AT5160

High Efficiency, Constant Current 40V White-LEDs Driver

Feature

- **Operating Voltage: 2.5V to 5.5V.**
- **High Operating Frequency: 1MHz**
- **High Output Voltage: Up to 40V(Typ.)**
- **Digital Dimming Control.**
- **Built-in Cycle-by Cycle Current-Limiting.**
- **Built-in Soft-Start Function.**
- **0.2V Low Reference Voltage**
- **Thermal Overload Protection**
- **TSOT-23-6 Package**

Application

- **GPS Navigation System**
- **Compact Back Light Module**
- **Constant Current Source**
- **LED Module**

Description

The AT5160 step-up converter drives white LEDs with a constant current to provide backlight in cell phones, PDAs, and other hand-held devices. It features allowing series connection of the white LEDs so that the LED currents are identical for uniform brightness. An enable input can be pulsed repeatedly to adjust LED's brightness. The fast 1.0MHz current-mode PWM control allows for smaller capacitor and inductor. Fault condition protection uses cycle-by-cycle current limiting to sense maximum inductor current, thermal protection and over-voltage protection. Also included soft-start eliminates inrush current during start-up. The 0.2V low reference voltage minimized the power loss across the current-setting resistor.

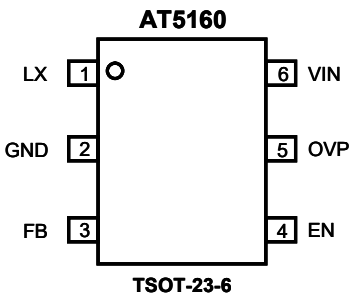
The AT5160 is available in TSOT-23-6 packages.

Ordering Information

ORDER NUMBER	MARKING	TEMP. RANGE	PACKAGE (Green)
AT5160TP1U	5160x	-40°C to 85°C	TSOT-23-6

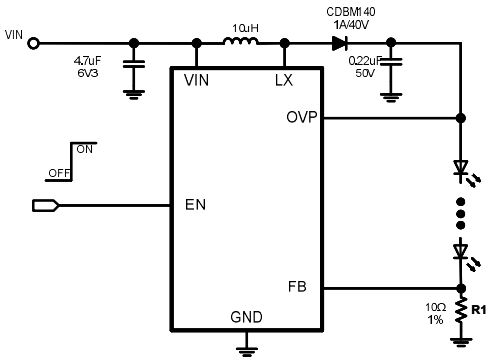
Note: TP: TSOT-23-6
1: Bonding Code
U: Tape & Reel
Green : Lead Free / Halogen Free.

Pin Configuration



Typical Application Circuit

※ *Use the tantalum capacitor to eliminate inductor noise on output terminal when you want to control dimming function.*



Absolute Maximum Ratings*1

Parameter		Rated Value	Unit
VIN voltage		-0.3 to +6.0	V
LX , OVP voltage		-0.3 to +45	V
EN , FB to GND		-0.3 to +6.0	V
Continuous power dissipation (TSOT-23-6 T_A=+25°C)		0.35	W
Operating Temperature Range		-40 to 85	°C
Maximum Junction Temperature		170	°C
Reflow Temperature (Soldering 5 sec)		260	°C
Storage Temperature		-65 to 125	°C
Package Thermal Resistance (Θ_{JA})*3		100~250	°C /W
ESD Susceptibility*2	HBM	2	kV
	MM	200	V

1. Stresses beyond those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.
2. Device are ESD sensitive. Handling precaution recommended. The Human Body model is a 100pF capacitor discharged through a 1.5kΩ resistor into each pin.
3. Depending on PC board layout.

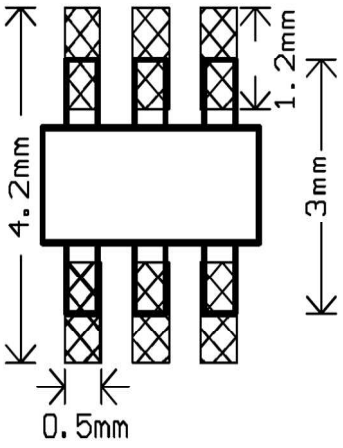
Recommended Operation Conditions

Parameter	Symbol	Values			Unit
		Min.	Typ.	Max.	
Power supply voltage	V_{IN}	2.5	–	5.5	V
Operating temperature*	Top	-40	+25	+85	°C

***Using X5R or X7R capacitor**

Minimum Footprint PCB Layout Section

TSOT-23-6



Electrical Characteristics

(V_{IN}=3.6V, T_A=+25°C.)

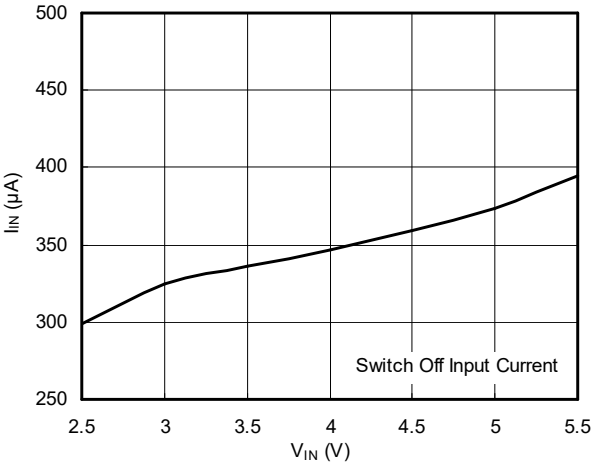
The device is not guaranteed to function outside its operating conditions. Parameters with MIN and/or MAX limits are 100% tested at +25°C, unless otherwise specified.

Parameter	Symbol	Test Condition	Min.	Typ.	Max.	Units
Operating V_{IN} Range	V_{IN}	V_{IN} input Voltage	2.5	---	5.5	V
Under Voltage Thershold	UVLO	V_{IN} falling, 100mV hysteresis	1.8	2.0	2.3	V
Switch- Off Input Current	I_{IN1}	No Switching, FB=0.3V	---	400	600	μA
Shutdown Current	I_{IN3}	V_{IN}=5V, EN=0V	---	1	4	μA
Supply Current	I_{OP}	V_{FB} =0.1V	---	1.0	---	mA
Feedback Reference	V_{FB}		0.190	0.2	0.210	V
FB Input Bias Current	I_{FB}	V_{FB} =0.2V	---	---	1	μA
Over-voltage Threshold	V_{OVP}		38	40	42	V
Over-voltage Hysteresis			---	5.5	---	V
OVP Leakage Current	I_{OVP}	EN=0V	---	---	1	μA
Output Voltage Line Regulation		2.5V< V_{IN} <6.0V	---	1	---	%
Switching Frequency	f_{OSC}		0.75	1	1.25	MHz
Maximum Duty	D_{MAX}		90	92	---	%
Soft-Start charging time	t_{SS}		---	5	---	ms
Switching Current Limit	I_{LX}		1000	1200	---	mA
LX ON Resistance	R_{LX}	V_{IN} =3.6V, I_{LX} =500mA	---	0.7	1.2	Ω
LX Leakage Current	$I_{Leakage}$	V_{LX} =40V, EN=0V	---	---	5	μA
EN Dimming Clock Rate	f_{EN}	Duty=5%~100%	100	---	200k	Hz
EN Input Current	I_{EN}	EN=5V	---	---	5	μA
EN Input Level	V_{IH}	0.25V hysteresis	1.4	---	VCC	V
	V_{IL}		---	---	0.5	V
EN low Shutdown Delay			20	---	---	ms
Over-Temperature-Protection	TOCP		---	165	---	°C
OTP Hystersis			---	50	---	°C

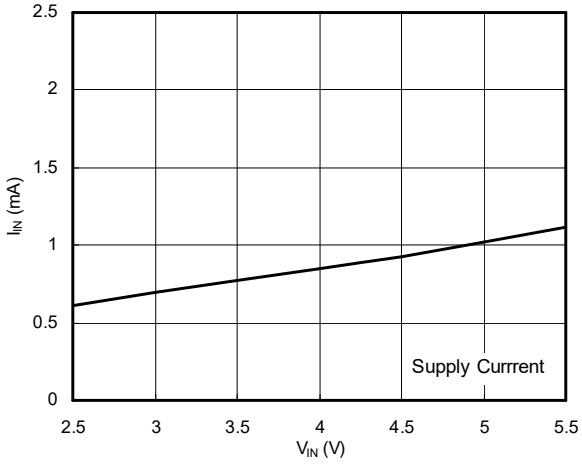
Typical Performance Characteristics

(V_{IN}=3.6V , C_{IN}=4.7μF , C_{OUT}=0.22μF ,L=10μH With 10*LED at 20mA ,T_A=+25 °C, unless otherwise noted.)

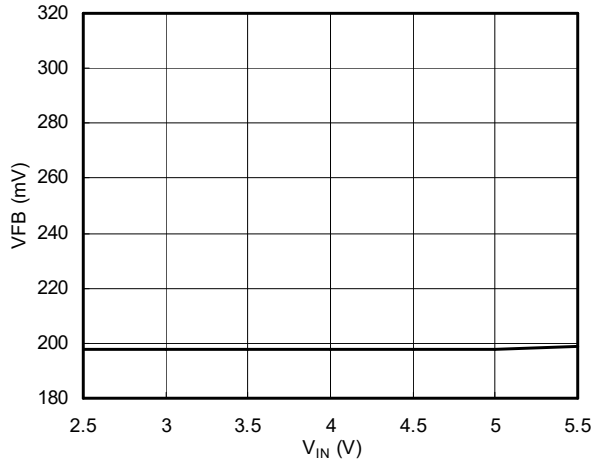
Switch Off Input Current VS. Input Voltage



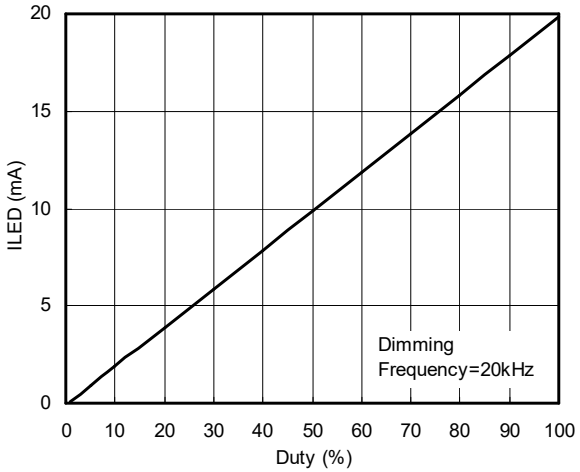
Supply Current VS. Input Voltage



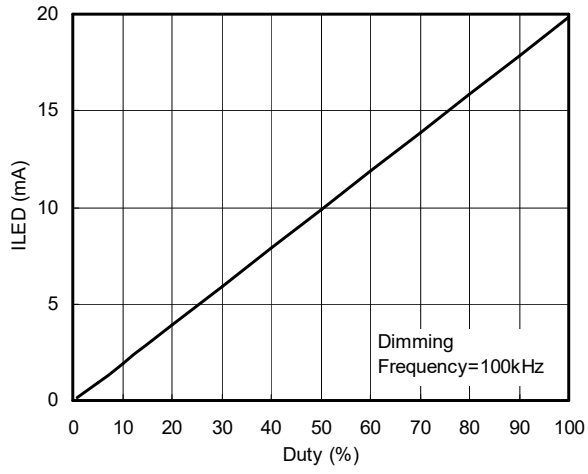
FB Pin Voltage VS. Input Voltage



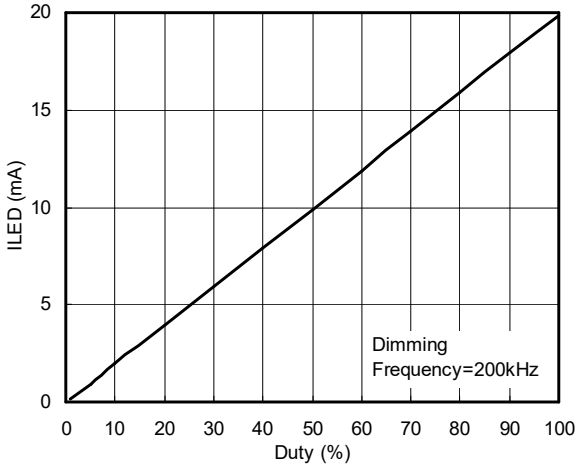
LED Current VS. PWM Dimming



LED Current VS. PWM Dimming

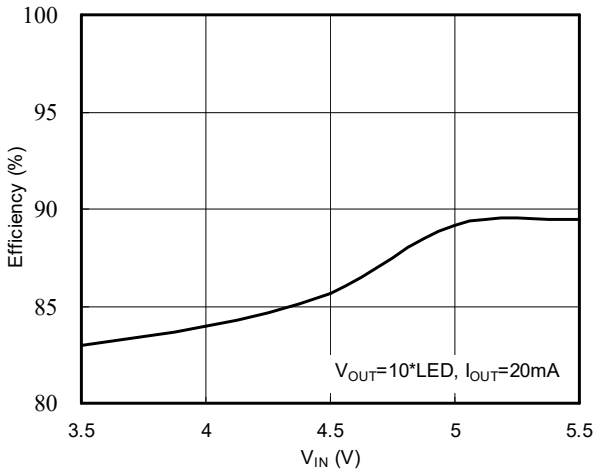


LED Current VS. PWM Dimming

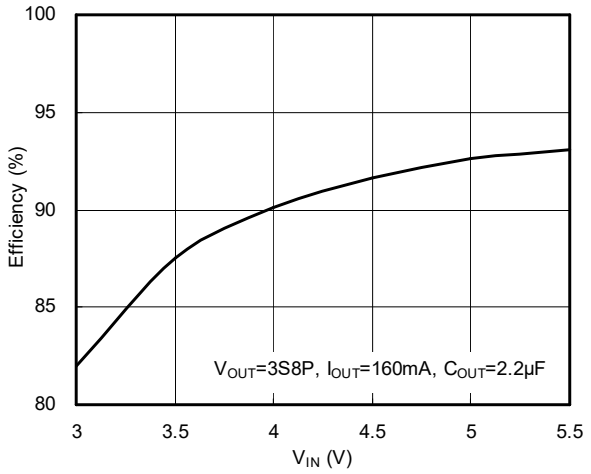


Typical Performance Characteristics (continued)

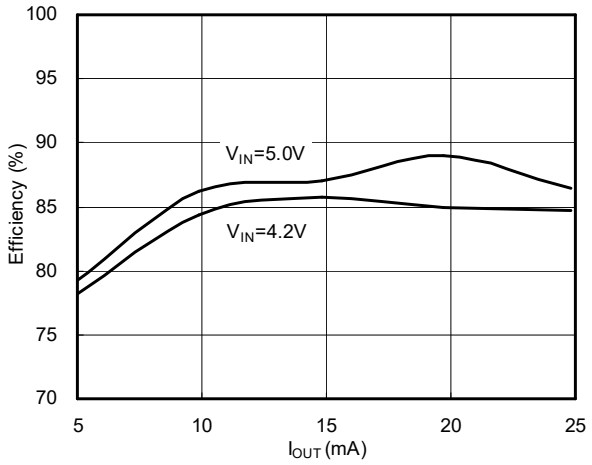
Efficiency VS. Input Voltage



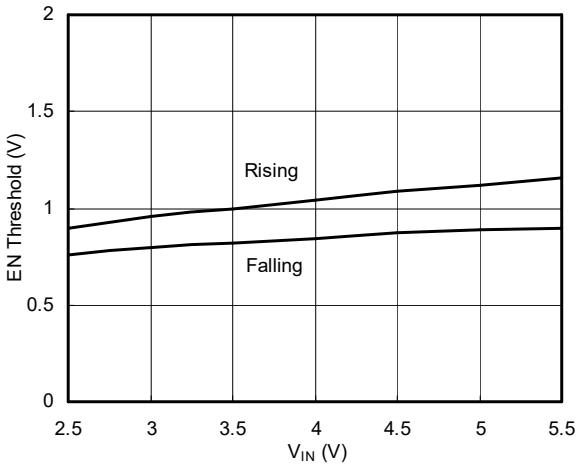
Efficiency VS. LED Current



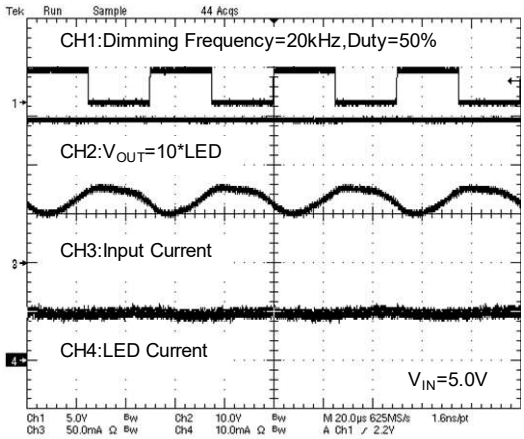
Efficiency VS. LED Current



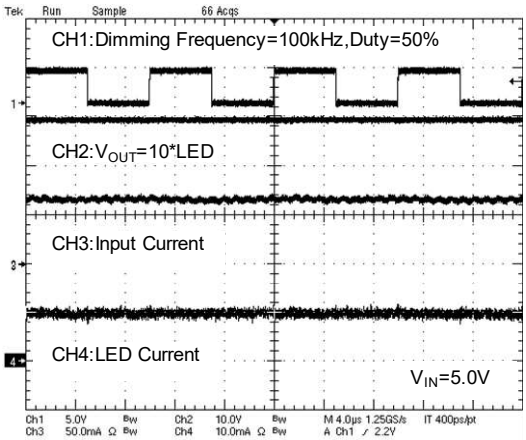
EN Threshold VS. Input Voltage



Dimming Operation

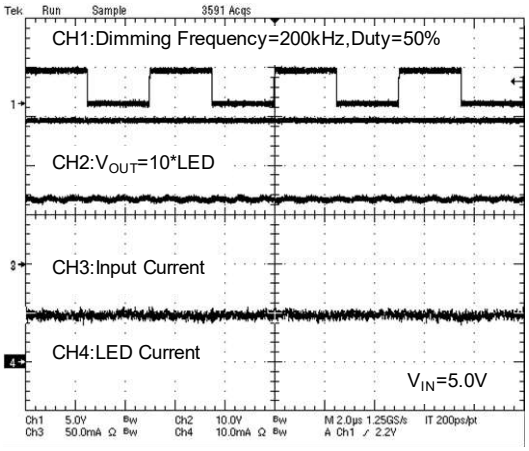


Dimming Operation

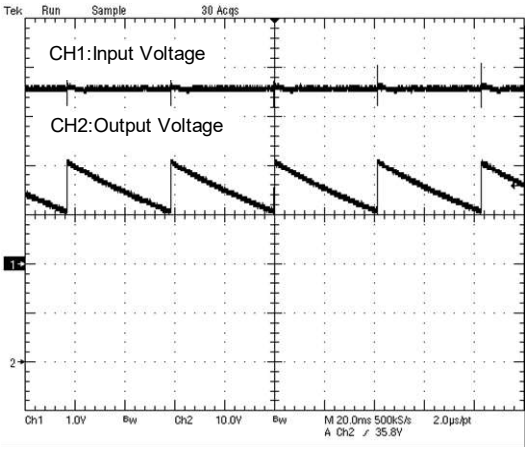


Typical Performance Characteristics (continued)

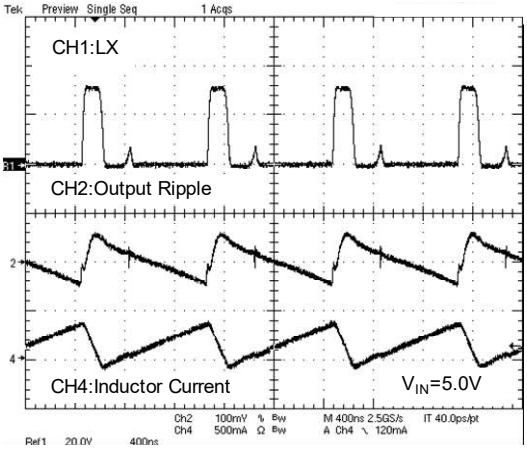
Dimming Operation



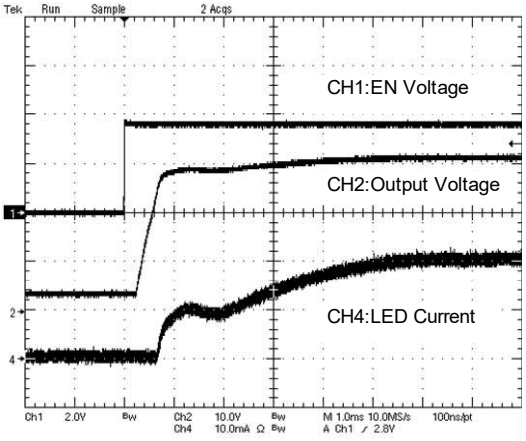
Output Over-Voltage Protection



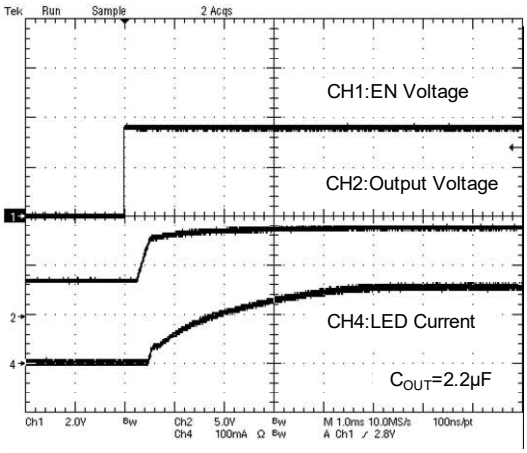
Switching Waveforms



Power Up with 3LEDs at 20mA



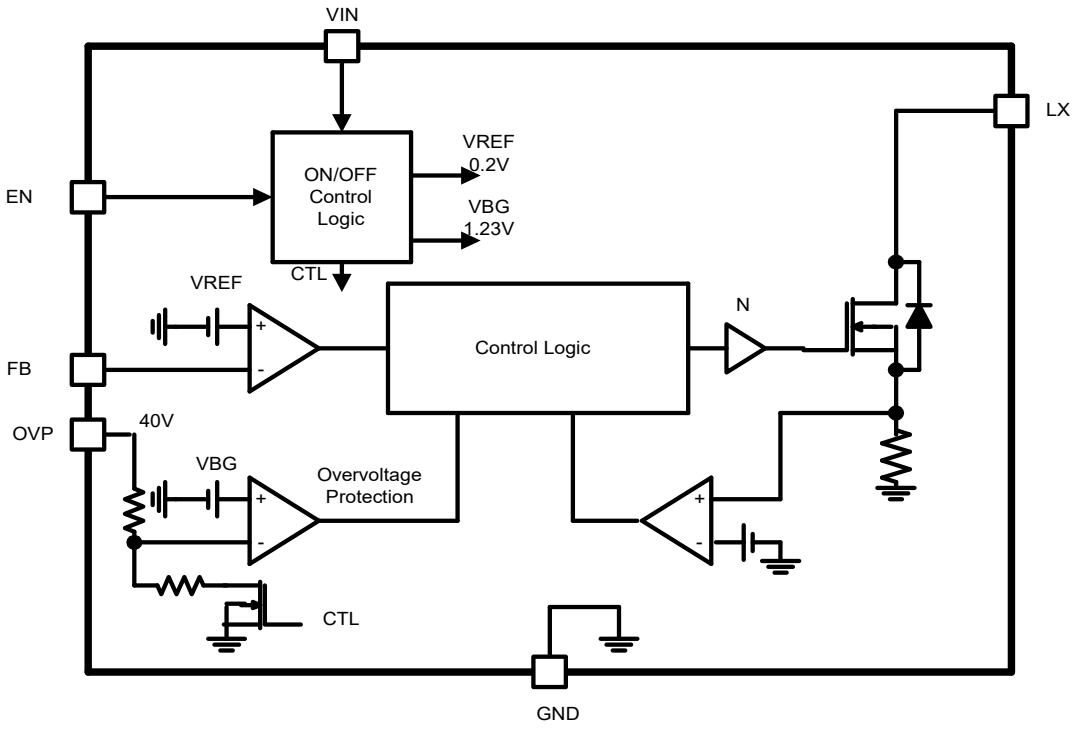
Power Up with 3S8P at 160mA



Pin Description

Pin N0.	Symbol	I / O	Description
1	LX	I	Step-up Regulator N-MOS Drain. Place output diode and inductor.
2	GND	P	Ground
3	FB	I	Step-Up Regulator Feedback Input. Connect a sense resistor from FB to ground.
4	EN	I	Enable and Dimming Control Input. LED brightness and IC shutdown are controlled by the voltage on EN. Driving low for longer than 6ms to shutdown the IC.
5	OVP	I	Over-voltage protection input. Connect to the output.
6	VIN	P	Power supply.

Block Diagram



Function Description

The AT5160 is high efficiency and constant current DC-DC converter IC which is designed primarily for use in LED module applications. The output voltage of the step-up converter can be set from Vin to 40V with external sense resistor. The device suits to drive series-connected LEDs and provides even illumination by sourcing the same output current through each LED. AT5160 series also consists of a logic shutdown, cycle-by-cycle current-limited, soft-start functions.

Logic control input or PWM duty cycle control allows easy adjustment of LEDs brightness and on/off control. The average LED current is proportional to the duty-cycle of the PWM signal. Typical PWM frequency should be between 100Hz and 200kHz, Duty 5% to 100%.

The boost converter operates in current-mode PWM and a constant frequency of 1.0MHz. Depending on duty cycle of each switching cycle can regulate output voltage. On the rising edge of the internal clock, the control and driver logic block sets internal flip-flop when the output voltage is too low, which turns on the N-MOS. The external inductor current ramps up linearly, storing energy in a magnetic filed. Once peak current of inductor over trans-conductance output level, the N-MOS turns off, the flip-flop resets, and external schottky diode turns on. This forces the current through the inductor to ramp back down, transferring the energy stored in the magnetic field to the output capacitor and LEDs. To reduce external components, the device will be built-in internal loop compensation.

Enable Control

Digital logic of EN provides an electrical ON/OFF control of the power supply. Connecting this pin to ground or to any voltage less than 0.8V and sustain the level over 20ms will completely turn off the regulator. In this state, current drain from the input supply is less than 1μA, the internal reference, error amplifier, comparators, and biasing circuitry turn off. If holding time of low level is less than 20ms on this pin, then the device only shutdown driver logic block.

Dimming Control

After VIN is above UVLO, apply a PWM signal to EN pin for a WLED current that is proportional to PWM signal's duty cycle(0% duty cycle corresponds to zero LED current and 100% duty cycle correspond to full LED current). Restrict PWM frequency to between 100Hz to 200kHz, Duty 5% to 100%. for a maximum LED current accuracy. If dimming control is not required, EN works as a simple on/off control. Drive EN high to enable the IC, or drive EN low for shutdown.

LED Current Setting

LED current can be set with feedback resister (R1)

I_{LED} = 0.2 / R1

Soft-Start

Soft-start allows a gradual increase of the internal current-limit level for the step-up converter during power-up to reduce input surge currents. As the internal current source charges the internal soft-start capacitor, the peak N-MOS current is limited by the voltage on the capacitor. In another story, when toggle or a logic-level transition on EN pin from low to high, soft-start function must work to enable constant current charging internal capacitor. When soft-start process has finished or appeared falling edge of PWM signal on EN pin, soft-start capacitor must be discharged to ground level.

Cycle-by-Cycle Over-Current Protection

The AT5160 is provides cycle-by-cycle over-current protection. Current limit is accomplished using a separate dedicated comparator. The cycle-by-cycle current limit abbreviates the on-time of the N-MOS in event that the current of flowing N-MOS is greater than the current limit value. The current-limit feature protection against a hard short or over-current fault at the output.

Over-Voltage Protection

If V_{OUT} is above 40V or LEDs are disconnected from the circuit, the FB pin is similar to pull down to ground with a sense resistor. This will cause N-MOS to switch with a maximum duty cycle and come out output over-voltage. This may cause the LX pin voltage to exceed its maximum voltage rating to damage built-in N-MOS. In the state, the OVP protection circuitry stops the internal N-MOS. When V_{OUT} falls below 40V, IC will automatically recover normal operation.

Thermal-Overload Protection

Thermal-overload protection limits total power dissipation in the AT5160 series. When the junction temperature exceeds Tj=165°C, a thermal sensor activates the thermal protection, which shuts down the IC, allowing the IC to cool. Once the device cools down by 50°C, IC will automatically recover normal operation. For continuous operation, do not exceed the absolute maximum junction-temperature rating of Tj=115°C.

Power dissipation consideration

The AT5160 series maximum power dissipation depends on the thermal resistance of the IC package and circuit board, the temperature difference between the die junction and ambient air, and the rate of any airflow. The power dissipation in the device depends on the operating conditions of the regulator. In continuous condition, the step-up converter power dissipated internally across the internal N-MOS can be approximated by :

$$P_{boost} = [(\frac{I_O \times V_O}{V_{in}})^2 + \frac{1}{12}(\frac{V_{in} \times D}{f_{OSC} \times L})^2] \times R_{DS(ON)} \times D$$

where

I_O : It is the load current.

f_{OSC} : It is a switching frequency.

Application Information

External components of boost converter can be designed by performing simple calculations.

Boost inductor

Inductor selection depends on input voltage, output voltage, maximum output current, switching frequency and availability of inductor values. The following boost circuit equations are useful in choosing the inductor values based on the application. They allow the trading of peak current and inductor value while allowing for consideration of component availability and cost.

The peak inductor current is given by:

$$I_{Lpeak} = I_{LAVG} + \frac{\Delta I_L}{2}$$

$$I_{LAVG} = \frac{I_O}{1 \quad D}$$

where:

$\triangle I_L$ is the inductor peak-to-peak current ripple and is decided by:

$$\Delta I_L = \frac{V_{in}}{L} \times \frac{D}{f_{OSC}}$$

D is the MOSFET turn on ratio and is decided by:

$$D = \frac{V_O \quad V_{in}}{V_O}$$

f_{OSC} is the switching frequency.

The inductor should be chosen to be able to handle this current and inductor saturation current rating should be greater than I_{PEAK}.

Input Capacitor

The AT5160 only requires small ceramic capacitors of 4.7μF on the input for all normal condition. For applications with higher output power, a larger input capacitor of 10μF may be appropriate. X5R and X7R capacitor types are ideal due to their stability across temperature range.

Diode selection

The output diode has average current of I_O, and peak current the same as the inductor's peak current and a voltage rating at least 1.5 times the output voltage. Schottky diode is recommended and it should be able to handle those current.

Output Capacitor

The AT5160 is specially compensated to be stable with capacitors which have a worst- case minimum value of 0.22μF at the particular V_{OUT} being set. For applications with higher output power, a larger input capacitor of 2.2μF~10μF may be appropriate. Output ripple voltage requirements also determine the minimum value and type of capacitors. Output ripple voltage consists of two components the voltage drop caused by the switching current through the ESR of the output capacitor and the charging and discharging of the output capacitor:

$$V_{RIPPLE} = I_{LPEAK} \times ESR + \frac{V_O \quad V_{in}}{V_O} \times \frac{I_O}{C_{OUT} \times f_{OSC}}$$

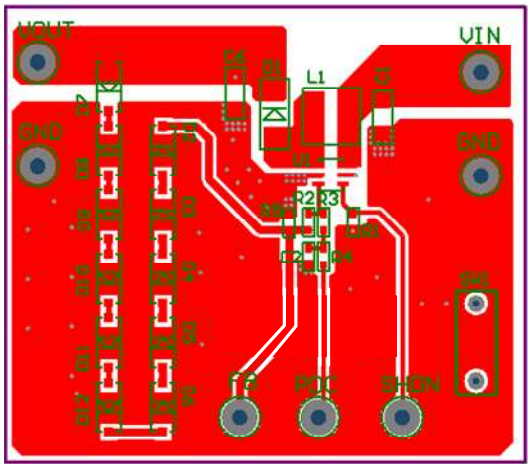
For low ESR ceramic capacitors, the output ripple is dominated by the charging or discharging of the output capacitor. X5R and X7R capacitor types are ideal due to their stability across temperature range.

PCB layout guidelines

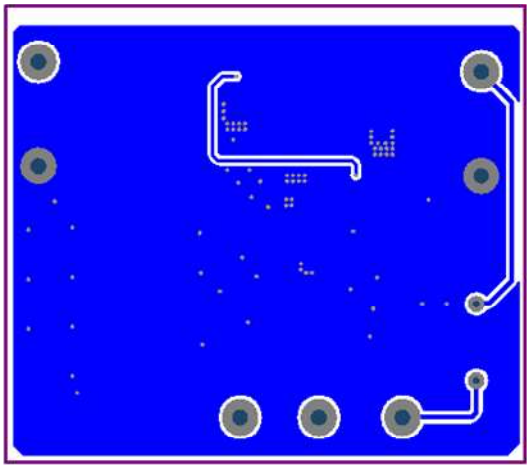
Careful printed circuit layout is extremely important to avoid causing parasitical capacitance and line inductance. The following layout guidelines are recommended to achieve optimum performance.

- Please the boost converter diode and inductor close to the LX pin and no via. Keep traces short, direct, and wide.
- Please ceramic bypass capacitors near the input/output pin.
- Locate all feedback sense resistors as close to the feedback pins as possible.
- The ground connections of V_{IN} and V_{OUT} should be as close together as possible.
- Please keep the AT5160 away from high frequency signal sources to avoid radio frequency interference (RFI)

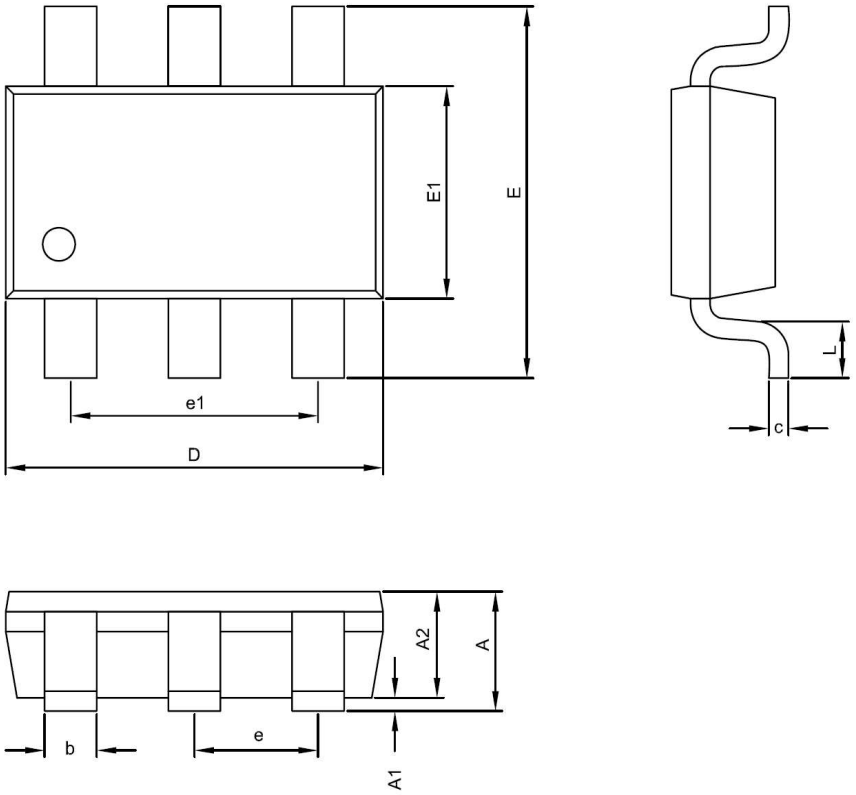
Top Layer



Bottom Layer



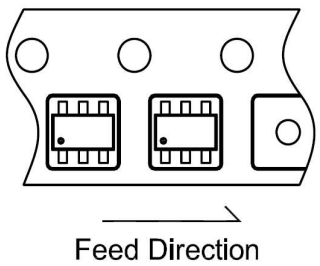
Packing Information



TSOT-23-6 Package

Symble	DIMENSION IN MM			DIMENSION IN INCH		
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.
A	- - -	- - -	0.90	- - -	- - -	0.035
A1	0.00	0.05	0.10	0.000	0.002	0.004
A2	0.70	0.75	0.80	0.028	0.030	0.031
D	2.70	2.90	3.10	0.106	0.114	0.122
E	2.60	2.80	3.00	0.102	0.110	0.118
E1	1.50	1.60	1.70	0.059	0.063	0.067
c	0.08	0.15	0.25	0.003	0.006	0.010
b	0.30	0.40	0.50	0.012	0.016	0.020
e	0.95 BSC			0.037 BSC		
e1	1.90 BSC			0.075 BSC		
L	0.30	0.45	0.60	0.012	0.018	0.024

Taping Specification



PACKAGE	Q'TY/REEL
TSOT-23-6	3,000 ea