

# LP2950/LP2951

## Series of Adjustable Micropower Voltage Regulators

### General Description

The LP2950 and LP2951 are micropower voltage regulators with very low quiescent current (75  $\mu\text{A}$  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 is available in the surface-mount D-Pak package, and in the popular 3-pin TO-92 package for pin-compatibility 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.

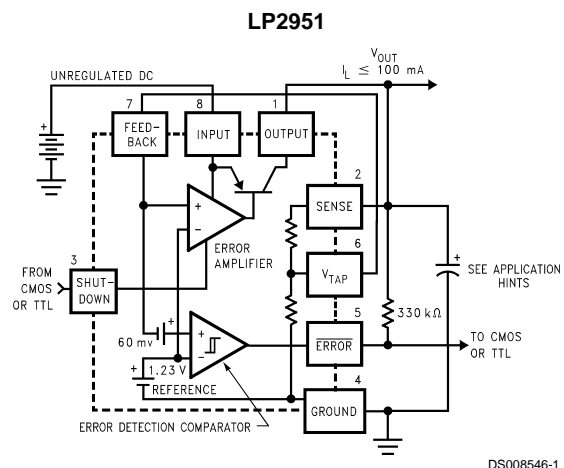
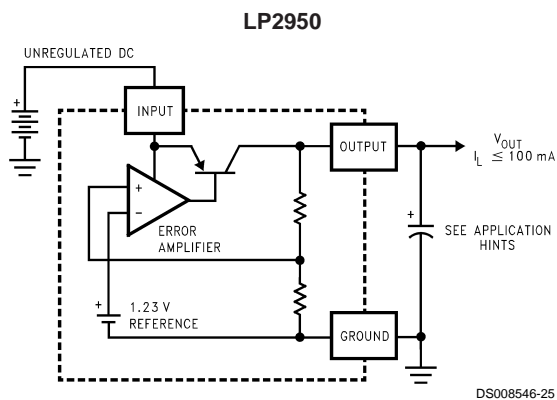
### Features

- 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

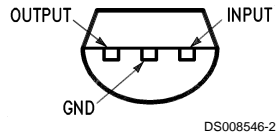
- Error flag warns of output dropout
- Logic-controlled electronic shutdown
- Output programmable from 1.24 to 29V

### Block Diagram and Typical Applications



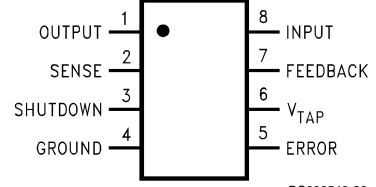
# Connection Diagrams

**TO-92 Plastic Package (Z)**



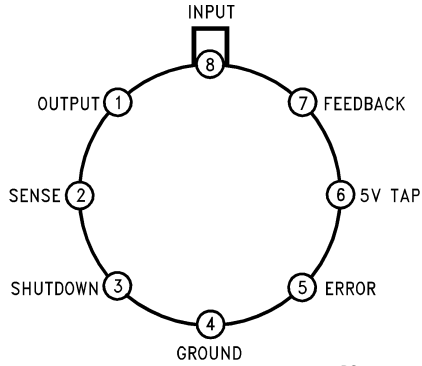
**Bottom View**

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



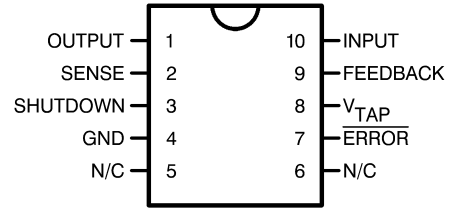
**Top View**

**Metal Can Package (H)**



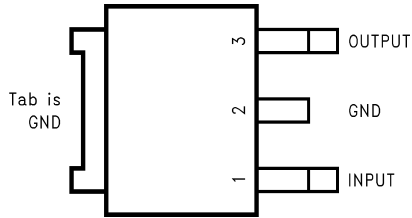
**Top View**

**10-Lead Ceramic Surface-Mount Package (WG)**



**Top View**

**TO-252 (D-Pak)**



**Front View**

## Ordering Information

Package	Output Voltage			Temperature (°C)
	3.0V	3.3V	5.0V	
TO-92 (Z)	LP2950ACZ-3.0	LP2950ACZ-3.3	LP2950ACZ-5.0	-40 < T <sub>J</sub> < 125
	LP2950CZ-3.0	LP2950CZ-3.3	LP2950CZ-5.0	
TO-252 (D-Pak)	LP2950CDT-3.0	LP2950CDT-3.3	LP2950CDT-5.0	-40 < T <sub>J</sub> < 125
N (N-08E)	LP2951ACN-3.0	LP2951ACN-3.3	LP2951ACN	-40 < T <sub>J</sub> < 125
	LP2951CN-3.0	LP2951CN-3.3	LP2951CN	
M (M08A)	LP2951ACM-3.0	LP2951ACM-3.3	LP2951ACM	-40 < T <sub>J</sub> < 125
	LP2951CM-3.0	LP2951CM-3.3	LP2951CM	
MM (MUA08A) in Tape and Reel	LP2951ACMM-3.0	LP2951ACMM-3.3	LP2951ACMM	-40 < T <sub>J</sub> < 125
	LP2951CMM-3.0	LP2951CMM-3.3	LP2951CMM	
J (J08A)			LP2951ACJ	-40 < T <sub>J</sub> < 125
			LP2951CJ	
			LP2951J	-55 < T <sub>J</sub> < 150
			LP2951J/883 5926-3870501MPA	
H (H08C)			LP2951H/883	-55 < T <sub>J</sub> < 150
			5962-3870501MGA	
WG (WG10A)			LP2951WG/883 5962-3870501MXA	-55 < T <sub>J</sub> < 150

### Package Marking for MM Package:

Order Number	Package Marking
LP2951ACMM	LODA
LP2951CMM	LODB
LP2951ACMM-3.3	LOCA
LP2951CMM-3.3	LOCB
LP2951ACMM-3.0	LOBA
LP2951CMM-3.0	LOBB

### 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 <sub>J</sub> )	+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 <sub>J</sub> ) (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)	
<b>3V VERSIONS (Note 17)</b>										
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	3.0	<b>3.045</b>	3.0		<b>3.042</b>	3.0		<b>3.072</b>	V max
	T <sub>J</sub> ≤ T <sub>JMAX</sub>		<b>2.955</b>			<b>2.958</b>			<b>2.928</b>	V min
<b>3.3V VERSIONS (Note 17)</b>										
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	3.3	<b>3.350</b>	3.3		<b>3.346</b>	3.3		<b>3.379</b>	V max
	T <sub>J</sub> ≤ T <sub>JMAX</sub>		<b>3.251</b>			<b>3.254</b>			<b>3.221</b>	V min
<b>5V VERSIONS (Note 17)</b>										
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	5.0	<b>5.075</b>	5.0		<b>5.075</b>	5.0		<b>5.12</b>	V max
	T <sub>J</sub> ≤ T <sub>JMAX</sub>		<b>4.925</b>			<b>4.925</b>			<b>4.88</b>	V min
<b>ALL VOLTAGE OPTIONS</b>										
Output Voltage Temperature Coefficient	(Note 12)	<b>20</b>	<b>120</b>	<b>20</b>		<b>100</b>	<b>50</b>		<b>150</b>	ppm/°C
Line Regulation (Note 14)	(V <sub>O</sub> NOM + 1)V ≤ V <sub>in</sub> ≤ 30V (Note 15)	0.03	0.1	0.03	0.1		0.04	0.2		% max
			<b>0.5</b>			<b>0.2</b>			<b>0.4</b>	% max
Load Regulation (Note 14)	100 μA ≤ I <sub>L</sub> ≤ 100 mA	0.04	0.1	0.04	0.1		0.1	0.2		% max
			<b>0.3</b>			<b>0.2</b>			<b>0.3</b>	% 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)	
<b>ALL VOLTAGE OPTIONS</b>										
Dropout Voltage (Note 5)	$I_L = 100 \mu\text{A}$	50	80 <b>150</b>	50	80	<b>150</b>	50	80	<b>150</b>	mV max mV max
	$I_L = 100 \text{mA}$	380	450 <b>600</b>	380	450	<b>600</b>	380	450	<b>600</b>	mV max mV max
Ground Current	$I_L = 100 \mu\text{A}$	75	120 <b>140</b>	75	120	<b>140</b>	75	120	<b>140</b>	$\mu\text{A}$ max $\mu\text{A}$ max
	$I_L = 100 \text{mA}$	8	12 <b>14</b>	8	12	<b>14</b>	8	12	<b>14</b>	mA max mA max
Dropout Ground Current	$V_{in} = (V_{O\text{NOM}} - 0.5)\text{V}$ $I_L = 100 \mu\text{A}$	110	170 <b>200</b>	110	170	<b>200</b>	110	170	<b>200</b>	$\mu\text{A}$ max $\mu\text{A}$ max
Current Limit	$V_{out} = 0$	160	200 <b>220</b>	160	200	<b>220</b>	160	200	<b>220</b>	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	$C_L = 1 \mu\text{F}$ (5V Only)	430		430			430			$\mu\text{V}$ rms
	$C_L = 200 \mu\text{F}$	160		160			160			$\mu\text{V}$ rms
	$C_L = 3.3 \mu\text{F}$ (Bypass = 0.01 $\mu\text{F}$ Pins 7 to 1 (LP2951))	100		100			100			$\mu\text{V}$ rms
<b>8-PIN VERSIONS ONLY</b>										
Reference Voltage		1.235	1.25 <b>1.26</b> 1.22 <b>1.2</b>	1.235	1.25 1.22	<b>1.26</b> <b>1.2</b>	1.235	1.26 1.21	<b>1.27</b> <b>1.2</b>	V max V max V min V min
	(Note 7)		<b>1.27</b> <b>1.19</b>			<b>1.27</b> <b>1.19</b>			<b>1.285</b> <b>1.185</b>	V max V min
	Feedback Pin Bias Current	20	40 <b>60</b>	20	40	<b>60</b>	20	40	<b>60</b>	nA max nA max
	Reference Voltage Temperature Coefficient	(Note 12)	20		20			50		
Feedback Pin Bias Current Temperature Coefficient		0.1		0.1			0.1			nA/°C
<b>Error Comparator</b>										
Output Leakage Current	$V_{OH} = 30\text{V}$	0.01	1 <b>2</b>	0.01	1	<b>2</b>	0.01	1	<b>2</b>	$\mu\text{A}$ max $\mu\text{A}$ max
Output Low Voltage	$V_{in} = (V_{O\text{NOM}} - 0.5)\text{V}$ $I_{OL} = 400 \mu\text{A}$	150	250 <b>400</b>	150	250	<b>400</b>	150	250	<b>400</b>	mV max mV max
Upper Threshold Voltage	(Note 6)	60	40 <b>25</b>	60	40	<b>25</b>	60	40	<b>25</b>	mV min mV min
Lower Threshold Voltage	(Note 6)	75	95 <b>140</b>	75	95	<b>140</b>	75	95	<b>140</b>	mV max mV max
Hysteresis	(Note 6)	15		15			15			mV
<b>Shutdown Input</b>										
Input Logic Voltage	Low (Regulator ON) High (Regulator OFF)	1.3	<b>0.6</b> <b>2.0</b>	1.3		<b>0.7</b> <b>2.0</b>	1.3		<b>0.7</b> <b>2.0</b>	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)	
<b>Shutdown Input</b>										
Shutdown Pin Input Current	$V_{\text{shutdown}} = 2.4\text{V}$	30	50 <b>100</b>	30	50	<b>100</b>	30	50	<b>100</b>	$\mu\text{A max}$ $\mu\text{A max}$
	$V_{\text{shutdown}} = 30\text{V}$	450	600 <b>750</b>	450	600	<b>750</b>	450	600	<b>750</b>	$\mu\text{A max}$ $\mu\text{A max}$
Regulator Output Current in Shutdown	(Note 11)	3	10 <b>20</b>	3	10	<b>20</b>	3	10	<b>20</b>	$\mu\text{A max}$ $\mu\text{A max}$

**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  $V_{\text{IN}} = (V_{\text{ONOM}} + 1)\text{V}$ ,  $I_{\text{L}} = 100 \mu\text{A}$  and  $C_{\text{L}} = 1 \mu\text{F}$  for 5V versions and  $2.2 \mu\text{F}$  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:**  $V_{\text{ref}} \leq V_{\text{out}} \leq (V_{\text{in}} - 1\text{V})$ ,  $2.3\text{V} \leq V_{\text{in}} \leq 30\text{V}$ ,  $100 \mu\text{A} \leq I_{\text{L}} \leq 100 \text{ mA}$ ,  $T_{\text{J}} \leq T_{\text{JMAX}}$ .

**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), and  $160^\circ\text{C/W}$  for the metal can package (H). The above thermal resistances for the N, J, M, and MM packages apply when the package is soldered directly to the PCB. Junction-to-case thermal resistance for the H package is  $20^\circ\text{C/W}$ . Junction-to-case thermal resistance for the TO-252 package is  $5.4^\circ\text{C/W}$ .

**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  $V_{\text{IN}} = 30\text{V}$  (1.25V 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.

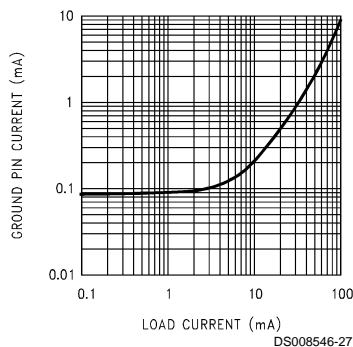
**Note 15:** Line regulation for the LP2951 is tested at  $150^\circ\text{C}$  for  $I_{\text{L}} = 1 \text{ mA}$ . For  $I_{\text{L}} = 100 \mu\text{A}$  and  $T_{\text{J}} = 125^\circ\text{C}$ , line regulation is guaranteed by design to 0.2%. See Typical Performance Characteristics for line regulation 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, WG, or J may also be procured as Standard Military Drawing Spec #5962-3870501MGA, MXA, or MPA.

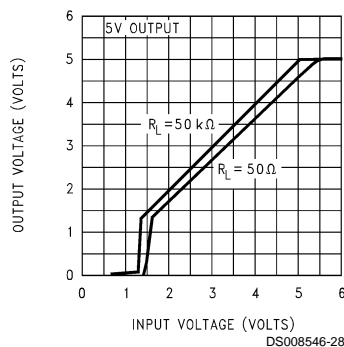
**Note 17:** All LP2950 devices have the nominal output voltage coded as the last two digits of the part number. In the LP2951 products, the 3.0V and 3.3V versions are designated by the last two digits, but the 5V version is denoted with no code at this location of the part number (refer to ordering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

## Typical Performance Characteristics

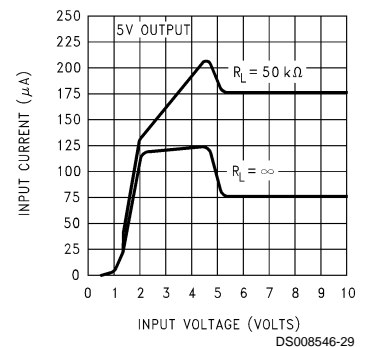
**Quiescent Current**



**Dropout Characteristics**

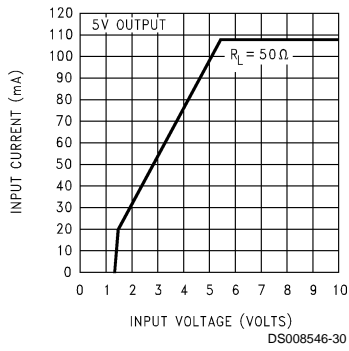


**Input Current**

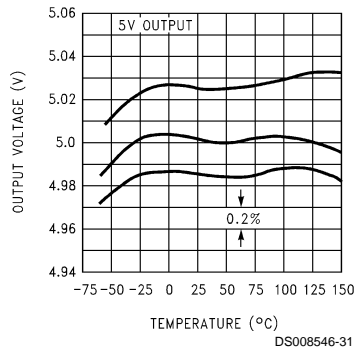


# Typical Performance Characteristics (Continued)

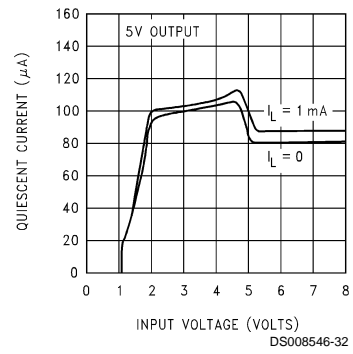
**Input Current**



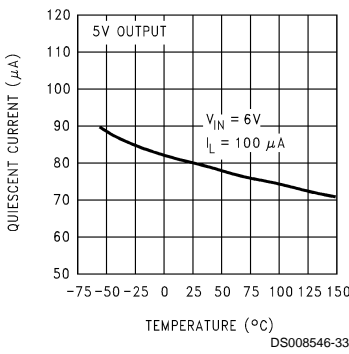
**Output Voltage vs. Temperature of 3 Representative Units**



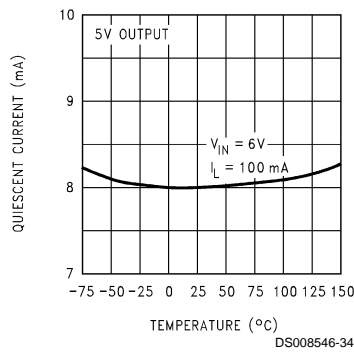
**Quiescent Current**



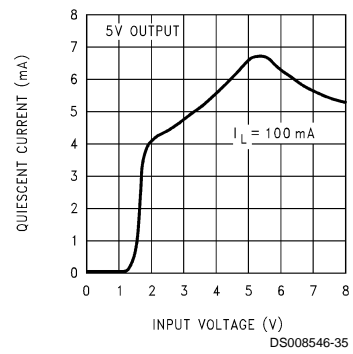
**Quiescent Current**



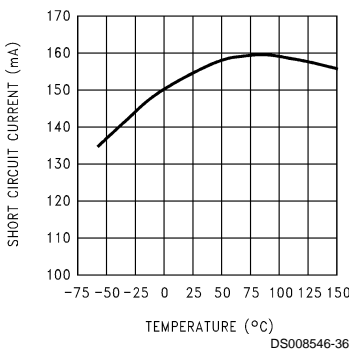
**Quiescent Current**



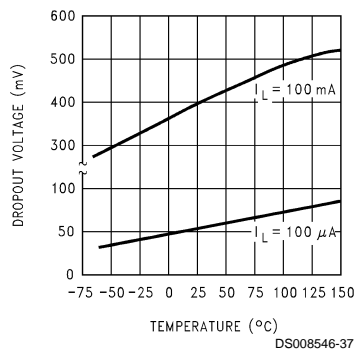
**Quiescent Current**



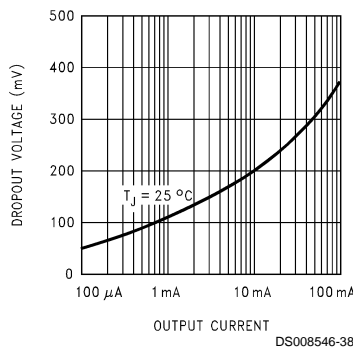
**Short Circuit Current**



**Dropout Voltage**

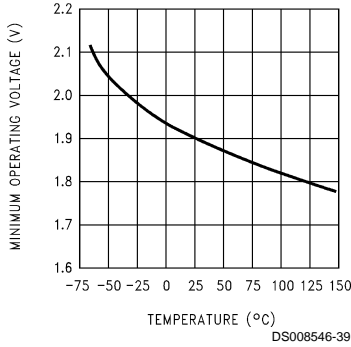


**Dropout Voltage**

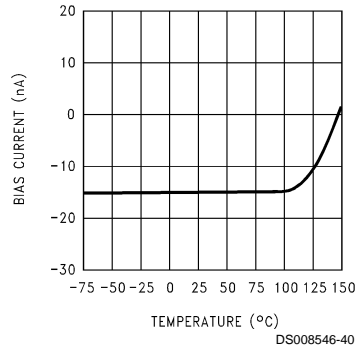


# Typical Performance Characteristics (Continued)

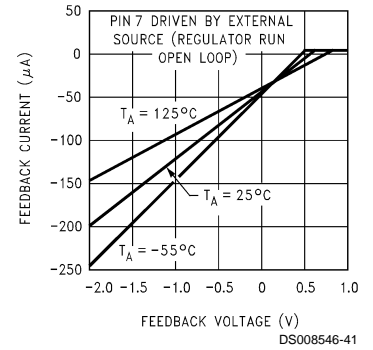
**LP2951**  
Minimum Operating Voltage



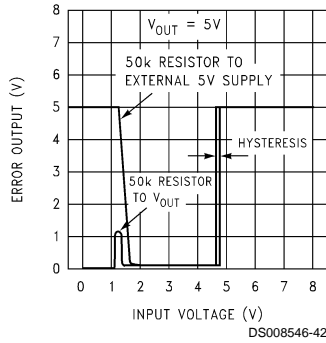
**LP2951**  
Feedback Bias Current



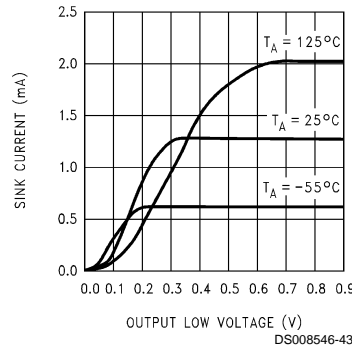
**LP2951**  
Feedback Pin Current



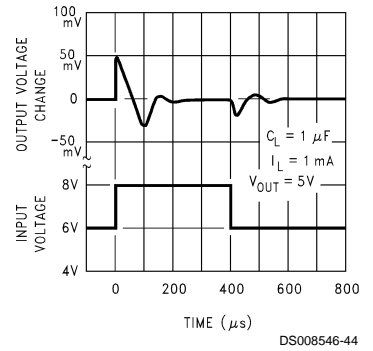
**LP2951**  
Error Comparator Output



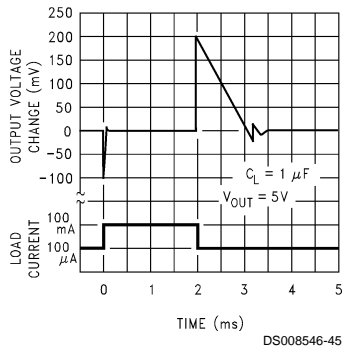
**LP2951**  
Comparator Sink Current



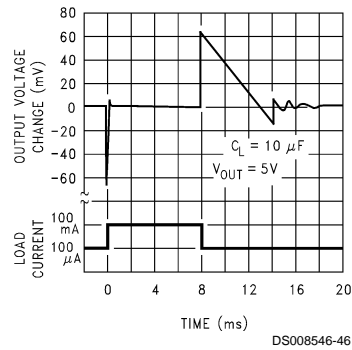
**Line Transient Response**



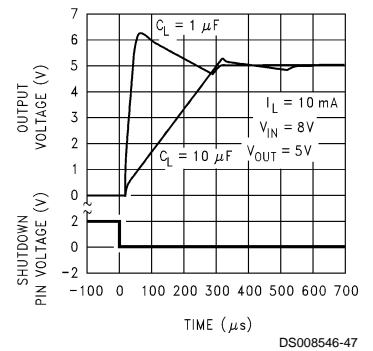
**Load Transient Response**



**Load Transient Response**



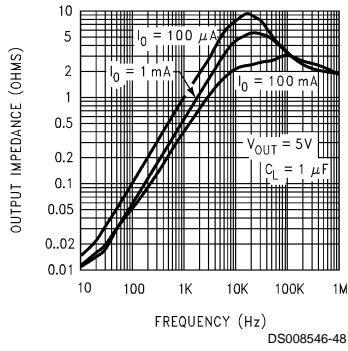
**LP2951**  
Enable Transient





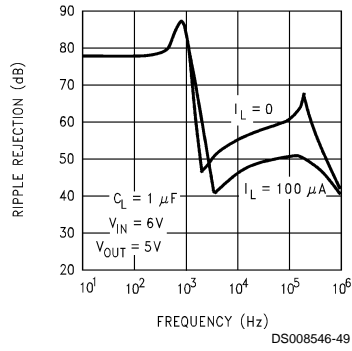
# Typical Performance Characteristics (Continued)

## Output Impedance



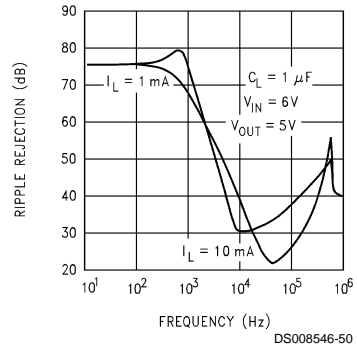
DS008546-48

## Ripple Rejection



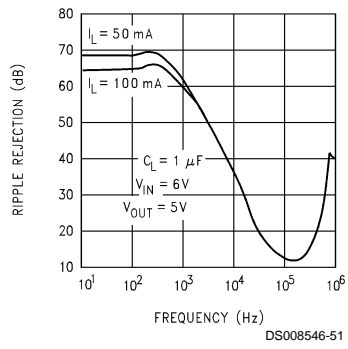
DS008546-49

## Ripple Rejection



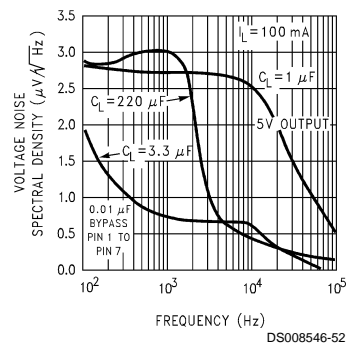
DS008546-50

## Ripple Rejection



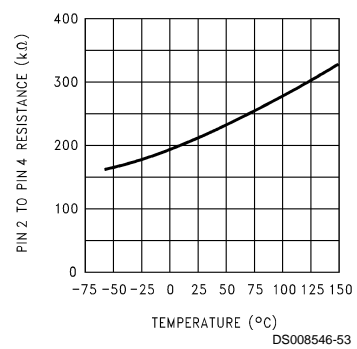
DS008546-51

## LP2951 Output Noise



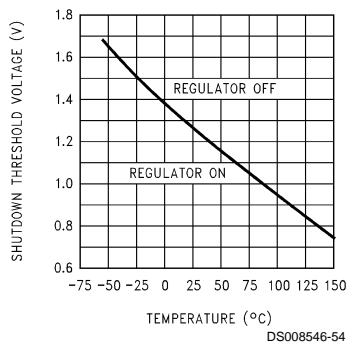
DS008546-52

## LP2951 Divider Resistance



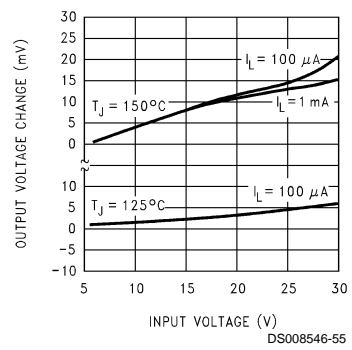
DS008546-53

## Shutdown Threshold Voltage



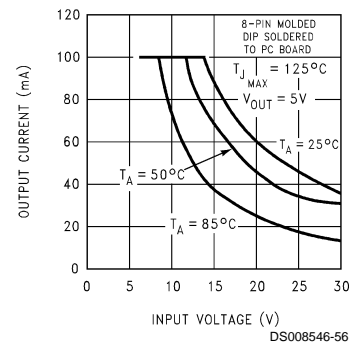
DS008546-54

## Line Regulation



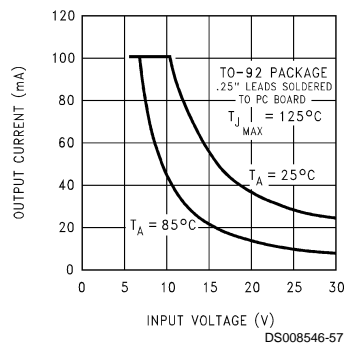
DS008546-55

## LP2951 Maximum Rated Output Current



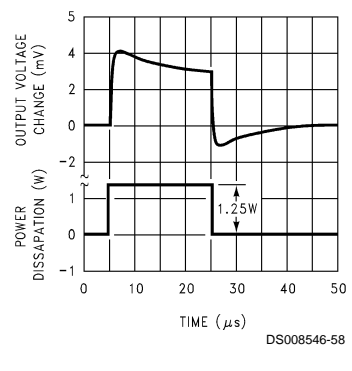
DS008546-56

## LP2950 Maximum Rated Output Current



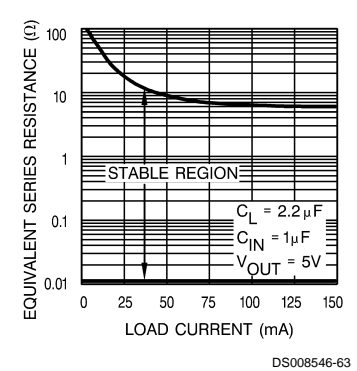
DS008546-57

## Thermal Response



DS008546-58

## Output Capacitor ESR Range



DS008546-63

## 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.

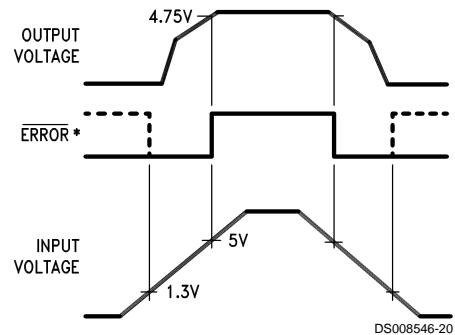
### ERROR DETECTION COMPARATOR OUTPUT

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.  $\overline{\text{ERROR}}$  Output Timing

### PROGRAMMING THE OUTPUT VOLTAGE (LP2951)

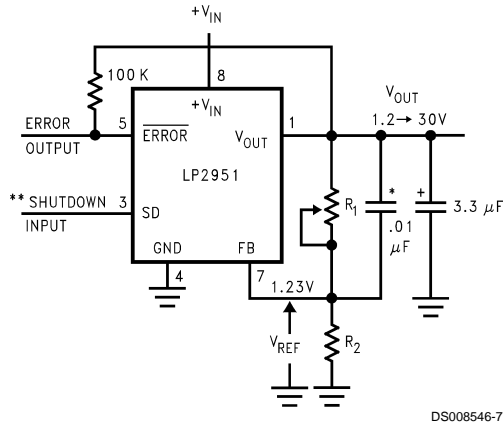
The LP2951 may be pin-strapped for the nominal fixed output voltage using its internal voltage divider by tying the output and sense pins together, and also tying the feedback and  $V_{\text{TAP}}$  pins together. Alternatively, it may be programmed for any output voltage between its 1.235V reference 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)



\*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.

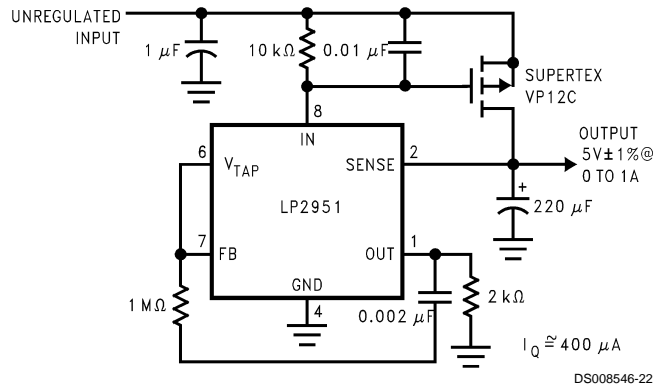
Noise can be reduced fourfold by a bypass capacitor across  $R_1$ , since it reduces the high frequency gain from 4 to unity. Pick

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

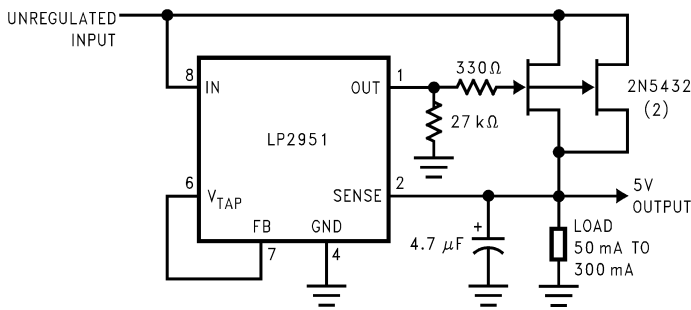
or about 0.01  $\mu$ F. When doing this, the output capacitor must be increased to 3.3  $\mu$ F to maintain stability. These changes reduce the output noise from 430  $\mu$ V to 100  $\mu$ V rms for a 100 kHz bandwidth at 5V output. With the bypass capacitor added, noise no longer scales with output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

# Typical Applications

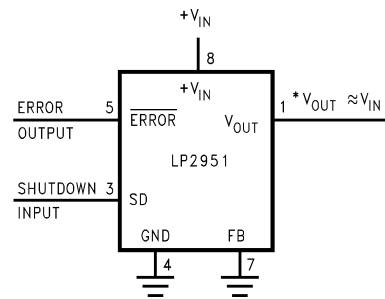
**1A Regulator with 1.2V Dropout**



**300 mA Regulator with 0.75V Dropout**



**Wide Input Voltage Range Current Limiter**

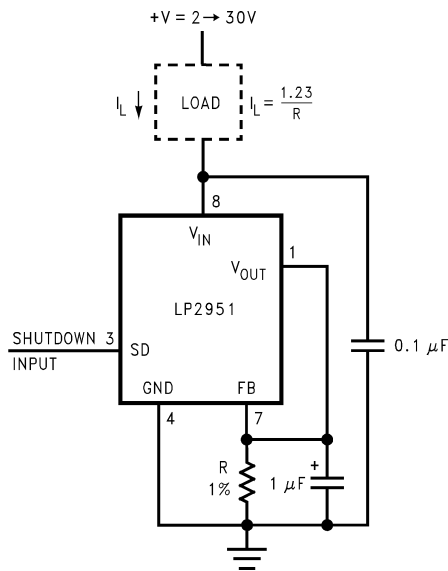


DS008546-21

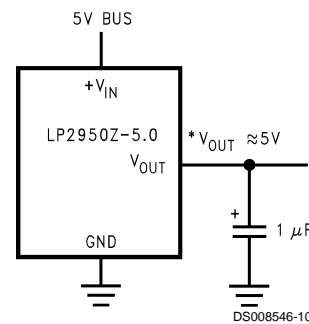
DS008546-9

\*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**



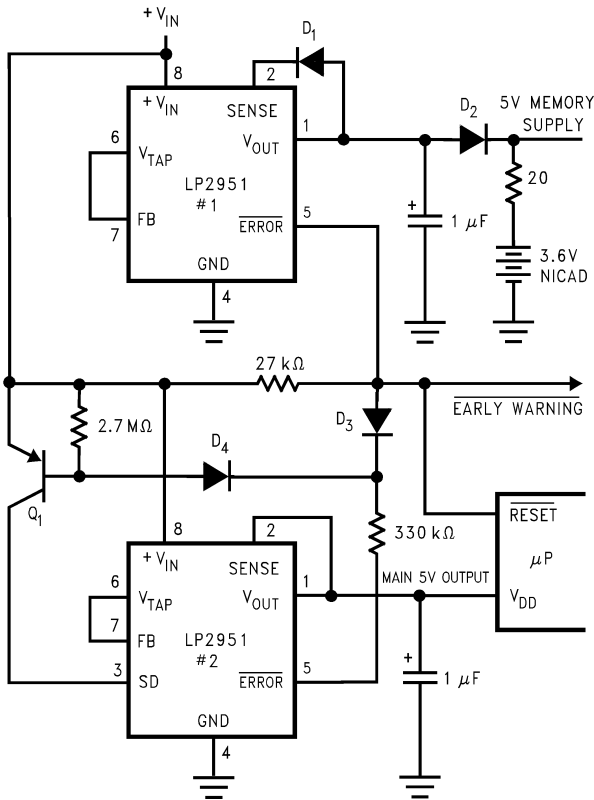
**5 Volt Current Limiter**



\*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

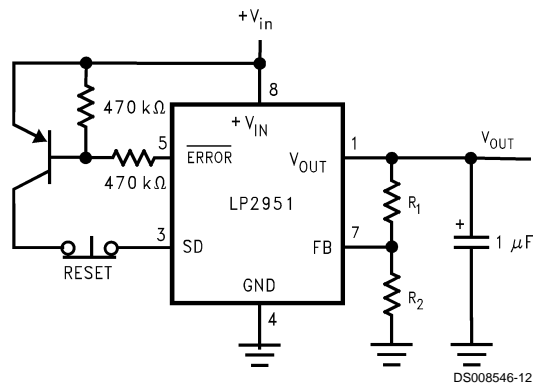


DS008546-11

- 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  $Q_1$  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  $D_3$ .

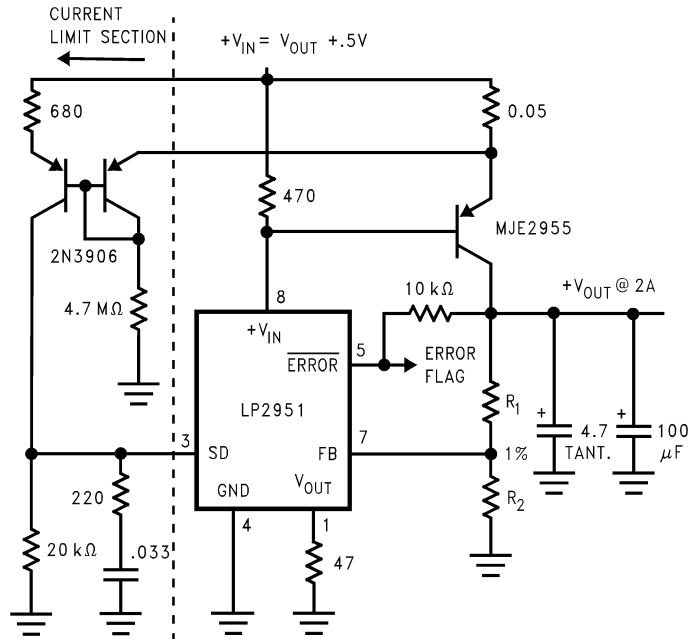
## Latch Off When Error Flag Occurs



DS008546-12

Typical Applications (Continued)

2 Ampere Low Dropout Regulator

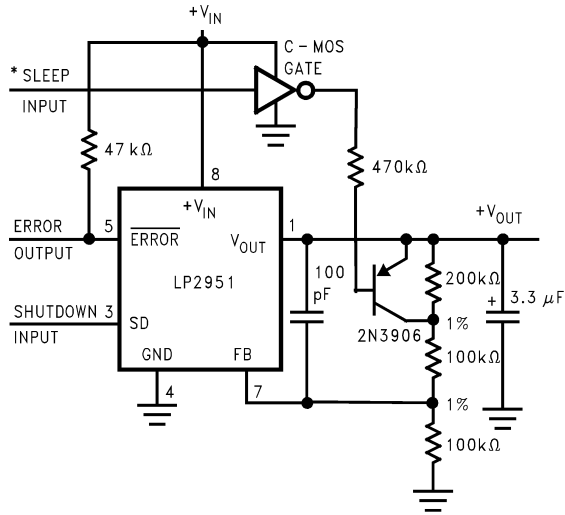


DS008546-13

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

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

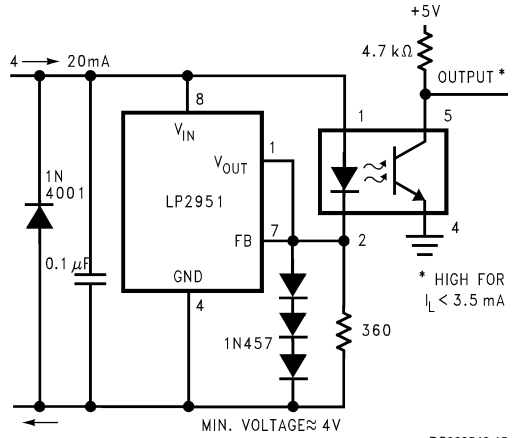
5V Regulator with 2.5V Sleep Function



DS008546-14

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

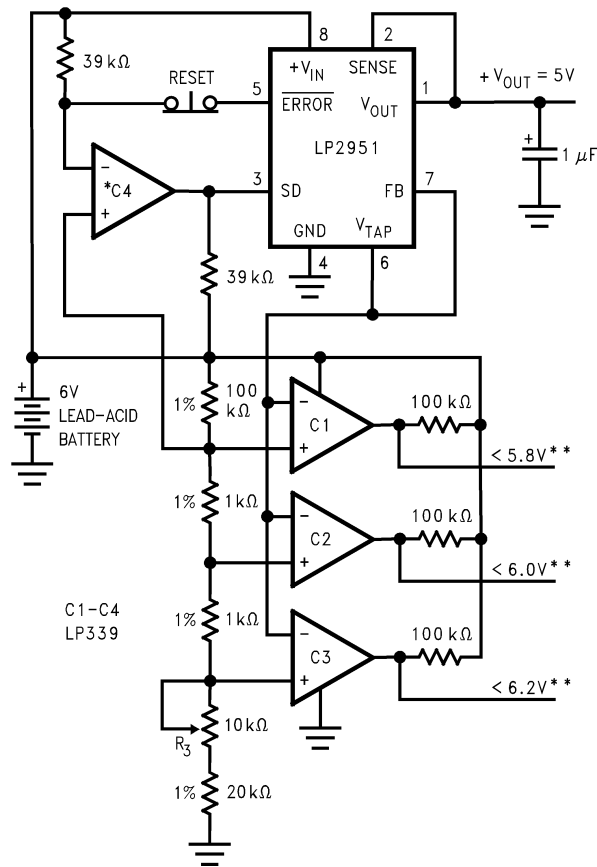
Open Circuit Detector for 4 → 20 mA Current Loop



DS008546-15

Typical Applications (Continued)

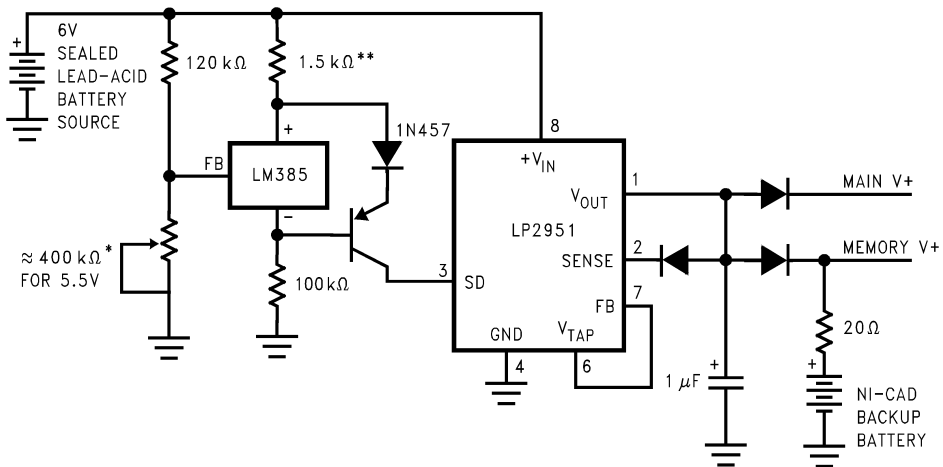
Regulator with State-of-Charge Indicator



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

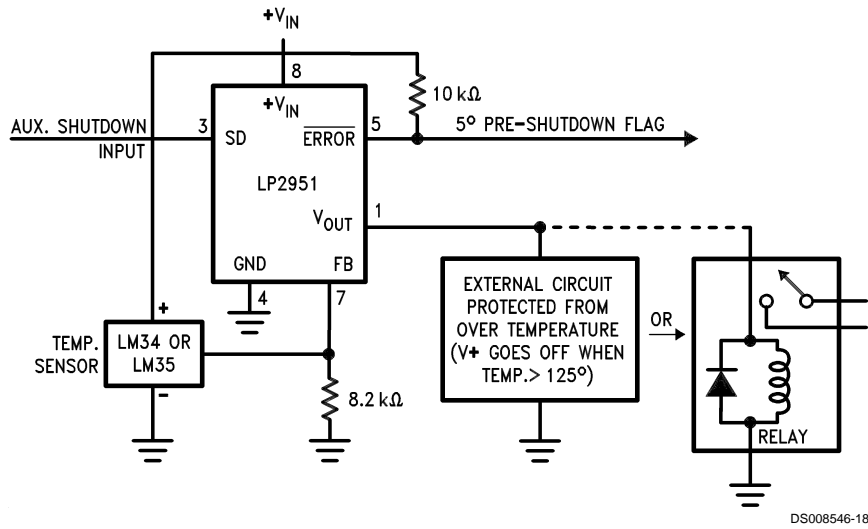


DS008546-17

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

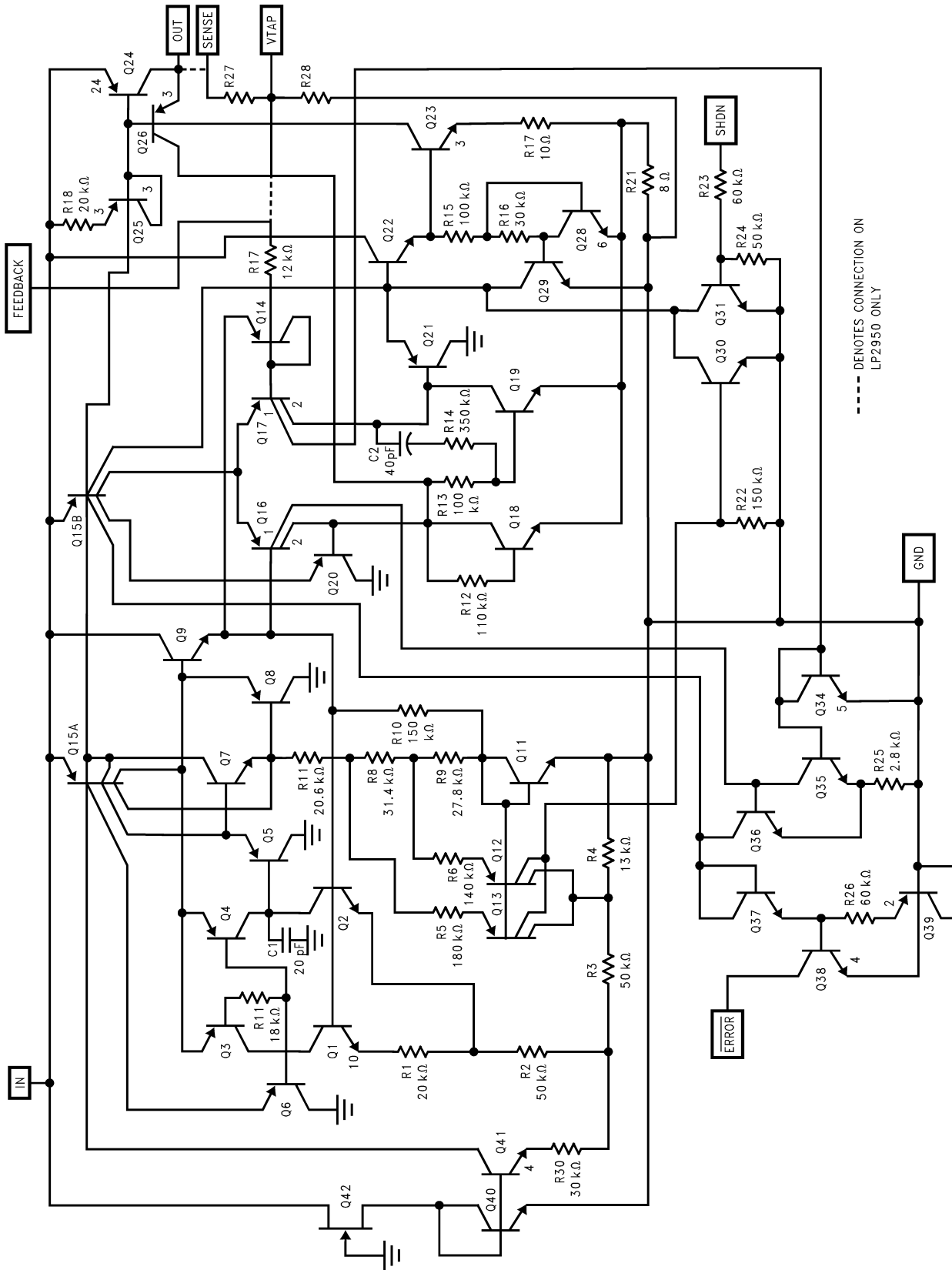


DS008546-18

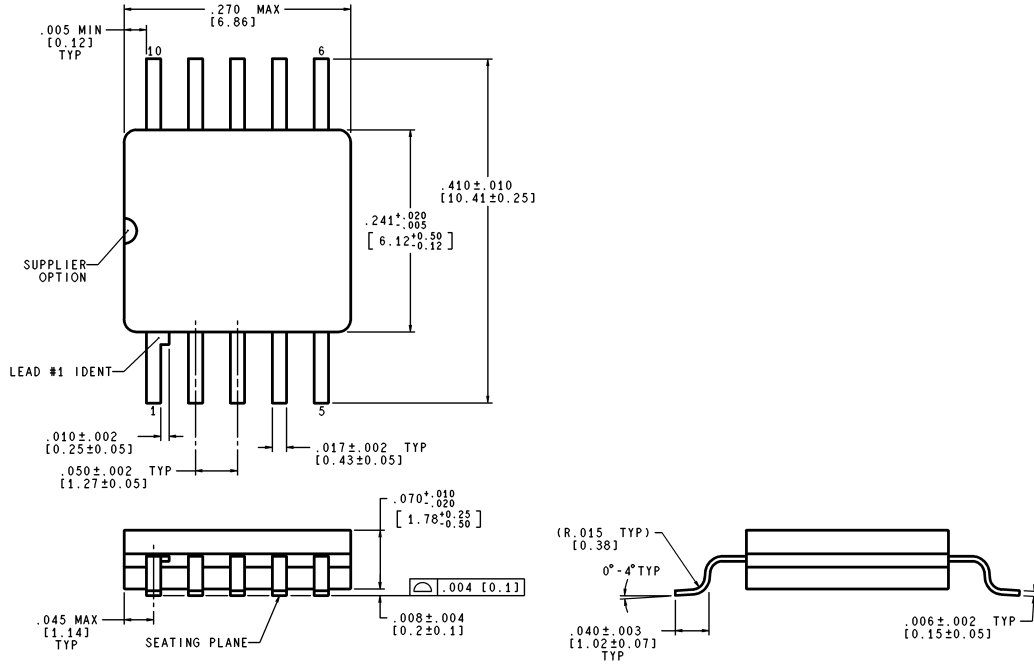
LM34 for 125°F Shutdown  
 LM35 for 125°C Shutdown



# Schematic Diagram



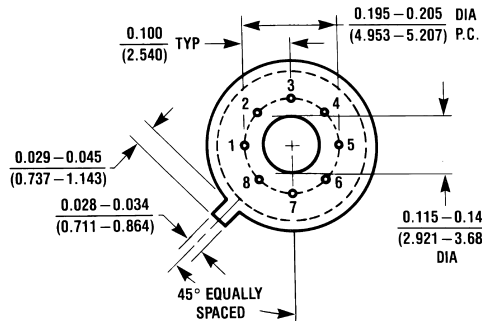
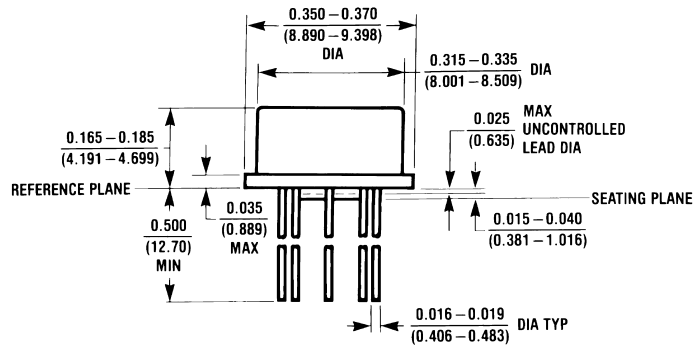
**Physical Dimensions** inches (millimeters) unless otherwise noted



CONTROLLING DIMENSION IS INCH  
VALUES IN [ ] ARE MILLIMETERS

WG10A (Rev C)

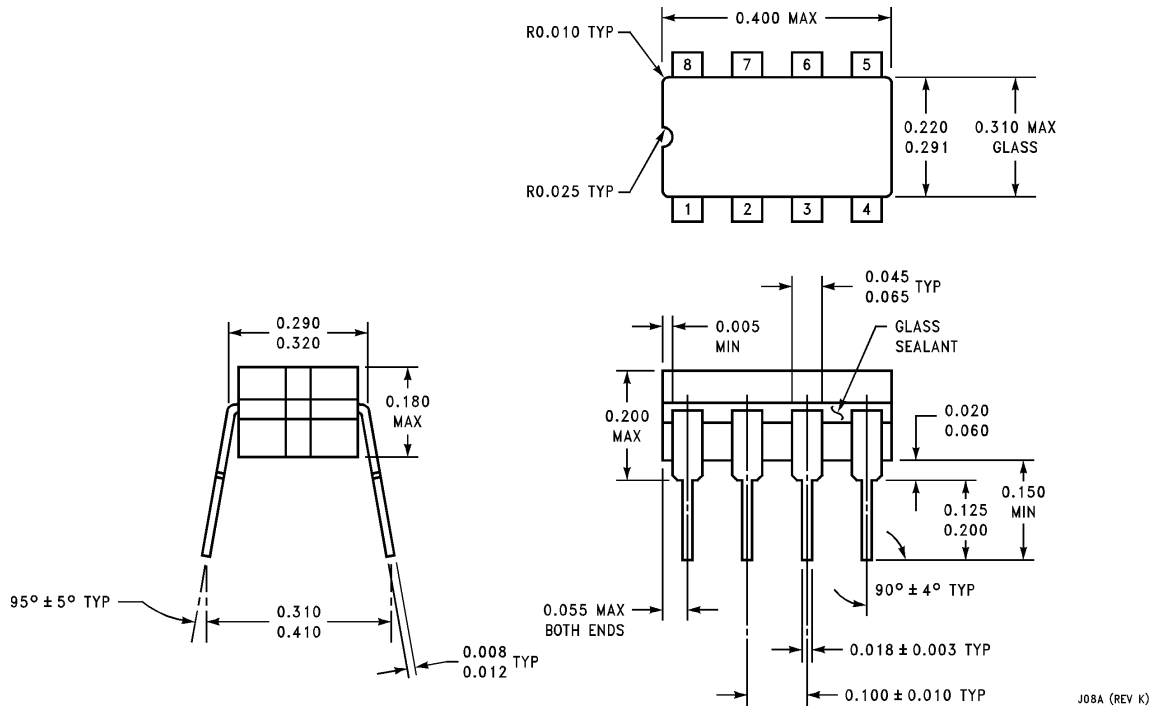
**Order Number LP2951WG/883 or 5962-3870501MXA**  
**NS Package Number WG10A**



H08C (REV E)

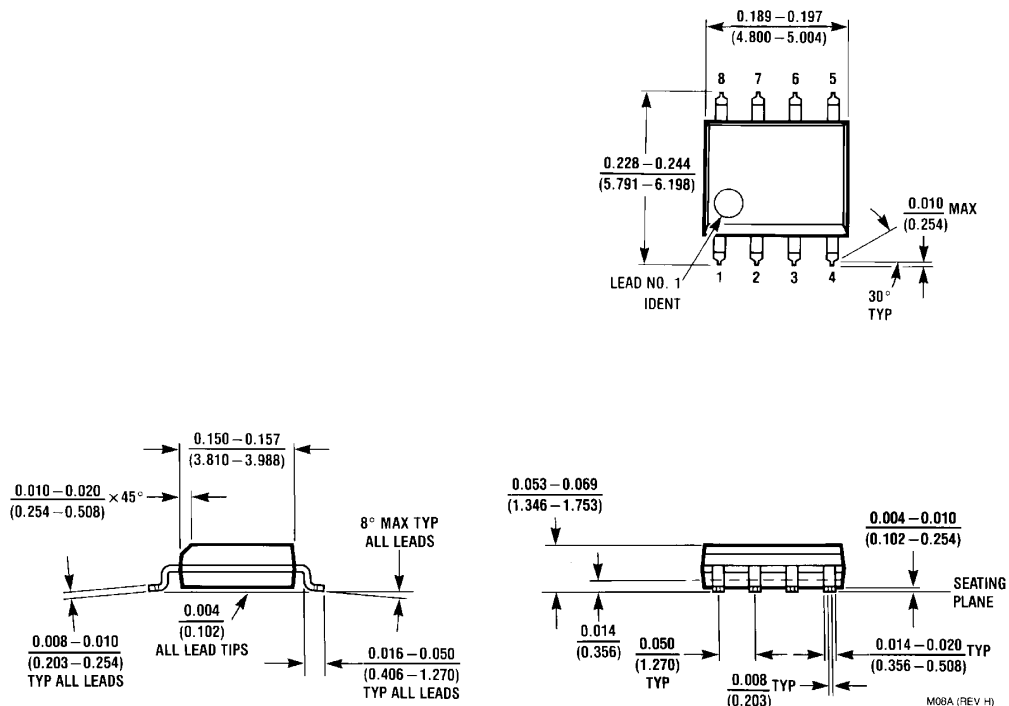
**Metal Can Package (H)**  
**Order Number LP2951H/883 or 5962-3870501MGA**  
**NS Package Number H08C**

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



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

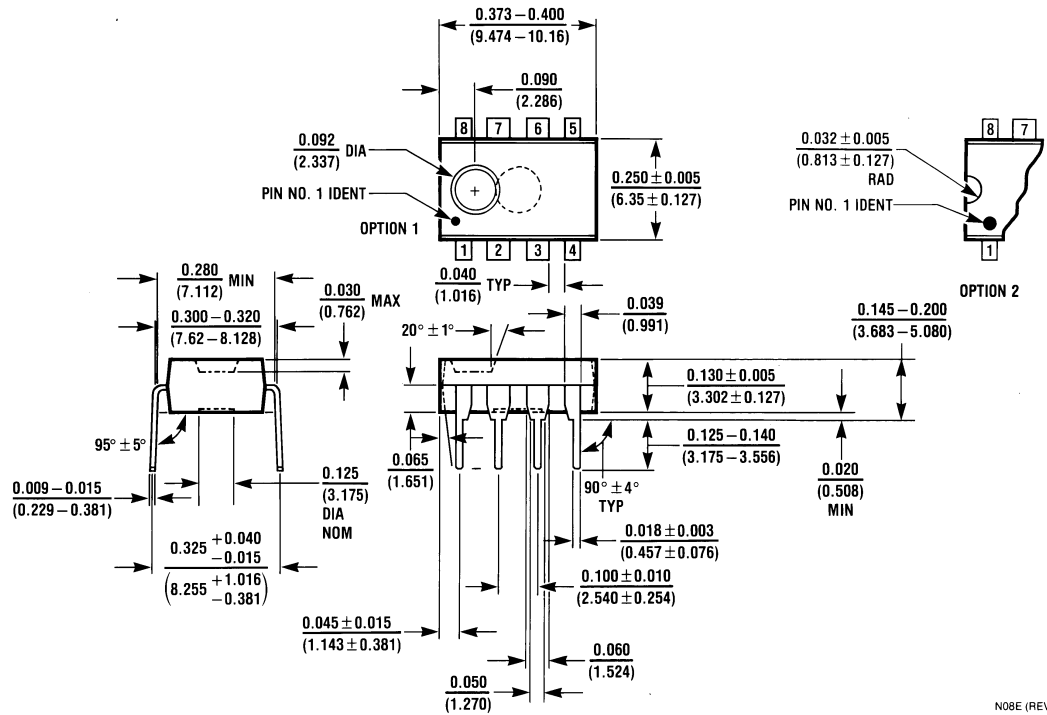
Order Number LP2951CJ, LP2951ACJ, LP2951J, LP2951J/883 or 5962-3870501MPA  
NS Package Number J08A



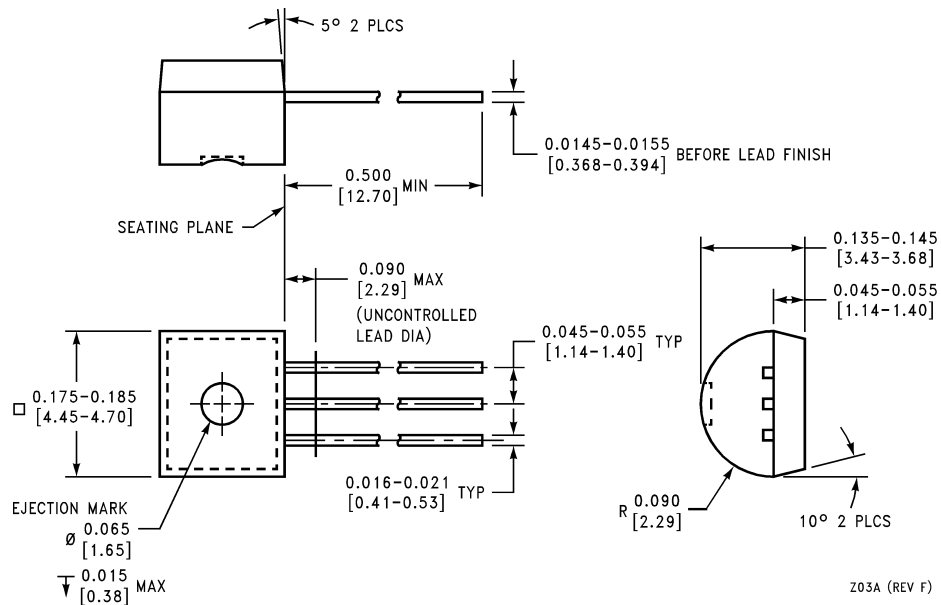
**Surface Mount Package (M)**

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)

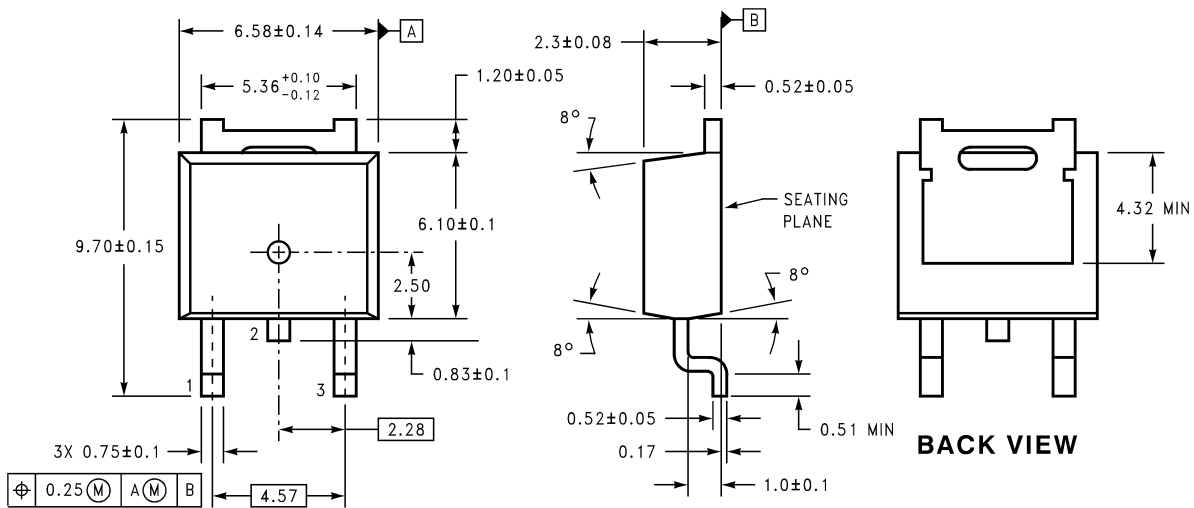
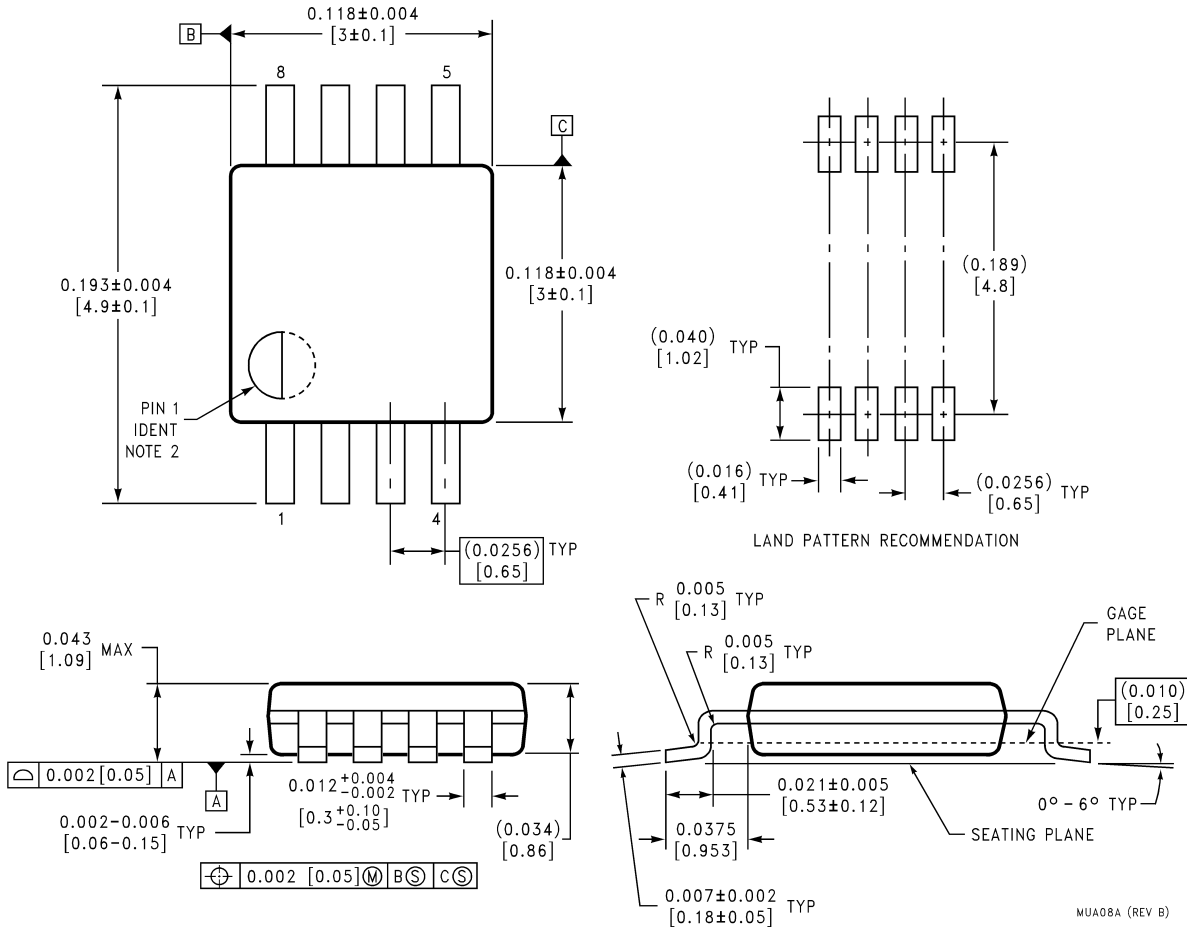


**Molded Dual-In-Line Package (N)**  
 Order Number LP2951ACN, LP2951CN, LP2951ACN-3.0,  
 LP2951CN-3.0, or LP2951ACN-3.3 or LP2951CN-3.3  
 NS Package Number N08E



**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)



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