National Semiconductor

June 1994

LM2940/LM2940C 1A Low Dropout Regulator

General Description

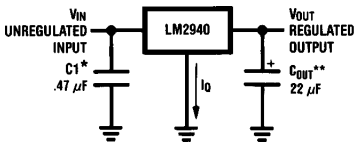
The LM2940/LM2940C positive voltage regulator features the ability to source 1A of output current with a dropout voltage of typically 0.5V and a maximum of 1V over the entire temperature range. Furthermore, a quiescent current reduction circuit has been included which reduces the ground current when the differential between the input voltage and the output voltage exceeds approximately 3V. The quiescent current with 1A of output current and an input-output differential of 5V is therefore only 30 mA. Higher quiescent currents only exist when the regulator is in the dropout mode ($V_{IN} - V_{OUT} \leq 3V$).

Designed also for vehicular applications, the LM2940/LM2940C and all regulated circuitry are protected from reverse battery installations or 2-battery jumps. During line transients, such as load dump when the input voltage can momentarily exceed the specified maximum operating voltage, the regulator will automatically shut down to protect both the internal circuits and the load. The LM2940/LM2940C cannot be harmed by temporary mirror-image insertion. Familiar regulator features such as short circuit and thermal overload protection are also provided.

Features

- Dropout voltage typically 0.5V @I_O = 1A
- Output current in excess of 1A
- Output voltage trimmed before assembly
- Reverse battery protection
- Internal short circuit current limit
- Mirror image insertion protection
- P+ Product Enhancement tested

Typical Application



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

**C_{OUT} 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 the ESR is critical; see curve.

Ordering Information

Temperature Range	Output Voltage						Package
	5.0	8.0	9.0	10	12	15	
$0°C \leq T_A \leq 125°C$	LM2940CT-5.0		LM2940CT-9.0		LM2940CT-12	LM2940CT-15	TO-220
	LM2940CS-5.0		LM2940CS-9.0		LM2940CS-12	LM2940CS-15	TO-263
$-40°C \leq T_A \leq 125°C$	LM2940T-5.0	LM2940T-8.0	LM2940T-9.0	LM2940T-10	LM2940T-12		TO-220
	LM2940S-5.0	LM2940S-8.0	LM2940S-9.0	LM2940S-10	LM2940S-12		TO-263
$-55°C \leq T_A \leq 125°C$	LM2940K-5.0/883	LM2940K-8.0/883			LM2940K-12/883	LM2940K-15/883	TO-3

RRD-B30M75/Printed in U. S. A.

Absolute Maximum Ratings (Note 1)

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

LM2940S, T ≤ 100 ms	60V
LM2940T, T ≤ 100 ms	60V
LM2940K/883, T ≤ 20 ms	40V
LM2940CT, T ≤ 1 ms	45V
LM2940CS, T ≤ 1 ms	45V
Internal Power Dissipation (Note 3)	Internally Limited
Maximum Junction Temperature	150°C
Storage Temperature Range	$-65°C \le T_J \le +150°C$
Lead Temperature (Soldering, 10 seconds)	
TO-3 (K) Package	300°C
TO-220 (T) Package	260°C
TO-263 (S) Package	260°C
ESD Susceptibility (Note 4)	2 kV

Operating Conditions (Note 1)

Input Voltage	26V
Temperature Range	
LM2940K/883	$-55°C \le T_A \le 125°C$
LM2940T, LM2940S	$-40°C \le T_A \le 125°C$
LM2940CT, LM2940CS	$0°C \le T_A \le 125°C$

Electrical Characteristics

$V_{IN} = V_O + 5V$, $I_O = 1A$, $C_O = 22\ \mu F$, unless otherwise specified. **Boldface limits apply over the entire operating temperature range of the indicated device.** All other specifications apply for $T_A = T_J = 25°C$

Output Voltage (V_O)		5V			8V			Units
Parameter	**Conditions**	**Typ**	**LM2940 Limit (Note 5)**	**LM2940/883 Limit (Note 6)**	**Typ**	**LM2940 Limit (Note 5)**	**LM2940/883 Limit (Note 6)**	
		$6.25V \le V_{IN} \le 26V$			**$9.4V \le V_{IN} \le 26V$**			
Output Voltage	$5\ mA \le I_O \le 1A$	5.00	4.85/**4.75** 5.15/**5.25**	4.85/**4.75** 5.15/**5.25**	8.00	7.76/**7.60** 8.24/**8.40**	7.76/**7.60** 8.24/**8.40**	V_{MIN} V_{MAX}
Line Regulation	$V_O + 2V \le V_{IN} \le 26V$, $I_O = 5\ mA$	20	50	40/**50**	20	80	50/**80**	mV_{MAX}
Load Regulation	$50\ mA \le I_O \le 1A$ LM2940, LM2940/883 LM2940C	 35 35	 50/**80** 50	 50/**100**	 55 55	 80/**130** 80	 80/**130**	mV_{MAX}
Output Impedance	100 mADC and 20 mArms, $f_O = 120\ Hz$	35		1000/**1000**	55		1000/**1000**	mΩ
Quiescent Current	$V_O + 2V \le V_{IN} \le 26V$, $I_O = 5\ mA$ LM2940, LM2940/883 LM2940C	 10 10	 15/**20** 15	 15/**20**	 10	 15/**20**	 15/**20**	mA_{MAX}
	$V_{IN} = V_O + 5V$, $I_O = 1A$	30	45/**60**	50/**60**	30	45/**60**	50/**60**	mA_{MAX}
Output Noise Voltage	10 Hz − 100 kHz, $I_O = 5\ mA$	150		700/**700**	240		1000/**1000**	μV_{rms}
Ripple Rejection	$f_O = 120\ Hz$, $1\ V_{rms}$, $I_O = 100\ mA$ LM2940 LM2940C	 72 72	 60/**54** 60		 66 66	 54/**48** 54		dB_{MIN}
	$f_O = 1\ kHz$, $1\ V_{rms}$, $I_O = 5\ mA$			60/**50**			54/**48**	dB_{MIN}
Long Term Stability		20			32			mV/ 1000 Hr
Dropout Voltage	$I_O = 1A$	0.5	0.8/**1.0**	0.7/**1.0**	0.5	0.8/**1.0**	0.7/**1.0**	V_{MAX}
	$I_O = 100\ mA$	110	150/**200**	150/**200**	110	150/**200**	150/**200**	mV_{MAX}

Electrical Characteristics $V_{IN} = V_O + 5V$, $I_O = 1A$, $C_O = 22\ \mu F$, unless otherwise specified. **Boldface limits apply over the entire operating temperature range of the indicated device.** All other specifications apply for $T_A = T_J = 25°C$ (Continued)

Output Voltage (V_O)		5V			8V			Units
Parameter	**Conditions**	**Typ**	**LM2940 Limit (Note 5)**	**LM2940/883 Limit (Note 6)**	**Typ**	**LM2940 Limit (Note 5)**	**LM2940/883 Limit (Note 6)**	
Short Circuit Current	(Note 7)	1.9	1.6	1.5/**1.3**	1.9	1.6	1.6/**1.3**	A_{MIN}
Maximum Line Transient	$R_O = 100\Omega$ LM2940, T ≤ 100 ms LM2940/883, T ≤ 20 ms LM2940C, T ≤ 1 ms	75 55	60/**60** 45	40/**40**	75 55	60/**60** 45	40/**40**	V_{MIN}
Reverse Polarity DC Input Voltage	$R_O = 100\Omega$ LM2940, LM2940/883 LM2940C	−30 −30	−15/−**15** −15	−15/−**15**	−30 −30	−15/−**15** −15	−15/−**15**	V_{MIN}
Reverse Polarity Transient Input Voltage	$R_O = 100\Omega$ LM2940, T ≤ 100 ms LM2940/883, T ≤ 20 ms LM2940C, T ≤ 1 ms	−75 −55	−50/−**50** −45/−**45**	−45/−**45**	−75	−50/−**50**	−45/−**45**	V_{MIN}

Electrical Characteristics

$V_{IN} = V_O + 5V$, $I_O = 1A$, $C_O = 22\ \mu F$, unless otherwise specified. **Boldface limits apply over the entire operating temperature range of the indicated device.** All other specifications apply for $T_A = T_J = 25°C$ (Continued)

Output Voltage (V_O)		9V		10V		Units
Parameter	**Conditions**	**Typ**	**LM2940 Limit (Note 5)**	**Typ**	**LM2940 Limit (Note 5)**	
		10.5V ≤ V_{IN} ≤ 26V		**11.5V ≤ V_{IN} ≤ 26V**		
Output Voltage	5 mA ≤ I_O ≤ 1A	9.00	8.73/**8.55** 9.27/**9.45**	10.00	9.70/**9.50** 10.30/**10.50**	V_{MIN} V_{MAX}
Line Regulation	$V_O + 2V \le V_{IN} \le 26V$, $I_O = 5$ mA	20	90	20	100	mV_{MAX}
Load Regulation	50 mA ≤ I_O ≤ 1A LM2940 LM2940C	 60 60	 90/**150** 90	65	100/**165**	mV_{MAX}
Output Impedance	100 mADC and 20 mArms, f_O = 120 Hz	60		65		mΩ
Quiescent Current	$V_O + 2V \le V_{IN} < 26V$, $I_O = 5$ mA LM2940 LM2940C	 10 10	 15/**20** 15	10	15/**20**	mA_{MAX}
	$V_{IN} = V_O + 5V$, $I_O = 1A$	30	45/**60**	30	45/**60**	mA_{MAX}
Output Noise Voltage	10 Hz − 100 kHz, $I_O = 5$ mA	270		300		μV_{rms}
Ripple Rejection	f_O = 120 Hz, 1 V_{rms}, $I_O = 100$ mA LM2940 LM2940C	 64 64	 52/**46** 52	63	51/**45**	dB_{MIN}
Long Term Stability		34		36		mV/ 1000 Hr
Dropout Voltage	$I_O = 1A$	0.5	0.8/**1.0**	0.5	0.8/**1.0**	V_{MAX}
	$I_O = 100$ mA	110	150/**200**	110	150/**200**	mV_{MAX}
Short Circuit Current	(Note 7)	1.9	1.6	1.9	1.6	A_{MIN}
Maximum Line Transient	$R_O = 100\Omega$ T ≤ 100 ms LM2940 LM2940C	 75 55	 60/**60** 45	75	60/**60**	V_{MIN}
Reverse Polarity DC Input Voltage	$R_O = 100\Omega$ LM2940 LM2940C	 −30 −30	 −15/−**15** −15	−30	−15/−**15**	V_{MIN}
Reverse Polarity Transient Input Voltage	$R_O = 100\Omega$ T ≤ 100 ms LM2940 LM2940C	 −75 −55	 −50/−**50** −45/−**45**	−75	−50/−**50**	V_{MIN}

Electrical Characteristics

$V_{IN} = V_O + 5V$, $I_O = 1A$, $C_O = 22\ \mu F$, unless otherwise specified. **Boldface limits apply over the entire operating temperature range of the indicated device.** All other specifications apply for $T_A = T_J = 25°C$ (Continued)

Output Voltage (V_O)		12V			15V			Units
Parameter	**Conditions**	**Typ**	**LM2940 Limit (Note 5)**	**LM2940/833 Limit (Note 6)**	**Typ**	**LM2940 Limit (Note 5)**	**LM2940/833 Limit (Note 6)**	
		13.6V ≤ V_{IN} ≤ 26V			**16.75V ≤ V_{IN} ≤ 26V**			
Output Voltage	5 mA ≤ I_O ≤1A	12.00	11.64/**11.40** 12.36/**12.60**	11.64/**11.40** 12.36/**12.60**	15.00	14.55/**14.25** 15.45/**15.75**	14.55/**14.25** 15.45/**15.75**	V_{MIN} V_{MAX}
Line Regulation	$V_O + 2V \le V_{IN} \le 26V$, $I_O = 5$ mA	20	120	75/**120**	20	150	95/**150**	mV_{MAX}
Load Regulation	50 mA ≤ I_O ≤ 1A LM2940, LM2940/883 LM2940C	 55 55	 120/**200** 120	 120/**190**	 70	 150	 150/**240**	mV_{MAX}
Output Impedance	100 mADC and 20 mArms, f_O = 120 Hz	80		1000/**1000**	100		1000/**1000**	mΩ
Quiescent Current	$V_O + 2V \le V_{IN} \le 26V$, $I_O = 5$ mA LM2940, LM2940/883 LM2940C	 10 10	 15/**20** 15	 15/**20**	 10	 15	 15/**20**	mA_{MAX}
	$V_{IN} = V_O + 5V$, $I_O = 1A$	30	45/**60**	50/**60**	30	45/**60**	50/**60**	mA_{MAX}
Output Noise Voltage	10 Hz − 100 kHz, $I_O = 5$ mA	360		1000/**1000**	450		1000/**1000**	μV_{rms}
Ripple Rejection	f_O = 120 Hz, 1 V_{rms}, I_O = 100 mA LM2940 LM2940C	 66 66	 54/**48** 54		 64	 52		dB_{MIN}
	f_O = 1 kHz, 1 V_{rms}, $I_O = 5$ mA			52/**46**			48/**42**	dB_{MIN}
Long Term Stability		48			60			mV/ 1000 Hr
Dropout Voltage	I_O = 1A	0.5	0.8/**1.0**	0.7/**1.0**	0.5	0.8/**1.0**	0.7/**1.0**	V_{MAX}
	I_O = 100 mA	110	150/**200**	150/**200**	110	150/**200**	150/**200**	mV_{MAX}
Short Circuit Current	(Note 7)	1.9	1.6	1.6/**1.3**	1.9	1.6	1.6/**1.3**	A_{MIN}
Maximum Line Transient	R_O = 100Ω LM2940, T ≤ 100 ms LM2940/883, T ≤ 20 ms LM2940C, T ≤ 1 ms	 75 55	 60/**60** 45	 40/**40**	 55	 45	 40/**40**	V_{MIN}
Reverse Polarity DC Input Voltage	R_O = 100Ω LM2940, LM2940/883 LM2940C	 −30 −30	 −15/−**15** −15	 −15/−**15**	 −30	 −15	 −15/−**15**	V_{MIN}
Reverse Polarity Transient Input Voltage	R_O = 100Ω LM2940, T ≤ 100 ms LM2940/883, T ≤ 20 ms LM2940C, T ≤ 1 ms	 −75 −55	 −50/−**50** −45/−**45**	 −45/−**45**	 −55	 −45/−**45**	 −45/−**45**	V_{MIN}

Note 1: Absolute Maximum Ratings are limits beyond which damage to the device may occur. Operating Conditions are conditions under which the device functions but the specifications might not be guaranteed. For guaranteed specifications and test conditions see the Electrical Characteristics.

Note 2: Military specifications complied with RETS/SMD at the time of printing. For current specifications refer to RETS LM2940K-5.0, LM2940K-8.0, LM2940K-12, and LM2940K-15. SMD numbers are 5962-8958701YA(5V), 5962-9083301YA(8V), 5962-9088401YA(12V), and 5962-9088501YA(15V).

Note 3: The maximum power dissipation is a function of the maximum junction temperature, $T_J = 150°C$, the junction-to-ambient thermal resistance, θ_{JA}, and the ambient temperature, T_A. The maximum allowable power dissipation at any ambient temperature is $P_{DMAX} = (150 - T_A)/\theta_{JA}$. If this dissipation is exceeded, the die temperature will rise above 150°C and the LM2940 will go into thermal shutdown. For the LM2940T and LM2940CT, the junction-to-ambient thermal resistance (θ_{JA}) is 53°C/W. When using a heatsink, θ_{JA} is the sum of the 3°C/W junction-to-case thermal resistance (θ_{JC}) of the LM2940T or LM2940CT and the case-to-ambient thermal resistance of the heatsink. If the TO-263 package is used, the thermal resistance can be used by increasing the P.C. board copper area thermally connected to the package. Using 0.5 square inches of copper area, θ_{JA} is 50°C/W; with 1 square inch of copper area, θ_{JA} is 37°C/W; and with 1.6 or more square inches of copper area , θ_{JA} is 32°C/W. For the LM2940K, θ_{JA} is 39°C/W and θ_{JC} is 4°C/W.

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

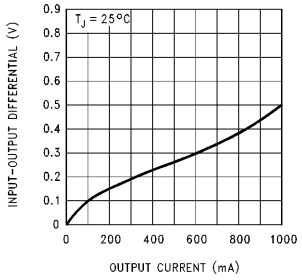
Note 5: All limits are guaranteed at $T_A = T_J = 25°C$ only (standard typeface) or over the entire operating temperature range of the indicated device (**boldface type**). All limits at $T_A = T_J = 25°C$ are 100% production tested. All limits at temperature extremes are guaranteed via correlation using standard Statistical Quality Control methods.

Note 6: All limits are guaranteed at $T_A = T_J = 25°C$ only (standard typeface) or over the entire operating temperature range of the indicated device (**boldface type**). All limits are 100% production tested and are used to calculate Outgoing Quality Levels.

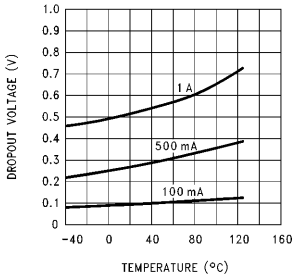
Note 7: Output current will decrease with increasing temperature but will not drop below 1A at the maximum specified temperature.

Typical Performance Characteristics

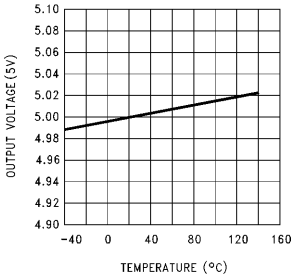
Dropout Voltage



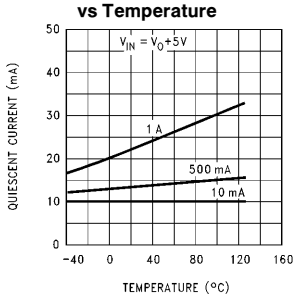
Dropout Voltage vs Temperature



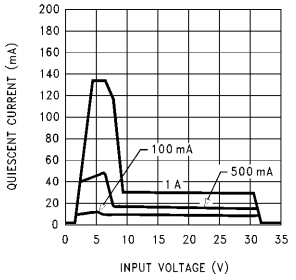
Output Voltage vs Temperature



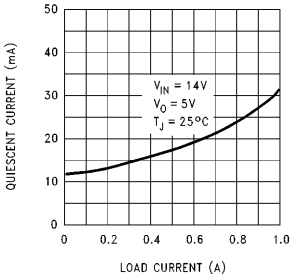
Quiescent Current vs Temperature



Quiescent Current



Quiescent Current



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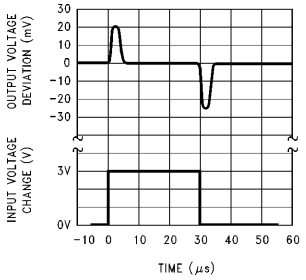
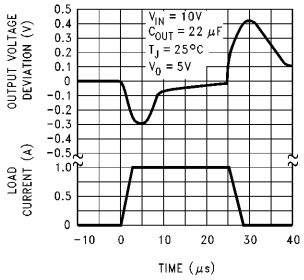
Typical Performance Characteristics (Continued)

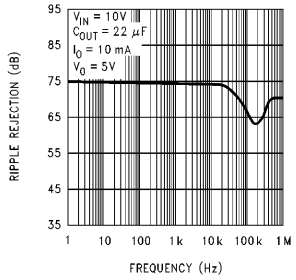
Line Transient Response



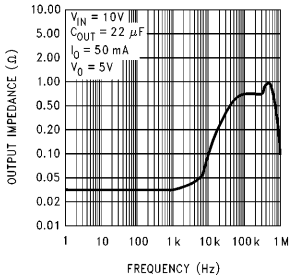
Load Transient Response



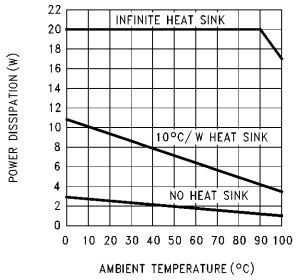
Ripple Rejection



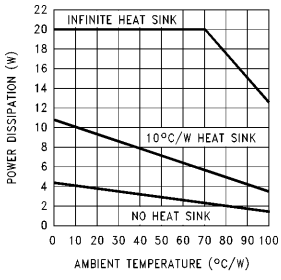
Output Impedance



Maximum Power Dissipation (TO-220)



Maximum Power Dissipation (TO-3)



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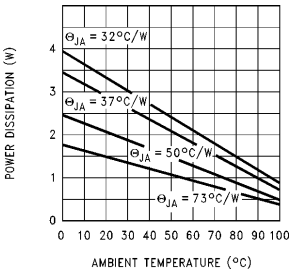
Maximum Power Dissipation (TO-263) (See Note 3)



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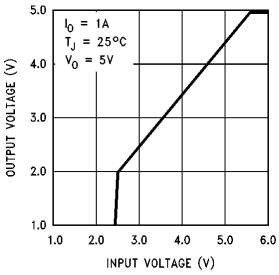
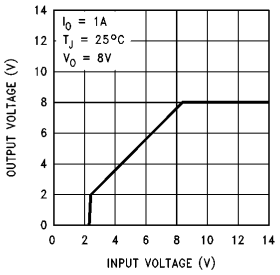
Typical Performance Characteristics (Continued)

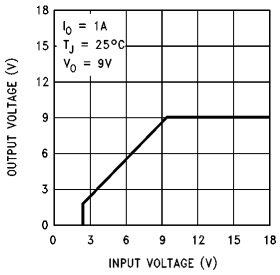
Low Voltage Behavior



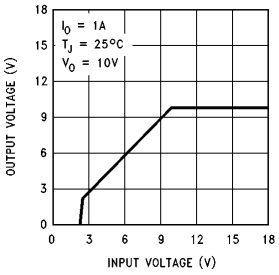
Low Voltage Behavior



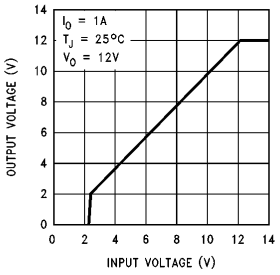
Low Voltage Behavior



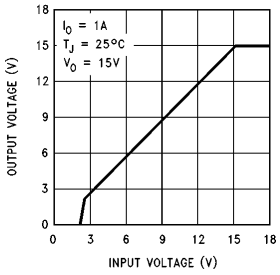
Low Voltage Behavior



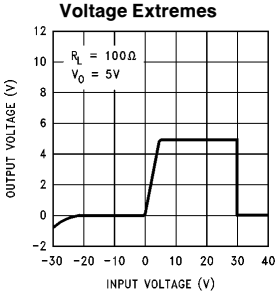
Low Voltage Behavior



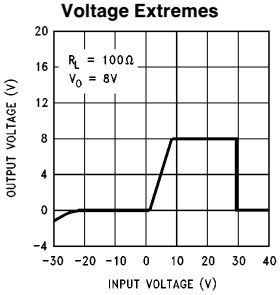
Low Voltage Behavior



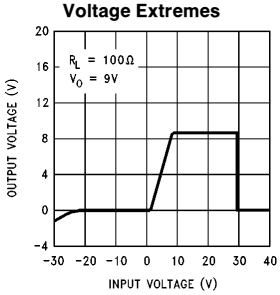
Output at Voltage Extremes



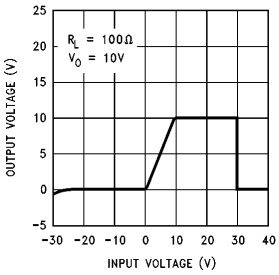
Output at Voltage Extremes



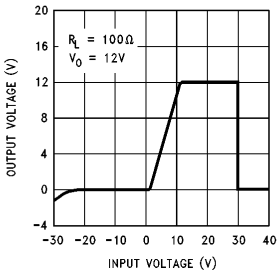
Output at Voltage Extremes



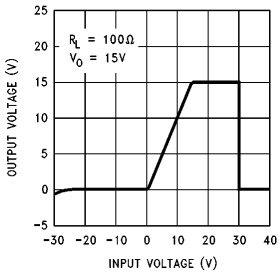
Output at Voltage Extremes



Output at Voltage Extremes



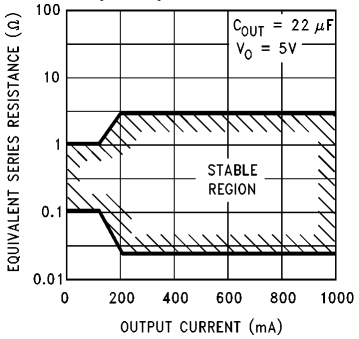
Output at Voltage Extremes



TL/H/8822–5

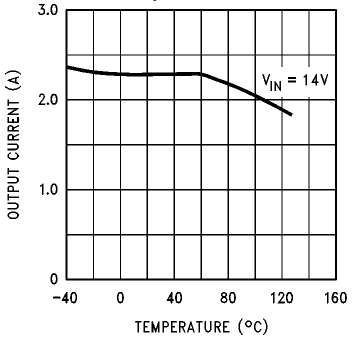
Typical Performance Characteristics (Continued)

Output Capacitor ESR



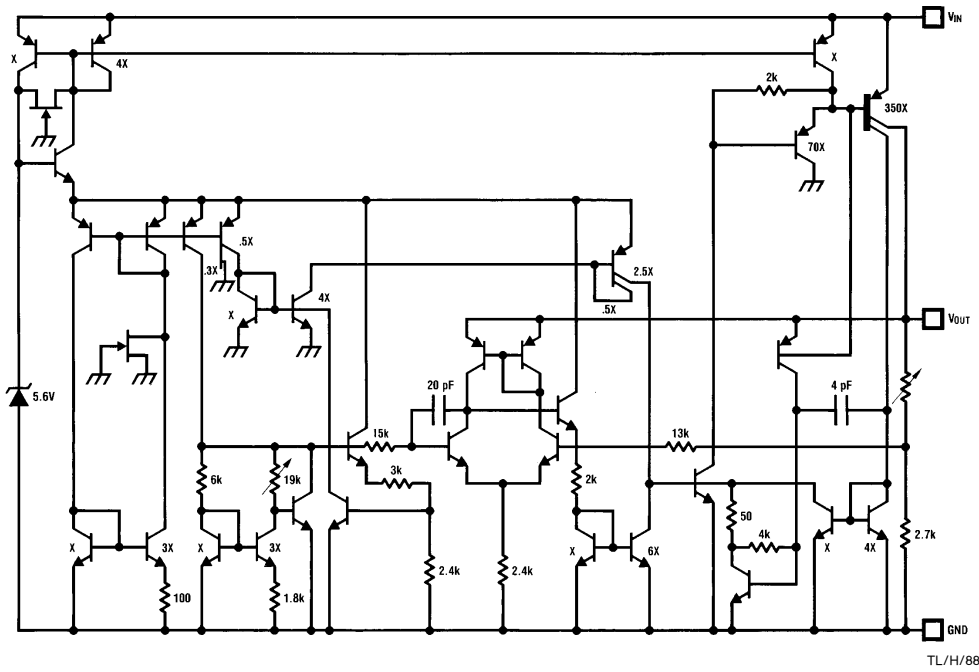
TL/H/8822–6

Peak Output Current



TL/H/8822–8

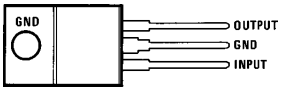
Equivalent Schematic Diagram



TL/H/8822–1

Connection Diagrams

(TO-220) Plastic Package

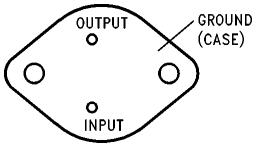


TL/H/8822–2

Front View

Order Number LM2940CT-5.0, LM2940CT-9.0, LM2940CT-12, LM2940CT-15, LM2940T-5.0, LM2940T-8.0, LM2940T-9.0, LM2940T-10 or LM2940T-12
See NS Package Number TO3B

TO-3 Metal Can Package (K)



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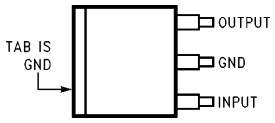
Bottom View
Order Number LM2940K-5.0/883, LM2940K-8.0/883, LM2940K-12/883, LM2940K-15/883
See NS Package Number K02A

(TO-263) Surface-Mount Package



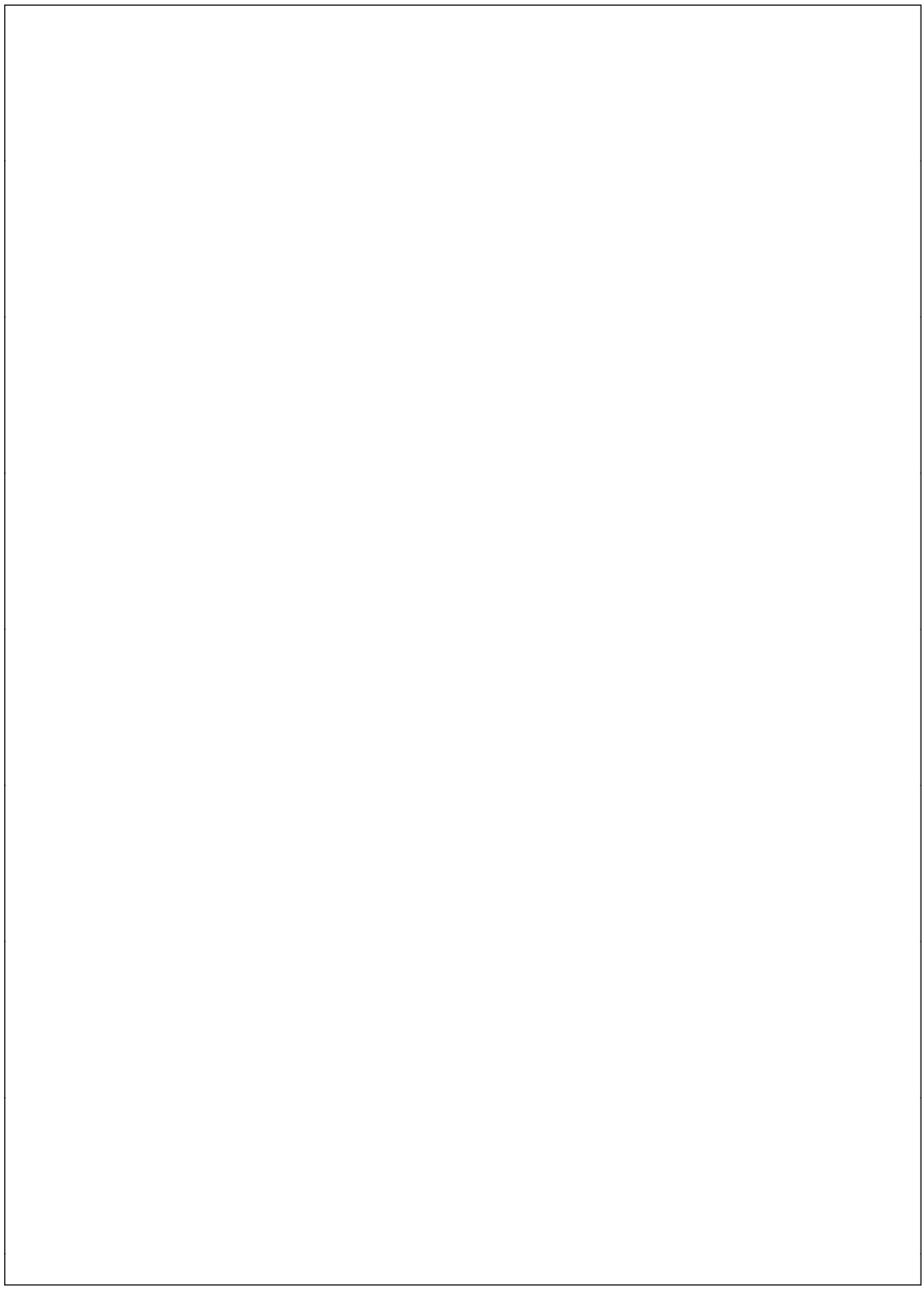
TL/H/8822–11

Top View

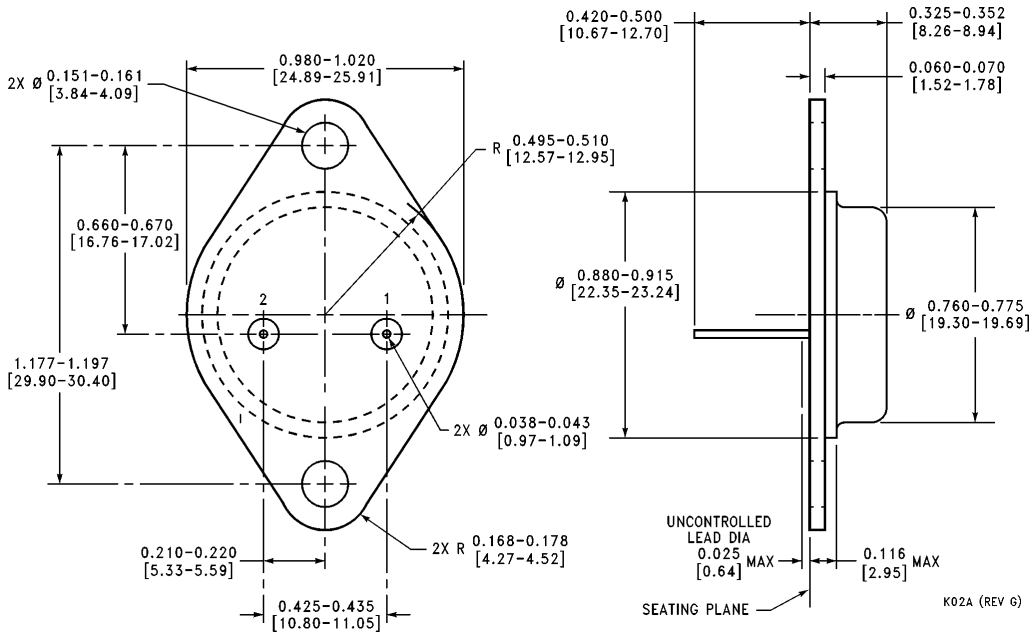
TL/H/8822–12

Side View

Order Number LM2940CS-5.0, LM2940CS-9.0, LM2940CS-12, LM2940CS-15, LM2940S-5.0, LM2940S-8.0, LM2940S-9.0, LM2940S-10 or LM2940S-12
See NS Package Number TS3B

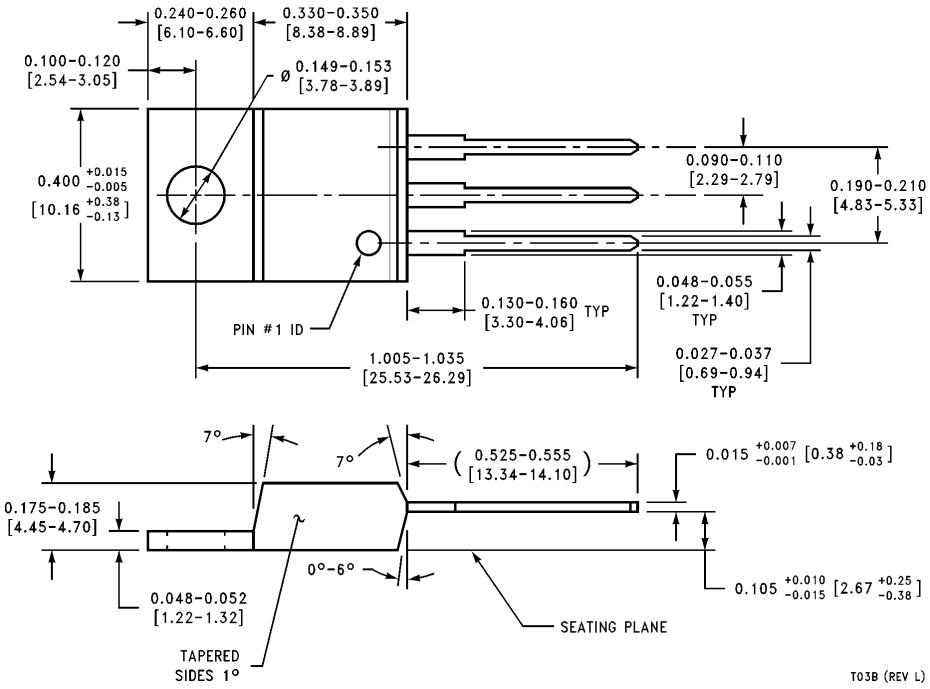


Physical Dimensions inches (millimeters)



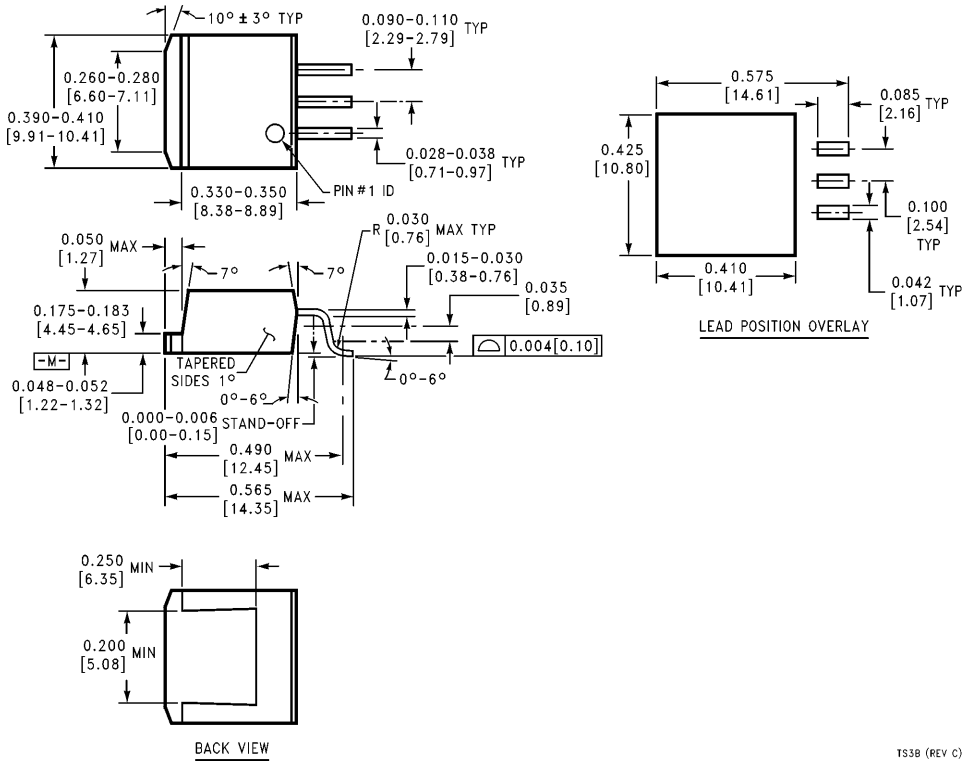
2 Lead TO-3 Metal Can Package (K)
Order Number LM2940K-5.0/883,
LM2940K-8.0/883, LM2940K-12/883, LM2940K-15/883
NS Package Number K02A

Physical Dimensions inches (millimeters) (Continued)



3-Lead TO-220 Plastic Package (T)
Order Number LM2940T-5.0, LM2940T-8.0,
LM2940T-9.0, LM2940T-10, LM2940T-12, LM2940CT-5.0,
LM2940CT-12 or LM2940CT-15
NS Package Number TO3B

Physical Dimensions inches (millimeters) (Continued)



3-Lead TO-263 Surface Mount Package
Order Number LM2940S-5.0, LM2940S-8.0,
LM2940S-9.0, LM2940S-10, LM2940S-12,
LM2940CS-5.0, LM2940CS-12 or LM2940CS-15
NS Package Number TS3B

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