

## **3A, 18V, 700kHz ACOT™ Synchronous Step-Down Converter**

### **General Description**

The RT7266 is an adaptive on-time ACOT™ mode synchronous buck converter. The adaptive on-time ACOT™ mode control provides a very fast transient response with few external components. The low impedance internal MOSFET can support high efficiency operation with wide input voltage range from 4.5V to 18V. The proprietary circuit of the RT7266 enables to support all ceramic capacitors. The output voltage can be adjustable between 0.8V and 8V. The soft-start is adjustable by an external capacitor.

### **Ordering Information**

RT7266□□

Package Type  
SP : SOP-8 (Exposed Pad-Option 2)

Lead Plating System  
Z : ECO (Ecological Element with Halogen Free and Pb free)

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.

### **Marking Information**

RT7266  
ZSPYMDNN  
●

RT7266ZSP : Product Number  
YMDNN : Date Code

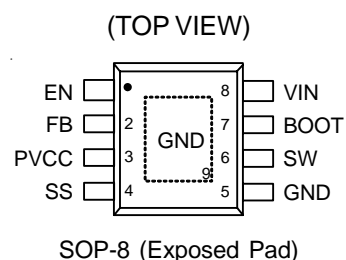
### **Features**

- ACOT™ Mode Enables Fast Transient Response
- 4.5V to 18V Input Voltage Range
- 3A Output Current
- 60mΩ Internal Low Side N-MOSFET
- Adaptive On-Time Control
- Fast Transient Response
- Support All Ceramic Capacitors
- Up to 95% Efficiency
- 700kHz Switching Frequency
- Adjustable Output Voltage from 0.8V to 8V
- Adjustable Soft-Start
- Cycle-by-Cycle Current Limit
- Input Under Voltage Lockout
- Thermal Shutdown Protection
- RoHS Compliant and Halogen Free

### **Applications**

- Industrial and Commercial Low Power Systems
- Computer Peripherals
- LCD Monitors and TVs
- Green Electronics/Appliances
- Point of Load Regulation for High-Performance DSPs, FPGAs, and ASICs

### **Pin Configurations**



## Typical Application Circuit

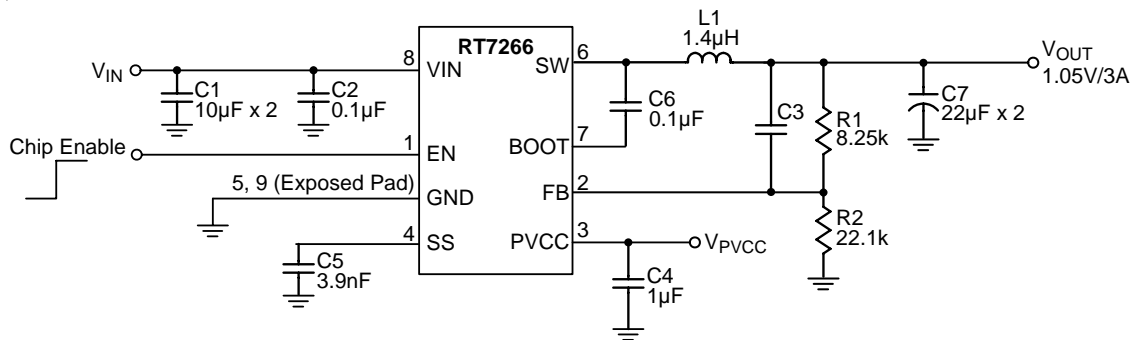


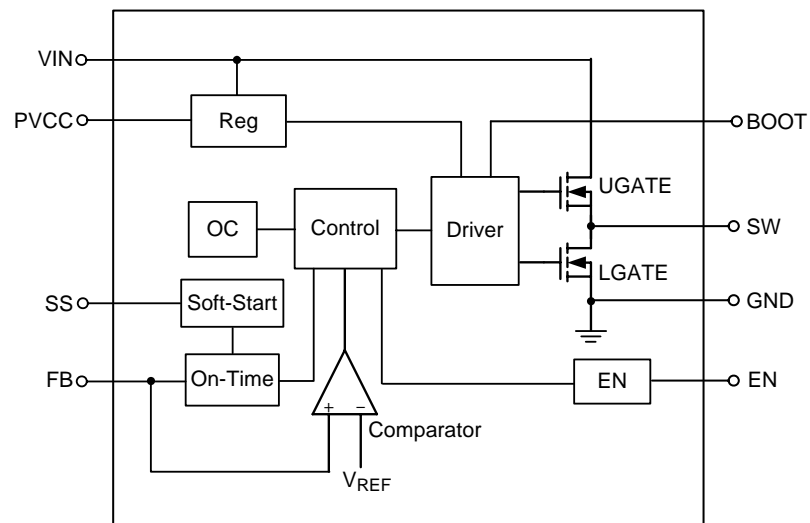
Table 1. Suggested Component Values

V <sub>OUT</sub> (V)	R1 (kΩ)	R2 (kΩ)	C3 (pF)	L1 (μH)	C7 (μF)
1	6.81	22.1	--	1.4	22 to 68
1.05	8.25	22.1	--	1.4	22 to 68
1.2	12.7	22.1	--	1.4	22 to 68
1.8	30.1	22.1	5 to 22	2	22 to 68
2.5	49.9	22.1	5 to 22	2	22 to 68
3.3	73.2	22.1	5 to 22	2	22 to 68
5	124	22.1	5 to 22	3.3	22 to 68
7	180	22.1	5 to 22	3.3	22 to 68

## Functional Pin Description

Pin No.	Pin Name	Pin Function
1	EN	Enable Input. A logic-high enables the converter; a logic-low forces the RT7266 into shutdown mode reducing the supply current to less than 10μA. Attach this pin to VIN with a 100kΩ pull up resistor for automatic start-up.
2	FB	Feedback Input. It is used to regulate the output of the converter to a set value via an external resistive voltage divider. The feedback reference voltage is 0.765V typically.
3	PVCC	Internal Regulator Output. Connect a 1μF capacitor to GND to stabilize output voltage.
4	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 3.9nF capacitor sets the soft-start period to 1.5ms.
5, 9 (Exposed pad)	GND	Ground. The Exposed pad should be soldered to a large PCB and connected to GND for maximum thermal dissipation.
6	SW	Switch Node. Connect this pin to an external L-C filter.
7	BOOT	Bootstrap for High Side Gate Driver. Connect a 0.1μF or greater ceramic capacitor from BOOT to SW pins.
8	VIN	Supply Input. The input voltage range is from 4.5V to 18V. Must bypass with a suitable large ( $\geq 10\mu\text{F} \times 2$ ) ceramic capacitor.

## Function Block Diagram



**Absolute Maximum Ratings** (Note 1)

- Supply Voltage,  $V_{IN}$  ----- -0.3V to 20V
- Switch Voltage,  $SW$  ----- -0.8V to ( $V_{IN} + 0.3V$ )  
 $< 10ns$  ----- -5V to 25V
- BOOT to  $SW$  ----- -0.3V to 6V
- All Other Pins ----- -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),  $\theta_{JC}$  -----  $15^\circ C/W$
- Junction Temperature Range -----  $150^\circ C$
- Lead Temperature (Soldering, 10 sec.) -----  $260^\circ C$
- Storage Temperature Range -----  $-65^\circ C$  to  $150^\circ C$

**Recommended Operating Conditions** (Note 3)

- Supply Voltage,  $V_{IN}$  ----- 4.5V to 18V
- 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
Supply Current							
Shutdown Current		I <sub>SHDN</sub>	V <sub>EN</sub> = 0V	--	1	10	μA
Quiescent Current		I <sub>Q</sub>	V <sub>EN</sub> = 3V, V <sub>FB</sub> = 1V	--	0.7	--	mA
Logic Threshold							
EN Voltage	Logic-High			2	--	5.5	V
	Logic-Low			--	--	0.4	
V <sub>REF</sub> Voltage and Discharge Resistance							
Feedback Reference Voltage		V <sub>REF</sub>	4.5V ≤ V <sub>IN</sub> ≤ 18V	0.753	0.765	0.777	V
Feedback Input Current		I <sub>FB</sub>	V <sub>FB</sub> = 0.8V	−0.1	0	0.1	μA
V <sub>PVCC</sub> Output							
V <sub>PVCC</sub> Output Voltage		V <sub>PVCC</sub>	6V ≤ V <sub>IN</sub> ≤ 18V, 0 < I <sub>PVCC</sub> < 5mA	4.7	5.1	5.5	V
Line Regulation			6V ≤ V <sub>IN</sub> ≤ 18V, I <sub>PVCC</sub> = 5mA	--	--	20	mV
Load Regulation			0 < I <sub>PVCC</sub> < 5mA	--	--	60	mV
Output Current		I <sub>PVCC</sub>	V <sub>IN</sub> = 6V, V <sub>PVCC</sub> = 4V	--	110	--	mA
R <sub>DS(ON)</sub>							
Switch On Resistance	High Side	R <sub>DS(ON)_H</sub>		--	90	--	mΩ
	Low Side	R <sub>DS(ON)_L</sub>		--	60	--	
Current Limit							
Current limit		I <sub>LIM</sub>		3.5	4.1	5.7	A

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Thermal Shutdown						
Thermal Shutdown Threshold	T <sub>SD</sub>		--	150	--	°C
Thermal Shutdown Hysteresis	ΔT <sub>SD</sub>		--	20	--	
On-Time Timer Control						
On-Time	t <sub>ON</sub>	V <sub>IN</sub> = 12V, V <sub>OUT</sub> = 1.05V	--	145	--	ns
Minimum On-Time	t <sub>ON(MIN)</sub>		--	60	--	ns
Minimum Off-Time	t <sub>OFF(MIN)</sub>		--	230	--	ns
Soft-Start						
SS Charge Current		V <sub>SS</sub> = 0V	1.4	2	2.6	μA
SS Discharge Current		V <sub>SS</sub> = 0.5V	0.05	0.1	--	mA
UVLO						
UVLO Threshold		V <sub>IN</sub> Rising to Wake up V <sub>PVCC</sub>	3.55	3.85	4.15	V
Hysteresis			--	0.3	--	

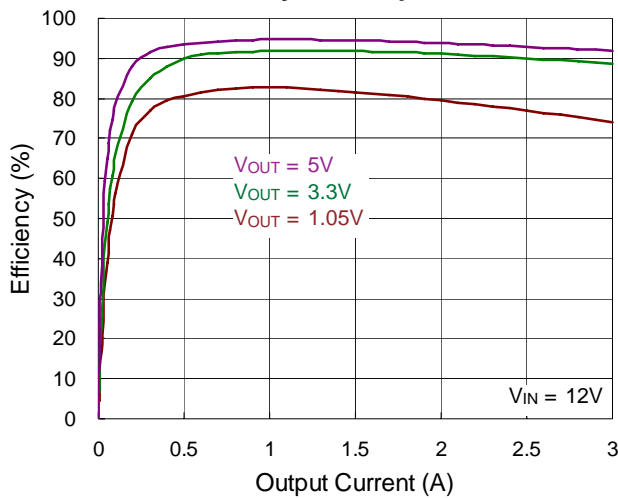
**Note 1.** Stresses beyond those listed “Absolute Maximum Ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied.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

**Note 2.**  $\theta_{JA}$  is measured at  $T_A = 25^\circ\text{C}$  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.

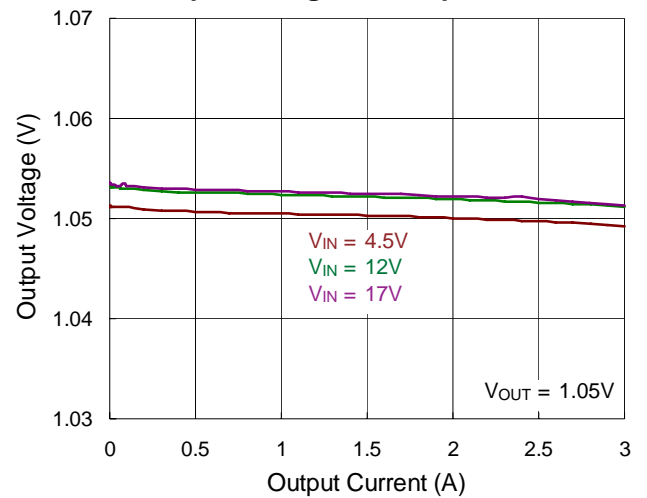
**Note 3.** The device is not guaranteed to function outside its operating conditions.

## Typical Operating Characteristics

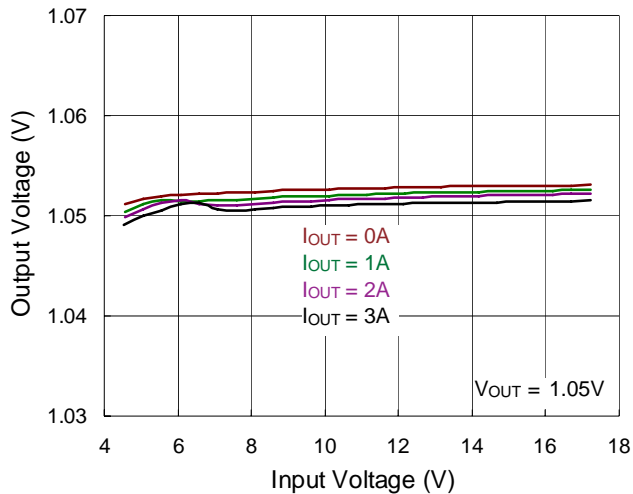
### Efficiency vs. Output Current



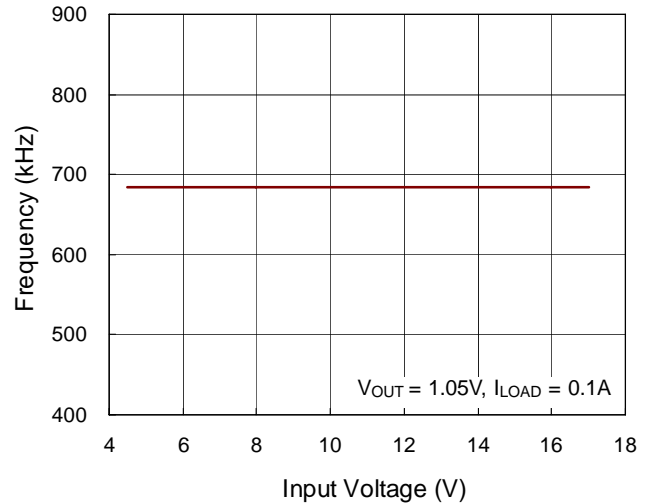
### Output Voltage vs. Output Current



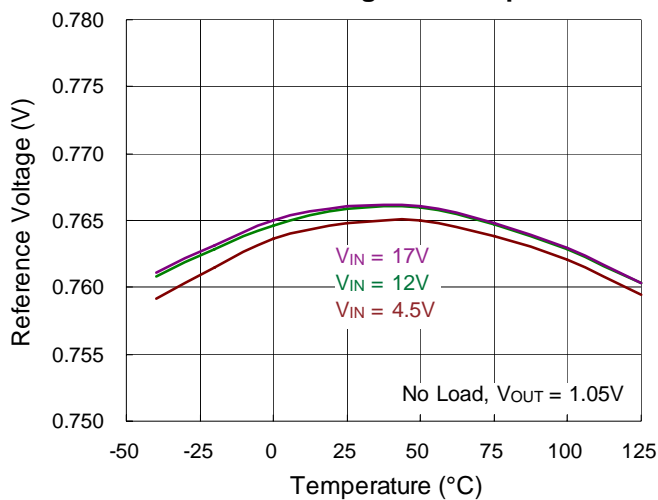
### Output Voltage vs. Input Voltage



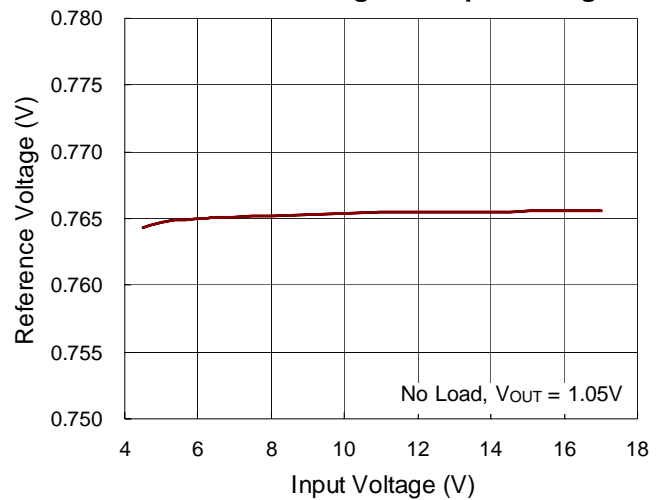
### Frequency vs. Input Voltage



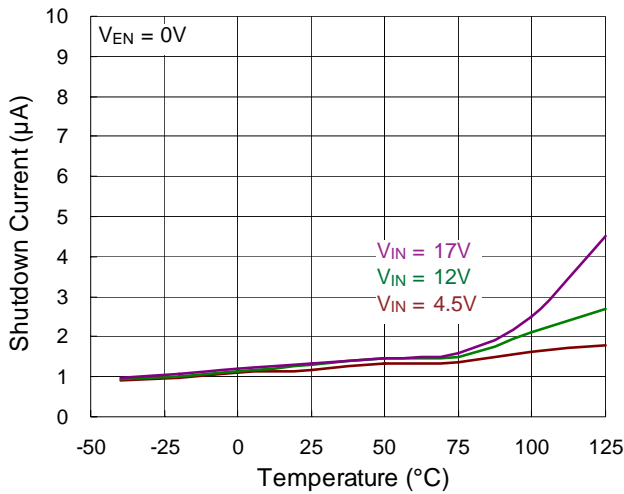
### Reference Voltage vs. Temperature



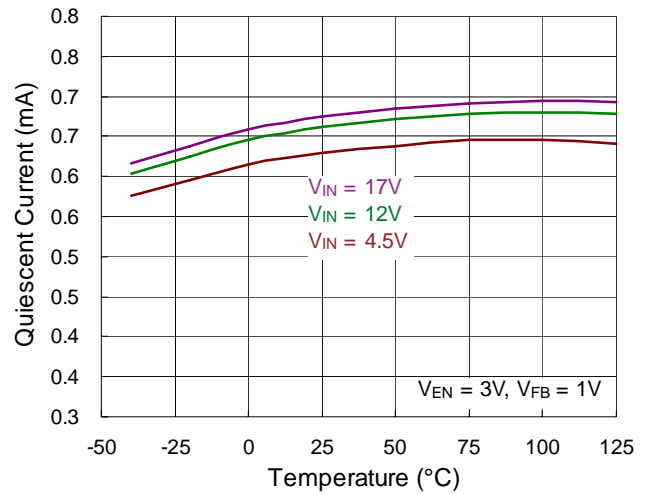
### Reference Voltage vs. Input Voltage



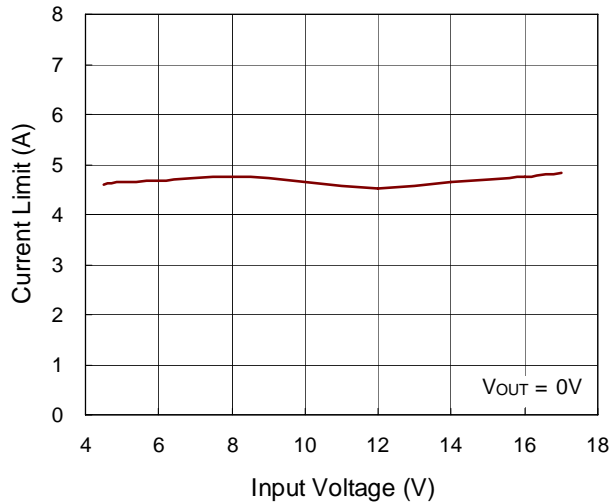
Shutdown Current vs. Temperature



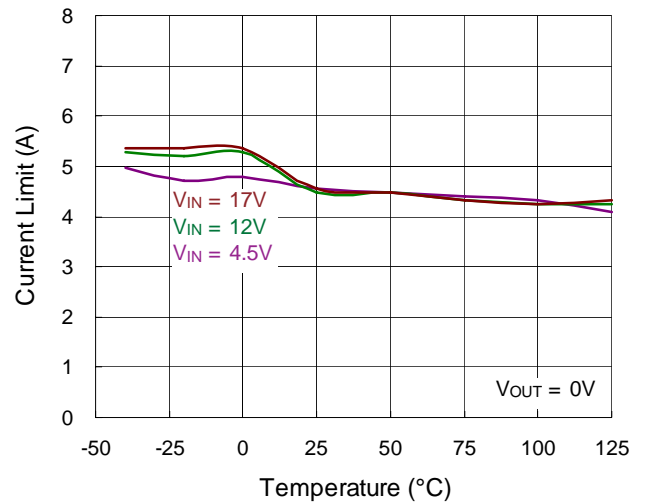
Quiescent Current vs. Temperature



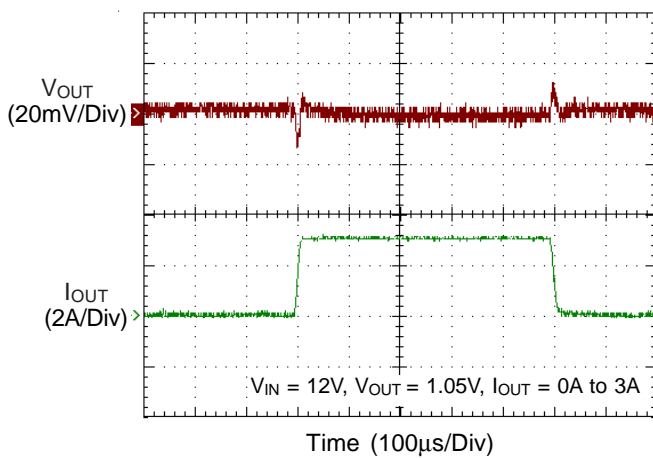
Current Limit vs. Input Voltage



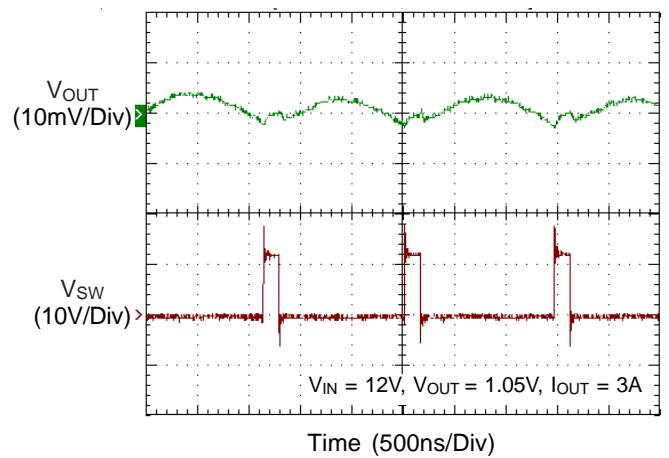
Current Limit vs. Temperature



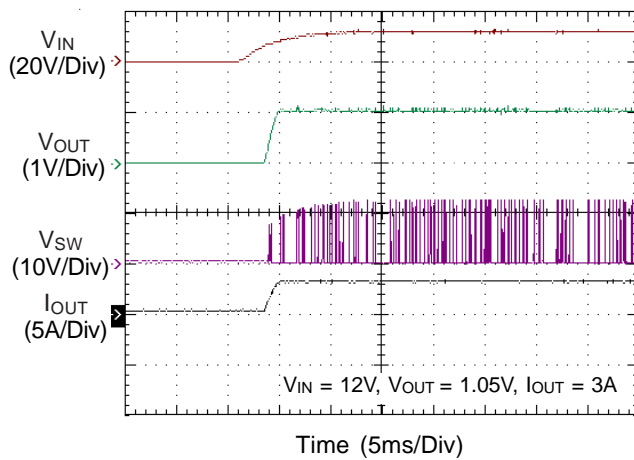
Load Transient Response



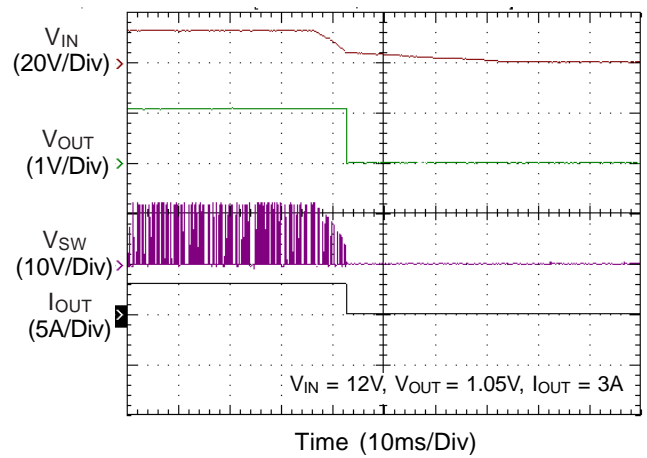
Output Voltage Ripple



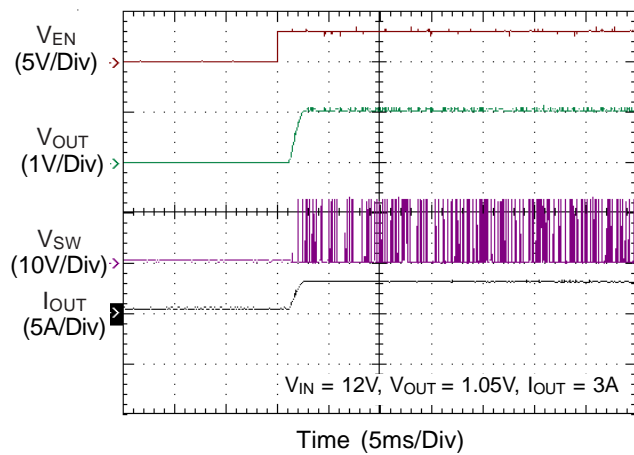
### Power On from $V_{IN}$



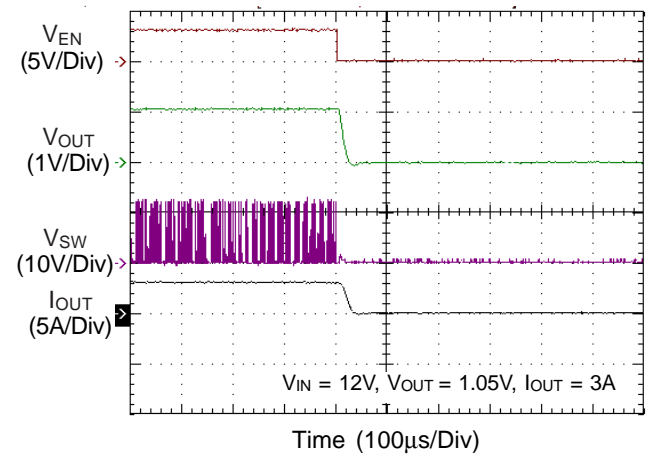
### Power Off from $V_{IN}$



### Power On from $V_{EN}$



### Power Off from $V_{EN}$





## Application Information

The RT7266 is a synchronous high voltage buck converter that can support the input voltage range from 4.5V to 18V and the output current can be up to 3A. It operates using adaptive on-time ACOT™ mode control and provides a very fast transient response with few external compensation components. The RT7266 allows low external component count configuration with both low ESR and ceramic output capacitors.

### PWM Operation

It is suitable for low external component count configuration with appropriate amount of Equivalent Series Resistance (ESR) capacitor(s) at the output. The output ripple valley voltage is monitored at a feedback point voltage. The synchronous high side MOSFET is turned on at the beginning of each cycle. After the internal one shot timer expires, the MOSFET is turned off. The pulse width of this one shot is determined by the converter's input and output voltages to keep the frequency fairly constant over the entire input voltage range.

### Adaptive On-Time Control

The RT7266 has a unique circuit to ensure the switching frequency on 700kHz over full input voltage range and full loading range. This circuit sets the on-time one-shot timer by monitoring the input voltage and SW signal. The switching frequency will keep constant if the duty ratio is  $V_{OUT}/V_{IN}$ .

$$\text{Duty Ratio} = V_{OUT}/V_{IN} = t_{ON} / T$$

For Fixed T,  $t_{ON}$  is proportional to  $V_{OUT}/V_{IN}$ .

### Soft-Start

The RT7266 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 2μA charge current for the external capacitor. If a 3.9nF capacitor is used, the soft-start will be 2ms (typ.). The available capacitance range is from 2.7nF to 220nF.

$$t_{SS} \text{ (ms)} = \frac{C5 \text{ (nF)} \times 1.065}{I_{SS} \text{ (}\mu\text{A)}}$$

### 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 RT7266 quiescent current drops to lower than 10μA. Driving the EN pin high (>2V, <5.5V) will turn on the device again. For external timing control, 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 1).

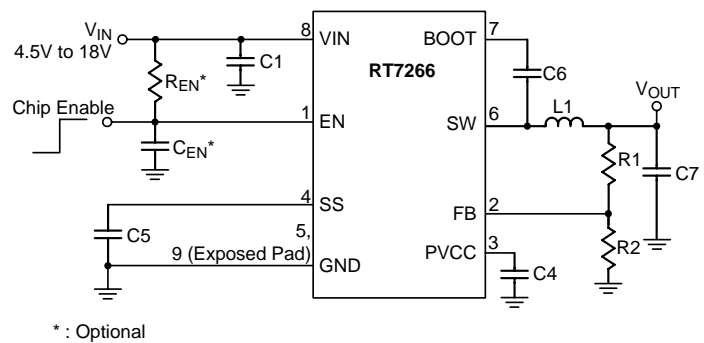


Figure 1. External Timing Control

An external MOSFET can be added to implement digital control on the EN pin when no system voltage above 2V is available, as shown in Figure 2. 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.

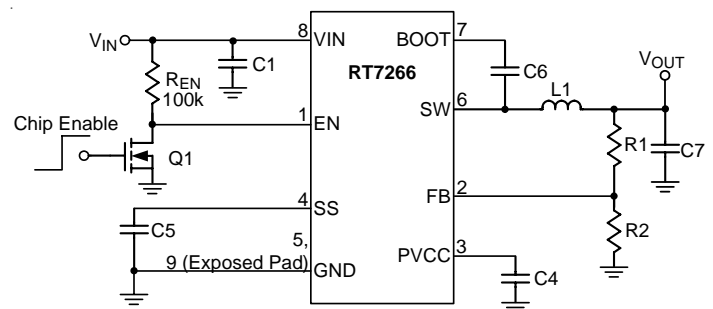


Figure 2. Logic Control with Low Voltage

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 3. 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.

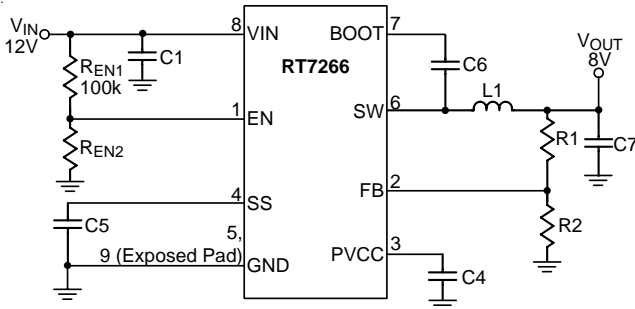


Figure 3. The Resistors can be Selected to Set IC Lockout Threshold

## Output Voltage Setting

The resistive divider allows the FB pin to sense the output voltage as shown in Figure 4.

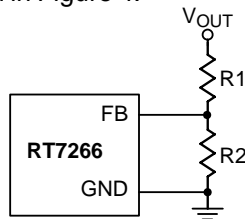


Figure 4. Output Voltage Setting

The output voltage is set by an external resistive divider according to the following equation. It is recommended to use 1% tolerance or better divider resistors.

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

Where  $V_{FB}$  is the feedback reference voltage (0.765V typ.).

## Under Voltage Lockout Protection

The RT7266 has Under Voltage Lockout Protection (UVLO) that monitors the voltage of PVCC pin. When the  $V_{PVCC}$  voltage is lower than UVLO threshold voltage, the RT7266 will be turned off in this state. This is non-latch protection.

## Over Temperature Protection

The RT7266 equips an Over Temperature Protection (OTP) circuitry to prevent overheating due to excessive power

dissipation. The OTP will shut down switching operation when junction temperature exceeds 150°C. Once the junction temperature cools down by approximately 20°C the main converter will resume operation. To maintain continuous operation maximum, the junction temperature should be prevented from rising above 150°C.

## Inductor Selection

The inductor value and operating frequency determine the ripple current according to a specific input and an 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  $\Delta I_L = 0.2(I_{MAX})$  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 :

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

## C<sub>IN</sub> and C<sub>OUT</sub> 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 and 0.1μF low ESR ceramic capacitors are recommended.

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. 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 requirements.

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.

### External Bootstrap Diode

Connect a 0.1 $\mu$ F low ESR ceramic capacitor between the BOOT and SW pins. 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 the 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 1N4148 or BAT54. The external 5V can be a 5V fixed input from system or a 5V output of the RT7266. Note that the external boot voltage must be lower than 5.5V

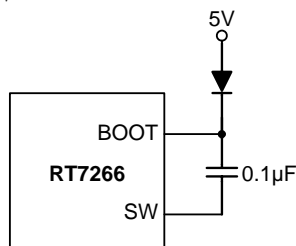


Figure 5. External Bootstrap Diode

### PVCC Capacitor Selection

Decouple with a 1 $\mu$ F ceramic capacitor. X7R or X5R grade dielectric ceramic capacitors are recommended for their stable temperature characteristics.

### Over Current Protection

When the output shorts to ground, the inductor current decays very slowly during a single switching cycle. A over current detector is used to monitor inductor current to prevent current runaway. The over current detector monitors the voltage between SW and GND during the low-side MOS turn-on state. This is cycle-by-cycle protection. The over current detector also supports temperature compensated.

### Thermal Considerations

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

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

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

For recommended operating condition specifications, the maximum junction temperature is 125°C. The junction to ambient thermal resistance,  $\theta_{JA}$ , is layout dependent. For SOP-8 (Exposed Pad) packages, the thermal resistance,  $\theta_{JA}$ , is 75°C/W on a standard JEDEC 51-7 four-layer thermal test board. The maximum power dissipation at  $T_A = 25^\circ\text{C}$  can be calculated by the following formulas :

$$P_{D(MAX)} = (125^\circ\text{C} - 25^\circ\text{C}) / (75^\circ\text{C/W}) = 1.333\text{W for SOP-8 (Exposed Pad) package}$$

The maximum power dissipation depends on the operating ambient temperature for fixed  $T_{J(MAX)}$  and thermal resistance,  $\theta_{JA}$ . The derating curves in Figure 6 allow the designer to see the effect of rising ambient temperature on the maximum power dissipation.

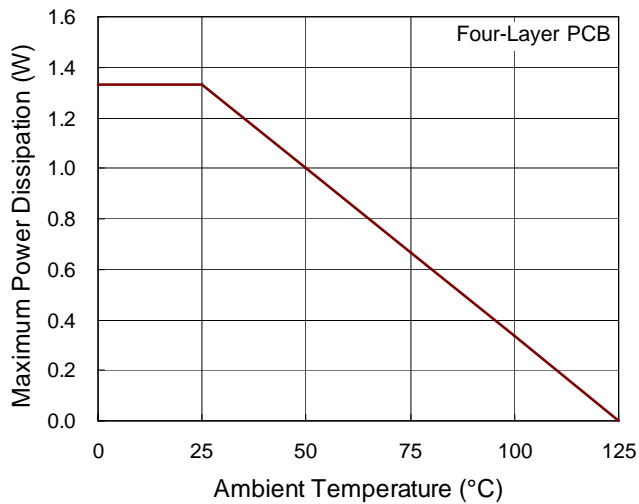


Figure 6. Derating Curve of Maximum Power Dissipation

## Layout Consideration

Follow the PCB layout guidelines for optimal performance of the RT7266

- ▶ 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).
- ▶ SW node is with high frequency voltage swing and should be kept at small area. Keep sensitive components away from the SW node to prevent stray capacitive noise pickup.
- ▶ Connect feedback network behind the output capacitors. Keep the loop area small. Place the feedback components near the RT7266.
- ▶ The GND and Exposed Pad should be connected to a strong ground plane for heat sinking and noise protection.

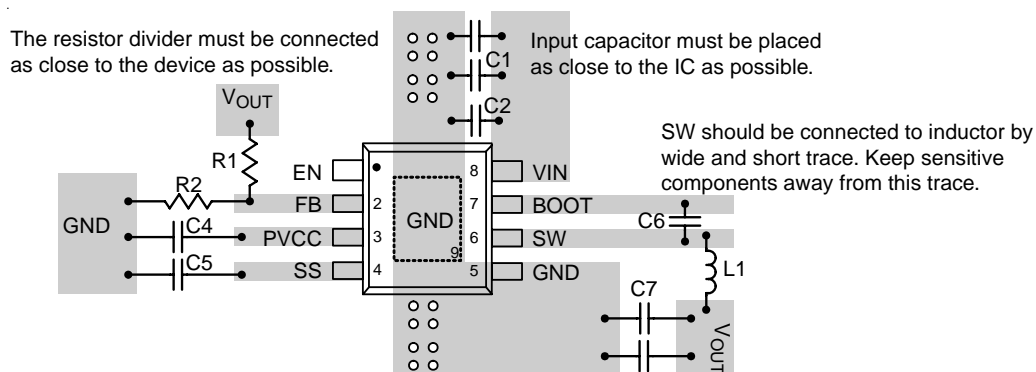
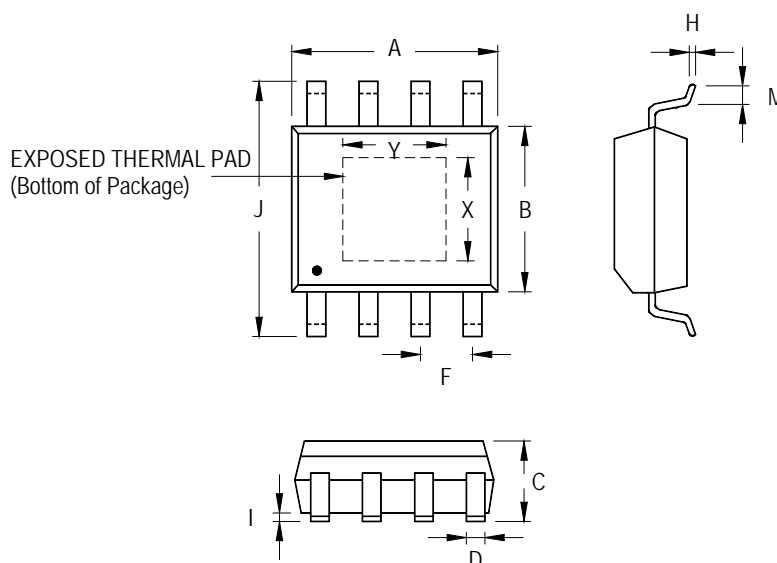


Figure 7. PCB Layout Guide

# 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**

## Richtek Technology Corporation

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