

### Features

- 2A Output Current
- Wide 4.5V to 23V Operating Input Range
- Integrated Power MOSFET Switches
- Output Adjustable from 0.925V to 18V
- Up to 96% Efficiency
- Programmable Soft-Start
- Stable with Low ESR Ceramic Output Capacitors
- Fixed 340KHZ Frequency
- Cycle-by-Cycle Over Current Protection
- Input Under Voltage Lockout
- Package : SOP-8L

### General Description

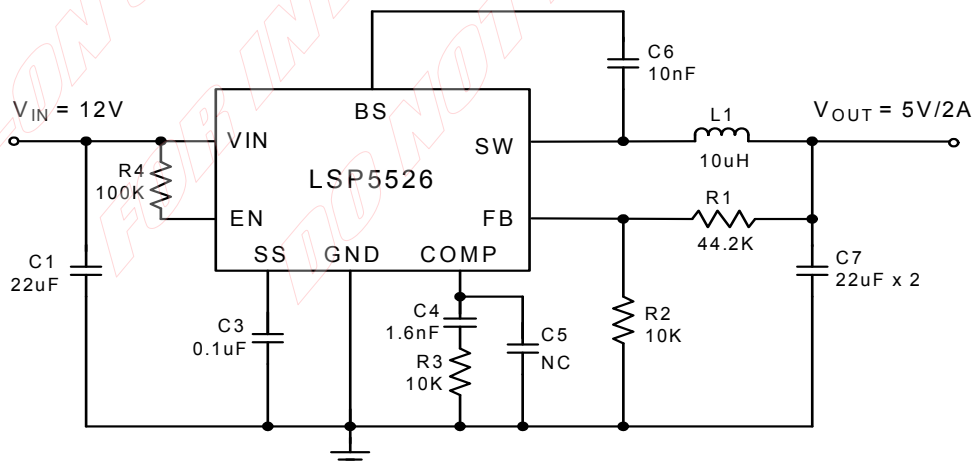
The LSP5526 is a monolithic synchronous buck regulator. The device integrates 95mΩ MOSFETS that provide 2A continuous load current over a wide operating input voltage of 4.5V to 23V. Current mode control provides fast transient response and cycle-by-cycle current limit.

An adjustable soft-start prevents inrush current at turn on. In shutdown mode, the supply current drops below 1uA.

### Applications

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

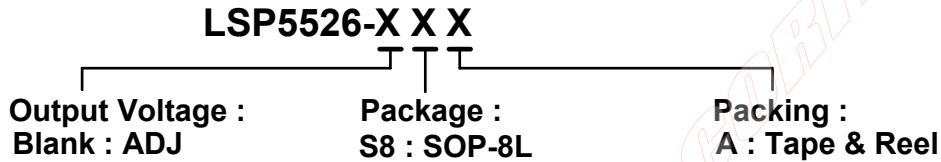
### Typical Application Circuit



shows a sample LSP5526 application circuit generating 5V/2A output

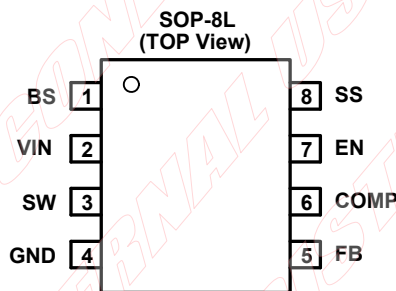
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**Ordering Information**



Device	Package Code	Package	Tape & Reel	
			Quantity	Part Number Suffix
LSP5526-S8A	S8	SOP-8L	2500	A

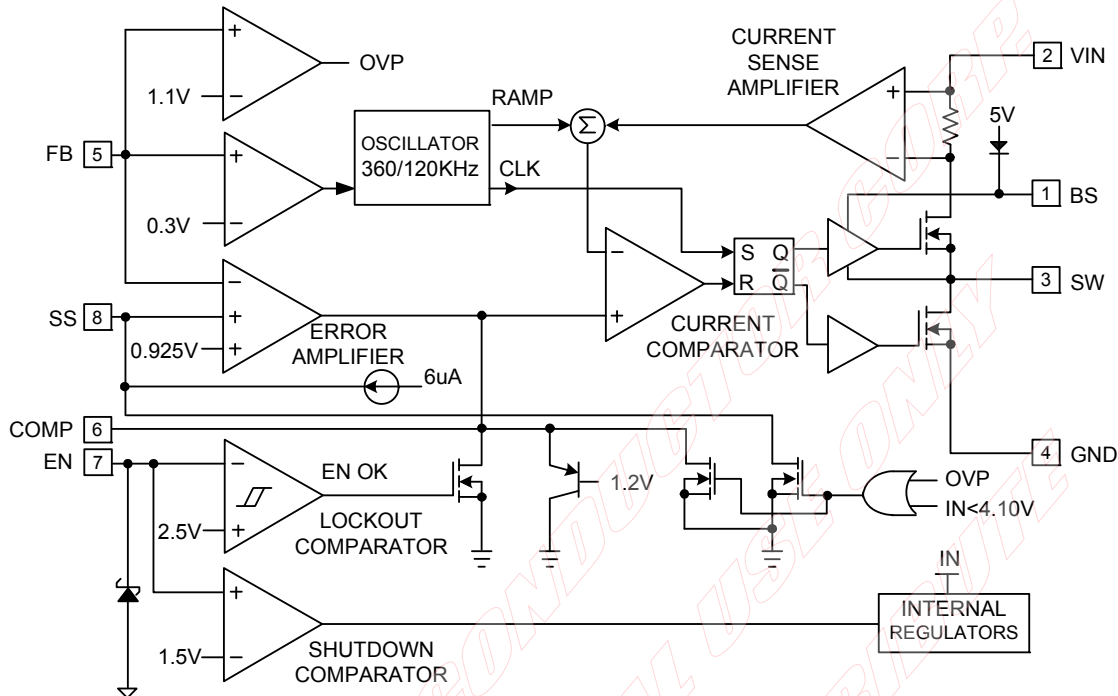
**Pin Assignments**



**Pin Descriptions**

Pin Number	Name	Description
1	BS	Bootstrap. This pin acts as the positive rail for the high-side switch's gate driver. Connect a 0.1uF capacitor between BS and SW.
2	VIN	Input Supply. Bypass this pin to G with a low ESR capacitor. See Input Capacitor in the Application Information section.
3	SW	Switch Output. Connect this pin to the switching end of the inductor.
4	GND	Ground.
5	FB	Feedback Input. The voltage at this pin is regulated to 0.925V. Connect to the resistor divider between output and ground to set output voltage.
6	COMP	Compensation Pin. See Stability Compensation in the Application Information section.
7	EN	Enable Input. When higher than 2.5V, this pin turns the IC on. When lower than 1.3V, this pin turns the IC off. Output voltage is discharged when the IC is off. This pin should not be left open.
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 0.1uF capacitor sets the soft-start period to 15ms. To disable the soft-start feature, leave SS unconnected.

**Block Diagram**



**Absolute Maximum Ratings**

Parameter	Value	Unit
Input Supply Voltage	-0.3 to 25	V
SW Voltage	-1 to $V_{IN} + 0.3$	V
BS Voltage	$V_{SW} - 0.3$ to $V_{SW} + 6$	V
EN, FB, COMP Voltage	-0.3 to 5.	V
Continuous SW Current	Internally limited	A
Junction to Ambient Thermal Resistance ( $\theta_{JA}$ ) (Test on Approximately 3 in <sup>2</sup> Copper Area 1oz copper FR4 board)	87	°C/W
Junction to Ambient Case Resistance ( $\theta_{JC}$ )	20	°C/W
SOP-8L Power Dissipation	0.76	W
Maximum Junction Temperature	150	°C
Storage Temperature Range	-65 to 150	°C

(Note: Exceeding these limits may damage the device. Exposure to absolute maximum rating conditions for long periods may affect device reliability.)

**Recommended Operating Conditions**

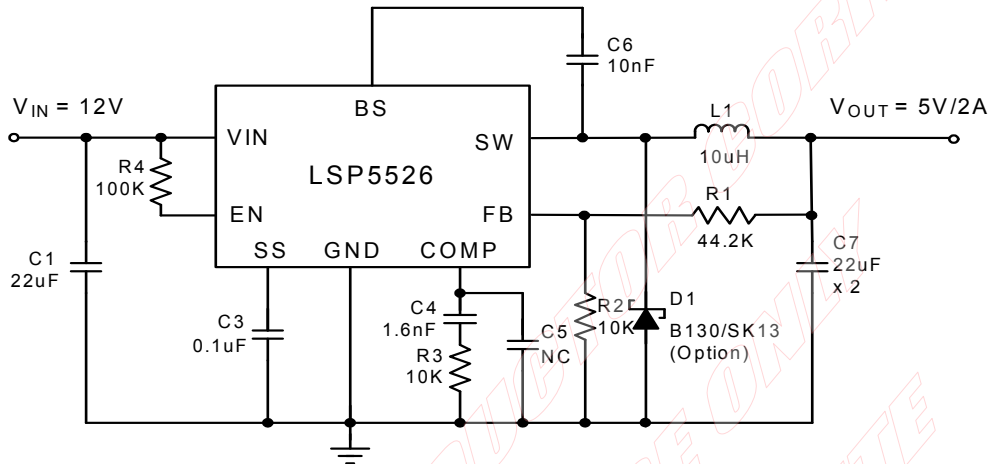
Parameter	Min	Max	Unit
Input Supply Voltage	4.5	23	V
Operating Junction Temperature	-20	+125	°C

**Electrical Characteristics**

( $V_{IN} = 12V$ ,  $T_A = 25^\circ C$  unless otherwise specified.)

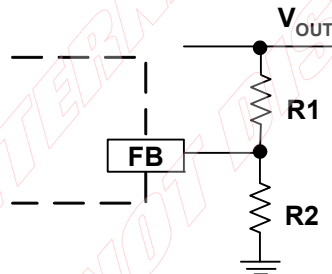
Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Feedback Voltage	$V_{FB}$	$4.5V \leq V_{IN} \leq 23V$	0.900	0.925	0.950	V
Feedback Overvoltage Threshold				1.1		V
High-Side Switch-On Resistance				95		mΩ
Low-Side Switch-On Resistance				95		mΩ
High-Side Switch Leakage		$V_{EN} = 0V, V_{SW} = 0V$		0.1	10	μA
Upper Switch Current Limit				3.5	4.0	A
COMP to Current Limit Transconductance	$G_{COMP}$			3.3		A/V
Error Amplifier Transconductance	$G_{EA}$	$\Delta I_{COMP} = \pm 10\mu A$		920		μA/V
Error Amplifier DC Gain	$A_{VEA}$			480		V/V
Switching Frequency	$f_{SW}$			340		KHz
Short Circuit Switching Frequency		$V_{FB} = 0$		120		KHz
Maximum Duty Cycle	$D_{MAX}$	$V_{FB} = 0.8V$		92		%
Minimum On Time				220		nS
EN Shutdown Threshold Voltage		$V_{EN}$ Rising	1.1	1.4	2	V
EN Shutdown Threshold Voltage Hys-terisis				180		mV
EN Lockout Threshold Voltage			2.2	2.5	2.7	V
EN Lockout Hysteresis				130		mV
Supply Current in Shutdown		$V_{EN} = 0$		0.3	3.0	μA
IC Supply Current in Operation		$V_{EN} = 3V, V_{FB} = 1.0V$		1.3	1.5	mA
Input UVLO Threshold Rising	UVLO	$V_{EN}$ Rising	3.80	4.05	4.40	V
Input UVLO Threshold Hysteresis				100		mV
Soft-start Current		$V_{SS} = 0V$		6		μA
Soft-start Period		$C_{SS} = 0.1\mu F$		15		mS
Thermal Shutdown Temperature		Hysteresis = $25^\circ C$		160		$^\circ C$

**Application Description**



shows a sample LSP5526 application circuit generating 5V/2A output.

**Output Voltage Setting**



**Figure1. Output Voltage Setting**

Figure 1 shows the connections for setting the output voltage. Select the proper ratio of the two feedback resistors  $R_{FB1}$  and  $R_{FB2}$  based on the output voltage. Typically, use  $R_{FB2} \approx 10K\Omega$  and determine  $R_{FB1}$  from the following equation:

**Table1 – Recommended Resistance Values**

$$R_{FB1} = R_{FB2} \left( \frac{V_{OUT}}{0.925V} - 1 \right) \quad (1)$$

V <sub>OUT</sub>	R <sub>FB1</sub>	R <sub>FB2</sub>
1.0V	1.0 KΩ	12 KΩ
1.2V	3.0 KΩ	10 KΩ
1.8V	9.53 KΩ	10 KΩ
2.5V	16.9 KΩ	10 KΩ
3.3V	26.1 KΩ	10 KΩ
5V	44.2 KΩ	10 KΩ
12V	121 KΩ	10 KΩ

**Inductor Selection**

The inductor maintains a continuous current to the output load. This inductor current has a ripple that is dependent on the inductance value: higher inductance reduces the peak-to-peak ripple current. The trade off for high inductance value is the increase in inductor core size and series resistance, and the reduction in current handling capability. In general, select an inductance value L based on the ripple current requirement:

$$L = \frac{V_{OUT} \cdot (V_{IN} - V_{OUT})}{V_{IN} f_{SW} I_{OUTMAX} K_{RIPPLE}} \quad (2)$$

where V<sub>IN</sub> is the input voltage, V<sub>OUT</sub> is the output voltage, f<sub>SW</sub> is the switching frequency, I<sub>OUTMAX</sub> is the maximum output current, and K<sub>RIPPLE</sub> is the ripple factor. Typically, choose K<sub>RIPPLE</sub> = 30% to correspond to the peak-to-peak ripple current being 30% of the maximum output current.

With this inductor value, the peak inductor current is I<sub>OUT</sub> • (1 + K<sub>RIPPLE</sub> / 2). Make sure that this peak inductor current is less than the 3A current limit. Finally, select the inductor core size so that it does not saturate at 3A. Typical inductor values for various output voltages are shown in Table 1.

V <sub>OUT</sub>	1.0V	1.2V	1.5V	1.8V	2.5V	3.3V	5V	9V
L	10uH	10uH	10uH	10uH	10uH	10uH	10uH	33uH

**Table 1. Typical Inductor Values**

**Input Capacitor**

The input capacitor needs to be carefully selected to maintain sufficiently low ripple at the supply input of the converter. A low ESR capacitor is highly recommended. Since large current flows in and out of this capacitor during switching, its ESR also affects efficiency.

The input capacitance needs to be higher than 10uF. The best choice is the ceramic type; however, low ESR tantalum or electrolytic types may also be used provided that the RMS ripple current rating is higher than 50% of the output current. The input capacitor should be placed close to the VIN and GND pins of the IC, with the shortest traces possible. In the case of tantalum or electrolytic types, they can be further away if a small parallel 0.1uF ceramic capacitor is placed right next to the IC.

**Output Capacitor**

The output capacitor also needs to have low ESR to keep low output voltage ripple. The output ripple voltage is:

$$V_{RIPPLE} = I_{OUTMAX} K_{RIPPLE} R_{ESR} + \frac{V_{IN}}{28 \cdot f_{SW}^2 LC_{OUT}} \quad (3)$$

where  $I_{OUTMAX}$  is the maximum output current,  $K_{RIPPLE}$  is the ripple factor,  $R_{ESR}$  is the ESR of the output capacitor,  $f_{SW}$  is the switching frequency,  $L$  is the inductor value, and  $C_{OUT}$  is the output capacitance. In the case of ceramic output capacitors,  $R_{ESR}$  is very small and does not contribute to the ripple. Therefore, a lower capacitance value can be used for ceramic capacitors. In the case of tantalum or electrolytic capacitors, the ripple is dominated by  $R_{ESR}$  multiplied by the ripple current. In that case, the output capacitor is chosen to have sufficiently low ESR.

For ceramic output capacitors, typically choose a capacitance of about 22uF. For tantalum or electrolytic capacitors, choose a capacitor with less than 50mΩ ESR.

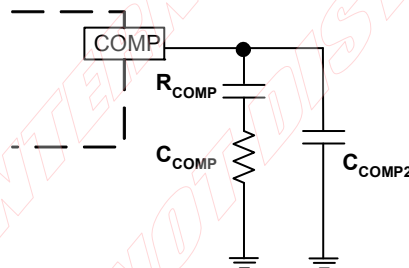
### Optional Schottky Diode

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 2 lists example Schottky diodes and their Manufacturers.

**Table 2 – Diode Selection Guide**

Part Number	Voltage/Current Rating	Vendor
B130	30V, 1A	Lite-on semiconductor corp.
SK13	30V, 1A	Lite-on semiconductor corp.

### Stability Compensation



$C_{COMP2}$  is needed only for high ESR output capacitor

**Figure 2. Stability Compensation**

The feedback loop of the IC is stabilized by the components at the COMP pin, as shown in Figure 2. The DC loop gain of the system is determined by the following equation:

$$A_{VDC} = \frac{0.925V}{I_{OUT}} A_{VEA} G_{CS} \quad (4)$$

The dominant pole P1 is due to  $C_{COMP}$ :

$$f_{P1} = \frac{G_{EA}}{2\pi A_{VEA} C_{COMP}} \quad (5)$$

The second pole P2 is the output pole:

$$f_{P2} = \frac{I_{OUT}}{2\pi V_{OUT} C_{OUT}} \quad (6)$$

The first zero Z1 is due to R<sub>COMP</sub> and C<sub>COMP</sub>:

$$f_{Z1} = \frac{1}{2\pi R_{COMP} C_{COMP}} \quad (7)$$

And finally, the third pole is due to R<sub>COMP</sub> and C<sub>COMP2</sub> (if C<sub>COMP2</sub> is used):

$$f_{P3} = \frac{1}{2\pi R_{COMP} C_{COMP2}} \quad (8)$$

The following steps should be used to compensate the IC:

**STEP1. Set the crossover frequency at 1/10 of the switching frequency via R<sub>COMP</sub>:**

$$R_{COMP} = \frac{2\pi V_{OUT} C_{OUT} f_{SW}}{10 G_{EA} G_{CS} \cdot 0.925V} \quad (9)$$

but limit R<sub>COMP</sub> to 10KΩ maximum.

**STEP2. Set the zero fZ1 at 1/4 of the crossover frequency. If R<sub>COMP</sub> is less than 10KΩ, the equation for C<sub>COMP</sub> is:**

$$C_{COMP} = \frac{1.68 \times 10^{-5}}{R_{COMP}} (F) \quad (10)$$

If R<sub>COMP</sub> is limited to 10KΩ, then the actual crossover frequency is 10/ (V<sub>OUT</sub>C<sub>OUT</sub>). Therefore:

$$C_{COMP} = 1.66 \times 10^{-11} V_{OUT} C_{OUT} (F) \quad (11)$$

**STEP3. If the output capacitor's ESR is high enough to cause a zero at lower than 4 times the crossover frequency, an additional compensation capacitor C<sub>COMP2</sub> is required. The condition for using C<sub>COMP2</sub> is:**

$$8\pi C_{OUT} \cdot R_{ESR} \cdot f_C \geq 1 \quad (12)$$

And the proper value for C<sub>COMP2</sub> is:

$$C_{COMP2} = \frac{C_{OUT} R_{ESR} C_{OUT}}{R_{COMP}} \quad (13)$$



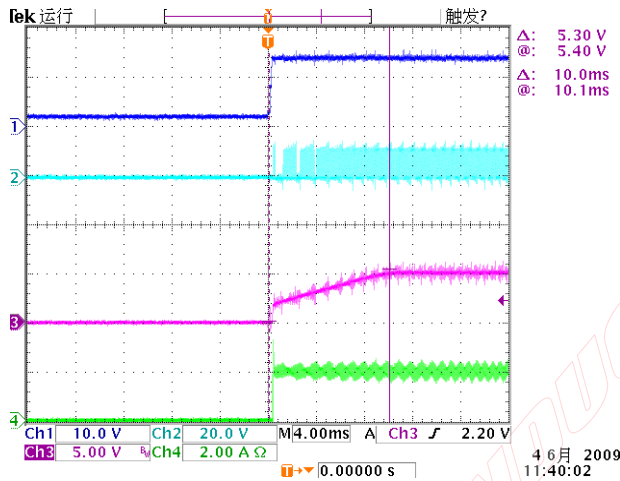
A reference table as follows:

**Table 3— Component Selection Guide for Stability Compensation**

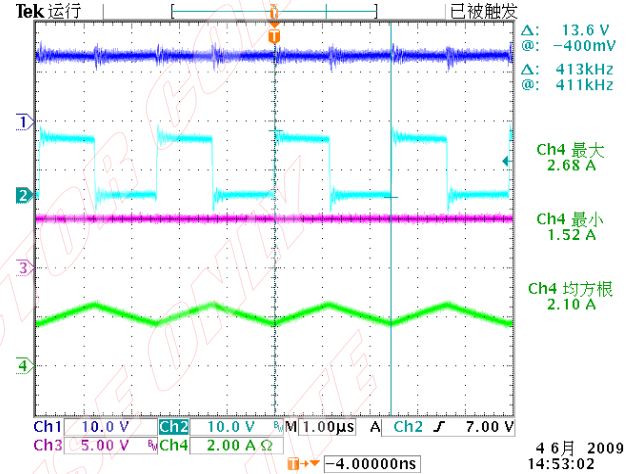
Vin Range (V)	Vout (V)	Cout	Rcomp (R3) (kΩ)	Ccomp (C4) (nF)	Ccomp2 (C5) (pF)	Inductor (uH)
5 - 12	1.0	22uF x2 Ceramic	10	3.6	none	4.7
5 - 12	1.2		10	3.6	none	4.7
5 - 19	1.8		10	2.2	none	10
5 - 24	2.5		10	1.8	none	10
5 - 24	3.3		10	1.5	none	10
5 - 24	5		14	1.5	none	10
5 - 12	1.0	470uF/ 6.3V/ 120mΩ	10	6.8	680	4.7
5 - 12	1.2					10
5 - 19	1.8					
5 - 23	2.5					
5 - 23	3.3					
5 - 23	5					

**Typical Performance Characteristics**

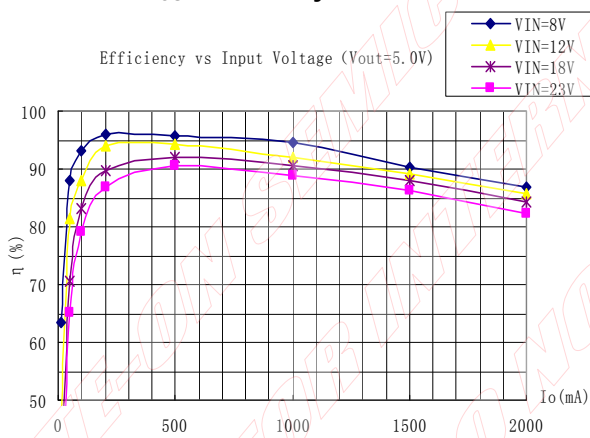
Start up soft start  $V_{IN}=12V$ ,  $V_{OUT}=5V$   $I_{OUT}=2A$



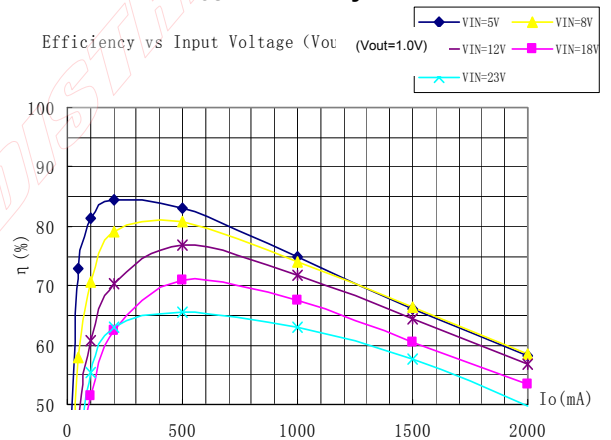
Operating status  $V_{IN}=12V$ ,  $V_{OUT}=5V$   $I_{OUT}=2A$



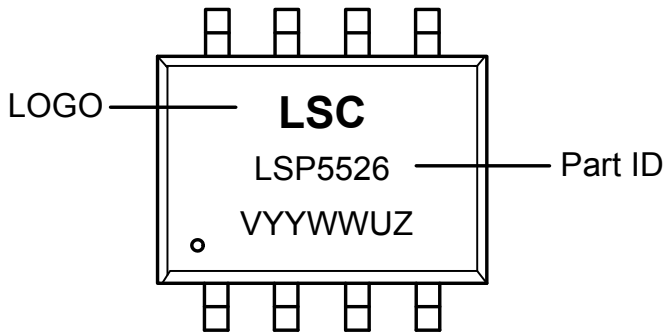
12V<sub>IN</sub> 5.0V<sub>OUT</sub> Efficiency curve



12V<sub>IN</sub> 1.0V<sub>OUT</sub> Efficiency curve



**Marking Information**



V YYWW UZ

Internal Code  
Date code

YY : Year(09=2009,10=2010,11=2011,12=2012...)

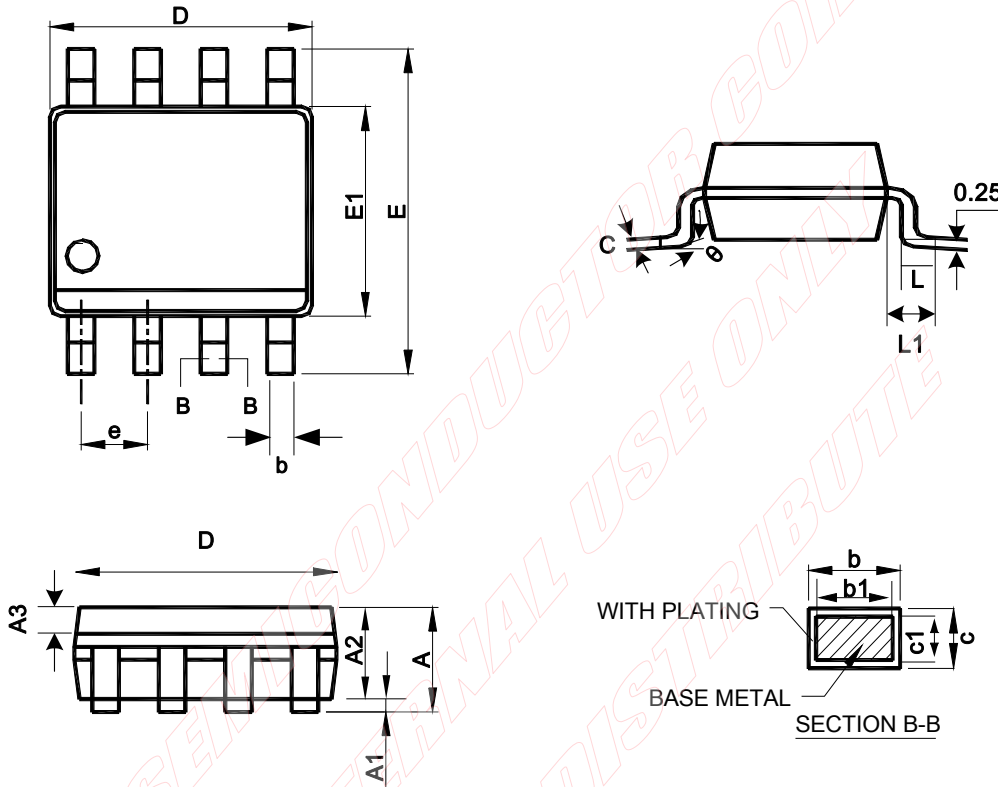
WW : Week(01~53)

Output Voltage

Blank : ADJ

**Package Information** (All Dimensions in min)

SOP-8L



Symbol	Dimensions In Millimeters		
	Min	Nom	Max
A	-	-	1.75
A1	0.10	-	0.25
A2	1.30	1.40	1.50
A3	0.60	0.65	0.70
b	0.39	-	0.48
b1	0.38	0.41	0.43
c	0.21	-	0.26
c1	0.19	0.20	0.21
D	4.70	4.90	5.10
E	5.80	6.00	6.20
E1	3.70	3.90	4.10
e	1.27BSC		
L	0.50	-	0.80
L1	1.05BSC		
$\theta$	0	-	8°