

High Performance, Constant Current LED Driver with PWM Brightness Control

Features

- 2.5V to 5.5V Input Voltage
- Drivers up to 8 Series WLEDs
- Low 250mV Feedback Voltage
- 1.2MHz Fixed Switching Frequency
- Internal 1.6A Switch Current Limit
- Internal Compensation
- Thermal Shutdown
- Over Voltage Protection
- Dimming with wide Frequency Range
- Available in SOT23-6 package

Applications

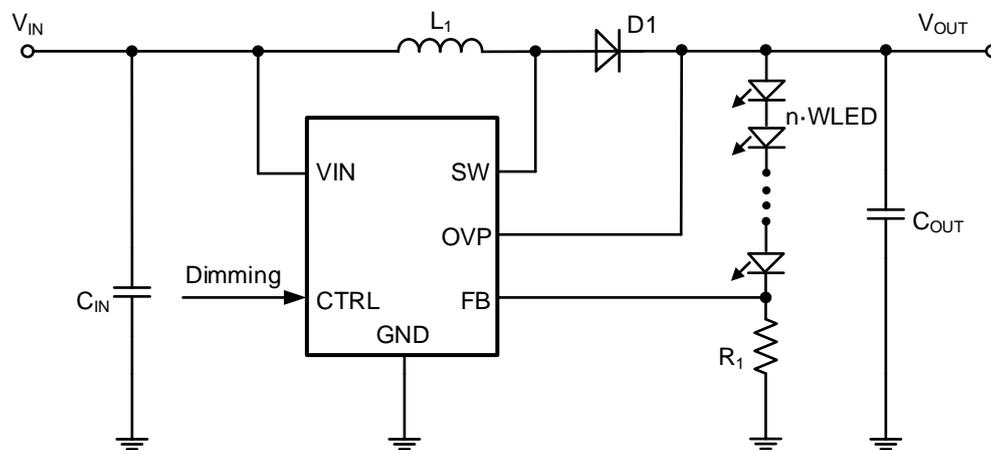
- Camera Flash White LED
- Digital still cameras
- PDA LED back light

General Description

The ASP3730 is a step-up converter designed for driving up to 8 Series white LED's from a single cell Lithium Ion battery. The device features integrated overvoltage protection and Its low 250mV feedback voltage reduces power loss and improves efficiency.

Optimized operation frequency can meet the requirement of small LC filters value and low operation current with high efficiency. Internal soft start function can reduce the inrush current. SOT23-6 package type provides the best solution for PCB space saving and total BOM cost.

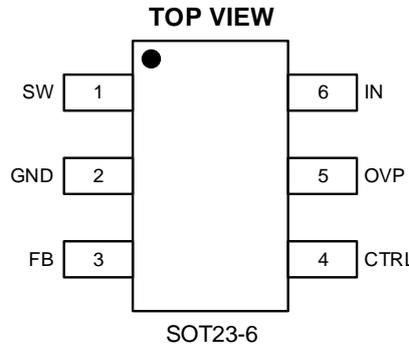
Typical Application Circuit



Typical Application Circuit

Package and Pin Description

Pin Configuration



Pin Description

Pin	Name	Function
1	SW	Power Switch Output. SW is the drain of the internal MOSFET switch. Connect the power inductor and output rectifier to SW. SW can swing between GND and 30V.
2	GND	Ground Pin.
3	FB	Feedback Reference Voltage Pin. Series connect a resistor between WLED and ground as a current sense. Sense the current feedback voltage to set the current rating.
4	CTRL	CTRL pin of the boost converter. It is a multi-functional pin which can be used for enable control and PWM dimming. Should not be left floating.
5	OVP	Over Voltage Input. OVP pin measures the output voltage for open circuit protection. Connect OVP to the output at the top of the LED string.
6	IN	Input Supply Pin. Must be locally bypassed.

Order Information

Device No.	Package	Quantity
ASP3730ZC-R	SOT23-6	3000pcs/Reel

Note: "ZC" stands for package. "ZC" : SOT23-6.

Note: "R" stands for Packing, Tape&Reel.

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Specifications

Absolute Maximum Ratings ^{(1) (2)}

Item	Min	Max	Unit
V _{IN} , V _{CTRL} voltage	-0.3	6	V
V _{SW} , V _{OVP} voltage	-0.3	35	V
V _{SW} , V _{OVP} voltage (10ns transient)	-5	36	V
All Other Pins	-0.3	6	V
Power dissipation ⁽³⁾	Internally Limited		
Operating junction temperature, T _J	-40	150	°C
Storage temperature, T _{stg}	-65	150	°C
Lead Temperature (Soldering, 10sec.)		260	°C

Note (1): Exceeding these ratings may damage the device.

Note (2): The device is not guaranteed to function outside of its operating conditions.

Note (3): The maximum allowable power dissipation is a function of the maximum junction temperature, T_{J(MAX)}, the junction-to-ambient thermal resistance, R_{θJA}, and the ambient temperature, T_A. The maximum allowable power dissipation at any ambient temperature is calculated using: P_{D(MAX)} = (T_{J(MAX)} - T_A)/R_{θJA}. Exceeding the maximum allowable power dissipation causes excessive die temperature, and the regulator goes into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage. Thermal shutdown engages at T_J=160°C (typical) and disengages at T_J= 130°C (typical).

ESD Ratings

Item	Description	Value	Unit
V _(ESD-HBM)	Human Body Model (HBM) ANSI/ESDA/JEDEC JS-001-2014 Classification, Class: 2	±2000	V
V _(ESD-CDM)	Charged Device Mode (CDM) ANSI/ESDA/JEDEC JS-002-2014 Classification, Class: C0b	±200	V
I _{LATCH-UP}	JEDEC STANDARD NO.78E APRIL 2016 Temperature Classification, Class: I	±150	mA

Recommended Operating Conditions

Item	Min	Max	Unit
Operating junction temperature ⁽¹⁾	-40	125	°C
Operating temperature range	-40	85	°C
Input voltage V _{IN}	2.5	5.5	V
Output voltage V _{OUT}	V _{IN}	30	V

Note (1): All limits specified at room temperature (T_A = 25°C) unless otherwise specified. All room temperature limits are 100% production tested. All limits at temperature extremes are ensured through correlation using standard Statistical Quality Control (SQC) methods. All limits are used to calculate Average Outgoing Quality Level (AOQL).

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Thermal Information

Item	Description	Value	Unit
R _{θJA}	Junction-to-ambient thermal resistance ⁽¹⁾⁽²⁾	105	°C/W
R _{θJC(top)}	Junction-to-case (top) thermal resistance	55	°C/W
R _{θJB}	Junction-to-board thermal resistance	17.5	°C/W
ψ _{JT}	Junction-to-top characterization parameter	3.5	°C/W
ψ _{JB}	Junction-to-board characterization parameter	17.5	°C/W

Note (1): The package thermal impedance is calculated in accordance to JESD 51-7.

Note (2): Thermal Resistances were simulated on a 4-layer, JEDEC board

Electrical Characteristics (1) (2)

V_{IN}=5V, T_A=25°C, unless otherwise specified.

Parameter	Test Conditions	Min	Typ.	Max	Unit
Input voltage range		2.5		5.5	V
Output voltage range				30	V
Supply Current (Quiescent)	V _{FB} = 110%		200	250	μA
Supply Current (Shutdown)	V _{CTRL} = 0 or C _{CTRL} = GND		0.1	1	μA
Feedback Voltage		244	250	256	mV
SW On Resistance			400	650	mΩ
Current Limit			1.6		A
Output Over Voltage Protection Threshold			35		V
Switching Frequency			1.2		MHz
Maximum Duty Cycle	V _{FB} =90%		85		%
Minimum On-Time			80		ns
EN Rising Threshold		1.1			V
EN Falling Threshold				0.9	V
EN Threshold Hysteresis			200		mV
Under-Voltage Lockout Threshold	Wake up V _{IN} Voltage		2.4	2.5	V
	Shutdown V _{IN} Voltage	2	2.1		V
	Hysteresis V _{IN} voltage		300		mV
Soft Start			1		mS
Thermal Shutdown			160		°C
Thermal Hysteresis			30		°C

Note (1): MOSFET on-resistance specifications are guaranteed by correlation to wafer level measurements.

Note (2): Thermal shutdown specifications are guaranteed by correlation to the design and characteristics analysis.

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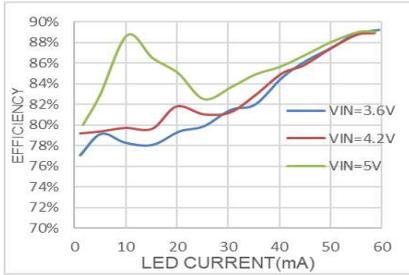
Typical Performance Characteristics (1) (2)

Note (1): Performance waveforms are tested on the evaluation board.

Note (2): $V_{IN}=5V$, $V_{OUT}=15V$, 5 LEDs, $T_A = +25^{\circ}C$, unless otherwise noted.

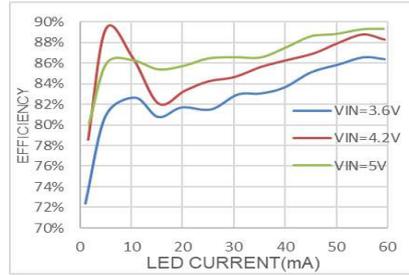
Efficiency vs. LED Current

$V_{OUT}=9V$, 3 LEDs



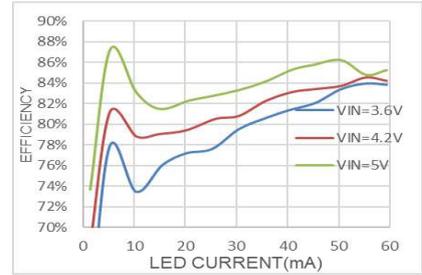
Efficiency vs. LED Current

$V_{OUT}=15V$, 5 LEDs



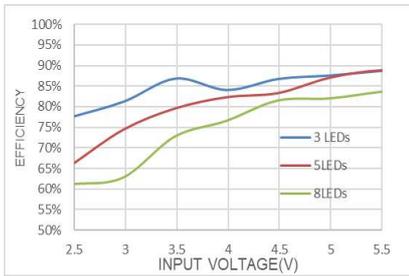
Efficiency vs. LED Current

$V_{OUT}=24V$, 8 LEDs



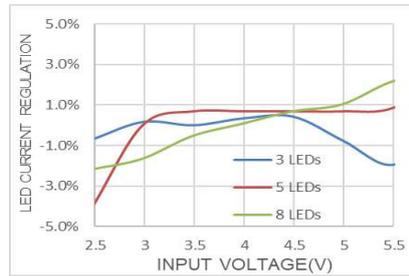
Efficiency vs. Input Voltage

Typical $I_{LED}=11.5mA$



LED Current Regulation vs. Input Voltage

Typical $I_{LED}=11.5mA$



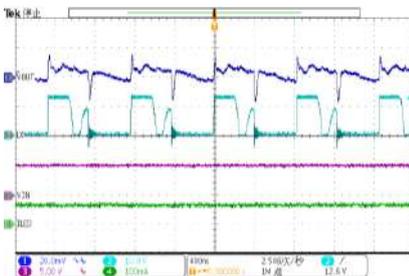
LED Current vs. PWM Duty Cycle

$V_{IN}=5V$, $V_{OUT}=15V$, 5 LEDs



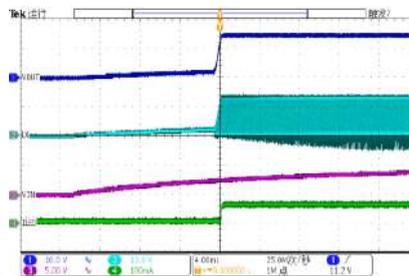
Steady State Operation

$V_{IN}=5V$, $V_{OUT}=15V$, 5LEDs, $I_{LED}=60mA$



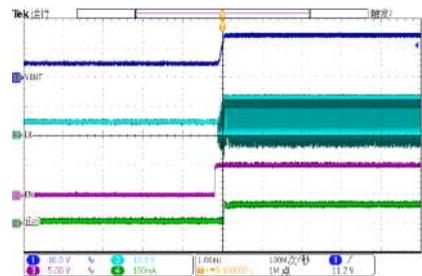
V_{IN} Startup

$V_{IN}=5V$, $V_{OUT}=15V$, 5 LEDs, $I_{LED}=60mA$



Enable Startup

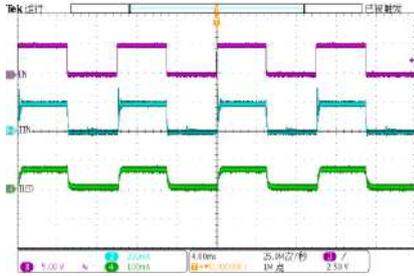
$V_{IN}=5V$, $V_{OUT}=15V$, 5 LEDs, $I_{LED}=60mA$



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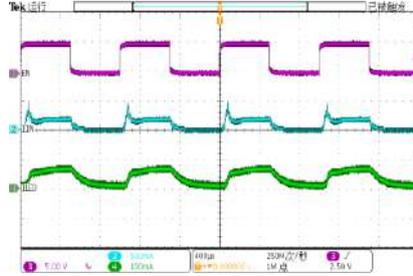
Dimming Operation

$V_{IN}=5V$, $V_{OUT}=15V$, 5LEDs, $f=100Hz$



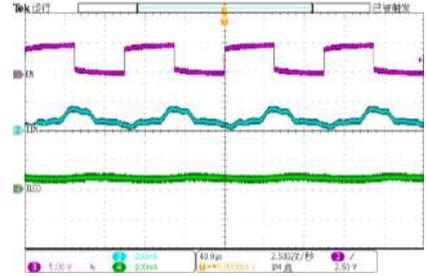
Dimming Operation

$V_{IN}=5V$, $V_{OUT}=15V$, 5LEDs, $f=1KHz$



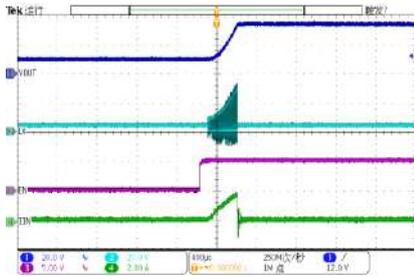
Dimming Operation

$V_{IN}=5V$, $V_{OUT}=15V$, 5LEDs, $f=10KHz$



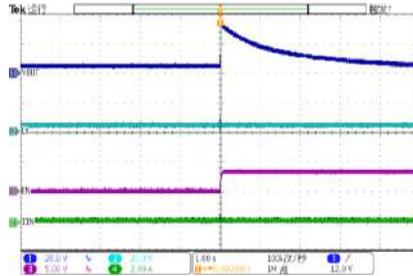
Open Load Protection

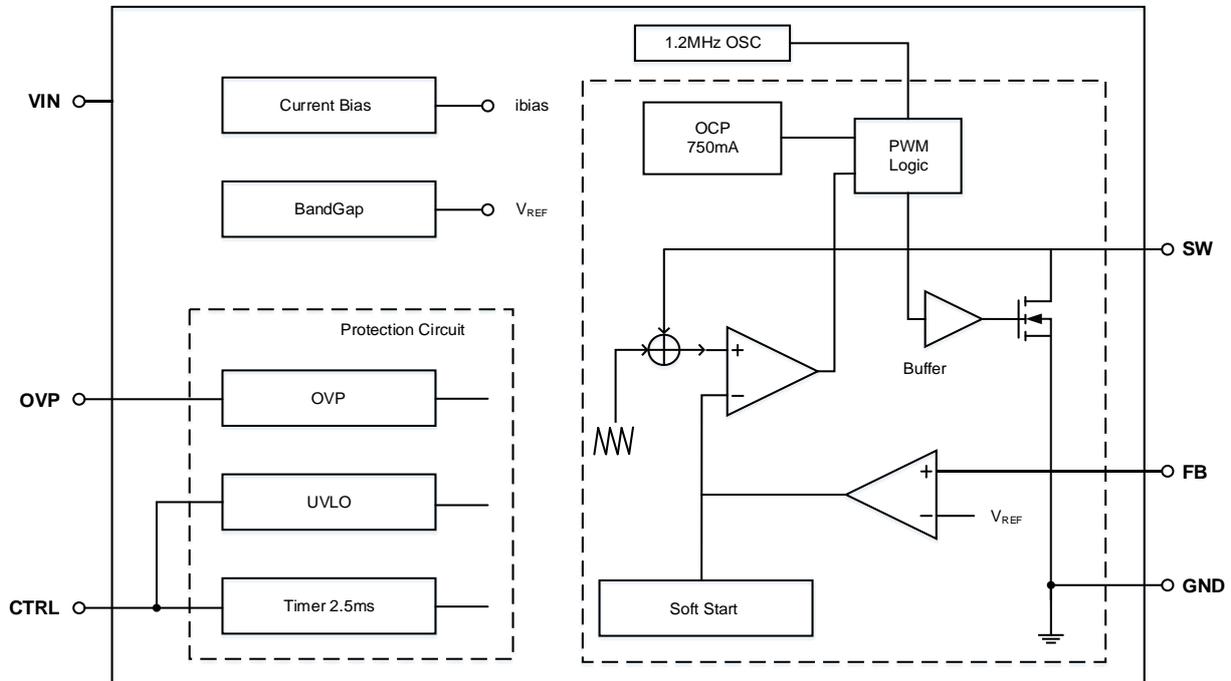
$V_{IN}=5V$, V_{OUT} Open



Open Load Protection

$V_{IN}=5V$, V_{OUT} Open



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Functional Block Diagram


Block Diagram

Functions Description
Under-Voltage Lockout (UVLO)

Under-voltage lockout (UVLO) protects the chip from operating at an insufficient supply voltage. UVLO protection monitors the internal regulator voltage. When the voltage is lower than UVLO threshold voltage, the device is shut off. When the voltage is higher than UVLO threshold voltage, the device is enabled again.

Enable and Disable

When the input voltage is above maximal UVLO rising threshold and the CTRL pin is pulled high, the ASP3730 is enabled. When the CTRL pin is pulled low, the ASP3730 goes into shutdown mode. In shutdown mode, less than 1 μ A input current is consumed. Because there is a conductive path from the input to the output through the inductor and Schottky diode, the output voltage is equal to the input voltage during shutdown. The CTRL pin allows disabling and enabling of the device as well as brightness control of the LEDs by applying a PWM signal up to typically 1kHz. When a PWM signal is applied, the LED current is turned on when the CTRL is high and off when CTRL is pulled low. Changing the PWM duty cycle therefore changes the LED brightness.

Soft-Start

The ASP3730 begins soft start when the CTRL pin is pulled high. at the beginning of the soft start period, the isolation FET is turned on slowly to charge the output capacitor. After the pre-charge phase, the ASP3730 starts switching. This is called switching soft start phase. An internal soft start circuit limits the peak inductor current according to the output voltage. The switching soft start phase is about 1ms typically. The soft start function reduces the inrush current during startup.

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As with any current source, the output voltage rises when the output gets high impedance or disconnected. To prevent the output voltage exceeding the maximum switch voltage rating (35V) of the main switch, an overvoltage protection circuit is integrated. As soon as the output voltage exceeds the OVP threshold, the converter stops switching and the output voltage falls.

Efficiency and Feedback Voltage

The feedback voltage has a direct effect on the converter efficiency. Because the voltage drop across the feedback resistor does not contribute to the output power (LED brightness), the lower the feedback voltage, the higher the efficiency. Especially when powering only three or less LEDs, the feedback voltage impacts the efficiency around 2% depending on the sum of the forward voltage of the LEDs.

Thermal Shutdown

Thermal shutdown prevents the chip from operating at exceedingly high temperatures. When the silicon die temperature exceeds 160°C, it shuts down the whole chip. When the temperature falls below its lower threshold (Typ. 130°C) the chip is enabled again.

Applications Information

Setting the LED Current

The LED current is controlled by the feedback resistor, R_1 , in the following table. The current through the LEDs is given by the equation $250\text{mV}/R_1$. Following table shows the selection of resistors for a given LED current.

I_{LED} (mA)	R_1 (Ω)
1	250
5	50
10	25
20	12.5
50	5

$$R_1 = 0.25 / I_{LED}$$

I_{LED} is average LED current.

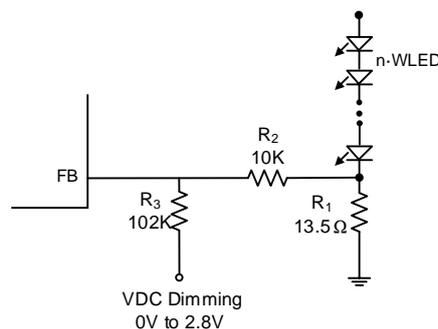
Dimming Control

1. Using a PWM Signal to CTRL Pin

For controlling the LED brightness, the ASP3730 can perform the dimming control by applying a PWM signal to CTRL pin. The internal soft start and the wide range dimming frequency can eliminate inrush current and audio noise when dimming. The average LED current is proportional to the PWM signal duty cycle. The magnitude of the PWM signal should be higher than the minimum enable voltage of CTRL pin, in order to let the dimming control, perform correctly for preventing the flicker issue, the selected PWM frequency is $\geq 100\text{Hz}$ and $\leq 10\text{KHz}$.

2. Using a DC Voltage

When CTRL remains high level, using a variable DC voltage to adjust the brightness is a popular method in some applications. According to the Superposition Theorem, as the DC voltage increases, the voltage contributed to V_{FB} increases and the voltage drop on R_2 decreases, i.e. the LED current decreases. For example, if the VDC range is from 0V to 2.8V, the selection of resistors sets dimming control of LED current from 20mA to 0mA.



The LED current can be calculated by the following Equation:

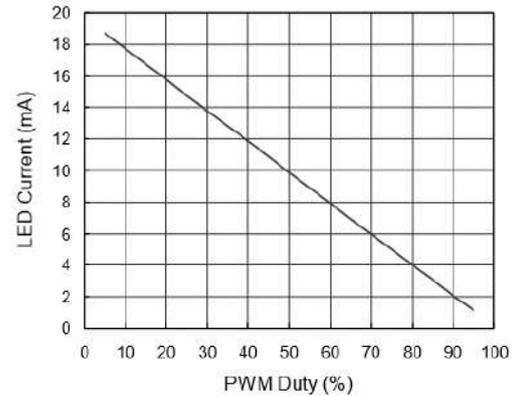
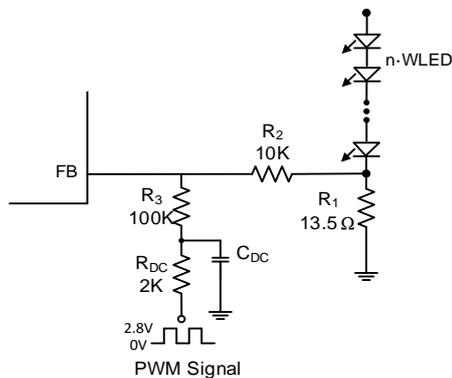
$$I_{LED} = \frac{V_{FB} - \frac{R_2 \times (V_{DC} - V_{FB})}{R_3}}{R_1}$$

3. Using a Filtered PWM signal

Another common application is using a filtered PWM signal as an adjustable DC voltage for LED dimming control. A filtered PWM signal acts as the DC voltage to regulate the output current. In this circuit, the output ripple depends

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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.



The LED current can be calculated by the following Equation:

$$I_{LED} = \frac{V_{FB} - \frac{R_2 \times (V_{PWM} \times Duty - V_{FB})}{R_3 + R_{DC}}}{R_1}$$

Inductor Selection

The recommended value of inductor for most applications are 4.7 to 22μH. Small size and better efficiency are the major concerns for portable device, such as ASP3730 used for mobile phone. When selecting the inductor, the inductor saturation current should be rated as high as the peak inductor current at maximum load, and respectively, maximum LED current.

Output Capacitor Selection

The device is designed to operate with a wide selection of ceramic output capacitors. The selection of the output capacitor value is a trade-off between output voltage ripple and capacitor cost and form factor. In general, capacitor values of 10μF up to 44μF can be used. 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.

Input Capacitor Selection

For good input voltage filtering, low ESR ceramic capacitors are recommended. A 1μF ceramic input capacitor is sufficient for most of the applications. For better input voltage filtering and EMI reduction, this value can be increased. The input capacitor should be placed as close as possible to the input pin of the converter.

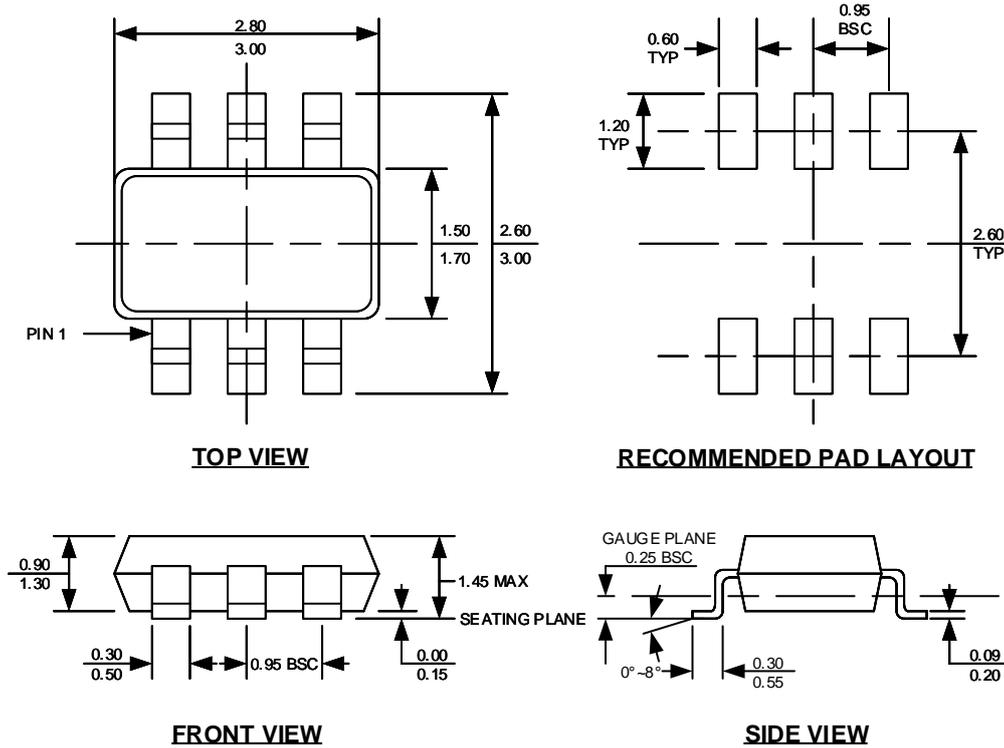
Diode Selection

A Schottky diode should be used for the output diode. The forward current rating of the diode should be higher than the load current, and the reverse voltage rating must be higher than the output voltage. Do not use ordinary rectifier diodes, since slow switching speeds and long recovery times cause the efficiency and the load regulation to suffer.

Layout Guidelines

PC board layout is an important part of DC-DC converter design. Poor board layout can disrupt the performance of a DC-DC converter and surrounding circuitry by contributing to EMI, ground bounce, and resistive voltage loss in the traces. These can send erroneous signals to the DC-DC converter resulting in poor regulation or instability. Good layout can be implemented by following a few simple design rules.

1. Minimize area of switched current loops. Input capacitor should be placed as close as possible to the VIN terminal. Grounding for both the input and output capacitors should consist of a small localized topside plane that connects to GND. The inductor should be placed as close as possible to the SW pin and output capacitor.
2. Minimize the copper area of the switch node. The SW terminals should be directly connected with a trace that runs on top side directly to the inductor. To minimize IR losses this trace should be as short as possible and with an enough width. However, a trace that is wider than 100 mils will increase the copper area and cause too much capacitive loading on the SW terminal. The inductors should be placed as close as possible to the SW terminals to further minimize the copper area of the switch node.
3. Have a single point ground for all device analog grounds. The ground connections for the feedback components should be connected then routed to the GND pin of the device. This prevents any switched or load currents from flowing in the analog ground plane. If not properly handled, poor grounding can result in degraded load regulation or erratic switching behavior.
4. Minimize trace length to the FB terminal. The feedback trace should be routed away from the SW pin and inductor to avoid contaminating the feedback signal with switch noise.
5. Make input and output bus connections as wide as possible. This reduces any voltage drops on the input or output of the converter and can improve efficiency. If voltage accuracy at the load is important make sure feedback voltage sense is made at the load. Doing so will correct for voltage drops at the load and provide the best output accuracy.

**High Performance, Constant Current LED Driver
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Package Description
SOT23-6

NOTE:

1. CONTROL DIMENSION IS IN INCHES. DIMENSION IN BRACKET IS IN MILLIMETERS.
2. PACKAGE LENGTH DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS.
3. PACKAGE WIDTH DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSIONS.
4. LEAD COPLANARITY (BOTTOM OF LEADS AFTER FORMING) SHALL BE 0.004" INCHES MAX.
5. DRAWING CONFORMS TO JEDEC MS-012, VARIATION BA.
6. DRAWING IS NOT TO SCALE.

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