0.9V Boost Driver for White LEDs PR4401/4402

Requires Only One External Component

The PR4401 and PR4402* are single cell step-up converters for white LEDs operating from a supply voltage of less than 0.9V. Only one external inductor is needed for operation of a white LED. PR4401 is recommended for mean LED currents of up to 20mA, PR4402 for up to 40mA. This makes PR4401 and PR4402 ideal for use in low-cost or small-sized applications such as LED flashlights or LCD backlighting for portable devices.

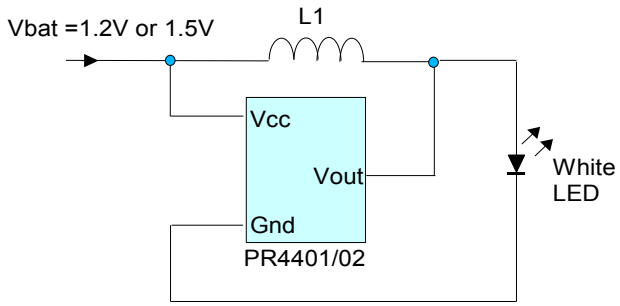
Features

- minimum startup voltage 0.9V
- 200/250mA peak output current
- only one external component required
- battery deep discharge protection

Applications

- Small-sized LED torches
- LCD backlighting
- LED indicator lights

Typical Application



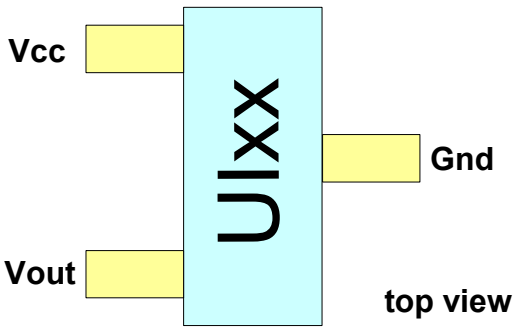
For output currents higher than 20mA an additional blocking capacitor at Vcc is recommended.

The inductance L1 determines the LED current:

Inductance L1	*Mean current*	*for*
47µH	6.5 mA	PR4401
32µH	8.3 mA	PR4401
26.7µH	10.8 mA	PR4401
22 µH	11 mA	PR4401
14.7 µH	14 mA	PR4401
10 µH	22 mA	PR4401/4402
6.8 µH *	32 mA *	PR4402
4.7 µH *	40 mA *	PR4402

* PR4402 only measured with inductor Murata type LQH32C series
10-22µH: one white LED
4.7-6.8µH: two white LEDs in parallel

Pin Description



PIN Name	*PIN Function Description*
Vcc	Supply voltage
Vout	Output voltage, LED connection
Gnd	Ground connection

Topside marking: "UI" (PR4401) or "UJ" (PR4402) with a two-digit lot code
Package SOT23-3 or COB on request

New Edition: Includes PR4402

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Absolute Maximum Ratings (PR4401 and PR4402)

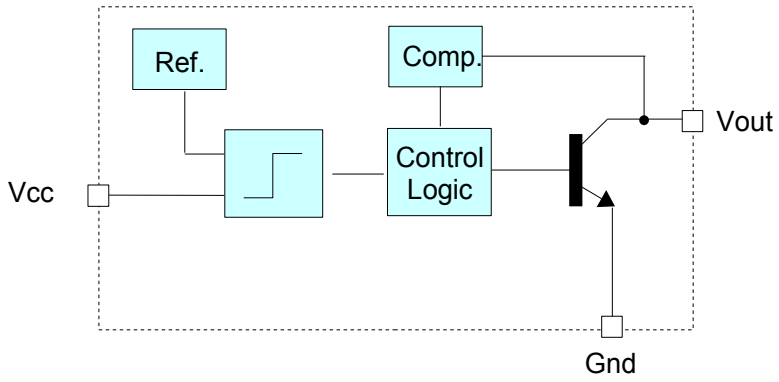
Parameter	Min	Typ	Max	Units
V_{CC} (no damage)	-0.3		8	V
Operating Temperature Range	-20		85	°C
Storage Temperature Range	-55		150	°C
Electrostatic Discharge (ESD) Protection	2			kV

Electrical Characteristics

Vcc=1.5V, Ta = 25°C, 10-22µH: one white LED / 4.7-6.8µH: two white LEDs in parallel, unless otherwise noted.

Parameter	Conditions	Min	Typ	Max	Min	Typ	Max	Units
		PR4401			PR4402			
Supply Voltage, min. operating min. startup max. operating	L1 = 10...22µH Ta = 25°C	 1.90	0.70 0.90	0.80 0.95	 1.90	0.70 0.90	0.80 0.95	V V V
Supply Voltage, min. operating min. startup max. operating	L1 = 10...22µH Ta = 0...60°C	 1.90	0.80 1.00	0.90 1.05	 1.90	0.80 1.00	0.90 1.05	V V V
LED Mean Current measured with L1 type LQH32C Murata	L1 = 47µH L1 = 32µH L1 = 26.7µH L1 = 22µH L1 = 14.7µH L1 = 10µH L1 = 6.8µH L1 = 4.7µH		6.5 8.3 10.8 12 15 23 -- --			-- -- -- 12 15 23 32 40		mA mA mA mA mA
Switching Current at Vout	Vout = 0.4V	200			250			mA
Switching Frequency			500			500		kHz
Quiescent supply current	Vcc > 950mV Vcc = 600mV Vcc = 400mV		4 50 10	5		8 100 20	10	mA µA µA
Efficiency			80			80		%
Vout		Vcc		15			15	V

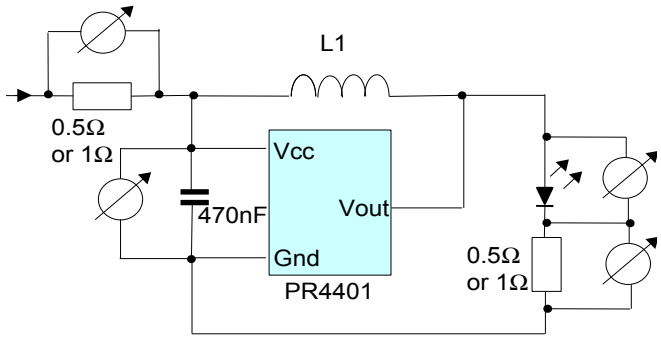
Block Diagram



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Typical Characteristics

Test circuit



Measurement and Calculation of Efficiency

$$Efficiency\,(\%) = \frac{\frac{1}{T}\int_0^T \left(V_{LED} \cdot I_{LED}\right) dt}{\frac{1}{T}\int_0^T \left(V_{in} \cdot I_{in}\right) dt} \cdot 100$$

Depending on test setup and measuring method, efficiency values can vary by approx. ±5%, and peak current values can vary by up to ±20%, Accuracy of mean currents: ±1mA.

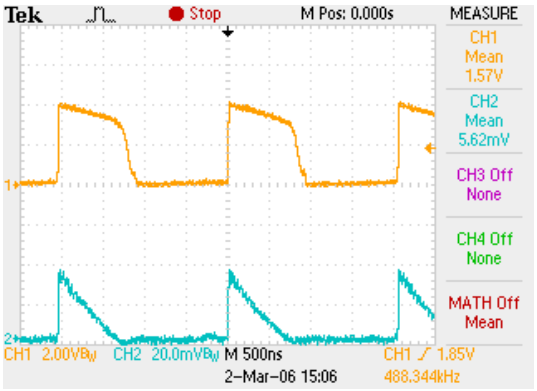
Measuring conditions for all diagrams, unless otherwise noted:

- Ta = 25°C
- one LED connected (peak voltage 4.2...5.8V)

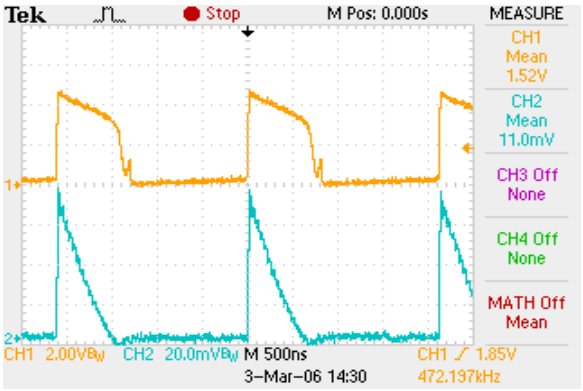
A LQH32C from Murata has been used as reference inductor, the DC resistance is specified as 0.44 Ω ± 30% for 10 µH (max current 300 mA), 0.71 Ω ± 30% for 22 µH (max. current 250 mA) and 1.30 Ω ± 30% for a 47 µH inductor (max. current 170 mA).

Oscilloscope Displays

PR4401; LED voltage (CH1) and LED current (CH2, over 0.5 Ohm resistor)



with L1 = 22 µH

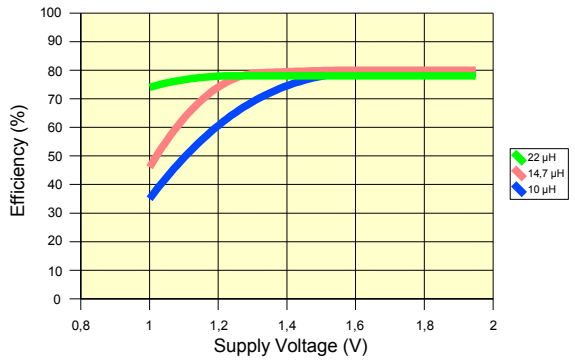


L1 = 10 µH

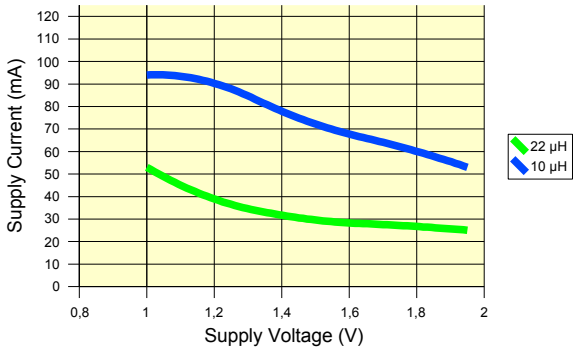
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PR4401 data

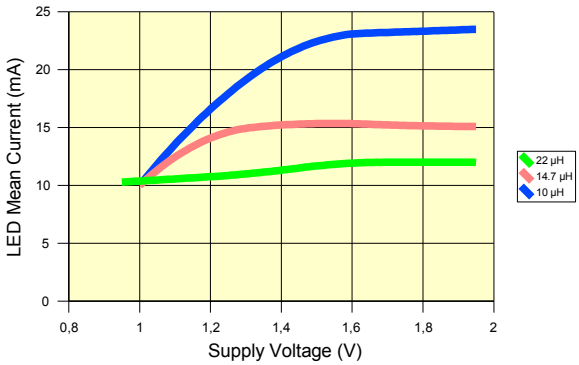
Efficiency vs. Supply Voltage



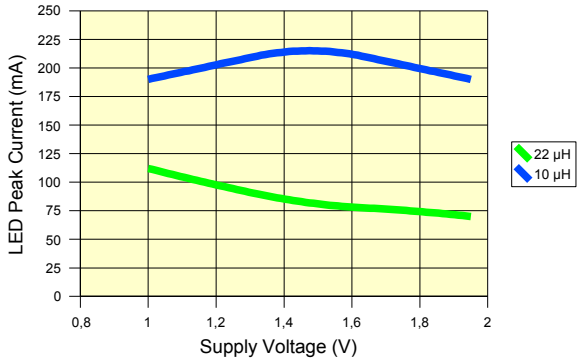
Mean Supply Current vs. Supply Voltage



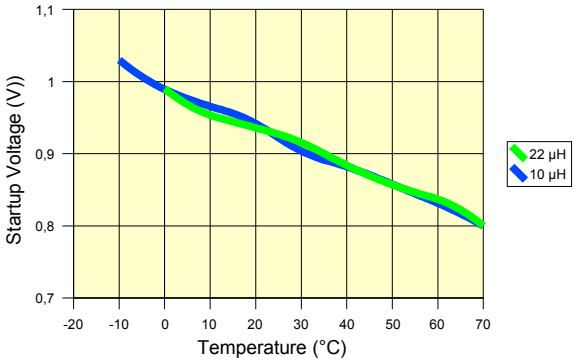
Mean LED Current vs. Supply Voltage



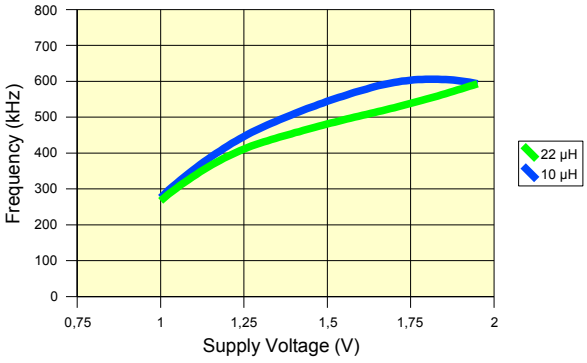
Peak LED Current vs. Supply Voltage



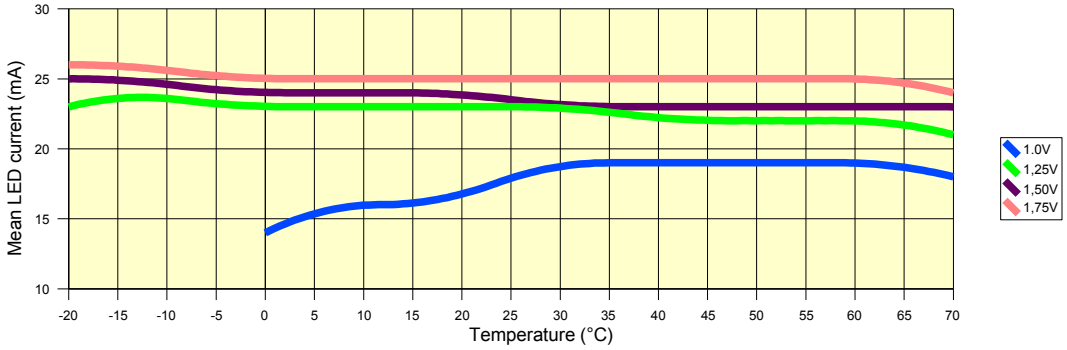
Startup Voltage vs. Temperature



Oscillation Frequency vs. Supply Voltage

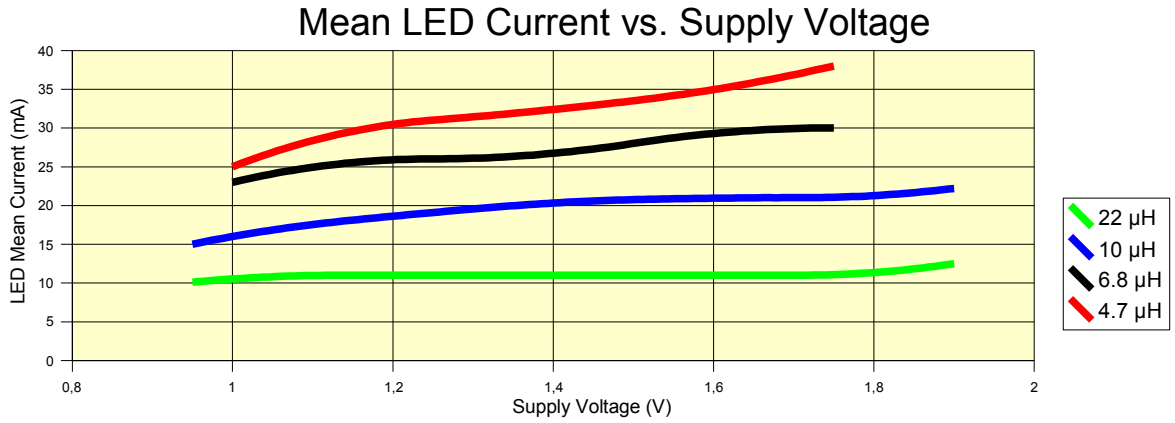


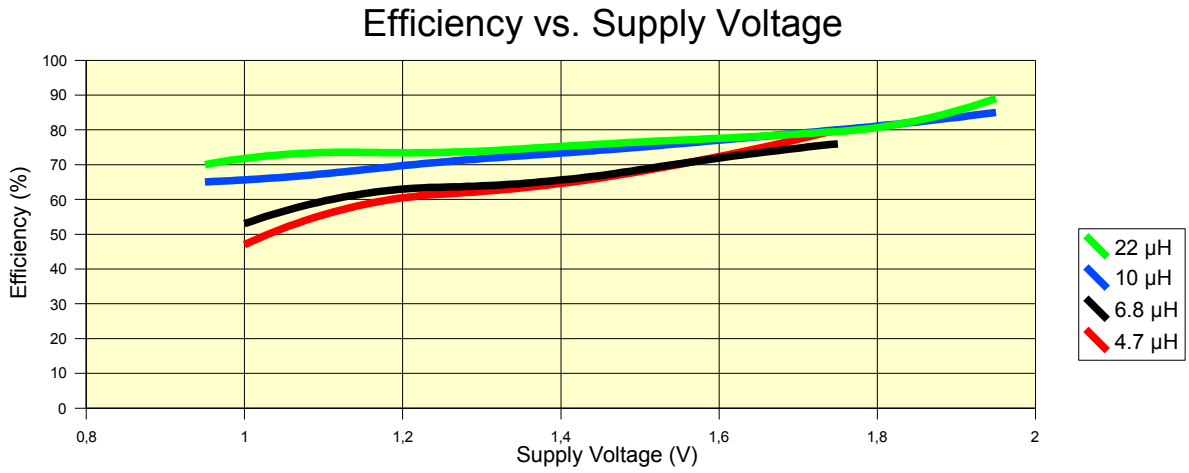
Mean LED Current vs. Temp. @ L1=10µH

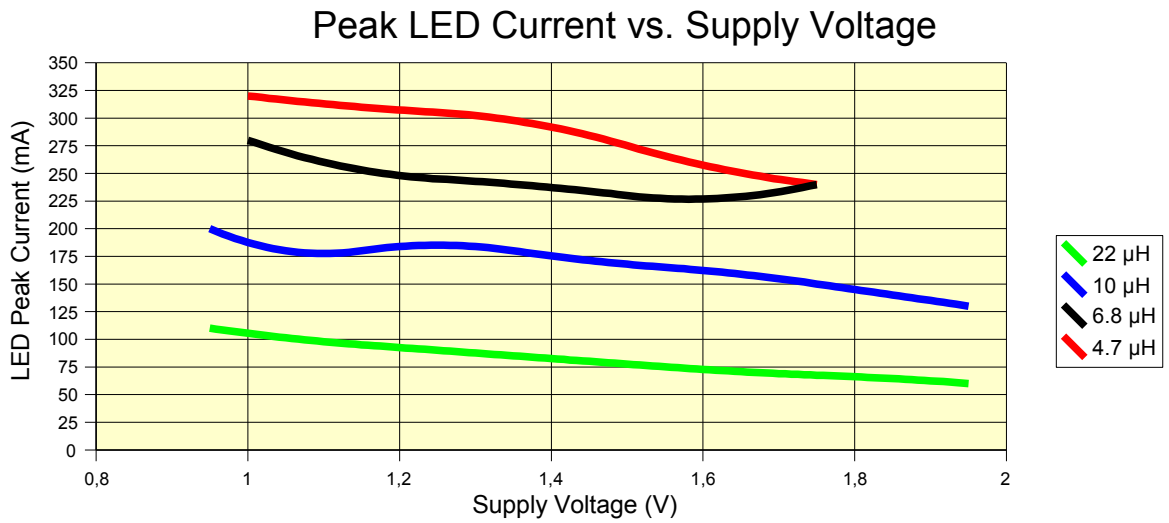


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PR4402 data







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Influence of the LED Forward Voltage

measured with 1 LED / 2 LEDs in parallel; Vcc = 1.5V

Circuit	*LED Peak Forward Voltage*	*LED Mean Current*	*Mean Supply Current*	*Efficiency*
10 µH, 1 LED	5.8 V	20 mA	70 mA	77 %
10 µH, 2 LEDs ||	4.6 V	24 mA	70 mA	80 %
22 µH, 1 LED	4.2 V	13 mA	33 mA	82 %
22 µH, 2 LEDs ||	3.5 V	14 mA	32 mA	82 %

Peak forward voltages above approx. 5V are often considered as an overload condition and may lead to a lower LED efficiency.

Application Notes

Selection of PR4401 and PR4402

The circuit type should be selected according to the required LED current.
PR4401 is best operated with inductors between 10 and 22µH.
PR4402 is best operated with inductors between 4.7 and 10µH.
Using lower inductances may lead to erratic behaviour, especially at low supply voltages and should be avoided.
Operating with higher inductances is possible and will lead to lower supply and LED current.
However the quiescent current which is independent of the inductance will lead to a lower overall efficiency. Since PR4402 has about twice the quiescent current of PR4401, it is not recommended for small LED currents.

LED compatibility

It must be considered that the peak current through the LED is a factor of up to 7 higher than the mean current. LED lifetime may be affected if operated outside the range specified by the LED vendor.
Since the emission spectrum of white LEDs usually depends on the current, the light color may shift to blueish white. High peak currents may also saturate the LED and reduce the light efficiency of the LED.
If the rated LED peak current is exceeded, it is recommended to use a smoothing capacitor and diode to provide a continuous output current (see below). With most standard LEDs, this will improve the overall performance with inductors of 10µH and less, or mean output currents of 23mA and more.
Note that with especially with the higher currents of PR4402 the current rating of most standard LEDs is exceeded, and more powerful or multiple LEDs must be used.

Inductor compatibility

While the series resistance of the coil has a small impact on the LED current, it is important that the saturation current is higher than the maximum peak current over the supply voltage range. Inductors optimized for DC-DC converters are mostly suitable.

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Connection from Battery

Due to high peak currents, it is important to connect the PR4401/PR4402 to the battery with short, low resistance wires, to achieve the best performance. A voltage drop along the wire affects LED current, efficiency and minimum startup and operating voltage.
This is most critical for applications with low inductivity and high current.
In cases where a longer wire from the battery cannot be avoided, a capacitor should be placed close to the Vcc and Gnd pin of PR4401. Typically capacitors between 220nF and 1µF are used.
With PR4402 operated at higher currents, a blocking capacitor is usually necessary even if wires or board layout are optimized.

Using Different Battery Types

The input voltage must be 1.90V at maximum. At higher voltages the circuit may not trigger and start up correctly. Therefore operation with one Alkaline, NiCd, or NiMH cell (AA or AAA type) is recommended.
Alkaline button cells can also be used for supply. However, since high peak currents are drawn from the battery, button cells are recommended only with inductors of 22µH or more, depending on the battery type. A capacitor at the supply pins of PR4401 may also improve performance with button cells.
Lithium batteries are not suitable due to their higher voltage.

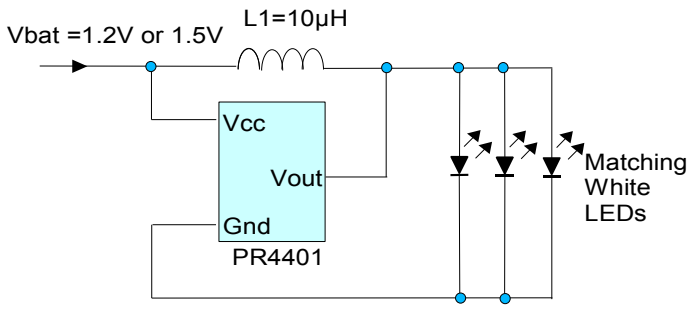
Approximate battery lifetime:

Battery	***Battery Lifetime, typical*** ***L1= 22µH, LED mean current 12mA***	***Battery Lifetime, typical*** ***L1= 10µH, LED mean current 23mA***
AA (Mignon, LR 6/AM-3)	55 h	27 h
AAA (Micro, LR 03/AM-4)	22 h	8 h

Conditions: one white LED connected, measured with single 1.5V TDK Alkaline battery.
Battery lifetime depends on battery capacity and operating conditions. Therefore the times indicated here can only give a rough indication of achievable times.

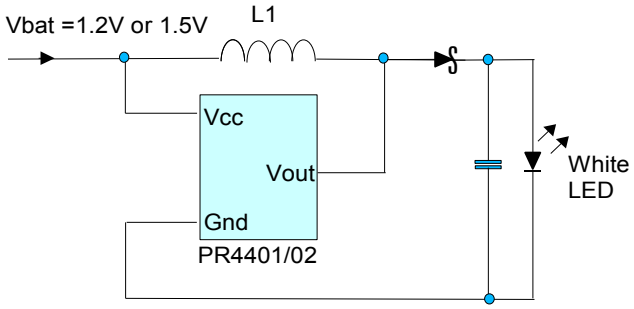
Connecting several LEDs in parallel

When several LEDs are connected in parallel, it is necessary to match the forward voltage of these LEDs, to achieve a uniform brightness. The total current of all LEDs together corresponds approximately to the mean output current for operation with one LED.

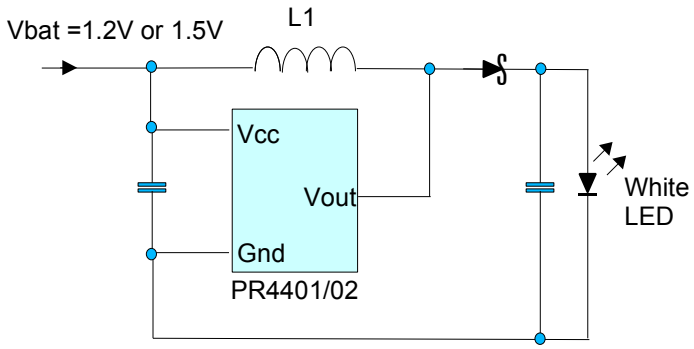


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Operation of LED with smoothed current (rectifier)
With a diode (preferably a Schottky diode) and a smoothing capacitor the voltage at the LED can be buffered if necessary. The capacitance must be small enough so that the voltage at the capacitor will exceed a voltage of 2.5V in the first cycle, otherwise the circuit may not start up. In most cases, values between 100nF and 1µF are appropriate.
Due to different load characteristics, output current and efficiency are typically higher than without capacitor, especially in the high-current range.



Recommended configuration for higher LEDs currents
While for lower LED currents it is possible to operate PR4401 with the minimum number of components, it is recommended to provide both rectifier circuit a the output and buffer capacitor at the input at high LED currents, to achieve the best performance.



Whether the extra components are necessary or not depends largely on the performance of the components used, most importantly the peak current of the LED, the internal resistance of the battery and the resistance of the battery cables. If by adding the extra components the mean LED current increases significantly, it is usually advisable to add them permanently to achieve a high efficiency.
As a rule of thumb, with a 22µH inductor the extra components will usually not increase the current significantly, while for inductors below 10µH they will usually improve the performance noticeably.
Buffer capacitor and rectifier circuit are independent measures. For powerful LEDs, or two or more LEDs in parallel at the output, the rectifier may not be necessary, but the buffer capacitor will still prevent high voltage drops along the supply wire.
For the buffer capacitor, values between 220nF and 1µF are common.

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Connecting two LEDs in series

It is possible to operate PR4401 and PR4402 with two LEDs in series at the output. However, while the peak output current is nearly independent of the output load, the mean output current with two LEDs in series is reduced to half the current with one LED. In addition, at high output voltages the efficiency drops significantly, depending on operating conditions, and current pulses become shorter and sharper.
Therefore, although possible and useful in some cases, this operation mode is not recommended for general applications and not specified further.

Using red, green or yellow LEDs

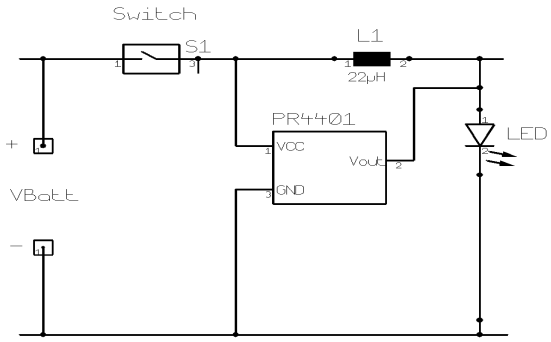
Although PR4401/PR4402 is optimized for operation with white or blue LEDs, it will usually also work with red, green or yellow LEDs, with the following restrictions:

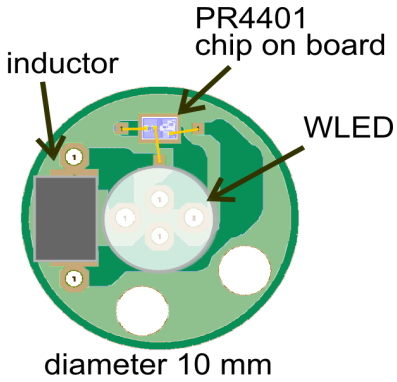
a) The LED must build up a sufficient forward voltage to trigger PR4401/PR4402. Due to the internal resistance of the LED, this condition is usually met. However, no guarantee can be assumed for proper operation under all conditions, and you need to qualify the system yourself

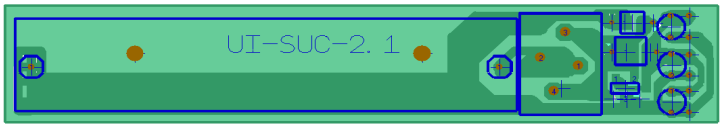
b) Due to the different forward voltage level and internal resistance of colored LEDs, the timing is different, and mean currents are mostly lower than for white LEDs. Also other parameters may deviate from this data sheet.

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Sample Board Layouts



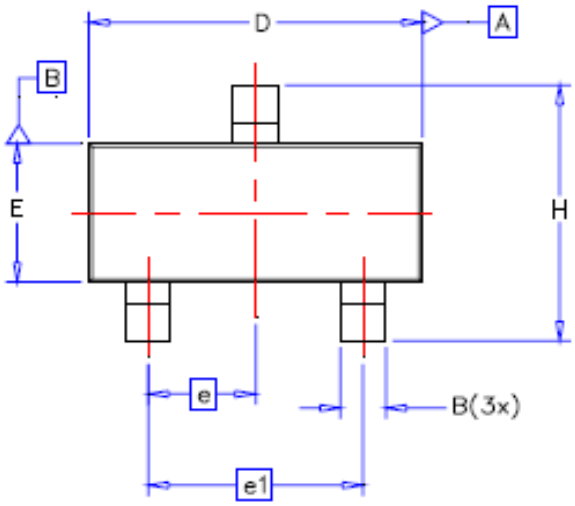




Flashlight board with AAA battery holder
Size: 77.5 mm x 14 mm

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Available Packages



Typical Dimensions

B = 0.40 mm D = 2.92 mm
E = 1.30 mm H = 2.37 mm
e1 = 1.92 mm

PR4401/PR4402 SOT23 package in tape and reel
Packing unit: 3000 ICs per reel (reel diameter 7" / 178mm)

Delivery in die form on request

All parts delivered comply with RoHS. Finish is pure tin.

Pb-free pure tin

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