General Description

The EC3286 is a monolithic synchronous buck regulator. The device integrates two 90mΩ MOSFETs, and provides 3A of continuous load current over a wide input voltage of 4.75V to 32V. Current mode control provides fast transient response and cycle-by-cycle current limit.
An adjustable soft-start prevents inrush current at turn-on, and in shutdown mode the supply current drops to 1μA.The EC3286 regulates the output voltage in automatic PSM/PWM mode operation, depending on the output current, for high efficiency operation over light to full load current.
This device, available in an SOP-8(Exposed PAD) package, provides a very compact solution with minimal external components.

Features

- 3A Output Current
- Wide 4.75V to 32V Operating Input Range
- Integrated 90mΩ Power MOSFET Switches
- Output Adjustable from 0.923V to 30V
- Up to 93% Efficiency
- Pulse Save Mode(PSM)/PWM Mode Operation
- Programmable Soft-Start
- Stable with Low ESR Ceramic Output Capacitors
- Fixed 340KHz Frequency
- Cycle-by-Cycle Over Current Protection
- Input Under Voltage Lockout

Applications

- Distributed Power Systems
- Networking Systems
- FPGA, DSP, ASIC Power Supplies
- Green Electronics/ Appliances
- Notebook Computers

Package Types

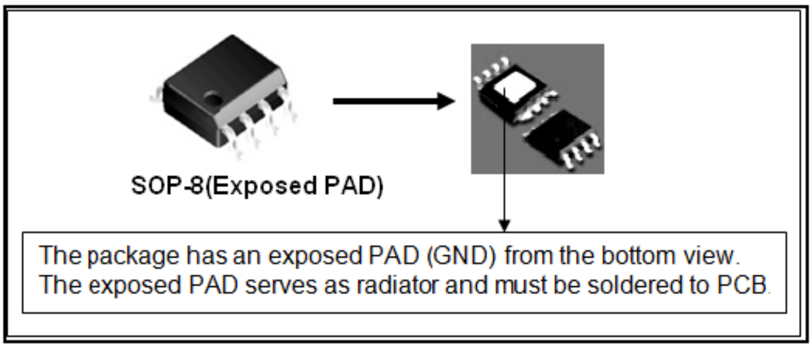


Figure 1. Package Types of EC3286

Pin Configurations

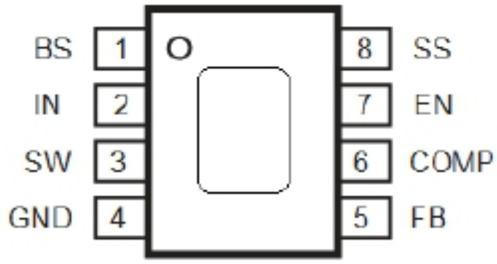
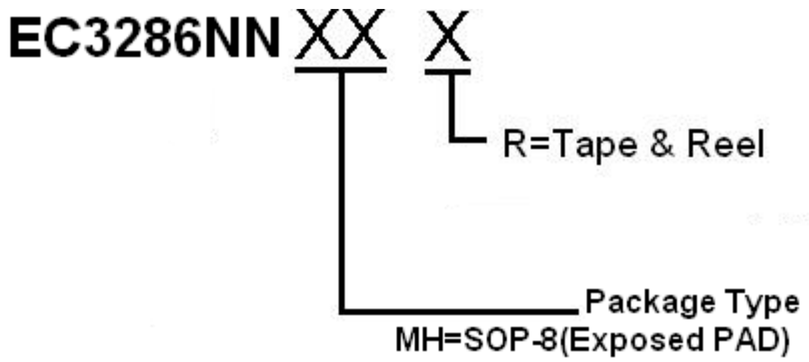


Figure 2 Pin Configuration of EC3286(Top View)

Pin Description

Pin Number	Pin Name	Description
1	BS	High-Side Gate Drive Boost Input. BS supplies the drive for the high-side N-Channel MOSFET switch. Connect a 0.01μF or greater capacitor from SW to BS to power the high side switch.
2	IN	Power Input. IN supplies the power to the IC, as well as the step-down converter switches. Drive IN with a 4.75V to 32V power source. Bypass IN to GND with a suitably large capacitor to eliminate noise on the input to the IC. See *Input Capacitor*.
3	SW	Power Switching Output. SW is the switching node that supplies power to the output. Connect the output LC filter from SW to the output load. Note that a capacitor is required from SW to BS to power the high-side switch.
4	GND	Ground.
5	FB	Feedback Input. FB senses the output voltage to regulate that voltage. Drive FB with a resistive voltage divider from the output voltage. The feedback threshold is 0.923V. See *Setting the Output Voltage*.
6	COMP	Compensation Node. COMP is used to compensate the regulation control loop. Connect a series RC network from COMP to GND to compensate the regulation control loop. In some cases, an additional capacitor from COMP to GND is required. See *Compensation Components.*
7	EN	Enable Input. EN is a digital input that turns the regulator on or off. Drive EN high to turn on the regulator, drive it low to turn it off. Pull up with 100kΩ 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 15ms. To disable the soft-start feature, leave SS unconnected.

Ordering Information



Part Number	Package	Marking	Marking Information
EC3286NNMHR	SOP-8L (Exposed PAD)	EC3286 LLLLL YYWWT	LLLLL is Lot Number YYWW is date code T is internal tracking code

Function Block

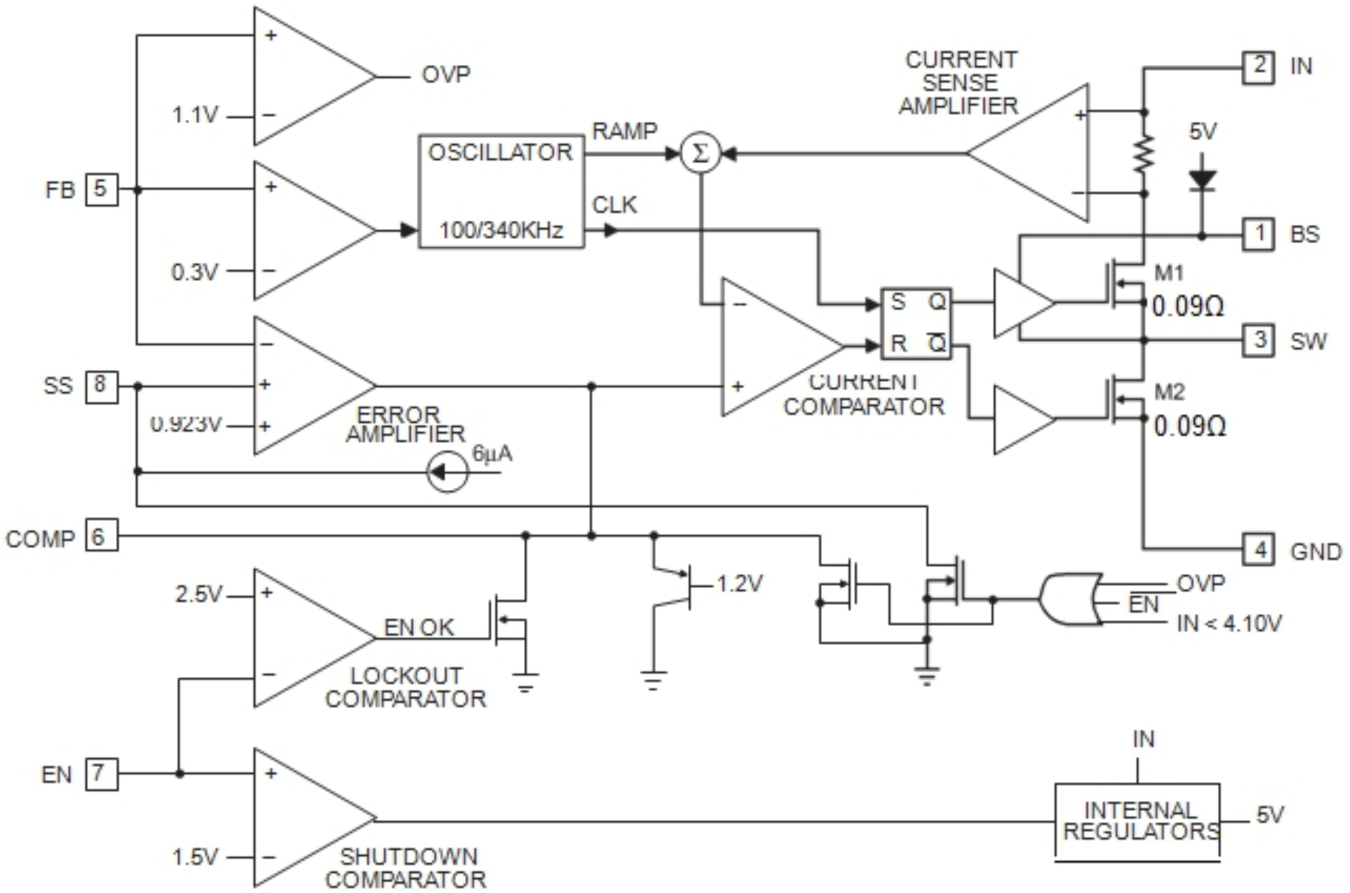


Figure 3 Function Block Diagram of EC3286

Absolute Maximum Ratings

Parameter	Symbol	Value	Unit
Supply Voltage	V_{IN}	-0.3 to 32	V
Switch Node Voltage	V_{SW}	30	V
Boost Voltage	V_{BS}	V_{SW} – 0.3V to V_{SW}+6V	V
Output Voltage	V_{OUT}	0.923V to 30	V
All Other Pins		–0.3V to +6V	V
Operating Junction Temperature	T_J	150	ºC
Storage Temperature	T_{STG}	-65 to 150	ºC
Lead Temperature (Soldering, 10 sec)	T_{LEAD}	260	ºC
ESD (HBM)		2000	V
MSL		Level3	
Thermal Resistance-Junction to Ambient	$R_{\theta JA}$	50	ºC / W
Thermal Resistance-Junction to Case	$R_{\theta JC}$	10	ºC / W

Electrical Characteristics

VIN = 12V, Ta = 25℃ unless otherwise specified.

Parameters	Symbol	Test Condition	Min.	Typ.	Max.	Unit
Shutdown Supply Current		VEN = 0V		1	3.0	μA
Supply Current		VEN = 2.0V; VFB = 1.0V		1.3	1.5	mA
Feedback Voltage	VFB	4.75V ≤ VIN ≤ 23V	0.900	0.923	0.946	V
Feedback Overvoltage Threshold				1.1		V
Error Amplifier Voltage Gain *	AEA			400		V/V
Error Amplifier Transconductance	GEA	∆IC = ±10μA		800		μA/V
High-Side Switch On Resistance *	RDS(ON)1			90		mΩ
Low-Side Switch On Resistance *	RDS(ON)2			90		mΩ
High-Side Switch Leakage Current		VEN = 0V, VSW = 0V			10	μA
Upper Switch Current Limit		Minimum Duty Cycle	4.0	5.8		A
Lower Switch Current Limit		From Drain to Source		0.9		A
COMP to Current Sense Transconductance	GCS			4.8		A/V
Oscillation Frequency	Fosc1			340		KHz
Short Circuit Oscillation Frequency	Fosc2	VFB = 0V		100		KHz
Maximum Duty Cycle	DMAX	VFB = 1.0V		90		%
Minimum On Time *				220		ns
EN Shutdown Threshold Voltage		VEN Rising	1.1	1.5	2.0	V
EN Shutdown Threshold Voltage Hysteresis				210		mV
EN Lockout Threshold Voltage			2.2	2.5	2.7	V
EN Lockout Hysterisis				210		mV

Electrical Characteristics

VIN = 12V, Ta = 25℃ unless otherwise specified.

Parameters	Symbol	Test Condition	Min.	Typ.	Max.	Unit
Input Under Voltage Lockout Threshold		V_{IN} Rising	3.80	4.10	4.40	V
Input Under Voltage Lockout Threshold Hysteresis				210		mV
Soft-Start Current		V_{SS} = 0V		6		μA
Soft-Start Period		C_{SS} = 0.1μF		15		ms
Thermal Shutdown *				160		°C

Typical Performance Characteristics

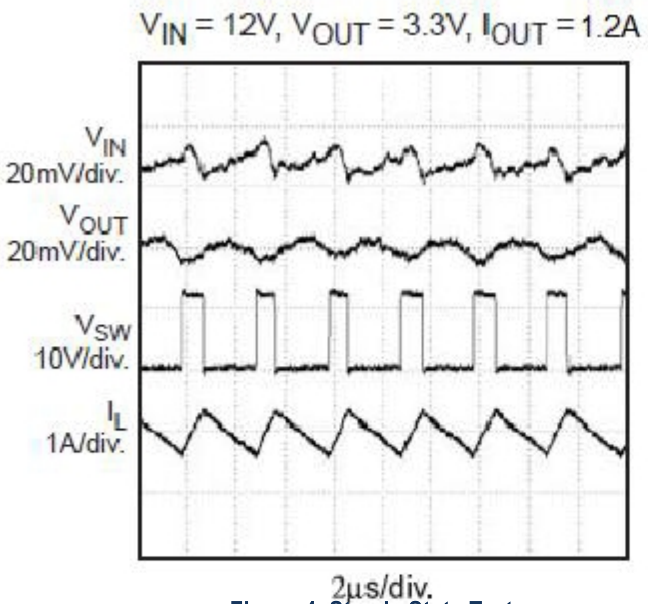


Figure 4. Steady State Test

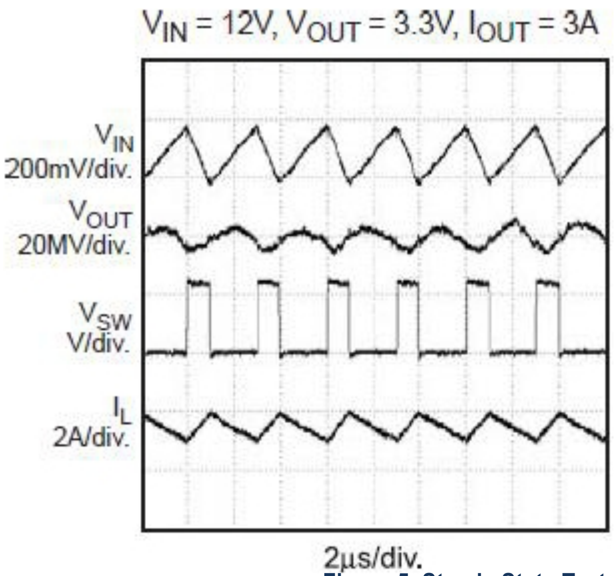


Figure 5. Steady State Test

Typical Performance Characteristics(Cont.)

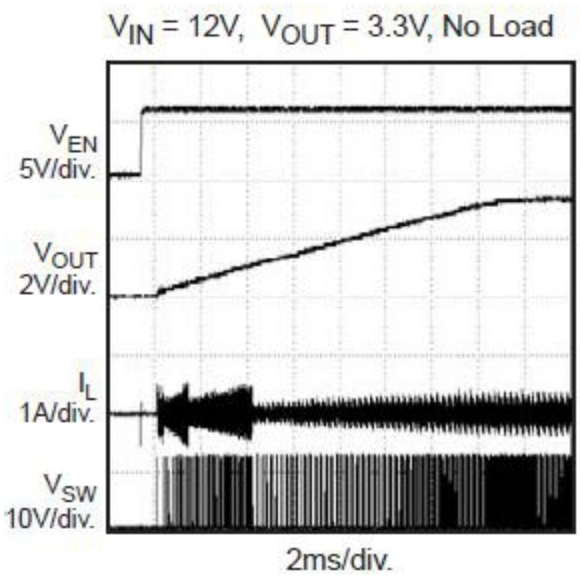


Figure 6. Startup through Enable

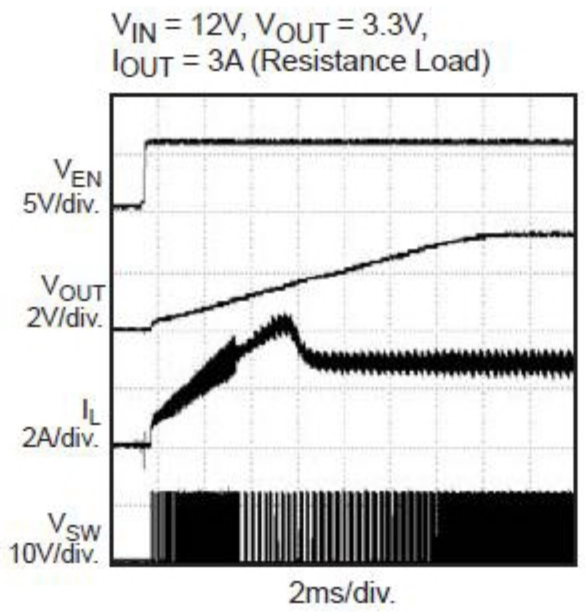


Figure 7. Startup through Enable

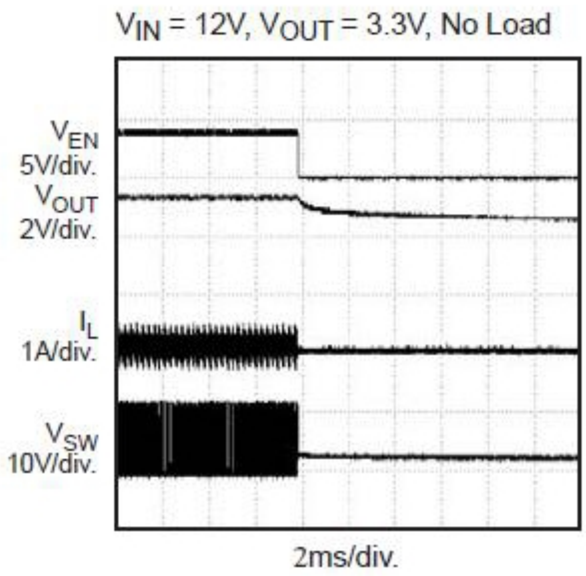


Figure 8. Shutdown through Enable

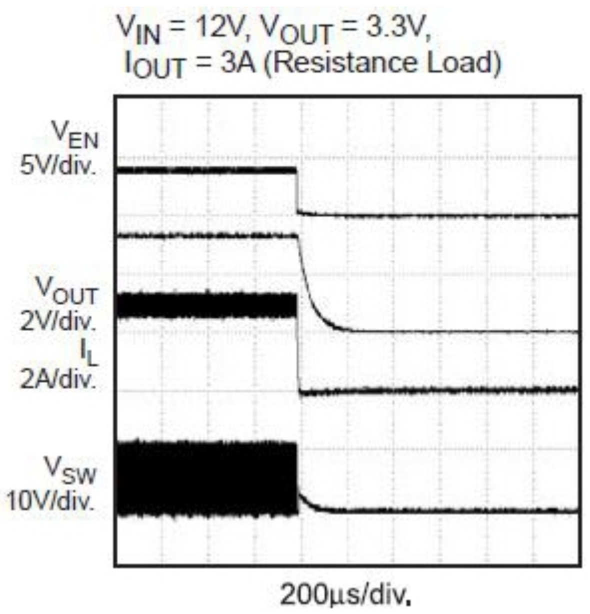


Figure 9. Shutdown through Enable

Typical Performance Characteristics(Cont.)

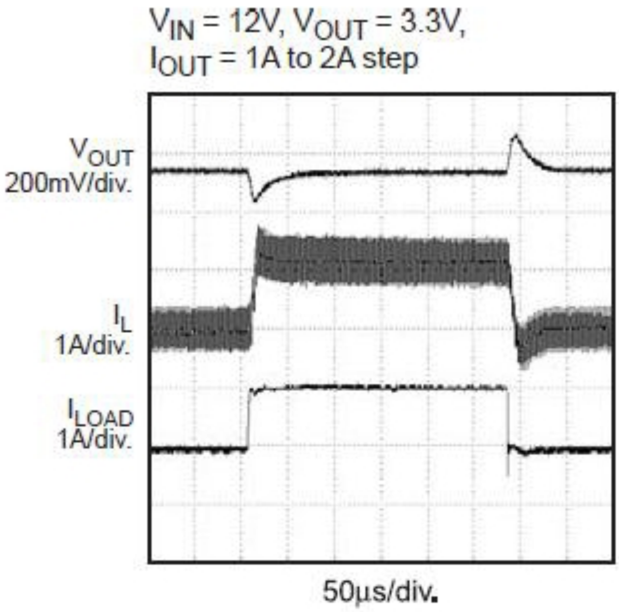


Figure 10. Load Transient Test

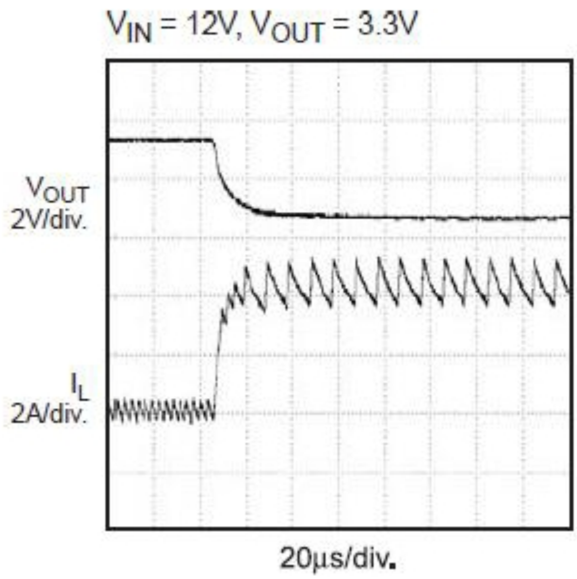


Figure 11. Short Circuit Test

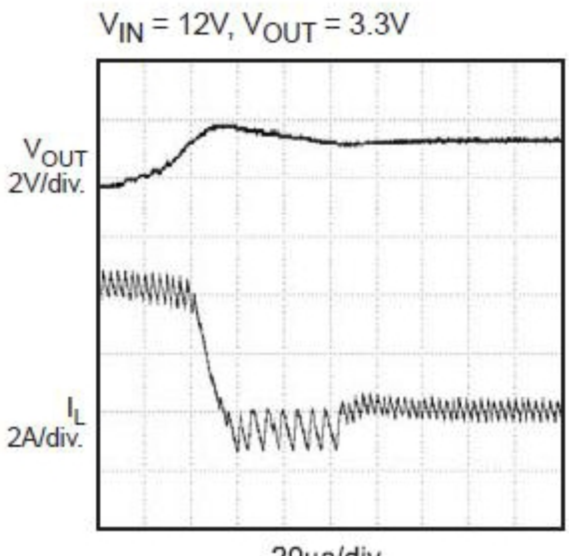
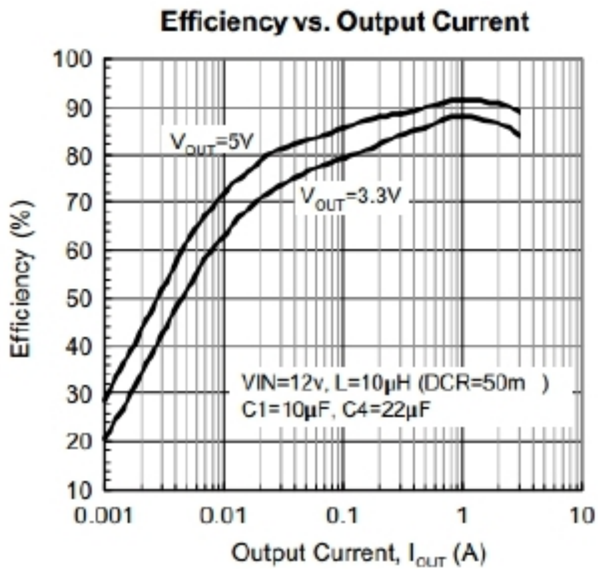


Figure 12. Short Circuit Recovery



Typical Application Circuit

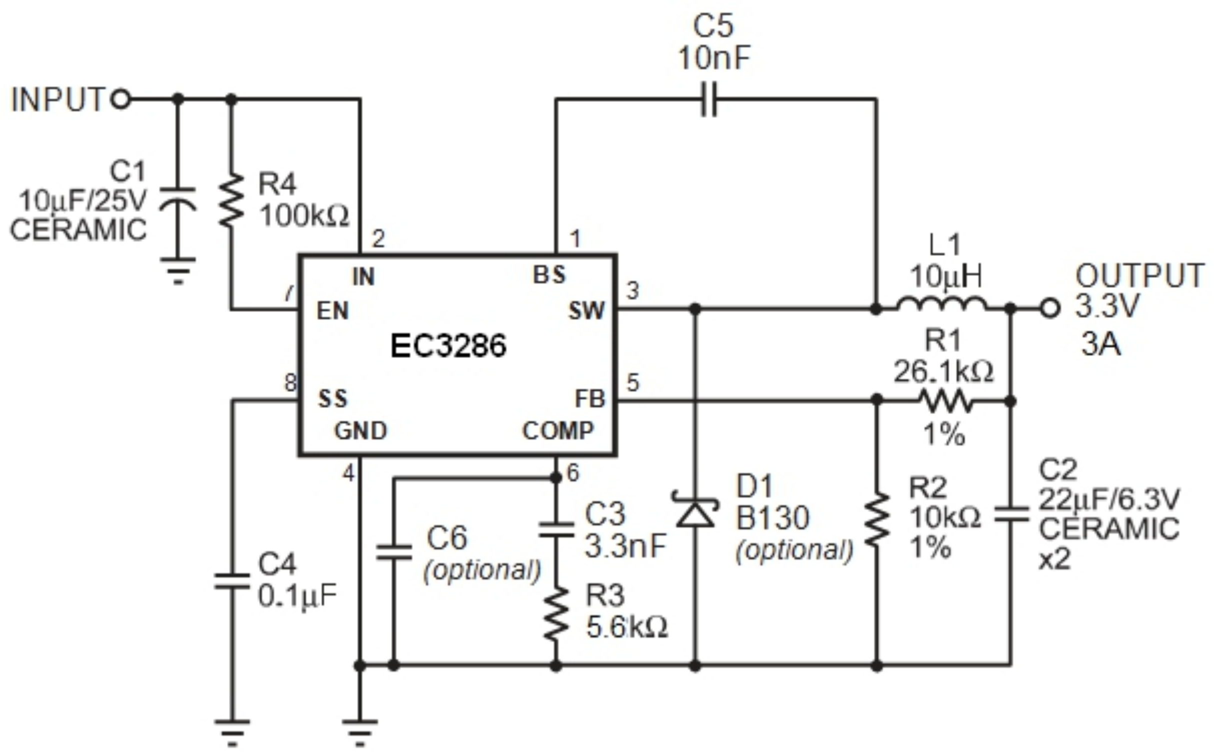


Fig13. EC3286 with 3.3V Output, 22µF/6.3V Ceramic Output Capacitor

Function Description

PWM Operation

The EC3286 utilizes DEM control to improve light load efficiency. Depending on the load current, the controller automatically operates in Diode Emulation Mode (DEM) or in Continuous Conduction Mode (CCM) with fixed frequency PWM.
At light load condition, the EC3286 automatically operates in diode emulation mode to reduce switching frequency to improve efficiency. As the output current decreases from heavy load condition, the inductor current decreases, and eventually the inductor valley current decreases to zero, which is the boundary between continuous conduction mode and discontinuous conduction mode. By emulating the behavior of diodes, the low side MOSFET allows only partial negative current to flow when the inductor freewheeling current becomes negative. As the load current further decreases, it takes longer and longer to discharge the output capacitor to the level that allows the next UGATE on-time to begin. When the output current increases from light load to heavy load, the switching frequency increases to the CCM value as the inductor current reaches the continuous conduction condition. The controller will then operate in continuous conduction mode with 340kHz fixed PWM switching frequency.

Setting the Output Voltage

The output voltage is set using a resistive voltage divider from the output voltage to FB pin. The voltage divider divides the output voltage down to the feedback voltage by the ratio:

$$V_{FB} = V_{OUT}\frac{R2}{R1+R2}$$

Where V_{FB} is the feedback voltage and VOUT is the output voltage. Thus the output voltage is:

$$V_{OUT} = 0.923 \times \frac{R1+R2}{R2}$$

R2 can be as high as 100kΩ, but a typical value is 10kΩ. Using the typical value for R2, R1 is determined by:

$$R1 = 10.83 \times (V_{OUT} - 0.923)\ (k\Omega)$$

For example, for a 3.3V output voltage, R2 is 10kΩ, and R1 is 26.1kΩ.

Inductor

The inductor is required to supply constant current to the output load while being driven by the switched input voltage. A larger value inductor will result in less ripple current that will result in lower output ripple voltage. However ,the larger value inductor will have a larger physical size, higher series resistance, and/or lower saturation current. A good rule for determining the inductance to use is to allow the peak-to-peak ripple current in the inductor to be approximately 30% of the maximum switch current limit. Also, make sure that the peak inductor current is below the maximum switch current limit. The inductance value can be calculated by:

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

Where V_{OUT} is the output voltage, VIN is the input voltage, f_S is the switching frequency, and ΔIL is the peak-to-peak inductor ripple current.
Choose an inductor that will not saturate under the maximum inductor peak current. The peak inductor current can be calculated by:

$$I_{LP} = I_{LOAD} + \frac{V_{OUT}}{2 \times f_S \times L} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

Where I_{LOAD} is the load current.
The choice of which style inductor to use mainly depends on the price vs. size requirements and any EMI requirements.

Optional Schottky Diode

During the transition between high-side switch and low-side switch, the body diode of the low-side power MOSFET conducts the inductor current. The forward voltage of this body diode is high. An optional Schottky diode may be paralleled between the SW pin and GND pin to improve overall efficiency. Table 1 lists example Schottky diodes and their Manufacturers.

Part Number	Voltage/Current	Vendor
B130	30V, 1A	Diodes, Inc.
SK13	30V, 1A	Diodes, Inc.
MBRS130	30V, 1A	International Rectifier

Input Capacitor

The input current to the step-down converter is discontinuous, therefore a capacitor is required to supply the AC current to the step-down converter while maintaining the DC input voltage. Use low ESR capacitors for the best performance. Ceramic capacitors are preferred, but tantalum or low-ESR electrolytic capacitors may also suffice. Choose X5R or X7R dielectrics when using ceramic capacitors. Since the input capacitor (C1) absorbs the input switching current it requires an adequate ripple current rating. The RMS current in the input capacitor can be estimated by:

$$I_{C1} = I_{LOAD} \times \sqrt{\frac{V_{OUT}}{V_{IN}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)}$$

The worst-case condition occurs at VIN = $2V_{OUT}$,where $I_{C1} = I_{LOAD/2}$. For simplification, choose the input capacitor whose RMS current rating greater than half of the maximum load current. The input capacitor can be electrolytic, tantalum or ceramic. When using electrolytic or tantalum capacitors, a small, high quality ceramic capacitor, i.e. 0.1μF, should be placed as close to the IC as possible. When using ceramic capacitors, make sure that they have enough capacitance to provide sufficient charge to prevent excessive voltage ripple at input. The input voltage ripple for low ESR capacitors can be estimated by:

$$\Delta V_{IN} = \frac{I_{LOAD}}{C1 \times f_S} \times \frac{V_{OUT}}{V_{IN}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

Where C1 is the input capacitance value.

Output Capacitor

The output capacitor is required to maintain the DC output voltage. Ceramic, tantalum, or low ESR electrolytic capacitors are recommended. Low ESR capacitors are preferred to keep the output voltage ripple low. The output voltage ripple can be estimated by:

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_S \times L} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \times \left(R_{ESR} + \frac{1}{8 \times f_S \times C2}\right)$$

Where C2 is the output capacitance value and RESR is the Equivalent series resistance (ESR) value of the output capacitor.

In the case of ceramic capacitors, the impedance at the switching frequency is dominated by the capacitance. The output voltage ripple is mainly caused by the capacitance. For simplification, the output voltage ripple can be estimated by:

$$\Delta V_{OUT} = \frac{V_{OUT}}{8 \times f_S^{2} \times L \times C2} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

In the case of tantalum or electrolytic capacitors, the ESR dominates the impedance at the switching frequency. For simplification, the output ripple can be approximated to:

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_S \times L} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \times R_{ESR}$$

The characteristics of the output capacitor also affect the stability of the regulation system. The EC3286 can be optimized for a wide range of capacitance and ESR values

Compensation Components

EC3286 employs current mode control for easy compensation and fast transient response. The system stability and transient response are controlled through the COMP pin. COMP pin is the output of the internal transconductance error amplifier. A series capacitor-resistor combination sets a pole-zero combination to control the characteristics of the control system. The DC gain of the voltage feedback loop is given by:

$$A_{VDC} = R_{LOAD} \times G_{CS} \times A_{VEA} \times \frac{V_{FB}}{V_{OUT}}$$

Where A_{VEA} is the error amplifier voltage gain; G_{CS} is the current sense transconductance and R_{LOAD} is the load resistor value.

The system has two poles of importance. One is due to the compensation capacitor (C3) and the output resistor of the error amplifier, and the other is due to the output capacitor and the load resistor. These poles are located at:

$$f_{P1} = \frac{G_{EA}}{2\pi \times C3 \times A_{VEA}}$$

$$f_{P2} = \frac{1}{2\pi \times C2 \times R_{LOAD}}$$

Where G_{EA} is the error amplifier transconductance.

The system has one zero of importance, due to the compensation capacitor (C3) and the compensation resistor (R3). This zero is located at:

$$f_{Z1} = \frac{1}{2\pi \times C3 \times R3}$$

The system may have another zero of importance, if the output capacitor has a large capacitance and/or a high ESR value. The zero, due to the ESR and capacitance of the output capacitor, is located at:

$$f_{ESR} = \frac{1}{2\pi \times C2 \times R_{ESR}}$$

In this case (as shown in Figure 14), a third pole set by the compensation capacitor (C6) and the compensation resistor (R3) is used to compensate the effect of the ESR zero on the loop gain. This pole is located at:

$$f_{P3} = \frac{1}{2\pi \times C6 \times R3}$$

The goal of compensation design is to shape the converter transfer function to get a desired loop gain. 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 instability. A good rule of thumb is to set the crossover frequency below one-tenth of the switching frequency. To optimize the compensation components, the following procedure can be used.

1. Choose the compensation resistor (R3) to set the desired crossover frequency.

Determine the R3 value by the following equation:

$$R3 = \frac{2\pi \times C2 \times f_C}{G_{EA} \times G_{CS}} \times \frac{V_{OUT}}{V_{FB}} < \frac{2\pi \times C2 \times 0.1 \times f_S}{G_{EA} \times G_{CS}} \times \frac{V_{OUT}}{V_{FB}}$$

Where f_C is the desired crossover frequency which is typically below one tenth of the switching frequency.

2. Choose the compensation capacitor (C3) to achieve the desired phase margin. For applications with typical inductor values, setting the compensation zero, fZ1, below one-forth of the crossover frequency provides sufficient phase margin. Determine the C3 value by the following equation:

$$C3 > \frac{4}{2\pi \times R3 \times f_C}$$

Where R3 is the compensation resistor.

3. Determine if the second compensation capacitor (C6) is required. It is required if the ESR zero of the output capacitor is located at less than half of the switching frequency, or the following relationship is valid:

$$\frac{1}{2\pi \times C2 \times R_{ESR}} < \frac{f_S}{2}$$

If this is the case, then add the second compensation capacitor (C6) to set the pole fP3 at the location of the ESR zero. Determine the C6 value by the equation:

$$C6 = \frac{C2 \times R_{ESR}}{R3}$$

External Bootstrap Diode

An external bootstrap diode may enhance the efficiency of the regulator, the applicable conditions of external BST diode are: V_{OUT}=5V or 3.3V; and Duty cycle is high:

$$D = \frac{V_{OUT}}{V_{IN}} > 65\%$$

In these cases, an external BST diode is recommended from the output of the voltage regulator to BST pin, as shown in Fig.14

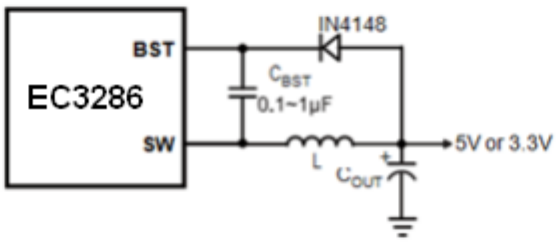
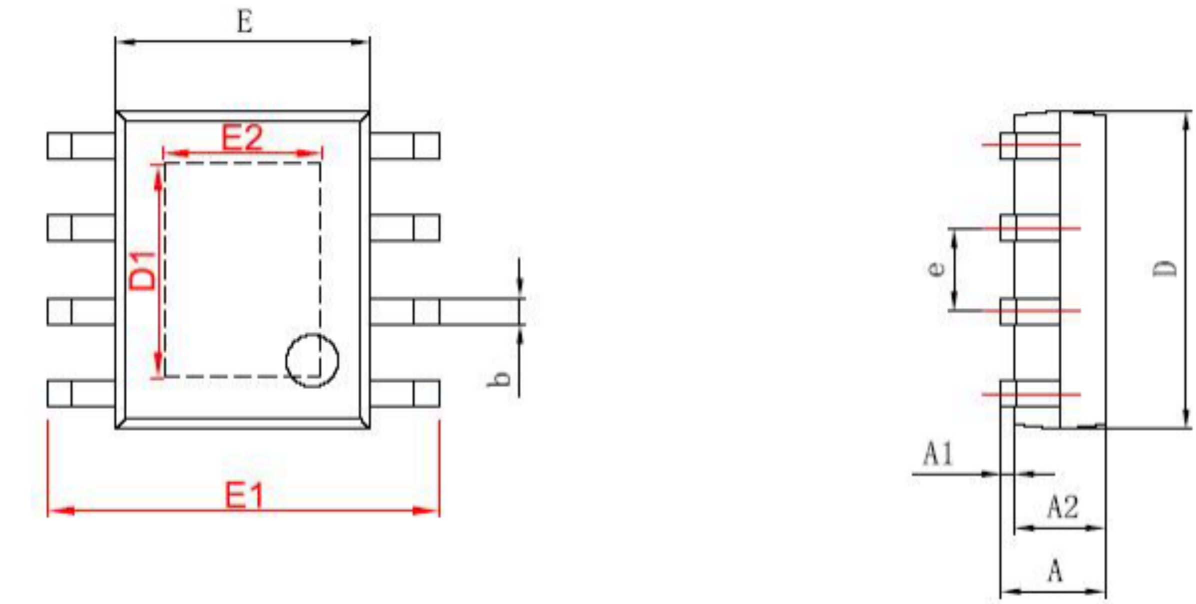


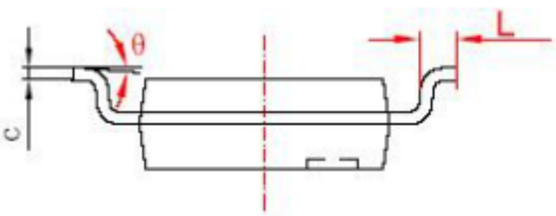
Figure14.Add Optional External Bootstrap Diode to Enhance Efficiency

The recommended external BST diode is IN4148, and the BST cap is 0.1~1μF.

Package Information

SOP-8(Exposed PAD) Package Outline Dimensions





	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	1.350	1.750	0.053	0.069
A1	0.050	0.150	0.004	0.010
A2	1.350	1.550	0.053	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.006	0.010
D	4.700	5.100	0.185	0.200
D1	3.202	3.402	0.126	0.134
E	3.800	4.000	0.150	0.157
E1	5.800	6.200	0.228	0.244
E2	2.313	2.513	0.091	0.099
e	1.270(BSC)		0.050(BSC)	
L	0.400	1.270	0.016	0.050
θ	0°	8°	0°	8°