General Description

The EC3293 is a high-frequency, synchronous, rectified, step-down, switch-mode converter with internal power MOSFETs. It offers a very compact solution to achieve a 3A continuous output current over a wide input supply range, with excellent load and line regulation.
The EC3293 has synchronous-mode operation for higher efficiency over the output current-load range.
Current-mode operation provides fast transient response and eases loop stabilization.
Protection features include over-current protection and thermal shutdown.
The EC3293 requires a minimal number of readily available, standard external components and is available in a space-saving SOP-8L(Exposed Pad) package.

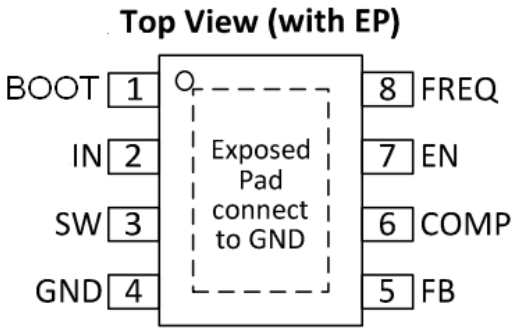
Features

- 4.75V to 18V input voltage
- Output adjustable from 0.923V to 15V
- Output current up to 3A
- Integrated 105mΩ/85mΩ power MOSFET switches
- Shutdown current 3μA typical
- Efficiency up to 95%
- Programmable switching frequency up to 1.5MHz
- Internal soft start
- Over current protection and Hiccup
- Over temperature protection
- RoHS Compliant and 100% Lead (Pb) Free

Applications

- Distributed power systems
- Networking systems
- FPGA, DSP, ASIC power supplies
- Notebook computers
- Green electronics or appliance

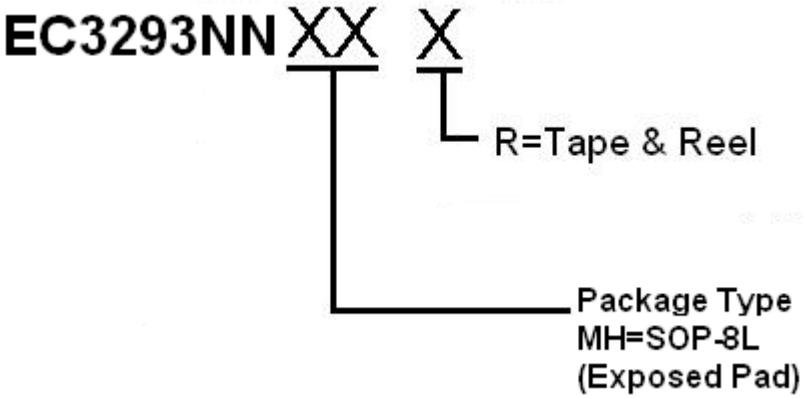
Pin Assignments



Pin Description

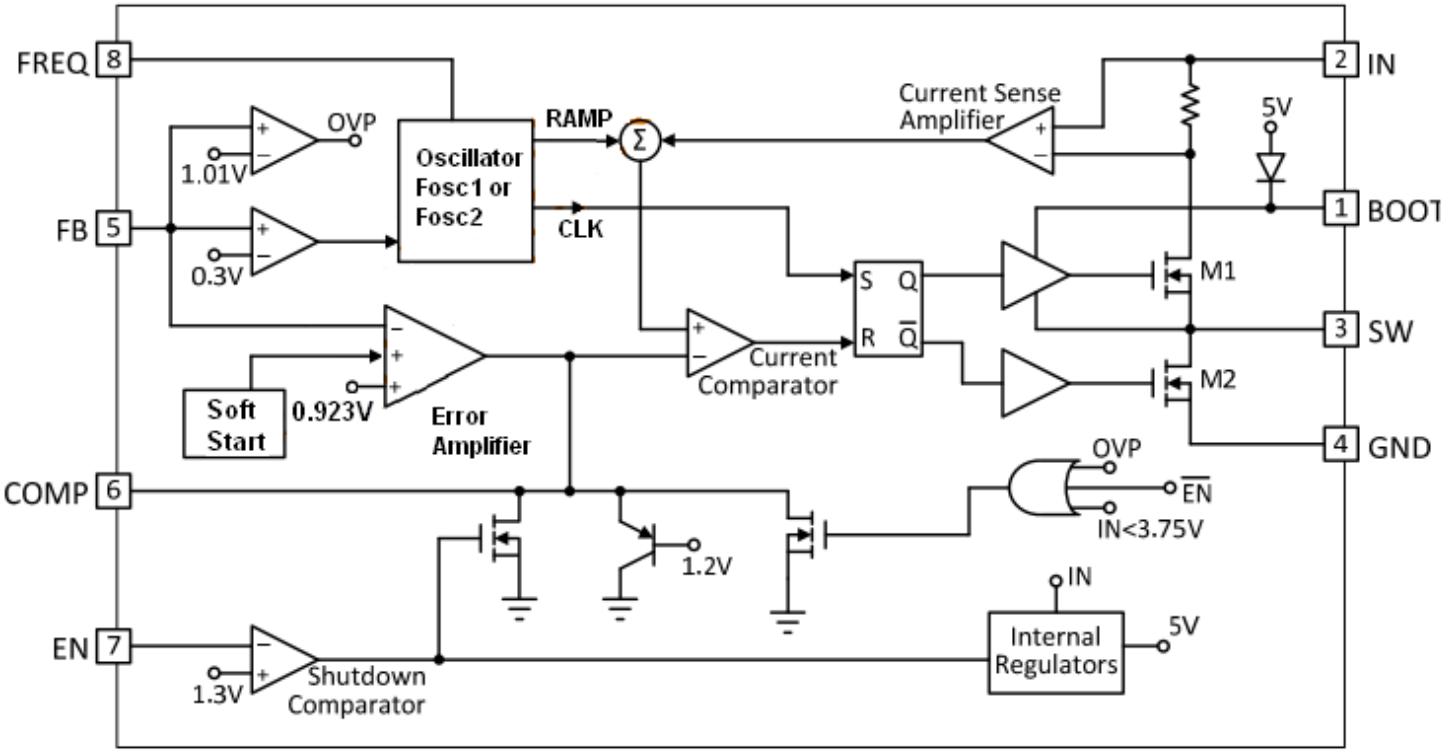
Pin	Symbol	Description
1	BOOT	High-side Gate drive boost input.
2	IN	Power Input
3	SW	Power Switching Output.
4	GND	Ground.
5	FB	Feedback input.
6	COMP	Compensation node
7	EN	Enable Input.
8	FREQ	Switching Frequency Program Input.

Ordering Information

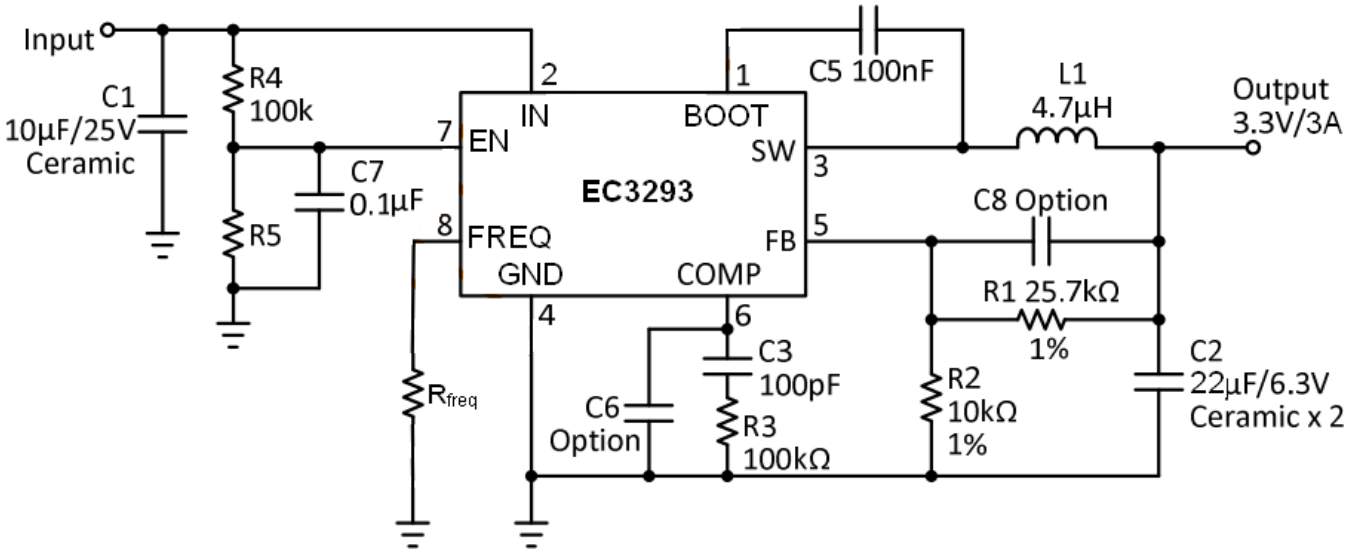


Part Number	Package	Marking	Marking Information
EC3293NNMHR	SOP-8L (Exposed Pad)	EC3293 LLLLL YYWWT	1. LLLLL：Lot No 2. YYWW：Date Code 3. T：Internal Tracking Code

Functional Block Diagram



Typical Application Circuit



Note: R5 and C7 are optional.
Details please see the DVT report.

Absolute Maximum Ratings

Supply Voltage V_{IN} ..... –0.3V to +20V
Switch Node V_{SW} ..... –0.3V to V_{IN}+0.3V
Boost V_{BOOT} ..... V_{SW}–0.3V to V_{SW}+6V
All Other Pins ..... –0.3V to +6V
Junction Temperature ..... +150°C
Lead Temperature ..... +260°C
Storage Temperature Range ..... –65°C to +150°C

CAUTION: Stresses above those listed in "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress only rating and operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied.

Recommended Operating Conditions

Supply Voltage V_{IN} ..... 4.75V to 18V
Output Voltage V_{OUT} ..... 0.923V to V_{IN}–3V
Operating Temperature Range ..... –40°C to +125°C

Package Thermal Characteristics

Thermal Resistance, θ_{JA} ..... 50°C/W
Thermal Resistance, θ_{JC} ..... 10°C/W

Electrical Characteristics

(T_A = +25°C, V_{IN} = +12V, unless otherwise noted.)

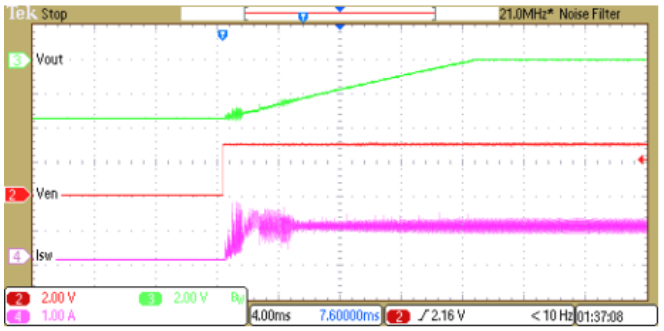
PARAMETER	Symbol	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Supply Voltage	V_{IN}		4.75		18	V
Output Voltage	V_{OUT}		0.923		15	V
Shutdown Supply Current		V_{EN} = 0V		3	6	μA
Supply Current		V_{EN} = 2.0V, V_{FB} = 1.0V		0.09		mA
Feedback Voltage	V_{FB}	4.75V ≤ V_{IN} ≤ 18V	0.9	0.923	0.946	V
Feedback Over-voltage Threshold				1.01		V
Error Amplifier Voltage Gain *	A_{EA}			1000		V/V
Error Amplifier Transconductance	G_{EA}	ΔIC = ±10μA		120		μA/V
High-Side Switch-On Resistance *	$R_{DS(ON)1}$			105		mΩ
Low-side Switch-On Resistance *	$R_{DS(ON)2}$			85		mΩ
High-Side Switch Leakage Current		V_{EN} = 0V, V_{SW} = 0V, T_A = +125°C			10	μA
Upper Switch Current Limit		Minimum Duty Cycle	3.7	4.3		A
Lower Switch Current Limit		From Drain to Source		0		A
COMP to Current Sense Transconducta	G_{CS}			5.6		A/V
Oscillation Frequency	F_{OSC1}	Rfreq = 175K	400	500	600	KHz
Short Circuit Oscillation Frequency	F_{OSC2}	Rfreq = 175K, V_{FB} = 0	100	125	150	KHz
Maximum Duty Cycle	D_{MAX}	V_{FB} = 0.5V		90		%
Minimum On Time *				120		ns
EN Falling Threshold Voltage		V_{EN} Falling		1.22		V
EN Rising Threshold Voltage		V_{EN} Rising		1.32		V
Input Under Voltage Lockout Threshold		V_{IN} Rising		3.75		V
Input Under Voltage Lockout Threshold Hysteresis				200		mV
Soft-Start Period		Fsw = 500KHz		16		ms
Thermal Shutdown *				150		°C

* Guaranteed by design, not tested.

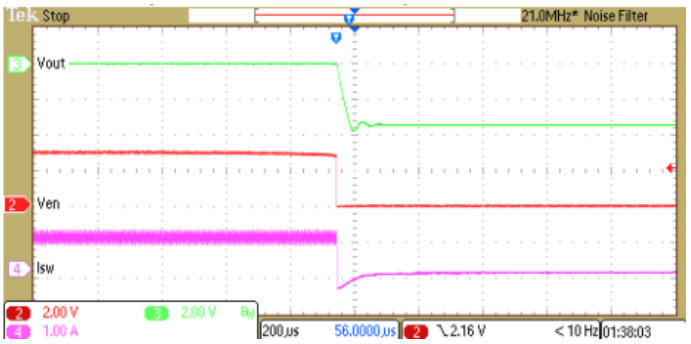
Typical Characteristics

V_{IN} = 12V, V_O = 3.3V, L1 = 4.7μH, C1 = 10μF, C2 = 22μF x 2, T_A = +25°C, unless otherwise noted.

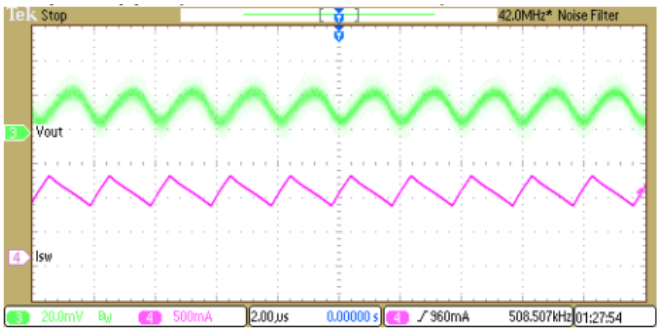
Start UP & Inrush Current 12V→3.3V (Load 1A)



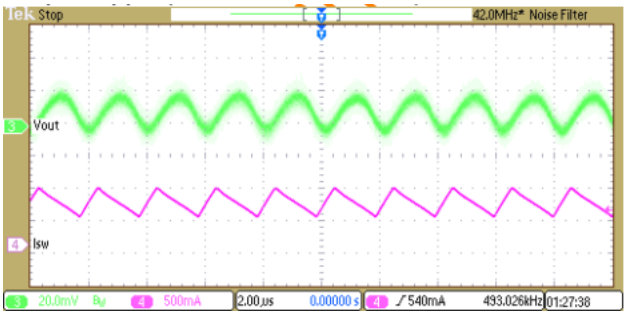
Shut Down (Iout 1A→Shut down)



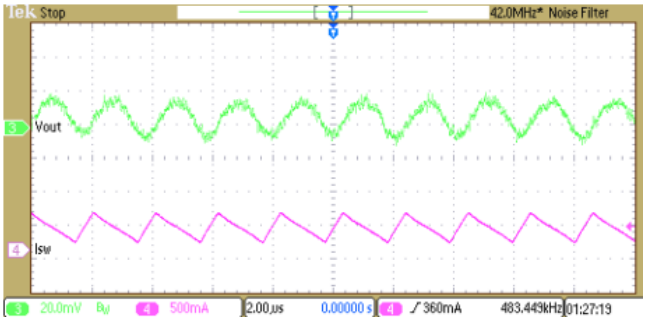
Output Ripple (12V => 3.3V, Load=3A)



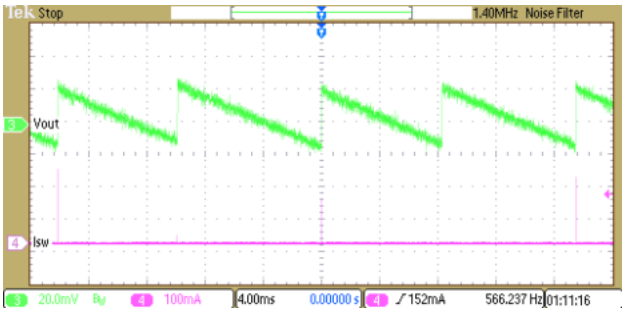
Output Ripple (12V => 3.3V, Load=2A)



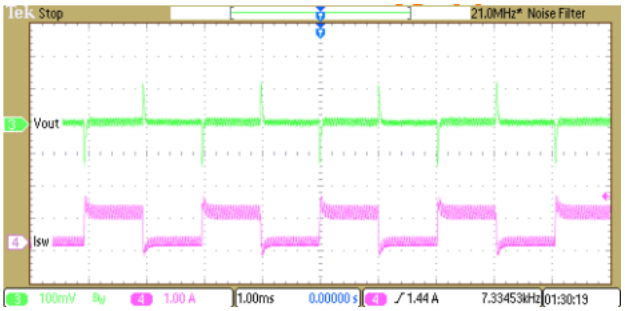
Output Ripple (12V => 3.3V, Load=1A)



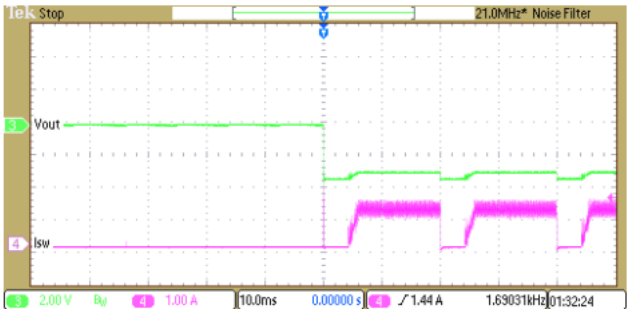
Output Ripple (12V => 3.3V, Load=0A)



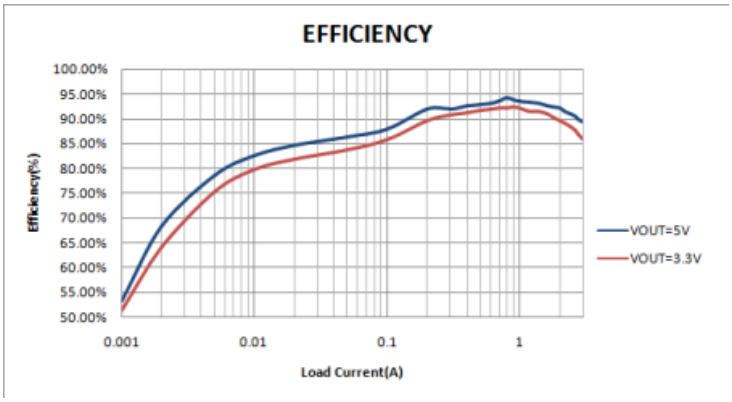
Dynamic Load(Iload=0.2A_3A Vout=3.3V)



Short Circuit Protection



Efficiency



Application Information

Overview

The EC3293 is a synchronous rectified, current-mode, step-down regulator. It regulates input voltages from 4.75V to 18V down to an output voltage as low as 0.923V, and supplies up to 3A of load current.
The EC3293 uses current-mode control to regulate the output voltage. The output voltage is measured at FB through a resistive voltage divider and amplified through the internal transconductance error amplifier. The voltage at the COMP pin is compared to the switch current measured internally to control the output voltage.
The converter uses internal N-Channel MOSFET switches to step-down the input voltage to the regulated output voltage. Since the high side MOSFET requires a gate voltage greater than the input voltage, a boost capacitor connected between SW and BOOT is needed to drive the high side gate. The boost capacitor is charged from the internal 5V rail when SW is low.
When the EC3293 FB pin exceeds 10% of the nominal regulation voltage of 0.923V, the over voltage comparator is tripped and the COMP pin is discharged to GND, forcing the high-side switch off.

Pins Description

BOOT: High-Side Gate Drive Boost Input. BOOT supplies the drive for the high-side N-Channel MOSFET switch. Connect a 0.1μF or greater capacitor from SW to BOOT to power the high side switch.

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 18V power source. Bypass IN to GND with a suitably large capacitor to eliminate noise on the input to the IC.

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 BOOT to power the high-side switch.

GND: Ground.

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.

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.

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.

FREQ: Switching Frequency Program Input. Connect a resistor from this pin to ground to set the 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:
$V_{FB} = V_{OUT} \times R2 / (R1 + R2)$
Where V_{FB} is the feedback voltage and V_{OUT} is the output voltage.
Thus the output voltage is:
$V_{OUT} = 0.923 \times (R1 + R2) / R2$
R2 can be as high as 100kΩ, but a typical value is 10kΩ.
Using the typical value for R2, R1 is determined by:
$R1 = 10.83 \times (V_{OUT} - 0.923V)$ (KΩ)

Programmable Oscillator

The EC3293 oscillating frequency is set by an external resistor, Rfreq from the FREQ pin to ground. The value of Rfreq can be calculated from:
$R_{freq}(K\Omega) = 87000/F_{OSC1}(KHz)$

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

Application Information(Cont.)

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:

$L = [V_{OUT} / (f_S \times \Delta I_L)] \times (1 - V_{OUT}/V_{IN})$

Where V_{OUT} is the output voltage, V_{IN} is the input voltage, f_S is the switching frequency, and ΔI_L 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:

$I_{LP} = I_{LOAD} + [V_{OUT} / (2 \times f_S \times L)] \times (1 - V_{OUT}/V_{IN})$

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 and Current Rating	Vendor
B130	30V, 1A	Diodes Inc.
SK13	30V, 1A	Diodes Inc.
MBRS130	30V, 1A	International Rectifier

Table 1. Diode Selection guide

Input Capacitor

The input current to the step-down converte 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:

$I_{C1} = I_{LOAD} \times [(V_{OUT}/V_{IN}) \times (1 - V_{OUT}/V_{IN})]^{1/2}$

The worst-case condition occurs at $VI_N = 2V_{OUT}$, 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:

$$\Delta V_{IN} = [I_{LOAD}/(C1 \times f_S)] \times (V_{OUT}/V_{IN}) \times (1 - V_{OUT}/V_{IN})$$

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:

$$\Delta V_{OUT} = [V_{OUT}/(f_S \times L)] \times (1 - V_{OUT}/V_{IN}) \times [R_{ESR} + 1 / (8 \times f_S \times C2)]$$

Where C2 is the output capacitance value and R_{ESR} 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:

$\Delta V_{OUT} = [V_{OUT}/(8 \times f_S^2 \times L \times C2)] \times (1 - V_{OUT}/V_{IN})$

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:

$\Delta V_{OUT} = [V_{OUT}/(f_S \times L)] \times (1 - V_{OUT}/V_{IN}) \times R_{ESR}$

The characteristics of the output capacitor also affect the stability of the regulation system. The EC3293

can be optimized for a wide range of capacitance and ESR values.

Compensation Components

EC3293 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 and 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:

$A_{VDC} = R_{LOAD} \times G_{CS} \times A_{EA} \times V_{FB}/V_{OUT}$

Where A_{EA} 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:

$f_{P1} = G_{EA} / (2\pi \times C3 \times A_{EA})$

$f_{P2} = 1 / (2\pi \times C2 \times R_{LOAD})$

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:

$f_{Z1} = 1 / (2\pi \times C3 \times R3)$

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:

$f_{ESR} = 1 / (2\pi \times C2 \times R_{ESR})$

In this case, 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:

$f_{P3} = 1 / (2\pi \times C6 \times R3)$

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:

$R3 = [(2\pi \times C2 \times f_C) / (G_{EA} \times G_{CS})] \times (V_{OUT}/V_{FB})$

$< [(2\pi \times C2 \times 0.1 \times f_S) / (G_{EA} \times G_{CS})] \times (V_{OUT}/V_{FB})$

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, f_{Z1}, below one-forth of the crossover frequency provides sufficient phase margin.

Determine the C3 value by the following equation:

$C3 > 4 / (2\pi \times R3 \times f_C)$

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:

$1 / (2\pi \times C2 \times R_{ESR}) < f_S/2$

If this is the case, then add the second compensation capacitor (C6) to set the pole f_{P3} at the location of the ESR zero. Determine the C6 value by the equation:

$C6 = (C2 \times R_{ESR}) / R3$

External Bootstrap Diode

An external bootstrap diode may enhance the efficiency of the regulator, the applicable conditions of external BOOT diode are:

- V_{OUT} = 5V or 3.3V; and
- Duty cycle is high: D = V_{OUT}/V_{IN} > 65%

In these cases, an external BOOT diode is recommended from the output of the voltage regulator to BOOT pin, as shown in Figure 1.

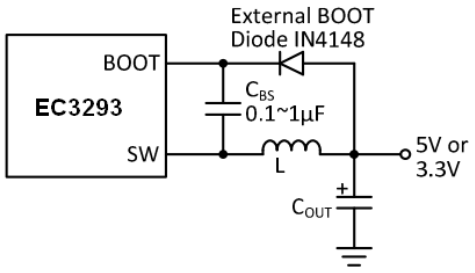


Figure 1: Add optional external bootstrap diode to enhance efficiency.

The recommended external BOOT diode is IN4148, and the BOOT capacitor is 0.1 ~ 1μF.

When V_{IN} ≤ 6V, for the purpose of promote the efficiency, it can add an external Schottky diode between IN and BOOT pins, as shown in Figure 2.

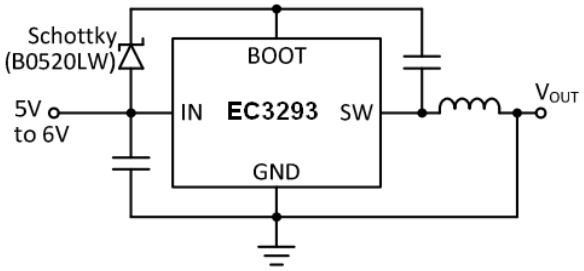


Figure 2: Add a Schottky diode to promote efficiency when V_{IN} ≤ 6V.

	L1	R1	R2	R3	C2	C3	Rfreq	C8
Vout = 5.0V	6.8uH	44.2K	10K	100K	22uFx2	100pF	175K	100pF
Vout = 3.3V	4.7uH	25.7K	10K	100K	22uFx2	100pF	175K	100pF
Vout = 2.5V	4.7uH	17.1K	10K	100K	22uFx2	100pF	175K	50pF
Vout = 1.8V	3.3uH	9.5K	10K	100K	22uFx2	100pF	175K	50pF
Vout = 1.2V	2.2uH	3K	10K	62K	22uFx2	200pF	240K	20pF
Vout = 1.0V	2.2uH	0.834K	10K	62K	22uFx2	200pF	240K	20pF

Table 3: BOM selection table II.
Note: To guarantee the bandwidth, if decrease the value of C2, then R3 must be reduced in proportion to C2, and C3 must be increased in proportion to C2.

PCB Layout Guide

PCB layout is very important to achieve stable operation. Please follow the guidelines below.

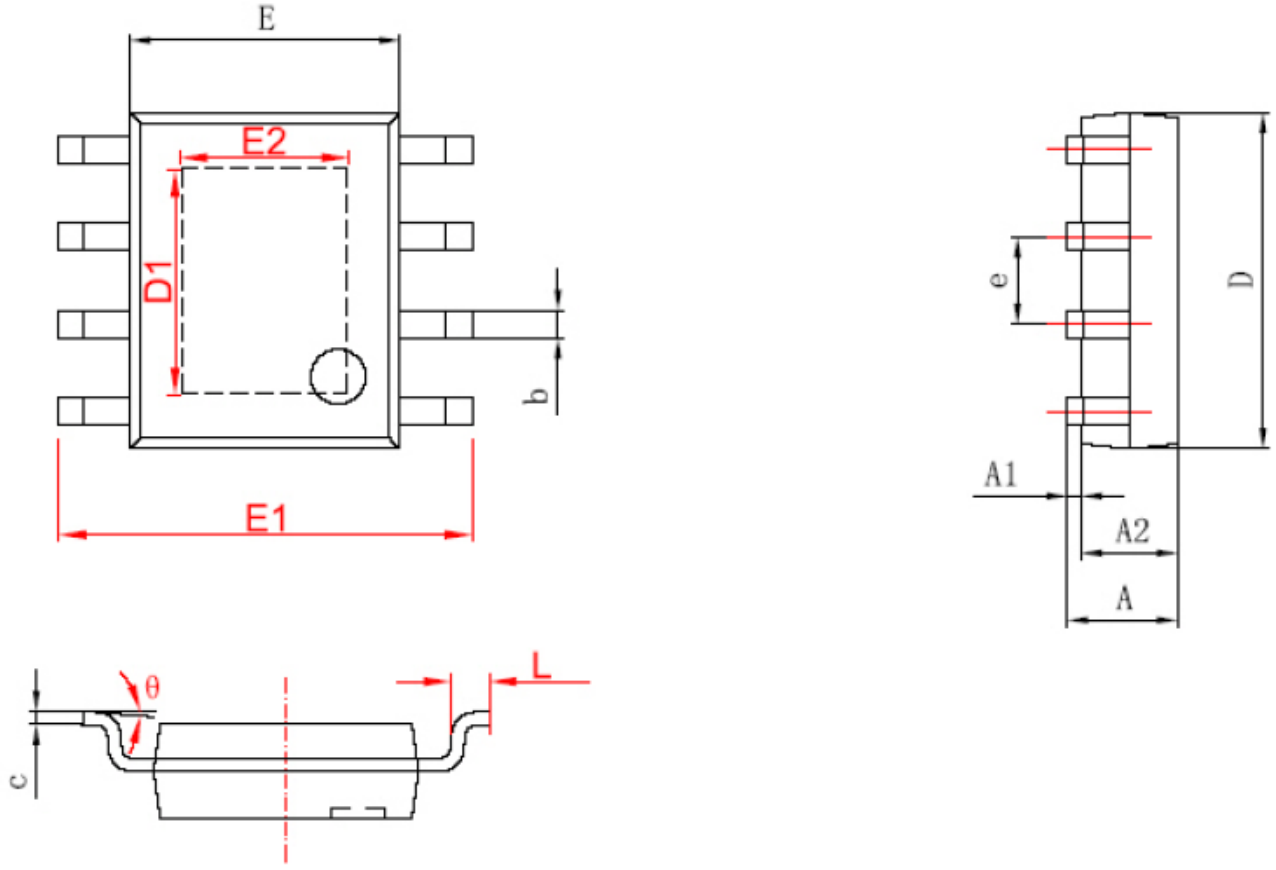
1) Keep the path of switching current short and minimize the loop area formed by Input capacitor, high-side MOSFET and low-side MOSFET.
2) Bypass ceramic capacitors are suggested to be put close to the V_{IN} Pin.
3) Ensure all feedback connections are short and direct. Place the feedback resistors and compensation components as close to the chip as possible.
4) Rout SW away from sensitive analog areas such as FB.
5) Connect IN, SW, and especially GND respectively to a large copper area to cool the chip to improve thermal performance and long-term reliability.

BOM of EC3293
Please refer to the Typical Application Circuit.

Item	Reference	Part
1	C1	10μF
2	C5	100nF
3	C7	0.1μF
4	R4	100K

Table 2: BOM selection table I.

Package Information



	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°