LA8005

1MHz, 5V/3A Synchronous Step-Down Converter

General Description

The LA8005 is a current mode, synchronous step-down DC-DC converter that is designed to meet 3A output current, and utilizes PWM control scheme that switches with 1MHz fixed frequency.

The input voltage range of LA8005 is from 2.5V to 5.5V, and available in adjustable output voltage from 0.8V to V_{IN}. The supply current is only 0.6mA during operation and under 25uA in shutdown.

This device provides an enable function that can be controlled by external logic signal. It also provides excellent regulation during line or load transient due to the current mode operation. Other features of soft-start, current limit, thermal shutdown protection, short circuit protection, and over voltage protection are also included. The under voltage lockout prevents low input voltage start-up until it reaches the UVLO threshold voltage. It is available in the Exposed Pad SOP-8 (ESOP) package.

Features

- Continuous 3A Output Capability
- 0.8V Reference Voltage
- 2.5V to 5.5V Input Voltage Range
- Adjustable Output from 0.8V to V_{IN}
- 1MHz Oscillation Frequency
- 0.6mA Low Supply Current
- 25uA Low Shutdown Current
- Internal Soft-Start & Current Limit
- Current Mode for Excellent Response
- Short Circuit Protection
- Thermal shutdown Protection
- Over Voltage Protection
- Under Voltage Lockout
- Available in ESOP-8 Package
- Meet RoHS Standard

Applications

- LCD TV / Monitor
- Set-Top-Box
- Portable & Storage Device
- Wireless & Broadband Communication

Ordering Information

LA8005 **1 2 3 4**

1 (Package Type) => P: ESOP
2 (Number of Pins) => G: 8 pin
3 (Output Voltage) => Blank: Adjustable
4 (Special Feature) => Blank: N/A

Available Part Number

LA8005PG

Marking Information

(ESOP-8 Package)

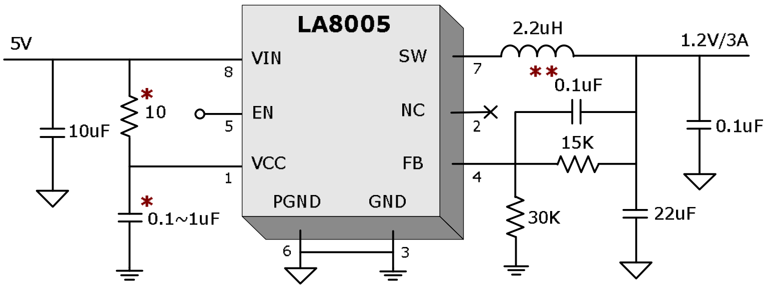
1 2 (Date Code)

For date code rule, please contact our sales representative directly.

3 4 (Internal Code)

Typical Application

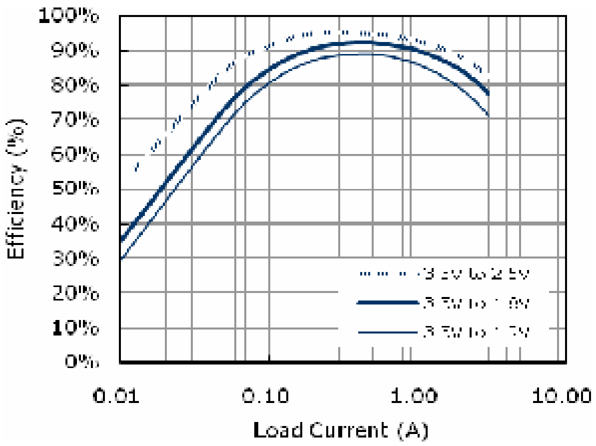
V_{IN}=5V, V_{OUT}=1.2V

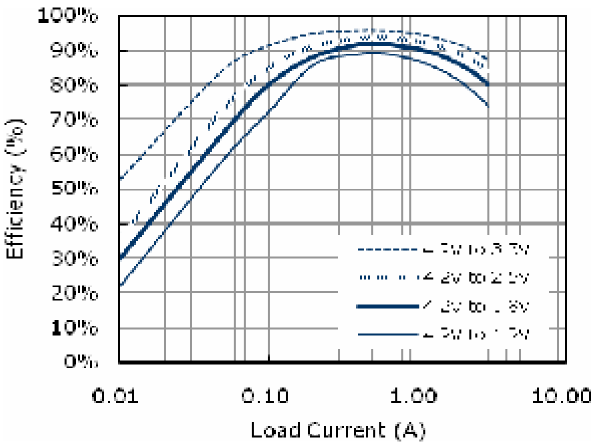


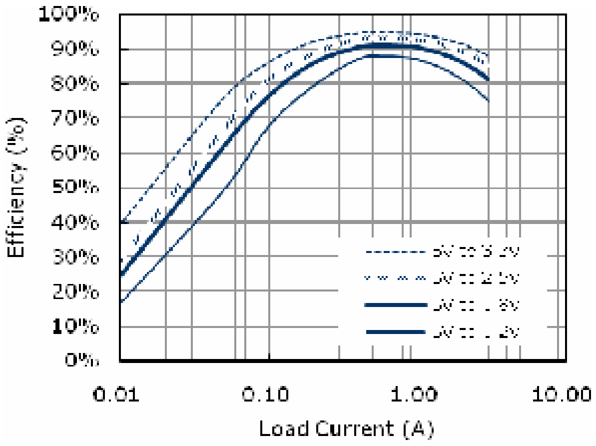
* *Optional Low-Pass Filter. It can reduce noise at VCC if needed.*

** *Optional Feed-forward Capacitor. A 0.1uF is recommended for improve the load transient response.*

Efficiency Curve







Quick Design Table

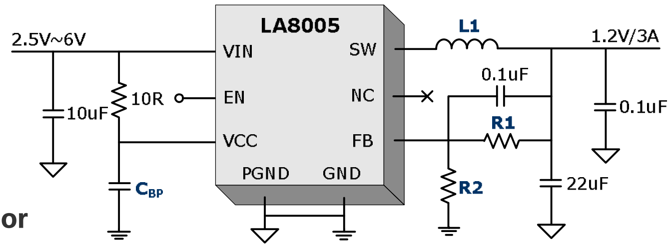
For 3A output current application, $\triangle I_L$ = 0.3A, continuous current mode operation.

L1: **Recommended Inductor**

R1: **Output Voltage Divider**

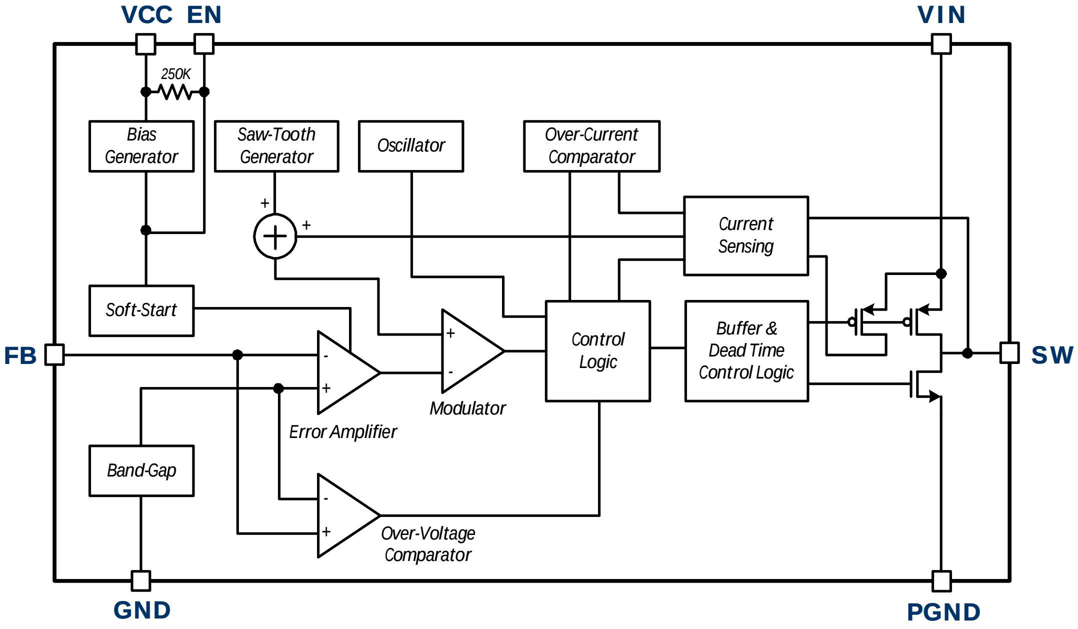
R2: **Output Voltage Divider**

C_{BP}: **Recommended Decoupling Capacitor**

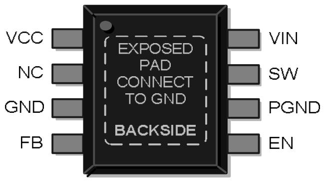


V_{IN} V_{OUT}	Li-Ion Battery	3.3V	5V
1.0V	L1 : 2.2uH R1 : 6.8KOhm R2 : 27Kohm C_{BP} : 0.1uF	L1 : 2.2uH R1 : 6.8KOhm R2 : 27Kohm C_{BP} : 0.1uF	L1 : 1uH R1 : 6.8KOhm R2 : 27Kohm C_{BP} : 0.1uF
1.1V	L1 : 2.2uH R1 : 10KOhm R2 : 27KOhm C_{BP} : 0.1uF	L1 : 2.2uH R1 : 10KOhm R2 : 27KOhm C_{BP} : 0.1uF	L1 : 2.2uH R1 : 10KOhm R2 : 27KOhm C_{BP} : 0.1uF
1.2V	L1 : 2.2uH R1 : 15KOhm R2 : 30KOhm C_{BP} : 0.1uF	L1 : 2.2uH R1 : 15KOhm R2 : 30KOhm C_{BP} : 0.1uF	L1 : 2.2uH R1 : 15KOhm R2 : 30KOhm C_{BP} : 0.1uF
1.5V	L1 : 2.2uH R1 : 13KOhm R2 : 15KOhm C_{BP} : 0.1uF	L1 : 2.2uH R1 : 13KOhm R2 : 15KOhm C_{BP} : 0.1uF	L1 : 3.3uH R1 : 13KOhm R2 : 15KOhm C_{BP} : 0.1uF
1.8V	L1 : 3.3uH R1 : 15KOhm R2 : 12KOhm C_{BP} : 0.1uF	L1 : 3.3uH R1 : 15KOhm R2 : 12KOhm C_{BP} : 0.1uF	L1 : 3.3uH R1 : 15KOhm R2 : 12KOhm C_{BP} : 0.1uF
2.5V	L1 : 3.3uH R1 : 10KOhm R2 : 4.7KOhm C_{BP} : 1uF	L1 : 4.7uH R1 : 10KOhm R2 : 4.7KOhm C_{BP} : 1uF	L1 : 3.3uH R1 : 10KOhm R2 : 4.7KOhm C_{BP} : 0.1uF
2.8V	L1 : 4.7uH R1 : 13KOhm R2 : 5.1KOhm C_{BP} : 1uF	L1 : 4.7uH R1 : 13KOhm R2 : 5.1KOhm C_{BP} : 1uF	L1 : 4.7uH R1 : 13KOhm R2 : 5.1KOhm C_{BP} : 0.1uF
3.0V	L1 : 4.7uH R1 : 13KOhm R2 : 4.7KOhm C_{BP} : 1uF		L1 : 4.7uH R1 : 13KOhm R2 : 4.7KOhm C_{BP} : 1uF
3.3V			L1 : 4.7uH R1 : 16KOhm R2 : 5.1KOhm C_{BP} : 1uF

Functional Block Diagram



Pin Configurations



(TOP VIEW)

Pin No.	Name	Description
1	VCC	Supply voltage. Connect to VIN directly and bypass with 0.1uF~1uF ceramic capacitor to ground. A low-pass filter can be connected between VIN and VCC to reduce input noise if needed.
2	NC	No Connection.
3	GND	Signal ground.
4	FB	Feedback. Connect this pin to a voltage divider to set the output voltage.
5	EN	This pin allows an external control signal to turn-on/off this device. Float EN or drive it HIGH to turn-on this device; drive it LOW to turn-off this device.
6	PGND	Power ground.
7	SW	This pin is the switching node that supplies power to the output. Connect a LC filter from this pin to the load.
8	VIN	Power supply input. Bypass with 10uF ceramic capacitor to ground.

Absolute Maximum Ratings

Parameter	Rating
Input Voltage	**6V**
SW Voltage Range	**-0.3V ~ VCC+0.3V**
FB Voltage Range	**-0.3V ~ VCC+0.3V**
EN Voltage Range	**-0.3V ~ VCC+0.3V**
Storage Temperature Range	**-65°C ~ 150°C**
Junction Temperature	**150 °C**
Lead Soldering Temperature (10 sec)	**300 °C**

These are stress ratings only and functional operation is not implied. Exposure to absolute maximum ratings for prolonged time periods may affect device reliability. All voltages are with respect to ground.

Recommended Operating Conditions

Parameter	Rating
Input Voltage Range	**2.5V ~ 5.5V**
Ambient Temperature Range	**-40°C ~ 85°C**
Junction Temperature Range	**-40°C ~ 125°C**

These are conditions under which the device functions but the specifications might not be guaranteed. For guaranteed specifications and test conditions, please see the *Electrical Specifications*.

Package Information

Parameter	Package	Symbol	Rating
Thermal Resistance (Junction to Case)	ESOP-8	θ_{JC}	**10 °C/W**
Thermal Resistance (Junction to Ambient)		θ_{JA}	**50 °C/W**

Electrical Specifications

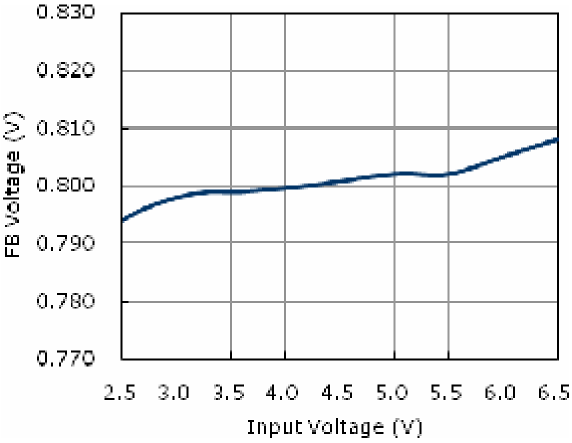
$V_{IN}=V_{CC}=3.6V$, $T_A=25^{O}C$, unless otherwise noted.

Parameter	Test Condition	Min.	Typ.	Max.	Units
Feedback Voltage		0.784	0.8	0.816	V
	-40°C ~ 85°C	0.776		0.824	
Oscillation Frequency		800	1000	1500	KHz
Short Circuit Frequency			200		KHz
Duty Cycle	$V_{FB}=0V$		100		%
	$V_{FB}=1.5V$		15		
P-Channel MOSFET On Resistance	$V_{IN}=5V$, $I=1A$		100		mΩ
N-Channel MOSFET On Resistance	$V_{IN}=5V$, $I=1A$		70		
Current Limit			4.8		A
Supply Current	$V_{FB}=1.5V$		0.6	1	mA
Shutdown Current	$V_{EN}=0V$		25	100	uA
EN Pin Input Threshold Voltage	Regulator OFF			V_{IN} x 15%	V
	Regulator ON	V_{IN} x 65%			
Switch Leakage Current	$V_{IN}=5V$, $V_{EN}=0V$, $V_{SW}=5.5V$			0.1	uA
	$V_{IN}=5V$, $V_{EN}=0V$, $V_{SW}=0V$	-0.1			
FB Pin Bias Current		-0.1		0.1	uA
Under Voltage Lockout			2.0		V
Line Regulation	$V_{IN}=3V\sim5.5V$, $I_{LOAD}=0.1A$		0.7		%
Load Regulation	$I_{LOAD}=0.1A\sim3A$		0.7		%
Thermal Shutdown Protection			150		°C
Thermal Shutdown Hysteresis			40		°C

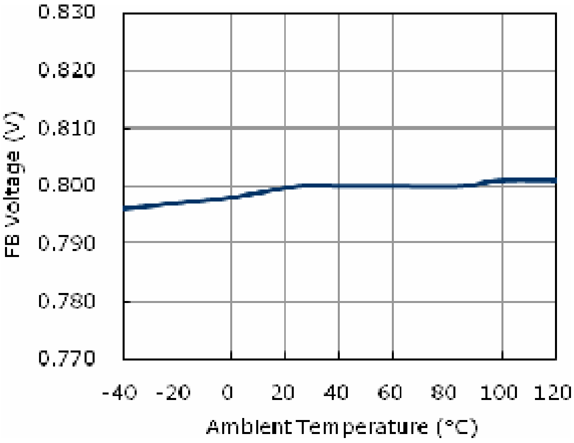
Typical Performance Characteristics

V_{IN}=3.6V, T_A=25°C, unless otherwise noted.

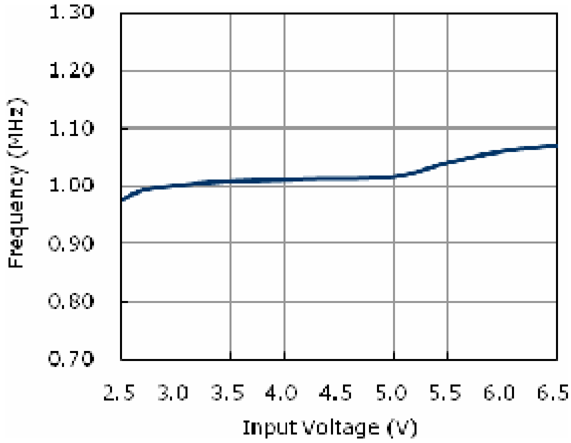
Feedback Voltage vs. Input Voltage



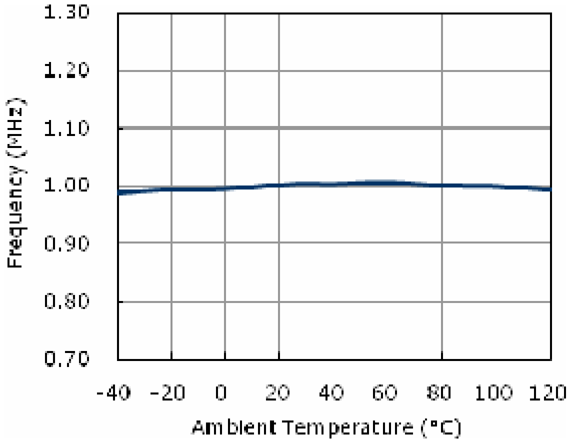
Feedback Voltage vs. Temperature



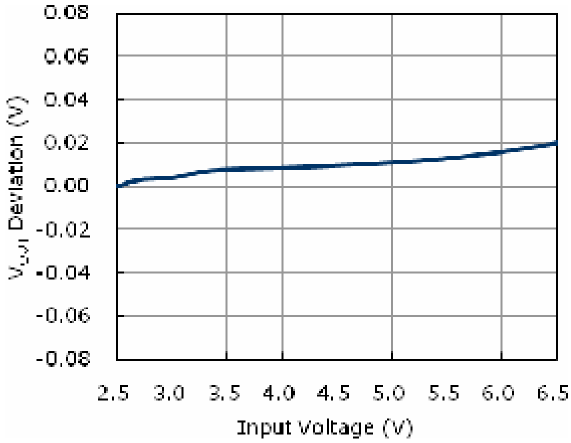
Frequency vs. Input Voltage



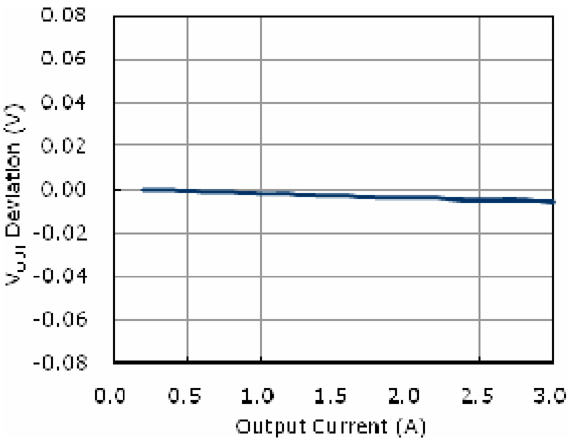
Frequency vs. Temperature



Line Regulation



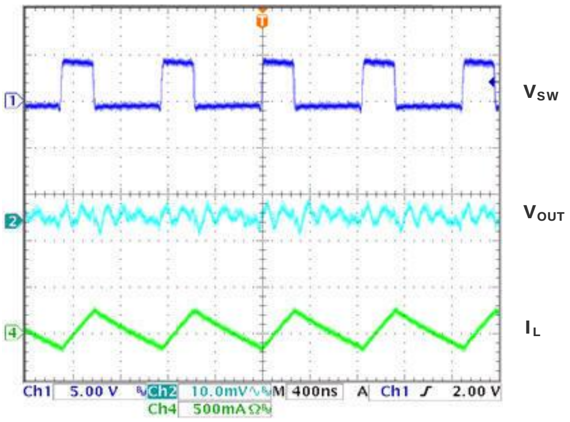
Load Regulation



Typical Performance Characteristics (Contd.)

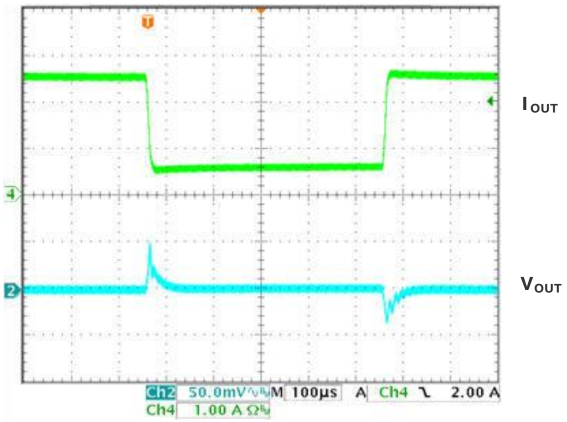
Output Voltage Ripple - CCM

V_{IN}=5V V_{OUT}=1.2V, I_{LOAD}=1.5A



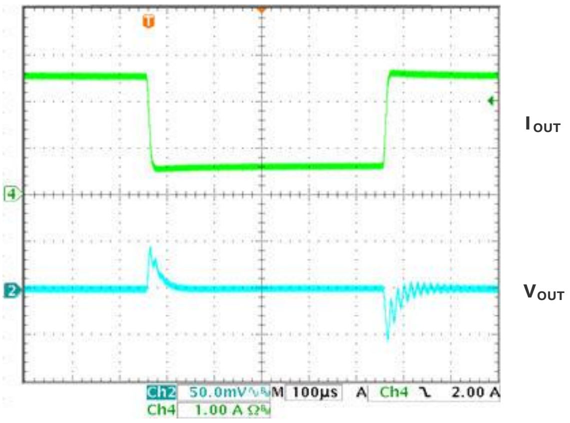
Load Transient

V_{IN}=5V V_{OUT}=1.2V, I_{LOAD}=0.5A~2.5A, T_r=T_f=0.1A/us



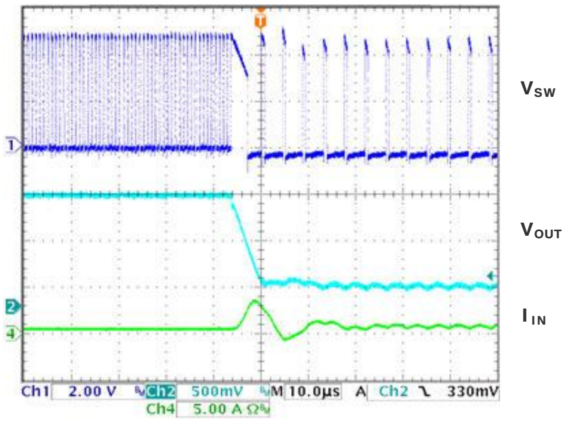
Load Transient

V_{IN}=3.3V V_{OUT}=1.2V, I_{LOAD}=0.5A~2.5A, T_r=T_f=0.1A/us



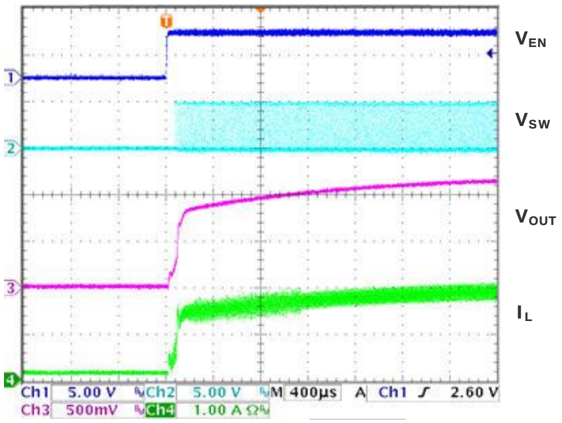
Short Circuit Protection

V_{IN}=5V V_{OUT}=1.2V, I_{LOAD}=2.5A



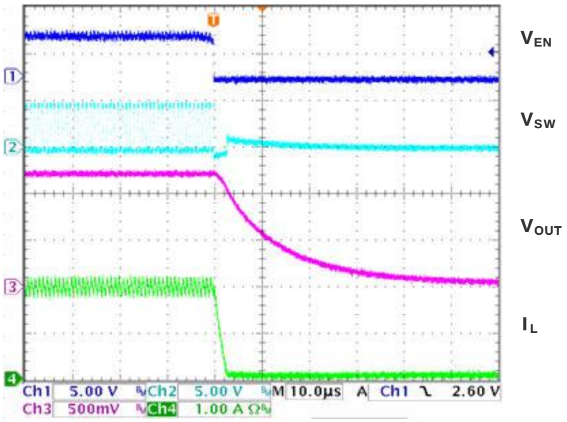
Start-up with EN

V_{IN}=5V V_{OUT}=1.2V, I_{LOAD}=2A



Shutdown with EN

V_{IN}=5V V_{OUT}=1.2V, I_{LOAD}=2A



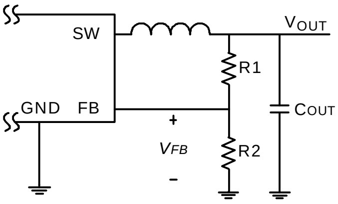
Application Information

Output Voltage Programming

LA8005 develops a band-gap between the feedback pin and ground pin. Therefore, the output voltage can be formed by R1 and R2. Use 1% metal film resistors for the lowest temperature coefficient and the best stability. Select lower resistor value to minimize noise pickup in the sensitive feedback pin, or higher resistor value to improve efficiency.

The output voltage is given by the following formula:

$V_{OUT} = V_{FB} \times (1 + R1 / R2)$ where $V_{FB} = 0.8V$



Short Circuit Protection

When the output is shorted to ground, the protection circuit will be triggered and force the oscillation frequency down to approximately 200KHz. The oscillation frequency will return to the normal value once the short circuit condition is removed.

Over Voltage Protection

The over voltage function monitors the output voltage by FB pin. When the FB voltage increase over 10% of the reference voltage (0.8V), the high-side MOSFET will be turned-off and force low-side MOSFET turns-on. This action actively pulls down the output voltage when the high-side MOSFET failure or output voltage overshooting.

Under Voltage Lockout

The under voltage lockout (UVLO) prevents this device from turning-on MOSFET at lower input voltage. It avoids wrong operation under undefined conditions. The threshold voltage of UVLO is approximately 2V.

Soft-Start

This device includes soft-start function without external circuit. It is useful to reduce supply inrush current, and prevent output voltage from overshooting during start-up.

Thermal Shutdown Protection

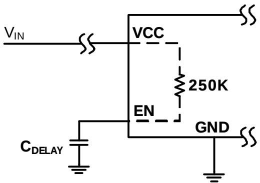
The thermal protection circuit limits total power dissipation in this device. When the junction temperature exceeds approximately 150°C, the thermal sensor signals the shutdown logic turning off this device. The thermal sensor will turn this device on again after the junction temperature cools by approximately 40°C.

Optional VCC Decoupling

Add a low-pass filter between VIN and VCC is recommended to decouple the high frequency noise. The decoupling circuit with the resistor of 10Ω from VCC to VIN, and the capacitor of 0.1uF~1uF from VCC to GND, is suitable for most applications. Keep the capacitor as close to VCC as possible. VIN and VCC can be shorted directly if no decoupling is needed.

Delay Start-up

The following circuit uses the EN pin to provide a time delay between the input voltage is applied and the output voltage comes up. As the instant of the input voltage rises, the charging of capacitor C_{DELAY} pulls the EN pin low, keeping the device off. Once the capacitor voltage rises above the EN threshold voltage, the device will start to operate. The start-up delay time can be calculated by the following formula:

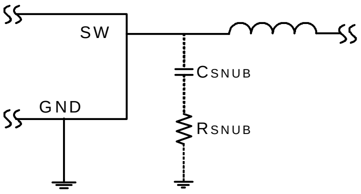


$$V_{IN} \text{ x } (1 - e^{-T/(RxC)}) > V_{EN(th)}$$

where T is the start-up delay time, R = 250KOhm, C is C_{DELAY}, and the $V_{EN(th)}$ = V_{IN} x 0.65.
This feature is useful in situations where the input power source is limited in the amount of current it can deliver. It allows the input voltage to rise to a higher voltage before the device starts operating.

Snubber Circuit

The simple RC snubber is used for voltage transient and ringing suppression. The high frequency ringing and voltage overshooting at the SW pin is caused by fast switching transition and resonating circuit parasitical elements in the power circuit. It maybe generates EMI and interferes with circuit performance. Reserve a snubber circuit in the PC board is preferred to damp the ringing due to the parasitical capacitors and inductors of layout. The following circuit is a simple RC snubber:



Choose the value of RC network by the following procedure:

(1) Measure the voltage ringing frequency (f_R) of the SW pin.

(2) Find a small capacitor and place it across the SW pin and the GND pin to damp the ringing frequency by half.

(3) The parasitical capacitance (C_{PAR}) at the SW pin is 1/3 the value of the added capacitance above. The parasitical inductance (L_{PAR}) at the SW pin is:

$$L_{PAR} = \frac{1}{(2\pi f_R)^2 \times C_{PAR}}$$

(4) Select the value of C_{SNUB} that should be more than 2~4 times the value of C_{PAR} but must be small enough so that the power dissipation of R_{SNUB} is kept to a minimum. The power rating of R_{SNUB} can be calculated by following formula:

$$P\_R_{SNUB} = C_{SNUB} \times V_{IN}^2 \times f_S$$

(5) Calculate the value of R_{SNUB} by the following formula and adjust the value to meet the expectative peak voltage.

$$R_{SNUB} = 2\pi \times f_R \times L_{PAR}$$

Thermal Considerations

For continuous operation, do not exceed the maximum operation junction temperature 125^{O}C. The power dissipation across this device can be calculated by the following formula:

$$P_D = I_{LOAD}{}^2 \times [R_{ON\_P} \times \frac{V_{OUT}}{V_{IN}} + R_{ON\_N} \times (1 - \frac{V_{OUT}}{V_{IN}})] + \frac{1}{2} \times V_{IN} \times I_{LOAD} \times (t_r + t_f) \times f_S + V_{IN} \times I_S$$

where R_{ON_P} is the ON resistance of the high-side power MOSFET, R_{ON_N} is ON resistance of the low-side power MOSFET, fs is the 1MHz switching frequency, (tr+tf) is the switching time that is approximately 10ns, and I_S is the 0.6mA supply current.

The maximum power dissipation of this device depends on the thermal resistance of the IC package and PCB layout, the temperature difference between the die junction and ambient air, and the rate of airflow. The maximum power dissipation can be calculated by the following formula:

$$P_{D(MAX)} = \frac{(T_J - T_A)}{\theta_{JA}}$$

Where T_J -T_A is the temperature difference between the die junction and surrounding environment, θ_{JA} is the thermal resistance from the junction to the surrounding environment.

The value of junction to case thermal resistance θ_{JC} is also popular to users. This thermal parameter is convenient for users to estimate the internal junction operated temperature of packages while IC operating. The operated junction temperature can be calculated by the following formula:

$$T_J = T_C + P_D \times \theta_{JC}$$

T_C is the package case temperature measured by thermal sensor. Therefore, it's easy to estimate the junction temperature by any condition.

There are many factors which affect the thermal resistance. Some of these factors include trace width, copper thickness, total PCB copper area, and etc. For the best thermal performance, wide copper traces and generous amounts of PCB copper should be used in the board layout. If further improve thermal characteristics are needed, double sided and multi-layer PCB with large copper areas and airflow will be recommended.

Layout Considerations

PC board layout is very important, especially for switching regulators of high frequencies and large peak currents. A good layout minimizes EMI on the feedback path and provides best efficiency. The following layout guides should be used to ensure proper operation of this device.

(1) The power charge path and discharge path which consist of the IN trace, the SW trace, the external inductor and the PGND trace should be kept wide and as short as possible.

(2) The feedback path of the voltage divider should be close to the FB pin and keep noisy traces away; also keep them separated by using grounded copper.

(3) The input and output capacitors should be connected to PGND. The feedback loop and bypass capacitor should be connected to GND. Keep the PGND and GND separate.

Component Selection

Inductor Selection

The conduction mode of power stage depends on input voltage, output voltage, output current, and the value of the inductor. Select an inductor to maintain this device operating in continuous conduction mode (CCM). The minimum value of inductor can be determined by the following procedure.

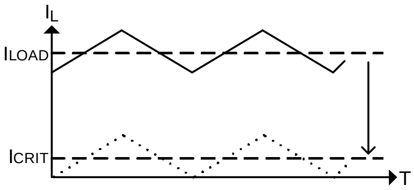
(1) Calculate the minimum duty cycle:

$$D_{(MIN)} = \frac{V_{OUT} + I_{LOAD} \times R_L + V_{DS\_NMOS}}{V_{IN(MAX)} - V_{DS\_PMOS} + V_{DS\_NMOS}} = \frac{T_{ON}}{T_S}$$

Where R_L is the DC resistance of the external inductor, V_{DS} is the turn-on voltage of the internal MOSFET, and Ts is the switching period. This formula can be simplified to

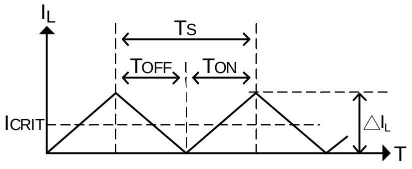
$$D_{(MIN)} = \frac{V_{OUT}}{V_{IN(MAX)}} = \frac{T_{ON}}{T_S} \quad ; \quad 0 \leq D \leq 1$$

(2) Define a value of minimum current that is approximately 10%~30% of full load current to maintain continuous conduction mode, usually referred to as the critical current (I_{CRIT}).



$$I_{CRIT} = \delta \times I_{LOAD} \quad ; \quad \delta = 0.1\sim0.3$$

(3) Calculate the inductor ripple current ($\triangle I_L$). In steady state conditions, the inductor ripple current increase, ($\triangle I_L+$), during the ON time and the current decrease, ($\triangle I_L-$), during the OFF time must be equal.



$$\Delta I_L = 2 \times I_{CRIT}$$

(4) Calculate the minimum value of inductor use maximum input voltage. That is the worst case condition because it gives the maximum $\triangle I_L$.

$$L \geq \frac{[V_{IN(MAX)} - I_{LOAD} \times (R_{DS(ON)} + R_L) - V_{OUT}] \times D_{(MIN)}}{\Delta I_L \times fs}$$

This formula can be simplified to

$$L \geq \frac{(V_{IN(MAX)} - V_{OUT}) \times D_{(MIN)}}{\Delta I_L \times fs}$$

The higher inductance results in lower output ripple current and ripple voltage. But it requires larger physical size and price.

(5) Calculate the inductor peak current and choose a suitable inductor to prevent saturation.

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

Coil inductors and surface mount inductors are all available. The surface mount inductors can reduce the board size but they are more expensive and its larger DC resistance results in more conduction loss. The power dissipation is due to the DC resistance can be calculated as below:

$$P_{D\_INDUCTOR} = I_{LOAD}^2 \times R_L$$

Output Capacitor Selection

The functions of the output capacitor are to store energy and maintain the output voltage. The low ESR (Equivalent Series Resistance) capacitors are preferred to reduce the output ripple voltage (△V_{OUT}) and conduction loss. The output ripple voltage can be calculated as below:

$$\Delta V_{OUT} = \Delta I_L \times (ESR\_{COUT} + \frac{1}{8 \times fs \times C_{OUT}})$$

Choose the suitable capacitors must define the expectative value of output ripple voltage first. A 22uF ceramic capacitor with X7R or X5R for most applications is sufficient because of the lower ESR and physical size.

The capacitors′ ESR and ripple current result in power dissipation that will increase the internal temperature and reduce the life time. Choose a smaller inductor causes higher ripple current which maybe result in the capacitor overstress. The RMS ripple current flowing through the output capacitor and power dissipation can be calculated as below:

$$I_{RMS} = \frac{\Delta I_L}{\sqrt{12}} = \Delta I_L \times 0.289$$

$$P_{D\_COUT} = I_{RMS}^2 \times ESR$$

Besides, the capacitor′s ESL (Equivalent Series Inductance) maybe causes ringing in the low MHz region. Choose low ESL capacitors, limiting lead length of PCB and capacitor, and parallel connecting several smaller capacitors to replace with a larger one will reduce the ringing phenomenon.

Input Capacitor Selection

The input capacitor is required to supply current to the regulator and maintain the DC input voltage. Low ESR capacitors are preferred those provide the better performance and the less ripple voltage.

The input capacitors need an adequate RMS current rating. It can be calculated by following formula and should not be exceeded.

$$I_{RMS\_CIN} = I_{LOAD(MAX)} \times \sqrt{D \times (1 - D)}$$

This formula has a maximum at $V_{IN}=2V_{OUT}$. That is the worst case and the above formula can be simplified to:

$$I_{RMS\_CIN} = \frac{I_{LOAD(MAX)}}{2}$$

Therefore, choose a suitable capacitor at input whose ripple current rating must greater than half of the maximum load current.

The input ripple voltage ($\triangle V_{IN}$) mainly depends on the input capacitor′s ESR and its capacitance. Assuming the input current of the regulator is constant, the required input capacitance for a given input ripple voltage can be calculated as below:

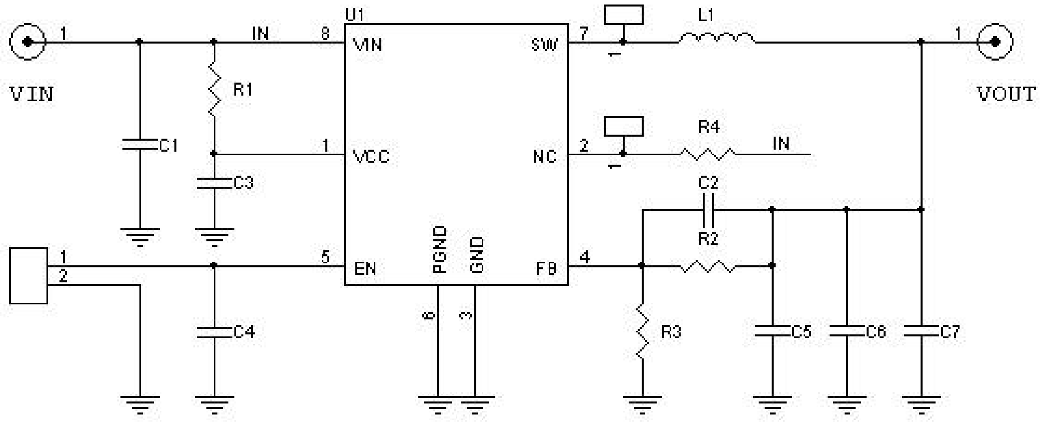
$$C_{IN} = \frac{I_{LOAD(MAX)} \times D \times (1 - D)}{fs \times (\Delta V_{IN} - I_{LOAD(MAX)} \times ESR\_{CIN})}$$

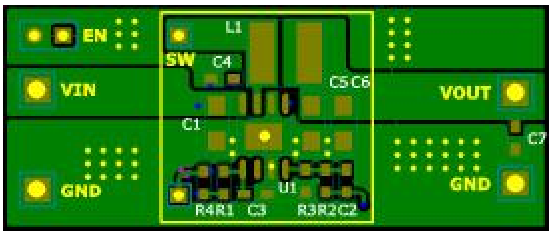
A 10uF ceramic capacitor with X7R or X5R for most applications is sufficient.

The power dissipation of input capacitor causes a small conduction loss can be calculated as below:

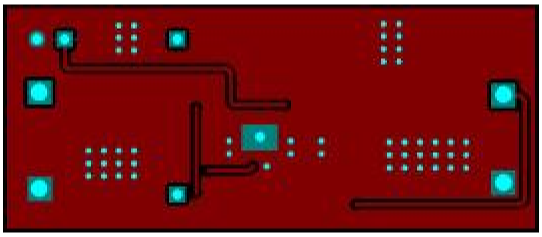
$$P_{D\_CIN} = (I_{RMS\_CIN})^2 \times ESR$$

Evaluation Board





(Top View)



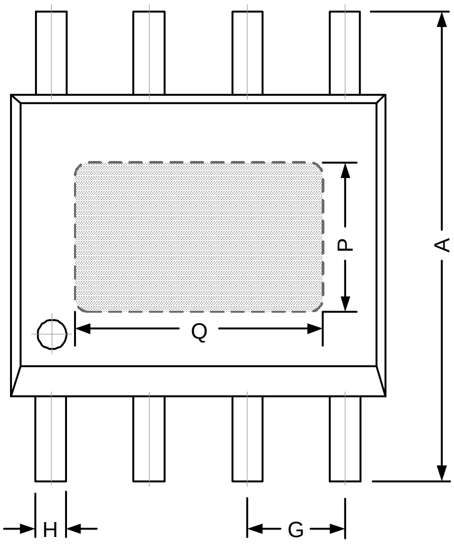
(Bottom View)

Key Components Supplier

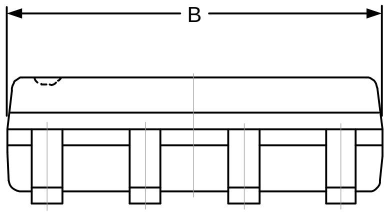
Item	*Manufacturer*	*Website*
Inductor (L)	**Chilisin**	*www.chilisin.com.tw*
	WE	*www.we-online.com*
Electrolytic Capacitor (C)	**Nippon Chemi-Con**	*www.chemi-con.co.jp*
	Jamicon	*www.jamicon.com.tw*
SMD Capacitor (C)	**Yageo**	*www.yageo.com*
	Taiyo Yuden	*www.yuden.co.jp*
	TDK	*www.tdk.com*
SMD Resistor (R)	**Yageo**	*www.yageo.com*

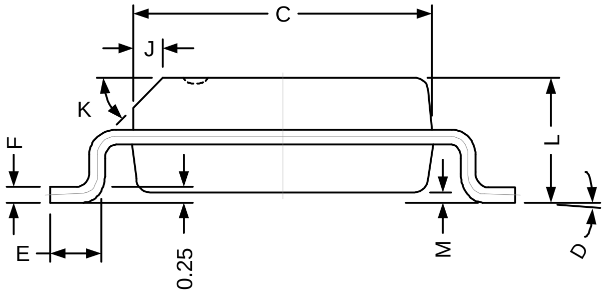
Package Outline

ESOP-8



REF.	DIMENSIONS	
	Millimeter	
	Min.	Max.
A	5.80	6.20
B	4.80	5.00
C	3.80	4.00
D	0°	8°
E	0.40	0.90
F	0.19	0.25
M	0.10	0.25
H	0.35	0.49
L	1.35	1.75
P	2.30	2.50
Q	3.20	3.40
J	0.375 REF.	
K	45°	
G	1.27 TYP.	





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