# LM2937 500 mA Low Dropout Regulator

**Check for Samples: LM2937**

## FEATURES

- **Fully Specified for Operation Over −40°C to +125°C**
- **Output Current in Excess of 500 mA**
- **Output Trimmed for 5% Tolerance Under all Operating Conditions**
- **Typical Dropout Voltage of 0.5V at Full Rated Load Current**
- **Wide Output Capacitor ESR Range, up to 3Ω**
- **Internal Short Circuit and Thermal Overload Protection**
- **Reverse Battery Protection**
- **60V Input Transient Protection**
- **Mirror Image Insertion Protection**

## DESCRIPTION

The LM2937 is a positive voltage regulator capable of supplying up to 500 mA of load current. The use of a PNP power transistor provides a low dropout voltage characteristic. With a load current of 500 mA the minimum input to output voltage differential required for the output to remain in regulation is typically 0.5V (1V ensured maximum over the full operating temperature range). Special circuitry has been incorporated to minimize the quiescent current to typically only 10 mA with a full 500 mA load current when the input to output voltage differential is greater than 3V.

The LM2937 requires an output bypass capacitor for stability. As with most low dropout regulators, the ESR of this capacitor remains a critical design parameter, but the LM2937 includes special compensation circuitry that relaxes ESR requirements. The LM2937 is stable for all ESR below 3Ω. This allows the use of low ESR chip capacitors.

Ideally suited for automotive applications, the LM2937 will protect itself and any load circuitry from reverse battery connections, two-battery jumps and up to +60V/−50V load dump transients. Familiar regulator features such as short circuit and thermal shutdown protection are also built in.

## Connection Diagrams

**Front View**

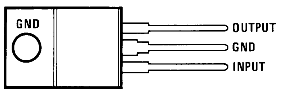

**Figure 1. TO-220 Plastic Package**
**See Package Number NDE0003B**

**Front View**

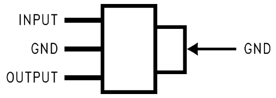

**Figure 2. SOT-223 Plastic Package**
**See Package Number DCY0004A**

**Top View**

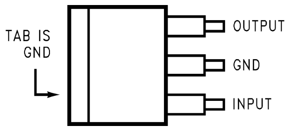

**Figure 3. DDPAK/TO-263 Surface-Mount Package**
**See Package Number KTT0003B**

**Side View**

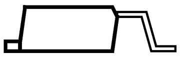

**Figure 4. DDPAK/TO-263 Surface-Mount Package**
**See Package Number KTT0003B**

These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

## Absolute Maximum Ratings(1)(2)

| | | |
|---|---|---|
| Input Voltage | Continuous | 26V |
| | Transient (t ≤ 100 ms) | 60V |
| Internal Power Dissipation(3) | | Internally Limited |
| Maximum Junction Temperature | | 150°C |
| Storage Temperature Range | | −65°C to +150°C |
| TO-220 (10 seconds) | | 260°C |
| DDPAK/TO-263 (10 seconds) | | 230°C |
| SOT-223 (Vapor Phase, 60 seconds) | | 215°C |
| SOT-223 (Infared, 15 seconds) | | 220°C |
| ESD Susceptibility(4) | | 2 kV |

(1) Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Electrical specifications do not apply when operating the device outside of its rated Operating Conditions.

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

(3) The maximum allowable power dissipation at any ambient temperature is $P_{MAX} = (125 - T_A)/\theta_{JA}$, where 125 is the maximum junction temperature for operation, $T_A$ is the ambient temperature, and $\theta_{JA}$ is the junction-to-ambient thermal resistance. If this dissipation is exceeded, the die temperature will rise above 125°C and the electrical specifications do not apply. If the die temperature rises above 150°C, the LM2937 will go into thermal shutdown. For the LM2937, the junction-to-ambient thermal resistance $\theta_{JA}$ is 65°C/W, for the TO-220 package, 73°C/W for the DDPAK/TO-263 package, and 174°C/W for the SOT-223 package. When used with a heatsink, $\theta_{JA}$ is the sum of the LM2937 junction-to-case thermal resistance $\theta_{JC}$ of 3°C/W and the heatsink case-to-ambient thermal resistance. If the DDPAK/TO-263 or SOT-223 packages are used, the thermal resistance can be reduced by increasing the P.C. board copper area thermally connected to the package (see Application Hints for more information on heatsinking).

(4) ESD rating is based on the human body model, 100 pF discharged through 1.5 kΩ.

## Operating Conditions(1)

| | | |
|---|---|---|
| Temperature Range(2) | LM2937ET, LM2937ES | $-40°C \le T_J \le 125°C$ |
| | LM2937IMP | $-40°C \le T_J \le 85°C$ |
| Maximum Input Voltage | | 26V |

(1) Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Electrical specifications do not apply when operating the device outside of its rated Operating Conditions.

(2) The maximum allowable power dissipation at any ambient temperature is $P_{MAX} = (125 - T_A)/\theta_{JA}$, where 125 is the maximum junction temperature for operation, $T_A$ is the ambient temperature, and $\theta_{JA}$ is the junction-to-ambient thermal resistance. If this dissipation is exceeded, the die temperature will rise above 125°C and the electrical specifications do not apply. If the die temperature rises above 150°C, the LM2937 will go into thermal shutdown. For the LM2937, the junction-to-ambient thermal resistance $\theta_{JA}$ is 65°C/W, for the TO-220 package, 73°C/W for the DDPAK/TO-263 package, and 174°C/W for the SOT-223 package. When used with a heatsink, $\theta_{JA}$ is the sum of the LM2937 junction-to-case thermal resistance $\theta_{JC}$ of 3°C/W and the heatsink case-to-ambient thermal resistance. If the DDPAK/TO-263 or SOT-223 packages are used, the thermal resistance can be reduced by increasing the P.C. board copper area thermally connected to the package (see Application Hints for more information on heatsinking).

## Electrical Characteristics

$V_{IN} = V_{NOM} + 5V$[1] $I_{OUTmax}$ = 500 mA for the TO-220 and DDPAK/TO-263 packages, $I_{OUTmax}$=400mA for the SOT-223 package, $C_{OUT}$ = 10 µF unless otherwise indicated. **Boldface limits apply over the entire operating temperature range of the indicated device.**, all other specifications are for $T_A = T_J = 25°C$.

| **Output Voltage ($V_{OUT}$)** | | **5V** | | **8V** | | **10V** | | **Units** |
|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Conditions** | **Typ** | **Limit** | **Typ** | **Limit** | **Typ** | **Limit** | |
| Output Voltage | $5 mA \le I_{OUT} \le I_{OUTmax}$ | 5.00 | 4.85<br>**4.75**<br>5.15<br>**5.25** | 8.00 | 7.76<br>**7.60**<br>8.24<br>**8.40** | 10.00 | 9.70<br>**9.50**<br>10.30<br>**10.50** | V(Min)<br>V(Min)<br>V(Max)<br>V(Max) |
| Line Regulation | $(V_{OUT} + 2V) \le V_{IN} \le 26V$, $I_{OUT} = 5 mA$ | 15 | **50** | 24 | **80** | 30 | **100** | mV(Max) |
| Load Regulation | $5 mA \le I_{OUT} \le I_{OUTmax}$ | 5 | **50** | 8 | **80** | 10 | **100** | mV(Max) |
| Quiescent Current | $(V_{OUT} + 2V) \le V_{IN} \le 26V$, $I_{OUT} = 5 mA$ | 2 | **10** | 2 | **10** | 2 | **10** | mA(Max) |
| | $V_{IN} = (V_{OUT} + 5V)$, $I_{OUT} = I_{OUTmax}$ | 10 | **20** | 10 | **20** | 10 | **20** | mA(Max) |
| Output Noise Voltage | 10 Hz–100 kHz, $I_{OUT} = 5 mA$ | 150 | | 240 | | 300 | | µVrms |
| Long Term Stability | 1000 Hrs. | 20 | | 32 | | 40 | | mV |
| Dropout Voltage | $I_{OUT} = I_{OUTmax}$ | 0.5 | **1.0** | 0.5 | **1.0** | 0.5 | **1.0** | V(Max) |
| | $I_{OUT} = 50 mA$ | 110 | **250** | 110 | **250** | 110 | **250** | mV(Max) |
| Short-Circuit Current | | 1.0 | **0.6** | 1.0 | **0.6** | 1.0 | **0.6** | A(Min) |
| Peak Line Transient Voltage | $t_f < 100 ms$, $R_L = 100Ω$ | 75 | **60** | 75 | **60** | 75 | **60** | V(Min) |
| Maximum Operational Input Voltage | | | **26** | | **26** | | **26** | V(Min) |
| Reverse DC Input Voltage | $V_{OUT} \ge −0.6V$, $R_L = 100Ω$ | −30 | **−15** | −30 | **−15** | −30 | **−15** | V(Min) |
| Reverse Transient Input Voltage | $t_r < 1 ms$, $R_L = 100Ω$ | −75 | **−50** | −75 | **−50** | −75 | **−50** | V(Min) |

(1) Typicals are at $T_J = 25°C$ and represent the most likely parametric norm.

## Electrical Characteristics

$V_{IN} = V_{NOM} + 5V$(1) $I_{OUTmax}$ = 500 mA for the TO-220 and DDPAK/TO-263 packages, $I_{OUTmax}$=400mA for the SOT-223 package, $C_{OUT}$ = 10 µF unless otherwise indicated. **Boldface limits apply over the entire operating temperature range of the indicted device.**, all other specifications are for $T_A = T_J = 25°C$.

| Output Voltage ($V_{OUT}$) | | 12V | | 15V | | Units |
|---|---|---|---|---|---|---|
| Parameter | Conditions | Typ | Limit | Typ | Limit | |
| Output Voltage | 5 mA ≤ $I_{OUT}$ ≤ $I_{OUTmax}$ | 12.00 | 11.64 | 15.00 | 14.55 | V (Min) |
| | | | **11.40** | | **14.25** | V(Min) |
| | | | 12.36 | | 15.45 | V(Max) |
| | | | **12.60** | | **15.75** | V(Max) |
| Line Regulation | ($V_{OUT}$ + 2V) ≤ $V_{IN}$ ≤ 26V, $I_{OUT}$ = 5 mA | 36 | **120** | 45 | **150** | mV(Max) |
| Load Regulation | 5 mA ≤ $I_{OUT}$ ≤ $I_{OUTmax}$ | 12 | **120** | 15 | **150** | mV(Max) |
| Quiescent Current | ($V_{OUT}$ + 2V) ≤ $V_{IN}$ ≤ 26V, $I_{OUT}$ = 5 mA | 2 | **10** | 2 | **10** | mA(Max) |
| | $V_{IN}$ = ($V_{OUT}$ + 5V), $I_{OUT}$ = $I_{OUTmax}$ | 10 | **20** | 10 | **20** | mA(Max) |
| Output Noise Voltage | 10 Hz–100 kHz, $I_{OUT}$ = 5 mA | 360 | | 450 | | µVrms |
| Long Term Stability | 1000 Hrs | 44 | | 56 | | mV |
| Dropout Voltage | $I_{OUT}$ = $I_{OUTmax}$ | 0.5 | **1.0** | 0.5 | **1.0** | V(Max) |
| | $I_{OUT}$ = 50 mA | 110 | **250** | 110 | **250** | mV(Max) |
| Short-Circuit Current | | 1.0 | **0.6** | 1.0 | **0.6** | A(Min) |
| Peak Line Transient Voltage | $t_f$ < 100 ms, $R_L$ = 100Ω | 75 | **60** | 75 | **60** | V(Min) |
| Maximum Operational Input Voltage | | | **26** | | **26** | V(Min) |
| Reverse DC Input Voltage | $V_{OUT}$ ≥ −0.6V, $R_L$ = 100Ω | −30 | **−15** | −30 | **−15** | V(Min) |
| Reverse Transient Input Voltage | $t_r$ < 1 ms, $R_L$ = 100Ω | −75 | **−50** | −75 | **−50** | V(Min) |

(1) Typicals are at $T_J$ = 25°C and represent the most likely parametric norm.

## Typical Performance Characteristics

**Dropout Voltage vs. Output Current**

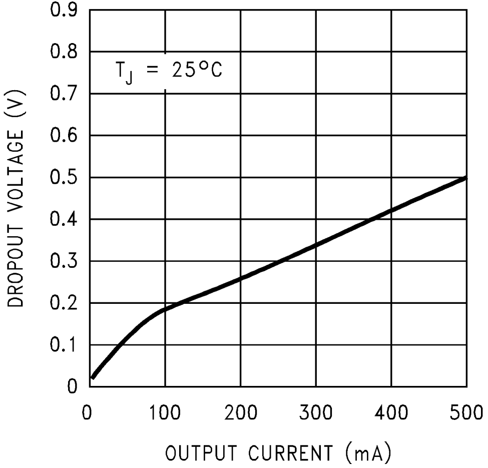

**Figure 5.**

**Dropout Voltage vs. Temperature**

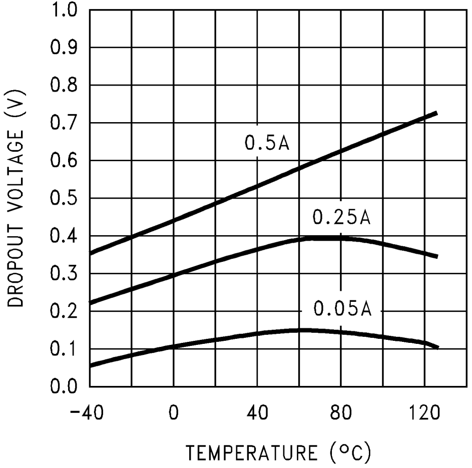

**Figure 6.**

**Output Voltage vs. Temperature**

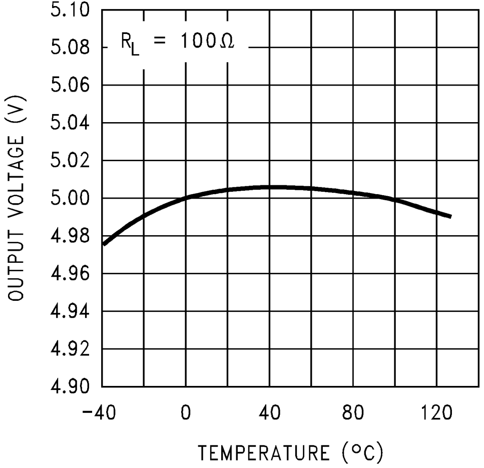

**Figure 7.**

**Quiescent Current vs. Temperature**

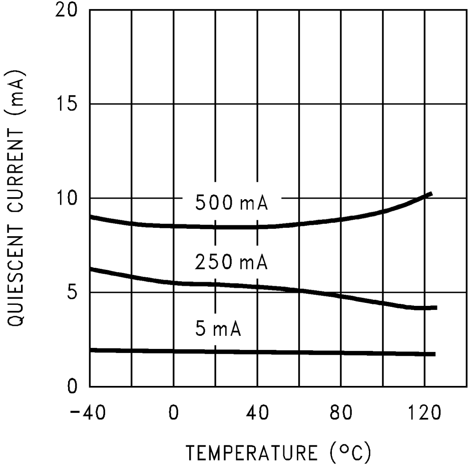

**Figure 8.**

**Quiescent Current vs. Input Voltage**

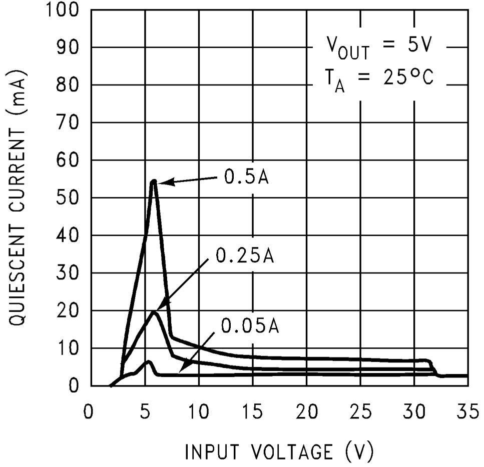

**Figure 9.**

**Quiescent Current vs. Output Current**

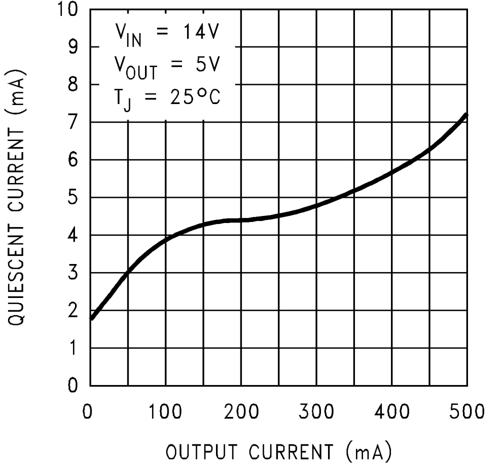

**Figure 10.**

## Typical Performance Characteristics (continued)

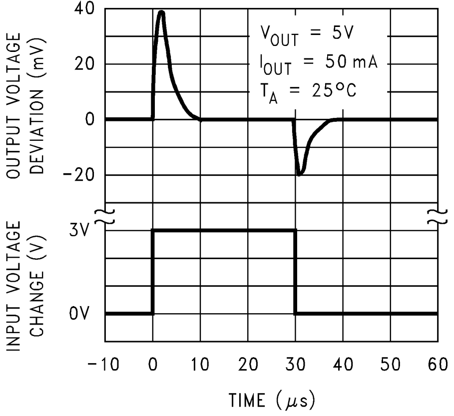
Line Transient Response

Figure 11.

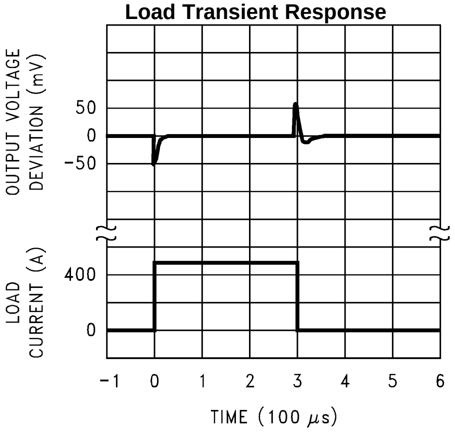
Load Transient Response

Figure 12.

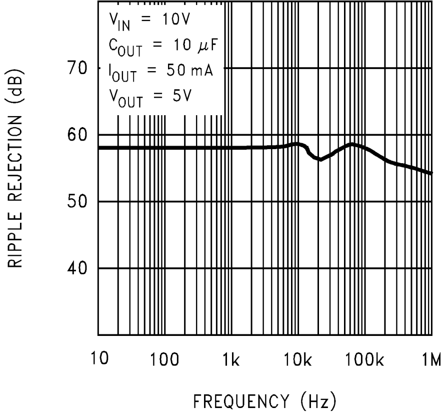
Ripple Rejection

Figure 13.

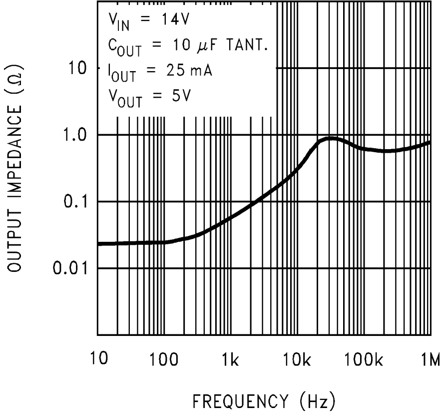
Output Impedance

Figure 14.

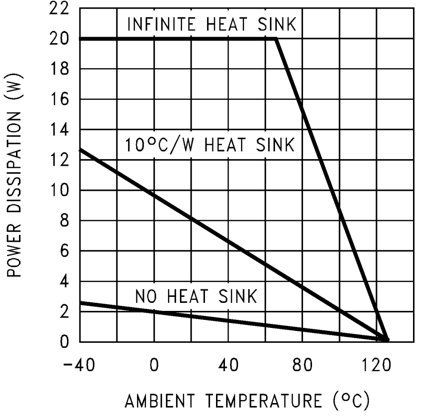
Maximum Power Dissipation (TO-220)

Figure 15.

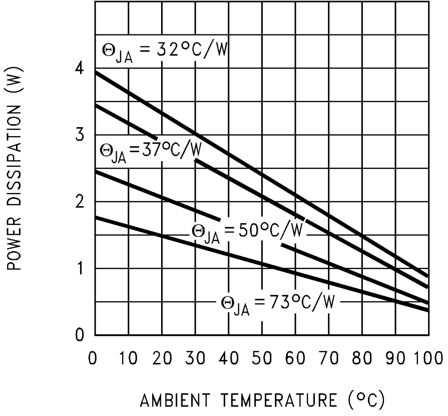
Maximum Power Dissipation (DDPAK/TO-263)(1)

Figure 16.

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(1) The maximum allowable power dissipation at any ambient temperature is $P_{MAX} = (125 - T_A)/\theta_{JA}$, where 125 is the maximum junction temperature for operation, $T_A$ is the ambient temperature, and $\theta_{JA}$ is the junction-to-ambient thermal resistance. If this dissipation is exceeded, the die temperature will rise above 125°C and the electrical specifications do not apply. If the die temperature rises above 150°C, the LM2937 will go into thermal shutdown. For the LM2937, the junction-to-ambient thermal resistance $\theta_{JA}$ is 65°C/W, for the TO-220 package, 73°C/W for the DDPAK/TO-263 package, and 174°C/W for the SOT-223 package. When used with a heatsink, $\theta_{JA}$ is the sum of the LM2937 junction-to-case thermal resistance $\theta_{JC}$ of 3°C/W and the heatsink case-to-ambient thermal resistance. If the DDPAK/TO-263 or SOT-223 packages are used, the thermal resistance can be reduced by increasing the P.C. board copper area thermally connected to the package (see Application Hints for more information on heatsinking).

## Typical Performance Characteristics (continued)

**Low Voltage Behavior**

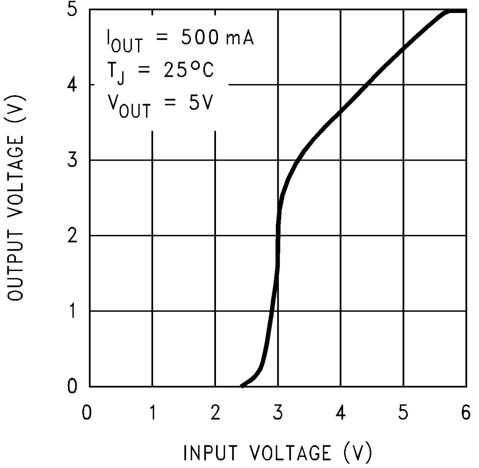


Figure 17.

**Low Voltage Behavior**

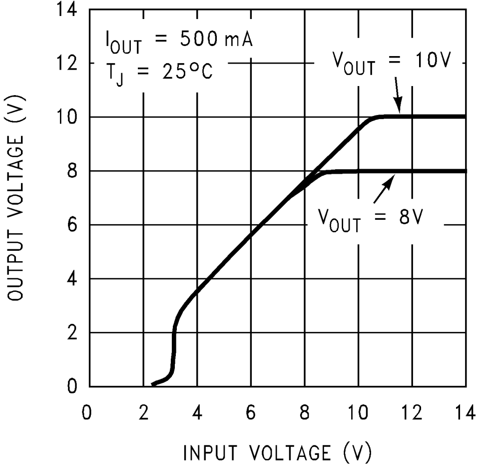


Figure 18.

**Low Voltage Behavior**

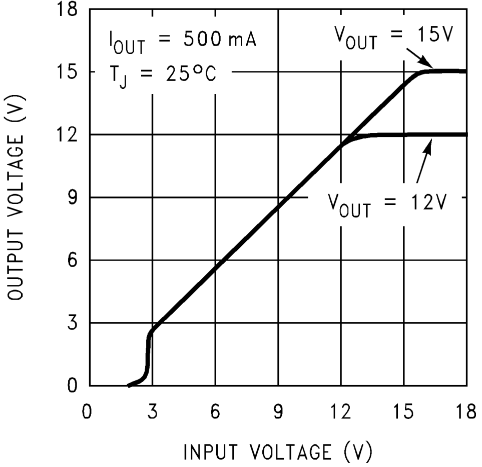


Figure 19.

**Output at Voltage Extremes**

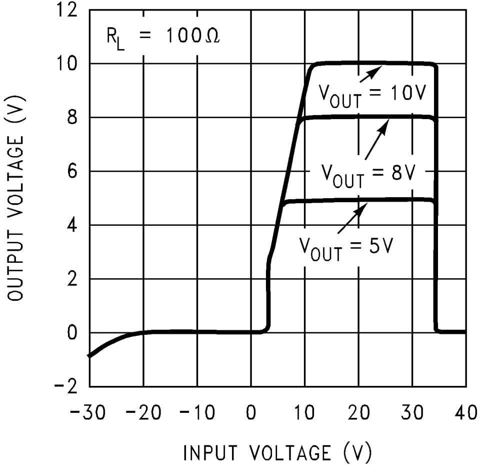


Figure 20.

**Output at Voltage Extremes**

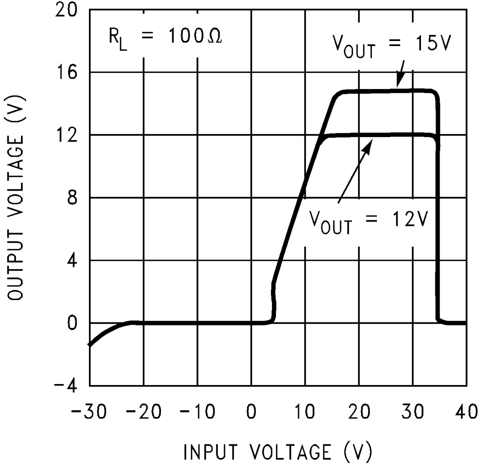


Figure 21.

## Typical Performance Characteristics (continued)

**Output Capacitor ESR**

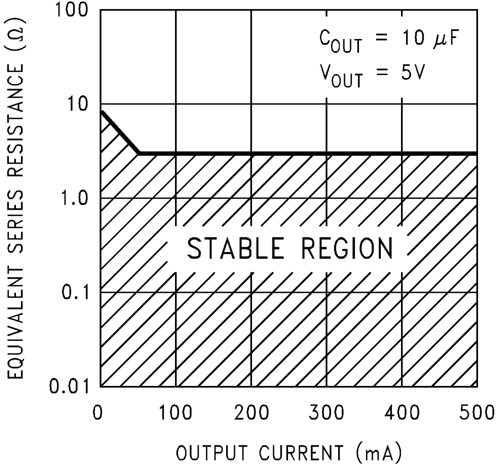


**Figure 22.**

**Peak Output Current**

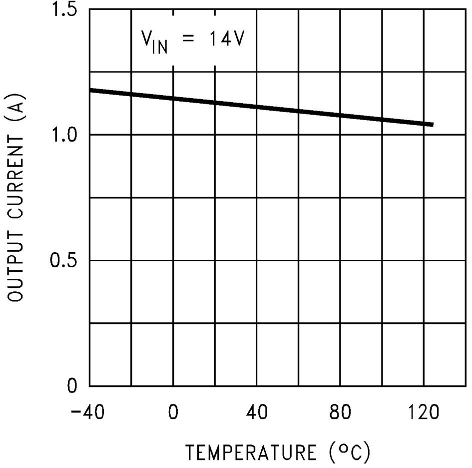
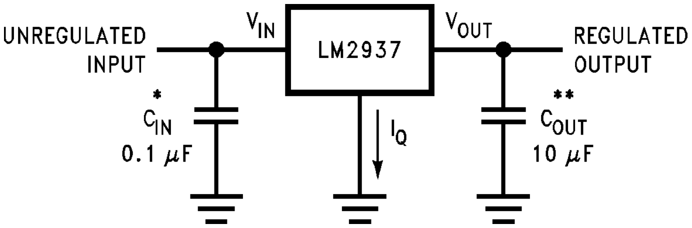


**Figure 23.**

## Typical Application



* Required if the regulator is located more than 3 inches from the power supply filter capacitors.

** Required for stability. $C_{out}$ must be at least 10 µF (over the full expected operating temperature range) and located as close as possible to the regulator. The equivalent series resistance, ESR, of this capacitor may be as high as 3Ω.

## APPLICATION HINTS

### EXTERNAL CAPACITORS

The output capacitor is critical to maintaining regulator stability, and must meet the required conditions for both ESR (Equivalent Series Resistance) and minimum amount of capacitance.

MINIMUM CAPACITANCE:

The minimum output capacitance required to maintain stability is 10 µF (this value may be increased without limit). Larger values of output capacitance will give improved transient response.

ESR LIMITS:

The ESR of the output capacitor will cause loop instability if it is too high or too low. The acceptable range of ESR plotted versus load current is shown in the graph below. ***It is essential that the output capacitor meet these requirements, or oscillations can result.***

### Output Capacitor ESR

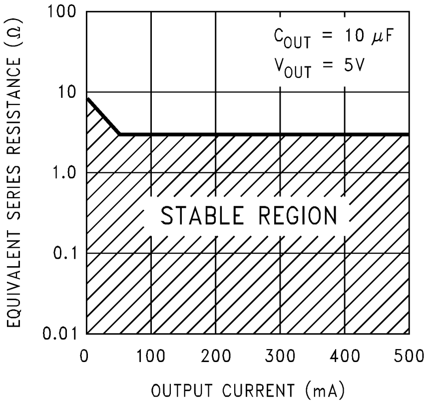


**Figure 24. ESR Limits**

It is important to note that for most capacitors, ESR is specified only at room temperature. However, the designer must ensure that the ESR will stay inside the limits shown over the entire operating temperature range for the design.

For aluminum electrolytic capacitors, ESR will increase by about 30X as the temperature is reduced from 25°C to −40°C. This type of capacitor is not well-suited for low temperature operation.

Solid tantalum capacitors have a more stable ESR over temperature, but are more expensive than aluminum electrolytics. A cost-effective approach sometimes used is to parallel an aluminum electrolytic with a solid Tantalum, with the total capacitance split about 75/25% with the Aluminum being the larger value.

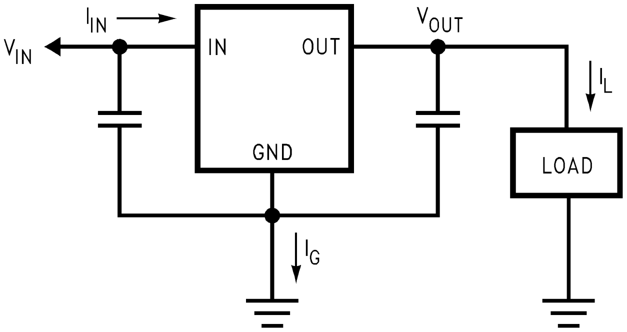
If two capacitors are paralleled, the effective ESR is the parallel of the two individual values. The “flatter” ESR of the Tantalum will keep the effective ESR from rising as quickly at low temperatures.

## HEATSINKING

A heatsink may be required depending on the maximum power dissipation and maximum ambient temperature of the application. Under all possible operating conditions, the junction temperature must be within the range specified under Absolute Maximum Ratings.

To determine if a heatsink is required, the power dissipated by the regulator, $P_D$, must be calculated.

The figure below shows the voltages and currents which are present in the circuit, as well as the formula for calculating the power dissipated in the regulator:



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

**Figure 25. Power Dissipation Diagram**

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

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

where

- $T_J$ (max) is the maximum allowable junction temperature, which is 125°C for commercial grade parts
- $T_A$ (max) is the maximum ambient temperature which will be encountered in the application (1)

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

$\theta_{(J-A)} = T_R\,(\max)/P_D$ (2)

**IMPORTANT:** If the maximum allowable value for $\theta_{(J-A)}$ is found to be ≥ 53°C/W for the TO-220 package, ≥ 80°C/W for the DDPAK/TO-263 package, or ≥174°C/W for the SOT-223 package, no heatsink is needed since the package alone will dissipate enough heat to satisfy these requirements.

If the calculated value for $\theta_{(J-A)}$ falls below these limits, a heatsink is required.

## HEATSINKING TO-220 PACKAGE PARTS

The TO-220 can be attached to a typical heatsink, or secured to a copper plane on a PC board. If a copper plane is to be used, the values of $\theta_{(J-A)}$ will be the same as shown in the next section for the DDPAK/TO-263.

If a manufactured heatsink is to be selected, the value of heatsink-to-ambient thermal resistance, $\theta_{(H-A)}$, must first be calculated:

$$\theta_{(H-A)} = \theta_{(J-A)} - \theta_{(C-H)} - \theta_{(J-C)}$$

where

- $\theta_{(J-C)}$ is defined as the thermal resistance from the junction to the surface of the case. A value of 3°C/W can be assumed for $\theta_{(J-C)}$ for this calculation
- $\theta_{(C-H)}$ is defined as the thermal resistance between the case and the surface of the heatsink. The value of $\theta_{(C-H)}$ will vary from about 1.5°C/W to about 2.5°C/W (depending on method of attachment, insulator, etc.). If the exact value is unknown, 2°C/W should be assumed for $\theta_{(C-H)}$ (3)

When a value for $\theta_{(H-A)}$ is found using the equation shown, *a heatsink must be selected that has a value that is less than or equal to this number.*

$\theta_{(H-A)}$ is specified numerically by the heatsink manufacturer in the catalog, or shown in a curve that plots temperature rise vs power dissipation for the heatsink.

## HEATSINKING DDPAK/TO-263 AND SOT-223 PACKAGE PARTS

Both the DDPAK/TO-263 (“S”) and SOT-223 (“MP”) packages use a copper plane on the PCB and the PCB itself as a heatsink. To optimize the heat sinking ability of the plane and PCB, solder the tab of the package to the plane.

Figure 26 shows for the DDPAK/TO-263 the measured values of $\theta_{(J-A)}$ for different copper area sizes using a typical PCB with 1 ounce copper *and no solder mask over the copper area used for heatsinking.*

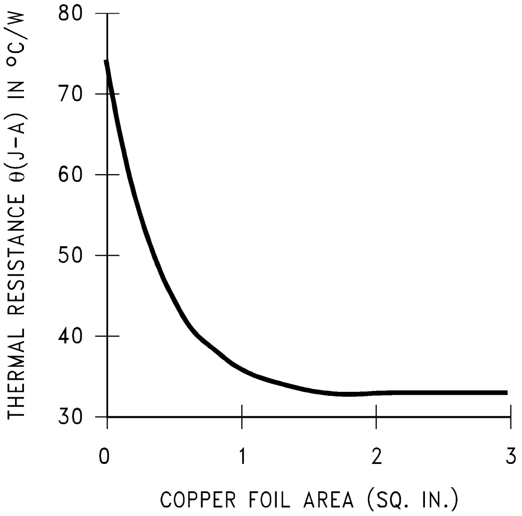


**Figure 26. $\theta_{(J-A)}$ vs. Copper (1 ounce) Area for the DDPAK/TO-263 Package**

As shown in the figure, increasing the copper area beyond 1 square inch produces very little improvement. It should also be observed that the minimum value of $\theta_{(J-A)}$ for the DDPAK/TO-263 package mounted to a PCB is 32°C/W.

As a design aid, Figure 27 shows the maximum allowable power dissipation compared to ambient temperature for the DDPAK/TO-263 device (assuming $\theta_{(J-A)}$ is 35°C/W and the maximum junction temperature is 125°C).

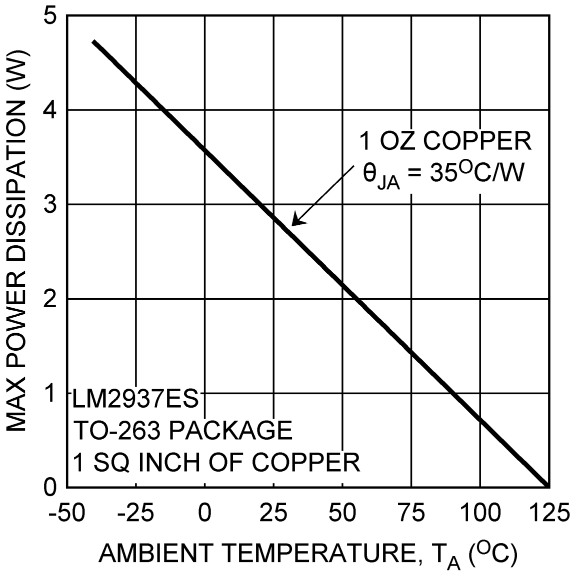


**Figure 27. Maximum Power Dissipation vs. $T_{AMB}$ for the DDPAK/TO-263 Package**

Figure 28 and Figure 29 show the information for the SOT-223 package. Figure 29 assumes a $\theta_{(J-A)}$ of 74°C/W for 1 ounce copper and 51°C/W for 2 ounce copper and a maximum junction temperature of +85°C.

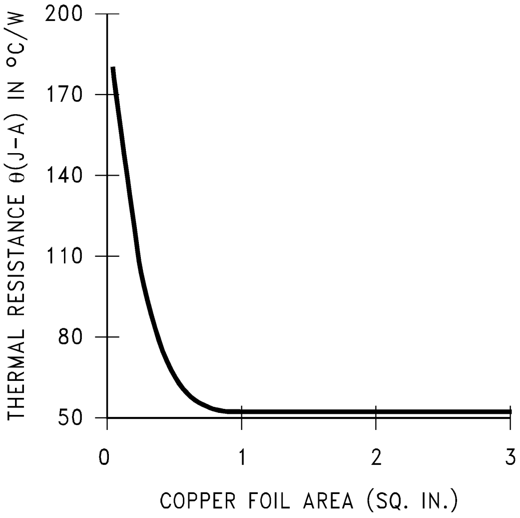


**Figure 28. $\theta_{(J-A)}$ vs Copper (2 ounce) Area for the SOT-223 Package**

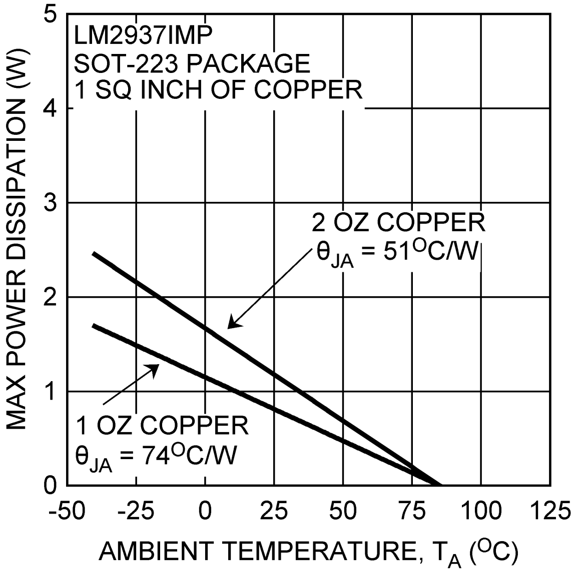


**Figure 29. Maximum Power Dissipation vs $T_{AMB}$ for the SOT-223 Package**

## SOT-223 SOLDERING RECOMMENDATIONS

It is not recommended to use hand soldering or wave soldering to attach the small SOT-223 package to a printed circuit board. The excessive temperatures involved may cause package cracking.

Either vapor phase or infrared reflow techniques are preferred soldering attachment methods for the SOT-223 package.

## REVISION HISTORY

| **Changes from Revision D (April 2013) to Revision E** | **Page** |
|---|---|
| • Changed layout of National Data Sheet to TI format | 12 |

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