

## 5V, 3A, 1.5MHz Buck Constant Current Switching Regulator for White LED



### General Description

The FP8013 is a PWM control buck converter designed to provide a simple, high efficiency solution for driving high power LEDs. With a 0.1V reference voltage feedback control to minimize power dissipation, an external resistor sets the current as needed for driving various types of LEDs. The FP8013 includes both high low side switch to realize high efficiency and compact PCB layout. To extend battery life for portable application, 100% duty cycle is supported for low-dropout operation. Other features include thermal shutdown, cycle-by cycle current limit and over current protection

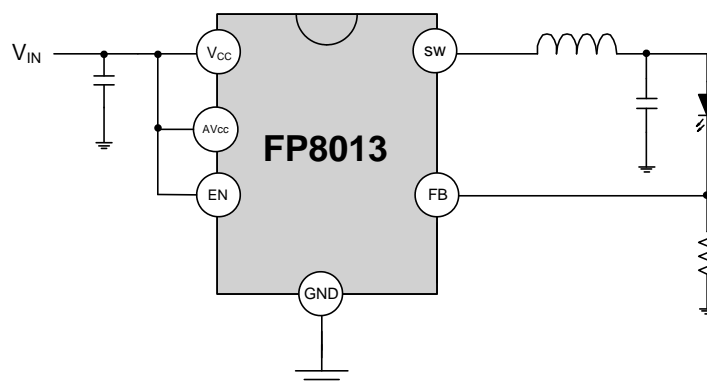
### Features

- Input Voltage Range: 2.5 to 5.5V
- Adjustable Output Voltage From 0.1V to  $V_{IN}$
- Precision Feedback Reference Voltage: 0.1V ( $\pm 10\%$ )
- Output Current: 3A (Max.)
- Duty Cycle: 0~100%
- Internal Fixed PWM Frequency: 1.5MHz
- Low Quiescent Current: 100 $\mu$ A
- No Schottky Diode Required
- Built-in Soft Start
- Current Mode Operation
- Over Temperature Protection
- Package: SOP-8L (EP)

### Applications

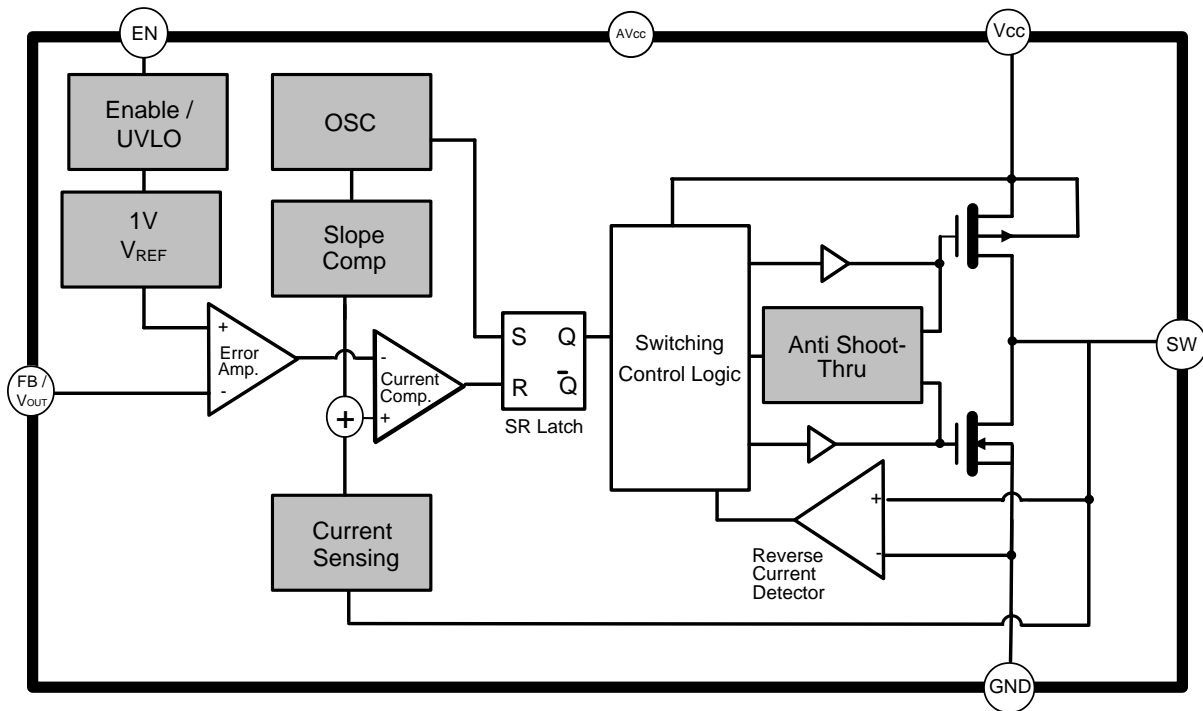
- LED Drivers

### Typical Application Circuit



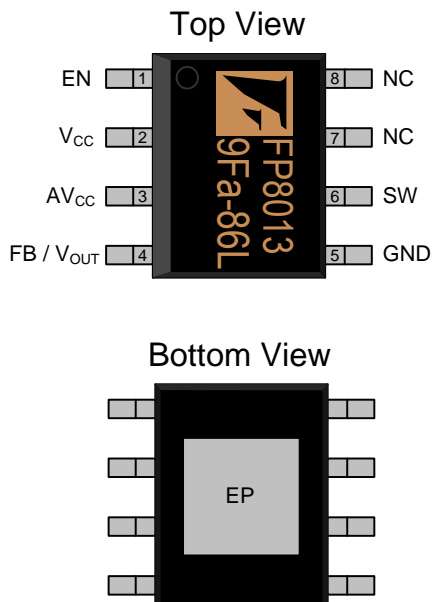
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## Function Block Diagram



## Pin Descriptions

### SOP-8L (EP)

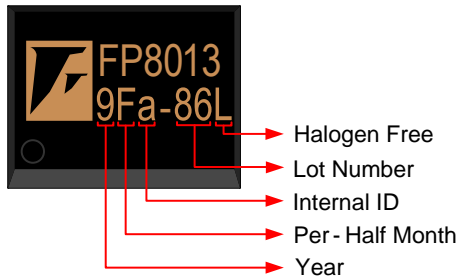


Name	No.	I / O	Description
EN	1	I	Enable / UVLO
V <sub>CC</sub>	2	P	Supply Voltage
AV <sub>CC</sub>	3	P	Analog Supply Voltage
FB / V <sub>OUT</sub>	4	I	Feedback
GND	5	P	Ground
SW	6	O	Switch
NC	7	NA	Not connected
NC	8	NA	Not connected
EP	9	P	Exposed PAD - Must connect to Ground

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## Marking Information

### SOP-8L (EP)



**Halogen Free:** Halogen free product indicator

**Lot Number:** Wafer lot number's last two digits

For Example: 132386TB → 86

**Internal ID:** Internal Identification Code

**Per-Half Month:** Production period indicated in half month time unit

For Example: January → A (Front Half Month), B (Last Half Month)

February → C (Front Half Month), D (Last Half Month)

**Year:** Production year's last digit

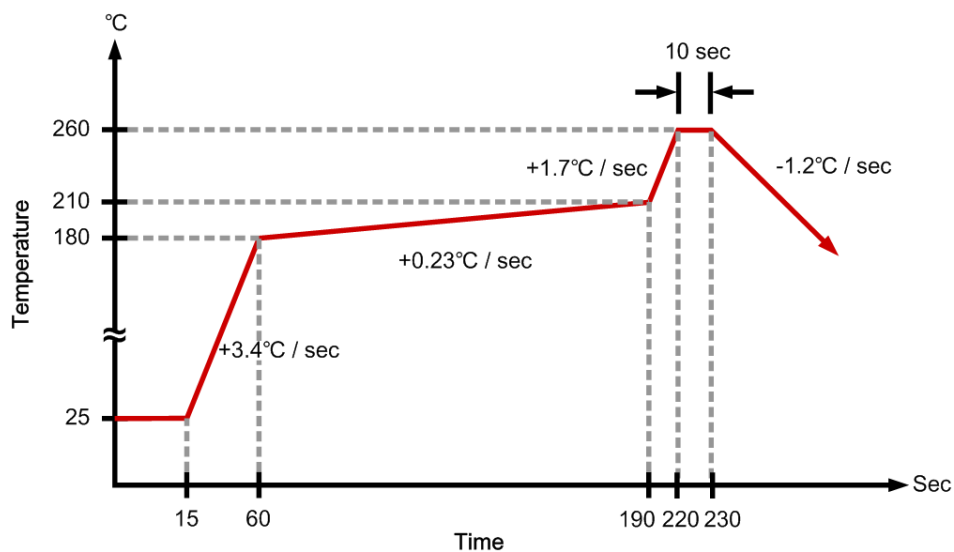
## Ordering Information

Part Number	Operating Temperature	Package	MOQ	Description
FP8013XR-G1	-40°C ~ +85°C	SOP-8L (EP)	2500EA	Tape & Reel

## Absolute Maximum Ratings

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Input Supply Voltage	$V_{IN}$		-0.3		6	V
EN, $V_{FB}$ , SW Voltage			-0.3		$V_{IN}$	V
P-Channel Switch Source Current (DC)					3.9	A
N-Channel Switch Source Current (DC)					3.9	A
Peak SW Switch Sink and Source Current (AC)					6	A
Thermal Resistance (Junction to Ambient)	$\theta_{JA}$	SOP-8L(EP)			+50	°C / W
Thermal Resistance (Junction to Case)	$\theta_{JC}$	SOP-8L(EP)			+10	°C / W
Junction Temperature					+150	°C
Storage Temperature			-65		+150	°C
Lead Temperature (soldering, 10 sec)					+260	°C

## Suggested IR Re-flow Soldering Curve



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## Recommended Operating Conditions

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Supply Voltage	$V_{IN}$		2.5		5.5	V
Operating Temperature			-40		+85	°C

## DC Electrical Characteristics ( $V_{IN}=3.6V$ , $T_A=25^\circ C$ , unless otherwise noted)

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Regulated Feedback Voltage	$V_{FB}$	$T_A=25^\circ C$	0.09	0.1	0.11	V
		$-40^\circ C \sim +85^\circ C$	0.085	0.1	0.115	V
Line Regulation with $V_{REF}$	$\Delta V_{FB}$	$V_{IN}=2.5V$ to $5.5V$		0.04	0.4	% / V
Output Voltage Line Regulation	$\Delta V_{OUT}$	$V_{IN}=2.5$ to $5.5V$		0.04	0.4	% / V
RDS (ON) of P-Channel FET	$R_{DS(ON) P}$	$I_{SW}=100mA$		60	90	mΩ
RDS (ON) of N-Channel FET	$R_{DS(ON) N}$	$I_{SW}=-100mA$		60	90	mΩ
SW Leakage	$I_{LSW}$	$V_{EN}=0V$ , $V_{IN}=5V$		$\pm 0.01$	$\pm 1$	μA
Peak Inductor Current	$I_{PK}$	$V_{FB}=0.08V$	3.75	5	6	A
Input Voltage Range	$V_{IN}$	$-40^\circ C \sim +85^\circ C$	2.5		5.5	V
Quiescent Current	$I_{CC}$	Shutdown, $V_{EN}=0V$		0.1	1	μA
		Active, $V_{FB}=0.08V$ , $V_{EN}=V_{IN}$		100		μA
		Active, $V_{FB}=0.12V$ , $V_{EN}=V_{IN}$		80		μA
EN Threshold	$V_{EN}$	$-40^\circ C \sim +85^\circ C$	0.3	1	1.5	V
EN Leakage Current	$I_{EN}$	$-40^\circ C \sim +85^\circ C$		$\pm 0.01$	$\pm 1$	μA
Oscillator Frequency	$F_{OSC}$	$V_{FB}=0.1V$ , $-40^\circ C \sim +85^\circ C$	1.2	1.5	1.8	MHz

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## Function Description

### Control Loop

The FP8013 is a high efficiency current mode synchronous buck regulator. Both the main (P-channel MOSFET) and synchronous (N-channel MOSFET) switches are built internally. With current mode operation, the PWM duty is controlled both by the error amplifier output and the peak inductor current. At the beginning of each cycle, the oscillator turn on the P-MOSFET switch to source current from  $V_{IN}$  to SW output. Then, the chip starts to compare the inductor current with the error amplifier output. Once the inductor current is larger than the error amplifier output, the P-MOSFET switch is turned off. When the load current increases, the feedback voltage FB will slightly drop. This causes the error amplifier to output a higher current level until the prior mentioned peak inductor current reach the same level. The output voltage then can be sustained at the same.

When the top P-MOSFET switch is off, the bottom synchronous N-MOSFET switch is turned on. Once the inductor current reverses, both top and bottom MOSFET will be turn off to leave the SW pin into high impedance state.

The FP8013's current mode control loop also includes slope compensation to suppress sub-harmonic oscillations at high duty cycles. This slope compensation is achieved by adding a compensation ramp to the inductor current signal.

### LDO Mode

The FP8013's maximum duty cycle can reach 100%. That means the driver's main switch is turn on through out whole clock cycle. Once the duty reaches 100%, the feedback path no longer controls the output voltage. The output voltage will be the input voltage minus the main switch voltage drop.

### Over Current Protection

FP8013 limits the peak main switch current cycle by cycle. When over current occurs, chip will turn off the main switch and turn the synchronous switch on until next cycle.

### Thermal Protection

FP8013 will shutdown automatically when the internal junction temperature reaches 150°C to protect both the part and the system.

## Application Information

### Input capacitor Selection

The input capacitor must be connected to the VIN pin and GND pin of FP8013 to maintain steady input voltage and filter out the pulsing input current. The voltage rating of input capacitor must be greater than maximum input voltage plus ripple voltage.

In switch mode, the input current is discontinuous in a buck converter. The source current waveform of the high-side MOSFET is a square wave. To prevent large voltage transients, a low ESR input capacitor sized for the maximum RMS current must be used. The RMS value of input capacitor current can be calculated by:

$$I_{\text{RMS}} = I_{\text{O\_MAX}} \sqrt{\frac{V_{\text{O}}}{V_{\text{IN}}} \left(1 - \frac{V_{\text{O}}}{V_{\text{IN}}}\right)}$$

It can be seen that when  $V_{\text{O}}$  is half of  $V_{\text{IN}}$ ,  $C_{\text{IN}}$  is under the worst current stress. The worst current stress on  $C_{\text{IN}}$  is  $I_{\text{O\_MAX}}/2$ .

### Inductor Selection

The value of the inductor is selected based on the desired ripple current. Large inductance gives low inductor ripple current and small inductance result in high ripple current. However, the larger value inductor has a larger physical size, higher series resistance, and/or lower saturation current. In experience, the value is to allow the peak-to-peak ripple current in the inductor to be 10%~20% maximum load current. The inductance value can be calculated by:

$$L = \frac{(V_{\text{IN}} - V_{\text{O}}) V_{\text{O}}}{f \times \Delta I_{\text{L}}} = \frac{(V_{\text{IN}} - V_{\text{O}}) V_{\text{O}}}{f \times [2 \times (10\% \sim 20\%) I_{\text{O}}]}$$

**The inductor ripple current can be calculated by:**

$$\Delta I_{\text{L}} = \frac{V_{\text{O}}}{f \times L} \times \left[1 - \frac{V_{\text{O}}}{V_{\text{IN}}}\right]$$

Choose an inductor that does not saturate under the worst-case load conditions, which is the load current plus half the peak-to-peak inductor ripple current, even at the highest operating temperature. The peak inductor current is:

$$I_{\text{L\_PEAK}} = I_{\text{O}} + \frac{\Delta I_{\text{L}}}{2}$$

The inductors in different shape and style are available from manufacturers. Shielded inductors are small and radiate less EMI issue. But they cost more than unshielded inductors. The choice depends on EMI requirement, price and size.

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Inductor Value (μH)	Dimensions (mm)	Component Supplier	Model
1.0	8.3×8.3×4.5	FENG-JUI	TPRH8D43-2R2M
1.0	10.3×10.3×4.0	FENG-JUI	TPRH10D40-2R2M
2.2	8.3×8.3×4.5	FENG-JUI	TPRH8D43-3R3M
2.2	10.3×10.3×4.0	FENG-JUI	TPRH10D40-3R3M

### Output Capacitor Selection

The output capacitor is required to maintain the DC output voltage. Low ESR capacitors are preferred to keep the output voltage ripple low. In a buck converter circuit, output ripple voltage is determined by inductor value, switching frequency, output capacitor value and ESR. The output ripple is determined by:

$$\Delta V_O = \Delta I_L \times \left( \text{ESR}_{\text{COUT}} + \frac{1}{8 \times f \times C_{\text{OUT}}} \right)$$

Where f = operating frequency, COUT= output capacitance and ΔIL = ripple current in the inductor. For a fixed output voltage, the output ripple is highest at maximum input voltage since ΔIL increases with input voltage.

Capacitor Value	Case Size	Component Supplier	Model
10μF	0805	Taiyo Yuden	JMK212BJ106MG
10μF	0805	TDK	C12012X5ROJ106K
22μF	0805 1206	TDK	C2012JB0J226M

### Using Ceramic Input and Output Capacitors

Care must be taken when ceramic capacitors are used at the input and the output. When a ceramic capacitor is used at the input and the power is supplied by a wall adapter through long wires, a load step at the output can induce ringing at the input, VIN. At best, this ringing can couple to the output and be mistaken as loop instability. At worst, a sudden inrush current through the long wires can potentially cause a voltage spike at VIN, which may large enough to damage the part. When choosing the input and output ceramic capacitors, choose the X5R or X7R specification. Their dielectrics have the best temperature and voltage characteristics of all the ceramics for a given value and size.

### Output Current Programming

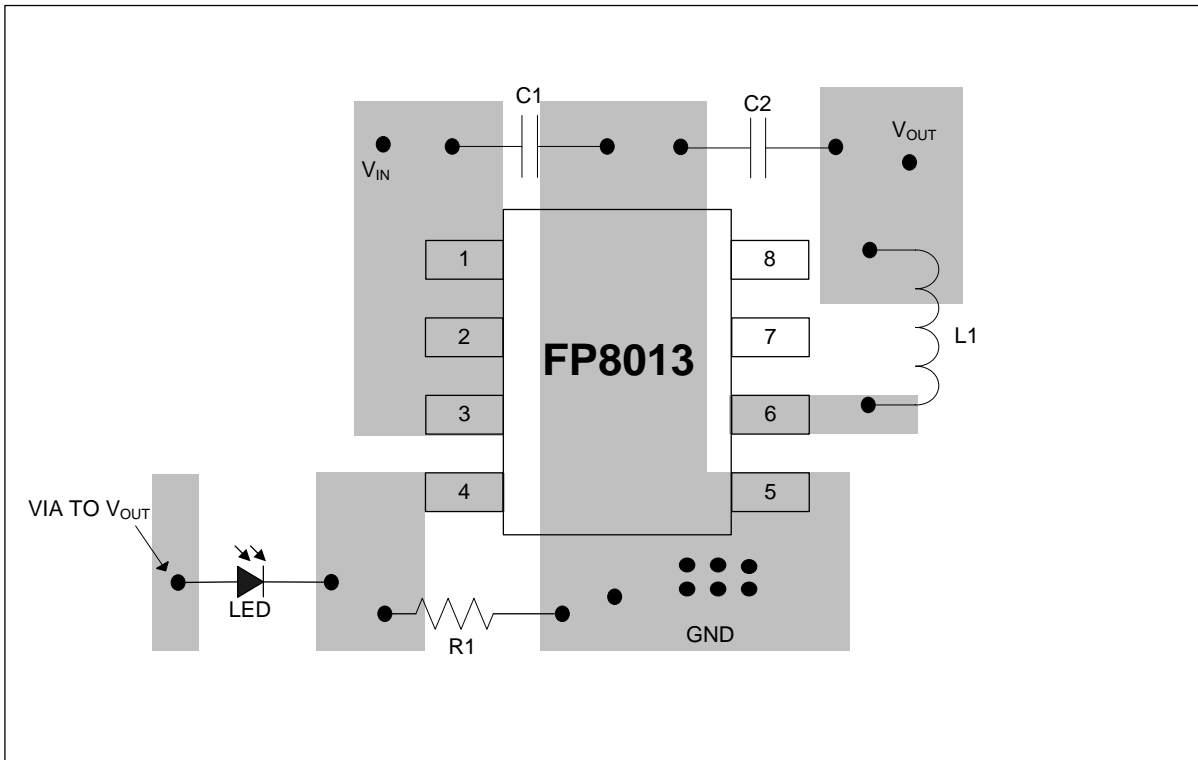
The output current is set by a resistor connected from FB pin to ground. The current is:

$$I_o = \frac{0.1V}{R_1}$$



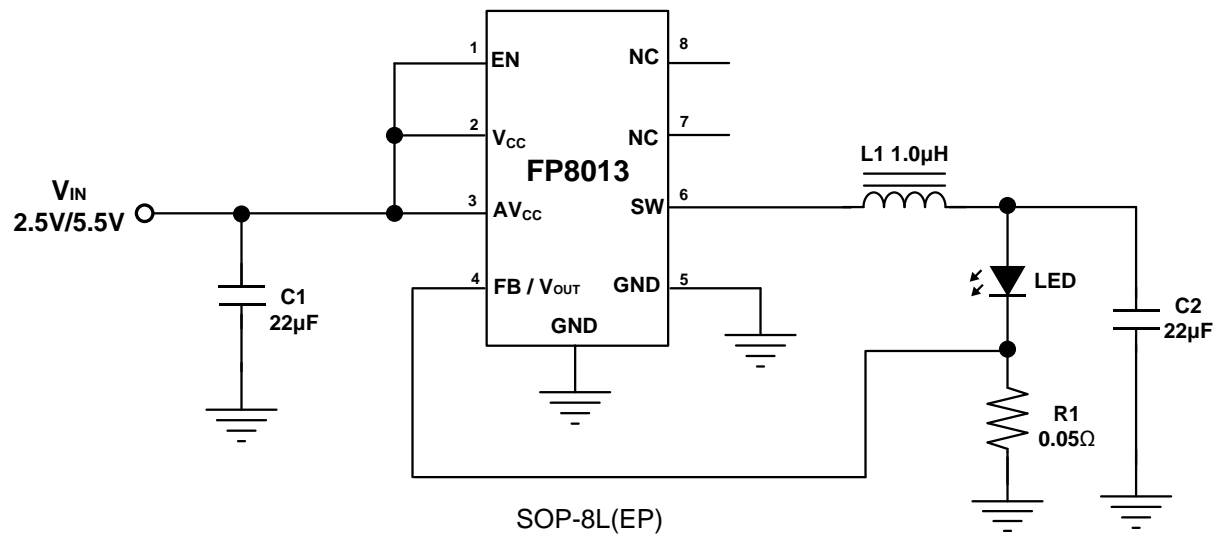
**PC Board Layout Checklist**

1. The power traces, consisting of the GND, SW and  $V_{IN}$  trace should be kept short, direct and wide.
2. Place  $C_{IN}$  near  $V_{IN}$  pin as closely as possible to maintain input voltage steady and filter out the pulsing input current.
3. The current setting resistor  $R_1$  must be connected to FB pin directly and as closely as possible.
4. FB is a sensitive node. Please keep it away from switching node, SW. A good approach is to route the feedback trace on another PCB layer and have a ground plane between the top and feedback trace routing layer. This reduces EMI radiation on to the DC-DC converter its own voltage feedback trace.
5. Keep the GND plates of  $C_{IN}$  and  $C_{OUT}$  as close as possible. Then connect this to the ground plane (if one is used) with several vias. This reduces ground plane noise by preventing the switching currents from circulating through the ground plane. It also reduces ground bounce at FP8013 by giving it a low impedance ground connection.



**Suggested Layout for SOP-8L(EP)**

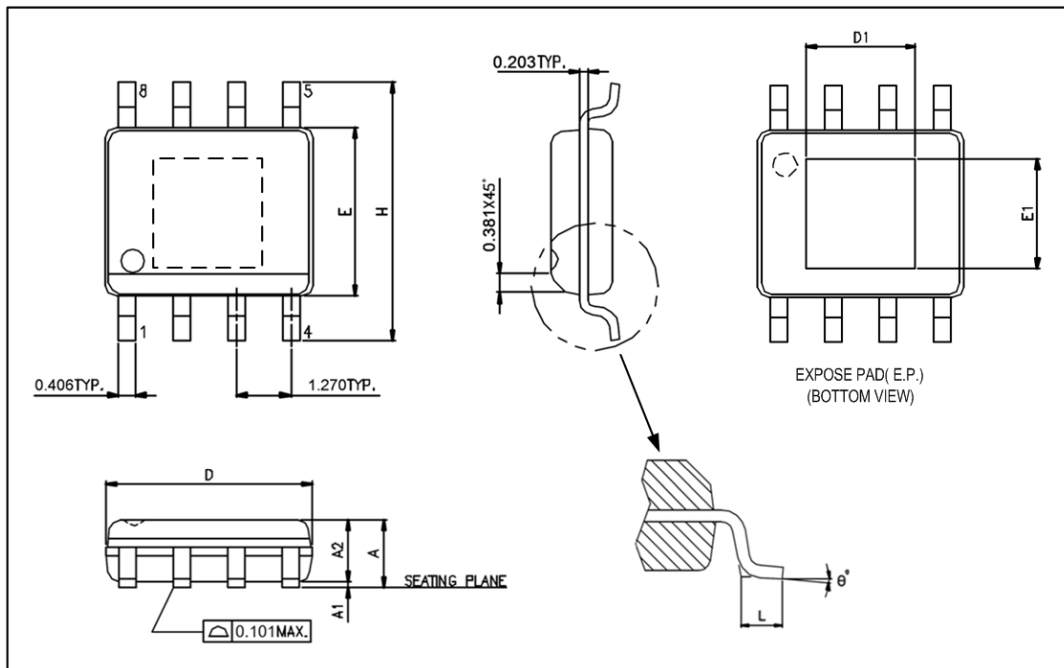
## Typical Application



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## Package Outline

### SOP-8L (EP)


**UNIT: mm**

Symbols	Min. (mm)	Max. (mm)
A	1.346	1.752
A1	0.050	0.152
A2		1.498
D	4.800	4.978
E	3.810	3.987
H	5.791	6.197
L	0.406	1.270
$\theta^\circ$	0°	8°

Exposed PAD Dimensions:

Symbols	Min. (mm)	Max. (mm)
E1		2.184 REF
D1		2.971 REF

**Note:**

1. Package dimensions are in compliance with JEDEC outline: MS-012 AA.
2. Dimension "D" does not include molding flash, protrusions or gate burrs.
3. Dimension "E" does not include inter-lead flash or protrusions

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