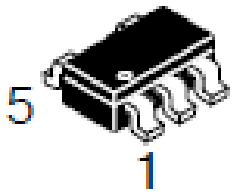
32V high-current white LED driver chip

Description

SL4139 is a DC/DC boost converter that provides precise constant current drive for multiple LEDs. With a fixed switching frequency of 1MHz, SL4139 can be paired with small external ceramic capacitors and inductors. Adjustable current, set by external resistor R1, allows SL4139 to drive series-connected LEDs. It is suitable for driving LEDs of the same type, with up to 9 white LEDs in series or a maximum driving voltage of 32V. LED brightness can be adjusted using a DC voltage, logic signal, or pulse width modulation (PWM). The shutdown control pin (SHDN) enables the device to operate in ultra-low static current standby mode.
In addition to thermal protection and overcurrent limiting, SL4139 enters ultra-low power mode in the event of LED open-circuit faults. The chip is packaged in a small SOT23-5 form factor.

Feature

- Switch peak current: 1A
- Maximum driving voltage: 32V
- Maximum power conversion efficiency: 90%
- Shutdown current less than 10uA
- Fixed frequency of 1MHz with low noise
- Surge current limitation during soft start
- LED open-circuit overvoltage protection
- 3.3V undervoltage lockout (UVLO)
- Overtemperature protection
- Suitable for automotive electronics
- RoHS compliant
- Industrial grade (-40°C to +85°C)



SOT-23-5

Pin Description

The SW pin is connected to the drain of the internal CMOS power switch of the boost converter. The anode of the inductor and Schottky diode should be connected to the SW pin.

Keep the connections to the SW pin as short as possible to minimize loop area. An overvoltage detection circuit is connected to the SW pin. When the voltage reaches 37V, the device enters low-power safe mode to prevent the SW voltage from exceeding its maximum rated value.

GND is the reference ground pin, which should be directly connected to the PCB ground.

The FB pin is the feedback pin, and the FB potential is clamped at 0.3V. Connect a resistor R1 between the FB pin and GND to set the LED current. The specific current value can be determined using formula 3.1.

$$I_{LED} = \frac{0.3V}{R1} \qquad 3.1$$

Note that the negative terminal of the LED's lowest potential should be connected to the FB pin.

$\overline{SHDN}$ pin serves as the logic input shutdown control terminal. When the voltage at this pin is below 0.4V, the device is in shutdown mode, consuming nearly zero current. When the voltage at this pin exceeds 1.5V, the device starts operating.

V_{IN} is the power supply input pin for the internal logic circuitry. The input voltage range for the V_{IN} pin is 3.3V to 32V. It is recommended to place a bypass ceramic capacitor (4.7uF) between the V_{IN} pin and ground. If the V_{IN} voltage drops below 3.3V, the device will stop operating.

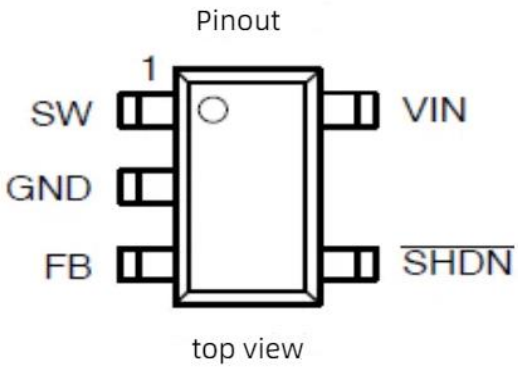


Table 3.1 Pin Description

Pin Number	Pin Name	Function
1	SW	Drain of the internal power switch
2	GND	Ground pin, connected to ground plane
3	F_B	Feedback pin, connected to the negative terminal of the final LED
4	$\overline{SHDN}$	Shutdown pin (logic low), pulled high to enable the driver
5	V_{IN}	Power input pin

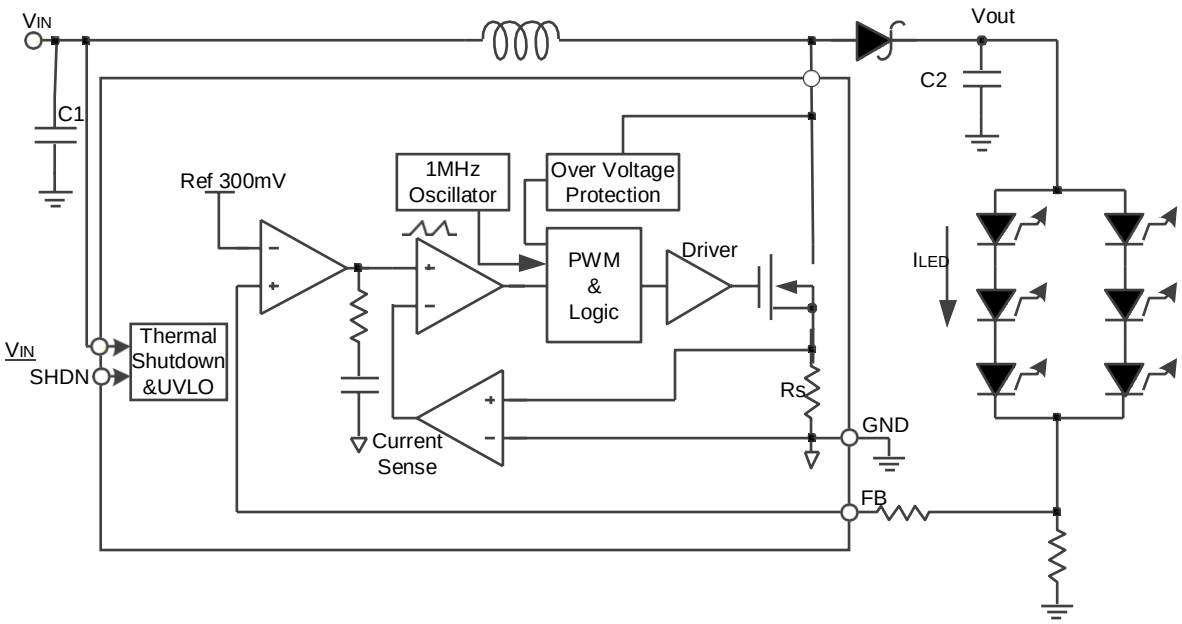


Figure 3-1 Chip functional diagram

Application information

SL4139 is a fixed-frequency (1MHz), low-noise, inductor boost converter that provides constant current with excellent linearity and load regulation. The device utilizes a high-voltage NMOS switch between the SW pin and GND pin to drive the inductor. When the NMOS switch is turned off, energy stored in the inductor is discharged to the load through a Schottky diode.

The duty cycle of the NMOS switch is adjusted and controlled internally based on the feedback voltage at the FB pin, ultimately outputting a constant regulation voltage of 0.3V at FB. The current flowing through the LED is inversely proportional to the resistance value (I = 0.3V/R1).

During initial power-up, the duty cycle of the internal NMOS switch is limited to restrain surge current, providing a soft-start operation.

In the event of an LED open circuit, the feedback control loop opens, causing the output voltage to continue increasing. Once the output voltage exceeds 37V, internal protection circuits activate, placing the device into a low-power safe mode.

The device includes over-temperature protection circuitry that disables operation automatically when the junction temperature exceeds 150°C, and resumes normal operation once the temperature decreases to 130°C.

Detailed information

SL4139 can be applied in GPS navigation systems, portable multimedia players, and handheld devices. Specific applications can be referenced in the typical application circuits shown in Figures 5-1, 5-2, and 5-3. The LED specifications are as follows:

- In Figure 5-1, the LED specifications are 3.3V/20mA.
- In Figures 5-2 and 5-3, the LED specifications are 2.1V/250mA.

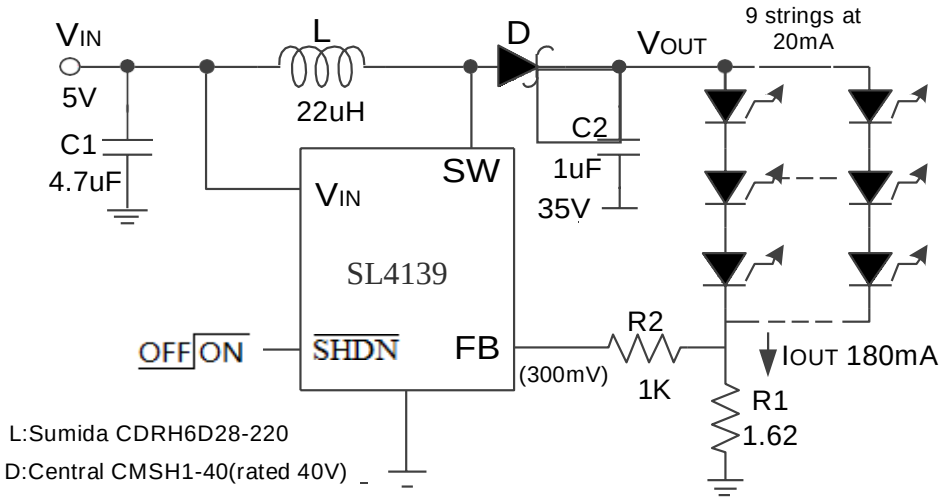


Figure 5-1 Typical application circuit 1

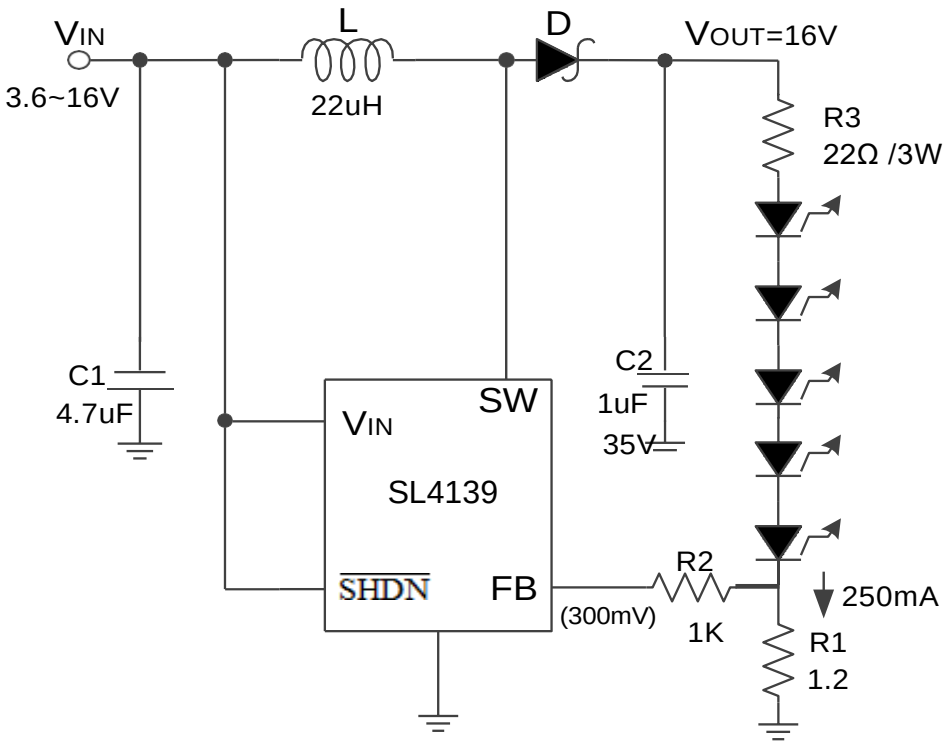


Figure 5-2 Typical application circuit 2

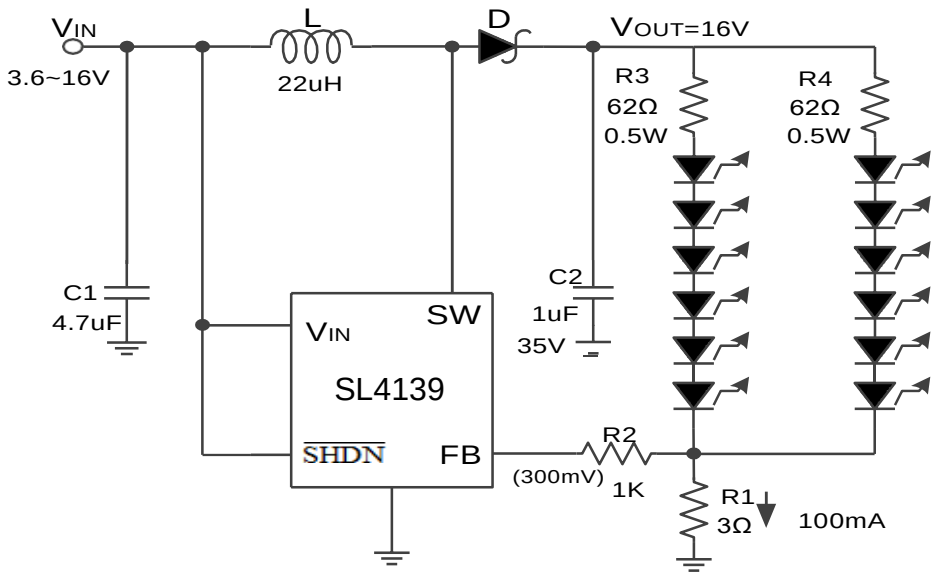


Figure 5-3 Typical application circuit 3

Table 5.1 Maximum rated range

Parameter	Symbol	range	Uint	Note
vin voltage	V_{IN}	-0.3～+42	V	
fb voltage	V_{FB}	-0.3～+7	V	
shdn voltage	V_{SHDN}	-0.3～+40	V	
sw voltage	V_{SW}	-0.3～+40	V	
storage temperature	T_{stg}	-40～+150	℃	
junction temperature	T_j	-40～+150	℃	
soldering temperature	$T_{soldering}$	300	℃	
thermal resistance	R_{thj-a}	220	K/W	
esd withstand voltage	$V_{ESD-HBM}$	±2000	V	human body model 1)

Ps: When the device operates beyond the maximum rated range specified in Table 5.1, the device may be damaged. Functional applications should not exceed the recommended operating conditions listed above.

1) ESD withstand voltage per Human Body Model (HBM) based on JESD22-A114.
2) ESD withstand voltage per Charged Device Model (CDM) based on JESD22-C101E.

Table 5.2 Recommended operating conditions
(based on the typical application circuit shown in Figure 5-1)

Parameter	range	Uint
V_{IN} pin voltage	3.6～30	V
S_W pin voltage	0～32	V
Ambient temperature range	-40～+150	℃

Ps：When the device is soldered onto the PCB, the thermal resistance of the SOT23-5 package is JA = 220 ℃/W

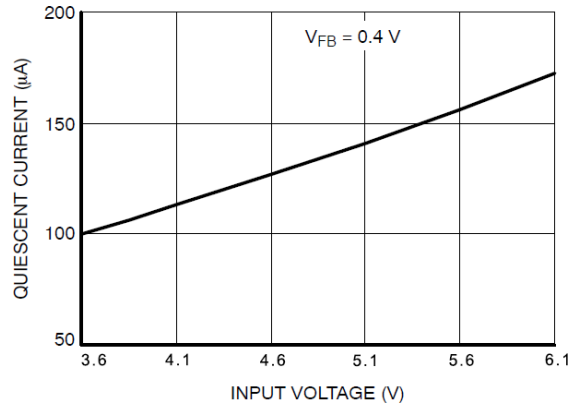
Table 5.3 DC electrical characteristics

(Unless otherwise specified: VIN=3.6V, Ta=25℃)

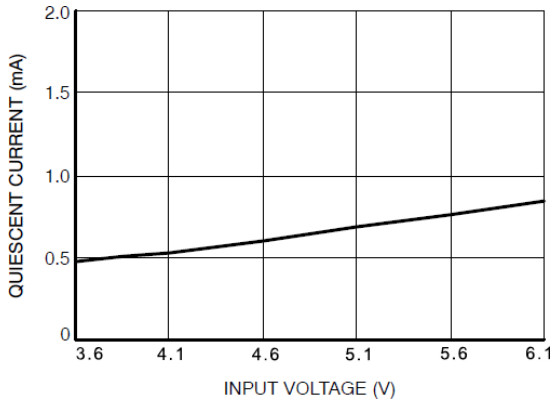
Parameter	Symbol	Condictions	Min	Typ	Max	Uint
I_Q	operating current	V_{FB} = 0.2V V_{FB} = 0.4V		0.8 0.1	1.5 0.6	mA
I_{SD}	shutdown current	V_{SHDN}=0V		6	10	uA
V_{FB}	fb pin voltage	I_{OUT} = 180mA	285	300	315	mV
I_{FB}	fb input current				1	uA
V_{ENH}	enable threshold	Enable turn-on voltage		1	1.5	V
V_{ENL}		Enable turn-off voltage	0.4	0.5		
F_{SW}	switching frequency		0.8	1	1.3	MHz
I_{LIM}	switch current limit	V_{IN}=3.6V V_{IN}=5V	600 750			A
R_{SW}	switch on-resistance	I_{SW} = 100 mA		1	2	Ω
L_{LEAK}	switch leakage current	E_N=0V，V_{SW}=5V			1	uA
T_{SD}	thermal shutdown			150		℃
T_{HYST}	thermal hysteresis			20		℃
V_{UVLO}	threshold voltage			3.3		V
V_{OV-DET}	over-voltage threshold detection			37		V
V_{OCL}	output clamping voltage	LED open circuit，F_B<0.2		37		V
D_C	maximum duty cycle			92		

Table 5.4 Typical Characterisitics

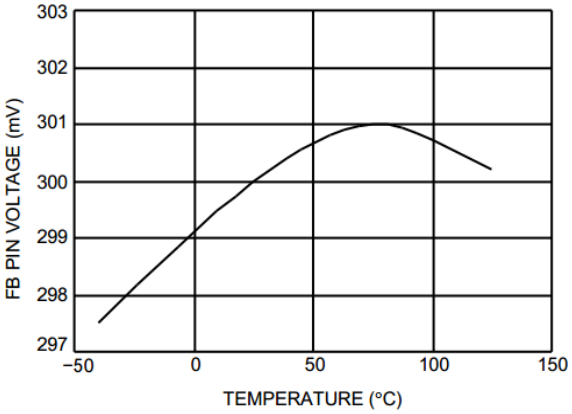
(V_{IN} = 5.0V, I_{OUT} = 180mA, T_{AMB} = 25°C, typical application circuit as shown in Figure 5-1 unless otherwise specified)



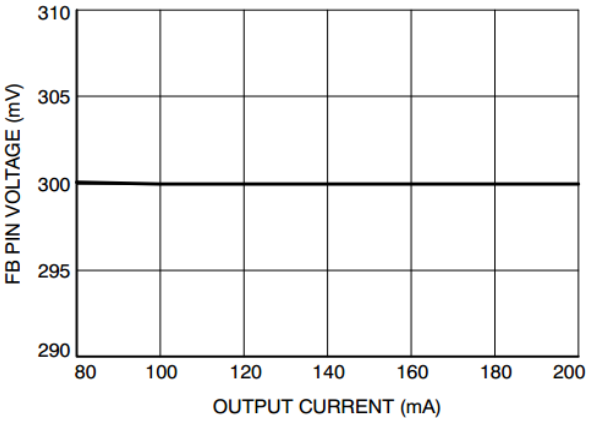
5-4 Static current vs. input voltage



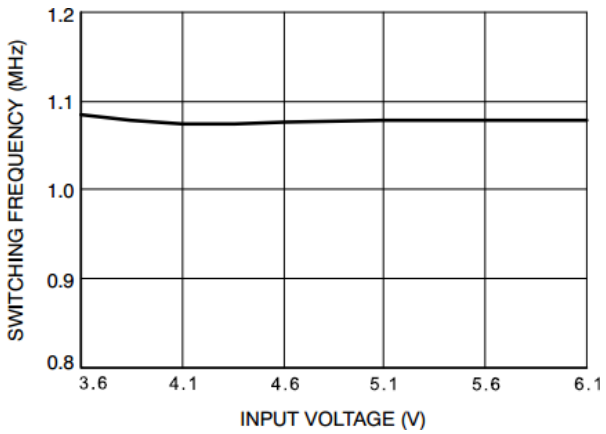
5-5 Static current vs. input voltage (operating condition)



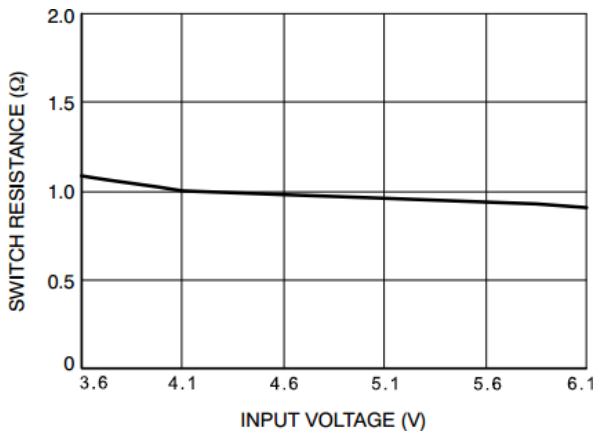
5-6 FB pin voltage vs. ambient temperature



5-7 FB pin voltage vs. input current



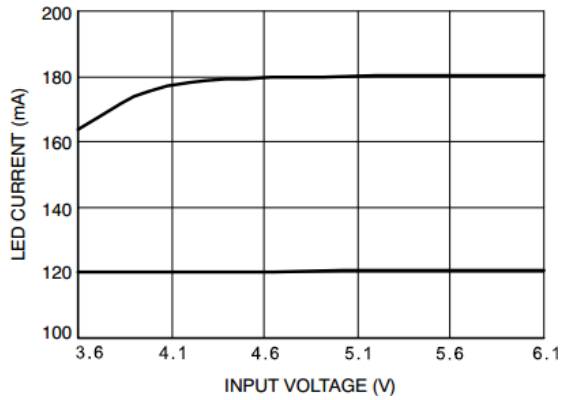
5-8 Switching frequency vs. supply voltage



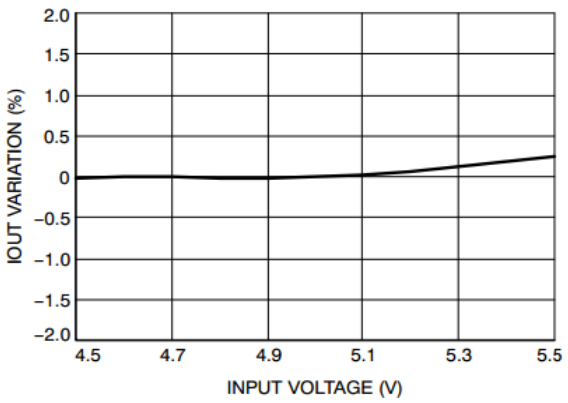
5-9 Conduction resistance vs. input voltage

Table 5.5 Typical Characterisitics

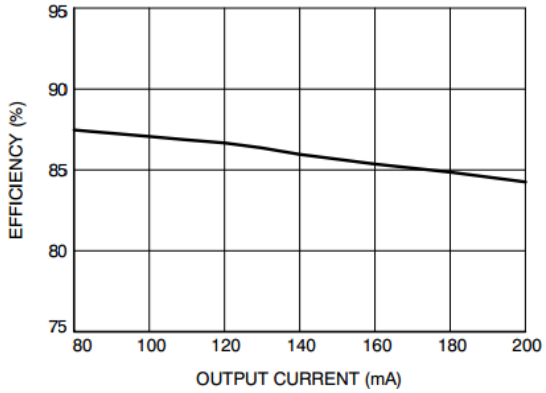
(V_{IN} = 5.0V, I_{OUT} = 180mA, T_{AMB} = 25°C, typical application circuit as shown in Figure 5-1 unless otherwise specified)



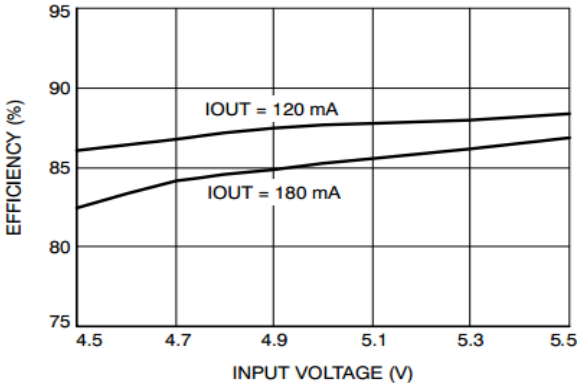
5-10 Output current vs. input voltage



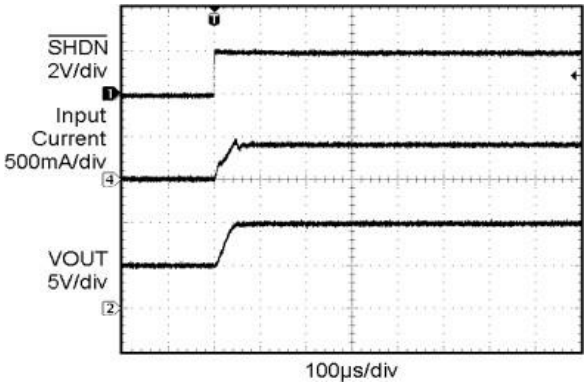
5-11 Output current vs. input voltage



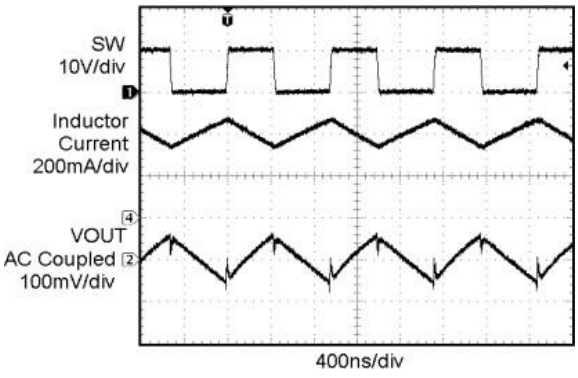
5-12 Efficiency vs. output current



5-13 Efficiency vs. Input current



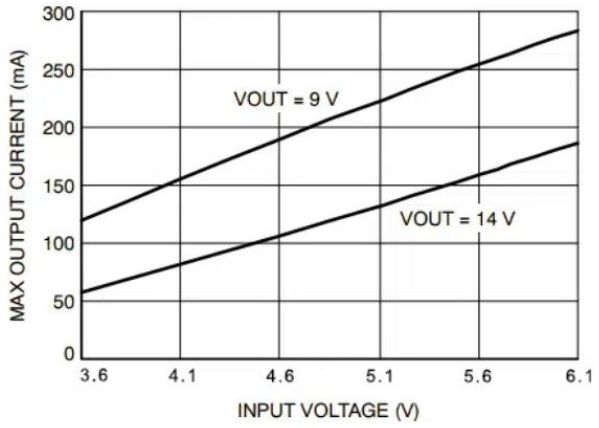
5-14 Power-on at 180mA load current



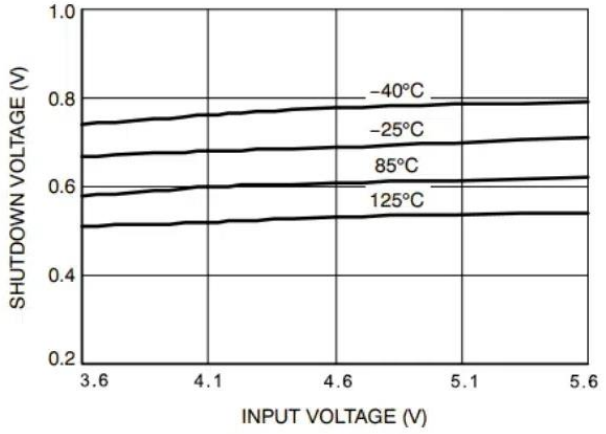
5-15 Switching waveform

Table 5.6 Typical Characterisitics

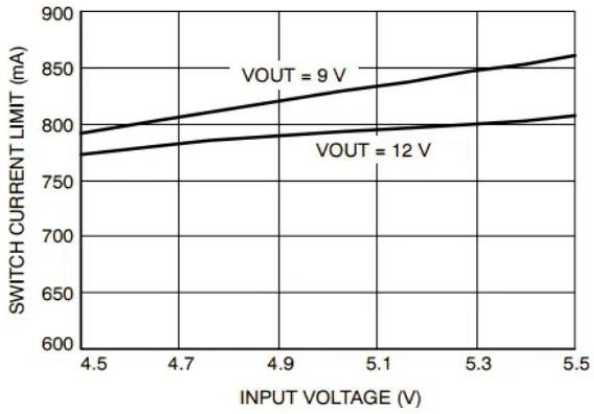
(V_{IN} = 5.0V, I_{OUT} = 180mA, T_{AMB} = 25°C, typical application circuit as shown in Figure 5-1 unless otherwise specified)



5-16 Maximum output current vs. input voltage



5-17 Shutdown voltage vs. input voltage



5-18 Switch current limit vs. input voltage

Application

External components

Capacitor

SL4139's input requires a parallel 4.7uF ceramic capacitor, and its output requires a parallel 1uF ceramic capacitor. Under normal conditions, a 4.7uF input capacitor is sufficient. For higher output power requirements, a 10uF or even larger input capacitor should be used. It is recommended that customers use X5R and X7R capacitors, as these types exhibit good stability within certain temperature ranges.

Inductor

In the typical application circuit shown in Figure 5-1, it is recommended to use a 22uH inductor. For circuits prioritizing efficiency, inductors with low series resistance are preferred. It is advised to use an inductor with a saturation current equal to or greater than 800mA. Customers are recommended to use the Sumida CDRH6D28-220 inductor (rated saturation current of 1.2A and typical series resistance (DCR) of 128mΩ) with a 22uF capacitance.

Schottky Diode

Schottky diodes must have a rated current greater than the peak current flowing through them. By measuring the voltage across the diode at a given current, its performance can be determined. For optimal efficiency, lower forward voltage is preferable. Response time is also crucial when operating at a frequency of 1MHz. It is recommended that customers use the Central Semiconductor Schottky rectifier CMSH1-40 (rated current 1A).

LED current

The magnitude of the LED current is set by an external resistor (R1) connected between the feedback pin (FB) and ground. The relationship between the resistor and the current is described by equation 6.1.:

$$R1 = \frac{0.3V}{\text{LED current}} \qquad 6.1$$

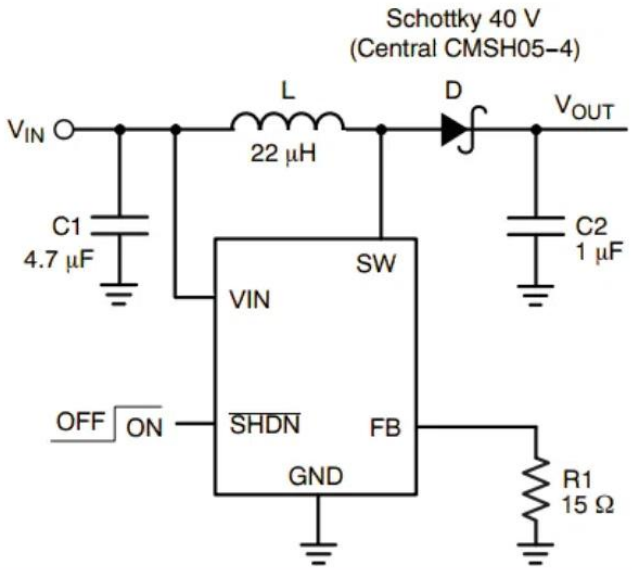
Table 6.1 Resistor (R1) and LED current

LED Current(mA)	R1(Ω)
20	15
25	12
30	10
100	3
300	1

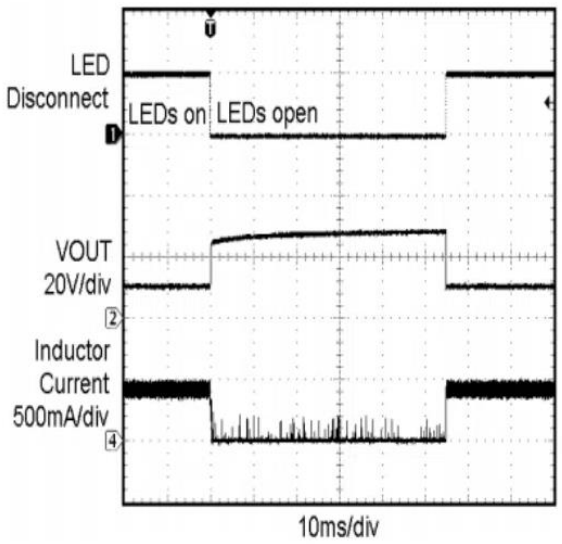
LED open-circuit protection

If an LED experiences an open circuit fault, the SL4139 will output maximum power, causing the output voltage to rise continuously until it reaches approximately 37V. Once the output exceeds 37V, the internal protection circuit immediately transitions the device into low-power mode, while limiting the total input power to about 6mW (with an input voltage of approximately 3.6V and input current of about 1.6mA).

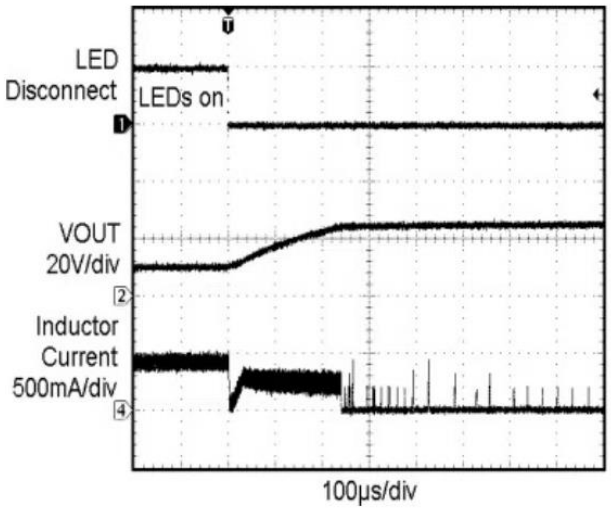
The clamp voltage at the SW pin is a maximum of 37V, and there is no need for a Schottky diode between VOUT and FB pins. However, a capacitor with a voltage rating greater than 37V is necessary to prevent device damage from overvoltage when the LED is open-circuited.



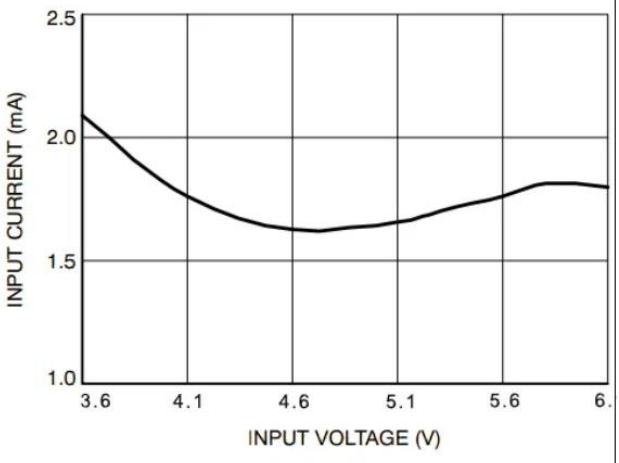
6-1 LED open-circuit protection circuit



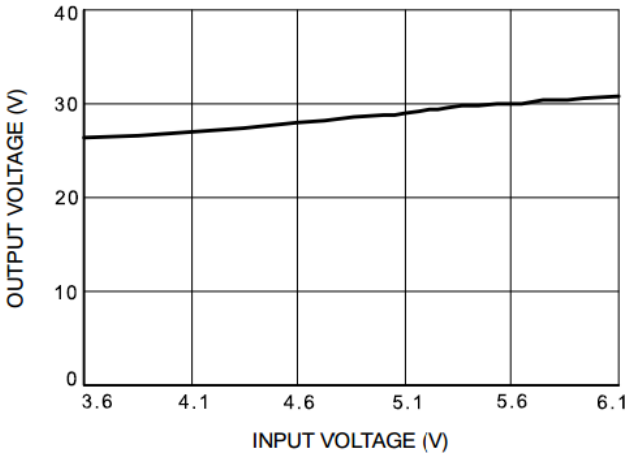
6-2 Reconnecting an LED



6-3 LED disconnected



6-4 The current in the circuit when the LED is open-circuited



6-5 Output voltage when the LED is open-circuited

Brightness control

There are several methods to control LED brightness.

Generating PWM signal using the $\overline{\text{SHDN}}$ pin

The brightness of the LED can be adjusted using PWM signals from the $\overline{\text{SHDN}}$ pin. Since the $\overline{\text{LED}}$ current is controlled by a switching regulator, the average current is proportional to the duty cycle. When the duty cycle is 100%, SHDN is always high, corresponding to an LED current of 0.3/R1. Figure 7-1 illustrates the relationship between the PWM waveform and the LED current waveform, where the input waveform to the SHDN pin has a frequency of 1 kHz and a 50% duty cycle.

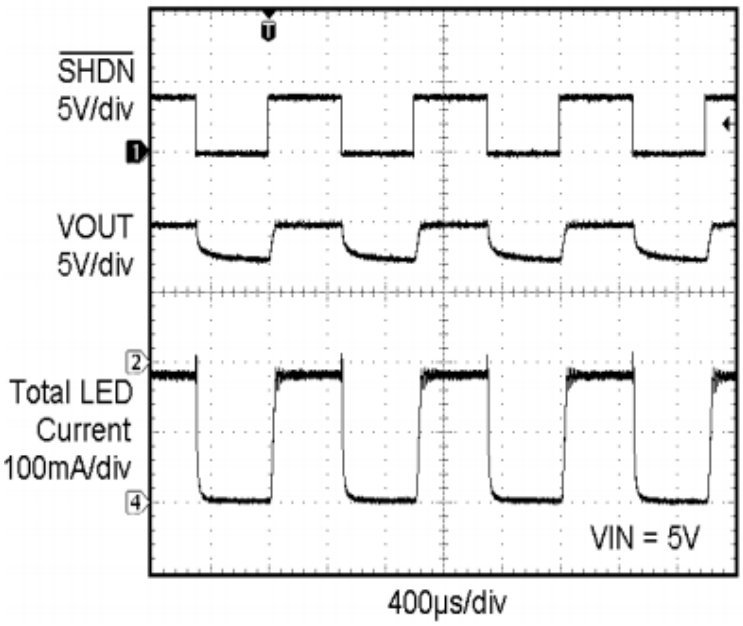


Figure 7-1 The switching waveform on the SHDN pin when a 1 kHz PWM signal is applied.

PWM signal filtering

A filtered PWM signal can be used as a variable DC voltage to control LED current. Figure 7-2 illustrates the PWM control circuit connected to the FB pin of SL4139.

The PWM signal has a voltage fluctuation range of 0V to 2.5V. The LED current can vary between 0mA to 20mA. The frequency of this PWM signal can range from 20kHz up to 200kHz.

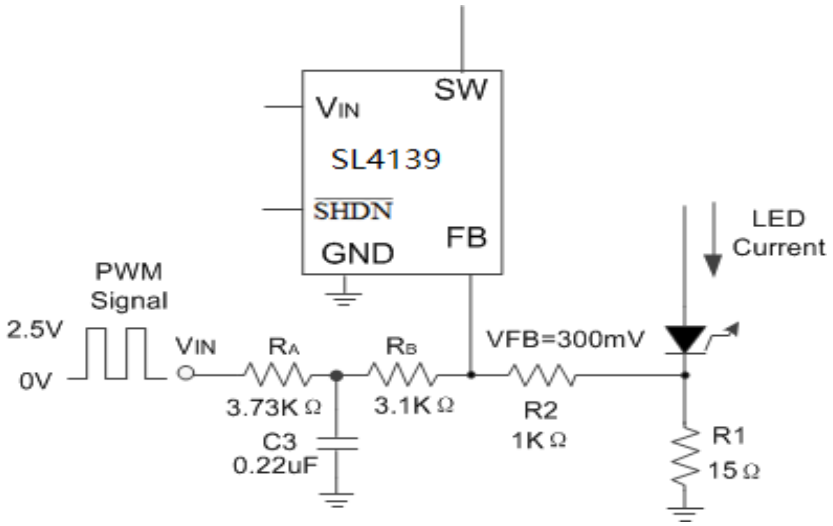


Figure 7-2 PWM signal filtering circuit

When the PWM signal is at 0V or 0% duty cycle, the maximum LED current is approximately 22mA. When the PWM duty cycle reaches 93% or higher, the current through the LED drops to 0mA. The relationship between PWM duty cycle and LED current is illustrated in Figure 7-3.

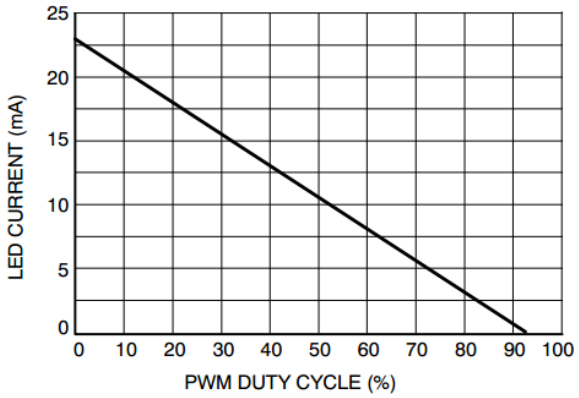
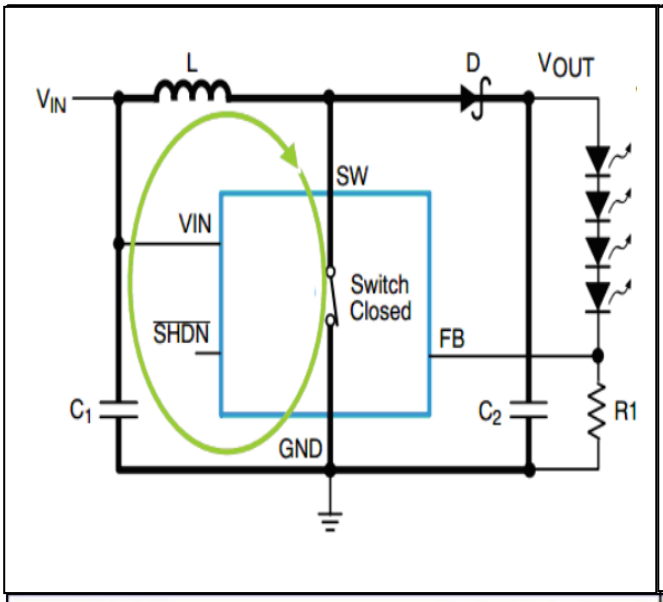


Figure 7-3 Relationship between filtered PWM signal and lamp current (0V to 2.5V)

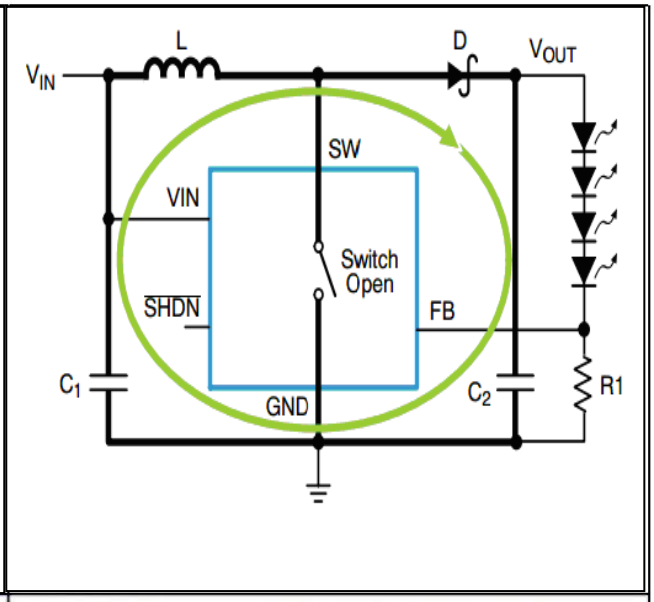
Circuit board

SL4139 is a high-frequency switch regulator. To minimize EMI, ripple, and noise, careful routing of high-frequency switch currents on the PCB is essential. The bold lines in Figure 8-1 depict the paths of high-frequency switch currents. These traces must be kept short and wide to reduce parasitic inductance and resistance. In Figure 8-1, the current path forms a loop when the internal switch of SL4139 is closed. In Figure 8-2, the current path forms a loop when the internal switch of SL4139 is open. Both loop areas should be minimized as much as possible.

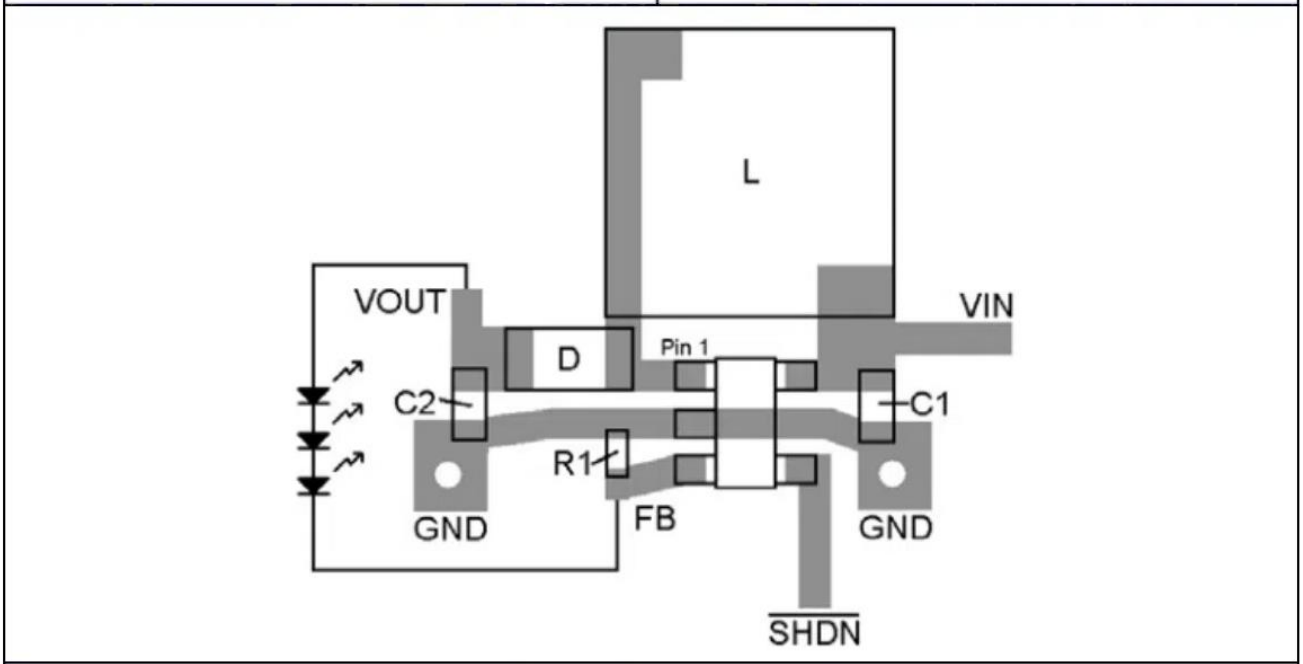
Capacitor C1 should be placed as close as possible to the VIN and GND pins. Capacitor C2 must be connected to the anode of the LED at its highest potential. It is recommended to connect capacitors directly to ground. Resistor R1 must be directly connected to the GND pin of SL4139.



8-1 The current loop when the switch is closed

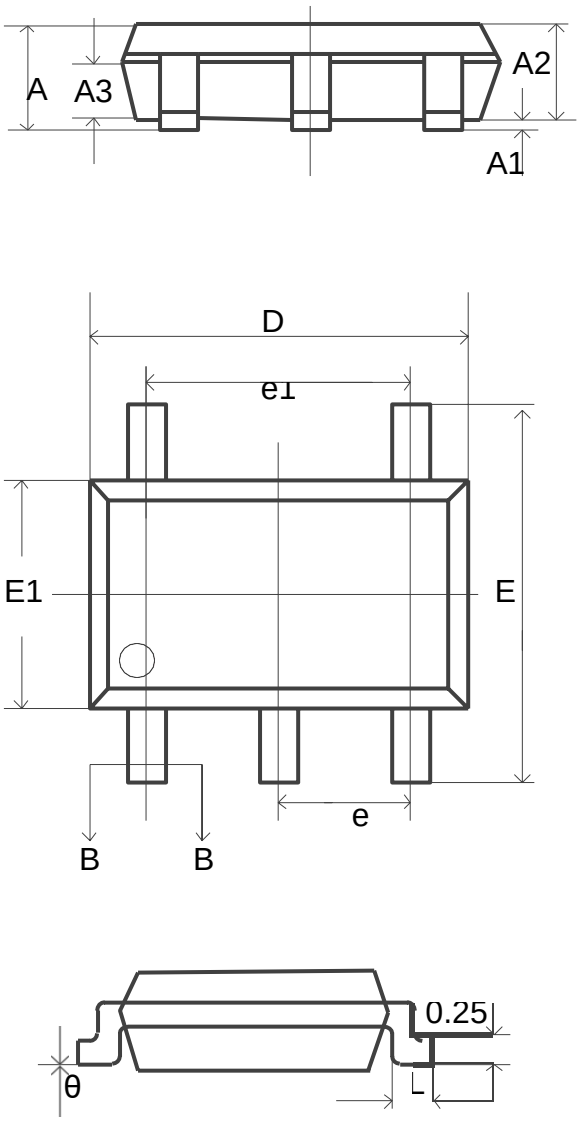


8-2 The current loop when the switch is open



8-3 Recommended PCB layout and wiring

Package dimension



Symbol	Millimeter		
	Min	Nom	Max
A	----	----	1.25
A1	0.04	----	0.10
A2	1.00	1.10	1.20
A3	0.55	0.65	0.75
b	0.38	-----	0.48
b1	0.37	0.40	0.43
c	0.11	-----	0.21
c1	0.10	0.13	0.16
D	2.72	2.92	3.12
E	2.60	2.80	3.00
E1	1.40	1.60	1.80
e	0.95 BSC		
e1	1.90 BSC		
L	0.30	----	0.60
θ	0	----	8°

9-1 SOT23-5

Ordering information

Device	Package	Information
SL4139	SOT23-5	3000pcs/Tape&Reel