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RYC9906
High Power LED Boost

Document: SCD 25567
Status: Released
Rev. Letter: B
Rev. Date: March 8, 2005

GENERAL DESCRIPTION

The RYC9906 device is a low-cost integrated boost converter IC specifically designed for driving high power LEDs. It can be operated from a single Lithium cell or two alkaline cells, and drives up to 5W of LEDs. The RYC9906 device regulates at constant current, yielding constant illumination over input voltage. The RYC9906 device features an active low enable pin and thermal protection, and is available in an SO-8 package.

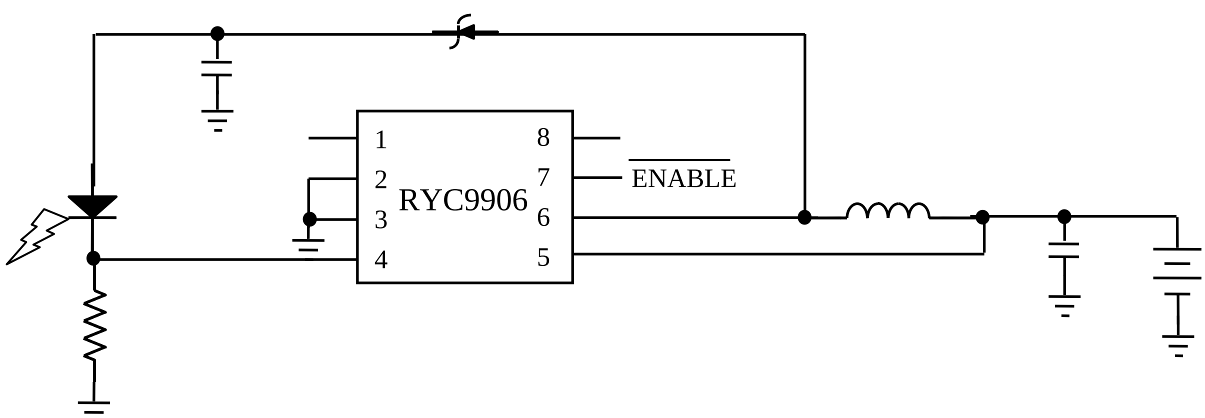
FEATURES

- Constant current regulation
- Up to 5W output power
- 1.9V to 5.5V input voltage range
- 25V maximum output voltage
- 1μA maximum shutdown current
- SO-8 package

APPLICATIONS

- Flashlights
- Electric vehicle headlights
- Portable lighting

TYPICAL APPLICATION SCHEMATIC



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ORDERING INFORMATION

Part Description	Part Number	Package	Tape and Reel Quantity
RYC9906	A39770-000	8-lead SOIC	2,500 pcs

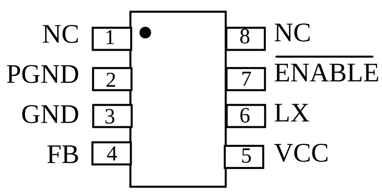
MATERIAL INFORMATION

ROHS Compliant — Directive 2002/95/EC Compliant

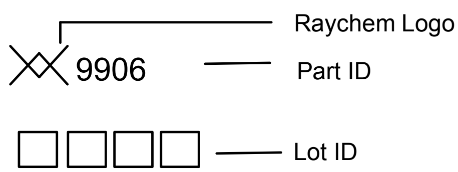
ELV Compliant — Directive 2000/53/EC Compliant

Pb-Free

PIN CONFIGURATION



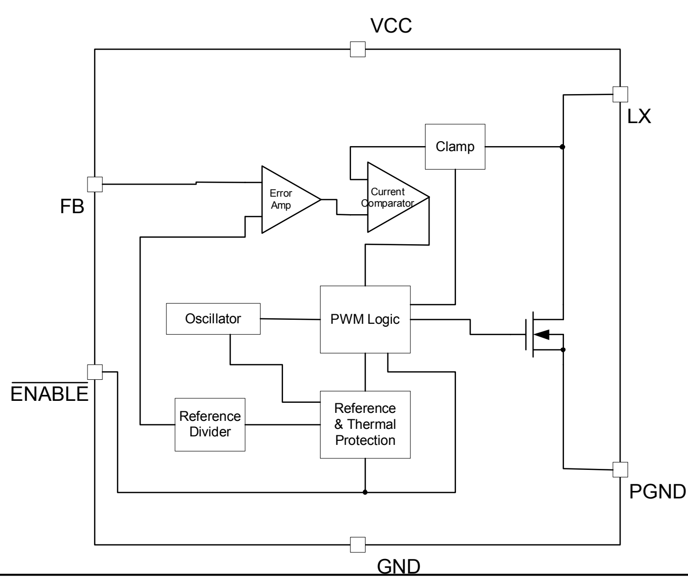
DEVICE MARKING



PIN DESCRIPTION

Pin Number	Pin Name	Pin Function
1,8	NC	**No Connect.**
2	PGND	**Power Ground.**
3	GND	**Ground.**
4	FB	**Feedback.** This pin is the feedback to the PWM to control the output current. Attach to a current sense resistor.
5	VCC	**VCC.** Battery input to run the IC.
6	LX	**Switch Node.** Connection to internal power MOSFET. Attach to inductor and diode.
7	$\overline{\text{ENABLE}}$	**Enable.** A logic low turns on the converter. A logic high or open turns off the converter. A PWM signal on this pin dims the output.

BLOCK DIAGRAM



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ABSOLUTE MAXIMUM RATINGS (Notes 1, 2)

Parameter	Min	Max	Units
VCC to GND	-0.3	+6.5	V
Lx to GND	-0.3	33	V
All Other Pins to GND	-0.3	VCC + 0.3	V
Continuous Power Dissipation (70°C) (Derate 8.7mW/°C above 70°C)		565	mW
Ambient operating temperature	-40	+85	°C
Storage temperature		– 65 to +150	°C
Max lead temperature during soldering (5 sec.)		260	°C

Note 1. Operation beyond absolute maximum rating or improper use may result in permanent damage to the device. Exposure to absolute maximum rating conditions for extended periods or to conditions beyond absolute maximum rating conditions may adversely affect device reliability. Functional operation under absolute maximum rating conditions is not implied.

Note 2. Devices are ESD sensitive. Handling precautions recommended. This device is rated at HBM ±2.0 kV.

ELECTRICAL CHARACTERISTICS

(Vcc = +3.5V, TA = 25°C, using circuit in Figure 1, unless otherwise noted)
(The • denotes specifications which apply over the full operating temperature range.)

Parameters	Condition		Min	Typ	Max	Units
VCC						
Supply voltage			1.9		5.5	V
Supply Current Disable Supply Current	V_{ENABLE} = 0V V_{ENABLE} = 3.5V			150 0.15	260 0.55	µA µA
ENABLE						
Threshold	Low-to-High High-to-Low	• •	 0.8	1.3 1.3	1.8	V V
Input Current	V_{ENABLE} = 0V V_{ENABLE} = 3.5V	• •	 -1	0.05 -0.05	1	µA
Turn-on Time				200		µs
LX						
LX Voltage					25	V
Switch Resistance				860		mΩ
Current Limit			1300		1900	mA
Current Limit Temperature Variation		•		±10		%
FB						
Feedback Voltage			300	340	370	mV
Feedback Voltage Temperature Variation		•		±5		%
Other						
Switching frequency			60	85	110	kHz
Frequency Temperature Variation		•		±10		%
Maximum Duty Cycle				75		%
Thermal Shutdown				135		°C
Thermal Shutdown Hysteresis				10		°C

RYC9906
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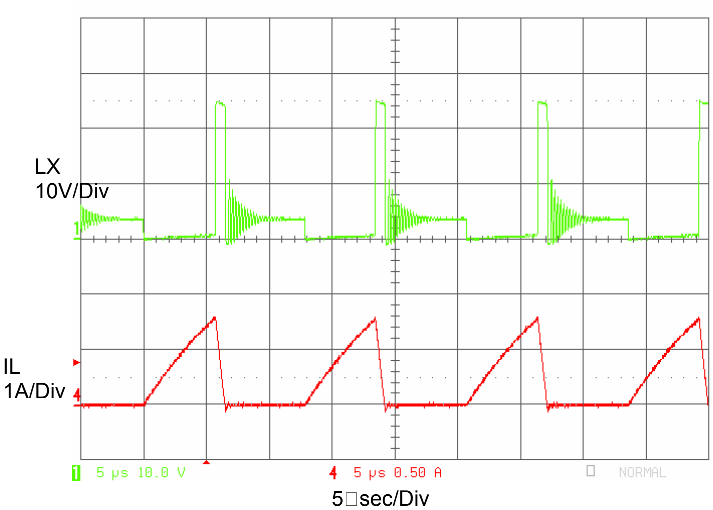
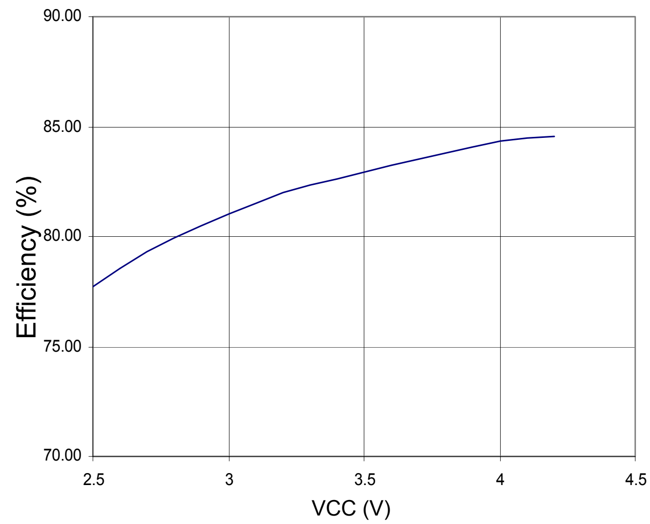
TYPICAL CHARACTERISTICS

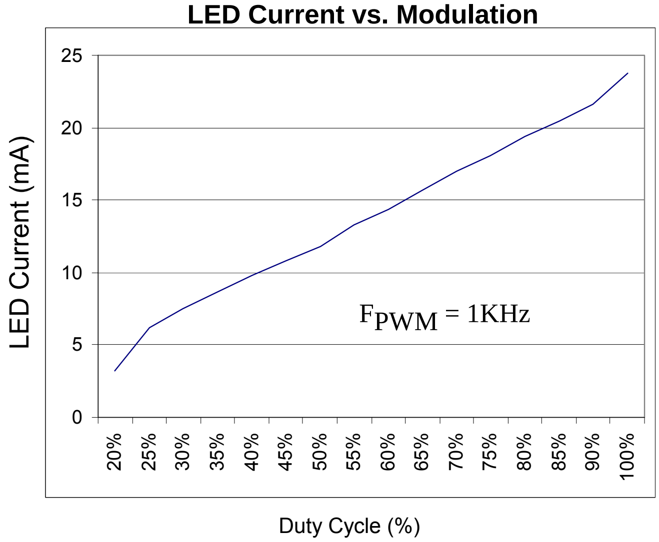
Switching Waveforms, Pout = 1W



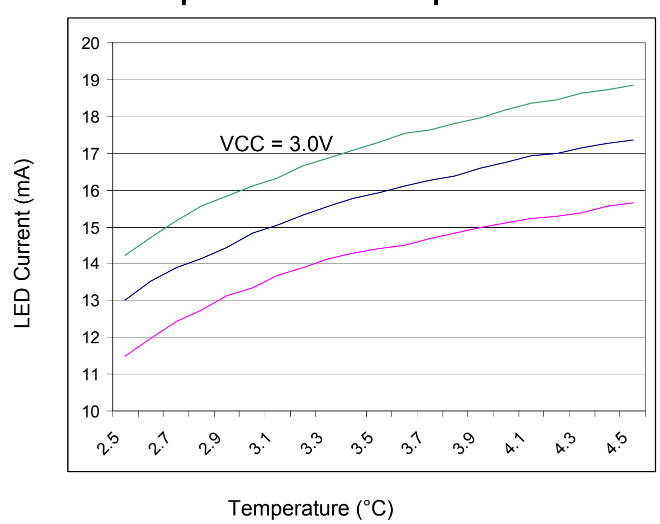
Efficiency, 1W Super-Bright White LED



LED Current vs. Modulation

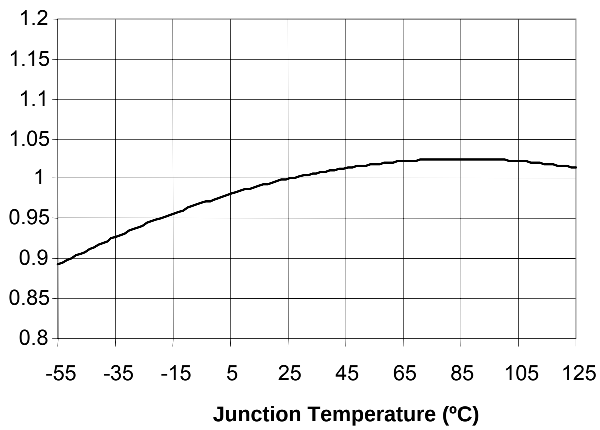


Output Current vs. Temperature

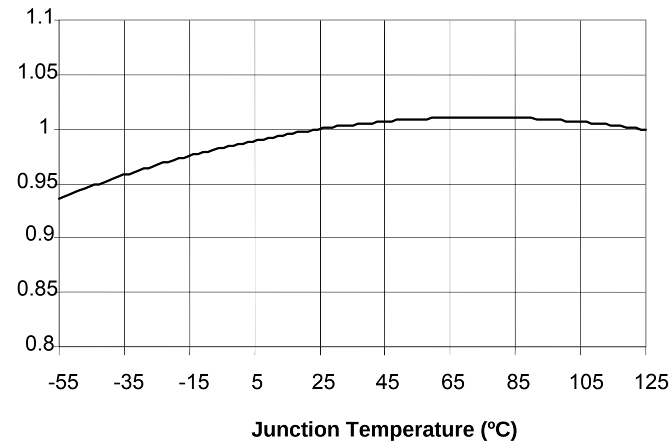


TYPICAL CHARACTERISTICS (CONT)

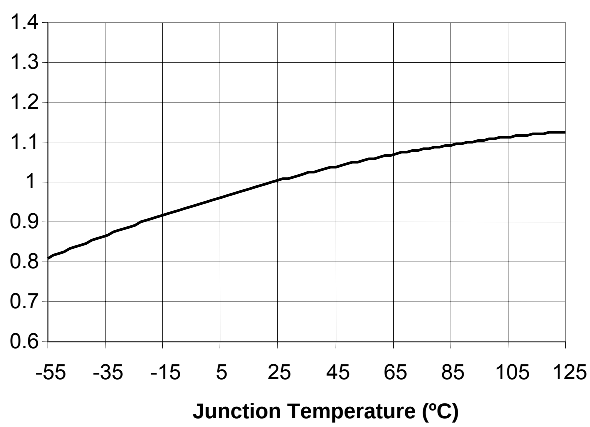
Frequency Normalized at 25°C



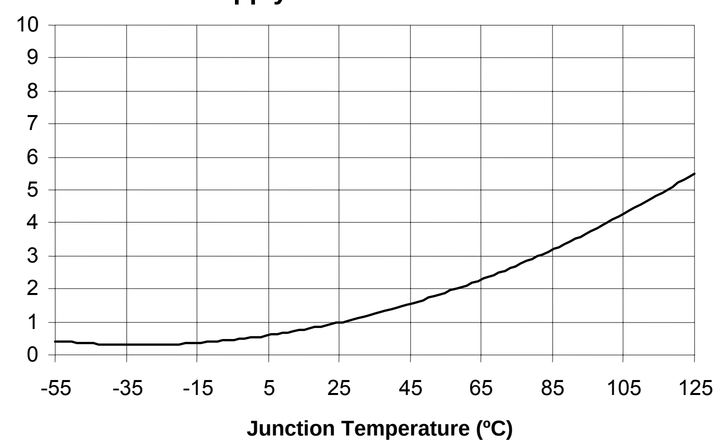
Feedback Voltage Normalized at 25°C



Supply Current Normalized at 25°C



Disable Supply Current Normalized at 25°C



APPLICATION CIRCUIT

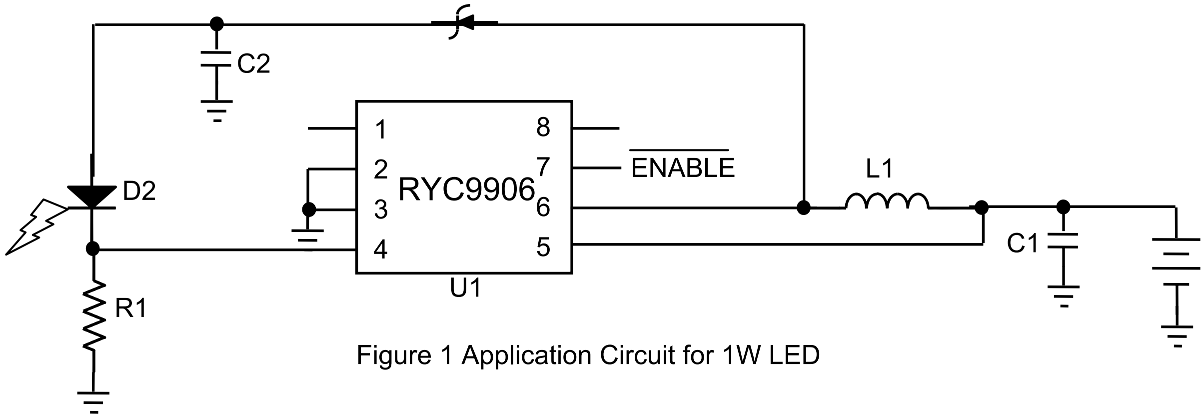


Figure 1 Application Circuit for 1W LED

TABLE 1. APPLICATION BILL OF MATERIALS FOR FIGURE 1

Reference	Manufacturer Example Part #	Quantity	Description	Notes
C1	Any	1	10μF, 6.3V Aluminum Electrolytic Cap	
C2	Any	1	100μF, 6.3V Aluminum Electrolytic Cap	
D1	Fairchild MBRS130	1	1A, 30V Schottky	
D2	Lumileds M	1	1W Super-Bright White LED	
R1	Any	1	1Ω, 1/4W	
L1		1	10μH, mΩ	I_{SAT} > A
U1	Raychem RYC9906	1	High Power LED Boost IC	

APPLICATION INFORMATION

The RYC9906 device is a low-cost integrated boost converter IC specifically designed for driving high power LEDs. It can be operated from a single Lithium cell or two alkaline cells, and drives up to 5W of LEDs. The RYC9906 device regulates at constant current, yielding uniform illumination. The RYC9906 device features an active low enable pin and thermal protection, and is available in an SO-8 package

Startup

The RYC9906 device does not require a soft-start. It has a current limit on the LX pin that is designed to avoid damage to the IC even by a short circuit. At startup, then, it simply runs at maximum current until the output capacitor is charged, at which time it enters normal operation.

Normal Operation

In normal operation, the RYC9906 device is intended to be operated as a discontinuous conduction mode non-isolated flyback converter. It boosts the input voltage to another DC voltage, which then passes through the LED and a sense resistor. The current is regulated by measuring the voltage across the sense resistor, and regulating the DC output voltage to be such that the voltage across the sense resistor is 340mV.

Input Capacitor

It may be desirable to include an input capacitor to this circuit. Even when the input to the converter is a battery, batteries have limited ability to source high-frequency currents. Thus, there may be significant voltage drops at the input unless an input capacitor is used.

The input capacitor must be rated to take the AC ripple current, which is given by:

$$I_{rms} = \sqrt{\frac{\sqrt{2}P}{3V_{in}}\left[\sqrt{LTP}\left(\frac{2}{L}+\frac{3P}{V_{in}^{2}T}\right)-\frac{3\sqrt{2}P}{V_{in}}\right]}$$

with L the inductance, V_{in} the input voltage, T the period (=11.8µsec), and P the input power (=output power / efficiency).

As an example, using the circuit in Figure 1, suppose that L = 10µH, V_{in} = 3V, and input power = 3.1V * 330mA / 85% = 1204mW, with an assumed efficiency of 85%. We calculate that I_{rms} = 538mA. The input capacitor should be rated to take this ripple current in steady-state.

Output Capacitor

Typical usage will require an electrolytic capacitor at the output of the converter. The output capacitor of a discontinuous conduction mode flyback converter sees high ripple current. The capacitor must be rated to take this current, which is given by:

$$I_{rms} = \sqrt{\frac{\sqrt{2}}{3}\frac{P^{2}}{T(V_{in}-V_{out})^{3}}\left[\sqrt{2}T(V_{in}-V_{out})+\sqrt{PTL}\right]}$$

with L the inductance, V_{in} the input voltage, V_{out} the output voltage, T the period (=11.8µsec), and P the input power (=output power / efficiency).

As an example, using the circuit in Figure 1, suppose that L = 10µH, V_{in} = 3V, V_{out} = 3.1V, and input power = 3.1V * 330mA / 85% = 1204mW, with an assumed efficiency of 85%. We calculate that I_{rms} = 534mA. The output capacitor must be rated to take this ripple current in steady-state.

Bootstrap Application

Efficiency of the RYC9906 device is somewhat limited by the low voltage available on the VCC pin to drive the internal MOSFET. If a higher voltage is not available, an alternative is to bootstrap the input. As shown in Figure 2, this can be accomplished by orring together the external supply voltage with the voltage across the LED, which latter is approximately 3-5V.

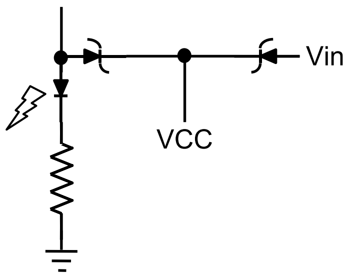


Figure 2. Bootstrapping Circuit

Enable

The RYC9906 device can be turned off by pulling the ENABLE pin high. In this condition, there is extremely low leakage current into the IC, and relatively low current into the LED, since the supply voltage (minus a diode drop) is less than the forward voltage required to turn on the LED.

Disconnecting the LEDs in Shutdown

For greater battery life, it may be desired to disconnect the LED when the RYC9906 device is disabled, and the circuit in Figure 3 may be used. When the IC is enabled, the voltage on the emitter of the PNP will be greater than the input voltage, and so the transistor will conduct current to the LEDs. When the IC is disabled, the voltage on the emitter will be a diode drop less than that on the base, and so the LED will be disconnected.

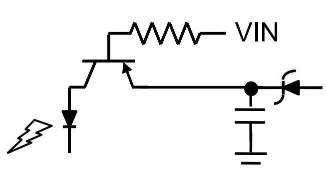


Figure 3. LED Disconnect Circuit

Dimming

Even with a fixed sense resistor, the RYC9906 device output current can be dimmed. There are two methods for dimming, either applying a PWM signal directly to the ENABLE pin, or else adding an analog signal to the FB pin.

Since the switching starts up approximately 200µsec after ENABLE is asserted, a low frequency PWM signal applied to the ENABLE pin turns the converter on and off, dimming the output. Since the switching is enabled by ENABLE low, the average output current to the LEDs will be proportional to 1 – DC, with DC the duty cycle of the PWM signal. As an example, applying a 1KHz PWM signal with high present for 700µsec, results in a light level that is (1msec – 700µsec) / 1msec = 30% of the level set by the sense resistor. It is not possible to use this method to achieve light levels higher than that set by the sense resistor. If higher light levels are desired, select a smaller sense resistor. PWM frequencies in excess of a couple of KHz are not feasible with this method.

The second method for dimming the RYC9906 device is to add in an analog signal to the FB pin, causing the IC to generate less current to add up to the total 340mV required on the FB pin. In the example shown in Figure 4, a high frequency PWM signal is integrated by an RC filter, which is then added together with the current sense signal. The resistor value is chosen with such a value that the HIGH voltage of the PWM is divided down to approximately 340mV by the resistor divider formed with the current sense resistor. The capacitor is chosen to filter the PWM frequency.

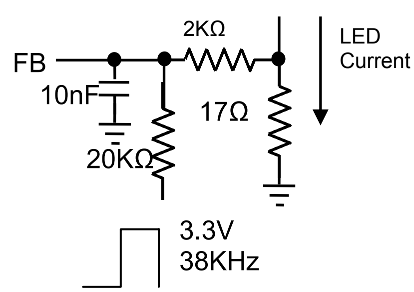


Figure 4. Dimming Circuit

Improving the Efficiency of Current Sense

For a single low-voltage LED, such as a 1W with a Vf of 3.1V, the 340mV regulation voltage on the FB pin may represent a significant loss of efficiency. In such a case, a lower voltage (such as 68mV) may be developed across a lower value resistor (such as 1/5 the normal value) and then the signal from this resistor may be amplified by an opamp (such as a gain of 5). This will dramatically decrease the efficiency loss in the sense resistor (from 11% to 2%). In this application, be sure to choose an opamp that can operate from the minimum supply voltage, and with rail-to-rail outputs. It may also be desirable to put a small capacitor across the opamp for noise filtering.

Operation with a High or Low Input Voltage

If the power source available is outside the recommended operating range of the IC, the RYC9906 device can still be use to drive LEDs. To do this, the power source may be connected to the inductor, while the VCC pin needs to receive a small amount of current within its operating range.

In the case of a high voltage power source, the inductor may be attached directly to a voltage up to about 25V, subject to the limitations mentioned above about the nature of non-isolated flybacks. The small current needed for the VCC pin can then be generated by a low-power resistor and a zener from the high voltage source. A 5V supply is recommended.

In the case of a voltage power source below the UVLO of the IC, the inductor may still be operated from the power source. All that is required is that the small current required by the RYC9906 be made available from a higher voltage supply; a 5V supply is recommended.

Open String

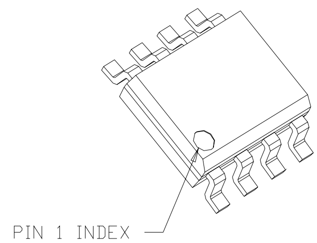
If the output of the RYC9906 device is open, as might happen if the LED fails open, the energy stored in the inductor each cycle is dissipated in the power device of the IC. Although not recommended, the RYC9906 device is rated to take this avalanche energy, which will not damage it, for up to one minute. If the energy is sufficiently high, the RYC9906 device may go into thermal shutdown. After cooling off, it will begin operation again. This cycling should not damage the IC. The output voltage in open string may rise as high as 40V, and the output capacitor and diode should be rated to withstand this voltage in this mode. Alternatively a 30V zener may be placed in parallel with the output cap.

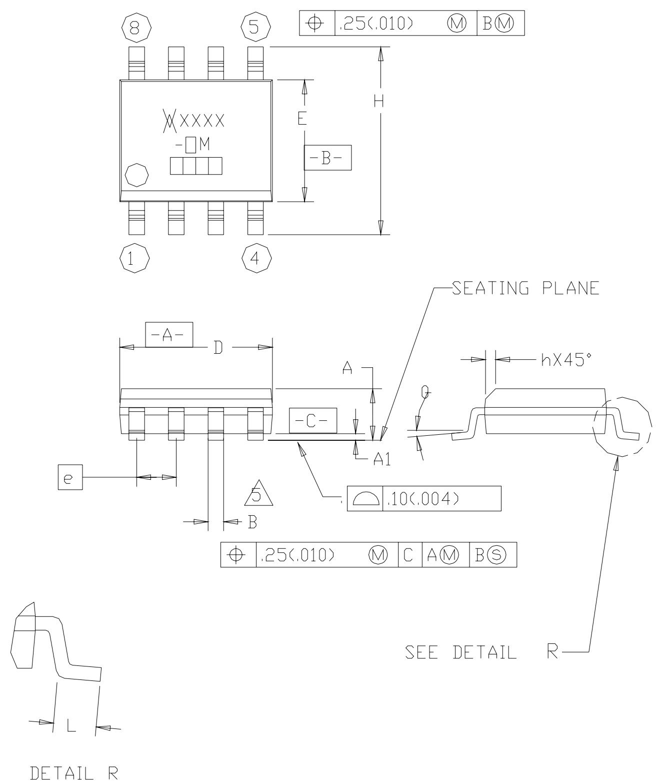
Thermal Shutdown

If the RYC9906 device die becomes excessively hot, the IC should shut itself down. It will then resume normal operation after cooling down sufficiently.

RYC9906
High Power LED Boost

PACKAGE INFORMATION





SYMBOL LIST

DIMENSIONS (mm)			
Sym	MIN	MAX	NOTE
A A1	1.35 0.10	1.75 0.25	
B C	0.33 0.19	0.51 0.25	-
D E	4.80 3.80	5.00 4.00	-
e	1.27 BSC	1.27 BSC	
H h	5.80 0.25	6.20 0.50	
L θ	0.40 0°	1.27 8°	

SO-8 PACKAGE NOTES:

1. Dimensions and tolerance per ANSI Y14.5M-1982.
2. Dimensions A and B are datums and T is a datum surface.
3. Controlling dimensions: Millimeters
4. Dimension A and B do not include mold flash. Mold flash shall not exceed 0.15mm [0.006] per side.
5. Dimension D does not include interlead flash. Interlead flash shall not exceed 0.25 mm [0.010].

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