3A 150KHZ 45V PWM Buck DC/DC Converter TD1501

General Description

The TD1501 is a of easy to use adjustable step-down (buck) switch-mode DC/DC converter. The device is available in an adjustable or fixed output version. It is capable of driving a 3A load with excellent line and load regulation.

The output voltage is guaranteed to ±3% tolerance under specified input voltage and output load conditions. The oscillator frequency is guaranteed to ±15%.

The PWM control circuit is able to adjust the duty ratio linearly from 0 to 100%. External shutdown is included, featuring typically 80 μA 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.

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

The TD1501 is available in TO-220B-5L and TO-263-5L packages.

Features

- Voltage mode non-synchronous PWM control
- Built- in switching transistor on chip
- Guaranteed 3A output load current
- Input voltage range up to 45V
- 3,3V,5V and Adjustable output versions
- adjustable version output from 1.23V to 42V
- Fixed 150KHz frequency internal oscillator
- Up to 90% efficiency
- ON/OFF shutdown control input
- Low power standby mode, I_Q typically 80 μA
- Thermal shutdown , current limit and short circuit protection
- Available in TO-220B and TO-263 packages
- RoHS Compliant (100% Green available)
- The minimum dropout @ Vout=5V/0.5A up to 0.9 V

Applications

- Simple High-efficiency step-down regulator
- On-card switching regulators
- Positive to negative converter
- LCD monitor and LCD TV
- DVD recorder and PDP TV
- Battery charger
- Step-down to 1.8/2.5/3.3/5.0 V for microprocessors

Package Types

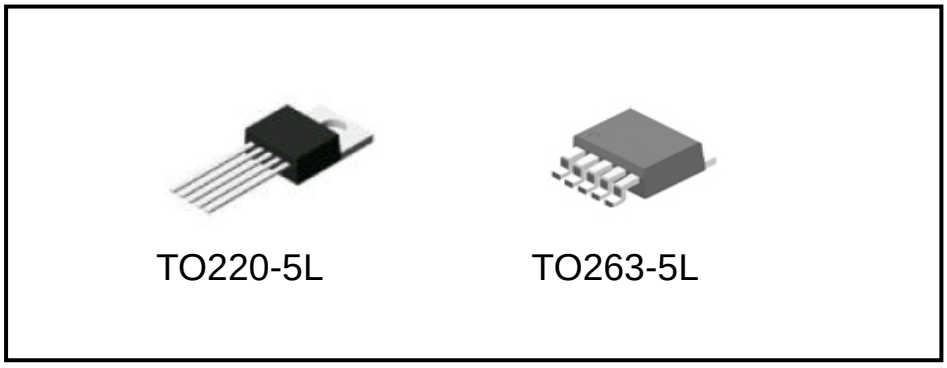
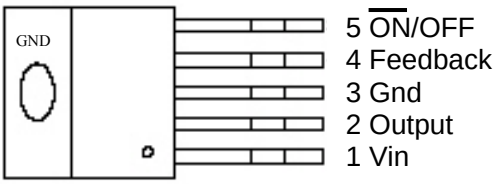


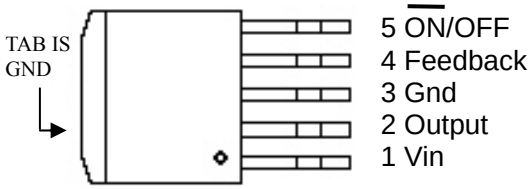
Figure 1. Package Types of TD1501

3A 150KHZ 45V PWM Buck DC/DC Converter TD1501

Pin Assignments



TO220-5L

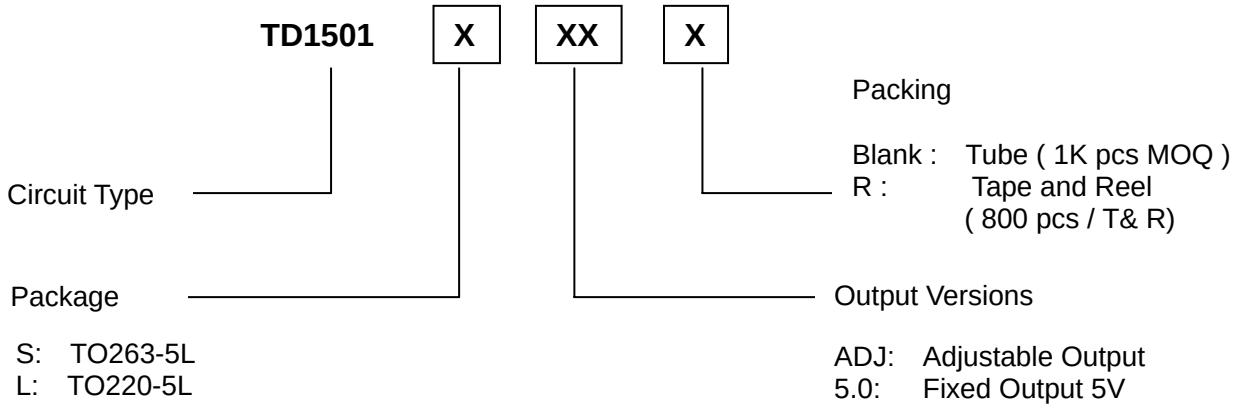


TO263-5L

Pin Descriptions

Name	Description
Vin	Input supply voltage
Output	Switching output
Gnd	Ground
Feedback	Output voltage feedback input
ON/OFF	ON/OFF shutdown Active is “Low” or Ground

Ordering Information



Function Description

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.

GND

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.

$\overline{\text{ON}}$/OFF

Allows the switching regulator circuit to be shutdown using logic level signals thus dropping the total input supply current to approximately 80uA. 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 32V) shuts the regulator down. If this shutdown feature is not needed, the ON /OFF pin can be wired to the ground pin , the regulator will be in the ON condition. The ON /OFF pin should not be left open .

Functional Block Diagram

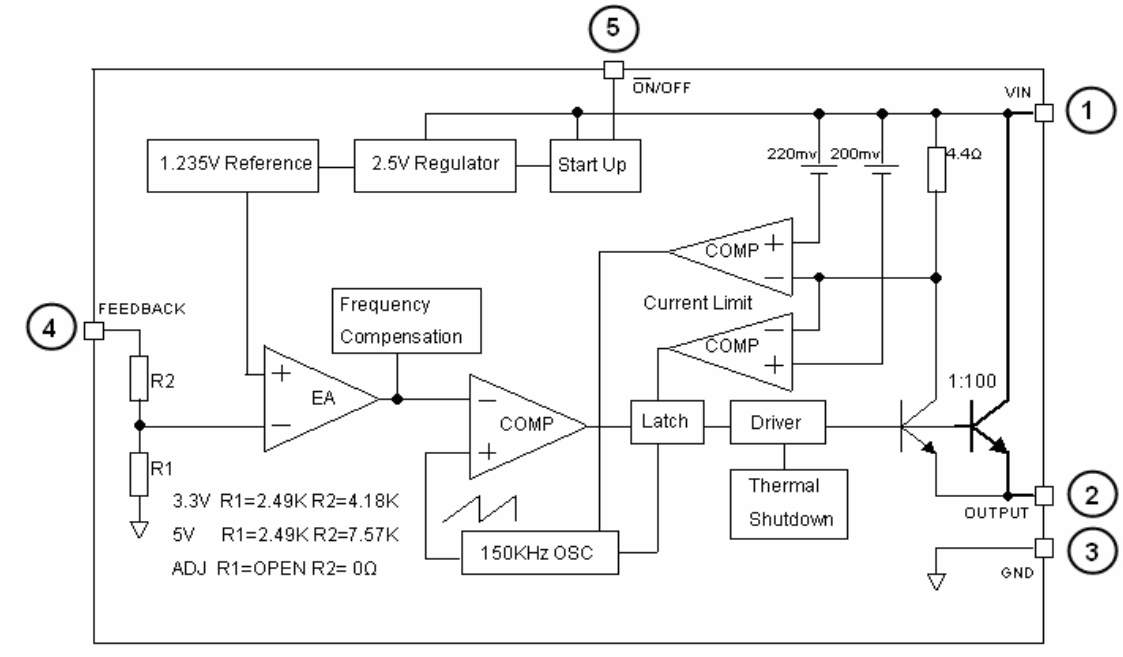


Figure 2. Functional Block Diagram of TD1501

Typical Application

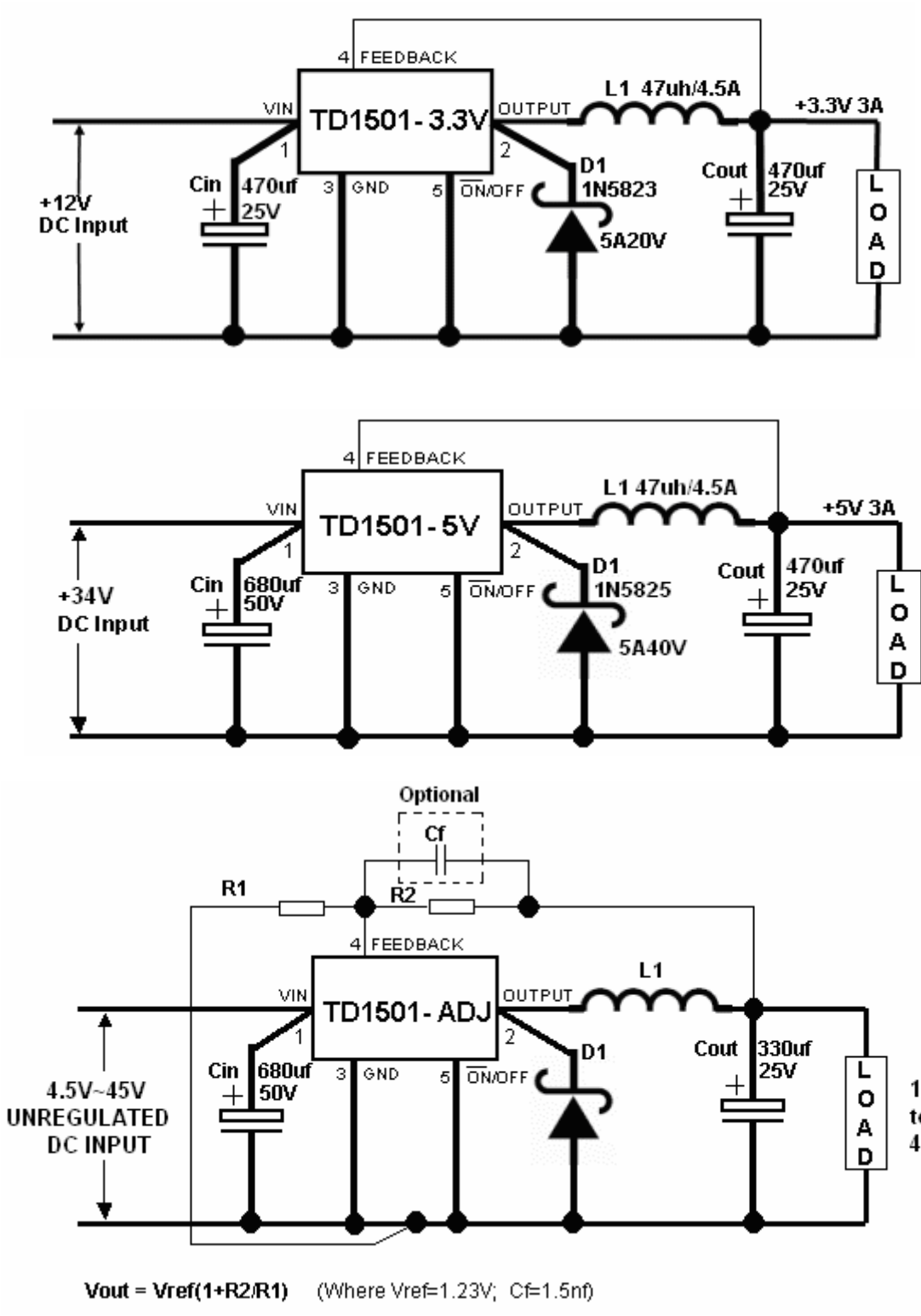


Figure 3. Typical Application of TD1501

Absolute Maximum Ratings

Parameter	Symbol	Value	Unit
Input Voltage	V_{IN}	-0.3 to 45	V
Feedback Pin Voltage	V_{FB}	-0.3 to 40	V
Enable Pin Voltage	Von-off	-0.3 to 40	V
Output Voltage to Ground (Steady State)e	V_{OUT}	-1	V
Power Dissipation	P_D	Internally limited	mW
Operating Junction Temperature	T_J	150	ºC
Storage Temperature	T_{STG}	-65 to 150	ºC
Lead Temperature (Soldering, 10 sec)	T_{LEAD}	260	ºC
ESD (HBM)	V_{ESD}	2000	V

Note1: Stresses greater than those listed under Maximum Ratings may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operation is not implied. Exposure to absolute maximum rating conditions for extended periods may affect reliability.

Recommended Operating Conditions

Parameter	Symbol	Min.	Max.	Unit
Input Voltage	V_{IN}	3.6	45	V
Operating Junction Temperature	T_J	-40	125	ºC
Operating Ambient Temperature	T_A	-40	85	ºC

Electrical Characteristics (All Output Voltage Versions)

Unless otherwise specified, VIN = 12V for 3.3V, 5V, adjustable version . I_{LOAD}= 0.5A
Ta = 25ºC.

Symbol	Parameter		Conditions		Min.	Typ.	Max.	Unit
V_{IN}	Input voltage				4.5		45	V
I_Q	Quiescent current		V_{FB}=12V force driver off			3	4	mA
I_L	Output=0V	Output leakage current	No outside circuit V_{FB}=12V force driver off				50	uA
	Output=-1V		V_{IN}=40V			2	30	mA
I_{STBY}	Standby quiescent current		ON/OFF pin=5V, V_{IN}=32V			80	200	uA
Fosc	Oscillator Frequency				125	150	170	KHz
FSCP	Oscillator Frequency of Short Circuit Protect		When current limit occurred and VFB < 0.5V, Ta = 25℃		10	30	50	KHz
V_{SAT}	Saturation voltage		I_{OUT}=3A No outside circuit V_{FB}= 0V force driver on			1.16	1.4	V
DC	Max. Duty Cycle (ON)		V_{FB}= 0V force driver on			100		%
	Min. Duty Cycle (OFF)		V_{FB}=12V force driver off			0		
V_{FB}	Feedback Voltage		V_{IN} = 4.5V to 45 V		1.21	1.235	1.26	V
I_{FB}	Feedback bias current		V_{FB}=1.3V **(Adjustable version only)**			10	50	nA
I_{CL}	Current Limit		Peak Current (V_{FB}=0V)			3.8	5.5	A
V_{IL}	ON/OFF pin logic input Threshold voltage		Low (Regulator ON)			1.3	**0.6**	V
V_{IH}			High (Regulator OFF)		**2.0**	1.3		V
I_H	ON/OFF pin logic input current		V_{LOGIC}=2.5V(OFF)				-0.01	uA
I_L	ON/OFF pin input current		V_{LOGIC}=0.5V(ON)			-0.1		uA
θ_{JC}	Thermal Resistance		TO220B-5L TO263-5L	Junction to Case		2.5 3.5		^{O}C/W
θ_{JA}	Thermal Resistance with a copper area of approximately 3 in^2		TO220B-5L TO263-5L	Junction to Ambient		28 23		^{O}C/W

Electrical Characteristics (Continued)

	Symbol	Parameter	Conditions	V_{Min}	Typ.	V_{MAX}	Unit
TD1501 3.3V	Vout	Output Voltage	4.75V≤V_{IN}≤45V 0.2A≤I_{LOAD}≤3A	3.168 **3.135**	3.3	3.432 **3.465**	V
	η	Efficiency	V_{IN}=12V, I_{LOAD}=3A		73		%
TD1501 5.0V	Vout	Output Voltage	7V≤V_{IN}≤45V 0.2A≤I_{LOAD}≤3A	4.800 **4.750**	5.0	5.200 **5.250**	V
	η	Efficiency	V_{IN}=12V, I_{LOAD}=3A		80		%
TD1501 ADJ	**V_{FB}**	Output Feedback	4.5V≤V_{IN} ≤45V 0.2A≤I_{LOAD}≤3A V_{OUT} programmed for 3V	1.193 **1.180**	1.23	1.267 **1.280**	V
	η	Efficiency	V_{IN}=12V,I_{LOAD}=3A		73		%
TD1501 ADJ	Vout	Output Voltage	15V≤V_{IN} ≤45V 0.2A≤I_{LOAD}≤3A V_{OUT} programmed for 12V	11.52 **11.4**	12	12.48 **12.6**	V
	η	Efficiency	V_{IN}=25V,I_{LOAD}=3A		90		%

Specifications with **boldface type** are for full operationg temperature range, the other type are for T_J=25^{O}C.

Typical Performance Characteristics

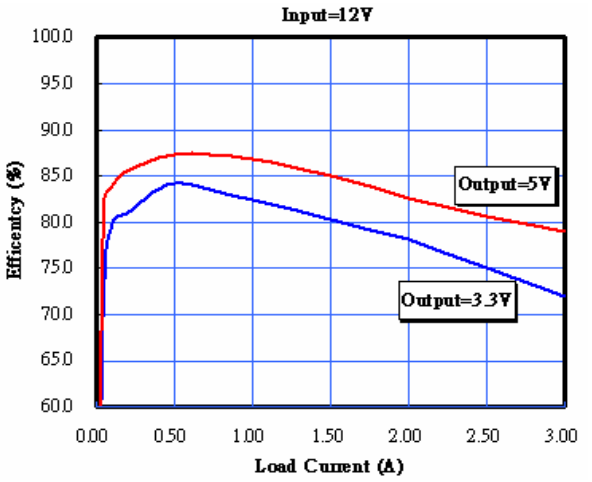


Figure 4. Efficiency vs. Load (Vin=12V)

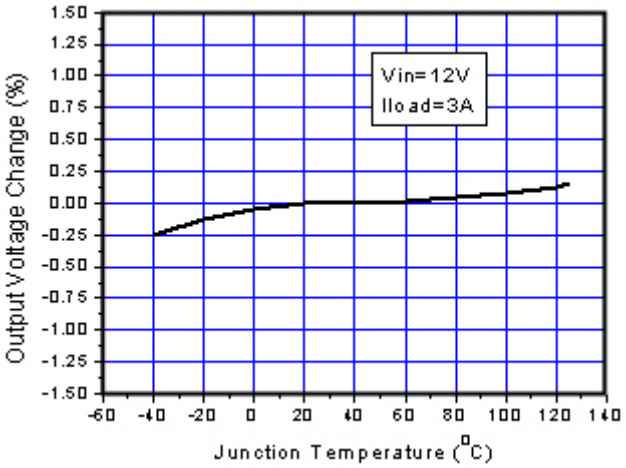


Figure 5. Output Voltage vs. Temperature

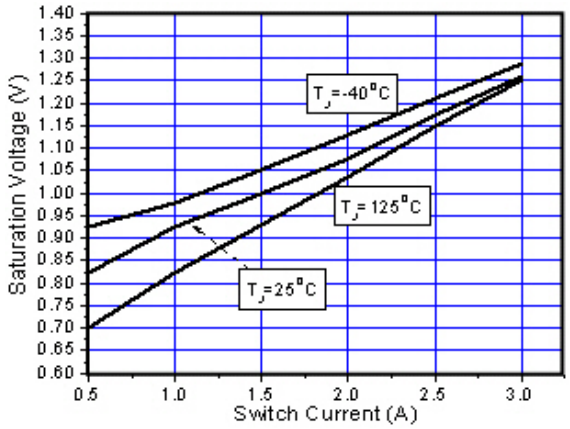


Figure 6. Output Saturation Characteristics

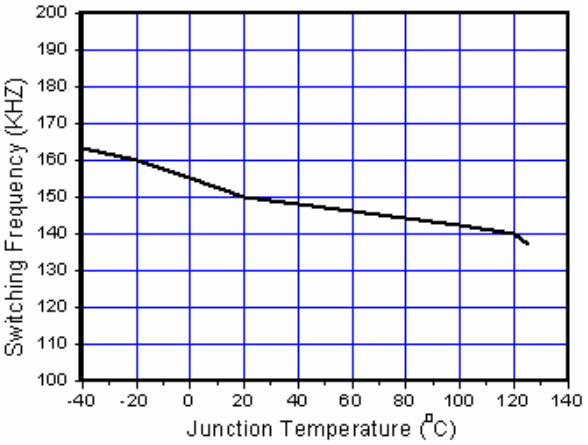


Figure 7. Switching Frequency vs. Temperature

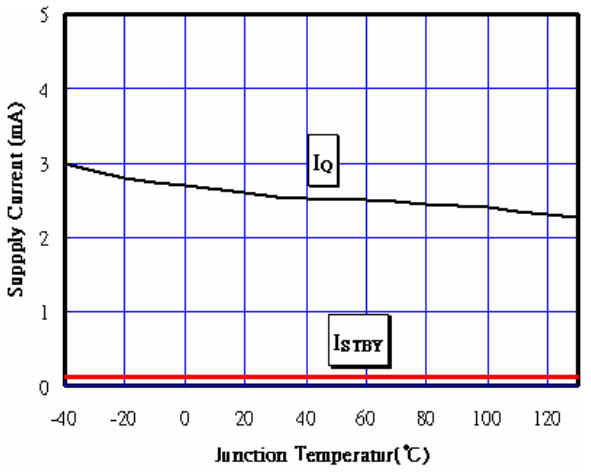


Figure 8. Quiescent Current vs. Temperature

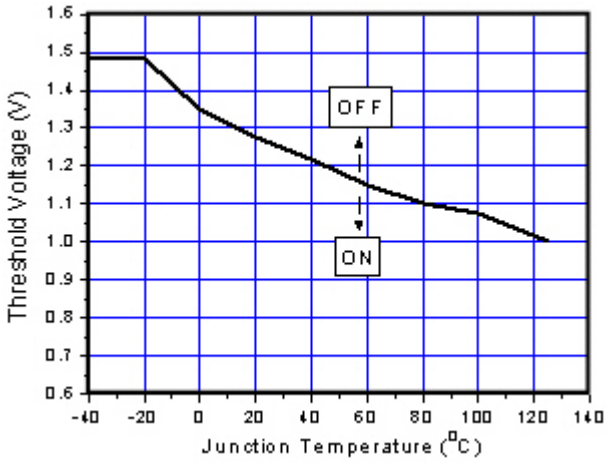


Figure 9. ON/OFF Pin Voltage

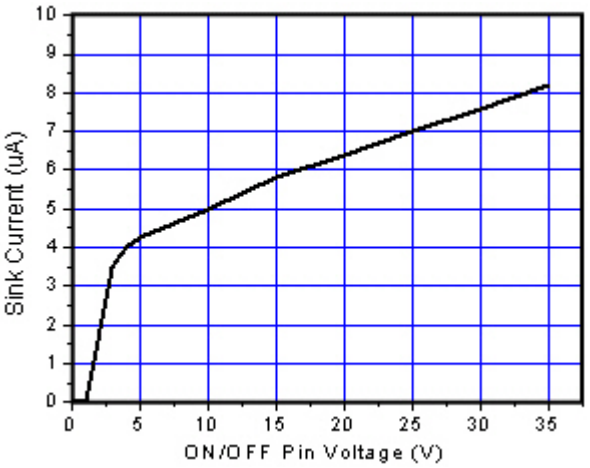


Figure 10. ON/OFF Pin Sink Current

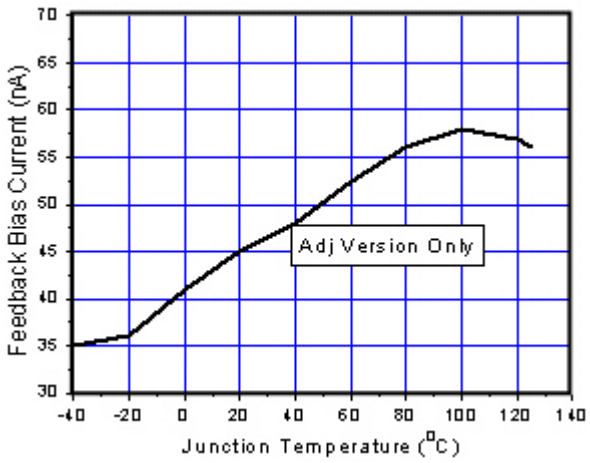


Figure 11. Output Saturation Characteristics

Typical Application Circuit (3.3V Fixed Output Voltage Version)

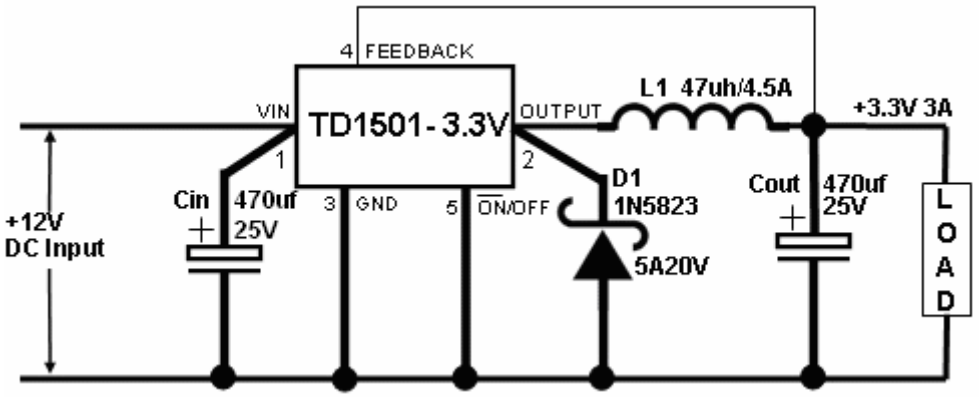


Figure 11. Typical Application of TD1501 For 3.3V

Input Voltage	Output Component			
	Inductor (L1)	Through Hole Electrolytic(Cout)	Surface Mount Tantalum(Cout)	Schottky Diode (D1)
4.5V ~ 18V	47uh	470uf/25V	330uf/6.3V	ref. Table 5
18V ~ 45V	68uh	560uf/25V	330uf/6.3V	

Table 1. TD1501 Series Buck Regulator Design Procedure For 3.3V

Typical Application Circuit (5V Fixed Output Voltage Version)

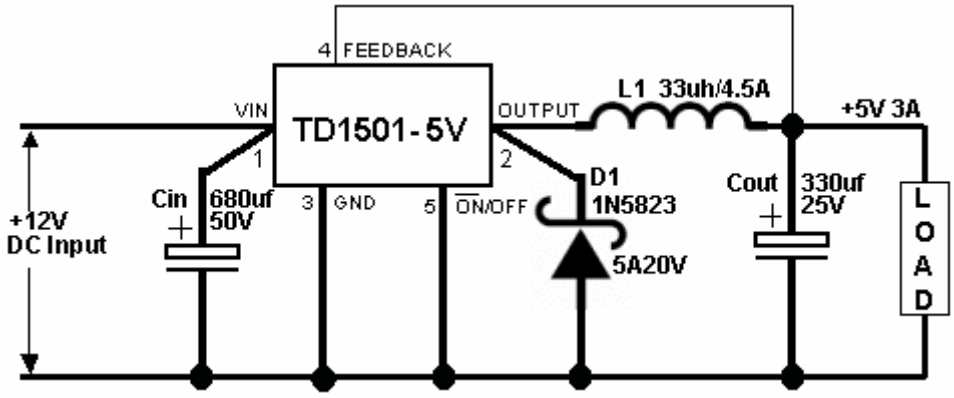


Figure 12. Typical Application of TD1501 For 5V

Input Voltage	Output Component			
	Inductor (L1)	Through Hole Electrolytic(Cout)	Surface Mount Tantalum(Cout)	Schottky Diode (D1)
7V ~ 18V	33uh	330uf/25V	220uf/10V	ref. Table 5
18V ~ 45V	47uh	470uf/25V	330uf/10V	

Table 2. TD1501 Series Buck Regulator Design Procedure For 5V

Typical Application Circuit (Adjustable Output Voltage Version)

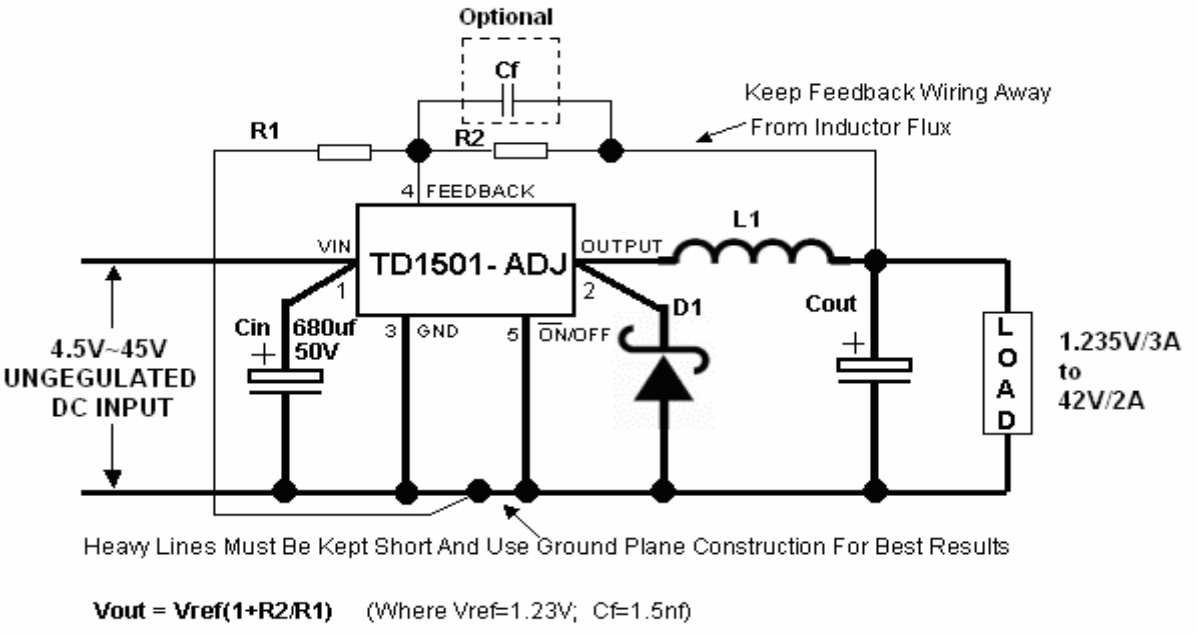


Figure 13. Typical Application of TD1501 For ADJ

Vout	R1	R2	Cf (Optional)
3.3V	1.6K	2.7K	33nf
5V	3.6K	11K	10nf
9V	6.8K	43K	1.5nf
12V	1.5K	13K	1nf

Table 3. Vout VS. R1, R2, Cf Select Table

Output Voltage	Input Voltage	Inductor (L1)	Output Component	
			Through Hole Electrolytic(Cout)	Schottky Diode (D1)
3.3V	4.5V ~ 18V	47uh	470uf/25V	ref. Table 5
	18V ~45V	68uh	560uf/25V	
5V	7V ~ 18V	33uh	330uf/25V	
	18V ~45V	47uh	470uf/25V	
9V	12V ~18V	47uh	330uf/25V	
	18V ~45V	47uh	470uf/25V	
12V	15V ~ 18V	47uh	220uf/25V	
	18V ~45V	47uh	330uf/25V	

Table 4. Typical Application Buck Regulator Design Procedure

Schottky Rectifier Selection Guide

Vin (Max)	2A Load Current			3A Load Current		
	Part Number	Package	Vendor	Part Number	Package	Vendor
20 V	B220/A	SMB/SMA	1	B320/B/A	SMC/B/A	1
	SS22	SMA	2,3	SS32	SMC	2,3
	-	-	-	MBRS320	SMC	4
	-	-	-	SK32	SMC	6
	-	-	-	IN5820	D0-201AD	6
30 V	B230/A	SMB	1	B330/B/A	SMC/B/A	1
	SS23	SMB	2,3	SS33	SMC	2,3
	20BQ030	SMB	4	MBRS330	SMC	4,5
	MBRS230	SMB	5	SK33	SMC	3,6
	SK23	SMB	6	IN5821	D0-201AD	2,6
40 V	B240/A	SMB/SMA	1	B340/B/A	SMC/B/A	1
	SS24	SMB	2,3,5	SS34	SMC	2,3
	MBRS240	SMB	5	30BQ040	SMC	4
	-	-	-	MBRS340TR	SMC	4,5
	-	-	-	SK34	SMC	6
	-	-	-	IN5822	DC-201AD	6
50 V	B250/A	SMB/SMA	1	B350/B/A	SMC/B/A	1
	SS25	SMB	2,3	SS35	SMC	2,3
	SK23	SMB	6	MBRS330	SMC	4,5
	-	-	-	SK35	SMC	3,6

Vin (Max)	4A Load Current			5A Load Current		
	Part Number	Package	Vendor	Part Number	Package	Vendor
20 V	SL42	SMC	2,3	B520C	SMC	1
	-	-	-	SR502	D0-201AD	1
	-	-	-	SB520	D0-201AD	2
	-	-	-	IN5823	D0-201AD	6
30 V	SL43	SMC	2,3	B530C	SMC	1
	-	-	-	SR503	D0-201AD	1
	-	-	-	SB530	D0-201AD	2,
	-	-	-	SSC53L	SMC	3
	-	-	-	IN5824	D0-201AD	6
40 V	SL44	SMC	2,3,5	B540C	SMC	1
	-	-	-	SR504	D0-201AD	1
	-	-	-	SB540	DC-201AD	2
	-	-	-	SSC54	SMC	3
	-	-	-	MBRS540T3	SMC	5
	-	-	-	IN5825	DC-201AD	6
50 V	-	-	-	B550C	SMC	1
	-	-	-	SB550	DC-201AD	2
	-	-	-	-	-	-

Table 5 Lists some rectifier manufacturers.

No.	Vendor	Web Site
1	Diodes, Inc.	www.diodes.com
2	Fairchild Semiconductor	www.fairchildsemi.com
3	General Semiconductor	www.gensemi.com
4	International Rectifier	www.irf.com
5	On Semiconductor	www.onsemi.com
6	Pan Jit International	www.panjit.com.tw

Table 6 Schottky Diode manufacturers.

Application Hints and Layout Guidelines

Heat Sink / Thermal Considerations

The TD1501 is available in two packages, a 5-pin TO-220B/TO220 and a 5-pin surface mount TO-263.

The TO-220B/TO220 package needs a heat sink under most conditions. The size of the heatsink depends on the input voltage, the output voltage, the load current and the ambient temperature. The TD1501 junction temperature rises above ambient temperature for a 3A load and different input and output voltages. The data for these curves was taken with the TD1501 (TO-220B/TO220 package) operating as a buck switching regulator in an ambient temperature of 25^{o}C (still air). These temperature rise numbers are all approximate and there are many factors that can affect these temperatures. Higher ambient temperatures require more heat sinking.

The TO-263 surface mount package tab is designed to be soldered to the copper on a printed circuit board. The copper and the board are the heat sink for this package and the other heat producing components, such as the catch diode and inductor. **The PC board copper area that the package is soldered to should be at least 0.4 in^2, and ideally should have 2 or more square inches of 2 oz. Additional copper area improves the thermal characteristics**, but with copper areas greater than approximately 6 in^2, only small improvements in heat dissipation are realized. If further thermal improvements are needed, double sided, multilayer PC board with large copper areas and/or airflow are recommended.

The TD1501 (TO-263 package) junction temperature rise above ambient temperature with a 3A load for various input and output voltages. This data was taken with the circuit operating as a buck switching regulator with all components mounted on a PC board to simulate the junction temperature under actual operating conditions. This curve can be used for a quick check for the approximate junction temperature for various conditions, but be aware that there are many factors that can affect the junction temperature. When load currents higher than 3A are used, double sided or multilayer PC boards with large copper areas and/or airflow might be needed, especially for high ambient temperatures and high output voltages.

For the best thermal performance, wide copper traces and generous amounts of printed circuit board copper should be used in the board layout. (Once exception to this is the output (switch) pin, which should not have large areas of copper.) Large areas of copper provide the best transfer of heat (lower thermal resistance) to the surrounding air, and moving air lowers the thermal resistance even further.

Output Voltage Ripple and Transients

The output voltage of a switching power supply will contain a sawtooth ripple voltage at the switcher frequency, typically about 1% of the output voltage, and may also contain short voltage spikes at the peaks of the sawtooth waveform.

The output ripple voltage is due mainly to the inductor sawtooth ripple current multiplied by the ESR of the output capacitor.

The voltage spikes are present because of the fast switching action of the output switch, and the parasitic inductance of the output filter capacitor, To minimize these voltage spikes, special low inductance capacitors can be used, and their lead lengths must be kept short. Wiring inductance, stray capacitance, as well as the scope probe used to evaluate these transients, all contribute to the amplitude of these spikes.

A large value inductor will also result in lower output ripple voltage , but will have a larger physical size,higher series reistance,and/or lower saturation current. An additional small LC filter can be added to the output (as shown in Figure 14) to further reduce the amount of output ripple and transients.

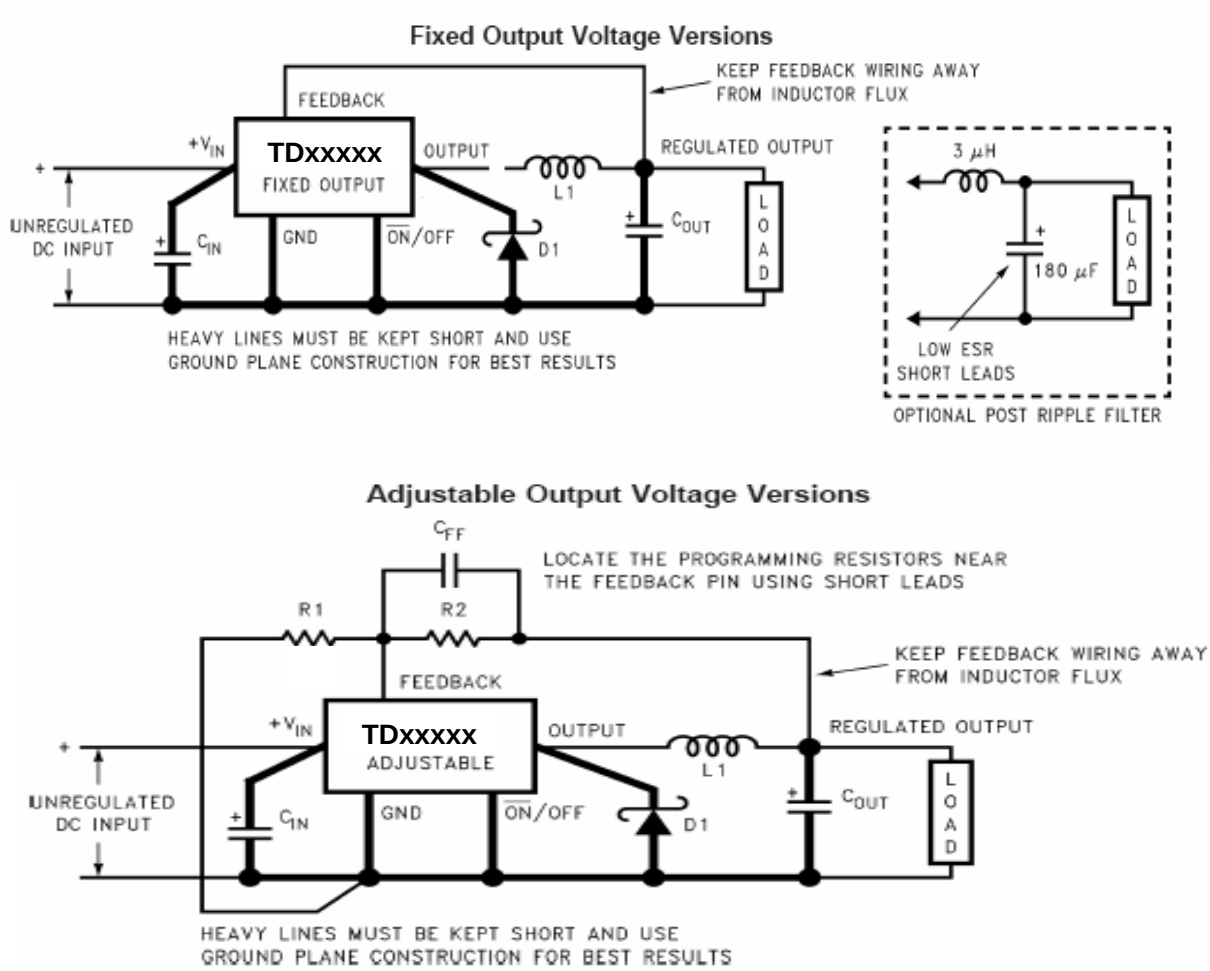
Layout Guidelines

As in any switching regulator, layout is very important. Rapidly switching currents associated with wiring inductance can generate voltage transients which can cause problems. For minimal inductance and ground loops, the wires indicated by **heavy lines should be wide printed circuit traces and should be kept as short as possible**. For best results, external components should be located as close to the switcher IC as possible using ground plane construction or single point grounding.

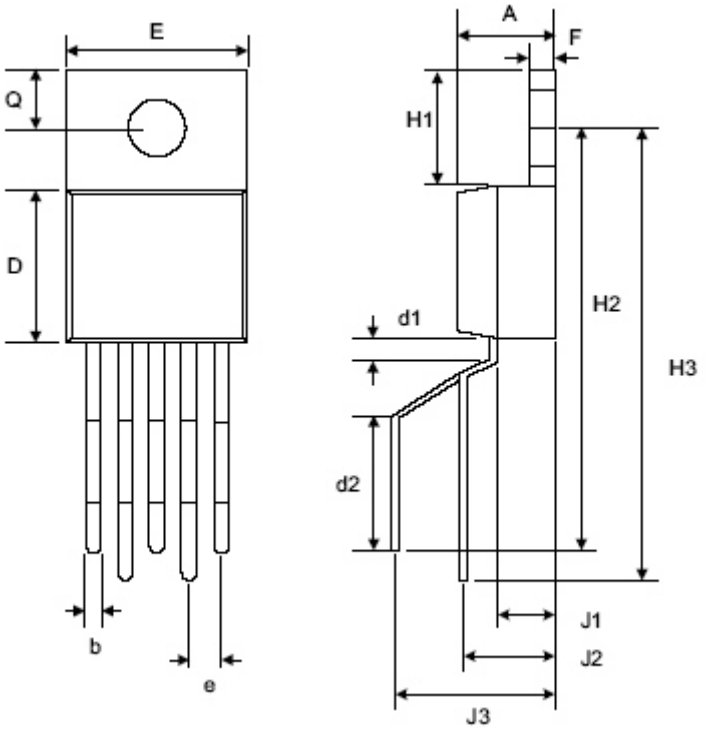
If open core inductors are used, special care must be taken as to the location and positioning of this type of inductor. Allowing the inductor flux to intersect sensitive feedback, IC groundpath and C_{OUT} wiring can cause problems.

When using the adjustable version, special care must be taken as to the location of the feedback resistors and the associated wiring. **Physically locate both resistors near the IC, and route the wiring away form the inductor especially an open core type of inductor**.

Figure 14, Layout Guidelines and Post Ripple Filter

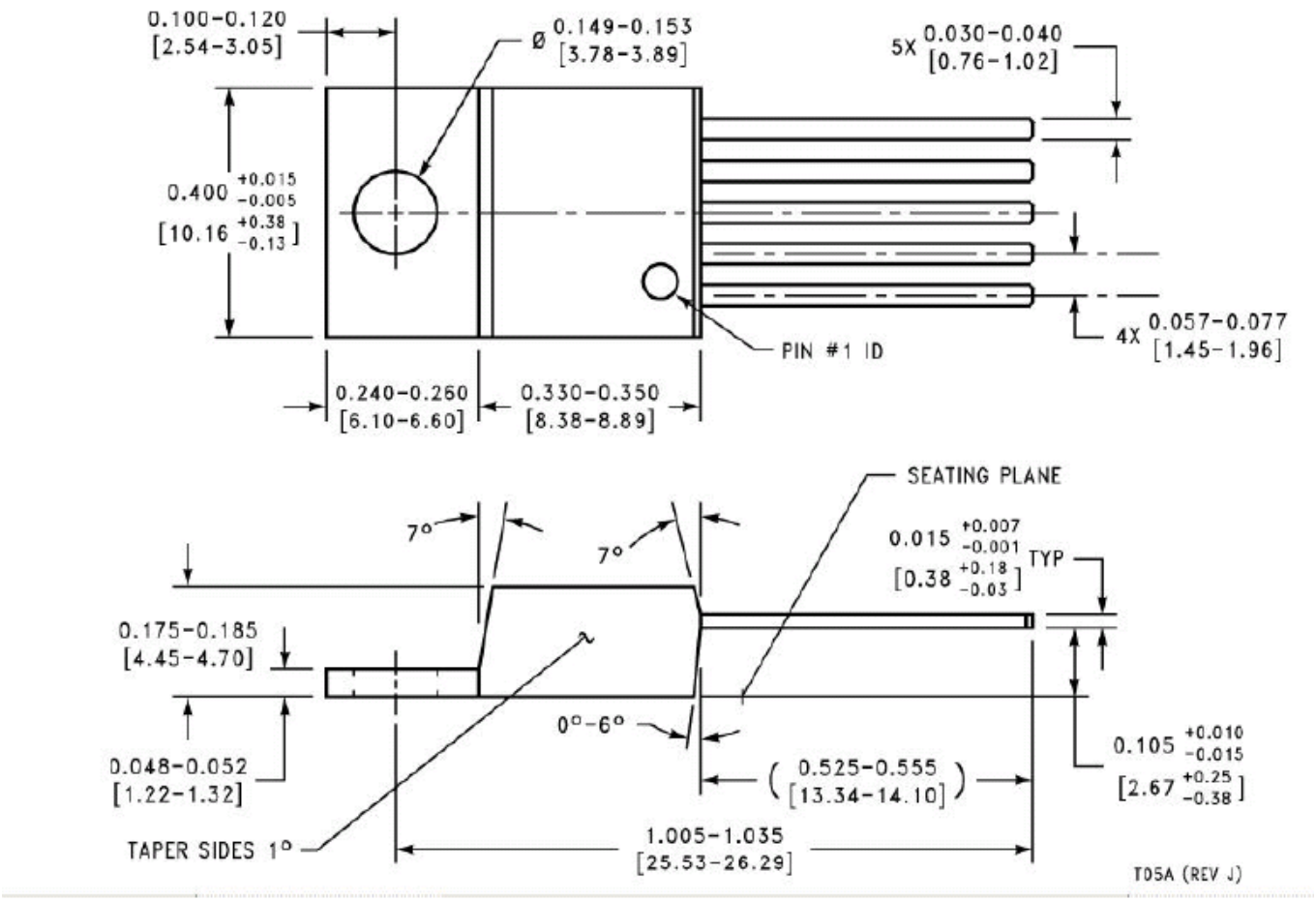


Package Information (TO220B-5L)

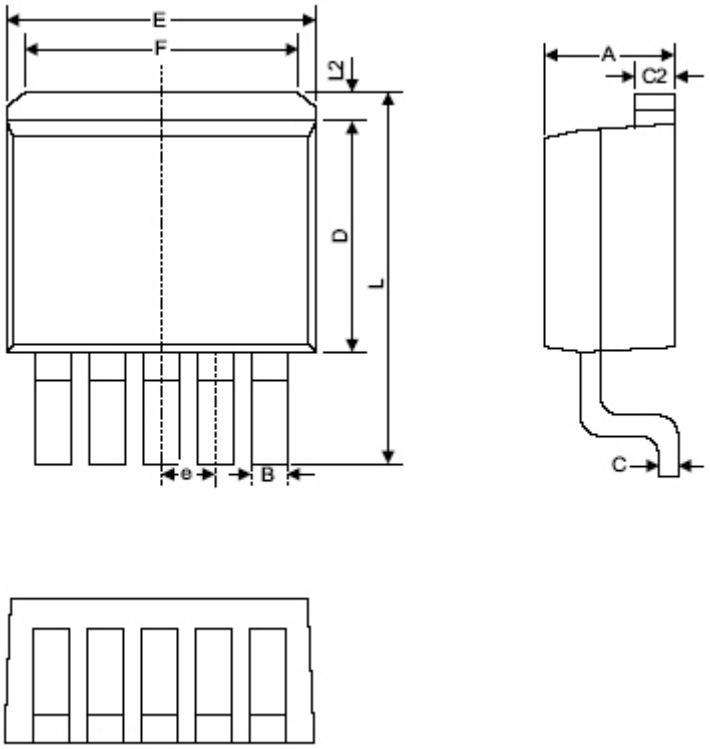


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min.	Max.	Min.	Max.
A	0.44	0.47	0.175	0.185
b	0.07	0.09	0.027	0.037
D	0.84	0.89	0.330	0.350
d1	0.10		0.039	
d2	0.63		0.248	
E	9.91	10.41	0.390	0.410
e	0.16	0.18	0.062	0.072
F	0.12	0.13	0.048	0.052
H1	0.64		0.250	
H2	2.08	2.24	0.820	0.880
H3	2.39	2.55	0.942	1.002
J1	0.27		0.105	
J2	0.37	0.53	0.147	0.207
J3	0.84		0.331	
Q	0.25	0.30	0.100	0.120

Package Information (TO220-5L)



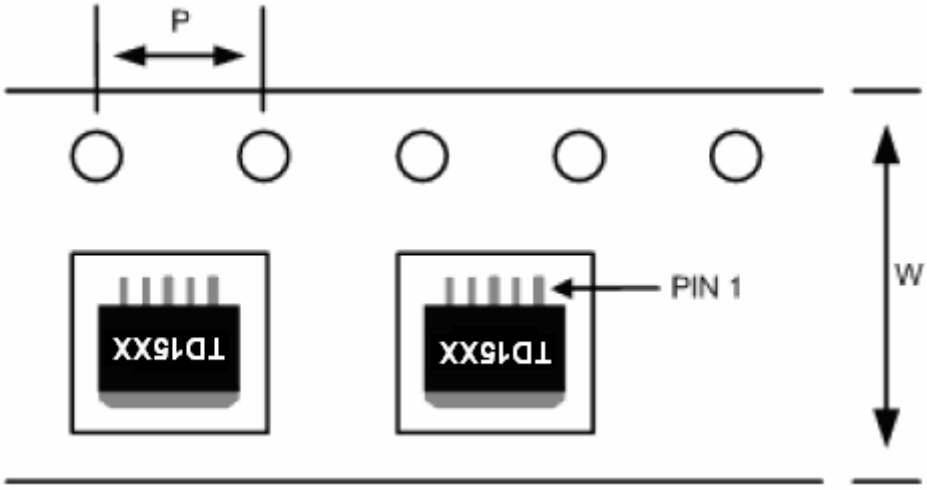
Package Information (TO263-5L)



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min.	Max.	Min.	Max.
A	4.45	4.7	0.175	0.185
B	0.71	0.97	0.028	0.038
C	0.38	0.76	0.015	0.030
C2	1.22	1.32	0.048	0.052
D	8.38	8.89	0.330	0.350
E	9.91	10.16	0.390	0.410
e	1.57	1.85	0.062	0.070
F	6.61	7.11	0.260	0.280
L	-	14.35	-	0.565
L2	-	1.27	-	0.050

Packing Information

TO263-5L Carrier Tape Outline Dimensions



Carrier Tape, Number of Components Per Reel and Reel Size

Package	Carrier Width (W)	Pitch (P)	Part Per Full Reel	Reel Size
TO263-5L	24.0 ± 0.1mm	4.0 ± 0.1mm	800 PCS	330 ± 2mm