CAT37
CMOS White LED Driver Boost Converter

FEATURES

- Low quiescent ground current (0.5mA typical)
- Power efficiency over 80%
- Compatible pinout with LT1937
- Adjustable output current (up to 40mA)
- High frequency 1.2MHz operation
- Input voltage operation down to 2.5V
- Low resistance (0.5Ω) power switch
- Drives up to 4 White LEDs in series
- Shutdown current less than 1μA
- Load fault protection against open-circuits
- Low value external components
- Low profile 5-lead SOT23 (1mm max) and TDFN (0.8mm) package

APPLICATIONS

- Color LCD and keypad backlighting
- Cellular phones
- Handheld terminals
- Digital cameras
- PDAs/Games
- Portable MP3 players

DESCRIPTION

The CAT37 is a DC/DC step up converter that delivers a regulated output current. Operation at a constant switching frequency of 1.2MHz allows the device to be used with very small value external inductor and ceramic capacitors.

The CAT37 is targeted to drive multiple white light-emitting diodes (LEDs) connected in series and provides the necessary regulated current to control the brightness and the color purity. An external resistor R1 controls the output current level. LED currents of up to 40mA can be supported over a wide range of input supply voltages from 2.5V to 7V, making the device ideal for battery-powered applications.

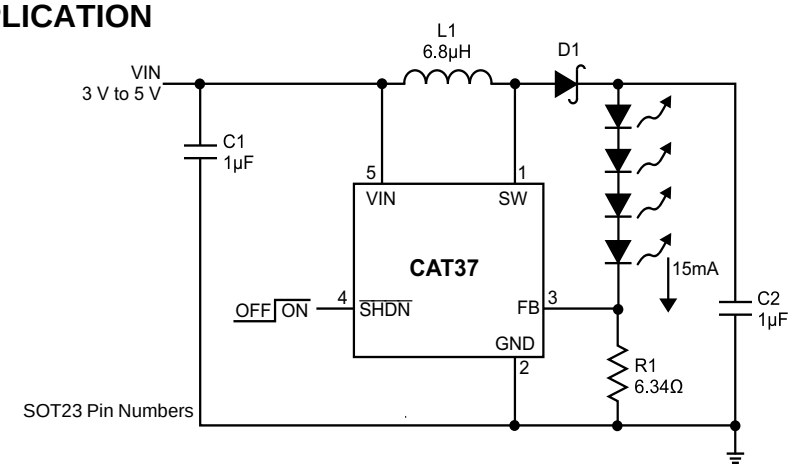
A high voltage output stage allows up to 4 White LEDs to be driven in series. Series drive provides inherent current matching.

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 “near zero” quiescent current.

In addition to overcurrent limiting protection, the device also includes detection circuitry to ensure protection against open-circuit load fault conditions.

The device is available in a low profile (1mm max height) 5-lead thin SOT23 package and in a TDFN (0.8mm max height) package.

TYPICAL APPLICATION



C1: Taiyo Yuden JMK212BJ475
C2: Taiyo Yuden EMK212BJ105
D1: Zetez ZHCS400
L1: Panasonic ELJEA6R8 or equivalent

Figure 1. Driver for Four High-Brightness White LEDs

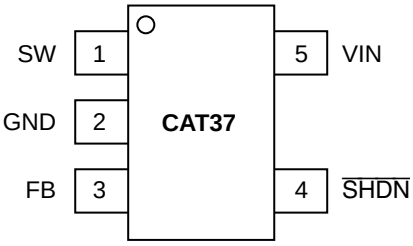
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Characteristics subject to change without notice

Doc No. 5005, Rev. R

ORDERING INFORMATION

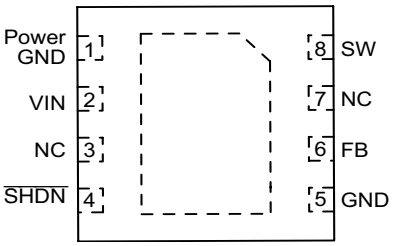
Part Number	Package	Tube Quantity	Reel Quantity	Package Marking Code
CAT37EKK-TE7	5-lead, thin SOT23	—	3000	BF
CAT37RD4-TE13	8-pad TDFN (3x3mm)	120	TBD	CCEW
CAT37TDI	5-lead, thin SOT23 Lead Free	—	—	LM

PIN CONFIGURATION



5-Lead SOT-23
1mm maximum height

θ_{JA} = 250°C/W
[Free Air]



(Top View)
TDFN Package: 3mm x 3mm
0.8mm maximum height
(RD4)

PIN DESCRIPTIONS

Pin Number SOT23	Pin Number TDFN	Name	Function
1	8	SW	Switch pin. This is the drain of the internal power switch. For minimum EMI, minimize the trace area connected to this pin.
2	5	GND	Ground pin. Connect pin 2 to ground.
3	6	FB	LED (cathode) connection pin.
4	4	$\overline{\text{SHDN}}$	Shutdown pin.
5	2	VIN	Input supply pin. This pin should be bypassed with a capacitor to ground. A 1µF capacitor mounted close to the pin is recommended.
—	1	Power Ground	Power Ground

ABSOLUTE MAXIMUM RATINGS

V_{IN} , FB, $\overline{SHDN}$ Voltage ..... 8 V

SW Voltage ..... 20 V

Junction Temperature ..... 125°C

Storage Temperature ..... -65°C to 160°C

ESD Rating - Human Body Model 2000V

Lead Soldering Temperature ..... 300°C

RECOMMENDED OPERATING CONDITIONS

Parameter	Range	Unit
V_{IN}	2.5 to 7	V
Ambient Temperature Range	-40 to +85	° C
Inductor L1	6.8 ±20% typical	µH
Input Capacitor C1	1.0 ±20% typical	µF
Output Capacitor C2	1.0 ±20% typical	µF
I_{LED} with 1 to 4 LEDs in series	0 to 20	mA

ELECTRICAL SPECIFICATIONS

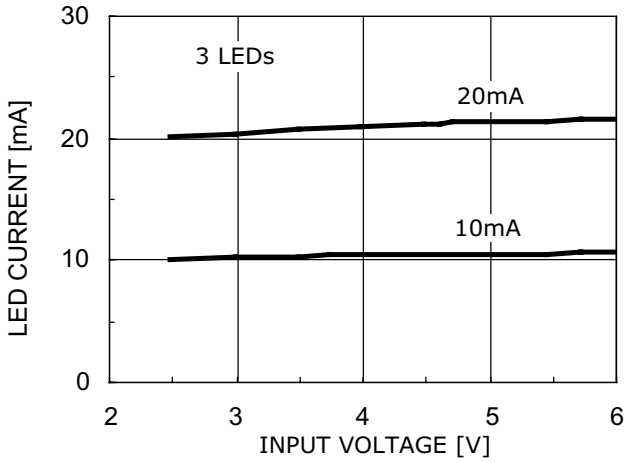
Over recommended operating conditions unless otherwise specified. T_A = 25˚C, V_{IN} = 3V and $V_{\overline{SHDN}}$ = 3V.

Symbol	Parameter	Conditions	Min	Typ	Max	Units
	Input Voltage Range		2.5		7	V
I_Q	Quiescent Current	V_{FB} = 0.2 V		0.5	0.7	mA
I_{SD}	Shutdown Current	$V_{\overline{SHDN}}$ = 0 V		0.05	1	µA
V_{FB}	FB Pin Voltage	4 LEDs at 15 mA	85	95	105	mV
I_{FB}	FB Pin Leakage Current			1	2	µA
	Shutdown High Threshold		0.85			V
	Shutdown Low Threshold				0.25	V
I_{SHDN}	Shutdown Pin Current				1	nA
f_{SW}	Boost Converter Frequency		0.8	1.2	1.6	MHz
DC	Maximum Switch Duty Cycle		90	95		%
I_{SWL}	Switch Current Limit		400	550	780	mA
	Switch Saturation Voltage	I_{SW} = 300 mA		150	200	mV
	Switch Leakage Current	Switch Off, V_{SW} = 5 V		0.01	5	µA
	Efficiency	Figure 1 with specified components		83		%

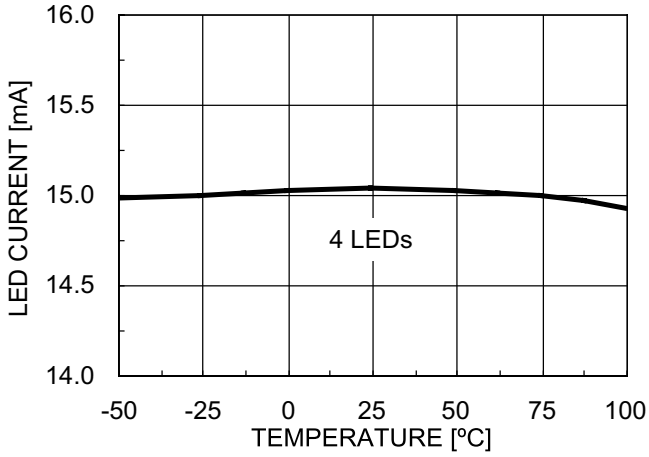
TYPICAL CHARACTERISTICS

V_{IN} = 3.6 V,T_{AMB} = 25°C, C_{IN} = 4.7 µF, C_{OUT} = 1µF, L = 6.8 µH, unless otherwise specified.

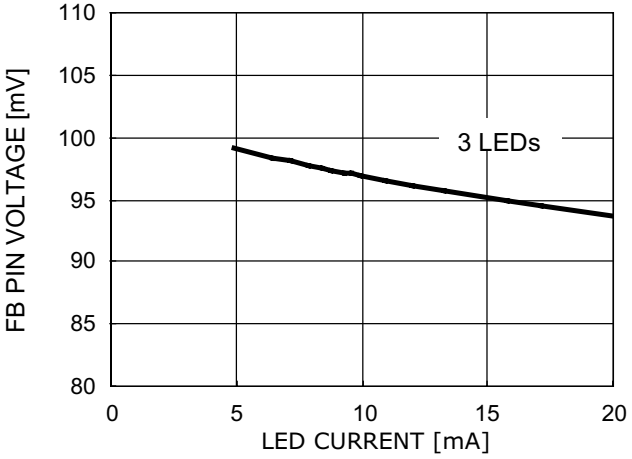
LED Current vs. Input Voltage



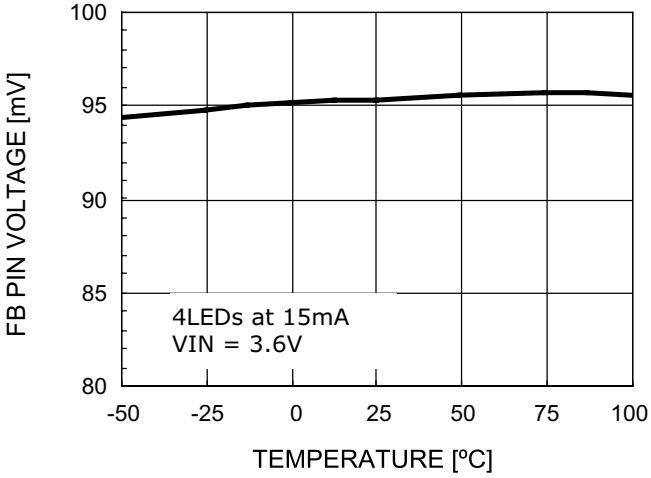
LED Current vs. Temperature



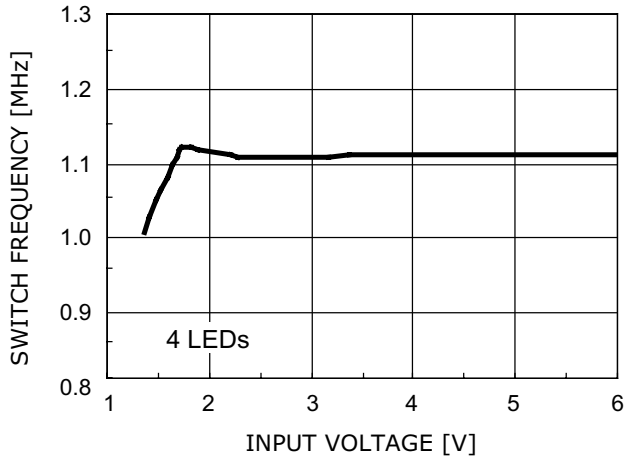
FB Pin Voltage vs. LED Current



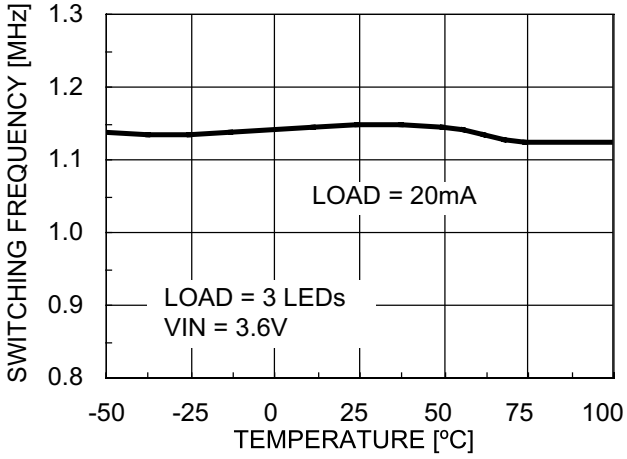
FB Pin Voltage vs. Temperature



Switching Frequency vs. Input Voltage



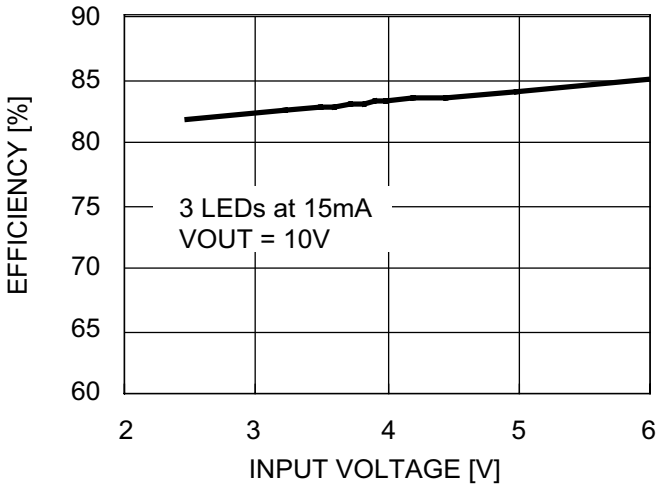
Switching Frequency vs. Temperature



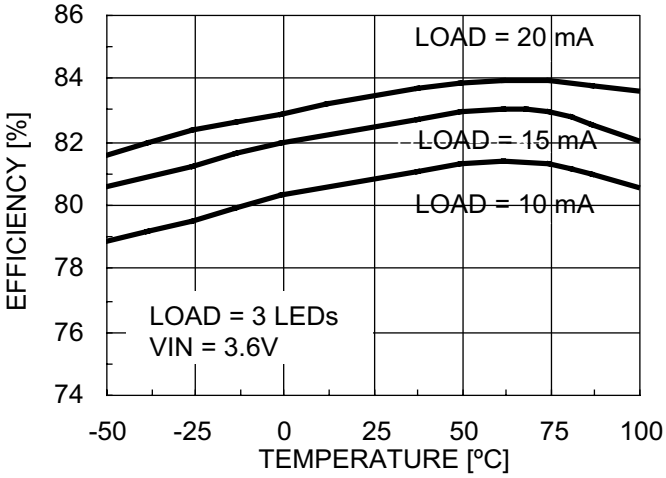
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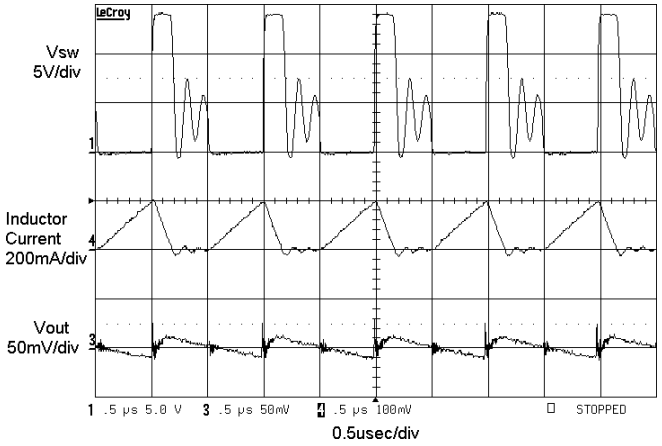
Efficiency vs. Input Voltage



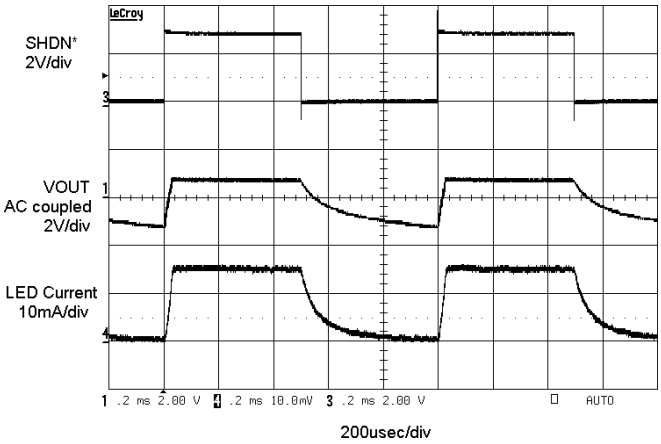
Efficiency vs. Temperature



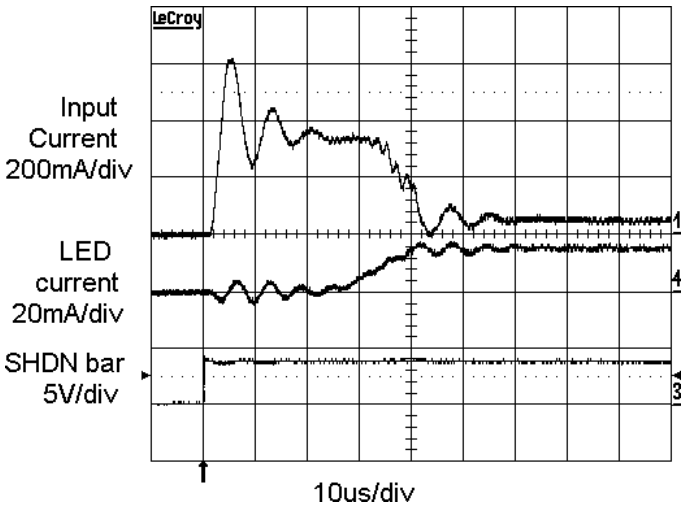
V_{SW}, I_L, & V_{OUT} Waveforms



PWM on $\overline{SHDN}$ pin at 1kHz



Enable Power-Up Waveforms



OPERATION

The CAT37 device is a high efficiency, constant frequency, current regulating boost driver for white LEDs.

The device includes a switch and an internally compensated loop for the regulation of the current in the LEDs.

Operation can be best understood by examining the block diagram. The FB pin is regulated at 95 mV and the current through the external resistor will set the regulated current in the LEDs at:

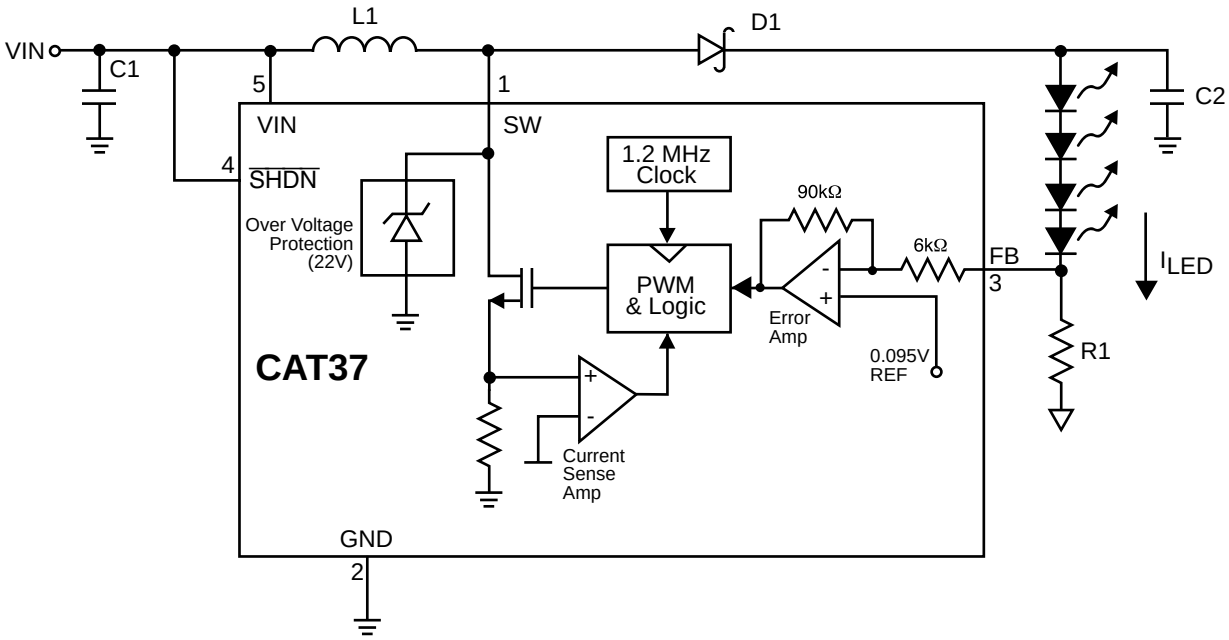
I_{LED} = 0.095/R1

While maintaining LED current regulation, the CAT37 boost converter automatically adjusts the FB pin voltage to be as low as possible. A low FB pin voltage ensures high efficiency.

Current through the internal power switch is continuously monitored cycle-by-cycle. If the current limit is exceeded, the switch is immediately turned off, protecting the device, for the remainder of the cycle.

PWM dimming operation can be achieved by switching the $\overline{SHDN}$ pin or by pulling the FB pin higher than 95mV.

BLOCK DIAGRAM



Note: SOT23 Pin Numbers

Figure 2. CAT37 Block Diagram

APPLICATION INFORMATION

CAPACITOR SELECTION

Low ESR (equivalent series resistance) capacitors should be used at the output to minimize the output ripple voltage. The low ESR and small package options available with multilayer ceramic capacitors make them excellent choices. The X5R and X7R capacitor types are preferred because they retain their capacitance over wider voltage and temperature ranges than the Y5V or Z5U types. A 1.0µF output capacitor is recommended for most applications.

The voltage rating of the output capacitor C2 depends on the number of LEDs driven in the series. A 16 V ceramic capacitor is recommended when driving 3 or 4 LEDs.

Low profile ceramic capacitors with a 1mm maximum height/thickness are available for designs height requirements. Ceramic capacitors also make a good choice for the input capacitor, which should be mounted as close as possible to the CAT37. A 1 µF or 4.7 µF input capacitor is recommended. Table 1 shows a list of several ceramic capacitor manufacturers. Consult the manufacturers for detailed information as new products and package options are introduced regularly.

Table 1. Ceramic Capacitor Manufacturers

Supplier	Web
Taiyo Yuden	www.t-yuden.com
Murata	www.murata.com
Kemet	www.kemet.com
AVX	www.avxcorp.com

DIODE SELECTION

Schottky diodes, with their low forward voltage drop and fast switching speed, are the ideal choice for high efficiency applications. Table 2 shows several different Schottky diodes that work well with the CAT37. Make sure that the diode has a voltage rating greater than the output voltage. The diode conducts current only when the power switch is turned off (typically less than one-third the time), so a 0.4A or 0.5A diode will be sufficient for most designs.

Table 2. Schottky Diode Suppliers

Part	Supplier
MBR0520	ON Semiconductor
MBR0530	www.onsemi.com
MBR0540	800.282.9855
ZHCS400	Zetex

LED CURRENT PROGRAMMING

The LED current is programmed with a single resistor connected to the FB pin. The FB pin is internally regulated to 95 mV, which sets the current flowing through R1 and the LEDs as equal to 0.095/R1.
For the best accuracy, a 1% or better resistor is recommended. Table 3 shows several typical 1% R1 values.

Table 3. R1 Resistor Values

I_{LED} (mA)	R1 (Ω)
40	2.37
30	3.16
20	4.75
15	6.34
12	7.87
10	9.53
5	19.1

For other LED current values, use the following equation to choose R1.

$$R1 = \frac{0.095}{I_{LED}}$$

Most white LEDs are driven at maximum currents of 15mA to 20mA. Some higher power designs will use two parallel strings of LEDs for greater light output, resulting in 30mA to 40mA (two strings of 15mA to 20mA) flowing through the R1 resistor.

LED DIMMING WITH DC SIGNAL

Dimming the LEDs can be done by applying a variable DC voltage as shown on Figure 3. As the V_{DC} increase the voltage across R1 decreases and therefore lower the LED current. The resistors R2 and R3 must be large enough so that their current (tens of μA) is much smaller than the LED current but much larger than the FB leakage current (I_{FB}). When adjusting V_{DC} between 0V and 2V, the resistors shown on Figure 3 will set the LED current between 0mA and 15mA.

LED DIMMING WITH PWM SIGNAL

PWM brightness control provides the widest dimming range (greater than 20:1). By turning the LEDs ON and OFF using the control signal, the LEDs operate at either zero or full current, but their average current changes with the PWM signal duty cycle. Typically, a 5kHz to 40kHz PWM signal is used.

A filtered PWM signal is used to dim the LEDs, as shown in Figure 4.

In addition to providing the widest dimming range, PWM brightness control also ensures the “purest” white LED color over the entire dimming range. The true color of a white LED changes with operating current, and is the “purest” white at a specific forward current, usually 15mA or 20mA. If the LED current is less than or more than this value, the emitted light becomes more blue. Applications involving color LCDs can find the blue tint objectionable.

LED DIMMING WITH A LOGIC SIGNAL

For applications that need to adjust the LED brightness in discrete steps, a logic signal can be used as shown in Figure 5. R_1 sets the minimum LED current value (when the NMOS switch is OFF):

$$R1 = \frac{0.095V}{I_{LED(MIN)}}$$

R_{INCR} determines how much LED current increases when the external NMOS switch is turned ON.

$$R_{INCR} = \frac{0.095V}{I_{LED(INCREASE)}}$$

PCB LAYOUT GUIDELINES

The CAT37 is a high-frequency switching regulator where proper PCB board layout and component placement can minimize noise and radiation and increase efficiency. To maximize efficiency, the CAT37 design has fast switch rise and fall times. To prevent radiation and high frequency resonance problems minimize the length and area of all traces connected to the SW pin and use a ground plane under the switching regulator.

The SW pin, schottky diode and capacitor C2 signal path should be kept as short as possible. The ground connection for the R1 resistor should be tied directly to the GND pin and not be shared with other components.

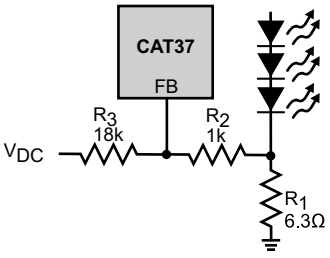


Figure 3. Dimming with a DC Voltage

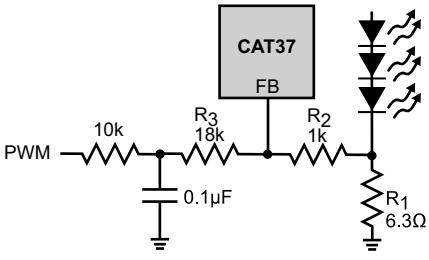


Figure 4. Dimming with a Filtered PWM Signal

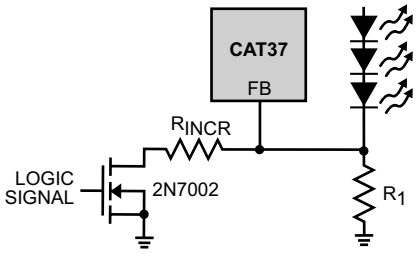
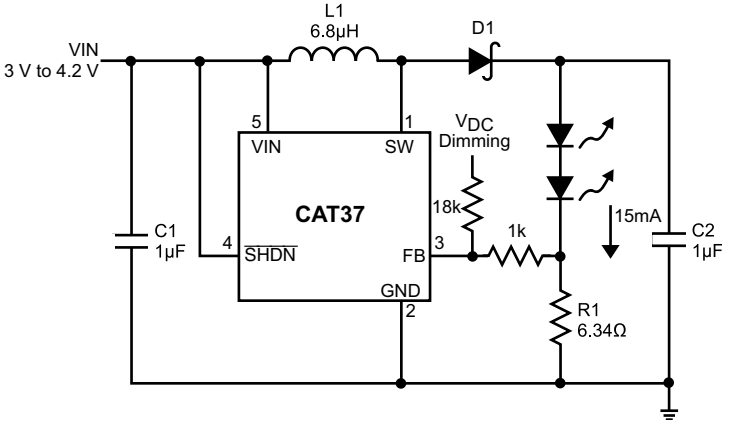


Figure 5. Dimming with a Logic Signal

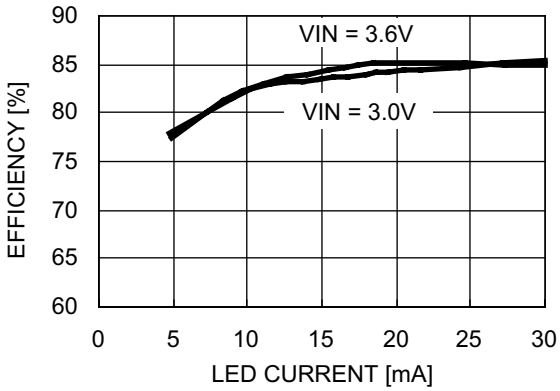
TYPICAL APPLICATION CIRCUITS

The application diagrams are shown for the SOT23 pin numbers.

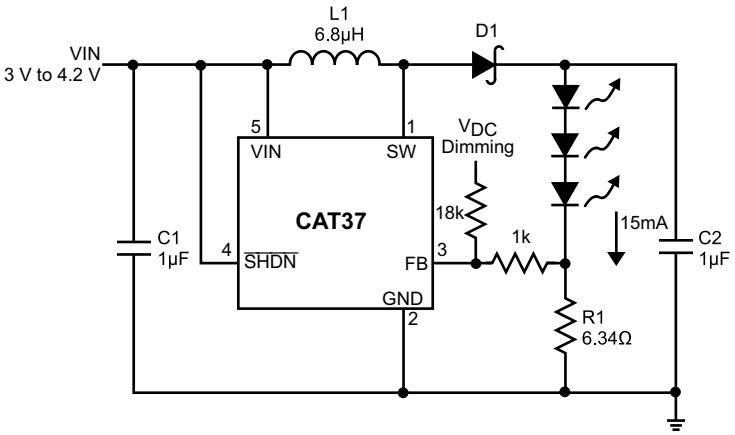
Two LEDs with DC Level Dimming Control



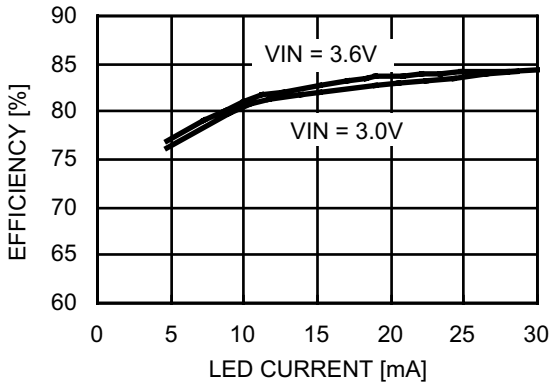
Efficiency - Two LEDs



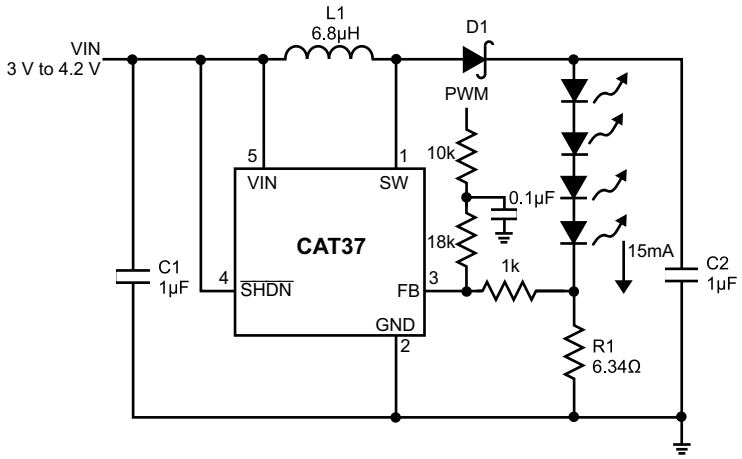
Three LEDs with DC Level Dimming Control



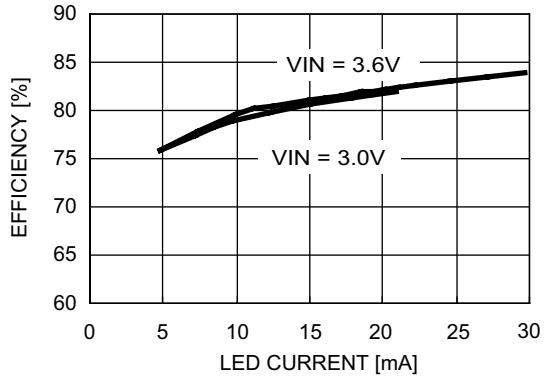
Efficiency - Three LEDs



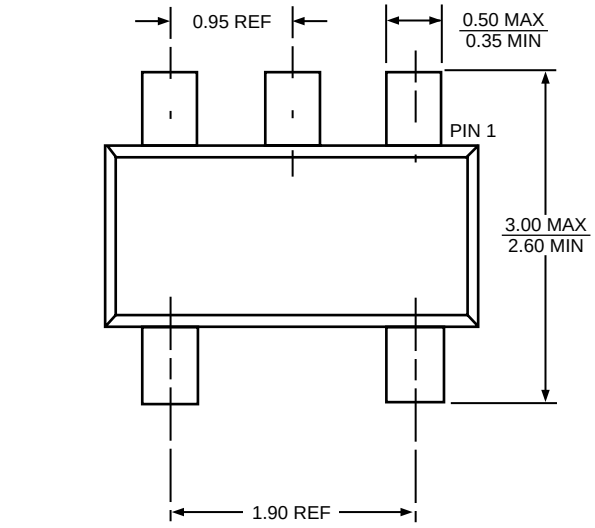
Four LEDs with PWM Dimming Control

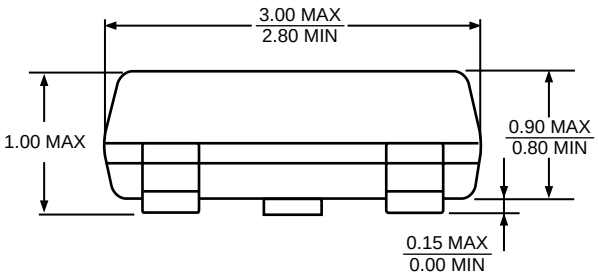


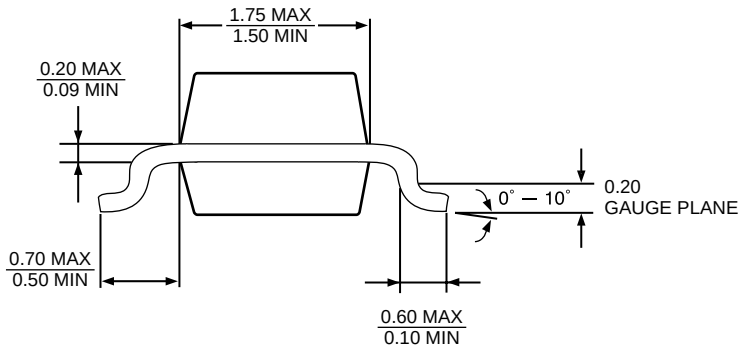
Efficiency - Four LEDs



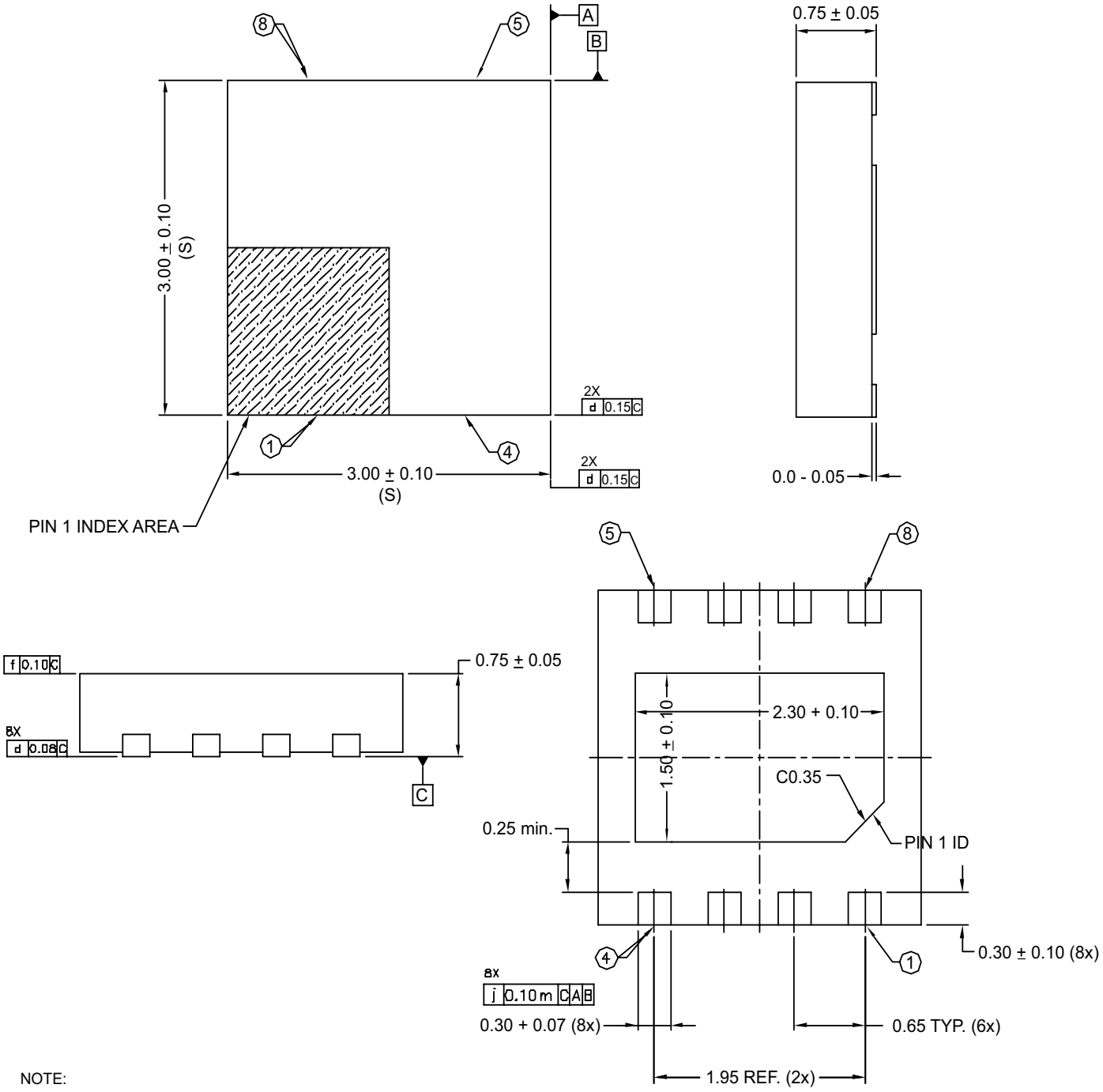
PACKAGE OUTLINES
5-LEAD SOT-23
ALL DIMENSIONS IN MILLIMETERS







TDFN 3X3 MM PACKAGE (RD4)



NOTE:

1. ALL DIMENSION ARE IN mm. ANGLES IN DEGREES.
2. COPLANARITY SHALL NOT EXCEED 0.08 mm.
3. WARPAGE SHALL NOT EXCEED 0.10 mm.
4. PACKAGE LENGTH / PACKAGE WIDTH ARE CONSIDERED AS SPECIAL CHARACTERISTIC(S)
5. REFER JEDEC MO-229 / WEEC

REVISION HISTORY

Date	Rev.	Reason
9/25/2003	H	Updated Ordering Information - part numers Changed L1 for each figure from 22 µH to 6.8 µH Changed VIN for Typical Application from 2.7V to 4.2 Vto 3V to 5V Changed C1 for each typical application circuit from 4.7 µF to 1 µF Changed C2 for each typical application circuit from 2.2 µF to 1 µF Changed VIN for each for each typical application circuit from 1.8 V to 3 V to 3 V to 4.2 V
9/25/2003	I	Updated Ordering Information - part numbers
11/6/2003	J	Updated Features Changed R1 for Typical Application figure and Typical Application Circuit figures from 6.34Ω to 6.8Ω Updated Description (2V to 2.5V input supply voltage) Updated Ordering Information (added package marking code) Updated Electrical Specifications Updated Table 4 (R1 Resistor Value) with new values Updated LED dimming with logic signal (0.095V to 0.105V)
12/8/2003	K	Updated Typical Application figures Updated Electrical Specifications Updated Operation text Updated LED current programming text Updated Table 4 (R1 Resistor Value) with new values Updated LED dimming equations Updated Typical Application Circuit figures
12/10/2003	L	Updated FB Pin Leakage Current in Electrical Specifications
12/18/2003	M	Added Typical Characteristics graphs (pages 4-6) Added Efficiency graphs to Typical Application Circuits Changed package drawing for 5-lead SOT-23
12/22/2003	N	Updated Absolute Maximum Ratings Deleted temp range from Electrical Specifications Added Recommended Operating Conditions Updated Block Diagram
6/9/2004	O	Updated Electrical Specifications (changed V_{RSET} to V_{FB} in I_Q
6/15/2004	P	Reoved Preliminary data sheet designation
9/22/2004	Q	Added Green Packages in all areas
11/1/2004	R	Eliminated TDFN (3x4.9mm) package Updated Ordering Information

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