

## 3.0A, 150Khz, Step-Down Switching Regulator

**LM2596**

### FEATURES

- 3.3V, 5.0V, 12V, 15V, and Adjustable Output Versions
- Adjustable Version Output Voltage Range, 1.23 to 37V  $\pm 4\%$ . Maximum Over Line and Load Conditions
- Guaranteed 3.0A Output Current
- Wide Input Voltage Range
- Requires Only 4 External Components
- 150Khz Fixed Frequency Internal Oscillator
- TTL Shutdown Capability, Low Power Standby Mode
- High Efficiency
- Uses Readily Available Standard Inductors
- Thermal Shutdown and Current Limit Protection
- Moisture Sensitivity Level(MSL) Equals 1

### Applications

- Simple High-Efficiency Step-Down(Buck) Regulator
- Efficient Pre-Regulator for Linear Regulators
- On-Card Switching Regulators
- Positive to Negative Converter(Buck-Boost)
- Negative Step-Up Converters
- Power Supply for Battery Chargers

### DESCRIPTION

The LM2596 series of regulators are monolithic integrated circuits ideally suited for easy and convenient design of a step-down switching regulator(buck converter).

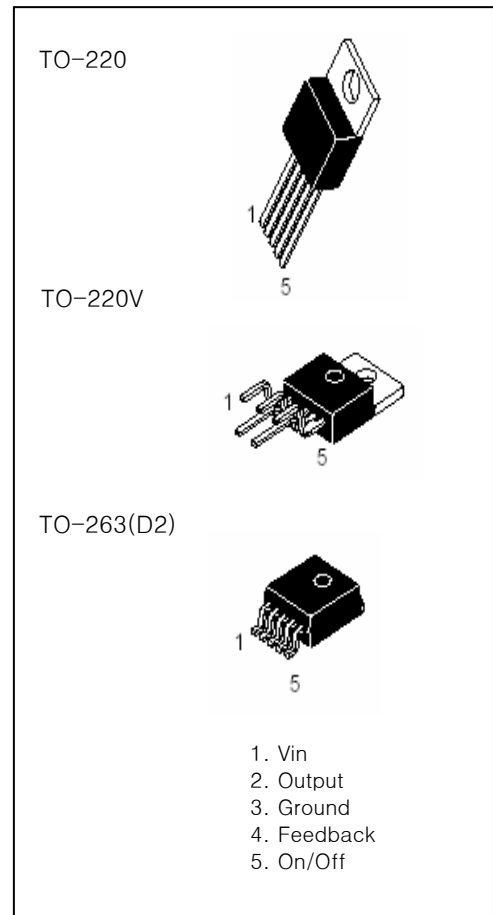
All circuits of this series are capable of driving a 3.0A load with excellent line and load regulation. These devices are available in fixed output voltages of 3.3V, 5.0V, 12V, 15V, and an adjustable output version.

These regulators were designed to minimize the number of external components to simplify the power supply design. Standard series of inductors optimized for use with the LM2576 are offered by several different inductor manufacturers.

Since the LM2596 converter is a switch-mode power supply, its efficiency is significantly higher in comparison with popular three-terminal linear regulators, especially with higher input voltages.

In many cases, the power dissipated is so low that no heatsink is required or its size could be reduced dramatically. A standard series of inductors optimized for use with the LM2596 are available from several different manufacturers. This feature greatly simplifies the design of switch-mode power supplies. The LM2596 features include a guaranteed  $\pm 4\%$  tolerance on output voltage within specified input voltages and output load conditions, and  $\pm 15\%$  on the oscillator frequency ( $\pm 2\%$  over 0°C to 125 °C).

External shutdown is included, featuring 80  $\mu$ A(typical) standby current. The output switch includes cycle-by-cycle current limiting, as well as thermal shutdown for full protection under fault conditions.



### ORDERING INFORMATION

Device	Marking	Package
LM2596T-X.X	LM2596T-X.X	TO-220
LM2596TV-X.X	LM2596T-X.X	TO-220V
LM2596R	LM2596R-X.X	TO-263

### Typical Application (Fixed Output Voltage Versions)

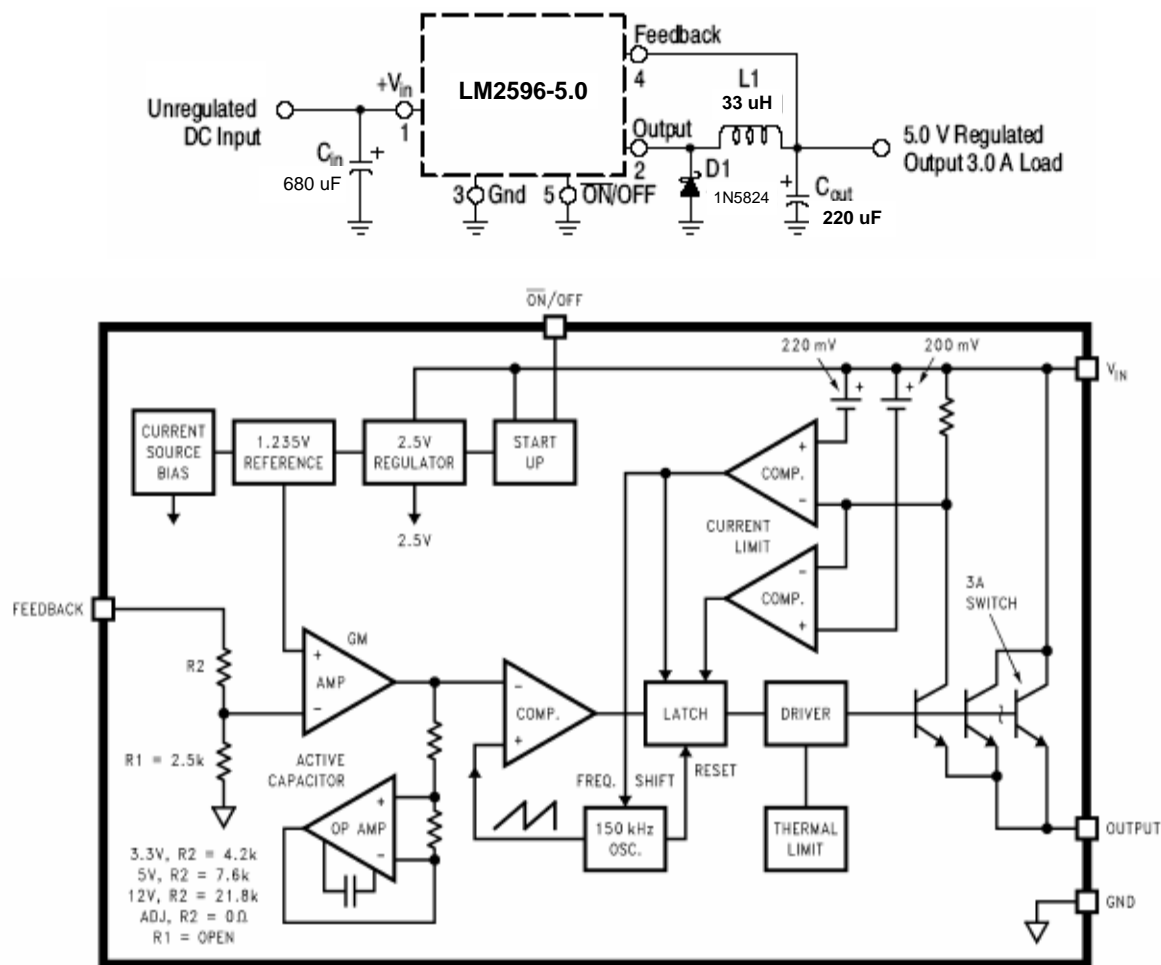


Figure 1. Block Diagram and Typical Application

### ABSOLUTE MAXIMUM RATINGS

(Absolute Maximum Ratings indicate limits beyond which damage to the device may occur.)

Rating	Symbol	Value	Unit
Maximum Supply Voltage	$V_{in}$	45	V
ON/OFF Pin Input Voltage	—	$-0.3 \text{ V} \leq V \leq +V_{in}$	V
Output Voltage to Ground (Steady-State)	—	-1.0	V
Power Dissipation TO-220, 5-Lead Thermal Resistance, Junction-to-Ambient Thermal Resistance, Junction-to-case TO-263 Thermal Resistance, Junction-to-Ambient Thermal Resistance, Junction-to-case	$P_D$ $R_{\theta JA}$ $R_{\theta JC}$ $P_D$ $R_{\theta JA}$ $R_{\theta JC}$	Internally Limited 65 5.0 Internally Limited 70 5.0	W °C/W °C/W W °C/W °C/W
Storage Temperature Range	$T_{stg}$	-65 to +150	°C
Minimum ESD Rating (Human Body Model: C = 100 pF, R = 1.5 kΩ)	—	2.0	kV
Lead Temperature (Soldering, 10 seconds)	—	260	°C
Maximum Junction Temperature	$T_J$	150	°C

**OPERATING RATINGS** (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.)

Rating	Symbol	Value	Unit
Operating Junction Temperature Range	$T_J$	-40 to +125	°C
Supply Voltage	$V_{in}$	40	V

## ELECTRICAL CHARACTERISTICS / SYSTEM PARAMETERS ([Note 1] Test Circuit Figure 2)

(Unless otherwise specified,  $V_{in} = 12$  V for the 3.3 V, 5.0 V, and Adjustable version,  $V_{in} = 25$  V for the 12 V version, and  $V_{in} = 30$  V for the 15 V version.  $I_{Load} = 500$  mA. For typical values  $T_J = 25^\circ\text{C}$ , for min/max values  $T_J$  is the operating junction temperature range that applies [Note 2], unless otherwise noted.)

Characteristics	Symbol	Min	Typ	Max	Unit
<b>LM2596-3.3</b> ([ Note 1]. Test Circuit Figure 2 )					
Output Voltage ( $V_{in} = 12$ V, $I_{Load} = 0.5$ A, $T_J = 25^\circ\text{C}$ )	$V_{out}$	3.234	3.3	3.366	V
Output Voltage ( $6.0\text{ V} \leq V_{in} \leq 40$ V, $0.5\text{ A} \leq I_{Load} \leq 3.0$ A) $T_J = 25^\circ\text{C}$ $T_J = -40$ to $+125^\circ\text{C}$	$V_{out}$	3.168 3.135	3.3 —	3.432 3.465	V
Efficiency ( $V_{in} = 12$ V, $I_{Load} = 3.0$ A)	$\eta$	—	73	—	%
<b>LM2596-5.0</b> ([ Note 1]. Test Circuit Figure 2 )					
Output Voltage ( $V_{in} = 12$ V, $I_{Load} = 0.5$ A, $T_J = 25^\circ\text{C}$ )	$V_{out}$	4.9	5.0	5.1	V
Output Voltage ( $8.0\text{ V} \leq V_{in} \leq 40$ V, $0.5\text{ A} \leq I_{Load} \leq 3.0$ A) $T_J = 25^\circ\text{C}$ $T_J = -40$ to $+125^\circ\text{C}$	$V_{out}$	4.8 4.75	5.0 —	5.2 5.25	V
Efficiency ( $V_{in} = 12$ V, $I_{Load} = 3.0$ A)	$\eta$	—	80	—	%
<b>LM2596-12</b> ([ Note 1]. Test Circuit Figure 2 )					
Output Voltage ( $V_{in} = 25$ V, $I_{Load} = 0.5$ A, $T_J = 25^\circ\text{C}$ )	$V_{out}$	11.76	12	12.24	V
Output Voltage ( $15\text{ V} \leq V_{in} \leq 40$ V, $0.5\text{ A} \leq I_{Load} \leq 3.0$ A) $T_J = 25^\circ\text{C}$ $T_J = -40$ to $+125^\circ\text{C}$	$V_{out}$	11.52 11.4	12 —	12.48 12.6	V
Efficiency ( $V_{in} = 15$ V, $I_{Load} = 3.0$ A)	$\eta$	—	90	—	%
<b>LM2596-15</b> ([ Note 1]. Test Circuit Figure 2 )					
Output Voltage ( $V_{in} = 30$ V, $I_{Load} = 0.5$ A, $T_J = 25^\circ\text{C}$ )	$V_{out}$	14.7	15	15.3	V
Output Voltage ( $18\text{ V} \leq V_{in} \leq 40$ V, $0.5\text{ A} \leq I_{Load} \leq 3.0$ A) $T_J = 25^\circ\text{C}$ $T_J = -40$ to $+125^\circ\text{C}$	$V_{out}$	14.4 14.25	15 —	15.6 15.75	V
Efficiency ( $V_{in} = 18$ V, $I_{Load} = 3.0$ A)	$\eta$	—	98	—	%
<b>LM2596-ADJ</b> ([ Note 1]. Test Circuit Figure 2 )					
Feedback Voltage ( $V_{in} = 12$ V, $I_{Load} = 0.5$ A, $V_{out} = 5.0$ V, $T_J = 25^\circ\text{C}$ )	$V_{out}$	1.217	1.23	1.243	V
Feedback Voltage ( $8.0\text{ V} \leq V_{in} \leq 40$ V, $0.5\text{ A} \leq I_{Load} \leq 3.0$ A, $V_{out} = 5.0$ V) $T_J = 25^\circ\text{C}$ $T_J = -40$ to $+125^\circ\text{C}$	$V_{out}$	1.193 1.18	1.23 —	1.267 1.28	V
Efficiency ( $V_{in} = 12$ V, $I_{Load} = 3.0$ A, $V_{out} = 5.0$ V)	$\eta$	—	73	—	%

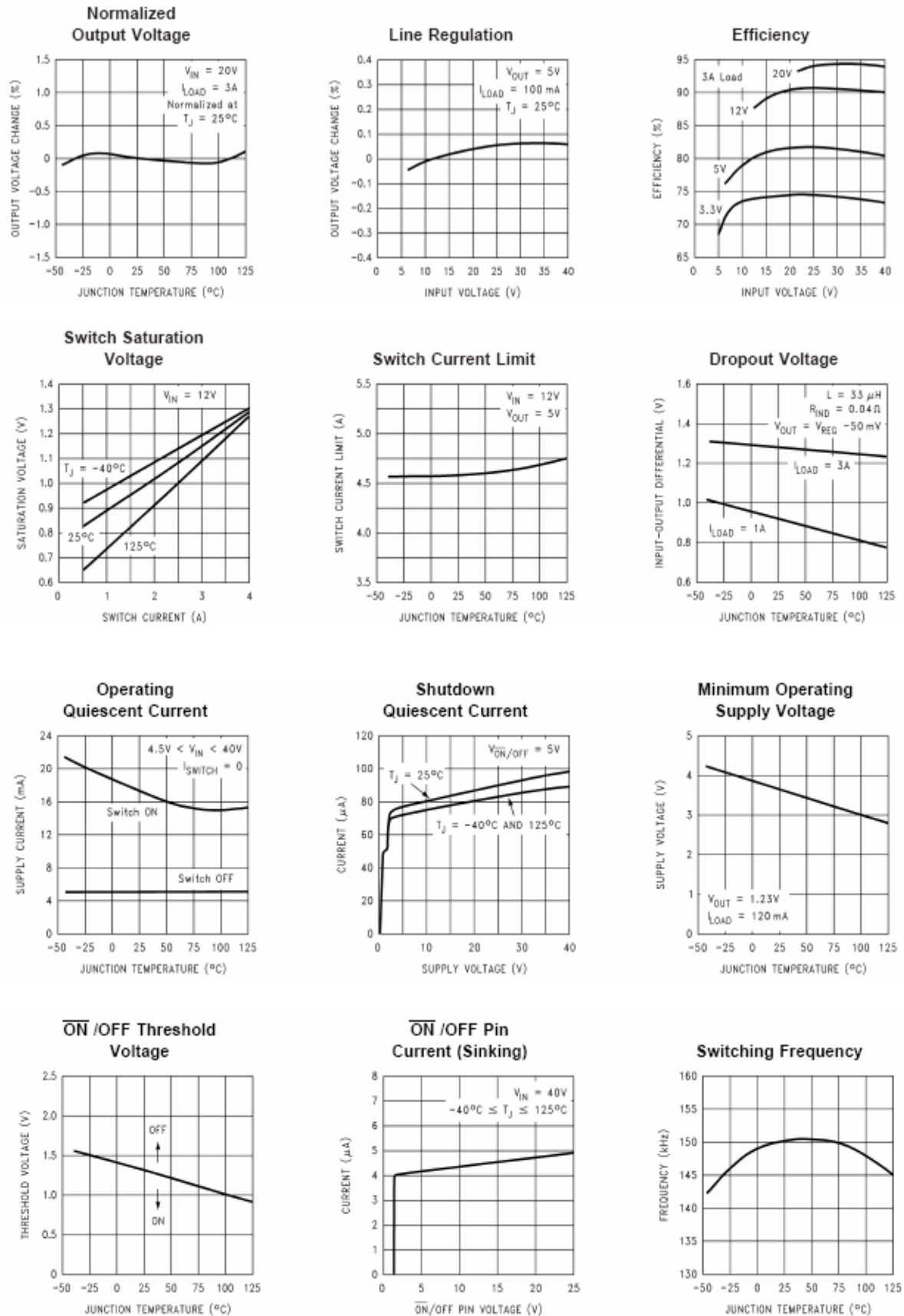
## ELECTRICAL CHARACTERISTICS / Device Parameters

(Unless otherwise specified,  $V_{in} = 12\text{ V}$  for the 3.3 V, 5.0 V, and Adjustable version,  $V_{in} = 25\text{ V}$  for the 12 V version, and  $V_{in} = 30\text{ V}$  for the 15 V version.  $I_{Load} = 500\text{ mA}$ . For typical values  $T_J = 25^\circ\text{C}$ , for min/max values  $T_J$  is the operating junction temperature range that applies [Note 2], unless otherwise noted.)

Characteristics	Symbol	Min	Typ	Max	Unit
<b>ALL OUTPUT VOLTAGE VERSIONS</b>					
Feedback Bias Current ( $V_{out} = 5.0\text{ V}$ [Adjustable Version Only]) $T_J = 25^\circ\text{C}$ $T_J = 0\text{ to }+125^\circ\text{C}$	$I_b$	– –	10 –	50 100	nA
Oscillator Frequency [Note 3] $T_J = 25^\circ\text{C}$ $T_J = 0\text{ to }+125^\circ\text{C}$	$f_{osc}$	127 110	150 – –	173 173	kHz
Saturation Voltage ( $I_{out} = 3.0\text{ A}$ [Note 4]) $T_J = 25^\circ\text{C}$ $T_J = 0\text{ to }+125^\circ\text{C}$	$V_{sat}$	– –	1.16 –	1.4 1.5	V
Max Duty Cycle ("on") [Note 5]	DC	–	100	–	%
Current Limit (Peak Current [Notes 3 and 4]) $T_J = 25^\circ\text{C}$ $T_J = 0\text{ to }+125^\circ\text{C}$	$I_{CL}$	3.6 3.4	4.5 –	6.9 7.5	A
Output Leakage Current [Notes 6 and 7], $T_J = 25^\circ\text{C}$ Output = 0 V Output = –1.0 V	$I_L$	– –	– 2	50 30	mA
Quiescent Current [Note 6] $T_J = 25^\circ\text{C}$ $T_J = 0\text{ to }+125^\circ\text{C}$	$I_Q$	– –	5 –	– 10	mA
Standby Quiescent Current ( $\overline{ON}/OFF$ Pin = 5.0 V ("off")) $T_J = 25^\circ\text{C}$ $T_J = 0\text{ to }+125^\circ\text{C}$	$I_{stby}$	– –	80 –	200 250	$\mu\text{A}$
$\overline{ON}/OFF$ Pin Logic Input Level (Test Circuit Figure 2.) $V_{out} = 0\text{ V}$ $T_J = 25^\circ\text{C}$ $T_J = 0\text{ to }+125^\circ\text{C}$ $V_{out} = \text{Nominal Output Voltage}$ $T_J = 25^\circ\text{C}$ $T_J = 0\text{ to }+125^\circ\text{C}$	$V_{IH}$	–	1.3 –	0.6 0.6	V
	$V_{IL}$	2.0 2.0	1.3 –	– –	
$\overline{ON}/OFF$ Pin Input Current (Test Circuit Figure 2.) $V_{LOGIC} = 2.5\text{ V}$ (Regulator OFF) $V_{LOGIC} = 0.5\text{ V}$ (Regulator ON)	$I_{IH}$	–	5	15	$\mu\text{A}$
	$I_{IL}$	–	0.02	5.0	

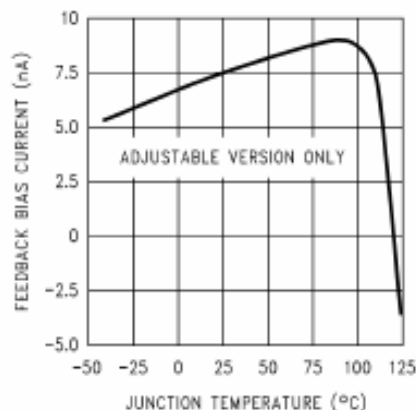
- External components such as the catch diode, inductor, input and output capacitors can affect switching regulator system performance.  
When the LM2596 is used as shown in the Figure 1 test circuit, system performance will be as shown in system parameters section.
- Tested junction temperature range for the LM2596 :  $T_{LOW} = -0^\circ\text{C}$   $T_{HIGH} = +125^\circ\text{C}$
- The oscillator frequency reduces to approximately 18 kHz in the event of an output short or an overload which causes the regulated output voltage to drop approximately 40% from the nominal output voltage. This self protection feature lowers the average dissipation of the IC by lowering the minimum duty cycle from 5% down to approximately 2%.
- Output (Pin 2) sourcing current. No diode, inductor or capacitor connected to output pin.
- Feedback (Pin 4) removed from output and connected to 0 V.
- Feedback (Pin 4) removed from output and connected to +12 V for the Adjustable, 3.3 V, and 5.0V versions, and +25 V for the 12 V and 15 V versions, to force the output transistor "off".
- $V_{in} = 40\text{ V}$ .

## TYPICAL PERFORMANCE CHARACTERISTICS (Circuit of Figure 2)

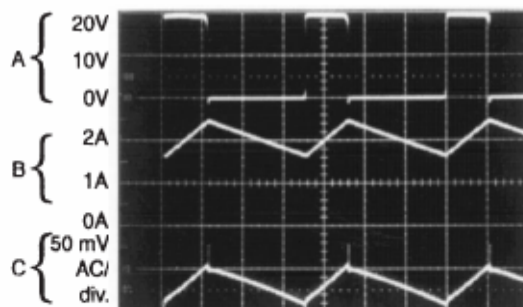


## TYPICAL PERFORMANCE CHARACTERISTICS (Circuit of Figure 2)

Feedback Pin Bias Current

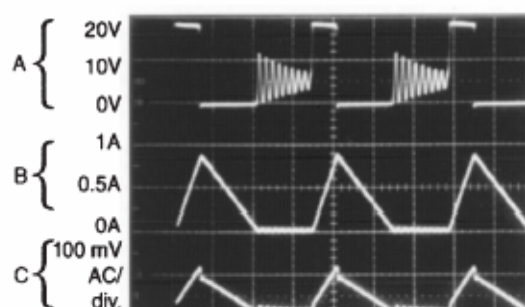


Continuous Mode Switching Waveforms

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

Horizontal Time Base: 2  $\mu s$ /div.

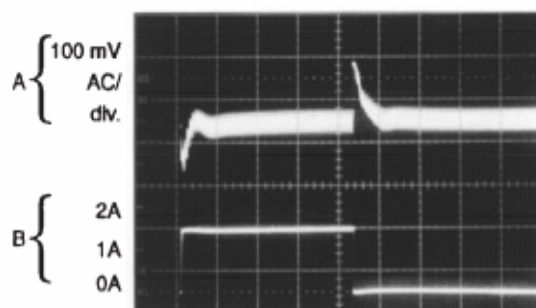
A: Output Pin Voltage, 10V/div.  
B: Inductor Current 1A/div.  
C: Output Ripple Voltage, 50 mV/div.

Discontinuous Mode Switching Waveforms

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

Horizontal Time Base: 2  $\mu s$ /div.

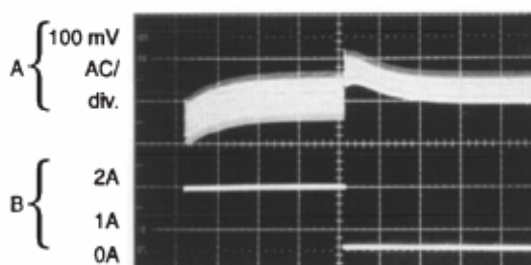
A: Output Pin Voltage, 10V/div.  
B: Inductor Current 0.5A/div.  
C: Output Ripple Voltage, 100 mV/div.

Load Transient Response for Continuous Mode

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

Horizontal Time Base: 100  $\mu s$ /div.

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

Load Transient Response for Discontinuous Mode

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

Horizontal Time Base: 200  $\mu s$ /div.

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

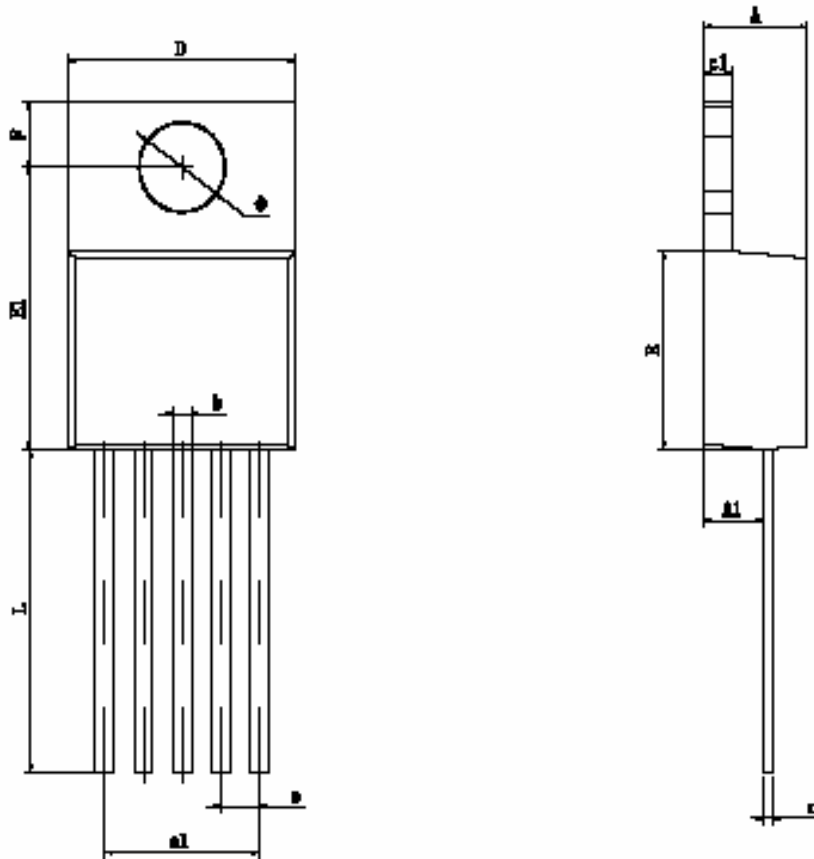


## PIN FUNCTION DESCRIPTION

	Symbol	Description
1	V <sub>in</sub>	This pin is the positive input supply for the LM2596 step-down switching regulator. In order to minimize voltage transients and to supply the switching currents needed by the regulator, a suitable input bypass capacitor must be present. (C <sub>in</sub> in Figure 1).
2	Output	This is the emitter of the internal switch. The saturation voltage V <sub>sat</sub> of this output switch is typically 1.5 V. It should be kept in mind that the PCB area connected to this pin should be kept to a minimum in order to minimize coupling to sensitive circuitry.
3	Gnd	Circuit ground pin. See the information about the printed circuit board layout.
4	Feedback	This pin senses regulated output voltage to complete the feedback loop. The signal is divided by the internal resistor divider network R <sub>2</sub> , R <sub>1</sub> and applied to the non-inverting input of the internal error amplifier. In the Adjustable version of the LM2596 switching regulator this pin is the direct input of the error amplifier and the resistor network R <sub>2</sub> , R <sub>1</sub> is connected externally to allow programming of the output voltage.
5	ON/OFF	It allows the switching regulator circuit to be shut down using logic level signals, thus dropping the total input supply current to approximately 80 mA. The threshold voltage is typically 1.4 V. Applying a voltage above this value (up to +V <sub>in</sub> ) shuts the regulator off. If the voltage applied to this pin is lower than 1.4V or if this pin is left open, the regulator will be in the "on" condition

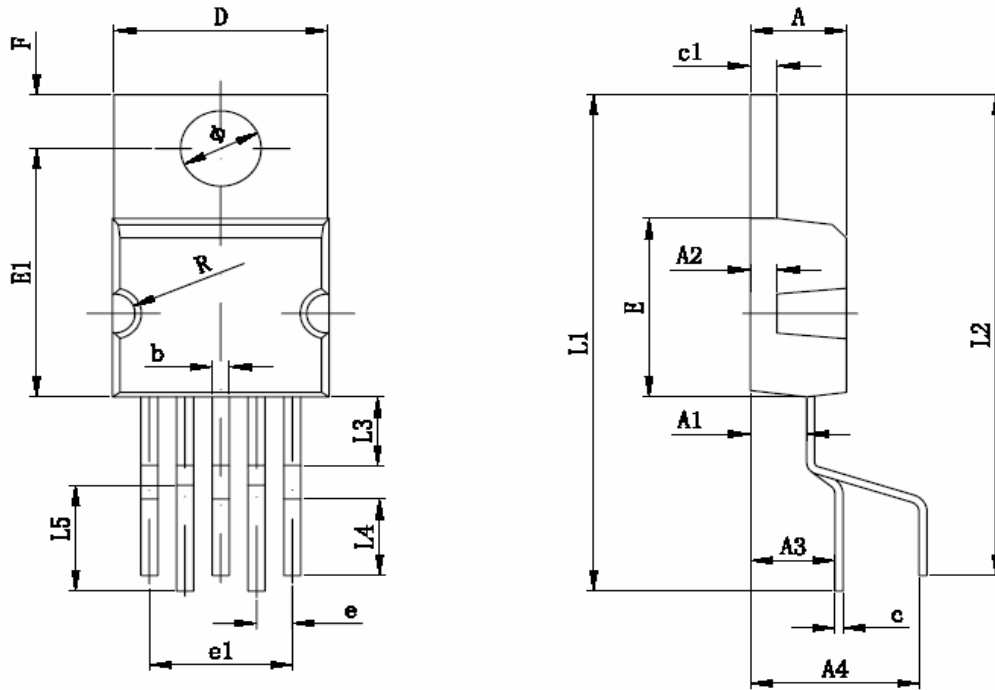


## PACKAGES DIMENSION : TO220-5L



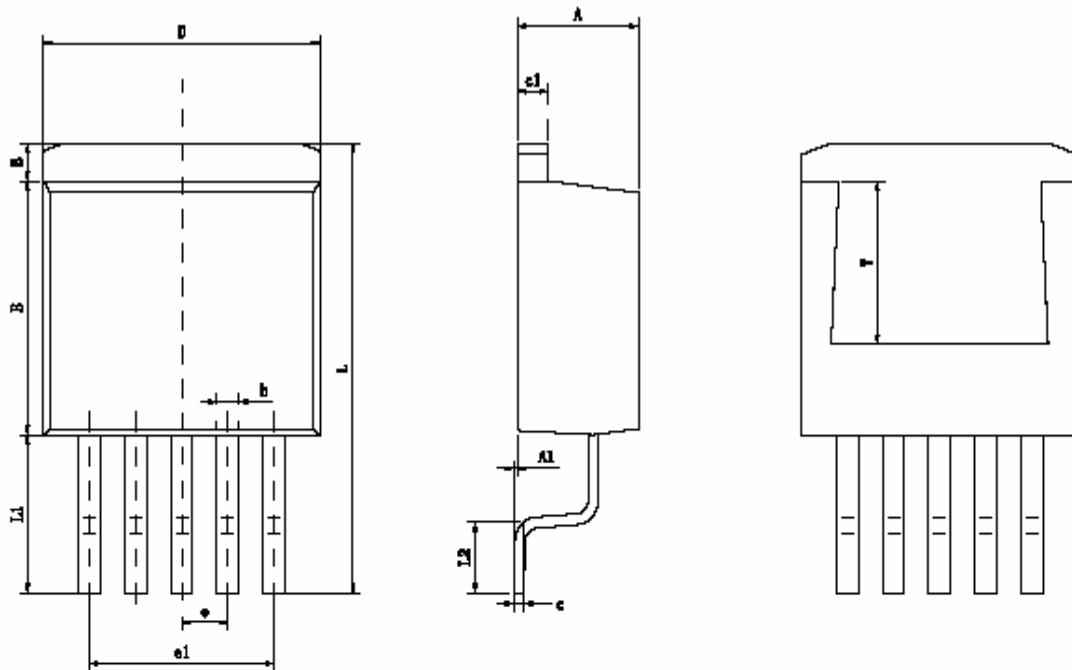
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	4.470	4.670	0.176	0.184
A1	2.520	2.820	0.099	0.111
b	0.710	0.910	0.028	0.036
c	0.310	0.530	0.012	0.021
c1	1.170	1.370	0.046	0.054
D	9.850	10.150	0.388	0.400
E	8.200	8.600	0.323	0.339
E1	11.760	12.160	0.463	0.479
e	1.700TYP		0.067TYP	
e1	6.700	6.900	0.264	0.272
F	2.590	2.890	0.102	0.114
L	13.500	13.900	0.531	0.547
Φ	3.790	3.890	0.149	0.153

## PACKAGES DIMENSION : TO220V-5L



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	4.470	4.670	0.176	0.184
A1	2.520	2.820	0.099	0.111
A2	1.170	1.370	0.046	0.054
A3	4.250	4.550	0.167	0.179
A4	8.250	8.550	0.325	0.337
b	0.710	0.910	0.028	0.036
c	0.310	0.530	0.012	0.021
c1	1.170	1.370	0.046	0.054
D	10.010	10.310	0.394	0.406
E	8.900	9.300	0.350	0.366
E1	12.460	12.860	0.491	0.506
e	1.700TYP		0.220TYP	
e1	6.700	6.900	0.264	0.272
e2	3.300	3.500	0.130	0.138
F	2.590	2.890	0.102	0.114
L1	25.100	25.500	0.988	1.004
L2	24.300	24.700	0.957	0.972
L3	3.400	3.600	0.134	0.142
L4	3.800	4.000	0.150	0.157
L5	5.300	5.500	0.209	0.217
R	0.950	1.050	0.037	0.041
Φ	3.790	3.890	0.149	0.153

## PACKAGES DIMENSION : TO263-5L



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	4.470	4.670	0.176	0.184
A1	0.000	0.150	0.000	0.006
B	1.560	1.760	0.061	0.069
b	0.710	0.910	0.028	0.036
c	0.310	0.530	0.012	0.021
c1	1.170	1.370	0.046	0.054
D	9.880	10.180	0.389	0.401
E	8.200	8.600	0.323	0.339
e	1.700TYP		0.067TYP	
e1	6.700	6.900	0.264	0.272
L	15.140	15.540	0.596	0.612
L1	5.080	5.480	0.200	0.216
L2	2.340	2.740	0.092	0.108
V	5.600REF		0.220REF	