

FEATURES

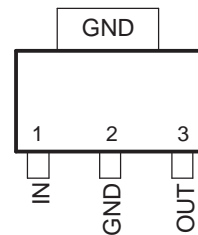
- Dropout Voltage 0.385 V (Typ) at $I_O = 1$ A
- Output Current in Excess of 1 A
- Output Voltage Trimmed Before Assembly
- Reverse-Battery Protection
- Internal Short-Circuit Current Limit
- Mirror-Image Insertion Protection
- Available in
 - Commercial Temperature (0°C to 125°C)
 - Extended Temperature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

DESCRIPTION/ORDERING INFORMATION

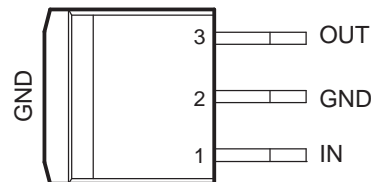
The LM2940 positive-voltage regulator features the ability to source 1 A of output current, with a typical dropout voltage of 0.385 V and a maximum of 800 mV over the entire temperature range. Furthermore, a quiescent current reduction circuit has been included, which reduces the ground current when 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 ($V_I - V_O \leq 3$ 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.

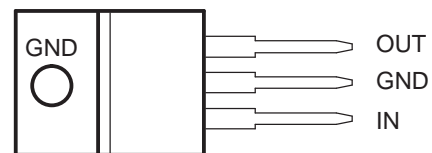
DCY (SOT-223) PACKAGE
(TOP VIEW)



KTT (TO-263) PACKAGE
(TOP VIEW)



KCS (TO-220) PACKAGE
(TOP VIEW)



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LM2940 1-A LOW-DROPOUT VOLTAGE REGULATOR

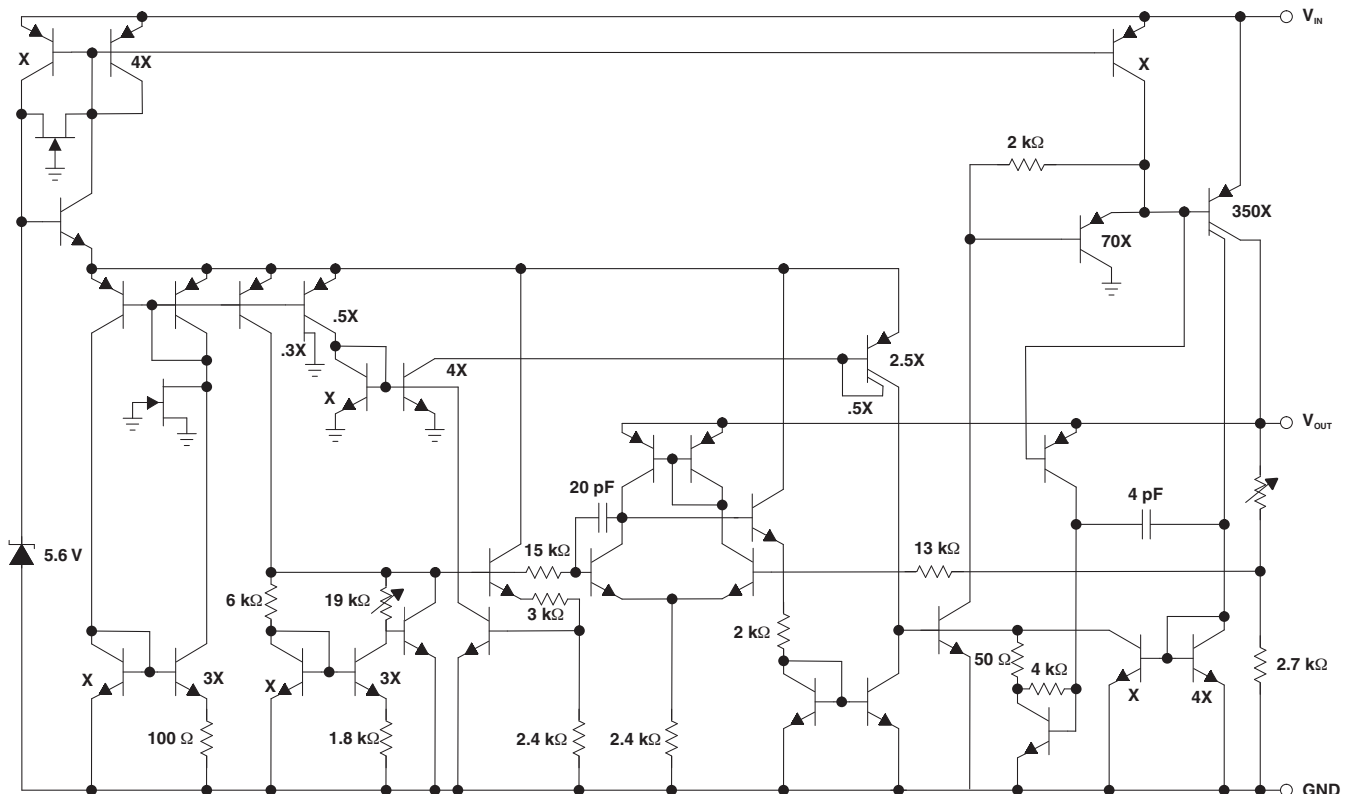
SLVS634–MAY 2006

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
θ _{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)}, θ_{JA}, and T_A. The maximum allowable power dissipation at any allowable ambient temperature is P_D = (T_{J(max)} – T_A)/θ_{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	

LM2940

1-A LOW-DROPOUT VOLTAGE REGULATOR

SLVS634–MAY 2006

LM2940x Electrical Characteristics

$V_I = V_O + 5\text{ V}$, $I_O = 1\text{ A}$, $C_O = 22\text{ }\mu\text{F}$ (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 $\leq I_O \leq 1\text{ A}$, 5 V: 6.25 V $\leq V_I \leq 26\text{ V}$, 8 V: 9.4 V $\leq V_I \leq 26\text{ V}$		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	$V_O + 2\text{ V} \leq V_I \leq 26\text{ V}$, $I_O = 5\text{ mA}$		25°C		20	50		20	80	mV
Load regulation	50 mA $\leq I_O \leq 1\text{ A}$	LM2940I	25°C		35	50		55	80	mV
		LM2940C	Full range			80			130	
Z_O Output impedance	100 mA _{dc} , 20 mA _{rms} , $f_O = 120\text{ Hz}$		25°C		35			55		m Ω
I_Q Quiescent current	$V_O + 2\text{ V} \leq V_I \leq 26\text{ V}$, $I_O = 5\text{ mA}$	LM2940I	25°C		10	15		10	15	mA
		LM2940C	Full range			20			20	
	$V_I = V_O + 5\text{ V}$, $I_O = 1\text{ A}$	LM2940I	25°C		10	15		10	15	
		LM2940C	Full range		30	45		30	45	
V_n Output noise voltage	$f_O = 10\text{ Hz}$ to 100 kHz, $I_O = 5\text{ mA}$		25°C		150			240		μV_{rms}
Ripple rejection	$f_O = 120\text{ Hz}$, 1 V_{rms} , $I_O = 100\text{ mA}$	LM2940I	25°C	60	72		54	66		dB
		LM2940C	Full range	54			48			
Long-term stability			25°C		20			32		mV/ 1000 h
$V_I - V_O$ Dropout voltage	$I_O = 1\text{ A}$			25°C	385	500		385	500	mV
				Full range		800			800	
	$I_O = 500\text{ mA}$			25°C		250	300			
				Full range			600			
	$I_O = 100\text{ mA}$			25°C				110	150	
				Full range					200	
$I_{O(\text{MAX})}$ Short-circuit current			25°C	1.6	1.9		1.6	1.9		A
Maximum line transient	$R_O = 100\text{ }\Omega$, $t \leq 100\text{ ms}$	LM2940I	25°C	60	75		60	75		V
	$R_O = 100\text{ }\Omega$, $t \leq 1\text{ ms}$	LM2940C	Full range	60			60			
Reverse polarity dc input voltage	$R_O = 100\text{ }\Omega$	LM2940I	25°C	-15	-30		-15	-30		V
		LM2940C	Full range	-15			-15			
Reverse polarity transient input voltage	$R_O = 100\text{ }\Omega$, $t \leq 100\text{ ms}$	LM2940I	25°C	-50	-75		-50	-75		V
		LM2940C	Full range	-50			-50			
	$R_O = 100\text{ }\Omega$, $t \leq 1\text{ ms}$	LM2940I	25°C	-45	-55		-45	-55		
		LM2940C	Full range	-45			-45			

(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

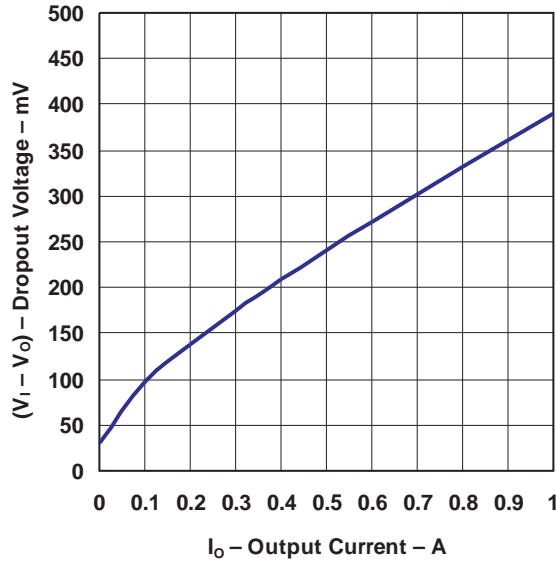
$V_I = V_O + 5\text{ V}$, $I_O = 1\text{ A}$, $C_O = 22\text{ }\mu\text{F}$ (unless otherwise noted)

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

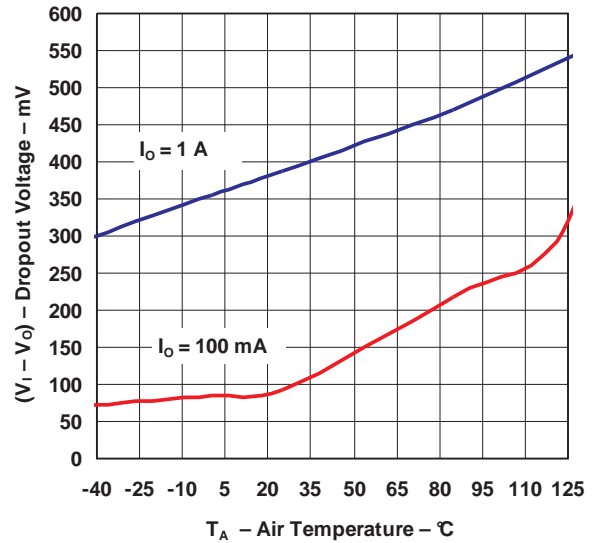
(1) Full range T_A is -40°C to 125°C for the LM2940I and 0°C to 125°C for the LM2940C.

TYPICAL CHARACTERISTICS

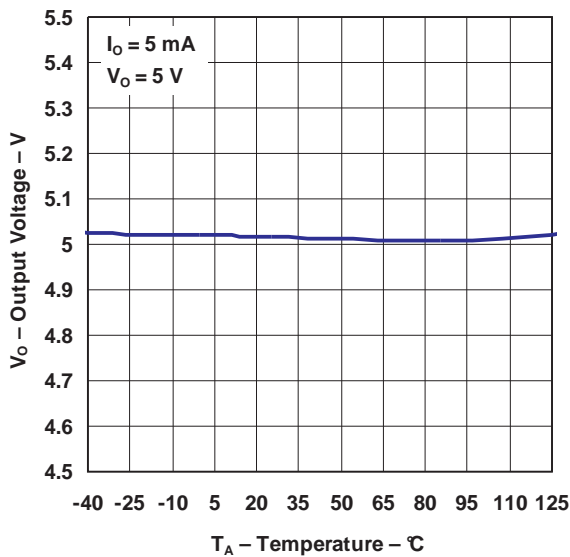
DROPOUT VOLTAGE
VS
OUTPUT CURRENT



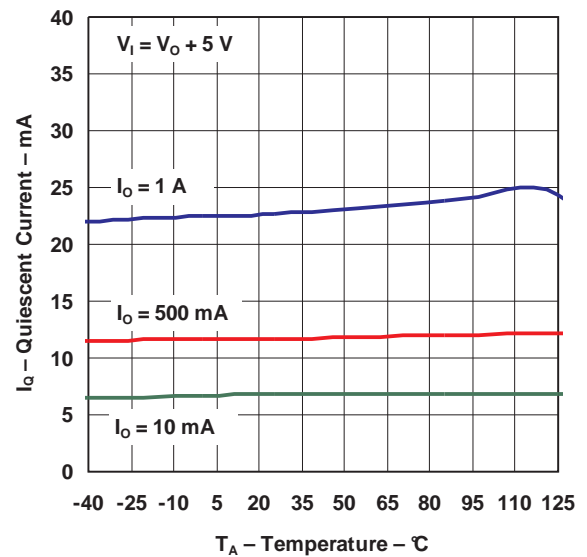
DROPOUT VOLTAGE
VS
TEMPERATURE



OUTPUT VOLTAGE
VS
TEMPERATURE

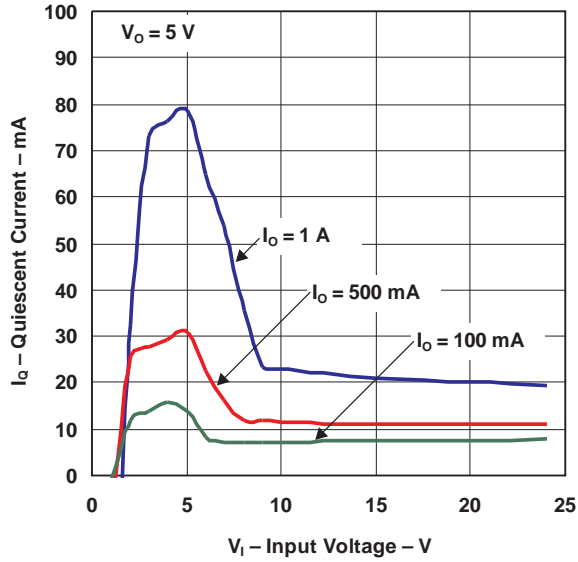


QUIESCENT CURRENT
VS
TEMPERATURE

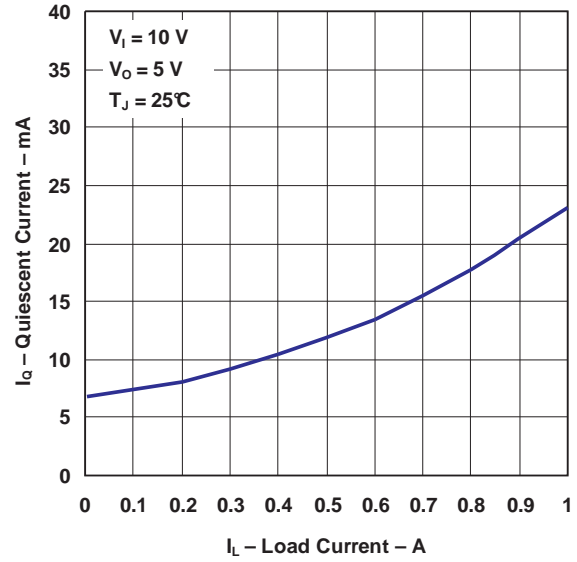


TYPICAL CHARACTERISTICS (continued)

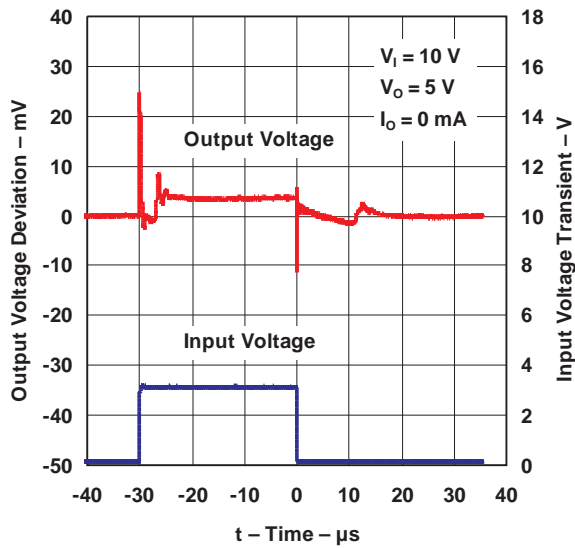
**QUIESCENT CURRENT
VS
INPUT VOLTAGE**



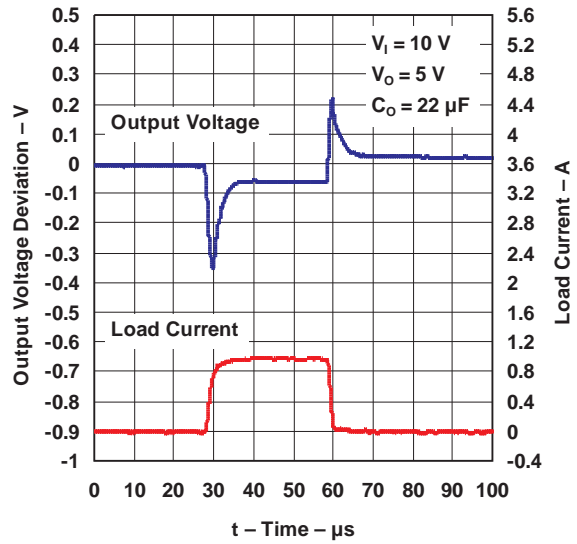
**QUIESCENT CURRENT
VS
LOAD CURRENT**



LINE TRANSIENT RESPONSE

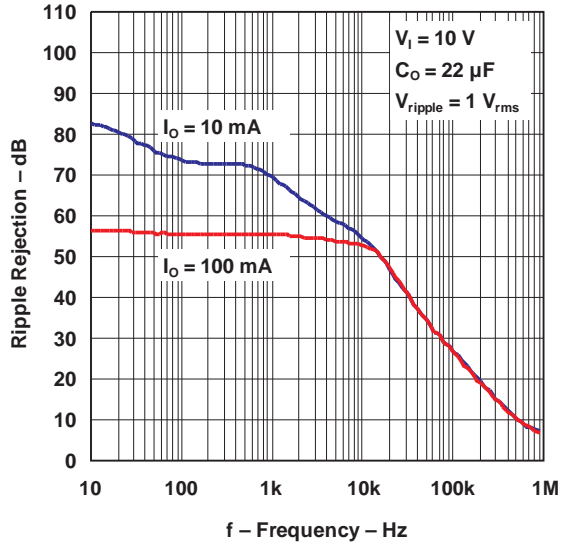


LOAD TRANSIENT RESPONSE

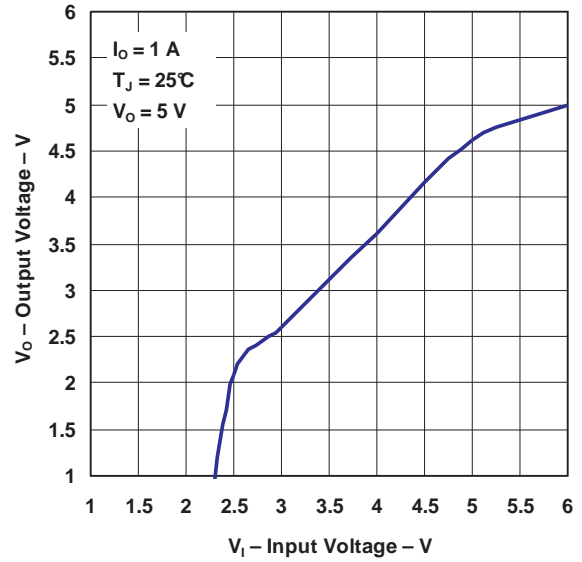


TYPICAL CHARACTERISTICS (continued)

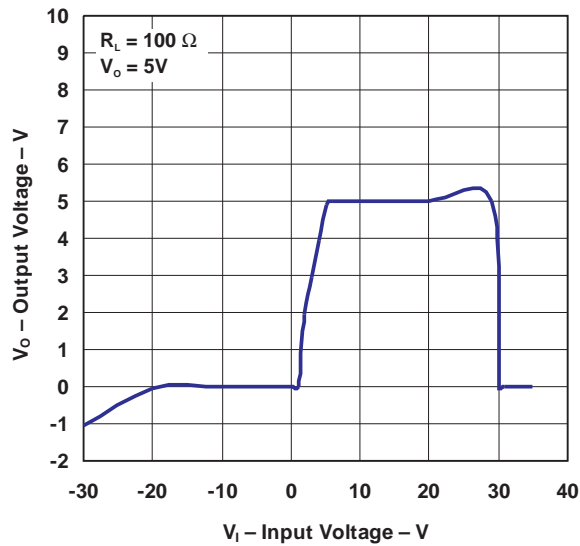
RIPPLE REJECTION
VS
FREQUENCY



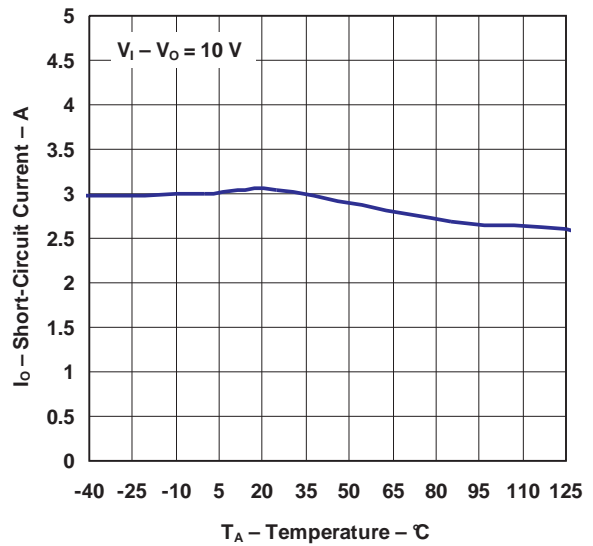
LOW-VOLTAGE BEHAVIOR
OUTPUT VOLTAGE
VS
INPUT VOLTAGE



OUTPUT AT VOLTAGE EXTREMES
OUTPUT VOLTAGE
VS
INPUT VOLTAGE

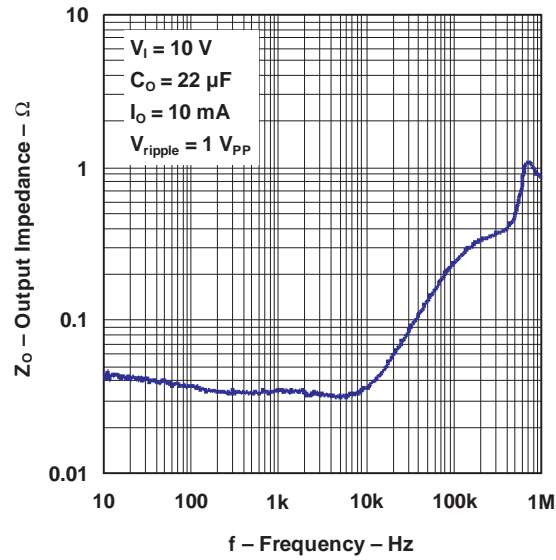


SHORT-CIRCUIT CURRENT
VS
TEMPERATURE



TYPICAL CHARACTERISTICS (continued)

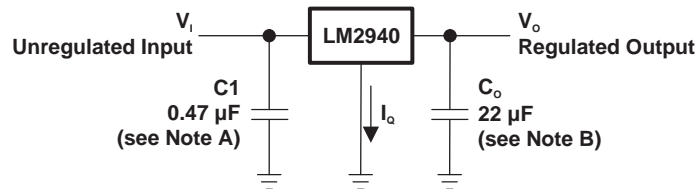
OUTPUT IMPEDANCE
VS
FREQUENCY



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 $22\ \mu\text{F}$ 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 $22\ \mu\text{F}$ (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.

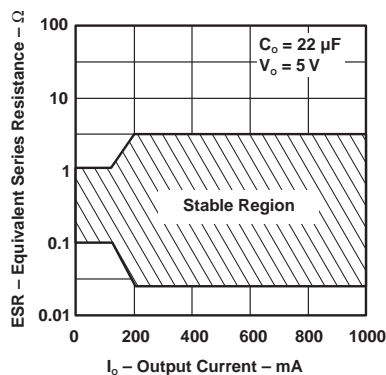


Figure 2. Output Capacitor ESR

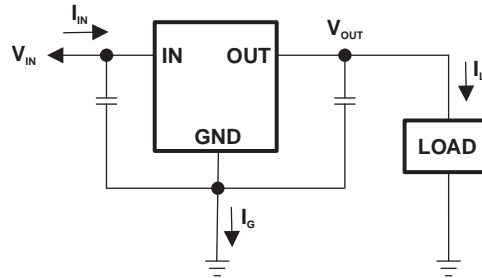
APPLICATION INFORMATION (continued)

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, $T_R(\text{max})$. This is calculated using the formula:

$$T_R(\text{max}) = T_J(\text{max}) - T_A(\text{max})$$

Where

$T_J(\text{max})$ is the maximum allowable junction temperature, which is 125°C for commercial parts.

$T_A(\text{max})$ is the maximum ambient temperature encountered in the application.

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

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

NOTE:

If the maximum allowable value for θ_{JA} is found to be $\geq 53^\circ\text{C/W}$ for the TO-220 package, $\geq 80^\circ\text{C/W}$ for the TO-263 package, or $\geq 174^\circ\text{C/W}$ 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 θ_{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 θ_{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, θ_{HA} , must be calculated:

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

Where

θ_{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 θ_{JC} for this calculation.

θ_{CH} is defined as the thermal resistance between the case and the surface of the heatsink. The value of θ_{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 θ_{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 θ_{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.

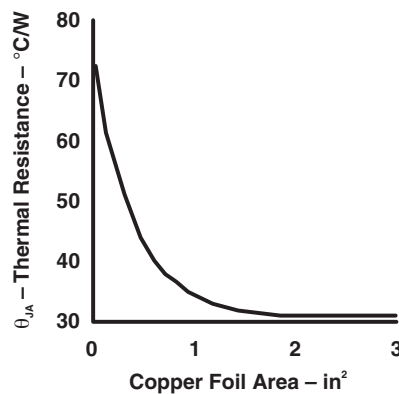


Figure 4. θ_{JA} vs Copper (1 oz) Area for TO-263 Package

As shown in Figure 4, increasing the copper area beyond 1 in² produces very little improvement. It should also be observed that the minimum value of θ_{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 θ_{JA} is 35°C/W and the maximum junction temperature is 125°C.

APPLICATION INFORMATION (continued)

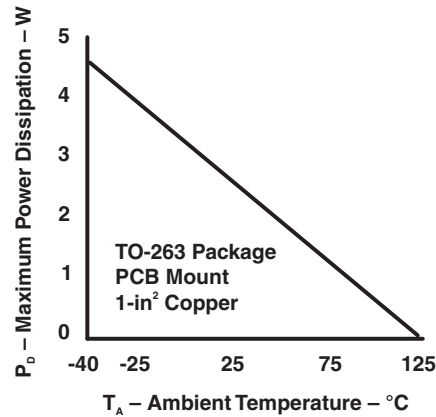


Figure 5. Maximum Power Dissipation vs Ambient Temperature for TO-263 Package

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

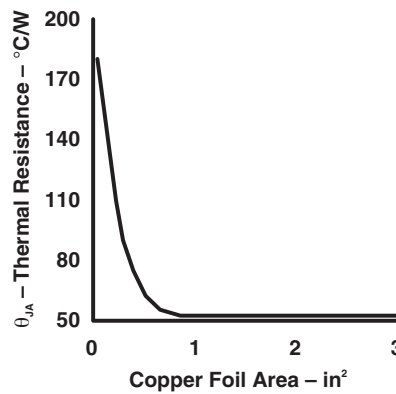


Figure 6. θ_{JA} vs Copper (2 oz) Area for SOT-223 Package

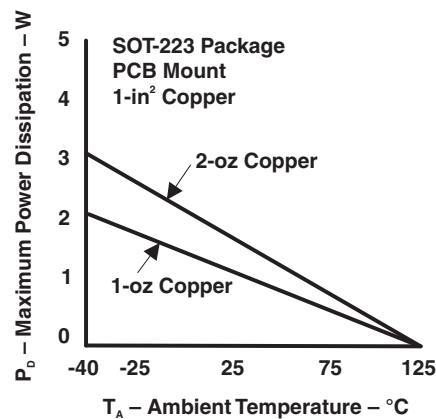


Figure 7. Maximum Power Dissipation vs Ambient Temperature for SOT-223 Package

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Mailing Address: Texas Instruments
Post Office Box 655303 Dallas, Texas 75265