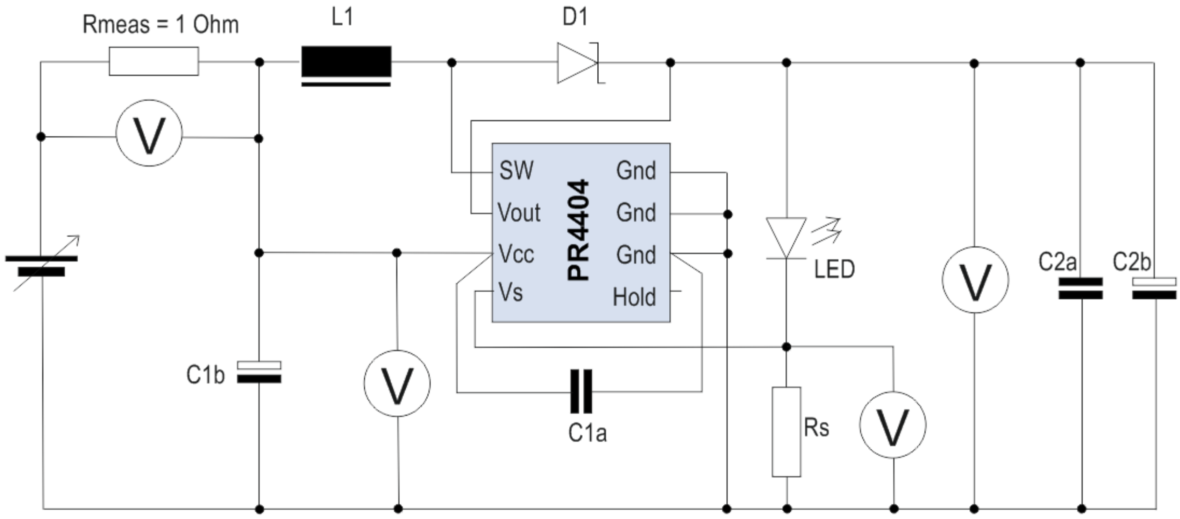
A and B are typical single battery-cell applications, C for two, and D for three cells. The behaviour at many other operating conditions can be estimated by interpolation or extrapolation.

Note that in the following diagrams the peak current through the output switch exceeds the maximum rating. Also the power dissipation can cause a junction temperature higher than the maximum rating under some operating conditions. These data should give an impression of the performance over the whole set of parameters, but the fact that they are shown here should not be regarded as an approval for operation under these conditions.

ABSOLUTE MAXIMUM RATINGS

Parameter	Min	Max	Units
V_{CC} (no damage)	-0.3	8	[V]
SW output peak current		1.5	[A]
Operating junction temperature	-20	125	[°C]
Storage Temperature Range	-55	150	[°C]
Electrostatic Discharge (ESD) Protection	2		[kV]

TEST CIRCUIT



C1a: 1 µF ceramic
C1b: 100 µF tantalum

L1: Würth WE-PD XS series; inductance see diagrams

D1: MBRS140
Rs: see diagrams

C2a: 1 µF ceramic
C2b: 100 µF tantalum

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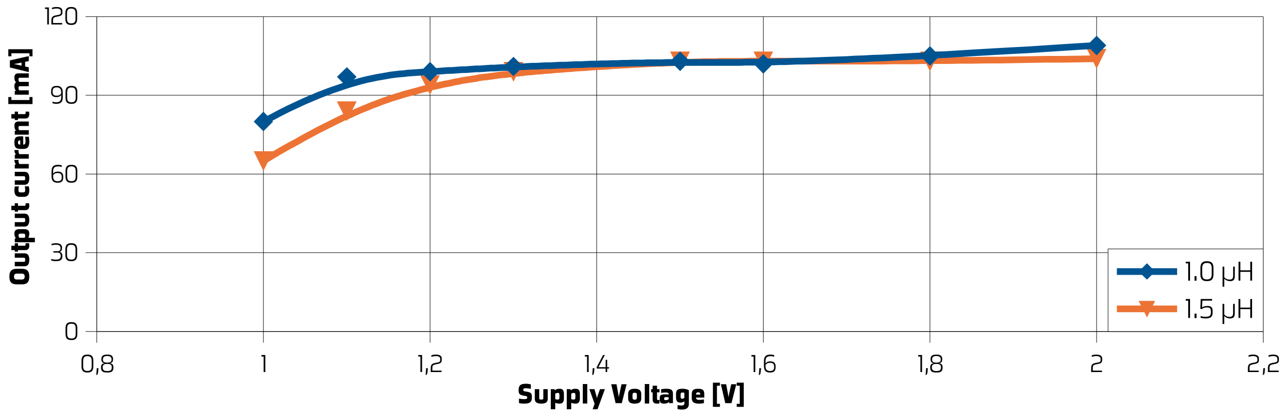
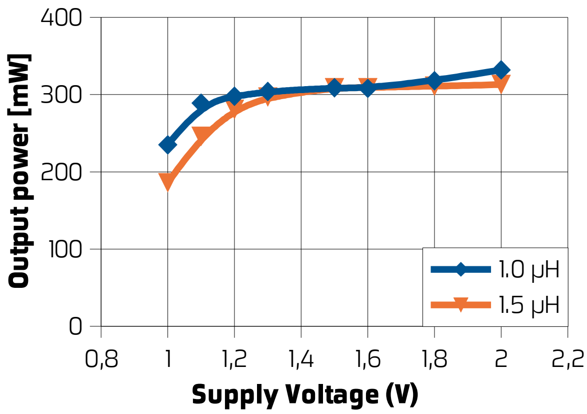
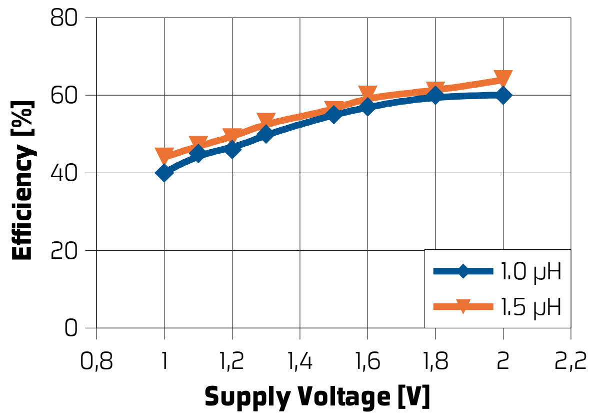
Characteristic Performance Curves

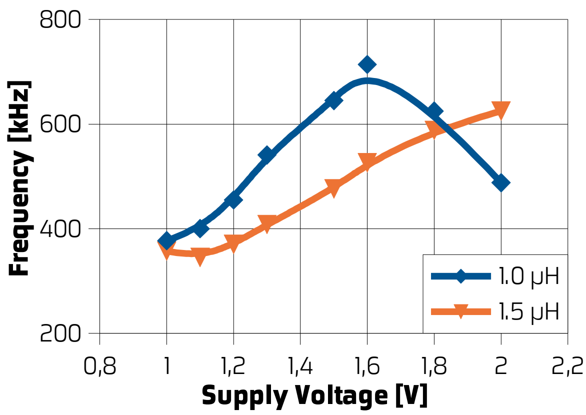
A SUPPLY VOLTAGE 1...3 V - TARGET CURRENT 100 mA - ONE LED

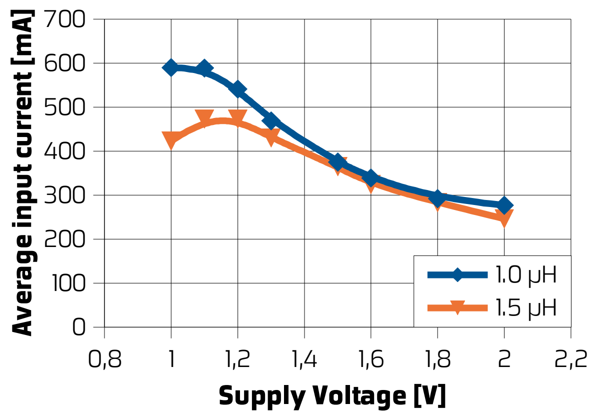
Rs = 2 Ω, L1 = 1.0 µH / 1.5 µH with I_{sat}=2.5 A











For best operation at supply voltages between 1.0 V and 1.6 V the 1.0 µH inductance is the best choice, while at higher voltages 1.5 µH are recommended. Generally, the peak input current is approximately twice the average input current.

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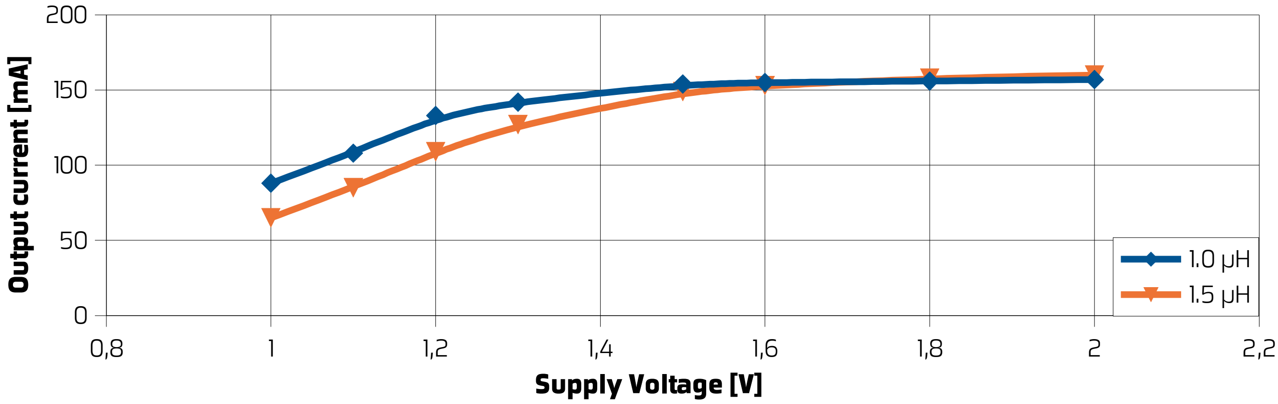
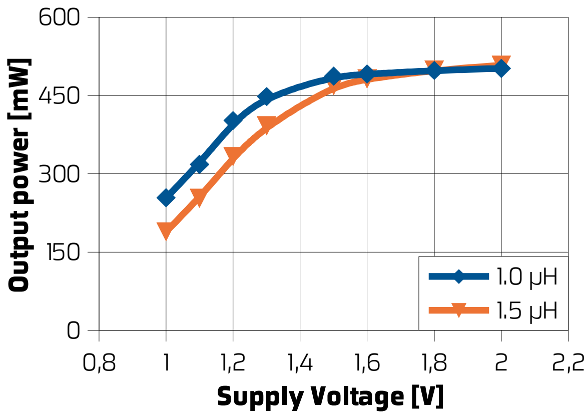
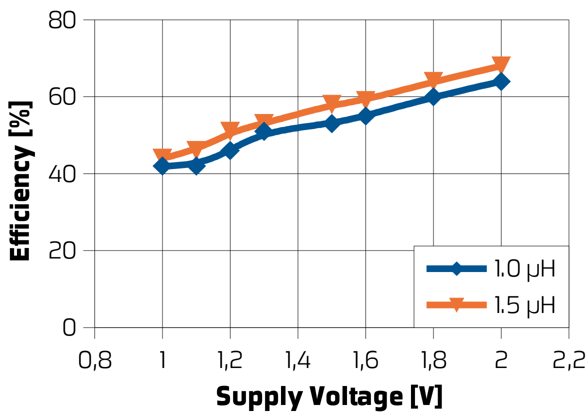
Characteristic Performance Curves

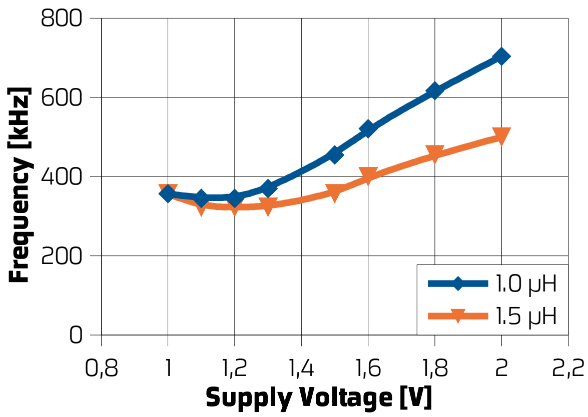
B SUPPLY VOLTAGE 1...2 V - TARGET CURRENT 150 mA - ONE LED

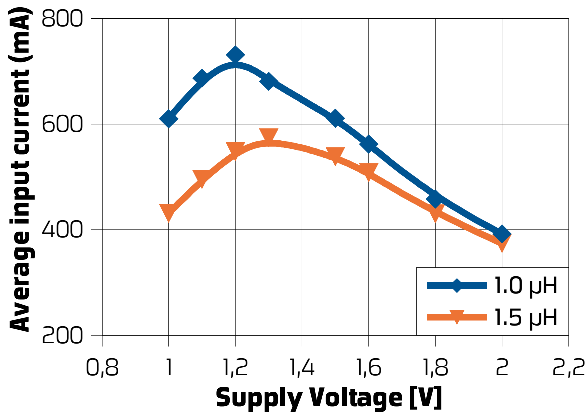
Rs = 1,33 Ω, L1 = 1.0 µH / 1.5 µH with I_{sat}=2.5 A











The peak input current is approximately twice the average input current. At some conditions this current is close to the SW current maximum rating.The allowed ambient temperature range is restricted by the maximum junction temperature rating!

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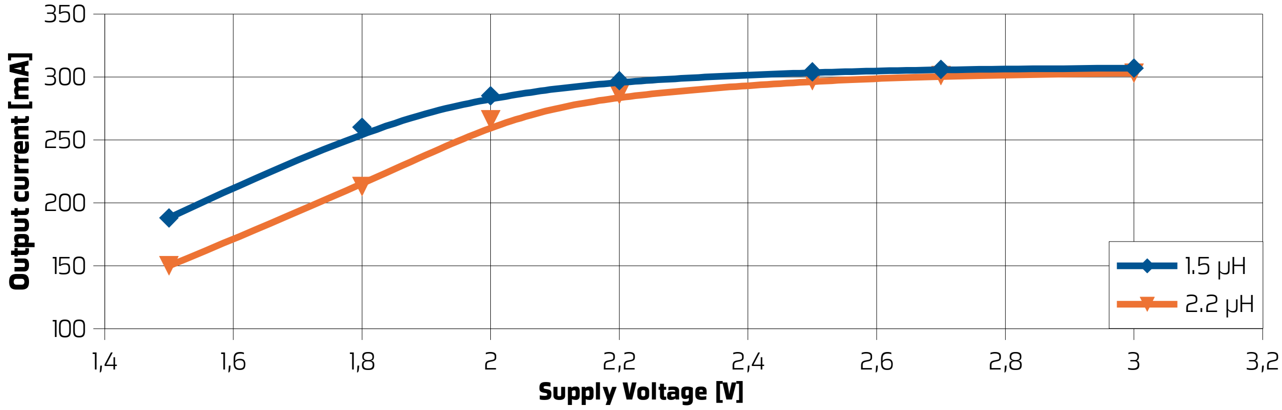
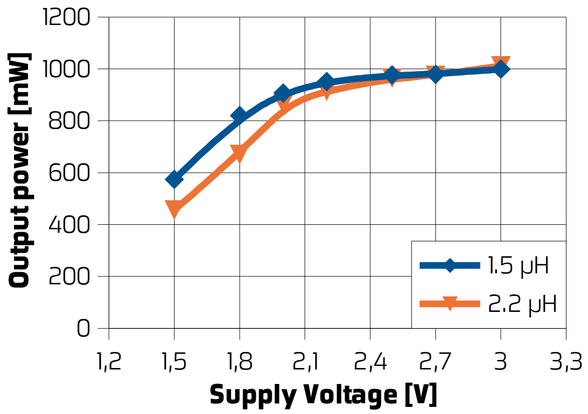
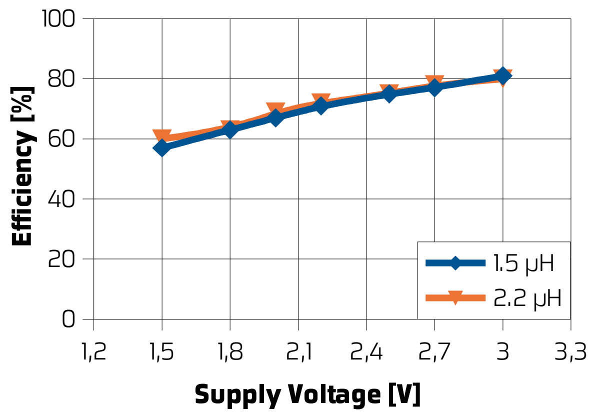
Characteristic Performance Curves

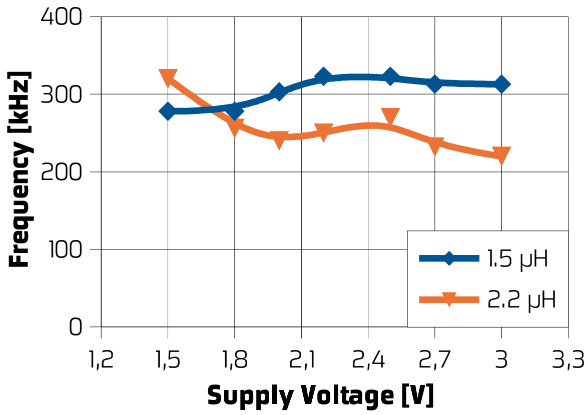
C SUPPLY VOLTAGE 1.5...3 V - TARGET CURRENT 300 mA - ONE LED

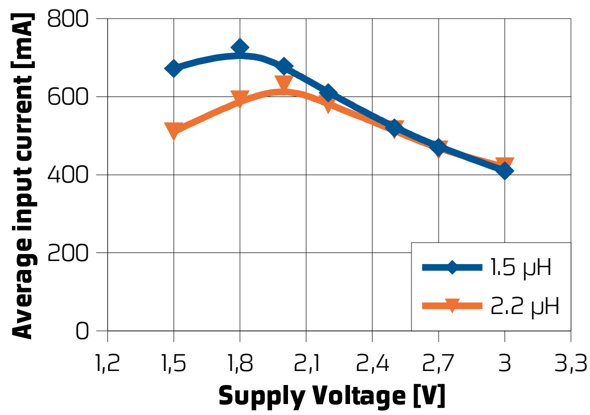
Rs = 0,67 Ω, L1 = 1.5 µH / 2.2 µH with I_{sat}=2.5 A











The peak input current is about twice the average input current. At some conditions this current is close to the SW current maximum rating.The allowed ambient temperature range is restricted by the maximum junction temperature rating!

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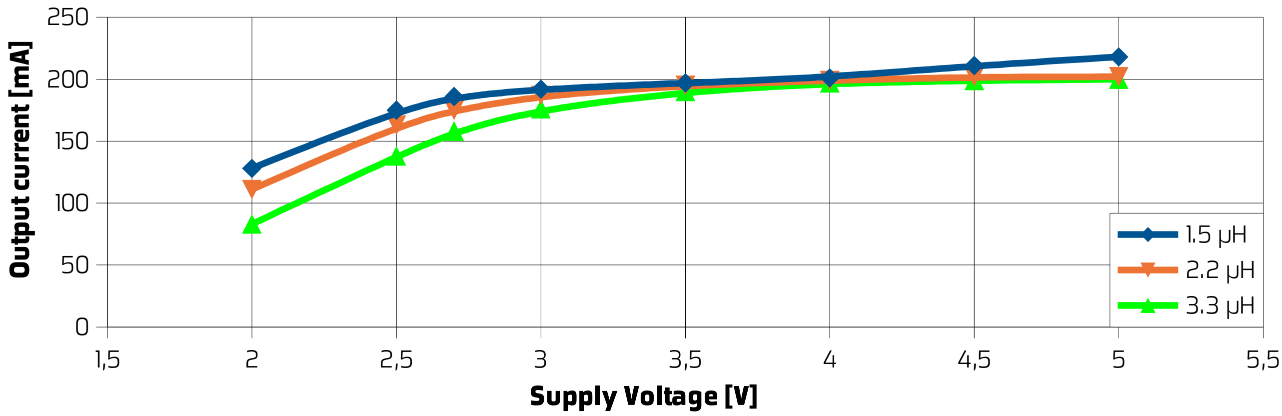
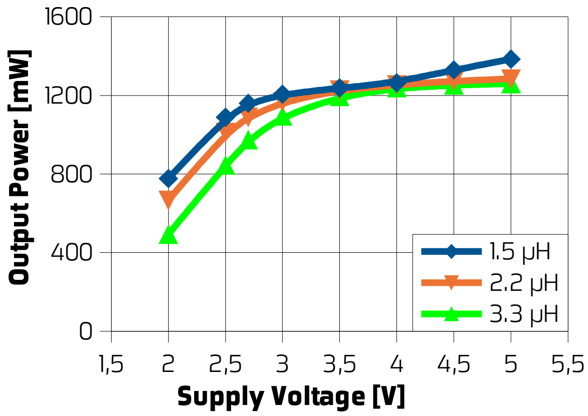
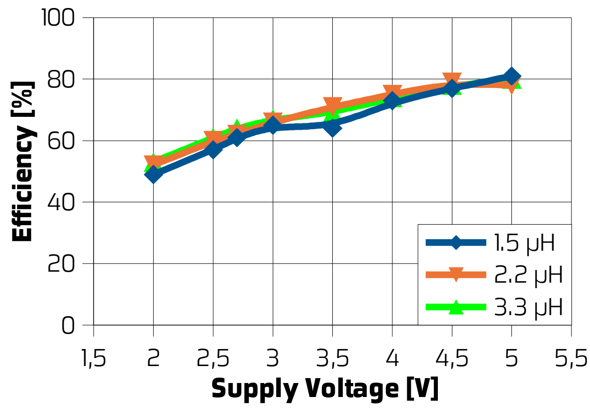
Characteristic Performance Curves

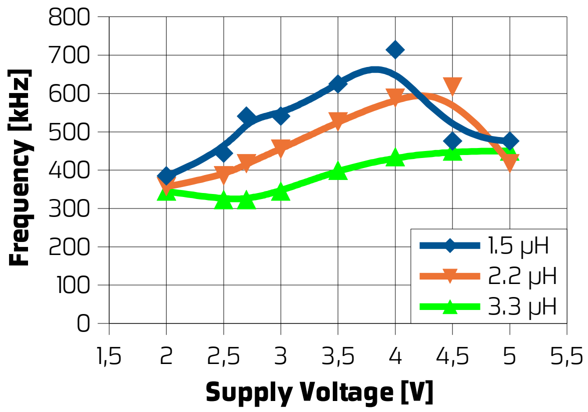
D SUPPLY VOLTAGE 2...5 V - TARGET CURRENT 200 mA - TWO LEDs IN SERIES

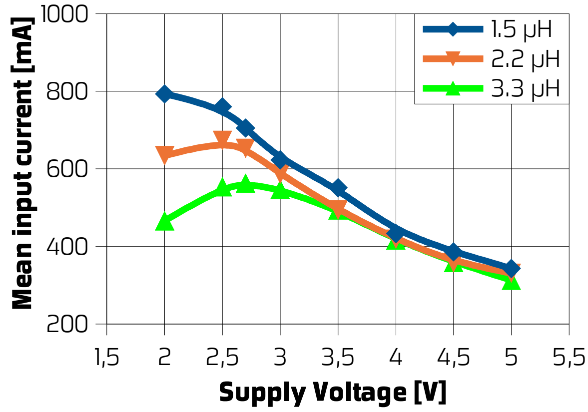
Rs = 1 Ω, L1 = 1.5 µH / 2.2 µH / 3.3 µH with I_{sat}=2.5 A











As PR4404 is a boost converter, input voltages higher than the LED forward voltage require two or three LEDs in series at the output. With two LEDs in series, a stable output current of 200 mA, or an output power of 1.2 W, can be achieved in the voltage range between 3.5 V and 5 V, which is interesting for three battery cell applications. Operation with a 2.2 µH yields optimum results with best margins.High input currents that occur at low input voltages can thermally overload the IC.

Application Notes – General Dimensioning Guidelines

CURRENT SENSE RESISTOR RS

Rs sets the peak output current, which is defined by

$$I_{peak} = \frac{V_{FB}}{Rs}$$

INDUCTOR L1

The best inductance depends mainly on the ratio between input and output voltage. A high inductance results in a low frequency, limiting the transfered power at low supply voltages. A low inductance causes a shorter charging time, allowing a higher power transfer, but resulting in a lower efficiency and eventually in an insufficient current regulation at higher supply voltages. So a proper balance between behaviour at the low end and high end of the supply voltage range in the respective application should be found. See diagrams and application examples for recommendations. The saturation current of the inductor must be at least equal to the peak current. The peak current is approximately two times the average input current under worst-case conditions, which mostly occur at low supply voltages.

SCHOTTKY DIODE D1

D1 must be capable driving the peak current, as for the inductor. A low forward voltage at this current and a fast recovery provide a high efficiency. Recommended diode types are MBRS140 or 1N5817.

LED

Any type of LED can be used, as far as specified for the current. However, the output voltage Vout must be higher than the input voltage Vcc; otherwise the current regulation will not work properly. Therefore it is usually possible to drive one white-light LED with V_F=3.2 V from two alkaline batteries with a nominal voltage of 3.0 V, but not from three NiMH cells with 3.6 V. The voltage at pin SW is internally clamped by a zener diode (for clamping voltage see electrical specification). Therefore operation without output load does not damage the chip. Nevertheless, prolonged operation without load should be avoided. It is possible to connect two or more LEDs in series at the output. With increasing ratio of Vout/Vcc the maximum output current decreases. Mind that the built-in zener diode at SW limits the achievable output voltage and therefore the number of LEDs that can be connected.

CAPACITORS C1, C2

C1 is a reservoir capacitor to stabilise the input voltage and prevent regulator oscillations. It usually consists of a ceramic capacitor C1a in parallel to a tantalum capacitor C1b. It is important to connect a ceramic capacitor of approx. 1 µF between Vcc and Gnd very close to the IC. The size of the tantalum or electrolytic capacitor depends on the application. In some cases it may be even dispensable, but mostly a capacitor of up to 100 µF will improve the performance, as it smoothes out the peak current drain from the power source and allows a battery to be used to a deeper discharge level. Also C2 consists of a ceramic capacitor C2a and an electrolytic reservoir capacitor C2b at the output, responsible for smoothing the pulsating output current through diode D1. Its value depends on the current level and the allowed ripple height. Find some recommended values in the application example circuits.

PCB

When designing the PCB layout, keep in mind that currents of up to 2 A are involved. All power lines, especially from the battery, inductor and SW input pin, must be sufficiently wide to keep the voltage drop as low as possible. The ceramic capacitor C1b must be placed close between Vcc and Gnd of the IC. A large ground plane is helpful for good performance and low EMI.

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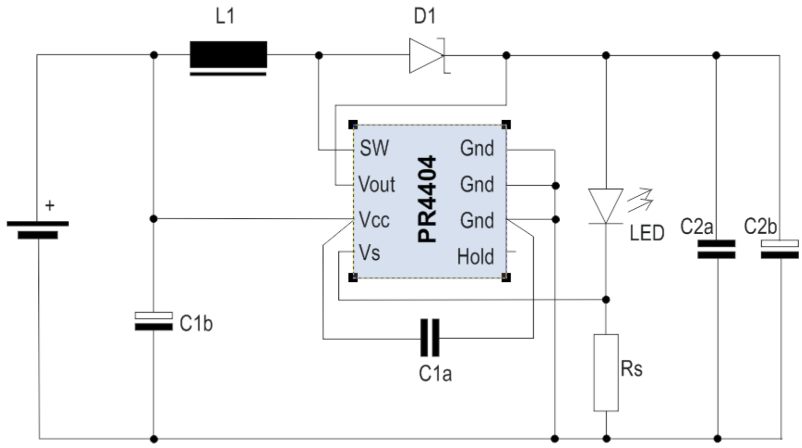
Examples for varying LED applications

POWER FLASHLIGHT

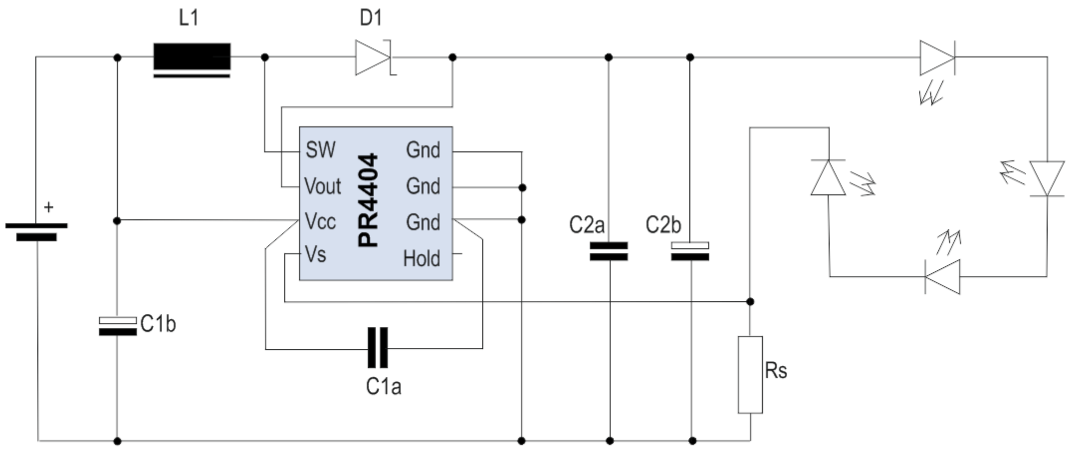


Components:

LED current	Vcc (nominal)	C1a	C1b	L1	D1	Rs	C2a	C2b
150 mA	1.2 – 1.5 V	1 µF	100 µF 6.3 V	1.0 µH Isat ≥ 1.2 A	MBRS140 1N5817	1.3 Ω	470 nF	22 µF 6.3 V
300 mA	2.4 – 3.0 V	470 nF	100 µF 6.3 V	1.5 µH Isat ≥ 1.6 A	MBRS140 1N5817	0.67 Ω	470 nF	22 µF 6.3 V

DRIVING A CHAIN OF LEDs

Output voltages up to 16 V are possible. As the output power of the circuit is limited, the maximum LED current is lower by a factor roughly equal to the number of LEDs compared with single LED applications. Recommended dimensions: see power flashlight, except R_s changed to V_{FB}/I_{LED}.



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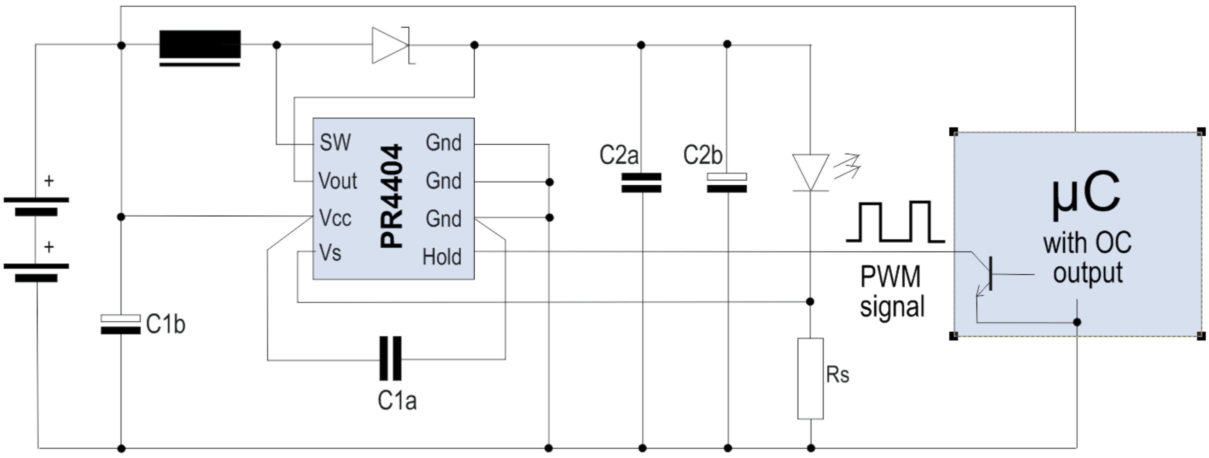
Examples for varying LED applications

PWM controlled LED

The Hold input allows to switch on and off the LED with a digital circuit, such as a microcontroller or a timer circuit. This can be used e.g. for a PWM brightness control, for blinker circuits and many other purposes.



Mind that no voltage must be applied at the Hold pin, but it must only be pulled down to Gnd. Only an open collector or open drain output must be connected to Hold! Due to the remaining quiescent current this feature is not recommended for soft-switching battery-operated lamps on and off.

CALCULATION OF THE MAXIMUM AMBIENT TEMPERATURE

Under some operating conditions, especially at high voltage transfer ratios and with low inductances, the IC can get into thermally critical states.
The following formula gives a rough estimation of the maximum temperature at which the circuit can be operated.

P_{out} output power
measured, or estimated from diagram
η efficiency
measured, or estimated from diagram
P_{IC} total power dissipation in IC

$$P_{IC} \approx \frac{(1-\eta)}{\eta} \cdot P_{out} - I_{out} \cdot V_{sense}$$

This formula assumes that the power loss occurs inside the IC and the current sense resistor, but neglects the losses in the inductor, Schottky diode, wiring and capacitors.

T_{amax} maximum ambient temperature
T_{Jmax} maximum junction temperature
see Absolute Maximum Ratings
Θ_{JA} thermal resistance of package
see Electrical Characteristics
T_{amax} maximum ambient temperature

$$T_{Amax} = T_{Jmax} - \Theta_{JA} \cdot P_{total}$$

EXAMPLE

According to the diagrams, with a target current of 300 mA, a 1.5 µH inductor and one LED at the output, at Vcc=2.2 V the actual output power is 950 mW, and the efficiency is 70 %. Thus, the power dissipated inside the IC can be estimated to be:

$$\begin{aligned} P_{IC} &\approx 0.43 \cdot 0.95\ \text{W} - 0.3\ \text{A} \cdot 0.2\ \text{V} \\ &\approx 0.40\ \text{W} - 0.06\ \text{W} \\ &\approx 0.34\ \text{W} \end{aligned}$$

Then the maximum ambient temperature is

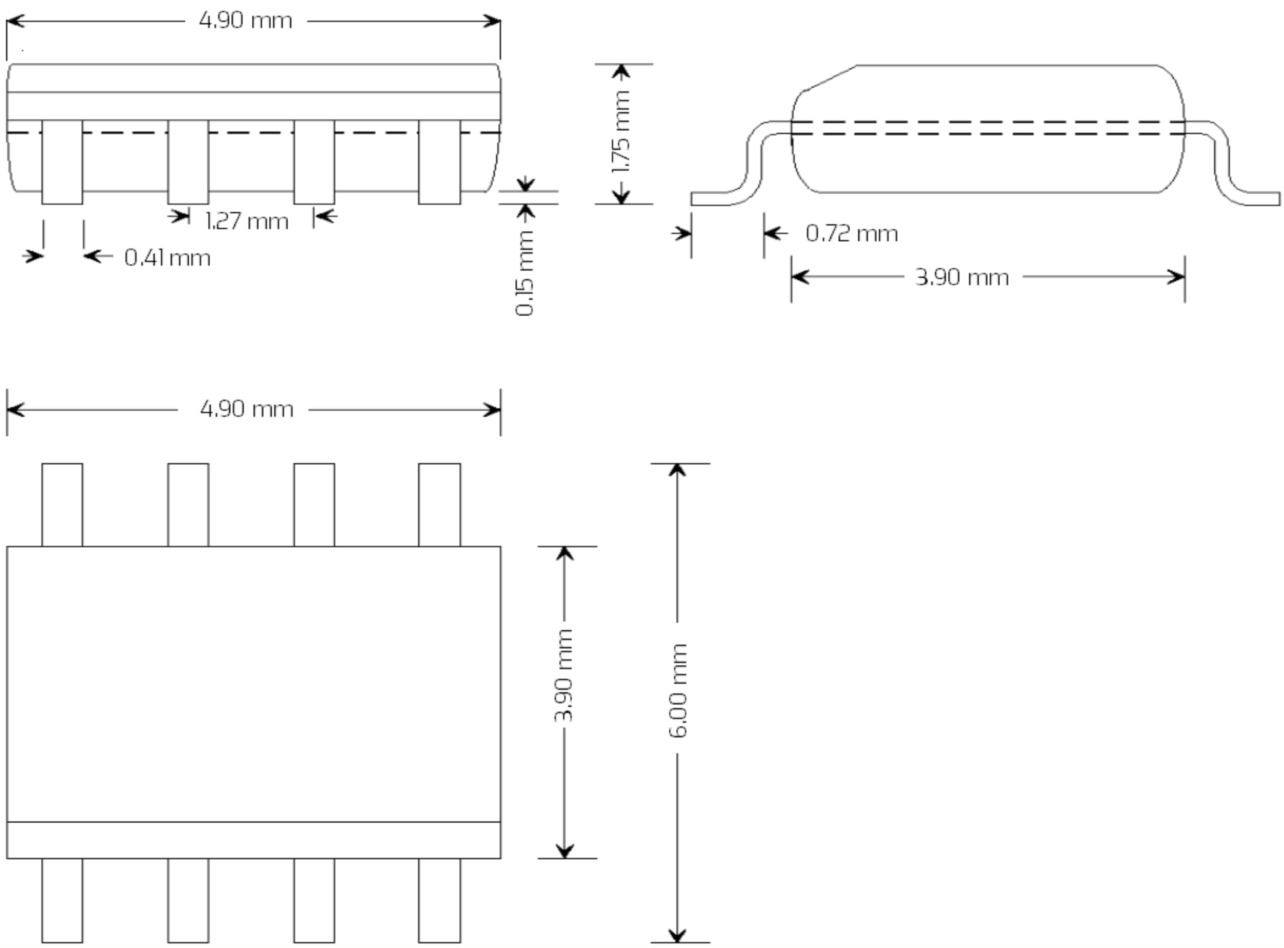
$$T_{Amax} = 125°C - 160\ K/W \cdot 0.34\ W = 70°C$$

For highest reliability a permanent operation near the thermal limits should be avoided. Actual operating limits will depend on several factors. E.g. a PCB design with good heat spreading and forced air convection may improve the situation, but a thermally sealed casing or heating from the LED or battery will make it worse.
Also the efficiency in the actual application may differ from the values given in the diagrams.

With decreasing supply voltage the voltage transfer ratio and therefore the input current rises, and the efficiency falls. As a consequence, the thermal load on the IC increases as the supply voltage falls. Therefore battery operated circuits must be designed that while discharging the battery no critical state can occur.

Available Package

Technical Drawing



Package type: 8L SOIC (150 mils)

LED Driver PR4404

All part delivered, comply with RoHS. Finish is pure tin.

Pb-free   pure tin

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PREMA Semiconductor GmbH
Robert-Bosch-Str. 6
55129 Mainz   Germany
Phone: +49-6131-5062-0
Fax: +49-6131-5062-220
Email: prema@prema.com   Web site: www.prema.com