

## 1.1MHz, High-Efficiency, Step-Up Converter for 7~8 White LEDs

### General Description

The XR3161 is a current-mode and fixed frequency boost converter with an integrated N-FET to drive up to 7~8 white LEDs in series. The series connection allows the LED current to be identical for uniform brightness. Its low on resistance of N-FET and feedback voltage reduce power loss and achieve high efficiency. Fast 1.1MHz current-mode PWM operation is available for input and output capacitors and a small inductor while minimizing ripple on the input supply. The OVP pin monitors the output voltage and stops switching if exceeds the over-voltage threshold. An internal soft-start circuit eliminates the inrush current during start-up. It can driver 3(series)\*9(parallel) LEDs or 3(series)\*12(parallel) LEDs.

The XR3161 also integrates under-voltage lockout, over-temperature protection, and current limit circuits. The XR3161 is available in a SOT-23-6 package.

### FEATURES

- Wide input Voltage from 2.5V to 6V
- 0.25V Reference Voltage
- Fixed 1.1MHz Switching Frequency
- High Efficiency up to 86%(8\*4) or 93%(3\*12)
- Wide Range for PWM Dimming (100Hz to 200kHz)
- Under-Voltage Lockout Protection
- Over-Temperature Protection
- 29V Over voltage protection
- Can driver 3\*9 WLEDs or 3\*12 WLEDs
- <math><1\mu\text{A}</math> Quiescent current During Shutdown
- SOT23-6 Package
- Lead Free and Green Devices Available (ROHS Compliant)

### Applications

- Cell Phone and Smart Phone
- PDA,PMP,MP3
- Digital Camera
- White LED Display Backlighting

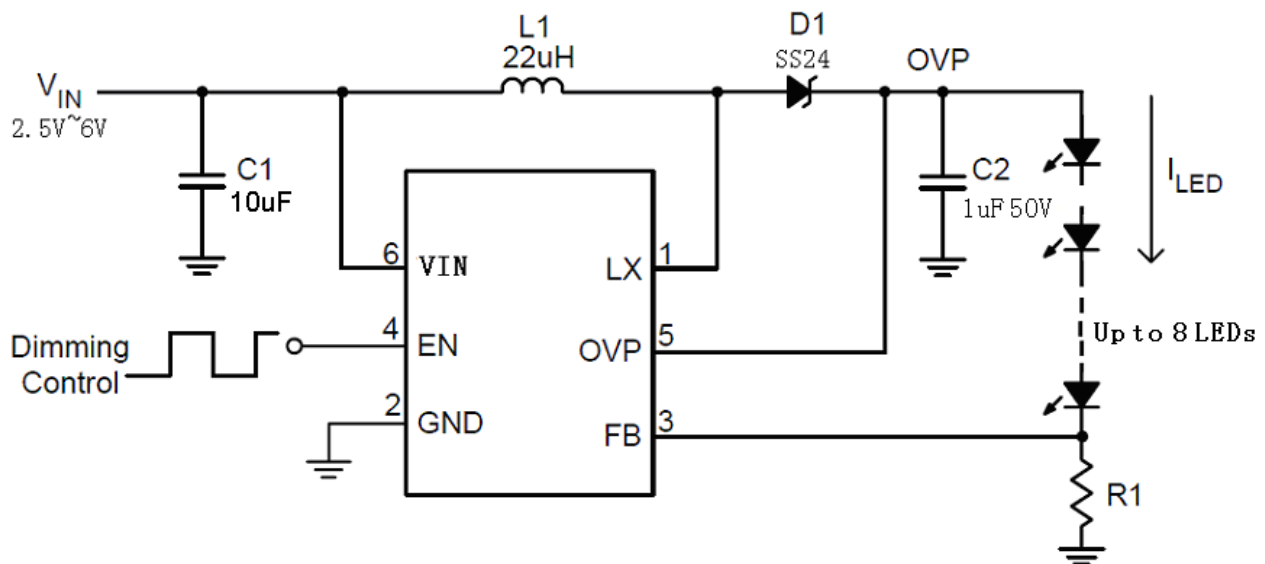


Figure 1. Typical Application Circuit 1

## ORDERING INFORMATION

PART NUMBER	TEMP RANGE	SWICHING FREQUENCY	OVP (V)	ILIM (A)	PACKAGE	PINS
XR3161	-40°C to 85°C	1.1MHZ	29	1.6	SOT23-6	6

## PIN CONFIGURATION

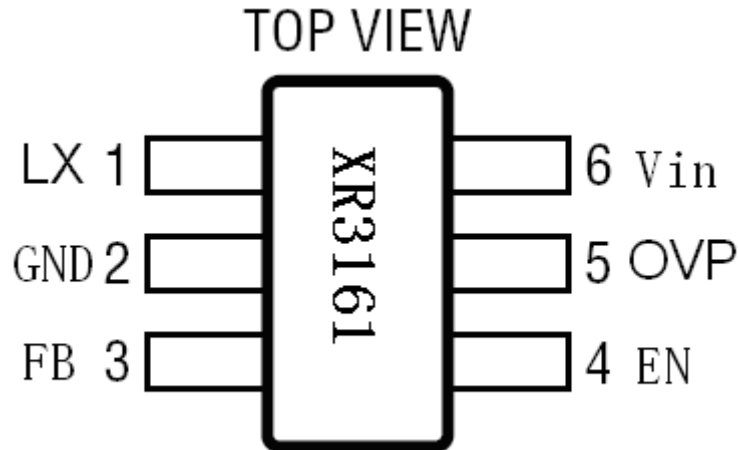


Figure 2. PIN Configuration

## PIN DESCRIPTION

PIN NUMBER	PIN NAME	PIN DESCRIPTION
1	LX	Switch pin, Connect this pin to inductor/diode here.
2	GND	Ground.
3	FB	Feedback Input, Reference voltage is 0.25 V, Connect this pin to cathode of the lowest LED calculate resistor value according to $R1=0.25V/I$ .
4	EN	Chip Enable (Active High). Voltage sensing input to trigger the function of over voltage protection. Note that this pin is high impedance. There should be a pull low 100kΩ resistor connected to GND when the control signal is floating.
5	OVP	Over Voltage Protection Pin. Voltage sensing input to trigger the function of over voltage protection. Leave it unconnected to disable this function.
6	Vin	Power supply, Bypass 1uF capacitor to GND to reduce the input noise.

## ABSOLUTE MAXIMUM RATINGS

(Note: Do not exceed these limits to prevent damage to the device. Exposure to absolute maximum rating conditions for long periods may affect device reliability.)

PARAMETER	VALUE	UNIT
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Supply Voltage $V_{IN}$	-0.3 to 6.5	V
FB, EN Voltage	-0.3 to $V_{IN}+0.3$	V
SW Voltage	28	V
Operating Ambient Temperature	-40 to 85	°C
Maximum Junction Temperature	125	°C
Storage Temperature	-55 to 150	°C
Lead Temperature (Soldering, 10 sec)	300	°C

## ELECTRICAL CHARACTERISTICS

( $V_{IN} = 3.6V$ ,  $T_A = 25^\circ C$  unless otherwise specified)

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Input Voltage Range	$V_{IN}$		2.5		6.0	V
Operating Supply Current	$I_q$	$V_{FB} = 0.3V$ , $I_{Load} = 0$	70	90	150	$\mu A$
Shutdown Supply Current		$V_{EN} = 0V$ ,		0.5	1	
Regulated Feedback Voltage	$V_{FB}$	$V_{en} = 1.5V$	0.235	0.250	0.265	V
Under Voltage Lockout	UVLO		2	2.2	2.4	V
Under Voltage Lockout Hysteresis			50	100	150	mV
Open Lamp Shutdown Threshold	OVP			29		V
Peak Inductor Current	$I_{PEAK}$	Duty Cycle = 60%	1.4	1.6	1.8	A
Oscillator Frequency	$F_{OSC}$		0.9	1.1	1.3	MHz
Rds(ON) of N-channel FET	Rds(ON)	$I_{SW} = -100mA$	0.2	0.3	0.4	Ohm
Enable Threshold		$V_{IN} = 2.5V$ to 6V	0.4	1	1.5	V
Enable Leakage Current			-0.1		+0.1	$\mu A$
SW Leakage Current		$V_{EN} = 0V$ , $V_{SW} = 0V$ or 5V, $V_{IN} = 5V$			1	$\mu A$

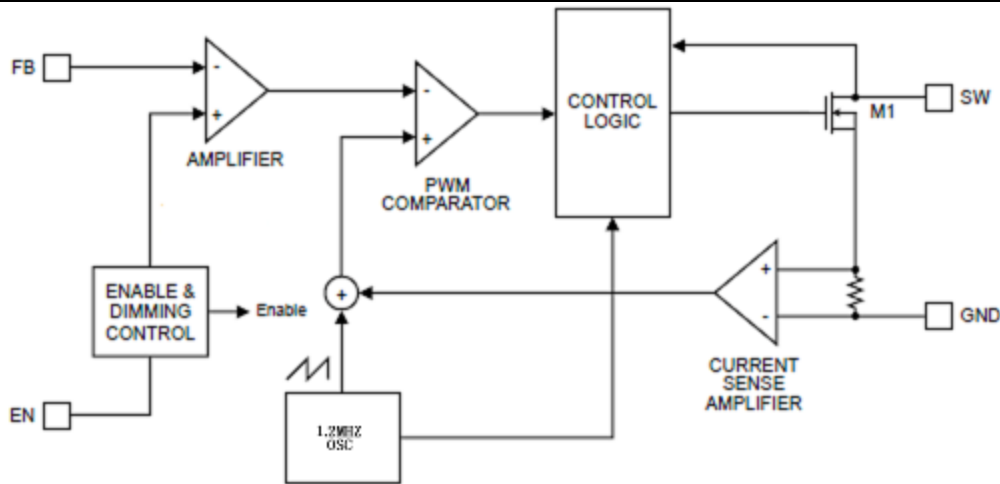


Figure 3. Functional Block Diagram

## FUNCTIONAL DESCRIPTION

### NORMAL OPERATION

The XR3161 uses a constant frequency, peak current mode boost regulator architecture to regulate the series string of white LEDs. The operation of the XR3161 can be understood by referring to the block diagram of Figure 3.

At the start of each oscillator cycle the FET is turned on through the control circuitry. To prevent sub-harmonic oscillations at duty cycles greater than 50 percent, a stabilizing ramp is added to the output of the current sense

amplifier and the result is fed into the positive input of the PWM comparator. When this voltage equals the output voltage of the error amplifier the power FET is turned off.

If the feedback voltage starts to drop, the output of the error amplifier increases. This results in more current flowing through the power FET, thus increasing the power delivered to the output.

## APPLICATION INFORMATION

### LED CURRENT CONTROL

The XR3161 regulates the LED current by setting the current sense resistor (R1) connecting to feedback and ground. As shown as below, The LED current ( $I_{LED}$ ) can be set by a resistor R1. In order to have an accurate LED current, a precision resistor is preferred (1% is recommended).

$$I_{led} = 0.25/R1$$

### DIMMING CONTROL

- a. Using a PWM Signal to EN Pin

For the brightness dimming control of the XR5161, the IC provides typically 250mV feedback voltage when the EN pin is pulled constantly high. However, EN pin allows a PWM signal to reduce this regulation voltage by changing the PWM duty cycle to achieve LED brightness dimming control. The relationship between the duty cycle and FB voltage can be calculated as following equation :

$$V_{fb} = \text{Duty} * 250\text{mV}$$

Where

Duty = duty cycle of the PWM signal

250mV = internal reference voltage

As shown in Figure 4, the duty cycle of the PWM signal

is used to cut the internal 250mV reference voltage. An internal low pass filter is used to filter the pulse signal.

And then the reference voltage can be made by connecting the output of the filter to the error amplifier for the FB pin voltage regulation.

However, the internal low pass filter 3db frequency is 500Hz. When the dimming frequency is lower than 500Hz,  $V_A$  is also a PWM signal and the LED current is controlled directly by this signal. When the frequency is higher than 500Hz, PWM is filtered by the internal low pass filter and the  $V_A$  approach a DC signal. And the LED current is a DC current which eliminate the audio noise.

Two figures of PWM Dimming from EN are shown in Typical Operating Characteristics section and the PWM dimming frequency is 200Hz and 20kHz respectively. But there is an offset in error amplifier which will cause the  $V_A$  variation. In low PWM duty signal situation, the filtered reference voltage is low and the offset can cause bigger variation of the output current. The minimum duty vs frequency is listed in following table..

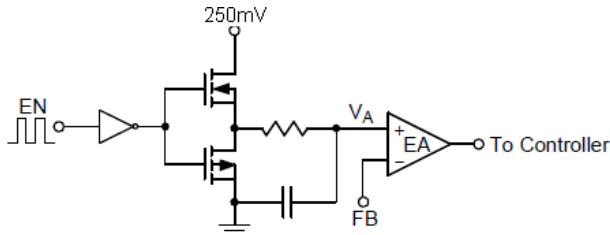


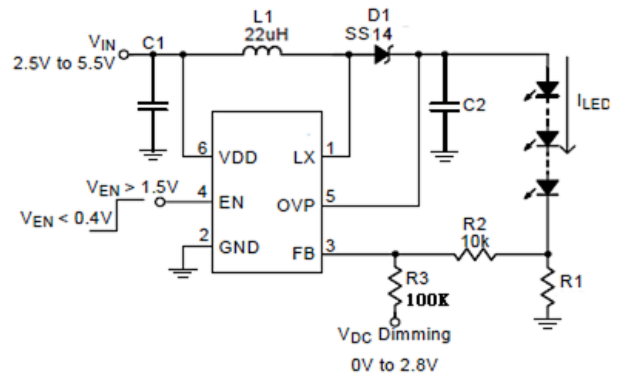
Figure 4. Block Diagram of Programmable FB Voltage Using PWM Signal

	Duty Minimum
Dimming frequency < 500Hz	4%
Dimming frequency > 500Hz	10%

b. Using a DC Voltage

Using a variable DC voltage to adjust the brightness is a popular method in some applications. The dimming control using a DC voltage circuit is shown in Figure 5. According to the Superposition Theorem, as the DC voltage increases, the voltage contributed to  $V_{FB}$  increases and the voltage drop on R2 decreases, i.e. the LED current decreases. For example, if the  $V_{DC}$  range is from 0V to

2.8V, the selection of resistors in Figure 5 sets dimming control of LED current from 20mA to 0mA.

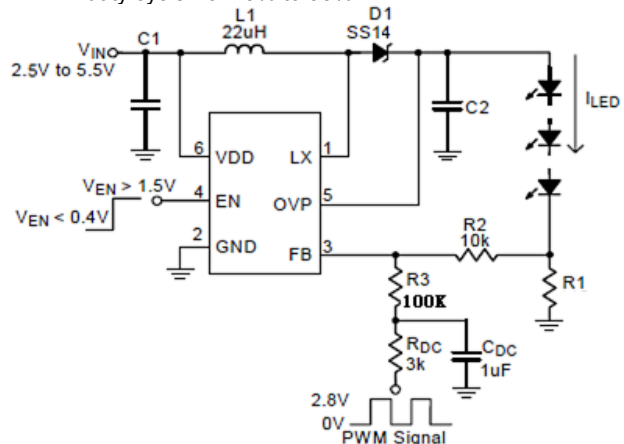


The LED current can be calculated by the following equation.

$$I_{LED} = \frac{V_{FB} - \frac{R2 \times (V_{DC} - V_{FB})}{R3}}{R1}$$

c. Using a Filtered PWM signal :

Another common application is using a filtered PWM signals an adjustable DC voltage for LED dimming control. A filtered PWM signal acts as the DC voltage to regulate the output current. The recommended application circuit is shown in the Figure 6. In this circuit, the output ripple depends on the frequency of PWM signal. For smaller output voltage ripple (<100mV), the recommended frequency of 2.8V PWM signal should be above 2kHz. To fix the frequency of PWM signal and change the duty cycle of PWM signal can get different output current as Figure 7. According to the application circuit of Figure 6, output current is from 18.7mA to 1.16mA by adjusting the PWM duty cycle from 5% to 95%.



The LED current can be calculated by the following equation.

$$I_{LED} = \frac{V_{FB} - \frac{R2 \times (V_{PWM} \times Duty - V_{FB})}{R3 + R_{DC}}}{R1}$$

## INDUCTOR SELECTION

The recommended value of inductor for 7 to 8 WLEDs applications are 22μH. Small size and better efficiency are the major concerns for portable device, such as XR3161 used for mobile phone. The inductor should have low core loss at 1.1MHz and low DCR for better efficiency. To avoid inductor saturation current rating should be considered.

Manufacturer	Part Number	Inductance (uH)	DRC max (Ohms)	Dimensions L*W*H (mm <sup>3</sup> )
Murata	LQH32PN	22	0.15	3.2*2.5*1.7
Sumida	CDRH3D16	22	0.17	4*4*1.8

Table 1. Recommend Surface Mount Inductors

## INPUT & OUTPUT CAPACITOR SELECTION

Input ceramic capacitors of 10μF and output of 1uF are recommended for XR3161 applications. For better

voltage filtering, ceramic capacitors with low ESR are recommended. X5R and X7R types are suitable because of their wider voltage and temperature ranges.

Such as Murata GRM32RR71H105KA01L and GRM32ER61A106KA01L

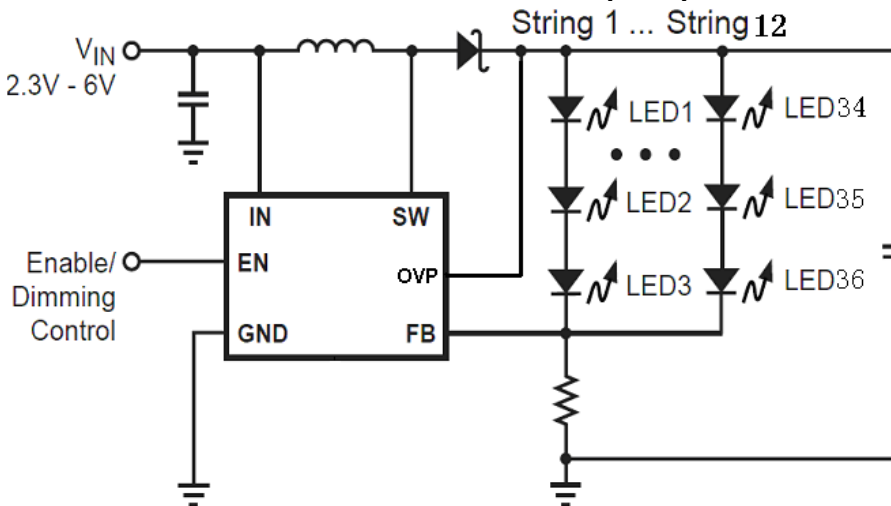
## DIODE SELECTION

Schottky diode is a good choice for XR3161 because of its low forward voltage drop and fast reverse recovery. Using Schottky diode can get better efficiency. The SS14, SS24 or Diodes B240A is recommend.

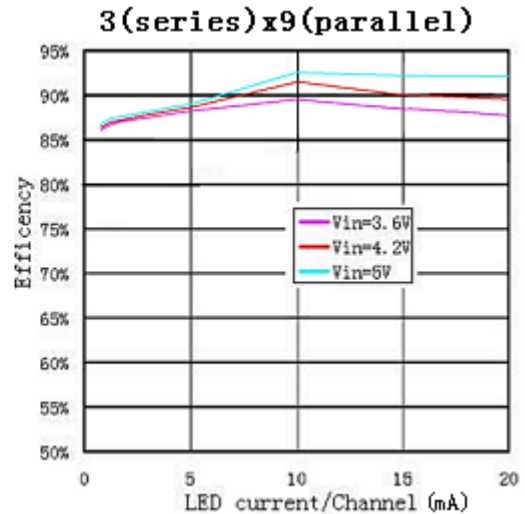
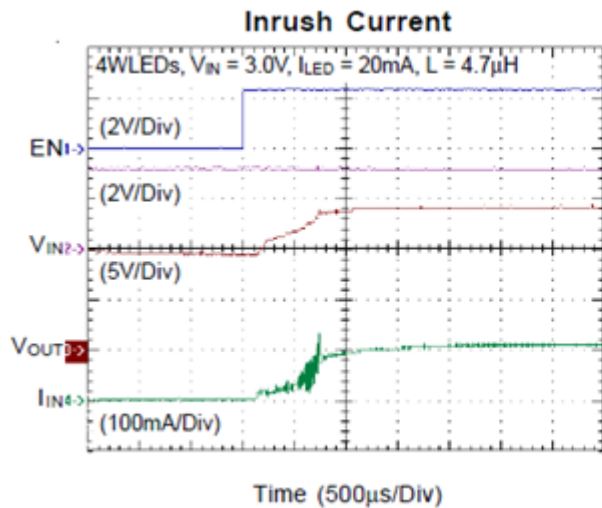
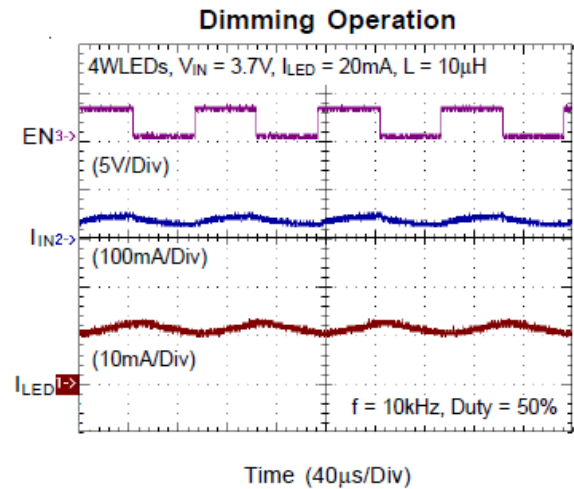
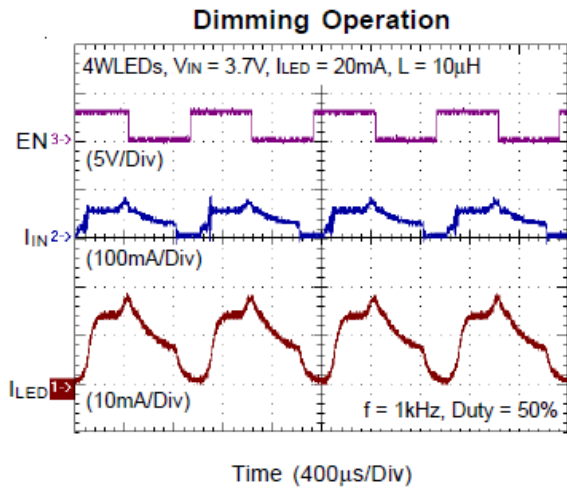
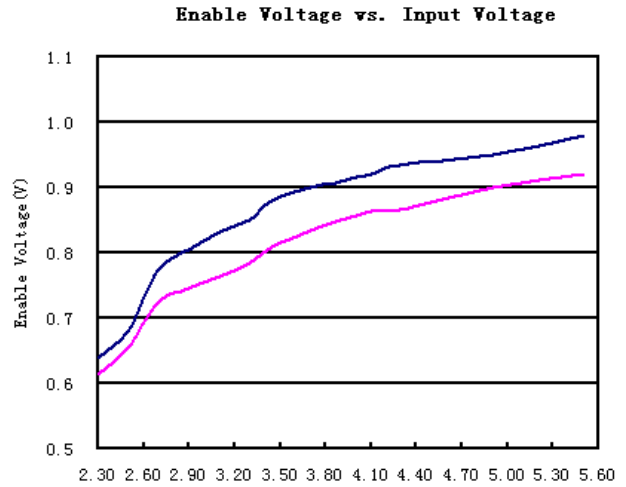
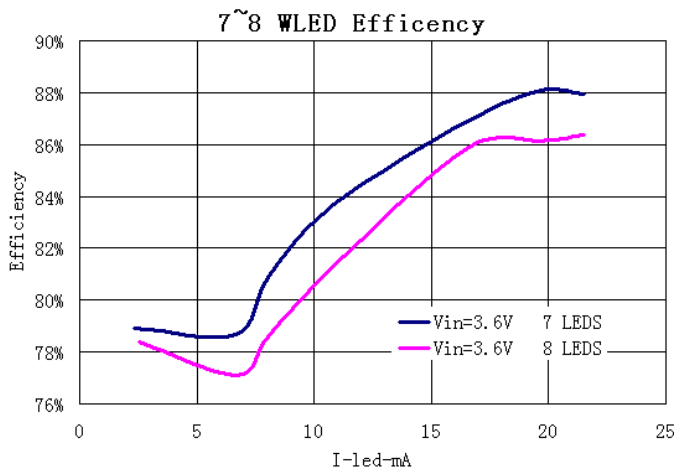
## LAYOUT GUIDE

- 1) VCC to GND noise bypass-Short and wide connection for the
- 1 MLCC capacitor between Pin6 and Pin2.
- 2) Minimized LX node copper area to reduce EMI.
- 3) Minimized FB node copper area and keep far away from noise sources
- 4) A full GND plane without gap break

## MULTI-CHANNEL LEDS' APPLICATION (3\*12)

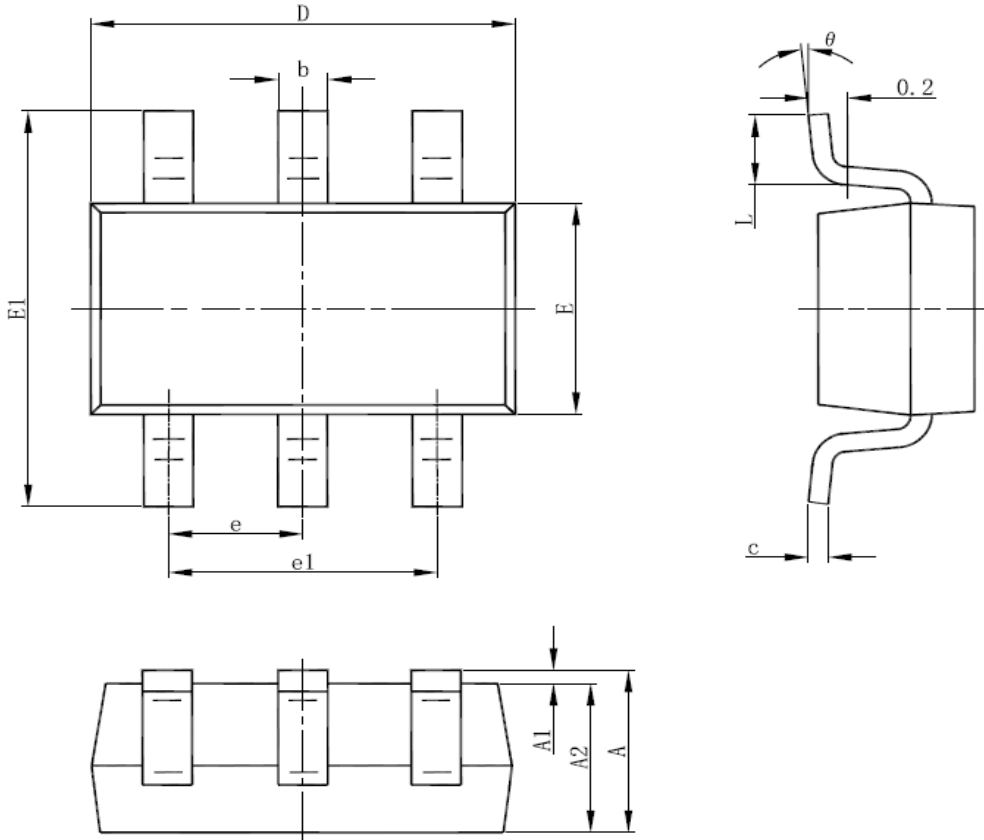


## TYPICAL PERFORMANCE CHARACTERISTICS



## PACKAGE OUTLINE

### SOT-23-6L PACKAGE OUTLINE DIMENSIONS



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	1.050	1.250	0.041	0.049
A1	0.000	0.100	0.000	0.004
A2	1.050	1.150	0.041	0.045
b	0.300	0.500	0.012	0.020
c	0.100	0.200	0.004	0.008
D	2.820	3.020	0.111	0.119
E	1.500	1.700	0.059	0.067
E1	2.650	2.950	0.104	0.116
e	0.950(BSC)		0.037(BSC)	
e1	1.800	2.000	0.071	0.079
L	0.300	0.600	0.012	0.024
θ	0°	8°	0°	8°