June 1999

National Semiconductor

LM2940/LM2940C
1A Low Dropout Regulator

General Description

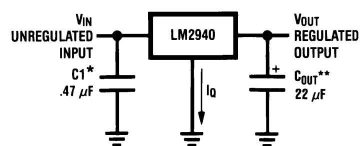
The LM2940/LM2940C positive voltage regulator features the ability to source 1A of output current with a dropout voltage of typically 0.5V and a maximum of 1V over the entire temperature range. Furthermore, a quiescent current reduction circuit has been included which reduces the ground current when 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 ≤ T_A ≤ 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 ≤ T_A ≤ 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
−40˚C ≤ T_A ≤ 85˚C	LM2940IMP-5.0	LM2940IMP-8.0	LM2940IMP-9.0	LM2940IMP-10	LM2940IMP-12	LM2940IMP-15	SOT-223
SOT-223 Package Marking	L53B	L54B	L0EB	L55B	L56B	L70B	

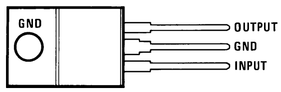
The physical size of the SOT-223 is too small to contain the full device part number. The package markings indicated are what will appear on the actual device.

Temperature Range	Output Voltage				Package
	5.0	8.0	12	15	
−55˚C ≤ T_A ≤ 125˚C	LM2940J-5.0/883 5962-8958701EA	LM2940J-8.0/883 5962-9088301QEA	LM2940J-12/883 5962-9088401QEA	LM2940J-15/883 5962-9088501QEA	J16A
	LM2940WG5.0/883 5962-8958701XA				WG16A

For information on military temperature range products, please go to the Mil/Aero Web Site at http://www.national.com/appinfo/milaero/index.html.

Connection Diagrams

(TO-220) Plastic Package



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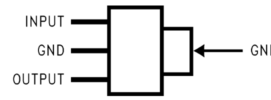
Front View
Order Number LM2940CT-5.0, LM2940CT-9.0, LM2940CT-12, LM2940CT-15, LM2940T-5.0, LM2940T-8.0, LM2940T-9.0, LM2940T-10 or LM2940T-12
See NS Package Number TO3B

3-Lead SOT-223



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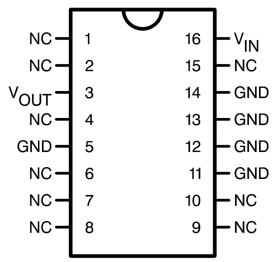
Front View
Order Part Number LM2940IMP-5.0, LM2940IMP-8.0, LM2940IMP-9.0, LM2940IMP-10, LM2940IMP-12 or LM2940IMP-15
See NS Package Number MA04A

16-Lead Dual-in-Line Package (J)



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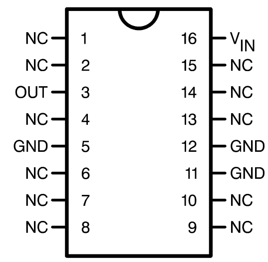
Top View
Order Number LM2940J-5.0/883 (5962-8958701EA), LM2940J-8.0/883 (5962-9088301QEA), LM2940J-12/883 (5962-9088401QEA), LM2940J-15/883 (5962-9088501QEA)
See NS Package Number J16A

16-Lead Ceramic Surface-Mount Package (WG)



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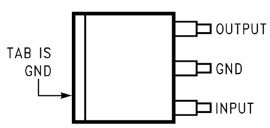
Top View
Order Number LM2940WG5.0/883 (5962-8958701XA)
See NS Package Number WG16A

(TO-263) Surface-Mount Package



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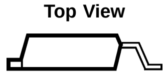
Top View



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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

Absolute Maximum Ratings (Note 1)

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

LM2940S, T, MP ≤ 100 ms	60V
LM2940CS, T ≤ 1 ms	45V
Internal Power Dissipation (Note 2)	Internally Limited
Maximum Junction Temperature	150˚C
Storage Temperature Range	−65˚C ≤ T_J ≤ +150˚C
Lead Temperature, Time for Wave Soldering	
TO-220 (T) Package	260˚C, 10s
TO-263 (S) Package	260˚C, 4s
SOT-223 (MP) Package	260˚C, 4s
ESD Susceptibility (Note 3)	2 kV

Operating Conditions (Note 1)

Input Voltage	26V
Temperature Range	
LM2940T, LM2940S	−40˚C ≤ T_A ≤ 125˚C
LM2940CT, LM2940CS	0˚C ≤ T_A ≤ 125˚C
LM2940IMP	−40˚C ≤ T_A ≤ 85˚C
LM2940J, LM2940WG	−55˚C ≤ T_A ≤ 125˚C

Electrical Characteristics

$V_{IN} = V_O + 5V$, I_O = 1A, C_O = 22 µF, 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 4)	LM2940/883 Limit (Note 5)	Typ	LM2940 Limit (Note 4)	LM2940/883 Limit (Note 5)	
		6.25V ≤ V_{IN} ≤ 26V			9.4V ≤ V_{IN} ≤ 26V			
Output Voltage	5 mA ≤ I_O ≤ 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 ≤ V_{IN} ≤ 26V, I_O = 5 mA	20	50	40/**50**	20	80	50/**80**	mV_{MAX}
Load Regulation	50 mA ≤ I_O ≤ 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 ≤ V_{IN} ≤ 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}
Short Circuit Current	(Note 6)	1.9	1.6	1.5/**1.3**	1.9	1.6	1.6/**1.3**	A_{MIN}

Electrical Characteristics (Continued)

$V_{IN} = V_O + 5V$, $I_O = 1A$, $C_O = 22\ \mu F$, 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 4)	LM2940/883 Limit (Note 5)	Typ	LM2940 Limit (Note 4)	LM2940/883 Limit (Note 5)	
Maximum Line Transient	$R_O = 100\Omega$							V_{MIN}
	LM2940, T ≤ 100 ms	75	60/**60**		75	60/**60**		
	LM2940/883, T ≤ 20 ms			40/**40**			40/**40**	
	LM2940C, T ≤ 1 ms	55	45		55	45		
Reverse Polarity DC Input Voltage	$R_O = 100\Omega$							V_{MIN}
	LM2940, LM2940/883	−30	−15/**−15**	−15/**−15**	−30	−15/**−15**	−15/**−15**	
	LM2940C	−30	−15		−30	−15		
Reverse Polarity Transient Input Voltage	$R_O = 100\Omega$							V_{MIN}
	LM2940, T ≤ 100 ms	−75	−50/**−50**		−75	−50/**−50**		
	LM2940/883, T ≤ 20 ms			−45/**−45**			−45/**−45**	
	LM2940C, T ≤ 1 ms	−55	−45/**−45**					

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)		9V		10V		Units
Parameter	Conditions	Typ	LM2940 Limit (Note 4)	Typ	LM2940 Limit (Note 4)	
		10.5V ≤ V_{IN} ≤ 26V		**11.5V ≤ V_{IN} ≤ 26V**		
Output Voltage	5 mA ≤ I_O ≤1A	9.00	8.73/**8.55**	10.00	9.70/**9.50**	V_{MIN}
			9.27/**9.45**		10.30/**10.50**	V_{MAX}
Line Regulation	V_O + 2V ≤ V_{IN} ≤ 26V, I_O = 5 mA	20	90	20	100	mV_{MAX}
Load Regulation	50 mA ≤ I_O ≤ 1A					
	LM2940	60	90/**150**	65	100/**165**	mV_{MAX}
	LM2940C	60	90			
Output Impedance	100 mADC and 20 mArms, f_O = 120 Hz	60		65		mΩ
Quiescent Current	V_O +2V ≤ V_{IN} < 26V, I_O = 5 mA					
	LM2940	10	15/**20**	10	15/**20**	mA_{MAX}
	LM2940C	10	15			
	$V_{IN} = V_O + 5V$, 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	64	52/**46**	63	51/**45**	dB_{MIN}
	LM2940C	64	52			
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}

Electrical Characteristics (Continued)

$V_{IN} = V_O + 5V$, $I_O = 1A$, $C_O = 22\ \mu F$, 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)		9V		10V		Units
Parameter	**Conditions**	**Typ**	**LM2940 Limit** (Note 4)	**Typ**	**LM2940 Limit** (Note 4)	
Short Circuit Current	(Note 6)	1.9	1.6	1.9	1.6	A_{MIN}
Maximum Line Transient	$R_O = 100\Omega$ $T \leq 100$ 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	$R_O = 100\Omega$ $T \leq 100$ 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 $T_A = T_J = 25°C$.

Output Voltage (V_O)		12V			15V			Units
Parameter	**Conditions**	**Typ**	**LM2940 Limit** (Note 4)	**LM2940/833 Limit** (Note 5)	**Typ**	**LM2940 Limit** (Note 4)	**LM2940/833 Limit** (Note 5)	
		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	$V_O + 2V \leq V_{IN} \leq 26V$, $I_O = 5$ 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	$V_O + 2V \leq V_{IN} \leq 26V$, $I_O = 5$ 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}

Electrical Characteristics (Continued)

$V_{IN} = V_O + 5V$, $I_O = 1A$, $C_O = 22\ \mu F$, 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)		12V			15V			Units
Parameter	Conditions	Typ	LM2940 Limit (Note 4)	LM2940/833 Limit (Note 5)	Typ	LM2940 Limit (Note 4)	LM2940/833 Limit (Note 5)	
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 6)	1.9	1.6	1.6/**1.3**	1.9	1.6	1.6/**1.3**	A_{MIN}
Maximum Line Transient	R_O = 100Ω							V_{MIN}
	LM2940, T ≤ 100 ms	75	60/**60**					
	LM2940/883, T ≤ 20 ms			40/**40**			40/**40**	
	LM2940C, T ≤ 1 ms	55	45		55	45		
Reverse Polarity DC Input Voltage	R_O = 100Ω							V_{MIN}
	LM2940, LM2940/883	−30	−15/**−15**	−15/**−15**			−15/**−15**	
	LM2940C	−30	−15		−30	−15		
Reverse Polarity Transient Input Voltage	R_O = 100Ω							V_{MIN}
	LM2940, T ≤ 100 ms	−75	−50/**−50**					
	LM2940/883, T ≤ 20 ms			−45/**−45**			−45/**−45**	
	LM2940C, T ≤ 1 ms	−55	−45/**−45**		−55	−45/**−45**		

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: The maximum allowable power dissipation is a function of the maximum junction temperature, T_J, the junction-to-ambient thermal resistance, θ_{J-A}, and the ambient temperature, T_A. Exceeding the maximum allowable power dissipation will cause excessive die temperature, and the regulator will go into thermal shutdown. The value of θ_{J-A} (for devices in still air with no heatsink) is 60°C/W for the TO-220 package, 80°C/W for the TO-263 package, and 174°C/W for the SOT-223 package. The effective value of θ_{J-A} can be reduced by using a heatsink (see Application Hints for specific information on heatsinking). The values of θ_{J-A} and θ_{J-C} for the K02A package are 39°C/W and 4°C/W respectively.

Note 3: ESD rating is based on the human body model, 100 pF discharged through 1.5 kΩ.

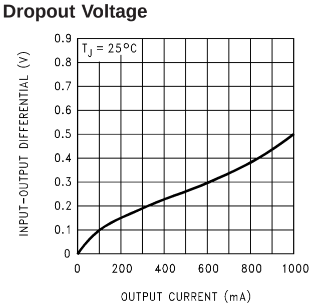
Note 4: All limits are guaranteed at $T_A = T_J = 25°C$ only (standard typeface) or over the entire operating temperature range of the indicated device (boldface type). All limits at $T_A = T_J = 25°C$ are 100% production tested. All limits at temperature extremes are guaranteed via correlation using standard Statistical Quality Control methods.

Note 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 are 100% production tested and are used to calculate Outgoing Quality Levels.

Note 6: Output current will decrease with increasing temperature but will not drop below 1A at the maximum specified temperature.

Typical Performance Characteristics

Dropout Voltage



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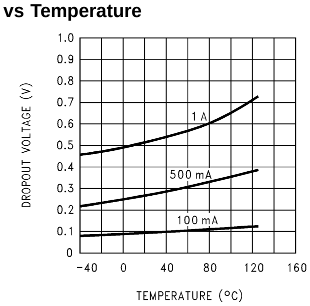
Dropout Voltage vs Temperature



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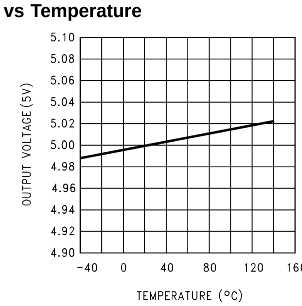
Output Voltage vs Temperature



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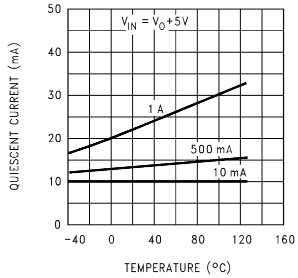
Typical Performance Characteristics (Continued)

Quiescent Current vs Temperature



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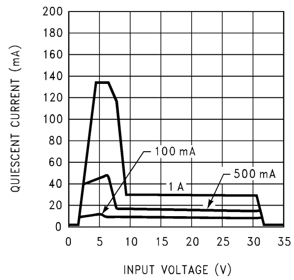
Quiescent Current



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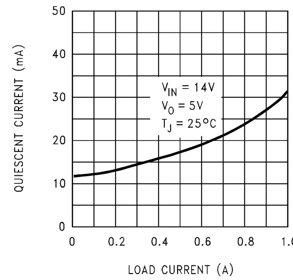
Quiescent Current



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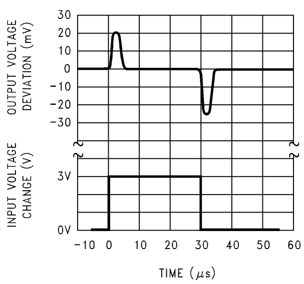
Line Transient Response



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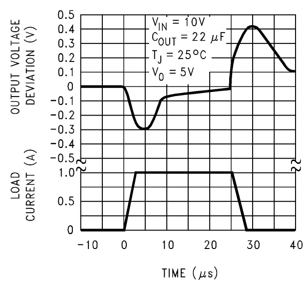
Load Transient Response



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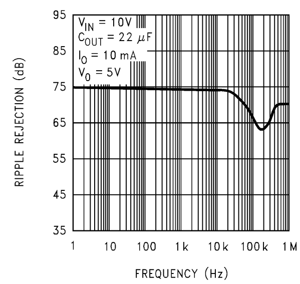
Ripple Rejection



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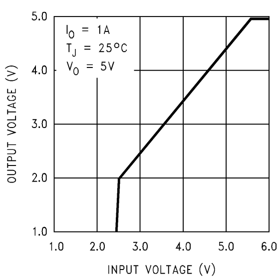
Low Voltage Behavior



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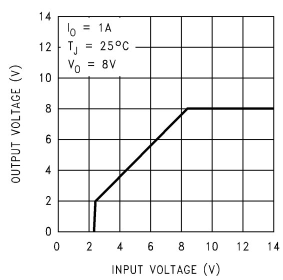
Low Voltage Behavior



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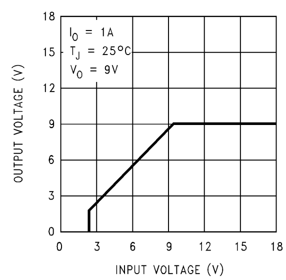
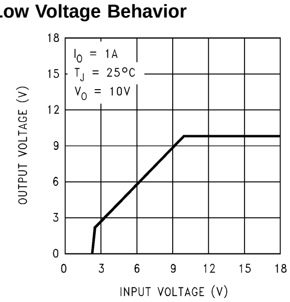
Low Voltage Behavior



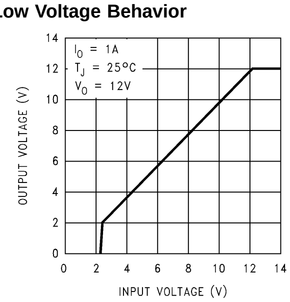
DS008822-27

Low Voltage Behavior



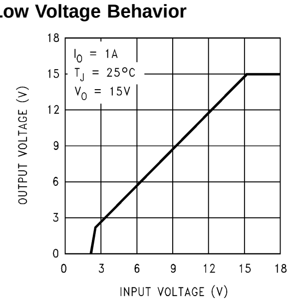
DS008822-28

Low Voltage Behavior



DS008822-29

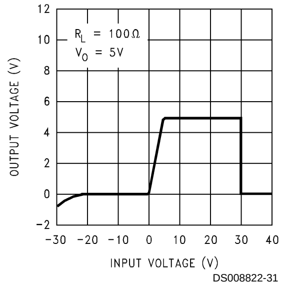
Low Voltage Behavior



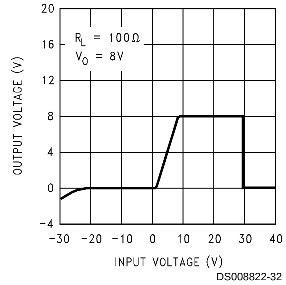
DS008822-30

Typical Performance Characteristics (Continued)

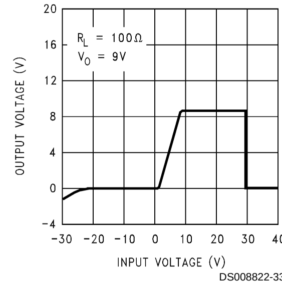
Output at Voltage Extremes



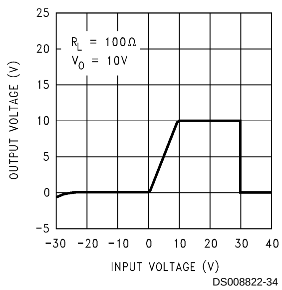
Output at Voltage Extremes



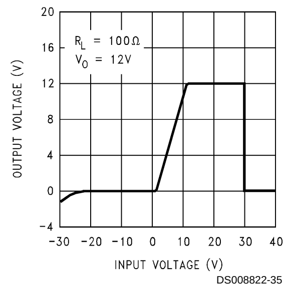
Output at Voltage Extremes



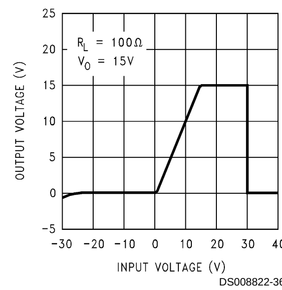
Output at Voltage Extremes



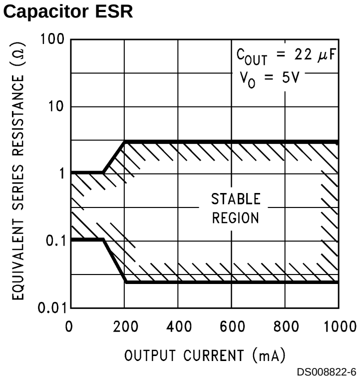
Output at Voltage Extremes



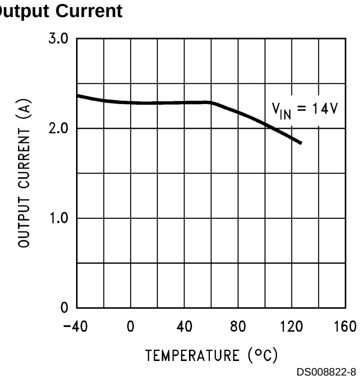
Output at Voltage Extremes



Output Capacitor ESR

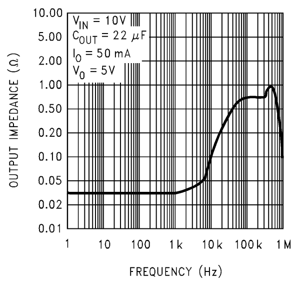


Peak Output Current



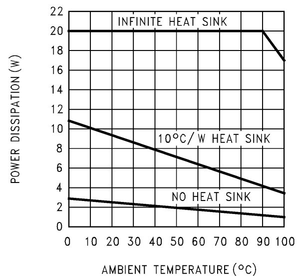
Typical Performance Characteristics (Continued)

Output Impedance



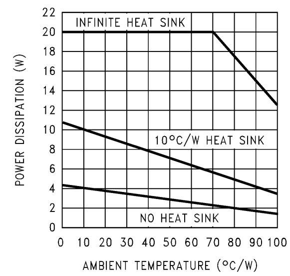
DS008822-22

Maximum Power Dissipation (TO-220)



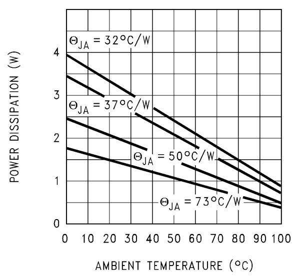
DS008822-23

Maximum Power Dissipation (TO-3)



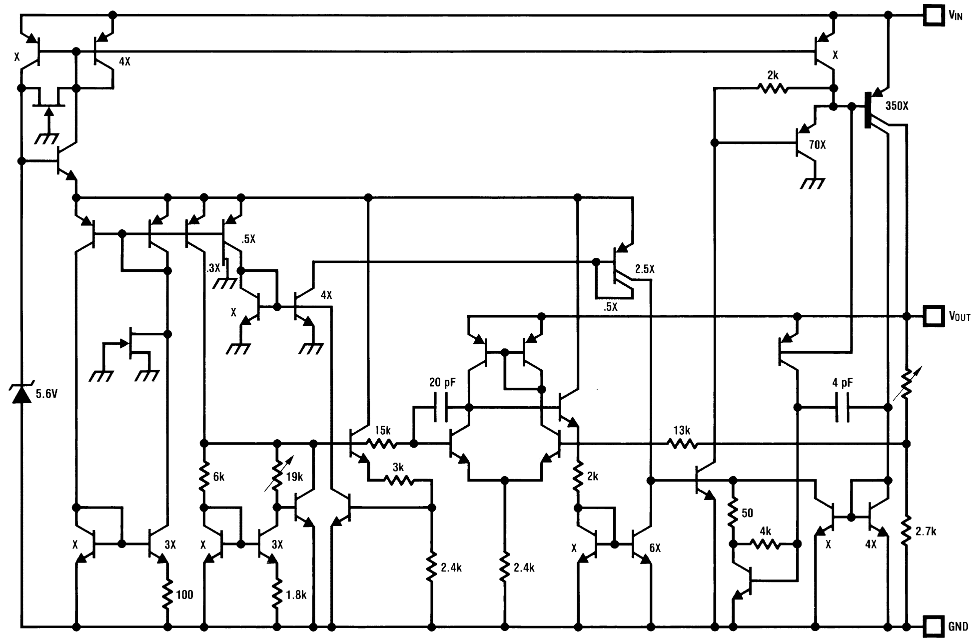
DS008822-24

Maximum Power Dissipation (TO-263) See (Note 2)



DS008822-10

Equivalent Schematic Diagram



DS008822-1

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.

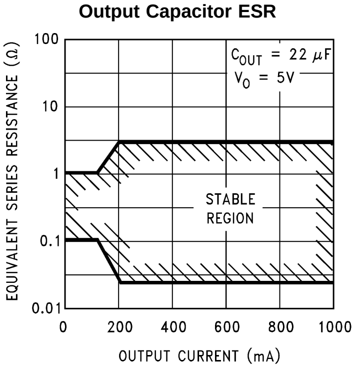
MINIMUM CAPACITANCE:

The minimum output capacitance required to maintain stability is 22 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



DS008822-6

FIGURE 1. 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

Application Hints (Continued)

an aluminum electrolytic with a solid Tantalum, with the total capacitance split about 75/25% with the Aluminum being the larger value.

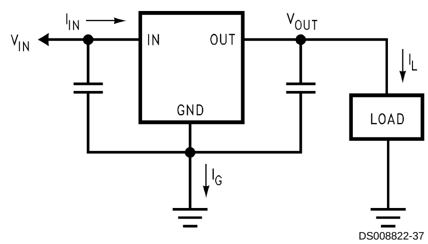
If two capacitors are paralleled, the effective ESR is the parallel of the two individual values. The "flatter" ESR of the Tantalum will keep the effective ESR from rising as quickly at low temperatures.

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:



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

FIGURE 2. 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.

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:

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

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 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 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 $\theta_{(C-H)}$.

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 TO-263 AND SOT-223 PACKAGE PARTS

Both the 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 3 shows for the 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.*

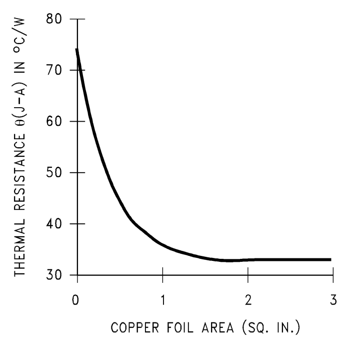


FIGURE 3. $\theta_{(J-A)}$ vs Copper (1 ounce) Area for the TO-263 Package

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 TO-263 package mounted to a PCB is 32˚C/W.

As a design aid, *Figure 4* shows the maximum allowable power dissipation compared to ambient temperature for the TO-263 device (assuming $\theta_{(J-A)}$ is 35˚C/W and the maximum junction temperature is 125˚C).

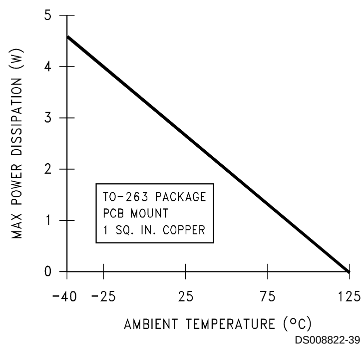


FIGURE 4. Maximum Power Dissipation vs T_{AMB} for the TO-263 Package

Figure 5 and *Figure 6* show the information for the SOT-223 package. *Figure 6* 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 125˚C.

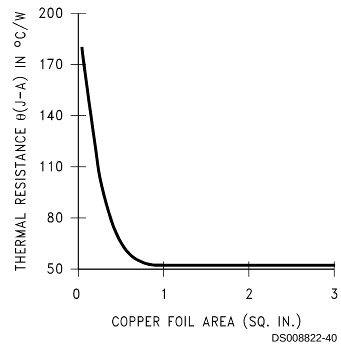


FIGURE 5. $\theta_{(J-A)}$ vs Copper (2 ounce) Area for the SOT-223 Package

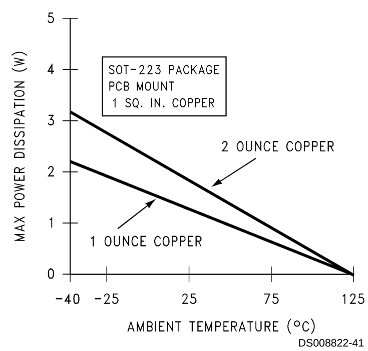
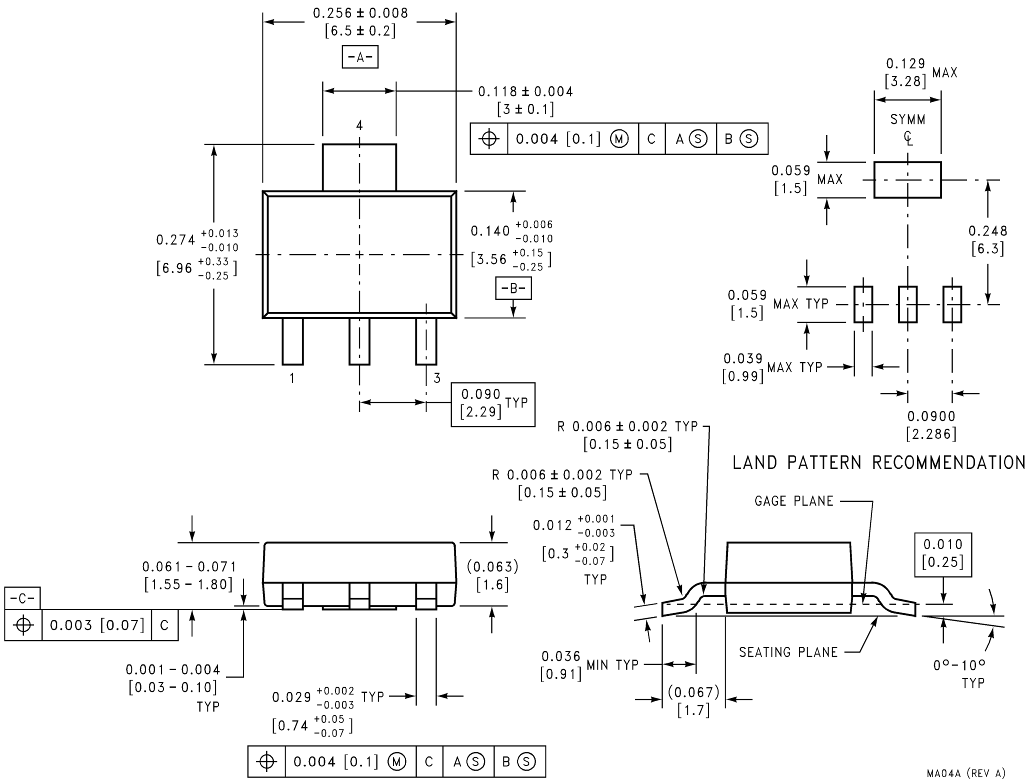


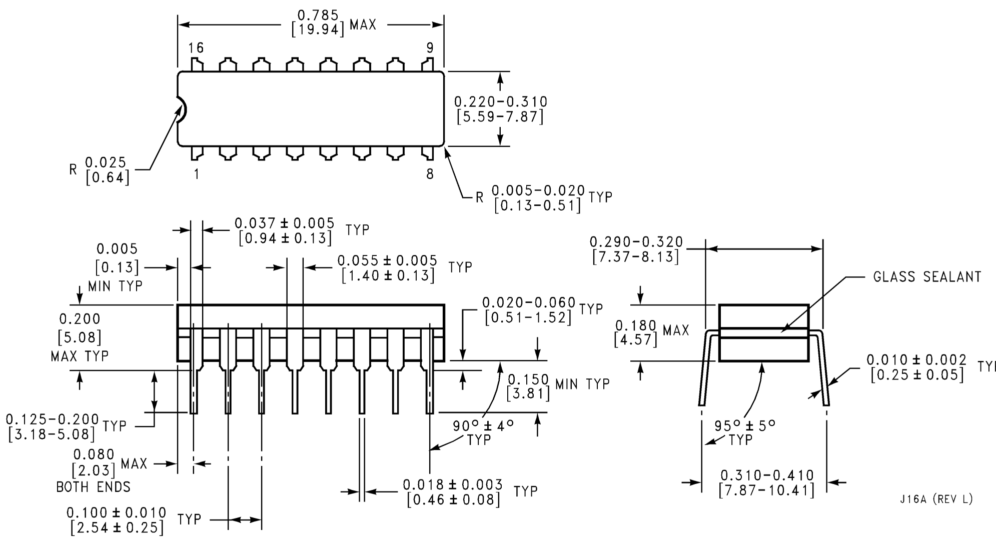
FIGURE 6. Maximum Power Dissipation vs T_{AMB} for the SOT-223 Package

Physical Dimensions inches (millimeters) unless otherwise noted



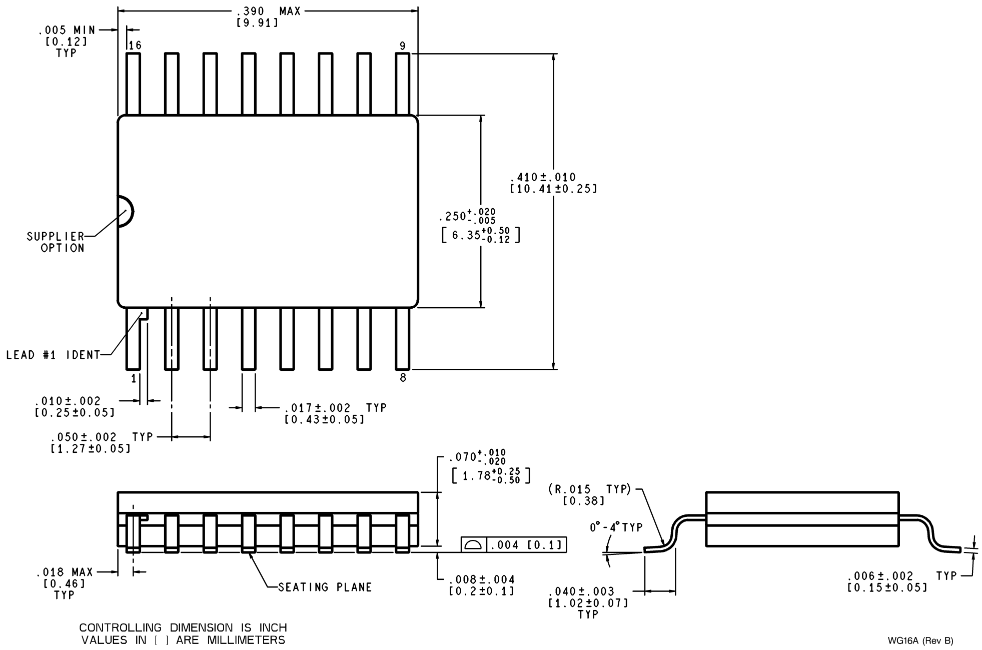
3-Lead SOT-223 Package
Order Part Number LM2940IMP-5.0
LM2940IMP-8.0 LM2940IMP-9.0
LM2940IMP-10 LM2940IMP-12 LM2940IMP-15
NS Package Number MA04A

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)



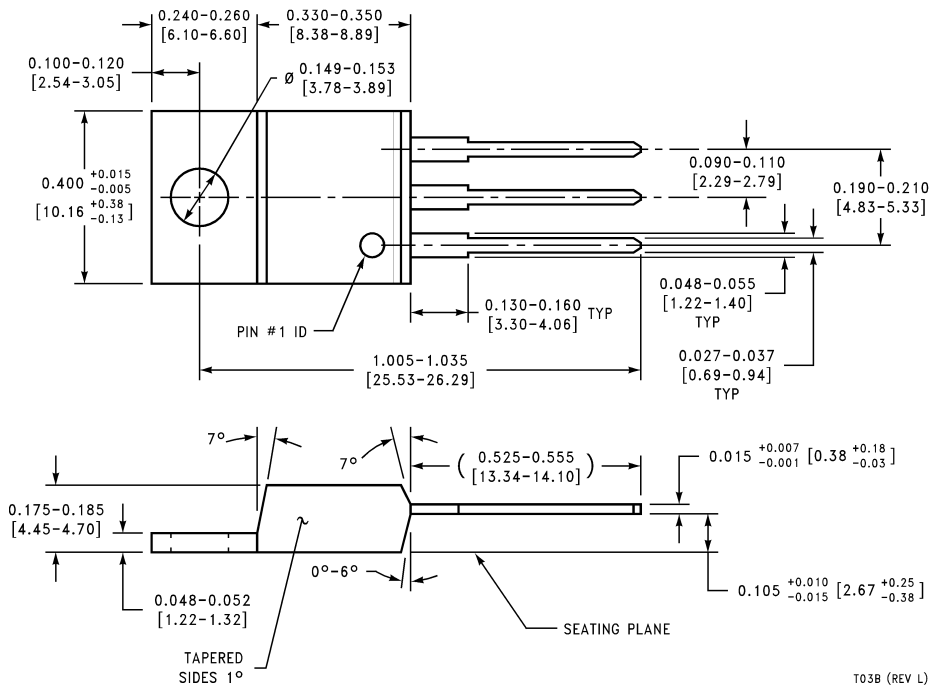
16 Lead Dual-in-Line Package (J)
Order Number LM2940J-5.0/883 (5962-8958701EA),
LM2940J-8.0/883 (5962-9088301QEA),
LM2940J-12/883 (5962-9088401QEA),
LM2940J-15/883 (5962-9088501QEA)
See NS Package Number J16A

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)



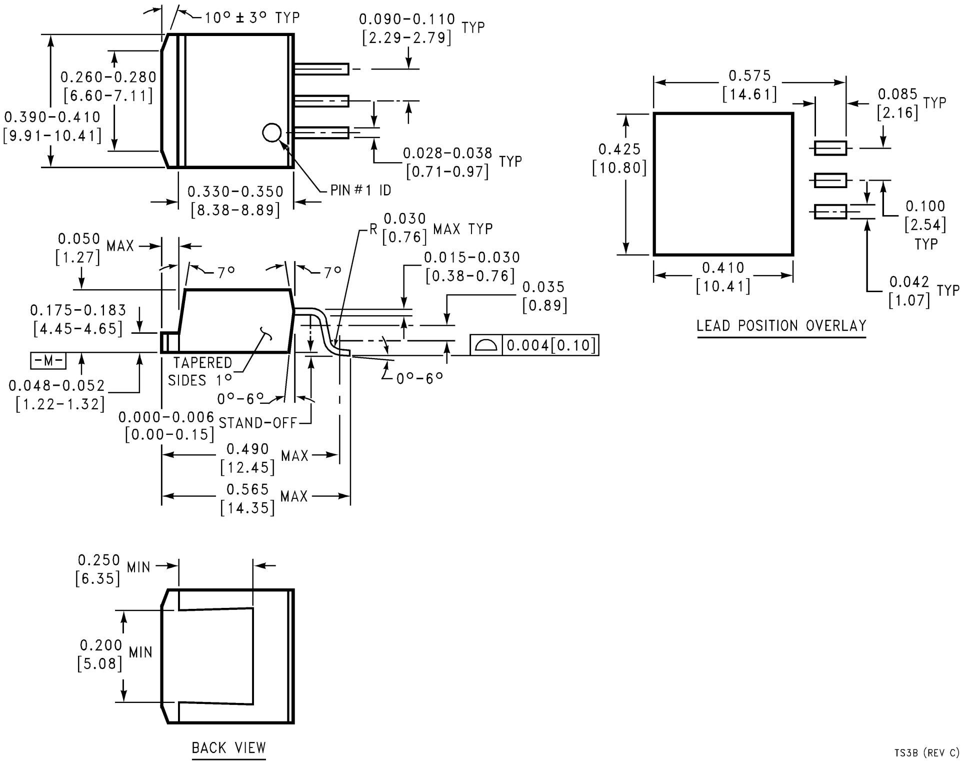
16 Lead Surface Mount Package (WG)
Order Number LM2940WG5.0/883 (5962-8958701XA)
See NS Package Number WG16A

Physical Dimensions inches (millimeters) unless otherwise noted (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) unless otherwise noted (Continued)



3-Lead TO-263 Surface Mount Package (MP)
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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