30V Output, 5.5V Input, 1.2MHz High Efficiency Boost WLED Driver

FEATURES

- Input Voltage Range: 2.5V to 5.5V
- High Efficiency: Up to 90%
- 1.2MHz Constant Frequency Operation
- Integrated 150mΩ Power MOSFET
- 30V Output Over Voltage Protection
- STI9287C: 200mV Typical V_{FB} Voltage
  STI9287CA: 250mV Typical V_{FB} Voltage
- EN Dimming with wide PWM Frequency Range: 1kHz to 200kHz
- UVLO, Thermal Shutdown
- Internal Current limit
- Minimize the External Component
- <1µA Shutdown Current
- SOT23-6 Package

APPLICATIONS

- Mobile Phone, Smart Phone LED Backlight
- PAD Display LED Backlighting
- Portable Media Players

GENERAL DESCRIPTION

The STI9287C and STI9287CA are boost converters designed for white LED driver with 30V OVP from a single cell Li-ion battery. The STI9287C and STI9287CA use current mode, fixed frequency architecture to regulate LED strings current, which is set with an external current sense resistor. Its low 200mV for STI9287C, 250mV for STI9287CA typical feedback voltage with EN/PWM Pulling High reduces power loss and improves efficiency.

The STI9287C and STI9287CA include under-voltage lockout, current limiting and thermal overload protection preventing damage in the event of an output overload.

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 APPILCATIONS
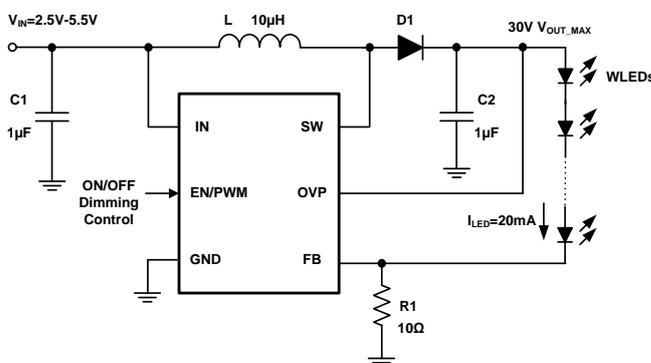
**Figure 1. STI9287C Basic Application Circuit**

Efficiency with 7LEDs
L=10µH, DCR=20mΩ, ILED=1mA to 100mA
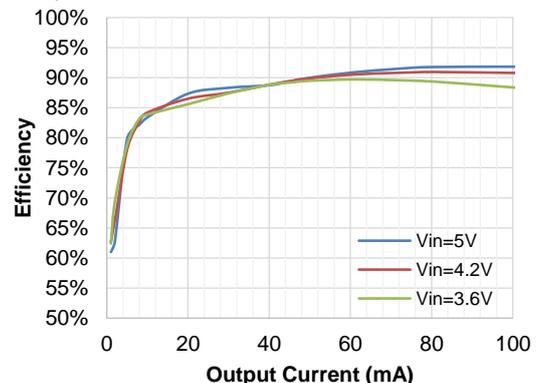
ABSOLUTE MAXIMUM RATINGS (Note1)

Parameter	Min	Max	Unit
Input Supply voltage	-0.3	7	V
SW, OVP voltage	-0.3	35	V
EN/PWM voltage	-0.3	V_{IN}	V
Junction Temperature (Note2)	-	160	°C
Power Dissipation	-	600	mW
Storage Temperature Range	-65	150	°C
Lead Temperature (Soldering, 10s)	-	260	°C

PACKAGE/ORDER INFORMATION

```
         ┌──────────────┐
SW    1  │   ◯          │  6   IN
         │              │
GND   2  │              │  5   OVP
         │              │
FB    3  │              │  4   EN/PWM
         └──────────────┘
              SOT23-6
```
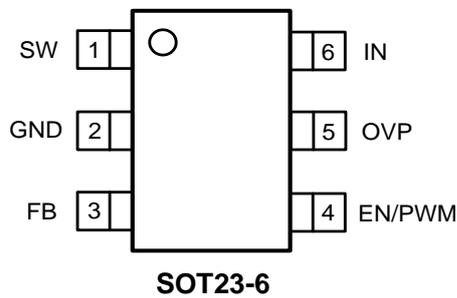
Top Mark: S87CXXX (S87C: Device Code, XXX: Inside Code) for STI9287C
Top Mark: S87AXXX (S87A: Device Code, XXX: Inside Code) for STI9287CA

Part Number	Package	Top mark	Quantity/ Reel
STI9287C	SOT23-6	S87CXXX	3000
STI9287CA	SOT23-6	S87AXXX	3000

STI9287C and STI9287CA devices are Pb-free and RoHS compliant.

PIN DESCRIPTIONS

Pin	Name	Function
1	SW	Power Switch Output. It is the switch node connection to inductor.
2	GND	Ground Pin
3	FB	Output Voltage Feedback Pin.
4	EN	Chip Enable Pin. Drive EN above 1.5V to turn on the part. Drive EN below 0.4V to turn it off. Do not leave EN floating.
5	OVP	Over Voltage Input. OV measures the output voltage for open circuit protection. Connect OV to the output at the top of the LED string.
6	IN	Power Supply Input. Must be closely decoupled to GND with a 1μF or greater ceramic capacitor.

ESD RATING

Items	Description	Value	Unit
V_{ESD_HBM}	Human Body Model for all pins	±2000	V
V_{ESD_CDM}	Charge Device Model for all pins	±1000	V

JEDEC specification JS-001

RECOMMENDED OPERATING CONDITIONS

Items	Description	Min	Max	Unit
Input Voltage Range	V_{IN}	2.5	5.5	V
Output Voltage Range	V_{OUT}	V_{IN}	30	V
T_J	Operating Junction Temperature Range	-40	125	°C

THERMAL RESISITANCE (Note 3)

Items	Description	Value	Unit
θ_{JA}	Junction-to-ambient thermal resistance	200	°C/W
θ_{JC}	Junction-to-case thermal resistance	65	°C/W

ELECTRICAL CHARACTERISTICS

($V_{IN}=V_{EN}=3.7V$, $T_A = 25°C$, unless otherwise noted.)

Parameter	Conditions	Min	Typ	Max	Unit
Input Voltage Range		2.5		5.5	V
UVLO Threshold			2.4	2.48	V
Under Voltage Lockout Hysteresis			200		mV
Shutdown Current	V_{EN}=0V		0.1	1	µA
Quiescent Current	V_{FB}=120%*V_{REF}, No switch		180	300	µA
Regulated Feedback Voltage	STI9287C	192	200	208	mV
	STI9287CA	242	250	258	mV
Oscillation Frequency		1.0	1.2	1.4	MHz
Maximum Duty Cycle			95		%
ON Resistance of NMOS			150		mΩ
Peak Current Limit	V_{IN}= 3.7V, Duty cycle=50%		1.5		A
EN High-Level Input Voltage		1.5			V
EN Low-Level Input Voltage				0.4	V
EN Leakage Current	V_{EN}=3.7V		0.1	1.0	µA
OVP Threshold	V_{OUT} Rising		30		V
OVP Hysteresis			2.5		V
Thermal Shutdown Threshold (Note 4)			160		°C
Thermal Shutdown Hysteresis (Note 4)			25		°C

Note 1: Absolute Maximum Ratings are those values beyond which the life of a device may be impaired.

Note 2: T_J is calculated from the ambient temperature T_A and power dissipation PD according to the following formula: $T_J = T_A + (PD) \times \theta_{JA}$.

Note 3: Measured on JESD51-7, 4-layer PCB.

Note 4: Guaranteed by design.

OPERATION

The STI9287C and STI9287CA use a constant frequency, peak current mode boost regulator architecture to regulate the current of white LEDs series string. At the start of each oscillator cycle the N-channel MOSFET 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 MOSFET is turned off. The voltage at the output of the error amplifier is an amplified version of the difference between the reference voltage and the feedback voltage. In this way the peak current level keeps the output in regulation. If the feedback voltage starts to drop, the output of the error amplifier increases. This results in more current flowing through the power MOSFET, thus increasing the power delivered to the output. When EN/PWM is connected to high logic, the inner reference of error amplifier input is 200mV for STI9287C and 250mV for STI9287CA. If PWM signal is supplied on EN/PWM pin, the inner reference of error amplifier input is equal to the value of 200mV multiplying duty of PWM signal. STI9287C and STI9287CA also have OVP function for LED strings open circuit protection. When OVP voltage is higher than 30V typically, device will stop switching, and the output voltage will fall down. When OVP voltage drops lower than 27.5V typically, the device will restart to switching operation.

FUNCTIONAL BLOCK DIAGRAM
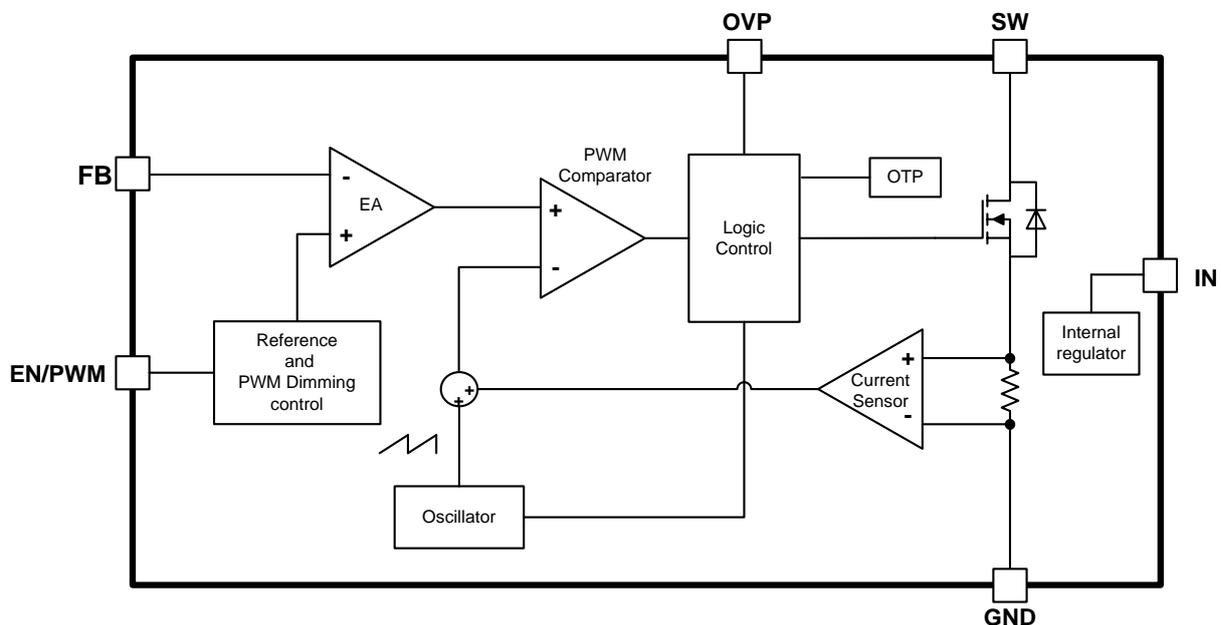
Figure 2. STI9287C/STI9287CA Block Diagram

APPLICATION INFORMATION

Setting the LED current

The LED current is controlled by the feedback resistor, R1, in Figure 1. The current through the LEDs is given by the equation $V_{REF}/R1$. Table 1 shows the selection of resistors for a given LED current.

Table 1—I_{LED} vs. R1

I_{LED} (mA)	R1 (Ω) for STI9287C	R1 (Ω) for STI9287CA
1	200	250
5	40	50
10	20	25
15	13.3	16.67
20	10	12.5

Dimming Control

a. Using a PWM Signal to EN/PWM Pin

For controlling the LED brightness, the STI9287C and STI9287CA can perform the dimming control by applying a PWM signal on EN/PWM pin. The average LED current is proportional to the PWM signal duty cycle. As shown in Figure 3, PWM signal applied on EN/PWM pin is chopped and filtered to a DC voltage that is equal to duty of PWM signal multiplied by V_{REF} (V_{REF}=200mV for STI9287C and V_{REF}=250mV for STI9287CA) and is used for inner reference input voltage of error amplifier to regulate feedback voltage.
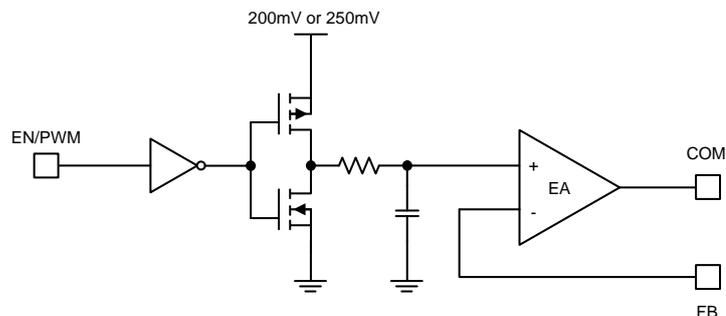
Figure 3. Dimming Control by a PWM Signal to EN Pin

EN/PWM pin also has device enable and disable function. When the device is in disable condition, EN/PWM should be pulled high and keeping high with duration time larger than 200µs, STI9287C and STI9287CA enter into enable status. In enable status, the recommended minimum PWM signal duty cycle is 0.5% for stable LED driving current and no blind dimming. The minimum PWM dimming frequency is limited by EN disable delay time which is larger than 1ms. The recommended minimum PWM dimming signal frequency range is 1kHz to 200kHz. The magnitude of the PWM signal should be higher than the high-level input voltage of EN/PWM pin.

$$I_{LED} = \frac{V_{REF} \times Duty}{R1}$$

Equation 1.
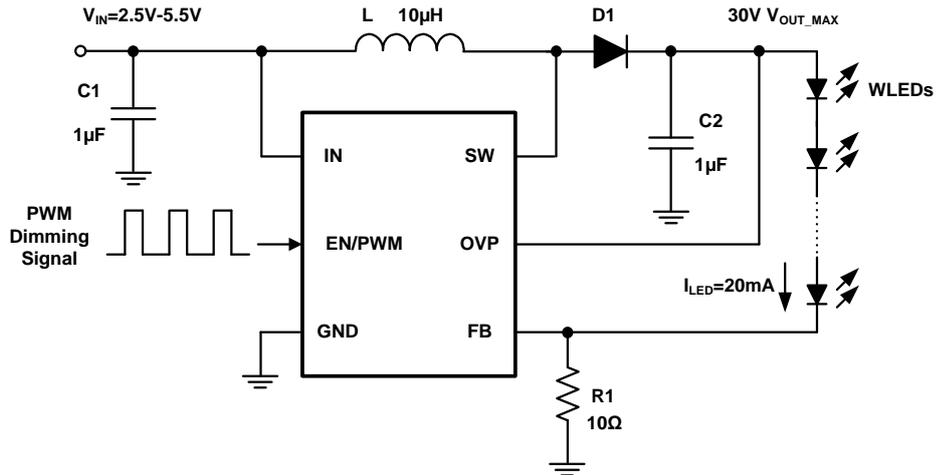
Figure 4. Dimming Control by a PWM Signal to EN Pin for STI9287C

b. Using a DC Voltage

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 R2 decreases, i.e. the LED current decreases. Please refer to the Figure 5, the LED current is given by the below equation:

$$I_{LED} = \frac{V_{REF}}{\frac{R3 \times R2}{R3+R2} \times R1} - \frac{V_{DC}}{R3 \times R1}$$

Equation 2.
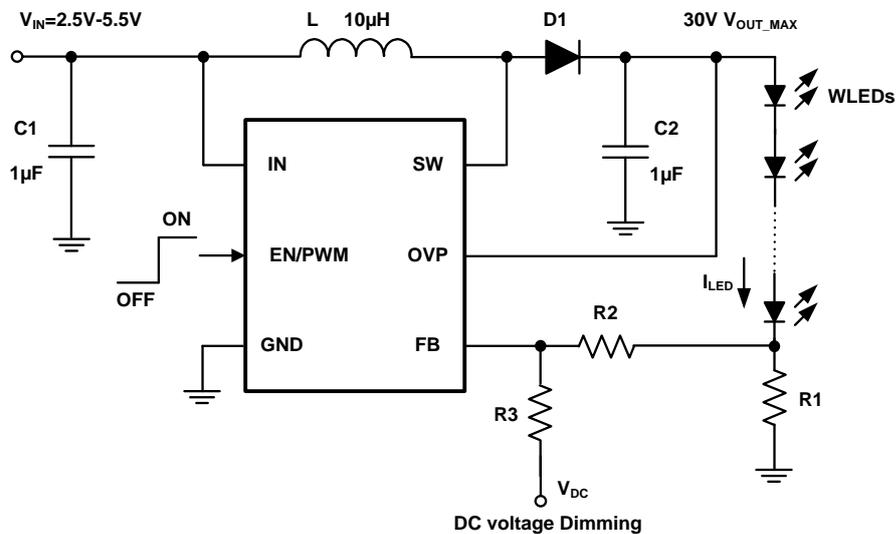
Figure 5. Dimming Control by a DC Voltage

c. 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. Please refer to the Figure 6, the LED current is given by the below equation:

$$I_{LED} = \frac{V_{REF}}{\frac{R3 \times R2}{R3+R2} \times R1} - \frac{Duty \times V_D}{R3 \times R1}$$

Equation 3.
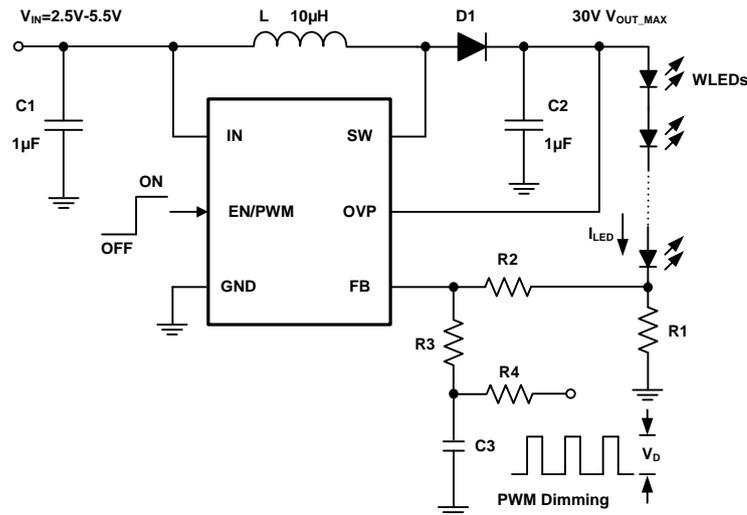
Figure 6. Dimming Control by a Filtered PWM Signal

Inductor Selection

Inductor selection is important for STI9287C application. Inductor value determines input inductor current ripple value.

$$\Delta I_L = \frac{V_{IN} \times D}{f_s \times L} = \frac{V_{IN}}{f_s \times L} \times \left(1 - \frac{V_{IN} \times \eta}{V_{OUT}}\right)$$ Equation 4.

Where:

D = duty cycle of boost converter

η = efficiency of the converter, e.g. estimated 90%

The inductor current ripple determines maximum output current according to device switching current limit value.

$$I_{OUT\_max} = I_{L\_max} \times (1 - D) = \left(I_{SW\_LIM} - \frac{\Delta I_L}{2}\right) \times (1 - D)$$ Equation 5.

Where：

I_{SW_LIM} = current limit of STI9287C and STI9287CA, it is 1.5A typically.

Generally, the inductor current ripple is estimated 10% to 40% of the input inductor average current. The recommended value of inductor is 2.2μH to 22μH for most backlight LED drive application. Small size and better efficiency are the major concerns for portable device, such as STI9287C and STI9287CA used for mobile phone. The inductor should have low core loss at 1.2MHz and low DCR for better efficiency. To avoid inductor saturation current rating should be considered according to the switching current limit of STI9287C and STI9287CA.

For Boost converter, the right-half plane zero (RHP zero) is inherent affecting on boost operation. In most application, the frequency of right-half plane zero should be put on higher than crossover frequency to reduce effect on loop phase margin and stability. The frequency of the right-half plane zero is shown as below:

$$f_{RHPzero} = \frac{(1-D)^2 \times R_{Load}}{2\pi \times L}$$

According to above expression, in low output voltage with heave load application condition, the frequency of the right-half plane zero decrease to lower frequency, in larger series LEDs string number with high output voltage larger than 12V, 10µH inductor and 1µF output capacitor are recommended, while in the application with less series LEDs string number and low output voltage, the smaller inductance and larger output capacitor should be adopted to provide enough stability of the control loop. The lower output voltage in application, the smaller inductance used. For example, to driver less than 4 series LED strings with larger 100mA totally LED current, STI9287C and STI9287CA with 4.7µH inductance is suitable for the application.

Capacitor Selection

Input and output ceramic capacitors of 1µF or larger capacitance are recommended for STI9287C andSTI9287CA 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. As to output capacitor, the voltage rating is important for high voltage application and ceramic capacitor's derating under DC bias. Ceramic capacitors could reduce more than 50% its capacitance at its rated voltage. The recommended minimum output capacitor is 1µF with 50V rated voltage X5R or X7R ceramic capacitor for larger number LED string with output voltage larger than 10V. In the application with lower number LED strings and lower than 10V output voltage, the recommended minimum output capacitor is 2.2µF.

Diode Selection

Schottky diode is a good choice for STI9287C and STI9287CA because of its low forward voltage drop and fast reverse recovery. Using Schottky diode can get better efficiency. The high speed rectification is also a good characteristic of Schottky diode for high switching frequency. Current rating of the diode must meet the root mean square of the peak current and output average current multiplication as following:

$$I_D(RMS) \approx \sqrt{I_{OUT} \times I_{PEAK}}$$
<div align="right">Equation 6.</div>

The diode's reverse breakdown voltage should be larger than the output voltage.

Layout Consideration

For best performance of the STI9287C andSTI9287CA, the following guide lines must be strictly followed.

1. Input and Output capacitors should be placed close to the IC and connected to ground plane to reduce noise coupling. Input Capacitor should be placed close to IN pin and GND. Output capacitor must be placed close to diode output node and GND to reduce switching loop.
2. Keep the main current traces as possible as short and wide.
3. SW node of DC-DC converter is with high frequency voltage swing. It should be kept at a small area.
4. Place the feedback resistor R1 as close as possible to the IC FB pin and keep away from the noisy devices since FB is a high impedance input pin that is sensitive to noise.

TYPICAL PERFORMANCE CHARACTERISTICS

Efficiency with 7LEDs
L=10µH, DCR=30mΩ, ILED=1mA to 100mA
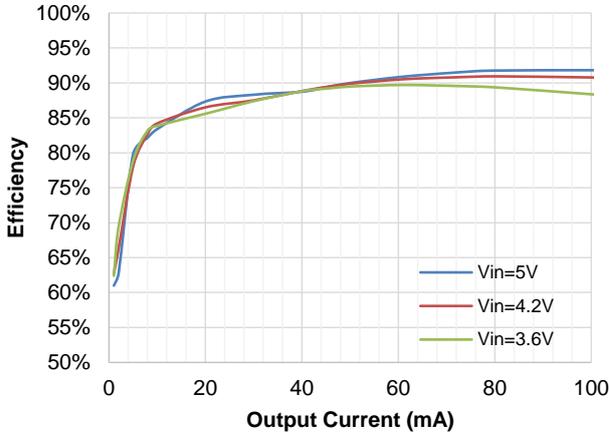
Efficiency with 6LEDs
L=10µH, DCR=30mΩ, ILED=1mA to 100mA
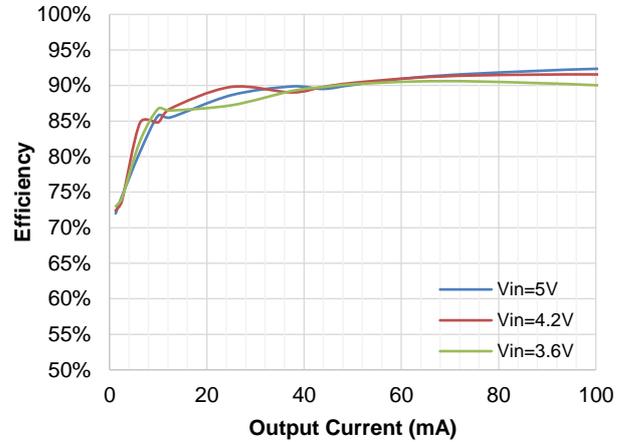
PWM Dimming Linearity
V_{IN}=4V, R_{SET}=2Ω, 20kHz PWM, Duty=0.5% to 50%
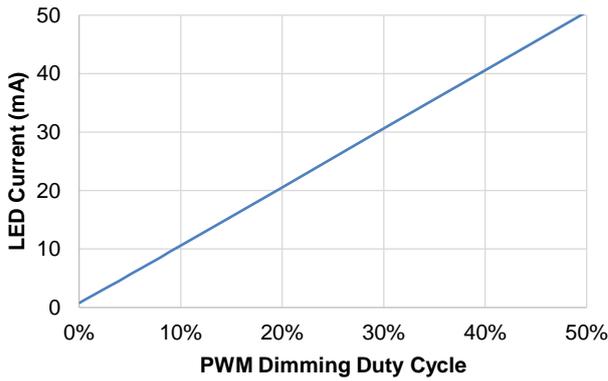
PWM Dimming Waveform
V_{IN}=4V, R_{SET}=2Ω, 7LEDs, 100kHz PWM, Duty=10%
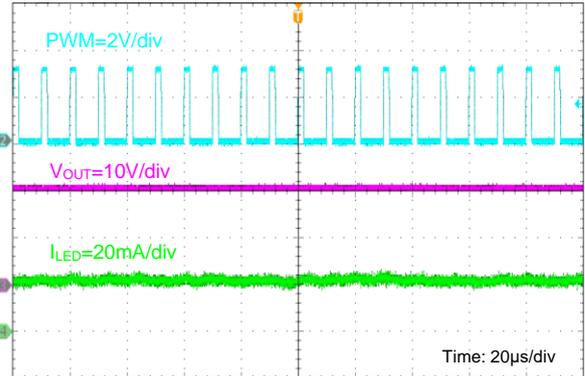
Steady State Operation
V_{IN} =4V, 7LEDs, L=10µH, I_{LED}=20mA
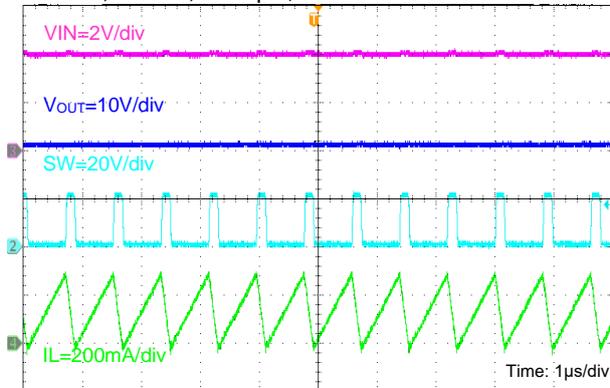
Steady State Operation
V_{IN} =4V, 7LEDs, L=10µH, I_{LED}=50mA
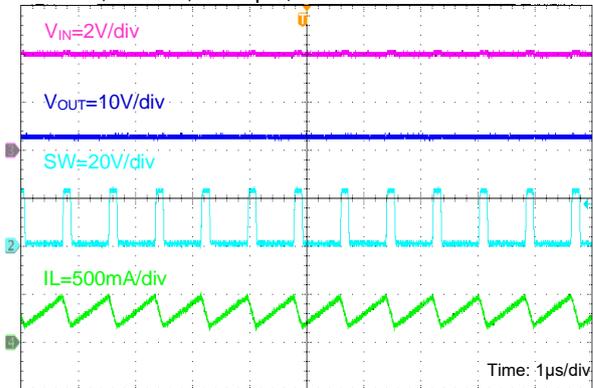
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

EN Enable Power On
V_{IN} =4V, 7LEDs, L=10µH, I_{LED}=20mA

EN=2V/div

V_{OUT}=10V/div

SW=20V/div

IL=1A/div

Time: 40µs/div
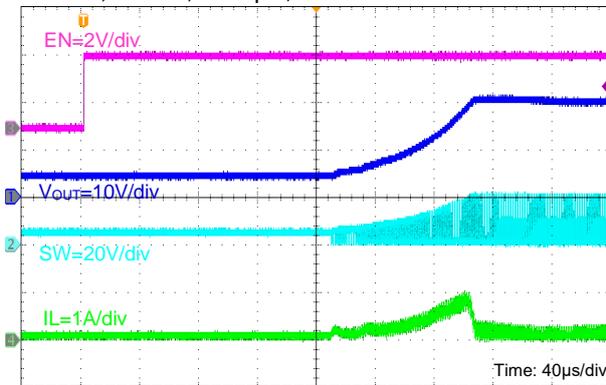
EN Disable Power down
V_{IN} =4V, 7LEDs, L=10µH, I_{LED}=20mA
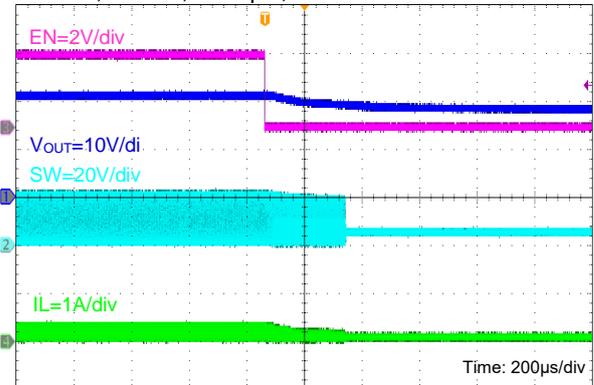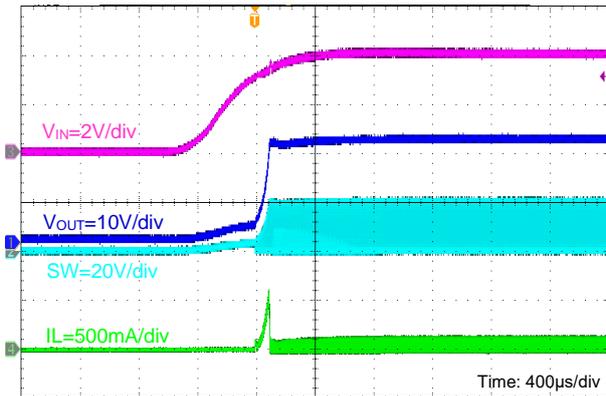
EN=2V/div

V_{OUT}=10V/di.

SW=20V/div

IL=1A/div

Time: 200µs/div

Input Power On
V_{IN} =4V, 7LEDs, L=10µH, I_{LED}=20mA

V_{IN}=2V/div

V_{OUT}=10V/div

SW=20V/div

IL=500mA/div

Time: 400µs/div

Input Power Down
V_{IN} =4V, 7LEDs, L=10µH, I_{LED}=20mA

V_{IN}=2V/div

V_{OUT}=10V/div

SW=20V/div

IL=500mA/div

Time: 4ms/div

LED Open OVP
V_{IN} =4V, 7LEDs, L=10µH, LED Open

V_{IN}=2V/div

V_{OUT}=10V/div

SW=20V/div

IL=500mA/div

Time:20ms/div

LED Open OVP
V_{IN} =4V, 7LEDs, L=10µH, LED Open

V_{IN}=2V/div

V_{OUT}=10V/div

SW=20V/div

IL=500mA/div

Time:40µs/div
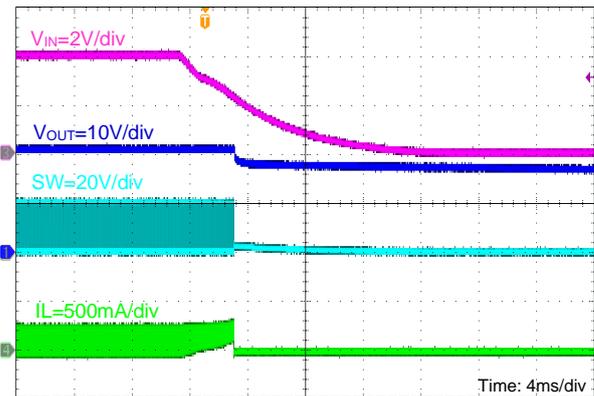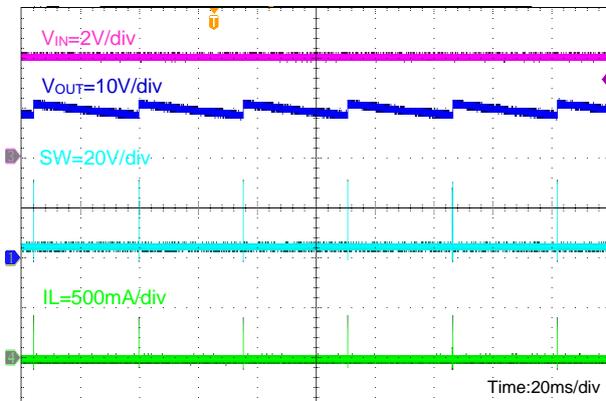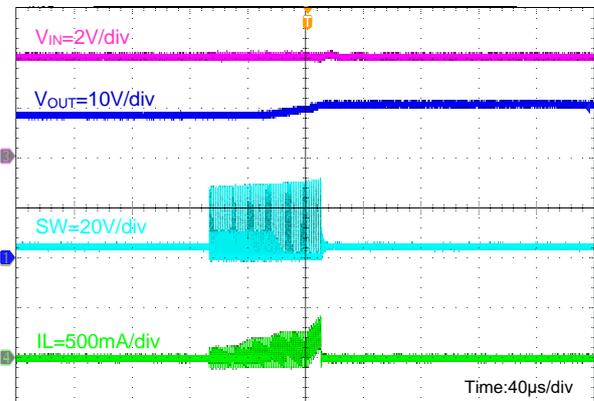
PACKAGE INFORMATION

SOT23-6
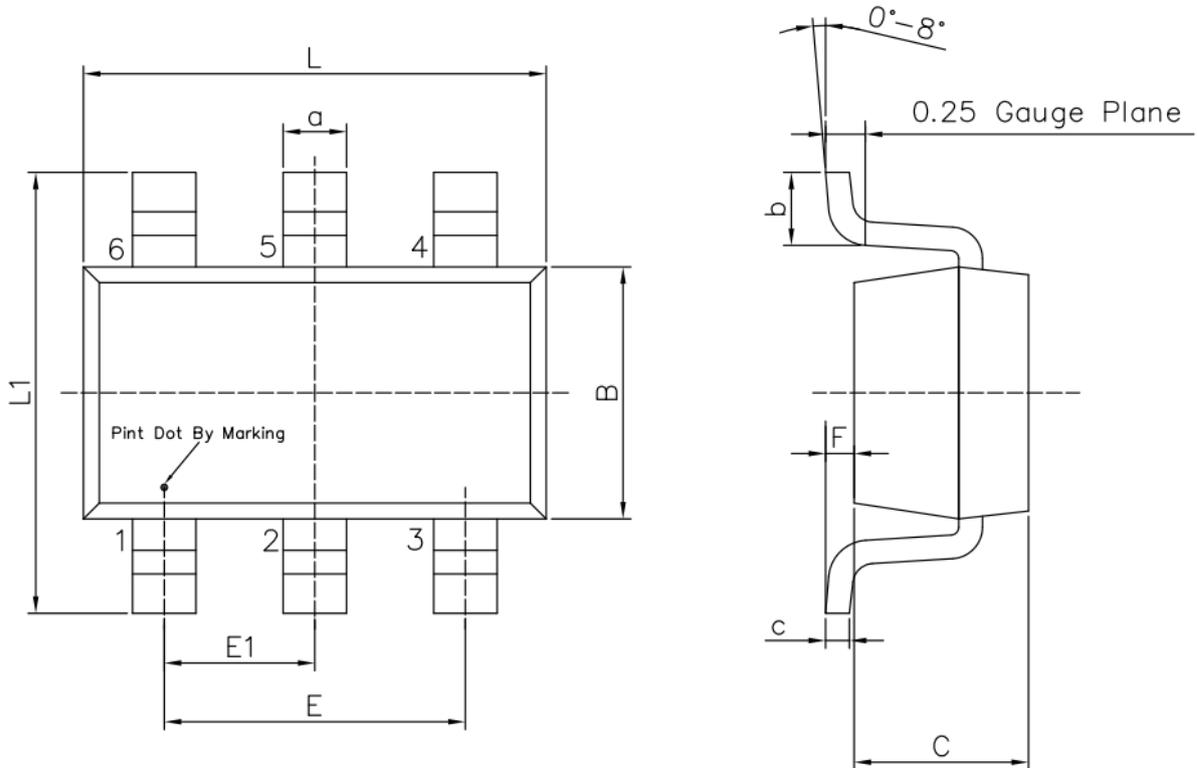
Unit: mm

| Symbol	Dimensions In Millimeters		Symbol	Dimensions In Millimeters	
	Min	Max		Min	Max
L	2.82	3.02	E1	0.85	1.05
B	1.50	1.70	a	0.35	0.50
C	0.90	1.30	c	0.10	0.20
L1	2.60	3.00	b	0.35	0.55
E	1.80	2.00	F	0	0.15

Note:

1) All dimensions are in millimeters.

2) Package length does not include mold flash, protrusion or gate burr.

3) Package width does not include inter lead flash or protrusion.

4) Lead popularity (bottom of leads after forming) shall be 0.10 millimeters max.

5) Pin 1 is lower left pin when reading top mark from left to right.

TAPE AND REEL INFORMATION

TAPE DIMENSIONS: SOT23-6

Direction of feed
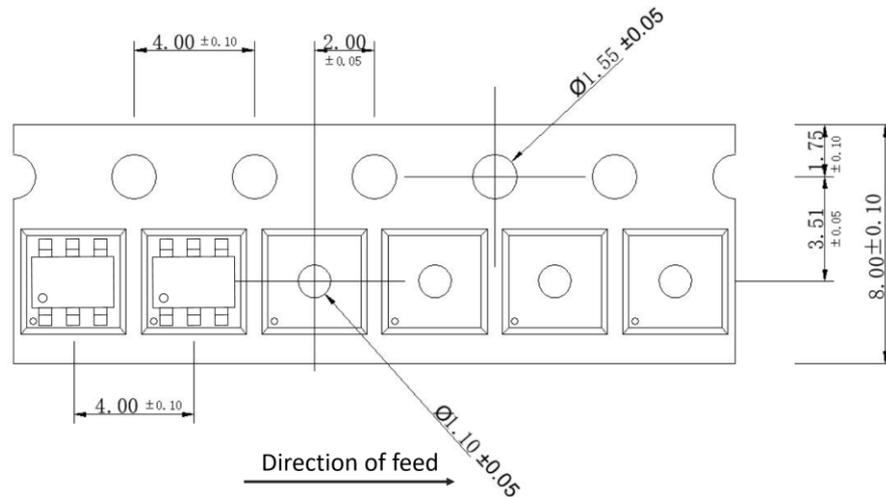
REEL DIMENSIONS: SOT23-6
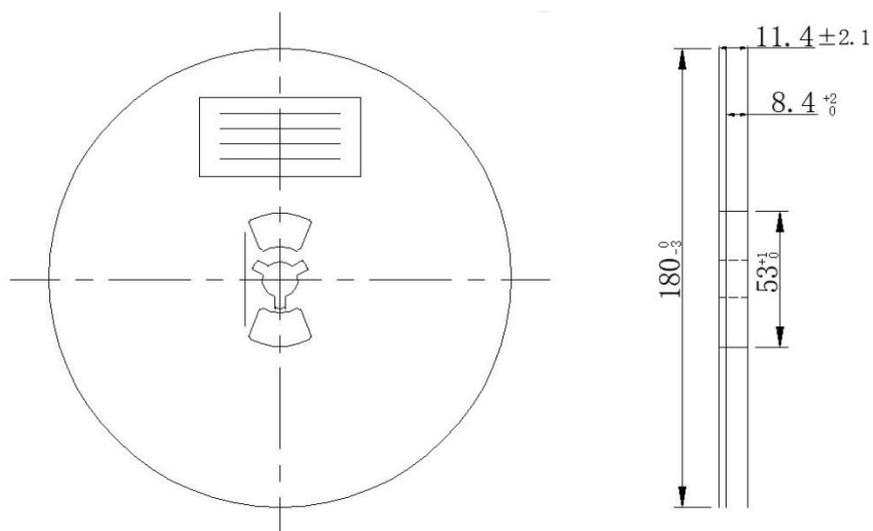
Note:

1) All Dimensions are in Millimeter
2) Quantity of Units per Reel is 3000
3) MSL level is level 3.