Wide Input 2.5A Step Down DC/DC Converter

■ FEATURES

- 2.5A Output Current
- Up to 90% Efficiency
- 7V to 30V Input Range
- 40µA Shutdown Supply Current
- 400kHz Switching Frequency
- Adjustable Output Voltage
- Cycle-by-Cycle Current Limit Protection
- Thermal Shutdown Protection
- Frequency Foldback at Short Circuit
- Stability with Wide Range of Capacitors, Including Low ESR Ceramic Capacitors
- SOP8L Package

■ TYPICAL APPLICATION

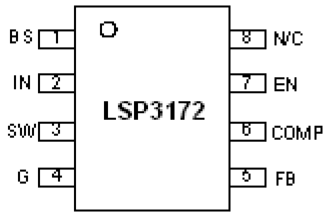
- TFT LCD Monitors
- Portable DVDs
- Car-Powered or Battery-Powered Equipments
- Set-Top Boxes
- Telecom Power Supplies
- DSL and Cable Modems and Routers
- Termination Supplies

■ GENERAL DESCRIPTION

The LSP3172 is a current-mode step-down DC/DC converter that generates up to 2.5A of output current at 400kHz switching frequency.
Consuming only 40µA in shutdown mode, the LSP3172 is highly efficient with peak operating efficiency at 90%. Protection features include cycle-by-cycle current limit, thermal shutdown, and frequency foldback at short circuit.
The LSP3172 is available in a SOP8L package and requires very few external devices for operation.

■ PIN ASSIGNMENT

(Top View)



■ PIN DESCRIPTION

Name	No.	Description
BS	1	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.
IN	2	Input Supply. Bypass this pin to G with a low ESR capacitor. See Input Capacitor in the Application Information section.
SW	3	Switch Output. Connect this pin to the switching end of the inductor.
G	4	Ground.
FB	5	Feedback Input. The voltage at this pin is regulated to 1.222V. Connect to the resistor divider between output and ground to set output voltage.
COMP	6	Compensation Pin. See Stability Compensation in the Application Information section.
EN	7	Enable Input. When higher than 2.5V, this pin turns the IC on. When lower than 2.0V, this pin turns the IC off. Output voltage is discharged when the IC is off. When left unconnected, EN is pulled high internally.
N/C	8	Not Connected.

ABSOLUTE MAXIMUM RATINGS

Parameter	Value	Unit
IN Supply Voltage	-0.3 to 35	V
SW Voltage	-1 to V_{IN} + 1	V
BS Voltage	V_{SW} – 0.3 to V_{SW} + 8	V
EN, FB, COMP Voltage	-0.3 to 30	V
Continuous SW Current	Internally limited	A
Junction to Ambient Thermal Resistance (θ_{JA})	105	°C/W
Junction to Case Thermal Resistance (θ_{JC})	50	°C/W
Maximum Power Dissipation	810	mW
Operating Junction Temperature	-40 to 150	°C
Storage Temperature	-55 to 150	°C
Lead Temperature (Soldering, 10 sec)	300	°C

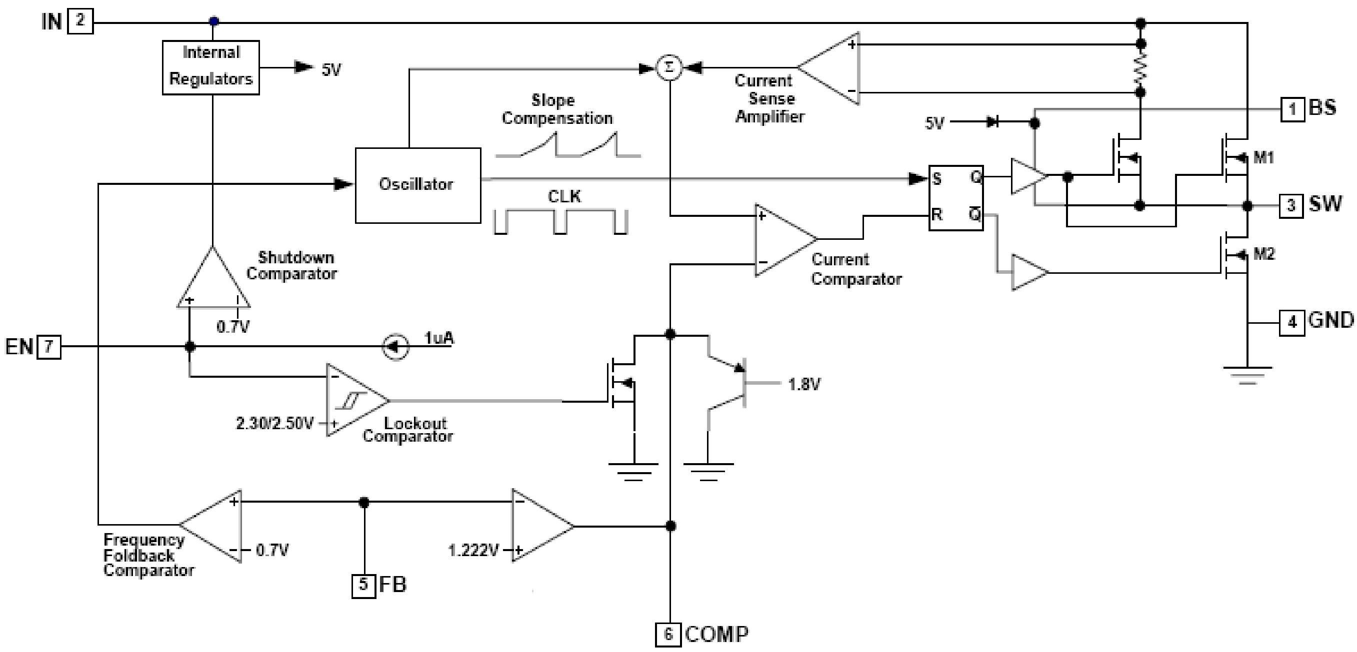
(Note: Exceeding these limits may damage the device. Exposure to absolute maximum rating conditions for long periods may affect device reliability.)

ELECTRICAL CHARACTERISTICS

(V_{IN} = 12V, TA= 25°C unless otherwise specified.)

Parameter	Symbol	Test Conditions	Min.	Typ.	Max.	Unit
Input Voltage	V_{IN}	V_{OUT} = 5V, I_{LOAD} = 0A to 1A	7		30	V
Feedback Voltage	V_{FB}	7V ≤ V_{IN} ≤ 20V, V_{COMP} = 1.5V	1.185	1.222	1.258	V
Saturation voltage of output driver	VCEsat	VIN=12V ILOAD=1A		500		mV
SW Leakage		V_{EN} = 0		0	10	µA
Current Limit	I_{LIMT}			3.6		A
COMP to Current Limit Transconductance	G_{COMP}			2.5		A/V
Error Amplifier Transconductance	G_{EA}	ΔI_{COMP} = ±10µA		850		µA/V
Error Amplifier DC Gain	A_{VEA}			350		V/V
Switching Frequency	f_{SW}		350	400	470	kHz
Short Circuit Switching Frequency		V_{FB} = 0		50		kHz
Maximum Duty Cycle	D_{MAX}	V_{FB} = 1.1V		90	95	%
Minimum Duty Cycle		V_{FB} = 1.4V			0	%
V_{COMP} Pin Maximum Switching Threshold		Duty cycle = 0%		0.35		V
Minimum Boost Voltage Above Switch		I_{SW} = 2.5A		1.8	2.7	V
Enable Threshold Voltage		Hysteresis = 0.1V	2.0		2.5	V
Enable Pull Up Current		Pin pulled up to 4.5V typically when left unconnected		2		µA
Supply Current in Shutdown		V_{EN} = 0		8	40	µA
IC Supply Current in Operation		V_{EN} = 3V, V_{FB} = 1.4V		2.2		mA
Thermal Shutdown Temperature		Hysteresis = 10°C		160		°C

FUNCTIONAL BLOCK DIAGRAM



FUNCTIONAL DESCRIPTION

As seen in the above Figure, Functional Block Diagram, the LSP3172 is a current mode pulse width modulation (PWM) converter. The converter operates as follows:

The LSP3172 is a current mode buck converter regulator.LSP3172 has an internal fixed-frequency clock. It uses two feedback loops that control the duty cycle of the internal power switch. The error amplifier functions like that of the voltage mode converter. The output of the error amplifier works as a switch current reference. This technique effectively removes one of the double poles in the voltage mode system. With this, it is much simpler to compensate a current mode converter to have better performance. The current sense amplifier in the LSP3172 monitors the switch current during each cycle. Overcurrent protection (OCP) is triggered when the current limit exceeds the upper limit of 3.6A, detected by a voltage on COMP greater than about 2V. When an OCP fault is detected, the switch is turned off and the external COMP capacitor is quickly discharged using an internal npn transistor. Once the COMP voltage has fallen below 250mV, an internal timer prevents any operation for 50µs, after which the part enters a normal startup cycle. In the case of sustained overcurrent or dead-short, the part will continually cycle through the retry sequence as

described above, at a rate dependent on the value of Ccomp.

The COMP voltage is the integration of the error between FB input and the internal 1.222V reference. If FB is lower than the reference voltage, COMP tends to go higher to increase current to the output. Current limit happens when COMP reaches its maximum clamp value of 2.55V.

Shutdown control

The LSP3172 has an enable input EN for turning the IC on or off. When EN is less than 2.0V, the IC is in 8µA low current shutdown mode and output is discharged through the Low-Side Power Switch. When EN is higher than 2.5V, the IC is in normal operation mode. EN is internally pulled up with a 2µA current source and can be left unconnected for always-on operation. Note that EN is a low voltage input with a maximum voltage of 6V; it should never be directly connected to IN.

Thermal Shutdown

The LSP3172 automatically turns off when its junction temperature exceeds 160°C.

APPLICATION INFORMATION

Output Voltage Setting

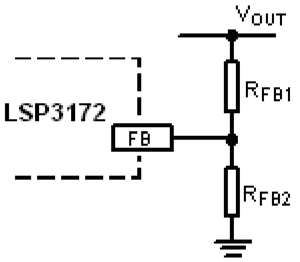


Figure1. Output Voltage Setting

Figure 1 shows the connections for setting the output voltage. Select the proper ratio of the two feedback resistors RFB1 and RFB2 based on the output voltage. Typically, use RFB2 ≈ 10kΩ and determine RFB1 from the following equation:

$$R_{FB1} = R_{FB2}\left(\frac{V_{OUT}}{1.222V} - 1\right) \quad (1)$$

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:

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

where V_{IN} is the input voltage, V_{OUT} is the output voltage, f_{SW} is the switching frequency, I_{OUTMAX} is the maximum output current, and K_{RIPPLE} is the ripple factor. Typically, choose K_{RIPPLE} = 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_{OUT} • (1 + K_{RIPPLE} / 2). Make sure that this peak inductor current is less that 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_{OUT}	1.5V	1.8V	2.5V	3.3V	5V
L	6.8µH	6.8µH	10µH	15µH	22µH

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 10µF. 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 IN and G 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 0.1µF 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:

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

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}

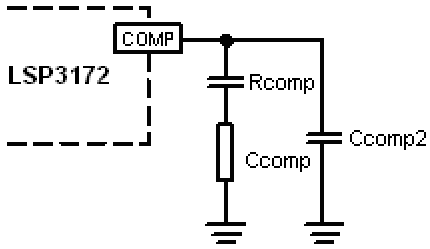
multiplied by the ripple current. In that case, the output capacitor is chosen to have sufficiently low ESR.

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

Rectifier Diode

Use a Schottky diode as the rectifier to conduct current when the High-Side Power Switch is off. The Schottky diode must have a current rating higher than the maximum output current and a reverse voltage rating higher than the maximum input voltage.

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:

$$A_{VDC} = \frac{1.222V}{I_{OUT}} A_{VEA} G_{COMP} \quad (4)$$

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_{COMP} and C_{COMP}:

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

And finally, the third pole is due to R_{COMP} and C_{COMP2} (if C_{COMP2} 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 RCOMP:

$$R_{COMP} = \frac{2\pi V_{OUT} C_{OUT} f_{SW}}{10 G_{EA} G_{COMP} \bullet 1.222V} \quad (9)$$

but limit RCOMP to 3.4kΩ maximum.

STEP2. Set the zero fZ1 at 1/4 of the crossover frequency. If RCOMP is less than 3.4kΩ, the equation for CCOMP is:

$$C_{COMP} = \frac{1.8 \times 10^{-5}}{R_{COMP}} \quad (F) \quad (10)$$

If RCOMP is limited to 3.4kΩ, then the actual crossover frequency is 3.4 / (VOUTCOUT). Therefore:

$$C_{COMP} = 1.2 \times 10^{-5} V_{OUT} C_{OUT} \quad (F) \quad (11)$$

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 CCOMP2 is required. The condition for using CCOMP2 is:

$$R_{ESRCOUT} \geq Min\left(\frac{1.1\times10^{-6}}{C_{OUT}}, 0.012 \bullet V_{OUT}\right) \quad (\Omega) \qquad (12)$$

And the proper value for C_{COMP2} is:

$$C_{COMP2} = \frac{C_{OUT} R_{ESRCOUT}}{R_{COMP}} \qquad (13)$$

Though C_{COMP2} is unnecessary when the output capacitor has sufficiently low ESR, a small value C_{COMP2} such as 100pF may improve stability against PCB layout parasitic effects.
Table 2 shows some calculated results based on the compensation method above.

V_{OUT}	C_{OUT}	R_{COMP}	C_{COMP}	C_{COMP2}
2.5V	22μF Ceramic	7.5kΩ	2.2nF	None
3.3V	22μF Ceramic	10kΩ	1.5nF	None
5V	22μF Ceramic	10kΩ	2.2nF	None
2.5V	47μF SP Cap	10kΩ	10nF	None
3.3V	47μF SP Cap	10kΩ	15nF	None
5V	47μF SP Cap	10kΩ	22nF	None
2.5V	470μF/6.3V/30mΩ	10kΩ	39nF	None
3.3V	470μF/6.3V/30mΩ	10kΩ	47nF	None
5V	470μF/10V/30mΩ	10kΩ	56nF	None

Table 2. Typical Compensation for Different Output Voltages and Output Capacitors

Figure 3 shows a sample LSP3172 application circuit generating 5V/2.5A output.

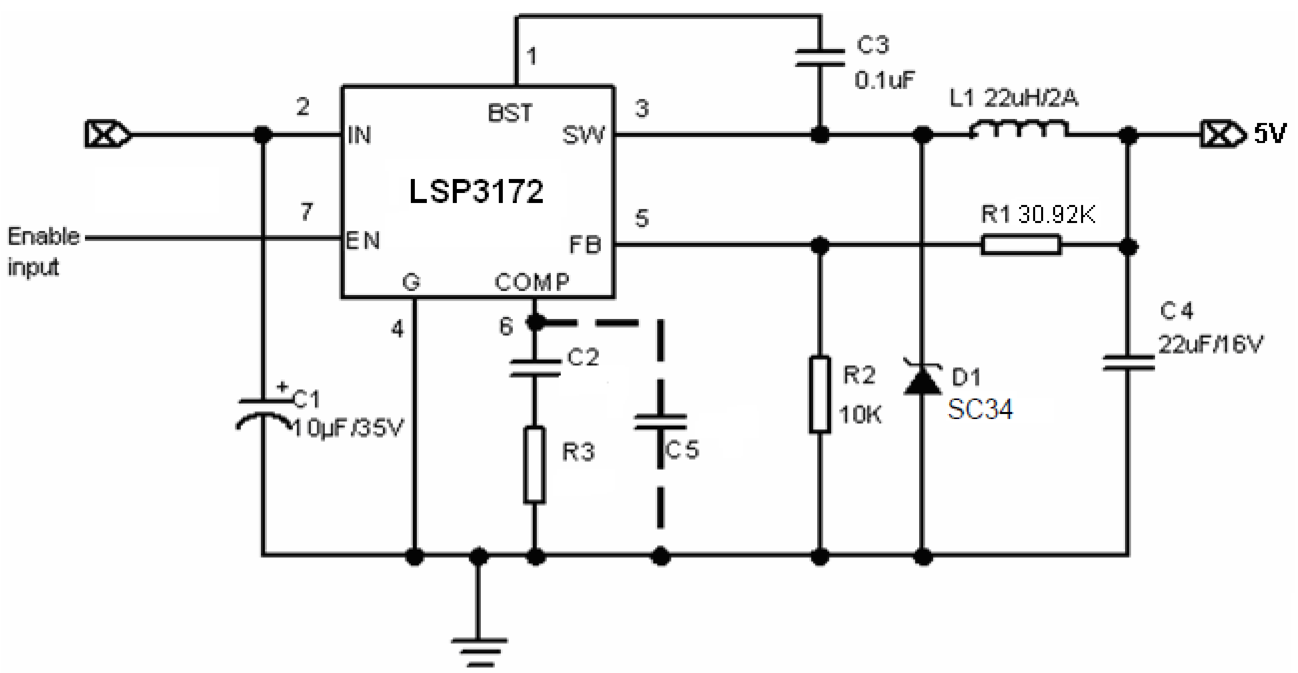
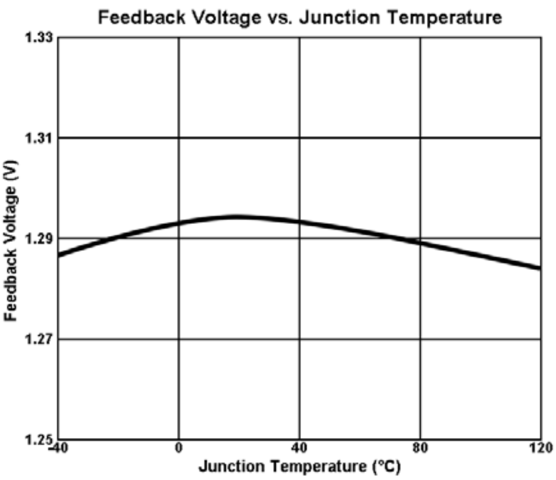
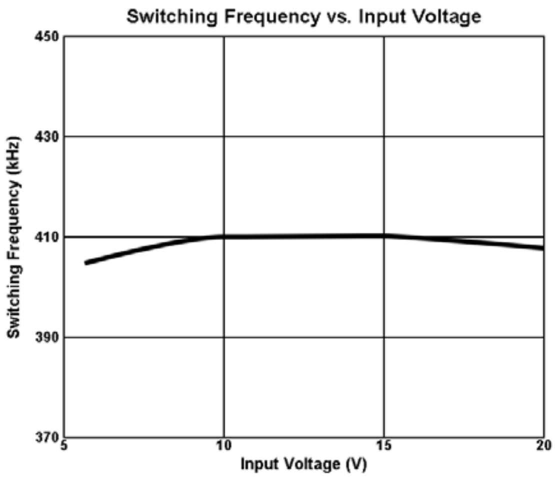
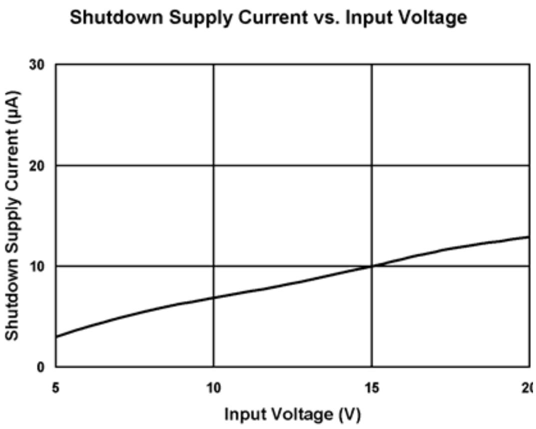


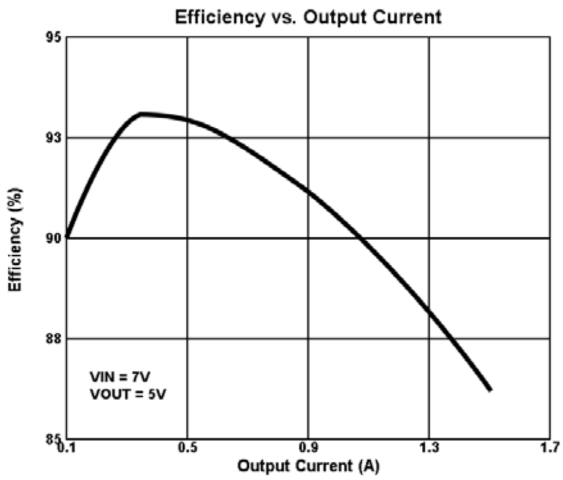
Figure3. LSP3172 5V/2.5A Output Application

■ TYPICAL CHARACTERISTICS

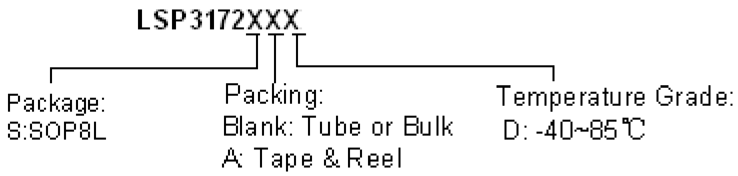




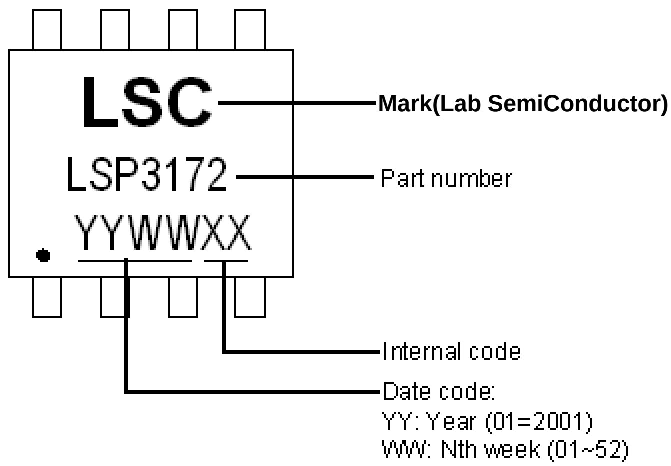




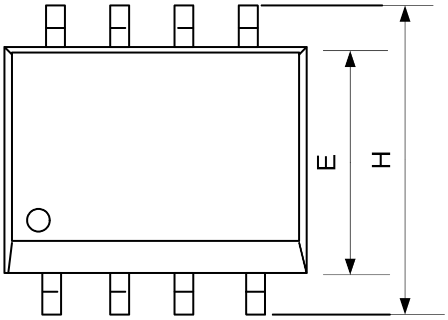
■ ORDERING INFORMATION

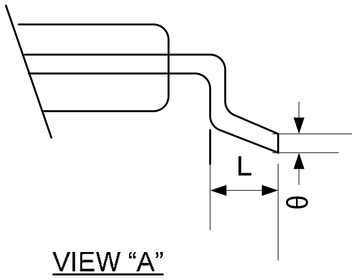


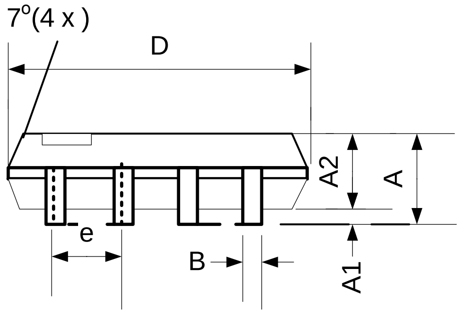
■ MARKING INFORMATION

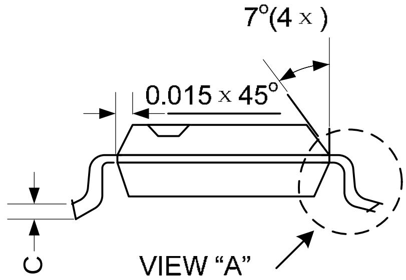


PACKAGE INFORMATION









Symbol	Dimensions In Millimeters			Dimensions In Inches		
	Min.	Nom.	Max.	Min.	Nom.	Max.
A	1.35	1.60	1.75	0.053	0.063	0.069
A1	0.10		0.25	0..004		0.010
A2	1.35	1.45	1.55	0.053	0.057	0.061
B	0.33	0.41	0.51	0.013	0.016	0.020
C	0.19	0.20	0.25	0.0075	0.008	0.010
D	4.80	4.90	5.00	0.192	0.196	0.200
E	3.80	3.90	4.00	0.148	0.154	0.160
e		1.27TYP.			0.050TYP.	
H	5.80	5.99	6.30	0.228	0.236	0.248
L	0.38	0.71	1.27	0.015	0.028	0.050
θ	0°		8°	0°		8°