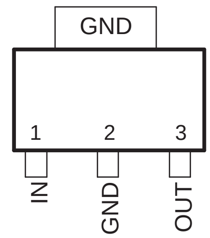
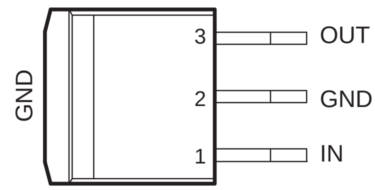
## FEATURES

- Dropout Voltage 0.385 V (Typ) at $I_O$ = 1 A
- Output Current in Excess of 1 A
- Output Voltage Trimmed Before Assembly
- Reverse-Battery Protection
- Internal Short-Circuit Current Limit
- Mirror-Image Insertion Protection
- Available in
  - – Commercial Temperature (0°C to 125°C)
  - – Extended Temperature (–40°C to 125°C)

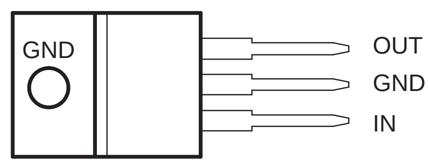
**DCY (SOT-223) PACKAGE**
**(TOP VIEW)**




**KTT (TO-263) PACKAGE**
**(TOP VIEW)**




**KCS (TO-220) PACKAGE**
**(TOP VIEW)**




## DESCRIPTION/ORDERING INFORMATION

The LM2940 positive-voltage regulator features the ability to source 1 A of output current, with a typical dropout voltage of 0.385 V and a maximum of 800 mV over the entire temperature range. Furthermore, a quiescent current reduction circuit has been included, which reduces the ground current when the differential between the input voltage and the output voltage exceeds approximately 3 V. The quiescent current with 1 A of output current and an input-output differential of 5 V is, therefore, only 30 mA. Higher quiescent currents only exist when the regulator is in the dropout mode ($V_I – V_O \le 3$ V).

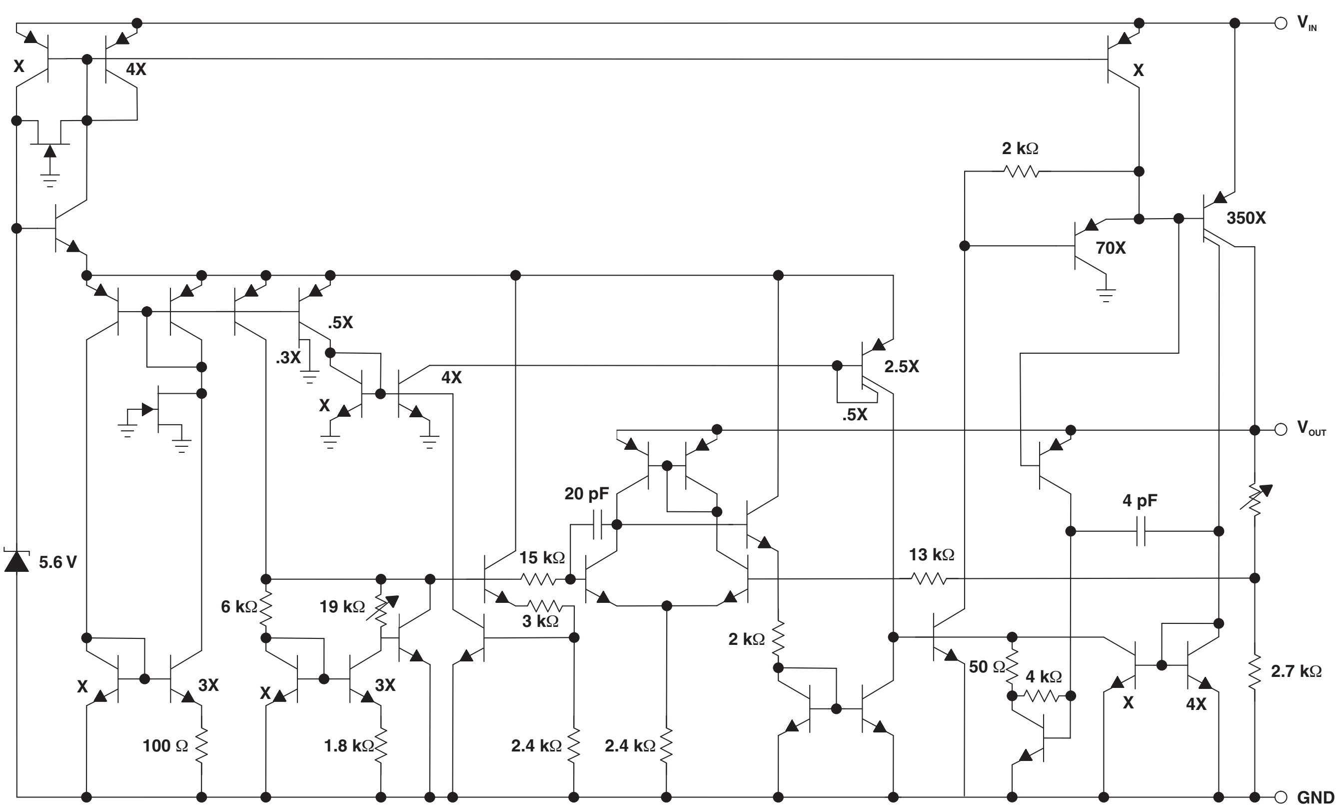
Also designed for vehicular applications, the LM2940 and all regulated circuitry are protected from reverse battery installations or two-battery jumps. During line transients, such as load dump when the input voltage can momentarily exceed the specified maximum operating voltage, the regulator automatically shuts down to protect both the internal circuits and the load. The LM2940 is not harmed by temporary mirror-image insertion. Familiar regulator features, such as short-circuit and thermal-overload protection, also are provided.

## ORDERING INFORMATION

| $T_A$ | $V_Z$ | PACKAGE[(1)] | | ORDERABLE PART NUMBER | TOP-SIDE MARKING |
|---|---|---|---|---|---|
| 0°C to 125°C | 5 V | SOT-223 (DCY) | Reel of 2500 | LM2940-50CDCYR | PREVIEW |
| | | TO-220 (KCS) | Tube of 50 | LM2940-50CKCSE3 | LM2940-50C |
| | | TO-263 (KTT) | Reel of 1000 | LM2940-50CKTTR | PREVIEW |
| | 8 V | SOT-223 (DCY) | Reel of 2500 | LM2940-80CDCYR | PREVIEW |
| | | TO-220 (KCS) | Tube of 50 | LM2940-80CKCS | PREVIEW |
| | | TO-263 (KTT) | Reel of 1000 | LM2940-80CKTTR | PREVIEW |
| | 12 V | SOT-223 (DCY) | Reel of 2500 | LM2940-120CDCYR | PREVIEW |
| | | TO-220 (KCS) | Tube of 50 | LM2940-120CKCS | PREVIEW |
| | | TO-263 (KTT) | Reel of 1000 | LM2940-120CKTTR | PREVIEW |
| –40°C to 125°C | 5 V | SOT-223 (DCY) | Reel of 2500 | LM2940-50IDCYR | PREVIEW |
| | | TO-220 (KCS) | Tube of 50 | LM2940-50IKCSE3 | LM2940-50I |
| | | TO-263 (KTT) | Reel of 1000 | LM2940-50IKTTR | PREVIEW |
| | 8 V | SOT-223 (DCY) | Reel of 2500 | LM2940-80IDCYR | PREVIEW |
| | | TO-220 (KCS) | Tube of 50 | LM2940-80IKCS | PREVIEW |
| | | TO-263 (KTT) | Reel of 1000 | LM2940-80IKTTR | PREVIEW |
| | 12 V | SOT-223 (DCY) | Reel of 2500 | LM2940-120IDCYR | PREVIEW |
| | | TO-220 (KCS) | Tube of 50 | LM2940-120IKCS | PREVIEW |
| | | TO-263 (KTT) | Reel of 1000 | LM2940-120IKTTR | PREVIEW |

(1) Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.

## SIMPLIFIED SCHEMATIC



## Absolute Maximum Ratings[1]

over free-air temperature range (unless otherwise noted)

| | | | | MIN | MAX | UNIT |
|---|---|---|---|---|---|---|
| $V_I$ | Input voltage range[2] | | | –0.3 | 45 | V |
| $\theta_{JA}$ | Package thermal impedance[3][4] | DCY package | | | 52.8 | °C/W |
| | | KCS package | | | 24.8 | |
| | | KTT package | | | 25.3 | |
| $T_J$ | Operating virtual junction temperature | | | | 150 | °C |
| $T_{stg}$ | Storage temperature range | | | –65 | 150 | °C |
| $T_L$ | Maximum lead temperature, time for wave soldering | DCY package | 4 s | | 260 | °C |
| | | KCS package | 10 s | | 260 | |
| | | KTT package | 4 s | | 245 | |

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) If load is returned to a negative power supply, the output must be diode clamped to GND.
(3) Maximum power dissipation is a function of $T_J$(max), $\theta_{JA}$, and $T_A$. The maximum allowable power dissipation at any allowable ambient temperature is $P_D = (T_J(max) – T_A)/\theta_{JA}$. Operating at the absolute maximum $T_J$ of 150°C can affect reliability.
(4) The package thermal impedance is calculated in accordance with JESD 51-7.

## Recommended Operating Conditions

| | | | MIN | MAX | UNIT |
|---|---|---|---|---|---|
| $V_I$ | Input voltage | | | 26 | V |
| $T_A$ | Free-air temperature range | Commercial temperature | 0 | 125 | °C |
| | | Extended temperature | –40 | 125 | |

TEXAS INSTRUMENTS
www.ti.com

## LM2940x Electrical Characteristics

$V_I = V_O + 5$ V, $I_O = 1$ A, $C_O = 22$ µF (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$ (1) | 5 V | | | 8 V | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_O$ | Output voltage | 5 mA ≤ $I_O$ ≤ 1 A,<br>5 V: 6.25 V ≤ $V_I$ ≤ 26 V,<br>8 V: 9.4 V ≤ $V_I$ ≤ 26 V | | 25°C | 4.85 | 5 | 5.15 | 7.76 | 8 | 8.24 | V |
| | | | | Full range | 4.75 | | 5.25 | 7.6 | | 8.4 | |
| | Line regulation | $V_O$ + 2 V ≤ $V_I$ ≤ 26 V, $I_O$ = 5 mA | | 25°C | | 20 | 50 | | 20 | 80 | mV |
| | Load regulation | 50 mA ≤ $I_O$ ≤ 1 A | LM2940I | 25°C | | 35 | 50 | | 55 | 80 | mV |
| | | | | Full range | | | 80 | | | 130 | |
| | | | LM2940C | 25°C | | 35 | 50 | | 55 | 80 | |
| $Z_O$ | Output impedance | 100 $mA_{dc}$, 20 $mA_{rms}$, $f_O$ = 120 Hz | | 25°C | | 35 | | | 55 | | mΩ |
| $I_Q$ | Quiescent current | $V_O$ + 2 V ≤ $V_I$ ≤ 26 V,<br>$I_O$ = 5 mA | LM2940I | 25°C | | 10 | 15 | | 10 | 15 | mA |
| | | | | Full range | | | 20 | | | 20 | |
| | | | LM2940C | 25°C | | 10 | 15 | | 10 | 15 | |
| | | $V_I = V_O$ + 5 V, $I_O$ = 1 A | | 25°C | | 30 | 45 | | 30 | 45 | |
| | | | | Full range | | | 60 | | | 60 | |
| $V_n$ | Output noise voltage | $f_O$ = 10 Hz to 100 kHz, $I_O$ = 5 mA | | 25°C | | 150 | | | 240 | | µ$V_{rms}$ |
| | Ripple rejection | $f_O$ = 120 Hz, 1 $V_{rms}$,<br>$I_O$ = 100 mA | LM2940I | 25°C | 60 | 72 | | 54 | 66 | | dB |
| | | | | Full range | 54 | | | 48 | | | |
| | | | LM2940C | 25°C | 60 | 72 | | 54 | 66 | | |
| | Long-term stability | | | 25°C | | 20 | | | 32 | | mV/<br>1000 h |
| $V_I – V_O$ | Dropout voltage | $I_O$ = 1 A | | 25°C | | 385 | 500 | | 385 | 500 | mV |
| | | | | Full range | | | 800 | | | 800 | |
| | | $I_O$ = 500 mA | | 25°C | | 250 | 300 | | | | |
| | | | | Full range | | | 600 | | | | |
| | | $I_O$ = 100 mA | | 25°C | | | | | 110 | 150 | |
| | | | | Full range | | | | | | 200 | |
| $I_{O(MAX)}$ | Short-circuit current | | | 25°C | 1.6 | 1.9 | | 1.6 | 1.9 | | A |
| | Maximum line transient | $R_O$ = 100 Ω,<br>t ≤ 100 ms | LM2940I | 25°C | 60 | 75 | | 60 | 75 | | V |
| | | | | Full range | 60 | | | 60 | | | |
| | | $R_O$ = 100 Ω, t ≤ 1 ms | LM2940C | 25°C | 45 | 55 | | 45 | 55 | | |
| | Reverse polarity dc input voltage | $R_O$ = 100 Ω | LM2940I | 25°C | –15 | –30 | | –15 | –30 | | V |
| | | | | Full range | –15 | | | –15 | | | |
| | | | LM2940C | 25°C | –15 | –30 | | –15 | –30 | | |
| | Reverse polarity transient input voltage | $R_O$ = 100 Ω,<br>t ≤ 100 ms | LM2940I | 25°C | –50 | –75 | | –50 | –75 | | V |
| | | | | Full range | –50 | | | –50 | | | |
| | | $R_O$ = 100 Ω, t ≤ 1 ms | LM2940C | 25°C | –45 | –55 | | –50 | –50 | | |
| | | | | Full range | –45 | | | –50 | | | |

(1) Full range $T_A$ is –40°C to 125°C for the LM2940I and 0°C to 125°C for the LM2940C.

## LM2940x Electrical Characteristics

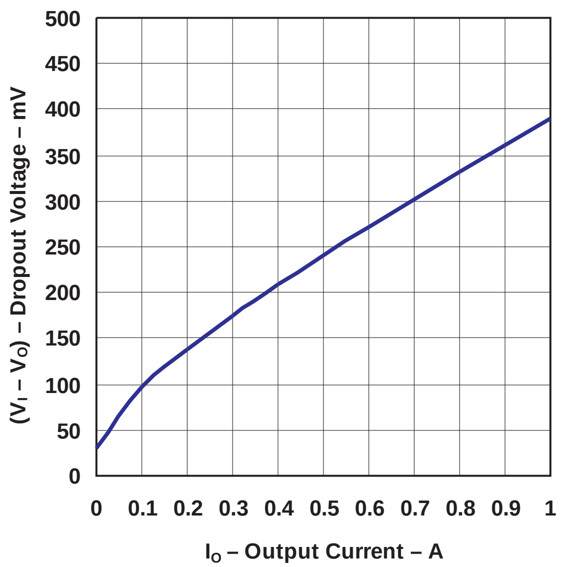
$V_I = V_O + 5$ V, $I_O = 1$ A, $C_O = 22$ µF (unless otherwise noted)

| | PARAMETER | TEST CONDITIONS | | $T_A$ (1) | 12 V MIN | 12 V TYP | 12 V MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_O$ | Output voltage | 5 mA ≤ $I_O$ ≤ 1 A, 9 V: 10.5 V ≤ $V_I$ ≤ 26 V, 12 V: 13.6 V ≤ $V_I$ ≤ 26 V | | 25°C | 11.64 | 12 | 12.36 | V |
| | | | | Full range | 11.4 | | 12.6 | |
| | Line regulation | $V_O$ + 2 V ≤ $V_I$ ≤ 26 V, $I_O$ = 5 mA | | 25°C | | 20 | 120 | mV |
| | Load regulation | 50 mA ≤ $I_O$ ≤ 1 A | LM2940I | 25°C | | 55 | 120 | mV |
| | | | | Full range | | | 200 | |
| | | | LM2940C | 25°C | | 55 | 120 | |
| $Z_O$ | Output impedance | 100 $mA_{dc}$, 20 $mA_{rms}$, $f_O$ = 120 Hz | | 25°C | | 80 | | mΩ |
| $I_Q$ | Quiescent current | $V_O$ + 2 V ≤ $V_I$ ≤ 26 V, $I_O$ = 5 mA | LM2940I | 25°C | | 10 | 15 | mA |
| | | | | Full range | | | 20 | |
| | | | LM2940C | 25°C | | 10 | 15 | |
| | | $V_I = V_O$ + 5 V, $I_O$ = 1 A | | 25°C | | 30 | 45 | |
| | | | | Full range | | | 60 | |
| $V_n$ | Output noise voltage | $f_O$ = 10 Hz to 100 kHz, $I_O$ = 5 mA | | 25°C | | 360 | | $\mu V_{rms}$ |
| | Ripple rejection | $f_O$ = 120 Hz, 1 $V_{rms}$, $I_O$ = 100 mA | LM2940I | 25°C | 54 | 66 | | dB |
| | | | | Full range | 48 | | | |
| | | | LM2940C | 25°C | 54 | 66 | | |
| | Long-term stability | | | 25°C | | 48 | | mV/ 1000 h |
| $V_I – V_O$ | Dropout voltage | $I_O$ = 1 A | | 25°C | | 400 | 500 | mV |
| | | | | Full range | | | 800 | |
| | | $I_O$ = 100 mA | | 25°C | | 110 | 150 | |
| | | | | Full range | | | 200 | |
| $I_{O(MAX)}$ | Short-circuit current | | | 25°C | 1.6 | 1.9 | | A |
| | Maximum line transient | $R_O$ = 100 Ω, t ≤ 100 ms | LM2940I | 25°C | 60 | 75 | | V |
| | | | | Full range | 60 | | | |
| | | $R_O$ = 100 Ω, t ≤ 1 ms | LM2940C | 25°C | 45 | 55 | | |
| | Reverse polarity dc input voltage | $R_O$ = 100 Ω | LM2940I | 25°C | –15 | –30 | | V |
| | | | | Full range | –15 | | | |
| | | | LM2940C | 25°C | –15 | –30 | | |
| | Reverse polarity transient input voltage | $R_O$ = 100 Ω, t ≤ 100 ms | LM2940I | 25°C | –50 | –75 | | V |
| | | | | Full range | –50 | | | |
| | | $R_O$ = 100 Ω, t ≤ 1 ms | LM2940C | 25°C | –45 | –55 | | |
| | | | | Full range | –45 | | | |

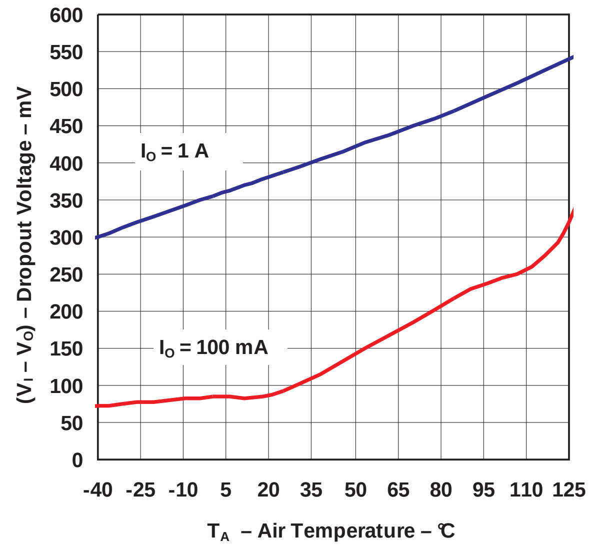
(1) Full range $T_A$ is –40°C to 125°C for the LM2940I and 0°C to 125°C for the LM2940C.

## TYPICAL CHARACTERISTICS

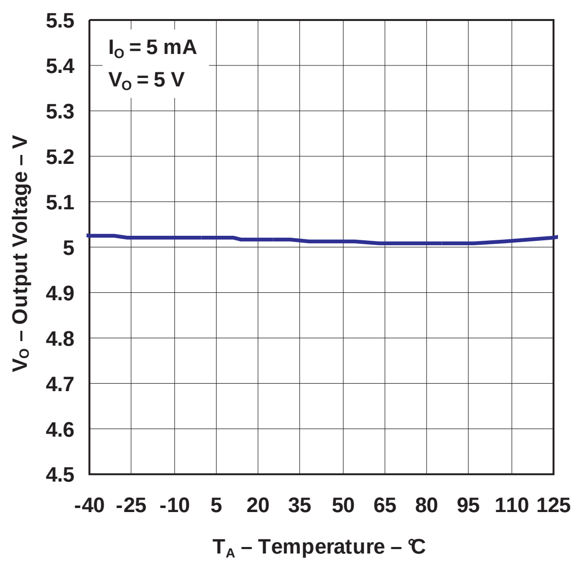
**DROPOUT VOLTAGE vs OUTPUT CURRENT**



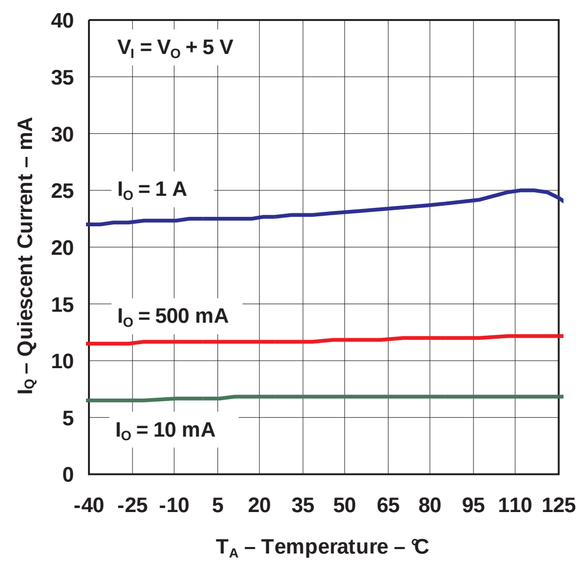

**DROPOUT VOLTAGE vs TEMPERATURE**




**OUTPUT VOLTAGE vs TEMPERATURE**

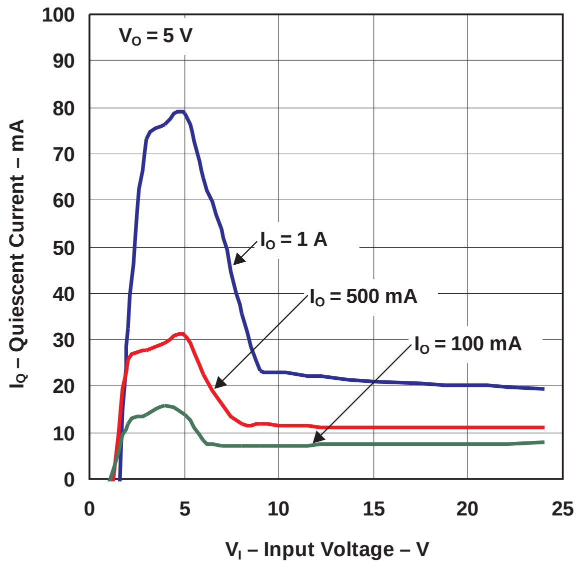



**QUIESCENT CURRENT vs TEMPERATURE**

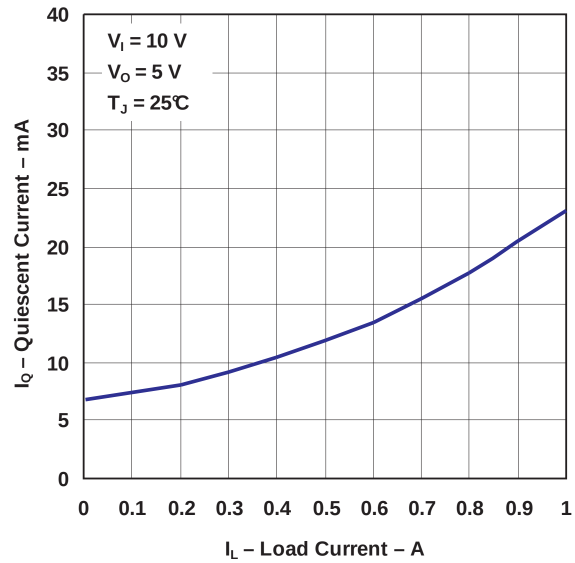


## TYPICAL CHARACTERISTICS (continued)

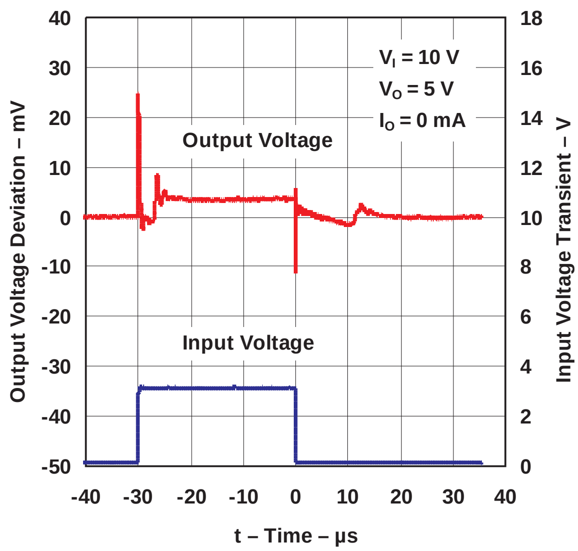
**QUIESCENT CURRENT vs INPUT VOLTAGE**



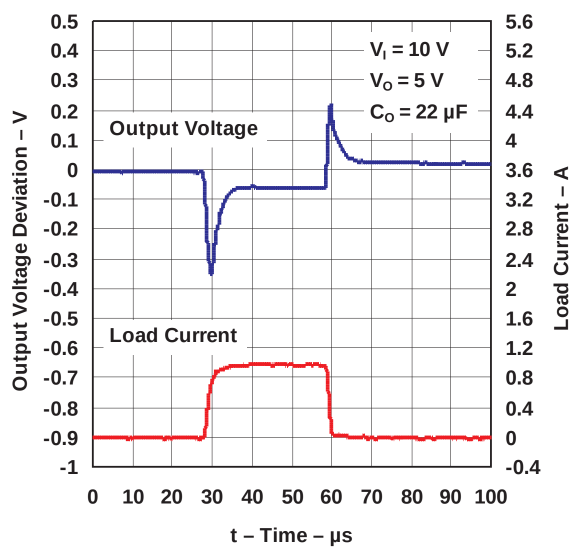

**QUIESCENT CURRENT vs LOAD CURRENT**




**LINE TRANSIENT RESPONSE**

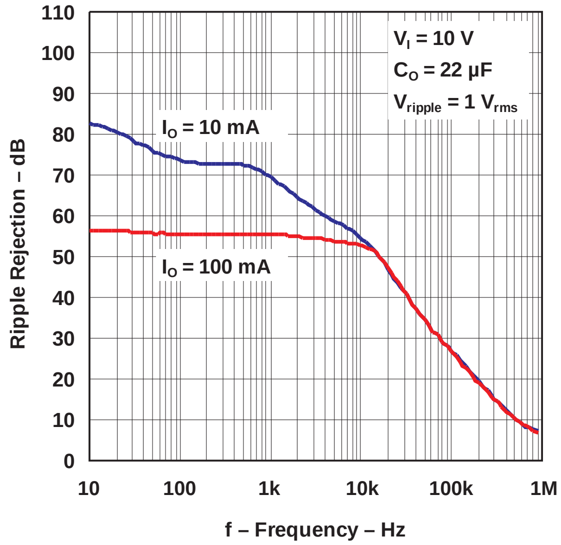



**LOAD TRANSIENT RESPONSE**

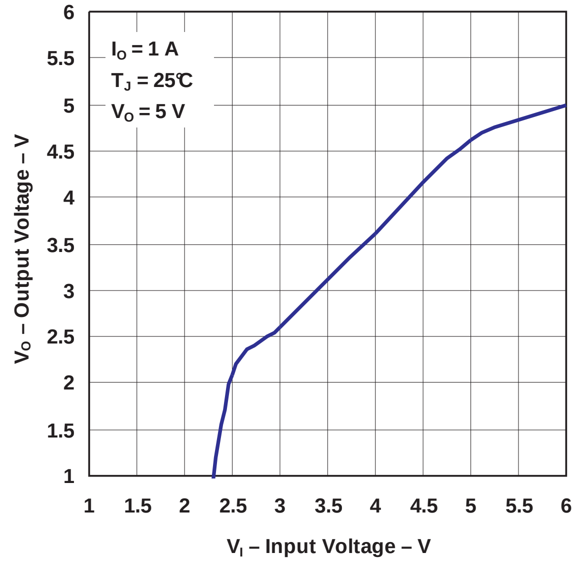


## TYPICAL CHARACTERISTICS (continued)

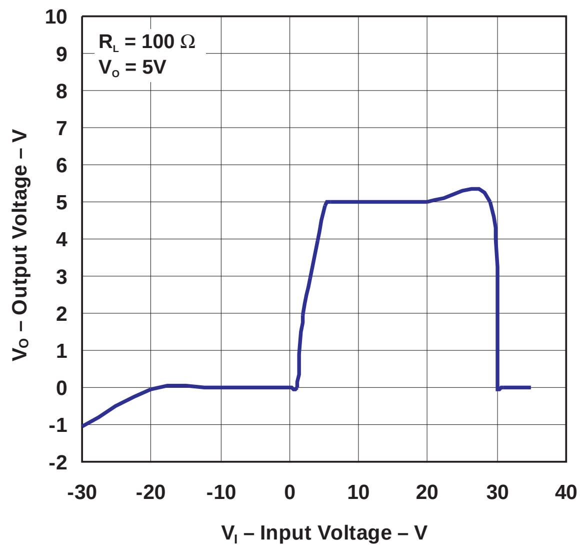
RIPPLE REJECTION
vs
FREQUENCY



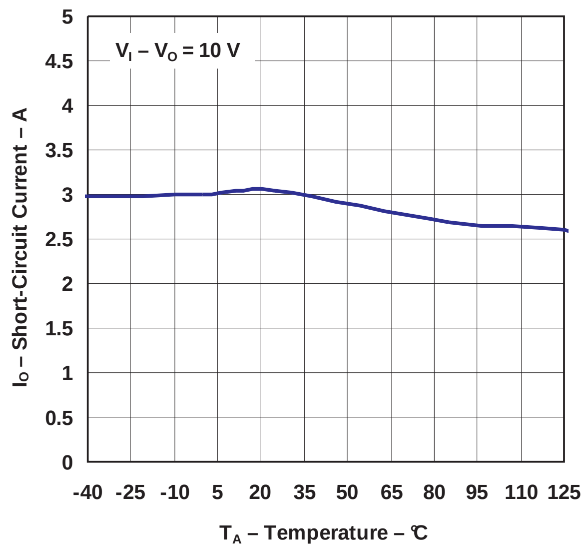

LOW-VOLTAGE BEHAVIOR
OUTPUT VOLTAGE
vs
INPUT VOLTAGE




OUTPUT AT VOLTAGE EXTREMES
OUTPUT VOLTAGE
vs
INPUT VOLTAGE

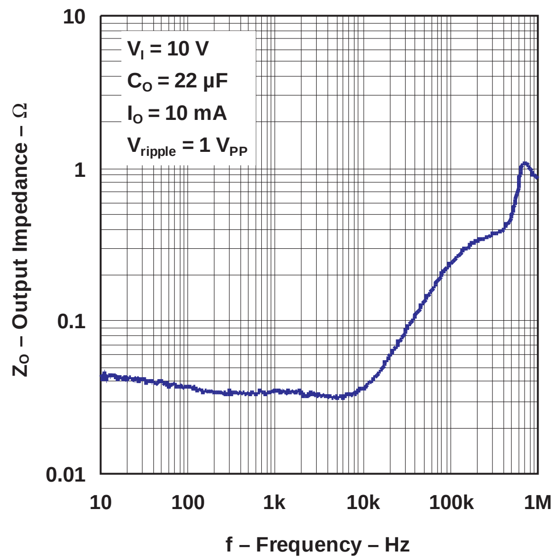



SHORT-CIRCUIT CURRENT
vs
TEMPERATURE



## TYPICAL CHARACTERISTICS (continued)

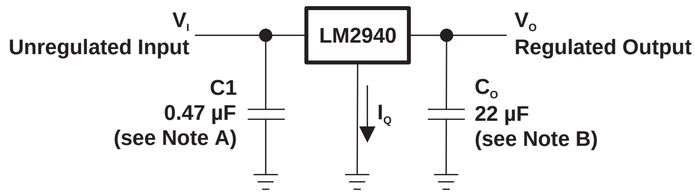
**OUTPUT IMPEDANCE vs FREQUENCY**



## APPLICATION INFORMATION

### Typical Application

Figure 1 shows a typical circuit configuration for the LM2940.




A. Required in regulator if located far from power-supply filter

B. $C_O$ must be at least 22 µF to maintain stability. May be increased without bound to maintain regulation during transients. Locate as close as possible to the regulator. This capacitor must be rated over the same operating temperature range as the regulator, and proper ESR is critical.

**Figure 1. Typical Application Circuit**

### External Capacitors

The output capacitor is critical to maintaining regulator stability and must meet the required conditions for both equivalent series resistance (ESR) and minimum capacitance.

#### Minimum Capacitance

The minimum output capacitance required to maintain stability is 22 µF (this value may be increased without limit). Larger values of output capacitance give improved transient response.

#### ESR Limits

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

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

For aluminum electrolytic capacitors, ESR can increase by about 30 times 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 or the tantalum keeps the effective ESR from rising as quickly at low temperatures.

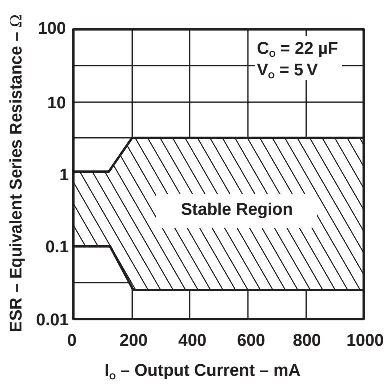



**Figure 2. Output Capacitor ESR**

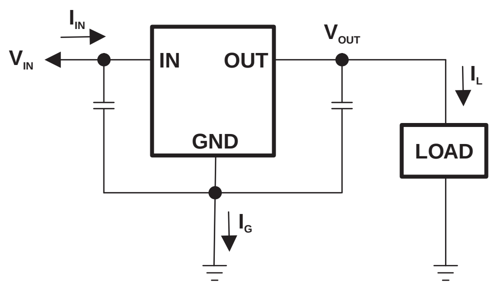
## APPLICATION INFORMATION (continued)

### 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.

Figure 3 shows the voltages and currents that are present in the circuit, as well as the formula for calculating the power dissipated in the regulator.




$I_I = I_L + I_G$

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

**Figure 3. Power Dissipation**

The next parameter that must be calculated is the maximum allowable temperature rise, $T_R$(max). This is calculated 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 parts.

$T_A$(max) is the maximum ambient temperature encountered in the application.

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

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

**NOTE:**

If the maximum allowable value for $\theta_{JA}$ is found to be ≥53°C/W for the TO-220 package, ≥80°C/W for the TO-263 package, or ≥174°C/W for the SOT-223 package, no heatsink is needed, because the package alone dissipates enough heat to satisfy these requirements.

If the calculated value for $\theta_{JA}$ falls below these limits, a heatsink is required.

## APPLICATION INFORMATION (continued)

### Heatsinking TO-220 Package Parts

The SOT-223 can be attached to a typical heatsink or secured to a copper plane on a PC board. If a copper plane is use, the values of $\theta_{JA}$ are the same as shown in under *Heatsinking TO-263 and SOT-223 Package Parts*.

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

$\theta_{HA} = \theta_{JA} - \theta_{CH} - \theta_{JC}$

Where

$\theta_{JC}$ 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 $\theta_{JC}$ for this calculation.

$\theta_{CH}$ is defined as the thermal resistance between the case and the surface of the heatsink. The value of $\theta_{CH}$ varies from about 1.5°C/W to about 2.5°C/W, depending on the method of attachment, insulator, etc. If the exact value is unknown, 2°C/W should be assumed for $\theta_{CH}$.

### Heatsinking TO-263 and SOT-223 Package Parts

Both the TO-263 and SOT-223 packages use a copper plane on the PCB and the PCB itself as a heatsink. To optimize the heatsinking ability of the plane and PCB, solder the tab of the package to the plane.

Figure 4 shows the measured values of $\theta_{JA}$ for the TO-263 for different copper area sizes using a typical PCB with 1-oz copper and no solder mask over the copper area used for heatsinking.

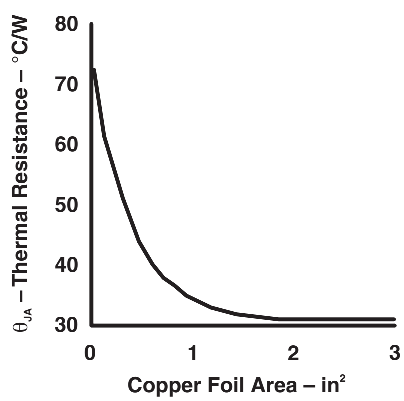



**Figure 4. $\theta_{JA}$ vs Copper (1 oz) Area for TO-263 Package**

As shown in Figure 4, increasing the copper area beyond 1 $in^2$ produces very little improvement. It should also be observed that the minimum value of $\theta_{JA}$ for the TO-263 package mounted to a PCB is 32°C/W.

As a design aid, Figure 5 shows the maximum allowable power dissipation compared to ambient temperature for the TO-263 device, assuming $\theta_{JA}$ is 35°C/W and the maximum junction temperature is 125°C.

## APPLICATION INFORMATION (continued)

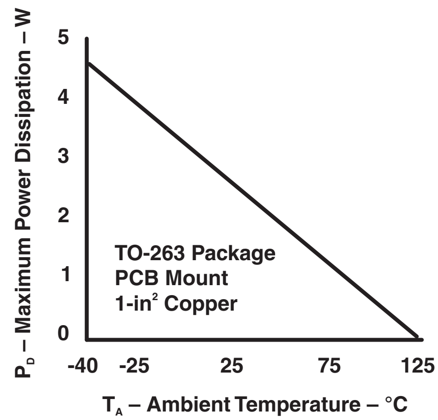



**Figure 5. Maximum Power Dissipation vs Ambient Temperature for TO-263 Package**

Figure 6 and Figure 7 show the information for the SOT-223 package. Figure 7 assumes a $\theta_{JA}$ of 74°C/W for 1-oz copper, 51°C/W for 2-oz copper, and a maximum junction temperature of 125°C.

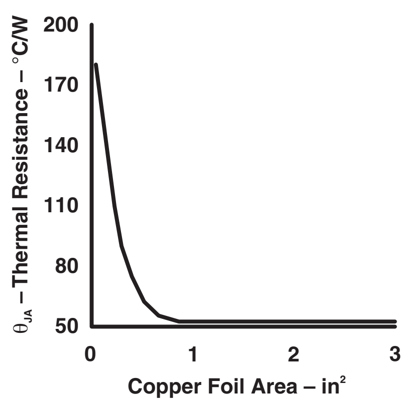



**Figure 6. $\theta_{JA}$ vs Copper (2 oz) Area for SOT-223 Package**

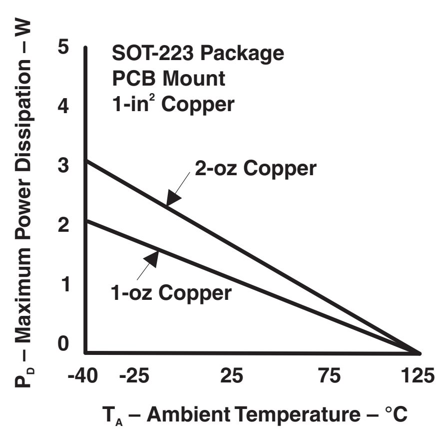



**Figure 7. Maximum Power Dissipation vs Ambient Temperature for SOT-223 Package**