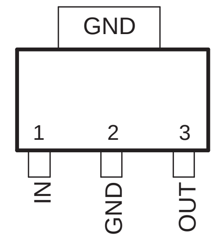
LM2940
1-A LOW-DROPOUT VOLTAGE REGULATOR

SLVS634 – MAY 2006

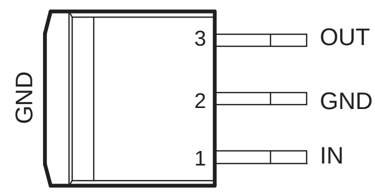
FEATURES

- 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)

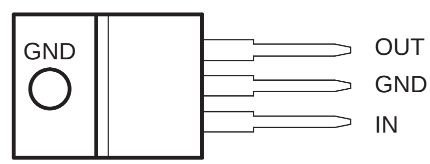
DCY (SOT-223) PACKAGE
(TOP VIEW)



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 ($V_I - V_O \leq 3$ V).

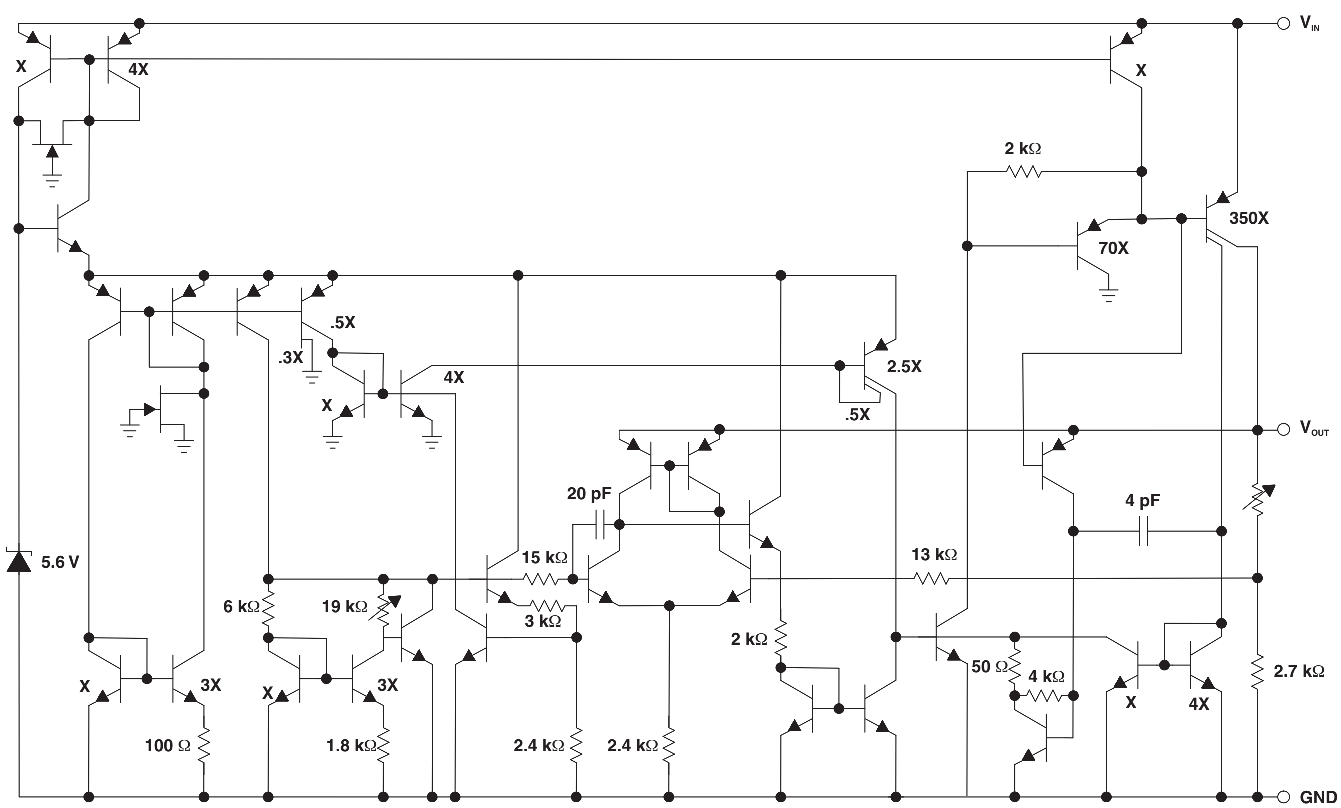
Also designed for vehicular applications, the LM2940 and all regulated circuitry are protected from reverse battery installations or two-battery jumps. During line transients, such as load dump when the input voltage can momentarily exceed the specified maximum operating voltage, the regulator automatically 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.

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 $P_D = (T_J(max) – T_A)/\theta_{JA}$. 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	

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 MIN	5 V TYP	5 V MAX	8 V MIN	8 V TYP	8 V MAX	UNIT
V_O	Output voltage	5 mA ≤ I_O ≤ 1 A, 5 V: 6.25 V ≤ V_I ≤ 26 V, 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, 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		µV_{rms}
	Ripple rejection	f_O = 120 Hz, 1 V_{rms}, 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/ 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, 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, 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

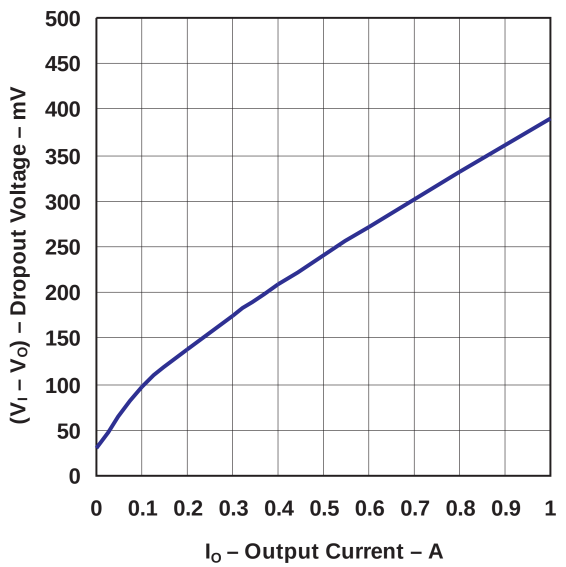
$V_I = V_O + 5$ V, $I_O = 1$ A, $C_O = 22$ µF (unless otherwise noted)

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		μV_{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			

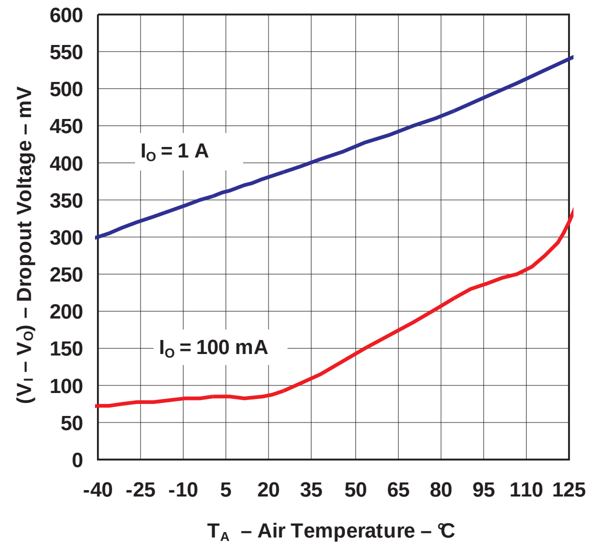
(1) Full range T_A is –40°C to 125°C for the LM2940I and 0°C to 125°C for the LM2940C.

TYPICAL CHARACTERISTICS

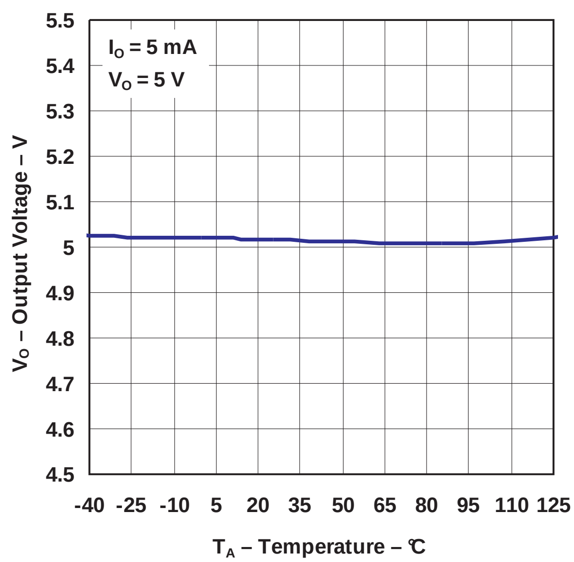
DROPOUT VOLTAGE vs OUTPUT CURRENT



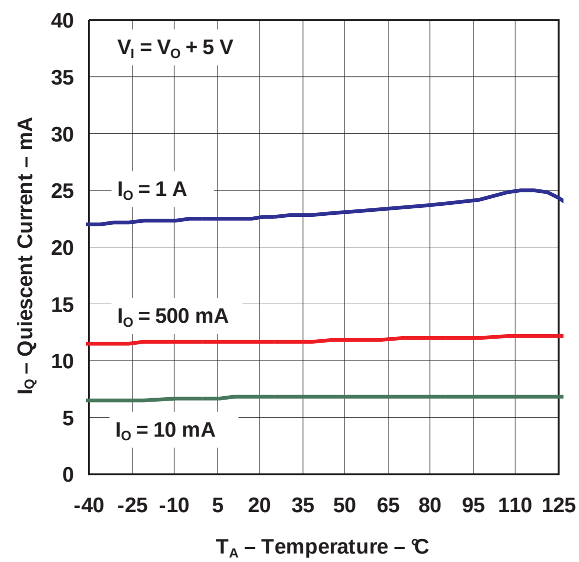
DROPOUT VOLTAGE vs TEMPERATURE



OUTPUT VOLTAGE vs TEMPERATURE

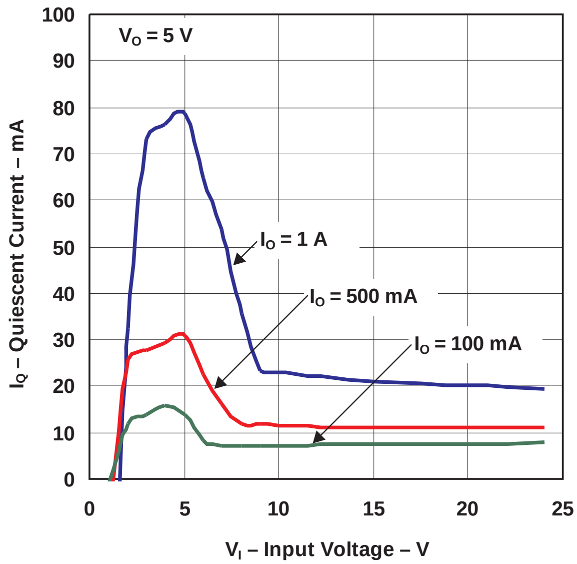


QUIESCENT CURRENT vs TEMPERATURE

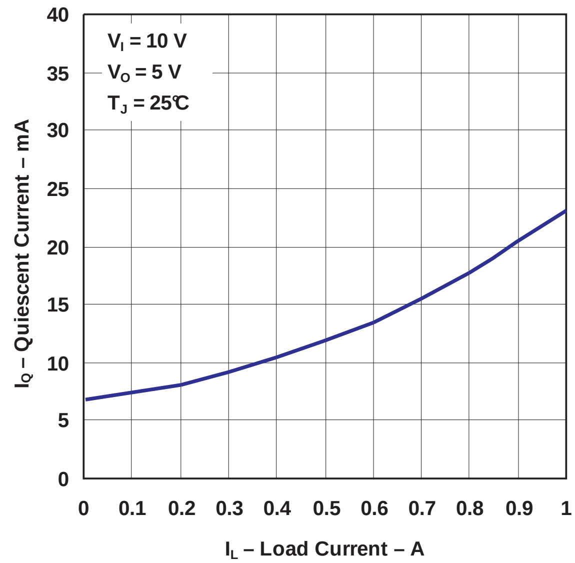


TYPICAL CHARACTERISTICS (continued)

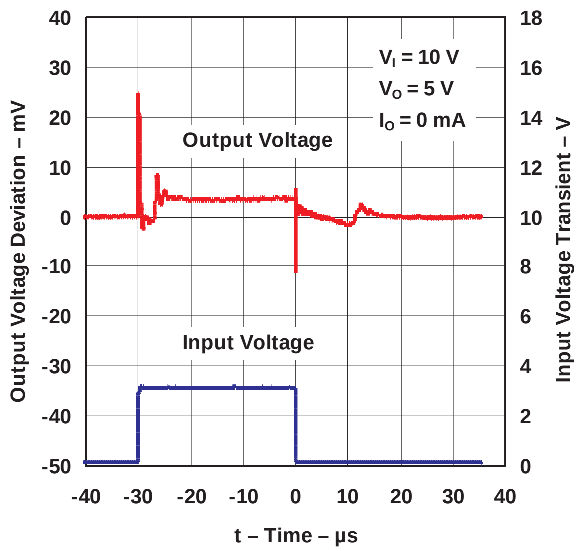
QUIESCENT CURRENT
vs
INPUT VOLTAGE



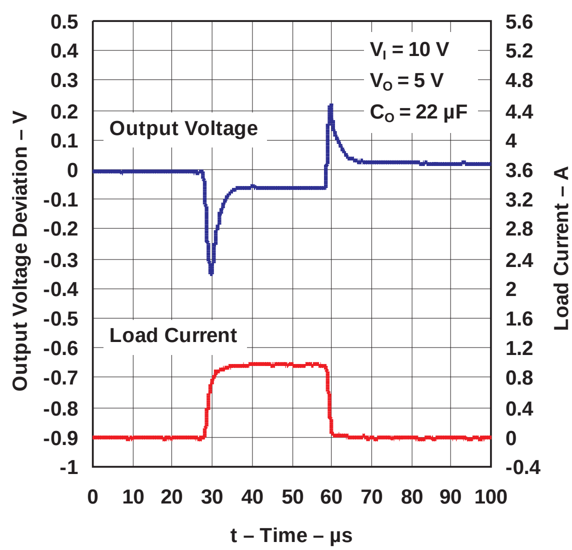
QUIESCENT CURRENT
vs
LOAD CURRENT



LINE TRANSIENT RESPONSE

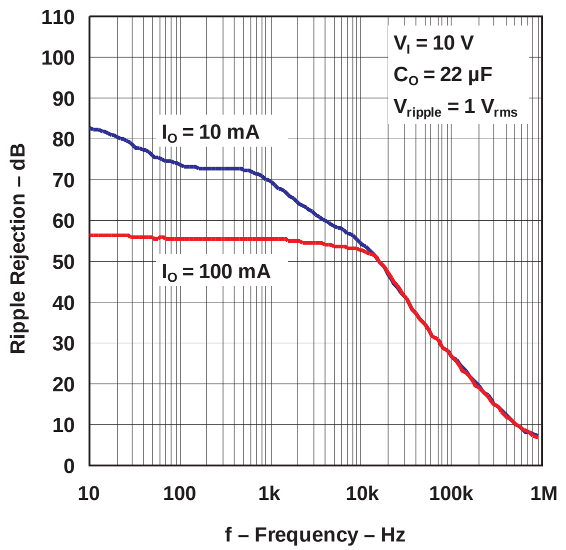


LOAD TRANSIENT RESPONSE

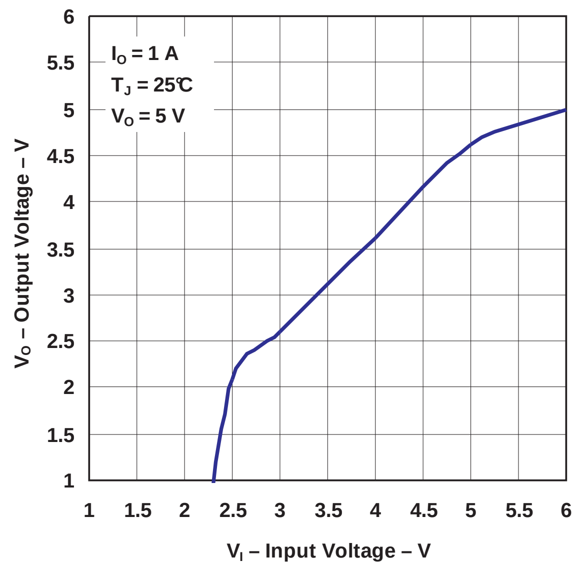


TYPICAL CHARACTERISTICS (continued)

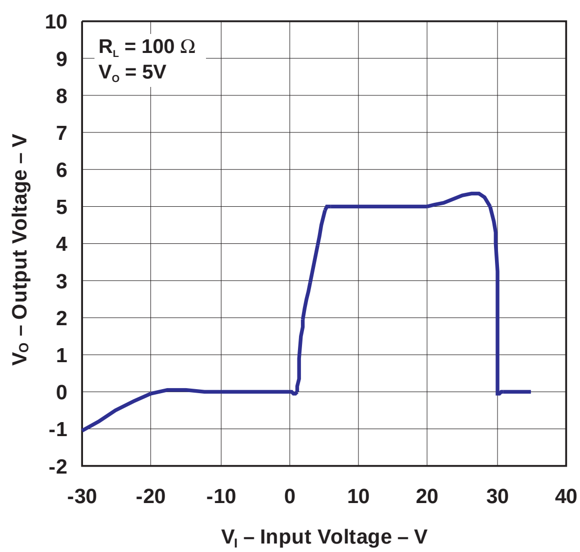
RIPPLE REJECTION
vs
FREQUENCY



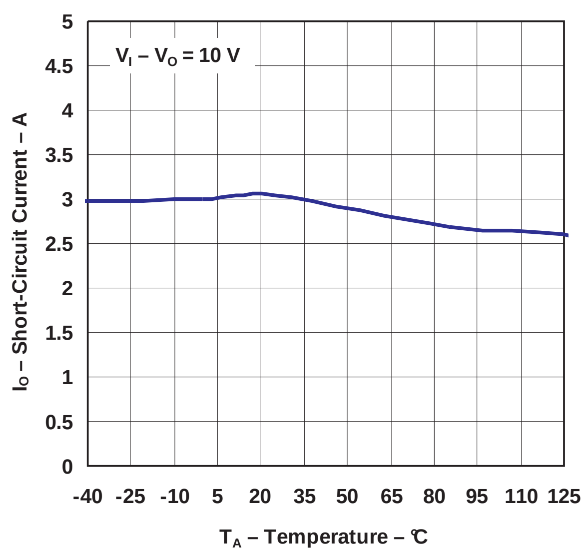
LOW-VOLTAGE BEHAVIOR
OUTPUT VOLTAGE
vs
INPUT VOLTAGE



OUTPUT AT VOLTAGE EXTREMES
OUTPUT VOLTAGE
vs
INPUT VOLTAGE

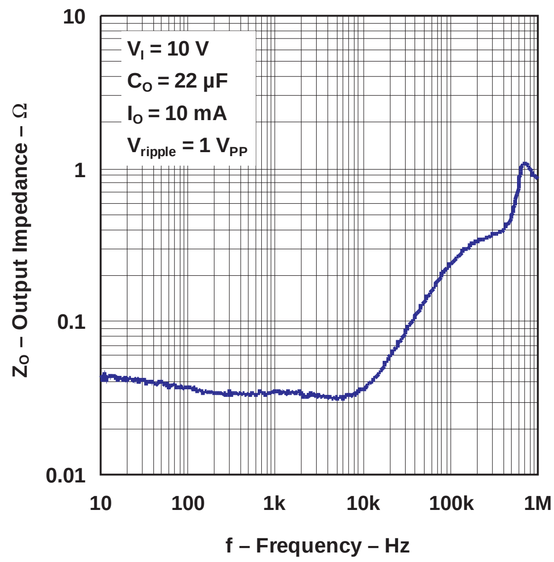


SHORT-CIRCUIT CURRENT
vs
TEMPERATURE



TYPICAL CHARACTERISTICS (continued)

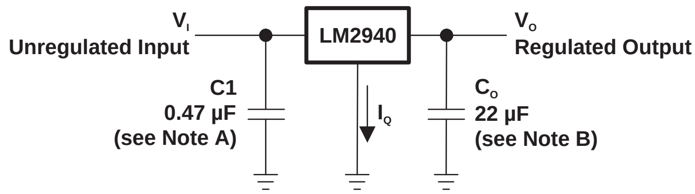
**OUTPUT IMPEDANCE
vs
FREQUENCY**



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.

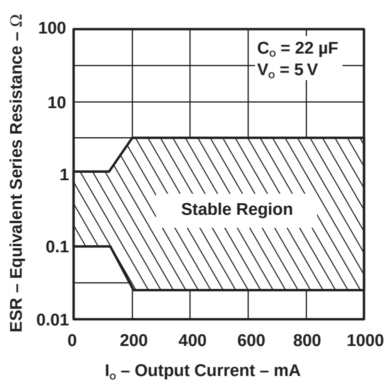


Figure 2. Output Capacitor ESR

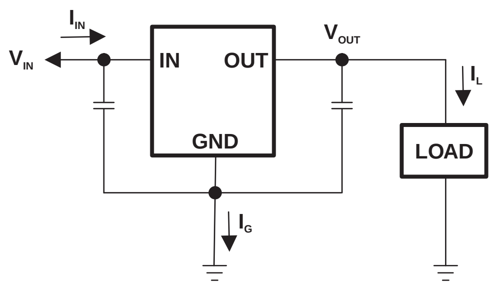
APPLICATION INFORMATION (continued)

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, θ_{JA}, now can be found:

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

NOTE:

If the maximum allowable value for θ_{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 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.

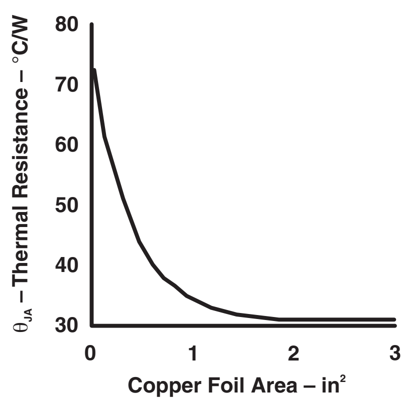


Figure 4. θ_{JA} vs Copper (1 oz) Area for TO-263 Package

As shown in Figure 4, increasing the copper area beyond 1 in^2 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)

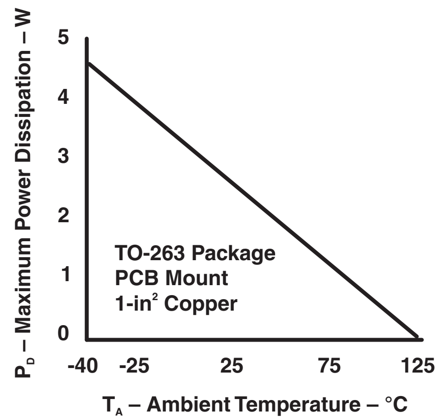


Figure 5. Maximum Power Dissipation vs Ambient Temperature for TO-263 Package

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.

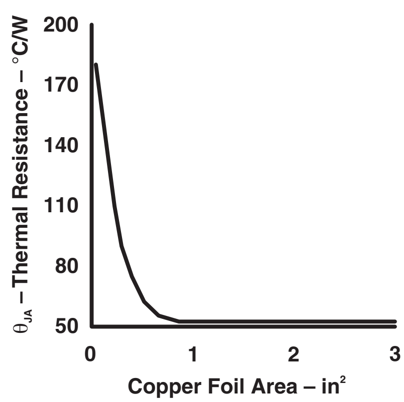


Figure 6. θ_{JA} vs Copper (2 oz) Area for SOT-223 Package

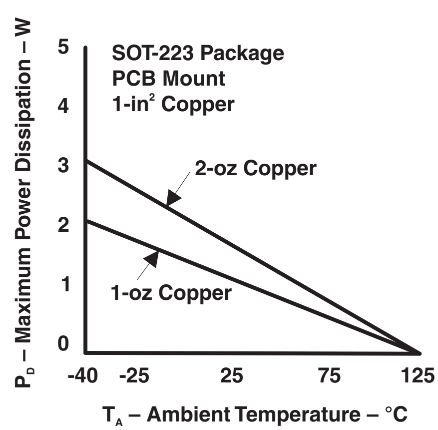


Figure 7. Maximum Power Dissipation vs Ambient Temperature for SOT-223 Package

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)
LM2940-50CKCSE3	ACTIVE	TO-220	KCS	3	50	Pb-Free (RoHS)	CU SN	N / A for Pkg Type
LM2940-50IKCSE3	ACTIVE	TO-220	KCS	3	50	Pb-Free (RoHS)	CU SN	N / A for Pkg Type

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

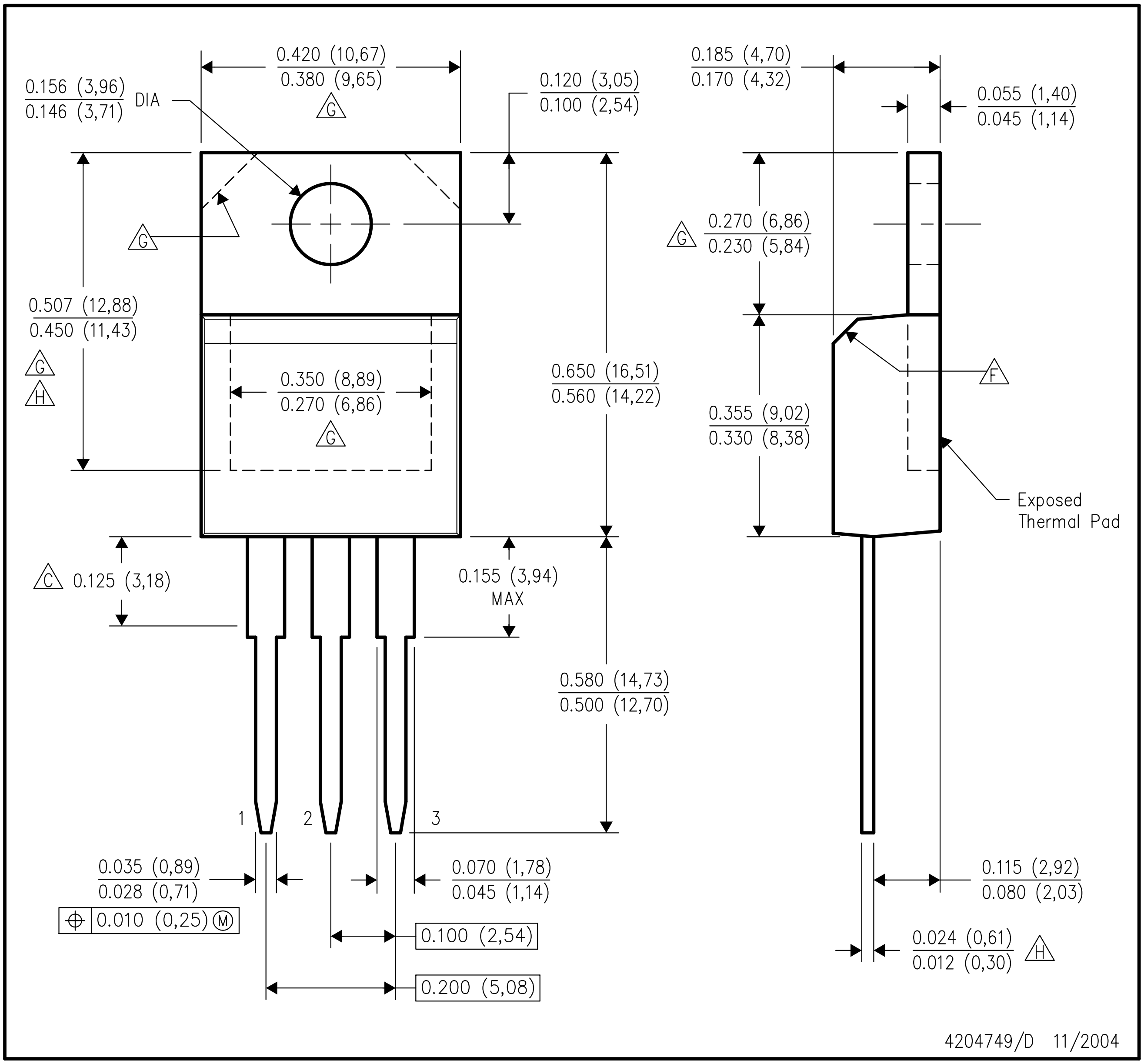
(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

KCS (R–PSFM–T3) PLASTIC FLANGE–MOUNT PACKAGE



NOTES:
- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. Lead dimensions are not controlled within this area.
- D. All lead dimensions apply before solder dip.
- E. The center lead is in electrical contact with the mounting tab.
- F. The chamfer is optional.
- G. Thermal pad contour optional within these dimensions.
- H. Falls within JEDEC TO–220 variation AB, except minimum lead thickness and minimum exposed pad length.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products		**Applications**	
Amplifiers	amplifier.ti.com	Audio	www.ti.com/audio
Data Converters	dataconverter.ti.com	Automotive	www.ti.com/automotive
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Logic	logic.ti.com	Military	www.ti.com/military
Power Mgmt	power.ti.com	Optical Networking	www.ti.com/opticalnetwork
Microcontrollers	microcontroller.ti.com	Security	www.ti.com/security
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