

500kHz, 18V, 4A Synchronous COT Step-Down Converter with ESOP8 Package

Features

- 60mΩ/35mΩ Low $R_{DS(ON)}$ internal FETs
- High Efficiency Synchronous-Mode Operation
- Wide Input Range: 4.5V to 18V
- Output Voltage from
TMI3286: 0.8V
TMI3286B: 0.925V
- 500kHz Switch Frequency
- Up to 4A Output Current
- COT control to achieve fast transient responses
- Power Save Mode at Light Load
- Integrated internal compensation
- Stable with Low ESR Ceramic Output Capacitors
- Over Current Protection with Hiccup Mode
- Thermal Shutdown
- Inrush Current Limit and Soft Start
- Build in Input Over Voltage Protection
- Available in ESOP8 Package

Description

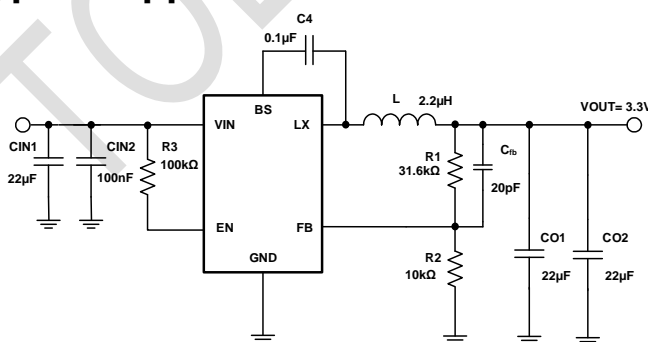
The TMI3286 and TMI3286B are a high efficiency 500kHz, Constant-on-Time (COT) control mode, and synchronous step-down DC-DC converter capable of delivering up to 4.0A current with 1.2V output voltage. TMI3286 integrates main switch and synchronous switch with very low $R_{DS(ON)}$ to minimize the conduction loss. Low output voltage ripple and small external inductor and capacitor size are achieved with 500kHz switching frequency. It adopts the COT architecture to achieve fast transient responses for high voltage step down applications.

The TMI3286 requires a minimum number of readily available standard external components and is available in an 8-pin ESOP8 RoHS compliant package for good thermal performance.

Application

- Digital Set Top Boxes
- Flat Panel Television and Monitors
- Notebook computer
- Wireless and DSL Modems

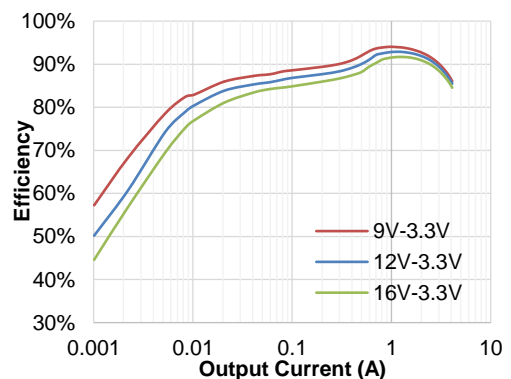
Typical Application



TMI3286 Typical Application Circuits

Efficiency

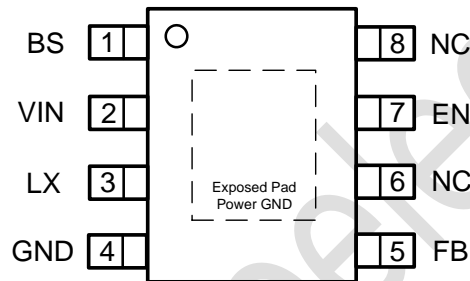
$V_{OUT}=3.3V$, $I_{OUT}=0.01A$ to 4A, $T_A=25^{\circ}C$



Absolute Maximum Ratings (Note 1)

Parameter	Min	Max	Unit
Input Supply Voltage, EN	-0.3	20	V
LX Voltages	-0.3	20	V
LX Voltage (<10ns transient)	-4.5	22	V
FB Voltage	-0.3	6	V
BS Voltage	-0.3	23	V
Storage Temperature Range	-65	150	°C
Junction Temperature <small>(Note2)</small>	160		°C
Power Dissipation	1500		mW
Lead Temperature (Soldering, 10s)	260		°C

Package



ESOP8

Top Marking: T3286/XXXXX for TMI3286

T3286B/XXXXX for TMI3286B

T3286 and T3286B: Device Code

XXXXX: Inside Code

Order Information

Part Number	Package	Top Marking	Quantity/Reel
TMI3286	ESOP8	T3286 XXXXX	3000
TMI3286B	ESOP8	T3286B XXXXX	3000

TMI3286 and TMI3286B devices are Pb-free and RoHS compliant.

Pin Functions

Pin	Name	Function
1	BS	Bootstrap. A capacitor connected between LX and BS pins is required to form a floating supply across the high-side switch driver.
2	VIN	Power supply Pin
3	LX	Switching Pin
4	GND	Ground Pin
5	FB	Output Voltage feedback input. Connect FB to the center point of the external resistor divider.
6	NC	No Connection
7	EN	Drive this pin to a logic-high to enable the IC. Drive to a logic-low to disable the IC and enter micro-power shutdown mode. Don't floating EN.
8	NC	No Connection
9	Thermal Pad	Connect to ground with PCB vias for thermal dissipation

ESD Rating

Items	Description	Value	Unit
V _{ESD_HBM}	Human Body Model for all pins	±2000	V
V _{ESD_CDM}	Charged Device Model for all pins	±2000	V

JEDEC specification JS-001

Recommended Operating Conditions

Items	Description	Min	Max	Unit
Voltage Range	IN	4.5	18	V
T _J	Operating Junction Temperature	-40	125	°C

Thermal Resistance (Note3)

Items	Description	Value	Unit
θ _{JA}	Junction-to-ambient thermal resistance	60	°C/W
θ _{JC}	Junction-to-case(bottom) thermal resistance	9	°C/W

Electrical Characteristics

$V_{IN}=12V$, $V_{OUT}=3.3V$, $T_A = 25^{\circ}C$, unless otherwise noted.

Parameter	Conditions	Min	Typ	Max	Unit
Input Voltage Range		4.5		18	V
OVP Threshold			19.3		V
UVLO Rising Threshold		4.0			V
UVLO Hysteresis			0.45		V
Quiescent Current	$V_{EN}=2V$, $V_{FB}=V_{REF} \times 105\%$		300		μA
Shutdown Current	$V_{IN}=12V$, $EN=0V$		5	10	μA
Feedback Voltage of TMI3286	$T_A=25^{\circ}C$,	0.784	0.800	0.816	V
Feedback Voltage of TMI3286B	$T_A=25^{\circ}C$	0.906	0.925	0.942	V
High-Side Switch On-Resistance			60		m Ω
Low-Side Switch On-Resistance			35		m Ω
High-Side Switch Leakage Current	$V_{EN}=0V$, $V_{LX}=0V$	1		10	μA
Switch Valley Current Limit	Minimum Duty Cycle		4.5		A
On Time	$V_{IN}=12V$, $V_{OUT}=1.2V$, $I_{OUT}=1A$	150	200	250	ns
Oscillation Frequency		370	500	650	kHz
Maximum Duty Cycle			80		%
Minimum On-Time			80		ns
Soft Start Time		0.7	1	1.3	ms
Hiccup on Time			1.6		ms
Hiccup Time Before Restart			6		ms
EN High-Level Input Voltage		0.85	1.05	1.2	V
EN Hysteresis			100		mV
Thermal Shutdown Threshold (Note 4)			165		$^{\circ}C$
Thermal Shutdown Hysteresis (Note 4)			30		$^{\circ}C$

Note 1: Absolute Maximum Ratings are those values beyond which the life of a device may be impaired.

Note 2: T_J is calculated from the ambient temperature T_A and power dissipation P_D according to the following formula: $T_J = T_A + P_D \times \theta_{JA}$. The maximum allowable continuous power dissipation at any ambient temperature is calculated by $P_{D(MAX)} = (T_{J(MAX)} - T_A) / \theta_{JA}$.

Note 3: Measured on JESD51-7, 4-layer PCB.

Note 4: Thermal shutdown threshold and hysteresis are guaranteed by design.

Block Diagram

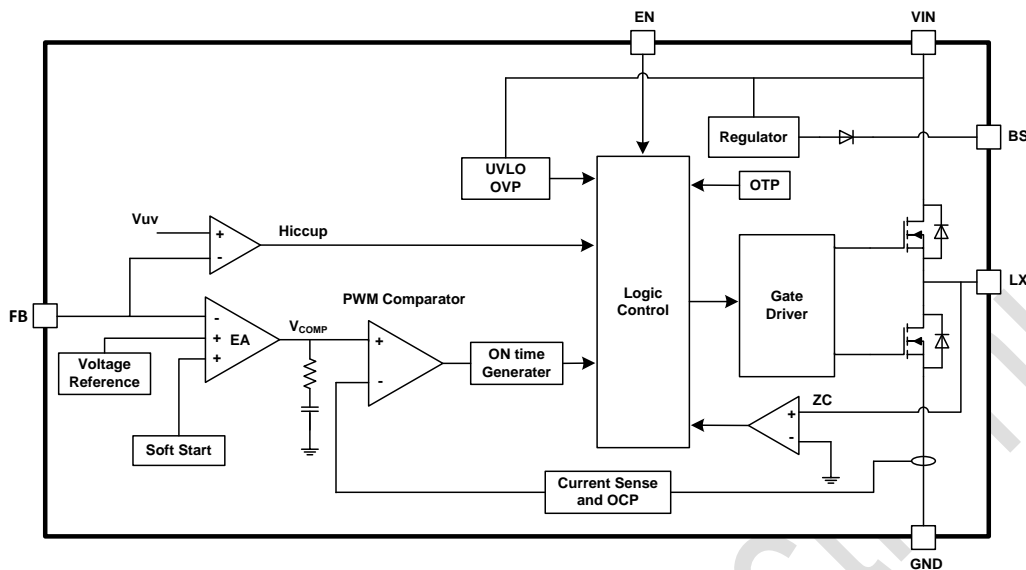


Figure 1. TMI3286 and TMI3286B Block Diagram

Operation Description

Internal Regulator

The TMI3286 and TMI3286B are constant on-time (COT) step down DC/DC converter that provides excellent transient response with no extra external compensation components. This device contains low resistance, high voltage high side and low side power MOSFETs, and operates at 500kHz operating frequency to ensure a compact, high efficiency design with excellent AC and DC performance.

Error Amplifier

TMI3286/B adopts operational transconductance amplifier (OTA) as error amplifier. The error amplifier compares the FB pin voltage with the internal FB reference (V_{REF}) and outputs a current proportional to the difference between the two. This output current is then used to charge or discharge the internal compensation network to form the V_{COMP} voltage, which is used to compare with the low side power MOSFET current sensing signal and trigger on time pulse. The optimized internal compensation network minimizes the external component counts and simplifies the control loop design.

Internal Soft-Start

The soft-start is implemented to prevent the converter output voltage from overshooting during startup. When the chip starts, the internal circuitry generates a soft-start voltage (SS) ramping up from 0V to V_{REF} . When it is lower than the internal FB reference (V_{REF}), SS overrides REF so the error amplifier uses SS as the reference. When SS is higher than V_{REF} , V_{REF} regains control. The SS time is internally fixed to 1ms typically.

Over-Current-Protection and Short Circuits Protection

The TMI3286/B has cycle-by-cycle valley current limit function. When the inductor current valley value is larger than the valley current limit during low side MOSFET on state, the device enters into valley over

current protection mode and low side MOSFET keeps on state until inductor current drops down to the value equal or lower than the valley current limit, and then on time pulse could be generated and high side MOSFET could turn on again.

If the output is short to GND and the output voltage drop until feedback voltage V_{FB} is below the output under-voltage V_{UV} threshold which is typically 45% of V_{REF} , TMI3286 and TMI3286B enter-into hiccup mode to periodically disable and restart switching operation. The hiccup mode helps to reduce power dissipation and thermal rise during output short condition. The period of TMI3286 hiccup mode is typically 7.6ms.

Startup and Shutdown

If both VIN and EN are higher than their appropriate thresholds, the chip starts switching operation. The reference block starts first, generating stable reference voltage and currents, and then the internal regulator is enabled. The regulator provides stable supply for the remaining circuitries. Three events can shut down the chip: EN low, VIN low and thermal shutdown. In the shutdown procedure, the signaling path is first blocked to avoid any fault triggering. The V_{COMP} voltage and the internal supply rail are then pulled down. The floating driver is not subject to this shutdown command.

Application Information

Setting the Output Voltage

The external resistor divider is used to set the output voltage (see Typical Application on page 1). Choose R1 and R2 between 1k and 50k for noise immunity:

Table 1: Selection for Common Output Voltages ($V_{FB}=0.8V$)

V_{OUT} (V)	R1 (k Ω)	R2 (k Ω)	C_{FB} (pF)	L (μ H)
5	35.7	6.8	20	4.7
3.3	31.6	10	20	4.7
2.5	21.5	10	20	2.2
1.8	12.4	10	20	2.2
1.5	8.66	10	20	2.2
1.2	4.99	10	20	1.5
1	2.49	10	20	1.0

Table 2: Selection for Common Output Voltages ($V_{FB}=0.925V$)

V_{OUT} (V)	R1 (k Ω)	R2 (k Ω)	C_{FB} (pF)	L (μ H)
5	44.2	10	20	4.7
3.3	26.1	10	20	4.7
2.5	16.9	10	20	2.2
1.8	9.53	10	20	2.2
1.5	6.2	10	20	2.2
1.2	3	10	20	1.5
1	2.67	33	20	1.0

Selecting the Inductor

A 1.0μH to 4.7μH inductor with a DC current rating of at least 25% percent higher than the maximum load current is recommended for most applications. For highest efficiency, the inductor DC resistance should be as small as possible. For most designs, the inductance value can be derived from the following equation.

$$L = \frac{V_{out} \times (V_{in} - V_{out})}{V_{in} \times \Delta I_L \times f_{OSC}}$$

Where ΔI_L is the inductor ripple current. Choose inductor ripple current to be approximately 30% if the maximum load current 4A. The maximum inductor peak current is:

$$I_{L(MAX)} = I_{LOAD} + \frac{\Delta I_L}{2}$$

Under light load conditions below 100mA, larger inductance is recommended for improved efficiency.

Selecting the Output Capacitor

The output capacitor (Co1 and Co2) 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:

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_s \times L} \times \left[1 - \frac{V_{OUT}}{V_{IN}} \right] \times \left[R_{ESR} + \frac{1}{8 \times f_s \times C_2} \right]$$

Where L is the inductor 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:

$$\Delta V_{OUT} = \frac{V_{OUT}}{8 \times f_s^2 \times L \times C_2} \times \left[1 - \frac{V_{OUT}}{V_{IN}} \right]$$

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 TMI3286 can be optimized for a wide range of capacitance and ESR values.

Typical Application Circuits

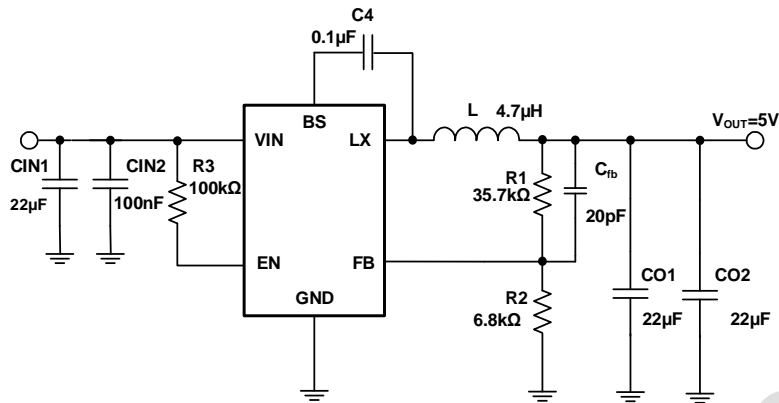


Figure 4. 12V_{IN}, 5V Output ($V_{FB}=0.8V$)

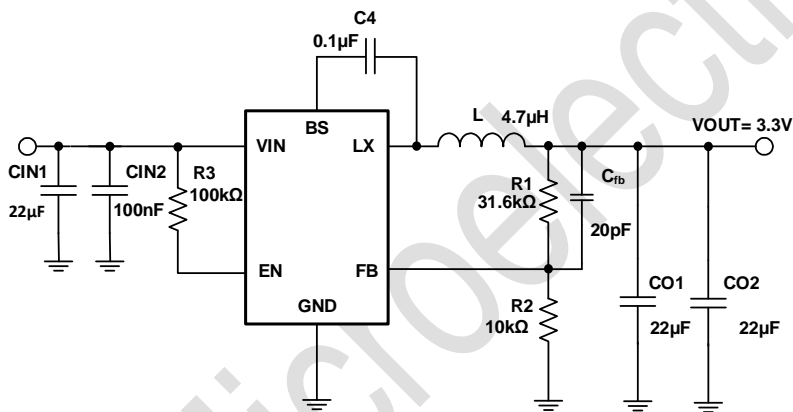


Figure 5. 12V_{IN}, 3.3V Output ($V_{FB}=0.8V$)

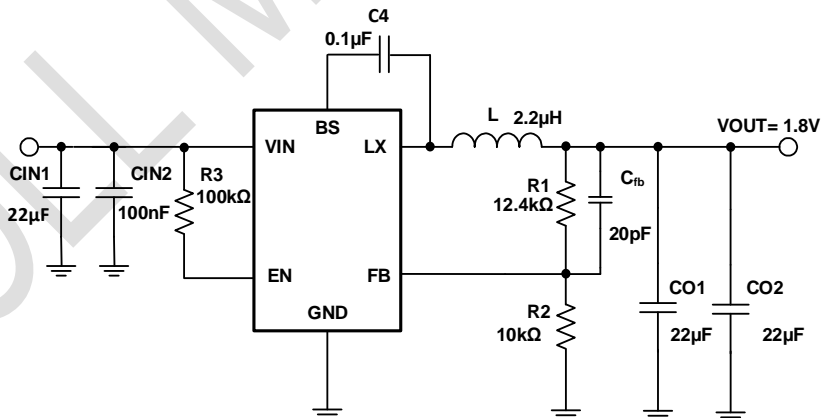


Figure 6. 12V_{IN}, 1.8V Output ($V_{FB}=0.8V$)

Typical Application Circuits(continued)

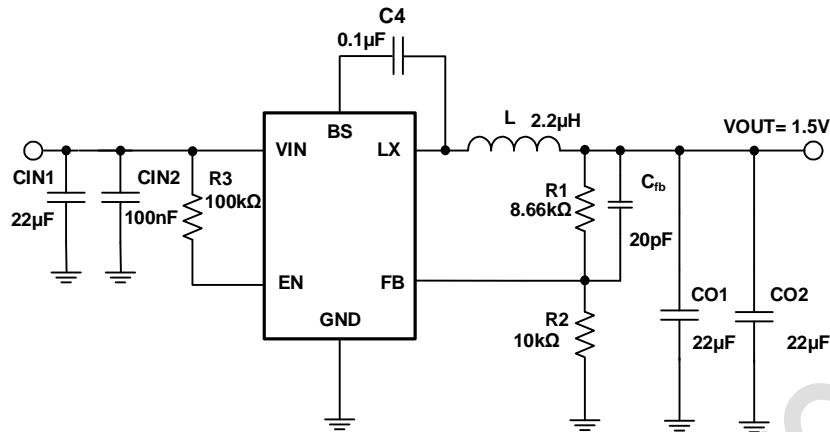


Figure 7. 12V_{IN}, 1.5V Output ($V_{FB}=0.8V$)

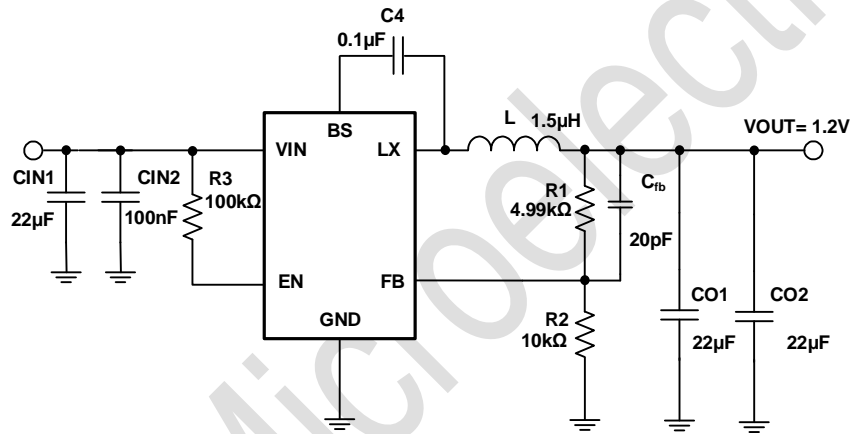


Figure 8. 12V_{IN}, 1.2V Output ($V_{FB}=0.8V$)

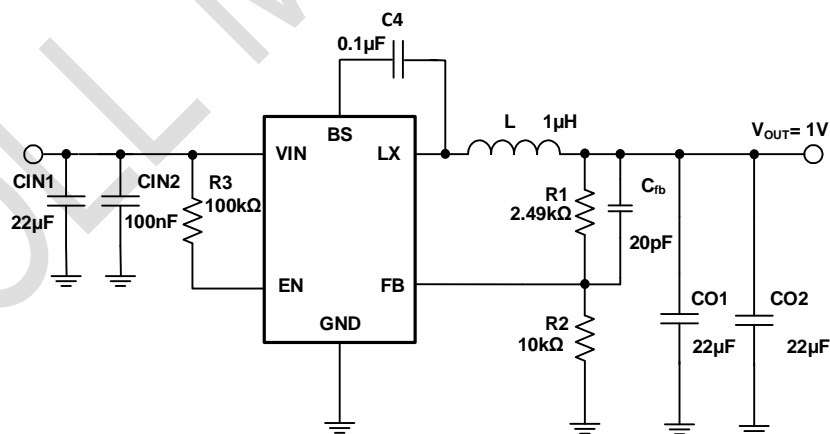


Figure 9. 12V_{IN}, 1V Output ($V_{FB}=0.8V$)

Typical Application Circuits(continued)

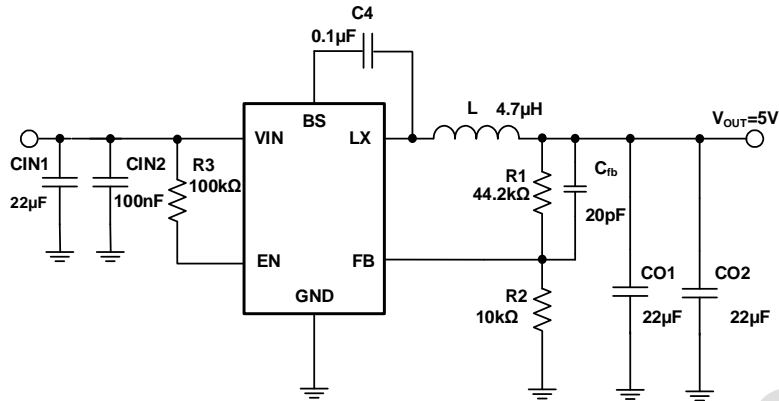


Figure 4. 12V_{IN}, 5V Output ($V_{FB}=0.925V$)

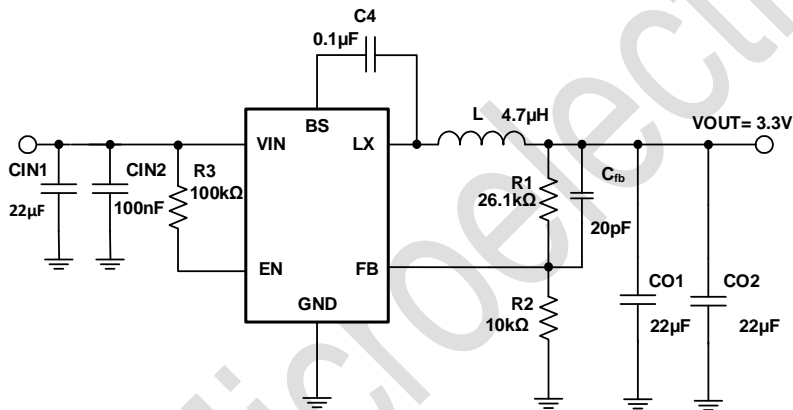


Figure 5. 12V_{IN}, 3.3V Output ($V_{FB}=0.925V$)

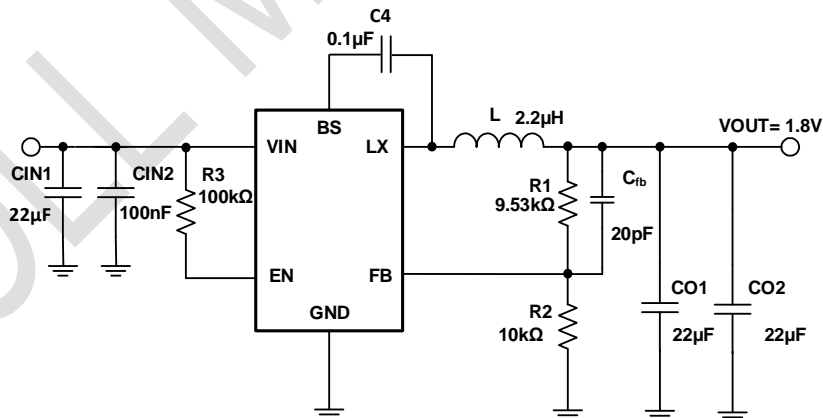


Figure 6. 12V_{IN}, 1.8V Output ($V_{FB}=0.925V$)

Typical Application Circuits(continued)

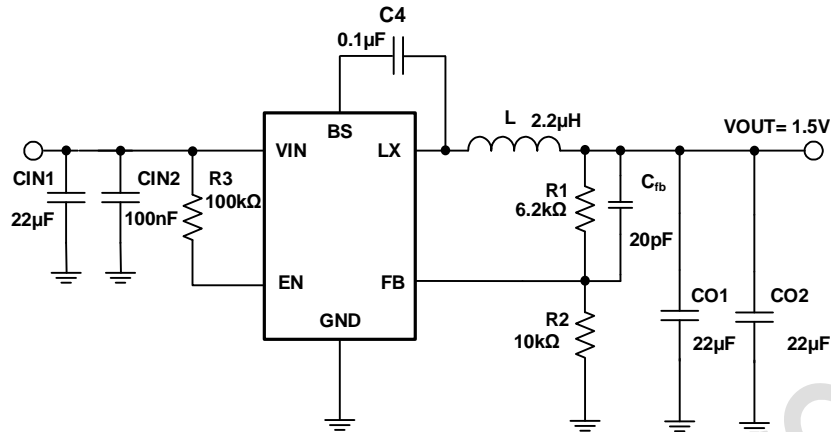


Figure 7. 12V_{IN}, 1.5V Output ($V_{FB}=0.925V$)

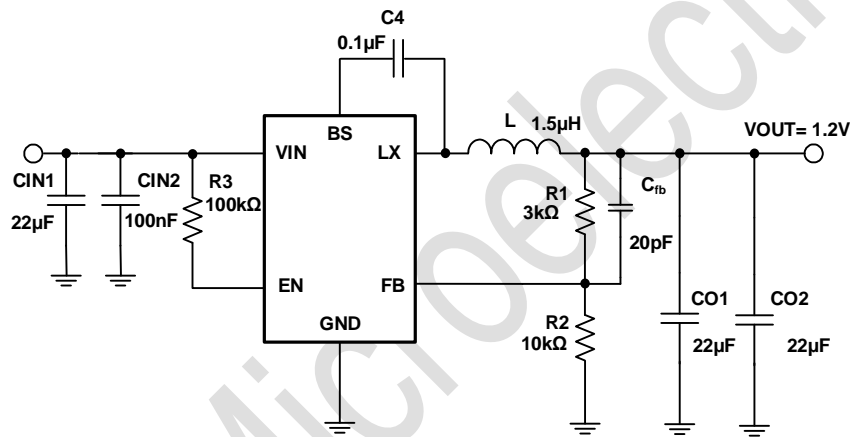


Figure 8. 12V_{IN}, 1.2V Output ($V_{FB}=0.925V$)

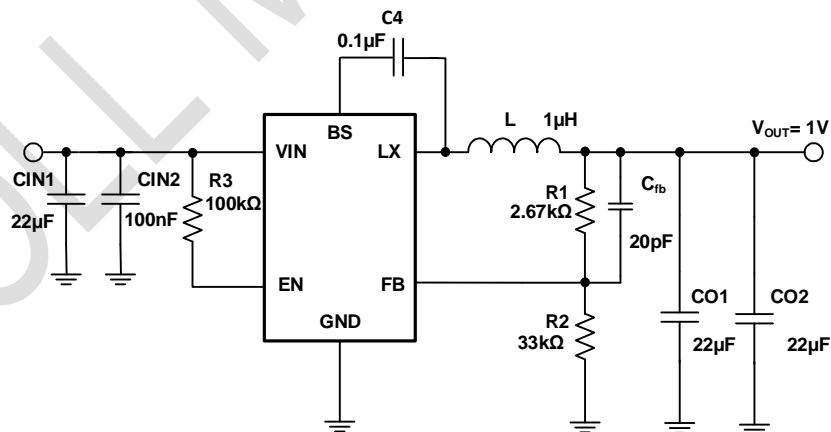


Figure 9. 12V_{IN}, 1V Output ($V_{FB}=0.925V$)

PCB Layout Guide

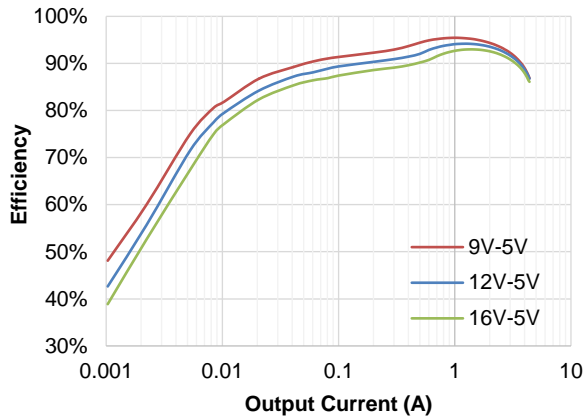
PCB layout is very important to achieve stable operation. If change is necessary, please follow these guidelines.

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

TYPICAL PERFORMANCE CHARACTERISTICS

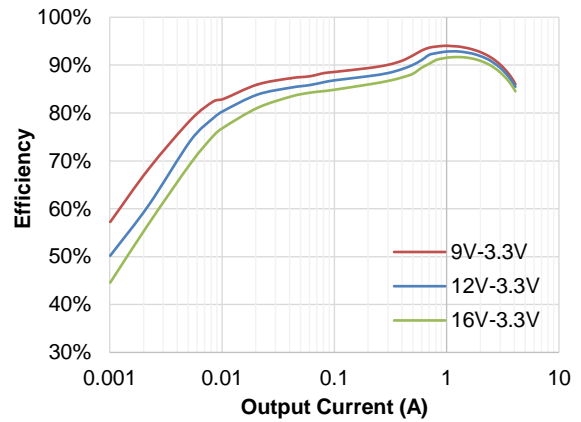
Efficiency at $V_{OUT} = 5V$

$V_{OUT} = 5V$, $L = 4.7\mu H$, $DCR = 30m\Omega$



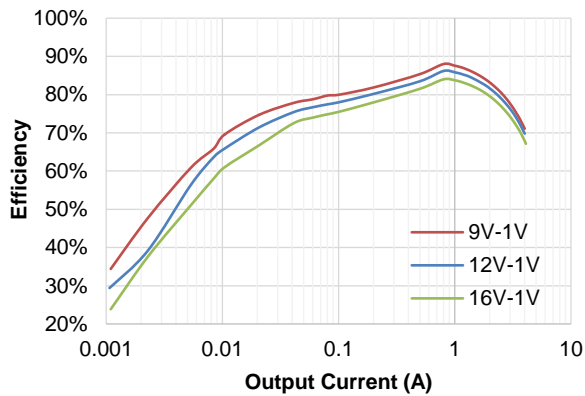
Efficiency at $V_{OUT} = 3.3V$

$V_{OUT} = 3.3V$, $L = 4.7\mu H$, $DCR = 30m\Omega$



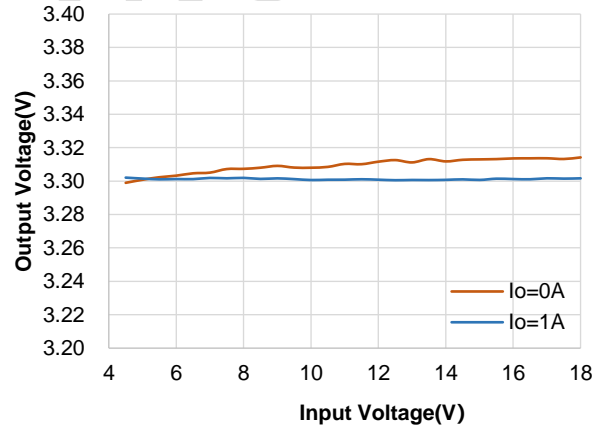
Efficiency at $V_{OUT} = 1V$

$V_{OUT} = 1V$, $L = 2.2\mu H$, $DCR = 20m\Omega$



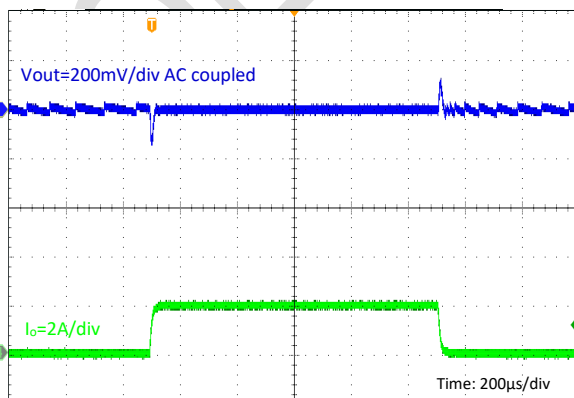
Line Regulation at $V_{OUT} = 3.3V$

$V_{OUT} = 3.3V$, $T_A = 25^\circ C$



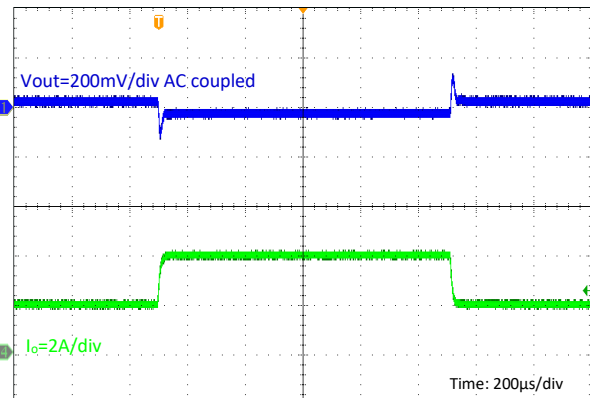
Load Transient

$V_{IN} = 12V$, $V_{OUT} = 3.3V$, $I_o = 0A$ to $2A$



Load Transient

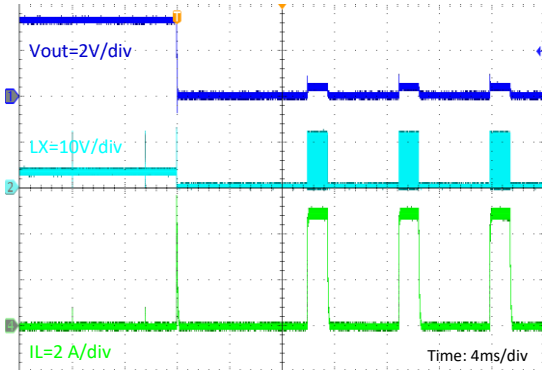
$V_{IN} = 12V$, $V_{OUT} = 3.3V$, $I_o = 2A$ to $4A$



TYPICAL PERFORMANCE CHARACTERISTICS (continued)

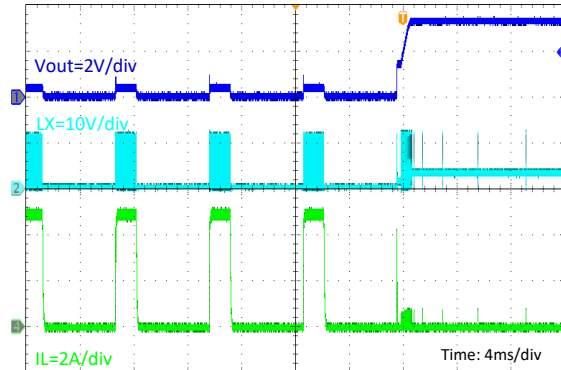
Output Short Entry

$V_{IN} = 12V, V_{OUT} = 3.3V, \text{No Load}$



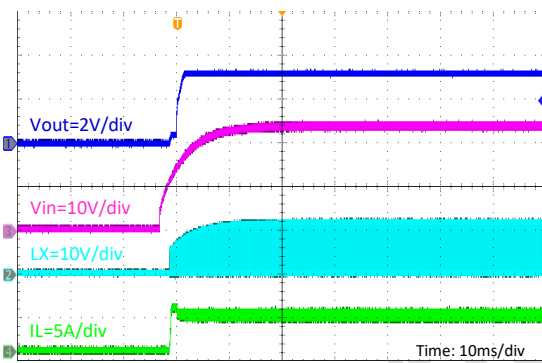
Output Short Recovery

$V_{IN} = 12V, V_{OUT} = 3.3V, \text{No Load}$



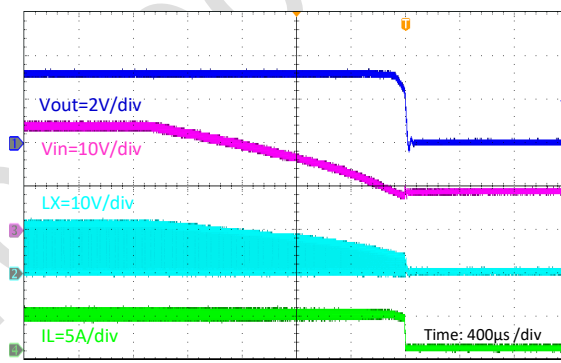
Input Power On

$V_{IN} = 12V, V_{OUT} = 3.3V, I_o = \text{Full Load}$



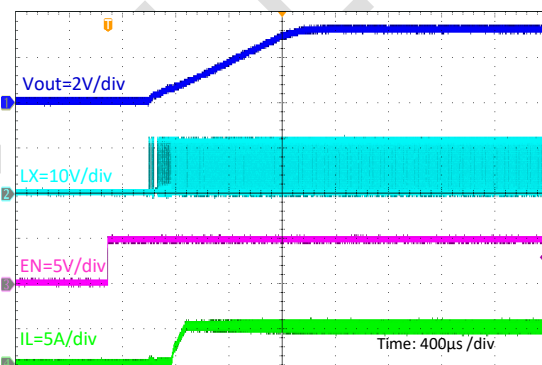
Input Power Down

$V_{IN} = 12V, V_{OUT} = 3.3V, I_o = \text{Full Load}$



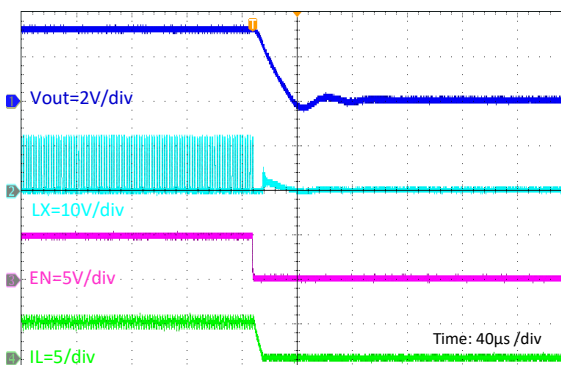
EN Enable

$V_{IN} = 12V, V_{OUT} = 3.3V, I_o = \text{Full Load}$



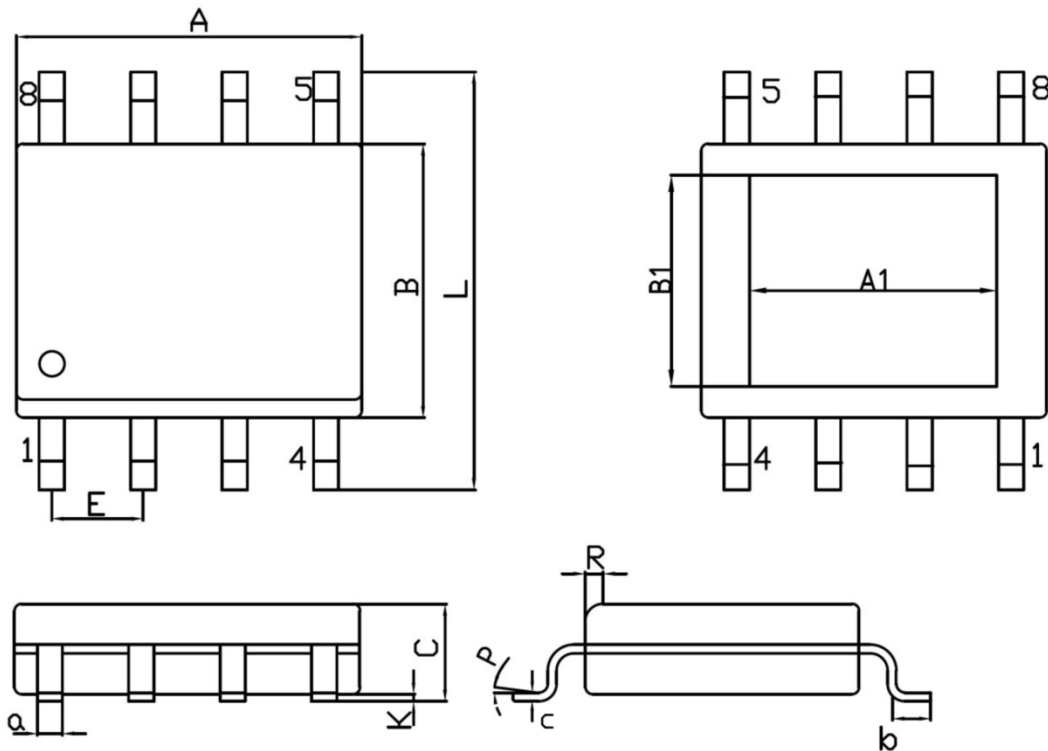
EN Disable

$V_{IN} = 12V, V_{OUT} = 3.3V, I_o = \text{Full Load}$



Package Information

ESOP8



Unit: mm

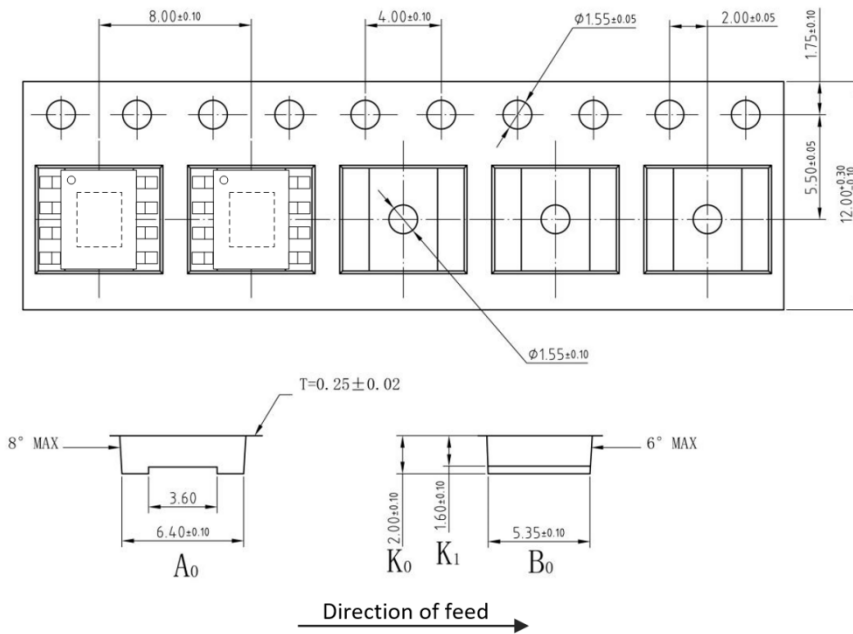
Symbol	Dimensions In Millimeters		Symbol	Dimensions In Millimeters	
	Min	Max		Min	Max
A	4.70	5.10	C	1.35	1.75
B	3.70	4.10	a	0.35	0.49
L	6.00	6.40	R	0.30	0.60
E	1.27 BSC		P	0°	7°
K	0.02	0.10	b	0.40	1.25
A1	3.1	3.5	B1	2.2	2.6
			c	0.203	0.243

Note:

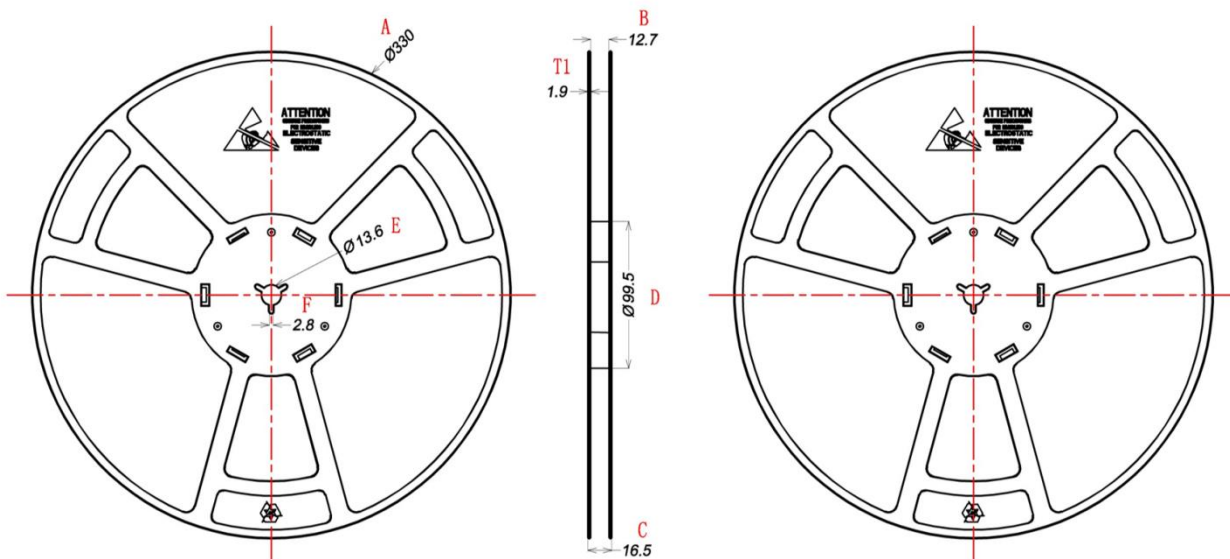
- 1) All dimensions are in millimeters.
- 2) Package length does not include mold flash, protrusion or gate burr.
- 3) Package width does not include inter lead flash or protrusion.
- 4) Lead popularity (bottom of leads after forming) shall be 0.10 millimeters max.
- 5) Pin 1 is lower left pin when reading top mark from left to right.

Tape and Reel Information

Tape Dimensions:



Reel Dimensions:



Unit: mm

Note:

- 1) All Dimensions are in Millimeter
- 2) Quantity of Units per Reel is 3000
- 3) MSL level is level 3.