Asymmetrical High Efficiency Three Channel Boost LED Driver

Features

- 2.7V to 6V input voltage range
- Up to 85% typical efficiency even for asymmetrical channel loads in terms of LED number, LED current and LED dropout
- Excellent 5 series x 3 parallel WLED drive capability
- Up to 140 mA/19V output current/voltage
- Independent current setting using an external low power resistor for each channel (no ballast resistors)
- No external frequency compensation needed
- Low (<1%) LED output voltage and current ripple
- Input undervoltage lockout and output over-voltage protection
- 1 MHz fixed switching frequency (0.5 MHz option available)
- Uses small inductor and ceramic capacitors
- Integrated low ON-Resistance (0.3 Ω) N-Channel MOSFET switch
- Disconnects LEDs during shutdown
- Low profile TQFN-16 package
- Optional RoHS compliant lead-free packaging

Applications

- Drives white LEDs for backlighting color LCD
- Cell phones
- MP3 players
- PDA, GPS
- Digital Still Cameras
- LED flashlights
- Handheld devices

Product Description

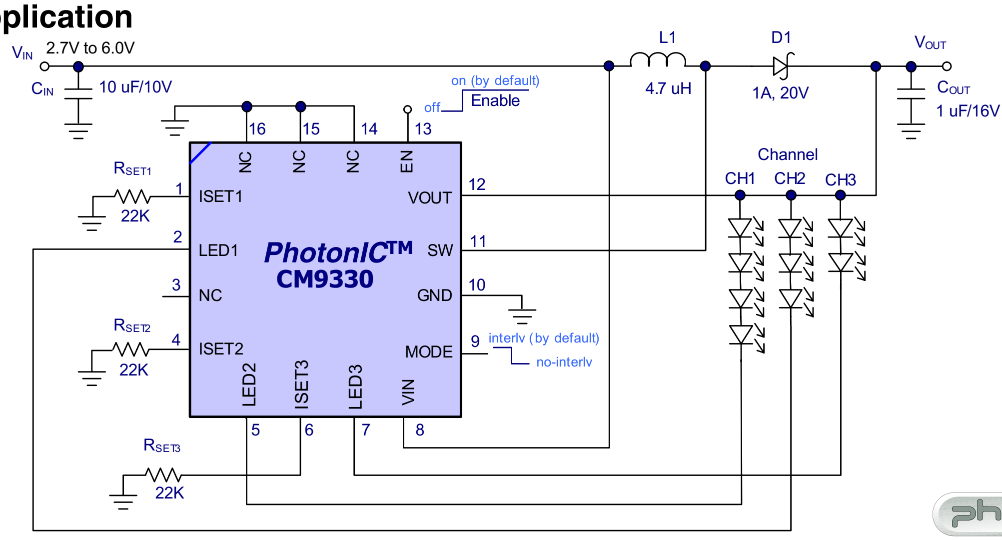
The CM9330 is a high frequency, three-channel inductor-based PWM boost regulator specifically designed for constant current white LED drive applications. With a maximum 140mA/19V output capability, the circuit can drive up to 15 WLEDs (5 series x 3 parallel) allowing up to 35 mA per channel. With a typical input voltage range from 2.7V to 6.0V, it can be operated from a single cell Li-Ion battery.

The proprietary *FlexBoost*™ architecture (patent pending) provides high efficiency (typical 85%) for a wide input voltage range, even for asymmetrical channel loads in terms of LED number, LED current and LED type. A standard (non-interleave) version is also available using a MODE selection pin (not available for mass production). The maximum LED current for each channel is independently programmed with external low-power resistors (no ballast resistors needed).

A 1 MHz constant frequency PWM saves board space, allowing small, low-cost external components, and permitting designers to avoid sensitive IF bands in RF applications. The output over-voltage protection circuit prevents damage in the case of a high impedance output (e.g. faulty LED). The controlled current limit circuit prevents large inductor current spikes, even at start-up. To avoid possible leakage currents, the EN control pin disconnects the LEDs from ground during shutdown.

The CM9330 is available in a compact TQFN-16 packages. It can operate over the industrial temperature range of -40°C to 85°C.

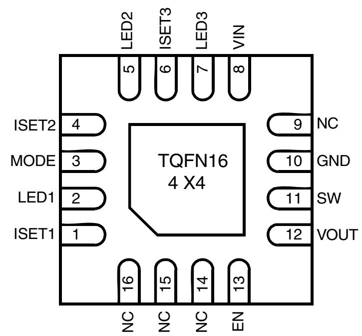
Typical Application



Package Pinout

PACKAGE / PINOUT DIAGRAM

Bottom View



16-Lead TQFN Package
(4mm x 4mm)

Note: This drawing is not to scale.

Ordering Information

PART NUMBERING INFORMATION

Pins	Package	Lead Free Finish: Ordering Part Number[1]	Lead Free Finish: Part Marking
16	TQFN	CM9330-01QE	

Note 1: Parts are shipped in Tape & Reel form unless otherwise specified.

Specifications

ABSOLUTE MAXIMUM RATINGS

PARAMETER	RATING	UNITS
ESD Protection (HBM)	± 2	kV
VIN to GND	[GND - 0.3] to +6.0	V
Pin Voltages V_{OUT}, SW to GND LED1, LED2, LED3 to GND ISET1, ISET2, ISET3 to GND	 20 20 [GND - 0.3] to +5.0	 V V V
Storage Temperature Range	-65 to +150	°C
Operating Temperature Range	-40 to +85	°C
Lead Temperature (Soldering, 10s)	300	°C

Specifications (cont'd)

ELECTRICAL OPERATING CHARACTERISTICS (SEE NOTE 1)						
V_{IN} = 3.6V; C_{IN} = 10µF, C_{OUT} = 1µF, L_1 = 4.7µH, **interleave mode**, T_A = 25°C (unless otherwise specified)						
SYMBOL	**PARAMETER**	**CONDITIONS**	**MIN**	**TYP**	**MAX**	**UNITS**
V_{IN}	Input Voltage Range		2.7		6.0	V
I_Q	Quiescent Current	I_{LED} < 0.6mA (each channel), non-switching		1.2	2.0	mA
V_{UVLO}	Undervoltage Lockout	V_{IN} Rising	2.0	2.2	2.4	V
V_{OVP}	Output Overvoltage Protection	V_{OUT} Rising	19.0	19.5	20.0	V
I_{SD}	Shutdown Current	V_{EN} = 0V		10	15	µA
V_{EN}	Device Enable Threshold	Device ON (by default) Device OFF	1.0		 0.2	V V
Channel 1						
I_{LED1}	LED Current (Note 1)	V_{IN} = 3.0V to 6.0V, R_{SET1}(kΩ) 4 WLED	2	$\frac{450}{R_{SET1}}$	35	mA
	Number of LEDs (Note 2)	V_{IN} = 2.7V to 6.0V	1		5	
V_{LED1}	Voltage on LED1 Pin	Standard load (Note 3)		0.80		V
Channel 2						
I_{LED2}	LED Current (Note 1)	V_{IN} = 3.0V to 6.0V, R_{SET2}(kΩ) 4 WLED	2	$\frac{450}{R_{SET2}}$	30	mA
	Number of LEDs (Note 2)	V_{IN} = 2.7V to 6.0V	1		5	
V_{LED2}	Voltage on LED2 Pin	Standard load (Note 3)		0.80		V
Channel 3						
I_{LED3}	LED Current (Note 1)	V_{IN} = 3.0V to 6.0V, R_{SET3}(kΩ) 4 WLED	2	$\frac{450}{R_{SET3}}$	30	mA
	Number of LEDs (Note 2)	V_{IN} = 2.7V to 6.0V	1		5	
V_{LED3}	Voltage on LED3 Pin	Standard load (Note 3)		0.80		V
Boost Circuit (Note 3)						
$\Delta I_{LED} / I_{LED} \cdot \Delta V_{IN}$	Line Regulation	V_{IN} = 3.0V to 6.0V Each Channel		1		%/V
I_{OUT}	Boost Output Current	V_{IN} = 3.0V to 6.0V	100			mA
V_{OUT}	Boost Output Voltage	$I_{LED\ 1,2,3}$ = 2mA to $I_{LED\ MAX}$	V_{IN}		20	V
D	Duty Cycle Range	V_{IN} = 2.7V to 6.0V, $I_{LED\ 1,2,3}$ = 2mA to $I_{LED\ MAX}$	5		95	%
V_{OUTR}	Output Voltage Ripple	Standard Load (Note 3)		50		mVpp
R_{DSON}	MOSFET ON Resistance	I_{SW} = 0.8A, V_{GS} = 15V		300	500	mΩ
Eff	Efficiency	Standard Load (Note 3)		85		%
I_{SW}	Switch Peak Current	Standard Load (Note 3)		0.65		A
P_{IN}	Input Power	$I_{LED\ 1,2,3}$ = 20mA, 4WLED+1W+1W		835		mW
Control						
$I_{LED\ acc}$	Channel Current Matching (Note 4)	1% R_{SET} Accuracy, Each Channel		3		%

Specifications (cont'd)

ELECTRICAL OPERATING CHARACTERISTICS (SEE NOTE 1)						
V_{IN} = 3.6V; C_{IN} = 10µF, C_{OUT} = 1µF, L_1 = 4.7µH, **interleave mode**, T_A = 25°C (unless otherwise specified)						
SYMBOL	**PARAMETER**	**CONDITIONS**	**MIN**	**TYP**	**MAX**	**UNITS**
I_{LEDR}	LED Current Ripple	Standard Load (Note 3)		0.2		mApp
I_{LEDNL}	No-Load Mode (Note 5)	All Channels	0		0.6	mA
fs	Switching Frequency	V_{IN} = 2.7V to 6.0V	0.8	1.0	1.2	MHz
V_{IN} = 3.6V; C_{IN} = 10µF, C_{OUT} = 1µF, L_1 = 4.7µH, **non-interleave mode** (Note 6), T_A = 25°C (unless otherwise specified)						
SYMBOL	**PARAMETER**	**CONDITIONS**	**MIN**	**TYP**	**MAX**	**UNITS**
I_{LED}	LED Current	V_{IN} = 3.0V to 6.0V, R_{SET}(kΩ)	2	$\frac{730}{R_{SET}}$	I_{MAX}	mA
$\Delta I_{LED} / \Delta V_{IN}$	Line Regulation @ High Load	L = 4.7µH, V_{IN} = 3.0V to 5.5V 4W+4W+4W, 40mA+40mA+40mA		1		%/V
		L = 10µH, VIN = 3.0V to 5.5V 4W+4W+4W, 60mA+40mA+40mA\		3		%/V
P_{IN}	Input Power	$I_{LED\ 1,2,3}$ = 20mA, 4WLED+1W+1W		975		mW

Note 1: I_{LED} is the average PWM current through the LED string with internal 2/3 duty cycle and a 6 ms period. The following formula must be used to calculate the LED current:

$$I_{LED}(mA) = \frac{450}{R_{SET(k\Omega)}}$$

Note 2: For lower LED forward voltage the number of LEDs can be increased up to the maximum output voltage limit.

Note 3: Standard Load is a 4 series x 3 parallel configuration set for I_{setLED} = 20 mA each channel ($R_{SET1,2,3}$ = 22 kΩ). Generally, a "4W+1W+1W" like formula denotes the WLED number of each channel, i.e. CH1+CH2+CH3 configurations.

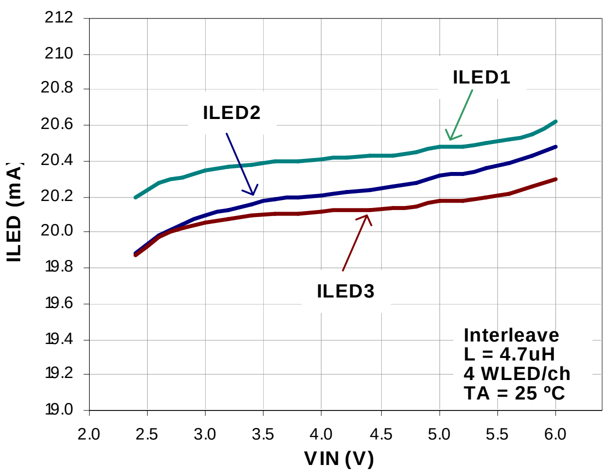
Note 4: [I_{LED}(set) - I_{LED}(effective)] / I_{LED}(set) for each channel.

Note 5: A LED current value below 0.6 mA for each channel set the circuit in No-load mode; all channels and MOSFET switch are in shutdown and DC circuit current consumption is limited to 1 mA (see quiescent current).

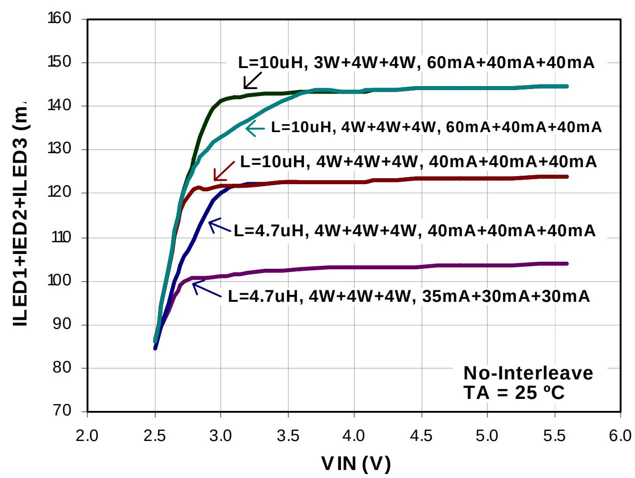
Note 6: For non-interleave mode, all parameters have the same min/typ/max interleave mode values, unless otherwise specified.

Typical Performance Curves

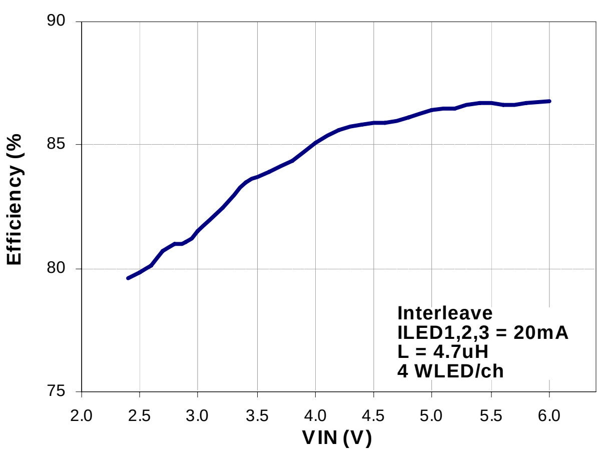
ILED vs. VIN



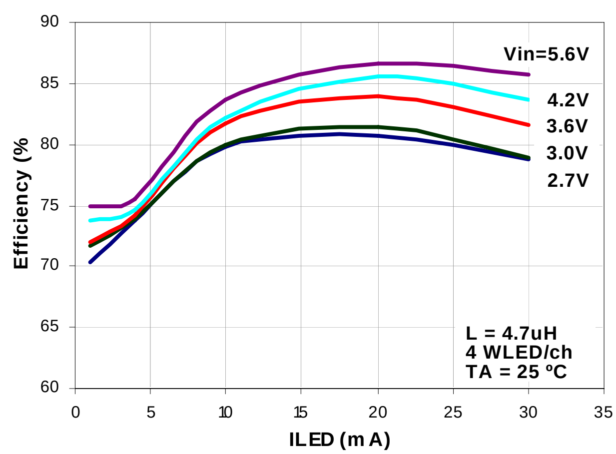
ILED vs. VIN (high current)



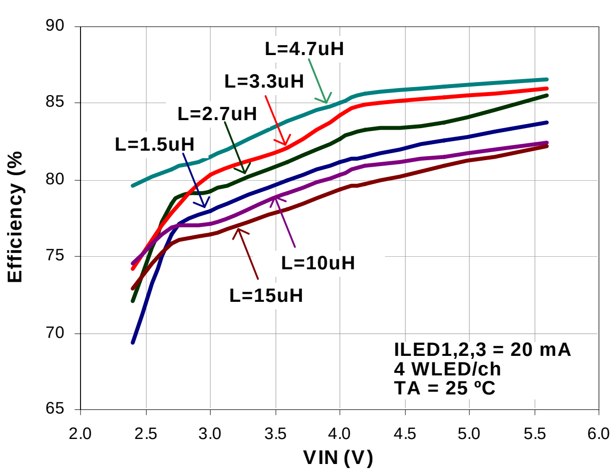
EFFICIENCY v.s VIN



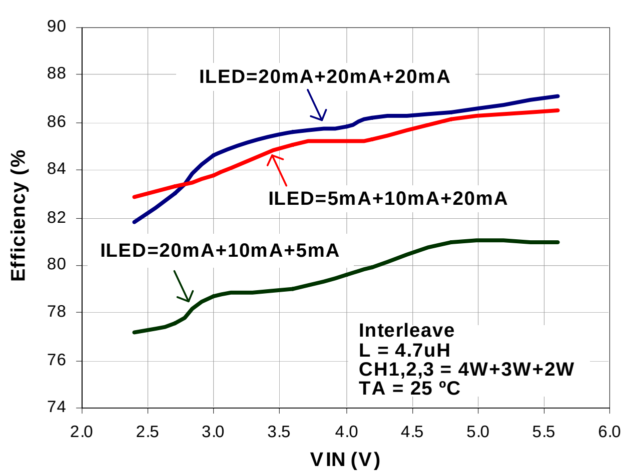
EFFICIENCY vs. ILED



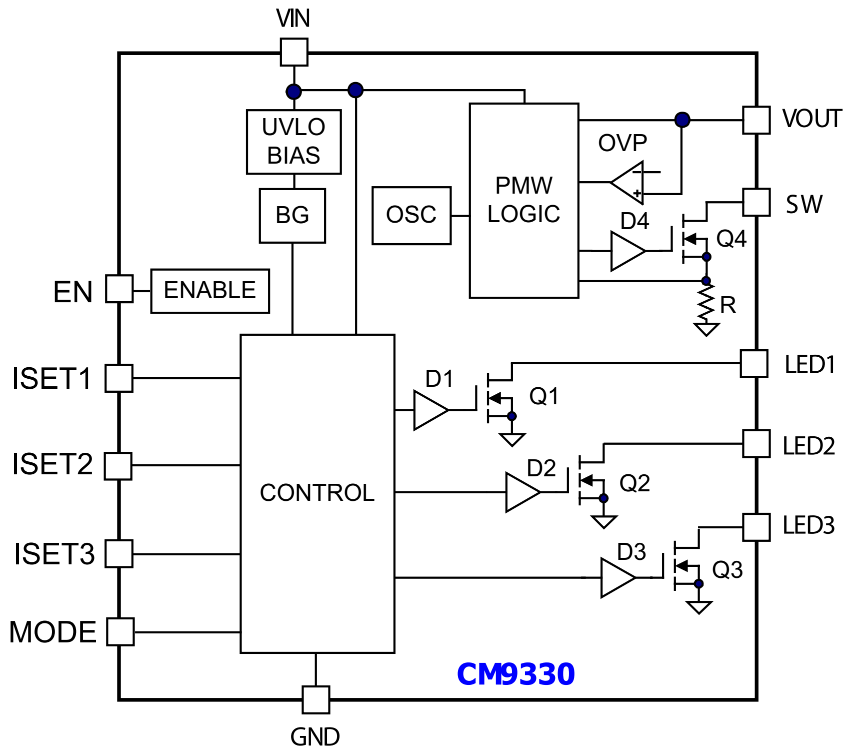
EFFICIENCY vs. INDUCTOR



EFFICIENCY vs. STRING CONFIGURATION



Functional Block Diagram



Pin Descriptions

PIN DESCRIPTIONS		
LEAD(s)	**NAME**	**DESCRIPTION**
1	ISET1	Channel 1 LED current set pin. Between this pin and GND connect the R_{SET1} resistor, calculated as follows: $R_{SET1}(k\Omega) = \frac{450}{I_{LED1}(mA)}$ where I_{LED1} is the DC LED current in channel 1.
2	LED1	Pin to cathode of channel 1 LED string.
3	NC	Not internally connected. For better heat flow, connect to GND.
4	ISET2	Channel 2 LED current set pin. Between this pin and GND connect the R_{SET2} resistor, calculated as follows: $R_{SET2}(k\Omega) = \frac{450}{I_{LED2}(mA)}$ where I_{LED2} is the DC LED current in channel 2.
5	LED2	Pin to cathode of channel 2 LED string.

Pin Descriptions (cont'd)

PIN DESCRIPTIONS		
6	ISET3	Channel 3 LED current set pin. Between this pin and GND connect the R_{SET3} resistor, calculated as follows: $R_{SET3}(k\Omega) = \frac{450}{I_{LED3}(mA)}$ where I_{LED3} is the DC LED current in channel 3.
7	LED3	Pin to cathode of channel 3 LED string.
8	VIN	Input supply voltage pin. Bypass with a 10 µF or larger ceramic capacitor to ground.
9	MODE	When MODE is HIGH (default), the circuit uses interleave mode. When MODE is LOW (GND), the circuit uses non-interleave mode.
10	GND	Ground terminal pin.
11	SW	Switching node. Internally connected to the drain of the integrated switch.
12	VOUT	Output voltage pin, which connects to the anodes of all LEDs. Bypass with a 1.0 µF or greater ceramic capacitor to ground for low output ripple voltage.
13	EN	Enable pin. The circuit is ON when VEN is above 1.0V. The circuit is OFF when VEN is below 0.2V. Active High (ON) by default.
14	NC	Not internally connected. For better heat flow, connect to GND.
15	NC	Not internally connected. For better heat flow, connect to GND.
16	NC	Not internally connected. For better heat flow, connect to GND.
EPad	GND	Ground; backside exposed pad.

Application Information

The CM9330 is a high efficiency, constant frequency current regulating boost driver ideally suited for driving white LEDs to backlight LCD color displays and a camera flash in Li-ion powered portable devices. The CM9330 is the perfect driver for portable applications such as cellular phones, digital still cameras, PDAs, and any application where small space, compact overall size, and low system cost, are critical.

With a maximum 140mA/19V output capability, the circuit can drive up to 15 WLEDs (5 series x 3 parallel) allowing up to 35 mA per channel. It includes a switch and an internally compensated loop for regulating the current into the LEDs. The CM9330 delivers a constant current to series-connected LEDs, ensuring uniform brightness and color purity regardless of any LED forward voltage variations.

The proprietary design architecture allows asymmetrical loading on each channel and maintains high efficiency (typ 85%) at low V_{IN} resulting in longer battery life, and cool, reliable operation when an adapter is supplying high V_{IN}. The maximum LED current for each channel is independently programmed with external low power resistors avoiding ballast resistors.

An 1MHz constant frequency PWM scheme saves board space using of small, low cost external components , allowing designers to avoid sensitive IF bands in RF applications. The circuit operates with low value inductor and low value output ceramic capacitor keeping voltage and current ripple in 1% range.

The output over-voltage protection circuit prevents damage in the case of a high impedance output (e.g. faulty LED). The controlled current limit circuit limit prevents large inductor current spikes, even at start-up. To avoid possible leakage currents the EN control pin disconnects the LEDs from ground during shutdown.

CM9330 Operation

When a voltage that exceeds the undervoltage lockout threshold (UVLO) is applied to the VIN pin, the CM9330 initiates a softstart which limits the inrush current while the output capacitors are charged. Following

Application Information (cont'd)

softstart, the CM9330's internal NMOS drives an external inductor and Schottky diode delivers the inductor's stored energy to the load.

Setting the LED Current

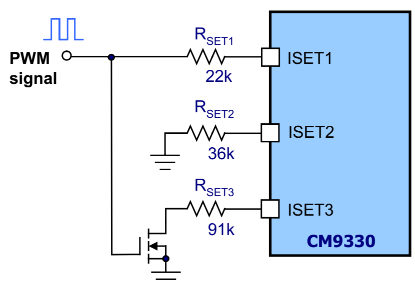
The output current is set by the value of the RSET connected between the ISET pin and GND, according to the equations:

(a) Interleave $R_{SET}(k\Omega) = \dfrac{450}{I_{LED}(mA)}$

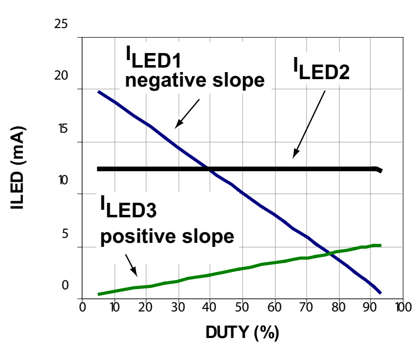
(b) Non-interleave $R_{SET}(k\Omega) = \dfrac{730}{I_{LED}(mA)}$

PWM Brightness Control

The brightness WLEDs level can be continuously controlled for each channel using a PWM signal in 1-50 KHz range (recommended value is 10 kHz). As an example the PWM signal can be applied directly through R_{SET} resistor for negative slope or by using a switch transistor for positive slope. See Figure 1 for different brightness control methods and results.



(a) Schematic



(b) Brightness Curves

Figure 1. Brightness Control Using Different Methods

Inductor Selection

The inductor is used to store energy in a boost converter. The amount of energy stored in the inductor and transferred to the load is controlled by the PWM. The inductor is operated in the discontinuous conduction mode, and to assume proper operation, the inductor value must be limited to a maximum value.

An inductor with low series resistance (DCR) decreases power losses and increases efficiency. The core material should be capable of operating at I MHz with minimal core losses. An inductance of 4.7-µH is optimum for most applications, but low DCR inductor values in 1.5-15uH range are also recommended for high efficiency applications.

To ensure proper operation of the current regulator over a wide range of conditions, the inductor should be selected based on the required load power and the minimum input voltage. The saturation current rating should be chosen well above the steady state peak inductor current. At minimum V_{IN} and full duty cycle (worse case), this is approximately:

$$I_{PEAK} \cong \frac{V_{IN(MIN)} \times t_{ON}}{L} \cong \frac{3V \times 0.95 \times \frac{1}{1MHz}}{4.7\mu H} \cong 0.7A$$

Diode Selection

The low forward voltage and fast switching time make Schottky diodes the choice for high efficiency operation. Make sure the diode has a reverse voltage rating greater than the maximum output voltage. The diode conducts only when the power switch is on, so a peak current rating above 1A should be sufficient for a typical design.

Capacitor Selection

For proper performance, use surface-mount, low ESR ceramic capacitors for CIN and COUT. X7R or X5R ceramic dielectric provides good stability over the operating temperature and voltage range.

In most LED applications, high frequency output ripple is not a concern because it will not cause intensity variations that are visible to the human eye.

Application Information (cont'd)

For such applications, when low ripple is needed, a 22µF input capacitor and/or 2.2 µF output capacitor are recommended.

REF DES	DESCRIPTION	SOURCE
C_{IN}	Capacitor, 10µF, 10V, Ceramic, 1206	Murata, GRM319R61A106KE19D Vishay, VJ1206G106KXQ
C_{OUT}	Capacitor, 1µF, 16V, Ceramic, 0805	Murata, GRM188R61C105KA93D TDK, C2012X5R1C105K
L_1	Inductor, 4.7µH, 1A, Low DCR	Coilcraft, LP06013-472ML TMP Electronics Co., SPC-03802-4R7 CHILISIN, SCD03015-4R7 SUMIDA, CDH3D13/S4R7
D_1	Schottky Diode, 1A, 20V, SMD	IR, MBRS120 CHENMKO, SSM5817S

Input Filter

If CM9330 is more than 4" from main power supply point, use an input RC filter to avoid high ripple and input transients to the circuit input pin (see Figure 2). In this case, because of small input ripple, the efficiency is about 2% higher.

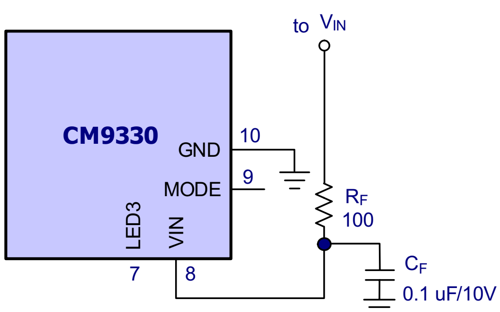


Figure 2. Input Filter Solution

Mode Selection

Two working modes are available for CM9330: interleave mode (output voltage is periodically adjusted depending on each channel load) and non-interleave mode (same output voltage level for all channels). For interleave option, keep MODE pin floating (HIGH by default) and for non-interleave option, connect MODE pin to GND.

Layout Guide

Components should be placed ase close as practical to the IC to assure good performance. The input and output capacitors should be close, with minimum trace resistance and inductance. Reflected input ripple depends on the impedance of the VIN source, such as the PCB traces and the Li-ion battery, which has elevated impedance at higher frequencies. The input capacitor located near the converter input reduces this source impedance and ripple. Any ESR from the capacitor will result in steps and spikes in the ripple waveform, and possibly produce EMI.

Route any noise sensitive traces away from the switching power components. Place the inductor and diode as close as possible to the SW pin to prevent noise emissions.

The ground connections for RSET(1,2,3) resistors should be kept separate from the high power grounds and connect directly to the ground pin to assure accurate current and voltage settings. For better heat flow, connect all NC pins to GND plane. Also connect the thermal landing to the bottom ground plane with thermal vias.

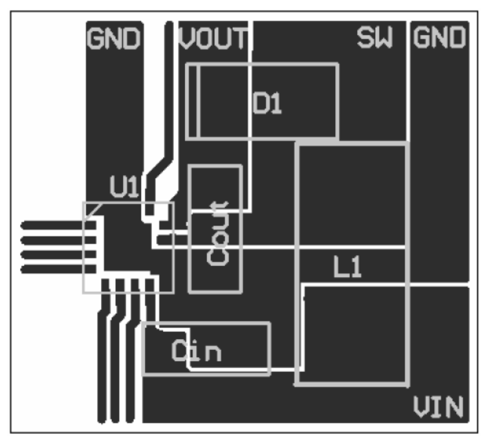


Figure 3. Example CM9330 PC Layout and Component Placement for Standard Application

Mechanical Details

TQFN-16 Mechanical Specifications

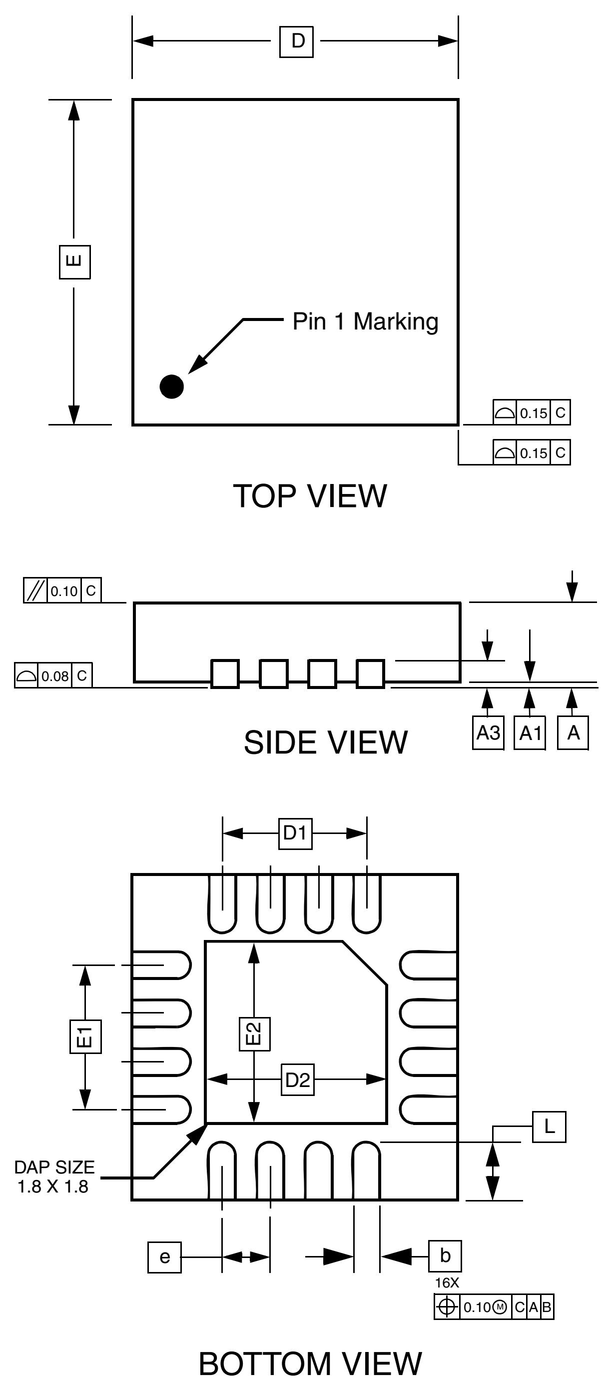
The CM9330 is supplied in a 16-lead, 4.0mm x 4.0mm TQFN package. Dimensions are presented below.

For complete information on the TQFN16, see the California Micro Devices TQFN Package Information document.

PACKAGE DIMENSIONS						
Package	TQFN-16 (4x4)					
Leads	16					
Dim.	Millimeters			Inches		
	Min	Nom	Max	Min	Nom	Max
A		0.80	0.84		0.031	0.033
A1	0.00		0.04	0.00		0.002
A3	0.20 REF			.008		
b	0.25		0.33	0.010		0.013
D	4.0 BSC			0.157		
D1	1.95 REF			0.077		
D2	2.05		2.15	0.081		0.085
E	4.0 BSC			0.157		
E1	1.95 REF			0.077		
E2	2.05		2.15	0.081		0.085
e	0.65 TYP.			0.026		
L	0.55		0.65	0.022		0.026
# per tube	xx pieces*					
# per tape and reel	xxxx pieces					
Controlling dimension: millimeters						

* This is an approximate number which may vary.

Mechanical Package Diagrams



Package Dimensions for 16-Lead TQFN