

## FEATURES

- Guaranteed Output Current of 5.0A
- Fixed Output Voltage: 1.5V, 1.8V, 2.5V, 3.3V and 5.0V
- 1% initial accuracy
- Low ground current
- Over-Temperature/Over-Current Protection
- Fast transient response
- TTL/CMOS compatible enable pin => LM39501
- Error flag output - LM39501 only
- Available in TO-263 and TO-220 packages
- - 40°C to 125°C Junction Temperature Range
- Moisture Sensitivity Level 3

## APPLICATION

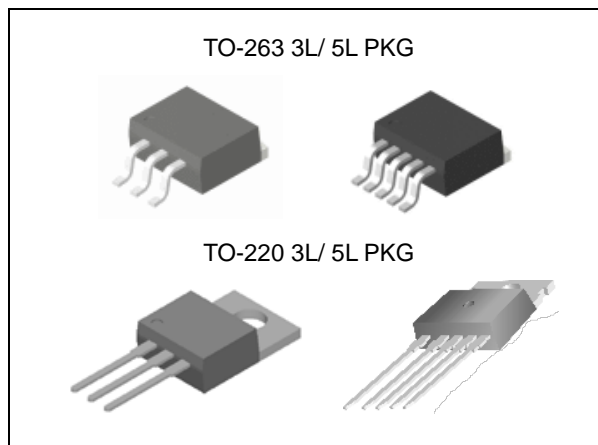
- Battery Powered Equipments
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- Battery Chargers

## DESCRIPTION

The LM39500, LM39501 and LM39502 are 5.0A low-dropout linear voltage regulators that provides a low voltage, high-current output with a minimum of external components. The LM39500/1 offers extremely low dropout (typically 400mV at 5.0A) and low ground current (typically 70mA at 3.0A). The LM39500/1/2 is ideal for PC add-in cards that need to convert from standard 5V or 3.3V down to new, lower core voltages. A guaranteed maximum dropout voltage of 500mV over all operating conditions allows the LM39500/1/2 to provide 2.5V from a supply as low as 3V. The LM39300/1/2 also has fast transient response for heavy switching applications. The device requires only 47F of output capacitance to maintain stability and achieve fast transient response. The LM39500/1 is fully protected with over current limiting, thermal shutdown, reversed-battery protection, reversed-leakage protection, and reversed-lead insertion. The LM39501 offers a TTL-logic compatible enable pin and an error flag that indicates under voltage and over current conditions. Offered in fixed voltages, the LM39500/1/2 comes in the TO-220 and TO-263 packages and is an ideal upgrade to older, NPN-based linear voltage regulators.

## Absolute Maximum Ratings <sup>(Note 1)</sup>

| CHARACTERISTIC                      | SYMBOL           | MIN.  | MAX.                 | UNIT |
|-------------------------------------|------------------|-------|----------------------|------|
| Supply Voltage                      | V <sub>IN</sub>  | - 0.3 | + 20                 | V    |
| Enable Voltage                      | V <sub>EN</sub>  | -     | + 20                 | V    |
| Output Voltage                      | V <sub>OUT</sub> | -0.3  | V <sub>IN</sub> +0.3 | V    |
| Lead Temperature (Soldering, 5 sec) | T <sub>SOL</sub> | -     | 260                  | °C   |
| Storage Temperature Range           | T <sub>STG</sub> | -65   | + 150                | °C   |



## ORDERING INFORMATION

| Device       | Package   |
|--------------|-----------|
| LM39500R-X.X | TO-263 3L |
| LM39500T-X.X | TO-220 3L |
| LM39501R-X.X | TO-263 5L |
| LM39501T-X.X | TO-220 5L |
| LM39502R     | TO-263 5L |
| LM39502T     | TO-220 5L |

X.X = Output Voltage = 1.5, 1.8, 2.5, 3.3, 5.0

# 5A Low-Voltage Low-Dropout Regulator

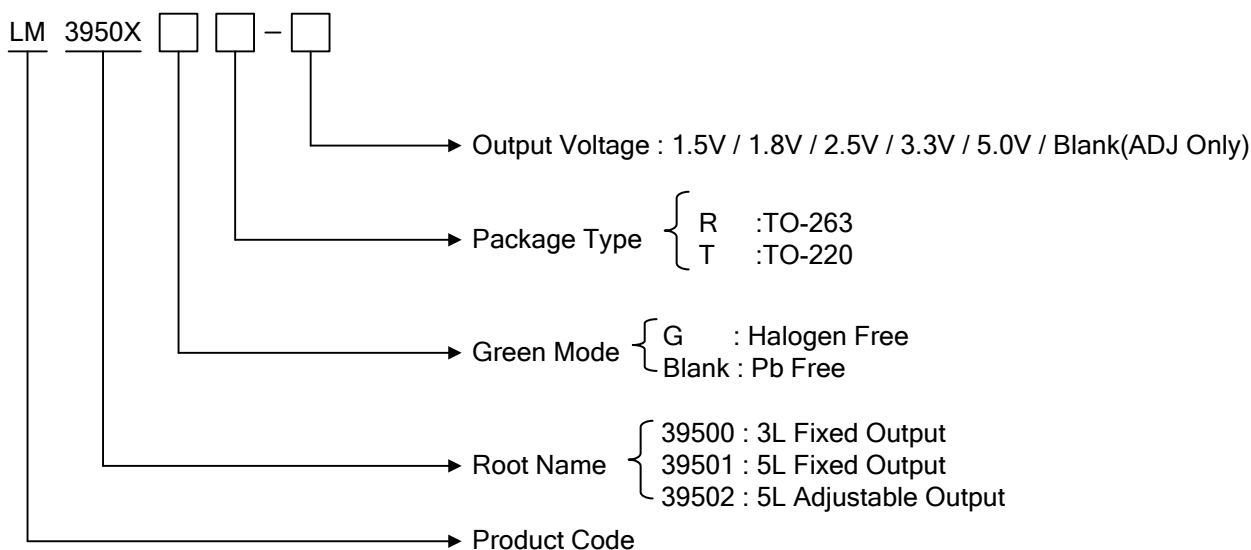
# LM39500/39501/39502

## Operating Ratings (Note 2)

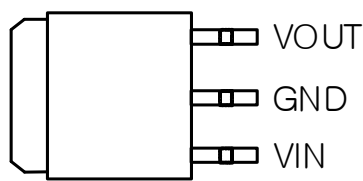
| CHARACTERISTIC             | SYMBOL               | MIN.     | MAX.     | UNIT |
|----------------------------|----------------------|----------|----------|------|
| Supply Voltage             | $V_{IN}$             | + 2.25   | + 16     | V    |
| Enable Voltage             | $V_{EN}$             | + 2.25   | + 16     | V    |
| Maximum Power Dissipation  | $PD_{(max)}$         | (Note 3) | (Note 3) |      |
| Junction Temperature       | $T_J$                | -40      | + 125    | °C   |
| Package Thermal Resistance | $\theta_{JA-TO-263}$ | 80       |          | °C/W |
|                            | $\theta_{JA-TO-220}$ | 70       |          | °C/W |

## Ordering Information

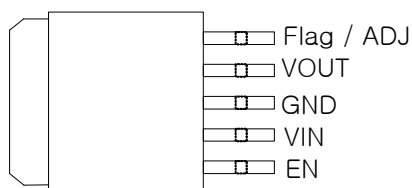
| $V_{OUT}$ | Package   | Order No.     | Description            | Supplied As | Status   |
|-----------|-----------|---------------|------------------------|-------------|----------|
| 1.5 V     | TO-263 3L | LM39500R-1.5  | 5A, Fixed              | Reel        | Active   |
|           | TO-263 3L | LM39500GR-1.5 | 5A, Fixed              | Reel        | Obsolete |
|           | TO-263 5L | LM39501R-1.5  | 5A, Fixed, Enable      | Reel        | Active   |
|           | TO-263 5L | LM39501GR-1.5 | 5A, Fixed, Enable      | Reel        | Obsolete |
|           | TO-220 3L | LM39500T-1.5  | 5A, Fixed              | Reel        | Active   |
|           | TO-220 5L | LM39501T-1.5  | 5A, Fixed, Enable      | Reel        | Obsolete |
| 1.8V      | TO-263 3L | LM39500R-1.8  | 5A, Fixed              | Reel        | Active   |
|           | TO-263 3L | LM39500GR-1.8 | 5A, Fixed              | Reel        | Obsolete |
|           | TO-263 5L | LM39501R-1.8  | 5A, Fixed, Enable      | Reel        | Active   |
|           | TO-263 5L | LM39501GR-1.8 | 5A, Fixed, Enable      | Reel        | Obsolete |
|           | TO-220 3L | LM39500T-1.8  | 5A, Fixed              | Reel        | Active   |
|           | TO-220 5L | LM39501T-1.8  | 5A, Fixed, Enable      | Reel        | Active   |
| 2.5 V     | TO-263 3L | LM39500R-2.5  | 5A, Fixed              | Reel        | Active   |
|           | TO-263 3L | LM39500GR-2.5 | 5A, Fixed              | Reel        | Obsolete |
|           | TO-263 5L | LM39501R-2.5  | 5A, Fixed, Enable      | Reel        | Active   |
|           | TO-263 5L | LM39501GR-2.5 | 5A, Fixed, Enable      | Reel        | Obsolete |
|           | TO-220 3L | LM39500T-2.5  | 5A, Fixed              | Reel        | Active   |
|           | TO-220 5L | LM39501T-2.5  | 5A, Fixed, Enable      | Reel        | Active   |
| 3.3 V     | TO-263 3L | LM39500R-3.3  | 5A, Fixed              | Reel        | Active   |
|           | TO-263 3L | LM39500GR-3.3 | 5A, Fixed              | Reel        | Obsolete |
|           | TO-263 5L | LM39501R-3.3  | 5A, Fixed, Enable      | Reel        | Active   |
|           | TO-263 5L | LM39501GR-3.3 | 5A, Fixed, Enable      | Reel        | Obsolete |
|           | TO-220 3L | LM39500T-3.3  | 5A, Fixed              | Reel        | Active   |
|           | TO-220 5L | LM39501T-3.3  | 5A, Fixed, Enable      | Reel        | Active   |
| 5.0 V     | TO-263 3L | LM39500R-5.0  | 5A, Fixed              | Reel        | Active   |
|           | TO-263 3L | LM39500GR-5.0 | 5A, Fixed              | Reel        | Obsolete |
|           | TO-263 5L | LM39501R-5.0  | 5A, Fixed, Enable      | Reel        | Active   |
|           | TO-263 5L | LM39501GR-5.0 | 5A, Fixed, Enable      | Reel        | Obsolete |
|           | TO-220 3L | LM39500T-5.0  | 5A, Fixed              | Reel        | Active   |
|           | TO-220 5L | LM39501T-5.0  | 5A, Fixed, Enable      | Reel        | Active   |
| ADJ       | TO-263 5L | LM39502R      | 5A, Adjustable, Enable | Reel        | Active   |
|           | TO-263 5L | LM39502GR     | 5A, Adjustable, Enable | Reel        | Obsolete |
|           | TO-220 5L | LM39502T      | 5A, Adjustable, Enable | Reel        | Active   |



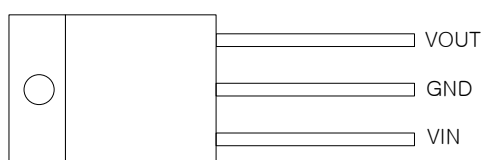
## PIN CONFIGURATION



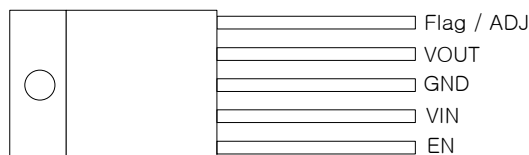
TO263-3L



TO263-5L



TO220-3L

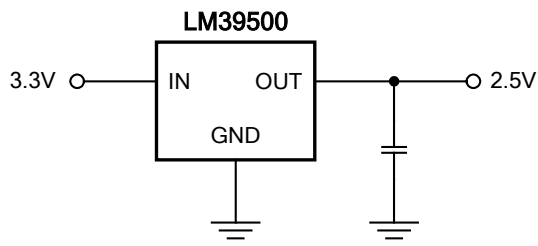


TO220-5L

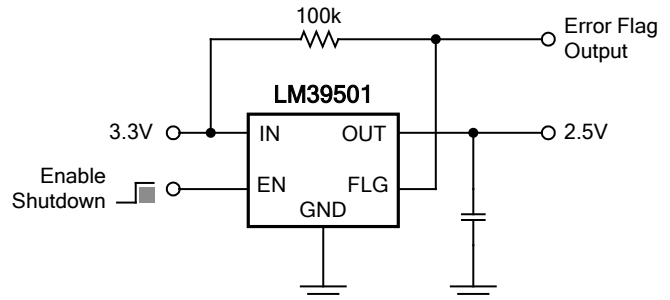
## PIN DESCRIPTION

| Pin No. | TO-263 3L / TO-220 3L (for 39500) |                | TO-263 5L / TO-220 5L (for 39501/2) |                                    |
|---------|-----------------------------------|----------------|-------------------------------------|------------------------------------|
|         | Name                              | Function       | Name                                | Function                           |
| 1       | VIN                               | Input Supply   | EN                                  | Chip Enable                        |
| 2       | GND                               | Ground         | VIN                                 | Input Supply                       |
| 3       | VOUT                              | Output Voltage | GND                                 | Ground                             |
| 4       |                                   |                | VOUT                                | Output Voltage                     |
| 5       |                                   |                | FLG / ADJ                           | Error Flag Output or Output Adjust |

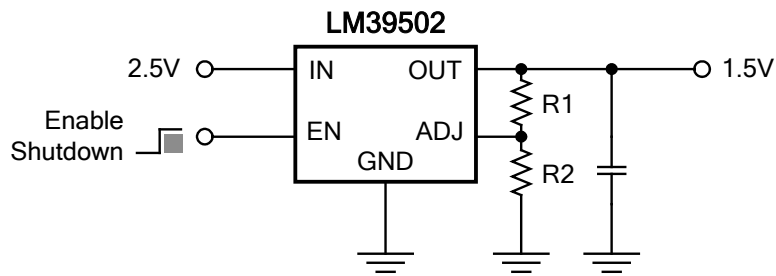
## TYPICAL APPLICATION



**2.5V / 5A Regulator**



**2.5V / 5A Regulator with Error Flag**

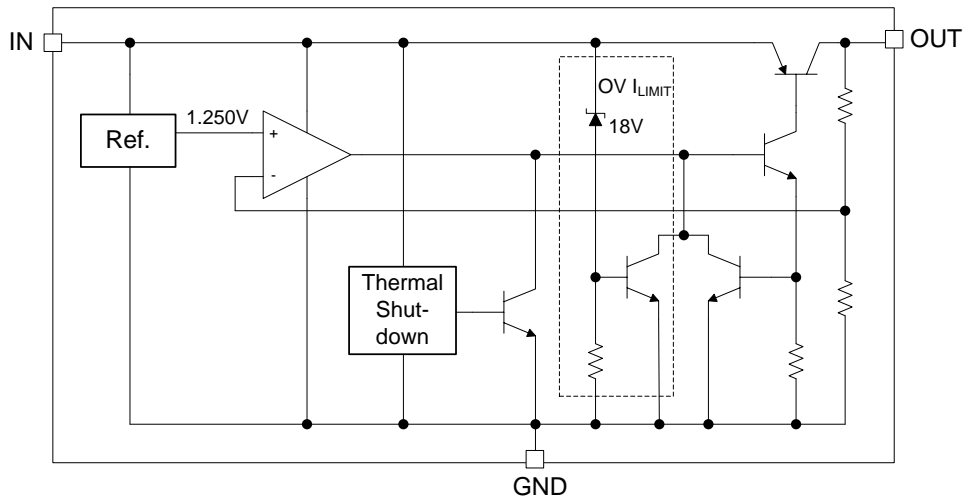


**1.5V / 5A Adjustable Regulator**

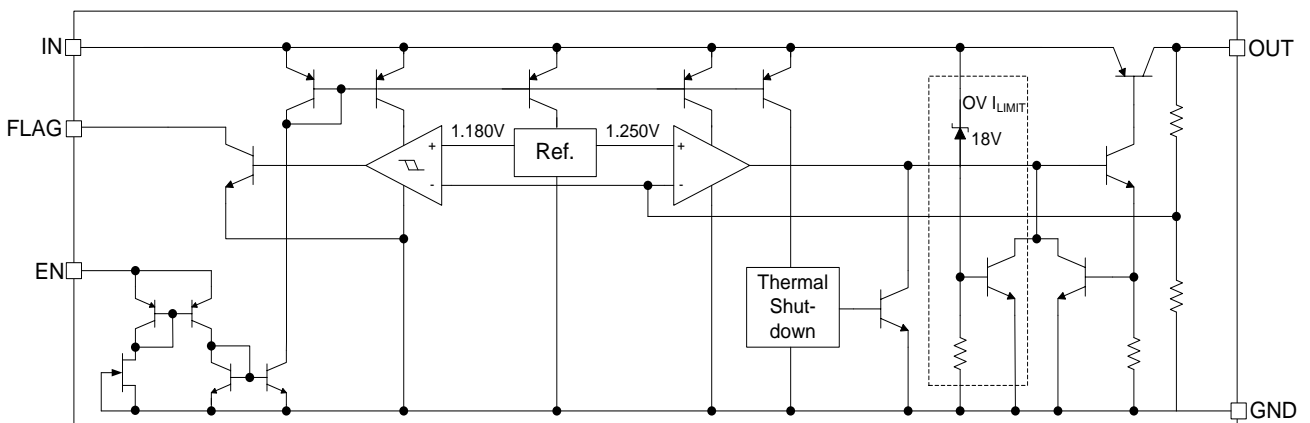
# 5A Low-Voltage Low-Dropout Regulator

# LM39500/39501/39502

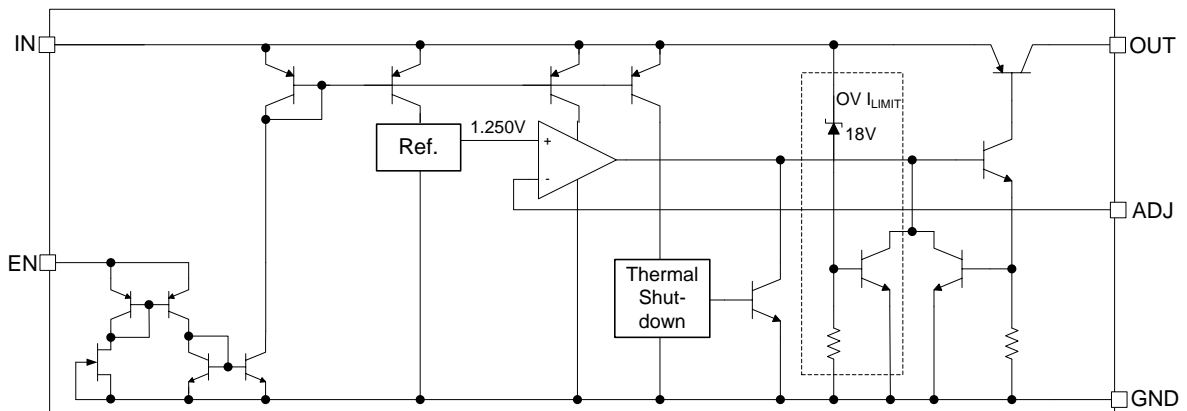
## Block Diagram



**LM39500 Fixed (1.5V, 1.8V, 2.5V, 3.3V, 5.0V)**



**LM39501 Fixed with Flag and Enable**



**LM39502 Adjustable**

# 5A Low-Voltage Low-Dropout Regulator

# LM39500/39501/39502

## ELECTRICAL CHARACTERISTICS

$V_{IN} = V_{OUT} + 1V$ ;  $V_{EN} = 2.25V$ ;  $T_J = 25^\circ C$ , **bold** values indicate  $-40^\circ C \leq T_J \leq +125^\circ C$ ; unless noted

| Symbol                    | Parameters                                | Condition   | Min.      | Typ.      | Max.       | Unit         |
|---------------------------|---|---|-----------|-----------|------------|--------------|
| $V_{OUT}$                 | Output Voltage                            | 10mA  | -1        |           | 1          | %            |
|                           |   | $10mA \leq I_{OUT} \leq 5A, V_{OUT} + 1V \leq V_{IN} \leq 8V$ | <b>-2</b> |           | <b>2</b>   | %            |
|                           | Line Regulation                           | $I_{OUT} = 10mA, V_{OUT} + 1V \leq V_{IN} \leq 16V$           |           | 0.06      | 0.5        | %            |
|                           | Load Regulation                           | $V_{IN} = V_{OUT} + 1V, 10mA \leq I_{OUT} \leq 5A$            |           | 0.2       | 1          | %            |
| $\Delta V_{OUT}/\Delta T$ | Output Voltage Temp. Coefficient (Note 4) |   |           | <b>20</b> | <b>100</b> | ppm/°C       |
| $V_{DO}$                  | Dropout Voltage (Note 5)                  | $I_{OUT} = 250mA, \Delta V_{OUT} = -2\%$                      |           | 125       | <b>200</b> | mV           |
|                           |   | $I_{OUT} = 2.5A, \Delta V_{OUT} = -2\%$                       |           | 320       |            | mV           |
|                           |   | $I_{OUT} = 5A, \Delta V_{OUT} = -2\%$                         |           | 400       | <b>575</b> | mV           |
| $I_{GND}$                 | Ground Current (Note 6)                   | $I_{OUT} = 2.5A, V_{IN} = V_{OUT} + 1V$                       |           | 15        |            | mA           |
|                           |   | $I_{OUT} = 5A, V_{IN} = V_{OUT} + 1V$                         |           | 70        |            | mA           |
| $I_{OUT(lim)}$            | Current Limit                             | $V_{OUT} = 0V, V_{IN} = V_{OUT} + 1V$                         |           | 7.5       |            | A            |
| $e_n$                     | Output Noise Voltage                      | $C_{OUT} = 47\mu F, I_{OUT} = 100mA, 10Hz$ to 100kHz          |           | 260       |            | $\mu V(rms)$ |

### Enable Input

|                 |                         |                   |            |    |            |         |
|-----------------|-------------------------|-------------------|------------|----|------------|---------|
| $V_{EN}$        | Enable Input Voltage    | logic low (off)   |            |    | <b>0.8</b> | V       |
|                 |                         | logic high (on)   | <b>2.5</b> |    |            | V       |
| $I_{EN}$        | Enable Input Current    | $V_{EN} = V_{IN}$ |            | 30 | 35         | $\mu A$ |
|                 |                         | $V_{EN} = 0.8V$   |            |    | 2          | $\mu A$ |
| $I_{OUT(shdn)}$ | Shutdown Output Current | (Note 7)          |            | 10 |            | $\mu A$ |

### Flag Output

|                 |                        |  |  |      |          |         |
|-----------------|------------------------|--|--|------|----------|---------|
| $I_{FLG(leak)}$ | Output Leakage Current | $V_{OH} = 16V$                                 |  | 0.01 | 1        | $\mu A$ |
|                 |                        |  |  |      | <b>2</b> | $\mu A$ |
| $V_{FLG(do)}$   | Output Low Voltage     | $V_{IN} = 2.25V, I_{OL} = 250\mu A$ , (Note 8) |  | 220  | 300      | mV      |
|                 |                        |  |  |      | 400      | mV      |

## LM39502 Only

|  |   |         |                       |       |                       |          |
|--|---|---------|-----------------------|-------|-----------------------|----------|
|  | Reference Voltage                         | (Note9) | 1.238<br><b>1.225</b> | 1.250 | 1.262<br><b>1.275</b> | V<br>V   |
|  |   |         | <b>1.213</b>          |       | <b>1.277</b>          | V        |
|  | Adjust Pin Bias Current                   |         |                       | 40    | 80<br><b>120</b>      | nA<br>nA |
|  | Reference Voltage Temp. Coefficient       |         |                       | 20    |                       | ppm/ °C  |
|  | Adjust Pin Bias Current Temp. Coefficient |         |                       | 0.1   |                       | nA/ °C   |

Note 1. Exceeding the absolute maximum ratings may damage the device.

Note 2. The device is not guaranteed to function outside its operating rating.

Note 3.  $PD (max) = (T_{J(max)} - T_A) \div \theta_{JA}$ , where  $\theta_{JA}$  - junction-to-ambient thermal resistance.

Note 4. Output voltage temperature coefficient is  $\Delta V_{OUT} (worst\ case) \div (T_{J(max)} - T_{J(min)})$  where  $T_{J(max)}$  is +125°C and  $T_{J(min)}$  is 0°C.

Note 5.  $V_{DO} = V_{IN} - V_{OUT}$  when  $V_{OUT}$  decreases to 99% of its nominal output voltage with  $V_{IN} = V_{OUT} + 1V$ . For output voltages below 2.25V, dropout voltage is the input-to-output voltage differential with the minimum input voltage being 2.25V. Minimum input operating voltage is 2.25V.

Note 6.  $I_{GND}$  is the quiescent current.  $I_{IN} = I_{GND} + I_{OUT}$ .

Note 7.  $V_{EN} = 0.8V$ ,  $V_{IN} = 8V$ ,  $V_{OUT} = 0V$

Note 8. For a 2.5V device,  $V_{IN} = 2.250V$  (device is in dropout).

Note 9.  $V_{REF} \leq V_{OUT} \leq (V_{IN} - 1V)$ ,  $2.25V \leq V_{IN} \leq 16V$ ,  $10mA \leq I_L \leq 5A$ .

## APPLICATION INFORMATION

The LM39500/1 is a high-performance low-dropout voltage regulator suitable for moderate to high-current voltage regulator applications. Its 500mV dropout voltage at full load makes it especially valuable in battery-powered systems and as a high-efficiency noise filter in post-regulator applications. Unlike older NPN-pass transistor designs, where the minimum dropout voltage is limited by the base-to-emitter voltage drop and collector-to-emitter saturation voltage, dropout performance of the PNP output of these devices is limited only by the low VCE saturation voltage. A trade-off for the low dropout voltage is a varying base drive requirement. The LM39500/1/2 regulator is fully protected from damage due to fault conditions. Current limiting is provided. This limiting is linear output current during overload conditions is constant. Thermal shutdown disables the device when the die temperature exceeds the maximum safe operating temperature. Transient protection allows device (and load) 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

The LM39500/1/2 requires an output capacitor to maintain stability and improve transient response. Proper capacitor selection is important to ensure proper operation. The LM39500/1/2 output capacitor selection is dependent upon the ESR (equivalent series resistance) of the output capacitor to maintain stability. When the output capacitor is 47F or greater, the output capacitor should have less than 1 of ESR. This will improve transient response as well as promote stability. Ultralow ESR capacitors, 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 electrolytic can also be used, as long as the ESR of the capacitor is < 1. 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

An input capacitor of 1F or greater is recommended when the device is more than 4 inches away from the bulk ac supply capacitance, or when the supply is a battery. Small, surface-mount, ceramic chip capacitors can be used for the 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 LM39500/1/2 regulator 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.

### Transient Response and 3.3V to 2.5V Conversion

The LM39500/1/2 has excellent transient response to variations in input voltage and load current. The device has 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 47F 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-based designs. When converting from 3.3V to 2.5V, the NPN-based regulators are already operating in dropout, with typical dropout



## 5A Low-Voltage Low-Dropout Regulator LM39500/39501/39502

requirements of 1.2V or greater. To convert down to 2.5V without operating in dropout, NPN-based regulators require an input voltage of 3.7V at the very least. The LM39500/1/2 regulator will provide excellent performance with an input as low as 3.0V. This gives the PNP-based regulators a distinct advantage over older, NPN-based linear regulator.

### Error Flag

The LM39501 version features an error flag circuit which monitors the output voltage and signals an error condition when the voltage drops 5% below the nominal output voltage. The error flag is an open-collector output that can sink 10mA during a fault condition. Low output voltage can be caused by a number of problems, including an over current fault (device in current limit) or low input voltage. The flag is inoperative during over temperature shutdown.

### Enable Input

The LM39501 version features an enable input for on/off control of the device. Its shutdown state draws “zero” current (only microamperes of leakage). The enable input is TTL/ CMOS compatible for simple logic interface, but can be connected to up to 20V. When enabled, it draws approximately 15A.

### Adjustable Regulator Design

The LM39502 allows programming the output voltage any-where between 1.25V and the 16V maximum operating rating of the family. Two resistors are used. Resistors can be quite large, up to 1M $\Omega$ , because of the very high input impedance and low bias current of the sense comparator: The resistor values are calculated by:  $R1=R2(V_{out}/1.250-1)$

Where  $V_O$  is desired output voltage. Figure 1 shows component definition. Applications with widely varying load currents may scale the resistors to draw the minimum load current required for proper operation (see below).

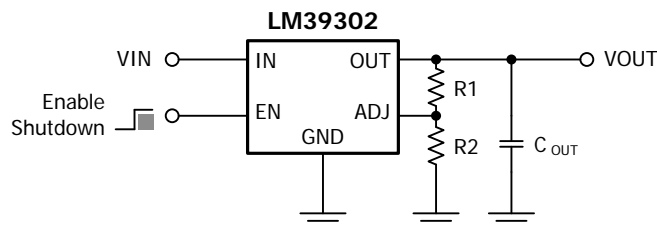


Figure 1. Adjustable Regulator with Resistors

### Maximum Output Current Capability

The LM39500/1/2 can deliver a continuous current of 5A over the full operating junction temperature range. However, the output current is limited by the restriction of power dissipation which differs from packages. A heat sink may be required depending on the maximum power dissipation and maximum ambient temperature of application. With respect to the applied package, the maximum output current of 5A may be still undeliverable due to the restriction of the power dissipation of LM39500/1/2. Under all possible conditions, the junction temperature must be within the range specified under operating conditions. The temperatures over the device are given by:

$$T_C = T_A + P_D \times \theta_{CA} / \quad T_J = T_C + P_D \times \theta_{JC} / \quad T_J = T_A + P_D \times \theta_{JA}$$

## 5A Low-Voltage Low-Dropout Regulator LM39500/39501/39502

Where  $T_J$  is the junction temperature,  $T_C$  is the case temperature,  $T_A$  is the ambient temperature,  $P_D$  is the total power dissipation of the device,  $\theta_{CA}$  is the thermal resistance of case-to-ambient,  $\theta_{JC}$  is the thermal resistance of junction-to-case, and  $\theta_{JA}$  is the thermal resistance of junction to ambient. The total power dissipation of the device is given by:

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

Where  $I_{GND}$  is the operating ground current of the device which is specified at the Electrical Characteristics. The maximum allowable temperature rise ( $T_{Rmax}$ ) depends on the maximum ambient temperature ( $T_{Amax}$ ) of the application, and the maximum allowable junction temperature ( $T_{Jmax}$ ):

$$T_{Rmax} = T_{Jmax} - T_{Amax}$$

The maximum allowable value for junction-to-ambient thermal resistance,  $\theta_{JA}$ , can be calculated using the formula:

$$\theta_{JA} = T_{Rmax} / P_D = (T_{Jmax} - T_{Amax}) / P_D$$

LM39500/1/2 is available in TO-263 and TO-220 package. The thermal resistance depends on amount of copper area or heat sink, and on air flow. If the maximum allowable value of  $\theta_{JA}$  calculated above is over 80°C/W for TO-263 package, 70°C/W for TO-220 package, no heat sink is needed since the package can dissipate enough heat to satisfy these requirements. If the value for allowable  $\theta_{JA}$  falls near or below these limits, a heat sink or proper area of copper plane is required. In summary, the absolute maximum ratings of thermal resistances are as follow:

### Absolute Maximum Ratings of Thermal Resistance

| Characteristic                                  | Symbol               | Rating | Unit |
|---|----------------------|--------|------|
| Thermal Resistance Junction-To-Ambient / TO-263 | $\theta_{JA-TO-263}$ | 80     | °C/W |
| Thermal Resistance Junction-To-Ambient / TO-220 | $\theta_{JA-TO-220}$ | 70     | °C/W |

No heat sink / No air flow / No adjacent heat source / 20 mm<sup>2</sup> copper area. ( $T_A=25^\circ\text{C}$ )

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