# SM74503

***SM74503 800mA Low-Dropout Linear Regulator***

Literature Number: SNVS722

November 30, 2011

Texas Instruments

# SM74503

# 800mA Low-Dropout Linear Regulator

## General Description

The SM74503 is a series of low dropout voltage regulators with a dropout of 1.2V at 800mA of load current. It has the same pin-out as National Semiconductor's industry standard LM317.

The SM74503 is available in two fixed voltages, 3.3V and 5V.

The SM74503 offers current limiting and thermal shutdown. Its circuit includes a zener trimmed bandgap reference to assure output voltage accuracy to within ±1%.

The SM74503 series is available in SOT-223 and TO-252 D-PAK packages. A minimum of 10µF tantalum capacitor is required at the output to improve the transient response and stability.

## Features

- Renewable Energy Grade
- Available in 3.3V and 5V Versions
- Space Saving SOT-223 Package
- Current Limiting and Thermal Protection
- Output Current 800mA
- Line Regulation 0.2% (Max)
- Load Regulation 0.4% (Max)
- Temperature Range −40°C to 125°C

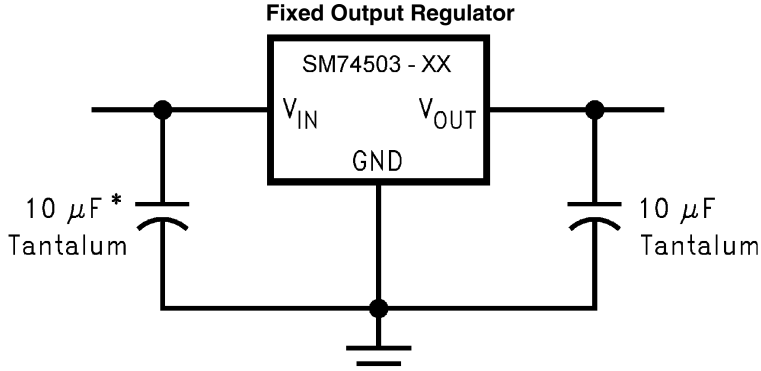
## Applications

- Photovoltaic Electronics
- Post Regulator for Switching DC/DC Converter
- High Efficiency Linear Regulators
- Battery Charger
- Battery Powered Instrumentation

SolarMagic by National Semiconductor

## Typical Application

**Fixed Output Regulator**




* Required if the regulator is located far from the power supply filter.

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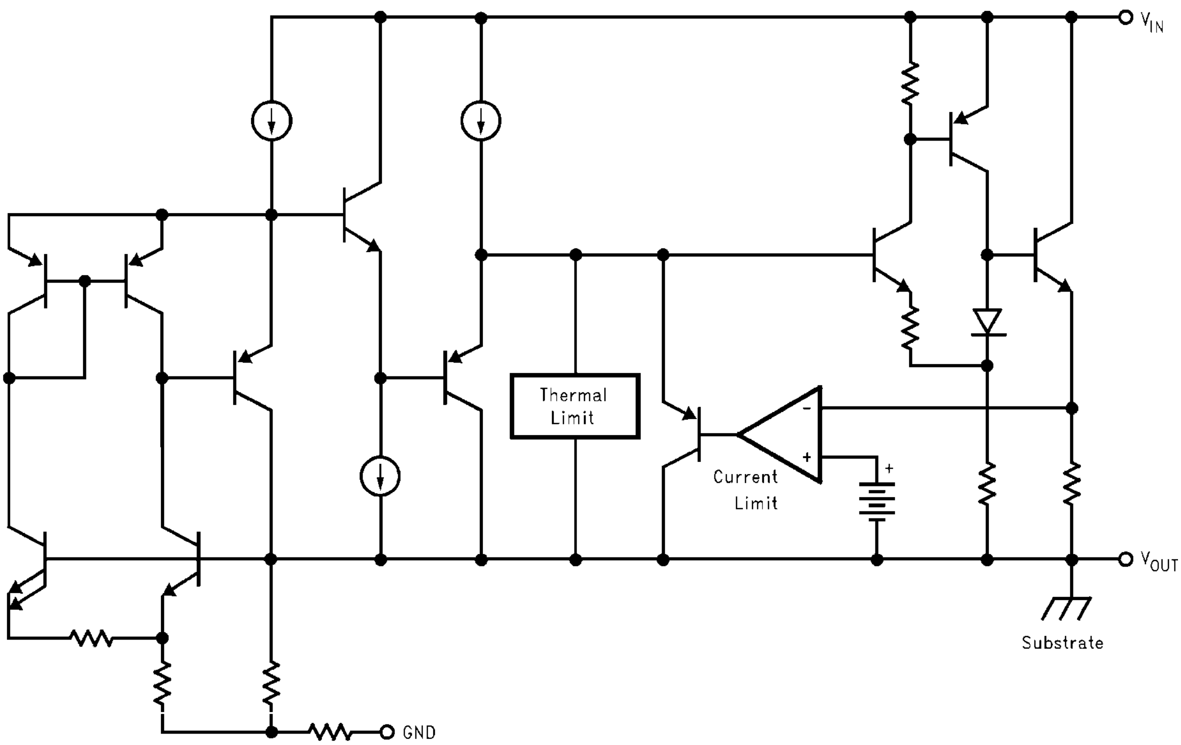
## Ordering Information

| Package | Part Number | Packaging Marking | Transport Media | NSC Drawing |
|---|---|---|---|---|
| 4-lead SOT-223 | SM74503MP-3.3 | S503 | 1000 UnitsTape and Reel | MP04A |
| | SM74503MPE-3.3 | S503 | 250 UnitsTape and Reel | |
| | SM74503MPX-3.3 | S503 | 2000 UnitsTape and Reel | |
| | SM74503MP-5.0 | S503 | 1000 UnitsTape and Reel | |
| | SM74503MPE-5.0 | S503 | 250 UnitsTape and Reel | |
| | SM74503MPX-5.0 | S503 | 2000 UnitsTape and Reel | |
| 3-lead TO-252 | SM74503TD-3.3 | S74503-3.3 | 75 Unit Raill | TD03B |
| | SM74503TDE-3.3 | S74503-3.3 | 250 UnitsTape and Reel | |
| | SM74503TDX-3.3 | S74503-3.3 | 2500 UnitsTape and Reel | |
| | SM74503TD-5.0 | S74503-5.0 | 75 Unit Rail | |
| | SM74503TDE-5.0 | S74503-5.0 | 250 UnitsTape and Reel | |
| | SM74503TDX-5.0 | S74503-5.0 | 2500 UnitsTape and Reel | |

## Block Diagram

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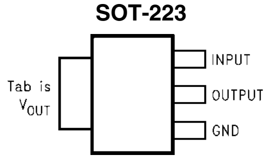
## Connection Diagrams

**SOT-223**

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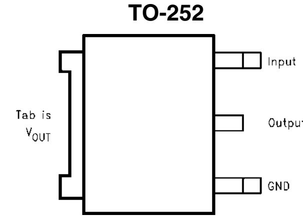
**Top View**

**TO-252**

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**Top View**

## Absolute Maximum Ratings (Note 1)

**If Military/Aerospace specified devices are required, please contact the Texas Instruments Sales Office/ Distributors for availability and specifications.**

| | |
|---|---|
| Maximum Input Voltage ($V_{IN}$ to GND) | 20V |
| Power Dissipation (Note 2) | Internally Limited |
| Junction Temperature ($T_J$) (Note 2) | 150°C |
| Storage Temperature Range | -65°C to 150°C |
| Lead Temperature | |
| SOT-223 (MP) Package | 260°C, 4 sec |
| ESD Tolerance (Note 3) | 2000V |

## Operating Ratings (Note 1)

| | |
|---|---|
| Input Voltage ($V_{IN}$ to GND) | 15V |
| Junction Temperature Range ($T_J$)(Note 2) | |
| SM74503 | −40°C to 125°C |

## SM74503 Electrical Characteristics

Typicals and limits appearing in normal type apply for $T_J$ = 25°C. Limits appearing in **Boldface** type apply over the entire junction temperature range for operation, −40°C to 125°C.

| Symbol | Parameter | Conditions | Min (Note 5) | Typ (Note 4) | Max (Note 5) | Units |
|---|---|---|---|---|---|---|
| $V_{OUT}$ | Output Voltage | SM74503-3.3<br>$I_{OUT}$ = 10mA, $V_{IN}$ = 5V, $T_J$ = 25°C<br>0 ≤ $I_{OUT}$ ≤ 800mA, 4.75V ≤ $V_{IN}$ ≤ 10V | 3.267<br>**3.168** | 3.300<br>3.300 | 3.333<br>**3.432** | V<br>V |
| | | SM74503-5.0<br>$I_{OUT}$ = 10mA, $V_{IN}$ = 7V, $T_J$ = 25°C<br>0 ≤ $I_{OUT}$ ≤ 800mA, 6.5V ≤ $V_{IN}$ ≤ 12V | 4.950<br>**4.800** | 5.000<br>5.000 | 5.050<br>**5.200** | V<br>V |
| $\Delta V_{OUT}$ | Line Regulation (Note 6) | SM74503-3.3<br>$I_{OUT}$ = 0mA, 4.75V ≤ $V_{IN}$ ≤ 15V | | 1 | **10** | mV |
| | | SM74503-5.0<br>$I_{OUT}$ = 0mA, 6.5V ≤ $V_{IN}$ ≤ 15V | | 1 | **15** | mV |
| $\Delta V_{OUT}$ | Load Regulation (Note 6) | SM74503-3.3<br>$V_{IN}$ = 4.75V, 0 ≤ $I_{OUT}$ ≤ 800mA | | 1 | **15** | mV |
| | | SM74503-5.0<br>$V_{IN}$ = 6.5V, 0 ≤ $I_{OUT}$ ≤ 800mA | | 1 | **20** | mV |
| $V_{IN}$-$V_{OUT}$ | Dropout Voltage (Note 7) | $I_{OUT}$ = 100mA | | 1.10 | **1.30** | V |
| | | $I_{OUT}$ = 500mA | | 1.15 | **1.35** | V |
| | | $I_{OUT}$ = 800mA | | 1.20 | **1.40** | V |
| $I_{LIMIT}$ | Current Limit | $V_{IN}$-$V_{OUT}$ = 5V, $T_J$ = 25°C | 800 | 1200 | 1500 | mA |
| | Quiescent Current | SM74503-3.3<br>$V_{IN}$ ≤ 15V | | 5 | **15** | mA |
| | | SM74503-5.0<br>$V_{IN}$ ≤ 15V | | 5 | **15** | mA |
| | Thermal Regulation | $T_A$ = 25°C, 30ms Pulse | | 0.01 | 0.1 | %/W |
| | Ripple Regulation | $f_{RIPPLE}$ =1 20Hz, $V_{IN}$-$V_{OUT}$ = 3V $V_{RIPPLE}$ = 1$V_{PP}$ | **60** | 75 | | dB |
| | Temperature Stability | | | 0.5 | | % |
| | Long Term Stability | $T_A$ = 125°C, 1000Hrs | | 0.3 | | % |
| | RMS Output Noise | (% of $V_{OUT}$), 10Hz ≤ f ≤10kHz | | 0.003 | | % |
| | Thermal Resistance Junction-to-Case | 4-Lead SOT-223 | | 15.0 | | °C/W |
| | | 3-Lead TO-252 | | 10 | | °C/W |
| | Thermal Resistance Junction-to-Ambient No air flow) | 4-Lead SOT-223 (No heat sink) | | 136 | | °C/W |
| | | 3-Lead TO-252 (No heat sink)(Note 8) | | 92 | | °C/W |

**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 specific performance is not guaranteed. For guaranteed specifications and the test conditions, see the Electrical Characteristics.

**Note 2:** The maximum power dissipation is a function of $T_{J(max)}$ , $\theta_{JA}$, and $T_A$. The maximum allowable power dissipation at any ambient temperature is $P_D = (T_{J(max)}-T_A)/\theta_{JA}$. All numbers apply for packages soldered directly into a PC board.

**Note 3:** For testing purposes, ESD was applied using human body model, 1.5kΩ in series with 100pF.

**Note 4:** Typical Values represent the most likely parametric norm.

**Note 5:** All limits are guaranteed by testing or statistical analysis.

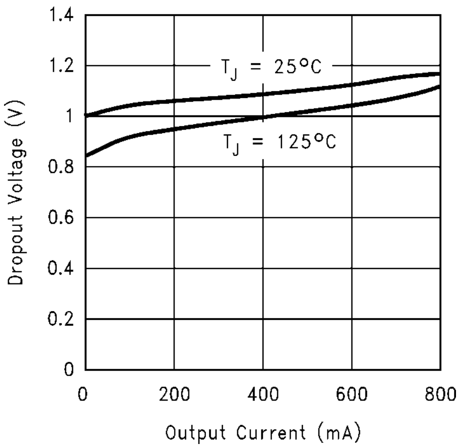
**Note 6:** Load and line regulation are measured at constant junction room temperature.

**Note 7:** The dropout voltage is the input/output differential at which the circuit ceases to regulate against further reduction in input voltage. It is measured when the output voltage has dropped 100mV from the nominal value obtained at $V_{IN} = V_{OUT} +1.5V$.

**Note 8:** Minimum pad size of 0.038in[2]

# Typical Performance Characteristics

**Dropout Voltage ($V_{IN}$-$V_{OUT}$)**

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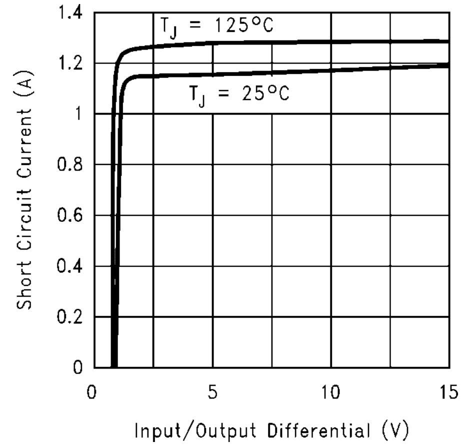
**Short-Circuit Current**

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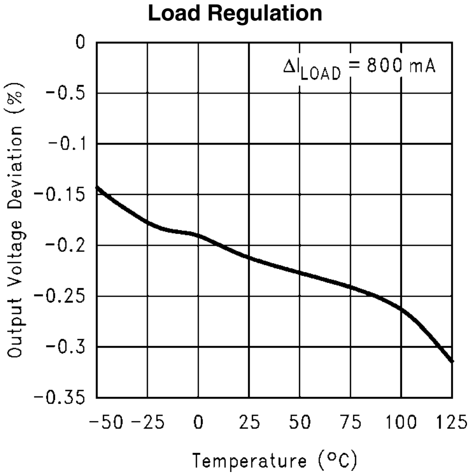
**Load Regulation**

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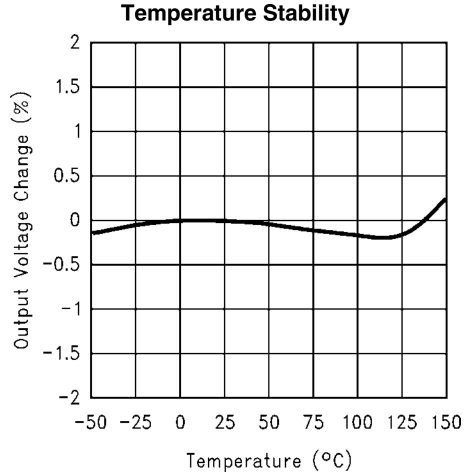
**Temperature Stability**

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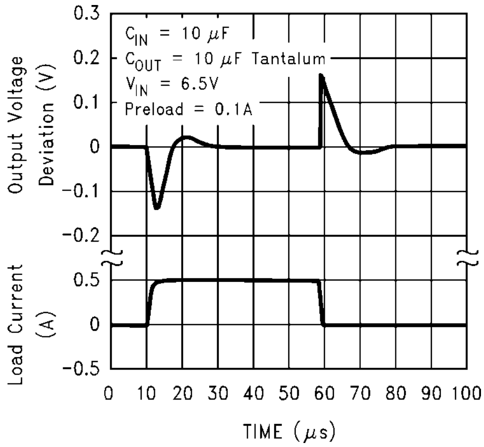
**SM74503-5.0 Load Transient Response**

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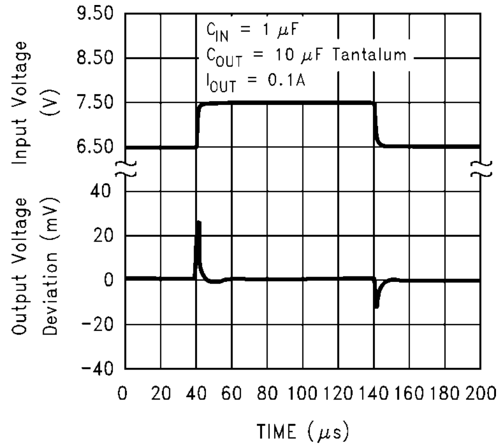
**SM74503-5.0 Line Transient Response**

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# Application Note

## 1.0 EXTERNAL CAPACITORS/STABILITY

### 1.1 Input Bypass Capacitor

An input capacitor is recommended. A 10µF tantalum on the input is a suitable input bypassing for almost all applications.

### 1.2 Output Capacitor

The output capacitor is critical in maintaining regulator stability, and must meet the required conditions for both minimum amount of capacitance and ESR (Equivalent Series Resistance). The minimum output capacitance required by the SM74503 is 10µF, if a tantalum capacitor is used. Any increase of the output capacitance will merely improve the loop stability and transient response. The ESR of the output capacitor should range between 0.3Ω - 22Ω.

## 2.0 LOAD REGULATION

The SM74503 regulates the voltage that appears between its output and ground pins. In some cases, line resistances can introduce errors to the voltage across the load. To obtain the best load regulation, a few precautions are needed.

*Figure 1*, shows a typical application using a fixed output regulator. The Rt1 and Rt2 are the line resistances. It is obvious that the $V_{LOAD}$ is less than the $V_{OUT}$ by the sum of the voltage drops along the line resistances. In this case, the load regulation seen at the $R_{LOAD}$ would be degraded from the data sheet specification. To improve this, the load should be tied directly to the output terminal on the positive side and directly tied to the ground terminal on the negative side.

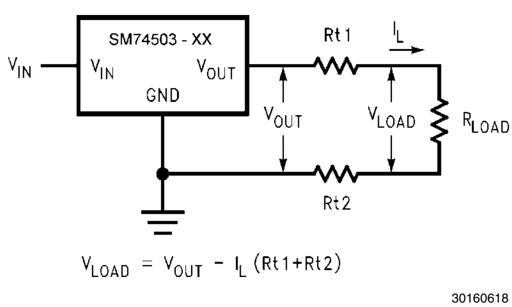



**FIGURE 1. Typical Application using Fixed Output Regulator**

## 3.0 PROTECTION DIODES

Under normal operation, the SM74503 regulators do not need any protection diode. When a output capacitor is connected to a regulator and the input is shorted to ground, the output capacitor will discharge into the output of the regulator. The discharge current depends on the value of the capacitor, the output voltage of the regulator, and rate of decrease of $V_{IN}$. In the SM74503 regulators, the internal diode between the output and input pins can withstand microsecond surge currents of 10A to 20A. With an extremely large output capacitor (≥1000 µF), and with input instantaneously shorted to ground, the regulator could be damaged.

In this case, an external diode is recommended between the output and input pins to protect the regulator, as shown in *Figure 2*.

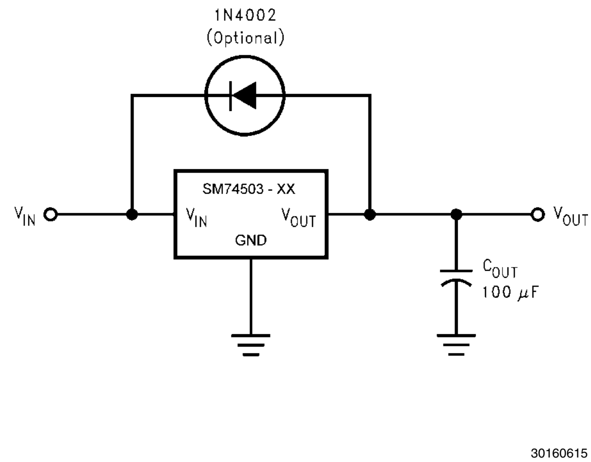



**FIGURE 2. Regulator with Protection Diode**

## 4.0 HEATSINK REQUIREMENTS

When an integrated circuit operates with an appreciable current, its junction temperature is elevated. It is important to quantify its thermal limits in order to achieve acceptable performance and reliability. This limit is determined by summing the individual parts consisting of a series of temperature rises from the semiconductor junction to the operating environment. A one-dimensional steady-state model of conduction heat transfer is demonstrated in *Figure 3*. The heat generated at the device junction flows through the die to the die attach pad, through the lead frame to the surrounding case material, to the printed circuit board, and eventually to the ambient environment. Below is a list of variables that may affect the thermal resistance and in turn the need for a heatsink.

| $R^{\theta}JC$ (Component Variables) | $R^{\theta}$ CA (Application Variables) |
| --- | --- |
| Leadframe Size & Material | Mounting Pad Size, Material, & Location |
| No. of Conduction Pins | Placement of Mounting Pad |
| Die Size | PCB Size & Material |
| Die Attach Material | Traces Length & Width |
| Molding Compound Size and Material | Adjacent Heat Sources |
| | Volume of Air |
| | Ambient Temperatue |
| | Shape of Mounting Pad |

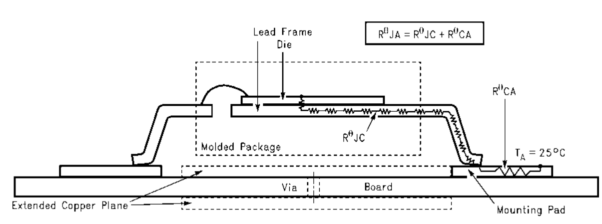



**FIGURE 3. Cross-sectional view of Integrated Circuit Mounted on a printed circuit board. Note that the case temperature is measured at the point where the leads contact with the mounting pad surface**

The SM74503 regulators have internal thermal shutdown to protect the device from over-heating. Under all possible operating conditions, the junction temperature of the SM74503 must be within the range of –40°C to 125°C. A heatsink may be required depending on the maximum power dissipation and maximum ambient temperature of the application. To determine if a heatsink is needed, the power dissipated by the regulator, $P_D$ , must be calculated:

$$I_{IN} = I_L + I_G$$

$$P_D = (V_{IN}-V_{OUT})I_L + V_{IN}I_G$$

*Figure 4* shows the voltages and currents which are present in the circuit.

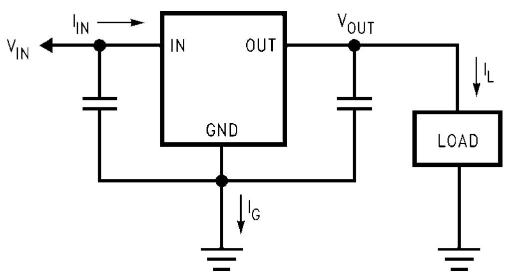



**FIGURE 4. Power Dissipation Diagram**

The next parameter which must be calculated is the maximum allowable temperature rise, $T_R$(max):

$$T_R(max) = T_J(max)-T_A(max)$$

where $T_J$(max) is the maximum allowable junction temperature (125°C), and $T_A$(max) is the maximum ambient temperature which will be encountered in the application.

Using the calculated values for $T_R$(max) and $P_D$, the maximum allowable value for the junction-to-ambient thermal resistance ($\theta_{JA}$) can be calculated:

$$\theta_{JA} = T_R(max)/P_D$$

If the maximum allowable value for $\theta_{JA}$ is found to be ≥136°C/W for SOT-223 package or ≥92°C/W for TO-252 package, no heatsink is needed since the package alone will dissipate enough heat to satisfy these requirements. If the calculated value for $\theta_{JA}$ falls below these limits, a heatsink is required.

As a design aid, *Table 1* shows the value of the $\theta_{JA}$ of SOT-223 and TO-252 for different heatsink area. The copper patterns that we used to measure these $\theta_{JA}$s are shown at the end of the Application Notes Section. *Figure 5* and *Figure 6* reflects the same test results as what are in the *Table 1*

*Figure 7* and *Figure 8* shows the maximum allowable power dissipation vs. ambient temperature for the SOT-223 and TO-252 device. *Figure 9* and *Figure 10* shows the maximum allowable power dissipation vs. copper area (in$^2$) for the SOT-223 and TO-252 devices. Please see AN1028 for power enhancement techniques to be used with SOT-223 and TO-252 packages.

**TABLE 1. $\theta_{JA}$ Different Heatsink Area**

| Layout | Copper Area | | Thermal Resistance | |
|---|---|---|---|---|
| | Top Side (in$^2$)* | Bottom Side (in$^2$) | ($\theta_{JA}$,°C/W) SOT-223 | ($\theta_{JA}$,°C/W) TO-252 |
| 1 | 0.0123 | 0 | 136 | 103 |
| 2 | 0.066 | 0 | 123 | 87 |
| 3 | 0.3 | 0 | 84 | 60 |
| 4 | 0.53 | 0 | 75 | 54 |
| 5 | 0.76 | 0 | 69 | 52 |
| 6 | 1 | 0 | 66 | 47 |
| 7 | 0 | 0.2 | 115 | 84 |
| 8 | 0 | 0.4 | 98 | 70 |
| 9 | 0 | 0.6 | 89 | 63 |
| 10 | 0 | 0.8 | 82 | 57 |
| 11 | 0 | 1 | 79 | 57 |
| 12 | 0.066 | 0.066 | 125 | 89 |
| 13 | 0.175 | 0.175 | 93 | 72 |
| 14 | 0.284 | 0.284 | 83 | 61 |
| 15 | 0.392 | 0.392 | 75 | 55 |
| 16 | 0.5 | 0.5 | 70 | 53 |

*Tab of device attached to topside copper

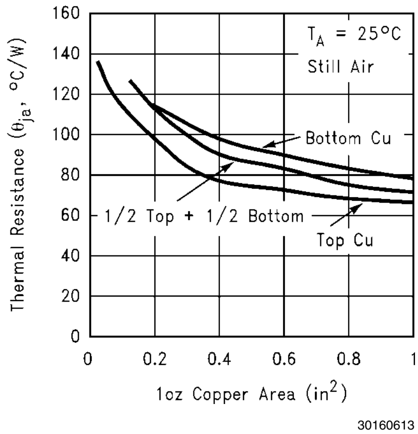



**FIGURE 5. $\theta_{JA}$ vs. 1oz Copper Area for SOT-223**

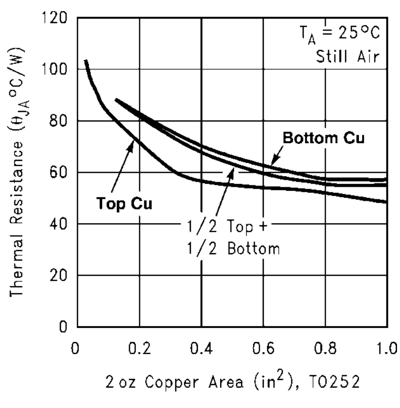



**FIGURE 6. $\theta_{JA}$ vs. 2oz Copper Area for TO-252**

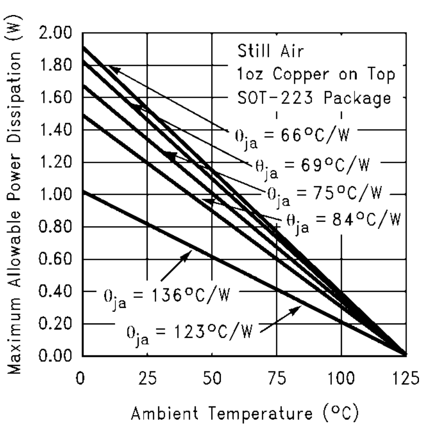



**FIGURE 7. Maximum Allowable Power Dissipation vs. Ambient Temperature for SOT-223**

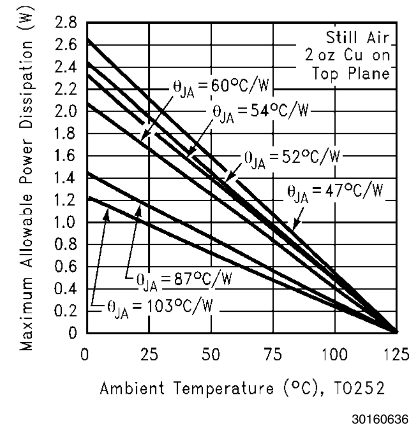



**FIGURE 8. Maximum Allowable Power Dissipation vs. Ambient Temperature for TO-252**

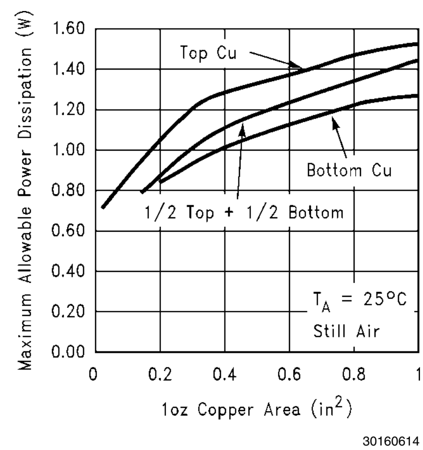



**FIGURE 9. Maximum Allowable Power Dissipation vs. 1oz Copper Area for SOT-223**

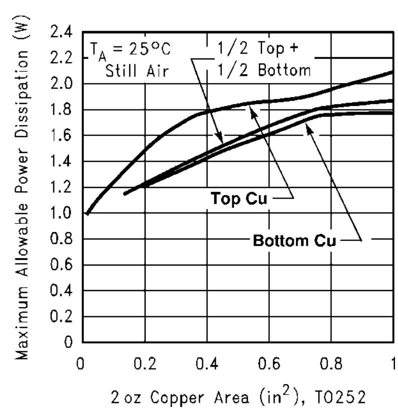



**FIGURE 10. Maximum Allowable Power Dissipation vs. 2oz Copper Area for TO-252**

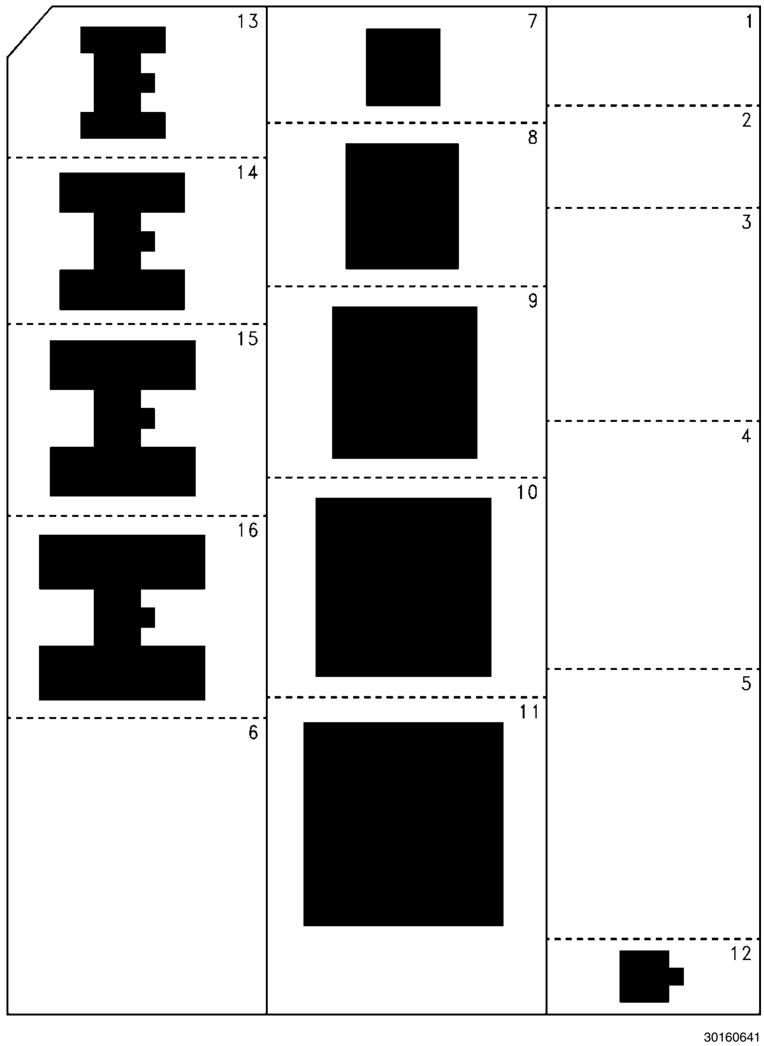



**FIGURE 11. Top View of the Thermal Test Pattern in Actual Scale**

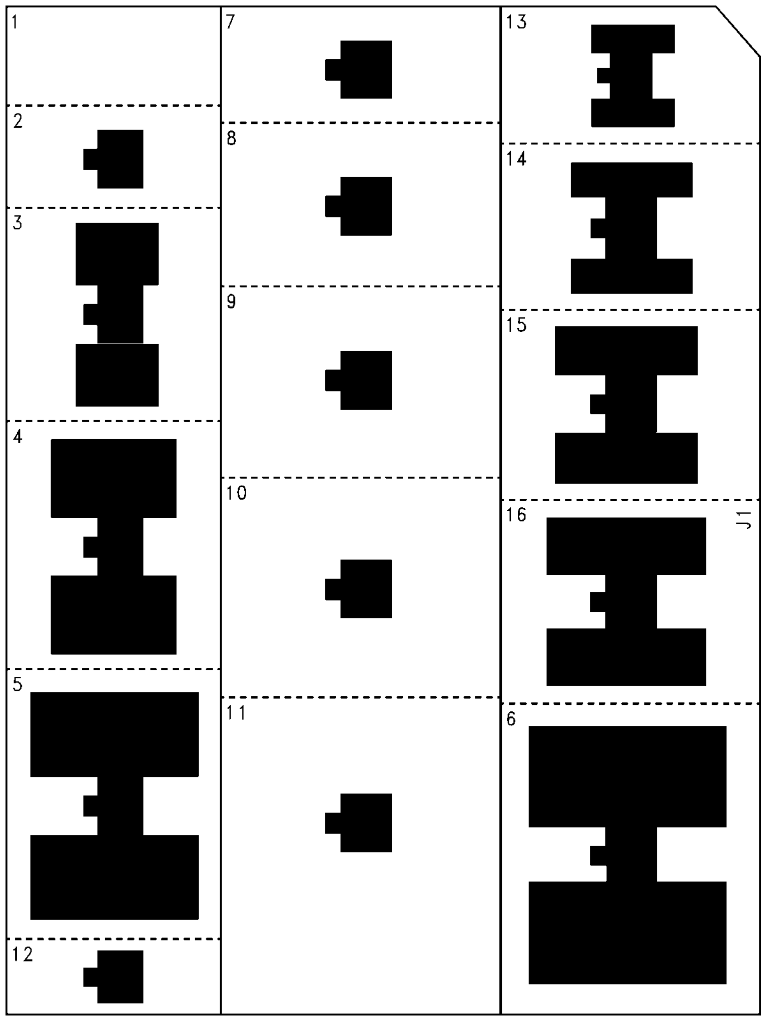
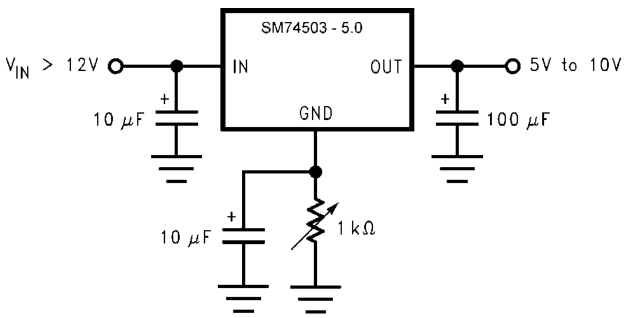



**FIGURE 12. Bottom View of the Thermal Test Pattern in Actual Scale**

## Typical Application Circuits

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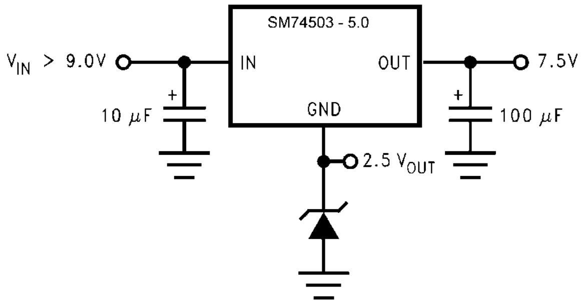
**Adjusting Output of Fixed Regulators**

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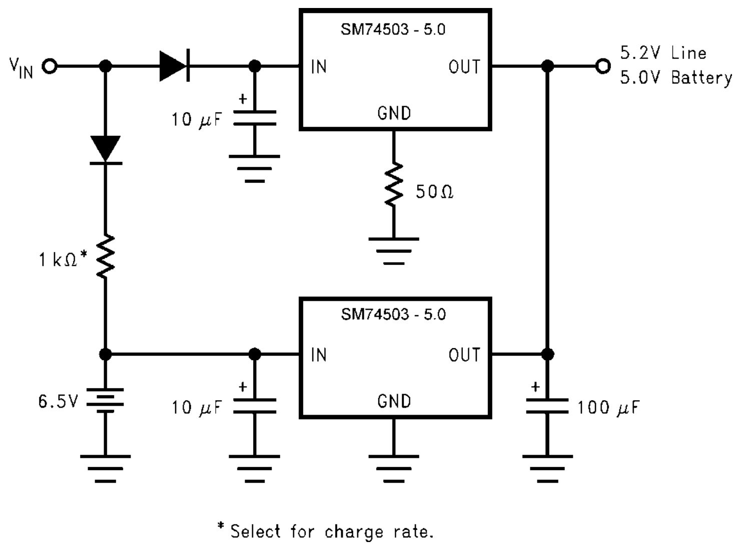
**Regulator with Reference**

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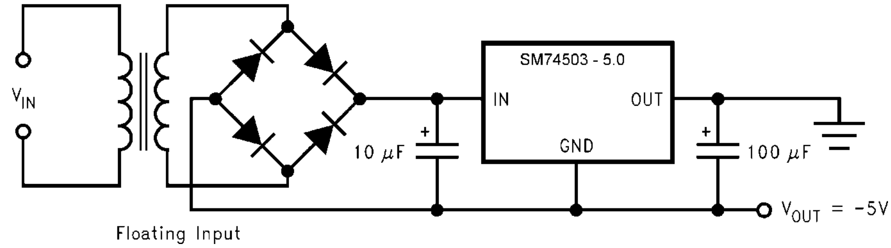
**Battery Backed-Up Regulated Supply**

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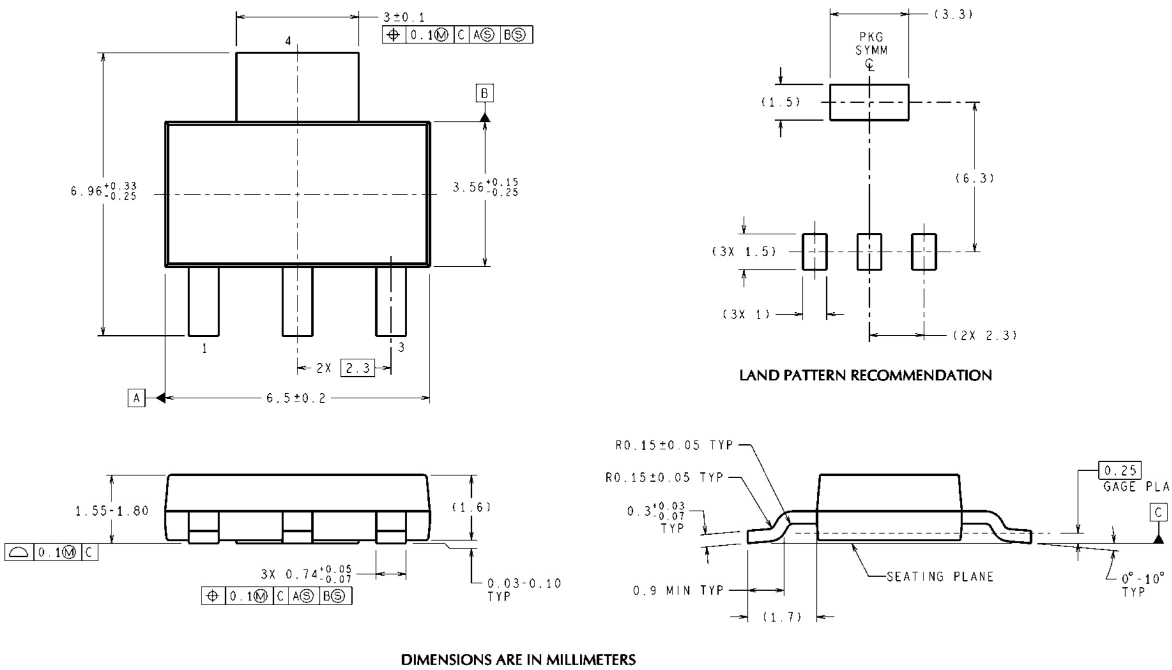
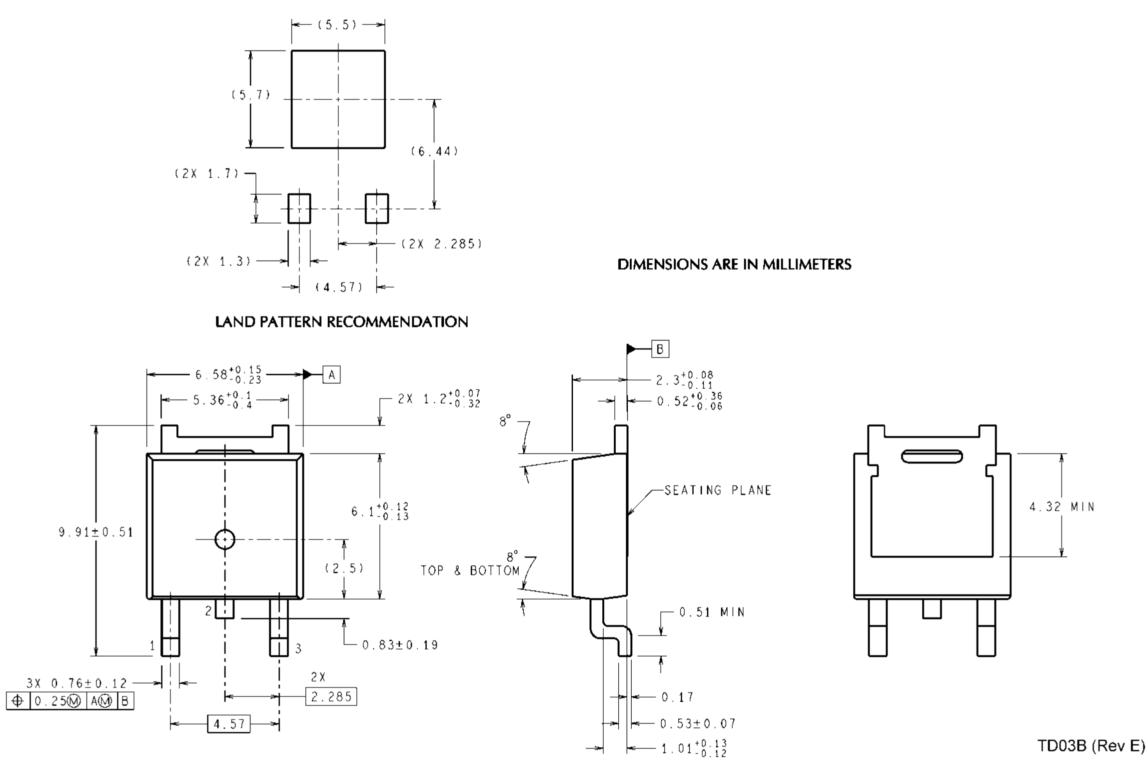
**Low Dropout Negative Supply**

## Physical Dimensions inches (millimeters) unless otherwise noted




MP04A (Rev B)

**4-Lead SOT-223**
**NS Package Number MP04A**




TD03B (Rev E)

**3-Lead TO-252**
**NS Package Number TD03B**

# Notes

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| DLP® Products | www.dlp.com | Energy and Lighting | www.ti.com/energy |
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| Clocks and Timers | www.ti.com/clocks | Medical | www.ti.com/medical |
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