CAT4240

6 Watt Boost LED Driver

Description

The CAT4240 is a DC/DC step−up converter that delivers an accurate constant current ideal for driving LEDs. Operation at a fixed switching frequency of 1 MHz allows the device to be used with small value external ceramic capacitors and inductor. LEDs connected in series are driven with a regulated current set by the external resistor R1. The CAT4240 high−voltage output stage is perfect for driving mid−size and large panel displays containing up to ten white LEDs in series.

LED dimming can be done by using a DC voltage, a logic signal, or a pulse width modulation (PWM) signal. The shutdown input pin allows the device to be placed in power−down mode with “zero” quiescent current.

In addition to thermal protection and overload current limiting, the device also enters a very low power operating mode during “Open LED” fault conditions. The device is housed in a low profile (1 mm max height) 5−lead thin SOT23 package for space critical applications.

Features

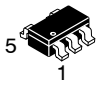
- Switch Current Limit 750 mA
- Drives High Voltage LED Strings (38 V)
- Up to 94% Efficiency
- Low Quiescent Ground Current 0.6 mA
- 1 MHz Fixed Frequency Low Noise Operation
- Soft Start “In−rush” Current Limiting
- Shutdown Current Less than 1 μA
- Open LED Overvoltage Protection
- Automatic Shutdown at 1.9 V (UVLO)
- Thermal Overload Protection
- Thin SOT23 5−lead (1 mm Max Height)
- These Devices are Pb−Free, Halogen Free/BFR Free and are RoHS Compliant

Applications

- GPS Navigation Systems
- Portable Media Players
- Handheld Devices, Digital Cameras

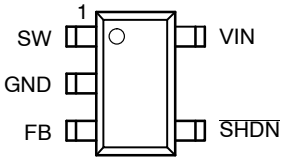
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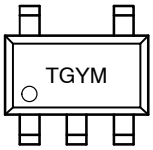
TSOT−23
TD SUFFIX
CASE 419AE

PIN CONNECTIONS



(Top View)

MARKING DIAGRAM



TG = Specific Device Code
Y = Production Year (Last Digit)
M = Production Month (1−9, A, B, C)

ORDERING INFORMATION

Device	Package	Shipping
CAT4240TD−GT3	TSOT−23 (Pb−Free) Green*	3,000/ Tape & Reel

* NiPdAu Plated Finish

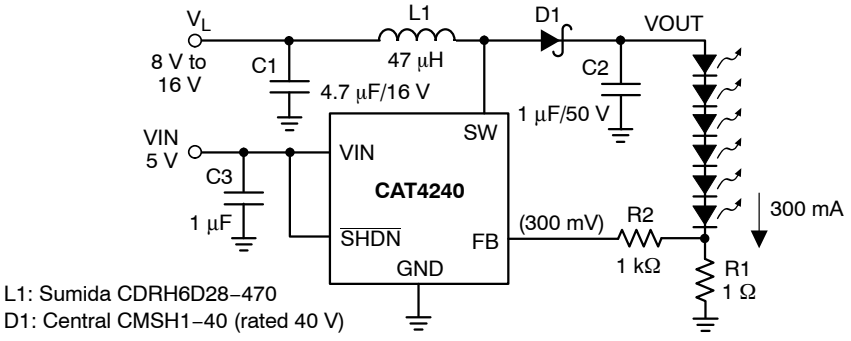


Figure 1. Typical Application Circuit

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Table 1. ABSOLUTE MAXIMUM RATINGS

Parameters	Ratings	Units
V_{IN}, FB voltage	−0.3 to +7	V
$\overline{SHDN}$ voltage	−0.3 to +7	V
SW voltage	−0.3 to 60	V
Storage Temperature Range	−65 to +160	°C
Junction Temperature Range	−40 to +150	°C
Lead Temperature	300	°C

Stresses exceeding Maximum Ratings may damage the device. Maximum Ratings are stress ratings only. Functional operation above the Recommended Operating Conditions is not implied. Extended exposure to stresses above the Recommended Operating Conditions may affect device reliability.

Table 2. RECOMMENDED OPERATING CONDITIONS

Parameters	Range	Units
V_{IN}	up to 5.5	V
SW pin voltage	0 to 38	V
Ambient Temperature Range (Note 1)	−40 to +85	°C

NOTE: Typical application circuit with external components is shown on page 1.

1. Thin SOT23−5 package thermal resistance θ_{JA} = 135°C/W when mounted on board over a ground plane.

Table 3. DC ELECTRICAL CHARACTERISTICS

(V_{IN} = 3.6 V, ambient temperature of 25°C (over recommended operating conditions unless otherwise specified))

Symbol	Parameter	Test Conditions	Min	Typ	Max	Units
I_Q	Operating Current	V_{FB} = 0.2 V V_{FB} = 0.4 V (not switching)		0.6 0.1	1.5 0.6	mA
I_{SD}	Shutdown Current	$V_{\overline{SHDN}}$ = 0 V		0.1	1	μA
V_{FB}	FB Pin Voltage	6 LEDs with I_{LED} = 75 mA	285	300	315	mV
I_{FB}	FB pin input leakage				1	μA
I_{LED}	Programmed LED Current	R1 = 10 Ω R1 = 5 Ω	28.5	30 60	31.5	mA
V_{IH} V_{IL}	$\overline{SHDN}$ Logic High $\overline{SHDN}$ Logic Low	Enable Threshold Level Shutdown Threshold Level	 0.4	0.8 0.7	1.5	V
F_{SW}	Switching Frequency		0.8	1.0	1.3	MHz
DC	Maximum Duty Cycle	V_{IN} = 3 V		92		%
I_{LIM}	Switch Current Limit	V_{IN} = 3.6 V V_{IN} = 5 V	600 750			mA
R_{SW}	Switch “On” Resistance	I_{SW} = 100 mA		1.0	2.0	Ω
I_{LEAK}	Switch Leakage Current	Switch Off, V_{SW} = 30 V		2	5	μA
	Thermal Shutdown			150		°C
	Thermal Hysteresis			20		°C
V_{UVLO}	Undervoltage Lockout (UVLO) Threshold			1.9		V
V_{OV-SW}	Overvoltage Detection Threshold			40		V
V_{OCL}	Output Voltage Clamp	“Open LED”		42		V

TYPICAL CHARACTERISTICS

(V_{IN} = 5 V, V_L = 13 V, T_{AMB} = 25°C, typical application circuit unless otherwise specified.)

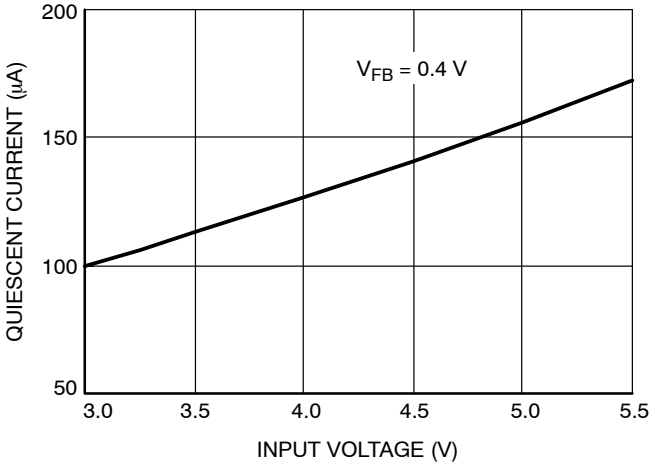


Figure 2. Quiescent Current vs. V_{IN} (Not Switching)

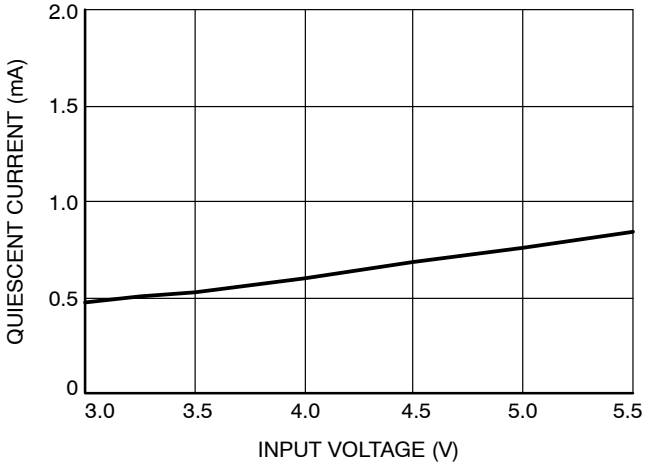


Figure 3. Quiescent Current vs. V_{IN} (Switching)

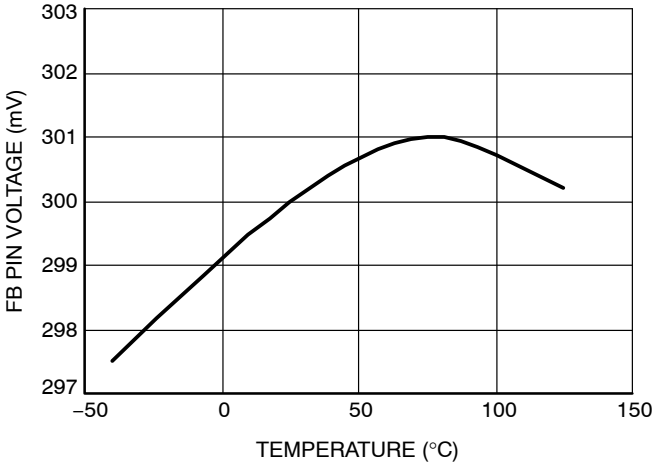


Figure 4. FB Pin Voltage vs. Temperature

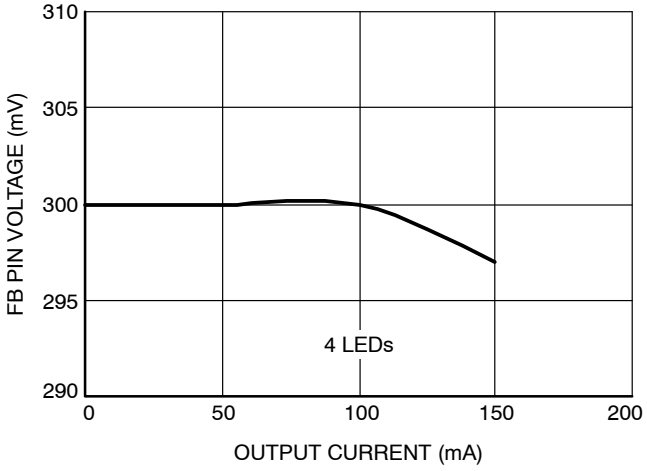


Figure 5. FB Pin Voltage vs. Output Current

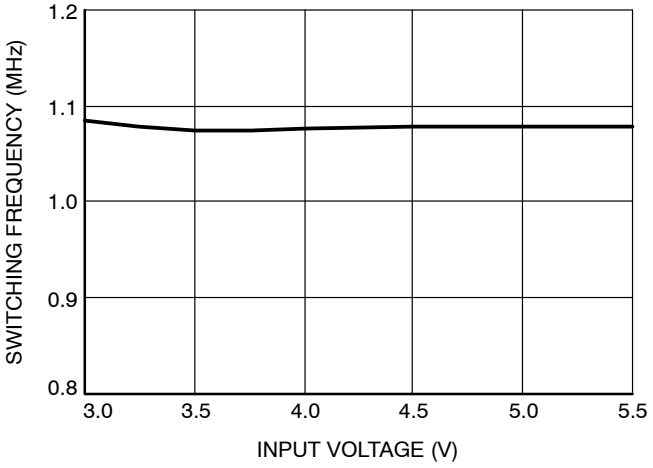


Figure 6. Switching Frequency vs. Supply Voltage

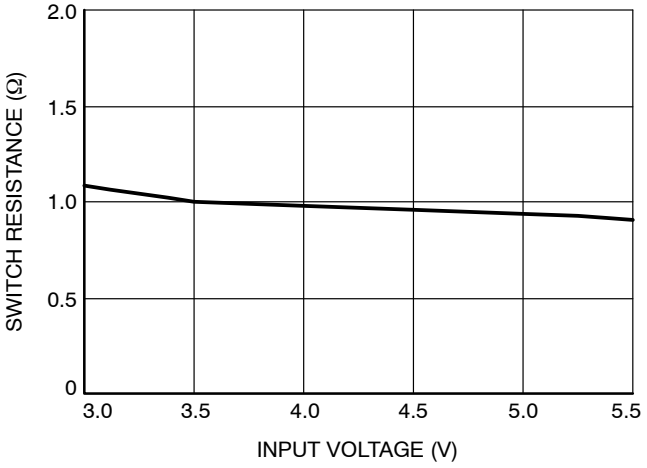


Figure 7. Switch ON Resistance vs. Input Voltage

TYPICAL CHARACTERISTICS

(V_{IN} = 5 V, V_L = 13 V, T_{AMB} = 25°C, typical application circuit unless otherwise specified.)

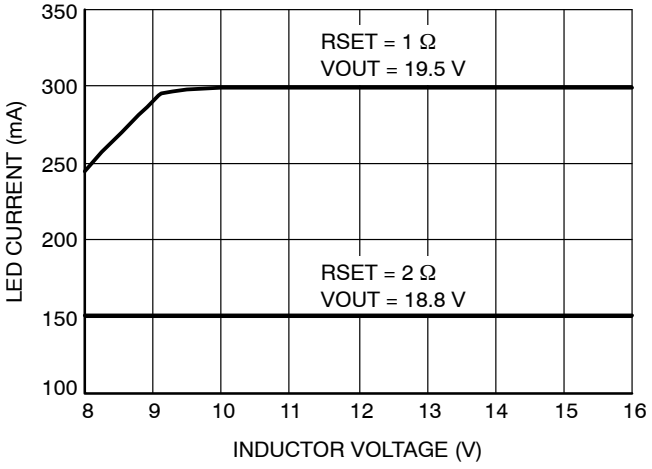


Figure 8. LED Current vs. Input Voltage

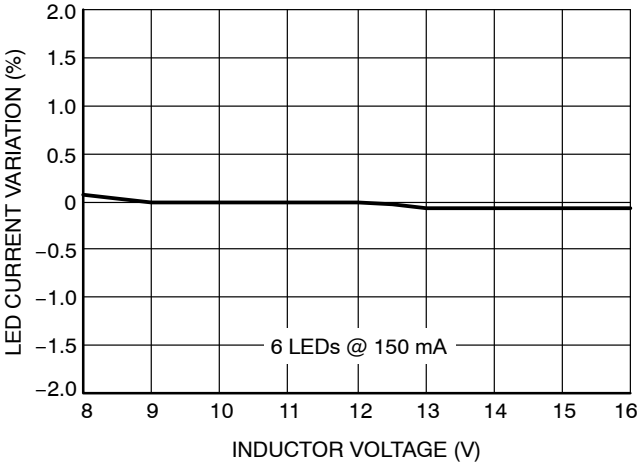


Figure 9. LED Current Regulation

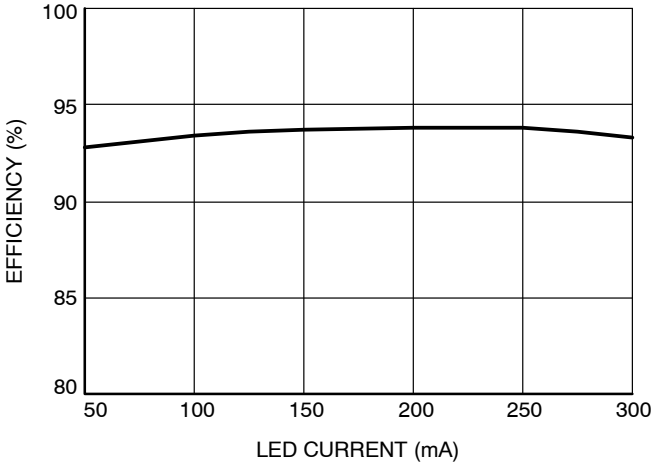


Figure 10. Efficiency vs. Load Current (6 LEDs)

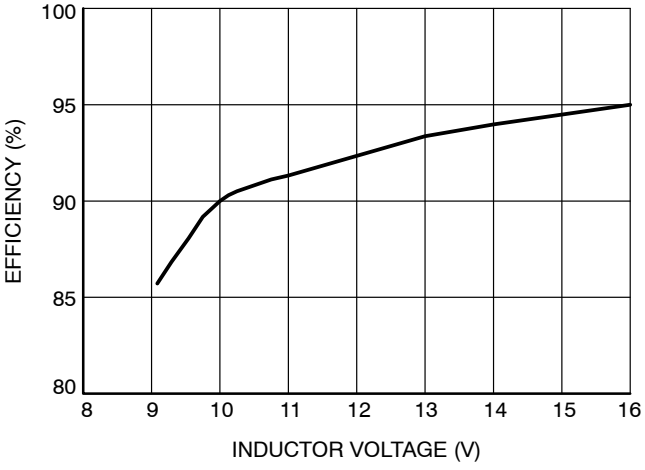


Figure 11. Efficiency vs. Inductor Voltage (6 LEDs)

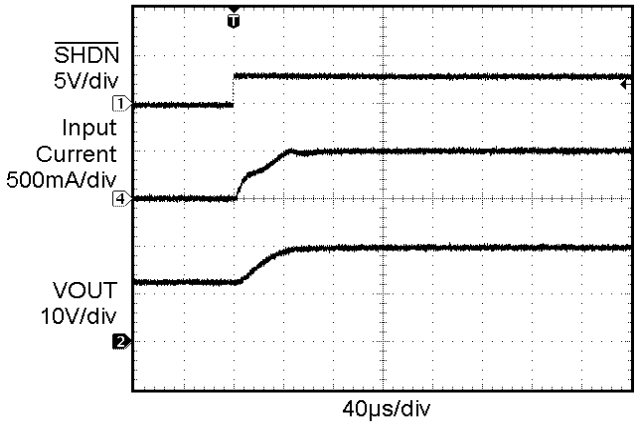


Figure 12. Power−up with 6 LEDs at 300 mA

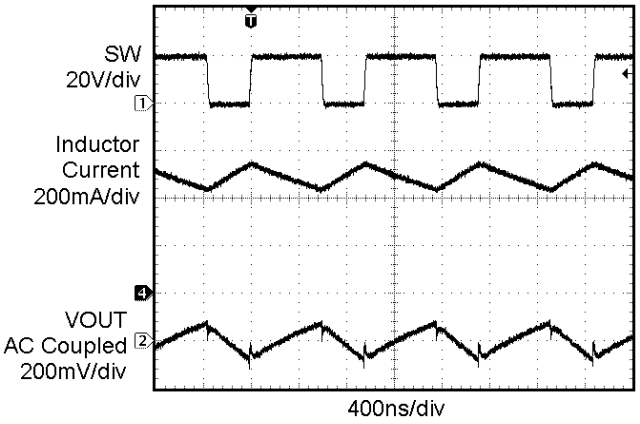


Figure 13. Switching Waveform

TYPICAL CHARACTERISTICS

(V_{IN} = 5 V, V_L = 13 V, T_{AMB} = 25°C, typical application circuit unless otherwise specified.)

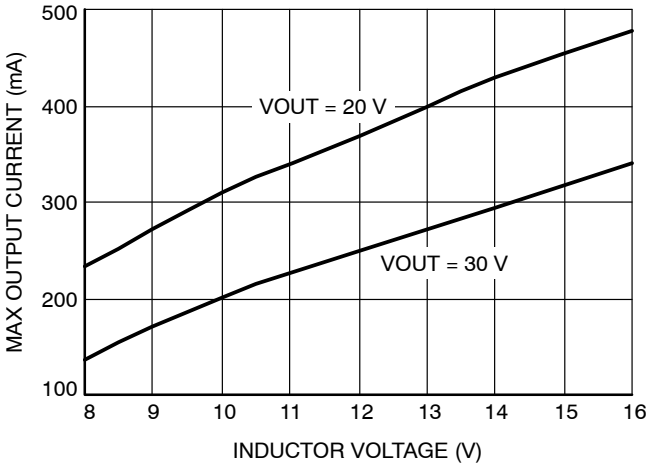


Figure 14. Maximum Output Current

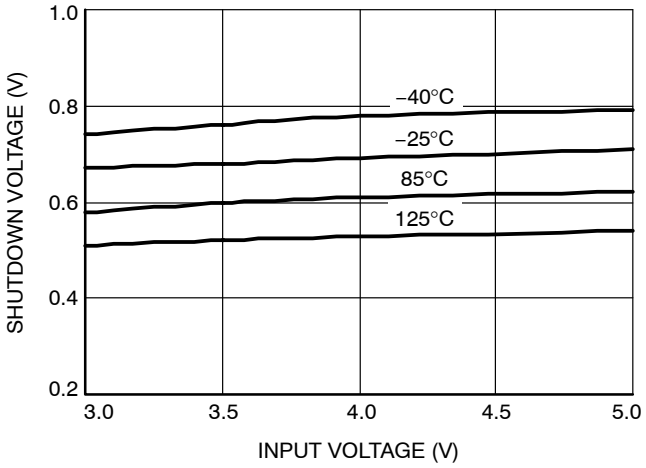


Figure 15. Shutdown Voltage

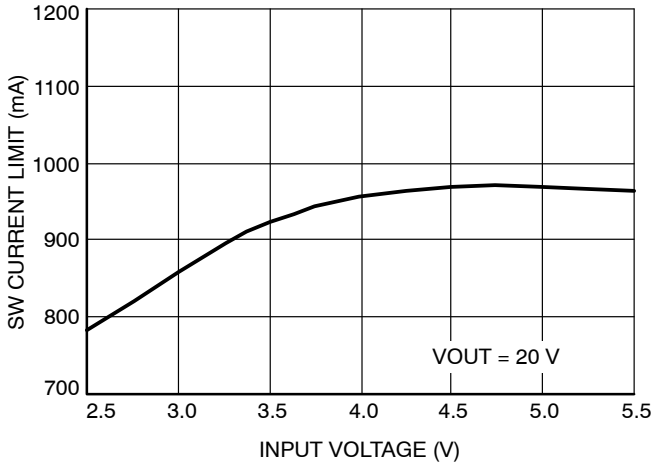


Figure 16. Switch Current Limit

Pin Description

VIN is the supply input for the internal logic. The device is compatible with supply voltages down to 2.8 V and up to 5.5 V. It is recommended that a small bypass ceramic capacitor (4.7 μF) be placed between the VIN and GND pins near the device. If the supply voltage drops below 1.9 V, the device stops switching.

$\overline{\text{SHDN}}$ is the shutdown logic input. When the pin is tied to a voltage lower than 0.4 V, the device is in shutdown mode, drawing nearly zero current. When the pin is connected to a voltage higher than 1.5 V, the device is enabled.

GND is the ground reference pin. This pin should be connected directly to the ground plane on the PCB.

SW pin is connected to the drain of the internal CMOS power switch of the boost converter. The inductor and the Schottky diode anode should be connected to the SW pin. Traces going to the SW pin should be as short as possible with minimum loop area. An over-voltage detection circuit is connected to the SW pin. When the voltage reaches 40 V, the device enters a low power operating mode preventing the SW voltage from exceeding the maximum rating.

FB feedback pin is regulated at 0.3 V. A resistor connected between the FB pin and ground sets the LED current according to the formula:

$$I_{LED} = \frac{0.3\ V}{R1}$$

The lower LED cathode is connected to the FB pin.

Table 4. PIN DESCRIPTIONS

Pin #	Name	Function
1	SW	Switch pin. This is the drain of the internal power switch.
2	GND	Ground pin. Connect the pin to the ground plane.
3	FB	Feedback pin. Connect to the last LED cathode.
4	$\overline{\text{SHDN}}$	Shutdown pin (Logic Low). Set high to enable the driver.
5	VIN	Power Supply input.

Simplified Block Diagram

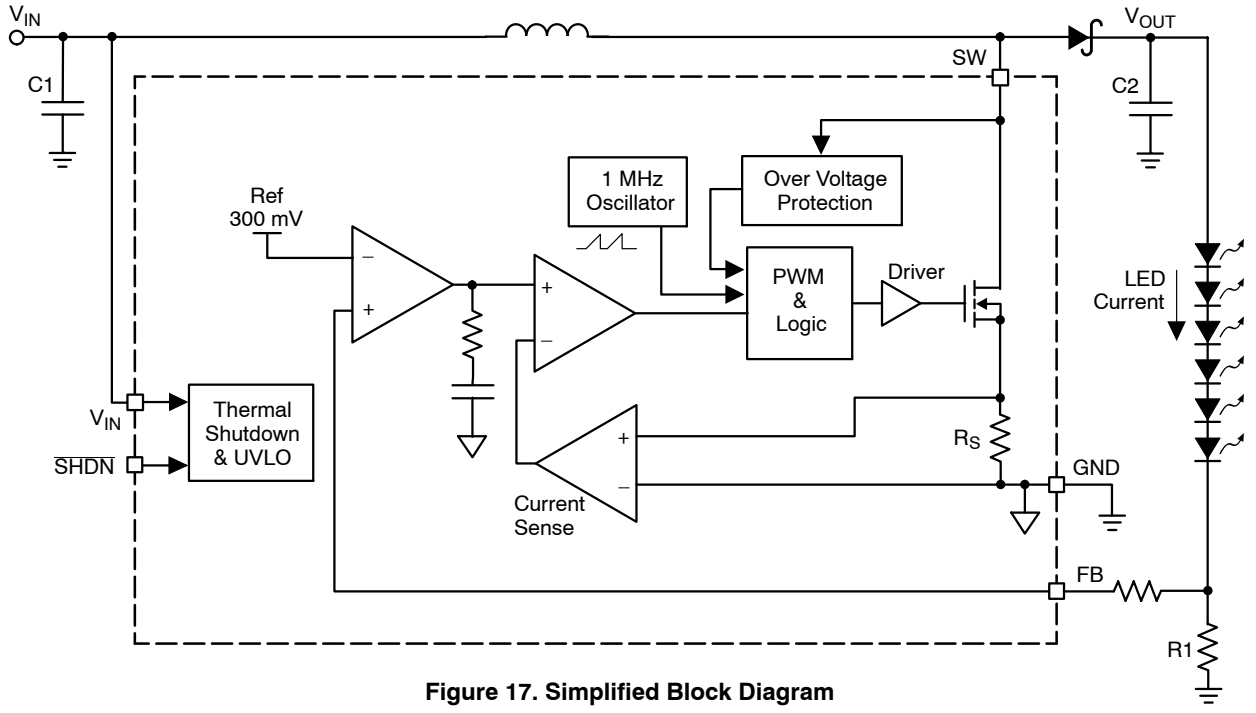


Figure 17. Simplified Block Diagram

Device Operation

The CAT4240 is a fixed frequency (1 MHz), low noise, inductive boost converter that provides a constant current with excellent line and load regulation. The device uses a high-voltage CMOS power switch between the SW pin and ground to energize the inductor. When the switch is turned off, the stored energy in the inductor is released into the load via the Schottky diode.

The on/off duty cycle of the power switch is internally adjusted and controlled to maintain a constant regulated voltage of 0.3 V across the feedback resistor connected to the feedback pin (FB). The value of the resistor sets the LED current accordingly ($0.3\ V/R_1$).

During the initial power−up stage, the duty cycle of the internal power switch is limited to prevent excessive in−rush currents and thereby provide a "soft−start" mode of operation.

When the inductor is connected to a 9 V supply or higher, the CAT4240 can drive 6 LEDs in series at 300 mA delivering a total power of 6 Watts into the load. A separate 5 V supply voltage is connected to the VIN pin.

In the event of an "Open LED" fault condition, where the feedback control loop becomes open, the output voltage will continue to increase. Once this voltage exceeds 40 V, an internal protection circuit will become active and place the device into a very low power safe operating mode.

Thermal overload protection circuitry has been included to prevent the device from operating at unsafe junction temperatures above 150°C. In the event of a thermal overload condition the device will automatically shutdown and wait till the junction temperatures cools to 130°C before normal operation is resumed.

Application Information

External Component Selection

Capacitors

The CAT4240 only requires small ceramic capacitors of 4.7 μF on the inductor input, 1 μF on the VIN pin and 1 μF on the output. Under normal condition, a 4.7 μF input capacitor is sufficient. For applications with higher output power, a larger input capacitor of 10 μF may be appropriate. X5R and X7R capacitor types are ideal due to their stability across temperature range.

Inductor

A 47 μH inductor is recommended for most of the CAT4240 applications. In cases where the efficiency is critical, inductances with lower series resistance are preferred. Inductors with current rating of 800 mA or higher are recommended for most applications. Sumida CDRH6D28−470 47 μH inductor has a rated current of 800 mA and a series resistance (D.C.R.) of 176 mΩ typical.

Schottky Diode

The current rating of the Schottky diode must exceed the peak current flowing through it. The Schottky diode performance is rated in terms of its forward voltage at a given current. In order to achieve the best efficiency, this forward voltage should be as low as possible. The response time is also critical since the driver is operating at 1 MHz. Central Semiconductor Schottky rectifier CMSH1−40 (1 A rated) is recommended for most applications.

LED Current Setting

The LED current is set by the external resistor R1 connected between the feedback pin (FB) and ground. The formula below gives the relationship between the resistor and the current:

$$R1 = \frac{0.3\ V}{LED}\ current$$

Table 5. RESISTOR R1 AND LED CURRENT

LED Current (mA)	R1 (Ω)
20	15
25	12
30	10
100	3
300	1

Open LED Protection

In the event of an “Open LED” fault condition, the CAT4240 will continue to boost the output voltage with maximum power until the output voltage reaches approximately 40 V. Once the output exceeds this level, the internal circuitry immediately places the device into a very low power mode where the total input power is limited to about 6 mW (about 1.6 mA input current with a 3.6 V supply). The SW pin clamps at a voltage below its maximum rating of 60 V. There is no need to use an external zener diode between Vout and the FB pin. A 50 V rated C_2 capacitor is required to prevent any overvoltage damage in the open LED condition.

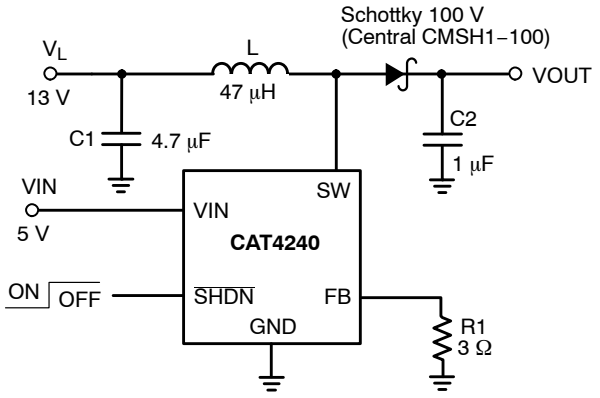


Figure 18. Open LED Protection without Zener

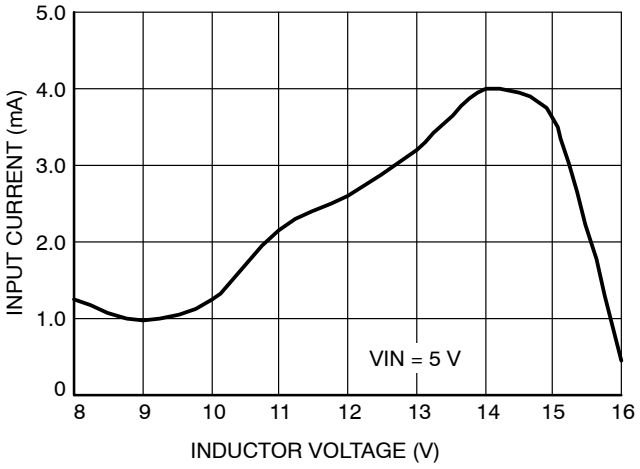


Figure 19. Open LED Supply Current vs. V_{IN} without Zener

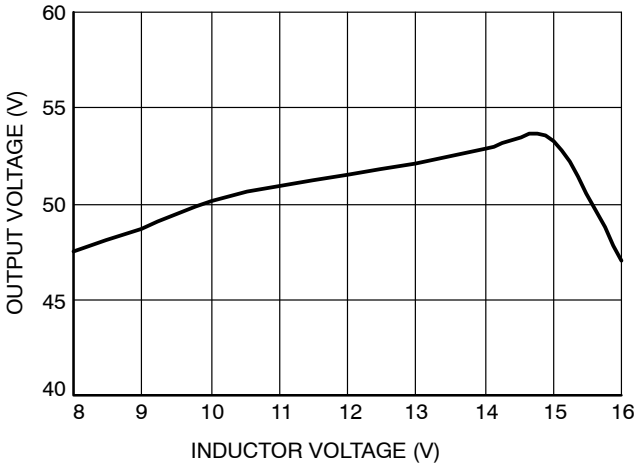


Figure 20. Open LED Output Voltage vs. V_{IN} without Zener

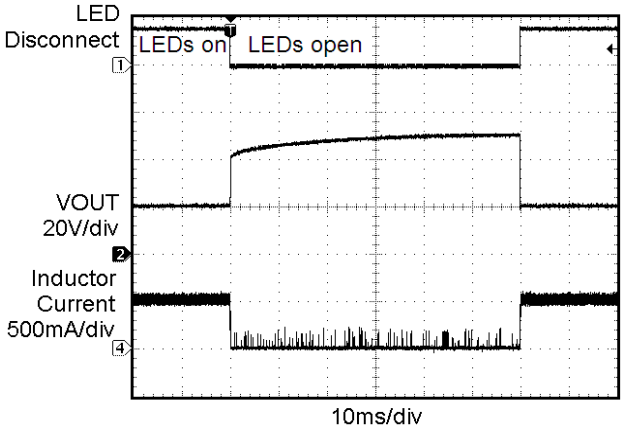


Figure 21. Open LED Disconnect and Reconnect

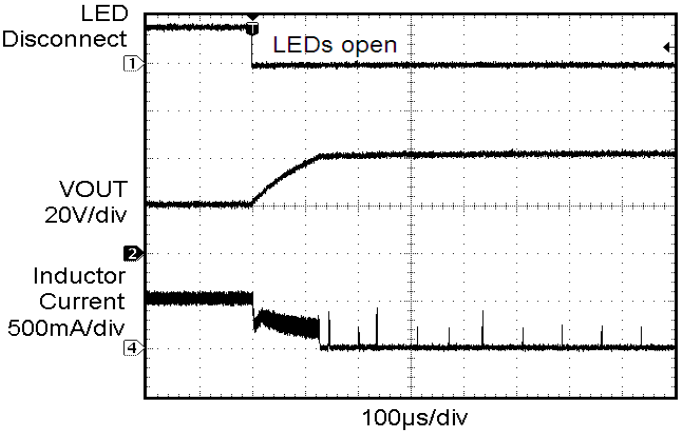


Figure 22. Open LED Disconnect

Dimming Control

There are several methods available to control the LED brightness.

PWM Signal on the $\overline{\text{SHDN}}$ Pin

LED brightness dimming can be done by applying a PWM signal to the $\overline{\text{SHDN}}$ input. The LED current is repetitively turned on and off, so that the average current is proportional to the duty cycle. A 100% duty cycle, with $\overline{\text{SHDN}}$ always high, corresponds to the LEDs at nominal current. Figure 23 shows a 1 kHz signal with a 50% duty cycle applied to the $\overline{\text{SHDN}}$ pin. The recommended PWM frequency range is from 100 Hz to 2 kHz.

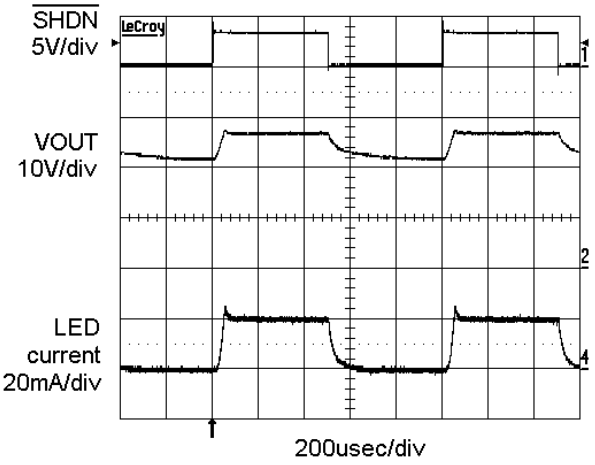


Figure 23. Switching Waveform with 1 kHz PWM on $\overline{\text{SHDN}}$

Filtered PWM Signal

A filtered PWM signal used as a variable DC voltage can control the LED current. Figure 24 shows the PWM control circuitry connected to the CAT4240 FB pin. The PWM signal has a voltage swing of 0 V to 2.5 V. The LED current can be dimmed within a range from 0 mA to 20 mA. The PWM signal frequency can vary from very low frequency up to 100 kHz.

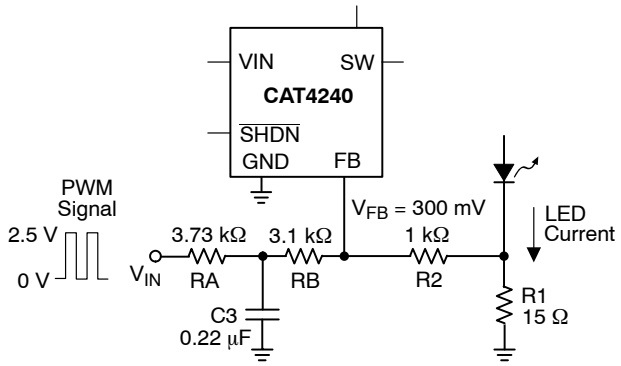


Figure 24. Circuit for Filtered PWM Signal

A PWM signal at 0 V DC, or a 0% duty cycle, results in a max LED current of about 22 mA. A PWM signal with a 93% duty cycle or more, results in an LED current of 0 mA.

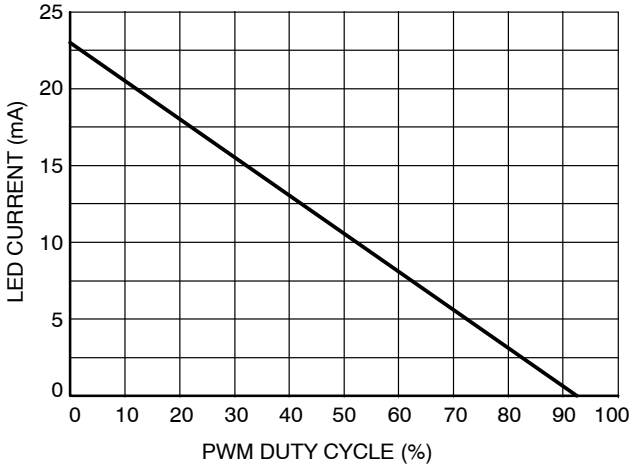


Figure 25. Filtered PWM Dimming (0 V to 2.5 V)

Board Layout

The CAT4240 is a high−frequency switching regulator. The traces that carry the high−frequency switching current have to be carefully laid out on the board in order to minimize EMI, ripple and noise in general. The thicker lines on Figure 26 show the switching current path. All these traces have to be short and wide enough to minimize the parasitic inductance and resistance. The loop shown on Figure 26 corresponds to the current path when the CAT4240 internal switch is closed. On Figure 27 is shown the current loop, when the CAT4240 switch is open. Both loop areas should be as small as possible.

Capacitor C_1 has to be placed as close as possible to the V_{IN} pin and GND. The capacitor C_2 has to be connected separately to the top LED anode. A ground plane under the CAT4240 allows for direct connection of the capacitors to ground. The resistor R_1 must be connected directly to the GND pin of the CAT4240 and not shared with the switching current loops and any other components.

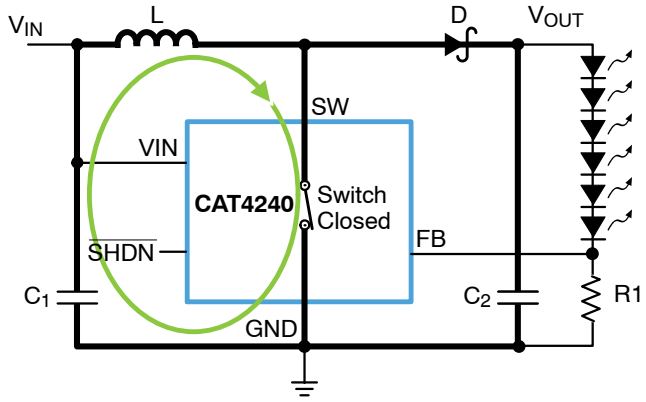


Figure 26. Closed−switch Current Loop

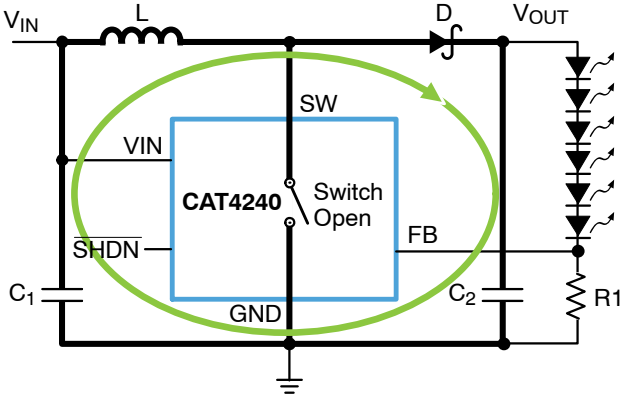


Figure 27. Open−switch Current Loop

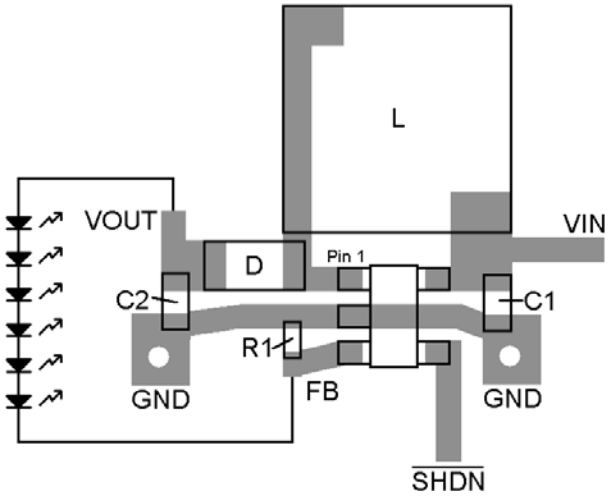
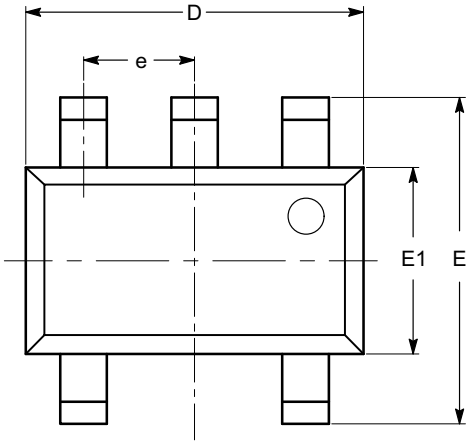


Figure 28. Recommended PCB Layout

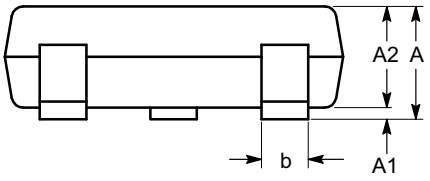
PACKAGE DIMENSIONS

TSOT−23, 5 LEAD
CASE 419AE−01
ISSUE O

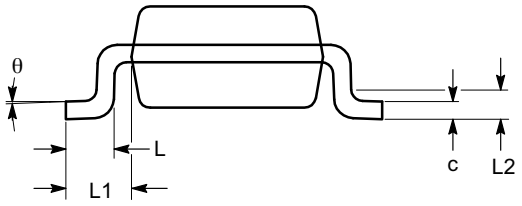


TOP VIEW

SYMBOL	MIN	NOM	MAX
A			1.00
A1	0.01	0.05	0.10
A2	0.80	0.87	0.90
b	0.30		0.45
c	0.12	0.15	0.20
D		2.90 BSC	
E		2.80 BSC	
E1		1.60 BSC	
e		0.95 TYP	
L	0.30	0.40	0.50
L1		0.60 REF	
L2		0.25 BSC	
θ	0º		8º



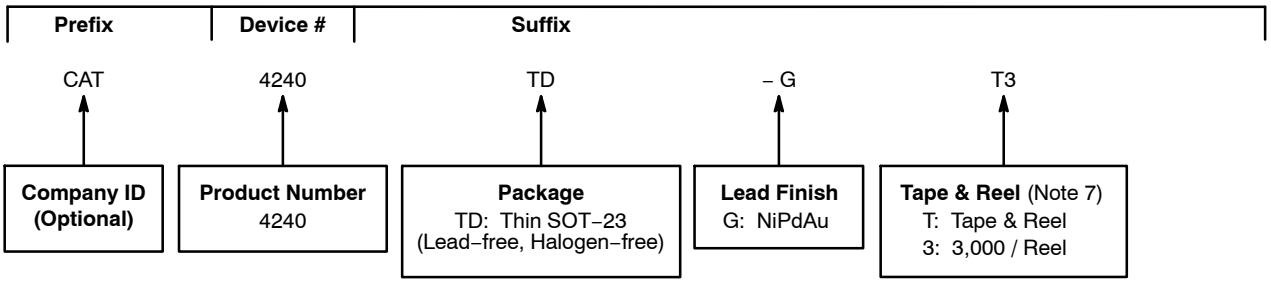
SIDE VIEW



END VIEW

Notes:
(1) All dimensions are in millimeters. Angles in degrees.
(2) Complies with JEDEC MO-193.

Example of Ordering Information (Note 4)



SERIES LED DRIVERS

Part Number	Description
CAT4137	CMOS Boost Converter – White LED Driver
CAT4237	High Voltage CMOS Boost White LED Driver
CAT4238	High Efficiency 10 LED Boost Converter
CAT4139	22 V High Current Boost White LED Driver
CAT4240	6 Watt Boost LED Driver

2. All packages are RoHS–compliant (Lead–free, Halogen–free).
3. The standard lead finish is NiPdAu.
4. The device used in the above example is a CAT4240TD–GT3 (TSOT–23, NiPdAu, Tape & Reel, 3,000/Reel).
5. For additional package and temperature options, please contact your nearest ON Semiconductor Sales office.
6. Switch current limit, typical values.
7. For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specifications Brochure, BRD8011/D.

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