

**150kHz, 3A PWM Buck DC/DC Converter**

# LM2596-XXE5/F5

## Description

The LM2596-XXE5/F5 series of regulators are monolithic ICs that provide all active functions for a step-down (buck) switching regulator, capable of driving 3A load with excellent line and load regulation. These devices are available in fixed output voltage of 3.3V, 5V, 12V and an adjustable output version. Requiring a minimum number of external components, these regulators are simple to use and include internal frequency compensation and a fixed-frequency oscillator.

The LM2596-XXE5/F5 series operates at a switching frequency of 150kHz, thus allowing smaller sized filter components than what would be needed with lower frequency switching regulators. Available in standard 5-lead TO-220 and TO-263 packages with several different lead bend options. A standard series of inductors are available from several different manufacturers optimized for use with the LM2596-XXE5/F5 series. This feature greatly simplifies the design of switch-mode power supplies. Other features include a guaranteed  $\pm 4\%$  tolerance on output voltage under specified input voltage and output load conditions, and  $\pm 15\%$  on the oscillator frequency. External shutdown is included, featuring 80 $\mu$ A standby current. Self protection features include a two stage frequency reducing current limit for the output switch and an over temperature shutdown for complete protection under fault conditions.

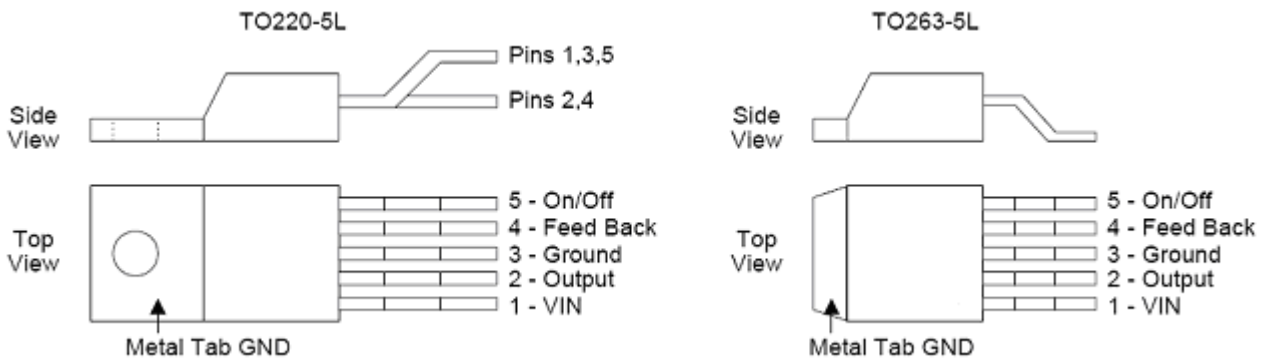
## Features

- 3.3V, 5V, 12V, and adjustable output versions
- Adjustable version output voltage range, 1.3V to 37V $\pm 4\%$  max over line and load conditions
- 150kHz $\pm 15\%$  fixed switching frequency
- TTL shutdown capability
- Operating voltage can be up to 40V
- Output load current: 3A
- TO220-5L and TO263-5L packages
- Low power standby mode.
- Thermal shutdown and current limit protection.
- High efficiency
- Built-in switching transistor on chip
- Requires only 4 external components
- Use readily available standard inductors

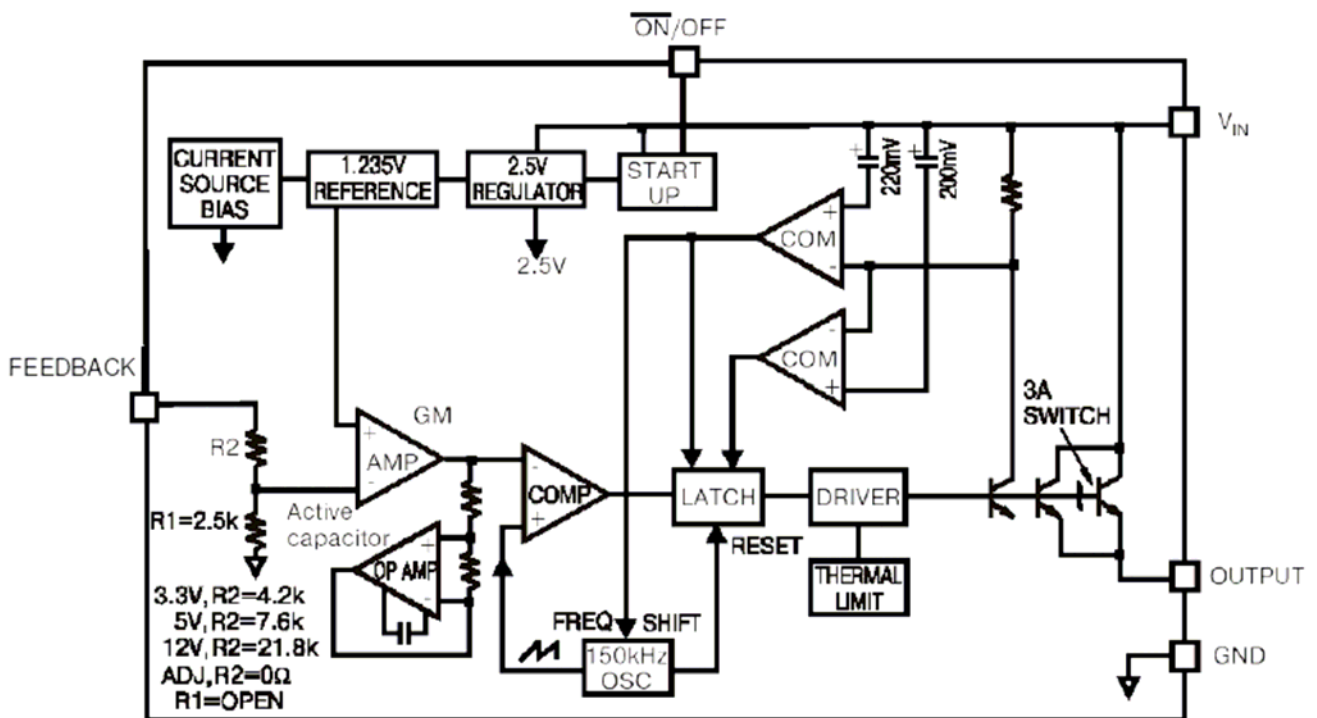
## Applications

- Simple high-efficiency step-down (buck) regulator.
- Positive to negative converter (Buck-Boost).
- On-card switching regulators.

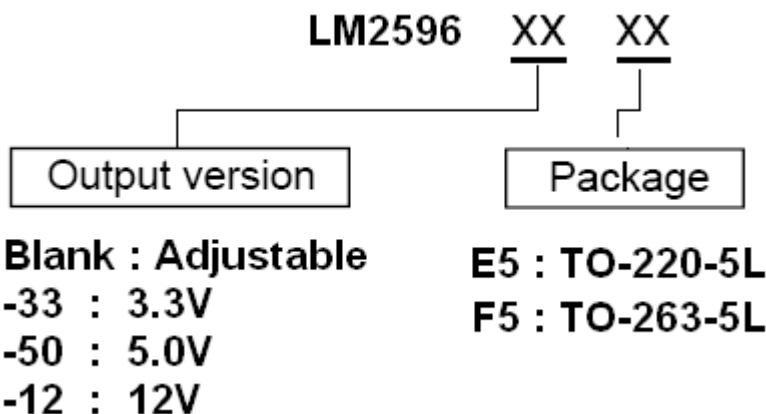
## Pin Assignment



## Block Diagram



## Ordering Information





**Absolute Maximum Ratings** (Note 1)

Parameter	Symbol	Value	Unit
Supply Voltage	V <sub>CC</sub>	45	V
On/Off Pin Input Voltage	V <sub>SD</sub>	-0.3 ~ +25	V
Feedback Pin Voltage	V <sub>FB</sub>	-0.3 ~ +25	V
Output Voltage to Ground	V <sub>OUT</sub>	-1	V
Power Dissipation	P <sub>D</sub>	Internally Limited	W
Operating Temperature	T <sub>opr</sub>	-40 ~ +125	°C
Storage Temperature	T <sub>stg</sub>	-65 ~ +150	°C
Operating Voltage	V <sub>OP</sub>	+4.5 ~ +40	V
ESD Susceptibility (Note 2)		2000	V

**Electrical Characteristics (All Output Voltage Versions)**

Specifications with **boldface type** are for full operating temperature range, the other type are for T<sub>J</sub>=25°C. (Unless otherwise specified, V<sub>IN</sub>=12V for the 3.3V, 5V, and adjustable version and V<sub>IN</sub>=24V for the 12V version, I<sub>LOAD</sub>=500mA)

Parameter	Symbol	Test Condition	Min	Typ	Max	Unit	
<i>Device parameters</i>							
Feedback Bias Current	I <sub>b</sub>	Adjustable Version Only, V <sub>FB</sub> =1.3V	-	10	50 <b>100</b>	nA	
Oscillator Frequency	f <sub>o</sub>	(Note 6)	127 <b>110</b>	150	173 <b>173</b>	KHz	
Saturation Voltage	V <sub>SAT</sub>	I <sub>OUT</sub> =3A (Note 7, 8)	-	1.16	1.4 <b>1.5</b>	V	
Max Duty Cycle (ON)	DC	(Note 8) (Note 9)	-	100	-	%	
Min Duty Cycle(OFF)				0			
Current Limit	I <sub>CL</sub>	Peak Current ( Note 7, 8)	3.6 <b>3.4</b>	4.5	6.9 <b>7.5</b>	A	
Output Leakage Current	I <sub>L</sub>	Output=0V (Note 7, 9)	-	-	50	μA	
		Output=-1V(Note 10)	-	2	30	mA	
Quiescent Current	I <sub>Q</sub>	(Note 9)	-	5	10	mA	
Standby Quiescent Current	I <sub>STBY</sub>	ON/OFF pin=5V (Note 10)	-	80	200 <b>250</b>	μA	
Thermal Resistance	θ <sub>JC</sub>	TO-220-5L	Junction to Case	-	2	-	°C/W
		TO-263-5L		-	3.5	-	
	θ <sub>JA</sub> (Note11)	TO-220-5L	Junction to Ambient	-	50	-	°C/W
		TO-263-5L		-	23	-	
<i>ON/OFF Control</i>							
ON/OFF Pin Logic Input Threshold Voltage	V <sub>IH</sub>	Low (Regulator ON)	-	1.3	0.6	V	
	V <sub>IL</sub>	High (Regulator OFF)	2.0		-		
ON/OFF Pin Input Current	I <sub>IH</sub>	V <sub>LOGIC</sub> =2.5V (Regulator OFF)	-	5	15	μA	
	I <sub>IL</sub>	V <sub>LOGIC</sub> =0.5V (Regulator ON)	-	0.02	5		



## Electrical Characteristics (Continued)

Specifications with **boldface type** are for full operating temperature range, the other type are for  $T_J=25^{\circ}\text{C}$ .

Part No.	Parameter	Symbol	Conditions	Min	Typ (Note 3)	Max (Note 4)	Units
LM2596-3.3	Output Voltage	$V_{OUT}$	$4.75\text{V} \leq V_{IN} \leq 40\text{V}$ , $0.2\text{A} \leq I_{LOAD} \leq 3\text{A}$	3.168 <b>3.135</b>	3.3	3.432 <b>3.465</b>	V
	Efficiency	$\eta$	$V_{IN}=12\text{V}$ , $I_{LOAD}=3\text{A}$	-	73	-	%
LM2596-5.0	Output Voltage	$V_{OUT}$	$7\text{V} \leq V_{IN} \leq 40\text{V}$ , $0.2\text{A} \leq I_{LOAD} \leq 3\text{A}$	4.800 <b>4.750</b>	5.0	5.200 <b>5.250</b>	V
	Efficiency	$\eta$	$V_{IN}=12\text{V}$ , $I_{LOAD}=3\text{A}$	-	80	-	%
LM2596-12	Output Voltage	$V_{OUT}$	$15\text{V} \leq V_{IN} \leq 40\text{V}$ , $0.2\text{A} \leq I_{LOAD} \leq 3\text{A}$	11.52 <b>11.40</b>	12.0	12.48 <b>12.60</b>	V
	Efficiency	$\eta$	$V_{IN}=25\text{V}$ , $I_{LOAD}=3\text{A}$	-	90	-	%
LM2596-ADJ	Output Feedback	$V_{FB}$	$4.5\text{V} \leq V_{IN} \leq 40\text{V}$ , $0.2\text{A} \leq I_{LOAD} \leq 3\text{A}$ $V_{OUT}$ programmed for 3V	1.180 <b>1.168</b>	1.230	1.280 <b>1.292</b>	V
	Efficiency	$\eta$	$V_{IN}=12\text{V}$ , $V_{OUT}=3\text{V}$ , $I_{LOAD}=3\text{A}$	-	77	-	%

**Note 1 :** Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is intended to be functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics.

**Note 2 :** The human body model is a 100pF capacitor discharged through a 1.5K resistor into each pin.

**Note 3 :** Typical numbers are at  $25^{\circ}\text{C}$  and represent the most likely norm.

**Note 4 :** All limits guaranteed at room temperature (standard face type) and at temperature extremes (bold face type). All room temperature limits are 100% production tested. All limits at temperature extremes are guaranteed via correlation using standard Statistical Quality Control (SQC) methods. All limits are used to calculate Average Outgoing Quality Level (AOQL).

**Note 5 :** External components such as the catch diode, inductor, input and output capacitors, and voltage programming resistors can affect switching regulator system performance.

**Note 6 :** The switching frequency is reduced when the second stage current limit is activated.

**Note 7 :** No diode, inductor or capacitor connected to output pin.

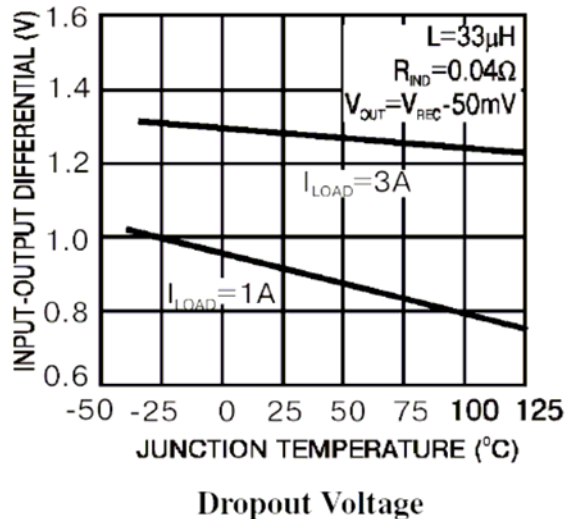
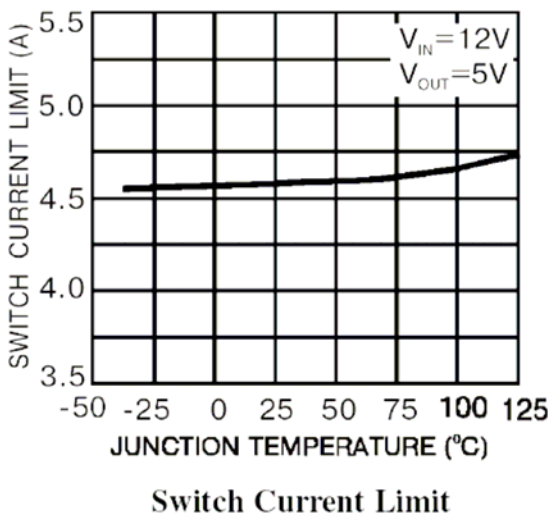
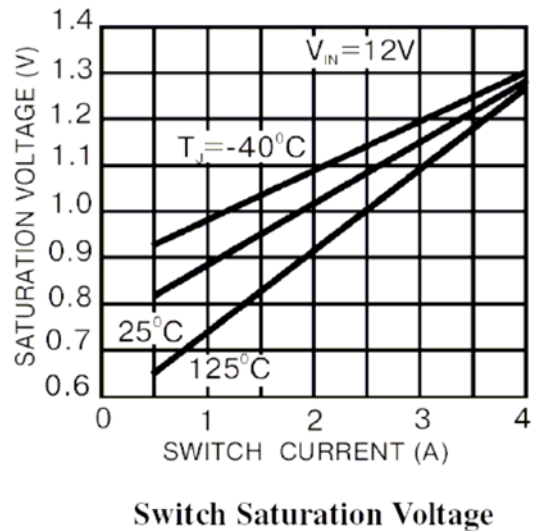
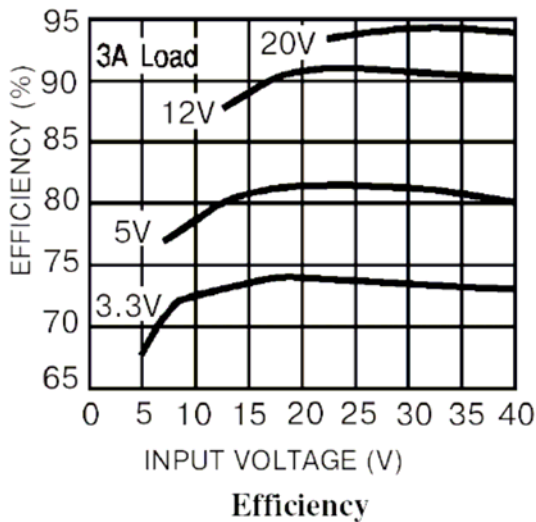
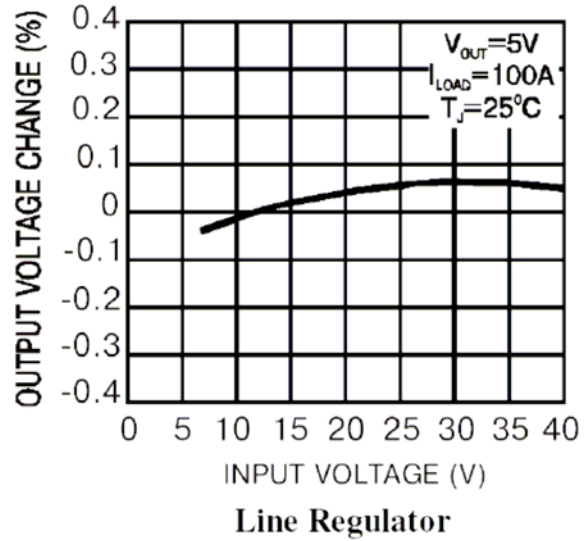
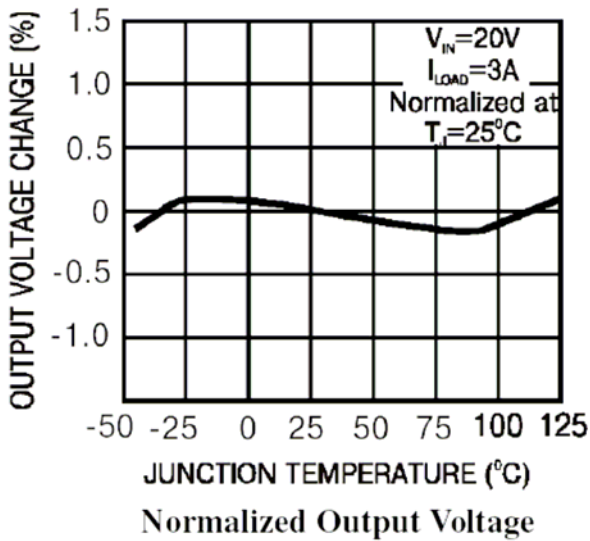
**Note 8 :** Feedback pin removed from output and connected to 0V to force the output transistor switch ON.

**Note 9 :** Feedback pin removed from output and connected to +12V for the 3.3V, 5V and adjustable version, and +15V for the 12V version, to force the output transistor switch OFF.

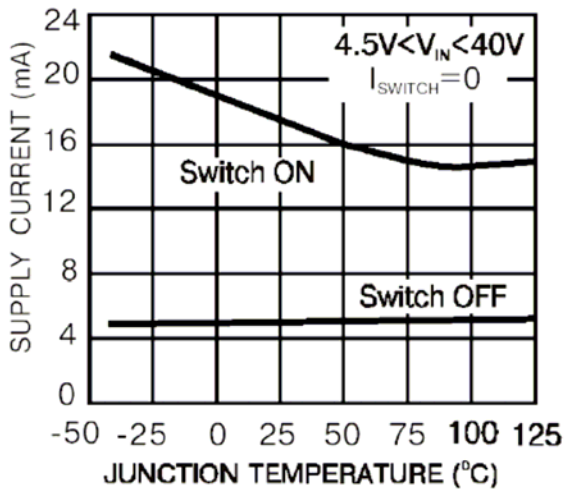
**Note 10 :**  $V_{IN}=40\text{V}$ .

**Note 11 :** Junction to Ambient thermal resistance. (With copper area of approximately 3 in<sup>2</sup>)

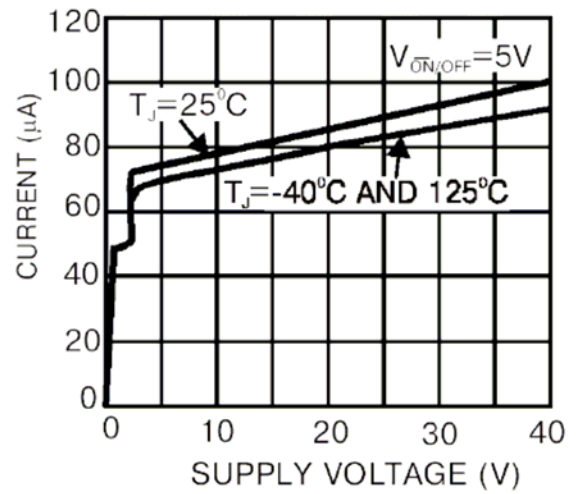
## Typical Performance Characteristics (circuit of Figure 2)



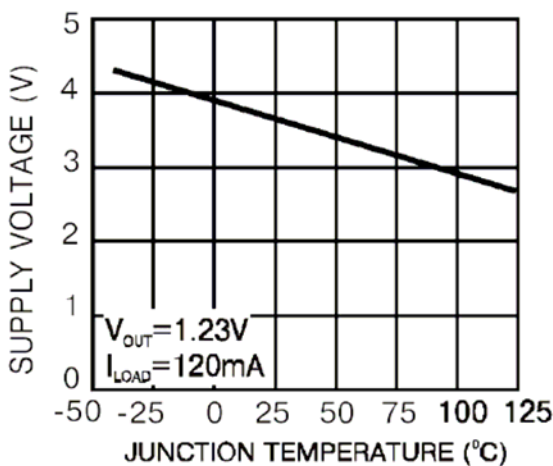
## Typical Performance Characteristics(Cont.)



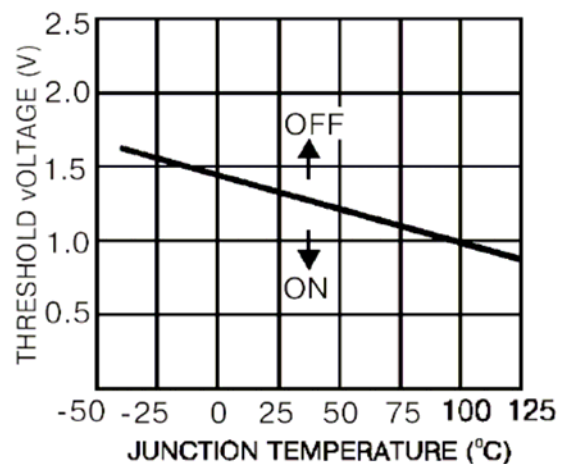
Operating Quiescent Current



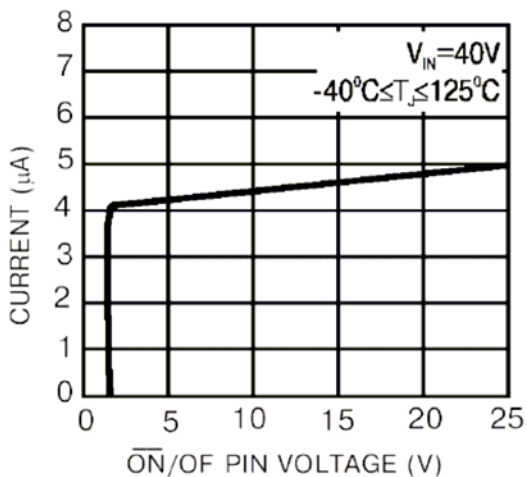
Shutdown Quiescent Current



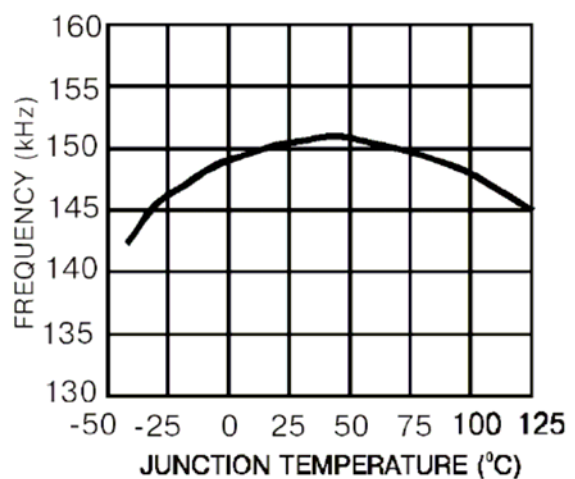
Minimum Operating Supply Voltage



$\overline{ON}/OFF$  Threshold Voltage

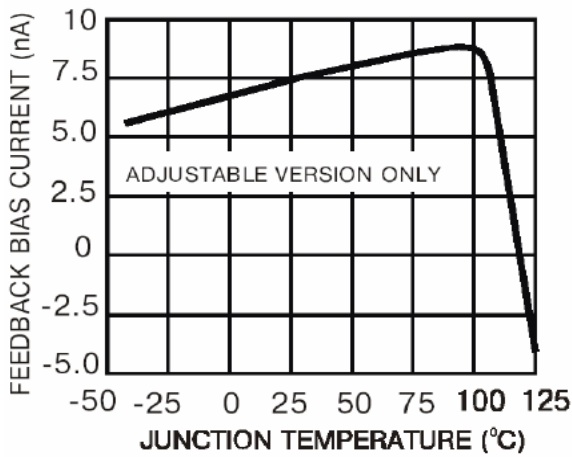


$\overline{ON}/OFF$  Pin Current (Sinking)



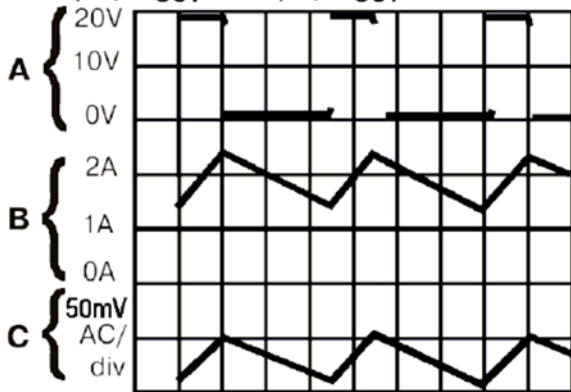
Switching Frequency

**Typical Performance Characteristics(Cont.)**



**Feedback Pin Bias Current**

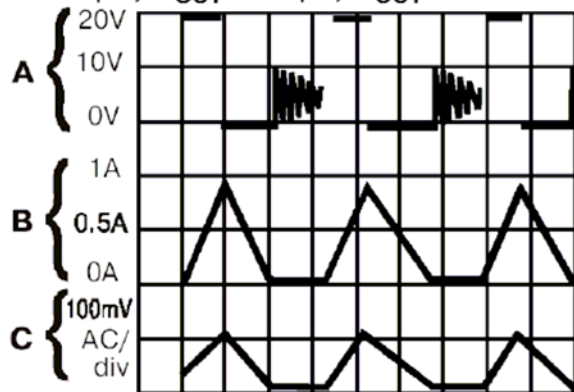
$V_{IN}=20V, V_{OUT}=5V, I_{LOAD}=2A$   
 $L=32\mu H, C_{OUT}=220\mu F, C_{OUT}ESR=50m\Omega$



A: Output Pin Voltage, 10V/div  
 B: Inductor Current 1A/div  
 C: Output Ripple Voltage, 50mV/div  
**Horizontal Time Base: 2µs/div**

**Continuous Mode Switching Waveforms**

$V_{IN}=20V, V_{OUT}=5V, I_{LOAD}=500mA$   
 $L=10\mu H, C_{OUT}=330\mu F, C_{OUT}ESR=45m\Omega$

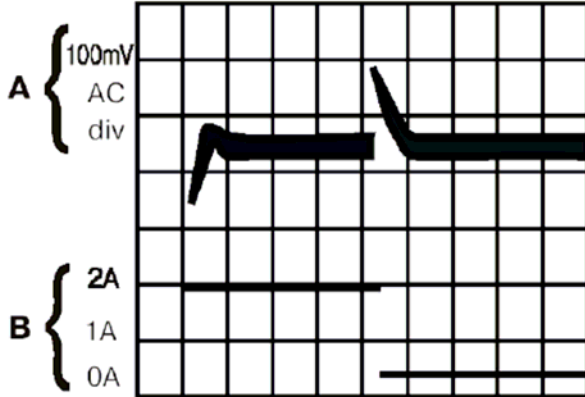


A: Output Pin Voltage, 10V/div  
 B: Inductor Current 1A/div  
 C: Output Ripple Voltage, 100mV/div  
**Horizontal Time Base: 2µs/div**

**Discontinuous Mode Switching Waveforms**

**Typical Performance Characteristics(Cont.)**

$V_{IN}=20V, V_{OUT}=5V, I_{LOAD}=500mA \text{ to } 2A$   
 $L=32\mu H, C_{OUT}=220\mu F, C_{OUTESR}=50m\Omega$

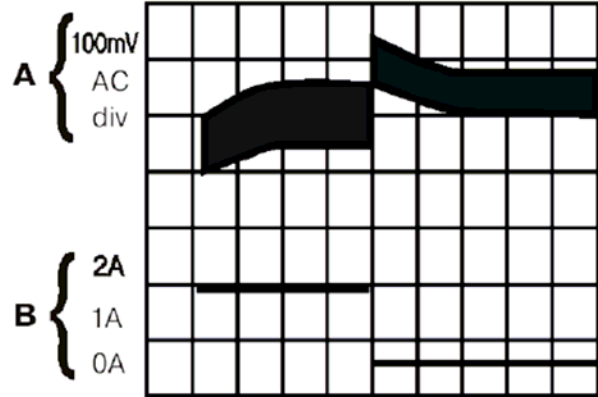


A: Output Voltage, 100mV/div.(AC)  
 B: 500mA to 2A Load Pulse

**Horizontal Time Base: 100µs/div**

**Load Transient Response  
 for Continuous Mode**

$V_{IN}=20V, V_{OUT}=5V, I_{LOAD}=500mA \text{ to } 2A$   
 $L=10\mu H, C_{OUT}=330\mu F, C_{OUTESR}=45m\Omega$



A: Output Voltage, 100mV/div. (AC)  
 B: 500mA to 2A Load Pulse

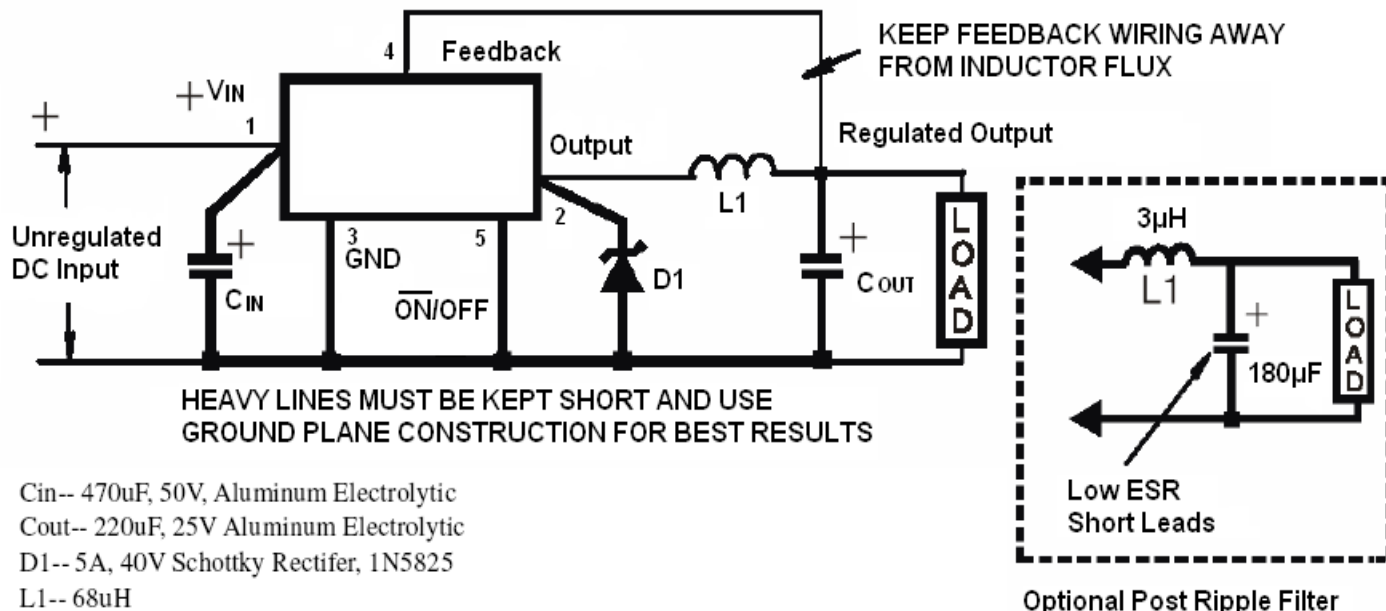
**Horizontal Time Base: 200µs/div**

**Load Transient Response  
 for Discontinuous Mode**

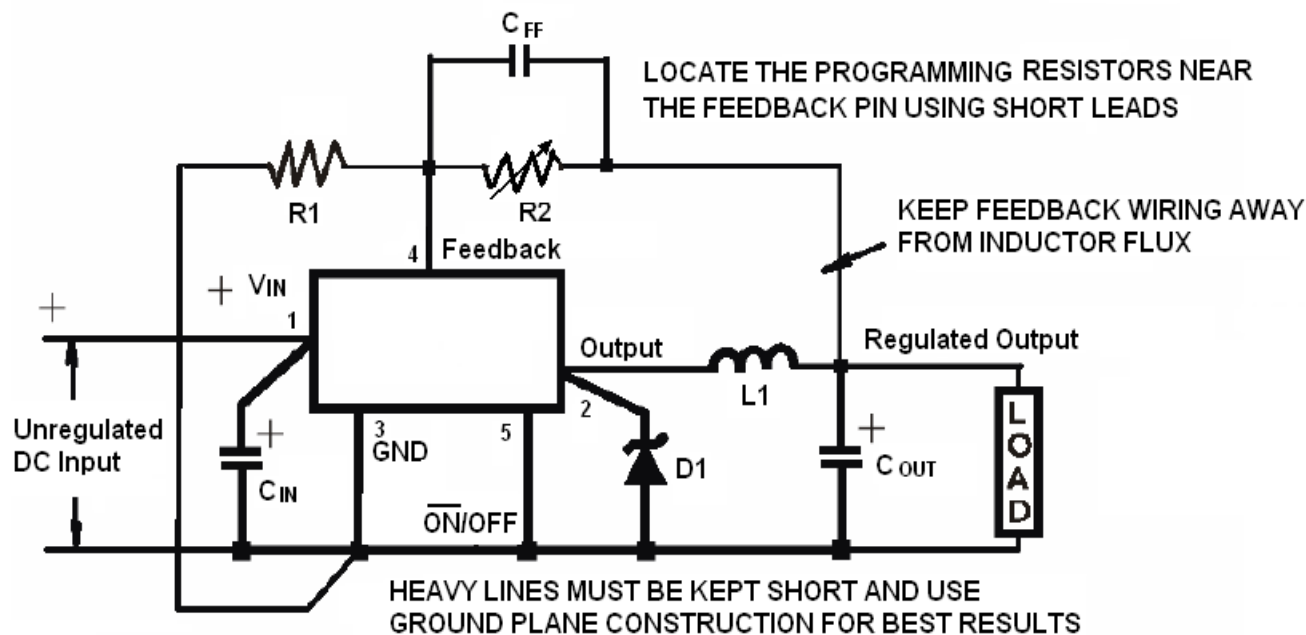


**Typical Application Circuit**

**Fixed Output Voltage Versions**



**Adjustable Output Voltage Versions**



$$V_{out} = V_{REF} * (1 + R2/R1)$$

Where  $V_{REF} = 1.23V$

$$R2 = R1 * (V_{out}/V_{REF} - 1)$$

Select R1 to be approximately 1kΩ, use a 1% resistor for best stability.

Cin-- 470uF, 50V, Aluminum Electrolytic

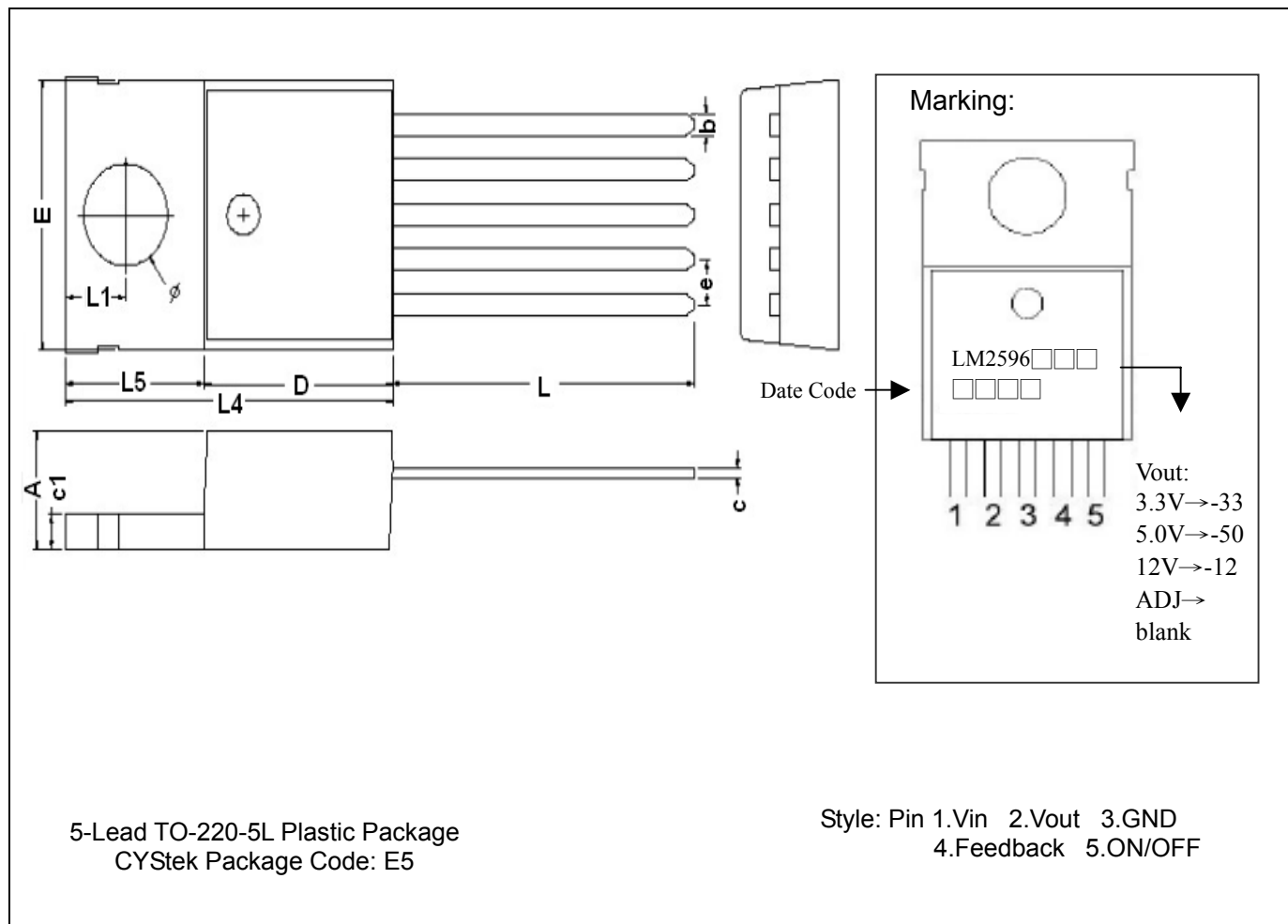
Cout-- 220uF, 35V Aluminum Electrolytic

D1-- 5A, 40V Schottky Rectifier, 1N5825

L1-- 68uH

**Figure 2 Standard Test Circuits and Layout**

## TO-263-5L Dimension



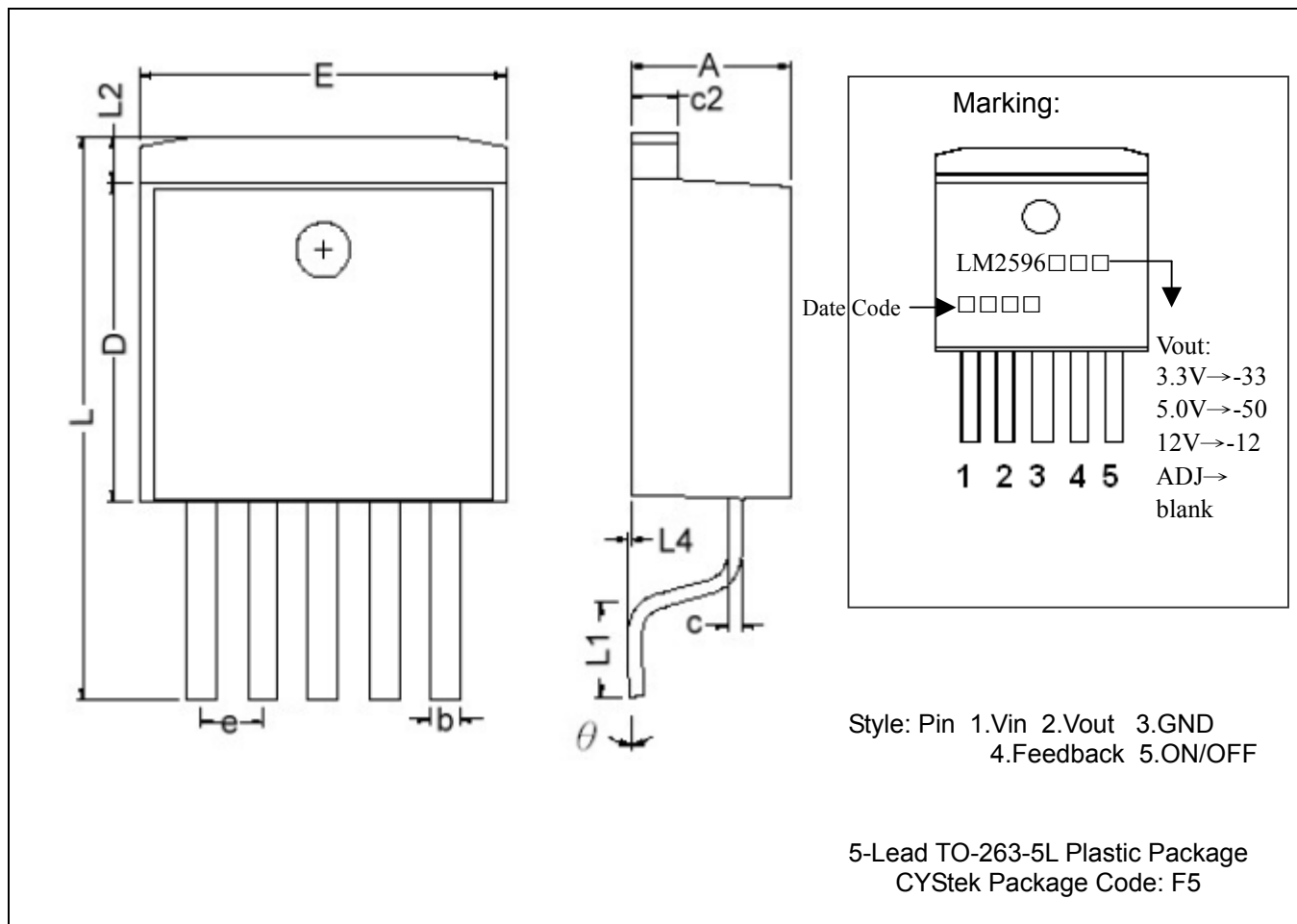
DIM	Inches		Millimeters		DIM	Inches		Millimeters	
	Min.	Max.	Min.	Max.		Min.	Max.	Min.	Max.
A	0.173	0.189	4.40	4.80	L5	0.244	0.260	6.20	6.60
b	0.030	0.039	0.76	1.00	c1	0.049	0.057	1.25	1.45
c	0.014	0.020	0.36	0.50	L	0.522	0.561	13.25	14.25
D	0.339	0.354	8.60	9.00	e	0.067 REF		1.70 REF	
E	0.386	0.409	9.80	10.4	L1	0.102	0.114	2.60	2.89
L4	0.579	0.602	14.7	15.3	φ	0.146	0.156	3.71	3.96

**Notes:** 1.Controlling dimension: millimeter  
 2.Maximum lead thickness includes lead finish thickness, and minimum lead thickness is the minimum thickness of base material.  
 3.If there is any question with packing specification or packing method, please contact your local CYStek sales office.

**Material:**

- Mold Compound: Epoxy resin family, flammability solid burning class: UL94V-0

## TO-263-5L Dimension



DIM	Inches		Millimeters		DIM	Inches		Millimeters	
	Min.	Max.	Min.	Max.		Min.	Max.	Min.	Max.
A	0.173	0.189	4.40	4.80	c2	0.049	0.057	1.25	1.45
b	0.026	0.036	0.66	0.91	L2	0.050 REF		1.27 REF	
L4	0.000	0.012	0.00	0.30	D	0.339	0.354	8.60	9.00
c	0.014	0.020	0.36	0.50	e	0.067 REF		1.70 REF	
L1	0.090	0.110	2.29	2.79	L	0.575	0.622	14.6	15.8
E	0.386	0.409	9.80	10.4	θ	0°	8°	0°	8°

Notes: 1.Controlling dimension :millimeter

- 2.Maximum lead thickness includes lead finish thickness, and minimum lead thickness is the minimum thickness of base material.  
 3.If there is any question with packing specification or packing method, please contact your local CYStek sales office.

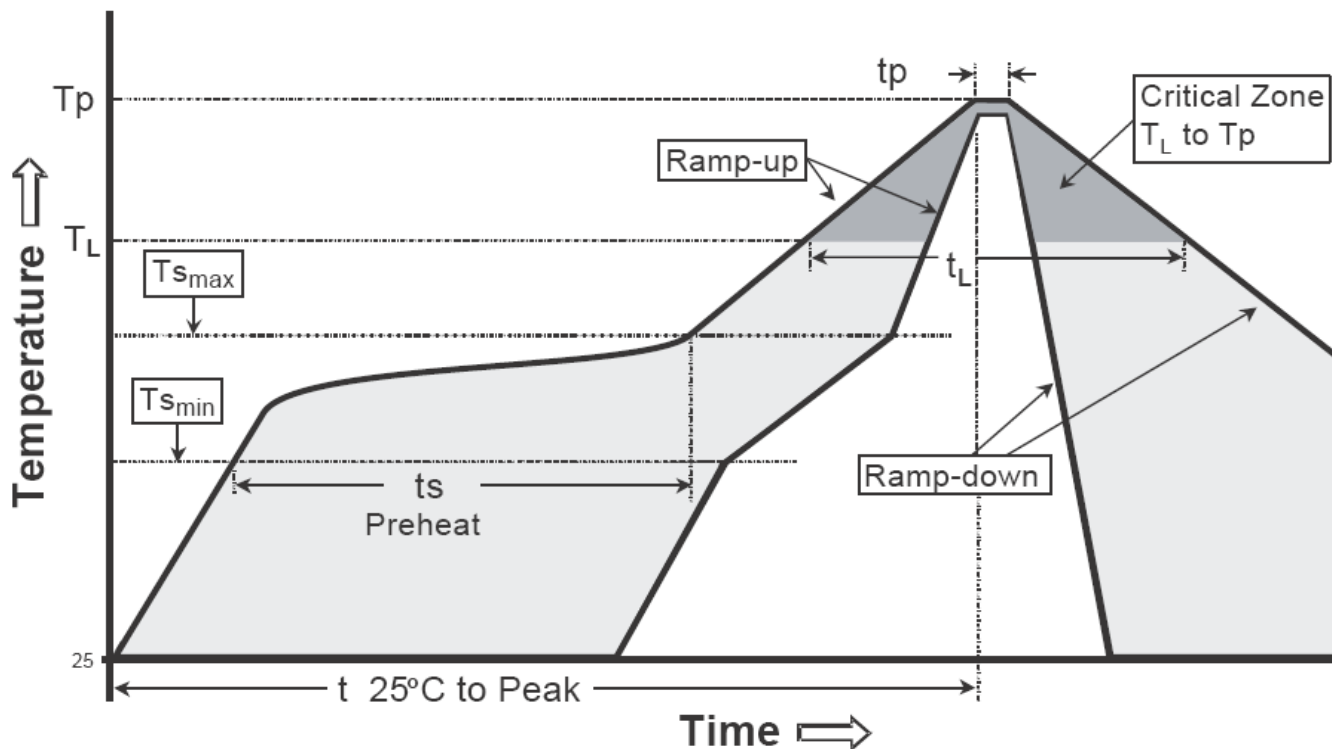
**Material:**

- Mold Compound: Epoxy resin family, flammability solid burning class: UL94V-0

## Recommended wave soldering condition

Product	Peak Temperature	Soldering Time
Pb-free devices	260 +0/-5 °C	5 +1/-1 seconds

## Recommended temperature profile for IR reflow



Profile feature	Sn-Pb eutectic Assembly	Pb-free Assembly
Average ramp-up rate (T <sub>smax</sub> to T <sub>p</sub> )	3°C/second max.	3°C/second max.
Preheat		
-Temperature Min(T <sub>s min</sub> )	100°C	150°C
-Temperature Max(T <sub>s max</sub> )	150°C	200°C
-Time(t <sub>s min</sub> to t <sub>s max</sub> )	60-120 seconds	60-180 seconds
Time maintained above:		
-Temperature (T <sub>L</sub> )	183°C	217°C
- Time (t <sub>L</sub> )	60-150 seconds	60-150 seconds
Peak Temperature(T <sub>p</sub> )	240 +0/-5 °C	260 +0/-5 °C
Time within 5°C of actual peak temperature(tp)	10-30 seconds	20-40 seconds
Ramp down rate	6°C/second max.	6°C/second max.
Time 25 °C to peak temperature	6 minutes max.	8 minutes max.

Note : All temperatures refer to topside of the package, measured on the package body surface.

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