

## LP2950/LP2951

### Series of Adjustable Micropower Voltage Regulators

#### General Description

The LP2950 and LP2951 are micropower voltage regulators with very low quiescent current (75  $\mu$ A typ.) and very low dropout voltage (typ. 40 mV at light loads and 380 mV at 100 mA). They are ideally suited for use in battery-powered systems. Furthermore, the quiescent current of the LP2950/LP2951 increases only slightly in dropout, prolonging battery life.

The LP2950-5.0 in the popular 3-pin TO-92 package is pin-compatible with older 5V regulators. The 8-lead LP2951 is available in plastic, ceramic dual-in-line, or metal can packages and offers additional system functions.

One such feature is an error flag output which warns of a low output voltage, often due to falling batteries on the input. It may be used for a power-on reset. A second feature is the logic-compatible shutdown input which enables the regulator to be switched on and off. Also, the part may be pin-strapped for a 5V, 3V, or 3.3V output (depending on the version), or programmed from 1.24V to 29V with an external pair of resistors.

Careful design of the LP2950/LP2951 has minimized all contributions to the error budget. This includes a tight initial tolerance (.5% typ.), extremely good load and line regulation

(.05% typ.) and a very low output voltage temperature coefficient, making the part useful as a low-power voltage reference.

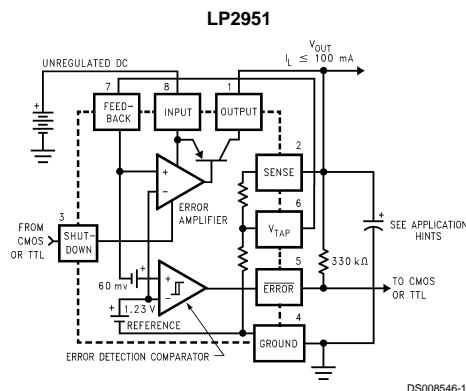
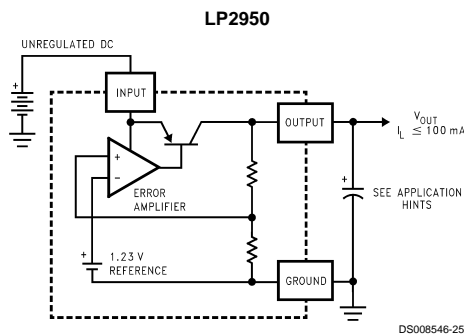
#### Features

- 5V, 3V, and 3.3V versions available
- High accuracy output voltage
- Guaranteed 100 mA output current
- Extremely low quiescent current
- Low dropout voltage
- Extremely tight load and line regulation
- Very low temperature coefficient
- Use as Regulator or Reference
- Needs minimum capacitance for stability
- Current and Thermal Limiting
- Stable with low-ESR output capacitors

#### LP2951 versions only

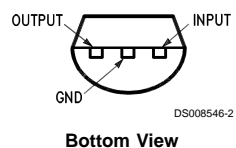
- Error flag warns of output dropout
- Logic-controlled electronic shutdown
- Output programmable from 1.24 to 29V

#### Block Diagram and Typical Applications

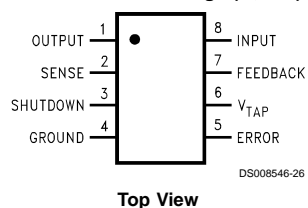


## Connection Diagrams

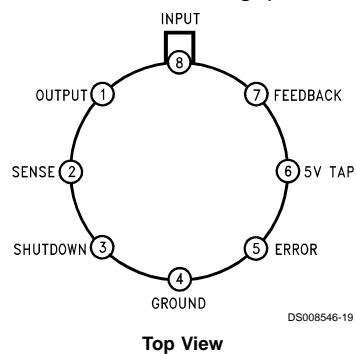
### TO-92 Plastic Package (Z)



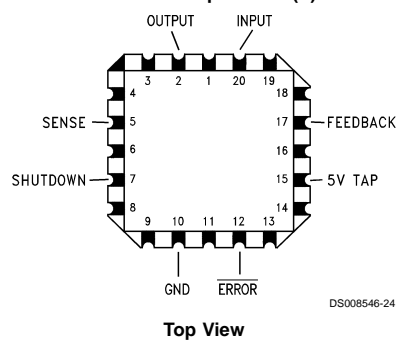
### Dual-In-Line Packages (N, J) Surface-Mount Package (M, MM)



### Metal Can Package ( )



### Leadless Chip Carrier (E)



## Ordering Information

Package	Output Voltage			Temperature (°C)
	3.0V	3.3V	5.0V	
TO-92 (Z)	LP2950ACZ-3.0 LP2950CZ-3.0	LP2950ACZ-3.3 LP2950CZ-3.3	LP2950ACZ-5.0 LP2950CZ-5.0	-40 < T <sub>J</sub> < 125
N (N-08E)	LP2951ACN-3.0 LP2951CN-3.0	LP2951ACN-3.3 LP2951CN-3.3	LP2951ACN LP2951CN	-40 < T <sub>J</sub> < 125
M (M08A)	LP2951ACM-3.0 LP2951CM-3.0	LP2951ACM-3.3 LP2951CM-3.3	LP2951ACM LP2951CM	-40 < T <sub>J</sub> < 125
MM (MUA08A)	LP2951ACMM-3.0 LP2951CMM-3.0	LP2951ACMM-3.3 LP2951CMM-3.3	LP2951ACMM LP2951CMM	-40 < T <sub>J</sub> < 125
J (J08A)			LP2951ACJ LP2951CJ  LP2951J LP2951J/883 5926-3870501MPA	-40 < T <sub>J</sub> < 125  -55 < T <sub>J</sub> < 150
H (H08C)			LP2951H/883 5962-3870501MGA	-55 < T <sub>J</sub> < 150
E (E20A)			LP2951E/883 5962-3870501M2A	-55 < T <sub>J</sub> < 150

### For MM Package:

Order Number	Package Marking
LP2951ACMM	L0DA
LP2951CMM	L0DB
LP2951ACMM-3.3	L0CA
LP2951CMM-3.3	L0CB
LP2951ACMM-3.0	L0BA
LP2951CMM-3.0	L0BB

**Absolute Maximum Ratings** (Note 1)

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

Input Supply Voltage	−0.3 to +30V
SHUTDOWN Input Voltage, Error Comparator Output Voltage, (Note 9)	
FEEDBACK Input Voltage (Note 9) (Note 10)	−1.5 to +30V
Power Dissipation	Internally Limited
Junction Temperature ( $T_J$ )	+150°C
Ambient Storage Temperature	−65° to +150°C

Soldering Dwell Time, Temperature

Wave	4 seconds, 260°C
Infrared	10 seconds, 240°C
Vapor Phase	75 seconds, 219°C
ESD	TBD

**Operating Ratings** (Note 1)

Maximum Input Supply Voltage	30V
Junction Temperature Range ( $T_J$ ) (Note 8)	
LP2951	−55° to +150°C
LP2950AC-XX, LP2950C-XX, LP2951AC-XX, LP2951C-XX	−40° to +125°C

**Electrical Characteristics** (Note 2)

Parameter	Conditions (Note 2)	LP2951		LP2950AC-XX LP2951AC-XX			LP2950C-XX LP2951C-XX			Units
		Typ	Tested Limit (Notes 3, 16)	Typ	Tested Limit (Note 3)	Design Limit (Note 4)	Typ	Tested Limit (Note 3)	Design Limit (Note 4)	
3V VERSIONS (Note 17)										
Output Voltage	T <sub>J</sub> = 25°C	3.0	3.015 2.985	3.0	3.015 2.985		3.0	3.030 2.970		V max V min
	–25°C ≤ T <sub>J</sub> ≤ 85°C	3.0		3.0		3.030 2.970	3.0		3.045 2.955	V max V min
	Full Operating Temperature Range	3.0	<b>3.036</b> <b>2.964</b>	3.0		<b>3.036</b> <b>2.964</b>	3.0		<b>3.060</b> <b>2.940</b>	V max V min
	Output Voltage	100 μA ≤ I <sub>L</sub> ≤ 100 mA T <sub>J</sub> ≤ T <sub>JMAX</sub>	3.0	<b>3.045</b> <b>2.955</b>	3.0		<b>3.042</b> <b>2.958</b>	3.0		<b>3.072</b> <b>2.928</b>
3.3V VERSIONS (Note 17)										
Output Voltage	T <sub>J</sub> = 25°C	3.3	3.317 3.284	3.3	3.317 3.284		3.3	3.333 3.267		V max V min
	–25°C ≤ T <sub>J</sub> ≤ 85°C	3.3		3.3		3.333 3.267	3.3		3.350 3.251	V max V min
	Full Operating Temperature Range	3.3	<b>3.340</b> <b>3.260</b>	3.3		<b>3.340</b> <b>3.260</b>	3.3		<b>3.366</b> <b>3.234</b>	V max V min
	Output Voltage	100 μA ≤ I <sub>L</sub> ≤ 100 mA T <sub>J</sub> ≤ T <sub>JMAX</sub>	3.3	<b>3.350</b> <b>3.251</b>	3.3		<b>3.346</b> <b>3.254</b>	3.3		<b>3.379</b> <b>3.221</b>
5V VERSIONS (Note 17)										
Output Voltage	T <sub>J</sub> = 25°C	5.0	5.025 4.975	5.0	5.025 4.975		5.0	5.05 4.95		V max V min
	–25°C ≤ T <sub>J</sub> ≤ 85°C	5.0		5.0		5.05 4.95	5.0		5.075 4.925	V max V min
	Full Operating Temperature Range	5.0	<b>5.06</b> <b>4.94</b>	5.0		<b>5.06</b> <b>4.94</b>	5.0		<b>5.1</b> <b>4.9</b>	V max V min
	Output Voltage	100 μA ≤ I <sub>L</sub> ≤ 100 mA T <sub>J</sub> ≤ T <sub>JMAX</sub>	5.0	<b>5.075</b> <b>4.925</b>	5.0		<b>5.075</b> <b>4.925</b>	5.0		<b>5.12</b> <b>4.88</b>
ALL VOLTAGE OPTIONS										
Output Voltage Temperature Coefficient	(Note 12)	20	120	20		100	50		150	ppm/°C
Line Regulation (Note 14)	(V <sub>O</sub> NOM + 1)V ≤ V <sub>in</sub> ≤ 30V (Note 15)	0.03	0.1 0.5	0.03	0.1	0.2	0.04	0.2	0.4	% max % max
Load Regulation (Note 14)	100 μA ≤ I <sub>L</sub> ≤ 100 mA	0.04	0.1 0.3	0.04	0.1	0.2	0.1	0.2	0.3	% max % max

## Electrical Characteristics (Note 2) (Continued)

Parameter	Conditions (Note 2)	LP2951		LP2950AC-XX LP2951AC-XX			LP2950C-XX LP2951C-XX			Units
		Typ	Tested Limit (Notes 3, 16)	Typ	Tested Limit (Note 3)	Design Limit (Note 4)	Typ	Tested Limit (Note 3)	Design Limit (Note 4)	
ALL VOLTAGE OPTIONS										
Dropout Voltage (Note 5)	I <sub>L</sub> = 100 μA	50	80 150	50	80	150	50	80	150	mV max mV max
	I <sub>L</sub> = 100 mA	380	450 600	380	450	600	380	450	600	mV max mV max
Ground Current	I <sub>L</sub> = 100 μA	75	120 140	75	120	140	75	120	140	μA max μA max
	I <sub>L</sub> = 100 mA	8	12 14	8	12	14	8	12	14	mA max mA max
Dropout Ground Current	V <sub>in</sub> = (V <sub>O</sub> NOM – 0.5)V I <sub>L</sub> = 100 μA	110	170 200	110	170	200	110	170	200	μA max μA max
Current Limit	V <sub>out</sub> = 0	160	200 220	160	200	220	160	200	220	mA max mA max
Thermal Regulation	(Note 13)	0.05	0.2	0.05	0.2		0.05	0.2		%/W max
Output Noise, 10 Hz to 100 kHz	C <sub>L</sub> = 1 μF (5V Only)	430		430			430			μV rms
	C <sub>L</sub> = 200 μF	160		160			160			μV rms
	C <sub>L</sub> = 3.3 μF (Bypass = 0.01 μF Pins 7 to 1 (LP2951))	100		100			100			μV rms
8-PIN VERSIONS ONLY		LP2951		LP2951AC-XX			LP2951C-XX			
Reference Voltage		1.235	1.25 1.26 1.22 1.2	1.235	1.25 1.22	1.26 1.2	1.235	1.26 1.21	1.27 1.2	V max V max V min V min
Reference Voltage	(Note 7)		1.27 1.19			1.27 1.19			1.285 1.185	V max V min
Feedback Pin Bias Current		20	40 60	20	40	60	20	40	60	nA max nA max
Reference Voltage Temperature Coefficient	(Note 12)	20		20			50			ppm/°C
Feedback Pin Bias Current Temperature Coefficient		0.1		0.1			0.1			nA/°C
Error Comparator										
Output Leakage Current	V <sub>OH</sub> = 30V	0.01	1 2	0.01	1	2	0.01	1	2	μA max μA max
Output Low Voltage	V <sub>in</sub> = (V <sub>O</sub> NOM – 0.5)V I <sub>OL</sub> = 400 μA	150	250 400	150	250	400	150	250	400	mV max mV max
Upper Threshold Voltage	(Note 6)	60	40 25	60	40	25	60	40	25	mV min mV min
Lower Threshold Voltage	(Note 6)	75	95 140	75	95	140	75	95	140	mV max mV max
Hysteresis	(Note 6)	15		15			15			mV
Shutdown Input										
Input Logic Voltage	Low (Regulator ON) High (Regulator OFF)	1.3	0.6 2.0	1.3		0.7 2.0	1.3		0.7 2.0	V V max V min

## Electrical Characteristics (Note 2) (Continued)

Parameter	Conditions (Note 2)	LP2951		LP2950AC-XX LP2951AC-XX			LP2950C-XX LP2951C-XX			Units
		Typ	Tested Limit (Notes 3, 16)	Typ	Tested Limit (Note 3)	Design Limit (Note 4)	Typ	Tested Limit (Note 3)	Design Limit (Note 4)	
Shutdown Input										
Shutdown Pin Input Current	V <sub>shutdown</sub> = 2.4V	30	50 100	30	50	100	30	50	100	µA max µA max
	V <sub>shutdown</sub> = 30V	450	600 750	450	600	750	450	600	750	µA max µA max
Regulator Output Current in Shutdown	(Note 11)	3	10 20	3	10	20	3	10	20	µA max µA max

**Note 1:** Absolute Maximum Ratings are limits beyond which damage to the device may occur. Operating Ratings are conditions under which operation of the device is guaranteed. Operating Ratings do not imply guaranteed performance limits. For guaranteed performance limits and associated test conditions, see the Electrical Characteristics tables.

**Note 2:** Unless otherwise specified all limits guaranteed for  $V_{\text{IN}} = (V_{\text{ONOM}} + 1)\text{V}$ ,  $I_{\text{L}} = 100\text{ }\mu\text{A}$  and  $C_{\text{L}} = 1\text{ }\mu\text{F}$  for 5V versions and  $2.2\text{ }\mu\text{F}$  for 3V and 3.3V versions. Limits appearing in **boldface** type apply over the entire junction temperature range for operation. Limits appearing in normal type apply for  $T_{\text{A}} = T_{\text{J}} = 25^{\circ}\text{C}$ . Additional conditions for the 8-pin versions are FEEDBACK tied to  $V_{\text{TAP}}$ , OUTPUT tied to SENSE, and  $V_{\text{SHUTDOWN}} \leq 0.8\text{V}$ .

**Note 3:** Guaranteed and 100% production tested.

**Note 4:** Guaranteed but not 100% production tested. These limits are not used to calculate outgoing AQL levels.

**Note 5:** Dropout Voltage is defined as the input to output differential at which the output voltage drops 100 mV below its nominal value measured at 1V differential. At very low values of programmed output voltage, the minimum input supply voltage of 2V (2.3V over temperature) must be taken into account.

**Note 6:** Comparator thresholds are expressed in terms of a voltage differential at the Feedback terminal below the nominal reference voltage measured at  $V_{\text{IN}} = (V_{\text{ONOM}} + 1)\text{V}$ . To express these thresholds in terms of output voltage change, multiply by the error amplifier gain  $= V_{\text{OUT}}/V_{\text{REF}} = (R1 + R2)/R2$ . For example, at a programmed output voltage of 5V, the Error output is guaranteed to go low when the output drops by  $95\text{ mV} \times 5\text{V}/1.235\text{V} = 384\text{ mV}$ . Thresholds remain constant as a percent of  $V_{\text{OUT}}$  as  $V_{\text{OUT}}$  is varied, with the dropout warning occurring at typically 5% below nominal, 7.5% guaranteed.

**Note 7:**  $V_{\text{REF}} \leq V_{\text{OUT}} \leq (V_{\text{IN}} - 1\text{V})$ ,  $2.3\text{V} \leq V_{\text{IN}} \leq 30\text{V}$ ,  $100\text{ }\mu\text{A} \leq I_{\text{L}} \leq 100\text{ mA}$ ,  $T_{\text{J}} \leq T_{\text{JMAX}}$ .

**Note 8:** The junction-to-ambient thermal resistances are as follows:  $180^{\circ}\text{C/W}$  and  $160^{\circ}\text{C/W}$  for the TO-92 package with 0.40 inch and 0.25 inch leads to the printed circuit board (PCB) respectively,  $105^{\circ}\text{C/W}$  for the molded plastic DIP (N),  $130^{\circ}\text{C/W}$  for the ceramic DIP (J),  $160^{\circ}\text{C/W}$  for the molded plastic SOP (M),  $200^{\circ}\text{C/W}$  for the molded plastic MSOP (MM),  $160^{\circ}\text{C/W}$  for the metal can package (H), and  $180^{\circ}\text{C/W}$  for the leadless chip carrier (E). The above thermal resistances for the N, J, M, MM, and E packages apply when the package is soldered directly to the PCB. Junction-to-case thermal resistances for the E and H packages are  $24^{\circ}\text{C/W}$  and  $20^{\circ}\text{C/W}$  respectively.

**Note 9:** May exceed input supply voltage.

**Note 10:** When used in dual-supply systems where the output terminal sees loads returned to a negative supply, the output voltage should be diode-clamped to ground.

**Note 11:**  $V_{\text{shutdown}} \geq 2\text{V}$ ,  $V_{\text{IN}} \leq 30\text{V}$ ,  $V_{\text{OUT}} = 0$ , Feedback pin tied to  $V_{\text{TAP}}$ .

**Note 12:** Output or reference voltage temperature coefficient is defined as the worst case voltage change divided by the total temperature range.

**Note 13:** Thermal regulation is defined as the change in output voltage at a time T after a change in power dissipation is applied, excluding load or line regulation effects. Specifications are for a 50 mA load pulse at  $V_{\text{IN}} = 30\text{V}$  (1.25W pulse) for  $T = 10\text{ ms}$ .

**Note 14:** Regulation is measured at constant junction temperature, using pulse testing with a low duty cycle. Changes in output voltage due to heating effects are covered under the specification for thermal regulation.

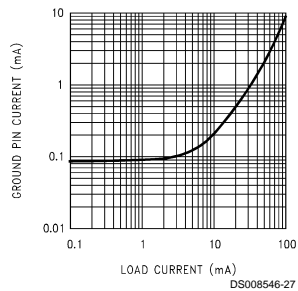
**Note 15:** Line regulation for the LP2951 is tested at  $150^{\circ}\text{C}$  for  $I_{\text{L}} = 1\text{ mA}$ . For  $I_{\text{L}} = 100\text{ }\mu\text{A}$  and  $T_{\text{J}} = 125^{\circ}\text{C}$ , line regulation is guaranteed by design to 0.2%. See Typical Performance Characteristics for line regulation versus temperature and load current.

**Note 16:** A Military RETS specification is available on request. At time of printing, the LP2951 RETS specification complied with the boldface limits in this column. The LP2951H, E, or J may also be procured as Standard Military Drawing Spec #5962-3870501MGA, M2A, or MPA.

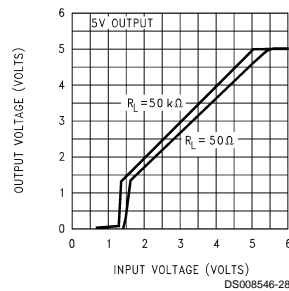
**Note 17:** All LP2950 devices have the nominal output voltage coded as the last two digits of the part number. In the LP2951 products, the 3.0V and 3.3V versions are designated by the last two digits, but the 5V version is denoted with no code at this location of the part number (refer to ordering information table).

## Typical Performance Characteristics

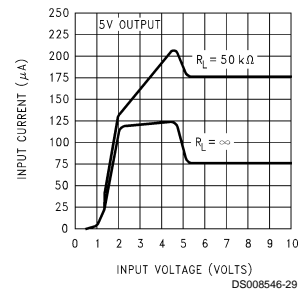
Quiescent Current



Dropout Characteristics

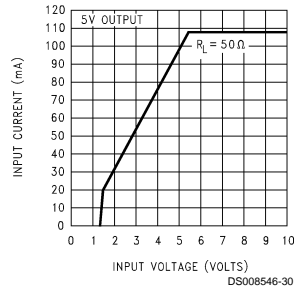


Input Current

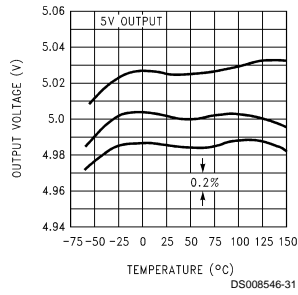


## Typical Performance Characteristics (Continued)

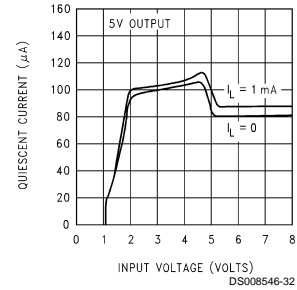
**Input Current**



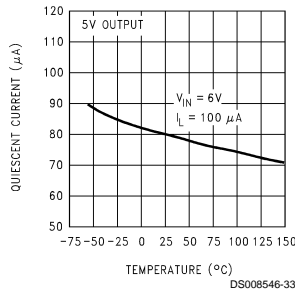
**Output Voltage vs. Temperature of 3 Representative Units**



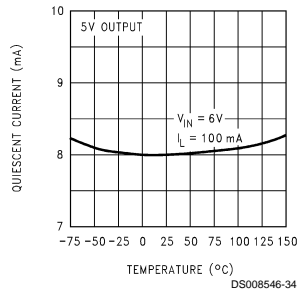
**Quiescent Current**



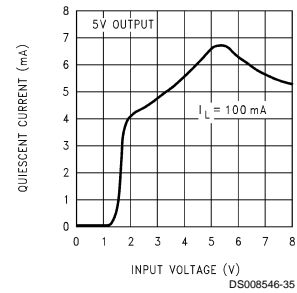
**Quiescent Current**



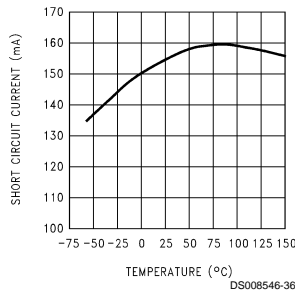
**Quiescent Current**



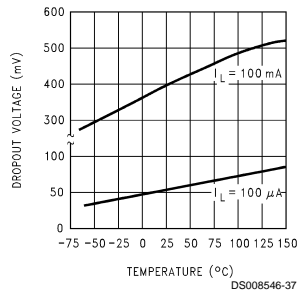
**Quiescent Current**



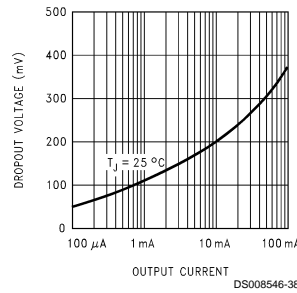
**Short Circuit Current**



**Dropout Voltage**



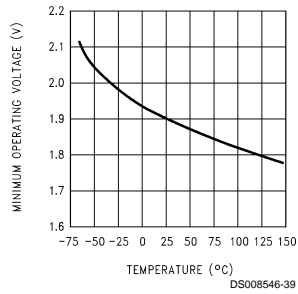
**Dropout Voltage**



## Typical Performance Characteristics (Continued)

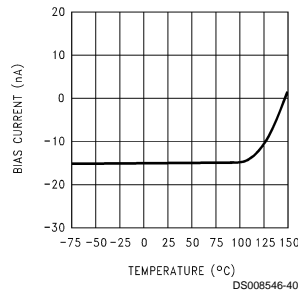
### LP2951

#### Minimum Operating Voltage



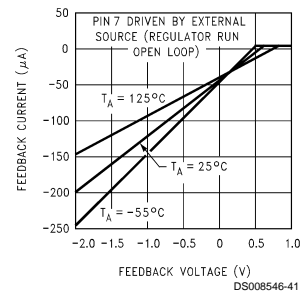
### LP2951

#### Feedback Bias Current



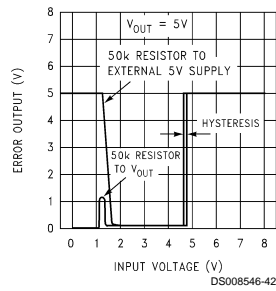
### LP2951

#### Feedback Pin Current



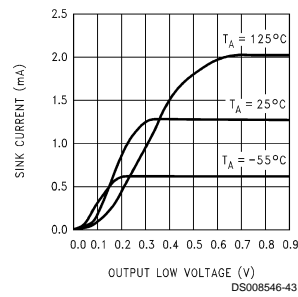
### LP2951

#### Error Comparator Output

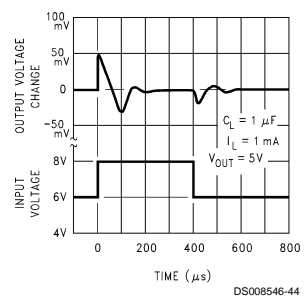


### LP2951

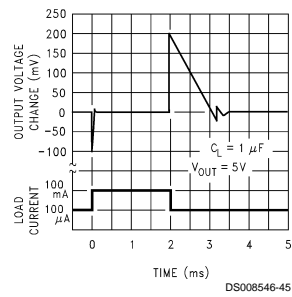
#### Comparator Sink Current



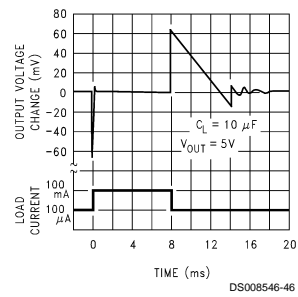
### Line Transient Response



### Load Transient Response

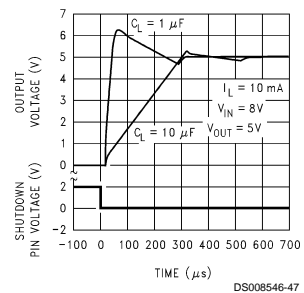


### Load Transient Response



### LP2951

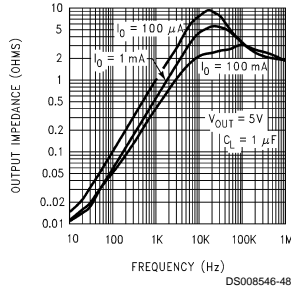
#### Enable Transient



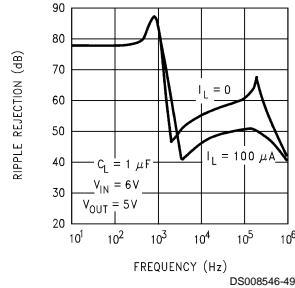


## Typical Performance Characteristics (Continued)

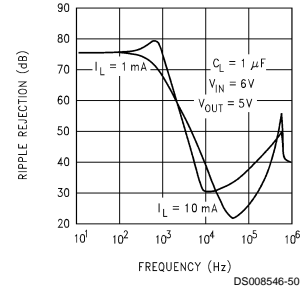
**Output Impedance**



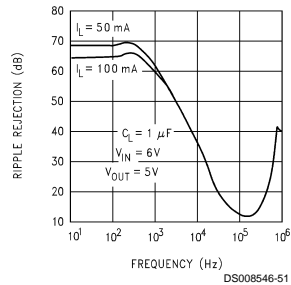
**Ripple Rejection**



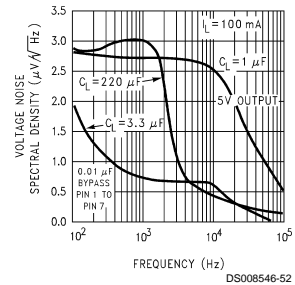
**Ripple Rejection**



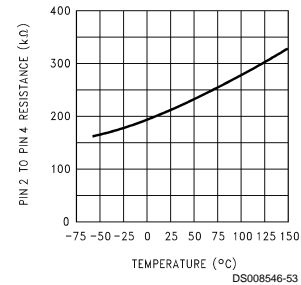
**Ripple Rejection**



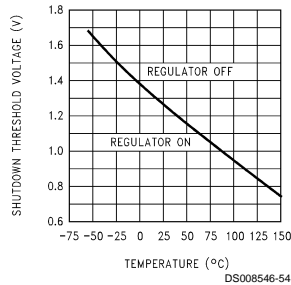
**LP2951 Output Noise**



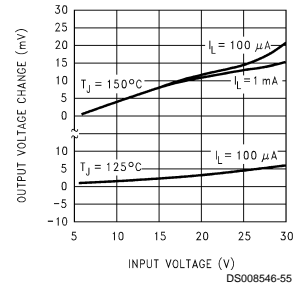
**LP2951 Divider Resistance**



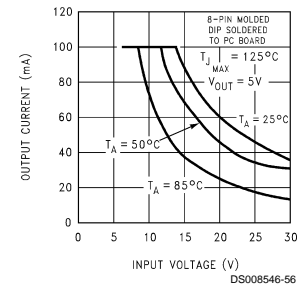
**Shutdown Threshold Voltage**



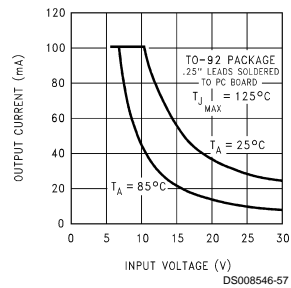
**Line Regulation**



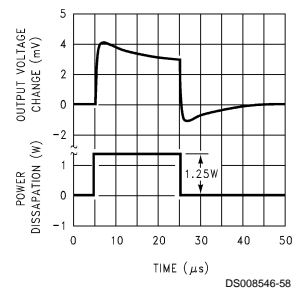
**LP2951 Maximum Rated Output Current**



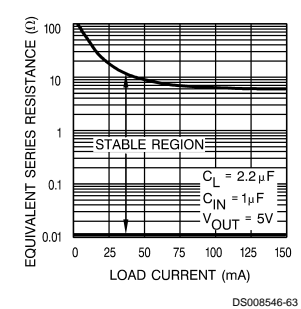
**LP2950 Maximum Rated Output Current**



**Thermal Response**



**Output Capacitor ESR Range**



## Application Hints

### EXTERNAL CAPACITORS

A 1.0  $\mu\text{F}$  (or greater) capacitor is required between the output and ground for stability at output voltages of 5V or more. At lower output voltages, more capacitance is required (2.2  $\mu\text{F}$  or more is recommended for 3V and 3.3V versions). Without this capacitor the part will oscillate. Most types of tantalum or aluminum electrolytics work fine here; even film types work but are not recommended for reasons of cost. Many aluminum electrolytics have electrolytes that freeze at about  $-30^{\circ}\text{C}$ , so solid tantalums are recommended for operation below  $-25^{\circ}\text{C}$ . The important parameters of the capacitor are an ESR of about 5  $\Omega$  or less and a resonant frequency above 500 kHz. The value of this capacitor may be increased without limit.

At lower values of output current, less output capacitance is required for stability. The capacitor can be reduced to 0.33  $\mu\text{F}$  for currents below 10 mA or 0.1  $\mu\text{F}$  for currents below 1 mA. Using the adjustable versions at voltages below 5V runs the error amplifier at lower gains so that more output capacitance is needed. For the worst-case situation of a 100 mA load at 1.23V output (Output shorted to Feedback) a 3.3  $\mu\text{F}$  (or greater) capacitor should be used.

Unlike many other regulators, the LP2950 will remain stable and in regulation with no load in addition to the internal voltage divider. This is especially important in CMOS RAM keep-alive applications. When setting the output voltage of the LP2951 versions with external resistors, a minimum load of 1  $\mu\text{A}$  is recommended.

A 1  $\mu\text{F}$  tantalum or aluminum electrolytic capacitor should be placed from the LP2950/LP2951 input to ground if there is more than 10 inches of wire between the input and the AC filter capacitor or if a battery is used as the input.

Stray capacitance to the LP2951 Feedback terminal can cause instability. This may especially be a problem when using high value external resistors to set the output voltage. Adding a 100 pF capacitor between Output and Feedback and increasing the output capacitor to at least 3.3  $\mu\text{F}$  will fix this problem.

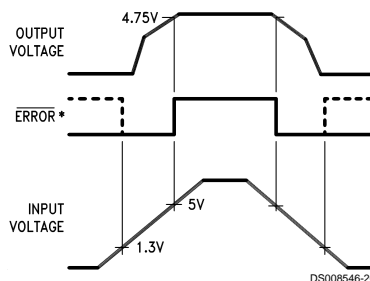
### ERROR DETECTION COMPARATOR OUTPUT

The comparator produces a logic low output whenever the LP2951 output falls out of regulation by more than approximately 5%. This figure is the comparator's built-in offset of about 60 mV divided by the 1.235 reference voltage. (Refer to the block diagram in the front of the datasheet.) This trip level remains "5% below normal" regardless of the programmed output voltage of the 2951. For example, the error flag trip level is typically 4.75V for a 5V output or 11.4V for a 12V output. The out of regulation condition may be due either to low input voltage, current limiting, or thermal limiting.

Figure 1 below gives a timing diagram depicting the  $\overline{\text{ERROR}}$  signal and the regulated output voltage as the LP2951 input is ramped up and down. For 5V versions, the  $\overline{\text{ERROR}}$  signal becomes valid (low) at about 1.3V input. It goes high at about 5V input (the input voltage at which  $V_{\text{OUT}} = 4.75\text{V}$ ). Since the LP2951's dropout voltage is load-dependent (see curve in typical performance characteristics), the input voltage trip point (about 5V) will vary with the load current. The output voltage trip point (approx. 4.75V) does not vary with load.

The error comparator has an open-collector output which requires an external pullup resistor. This resistor may be returned to the output or some other supply voltage depending on system requirements. In determining a value for this re-

sistor, note that while the output is rated to sink 400  $\mu\text{A}$ , this sink current adds to battery drain in a low battery condition. Suggested values range from 100k to 1 M $\Omega$ . The resistor is not required if this output is unused.



\*When  $V_{\text{IN}} \leq 1.3\text{V}$ , the error flag pin becomes a high impedance, and the error flag voltage rises to its pull-up voltage. Using  $V_{\text{OUT}}$  as the pull-up voltage (see Figure 2), rather than an external 5V source, will keep the error flag voltage under 1.2V (typ.) in this condition. The user may wish to divide down the error flag voltage using equal-value resistors (10 k $\Omega$  suggested), to ensure a low-level logic signal during any fault condition, while still allowing a valid high logic level during normal operation.

FIGURE 1. ERROR Output Timing

### PROGRAMMING THE OUTPUT VOLTAGE (LP2951)

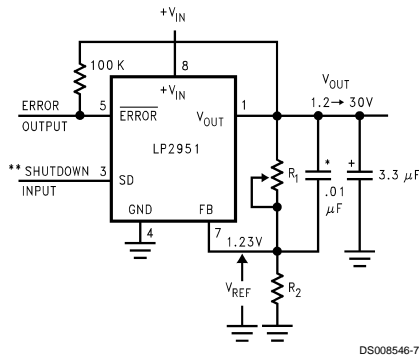
The LP2951 may be pin-strapped for the nominal fixed output voltage using its internal voltage divider by tying the output and sense pins together, and also tying the feedback and  $V_{\text{TAP}}$  pins together. Alternatively, it may be programmed for any output voltage between its 1.235V reference and its 30V maximum rating. As seen in Figure 2, an external pair of resistors is required.

The complete equation for the output voltage is

$$V_{\text{OUT}} = V_{\text{REF}} \cdot \left( 1 + \frac{R_1}{R_2} \right) + I_{\text{FB}} R_1$$

where  $V_{\text{REF}}$  is the nominal 1.235 reference voltage and  $I_{\text{FB}}$  is the feedback pin bias current, nominally  $-20\text{ nA}$ . The minimum recommended load current of 1  $\mu\text{A}$  forces an upper limit of 1.2 M $\Omega$  on the value of  $R_2$ , if the regulator must work with no load (a condition often found in CMOS in standby).  $I_{\text{FB}}$  will produce a 2% typical error in  $V_{\text{OUT}}$  which may be eliminated at room temperature by trimming  $R_1$ . For better accuracy, choosing  $R_2 = 100\text{k}$  reduces this error to 0.17% while increasing the resistor program current to 12  $\mu\text{A}$ . Since the LP2951 typically draws 60  $\mu\text{A}$  at no load with Pin 2 open-circuited, this is a small price to pay.

## Application Hints (Continued)



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\*See Application Hints

$$V_{out} = V_{Ref} \left( 1 + \frac{R_1}{R_2} \right)$$

\*\*Drive with TTL-high to shut down. Ground or leave open if shutdown feature is not to be used.

**Note:** Pins 2 and 6 are left open.

**FIGURE 2. Adjustable Regulator**

### REDUCING OUTPUT NOISE

In reference applications it may be advantageous to reduce the AC noise present at the output. One method is to reduce the regulator bandwidth by increasing the size of the output capacitor. This is the only way noise can be reduced on the 3 lead LP2950 but is relatively inefficient, as increasing the capacitor from 1  $\mu$ F to 220  $\mu$ F only decreases the noise from 430  $\mu$ V to 160  $\mu$ V rms for a 100 kHz bandwidth at 5V output.

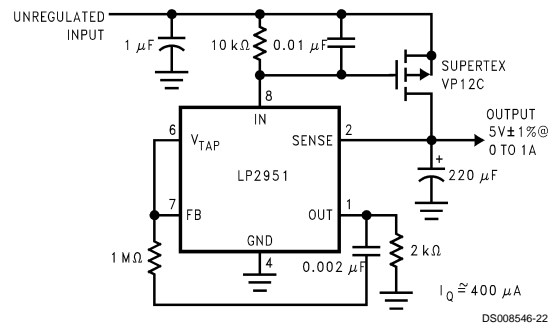
Noise can be reduced fourfold by a bypass capacitor across  $R_1$ , since it reduces the high frequency gain from 4 to unity. Pick

$$C_{BYPASS} \cong \frac{1}{2\pi R_1 \bullet 200 \text{ Hz}}$$

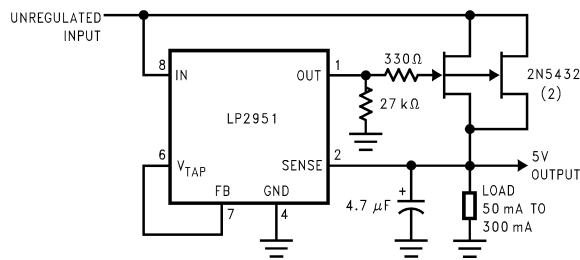
or about 0.01  $\mu$ F. When doing this, the output capacitor must be increased to 3.3  $\mu$ F to maintain stability. These changes reduce the output noise from 430  $\mu$ V to 100  $\mu$ V rms for a 100 kHz bandwidth at 5V output. With the bypass capacitor added, noise no longer scales with output voltage so that improvements are more dramatic at higher output voltages.

## Typical Applications

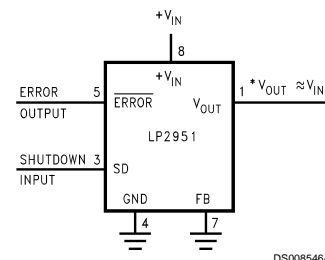
### 1A Regulator with 1.2V Dropout



### 300 mA Regulator with 0.75V Dropout

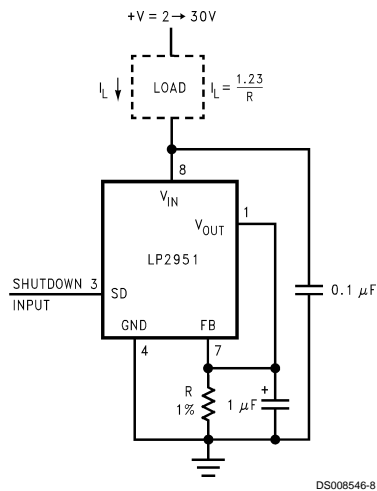


### Wide Input Voltage Range Current Limiter

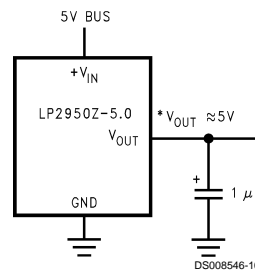


\*Minimum input-output voltage ranges from 40 mV to 400 mV, depending on load current. Current limit is typically 160 mA.

### Low Drift Current Source



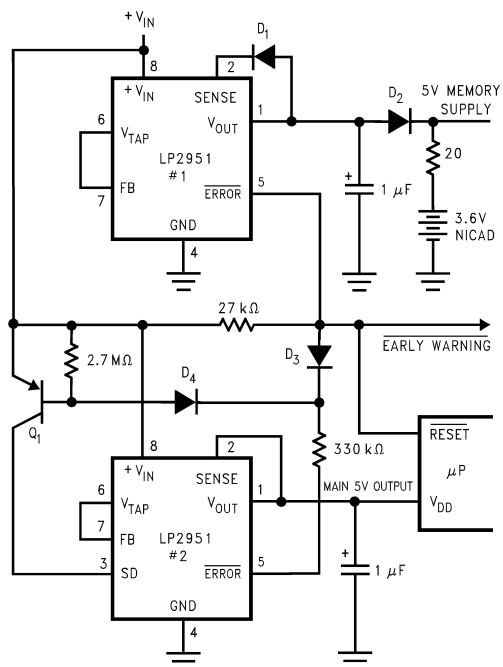
### 5 Volt Current Limiter



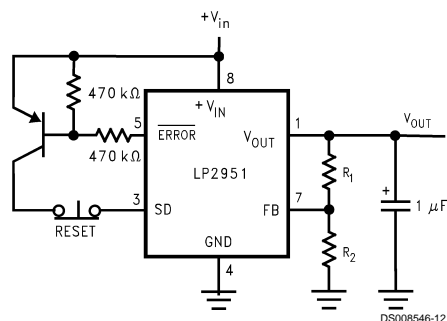
\*Minimum input-output voltage ranges from 40 mV to 400 mV, depending on load current. Current limit is typically 160 mA.

## Typical Applications (Continued)

### Regulator with Early Warning and Auxiliary Output



### Latch Off When Error Flag Occurs

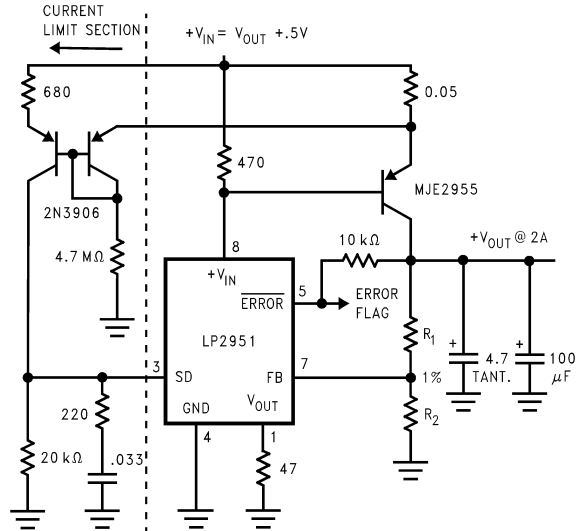


- Early warning flag on low input voltage
- Main output latches off at lower input voltages
- Battery backup on auxiliary output

Operation: Reg. #1's  $V_{out}$  is programmed one diode drop above 5V. Its error flag becomes active when  $V_{in} \leq 5.7V$ . When  $V_{in}$  drops below 5.3V, the error flag of Reg. #2 becomes active and via Q1 latches the main output off. When  $V_{in}$  again exceeds 5.7V Reg. #1 is back in regulation and the early warning signal rises, unlatching Reg. #2 via D3.

## Typical Applications (Continued)

### 2 Ampere Low Dropout Regulator

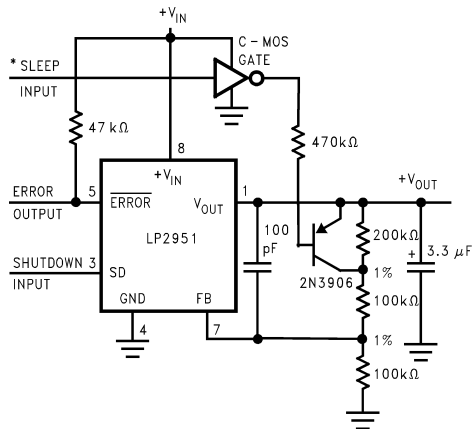


DS008546-13

$$V_{out} = 1.23V \left( 1 + \frac{R_1}{R_2} \right)$$

For 5V<sub>out</sub>, use internal resistors. Wire pin 6 to 7, & wire pin 2 to +V<sub>out</sub> Bus.

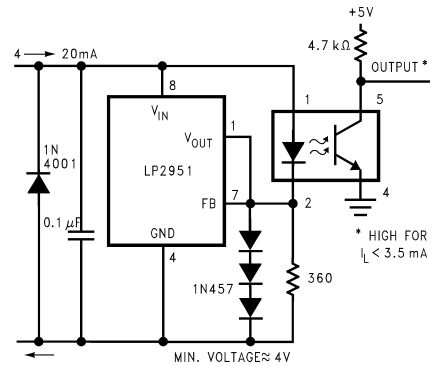
### 5V Regulator with 2.5V Sleep Function



DS008546-14

\*High input lowers V<sub>out</sub> to 2.5V

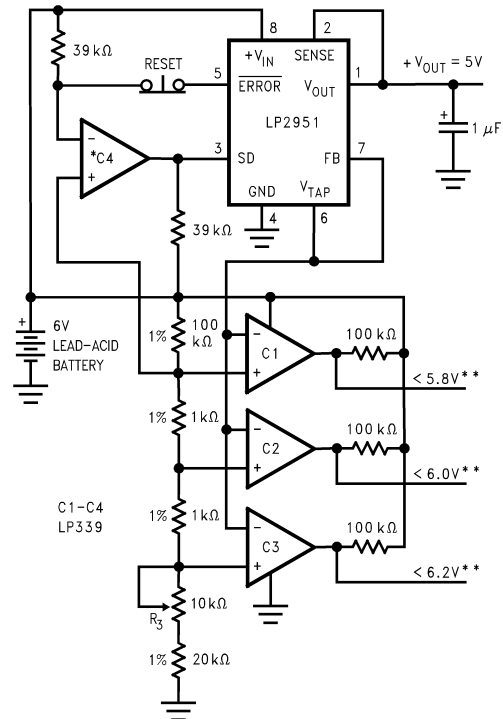
### Open Circuit Detector for 4 → 20 mA Current Loop



DS008546-15

## Typical Applications (Continued)

### Regulator with State-of-Charge Indicator

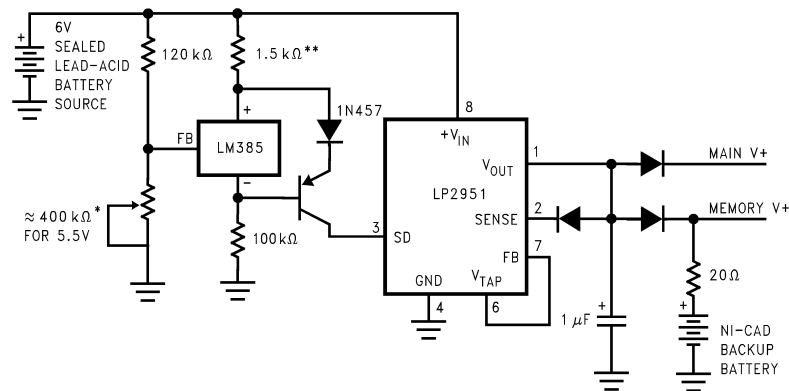


DS008546-16

\*Optional Latch off when drop out occurs. Adjust R3 for C2 Switching when  $V_{in}$  is 6.0V.

\*\*Outputs go low when  $V_{in}$  drops below designated thresholds.

### Low Battery Disconnect



DS008546-17

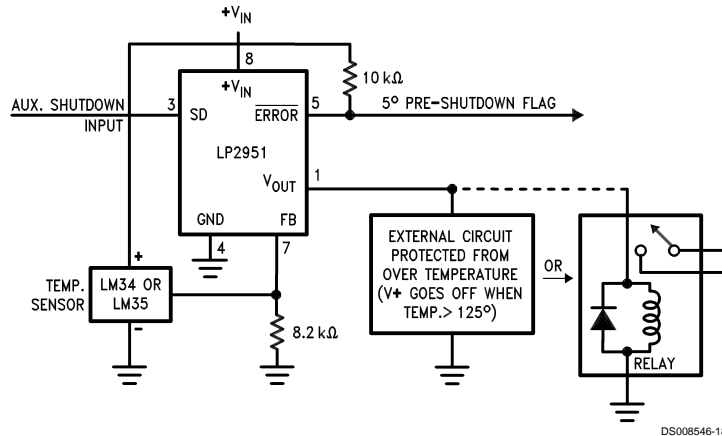
For values shown, Regulator shuts down when  $V_{in} < 5.5V$  and turns on again at 6.0V. Current drain in disconnected mode is  $\approx 150 \mu A$ .

\*Sets disconnect Voltage

\*\*Sets disconnect Hysteresis

## Typical Applications (Continued)

System Overtemperature Protection Circuit

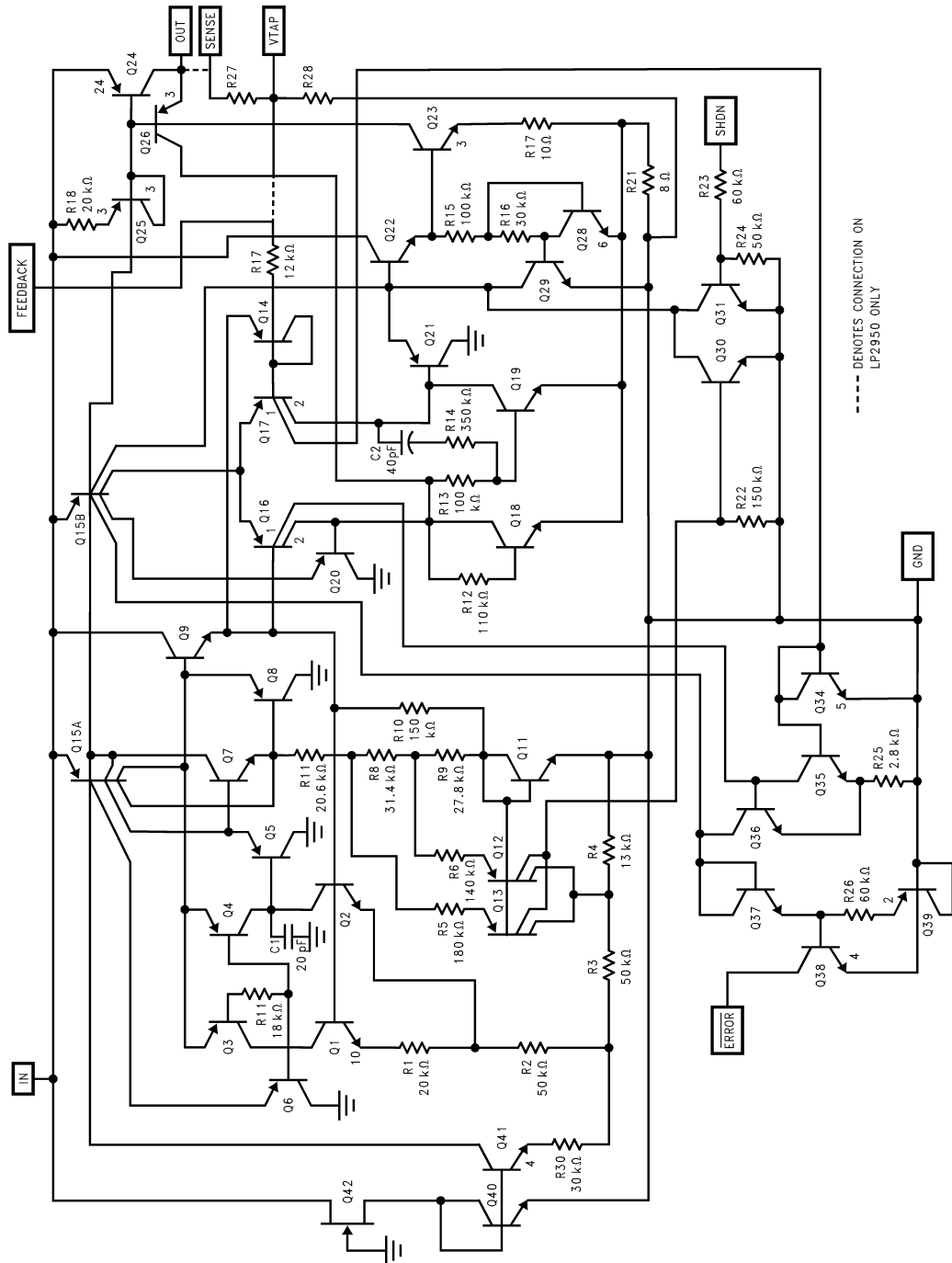


DS008546-18

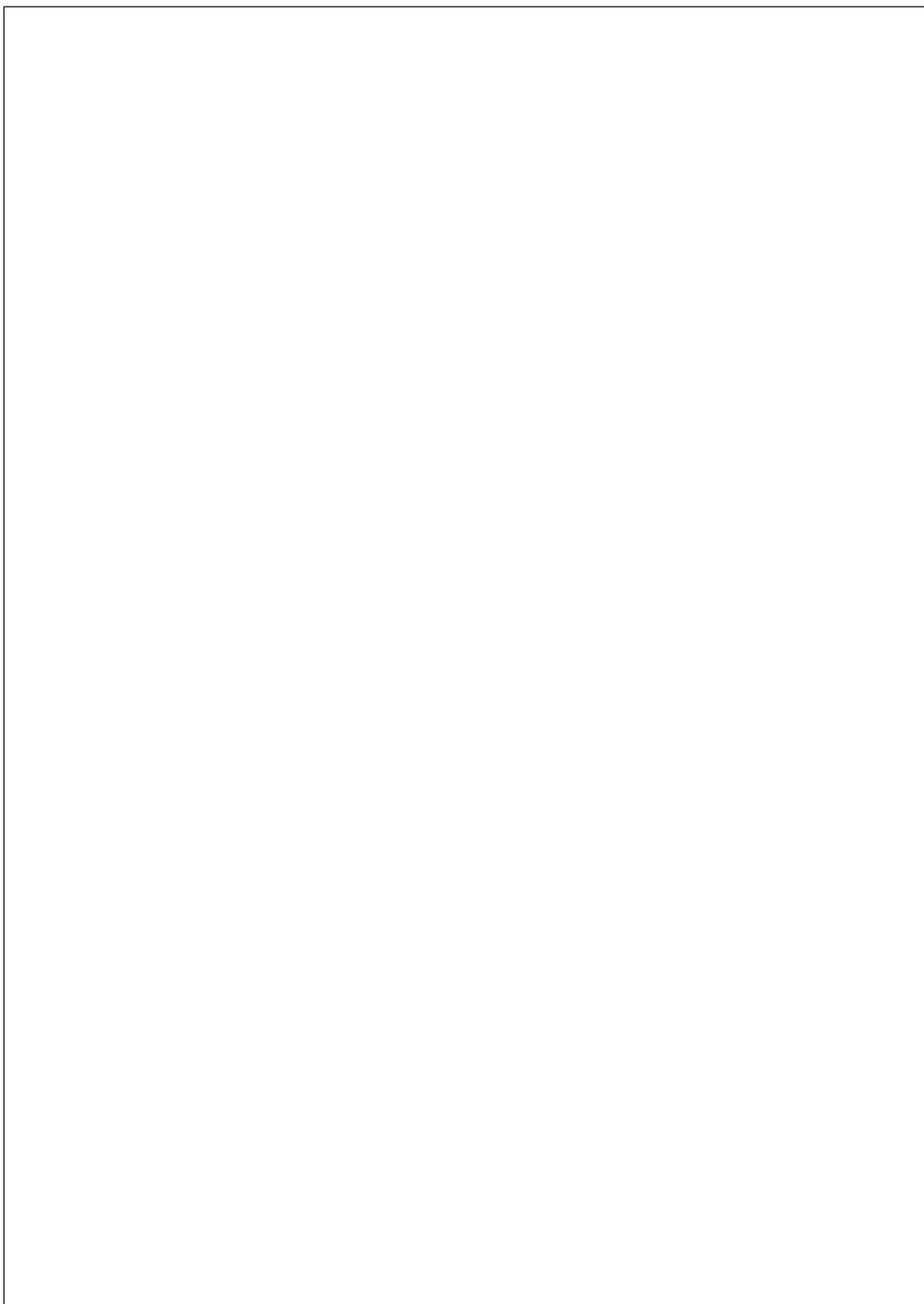
LM34 for 125°F Shutdown  
LM35 for 125°C Shutdown



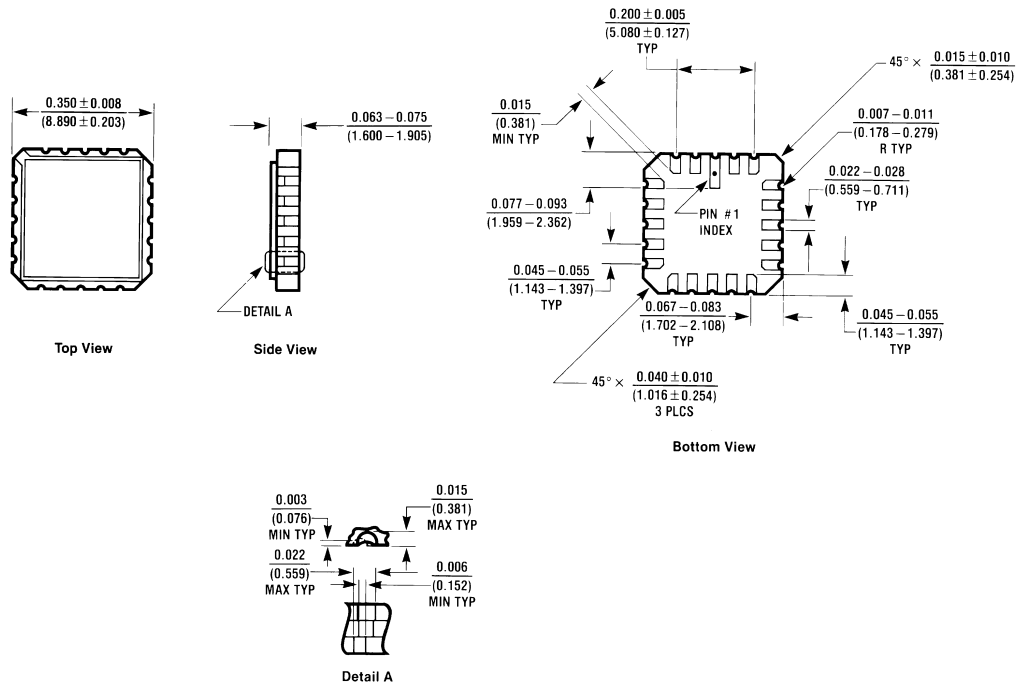
## Schematic Diagram



DS008546-23

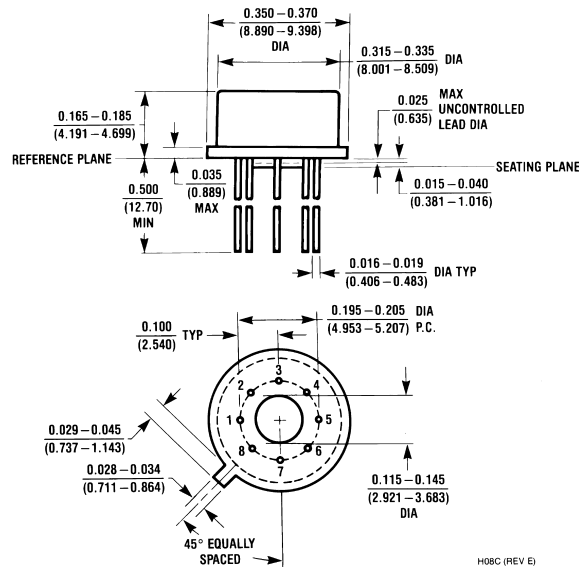


# Physical Dimensions inches (millimeters) unless otherwise noted



E20A (REV D)

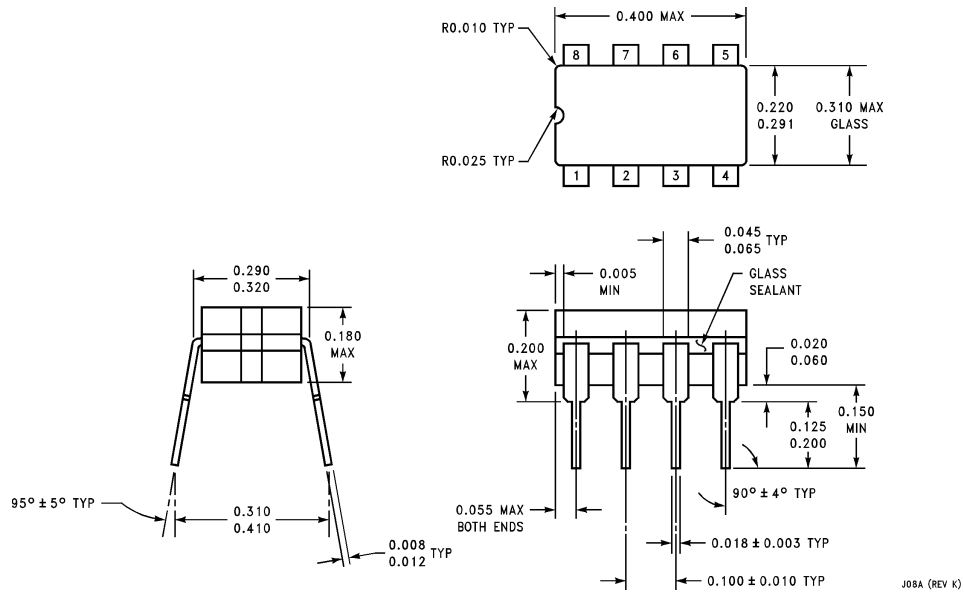
Order Number LP2951E/883 or 5962-3870501M2A  
NS Package Number E20A



H08C (REV E)

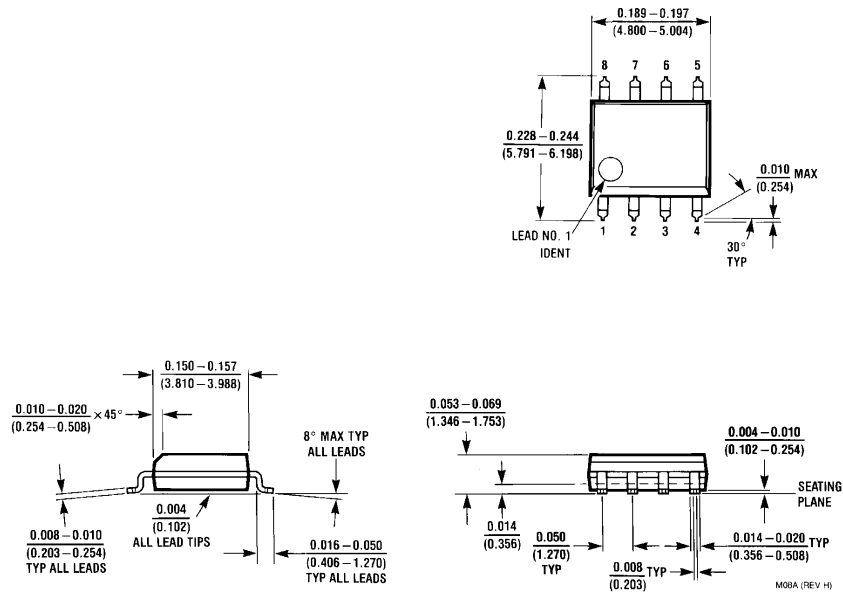
**Metal Can Package (H)**  
Order Number LP2951H/883 or 5962-3870501MGA  
NS Package Number H08C

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



**Ceramic Dual-In-Line Package (J)**

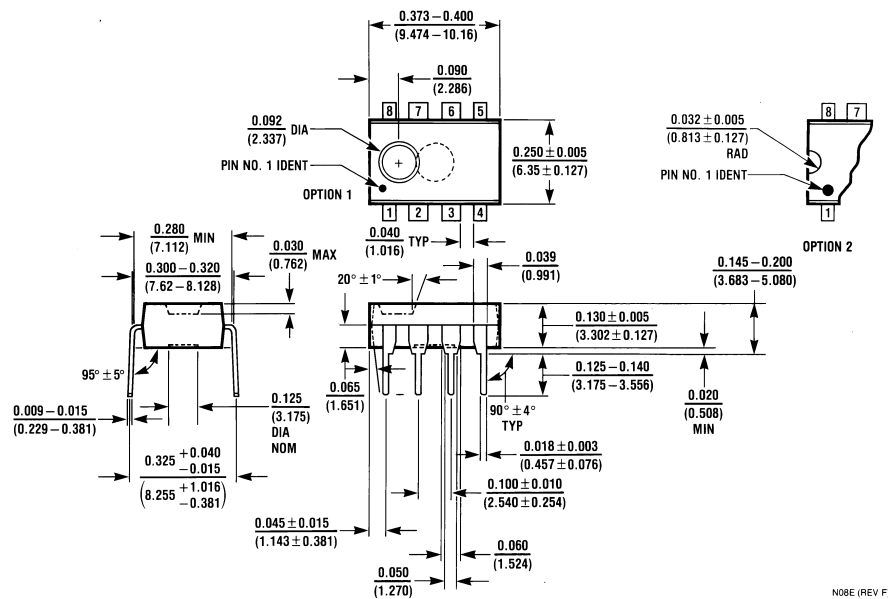
Order Number LP2951CJ, LP2951ACJ, LP2951J, LP2951J/883 or 5962-3870501MPA  
NS Package Number J08A



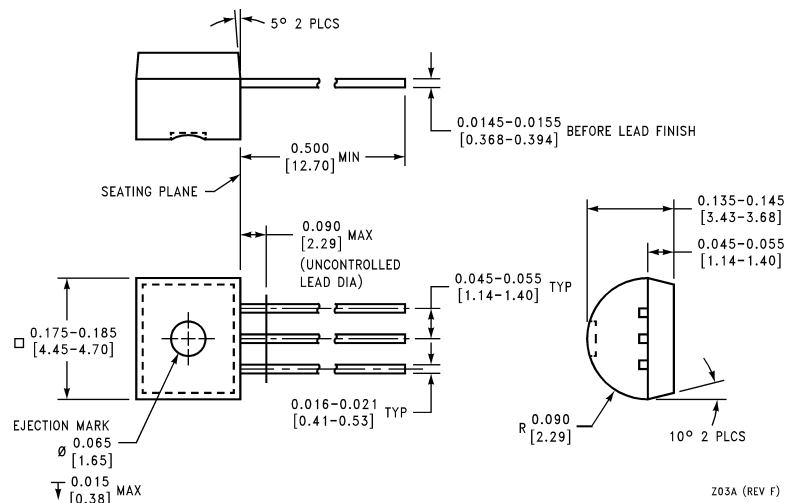
**Surface Mount Package (M)**

Order Number LP2951ACM, LP2951CM, LP2951ACM-3.0,  
LP2951CM-3.0, LP2951ACM-3.3 or LP2951CM-3.3  
NS Package Number M08A

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

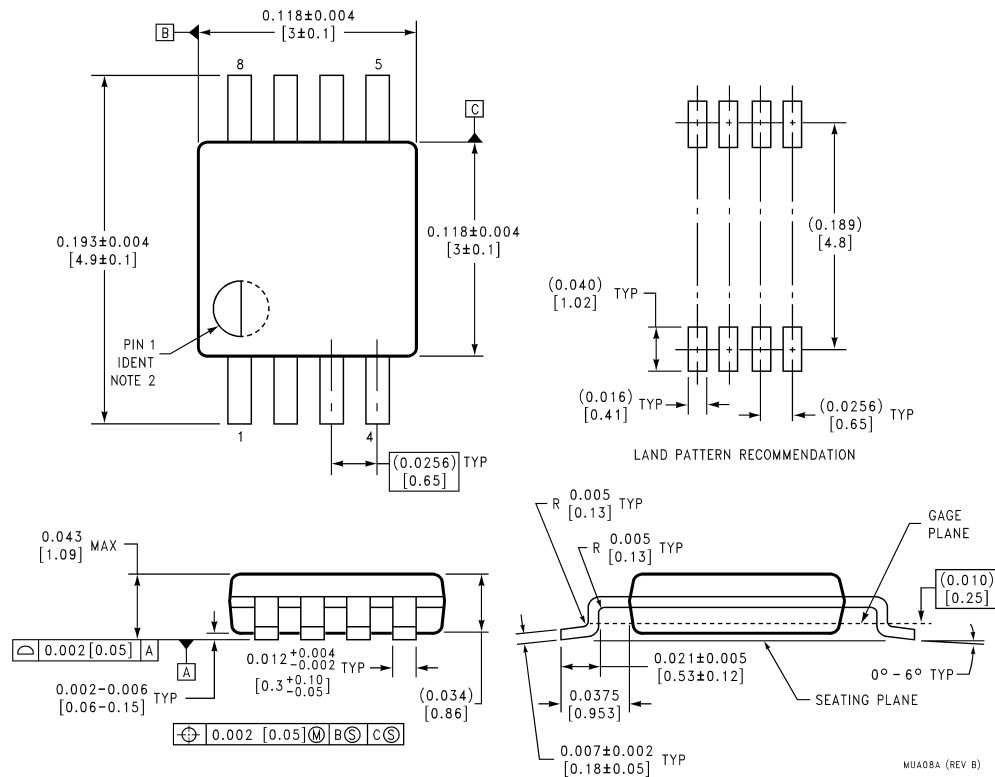


**Molded Dual-In-Line Package (N)**  
**Order Number LP2951ACN, LP2951CN, LP2951ACN-3.0,**  
**LP2951CN-3.0, or LP2951ACN-3.3 or LP2951CN-3.3**  
**NS Package Number N08E**



**Molded TO-92 Package (Z)**  
**Order Number LP2950ACZ-3.0 or LP2950CZ-3.0, LP2950ACZ-3.3,**  
**LP2950CZ-3.3, LP2950ACZ-5.0 or LP2950CZ-5.0**  
**NS Package Number Z03A**

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



**Surface Mount Package (MM)**  
**Order Number LP2951ACMM, LP2951CMM, LP2951ACMM-3.0,**  
**LP2951CMM-3.0, LP2951ACMM-3.3 or LP2951CMM-3.3**  
**NS Package Number MUA08A**

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