SIMPLE SWITCHER POWER CONVERTER

AE2596

● Features

※ 3.3V, 5V, 12V, and adjustable output versions
※ Adjustable version output voltage range,1.2V to 37V
※ TO-220 and TO-263 packages
※ Output load current 3A
※ Input voltage range up to 40V
※ Requires only 4 external components
※ 150 kHz fixed frequency internal oscillator
※ TTL shutdown capability
※ Low power standby mode, I_Q typically 80 μA
※ High efficiency
※ Thermal shutdown and current limit protection

● Application

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

● General Description

The AE2596 series of regulators are monolithic integrated circuits that provide all the active functions for a step-down(buck) switching regulator, capable of driving a 3A load with excellent line and load regulation. These devices are available in fixed output voltages of 3.3V, 5V, 12V, and an adjustable output version.

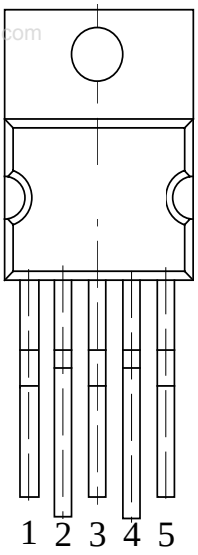
Requiring a minimum number of external components, these regulators are simple to use and include internal frequency compensation, and a fixed frequency oscillator.

The AE2596 series operates at a switching frequency of 150 kHz thus allowing smaller sized filter components than what would be needed with lower frequency switching regulators. Available in a standard 5-lead TO-220 package with several different lead bend options, and a 5-lead TO-263 surface mount package.

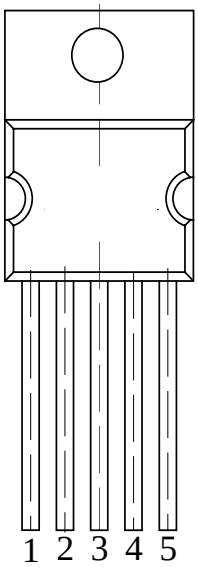
Other features include a guaranteed±4% tolerance on output voltage under specified input voltage and output load conditions, and±15% on the oscillator frequency. External shutdown is included, featuring typically 80 μA standby current. Selfprotection features include a two stage frequency reducing current limit for the output switch and an over temperature shutdown for complete protection under fault conditions.

● Pin Configuration

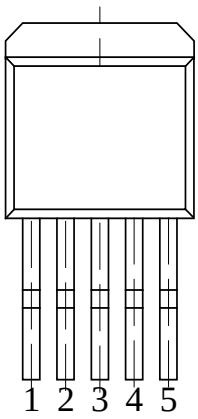
Pin No.	1	2	3	4	5
Symbol	VIN	Output	GND	Feedback	$\overline{ON}$/OFF
Parameter	DC Input	DC Output	Ground	Feedback signal	Standby control



5-LeadTO-220(B)

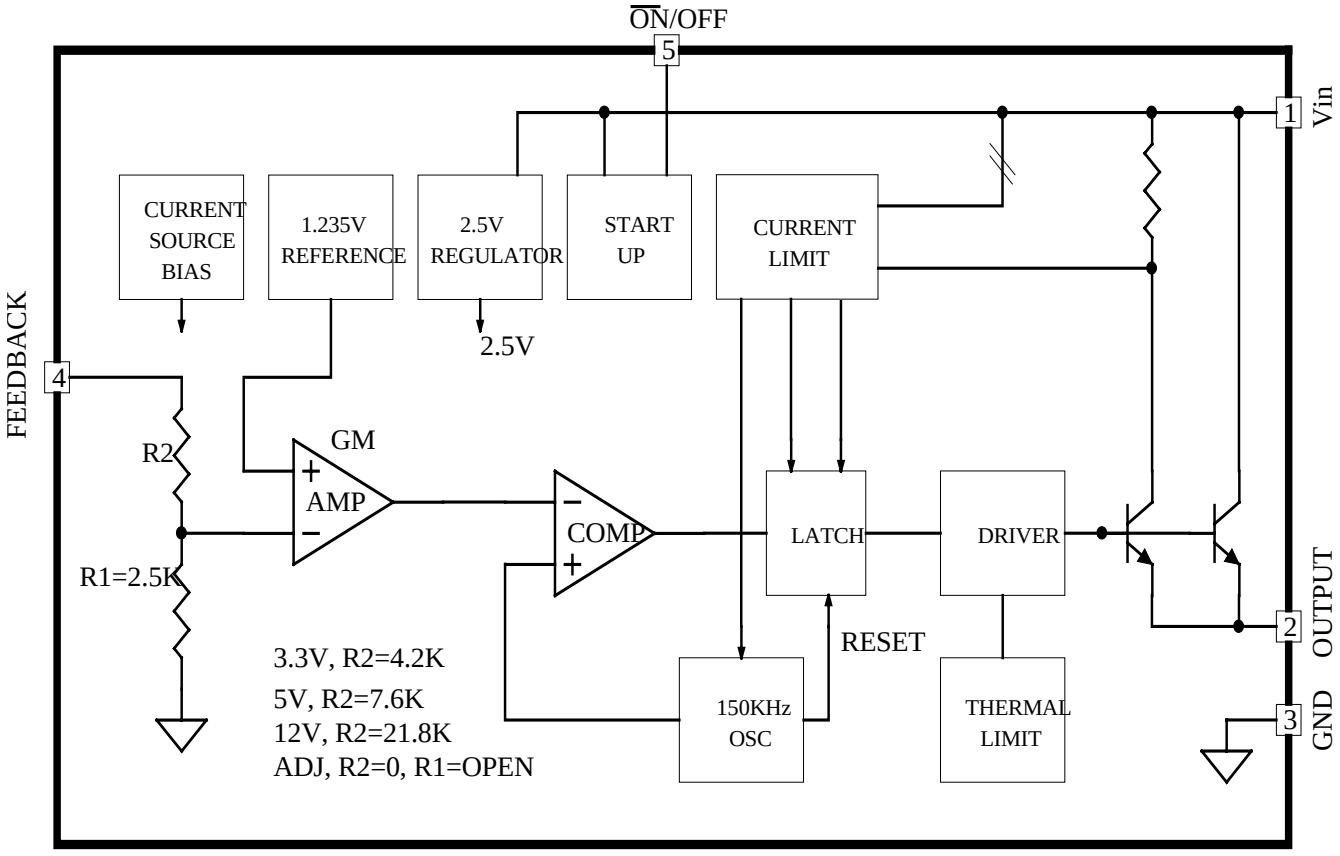


5-Lead TO-220(T)



5-Lead TO-263(S)

● Block Diagram



● Absolute Aaximum Ratings(note1)

Parameter		Rating	Unit
Maximum Supply Voltage		45	V
$\overline{ON}$/OFF Pin Input Voltage		-0.3～25	V
Feedback Pin Voltage		-0.3～25	V
Power Dissipation		Internally limited	--
Storage Temperature Range		-65～150	℃
Conditions	Maximum Junction Temperature	150	℃
	Temperature Range	-40～125	℃
	Supply Voltage	4.75～40	V

● Electrical Characteristics

V_O=3.3V						
Symbol	**Parameter**	**Conditions**	**Min** (Note 4)	**Typ** (Note 3)	**Max** (Note4)	**Units**
V_{OUT}	Output Voltage	5V≤V_{IN}≤40V 0.2A≤I_{LOAD}≤3A	3.18	3.30	3.40	V
η	Efficiency	V_{IN}=12V，I_{LOAD}=3A	--	72	--	%
V_O=5V						
V_{OUT}	Output Voltage	7V≤V_{IN}≤40V 0.2A≤I_{LOAD}≤3A	4.80	5.0	5.15	V
η	Efficiency	V_{IN}=12V，I_{LOAD}=3A	--	79	--	%
V_O=12V						
V_{OUT}	Output Voltage	15V≤V_{IN}≤40V 0.2A≤I_{LOAD}≤3A	11.65	12.0	12.35	V
η	Efficiency	V_{IN}=25V，I_{LOAD}=3A	--	88	---	%
Vout is adjustable						
V_{FB}	Feedback Voltage	4.5V≤V_{IN}≤40V 0.2A≤I_{LOAD}≤3A V_{OUT} programmed for 3V.	1.195	1.230	1.255	V
η	Efficiency	V_{IN}=12V， V_{OUT}=3V，I_{LOAD}=3A	--	71	--	%

● All Output Voltage Versions Electrical Characteristics(otherwise specified, V_{IN} = 12V for the 3.3V, 5V, and Adjustable version and V_{IN} = 24V for the 12V version.I_{LOAD} = 500 mA)

Symbol	Parameter	Conditions	AE2596－XX			Units
			Min (Note 4)	Typ (Note 3)	Max (Note)	
I_b	Feedback Bias Current	Adjustable Version Only, V_{FB} = 1.3V	--	10	60	nA
f_O	Oscillator Frequency	(Note 6)	135	150	173	KHz
V_{SAT}	VSAT Saturation Voltage	I_{OUT}=3A(Notes 7, 8)	--	1.36	1.60	V
DC	Max Duty Cycle	ON (Note 8)	--	100	--	%
	Min Duty Cycle	OFF(Note 9)	--	0	--	%
I_{CL}	Current Limit	Peak Current (Notes 7, 8)	4.0	4.80	5.50	A
I_{SC}	Output Short Current	R_{LOAD}=0	5.20	5.50	6.40	A
I_L	Output Leakage Current	Output = 0V (Notes 7, 9)	--	--	60	μA
		Output =-1V (Notes 10)	--	4	30	mA
I_Q	Quiescent Current	(Note 9)	--	7.60	12	mA
I_{STBY}	Standby Quiescent Current	$\overline{ON}$/*OFF* pin = 5V (OFF) (Note 10)	--	80	180	μA
θ_{JC}	Thermal Resistance	TO-220 or TO-263	--	2	--	°C/W
θ_{JA}		TO-220	--	50	--	°C/W
θ_{JA}		TO-263	--	50	--	°C/W
θ_{JA}		TO-263	--	30	--	°C/W
θ_{JA}		TO-263	--	20	--	°C/W
$\overline{ON}$/OFF	**CONTROL**					
	$\overline{ON}$/*OFF* Pin Logic Input		--	1.3	--	V
V_{IH}	Threshold Voltage	Low (Regulator on)	2.0	--	--	V
V_{IL}		High(Regulator off)	--	--	0.8	V
I_H	$\overline{ON}$/*OFF* Pin Input Current	V_{LOGIC}=2.5V (Regulator OFF)	--	4	15	μA
I_L		V_{LOGIC}=0.5V (Regulator ON)	--	0.02	2	μA

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 100 pF capacitor discharged through a 1.5k resistor into

each pin.

Note 3: Typical numbers are at 25℃ and represent the most likely norm.

Note4: All limits guaranteed at room temperature (standard type face) and at t emperature extremes (bold type face). 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).

Note5: External components such as the catch diode, inductor, input and output capacitors, and voltage programming resistors can affect switching regulator system performance.

Note6: The switching frequency is reduced when the second stage current limit is activated.

Note7: No diode, inductor or capacitor connected to output pin.

Note8: Feedback pin removed from output and connected to 0V to force the output transistor switch ON.

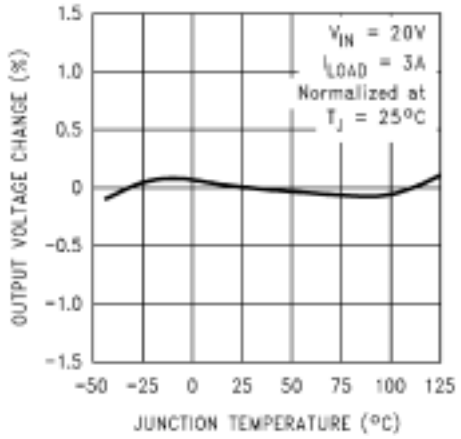
Note9: Feedback pin removed from output and connected to 12V for the 3.3V, 5V, and the ADJ. version, and 15V for the 12V version, to force the output transistor switch OFF.

Note10: V_{IN} = 40V.

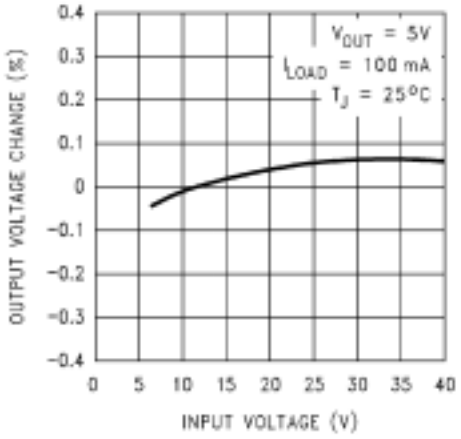
Note11: Junction to ambient thermal resistance (no external heat sink) for the TO-220 package mounted vertically, with the leads soldered to a printed circuit board with (1 oz.)copper area of approximately 1 in^2.

● Typical Performance Characteristics

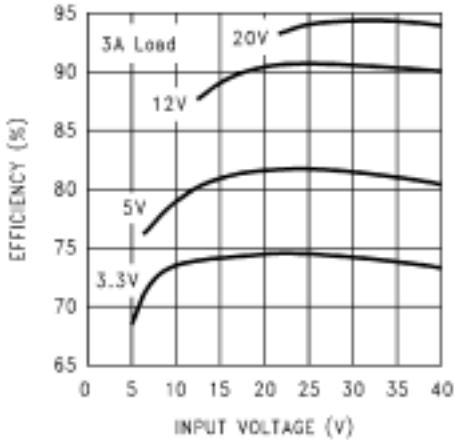
Normalized Output Voltage



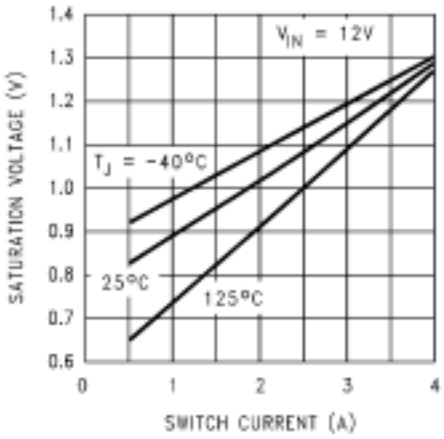
Line Regulation



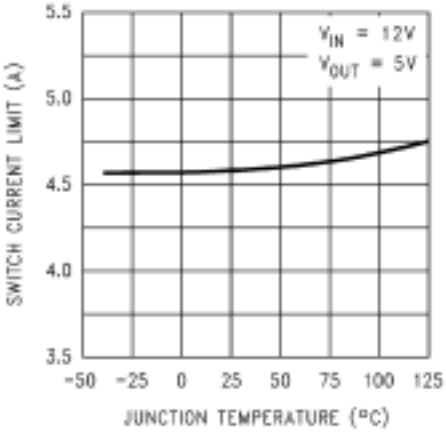
Efficiency



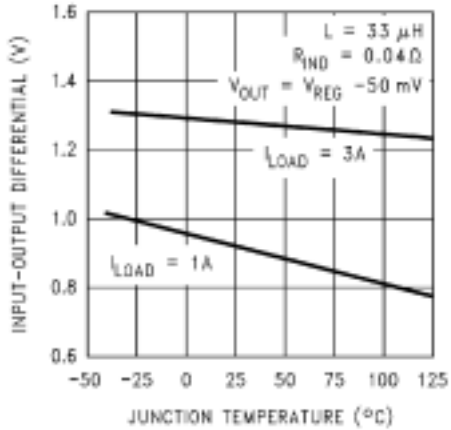
Switch Saturation Voltage



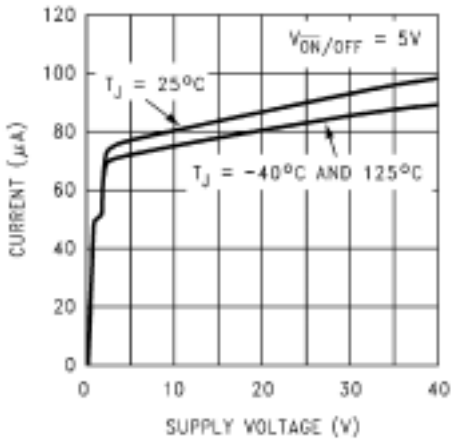
Switch Current Limit



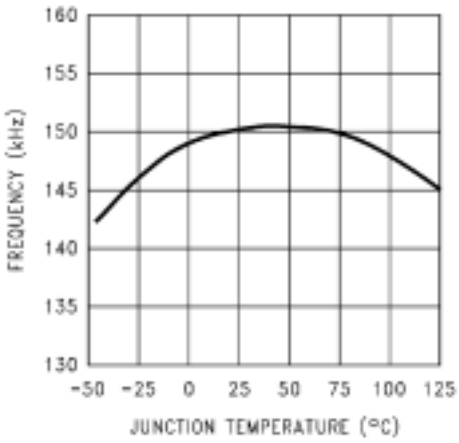
Dropout Voltage



Shutdown Quiescent Current

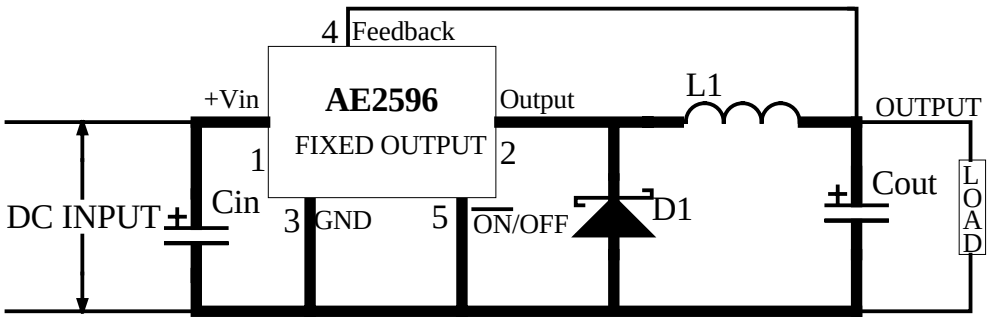


Switching Frequency



- Testing Circuit

Fixed Output Voltage Versions



C_{IN} —470 µF, 50V, Aluminum Electrolytic Nichicon “PL Series”

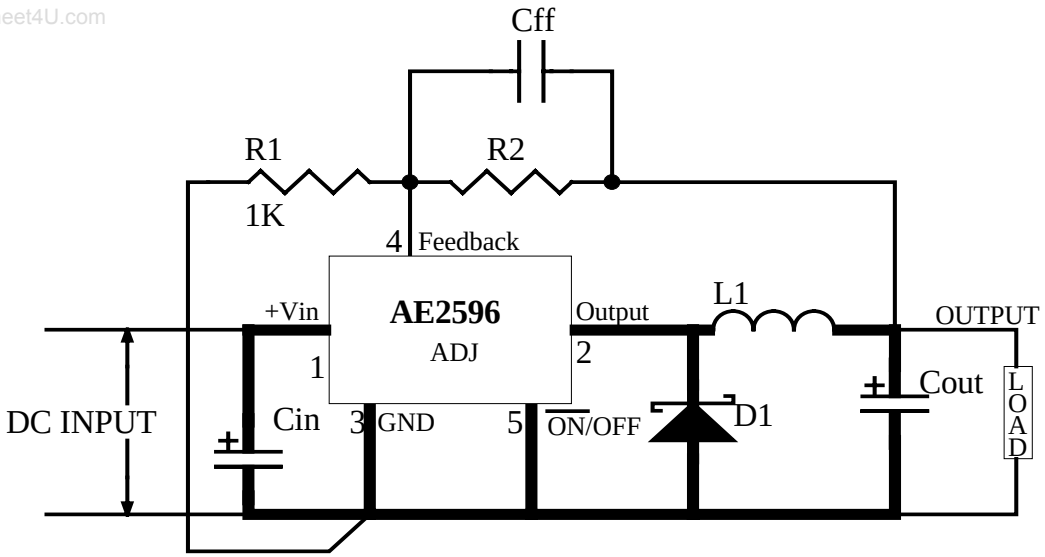
C_{OUT} —220 µF, 25V Aluminum Electrolytic, Nichicon “PL Series”

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

L1 —68 µH, L38

Note: Keep Feedback wiring away from inductor flux and heavy line must be kept short and use ground plane construction or best results.

Adjustable Output Voltage Versions



where VREF = 1.23V, $V_{OUT}=V_{REF}(1+\frac{R_2}{R_1})$ $R_2=R_1(\frac{V_{OUT}}{V_{REF}}-1)$

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

C_{IN} —470 µF, 50V, Aluminum Electrolytic Nichicon “PL Series”

C_{OUT} —220 µF, 35V Aluminum Electrolytic, Nichicon “PL Series”

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

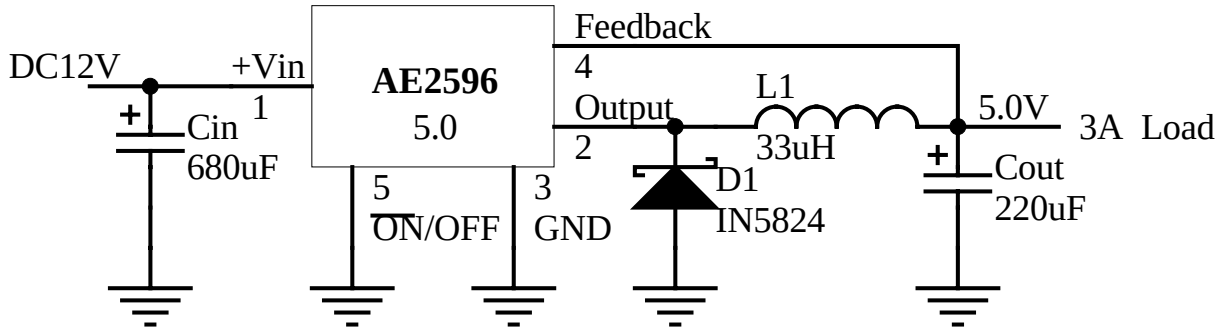
L1 —68 µH, L38

R1 —1 k , 1%

CFF —See Application Information Section

Note: Keep Feedback wiring away from inductor flux and heavy line must be kept short and use ground plane construction or best results.

● Typical Application circuit



● Pin Functions

$+V_{IN}$

This is the positive input supply for the IC switching regulator. A suitable input bypass capacitor must be present at this pin to minimize voltage transients and to supply the switching currents

needed by the regulator.

Ground

Circuit ground.

Output

Internal switch. The voltage at this pin switches between ($+V_{IN}$ – V_{SAT}) and approximately–0.5V,with a duty cycle of approximately V_{OUT} / V_{IN}. To minimize coupling to sensitive circuitry, the PC board copper area connected to this pin should be kept a minimum.

Feedback

Senses the regulated output voltage to complete the feedback loop.

$\overline{ON}$/OFF

Allows the switching regulator circuit to be shutdown using logic level signals thus dropping the total input supply current to approximately 150uA. Pulling this pin below a threshold voltage of approximately 1.3V turns the regulator on, and pulling this pin above 1.3V (up to a maximum of 25V) shuts the regulator down. If this shutdown feature is not needed, the $\overline{ON}$/*OFF* pin can be wired to the ground pin or it can be left open, in either case the regulator will be in the ON condition.

● External Components

INPUT CAPACITOR C_{IN} —A low ESR aluminum or tantalum bypass capacitor is needed between the input pin and ground pin **.** It must be located near the regulator using short leads. This capacitor prevents large voltage transients from appearing at the input, and provides the instantaneous current needed each time the switch turns on.Selecting an input capacitor requires consulting the manufa- cturers data sheet for maximum allowable RMS ripple current. For a maximum ambient temperature of 40°C, a general guideline would be to select a capacitor with a ripple current rating of approximately 50% of the DC load current. For ambient temperatures up to 70°C, a current rating of 75% of the DC load current would be a good choice for a conservative design. The capacitor voltage rating must be at least 1.25 times greater than the maximum input voltage,and often a much higher voltage capacitor is needed to satisfy the RMS current requirements.

FEEDFORWARD CAPACITOR (Adjustable Output Voltage Version) C_{FF} ----A feed forward Capacitor C_{FF}, shown across R2 in Figure1 is used when the ouput voltage is greater than 10V or when C_{OUT} has a very low ESR. This capacitor adds lead compensation to the feedback loop and increases the phase margin for better loop stability.

OUTPUT CAPACITOR C_{OUT} —-An output capacitor is required to filter the output and provide regulator loop stability. Low impedance or low ESR Electrolytic or solid tantalum capacitors designed for switching regulator applications must be used. When selecting an output capacitor, the important capacitor parameters are; the 100 kHz Equivalent Series esistance (ESR), the RMS ripple current rating, voltage rating, and capacitance value. For the output capacitor, the ESR value is the most important parameter.The output capacitor requires an ESR value that has an upper and lower limit. For low output ripple voltage, a low ESR value is needed. This value is determined by the maximum allowable output ripple voltage, typically 1% to 2% of the output voltage. But if the selected capacitor's ESR is extremely low, there is a possibility of an unstable feedback loop, resulting in an oscillation at the output.

CATCH DIODE D----Buck regulators require a diode to provide a return path for the inductor current when the switch turns off. This must be a fast diode and must be located close to the

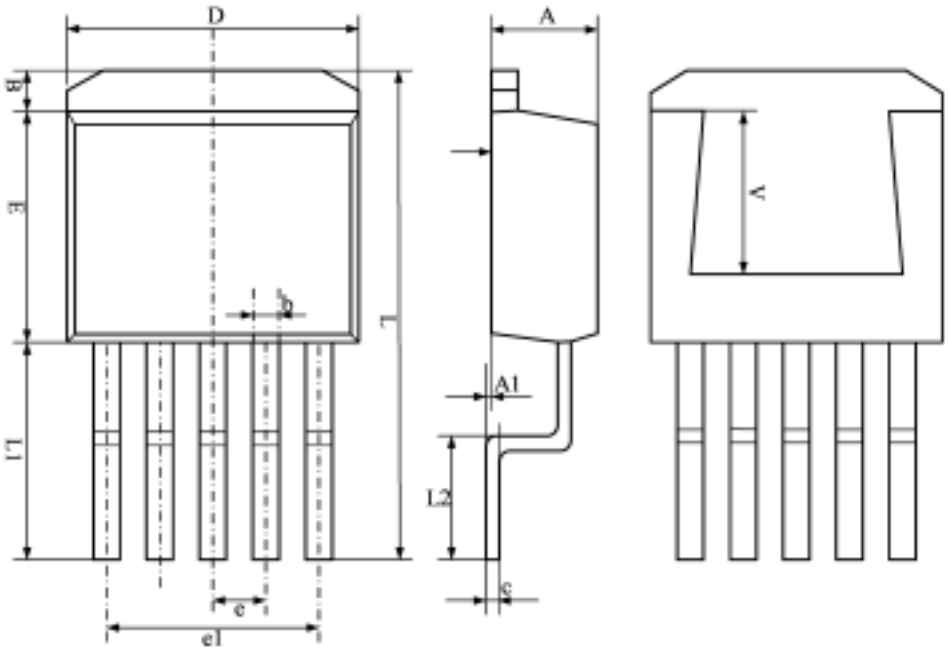
AE2596 using short leads and short printed circuit traces. Because of their very fast switching speed and low forwardvoltage drop, Schottky diodes provide the best performance, especially in low output voltage applications (5V and lower).Ultrafast recovery, or High-Efficiency rectifiers are also a good cho- ice, but some types with an abrupt turnoff characteristic may cause instability or EMI problems.

INDUCTOR SELECTION L----All switching regulators have two basic modes of operation; continuous and discontinuous. The difference between the two types relates to the inductor current, whether it is flowing continuously, or if it drops to zero for a period of time in the normal switching cycle. Each mode has distinctively different operating characteristics, which can affect the regulators performance and requirements. Most switcher designs will operate in the discontinuous mode when the load current is low.The AE2596 (or any of the Simple Switcher family) can beused for both continuous or discontinuous modes of operation.There is a formula for general applications:

$$L=(5\sim10)\frac{V_O}{300I_O}(1-\frac{V_O}{V_{IN}})mH$$

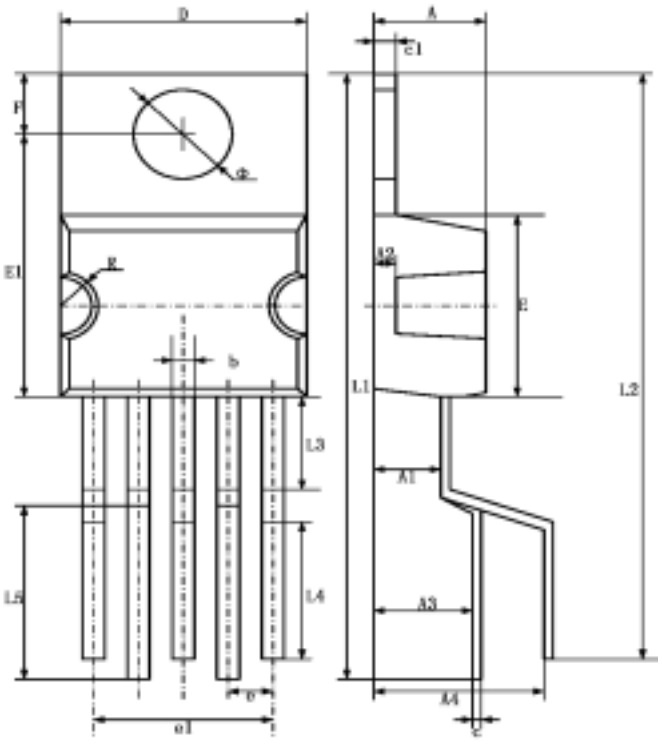
● Package Information

TO-263



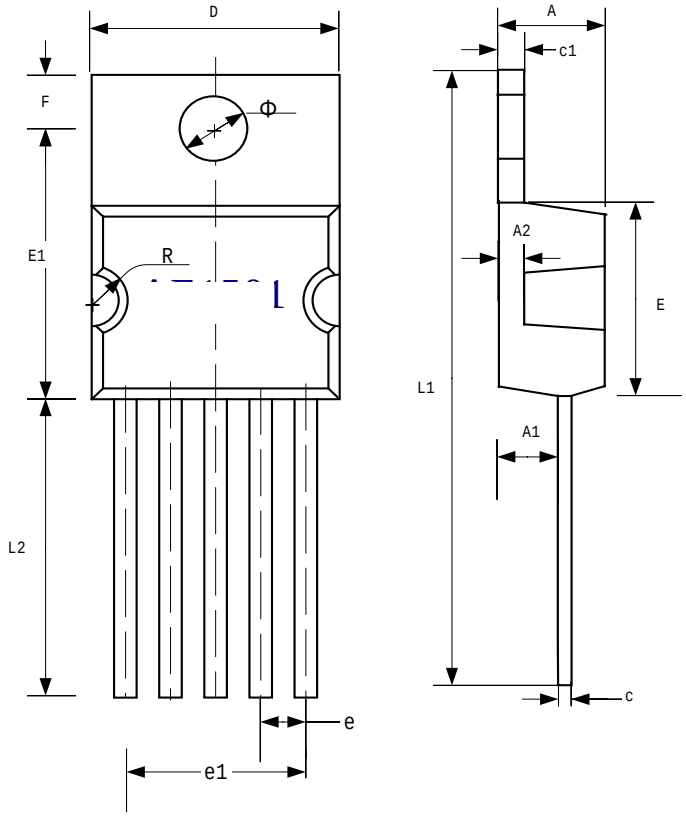
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	4.470	4.670	0.176	0.184
A1	0.000	0.150	0.000	0.006
B	1.560	1.760	0.061	0.069
b	0.710	0.910	0.028	0.036
C	0.310	0.530	0.012	0.021
c1	1.170	1.370	0.046	0.054
D	9.880	10.180	0.389	0.401
E	8.200	8.600	0.323	0.339
e	1.700TYP		0.067TYP	
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	

TO-220(B)



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
	12.460	12.860	0.491	0.506
e	1.700TYP		0.220TYP	
e1	6.700	6.900	0.264	0.272
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

TO-220(T)



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
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
F	2.590	2.890	0.102	0.114
L1	28.700	29.100	1.130	1.146
L2	13.36	13.76	0.526	0.542
R	0.950	1.050	0.037	0.041
Φ	3.790	3.890	0.149	0.153