

## Asymmetrical High Efficiency Two 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 2 parallel WLED drive capability
- Up to 100 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 TDFN-10 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

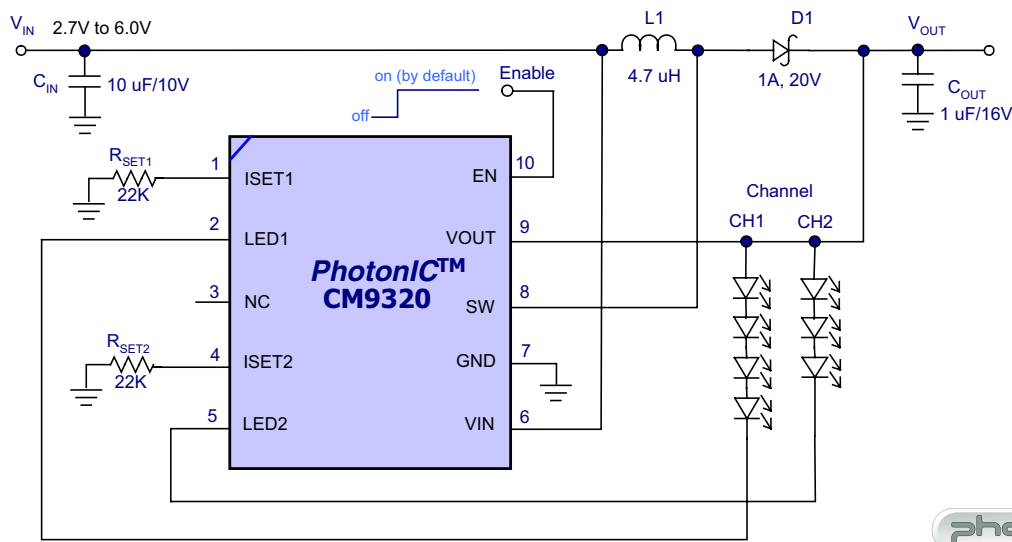
The CM9320 is a high frequency, two-channel inductor-based PWM boost regulator specifically designed for constant current white LED drive applications. With a maximum 100 mA/19V output capability, the circuit can drive up to 10 WLEDs (5 series x 2 parallel) allowing up to 35 mA per channel. With a typical 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. The maximum LED current for each channel is independently programmed with external low-power resistors (no ballast resistors needed).

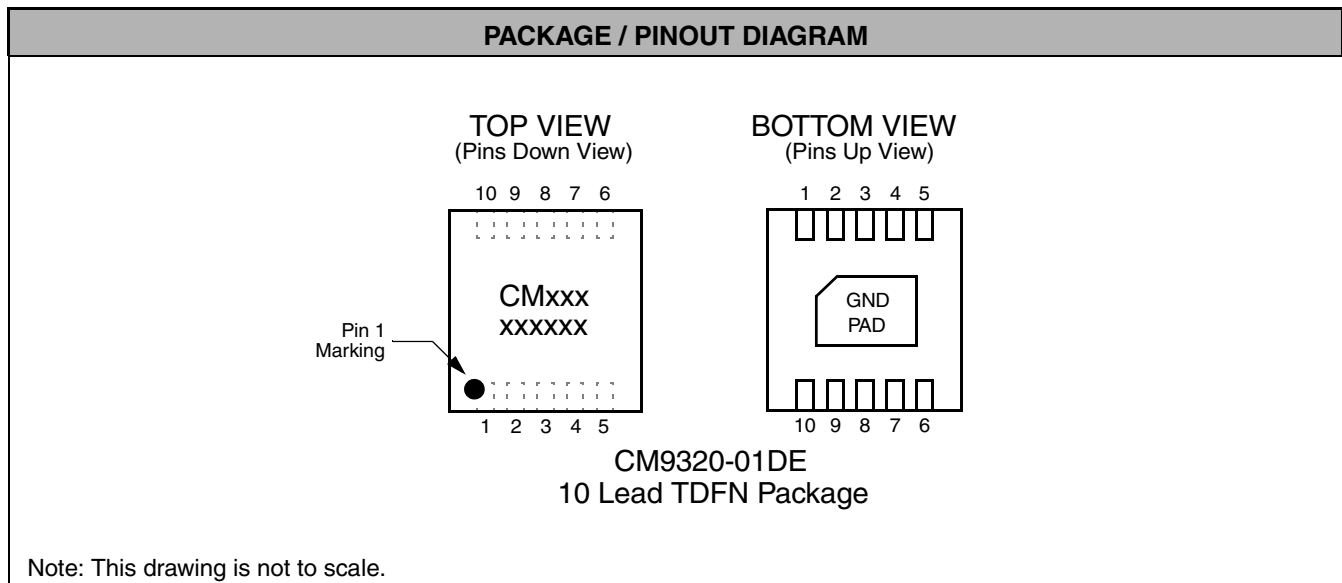
A 1 MHz constant frequency PWM saves board space, allowing small, low-cost external components, permitting designers to avoid sensitive IF bands in RF applications. The output over-voltage protection circuit prevents damage in case of a high impedance output (e.g. faulty LED). The controlled current 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 CM9320 is available in a compact TDFN-10 package. It can operate over the industrial temperature range of -40°C to 85°C.

### Typical Application



## Package Pinout



## Ordering Information

<b>PART NUMBERING INFORMATION</b>			
Pins	Package	Lead Free Finish	
		Ordering Part Number <sup>1</sup>	Part Marking
10	TDFN	CM9320-01DE	

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

## Specifications

<b>ABSOLUTE MAXIMUM RATINGS</b>		
PARAMETER	RATING	UNITS
ESD Protection (HBM)	$\pm 2$	kV
VIN to GND	[GND - 0.3] to +6.0	V
Pin Voltages		
V <sub>OUT</sub> , SW to GND	20	V
LED1, LED2 to GND	20	V
ISET1, ISET2 to GND	[GND - 0.3] to +5.0	V
Storage Temperature Range	-65 to +150	°C
Operating Temperature Range	-40 to +85	°C
Lead Temperature (Soldering, 10s)	300	°C

**Specifications (cont'd)**

<b>ELECTRICAL OPERATING CHARACTERISTICS (SEE NOTE 1)</b>						
<b>SYMBOL</b>	<b>PARAMETER</b>	<b>CONDITIONS</b>	<b>MIN</b>	<b>TYP</b>	<b>MAX</b>	<b>UNITS</b>
$V_{IN} = 3.6V$ ; $C_{IN} = 10\mu F$ , $C_{OUT} = 1\mu F$ , $L_1 = 4.7\mu H$ , <b>interleave mode</b> , $T_A = 25^\circ C$ (unless otherwise specified)						
$V_{IN}$	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	$\mu A$
$V_{EN}$	Device Enable Threshold	Device ON (by default) Device OFF	1.0		0.2	V V
<b>Channel 1</b>						
$I_{LED1}$	LED Current (Note 1)	$V_{IN} = 3.0V$ to $6.0V$ , $R_{SET1}(k\Omega)$ 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
<b>Channel 2</b>						
$I_{LED2}$	LED Current (Note 1)	$V_{IN} = 3.0V$ to $6.0V$ , $R_{SET2}(k\Omega)$ 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
<b>Boost Circuit (Note 3)</b>						
$\Delta I_{LED} / I_{LED} \cdot \Delta V_{IN}$	Line Regulation	$V_{IN} = 3.0V$ to $6.0V$ Each Channel		1		%/V
$I_{OUT}$	Boost Output Current	$V_{IN} = 3.0V$ to $6.0V$	80			mA
$V_{OUT}$	Boost Output Voltage	$I_{LED 1,2} = 2mA$ to $I_{LED MAX}$	$V_{IN}$		20	V
D	Duty Cycle Range	$V_{IN} = 2.7V$ to $6.0V$ , $I_{LED 1,2} = 2mA$ to $I_{LED MAX}$	5		95	%
$V_{OUTR}$	Output Voltage Ripple	Standard Load (Note 3)		50		mVpp
$R_{DS(on)}$	MOSFET ON Resistance	$I_{SW} = 0.8A$ , $V_{GS} = 15V$		300	500	$m\Omega$
Eff	Efficiency	Standard Load (Note 3)		85		%
$I_{SW}$	Switch Peak Current	Standard Load (Note 3)		0.5		A
$P_{IN}$	Input Power	$I_{LED 1,2} = 20mA$ , 4WLED+1W		835		mW
<b>Control</b>						
$I_{LED acc}$	Channel Current Matching (Note 4)	1% $R_{SET}$ Accuracy, Each Channel		3		%
$I_{LEDR}$	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

**Specifications (cont'd)**

<b>ELECTRICAL OPERATING CHARACTERISTICS (SEE NOTE 1)</b>						
<b>SYMBOL</b>	<b>PARAMETER</b>	<b>CONDITIONS</b>	<b>MIN</b>	<b>TYP</b>	<b>MAX</b>	<b>UNITS</b>
$V_{IN} = 3.6V$ ; $C_{IN} = 10\mu F$ , $C_{OUT} = 1\mu F$ , $L_1 = 4.7\mu H$ , <b>non-interleave mode</b> (Note 6), $T_A = 25^\circ C$ (unless otherwise specified)						
$I_{LED}$	LED Current	$V_{IN} = 3.0V$ to $6.0V$ , $R_{SET}(k\Omega)$	2	$\frac{730}{R_{SET}}$	$I_{MAX}$	mA
$\Delta I_{LED} / \Delta V_{IN}$	Line Regulation @ High Load	$L = 4.7\mu H$ , $V_{IN} = 3.0V$ to $5.5V$ 4W+4W, 40mA+40mA		1		%/V
		$L = 10\mu H$ , $V_{IN} = 3.0V$ to $5.5V$ 4W+4W, 50mA+40mA		3		%/V
		$L = 10\mu H$ , $V_{IN} = 2.8V$ to $5.5V$ 3W+4W, 60mA+40mA		1		%/V
$P_{IN}$	Input Power	$I_{LED\ 1,2} = 20mA$ , 4WLED+1W		730		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 2 parallel configuration set for  $I_{setLED} = 20$  mA each channel ( $R_{SET1,2} = 22$  k $\Omega$ ).

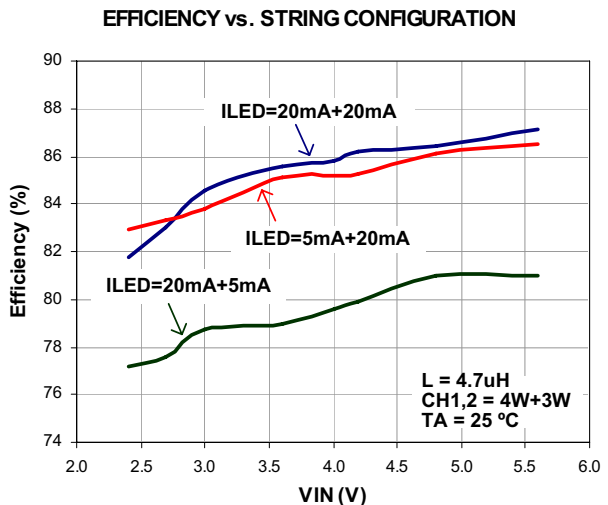
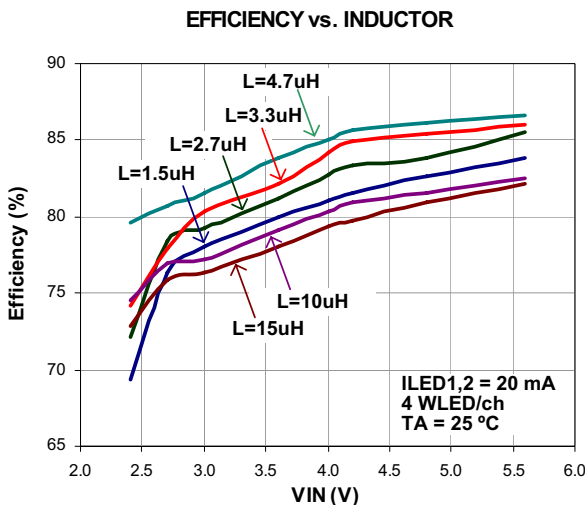
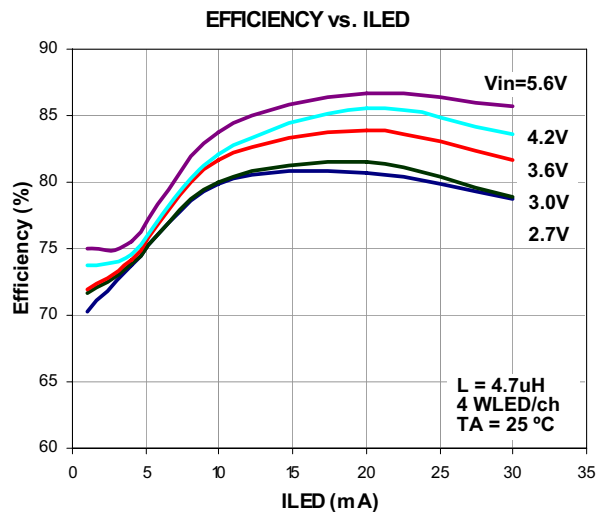
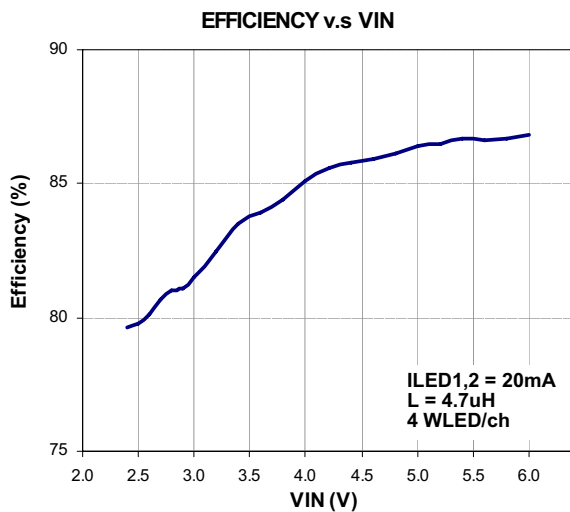
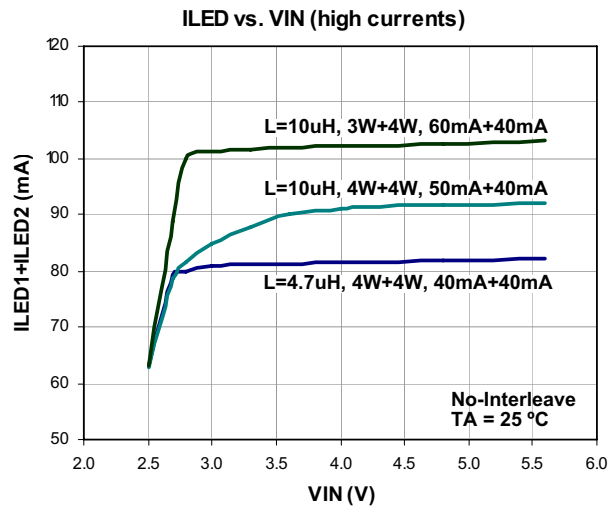
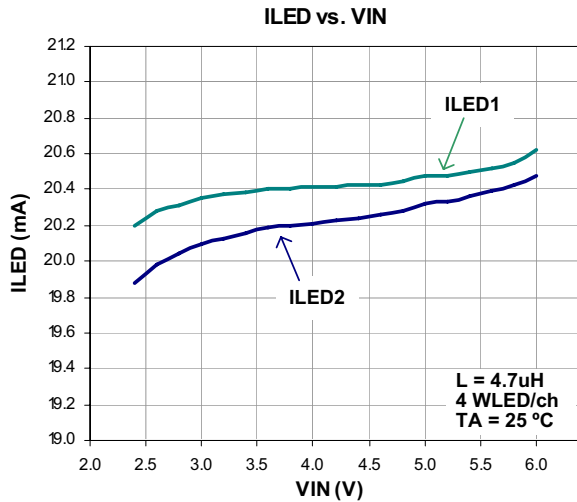
Generally, a "4W+1W" like formula denotes the WLED number of each channel, i.e. CH1+CH2 configurations.

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

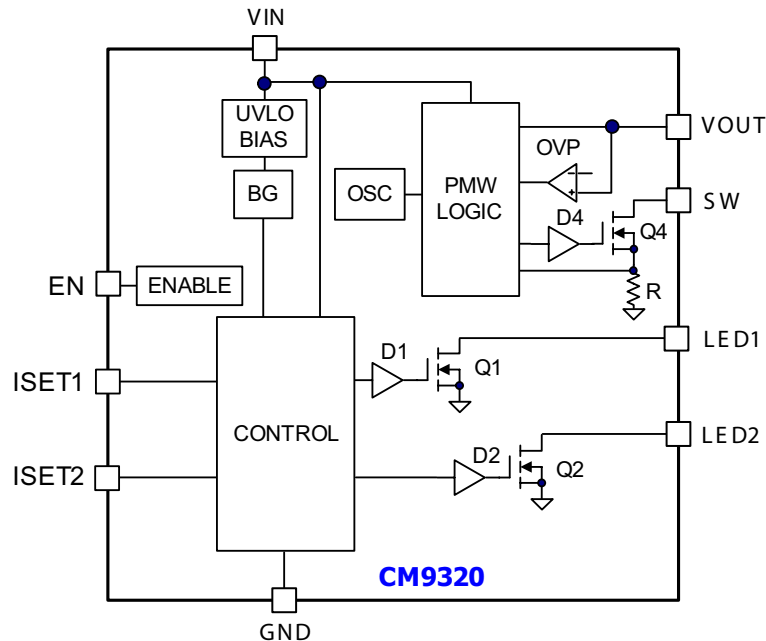
Note 5: A LED current value below 0.6 mA for each channel set the circuit in No-load mode; all channels and MOSFET switch are in shutdown and DC circuit current consumption is limited to 1 mA (see quiescent current).

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

Typical Performance Curves



## 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.
6	VIN	Input supply voltage pin. Bypass with a 10 $\mu$ F or larger ceramic capacitor to ground.
7	GND	Ground terminal pin.
8	SW	Switching node. Internally connected to the drain of the integrated switch.
9	VOUT	Output voltage pin, which connects to the anodes of all LEDs. Bypass with a 1.0 $\mu$ F or greater ceramic capacitor to ground for low output ripple voltage.

## Pin Descriptions (cont'd)

PIN DESCRIPTIONS		
10	EN	Enable pin. The circuit is ON when $V_{EN}$ is above 1.0V. The circuit is OFF when $V_{EN}$ is below 0.2V. Active High (ON) by default.
EPad	GND	Ground (backside exposed pad).

## Application Information

The CM9320 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 CM9320 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 100 mA/19V output capability, the circuit can drive up to 10 WLEDs (5 series x 2 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 CM9320 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 the need for ballast resistors.

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

The output over-voltage protection circuit prevents damage in 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.

### CM9320 Operation

When a voltage that exceeds the undervoltage lockout threshold (UVLO) is applied to the  $V_{IN}$  pin, the CM9320 initiates a softstart which limits the inrush current while the output capacitors are charged. Following softstart, the CM9320's internal NMOS drives an external inductor and Schottky diode that delivers the inductor's stored energy to the load.

#### Setting the LED Current

The output current is set by the value of the  $R_{SET}$  connected between the  $I_{SET}$  pin and GND, according to the equations:

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

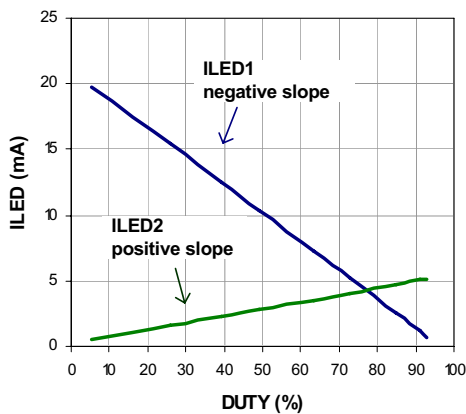
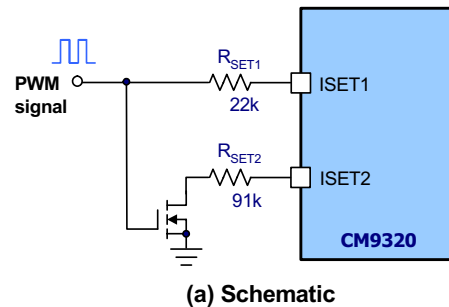
$$(b) \text{ Non-interleave } R_{SET}(k\Omega) = \frac{730}{I_{LED}(mA)}$$

#### 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

## Application Information (cont'd)

switch transistor for positive slope. See Figure 1 for different brightness control methods and results.



**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 1 MHz with minimum core losses. An inductance of 4.7μH is optimal for most applications, but low DCR inductor values in 1.5-15μH 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:

$$I_{PEAK} \cong \frac{V_{IN(MIN)} \times t_{ON}}{L} \cong \frac{3V \times 0.8 \times \frac{1}{1MHz}}{4.7\mu H} \cong 0.5A$$

### 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  $C_{IN}$  and  $C_{OUT}$ . 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.

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, MBR5120 CHENMKO, SSM5817S

### Input Filter

If CM9320 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).



### Application Information (cont'd)

In this case, because of small input ripple, the efficiency is about 2% higher.

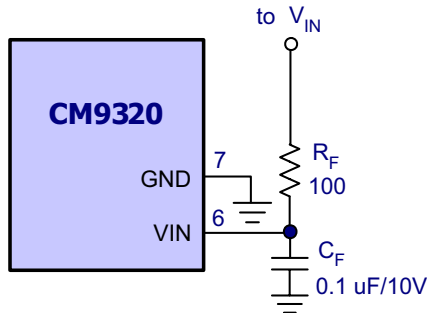


Figure 2. Input Filter Solution

### Layout Guide

Components should be placed as 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 have 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) 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.

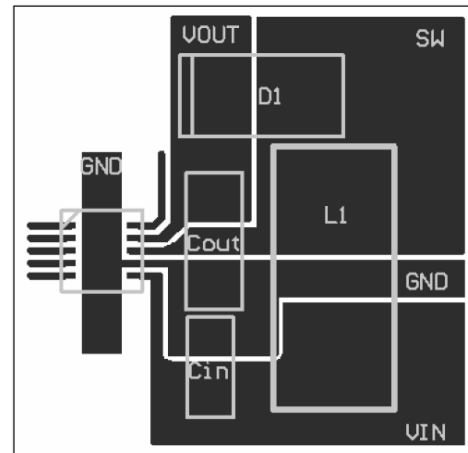


Figure 3. Example CM9320 PC Layout and Component Placement for Standard Application

## Mechanical Details

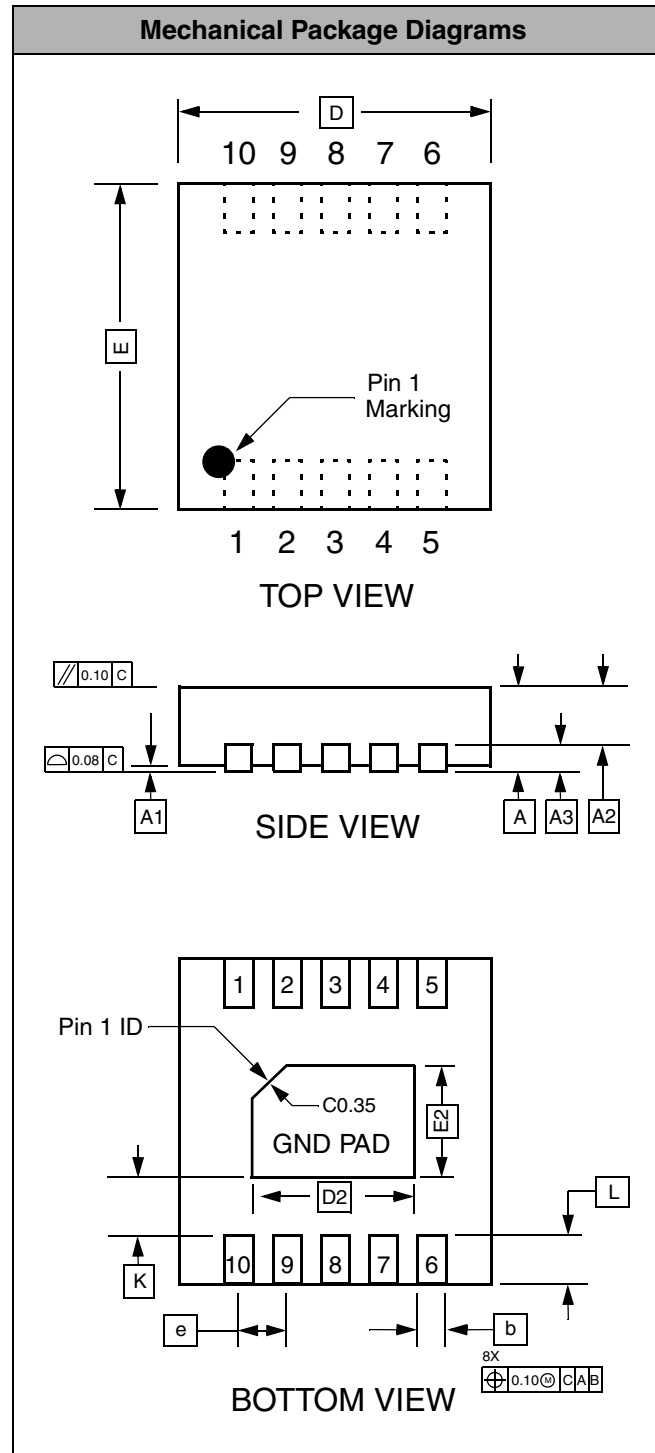
### TDFN-10 Mechanical Specifications

Dimensions for the CM9320 packaged in a 10-lead TDFN package are presented below.

For complete information on the TDFN-10, see the California Micro Devices TDFN Package Information document.

PACKAGE DIMENSIONS						
Package	TDFN					
JEDEC No.	MO-229 (Var. WEED-3) <sup>1</sup>					
Leads	10					
Dim.	Millimeters			Inches		
	Min	Nom	Max	Min	Nom	Max
A	0.70	0.75	0.80	0.028	0.030	0.031
A1	0.00	0.02	0.05	0.000	0.001	0.002
A2	0.45	0.55	0.65	0.018	0.022	0.026
A3		0.20			0.008	
b	0.18	0.25	0.30	0.007	0.010	0.012
D		3.00			0.118	
D2	2.20	2.30	2.40	0.087	0.091	0.094
E		3.00			0.118	
E2	1.40	1.50	1.60	0.055	0.060	0.063
e		0.50			0.020	
K	1.30	1.50	1.70	0.051	0.060	0.067
L	0.20	0.30	0.40	0.008	0.012	0.016
# per tube	NA					
# per tape and reel	3000 pieces					
Controlling dimension: millimeters						

<sup>1</sup>This package is compliant with JEDEC standard MO-229, variation WEED-3 with exception of the "D2" and "E2" dimensions as called out in the table above.



**Package Dimensions for 10-Lead TDFN**