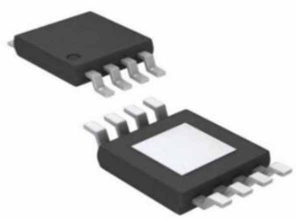
SCM1331A 40V Input Voltage， 2A LED Driver

Features

- Wide 4.5V to 40V Input Range
- Adjustable Switching Frequency from 200kHz to 1500kHz
- Output Current up to 2 A
- Internal Soft-Start
- 200mΩ High-Side MOSFET
- 4μA Shutdown Current
- Over-current Protection, and Thermal Protection

Packaging



Product Package: eSOP-8
(see "Ordering information" for details)

Application

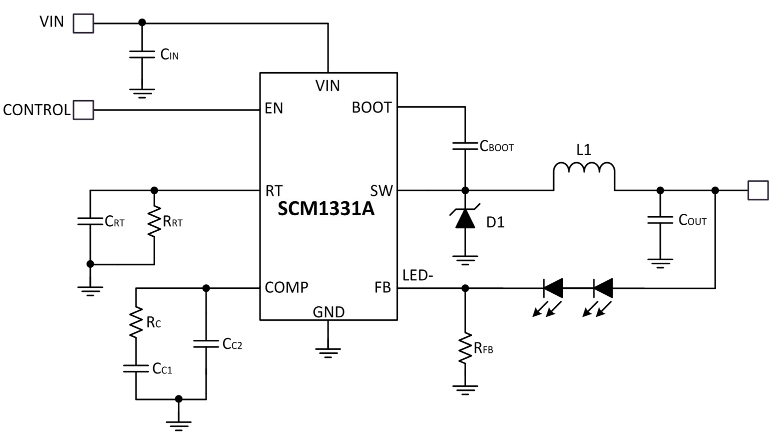
- High Power LED
- General Lighting
- Constant Source

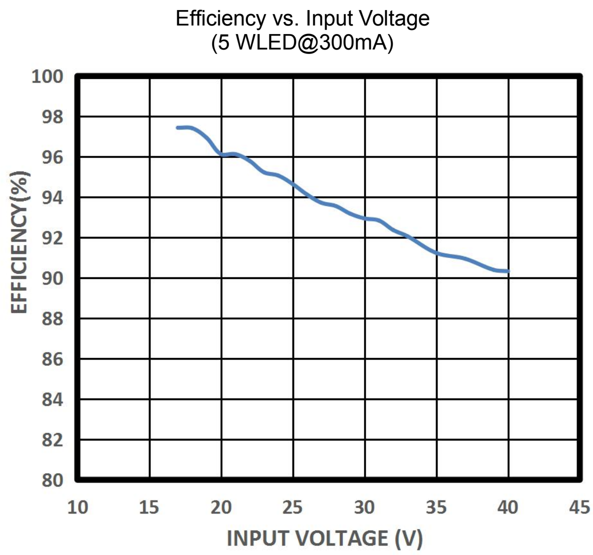
Description

The SCM1331A is a step-down regulator to deliver a constant current of up to 2A to LEDs, with a wide input range 4.5V to 40V and 4μA ultra-low shutdown current. Current mode control and 200mV reference is applied for fast loop response and easy compensation. The switching frequency in 200kHz~1500kHz, it is programmable with an external resistor, and this allows the device to be used with minimum external components to achieve low output voltage ripple. Soft start is implemented internally to reduce external components. The EN pin is used to realize PWM dimming.

The SCM1331A is used to drive single or multiple series, monochrome or infrared LED arrays, such as in cameras.The device has built-in thermal protection and short protection, and is available in the eSOP-8 package（4.9mm × 3.9mm ×1.4mm）.

Simplified Schematic

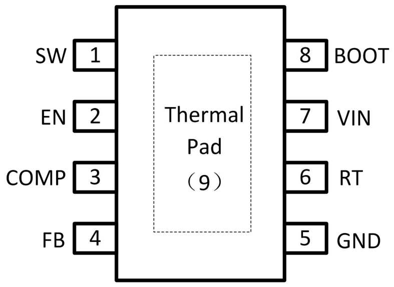




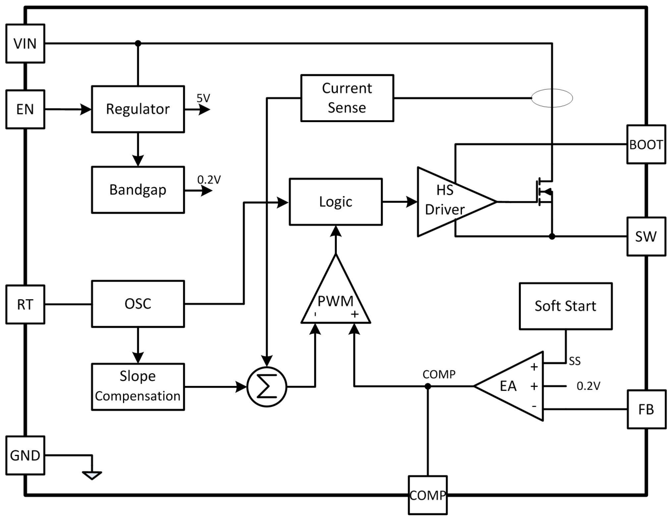
Contents

Pins

eSOP-8 package
(Top view)



Functional Block Diagram



Pin Description

Pin No.	Pin Name	I/O	DESCRIPTION
1	SW	O	Switching node. Connect to inductor, diode.
2	EN	I	Enable input pin. Pulling it up above the specified threshold or leaving it floating enables the device.
3	COMP	I	Compensation. External capacitor-resistor combination sets the compensation net.
4	FB	I	Feedback Pin. External LED diode and current sensing resistor is connected in series with the LEDs to GND.
5	GND	G	Ground pin.
6	RT	I	Switching frequency program input. Connect a resistor from this pin to ground to set the switching frequency.
7	VIN	I	Power input voltage pin.
8	BOOT	I	The positive power supply for high-side MOSFET driver. Connect 0.1uF cap between BOOT and SW.
9	Thermal PAD	G	Major heat dissipation path of the die. Must be connected to ground plane on PCB.

Absolute Maximum Ratings

General test conditions: free-air, normal operation temperature range (unless otherwise noted).

Parameters		MIN	MAX	UNIT
Input Voltages	VIN, EN to GND	-0.3	44	V
	BOOT to GND	-0.3	49	
	FB, COMP, RT to GND	-0.3	6	
Output Voltages	BOOT to SW		6	V
	SW to GND	-1	44	
Operating junction temperature	T_J	-40	150	℃
Storage temperature range	T_{STG}	-55	150	
Lead Temperature, Soldering for 10 seconds			260	
Moisture sensitivity level	MSL	MSL3		
Electrostatic discharge (ESD)	Human body model (HBM)	2		kV

Note: Stresses at or beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. Exposure to absolute maximum rated conditions for extended periods may affect device reliability. All voltage values are based on the ground.

Recommended Operating Conditions

T_A=+25℃, unless otherwise noted.

Parameters		MIN	MAX	UNIT
Buck regulator	VIN	4.5	40	V
	BOOT		45	
	SW	-0.7	40	
	COMP	0	5	
Control	EN	0	40	V
	RT	0	5	
Temperature	T_J	-40	125	℃

Electrical Characteristics

T_A=+25℃, V_{IN}=12V, V_{EN}=V_{IN}, unless otherwise noted.

Symbol	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
VIN (INPUT POWER SUPPLY)						
V_{IN}	Operating input voltage		4.5		40	V
I_{SHDN}	Shutdown supply current			4	10	μA
V_{UVLO}	Under-voltage lockout thresholds	Rising			4.4	V
		Hysteresis		0.3		V
I_Q	Quiescent current	V_{FB}=300mV		130		μA
ENABLE (EN PIN)						
V_{EN}	EN Threshold Voltage	Rising			2.5	V
		Falling	0.8			
I_{EN}	EN PIN current	V_{EN}=0		1		μA
VOLTAGE REFERENCE (FB PIN)						
V_{FB}	Feedback voltage		188	200	212	V
Error Amp(EA)						
A_{EA}	Voltage Gain			400		V/V
G_{EA}	Transconductance	I_{COMP}=±3μA		430		μA/V
I_{EA}	Source /Sink current	VFB=175mV/225mV		10		μA
HIGH-SIDE MOSFET						
R_{DSON_H}	On-resistance(1)	VIN=12V, BOOT - SW =5V		200		mΩ
I_{LIMIT}	Current limit threshold	VIN=12V, T=25℃, Open Loop		3.2		A
SWITCHING CHARACTERISTICS						
f_{SW}	Switching frequency	RT=197KΩ, 1% accuracy	400	500	600	kHz
t_{ON-MIN}	Minimum on time(1)	VIN=12V, BOOT - SW =5V, I_{LOAD} =1A		102		ns
THERMAL PERFORMANCE						
$T_{SHUTDOWN}$	Thermal shutdown threshold(1)	Rising		150		℃
T_{HYS}	Hysteresis(1)			20		℃

Note(1): Guaranteed by design.

Thermal Information

PARAMETER(1)		VALUE	UNIT
Junction to ambient thermal resistance	$θ_{JA}$	50	℃/W
Junction to top characterization parameter	$Ψ_{JT}$	10	℃/W

Note(1): All numbers apply for packages soldered directly onto a 7.62cm x 7.62cm PC board with 4 layers in still air.

T_A=+25℃, V_{IN}=24V, L=47μH, f_{sw}=645kHz, I_{LED}=300mA, 5 WLED series, unless otherwise noted.

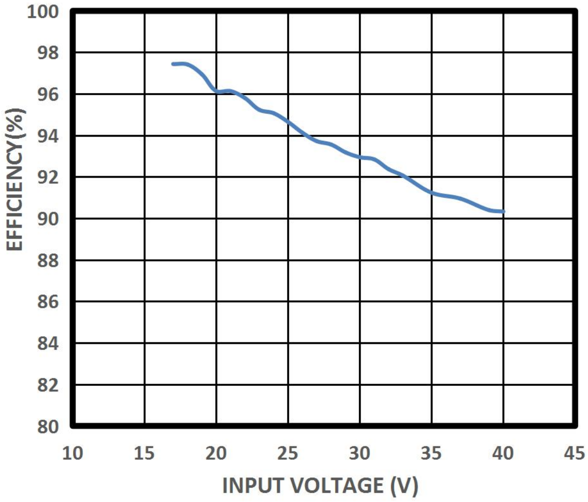


Figure 1. Efficiency VS. Input Voltage

(5 WLED@300mA)

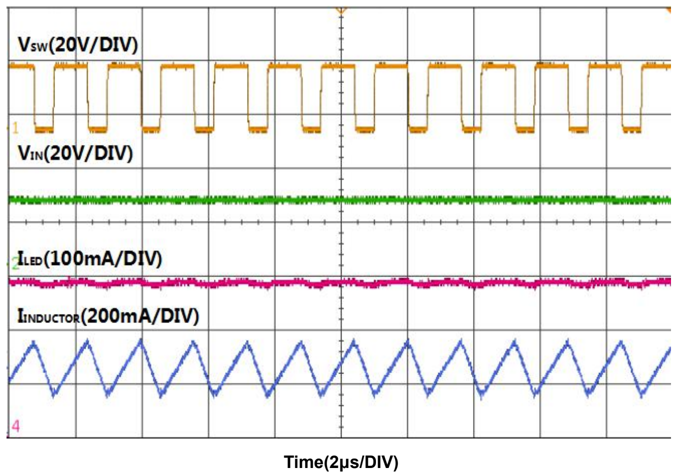


Figure 2. Steady State Operation

(V_{IN}=24V，5 WLED)

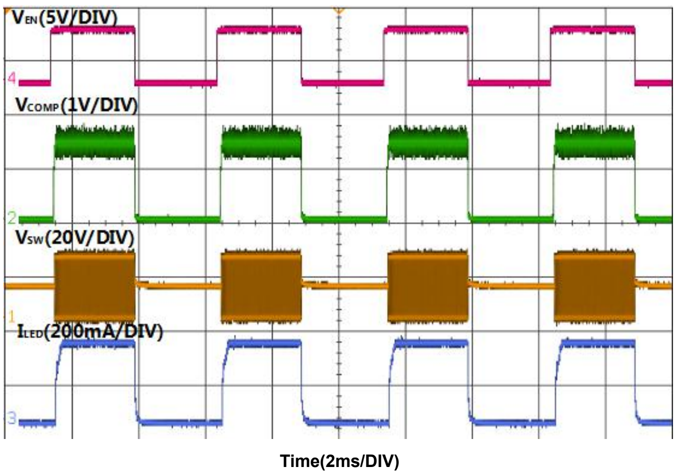


Figure 3. PWM Dimming

(V_{IN}=24V，f_{PWM} =200Hz，D_{PWM} =50%，5WLED)

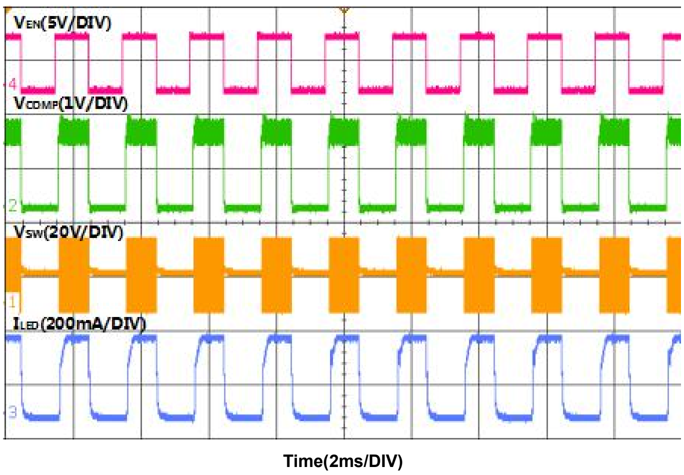


Figure 4. PWM Dimming

(V_{IN}=24V，f_{PWM} =500Hz，D_{PWM} =50%，5WLED)

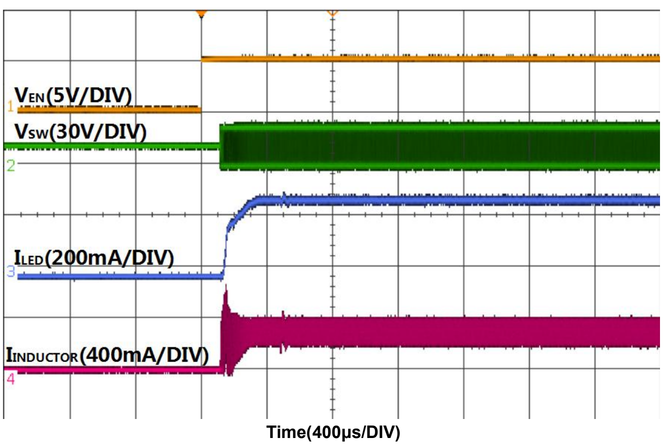


Figure 5. EN Start Up

(V_{IN}=24V，5 WLED)

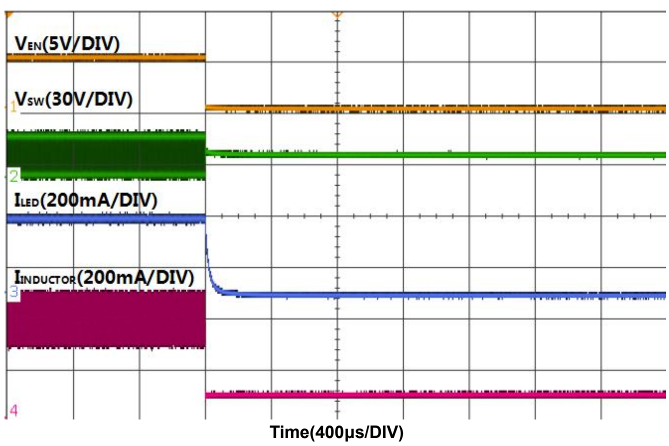


Figure 6. EN Shutdown

(V_{IN}=24V，5 WLED)

The SCM1331A is a 40V step-down (buck) regulator to deliver a constant current of up to 2A to LEDs, and integrates a 200mΩ(typical) high-side MOSFET. The buck regulator has a very low quiescent current during the light load with 4μA when EN shut down.

The SCM1331A adopts fixed frequency and current mode control. It is greatly increasing the application flexibility with external compensation adjustment. The SCM1331A has an integrated 5V regulator to provide the power for bootstrap capacitor, with bootstrap voltage under voltage detection function. When under voltage is detected, the high-side MOSFET is turned off using an UVLO circuit which allows the freewheeling diode to conduct and refresh the charge on the BOOT capacitor. The SCM1331A can operate at high duty cycle with the bootstrap refresh function. The switching frequency is programmable from 200kHz to 1500kHz by an external resistor.

Protection features include under-voltage lockout, peak current limit, short circuit protection and over-temperature shutdown.

PWM Mode

The SCM1331A implements peak current mode control. The output voltage is compared through external resistors on the FB pin to an internal voltage reference by an error amplifier which drives the internal COMP node. An internal oscillator initiates the turn on of the high side MOSFET, and the inductor current increases linearly. The SCM1331A senses the peak current, and high side MOSFET is turned off when the peak current reaches the threshold, which allows the freewheeling diode to conduct, and the current through the inductor falls linearly to zero or the value when next cycle restarts.

Light Load Mode

The SCM1331A operates in Skip mode at light load current. The Skip is an adaptive Light load mode. In Skip mode operation, the system controls the high side MOSFET operating condition by detecting COMP voltage, so as to reduce internal losses by increasing output voltage ripple.

EN and Internal Power Conversion

The internal power conversion circuit can be enabled when the EN pin is higher than 2.5V, then the high side MOSFET starts to switch. That will produce an output voltage and the device also be turned on. When EN is pulled down to 0 V, the device is turned off. In shutdown mode the supply current will be decreased to approximately 4μA. The enable pin implements with pull-up current source, so the device is enable if the EN pin is floating, and the maximum voltage to the EN pin should not exceed 40 V.

Bootstrap

The SCM1331A has an integrated boot regulator, and requires a small ceramic capacitor between the BOOT and SW pins to provide the gate drive voltage for the high side MOSFET. The boot capacitor is refreshed when the high side MOSFET is off and the freewheeling diode conducts. When the bootstrap voltage drops below threshold, the high-side MOSFET is turned off using an UVLO circuit.

Current Limit

The SCM1331A implements current mode control which uses the internal COMP voltage to turn off the high side MOSFET on a cycle by cycle basis. Each cycle the switch current and internal COMP voltage are compared, when the peak switch current intersects the COMP voltage, the high side MOSFET is turned off. During over-current conditions that pull the output voltage low, the error amplifier will respond by driving the COMP node high, increasing the switch current. The error amplifier output is clamped internally, and the switch current will be limited on a cycle by cycle basis.

External Compensation

The SCM1331A implements current mode control for easy compensation and fast transient response. The loop stability is controlled through the COMP pin. The COMP pin is the output of the internal error amplifier. External capacitor-resistor combination through the COMP pin sets the pole-zero points to control the loop stability. Determine the output resistance of error amplifier by the following equation:

$$R_{EA} = A_{VEA} / G_{EA}$$

Where A_{VEA} is the error amplifier voltage gain, 400V/V(typ); G_{EA} is the error amplifier transconductance, 430μA/V(typ).

Switching Frequency

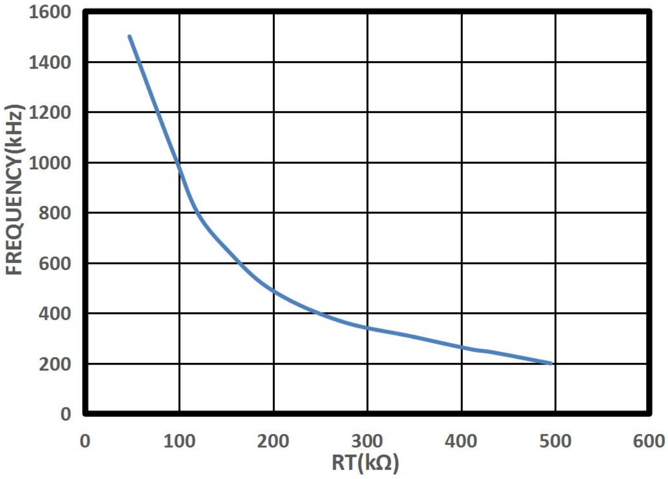
The switching frequency of the SCM1331A can be programmed by the resistor from the RT pin and GND pin. The switching frequency is 500 kHz if the RT pin is left floating. The RT pin can not be shorted to ground.

Thermal Shutdown

The device implements an internal thermal shutdown to protect itself if the junction temperature exceeds 150°C (typ). Once the junction temperature decreases below 130°C (typ), the device reinitiates the power up sequence.

Setting the Switching Frequency

The switching frequency of the SCM1331A can be programmed by the resistor from RT pin to GND pin.The corresponding relationship between R_T resistance and switching frequency is shown in the following curve.



The typical relationship between R_T resistance and switching frequency is shown in the following table.

R_T (kΩ)	f_{SW} (kHz)
495	200
270	370
197	500
150	645
98	1000
47	1500

Setting the LED Current

The LED current is set using a sensing resistor, (RFB) as on the application schematic. which is in series with the LEDs and connected to GND.

$$I_{LED} = \frac{V_{FB}}{R_{FB}}$$

For example, for a 700mA LED current, RFB is 286mΩ.

Inductor Selection

The output inductor will produce a steady current when the high-side MOSFET is turned off. Lower ripple current and output voltage ripple will require a larger value of inductance, but the larger value of inductance means larger size, larger ESR, lower saturation current. A reasonable value is setting the ripple current to be 30% of the maximum DC output current, this will enable the SCM1331A to current limit without saturating the inductor. The value of inductance can be calculated using below equation:

$$L1 = \frac{V_{OUT}}{f_S \times \Delta I_L} \times (1 - \frac{V_{OUT}}{V_{IN}})$$

V_{OUT} is the output voltage, V_{IN} is the input voltage，f is the switching frequency, ΔI_L is the peak-to-peak inductor ripple current.

Input Capacitor Selection

The input current of buck regulator is discontinuous, so the input capacitor is needed to stabilize the input voltage. A low ESR capacitor，for example, ceramic capacitor, tantalum capacitor or low ESR electrolytic capacitor, is needed to prevent the noises and interferences appearing at the input. One 10μF input capacitor with X7R or X5R dielectric is needed at least. Using the larger capacitance to accomplish the better filtering result is reasonable. The input capacitor must be placed close to the VIN pin in order to achieve the best performance when users design a PCB.

Output Capacitor Selection

The output capacitor will determine the DC output voltage and the loop stability. A low ESR capacitor will meet the better output voltage ripple. One 4.7μF output capacitor and low ESR ceramic capacitors are recommended. Using the larger the capacitance to accomplish the better output voltage ripple and transient load response is reasonable.The output voltage ripple can be estimated by:

$$\Delta V_{OUT} = \frac{V_{OUT}}{8 \times f_S{}^2 \times L1 \times C_{OUT}} \times (1 - \frac{V_{OUT}}{V_{IN}})$$

Compensation Components

The SCM1331A implements current mode control for easy compensation and fast transient response. The loop stability is controlled through the COMP pin. The COMP pin is the output of the internal error amplifier. External capacitor-resistor combination through the COMP pin sets the pole-zero points to control the loop stability. The DC gain of the current feedback loop by the following equation:

$$A_{VDC} = R_{FB} \times G_{CS} \times A_{VEA}$$

Where A_{VEA} is the error amplifier voltage gain, 400V/V(typ); G_{CS} is the current sense transconductance, 6.8A/V(typ), R_{FB} is current sensing resistor value.

The system has two poles of importance. One is due to the compensation capacitor and the output resistor of error amplifier. The other is due to the output capacitor and the LEDs' AC resistor. These poles are located at:

$$f_{P1} = \frac{1}{2\pi \times C_{C1} \times R_{EA}}$$

$$f_{P2} = \frac{1}{2\pi \times C_{OUT} \times R_{LED}}$$

Where C_{C1} is the compensation capacitor of COMP pin, R_{EA} is the output resistance of error amplifier, $R_{LED} = \Delta V_{OUT} / \Delta I_{LED}$ is the LEDs' AC resistor.

The system has one zero of importance, due to the compensation capacitor C_{C1} and the compensation resistor R_C. This zero is located at:

$$f_{Z1} = \frac{1}{2\pi \times C_{C1} \times R_C}$$

The system may have another zero of importance, due to the ESR and capacitance of the output capacitor, This zero is located at:

$$f_{ESR} = \frac{1}{2\pi \times C_{OUT} \times R_{ESR}}$$

In this case, a third pole set by the compensation capacitor C_{C2} and the compensation resistor is used to compensate the effect of the ESR zero on the loop gain. This pole is located

$$f_{P3} = \frac{1}{2\pi \times C_{C2} \times R_C}$$

The goal of compensation design is to shape the converter transfer function to get a desired loop gain and phase margin. The system crossover frequency where the feedback loop has the unity gain is important. Lower crossover frequencies result in slower line and load transient responses, while higher crossover frequencies could cause system unstable. A good rule of thumb is to set the crossover frequency to approximately one-tenth of the switching frequency. To optimize the compensation components for conditions, the following procedure can be used.

1. Choose the compensation resistor to set the desired crossover frequency. Determine the R_C value by the following equation:

$$R_C = \frac{2\pi \times C_{OUT} \times R_{LED} \times f_C}{R_{FB} \times G_{EA} \times G_{CS}}$$

Where f_C is the desired crossover frequency.

2. Choose the compensation capacitor to achieve the desired phase margin. For applications with typical inductor values, setting the compensation zero, f_{Z1}, below one forth of the crossover frequency provides sufficient phase margin. Determine the C_{C1} value by the following equation:

$$C_{C1} > \frac{4}{2\pi \times R_C \times f_C}$$

3. A third pole set by the compensation capacitor C_{C2} is used to compensate the effect of the ESR zero on the loop gain.It is required if the ESR zero of the output capacitor is located at less than half of the switching frequency:

$$\frac{1}{2\pi \times C_{OUT} \times R_{ESR}} < \frac{f_S}{2}$$

Determine the C_{C2} value by the equation:

$$C_{C2} = \frac{C_{OUT} \times R_{ESR}}{R_C}$$

The Schottky Diode Selection

The diode works as a freewheeling diode and supplies the current to the inductor when the high side MOSFET is turned off. To reduce losses due to the diode forward voltage, use a Schottky diode. Choose a diode whose maximum reverse voltage rating is greater than the maximum input voltage (transient overshoot voltage), and whose current rating is greater than the maximum load current.

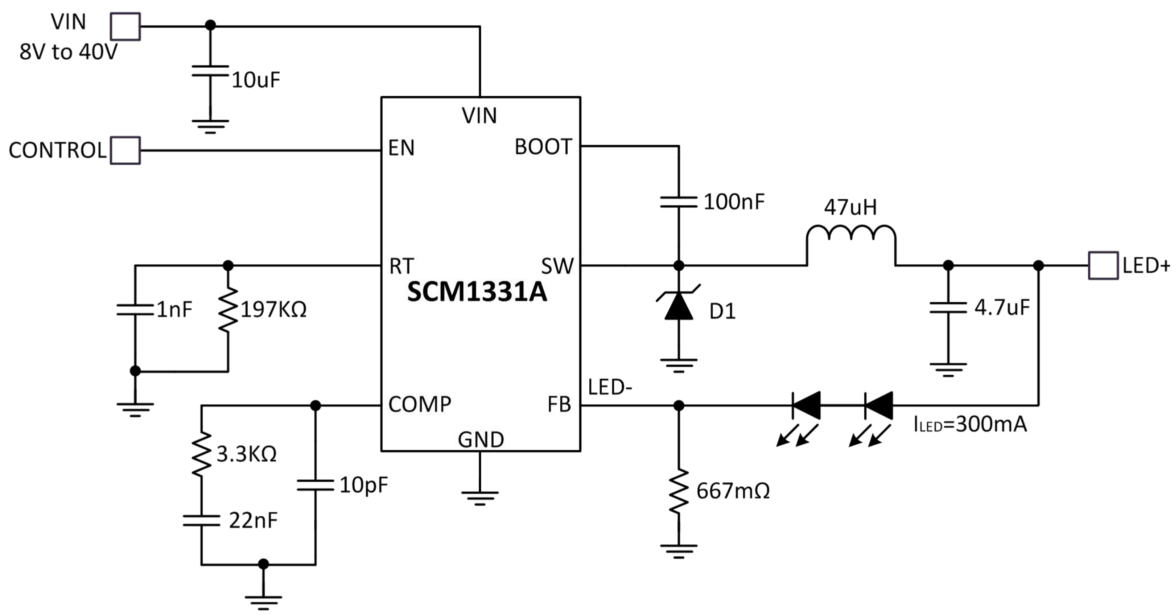
Thermal Shutdown

In order to avoid the device overheating shutdown, it is necessary to carry out thermal analysis according to different application. In principle, the maximum internal power consumption should not exceed junction temperature threshold.

$$P_{L(MAX)} = (T_{J(MAX)} - T_A) / \theta_{JA}$$

$T_{J(MAX)}$ is the maximum junction temperature, T_A is the ambient temperature, θ_{JA} is the junction to ambient thermal resistance.

Application Circuit



Ordering Information

Part number	Package	Number of pins	Product Marking	Tape & Reel
SCM1331ASA	eSOP-8	8	SCM1331ASA YM	4k/Reel

Product marking and data code:

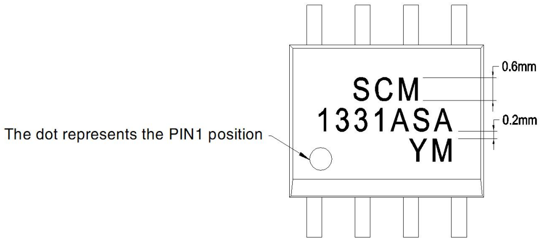
(1) SCM1331, Product designation.

(1) A, Version code information.

(3) S, Packaging definition code; S: eSOP-8 package.

(4) A, Operating temperature range; C: 0℃-70℃, I: -40℃-85℃, A: -40℃-125℃, M: -55℃-125℃.

(5) YM, Data code for product traceability.



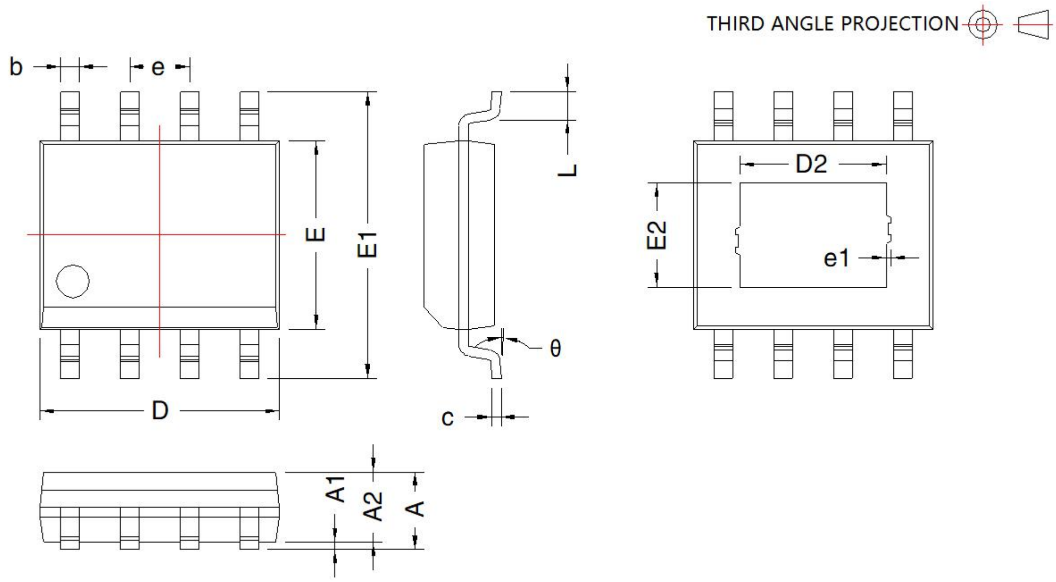
Note：

1、Typeface：Arial；

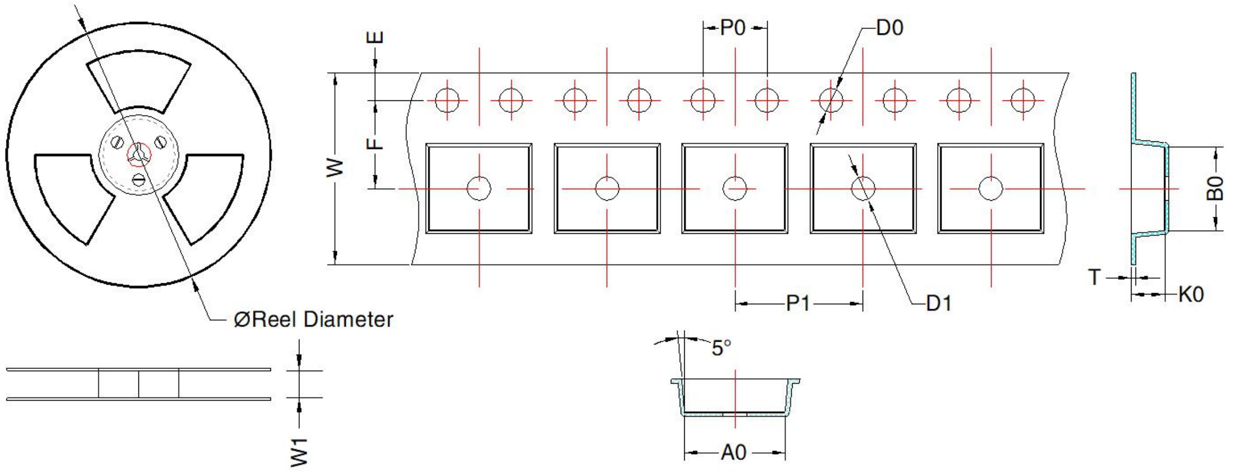
2、Character size：

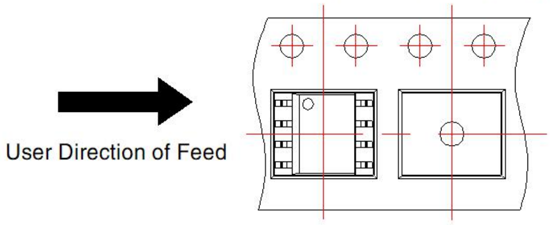
Height：0.6mm，Spacing：0.1mm，LineSpacing：0.2mm；

Package Information



ESOP-8				
Mark	Dimension(mm)		Dimension(inch)	
	Min	Max	Min	Max
A	—	1.65	—	0.065
A1	0.05	0.15	0.002	0.006
A2	1.30	1.50	0.051	0.059
D	4.80	5.00	0.189	0.197
E	3.80	4.00	0.150	0.157
E1	5.80	6.20	0.228	0.244
L	0.50	0.80	0.020	0.031
b	0.39	0.47	0.015	0.019
e	1.27TYP		0.05TYP	
c	0.20	0.24	0.008	0.009
θ	0°	8°	0°	8°
D2	2.09		0.082	
E2	2.09		0.082	
e1	0.16		0.006	





Device	Package Type	MPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	T (mm)	W (mm)	E (mm)	F (mm)	P1 (mm)	P0 (mm)	D0 (mm)	D1 (mm)
SCM1331ASA	ESOP-8	4000	330.0	12.4	6.5 ± 0.2	5.45 ± 0.2	2.0 ± 0.2	0.3 ± 0.05	12.0 ± 0.3	1.75 ± 0.1	5.5 ± 0.1	8.0 ± 0.1	4.0 ± 0.1	1.5 ± 0.1	1.5 ± 0.1

Note:The minimum order quantity is the minimum package quantity , the order quantity should be an integer multiple of MPQ .

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