

### 3A, 23V, 340kHz Synchronous Step-Down Converter

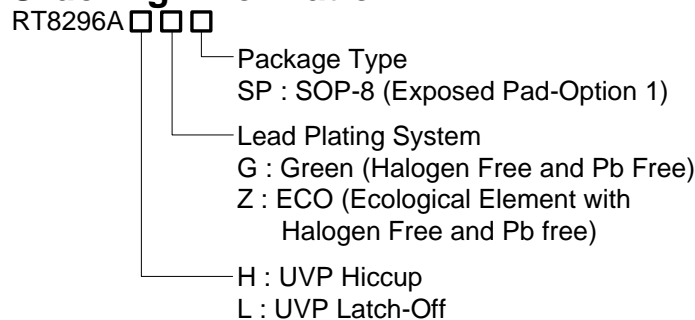
#### General Description

The RT8296A is a high efficiency, monolithic synchronous step-down DC-DC converter that can deliver up to 3A output current from a 4.5V to 23V input supply. The RT8296A's current mode architecture and external compensation allow the transient response to be optimized over a wide range of loads and output capacitors. Cycle-by-cycle current limit provides protection against shorted outputs and soft-start eliminates input current surge during start up. Fault conditions also include output under voltage protection and thermal shutdown. The low current (<3µA) shutdown mode provides output disconnect, enabling easy power management in battery powered systems. The RT8296A is available in a SOP-8 (Exposed Pad) package.

#### Features

- ±1.5% High Accuracy Feedback Voltage
- 4.5V to 23V Input Voltage Range
- 3A Output Current
- Integrated N-MOSFET Switches
- Current Mode Control
- Fixed Frequency Operation : 340kHz
- Output Adjustable from 0.8V to 20V
- Up to 95% Efficiency
- Programmable Soft-Start
- Stable with Low ESR Ceramic Output Capacitors
- Cycle-by-Cycle Over Current Protection
- Input Under Voltage Lockout
- Output Under Voltage Protection
- Thermal Shutdown Protection
- RoHS Compliant and Halogen Free

#### Ordering Information



Note :

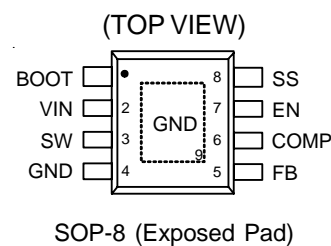
Richtek products are :

- ▶ RoHS compliant and compatible with the current requirements of IPC/JEDEC J-STD-020.
- ▶ Suitable for use in SnPb or Pb-free soldering processes.

#### Applications

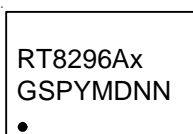
- Industrial and Commercial Low Power Systems
- Set Top Box
- LCD Monitors and TVs
- Green Electronics/Appliances
- Point of Load Regulation of High Performance DSPs
- Wireless AP/Router

#### Pin Configuration



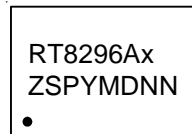
#### Marking Information

RT8296AxGSP



RT8296AxGSP : Product Number  
x : H or L  
YMDNN : Date Code

RT8296AxZSP



RT8296AxZSP : Product Number  
x : H or L  
YMDNN : Date Code

Typical Application Circuit

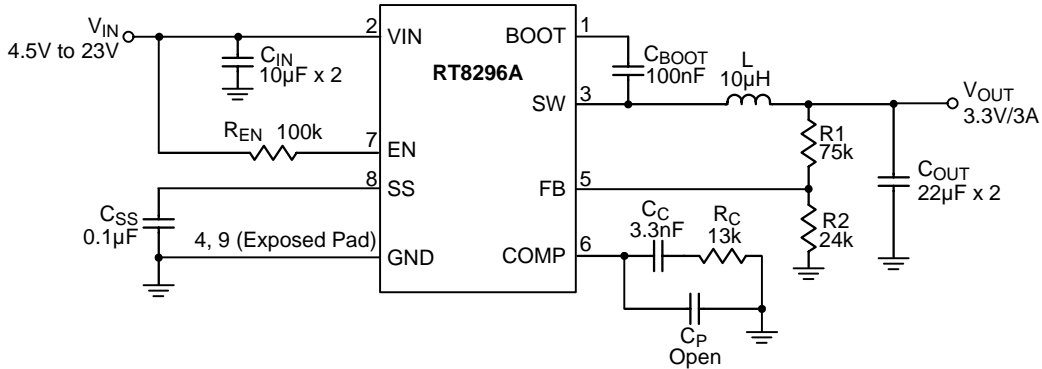


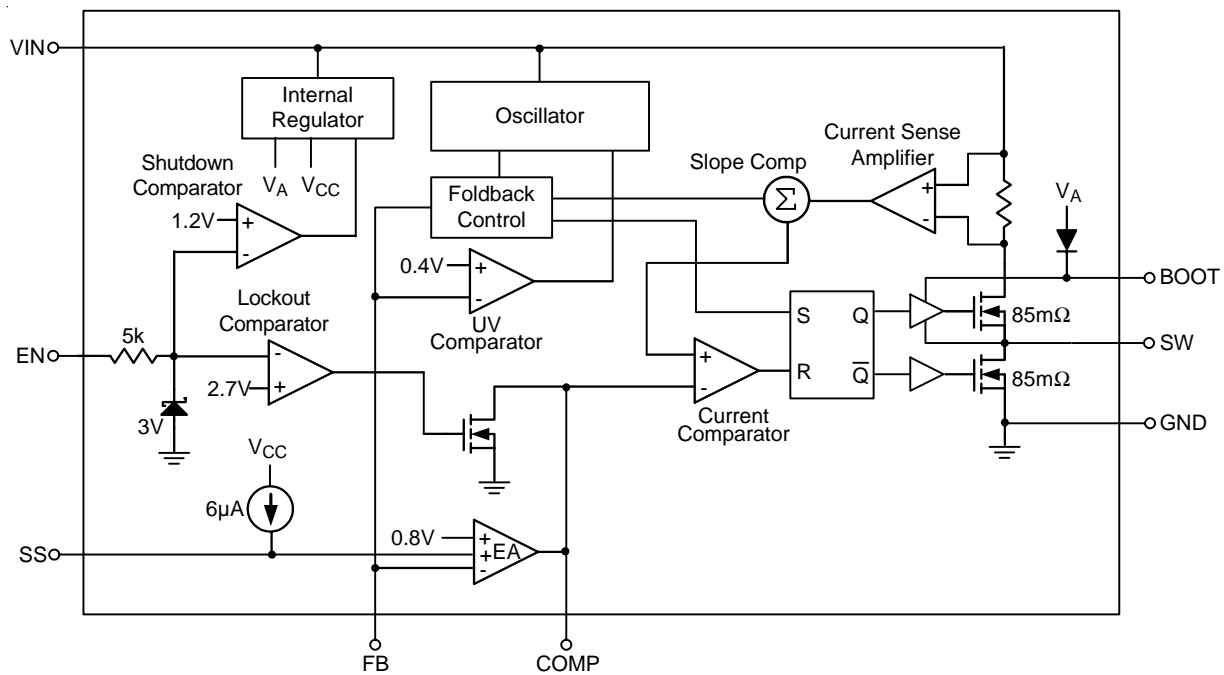
Table 1. Recommended Component Selection

V <sub>OUT</sub> (V)	R1 (kΩ)	R2 (kΩ)	R <sub>C</sub> (kΩ)	C <sub>C</sub> (nF)	L (µH)	C <sub>OUT</sub> (µF)
8	27	3	33	3.3	22	22 x 2
5	62	11.8	20	3.3	15	22 x 2
3.3	75	24	13	3.3	10	22 x 2
2.5	25.5	12	9.1	3.3	6.8	22 x 2
1.5	10.5	12	5.6	3.3	3.6	22 x 2
1.2	12	24	4.3	3.3	3.6	22 x 2
1	3	12	3.6	3.3	2	22 x 2

Functional Pin Description

Pin No.	Pin Name	Pin Function
1	BOOT	Bootstrap for high-side gate driver. Connect 0.1µF or greater ceramic capacitor from BOOT to SW pins.
2	VIN	Input supply voltage. Must bypass with a suitably large ceramic capacitor.
3	SW	Phase node. Connect to external L-C filter.
4, 9 (Exposed Pad)	GND	Ground. The exposed pad must be soldered to a large PCB and connected to GND for maximum power dissipation.
5	FB	Feedback input pin. This pin is connected to the converter output. It is used to set the output of the converter to regulate to the desired value via an internal resistive divider. For an adjustable output, an external resistive divider is connected to this pin.
6	COMP	Compensation node. COMP is used to compensate the regulation control loop. Connect a series RC network from COMP to GND. In some cases, an additional capacitor from COMP to GND is required.
7	EN	Enable input pin. A logic high enables the converter; a logic low forces the RT8296A into shutdown mode reducing the supply current to less than 3µA. Attach this pin to VIN with a 100kΩ pull up resistor for automatic startup.
8	SS	Soft-start control input. SS controls the soft-start period. Connect a capacitor from SS to GND to set the soft-start period. A 0.1µF capacitor sets the soft-start period to 13.5ms.

**Functional Block Diagram**



## Absolute Maximum Ratings (Note 1)

- Supply Input Voltage,  $V_{IN}$  ----- -0.3V to 25V
- Switch Node Voltage,  $V_{SW}$  ----- -0.3V to ( $V_{IN} + 0.3V$ )
- Switch Node Voltage,  $V_{SW}, < 50ns$  ----- -5V to 25.3V
- BOOT Pin Voltage,  $V_{BOOT}$  ----- -0.3V to 31.3V
- $V_{BOOT} - V_{SW}$  ----- -0.3V to 6V
- Other Pins Input Voltage ----- -0.3V to 6V
- Power Dissipation,  $P_D @ T_A = 25^\circ C$   
 SOP-8 (Exposed Pad) ----- 1.333W
- Package Thermal Resistance (Note 2)  
 SOP-8 (Exposed Pad),  $\theta_{JA}$  -----  $75^\circ C/W$   
 SOP-8 (Exposed Pad),  $\theta_{JC}$  -----  $15^\circ C/W$
- Lead Temperature (Soldering, 10 sec.) -----  $260^\circ C$
- Junction Temperature -----  $150^\circ C$
- Storage Temperature Range -----  $-65^\circ C$  to  $150^\circ C$
- ESD Susceptibility (Note 3)  
 HBM (Human Body Model) ----- 2kV

## Recommended Operating Conditions (Note 4)

- Supply Voltage,  $V_{IN}$  ----- 4.5V to 23V
- Junction Temperature Range -----  $-40^\circ C$  to  $125^\circ C$
- Ambient Temperature Range -----  $-40^\circ C$  to  $85^\circ C$

## Electrical Characteristics

( $V_{IN} = 12V, T_A = 25^\circ C$ , unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Shutdown Supply Current		$V_{EN} = 0V$	--	0.5	3	$\mu A$
Supply Current		$V_{EN} = 3V, V_{FB} = 0.9V$	--	0.8	1.2	mA
Feedback Reference Voltage	$V_{FB}$	$4.5V \leq V_{IN} \leq 23V$	0.788	0.8	0.812	V
Error Amplifier Transconductance	$G_{EA}$	$\Delta I_C = \pm 10\mu A$	--	940	--	$\mu A/V$
High Side Switch On Resistance	$R_{DS(ON)1}$		--	85	--	m $\Omega$
Low Side Switch On Resistance	$R_{DS(ON)2}$		--	85	--	m $\Omega$
High Side Switch Leakage Current		$V_{EN} = 0V, V_{SW} = 0V$	--	0	10	$\mu A$
Upper Switch Current Limit		Min. Duty Cycle, $V_{BOOT} - V_{SW} = 4.8V$	3.8	5.1	6.4	A
COMP to Current Sense Transconductance	$G_{CS}$		--	5.4	--	A/V
Oscillation Frequency	$f_{OSC1}$		300	340	380	kHz

Parameter		Symbol	Test Conditions	Min	Typ	Max	Unit
Short Circuit Oscillation Frequency		$f_{OSC2}$	$V_{FB} = 0V$	--	100	--	kHz
Maximum Duty Cycle		$D_{MAX}$	$V_{FB} = 0.7V$	--	93	--	%
Minimum On Time		$t_{ON}$		--	100	--	ns
Input Under Voltage Lockout Threshold			$V_{IN}$ Rising	3.8	4.2	4.5	V
Input Under Voltage Lockout Threshold Hysteresis				--	320	--	mV
EN Input Voltage	Logic-High	$V_{IH}$		2.7	--	5.5	V
	Logic-Low	$V_{IL}$		--	--	0.4	
Soft-Start Current		$I_{SS}$	$V_{SS} = 0V$	--	6	--	$\mu A$
Soft-Start Period		$t_{SS}$	$C_{SS} = 0.1\mu F$	--	13.5	--	ms
Thermal Shutdown		$T_{SD}$		--	150	--	$^{\circ}C$

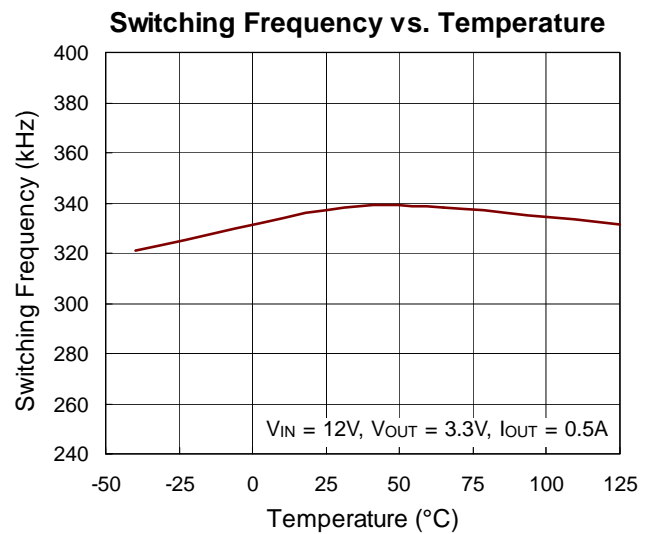
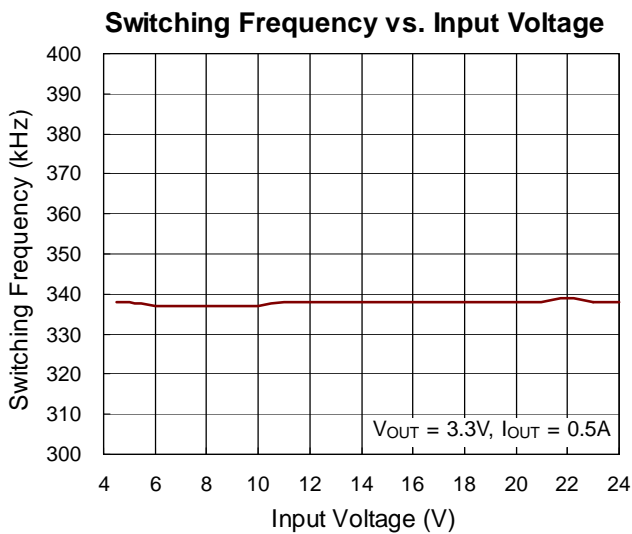
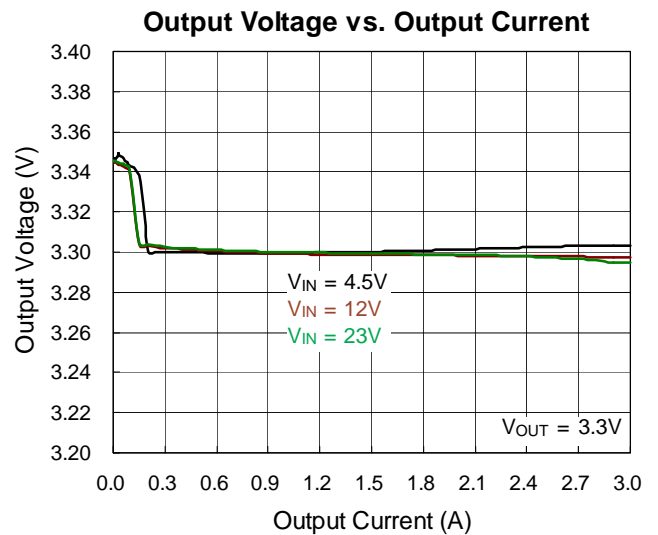
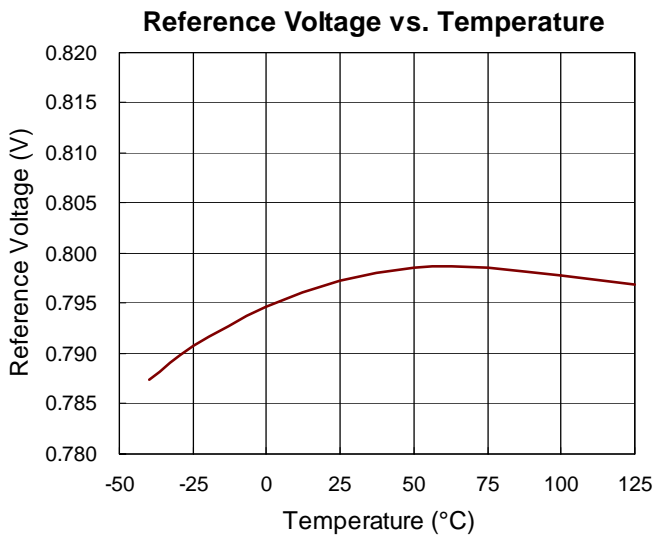
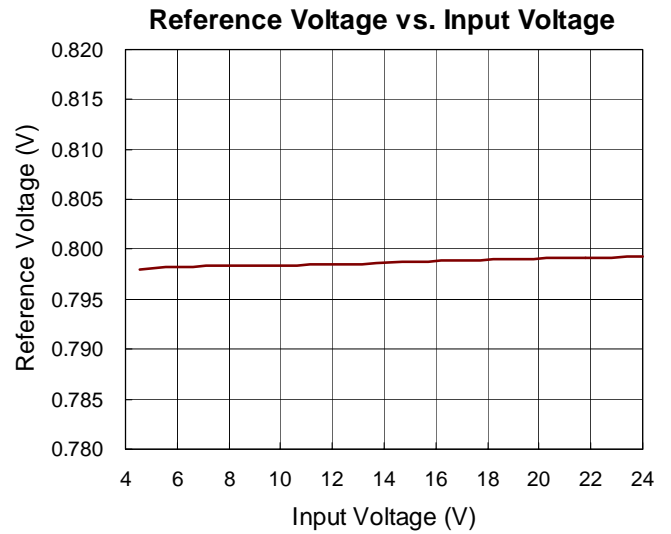
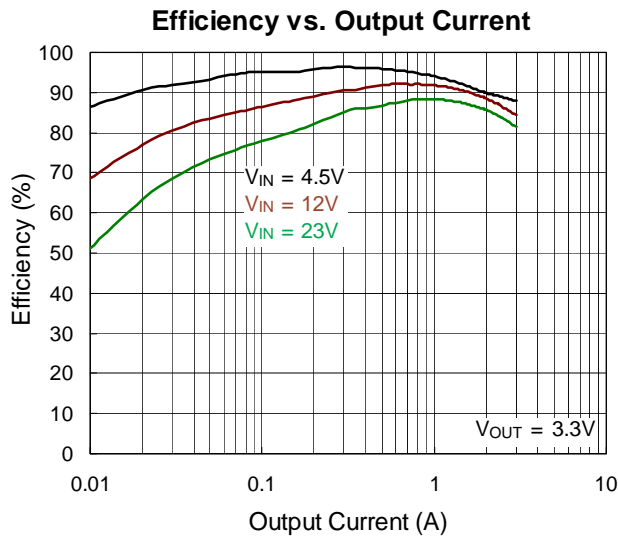
**Note 1.** Stresses beyond those listed "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions may affect device reliability.

**Note 2.**  $\theta_{JA}$  is measured at  $T_A = 25^{\circ}C$  on a high effective thermal conductivity four-layer test board per JEDEC 51-7.  $\theta_{JC}$  is measured at the exposed pad of the package.

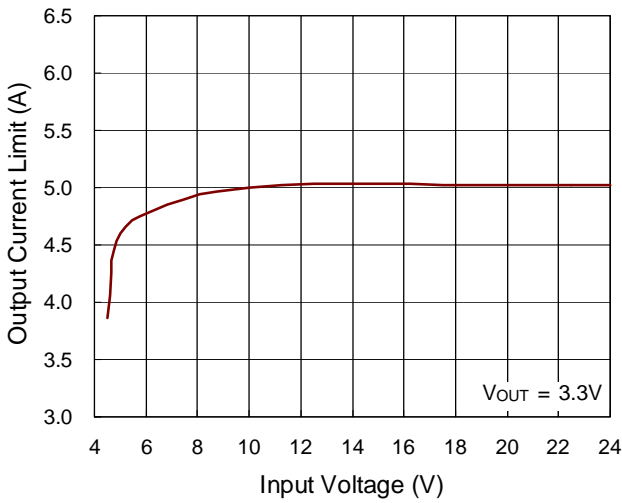
**Note 3.** Devices are ESD sensitive. Handling precaution is recommended.

**Note 4.** The device is not guaranteed to function outside its operating conditions.

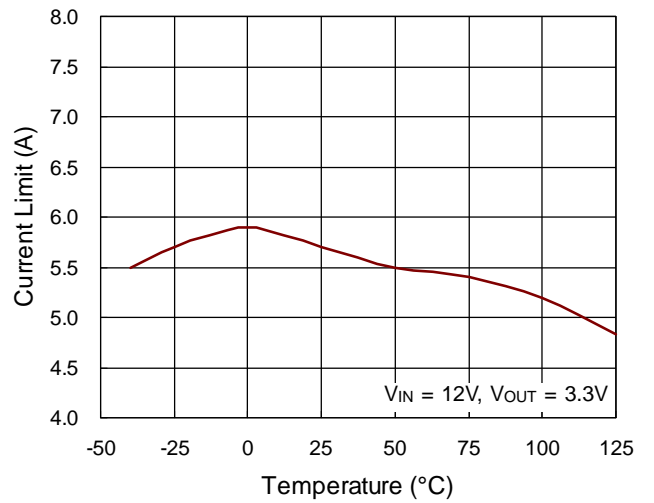
Typical Operating Characteristics



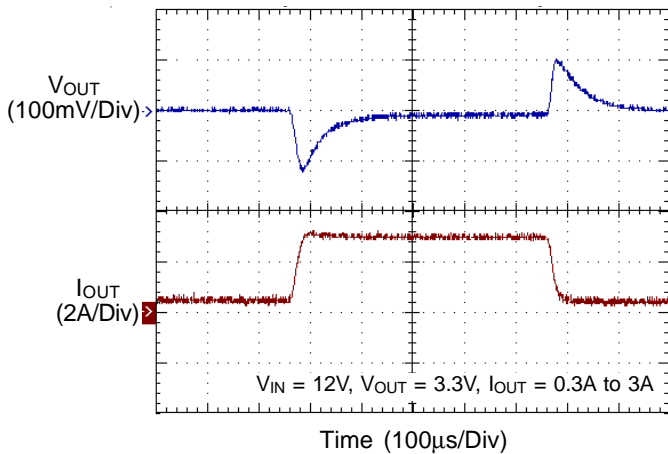
**Output Current Limit vs. Input Voltage**



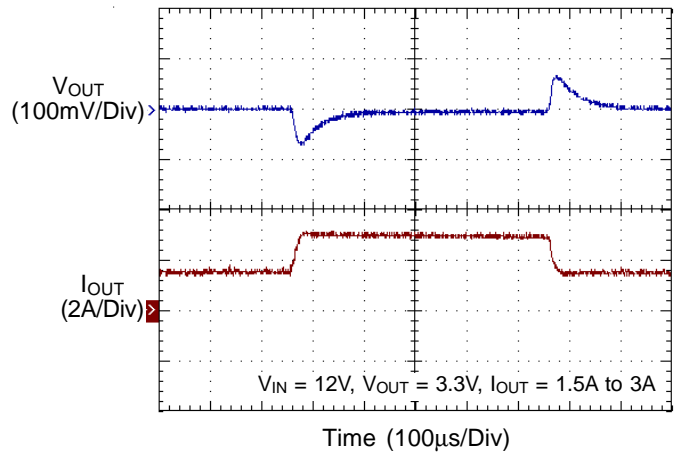
**Current Limit vs. Temperature**



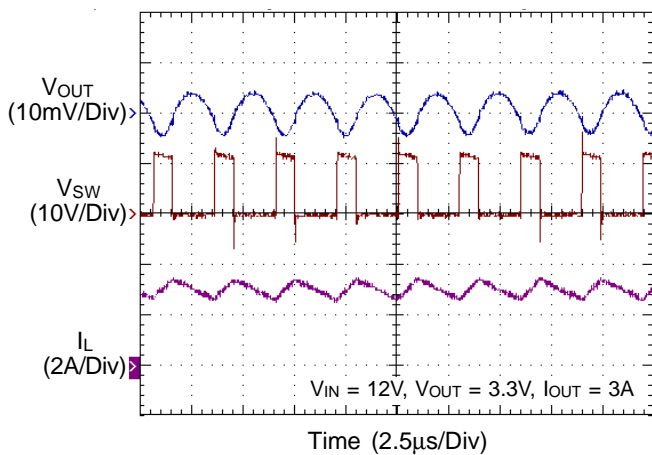
**Load Transient Response**



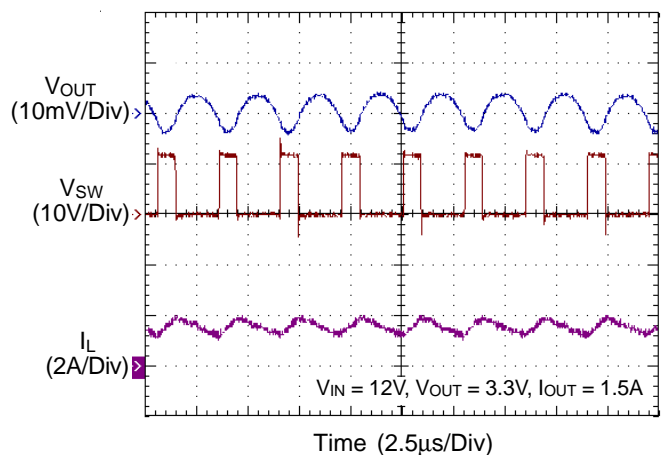
**Load Transient Response**



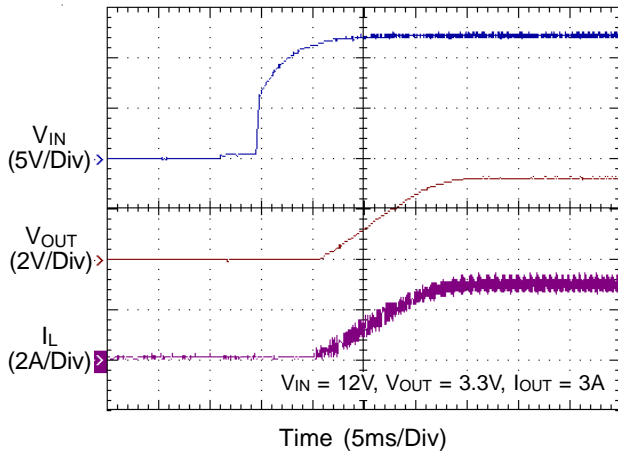
**Output Voltage Ripple**



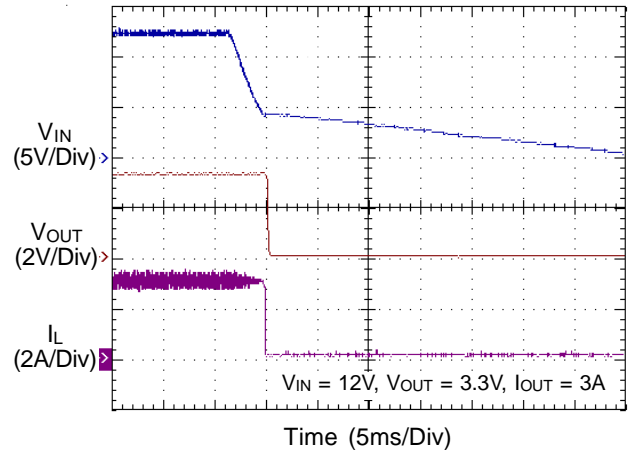
**Output Voltage Ripple**



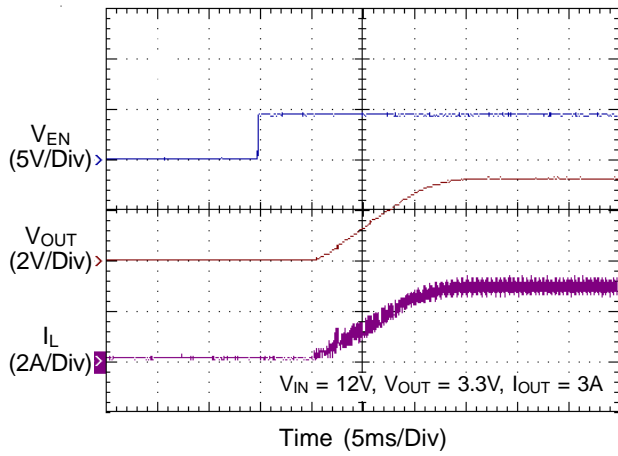
Power On from  $V_{IN}$



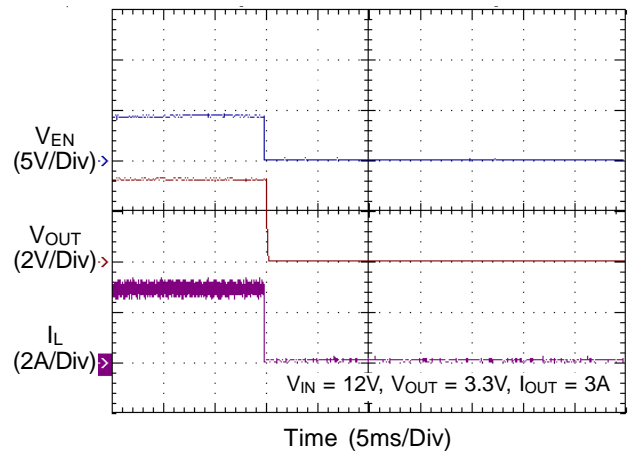
Power Off from  $V_{IN}$



Power On from EN



Power Off from EN





## Application Information

The RT8296A is a synchronous high voltage buck converter that can support the input voltage range from 4.5V to 23V and the output current can be up to 3A.

### Output Voltage Setting

The resistive divider allows the FB pin to sense the output voltage as shown in Figure 1.

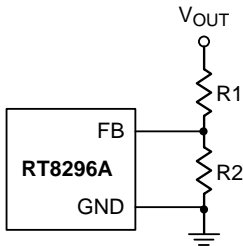


Figure 1. Output Voltage Setting

The output voltage is set by an external resistive voltage divider according to the following equation :

$$V_{OUT} = V_{FB} \left( 1 + \frac{R1}{R2} \right)$$

Where  $V_{FB}$  is the feedback reference voltage (0.8V typ.).

### External Bootstrap Diode

Connect a 100nF low ESR ceramic capacitor between the BOOT pin and SW pin. This capacitor provides the gate driver voltage for the high side MOSFET.

It is recommended to add an external bootstrap diode between an external 5V and BOOT pin for efficiency improvement when input voltage is lower than 5.5V or duty ratio is higher than 65%. The bootstrap diode can be a low cost one such as IN4148 or BAT54. The external 5V can be a 5V fixed input from system or a 5V output of the RT8296A. Note that the external boot voltage must be lower than 5.5V.

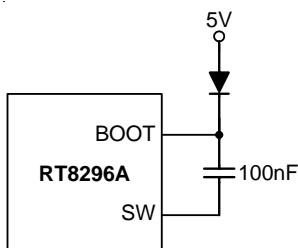


Figure 2. External Bootstrap Diode

### Soft-Start

The RT8296A contains an external soft-start clamp that gradually raises the output voltage. The soft-start timing can be programmed by the external capacitor between SS pin and GND. The chip provides a 6μA charge current for the external capacitor. If 0.1μF capacitor is used to set the soft-start, its period will be 13.5ms(typ.).

### Chip Enable Operation

The EN pin is the chip enable input. Pulling the EN pin low (<0.4V) will shutdown the device. During shutdown mode, the RT8296A quiescent current drops to lower than 3μA. Driving the EN pin high (>2.7V, < 5.5V) will turn on the device again. For external timing control (e.g.RC), the EN pin can also be externally pulled high by adding a  $R_{EN}^*$  resistor and  $C_{EN}^*$  capacitor from the VIN pin (see Figure 5).

An external MOSFET can be added to implement digital control on the EN pin when no system voltage above 2.5V is available, as shown in Figure 3. In this case, a 100kΩ pull-up resistor,  $R_{EN}$ , is connected between  $V_{IN}$  and the EN pin. MOSFET Q1 will be under logic control to pull down the EN pin.

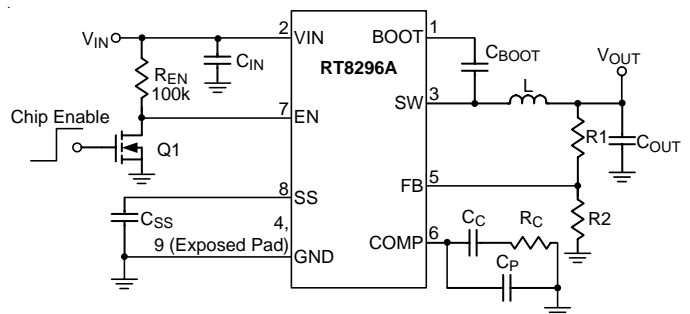


Figure 3. Enable Control Circuit for Logic Control with Low Voltage

To prevent enabling circuit when  $V_{IN}$  is smaller than the  $V_{OUT}$  target value, a resistive voltage divider can be placed between the input voltage and ground and connected to the EN pin to adjust IC lockout threshold, as shown in Figure 4. For example, if an 8V output voltage is regulated from a 12V input voltage, the resistor  $R_{EN2}$  can be selected to set input lockout threshold larger than 8V.

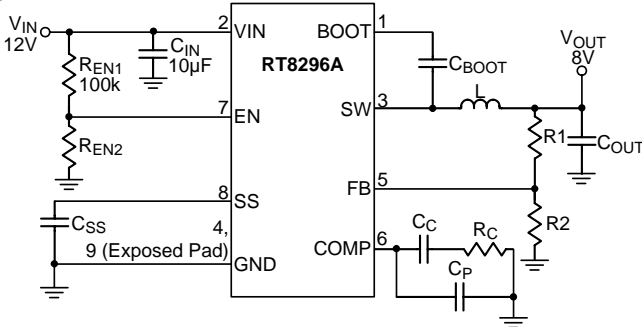


Figure 4. The Resistors can be Selected to Set IC Lockout Threshold

**Under Voltage Protection**

**Hiccup Mode**

For the RT8296AH, it provides Hiccup Mode Under Voltage Protection (UVP). When the FB voltage drops below half of the feedback reference voltage,  $V_{FB}$ , the UVP function will be triggered and the RT8296AH will shut down for a period of time and then recover automatically. The Hiccup Mode UVP can reduce input current in short-circuit conditions.

**Latch-Off Mode**

For the RT8296AL, it provides Latch-Off Mode Under Voltage Protection (UVP). When the FB voltage drops below half of the feedback reference voltage,  $V_{FB}$ , UVP will be triggered and the RT8296AL will shutdown in Latch-Off Mode. In shutdown condition, the RT8296AL can be reset by EN pin or power input VIN.

**Inductor Selection**

The inductor value and operating frequency determine the ripple current according to a specific input and output voltage. The ripple current  $\Delta I_L$  increases with higher  $V_{IN}$  and decreases with higher inductance.

$$\Delta I_L = \left[ \frac{V_{OUT}}{f \times L} \right] \times \left[ 1 - \frac{V_{OUT}}{V_{IN}} \right]$$

Having a lower ripple current reduces not only the ESR losses in the output capacitors but also the output voltage ripple. High frequency with small ripple current can achieve highest efficiency operation. However, it requires a large inductor to achieve this goal.

For the ripple current selection, the value of  $\Delta I_L = 0.24(I_{MAX})$  will be a reasonable starting point. The largest ripple current occurs at the highest  $V_{IN}$ . To guarantee that the

ripple current stays below the specified maximum, the inductor value should be chosen according to the following equation :

$$L = \left[ \frac{V_{OUT}}{f \times \Delta I_L(MAX)} \right] \times \left[ 1 - \frac{V_{OUT}}{V_{IN(MAX)}} \right]$$

The inductor's current rating (caused a 40°C temperature rising from 25°C ambient) should be greater than the maximum load current and its saturation current should be greater than the short circuit peak current limit. Please see Table 2 for the inductor selection reference.

**Table 2. Suggested Inductors for Typical Application Circuit**

Component Supplier	Series	Dimensions (mm)
TDK	VLF10045	10 x 9.7 x 4.5
TDK	SLF12565	12.5 x 12.5 x 6.5
TAIYO YUDEN	NR8040	8 x 8 x 4

**$C_{IN}$  and  $C_{OUT}$  Selection**

The input capacitance,  $C_{IN}$ , is needed to filter the trapezoidal current at the source of the high side MOSFET. To prevent large ripple current, a low ESR input capacitor sized for the maximum RMS current should be used. The RMS current is given by :

$$I_{RMS} = I_{OUT(MAX)} \frac{V_{OUT}}{V_{IN}} \sqrt{\frac{V_{IN}}{V_{OUT}} - 1}$$

This formula has a maximum at  $V_{IN} = 2V_{OUT}$ , where  $I_{RMS} = I_{OUT} / 2$ . This simple worst case condition is commonly used for design because even significant deviations do not offer much relief.

Choose a capacitor rated at a higher temperature than required. Several capacitors may also be paralleled to meet size or height requirements in the design.

For the input capacitor, two 10µF low ESR ceramic capacitors are recommended. For the recommended capacitor, please refer to table 3 for more detail.

The selection of  $C_{OUT}$  is determined by the required ESR to minimize voltage ripple.

Moreover, the amount of bulk capacitance is also a key for  $C_{OUT}$  selection to ensure that the control loop is stable. Loop stability can be checked by viewing the load transient response as described in a later section.

The output ripple,  $\Delta V_{OUT}$ , is determined by :

$$\Delta V_{OUT} \leq \Delta I_L \left[ ESR + \frac{1}{8fC_{OUT}} \right]$$

The output ripple will be highest at the maximum input voltage since  $\Delta I_L$  increases with input voltage. Multiple capacitors placed in parallel may be needed to meet the ESR and RMS current handling requirement. Dry tantalum, special polymer, aluminum electrolytic and ceramic capacitors are all available in surface mount packages. Special polymer capacitors offer very low ESR value. However, it provides lower capacitance density than other types. Although Tantalum capacitors have the highest capacitance density, it is important to only use types that pass the surge test for use in switching power supplies. Aluminum electrolytic capacitors have significantly higher ESR. However, it can be used in cost-sensitive applications for ripple current rating and long term reliability considerations. Ceramic capacitors have excellent low ESR characteristics but can have a high voltage coefficient and audible piezoelectric effects. The high Q of ceramic capacitors with trace inductance can also lead to significant ringing.

Higher values, lower cost ceramic capacitors are now becoming available in smaller case sizes. Their high ripple current, high voltage rating and low ESR make them ideal for switching regulator applications. However, care must be taken when these capacitors are used at input and 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,  $V_{IN}$ . At best, this ringing can couple to the output and be mistaken as loop instability. At worst, a sudden

inrush of current through the long wires can potentially cause a voltage spike at  $V_{IN}$  large enough to damage the part.

**Checking Transient Response**

The regulator loop response can be checked by looking at the load transient response. Switching regulators take several cycles to respond to a step in load current. When a load step occurs,  $V_{OUT}$  immediately shifts by an amount equal to  $\Delta I_{LOAD}$  (ESR) also begins to charge or discharge  $C_{OUT}$  generating a feedback error signal for the regulator to return  $V_{OUT}$  to its steady-state value. During this recovery time,  $V_{OUT}$  can be monitored for overshoot or ringing that would indicate a stability problem.

**EMI Consideration**

Since parasitic inductance and capacitance effects in PCB circuitry would cause a spike voltage on SW pin when high side MOSFET is turned-on/off, this spike voltage on SW may impact on EMI performance in the system. In order to enhance EMI performance, there are two methods to suppress the spike voltage. One is to place an R-C snubber between SW and GND and make them as close as possible to the SW pin (see Figure 5). Another method is adding a resistor in series with the bootstrap capacitor,  $C_{BOOT}$ . But this method will decrease the driving capability to the high side MOSFET. It is strongly recommended to reserve the R-C snubber during PCB layout for EMI improvement. Moreover, reducing the SW trace area and keeping the main power in a small loop will be helpful on EMI performance. For detailed PCB layout guide, please refer to the section of Layout Consideration.

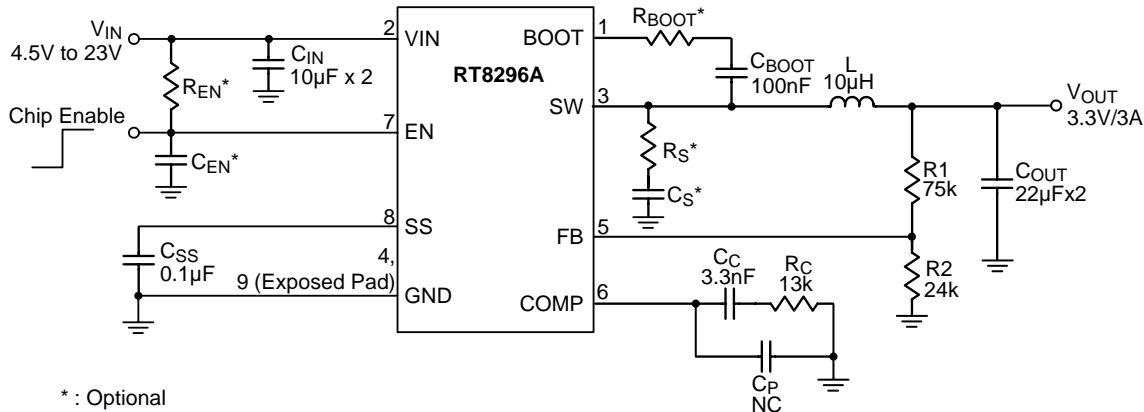


Figure 5. Reference Circuit with Snubber and Enable Timing Control

## Thermal Considerations

For continuous operation, do not exceed the maximum operation junction temperature 125°C. The maximum power dissipation depends on the thermal resistance of IC package, PCB layout, the rate of surroundings airflow and temperature difference between junction to ambient. The maximum power dissipation can be calculated by following formula :

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

Where  $T_{J(MAX)}$  is the maximum operation junction temperature ,  $T_A$  is the ambient temperature and the  $\theta_{JA}$  is the junction to ambient thermal resistance.

For recommended operating conditions specification of RT8296A, the maximum junction temperature is 125°C. The junction to ambient thermal resistance  $\theta_{JA}$  is layout dependent. For PSOP-8 package, the thermal resistance  $\theta_{JA}$  is 75°C/W on the standard JEDEC 51-7 four-layers thermal test board. The maximum power dissipation at  $T_A = 25^\circ\text{C}$  can be calculated by following formula :

$$P_{D(MAX)} = (125^\circ\text{C} - 25^\circ\text{C}) / (75^\circ\text{C/W}) = 1.333\text{W}$$

(min.copper area PCB layout)

$$P_{D(MAX)} = (125^\circ\text{C} - 25^\circ\text{C}) / (49^\circ\text{C/W}) = 2.04\text{W}$$

(70mm<sup>2</sup>copper area PCB layout)

The thermal resistance  $\theta_{JA}$  of SOP-8 (Exposed Pad) is determined by the package architecture design and the PCB layout design. However, the package architecture design had been designed. If possible, it's useful to increase thermal performance by the PCB layout copper design. The thermal resistance  $\theta_{JA}$  can be decreased by adding copper area under the exposed pad of SOP-8 (Exposed Pad) package.

As shown in Figure 6, the amount of copper area to which the SOP-8 (Exposed Pad) is mounted affects thermal performance. When mounted to the standard SOP-8 (Exposed Pad) pad (Figure 6.a),  $\theta_{JA}$  is 75°C/W. Adding copper area of pad under the SOP-8 (Exposed Pad) (Figure 6.b) reduces the  $\theta_{JA}$  to 64°C/W. Even further, increasing the copper area of pad to 70mm<sup>2</sup> (Figure 6.e) reduces the  $\theta_{JA}$  to 49°C/W.

The maximum power dissipation depends on operating ambient temperature for fixed  $T_{J(MAX)}$  and thermal resistance  $\theta_{JA}$ . For RT8296A packages, the Figure 7 of derating curves allows the designer to see the effect of rising ambient temperature on the maximum power dissipation allowed.

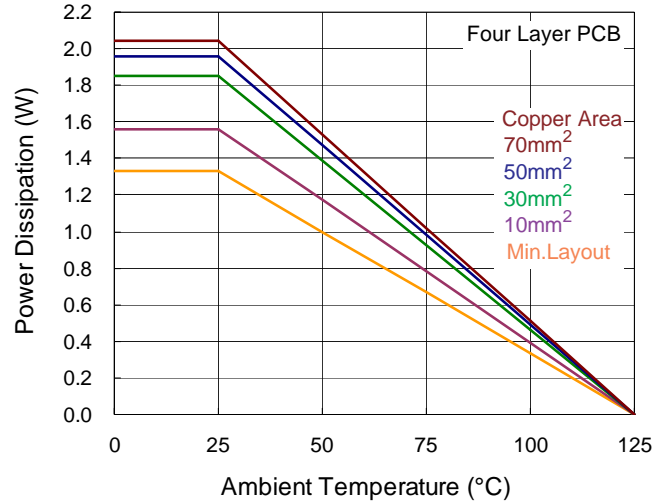
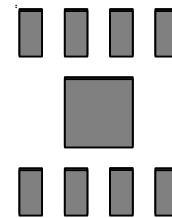
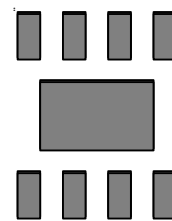


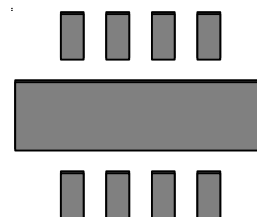
Figure 7. Derating Curves for RT8296A Package



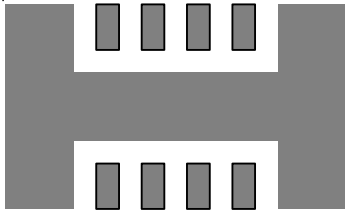
(a) Copper Area = (2.3 x 2.3) mm<sup>2</sup>,  $\theta_{JA} = 75^\circ\text{C/W}$



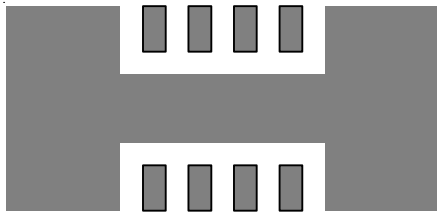
(b) Copper Area = 10mm<sup>2</sup>,  $\theta_{JA} = 64^\circ\text{C/W}$



(c) Copper Area = 30mm<sup>2</sup>,  $\theta_{JA} = 54^\circ\text{C/W}$



(d) Copper Area = 50mm<sup>2</sup>,  $\theta_{JA} = 51^{\circ}\text{C/W}$



(e) Copper Area = 70mm<sup>2</sup>,  $\theta_{JA} = 49^{\circ}\text{C/W}$

Figure 6. Thermal Resistance vs. Copper Area Layout Design

**Layout Consideration**

Follow the PCB layout guidelines for optimal performance of the RT8296A.

- ▶ Keep the traces of the main current paths as short and wide as possible.
- ▶ Put the input capacitor as close as possible to the device pins (VIN and GND).
- ▶ LX node is with high frequency voltage swing and should be kept at small area. Keep analog components away from the LX node to prevent stray capacitive noise pick-up.
- ▶ Connect feedback network behind the output capacitors. Keep the loop area small. Place the feedback components near the RT8296A.
- ▶ Connect all analog grounds to a command node and then connect the command node to the power ground behind the output capacitors.
- ▶ An example of PCB layout guide is shown in Figure 6 for reference.

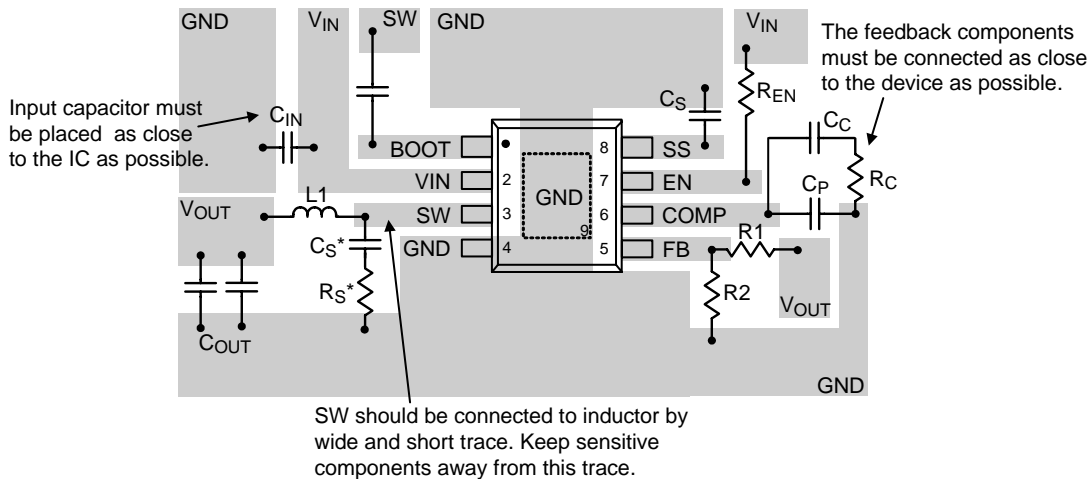
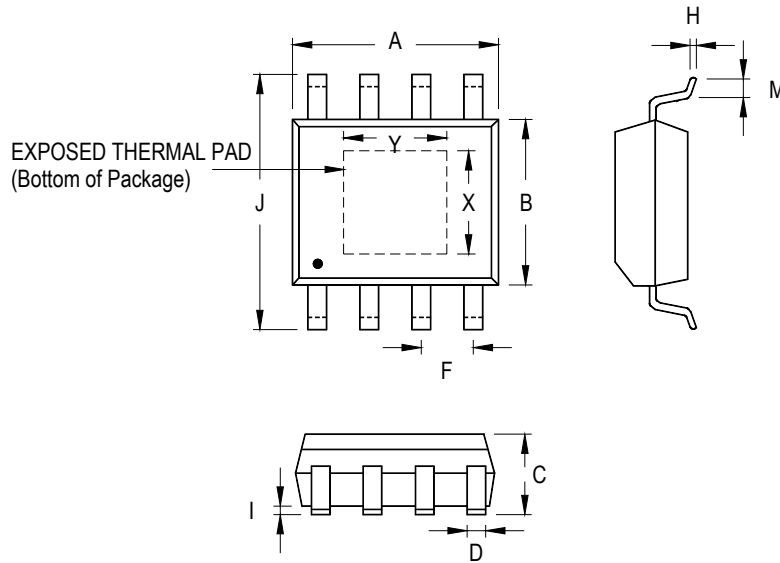


Figure 8. PCB Layout Guide

Outline Dimension



Symbol	Dimensions In Millimeters		Dimensions In Inches		
	Min	Max	Min	Max	
A	4.801	5.004	0.189	0.197	
B	3.810	4.000	0.150	0.157	
C	1.346	1.753	0.053	0.069	
D	0.330	0.510	0.013	0.020	
F	1.194	1.346	0.047	0.053	
H	0.170	0.254	0.007	0.010	
I	0.000	0.152	0.000	0.006	
J	5.791	6.200	0.228	0.244	
M	0.406	1.270	0.016	0.050	
Option 1	X	2.000	2.300	0.079	0.091
	Y	2.000	2.300	0.079	0.091
Option 2	X	2.100	2.500	0.083	0.098
	Y	3.000	3.500	0.118	0.138

8-Lead SOP (Exposed Pad) Plastic Package

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