High Power LED Buck Driver PR4101

The PR4101 is a LED driver for an external N-channel MOSFET switching transistor operated by an internal step down converter driving one or several LEDs in series. The supply voltage can be up to 40V, with an output current of more than 1A with an external switching transistor. The PR4101A is delivered in a SOP14 package, while the PR4101B is offered in SO8 package without PWM and PowerDown input.

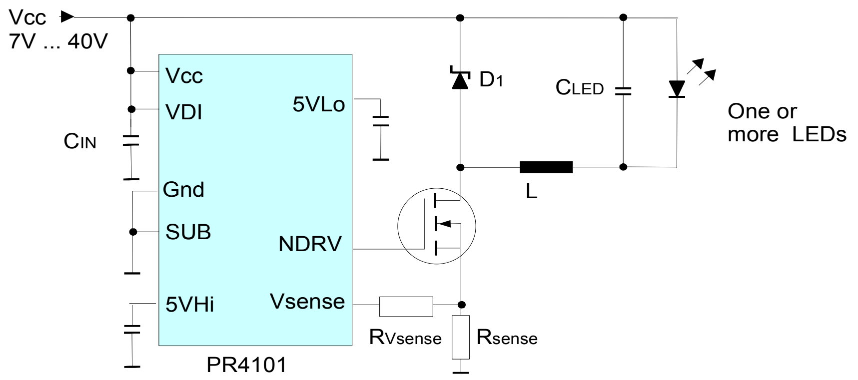
Features

- Adjustable output current of 1A and more
- Supply voltage up to 40V
- Dimming with phase-cut dimmer
- Brightness control with PWM (PR4101A only)
- Output current temperature compensation
- Delayed start possible (PR4101A only)
- Over temperature protection
- Frequency spreading for improved EMI
- Low standby current of < 35 µA
- Under voltage lockout

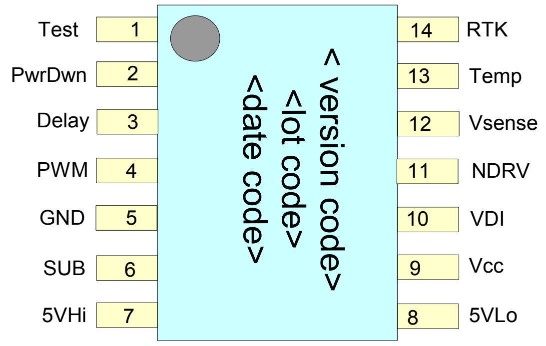
Applications

- Halogen lamp or filament bulb replacement by LEDs
- General illumination
- Warning lights
- Automotive lighting
- Indicator signs
- LCD backlighting

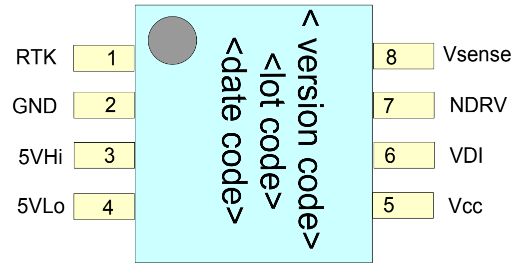
Typical Application



Pin Configurations



PR4101A: Package SOP14
Topside marking: version code "PR4101"



PR4101B: Package SOP8
Topside marking: version code "PR4101B"

Pin Description

Pin No. PR4101A	*Pin No. PR4101B*	*Pin Name*	*Pin Function Description*
1	n.c.	Test	For test and internal use only
2	n.c.	PwrDwn	Power Down, sleep mode for min. power consumption. When connected to GND, NDRV is clamped to GND.
3	n.c.	Delay	Not connected: Delay Start is disabled connected to GND: Delay Start is enabled
4	n.c.	PWM	If $V_{PWM} < V_{refPWM}$ the buck converter is switched off. If $V_{PWM} > V_{refPWM}$ the buck converter is switched on.
5	2	GND	Ground
6	n.c.	SUB	Substrate has to be connected to GND (internally connected for PR4101B)
7	3	5VHi	Internal 5V linear regulator output for high currents. Connect a capacitor of 100 nF to GND. Voltage is not for external use.
8	4	5VLo	Internal 5V linear regulator output for low currents. Connect a capacitor of 100 nF to GND. Voltage is not for external use.
9	5	Vcc	Supply voltage
10	6	VDI	Undervoltage detection pin. If unused, connect to Vcc. For use with phase fired controllers (see application notes).
11	7	NDRV	Gate connection for an external n-channel MOSFET.
12	8	VSense	Feedback for controlling the output current. Connect this pin to the series resistor R_{VSENSE} and the sense resistor R_{SENSE}. The external MOSFET is switched off when the voltage at this pin is higher than V_{SENSE}.
13	n.c.	Temp	Voltage output of the internal chip temperature sensor (over temperature protection). Please see „Electrical Characteristics“ for relationship between V_{TEMP} and the chip temperature T_{CHIP}.
14	1	RTK	Softstart feature and temperature compensation of the output current. By connecting for example a NTC resistor from RTK to GND the sensing threshold voltage Vsense will be decreased depending on the NTC´s temperature. A capacitor C_{SOFT} connected to GND offers a soft ramp up of the LED current.

Absolute Maximum Ratings

Parameter	Min	Typ	Max	Units
VCC, VDI (no damage)	-0.3		50	V
All other pins			14	V
Operating Chip Temperature Range (over temperature protection)	-20		125	°C
Storage Temperature Range	-55		150	°C
Electrostatic Discharge (ESD) Protection	2			kV

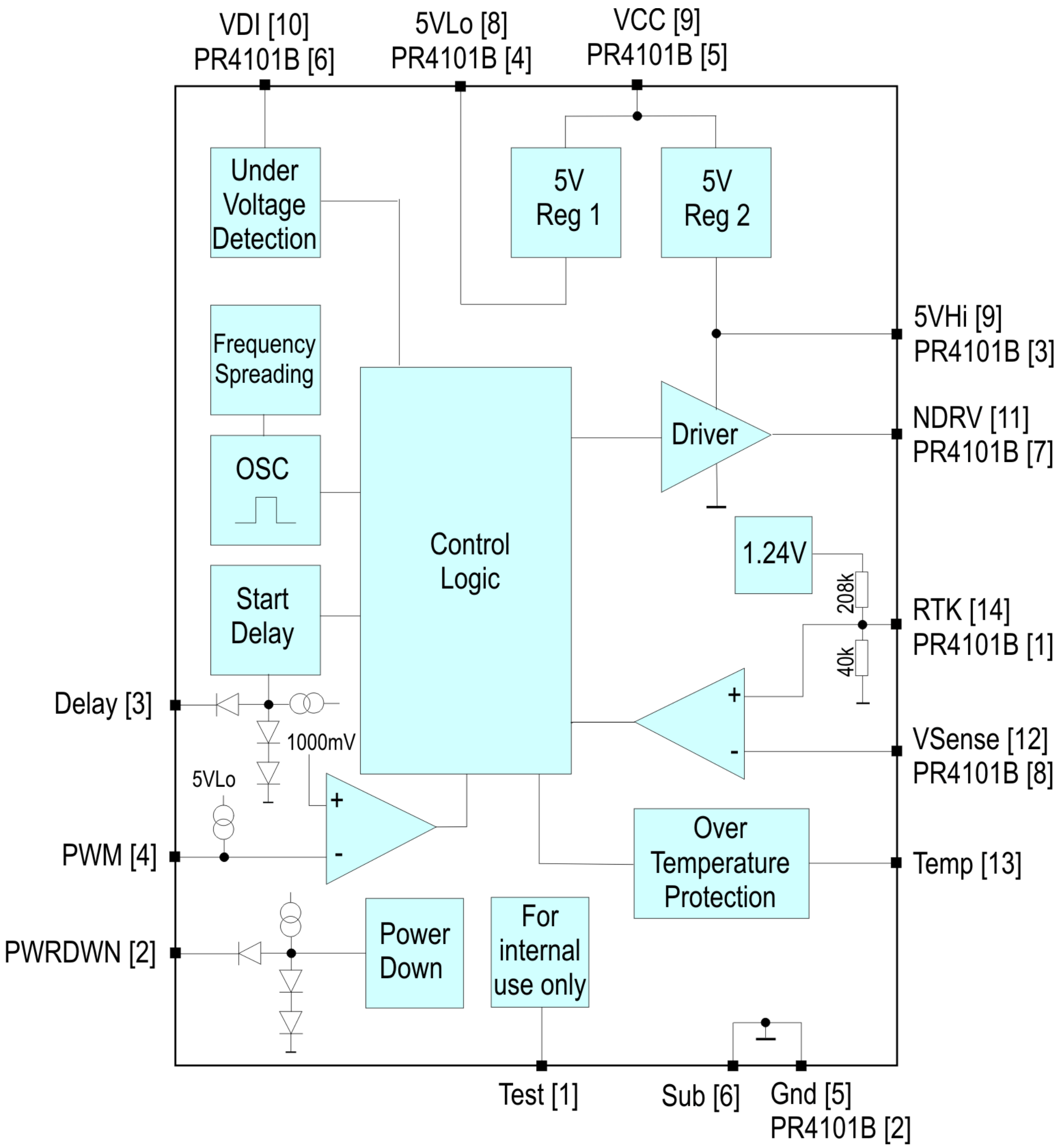
Electrical Characteristics

Vcc=12VDC, Ta = 25°C, L=470 µH (unless otherwise noted)

Symbol	Parameter	Conditions	Min	Typ	Max	Units
Vcc	Supply voltage		7		40	V
VDI	Undervoltage detection Start-up Shut-off		 6.0	 7.0	 9.0	 V V
$I_{suppOFF}$	Supply current, PwrDwn=0V			30		µA
I_{suppON}	Supply current, PwrDwn=open			3.0		mA
V_{NDRV}	Gate output voltage HIGH		3.0	3.8		V
$I_{OUTsource}$	Output source current at NDRV				50	mA
$I_{OUTsink}$	Output sink current at NDRV				20	mA
f_{OP}	Operating center frequency			125		kHz
f_{SP}	Frequency spreading			5		%
V_{SENSE}	Threshold voltage at R_{SENSE}	Pin RTK not connected		200		mV
t_{DELAY}	Delay start period (only PR4101A)			250		µs
V_{RefPWM}	Threshold voltage PWM input (only PR4101A)			1000		mV
f_{PWM}	Frequency of external PWM signal (only PR4101A)				500	Hz
t_{PWM}	Min. pulse duration of PWM (only PR4101A)		2			µs
V_{TEMP}	Output voltage of internal temperature sensor at pin TEMP (only PR4101A)	T_{chip} = 100°C T_{chip} = 0°C		1.60 2.15		V V
T_{OT}	Overtemperature protection junction temperature Shut-off Resume			 125 90		 °C °C

All data are preliminary

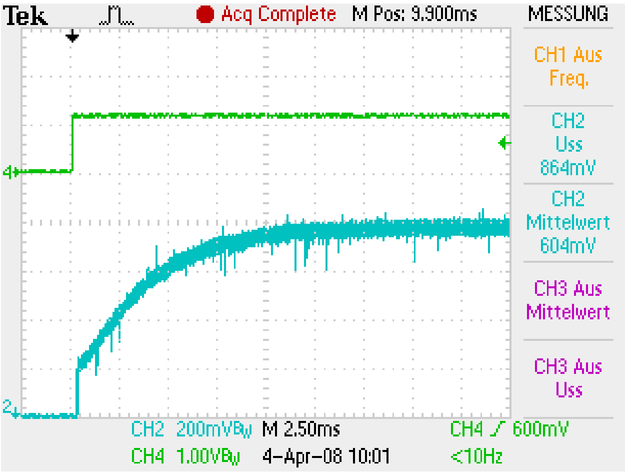
Block Diagram



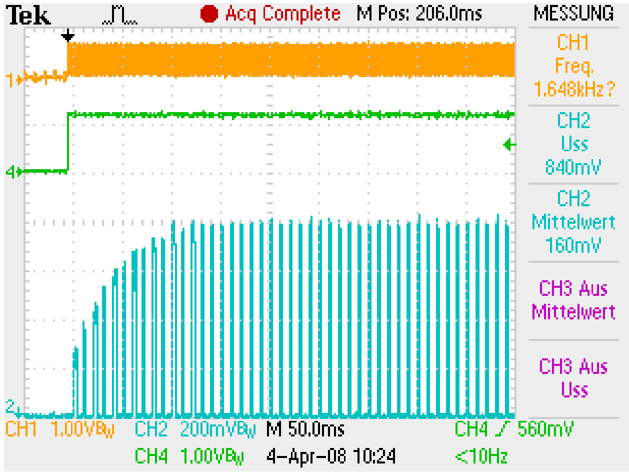
Typical Characteristics
Oscilloscope Displays

C_{IN}=470µF, R_{VSENSE}=1kΩ, C_{LED}=100µF, $C_{5VHi/Lo}$=220nF, L= 470 µH, Vcc=15V, R_{SENSE}=0.25Ω, LED:1x3W Luxeon
(unless otherwise noted)

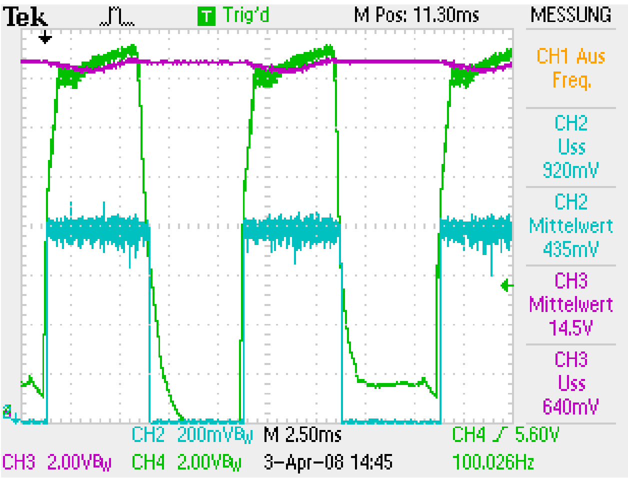
--- Vcc, --- PwrDwn, --- LED current, voltage at a 1Ω resistor, --- clock at test pin (unless otherwise noted)

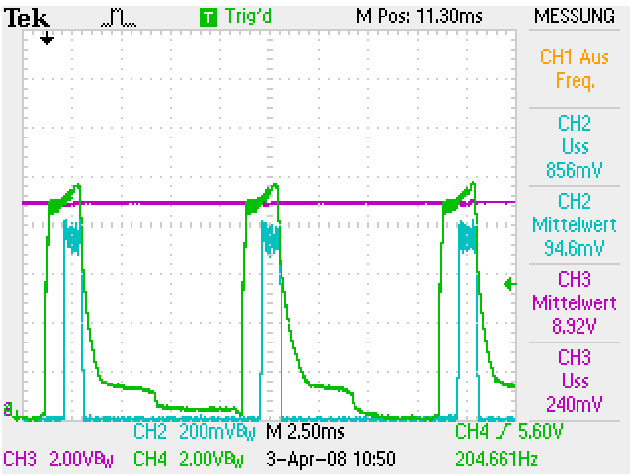


Softstart on RTK, C_{SOFT}=100nF

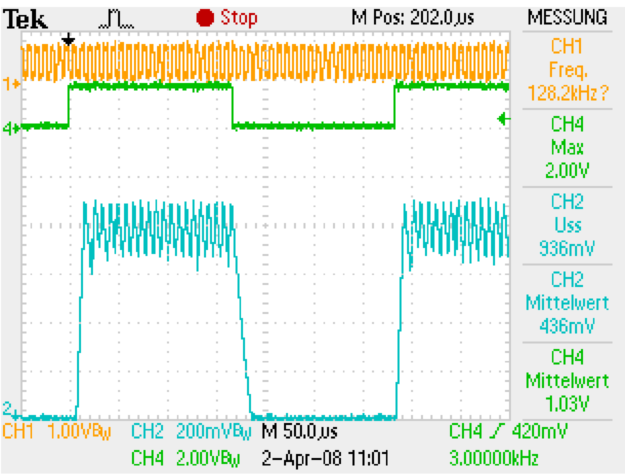


Softstart on RTK, C_{SOFT}=1µF, phase-cut input voltage

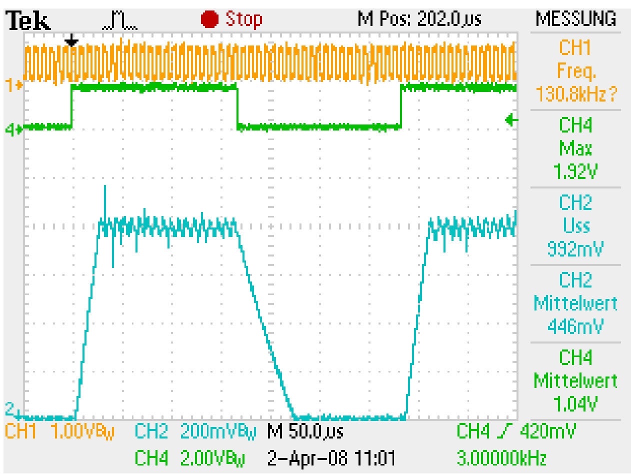




Phase-cut input voltage, C3=2,2nF, R3=100kOhm, C_{IN}: 2000µF, different duty cycles (--- VDI signal)



PWM controlled with L=100µH, duty cycle=50%

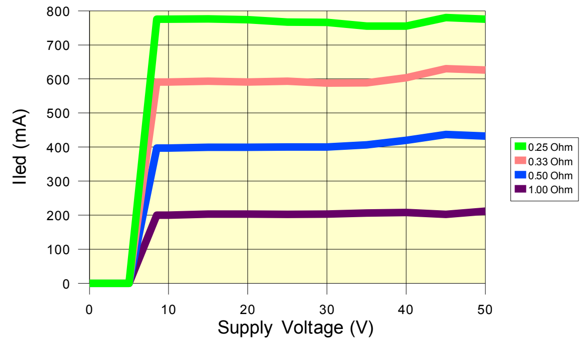


PWM controlled with L=330µH duty cycle=50%

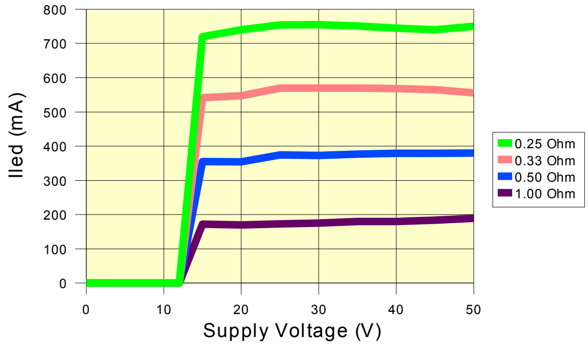
PR4101 data

C_{IN}=470µF, R_{VSENSE} = 1kΩ, C_{LED} = 100µF, $C_{5VHi/Lo}$ = 220nF, L= 470 µH, Vcc=15V (unless otherwise noted)

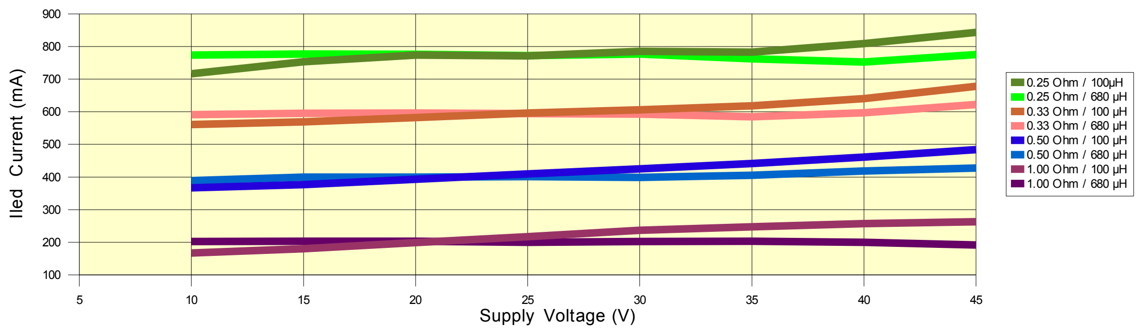
1x3W LED current vs. Supply Voltage



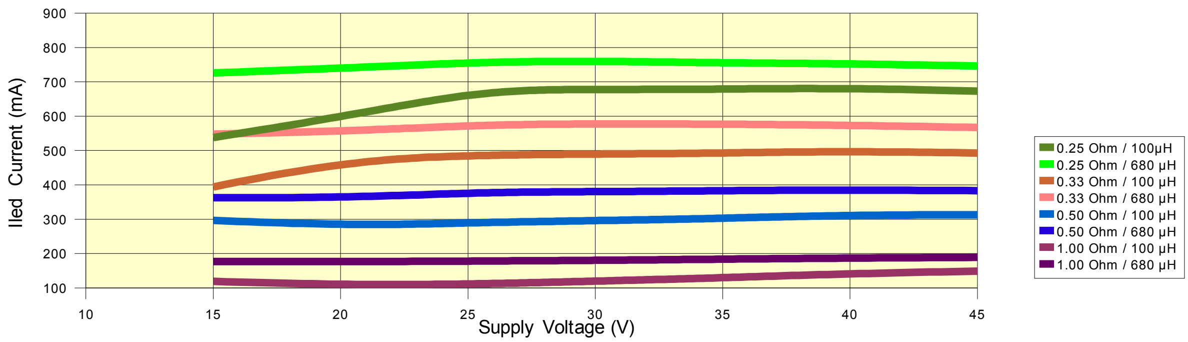
3x3.5W LED current vs. Supply Voltage



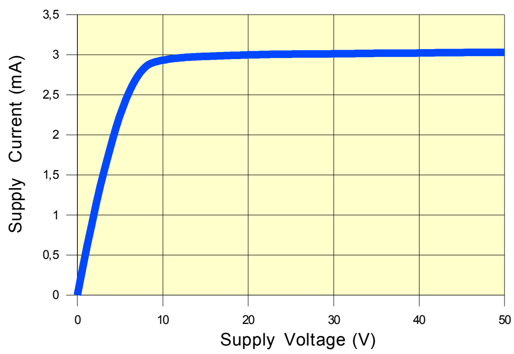
1x3W LED Current vs. Vcc @ L=100µH / 680µH



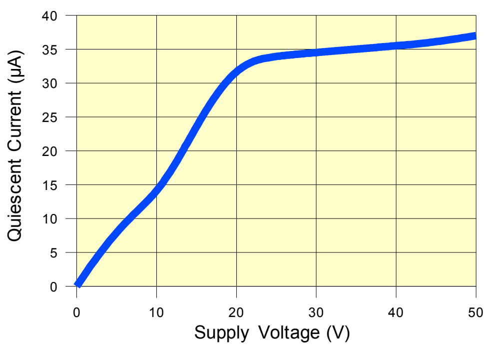
3x3.5W series LED Current vs. Vcc @ L=100µH / 680µH



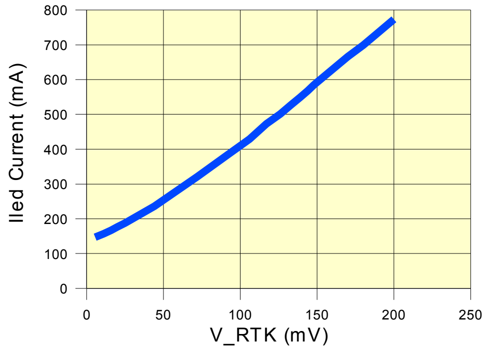
Supply Current vs. Supply Voltage



Quiescent Current vs. Supply Voltage

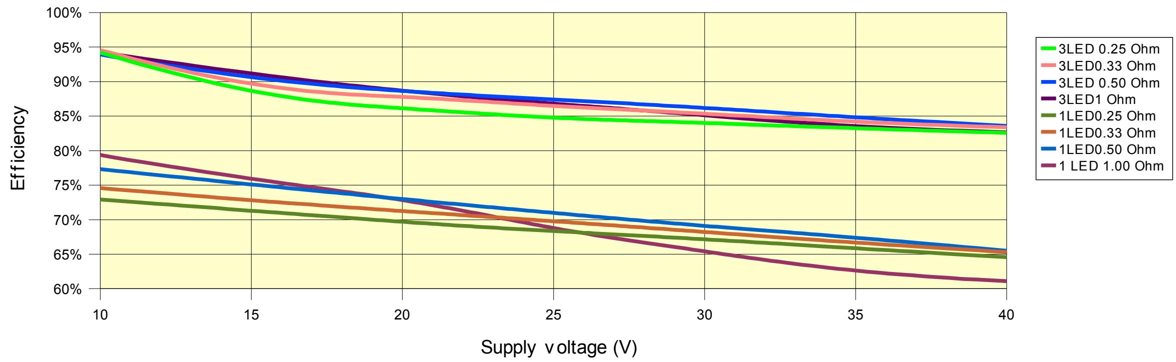


1x3W LED Current vs. V_RTK

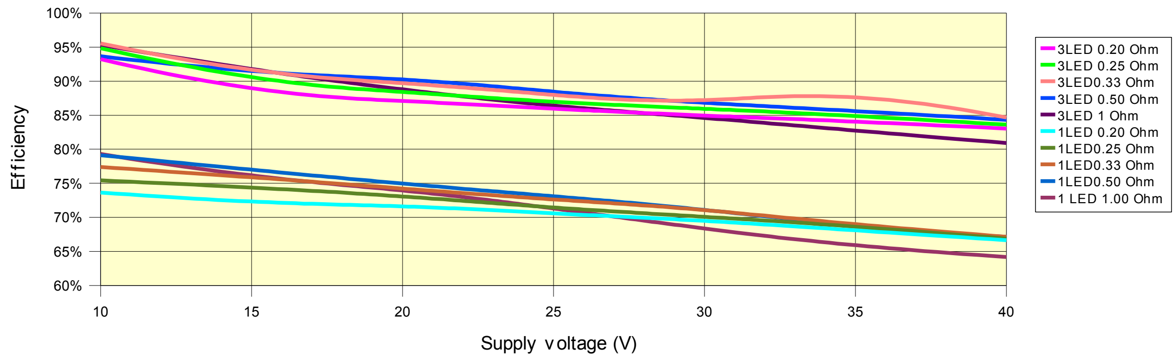


1x3W LED current vs. PWM @ Vcc=40V

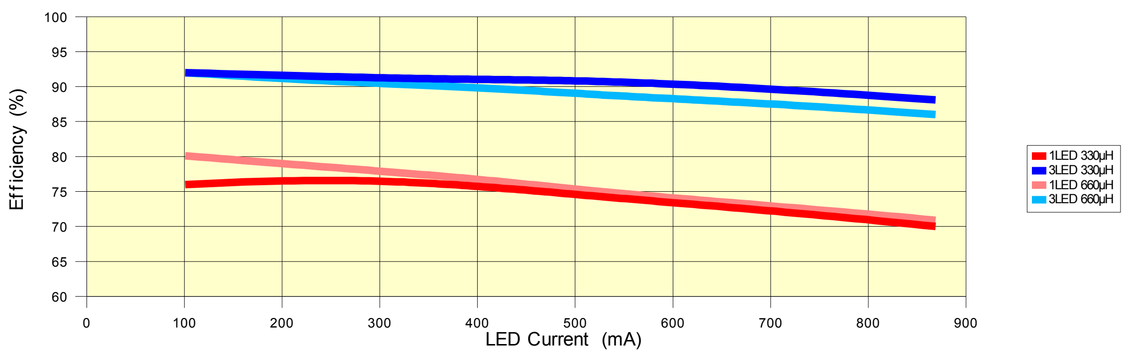
Efficiency 1x3W/3x3WLED vs. Vcc @ L=660µH



Efficiency 1x3W/3x3WLED vs. Vcc @ L=330µH



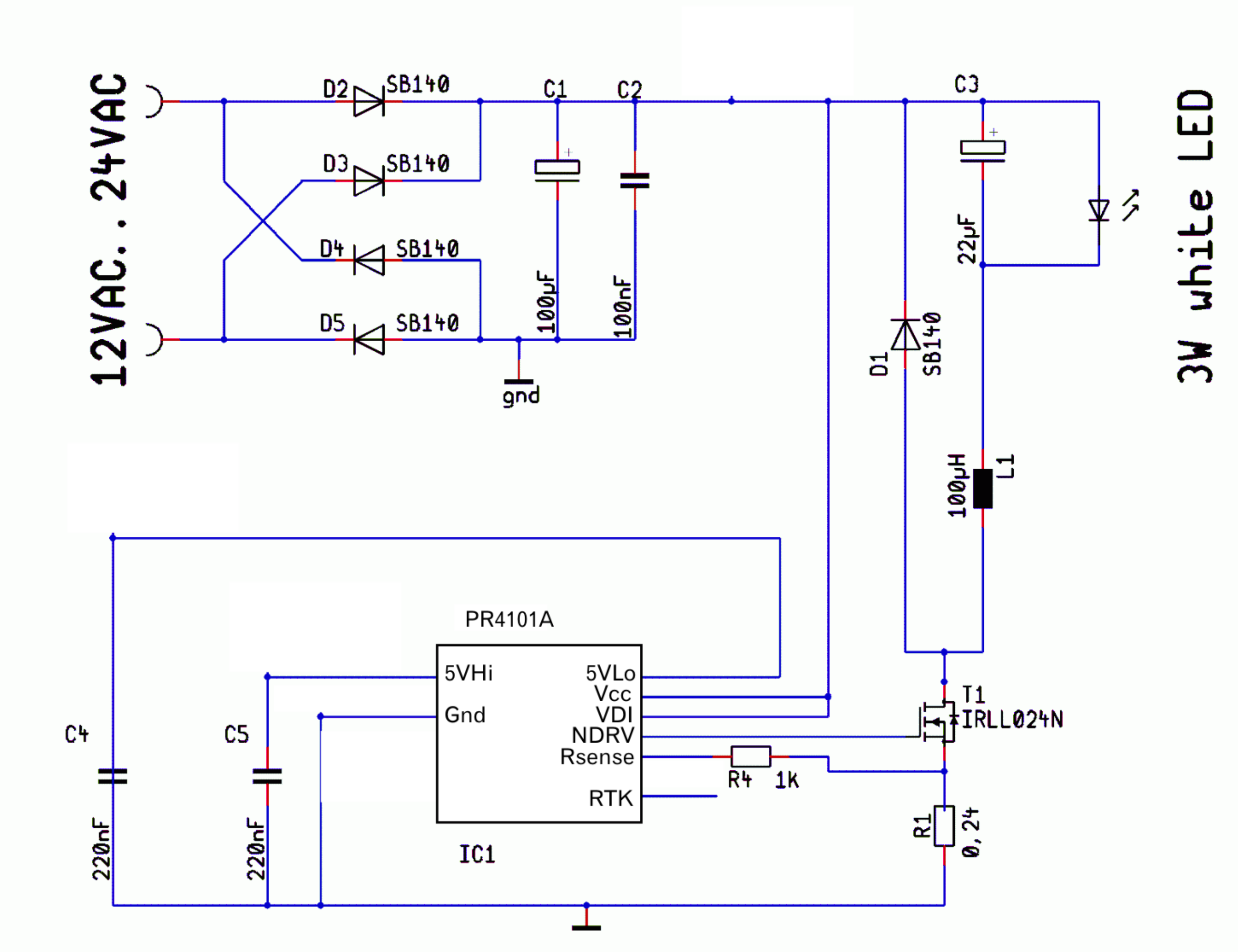
Efficiency vs. LED current @ L= 330 µH / 660 µH



Application Notes

Typical application with 12/24VAC supply for a minimum board size

The following circuit drives one LED from a 12...24VAC supply. This circuit uses the PR4101B in SOP8 package and is optimized for a low number of small-sized external components to have a small PCB.
LED and driver are supplied from the full-wave rectified and smoothed voltage. Ripples on the supply should be small enough to avoid a period in which the voltage becomes lower than the LED forward voltage, or below the undervoltage shut-off (see specification of VDI).
The undervoltage detection pin VDI is connected to Vcc.

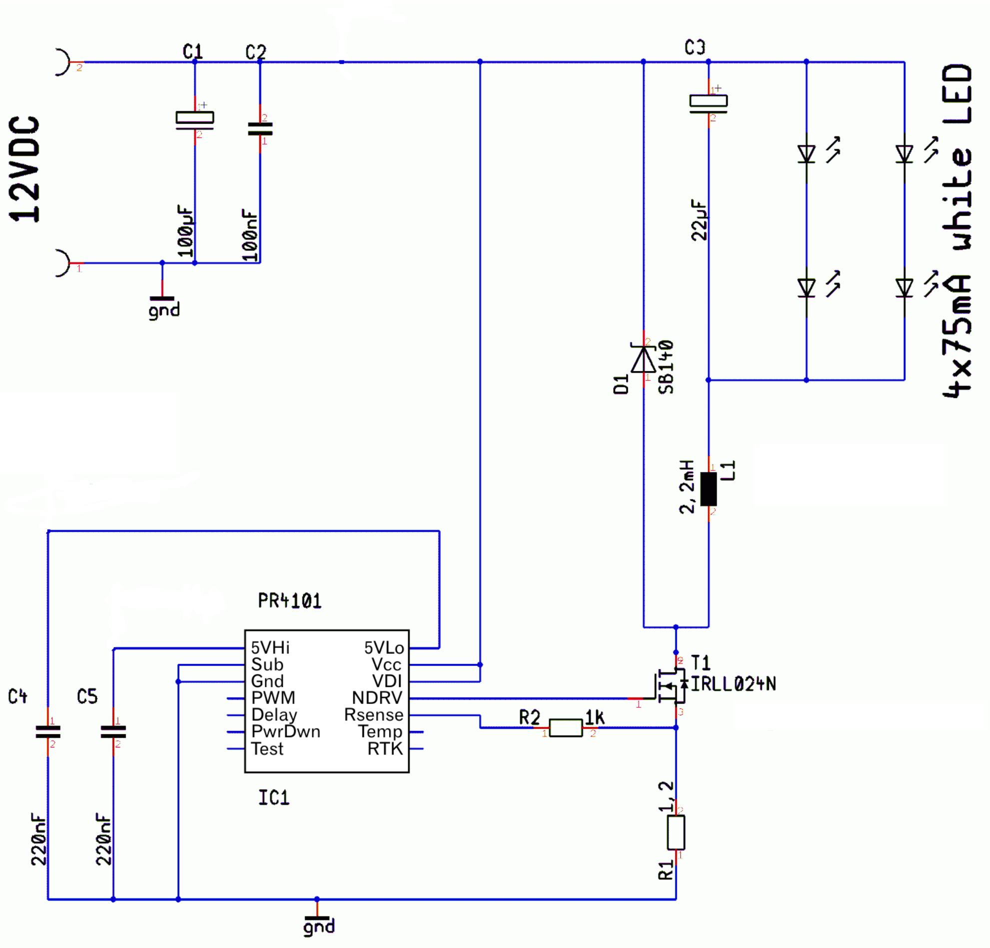


With R_{SENSE} = 0.24Ω as in the diagram, the LED current is approx. 850mA. For other currents see below **Selection of R_{SENSE}**.

Typical application with 12VDC supply

The circuit shown drives 2 strings of 2 LEDs in series from a 12 VDC supply.

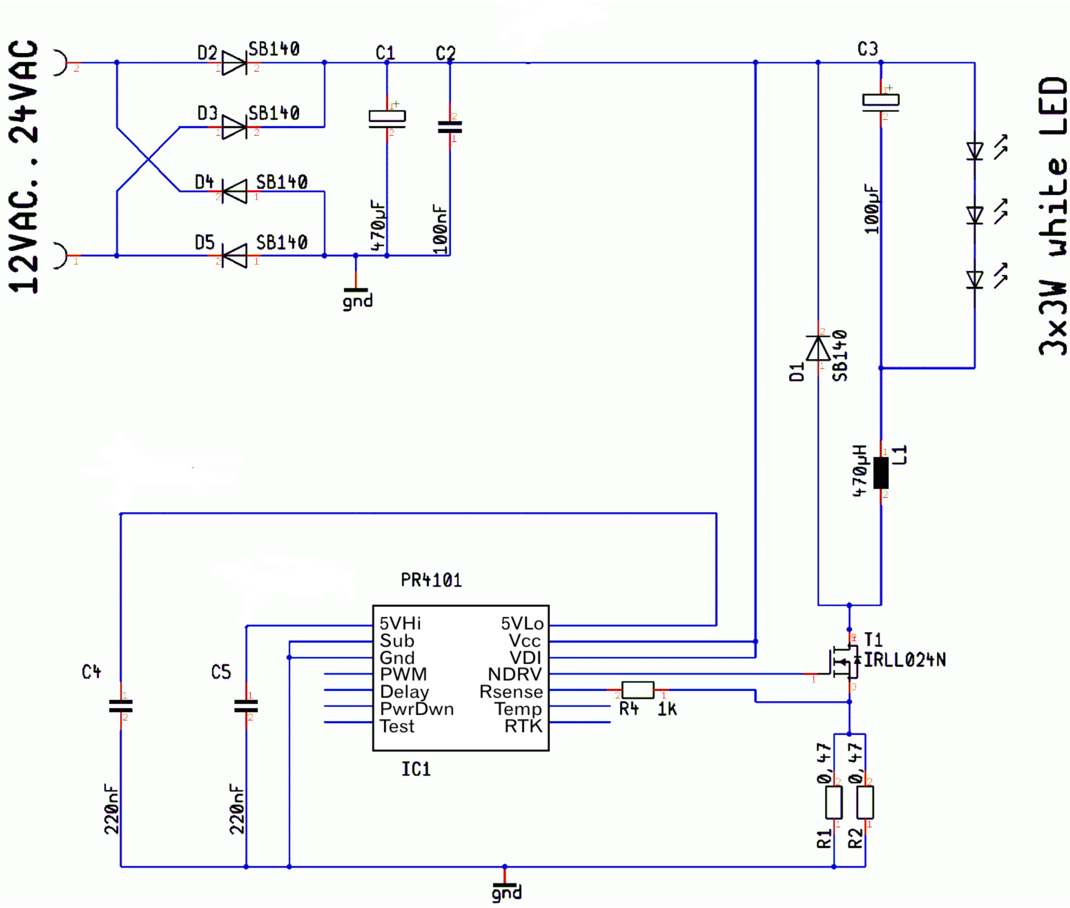
The minimum supply voltage is given by the forward voltage of the LEDs, the DC resistance of the inductor, and the R_{DSon} of the FET.
As a rule of thumb, in most cases the supply voltage should be at least 2V higher than the forward voltage of the LEDs.
Assuming a V_F of 3.5V per LED, this means that the circuit will work with a supply of 9V and higher.



As there are two strings of LEDs in parallel, the forward voltage of the LEDs must be matching to avoid an unequal current distribution.

Typical application with 12VAC supply

The following circuit drives three LEDs in series from a 12...24VAC supply.
LED and driver are supplied from the full-wave rectified and smoothed voltage.
Ideally, after the full-wave rectifier, Vcc is VAC x √2, which is sufficient to drive three LEDs in series from VAC=12V. Ripples on the supply should be small enough to avoid a period in which the voltage becomes lower than the LED forward voltage, or below the undervoltage shut-off (see specification of VDI).
The undervoltage detection pin VDI is connected to Vcc.

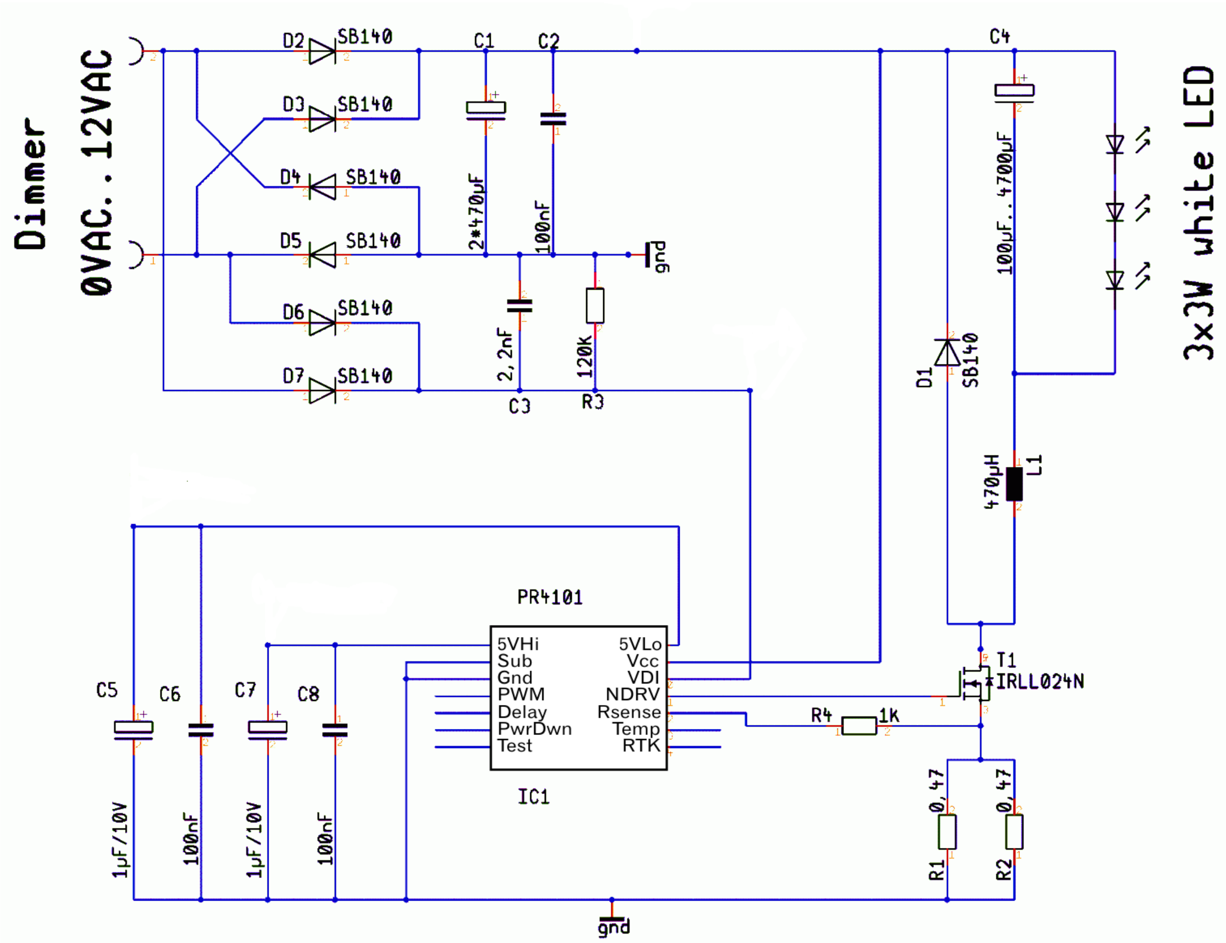


With R_{SENSE} = (0.47/2) Ω as in the diagram, the LED current is approx. 850mA. For other currents see below **Selection of R_{SENSE}**.

Typical application with 12VAC supply and phase cut dimmers

The circuit shown next allows dimming with phase-fired control by a conventional thyristor dimmer, operation with electronic dimmers and electronic transformers is also possible. The PR4101 is dimmable with leading and trailing edge phase control. In this application the undervoltage detection pin VDI is connected to the rectified, but unsmoothed AC, allowing to sense the pulse width of the phase-cut supply.
In this way the converter is shut off in the phase cut out by the phase fired controller, even if the smoothed supply at Vcc holds a sufficient voltage level, and the LED brightness is dimmed in a way similar to that of a conventional filament bulb.

Even without phase cutting, there is a period in which VDI falls below the undervoltage shut-off threshold, shutting the LED down in this period until the voltage reaches the startup threshold again. Therefore in the application shown the effective LED current is reduced against the circuit with VDI connected to the smoothed DC supply, e.g. at 12VAC/ 50Hz it is 68% of the nominal brightness.



Cutting at large phase angles, especially >90°, will reduce the supply voltage for the circuit. If it falls below the forward voltage of the LEDs, or below the undervoltage threshold, the circuit will stop working.
C3/R3 serves as a filter for high frequencies, e.g. from power supplies with switching regulators, that would interfere with the regulator loop of PR4101.

PWM Control (only PR4101A)
Brightness can also be controlled by an external PWM (pulse width modulation) signal via the PWM pin.
In this way a large dimming range can be achieved. The device will be turned off and on depending on the duty cycle of the control signal resulting in a proportional average output current. The PWM pin can be driven directly from a micro controller output or with a NPN transistor. The average output current will be

$I_{LED\,AVG} = I_{LED\,nom} \cdot D$ with the duty cycle D: $D = \frac{T_{OFF}}{(T_{ON} + T_{OFF})}$

A PWM frequency of 500 Hz, or lower is recommended, to minimize errors due to the rise an fall times of the converter output.

Selection of the input capacitor C_{in}
The input capacitor is necessary in case of AC supply voltages to smooth the supply voltage. A value between 100µF and 4,700µF for normal AC and of 470µF up to 10,000µF for phase-cut supply voltages is recommended.
In parallel a 100nF capacitor should be placed close to the IC supply pins.
Step-down regulators draw current from the input supply in pulses with very fast rise and fall times. The input capacitor is also required to reduce the resulting voltage ripple at the PR4101 input and to force this switching current into a tight local loop, minimizing EMI. The input capacitor must have a low impedance at the switching frequency to do this effectively, and it should have an adequate ripple current rating.

Selection of inductor and C_{LED}
Selection of the inductor value depends a lot on the supply voltage, the number of connected LEDs, but also on the allowed current ripple and the desired efficiency. For a smaller LED current higher values above 660µH should be used. In case that a minimized board size is desired inductor values around 100µH may be selected but efficiency and LED current ripple are not optimized in this case. The saturation current of the inductors must be higher than the LED peak current. A low DC resistance of the coil avoids additional loss of efficiency.

A capacitor value of C_{LED} between 22µF and 1000µF in parallel to the LED is recommended to reduce the LED current ripple and avoid exceeding the LED current rating.

Selection of external MOSFET
The n-channel MOSFET must have a gate threshold voltage of less than 3V and a low ON resistance. A recommended transistor is the International Rectifier IRLL024N.
To improve the behaviour of the module, long lines between the IC and the transistor should be avoided.

Selection of the external diode

A Schottky diode with fast recovery is needed to reduce the voltage drop. The diode must be able to carry the LED current flowing during the OFF time of the driver. The reverse voltage of the diode should be higher than the input voltage.

Selection of R_{VSENSE} and R_{SENSE}

The input V_{SENSE} needs a series resistor $\mathbf{R_{VSENSE}}$ = 1 kΩ while the LED current is defined by the selection of R_{SENSE}.
The nominal value of the current sense resistor can be calculated with the following formula:

$$R_{SENSE}=\frac{V_{SENSE}}{I_{LED}}$$

The value of V_{SENSE} can be found in the „Electrical Characteristics".
For example: With an LED current of 1A and V_{SENSE}=200mV, R_{SENSE} has a value of 200mΩ. The following table gives some resistor values

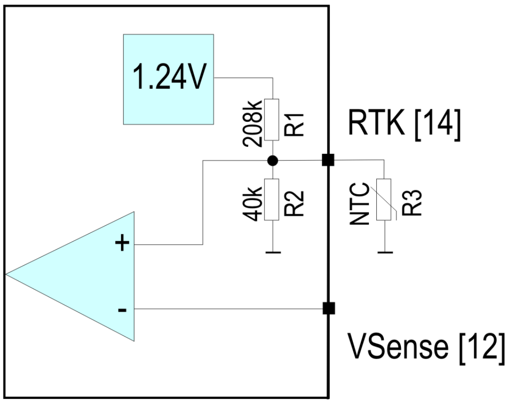
LED Current	R_{SENSE}
350 mA	0.571 Ω (0.56 Ω)
700 mA	0.286 Ω (0.56 Ω II 0.56 Ω)
1A	0.200 Ω (0.22 Ω)

(closest resistor value of E12 series in brackets)

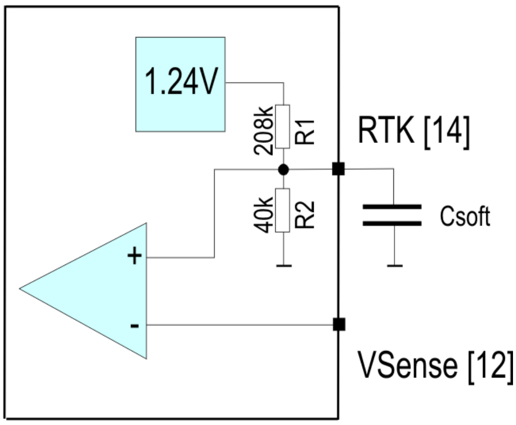
Delay start feature (Delay, only PR4101A)

A delayed start is possible by connecting the pin Delay to Gnd. Within the delay start period the output current is switched off. After the delay start period the output current rises to 100% of the nominal current. The delay start period is fixed and cannot be changed by external components.

Temperature compensation of the output current
High brightness LEDs often need to be supplied with a temperature compensated current in order to get a stable and reliable operation also at higher temperatures. This is normally achieved by reducing the LED current proportionally from its nominal set value when the LED temperature rises above a predefined threshold. For this thermal compensation a NTC resistor at the RTK pin can be used to sense the temperature. The NTC value has to be selected according to the application requirements. A nominal value around 470 kΩ is recommended.



Softstart
With an external capacitor at RTK the output current can ramp up continuously within a programmable period.



The following table gives some capacitor values

Soft Start Time	***C_{SOFT}***
10 ms	100 nF
100 ms	1 µF
3 s	22 µF

It is possible to combine temperature compensation and softstart functionality.

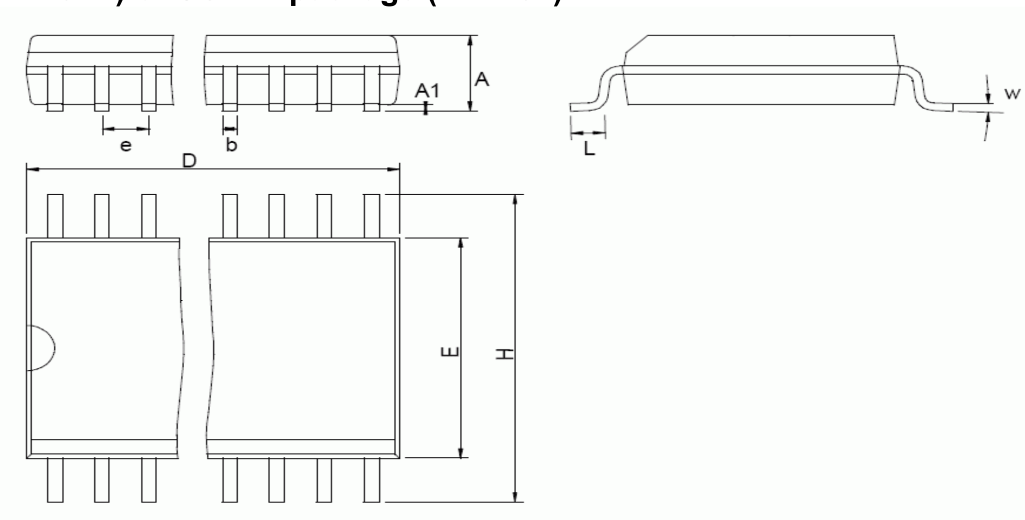
Over Temperature Protection (only PR4101)
An internal temperature sensor detects the chip temperature. Over temperature is detected at T_{OFF}, then the NDRV and the 5VHi-regulators are switched off and switched on again at a chip temperature of T_{ON}. The voltage V_{TEMP} at the pin TEMP relates to the internal chip temperature, please see „Electrical Characteristics".

Operation with insufficient voltage
If due to insufficient supply voltage in comparison to the LED forward voltage the current that can flow through the LEDs in DC mode is lower than the current programmed for the converter, the MOSFET is permanently switched through. Some features like PWM control do not work in this mode.
The converter can however be safely switched off with the PwrDwn signal.

Frequency Spreading
To reduce the EMI of the converter the switching frequency is varied in a range around the center frequency. This decreases the EMI power density that is otherwise concentrated at a single clock frequency.

Available Packages

SOP8 (PR4101A) or SOP14 package (PR4101)



Package		*D*	*E*	*H*	*A*	*A1*	*e*	*b*	*L*	*Copl.*	*w*
SOP 08L **PR4101A**	Nom max	4.90	3.90	6.00	1.75	0.15	1.27	0.41	0.72	0.10	4°
SOP 14L **PR4101**	Nom max	8.65	3.90	6.00	1.75	0.15	1.27	0.41	0.72	0.10	4°

Delivery in die form upon request.
All parts delivered comply with RoHS. Finish is pure tin.

Pb-free **pure tin**

Disclaimer
Information provided by PREMA is believed to be accurate and correct. However, no responsibility is assumed by PREMA for its use, nor for any infringements of patents or other rights of third parties which may result from its use. PREMA reserves the right at any time without notice to change circuitry and specifications.

Life Support Policy
PREMA Semiconductors products are not authorized for use as critical components in life support devices or systems without the express written approval of PREMA Semiconductor. As used herein:
1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.
2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

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