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MOTOROLA

LP2950
LP2951

Advance Information

Micropower Voltage Regulators

LOW DROPOUT MICROPOWER VOLTAGE REGULATORS

SEMICONDUCTOR TECHNICAL DATA

The LP2950 and LP2951 are micropower voltage regulators that are specifically designed to maintain proper regulation with an extremely low input–to–output voltage differential. These devices feature a very low quiescent bias current of 75 μA and are capable of supplying output currents in excess of 100 mA. Internal current and thermal limiting protection is provided.

The LP2951 has three additional features. The first is the $\overline{\text{Error}}$ Output that can be used to signal external circuitry of an out of regulation condition, or as a microprocessor power–on reset. The second feature allows the output voltage to be preset to 5.0 V or programmed from 1.25 V to 29 V. It consists of a pinned out resistor divider along with direct access to the Error Amplifier feedback input. The third feature is a Shutdown input that allows a logic level signal to turn–off or turn–on the regulator output.

Due to the low input–to–output voltage differential and bias current specifications, these devices are ideally suited for battery powered computer, consumer, and industrial equipment where an extension of useful battery life is desirable. These LP2950 is available in the three pin case 29 package, and the LP2951 is available in the eight pin dual–in–line SO–8 surface mount packages. The 'A' suffix devices feature an initial output voltage tolerance +0.5%.

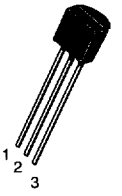
LP2950 and LP2951 Features:

- Low Quiescent Bias Current of 75 μA
- Low Input–to–Output Voltage Differential of 50 mV at 100 μA and 380 mV at 100 mA
- 5.0 V ±0.5% Allows Use as a Regulator or Reference
- Extremely Tight Line and Load Regulation
- Requires Only a 1.0 μF Output Capacitor for Stability
- Internal Current and Thermal Limiting

LP2951 Additional Features:

- $\overline{\text{Error}}$ Output Signals an Out of Regulation Condition
- Output Programmable from 1.25 V to 29 V
- Logic Level Shutdown Input

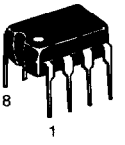
P SUFFIX
PLASTIC PACKAGE
CASE 29
(TO–226AA/TO–92)



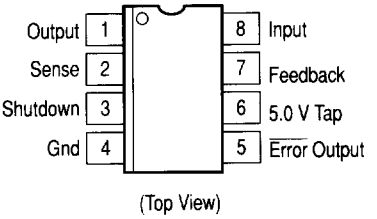
Pin: 1. Output
2. Ground
3. Input

D SUFFIX
PLASTIC PACKAGE
CASE 751
(SO–8)

P1 SUFFIX
PLASTIC PACKAGE
CASE 626



PIN CONNECTIONS



(Top View)

ORDERING INFORMATION

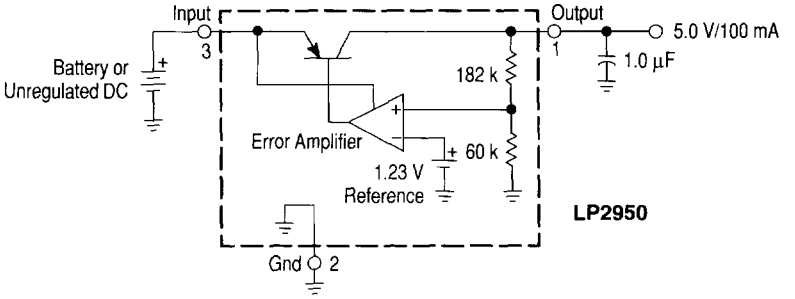
Device	Type	Tested Operating Temperature Range	Package
LP2950CP–5 LP2950ACP–5	5.0 V Fixed	T_A = –25° to +85°C	TO–226AA/ TO–92
LP2951CD–5 LP2951ACD–5	5.0 V Fixed or Adjustable		SO–8
LP2951CP1–5 LP2951ACP1–5	5.0 Fixed or Adjustable		Plastic

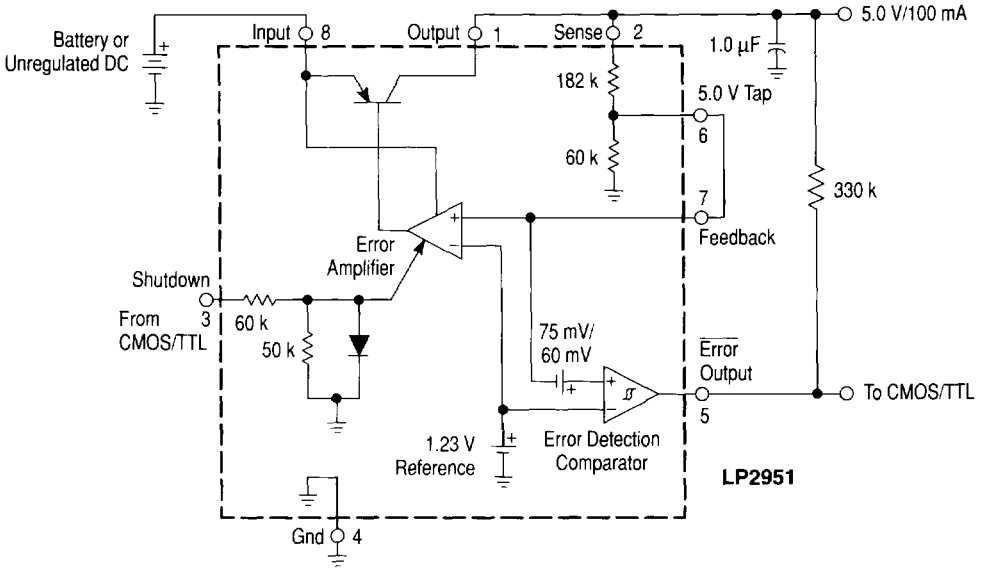
This document contains information on a product under development. Motorola reserves the right to change or discontinue this product without notice.

MAXIMUM RATINGS (T_A = 25°C, unless otherwise noted.)

Rating	Symbol	Value	Unit
Input Voltage	V_{CC}	30	Vdc
Power Dissipation and Thermal Characteristics Maximum Power Dissipation	P_D	Internally Limited	W
Case 751(SO–8) D Suffix			
Thermal Resistance, Junction–to–Ambient	$R_{\theta JA}$	180	°C/W
Thermal Resistance, Junction–to–Case	$R_{\theta JC}$	45	°C/W
Case 29 (TO–226AA/TO–92) P Suffix			
Thermal Resistance, Junction–to–Ambient	$R_{\theta JA}$	160	°C/W
Thermal Resistance, Junction–to–Case	$R_{\theta JC}$	83	°C/W
Case 626 P1 Suffix			
Thermal Resistance, Junction–to–Ambient	$R_{\theta JA}$	105	°C/W
Feedback Input Voltage	V_{fb}	−1.5 to +30	Vdc
Shutdown Input Voltage	V_{sd}	−0.3 to +30	Vdc
Error Comparator Output Voltage	V_{err}	−0.3 to +30	Vdc
Operating Junction Temperature	T_J	125	°C
Operating Ambient Temperature	T_A	−40 to +125	°C
Storage Temperature Range	T_{stg}	−65 to +150	°C

Representative Block Diagrams





This device contains 34 active transistors.

ELECTRICAL CHARACTERISTICS (V_{in} = 6.0 V, I_O = 100 μA, C_O = 1.0 μF, T_J = 25°C [Note 1], unless otherwise noted.)

Characteristic	Symbol	Min	Typ	Max	Unit
Output Voltage	V_O				V
V_{in} = 6.0 V, I_O = 100 μA, T_J = 25°C					
LP2950C/LP2951C		4.950	5.000	5.050	
LP2950AC/LP2951AC		4.975	5.000	5.025	
V_{in} = 6.0 V to 30 V, I_O < 100 mA, T_J = −25 to +85°C					
LP2950C/LP2951C		4.925	–	5.075	
LP2950AC/LP2951AC		4.950	–	5.050	
V_{in} = 6.0 V to 30 V, I_O < 100 mA, T_J = −40 to +125°C					
LP2950C/LP2951C		–	4.9 to 5.1	–	
LP2950AC/LP2951AC		–	4.94 to 5.06	–	
Line Regulation (V_{in} = 6.0 V to 30 V)	Reg_{line}				%
LP2950C/LP2951C		–	0.08	0.20	
LP2950AC/LP2951AC		–	0.04	0.10	
Load Regulation (I_O = 100 μA to 100 mA)	Reg_{load}				%
LP2950C/LP2951C		–	0.13	0.20	
LP2950AC/LP2951AC		–	0.05	0.10	
Dropout Voltage	$V_I - V_O$				mV
I_O = 100 μA		–	30	80	
I_O = 100 mA		–	350	450	
Supply Bias Current	I_{CC}				
I_O = 100 μA		–	93	120	μA
I_O = 100 mA		–	4.0	12	mA
Dropout Supply Bias Current (V_{in} = 4.5 V, I_O = 100 μA)	$I_{CCdropout}$	–	110	170	μA
Current Limit (V_O Shorted)	I_{Limit}	–	220	300	mA
Thermal Regulation	$Reg_{thermal}$	–	0.05	0.20	%/W
Output Noise Voltage (10 Hz to 100 kHz) [Note 2]	V_n				μVrms
C_L = 1.0 μF		–	126	–	
C_L = 100 μF		–	56	–	
LP2951A/LP2951AC ONLY					
Reference Voltage (T_J = 25°C)	V_{ref}				V
LP2951C		1.210	1.235	1.260	
LP2951AC		1.220	1.235	1.250	
Reference Voltage (T_J = −25 to +85°C)	V_{ref}				
LP2951C		1.185	–	1.285	
LP2951AC		1.190	–	1.270	
Reference Voltage (T_J = −40 to +125°C)	V_{ref}				
100 mA < I_O < 100 mA, V_{in} = 23 to 30 V					
LP2951C		–	1.185 to 1.285	–	
LP2951AC		–	1.195 to 1.270	–	
Feedback Pin Bias Current	I_{FB}	–	15	60	nA
ERROR COMPARATOR					
Output Leakage Current (V_{OH} = 30 V)	I_{lkg}	–	0.01	2.0	μA
Output Low Voltage (V_{in} = 4.5 V, I_{OL} = 400 μA)	V_{OL}	–	150	250	mV
Upper Threshold Voltage (V_{in} = 6.0 V)	V_{thu}	25	44	–	mV
Lower Threshold Voltage (V_{in} = 6.0 V)	V_{thl}	–	60	95	mV
Hysteresis (V_{in} = 6.0 V)	V_{hy}	–	15	–	mV
SHUTDOWN INPUT					
Input Logic Voltage	V_{shtdn}				V
Logic "0" (Regulator "On")		0	–	0.7	
Logic "1" (Regulator "Off")		2.0	–	30	
Shutdown Pin Input Current	I_{shtdn}				μA
V_{shtdn} = 2.4 V		–	35	50	
V_{shtdn} = 30 V		–	450	600	
Regulator Output Current in Shutdown Mode (V_{in} = 30 V, V_{shtdn} = 2.0 V, V_O = 0, Pins 6 and 7 shorted)	I_{off}	–	3.0	10	μA

NOTES: 1. Low duty pulse techniques are used during test to maintain junction temperature as close to ambient as possible.
2. Noise tests on the LP2951 are made with a 0.01 μF bypass capacitor connected across Pins 7 and 1.

DEFINITIONS

Dropout Voltage – The input/output voltage differential at which the regulator output no longer maintains regulation against further reductions in input voltage. Measured when the output drops 100 mV below its nominal value (which is measured at 1.0 V differential), dropout voltage is affected by junction temperature, load current and minimum input supply requirements.

Line Regulation – The change in output voltage for a change in input voltage. The measurement is made under conditions of low dissipation or by using pulse techniques such that average chip temperature is not significantly affected.

Load Regulation – The change in output voltage for a change in load current at constant chip temperature.

Maximum Power Dissipation – The maximum total device dissipation for which the regulator will operate within specifications.

Thermal Regulation – Change in output voltage, excluding load or line regulation effects, 10 ms after a 50 mA load pulse is applied when V_{in} = 30 V and V_O = 5.0 V. The resulting chip power dissipation is (30–5.0 V)(50 mA) = 1.25 W.

Bias Current – Current which is used to operate the regulator chip and is not delivered to the load.

Output Noise Voltage – The rms AC voltage at the output, with constant load and no input ripple, measured over a specified frequency range.

Leakage Current – Current drawn through a bipolar transistor collector–base junction, under a specified collector voltage, when the transistor is "off".

Upper Threshold Voltage – Voltage applied to the comparator input terminal, below the reference voltage which is applied to the other comparator input terminal, which causes the comparator output to change state from a logic "0" to "1".

Lower Threshold Voltage – Voltage applied to the comparator input terminal, below the reference voltage which is applied to the other comparator input terminal, which causes the comparator output to change state from a logic "1" to "0".

Hysteresis – The difference between Lower Threshold voltage and Upper Threshold voltage.

Figure 1. Quiescent Current

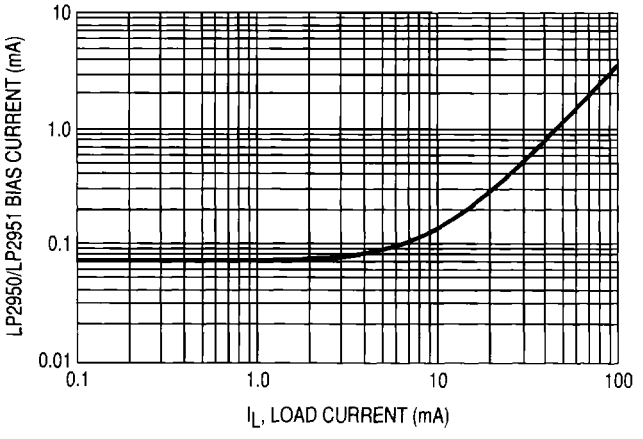


Figure 2. Dropout Characteristics

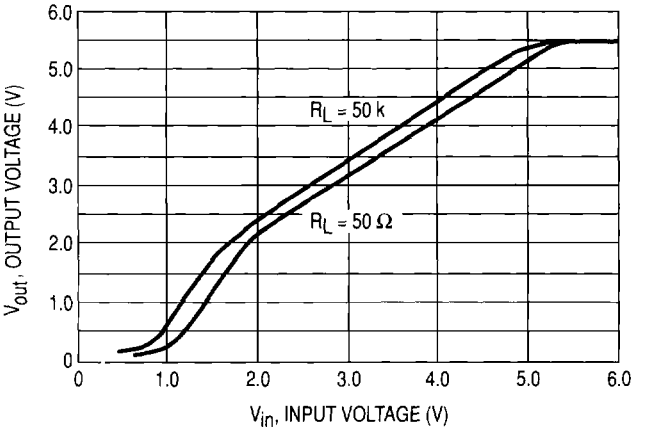


Figure 3. Input Current

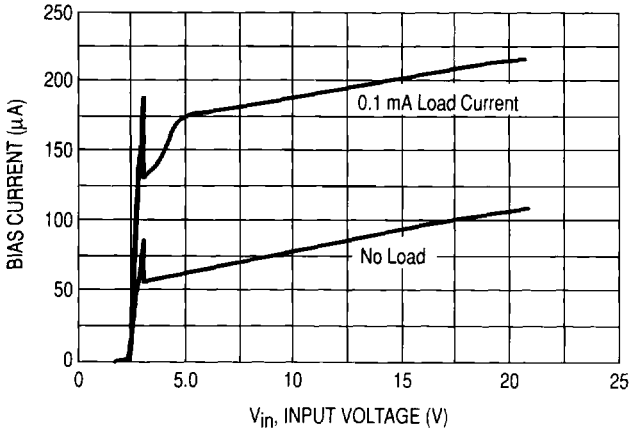


Figure 4. Output Voltage versus Temperature

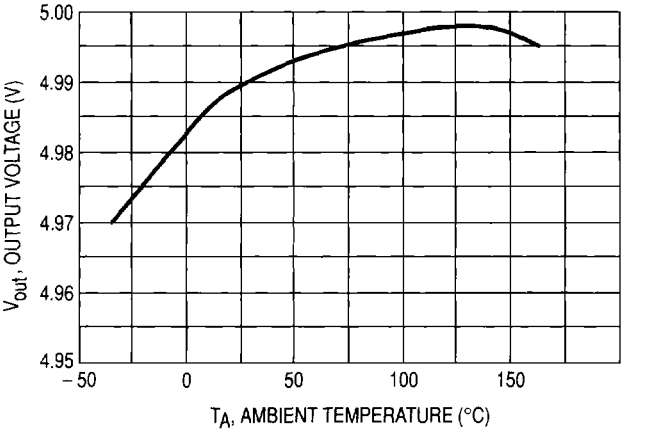


Figure 5. Dropout Voltage versus Output Current

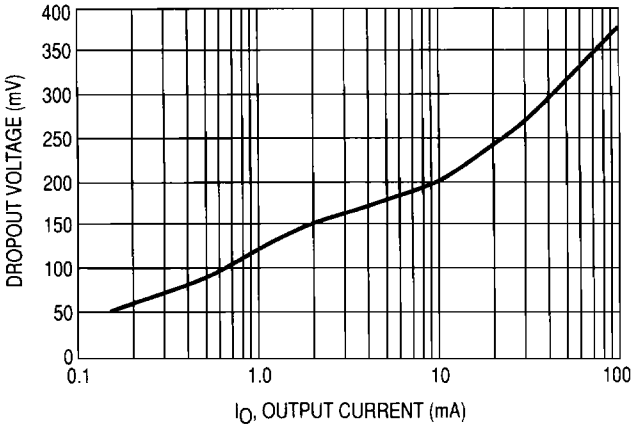


Figure 6. Dropout Voltage versus Temperature

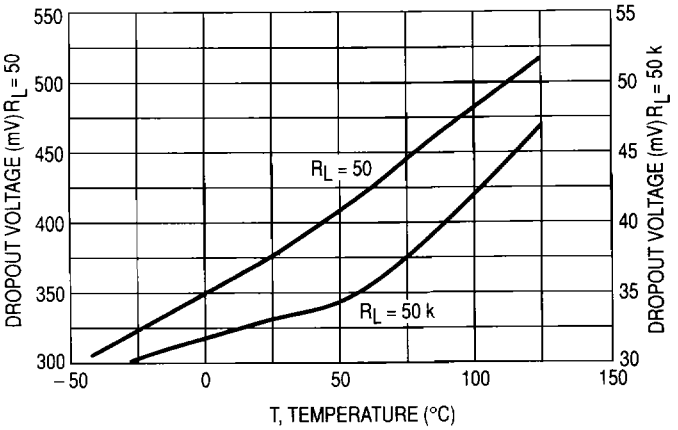


Figure 7. Error Comparator Output

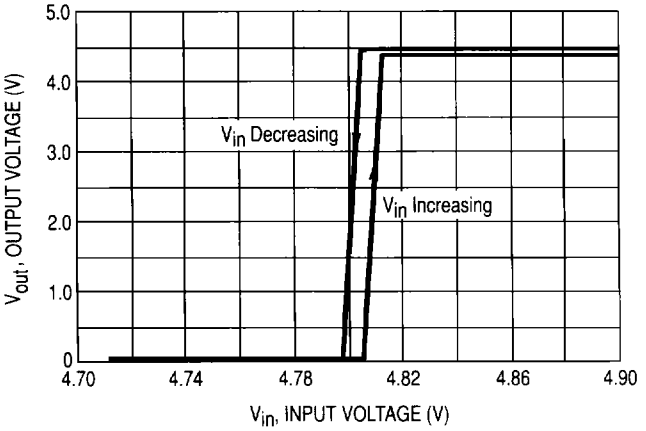


Figure 8. Line Transient Response

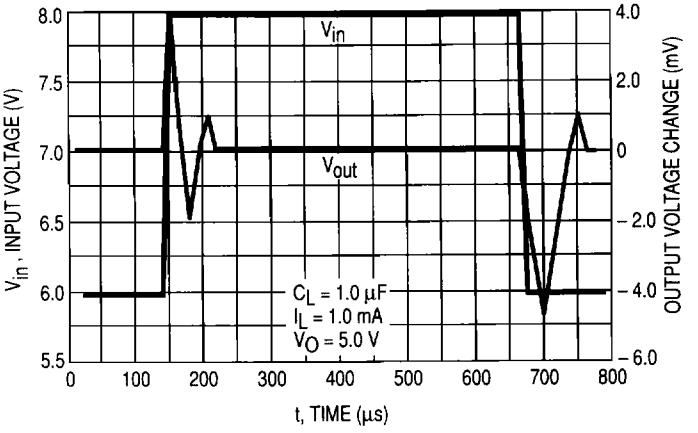


Figure 9. LP2951 Enable Transient

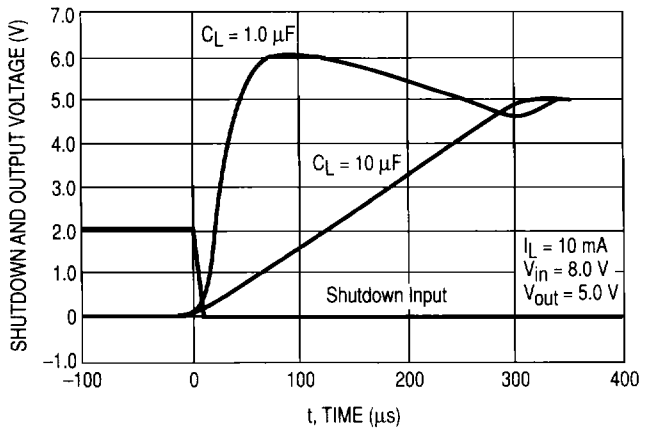


Figure 10. Load Transient Response

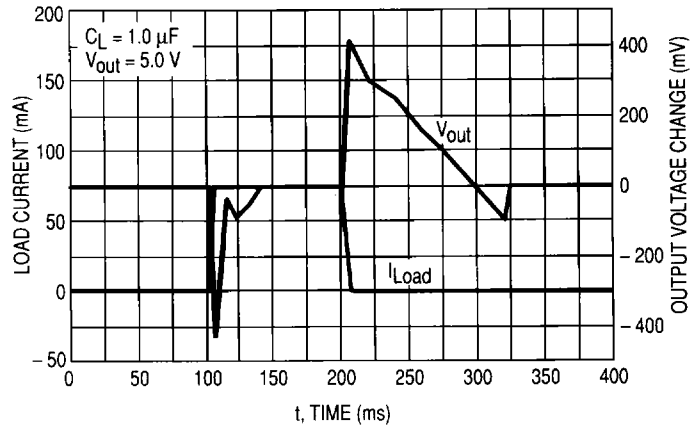


Figure 11. Ripple Rejection

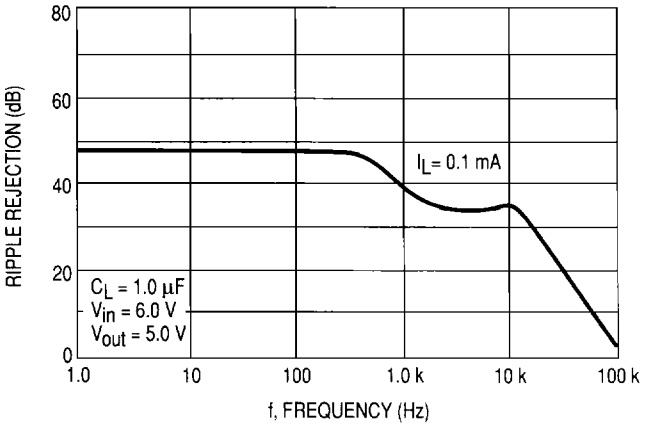


Figure 12. Output Noise

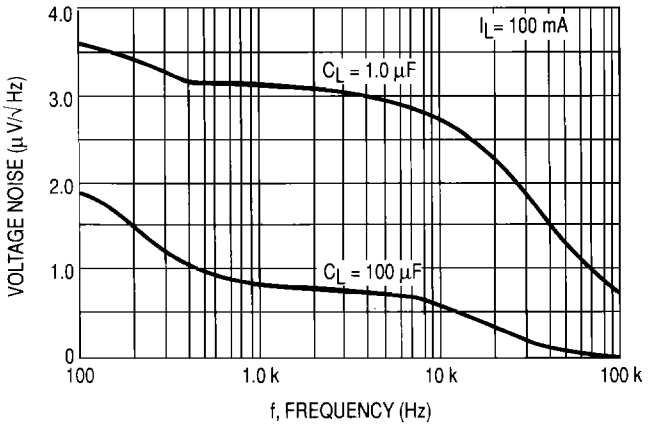


Figure 13. Shutdown Threshold Voltage versus Temperature

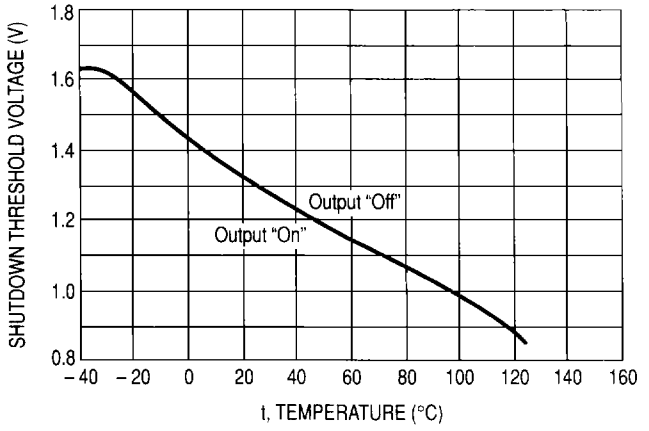
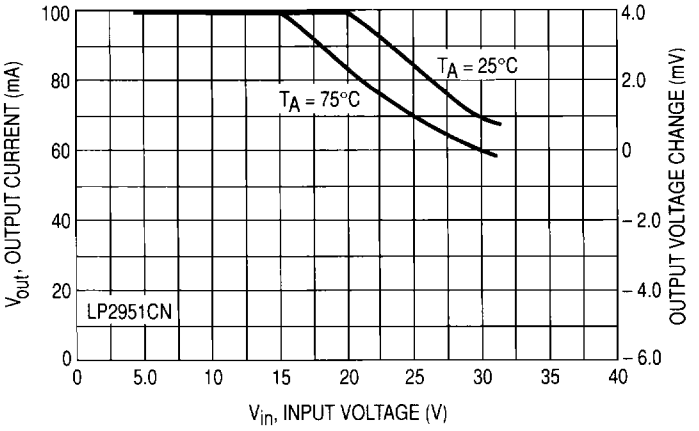


Figure 14. Maximum Rated Output Current



APPLICATIONS INFORMATION

Introduction

The LP2950/LP2951 regulators are designed with internal current limiting and thermal shutdown making them user–friendly. Typical application circuits for the LP2950 and LP2951 are shown in Figures 17 through 25.

These regulators are not internally compensated and thus require a 1.0 µF (or greater) capacitance between the LP2950/LP2951 output terminal and ground for stability. Most types of aluminum, tantalum or multilayer ceramic will perform adequately. Solid tantalums or appropriate multilayer ceramic capacitors are recommended for operation below 25°C.

At lower values of output current, less output capacitance is required for output stability. The capacitor can be reduced to 0.33 µF for currents less than 10 mA, or 0.1 µF for currents below 1.0 mA. Using the 8–pin versions at voltages less than 5.0 V operates the error amplifier at lower values of gain, so that more output capacitance is needed for stability. For the worst case operating condition of a 100 mA load at 1.23 V output (Output Pin 1 shorted to the feedback Pin 7) a 3.3 µF (or greater) capacitor should be used.

The LP2950 will remain stable and in regulation when operated with no output load. When setting the output voltage of the LP2951 with external resistors, the resistance values should be chosen to draw a minimum of 1.0 µA.

A bypass capacitor is recommended across the LP2950/LP2951 input to ground if more than 4 inches of wire connects the input to either a battery or power supply filter capacitor.

Input capacitance at the LP2951 Feedback Pin 7 can create a pole, causing instability if high value external resistors are used to set the output voltage. Adding a 100 pF capacitor between the Output Pin 1 and the Feedback Pin 7 and increasing the output filter capacitor to at least 3.3 µF will stabilize the feedback loop.

Error Detection Comparator

The comparator switches to a positive logic low whenever the LP2951 output voltage falls more than approximately 5.0% out of regulation. This value is the comparator's designed–in offset voltage of 60 mV divided by the 1.235 V

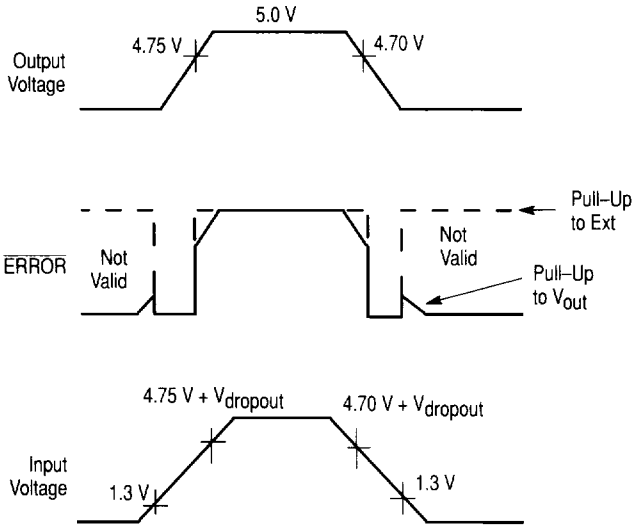
internal reference. As shown in the representative block diagram. This trip level remains 5.0% below normal regardless of the value of regulated output voltage. For example, the error flag trip level is 4.75 V for a normal 5.0 V regulated output, or 9.50 V for a 10 V output voltage.

Figure 1 is a timing diagram which shows the $\overline{\text{ERROR}}$ signal and the regulated output voltage as the input voltage to the LP2951 is ramped up and down. The $\overline{\text{ERROR}}$ signal becomes valid (low) at about 1.3 V input. It goes high when the input reaches about 5.0 V (V_{out} exceeds about 4.75 V). Since the LP2951's dropout voltage is dependent upon the load current (refer to the curve in the Typical Performance Characteristics), the input voltage trip point will vary with load current. The output voltage trip point does not vary with load.

The error comparator output is an open collector which requires an external pull–up resistor. This resistor may be returned to the 5.0 V output or some other voltage within the system. The resistance value should be chosen to be consistent with the 400 μA sink capability of the error comparator. A value between 100 k and 1.0 MΩ is suggested. No pull–up resistance is required if this output is unused.

When operated in the shutdown mode, the error comparator output will go high if it has been pulled up to an external supply. To avoid this invalid response, the error comparator output should be pulled up to V_{out} (see Figure 15).

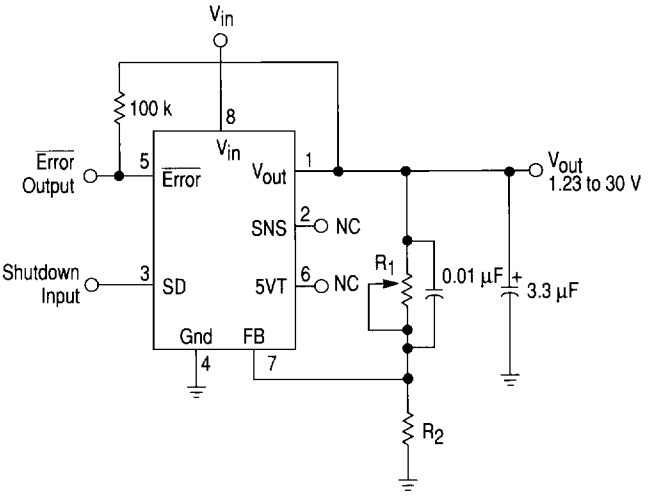
Figure 15. $\overline{\text{ERROR}}$ Output Timing



Programming the Output Voltage (LP2951)

The LP2951 may be pin–strapped for 5.0 V using its internal voltage divider by tying Pin 1 (output) to Pin 2 (sense) and Pin 7 (feedback) to Pin 6 (5.0 V tap). Alternatively, it may be programmed for any output voltage between its 1.235 reference voltage and its 30 V maximum rating. An external pair of resistors is required, as shown in Figure 16.

Figure 16. Adjustable Regulator



The complete equation for the output voltage is:

$$V_{out} = V_{ref}\left(1 + R_1/R_2\right) + I_{FB}\,R_1$$

where V_{ref} is the nominal 1.235 V reference voltage and I_{FB} is the feedback pin bias current, nominally −20 nA. The minimum recommended load current of 1.0 μA forces an upper limit of 1.2 MΩ on the value of R_2, if the regulator must work with no load. I_{FB} will produce a 2% typical error in V_{out} which may be eliminated at room temperature by adjusting R_1. For better accuracy, choosing R_2 = 100 k reduces this error to 0.17% while increasing the resistor program current to 12 μA. Since the LP2951 typically draws 75 μA at no load with Pin 2 open circuited, the extra 11 μA of current drawn is often a worthwhile tradeoff for eliminating the need to set output voltage in test.

Output Noise

In many applications it is desirable to reduce the noise present at the output. Reducing the regulator bandwidth by increasing the size of the output capacitor is the only method for reducing noise on the 3 lead LP2950. However, increasing the capacitor from 1.0 μF to 220 μF only decreases the noise from 430 μV to 160 μVrms for a 100 kHz bandwidth at the 5.0 V 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

$$C_{Bypass} \approx \frac{1}{2\pi R_1 \times 200\ Hz}$$

or about 0.01 μF. When doing this, the output capacitor must be increased to 3.3 μF to maintain stability. These changes reduce the output noise from 430 μV to 126 μVrms for a 100 kHz bandwidth at 5.0 V output. With bypass capacitor added, noise no longer scales with output voltage so that improvements are more dramatic at higher output voltages.

TYPICAL APPLICATIONS

Figure 17. 1.0 A Regulator with 1.2 V Dropout

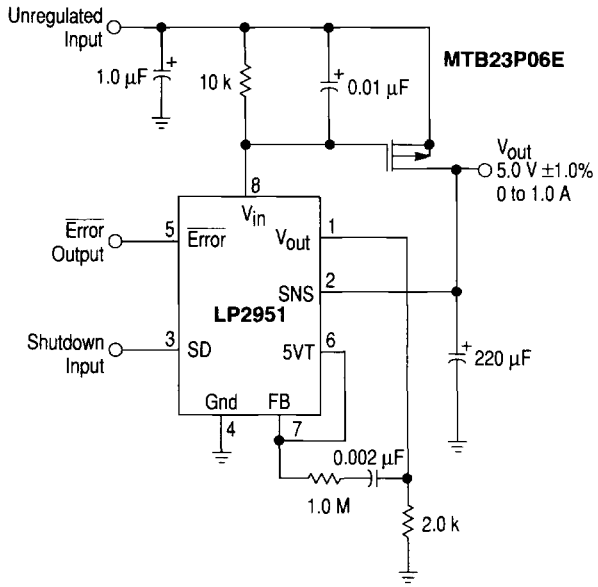


Figure 18. Lithium Ion Battery Cell Charger

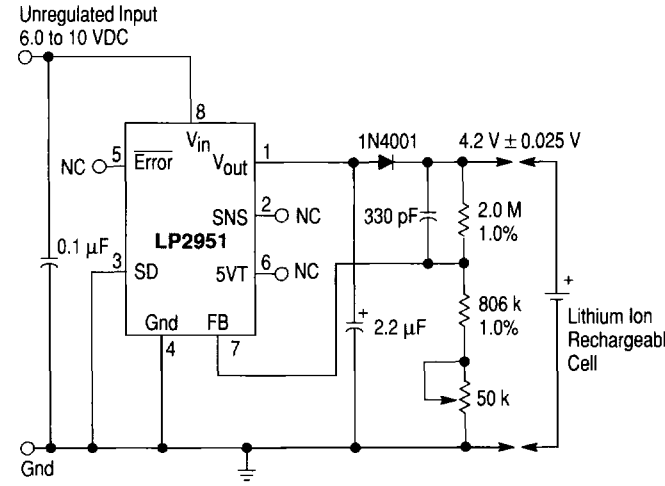


Figure 19. Low Drift Current Source

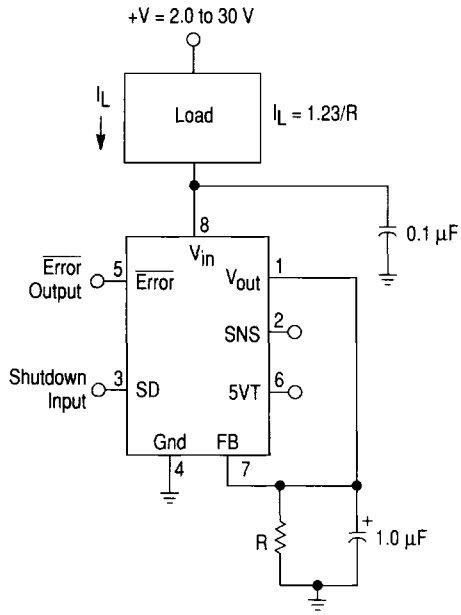


Figure 20. Latch Off When Error Flag Occurs

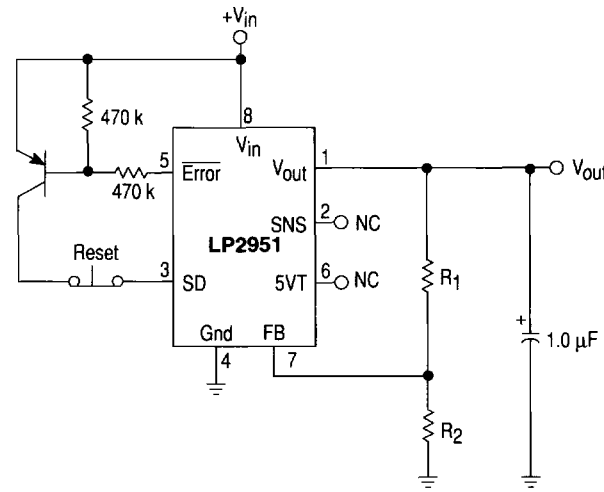


Figure 21. 5.0 V Regulator with 2.5 V Sleep Function

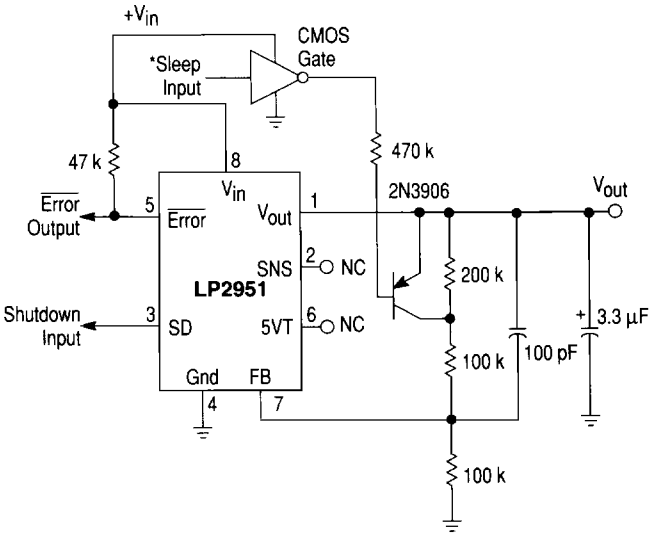
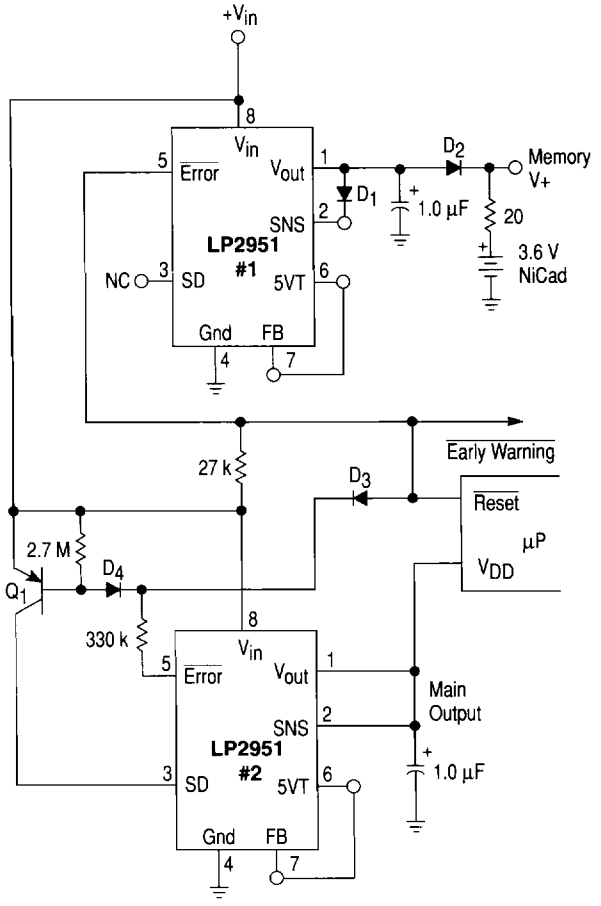


Figure 22. Regulator with Early Warning and Auxiliary Output



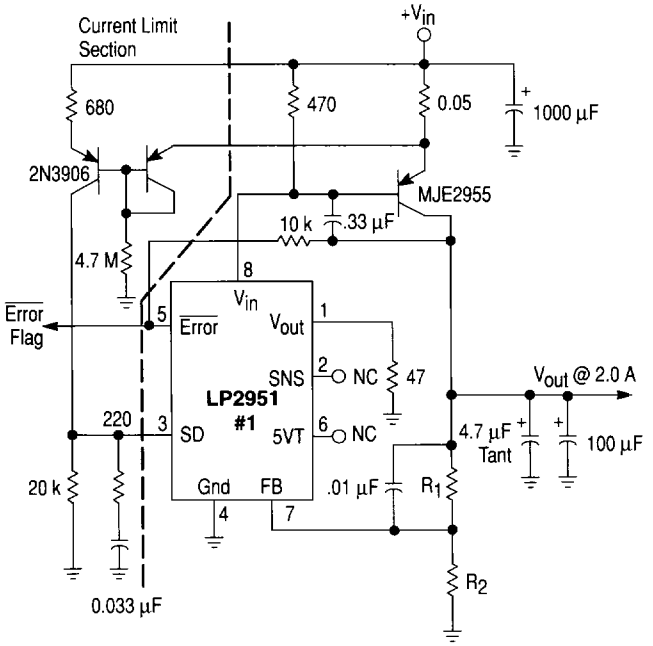
Early Warning flag on low input voltage.

Main output latches off at lower input voltages.

Battery backup on auxiliary output.

Operation: Regulator #1's V_{out} is programmed one diode drop above 5.0 V. Its error flag becomes active when $V_{in} \leq 5.7$ V. When V_{in} drops below 5.3 V, the error flag of regulator #2 becomes active and via Q_1 latches the main output "off". When V_{in} again exceeds 5.7 V, regulator #1 is back in regulation and the early warning signal rises, unlatching regulator #2 via D_3.

Figure 23. 2.0 A Low Dropout Regulator



$V_{out} = 1.25V\ (1.0 + R_1/R_2)$

For 5.0 V output, use internal resistors. Wire Pin 6 to 7, and wire Pin 2 to $+V_{out}$ Buss.

Figure 24. Open Circuit Detector for 4.0 to 20 mA Current Loop

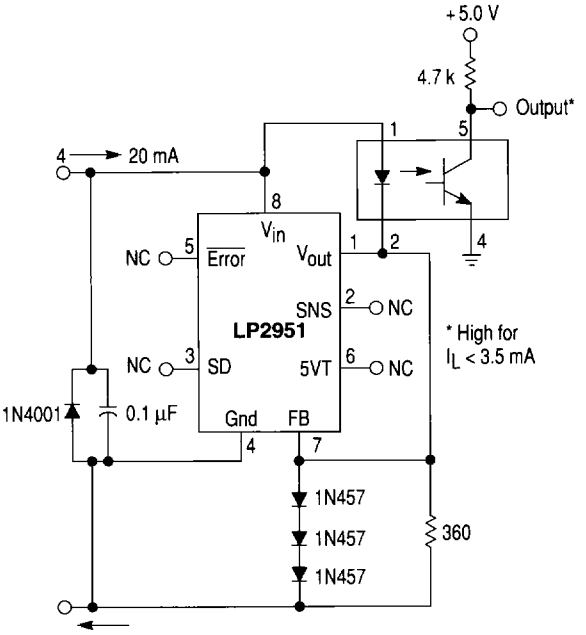
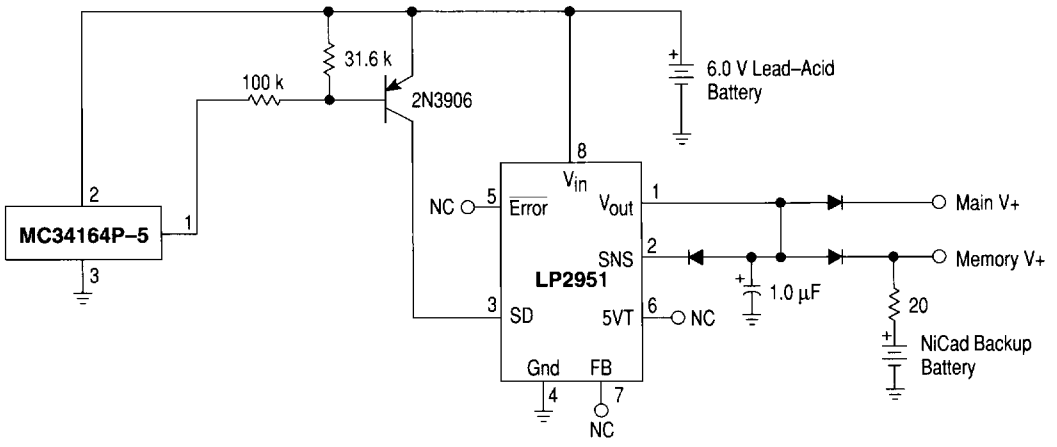
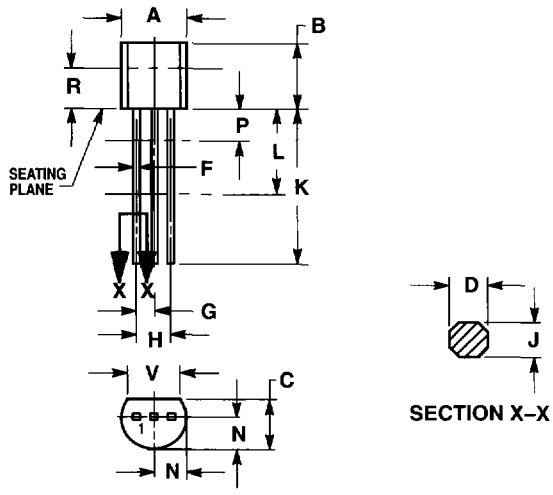


Figure 25. Low Battery Disconnect



OUTLINE DIMENSIONS

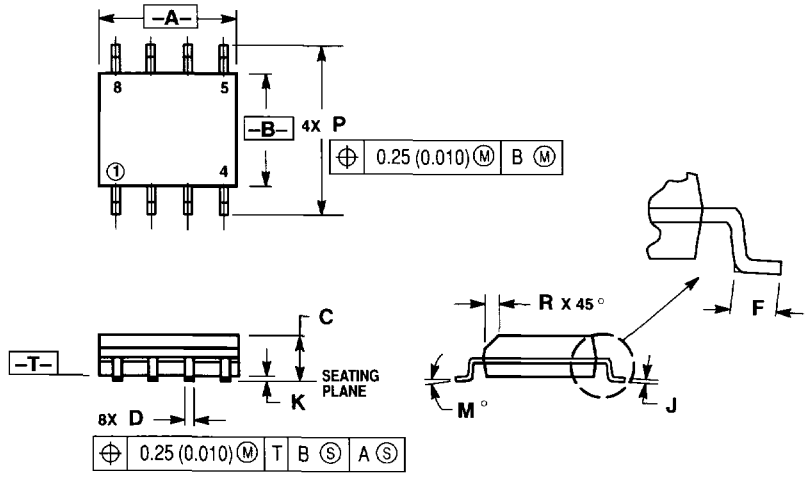
P SUFFIX
PLASTIC PACKAGE
CASE 29–04
(TO–226AA/TO–92)



NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.
3. CONTOUR OF PACKAGE BEYOND DIMENSION R IS UNCONTROLLED.
4. DIMENSION F APPLIES BETWEEN P AND L. DIMENSION D AND J APPLY BETWEEN L AND K MINIMUM. LEAD DIMENSION IS UNCONTROLLED IN P AND BEYOND DIMENSION K MINIMUM.

	INCHES		MILLIMETERS	
DIM	MIN	MAX	MIN	MAX
A	0.175	0.205	4.45	5.20
B	0.170	0.210	4.32	5.33
C	0.125	0.165	3.18	4.19
D	0.016	0.022	0.41	0.55
F	0.016	0.019	0.41	0.48
G	0.045	0.055	1.15	1.39
H	0.095	0.105	2.42	2.66
J	0.015	0.020	0.39	0.50
K	0.500	—	12.70	—
L	0.250	—	6.35	—
N	0.080	0.105	2.04	2.66
P	—	0.100	—	2.54
R	0.115	—	2.93	—
V	0.135	—	3.43	—

D SUFFIX
PLASTIC PACKAGE
CASE 751–05
(SO–8)

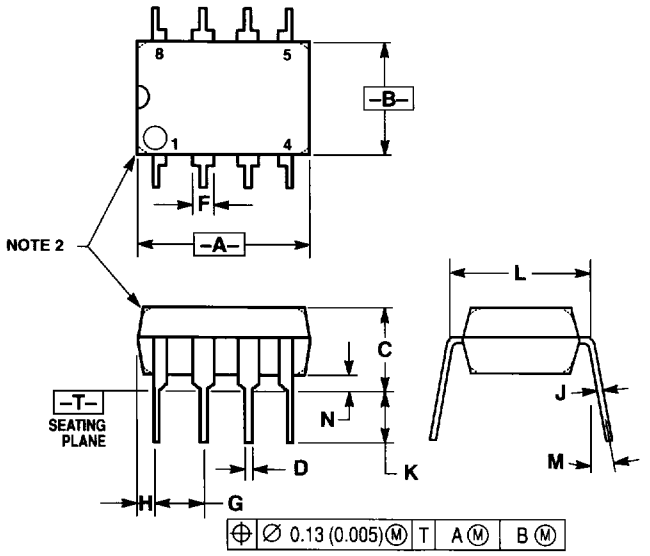


NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.
3. DIMENSIONS A AND B DO NOT INCLUDE MOLD PROTRUSION.
4. MAXIMUM MOLD PROTRUSION 0.15 (0.006) PER SIDE.
5. DIMENSION D DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.127 (0.005) TOTAL IN EXCESS OF THE D DIMENSION AT MAXIMUM MATERIAL CONDITION.

	MILLIMETERS		INCHES	
DIM	MIN	MAX	MIN	MAX
A	4.80	5.00	0.189	0.196
B	3.80	4.00	0.150	0.157
C	1.35	1.75	0.054	0.068
D	0.35	0.49	0.014	0.019
F	0.40	1.25	0.016	0.049
G	1.27 BSC		0.050 BSC	
J	0.18	0.25	0.007	0.009
K	0.10	0.25	0.004	0.009
M	0°	7°	0°	7°
P	5.80	6.20	0.229	0.244
R	0.25	0.50	0.010	0.019

OUTLINE DIMENSIONS

P1 SUFFIX
PLASTIC PACKAGE
CASE 626–05



NOTES:
1. DIMENSION L TO CENTER OF LEAD WHEN FORMED PARALLEL.
2. PACKAGE CONTOUR OPTIONAL (ROUND OR SQUARE CORNERS).
3. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.

	MILLIMETERS		INCHES	
DIM	MIN	MAX	MIN	MAX
A	9.40	10.16	0.370	0.400
B	6.10	6.60	0.240	0.260
C	3.94	4.45	0.155	0.175
D	0.38	0.51	0.015	0.020
F	1.02	1.78	0.040	0.070
G	2.54 BSC		0.100 BSC	
H	0.76	1.27	0.030	0.050
J	0.20	0.30	0.008	0.012
K	2.92	3.43	0.115	0.135
L	7.62 BSC		0.300 BSC	
M	–	10°	–	10°
N	0.76	1.01	0.030	0.040

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