

# LED Driver PR4403

## 0.9 V Boost Driver PR4403 for White LEDs in Solar Lamps

The PR4403 is a single cell step-up converter for white LEDs operating from a single rechargeable cell of 1.2 V supply voltage down to less than 0.9 V. An adjustable light threshold input enables an automatic switching of the LED light, e. g. by an additional light sensor or by the battery charging solar cell itself. Only three external components are required for operation of a white LED. The PR4403 is recommended for mean LED currents of up to 40 mA. This makes PR4403 ideal for use in low-cost or small-sized light applications such as solar LED lamps, LED flashlights or LCD backlighting for portable devices.

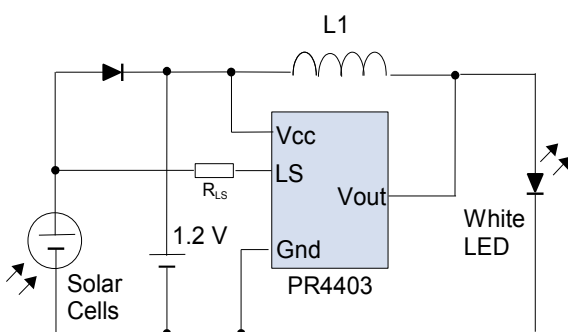
### FEATURES

- only one 1.2 V battery cell needed
- 250 mA peak output current
- low number of external components
- battery deep discharge protection
- adjustable light threshold for switching on

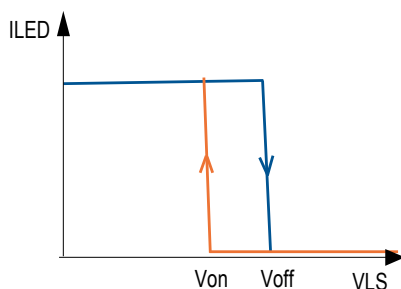
### APPLICATIONS

- Solar garden lamps: The "classic" application for PR4403
- Advertising objects as well as house numbers can be backlighted to make them visible and stand out during nighttime
- LED indicator lights with solar cells: Such as electronic traffic signs, illuminated control- and road markers, warning signs and similar applications
- Solar powered LED torches
- Model making, solar powered toys: Creative designers will find thousands of ways utilizing PR4403 for outstanding products

### TYPICAL APPLICATION



### SWITCHING BEHAVIOUR (EXAMPLE)



The inductance L1 determines the LED current:

Inductance L1	Mean current
47 $\mu\text{H}$	6.5 mA
32 $\mu\text{H}$	8.3 mA
26.7 $\mu\text{H}$	10.8 mA
14.7 $\mu\text{H}$	14 mA
10 $\mu\text{H}$	22 mA
6.8 $\mu\text{H}$	32 mA
4.7 $\mu\text{H}$	40 mA

measured with inductor Murata type LQH32CN series

- 10 - 22  $\mu\text{H}$ : one white LED
- 4.7 - 6.8  $\mu\text{H}$ : two white LEDs in parallel

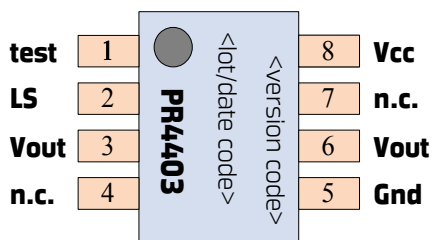
For output currents higher than 20 mA an additional blocking capacitor at Vcc is recommended.

The circuit is operating in case the pin LS is not connected or connected to Gnd (can be chosen). The circuit is shut down if the voltage at LS is higher than Voff.

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## Characteristics

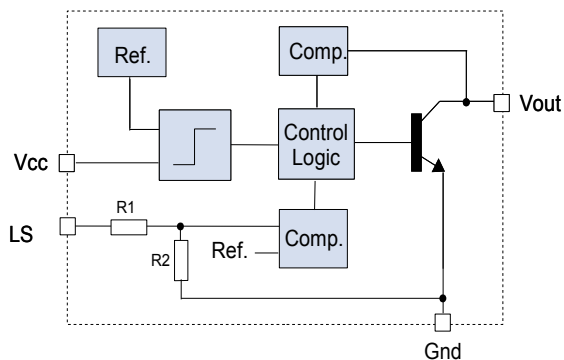
### PIN DESCRIPTION



Package S08 (150 mil)

Pin No	Pin Name	Pin Function Description
1	test	test pin - do not connect
2	LS	LS - Enable Pin
3	Vout	Output voltage, LED connection <b>Connect both pin 3 and 6!</b>
4	n.c.	Not connected
5	Gnd	Ground connection
6	Vout	Output voltage, LED connection <b>Connect both pin 3 and 6!</b>
7	n.c.	not connected
8	Vcc	Supply voltage

### BLOCK DIAGRAM



### ABSOLUTE MAXIMUM RATINGS

Parameter	Min	Max	Units
$V_{CC}$ (no damage)	-0.3	8	[V]
$V_{LS}$ (no damage)	-0.3	6	[V]
Operating Temperature Range	-20	85	[°C]
Storage Temperature Range	-55	150	[°C]
Electrostatic Discharge (ESD) Protection	2		[kV]

# LED Driver PR4403

## Electrical Characteristics

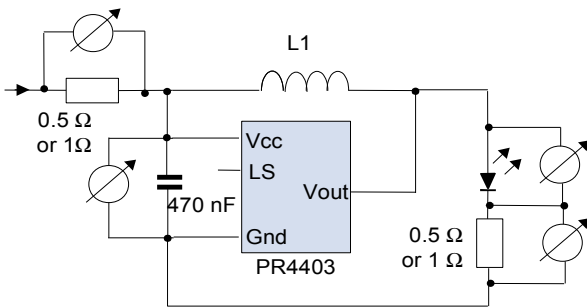
Vcc = 1.5 V, Ta = 25°C, 10 – 14.7 µH: one white LED / 4.7-6.8µH: two white LEDs in parallel, unless otherwise noted.

Parameter	Conditions	Min	Typ.	Max	Units	
Supply Voltage,	min. operating	L1 = 10...14.7 µH Ta = 25°C		0.70	0.80	[V]
	min. startup			0.90	0.95	[V]
	max. operating		1.90			[V]
Supply Voltage,	min. operating	L1 = 10...14.7 µH Ta = 0...60°C		0.80	0.90	[V]
	min. startup			1.00	1.05	[V]
	max. operating		1.90			[V]
LED Mean Current (at VLS < Voff) measured with L1 type LQH32CN Murata	L1 = 47 µH		6.5		[mA]	
	L1 = 32 µH		8.3		[mA]	
	L1 = 26.7 µH		10.8		[mA]	
	L1 = 22 µH		12		[mA]	
	L1 = 14.7 µH		15		[mA]	
	L1 = 10 µH		23		[mA]	
	L1 = 6.8 µH		32		[mA]	
L1 = 4.7 µH		40		[mA]		
Switching Current at Vout	Vout = 0.4 V	250			[mA]	
Switching Frequency			500		[kHz]	
Threshold Voff at LS *)	Vcc > 950 mV Ta = 25°C		0.27		[V]	
	Ta = 0...60°C	0.26		0.28	[V]	
Threshold Von at LS *)	Vcc > 950 mV Ta = 25°C		0.22		[V]	
	Ta = 0...60°C	0.21		0.23	[V]	
Quiescent supply current	VLS > Voff	Vcc > 850 mV		100	[µA]	
		Vcc = 600 mV		50	[µA]	
		Vcc = 400 mV		< 10	[µA]	
	VLS < Von	Vcc > 850 mV		8	[mA]	
		Vcc = 600 mV		100	[µA]	
		Vcc = 400 mV		< 10	[µA]	
Input resistance of LS input	series resistor R1		30		[kΩ]	
	resistor to Gnd R2		400		[kΩ]	
Internal reference (bandgap)	Vref		200		[mV]	
Efficiency			80		[%]	
Vout				15	[V]	

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## Electrical Characteristics

### TEST CIRCUIT



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: ±1 mA. Measuring conditions for all diagrams, unless otherwise noted:

- $T_a = 25^\circ\text{C}$
- one LED connected (peak voltage 4.2...5.8 V)

A LQH32CN from Murata has been used as reference inductor, the DC resistance is specified as

- $0.44 \Omega \pm 30 \%$  for  $10 \mu\text{H}$  (max. current 300 mA)
- $0.71 \Omega \pm 30 \%$  for  $22 \mu\text{H}$  (max. current 250 mA)
- $1.30 \Omega \pm 30 \%$  for  $47 \mu\text{H}$  (max. current 170 mA)

The LS pin is not connected.

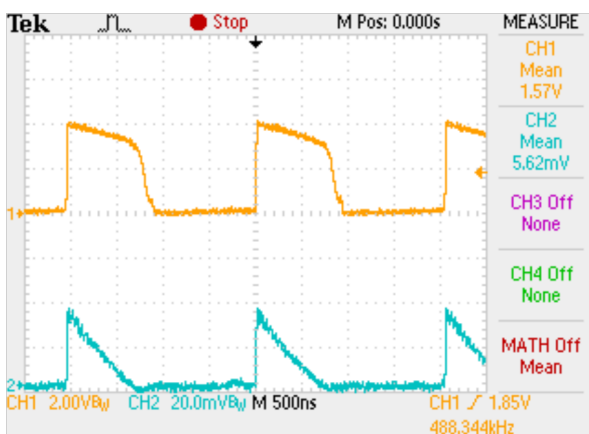
### CALCULATION OF THE EFFICIENCY

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

### OSCILLOSCOPE DISPLAYS

LED voltage (CH1) and LED current (CH2, over 0.5 Ω resistor)

(Oscilloscope images taken with PR4401. PR4403 shows similar behaviour, but may vary in detail.)



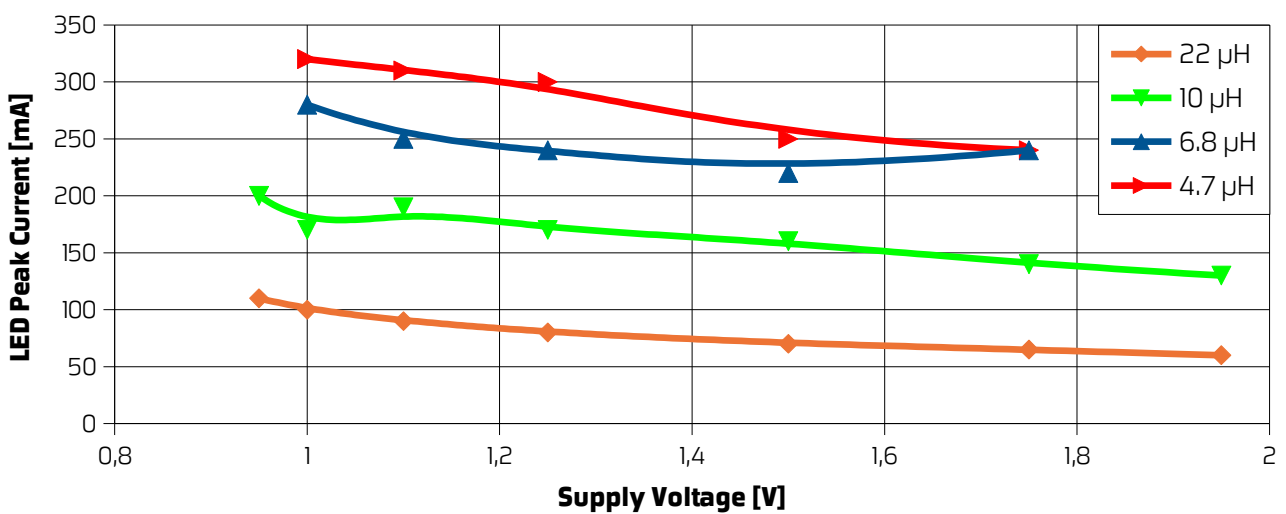
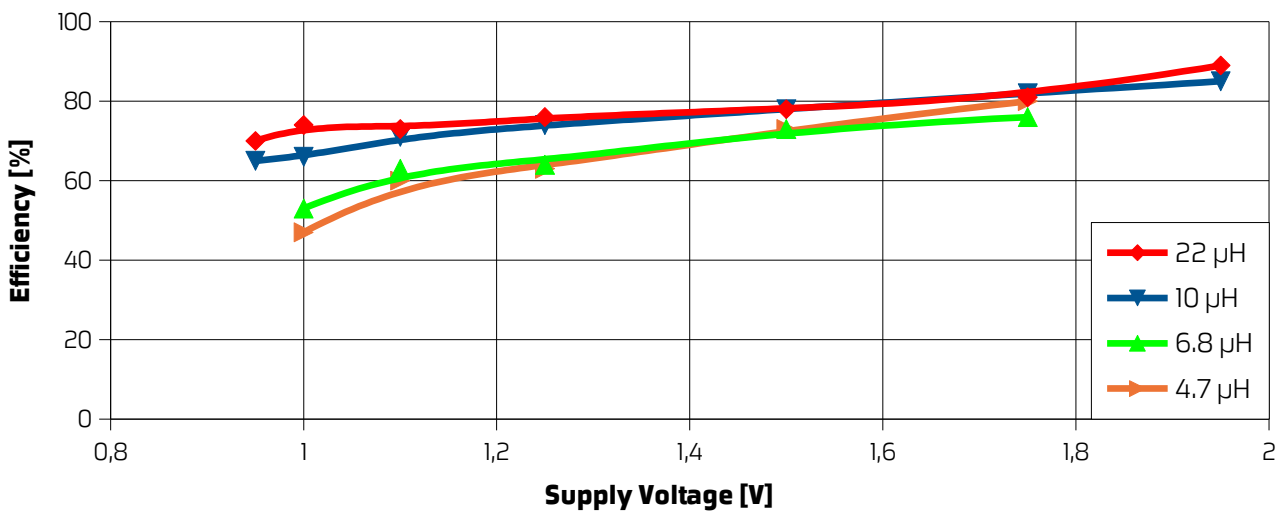
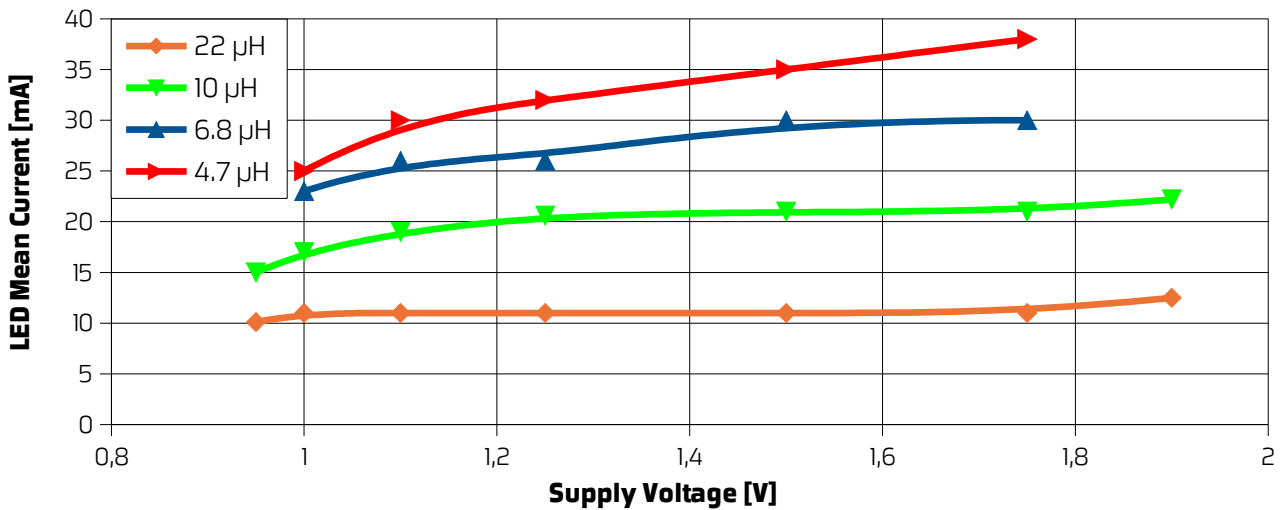
with  $L1 = 22 \mu\text{H}$



with  $L1 = 10.0 \mu\text{H}$

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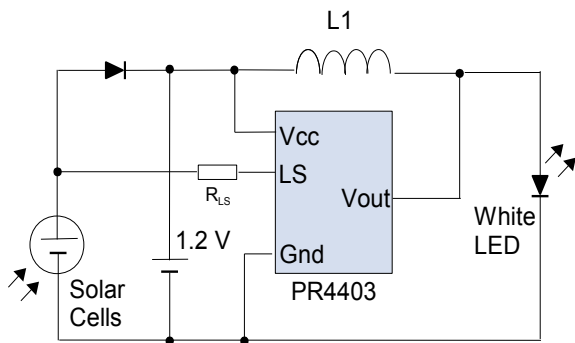
## Characteristic Performance Curves



# LED Driver PR4403

## Application Notes

### USE OF THE PR4403 IN A SOLAR GARDEN LAMP



Solar cell as a battery charger and light sensor

The PR4403 offers good properties to realize a step-up driver for one white LED powered by only one rechargeable 1.2V battery cell charged by a 2.4 V solar cell. The diode is recommended to be a 1N5819 Schottky diode. No additional photo sensor is required as the solar cell operates here as a light sensor. The resistor  $R_{LS}$  determines the light threshold at which the LED is automatically switched on (see Threshold voltage  $V_{ON}$  and  $V_{OFF}$  in „SWITCHING BEHAVIOUR“). A typical value of  $R_{LS}$  when using a solar cell is 1.2 M $\Omega$ .

### $R_{LS}$ AS A LIGHT SENSOR

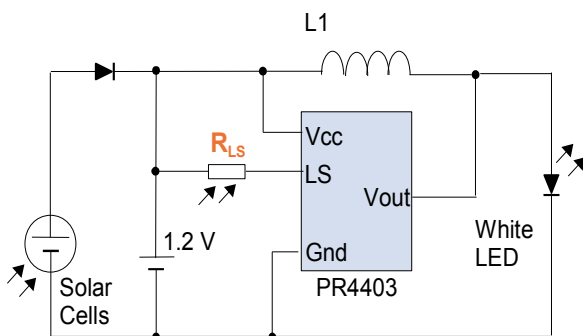


Photo resistor  $R_{LS}$  works as a light sensor

The resistor on the LS pin can be replaced by a photo resistor (for example a CDS resistor) instead of using the solar cell as light sensor.

Depending on the light resistance of the photo sensor an additional series resistor can be connected to the LS pin.

### INCREASING THE THRESHOLD VOLTAGE AT THE LS PIN

A series resistor can be used in case that a higher threshold voltage ( $V_{ON}$ ) is necessary at the LS pin. The resistor can be calculated as follows:

$$R_{LS} = \frac{V_{ON} \cdot R2}{V_{ref}} - (R1 + R2) \quad \text{with}$$

- $R1$ ,  $R2$  and  $V_{ref}$  specified in "Characteristics" (page 2)
- $V_{ON}$ : desired threshold voltage
- $R_{LS}$ : external resistor on the LS pin

For example:

A threshold voltage of 1 V is desired:

$$R_{LS} = 1 \text{ V} \times 400 \text{ k}\Omega / 200 \text{ mV} - (30 \text{ k}\Omega + 400 \text{ k}\Omega) = 1.57 \text{ M}\Omega$$

The following table defines the series resistor at LS:

Threshold Voltage $V_{ON}$	$R_{LS}$
1.9 V	3.3 M $\Omega$
1.0 V	1.5 M $\Omega$
0.72 V	1.0 M $\Omega$
0.4 V	390 k $\Omega$

# LED Driver PR4403

## Application Notes

### SELECTION OF INDUCTORS FOR PR4403

The inductor should be selected according to the required LED current. Using lower inductances than specified 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. 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.

### LED COMPATIBILITY

It must be considered that the peak current through the LED is up to 7 times 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 „Operation of LED with smoothed current (rectifier)“). With most standard LEDs, this will improve the overall performance with inductors of 10  $\mu$ H and less, or mean output currents of 23 mA and more. Note that with the higher currents of PR4403 the current rating of standard LEDs might be exceeded, and more powerful or multiple LEDs should be used.

### CONNECTION FROM BATTERY

Due to high peak currents, it is important to connect the PR4403 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 PR4403. Typically a few 100 nF will be enough. Operating 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 1.9 V 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 22  $\mu$ H or more, depending on the battery type. A capacitor at the supply pins of PR4403 may also improve performance with button cells. Lithium batteries are not suitable due to their higher voltage.

Battery	Lighting Duration (typical)	
	L1= 14.7 $\mu$ H, LED mean current 15 mA	L1= 10 $\mu$ H, LED mean current 23 mA
AA (Mignon, LR 6/AM-3)	40 h	27 h
AAA (Micro, LR 03/AM-4)	16 h	8 h

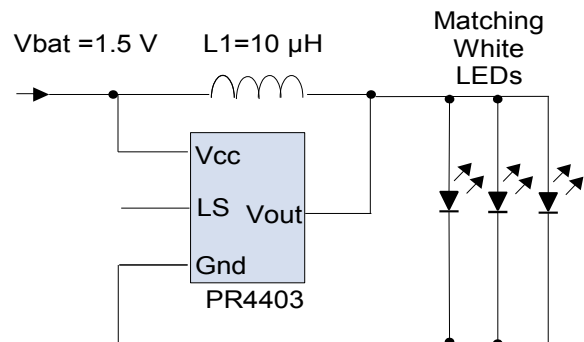
Conditions:  
One white LED connected, measured with single 1.5 V TDK Alkaline battery. Battery lifetime depends on battery capacity and operating conditions. Therefore the times indicated here can only give a rough indication of achievable times.

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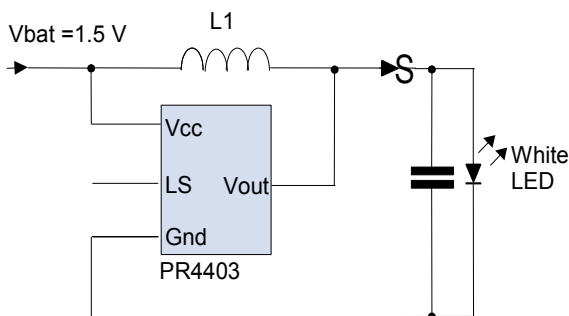
## Application Notes

### 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.



### OPERATION OF A LED WITH SMOOTHED CURRENT (RECTIFIER)



With a diode (preferably a Schottky diode) and a smoothing capacitor at the LED can be buffered. Output current and efficiency are typically higher than without a capacitor, especially in the high-current range, due to different load characteristics. The capacitance must be small enough so that the voltage at the capacitor will exceed a voltage of 2.5 V in the first cycle, otherwise the circuit may not start up. In most cases, values between 100 nF and 1 µF are appropriate. The LS pin is not connected or connected to a light sensor (see above).

### CONNECTING TWO LEDs IN SERIES

It is possible to operate PR4403 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 PR4403 is optimized for operation with white or blue LEDs, it will usually also work with red, green or yellow LEDs, with the following restrictions:

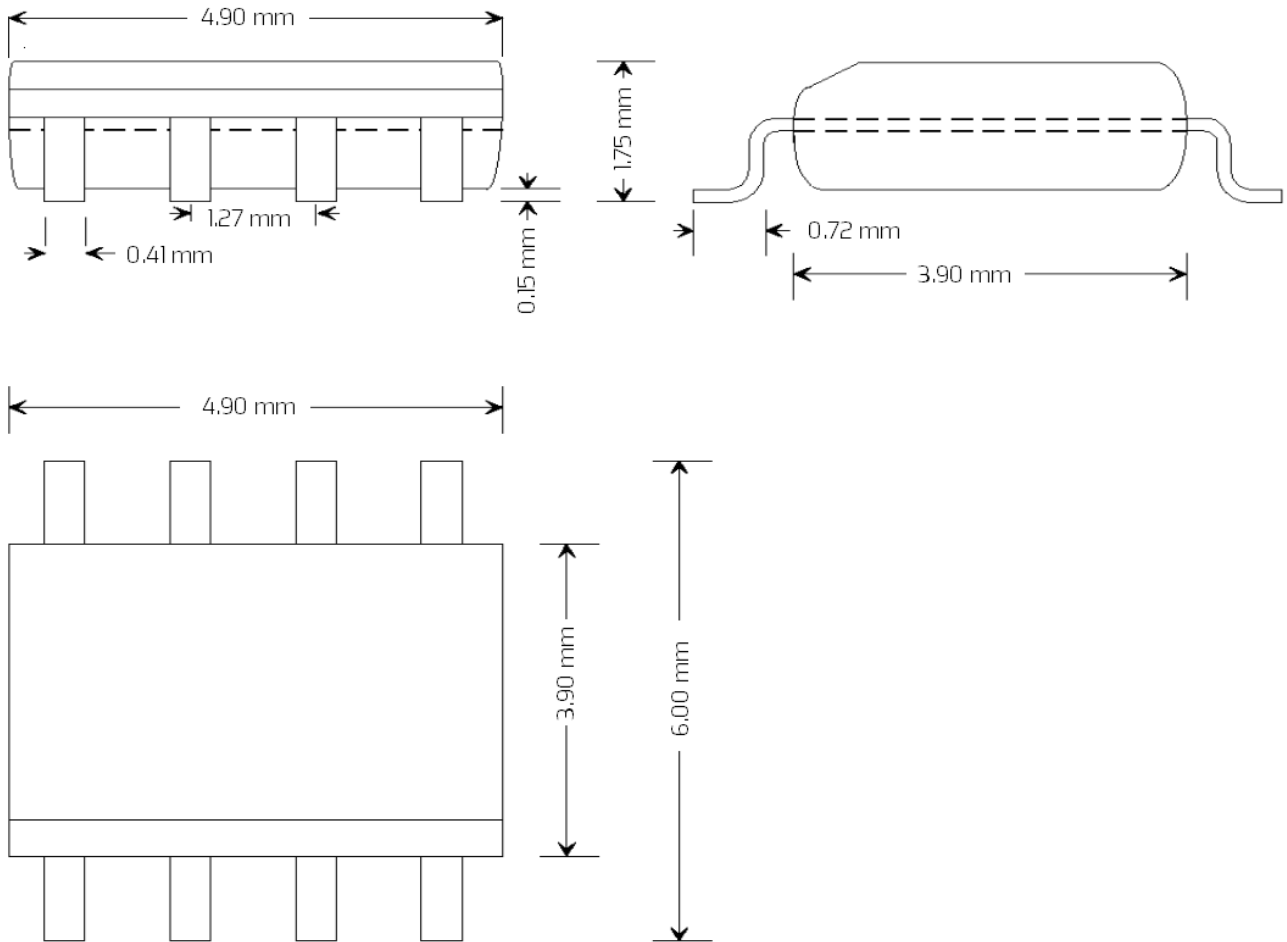
- The LED must build up a sufficient forward voltage to trigger PR4403. Due to the internal resistance of the LED, this condition is usually met. However, no guarantee can be assumed for proper operation under all conditions, and you need to qualify the system yourself
- Due to the different forward voltage level and internal resistance of coloured LEDs, the timing is different, and mean currents are mostly lower than for white LEDs. Also other parameters may deviate from this data sheet.



# LED Driver PR4403

## Available Package

### TECHNICAL DRAWING



PR4403 S08 package in plastic tubes

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



Pb-free



pure tin

# LED Driver PR4403

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