TAIWAN SEMICONDUCTOR

RoHS COMPLIANCE

TS39500/1/2/3

5A Ultra Low Dropout Positive Voltage Regulator

TO-220

TO-263 (D^2PAK)

TO-220-5L

TO-263-5L (D^2PAK)

Pin Definition:
TS39500
1. Input
2. Ground (tab)
3. Output

Pin Definition:

TS39501xx	**TS39502**	**TS39503xx**
1. Enable	1. Enable	1. Enable
2. Input	2. Input	2. Input
3. Ground	3. Ground	3. Ground
4. Output	4. Output	4. Output
5. Flag	5. Adjust	5. Sense

General Description

TS39500/1/2/3 are 5A ultra low dropout linear voltage regulators that provide low voltage, high current output with a minimum of external components. TS39500/1/2/3 offers extremely low dropout (typically 400mV at 5A) and low quiescent current (typically 36mA at 5A).

TS39500/1/2/3 is ideal for PC add-in cards that need to convert from standard 3.3V to 2.5V or 2.5V to 1.8V. A guaranteed maximum dropout voltage of 500mV over all operating conditions allows the TS39501/2/3/4 to provide 2.5V from a supply as low as 3V, and 1.8V from a supply as low as 2.5V. TS39500/1/2/3 also has fast transient response for heavy switching applications. The device requires only 47uF of output capacitor to maintain stability and achieve fast transient response.

On TS39500/1/2/3, the enable pin may be tied to input voltage if it is not required for enable control.

Features

- Dropout voltage typically 0.4V @ Io=5A
- Output Current up to 5A
- Low Ground Current
- Extremely Fast Transient Response
- Current Limit & Thermal Shutdown
- Reversed Leakage & Reverse Battery Protection
- Error Flag Signals Output (TS39501 only)
- Adjustable Version (TS39502 only)
- Output Voltage Sense (TS39503/4 only)

Application

- PowerPC™ Power Supplies
- Battery Powered Equipment
- Consumer and Personal Electronics
- High Efficiency Linear Power Supplies
- SMPS Post Regulator and DC to DC Modules
- High-efficiency Post Regulator for Switching Supply
- Low Voltage Microcontrollers and Digital Logic

Ordering Information

Part No.	Package	Packing
TS39500CZ**xx** C0	TO-220	50pcs / Tube
TS39500CM**xx** RN	TO-263	800pcs / 13” Reel
TS39501CZ5**xx** C0	TO-220-5L	50pcs / Tube
TS39501CM5**xx** RN	TO-263-5L	800pcs / 13” Reel
TS39502CZ5 C0	TO-220-5L	50pcs / Tube
TS39502CM5 RN	TO-263-5L	800pcs / 13” Reel
TS39503CZ**xx** C0	TO-220-5L	50pcs / Tube
TS39503CM**xx** RN	TO-263-5L	800pcs / 13” Reel

Note: Where **xx** denotes voltage option, available are
50=5V, **33**=3.3V, **25**=2.5V, **18**=1.8V
Contact to factory for addition output voltage option.

TS39500/1/2/3

5A Ultra Low Dropout Positive Voltage Regulator

Absolute Maximum Rating (Note 1)

Supply Voltage	V_{IN}	-20V ~ +20	V
Enable Voltage	V_{EN}	+20	V
Storage Temperature Range	T_{STG}	-65 ~ +150	°C
Lead Soldering Temperature (260°C)		5	S
ESD		(Note 3)	

Operating Rating (Note 2)

Operation Input Voltage	V_{IN} (operate)	+2.25 ~ +16	V
Operation Enable Voltage	V_{EN} (operate)	+2.25 ~ +16	V
Power Dissipation (Note 4)	P_D	Internally Limited	W
Operating Junction Temperature Range	T_J	-40 ~ +125	°C

Electrical Characteristics

V_{IN} = V_{OUT} + 1V, V_{IN} =2.5V for fixed reference output voltage, Venable= 2.25V, Ta = 25°C, unless otherwise specified.

Parameter	Conditions		Min	Typ	Max	Unit
Fixed Output Voltage	10mA ≤ I_L ≤ 5A, Vo+1V ≤ V_{IN} ≤ 8V		0.980|Vo|	V_{OUT}	1.020|Vo|	V
Fixed Reference Output Voltage	I_L=10mA		0.980|Vo|	1.24 (V_{REF})	1.020|Vo|	V
Fixed Reference Output Voltage	10mA ≤ I_L ≤ 5A, 2.5V ≤ V_{IN} ≤ 8V		0.970|Vo|		1.030|Vo|	
Line Regulation	I_L=10mA, Vo+1V ≤ V_{IN} ≤ 8V		--	0.05	0.5	%
Load Regulation	V_{IN} =Vout+1V, 10mA≤I_L≤5A		--	0.2	1.0	%
Output Voltage Temp. Coefficient			--	40	100	ppm/°C
Dropout Voltage (Note 5)	Δ V_{OUT} = -1%	I_L=100mA I_L=750mA I_L=1.5A I_L=5A	-- -- -- --	65 185 250 400	200 -- -- 550	mV
Quiescent Current (Note 6)	V_{IN}= V_{OUT} +1V	I_L=100mA I_L=750mA I_L=1.5A I_L=5A	-- -- -- --	6 10 17 45	10 20 -- --	mA
Current Limited	V_{OUT}=0, V_{IN} =V_{OUT}+1V		--	4.5	--	A
Reference (TS39502)						
Reference Voltage			0.980|Vo|	1.24	1.020|Vo|	
Reference Voltage	(Note 7)		0.970|Vo|		1.030|Vo|	V
Adjust Pin Bias Current			--	40	120	nA
Reference Voltage Temp. Coefficient	(Note 8)		--	20	--	ppm/°C
Adjust Pin Bias Current Temp. Coefficient			--	0.1	--	nA/°C
Enable Input (TS39501/2/3/4)						
Input Logic Voltage	Low (OFF)		--	--	0.8	V
	High (ON)		2.25	--	--	
Enable Pin Input Current	V_{EN} =2.25V		--	--	75	uA
	V_{EN} =0.8V		--	--	4	

Electrical Characteristics (Continue)

Flag Output (TS39501)					
Output Leakage Current	V_{OH}=16V	--	--	2	uA
Output Low Voltage (Note 9)	V_{IN}=0.9 * V_{OUT}, I_{OL}=250uA	--	--	400	mV
Upper Threshold Voltage	% of V_{OUT}	--	--	99	%
Lower Threshold Voltage	% of V_{OUT}	93	--	--	%
Hysteresis		--	1	--	%

Thermal Performance

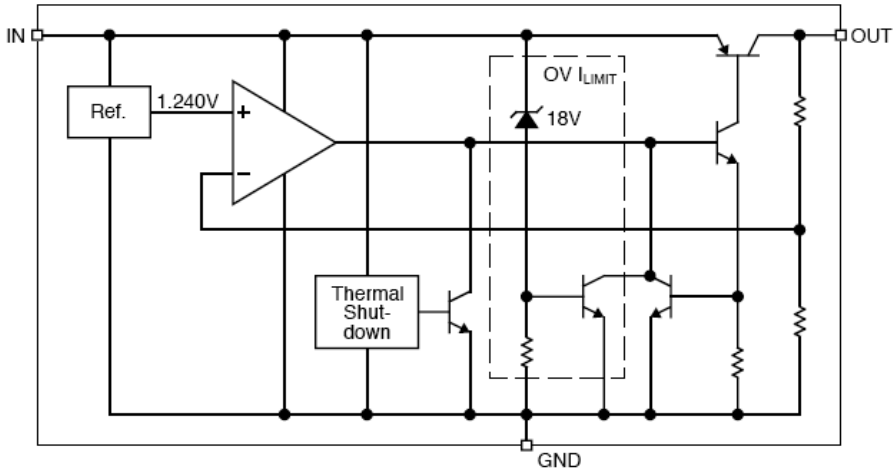
Condition	Package type	Typ	Unit
Thermal Resistance Junction to Case	TO-220 / TO-220-5L	80	°C/W
	TO-263 / TO-263-5L	80	

Note 1. Exceeding the absolute maximum ratings may be damaged the device.
Note 2. The device is not guaranteed to function outside its operating rating.
Note 3. Devices are ESD sensitive. Handling precautions recommended.
Note 4. $P_{D(max)} = (T_{J(max)} - Ta) + \Theta_{JA}$, where Θ_{JA} depends upon the printed circuit layout. See "Applications Information".
Note 5. Output voltage temperature coefficient is $\Delta V_{OUT\ (worst\ case)}+(T_{J(max)} – T_{J(MIN)})$ where $T_{J(max)}$ is +125°C and $T_{JMIN)}$ is -40°C.
Note 6. $V_{DROP} = V_{IN} - V_{OUT}$ when V_{OUT} decreases to 99% of its nominal output voltage with $V_{IN} = V_{OUT} + 1$. For output voltages below 2.5V, dropout voltage is the input-to-output voltage differential with the minimum input voltage being 2.5V. Minimum input operating voltage is 2.5V
Note 7. I_{GND} is the quiescent current. $I_{IN} = I_{GND} + I_{OUT}$
Note 8. V_{EN} <0.8V, V_{IN} <8V and V_{OUT} =0
Note 9. For 1.8V device, V_{IN} = 2.25V (device is in dropout)

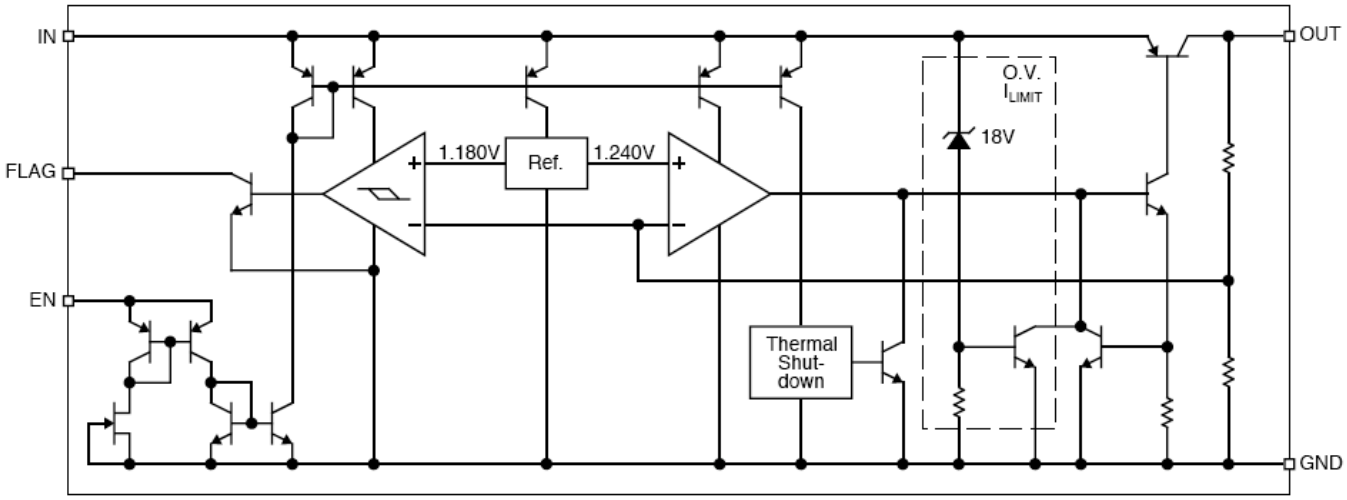
Pin Description

Pin Configuration	Pin Description
Enable	TTL/COMS compatible input. Logic high is enable; logic low or open is shutdown
Input	Unregulated input: +16V maximum supply
Ground	Ground: Ground pin and TAB / heat sink are internally connected.
Output	Regulator output
Flag **(fixed voltage)**	Error Flag (output): Open-collector output. Active low indicates an output fault condition, if no used, leave open.
Feed Back **(adjustable)**	Adjustment input: Feedback input. Connect to resistive voltage-divider network.
Sense	Sense pin is the input to the error amplifier

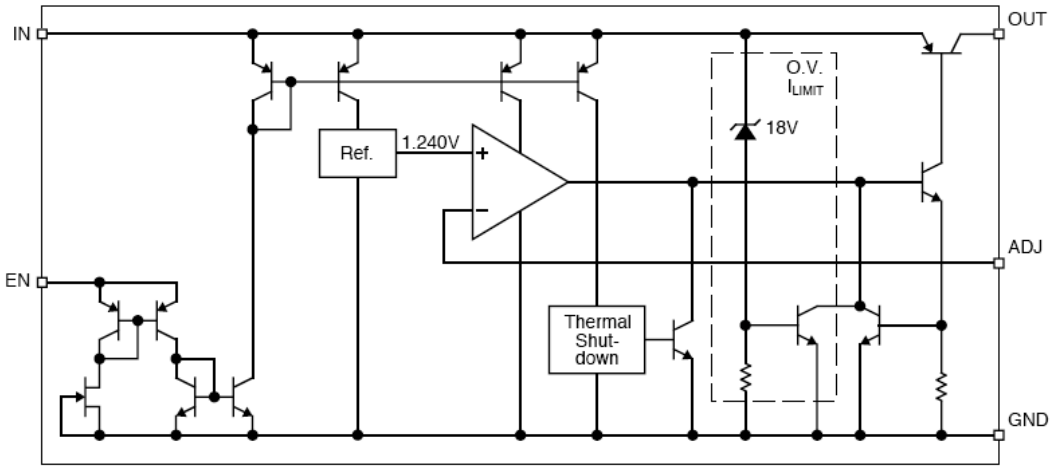
Functional Diagram



TS39500 Fixed Regulator Block Diagram



TS39501/3/4 Fixed Regulator with Flag and Enable Block Diagram



TS39502 Adjustable Regulator Block Diagram

Application Information

The TS39500/1/2/3 are high performance with low dropout voltage regulator suitable for moderate to high current and voltage regulator application. Its 630mV dropout voltage at full load and over temperature makes it especially valuable in battery power systems and as high efficiency noise filters in post regulator applications. Unlike normal NPN transistor design, where the base to emitter voltage drop and collector to emitter saturation voltage limit the minimum dropout voltage, dropout performance of the PNP output of these devices is limited only by low Vce saturation voltage. The TS39500/1/2/3 is fully protected from damage due to fault conditions. Linear current limiting is provided. Output current during overload conditions is constant. Thermal shutdown the device when the die temperature exceeds the maximum safe operating temperature. Transient protection allows device survival even when the input voltage spikes above and below nominal. The output structure of these regulators allows voltages in excess of the desired output voltage to be applied without reverse current flow.

Output Capacitor Requirement

The TS39500/1/2/3 requires an output capacitor to maintain stability and improve transient response is necessary. The value of this capacitor is dependent upon the output current, lower currents allow smaller capacitors. TS39500/1/2/3 output capacitor selection is dependent upon the ESR of the output capacitor to maintain stability. When the output capacitor is 10uF or greater, the output capacitor should have an ESR less than 2Ω. This will improve transient response as well as promote stability. Ultra low ESR capacitors (<100mΩ), such as ceramic chip capacitors, may promote instability. These very low ESR levels may cause an oscillation and/or under damped transient response. A low ESR solid tantalum capacitor works extremely well and provides good transient response and stability over temperature aluminum electrolytes can also be used, as long as the ESR of the capacitor is <2Ω. The value of the output capacitor can be increased without limit. Higher capacitance values help to improve transient response and ripple rejection and reduce output noise.

Input Capacitor Requirement

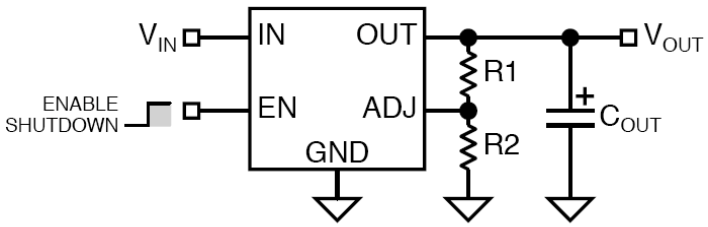
An input capacitor of 1uF or greater is recommended when the device is more than 4” away from the bulk AC supply capacitance or when the supply is a battery. Small, surface mount, ceramic chip capacitors can be used for bypassing. Larger values will help to improve ripple rejection by bypassing the input to the regulator, further improving the integrity of the output voltage.

Minimum Load Current

The TS39500/1/2/3 is specified between finite loads. If the output current is too small leakage currents dominate and the output voltage rises. A 10mA minimum load current is necessary for proper regulation.

Adjustable Regulator Design

The adjustable regulator versions (TS39502) is allow to programming the output voltage anywhere between 1.25 and the 16V maximum operating rating of the family.
Two resistors are used. Resistors can be quite large up to 1MΩ, because of the very high input impedance and low bias current of the sense comparator, the resistor values are calculated by:



$$V_{OUT} = 1.240V\left(1+\frac{R1}{R2}\right)$$

Where Vout is the desired output voltage. Above application circuit shows component definition. Applications with widely varying load currents may scale the resistors to draw the minimum load current required for proper operation.

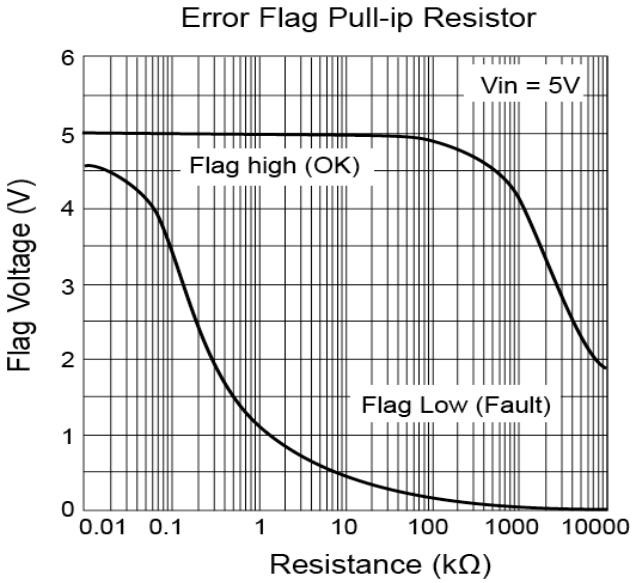
Application Information (Continue)

Enable Input

TS39501/2/3/4 versions feature an active-high enable (EN) input that allows ON/OFF control of the regulator. Current drain reduces to “zero” when the device is shutdown, with only micro-amperes of leakage current. The EN input has TTL/CMOS compatible thresholds for simple interfacing with logic interfacing. EN may be directly tied to V_{IN} and pulled up to the maximum supply voltage.

Error Flag

TS39501 versions feature an Error Flag, which looks at the output voltage and signals an error condition when this voltage drops 5% below its expected value. The error flag is an open-collector output that pulls low under fault conditions. It may sink 10mA. Low output voltage signifies a number of possible problems, including an over-current fault (the device is in current limit) or low input voltage. The flag output is inoperative during over temperature shutdown conditions. A pull-up resistor from error flag to either V_{IN} or V_{OUT} is required for proper operation. For information regarding the minimum and maximum values of pull-up resistance, refer the graph as follow:



Transient Response and 3.3V to 2.5V or 2.5V to 1.8V Conversion

TS39500/1/2/3 has excellent transient response to variations in input voltage and load current. The device have been designed to respond quickly to load current variations and input voltage variations. Large output capacitors are not required to obtain this performance. A standard 10uF output capacitor, preferably tantalum, is all that is required. Larger values help to improve performance even further. By virtue of its low dropout voltage, this device does not saturate into dropout as readily as similar NPN base designs. When converting from 3.3V to 2.5V or 2.5V to 1.8V, the NPN based regulators are already operating in dropout, with typical dropout requirements of 1.2V or greater,. To convert down to 2.5V or 1.8V without operating in dropout, NPN based regulators require an input voltage of 3.7V at the very least. The TS39500/1/2/3 regulator will provide excellent performance with an input as low as 3.0V or 2.5V respectively. This gives the PNP based regulators a distinct advantage over older, NPN based linear regulators.

Output Sense

Sense pin can be connected to the load and traces the load voltage, TS39503/4 will adjust the output voltage to maintain the load at expected voltage.

Application Information (Continue)

Thermal Characteristics

TS39500/1/2/3 linear regulators are simple to use, the most complicated design parameters to consider are thermal characteristics, thermal design requires the following application specification parameters:

- Maximum ambient temperature, T_A
- Output current, I_{OUT}
- Output voltage, V_{OUT}
- Input voltage, V_{IN}

Calculate the power dissipation of the regulator from these numbers and the device parameters from this datasheet, where the ground current is taken from data sheet.

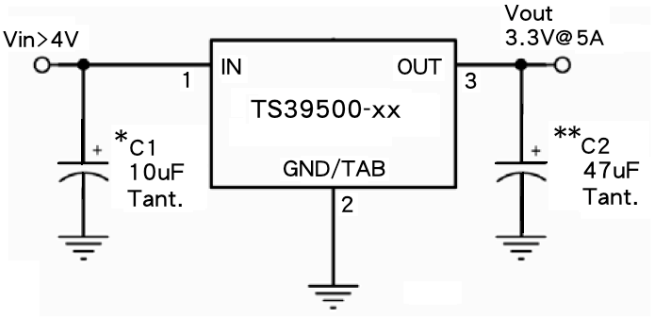
$$P_D = (V_{IN} – V_{OUT}) \times I_{OUT} + V_{IN} \times I_{GND}$$

The heat sink thermal resistance is determined by:

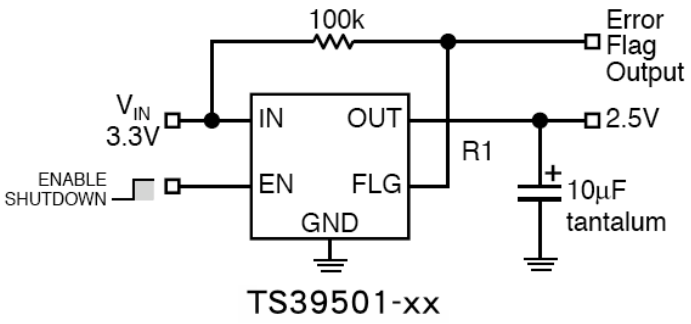
$$\Theta_{SA} = (T_{J(MAX)} – T_A) / P_D – (\Theta_{JC} + \Theta_{CS})$$

Where $T_{J(MAX)} \leq 125^oC$ and Θ_{CS} is between 0^oC and $2^oC/W$. The heat sink may by significantly reduced in applications where the minimum input voltage is know and is large compared with the dropout voltage and distribute the heat between this resistor and the regulator. The low dropout properties of vertical PNP regulators allow significant reductions in regulator power dissipation and the associated heat sink without compromising performance. When this technique is employed, a capacitor of at least 1uF is needed directly between the input and regulator ground.

Typical Application Circuit

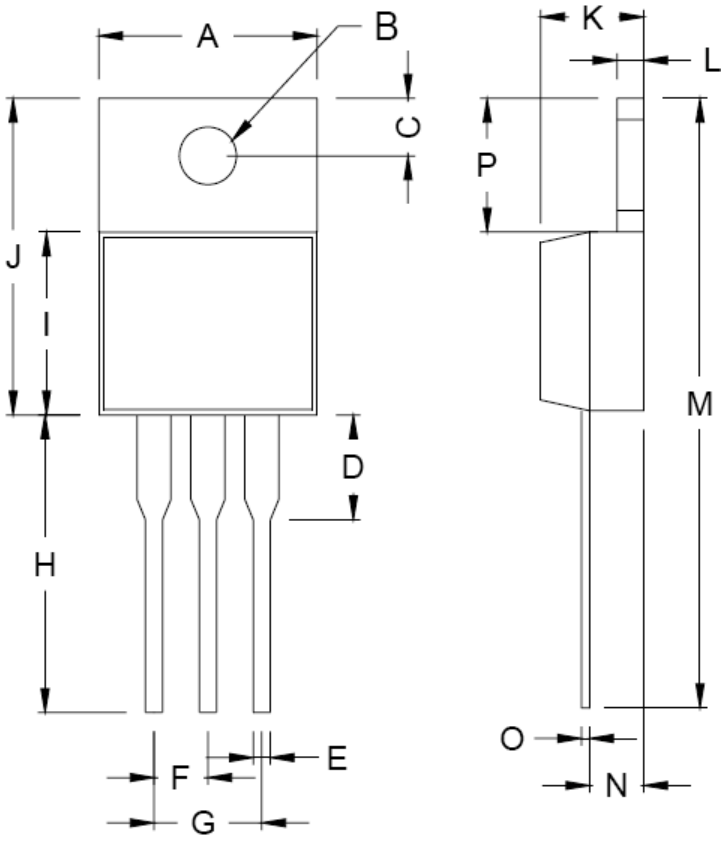


2.5V/5A Regulator



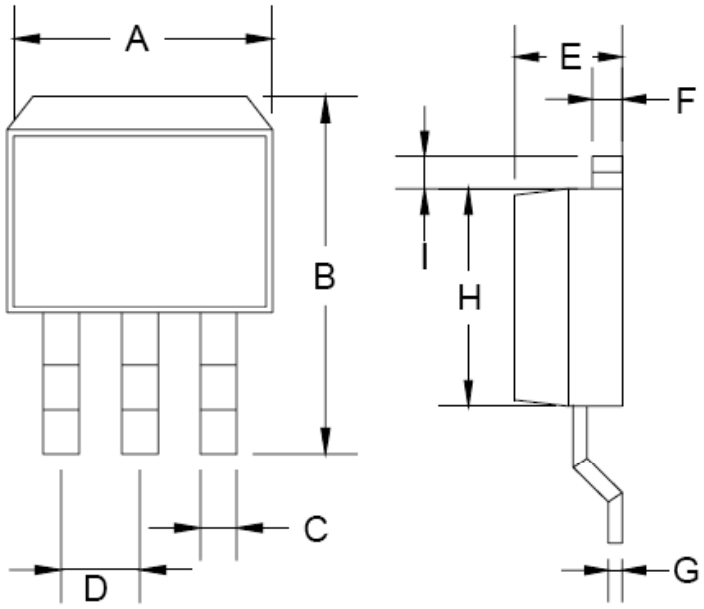
2.5V/5A Regulator with Error Flag

TO-220 Mechanical Drawing



TO-220 DIMENSION				
DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	10.000	10.500	0.394	0.413
B	3.740	3.910	0.147	0.154
C	2.440	2.940	0.096	0.116
D	-	6.350	-	0.250
E	0.381	1.106	0.015	0.040
F	2.345	2.715	0.092	0.058
G	4.690	5.430	0.092	0.107
H	12.700	14.732	0.500	0.581
I	8.382	9.017	0.330	0.355
J	14.224	16.510	0.560	0.650
K	3.556	4.826	0.140	0.190
L	0.508	1.397	0.020	0.055
M	27.700	29.620	1.060	1.230
N	2.032	2.921	0.080	0.115
O	0.255	0.610	0.010	0.024
P	5.842	6.858	0.230	0.270

TO-263 Mechanical Drawing

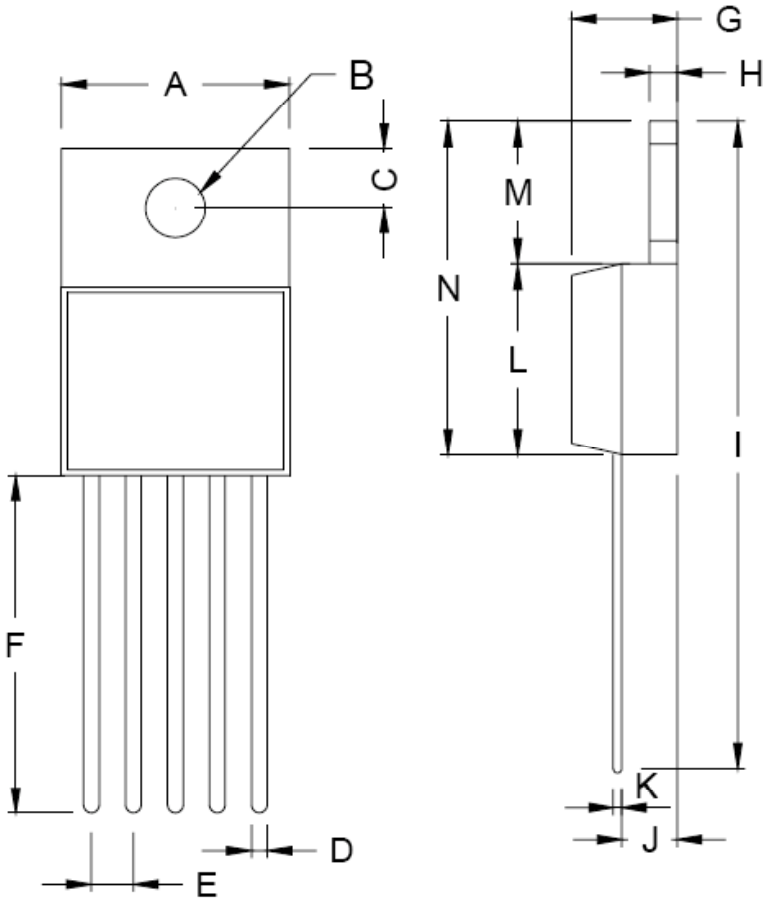


TO-263 DIMENSION				
DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	10.000	10.500	0.394	0.413
B	14.605	15.875	0.575	0.625
C	0.508	0.991	0.020	0.039
D	2.420	2.660	0.095	0.105
E	4.064	4.830	0.160	0.190
F	1.118	1.400	0.045	0.055
G	0.450	0.730	0.018	0.029
H	8.280	8.800	0.325	0.346
I	1.140	1.400	0.044	0.055
J	1.480	1.520	0.058	0.060

TS39500/1/2/3

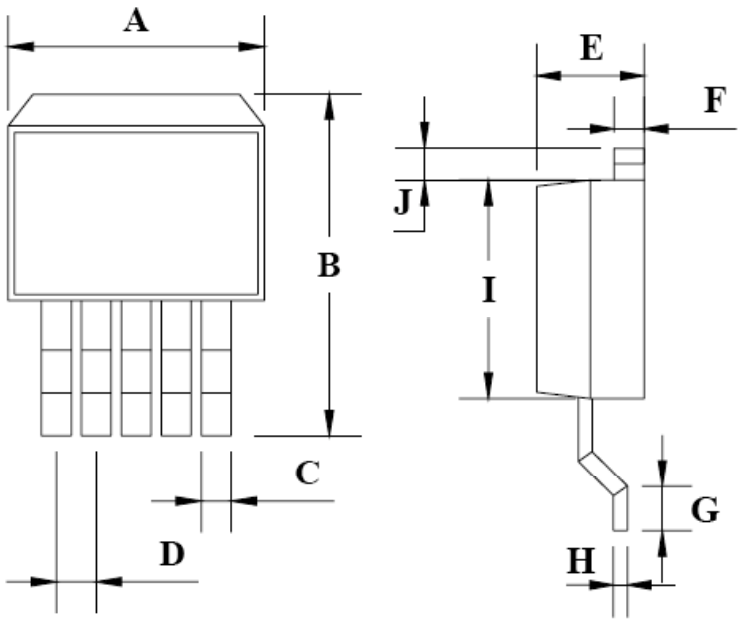
5A Ultra Low Dropout Positive Voltage Regulator

TO-220-5L Mechanical Drawing



TO-220-5L DIMENSION				
DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	10.00	10.50	0.394	0.413
B	3.240	4.440	0.128	0.175
C	2.440	2.940	0.096	0.116
D	0.260	1.020	0.010	0.040
E	1.570	1.830	0.062	0.072
F	13.31	14.13	0.524	0.556
G	4.475	5.225	0.176	0.206
H	1.170	1.370	0.046	0.054
I	27.60	29.44	1.087	1.159
J	2.175	2.925	0.086	0.115
K	0.297	0.477	0.012	0.019
L	8.280	8.800	0.326	0.346
M	6.010	6.510	0.237	0.256
N	14.29	15.31	0.563	0.603

TO-263-5L Mechanical Drawing



TO-263-5L DIMENSION				
DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	9.70	10.54	0.382	0.415
B	14.60	15.87	0.575	0.625
C	0.69	0.94	0.027	0.037
D	1.524	2.032	0.060	0.080
E	4.30	4.70	0.169	0.185
F	1.22	1.40	0.048	0.055
G	2.24	2.82	0.088	0.111
H	0.36	0.56	0.014	0.022
I	8.50	9.20	0.330	0.362
J	1.40 MAX		0.055 MAX	

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