

TO-220

**TO-263
(D²PAK)**

TO-220-5L

**TO-263-5L
(D²PAK)**

Pin Definition:
TS39500

1. Input
2. Ground (tab)
3. Output

Pin Definition:
TS39501xx TS39502

| | |
|-----------|-----------|
| 1. Enable | 1. Enable |
| 2. Input | 2. Input |
| 3. Ground | 3. Ground |
| 4. Output | 4. Output |
| 5. Flag | 5. Adjust |

General Description

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

Features

- Dropout voltage typically 0.4V @ $I_o=5A$
- 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)

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 |
|-----------------|-----------|-------------------|
| TS39500CZxx C0 | TO-220 | 50pcs / Tube |
| TS39500CMxx RN | TO-263 | 800pcs / 13" Reel |
| TS39501CZ5xx C0 | TO-220-5L | 50pcs / Tube |
| TS39501CM5xx RN | TO-263-5L | 800pcs / 13" Reel |
| TS39502CZ5 C0 | TO-220-5L | 50pcs / Tube |
| TS39502CM5 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.

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, $V_{enable} = 2.25V$, $T_a = 25^\circ C$, unless otherwise specified.

| Parameter | Conditions | Min | Typ | Max | Unit |
|----------------------------------|---|--|----------------------|-------------------------|------------------------|
| Fixed Output Voltage | $10mA \leq I_L \leq 5A$, $V_{O}+1V \leq V_{IN} \leq 8V$ | 0.980 V_O | V_{OUT} | 1.020 V_O | V |
| Fixed Reference Output Voltage | $I_L=10mA$ | 0.980 V_O | 1.24 | 1.020 V_O | |
| Fixed Reference Output Voltage | $10mA \leq I_L \leq 5A$, $2.5V \leq V_{IN} \leq 8V$ | 0.970 V_O | (V_{REF}) | 1.030 V_O | V |
| Line Regulation | $I_L=10mA$, $V_O+1V \leq V_{IN} \leq 8V$ | -- | 0.05 | 0.5 | % |
| Load Regulation | $V_{IN} = V_{out} + 1V$, $10mA \leq I_L \leq 5A$ | -- | 0.2 | 1.0 | % |
| Output Voltage Temp. Coefficient | | -- | 40 | 100 | ppm/°C |
| Dropout Voltage (Note 5) | $\Delta V_{OUT} = -1\%$ | $I_L=100mA$ $I_L=750mA$ $I_L=1.5A$ $I_L=5A$ | -- -- -- -- | 65 185 250 400 | 200 -- -- 550 |
| 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 -- -- |
| Current Limited | $V_{OUT}=0$, $V_{IN} = V_{OUT} + 1V$ | -- | 4.5 | -- | A |

Reference (TS39502)

| | | | | | |
|---|----------|--------------|------|--------------|--------|
| Reference Voltage | | 0.980 V_O | 1.24 | 1.020 V_O | |
| Reference Voltage | (Note 7) | 0.970 V_O | | 1.030 V_O | 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)

| | | | | | |
|--------------------------|------------------|------|----|-----|----|
| 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) | $V_{IN}=0.9 * V_{OUT}$, $I_{OL}=250\mu A$ | -- | -- | 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 | 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 ΔV_{OUT} (worst case) + $(T_{J(max)} - T_{J(MIN)})$ where $T_{J(max)}$ is +125°C and $T_{J(MIN)}$ 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. $I_{IN} = I_{GND} + I_{OUT}$

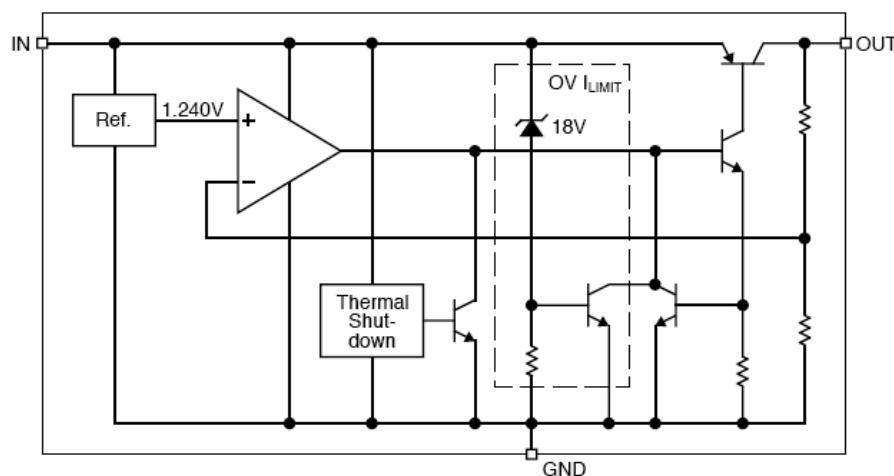
Note 8. $V_{EN} < 0.8V$, $V_{IN} < 8V$ and $V_{OUT} = 0$

Note 9. For 1.8V device, $V_{IN} = 2.25V$ (device is in dropout)

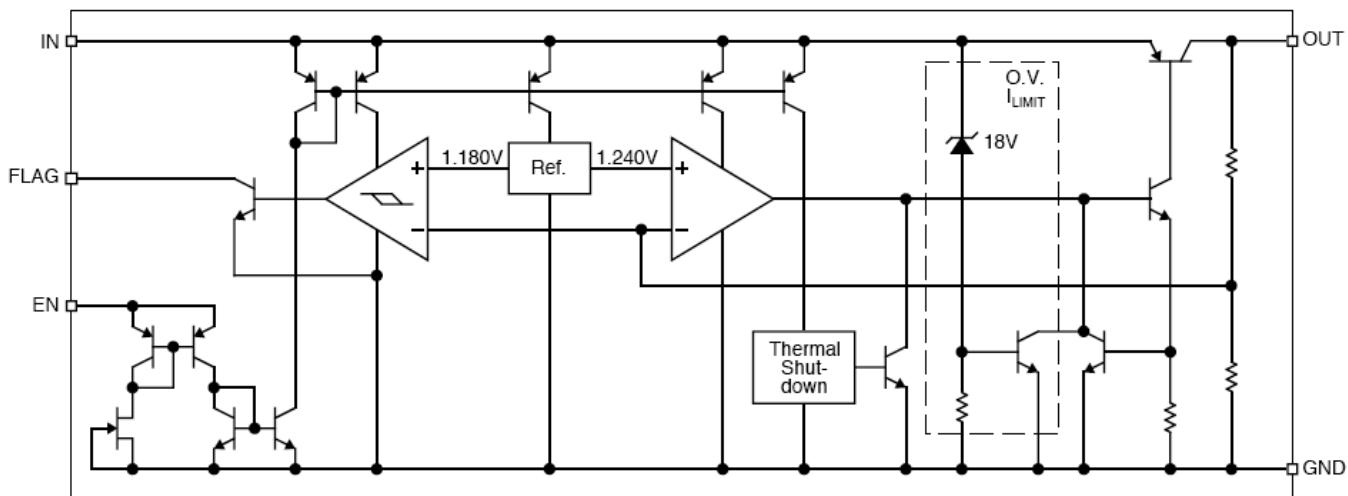
Pin Description

| 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. |

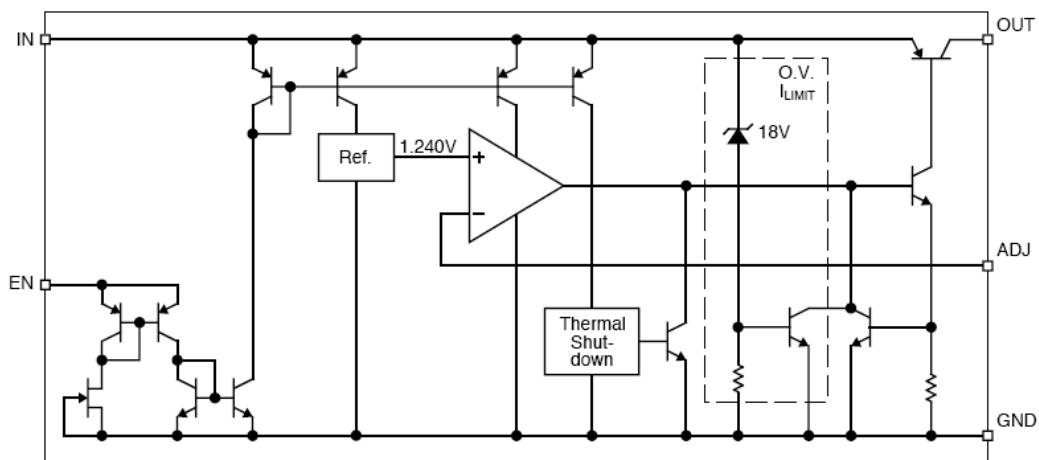
Functional Diagram



TS39500 Fixed Regulator Block Diagram



TS39501 Fixed Regulator with Flag and Enable Block Diagram



TS39502 Adjustable Regulator Block Diagram

Application Information

The TS39500/1/2 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 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 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 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.

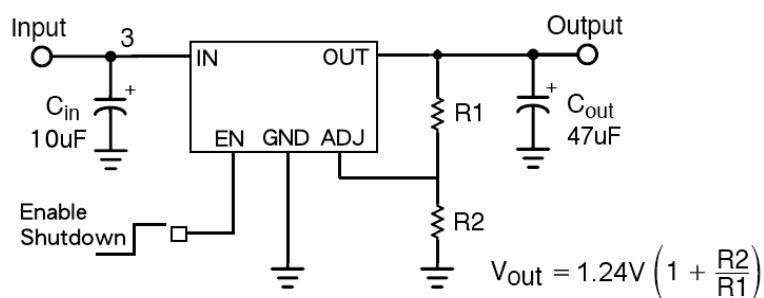
Minimum Load Current

The TS39500/1/2 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:



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.

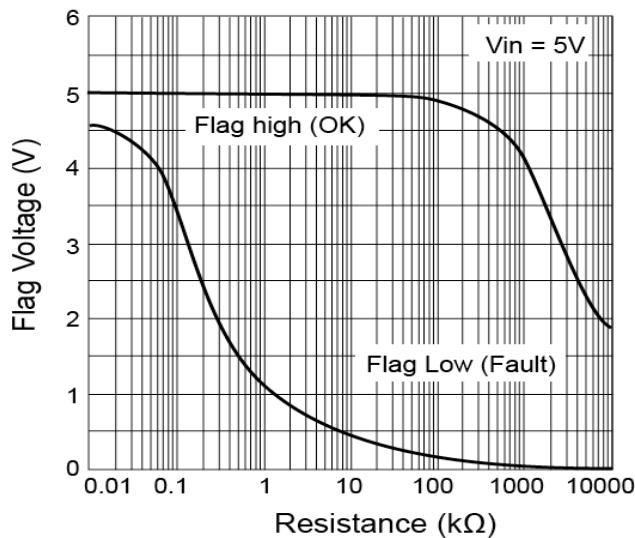
Application Information (Continue)**Enable Input**

TS39501/2 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:

Error Flag Pull-up Resistor

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

TS39500/1/2 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 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.

Application Information (Continue)

Thermal Characteristics

TS39500/1/2 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.

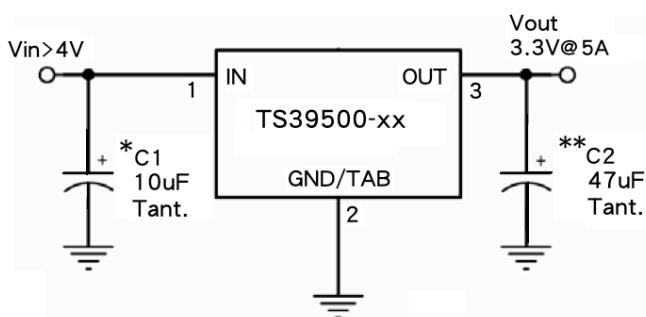
$$P_D = (V_{IN} - V_{OUT}) \times I_{OUT} + V_{IN} \times I_{GND}$$

The heat sink thermal resistance is determined by:

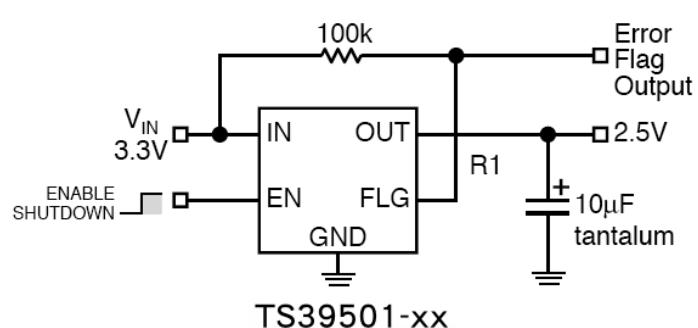
$$\Theta_{SA} = (T_{J(MAX)} - T_A) / P_D - (\Theta_{JC} + \Theta_{CS})$$

Where $T_{J(MAX)} \leq 125^\circ\text{C}$ and Θ_{CS} is between 0°C and 2°C/W . The heat sink may be significantly reduced in applications where the minimum input voltage is known 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 $1\mu\text{F}$ is needed directly between the input and regulator ground.

Typical Application Circuit

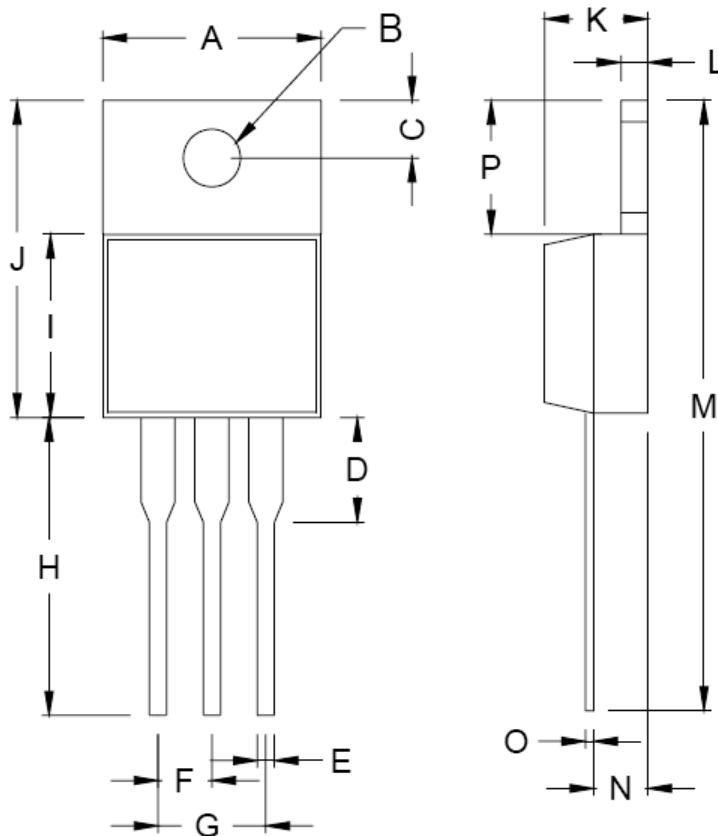


2.5V/5A Regulator



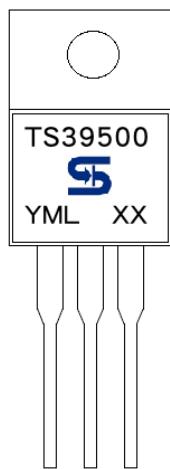
2.5V/5A Regulator with Error Flag

TO-220 Mechanical Drawing



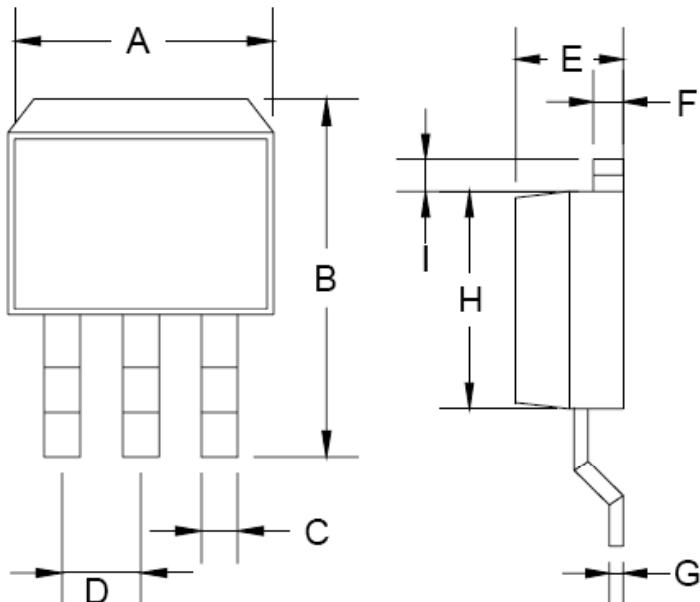
| DIM | MILLIMETERS | | INCHES | |
|-----|-------------|--------|--------|-------|
| | MIN | MAX | MIN | MAX |
| A | 10.000 | 10.500 | 0.394 | 0.413 |
| B | 3.740 | 3.910 | 0.147 | 0.154 |
| C | 2.440 | 2.940 | 0.096 | 0.116 |
| D | - | 6.350 | - | 0.250 |
| E | 0.381 | 1.106 | 0.015 | 0.044 |
| F | 2.345 | 2.715 | 0.092 | 0.107 |
| G | 4.690 | 5.430 | 0.185 | 0.214 |
| H | 12.700 | 14.732 | 0.500 | 0.580 |
| 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 | 1.091 | 1.166 |
| 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 |

Marking Diagram



- Y** = Year Code
- M** = Month Code
(**A**=Jan, **B**=Feb, **C**=Mar, **D**=Apr, **E**=May, **F**=Jun, **G**=Jul, **H**=Aug, **I**=Sep, **J**=Oct, **K**=Nov, **L**=Dec)
- L** = Lot Code
- XX** = Output Voltage
(**18**=1.8V, **25**=2.5V, **33**=3.3V, **50**=5V)

TO-263 Mechanical Drawing



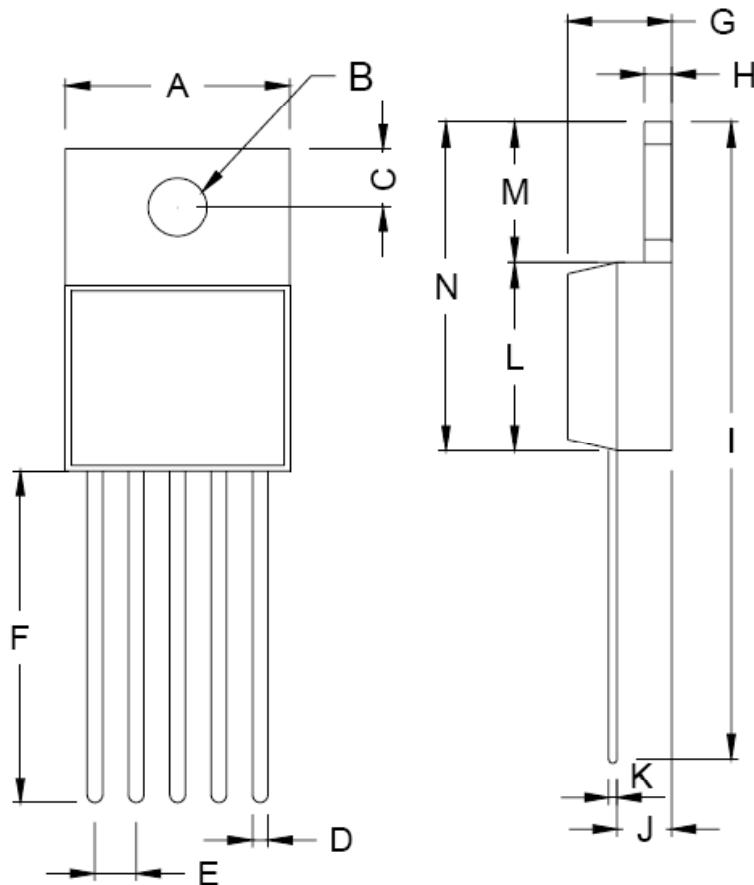
| TO-263 DIMENSION | | | | |
|------------------|-------------|--------|--------|-------|
| DIM | MILLIMETERS | | INCHES | |
| | MIN | MAX | MIN | MAX |
| A | 10.000 | 10.500 | 0.394 | 0.413 |
| B | 14.605 | 15.875 | 0.575 | 0.625 |
| C | 0.508 | 0.991 | 0.020 | 0.039 |
| D | 2.420 | 2.660 | 0.095 | 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 |

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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 |

Marking Diagram



TS39501 / TS39502

Y = Year Code

M = Month Code

(A=Jan, B=Feb, C=Mar, D=Apl, E=May, F=Jun, G=Jul, H=Aug, I=Sep,
J=Oct, K=Nov, L=Dec)

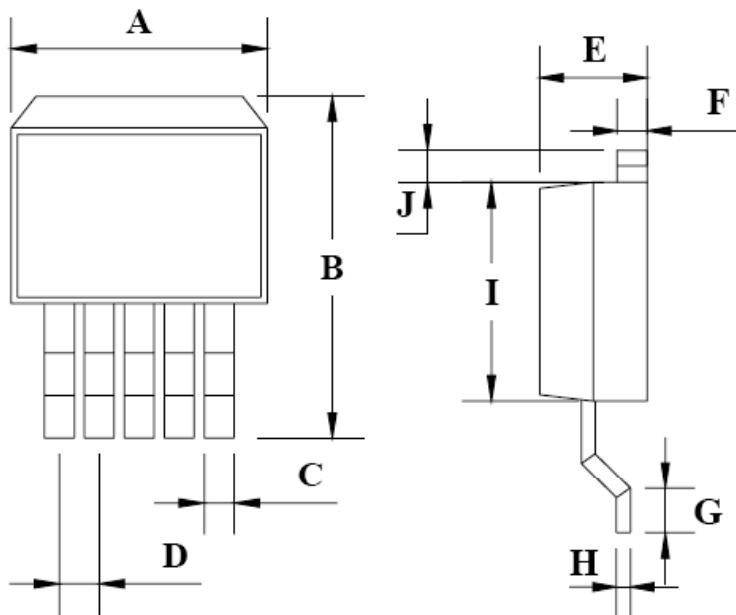
L = Lot Code

XX = Output Voltage – TS39501 only

(18=1.8V, 25=2.5V, 33=3.3V, 50=5V)

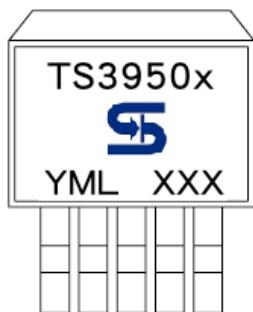
XXX = CZ5 – TS39502 only

TO-263-5L Mechanical Drawing



| TO-263-5L DIMENSION | | | | |
|---------------------|-------------|--------|--------|-------|
| DIM | MILLIMETERS | | INCHES | |
| | MIN | MAX | MIN | MAX |
| A | 10.220 | 10.260 | 0.402 | 0.404 |
| B | 14.600 | 15.870 | 0.575 | 0.625 |
| C | 0.750 | 0.770 | 0.030 | 0.030 |
| D | 1.573 | 1.827 | 0.062 | 0.072 |
| E | 4.560 | 4.570 | 0.179 | 0.180 |
| F | 1.240 | 1.270 | 0.049 | 0.050 |
| G | 2.280 | 2.790 | 0.090 | 0.110 |
| H | 0.280 | 0.320 | 0.011 | 0.013 |
| I | 8.240 | 8.280 | 0.324 | 0.326 |
| J | 1.540 | 1.800 | 0.060 | 0.071 |

Marking Diagram



TS39501 / TS39502

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L = Lot Code

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(**18**=1.8V, **25**=2.5V, **33**=3.3V, **50**=5V)

XXX = CM5 – TS39502 only

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