Advanced Monolithic Systems

LP2950/LP2951

100mA LOW DROPOUT VOLTAGE REGULATOR

FEATURES

- **5V, 3.3V, and 3V Versions at 100mA Output Current**
- **High Accuracy Output Voltage**
- **Extremely Low Quiescent Current**
- **Low Dropout Voltage**
- **Extremely Tight Load and Line Regulation**
- **Very Low Temperature Coefficient**
- **Current and Thermal Limiting**
- **Needs Minimum Capacitance (1µF) for Stability**
- **Unregulated DC Positive Transients 60V**

ADDITIONAL FEATURES (LP2951 ONLY)

- **1.24V to 29V Programmable Output**
- **Error Flag Warning of Voltage Output Dropout**
- **Logic Controlled Electronic Shutdown**

APPLICATIONS

- **Battery Powered Systems**
- **Portable Consumer Equipment**
- **Cordless Telephones**
- **Portable (Notebook) Computers**
- **Portable Instrumentation**
- **Radio Control Systems**
- **Automotive Electronics**
- **Avionics**
- **Low-Power Voltage Reference**

GENERAL DESCRIPTION

The LP2950 and LP2951 are micropower voltage regulators ideally suited for use in battery-powered systems. These devices feature very low quiescent current (typ.75µA), and very low dropout voltage (typ.45mV at light loads and 380mV at 100mA) thus prolonging battery life. The quiescent current increases only slightly in dropout. The LP2950/LP2951 has positive transient protection up to 60V and can survive unregulated input transient up to 20V below ground.

The LP2950 and LP2951 were designed to include a tight initial tolerance (typ. 0.5%), excellent load and line regulation (typ. 0.05%), and a very low output voltage temperature coefficient, making these devices useful as a low-power voltage reference.

The LP2950 is offered in the 3-pin TO-92 package. LP2951 is available in 8-pin plastic SOIC and DIP packages and offers three major additional system features. An error flag output warns of a low output voltage, often due to failing batteries on input. The LP2951 also features the logic-compatible shutdown input which enables the regulator to be switched on and off. The LP2951 device may be pin-strapped for a 5V, 3.3V, or 3V output, or programmed from 1.24V to 29V with an external pair of resistors.

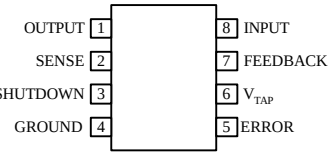
ORDERING INFORMATION

PACKAGE TYPE			OPERATING TEMP. RANGE
TO-92	8 LEAD PDIP	8 LEAD SOIC	
LP2950ACN-X	LP2951ACP-X	LP2951ACS-X	IND.
LP2950CN-X	LP2951CP-X	LP2951CS-X	IND

X = 3.3V, or 3V

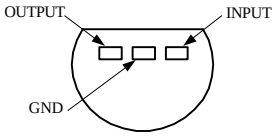
PIN CONNECTION

8L SOIC/ 8L PDIP



Top View

TO-92



Bottom View

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ABSOLUTE MAXIMUM RATINGS (Note 1)

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	+150°C
Storage Temperature	-65°C to +150°C
Soldering Dwell Time, Temperature	
Wave	4 seconds, 260°C
Infrared	4 seconds, 240°C
Vapor Phase	4 seconds, 219°C
ESD	TBD

OPERATING RATINGS (Note 1)

Max. Input Supply Voltage	30V
Junction Temperature Range (T_J) (Note 8)	
LP2950AC-XX, LP2950C-XX	
LP2951AC-XX, LP2951C-XX	-40°C to +125°C

ELECTRICAL CHARACTERISTICS at V_S=Vout+1V, Ta=25°C, unless otherwise noted.

Parameter	Conditions (Note 2)	LP2950AC LP2951AC Min.	LP2950AC LP2951AC Typ.	LP2950AC LP2951AC Max.	LP2950C LP2951C Min.	LP2950C LP2951C Typ.	LP2950C LP2951C Max.	Units
3 V Versions (Note 16)								
Output Voltage	T_J = 25°C (Note 3)	2.985	3.0	3.015	2.970	3.0	3.030	V
	-25°C ≤T_J ≤85°C	2.970	3.0	3.030	2.955	3.0	3.045	V
	Full Operating Temperature Range	**2.964**	3.0	**3.036**	**2.940**	3.0	**3.060**	V
Output Voltage	100 µA ≤I_L ≤100 mA T_J ≤T_{JMAX}	**2.958**	3.0	**3.042**	**2.928**	3.0	**3.072**	V
3.3 V Versions (Note 16)								
Output Voltage	T_J = 25°C (Note 3)	3.284	3.3	3.317	3.267	3.3	3.333	V
	-25°C ≤T_J ≤85°C	3.267	3.3	3.333	3.251	3.3	3.350	V
	Full Operating Temperature Range	**3.260**	3.3	**3.340**	**3.234**	3.3	**3.366**	V
Output Voltage	100 µA ≤I_L ≤100 mA T_J ≤T_{JMAX}	**3.254**	3.3	**3.346**	**3.221**	3.3	**3.379**	V
5 V Versions (Note 16)								
Output Voltage	T_J = 25°C (Note 3)	4.975	5.0	5.025	4.95	5.0	5.05	V
	-25°C ≤T_J ≤85°C	4.95	5.0	5.050	4.925	5.0	5.075	V
	Full Operating Temperature Range	**4.94**	5.0	**5.06**	**4.90**	5.0	**5.10**	V
Output Voltage	100 µA ≤I_L ≤100 mA T_J ≤T_{JMAX}	**4.925**	5.0	**5.075**	**4.88**	5.0	**5.12**	V
All Voltage Options								
Output Voltage Temperature Coefficient	(Note 12) (Note 4)		**20**			**50**		ppm/°C
Line Regulation (Note 14)	6V ≤V_{in} ≤30V (Note 15)		0.03	0.1		0.04	0.2	%
Load Regulation (Note 14)	100 µA ≤I_L ≤ 100 mA		0.04	0.1		0.1	0.2	%
Dropout Voltage (Note 5)	I_L = 100µ A		50	80		50	80	mV
	I_L = 100 mA		380	450		380	450	mV
Ground Current	I_L = 100 µA		75	120		75	120	µA
	I_L = 100 mA		8	12		8	12	mA
Current Limit	V_{out} = 0		160	200		160	200	mA
Thermal Regulation	(Note 13)		0.05	0.2		0.05	0.2	%/W

ELECTRICAL CHARACTERISTICS (Note 2) (Continued)

PARAMETER	CONDITIONS (Note 2)	LP2950AC LP2951AC			LP2950C LP2951C			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Noise, 10Hz to 100KHz	C_L = 1µF C_L = 200 µF C_L = 13.3 µF (Bypass = 0.01 µF pins 7 to 1(LP2951))		430 160 100			430 160 100		µV rms µV rms µV rms
8-Pin Versions only		**LP2951AC**			**LP2951C**			
Reference Voltage		1.22	1.235	1.25	1.21	1.235	1.26	V
Reference Voltage	Over Temperature (Note 7)	**1.19**		**1.27**	**1.185**		**1.285**	V
Feedback Pin Bias Current			40	60		40	60	nA
Reference Voltage Temperature Coefficient	(Note 12)		20				50	ppm/°C
Feedback Pin Bias Current Temperature Coefficient			0.1				0.1	nA/°C
Error Comparator								
Output Leakage Current	V_{OH} = 30V		0.01	1		0.01	1	µA
Output Low Voltage	V_{in} = 4.5V I_{OL} = 400µA		150	250		150	250	mV
Upper Threshold Voltage	(Note 6)	40	60		40	60		mV
Lower Threshold Voltage	(Note 6)		75	95		75	95	mV
Hysteresis	(Note 6)		15			15		mV
Shutdown Input								
Input logic Voltage	Low (Regulator ON) High (Regulator OFF)	**2**	1.3	**0.7**	**2**	1.3	**0.7**	V V
Shutdown Pin Input Current (Note 3)	Vs = 2.4V V_s = 30V		30 450	50 600		30 450	50 600	µA µA
Regulator Output Current in Shutdown (Note 3)	(Note 11)		3	10		3	10	µA

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_{IN} = (V_{ONOM} +1)V, I_L = 100 µA and C_L = 1 µF for 5V versions and 2.2µF 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_A = T_J = 25°C Additional conditions for the 8-pin versions are FEEDBACK tied to V_{TAP}, OUTPUT tied to SENSE and $V_{SHUTDOWN} \le 0.8V$.

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_{IN} = (V_{ONOM} +1)V. To express these thresholds in terms of output voltage change, multiply by the error amplifier gain = Vout/Vref = (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 mV x 5V/1.235 = 384 mV. Thresholds remain constant as a percent of V_{out} as V_{out} is varied, with the dropout warning occurring at typically 5% below nominal, 7.5% guaranteed.

Note 7: $V_{ref} \le V_{out} \le (V_{in} - 1V)$, $2.3 \le V_{in} \le 30V$, $100\mu A \le I_L \le 100$ mA, $T_J \le T_{JMAX}$.

Note 8: The junction-to-ambient thermal resistance are as follows:180°C/W and 160°C/W for the TO-92 (N) package with 0.40 inch and 0.25 inch leads to the printed circuit board (PCB) respectively, 105°C/W for the molded plastic DIP (P) and 160°C/W for the molded plastic SO-8 (S). The above thermal resistances for the N, S and P packages apply when the package is soldered directly to the PCB.

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: $V_{shutdown} \ge 2V$, $V_{in} \le 30V$, V_{out} =0, Feedback pin tied to $5V_{TAP}$.

Note 12: Output or reference voltage temperature coefficients 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 50mA load pulse at V_{IN} =30V (1.25W pulse) for T =10 ms.

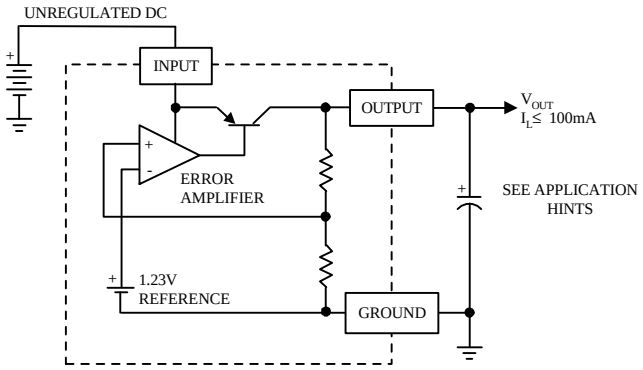
Note 14: Regulation is measured at constant junction temperature, using pulse testing with a low duty cycle. Changes in output voltage due to heating effects are covered under the specification for thermal regulation.

Note 15: Line regulation for the LP2951 is tested at 150°C for I_L = 1 mA. For I_L = 100 µA and T_J = 125°C, line regulation is guaranteed by design to 0.2%. See typical performance characteristics for line regulation versus temperature and load current.

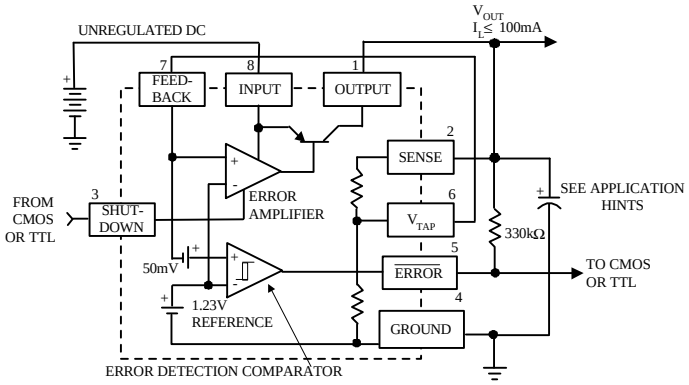
Note 16: All LP2950 devices have the nominal output voltage coded as the last two digits of the part number. In the LP2951 products, the 3.0V and 3.3V versions are designated by the last two digits, but the 5V version is denoted with no code of the part number.

BLOCK DIAGRAM AND TYPICAL APPLICATIONS

LP2950-XX

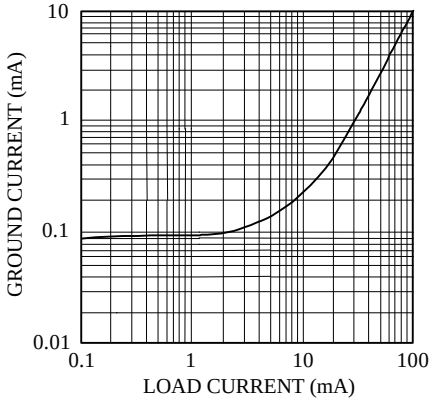


LP2951-XX

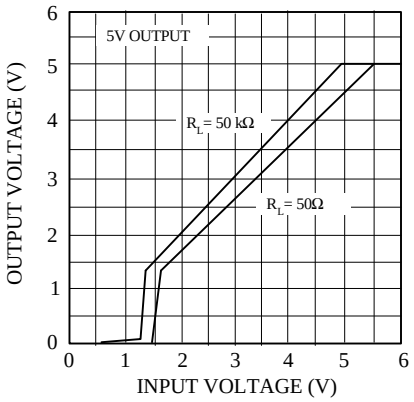


TYPICAL PERFORMANCE CHARACTERISTICS

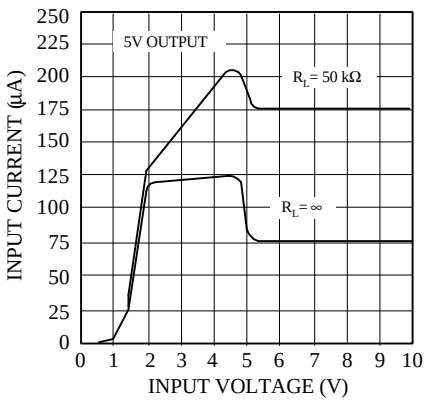
Quiescent Current



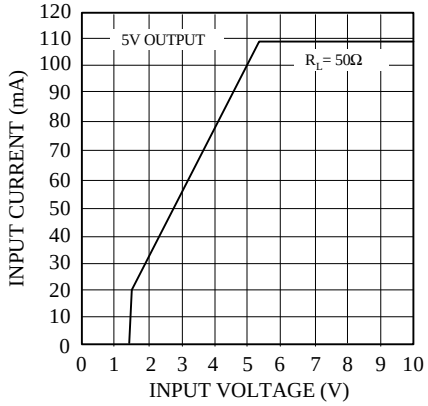
Dropout Characteristics



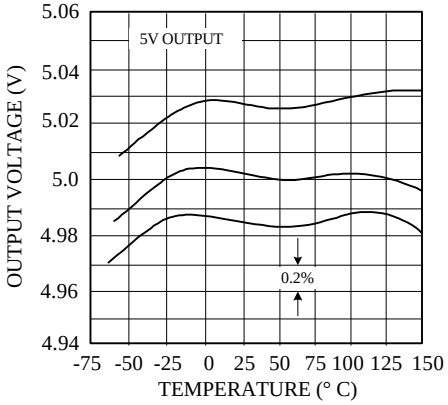
Input Current



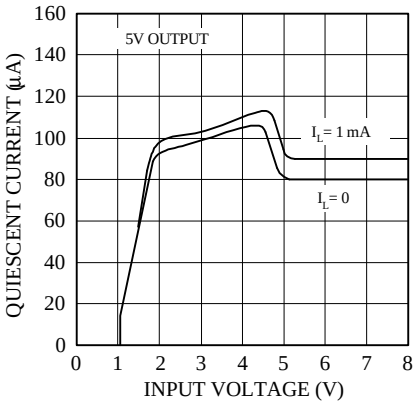
Input Current



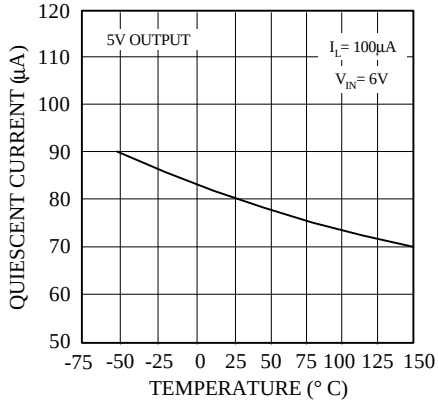
Temperature Drift of 3 Representative Units



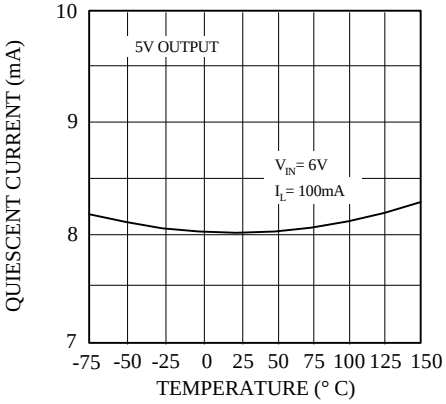
Quiescent Current



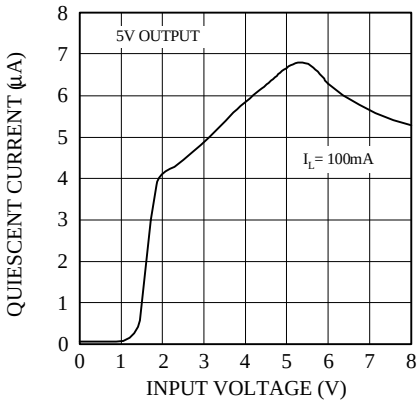
Quiescent Current



Quiescent Current

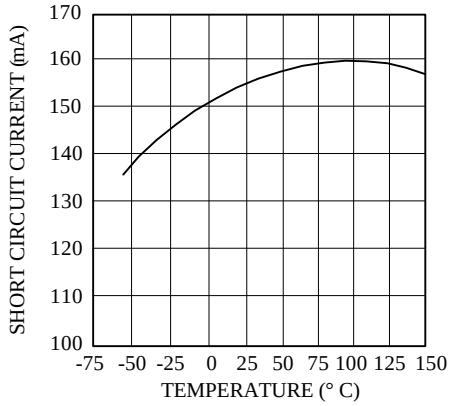


Quiescent Current

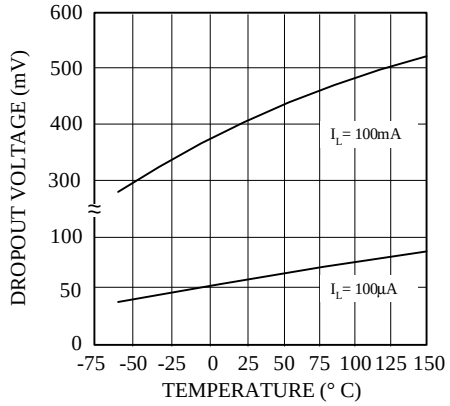


TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

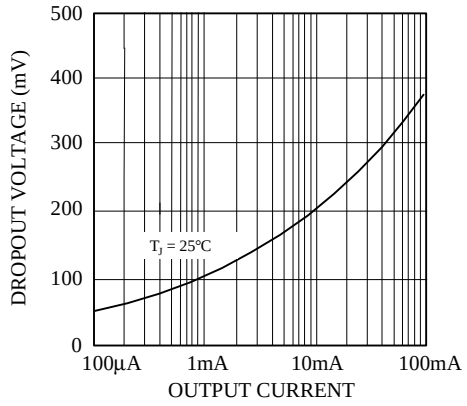
Short Circuit Current



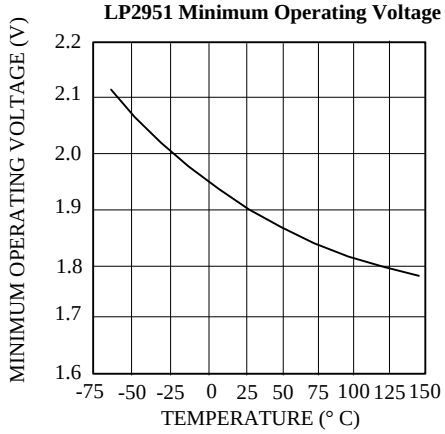
Dropout Voltage



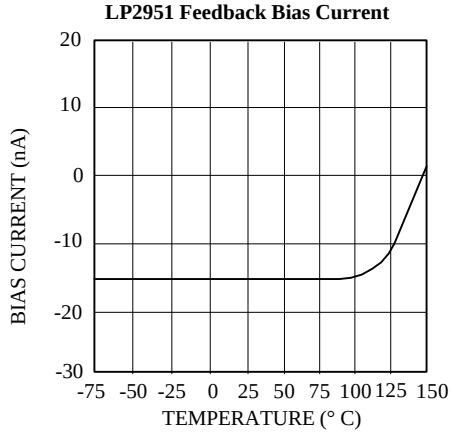
Dropout Voltage



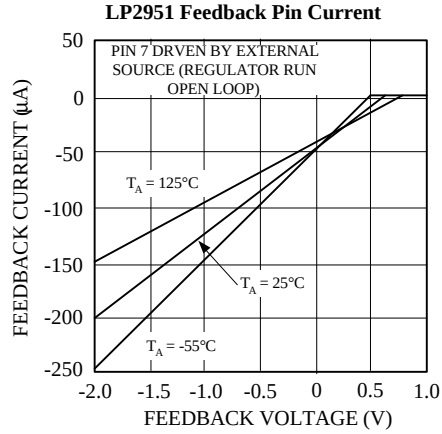
LP2951 Minimum Operating Voltage



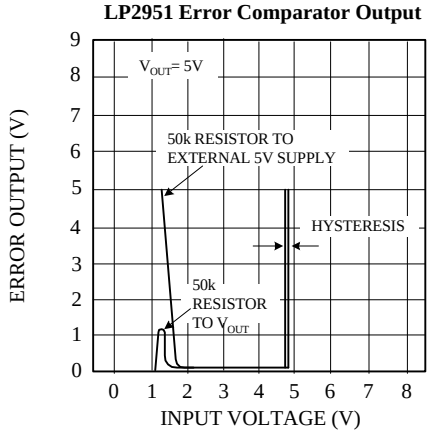
LP2951 Feedback Bias Current



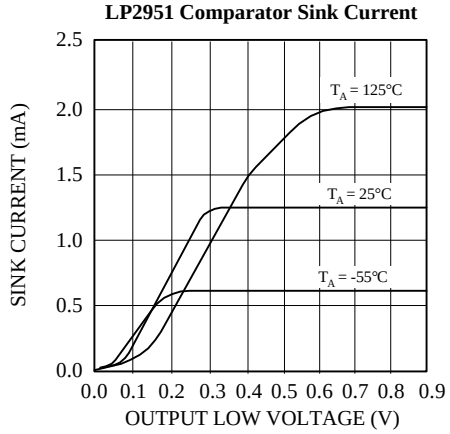
LP2951 Feedback Pin Current



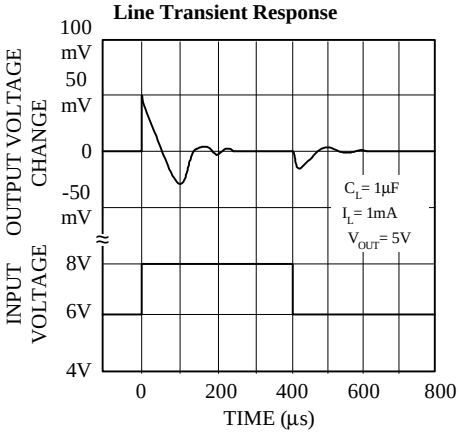
LP2951 Error Comparator Output



LP2951 Comparator Sink Current

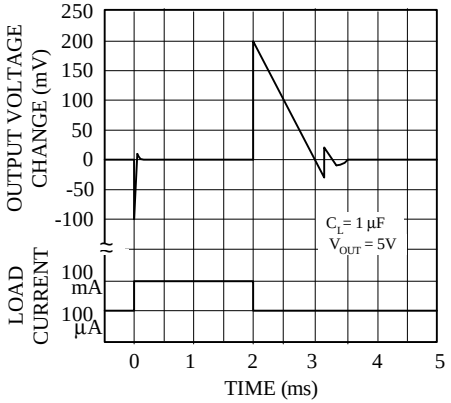


Line Transient Response

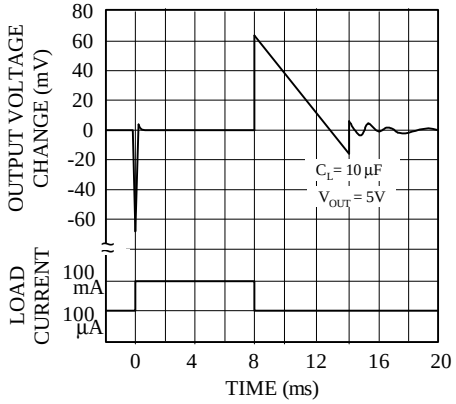


TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

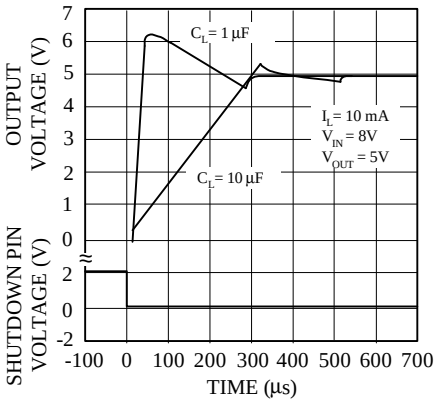
Load Transient Response



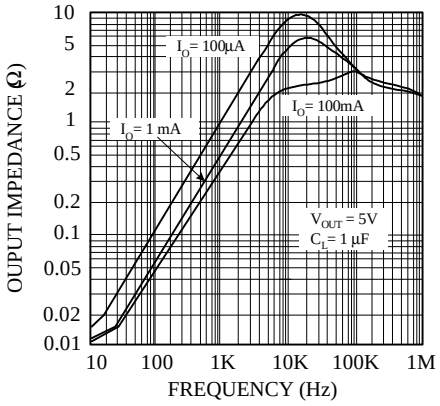
Load Transient Response



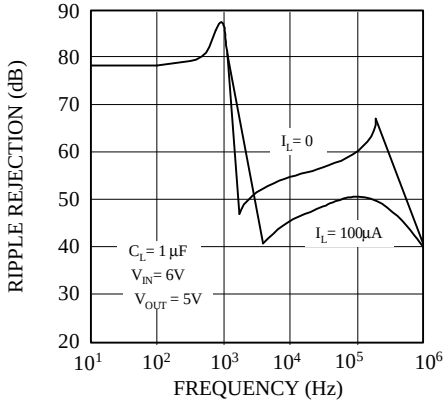
LP2951 Enable Transient



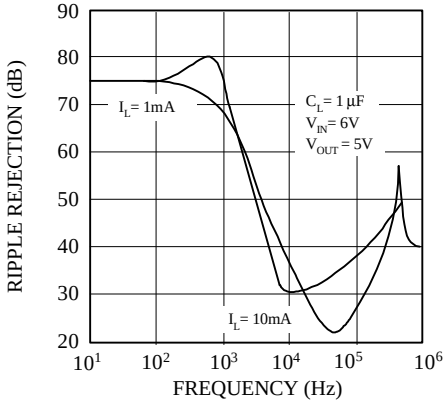
Output Impedance



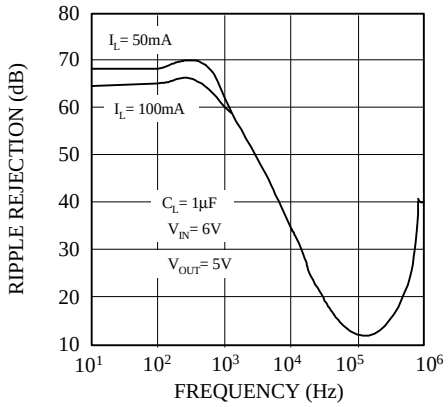
Ripple Rejection



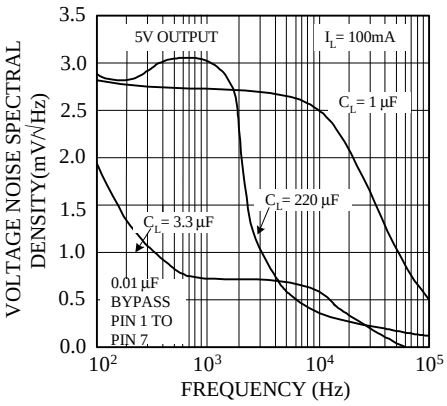
Ripple Rejection



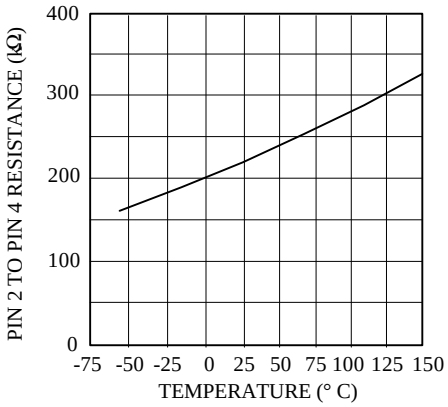
Ripple Rejection



LP2951 Output Noise

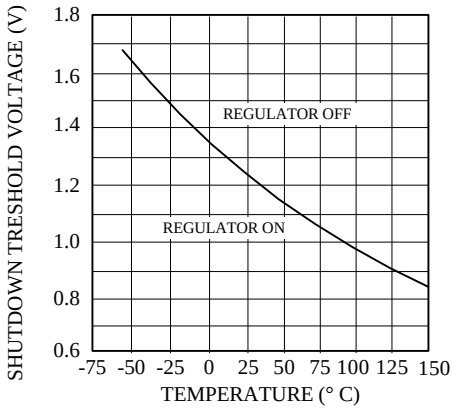


LP2951 Divider Resistance

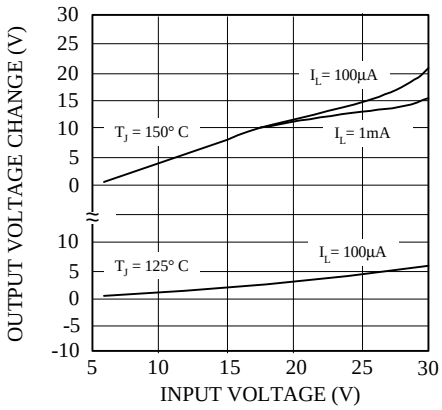


TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

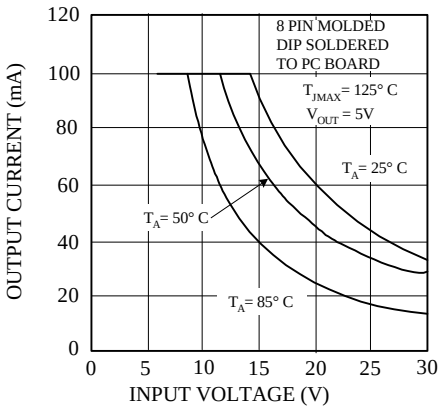
Shutdown Treshold Voltage



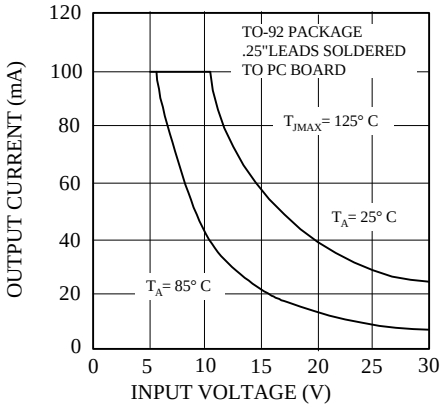
Line Regulation



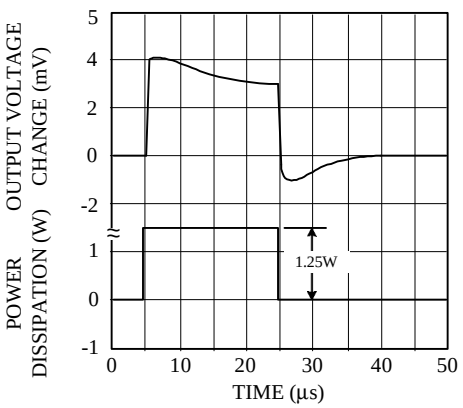
LP2951 Maximum Rated Output Current



LP2950 Maximum Rated Output Current



Thermal Response



APPLICATION HINTS

External Capacitors

A 1.0 µF or greater capacitor is required between output and ground for stability at output voltages of 5V or more. At lower output voltages, more capacitance is required (2.2µ or more is recommended for 3V and 3.3V versions). Without this capacitor the part will oscillate. Most types of tantalum or aluminum electrolytic works fine here; even film types work but are not recommended for reasons of cost. Many aluminum types have electrolytes that freeze at about -30°C, so solid tantalums are recommended for operation below -25°C. The important parameters of the capacitor are an ESR of about 5 Ω or less and resonant frequency above 500 kHz parameters in the value of the capacitor. 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 µF for currents below 10 mA or 0.1 µF 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 100mA load at 1.23V output (Output shorted to Feedback) a 3.3µF (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 version with external resistors, a minimum load of 1µA is recommended.

A 1µF tantalum or aluminum electrolytic capacitor should be placed from the LP2950/LP2951 input to the 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 a higher value of 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 µF 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 gives a timing diagram depicting the ERROR signal and the regulator output voltage as the LP2951 input is ramped up and down. For 5V versions the ERROR signal becomes valid (low) at about 1.3V input. It goes high at about 5V input (the input voltage at which Vout = 4.75).

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 resistor, note that the output is rated to sink 400µA, this sink current adds to battery drain in a low battery condition. Suggested values range from 100K to 1MΩ. The resistor is not required if this output is unused.

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_{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:

$$V_{out} = V_{REF} \times (1 + R_1/ R_2) + I_{FB}R_1$$

where V_{REF} is the nominal 1.235 reference voltage and I_{FB} is the feedback pin bias current, nominally -20 nA. The minimum recommended load current of 1 µA forces an upper limit of 1.2 MΩ on value of R_2, if the regulator must work with no load (a condition often found in CMOS in standby) I_{FB} will produce a 2% typical error in V_{OUT} which may be eliminated at room temperature by trimming R_1. For better accuracy, choosing R2 = 100k reduces this error to 0.17% while increasing the resistor program current by 12 µA. Since the LP2951 typically draws 60 µA at no load with Pin 2 open-circuited, this is a small price to pay.

Reducing Output Noise

In reference applications it may be an 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 that noise can be reduced on the 3 lead LP2950 but is relatively inefficient, as increasing the capacitor from 1 µF to 220 µF only decreases the noise from 430 µV to 160 µV rms for a 100 kHz bandwidth at 5V output.

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

$$C_{BYPASS} \cong 1 / 2\pi R_1 \times 200 \text{ Hz}$$

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 100 µV 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.

APPLICATION HINTS (Continued)

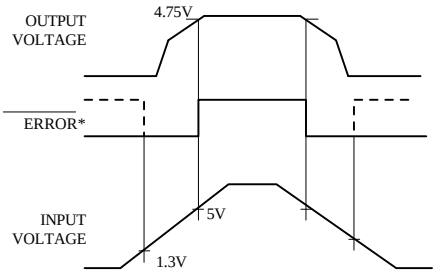


FIGURE 1. ERROR Output Timing

*When V_{IN} 1.3V the error flag pin becomes a high impedance, and the error flag voltage rises to its pull-up voltage. Using V_{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 drive down the error flag voltage using equal value resistors (10 k suggested), to ensure a low-level logic signal during any fault condition, while still allowing a valid high logic level during normal operation.

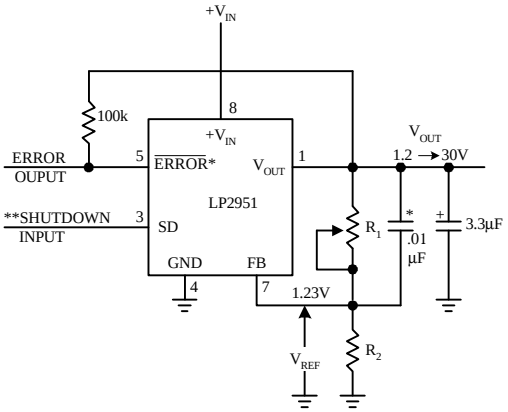


FIGURE 2. Adjustable Regulator

*See Application Hints.

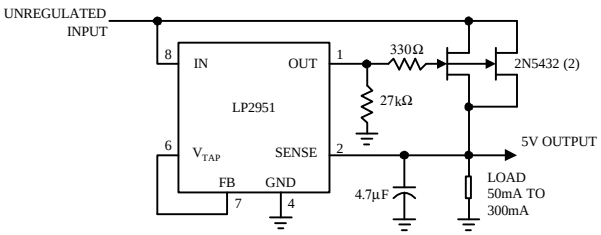
$V_{out} = V_{REF} \times (1 + R_1/ R_2)$

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

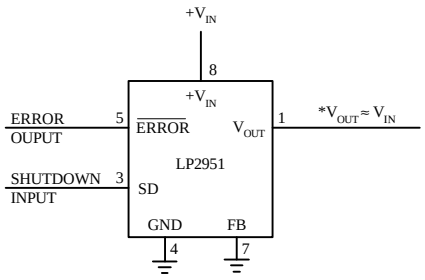
Note: Pins 2 and 6 are left open.

TYPICAL APPLICATIONS

300 mA Regulator with 0.75 Dropout



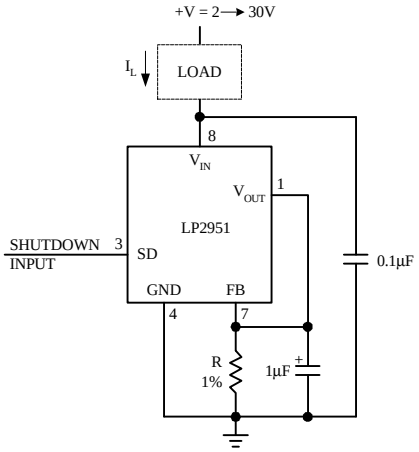
Wide Input Voltage Range Current Limiter



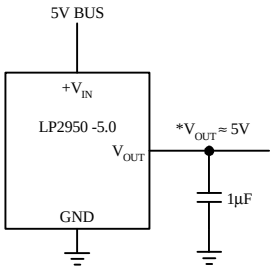
*Minimum Input-Output voltage ranges from 40mV to 400mV, depending on load current. Current limit is typically 160 mA

TYPICAL APPLICATIONS (Continued)

Low Drift Current Source

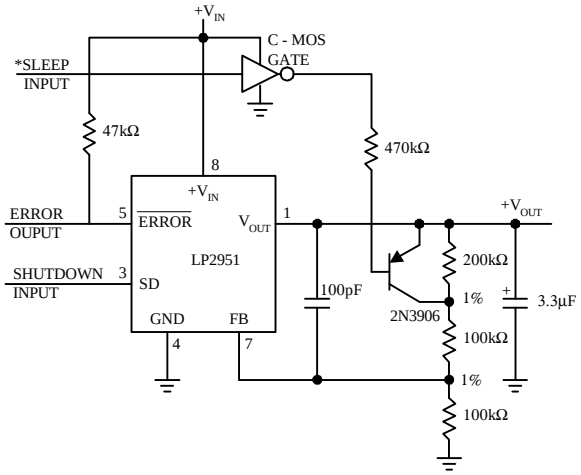


5Volt Current Limiter

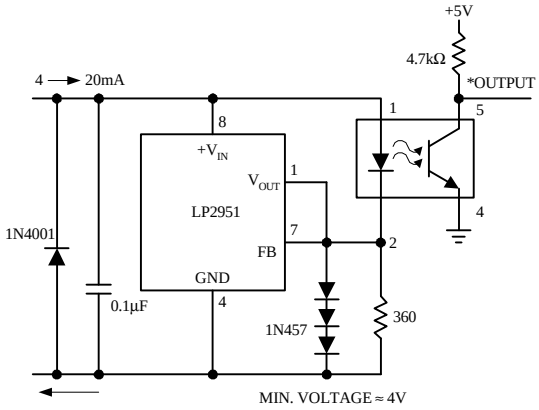


*Minimum Input-Output voltage ranges from 40mV to 400mV, depending on load current. Current limit is typically 160 mA

5V Regulator with 2.5V Sleep Function

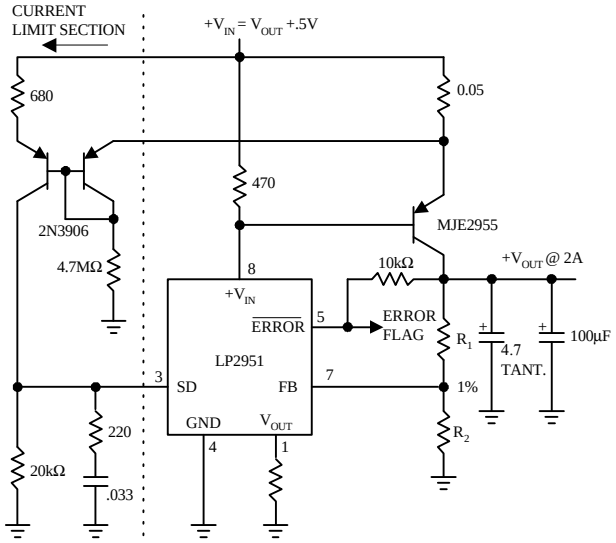


Open Circuit Detector for 4 to 20mA Current Loop



TYPICAL APPLICATIONS (Continued)

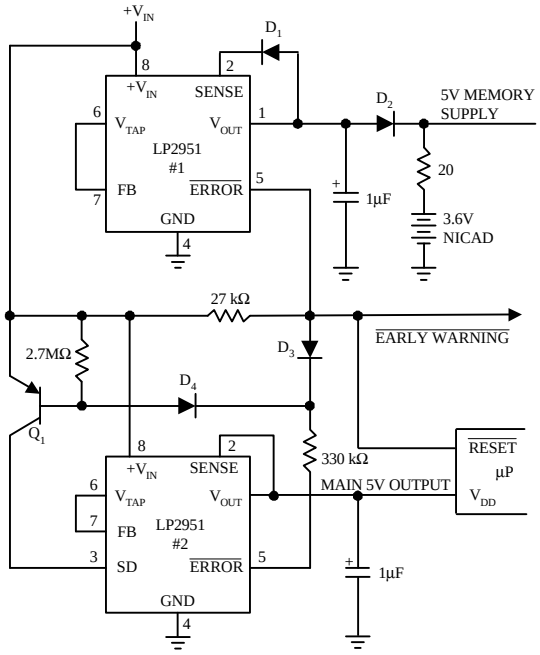
2 Ampere Low Dropout Regulator



VOUT = 1.23V(1+R1/R2)

For 5V V_{OUT}, use internal resistors. Wire pin 6 to 7 and pin 2 to +V_{OUT}Buss.

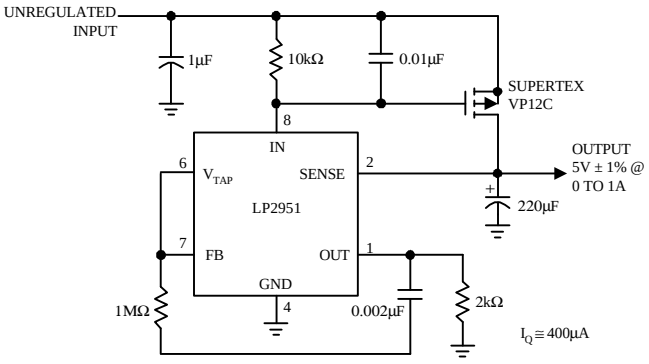
Regulator with Early Warning and Auxiliary Output



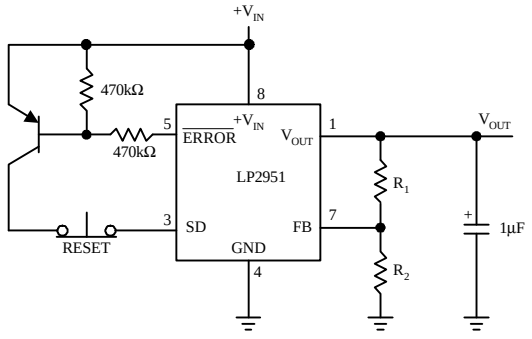
- Early warning flag on low input voltage
- Main output latches off at lower input voltages
- Battery backup on auxiliary output

Operation: Reg.#1's V_{OUT} is programmed one diode drop above 5V. It's 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.

1A Regulator with 1.2V Dropout

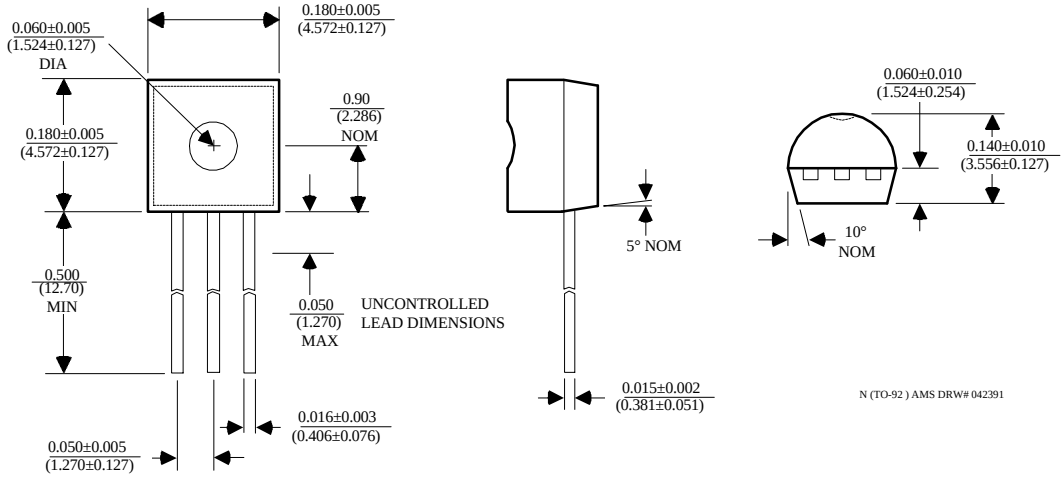


Latch Off When Error Flag Occurs

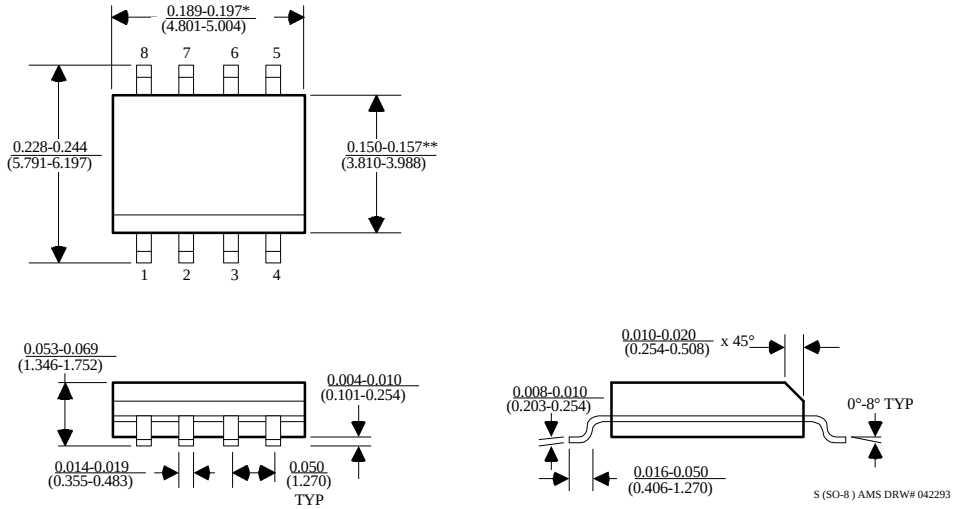


PACKAGE DIMENSIONS inches (millimeters) unless otherwise noted.

3 LEAD TO-92 PLASTIC PACKAGE (N)



8 LEAD SOIC PLASTIC PACKAGE (S)

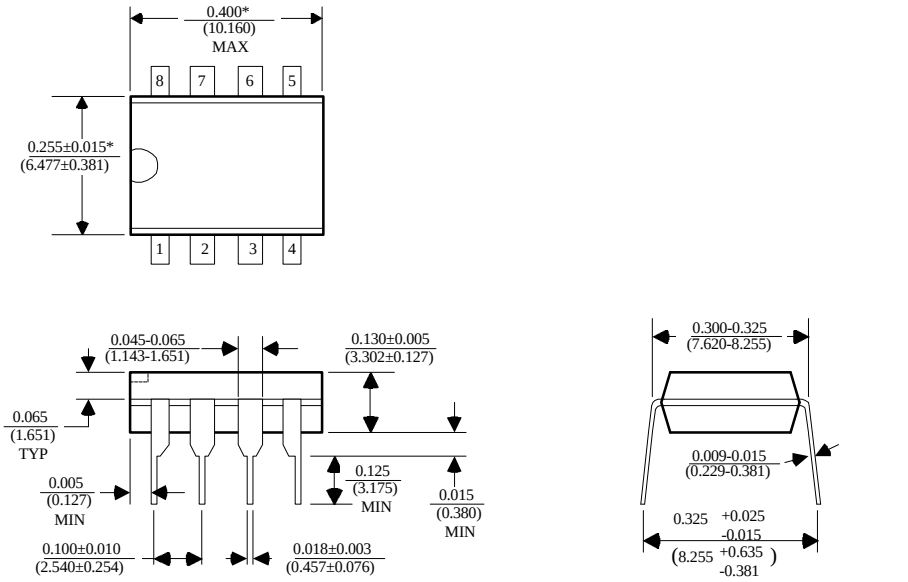


*DIMENSION DOES NOT INCLUDE MOLD FLASH. MOLD FLASH SHALL NOT EXCEED 0.006" (0.152mm) PER SIDE

**DIMENSION DOES NOT INCLUDE INTERLEAD FLASH. INTERLEAD FLASH SHALL NOT EXCEED 0.010" (0.254mm) PER SIDE

PACKAGE DIMENSIONS inches (millimeters) unless otherwise noted (Continued).

8 LEAD PLASTIC DIP PACKAGE (P)



P (8L PDIP) AMS DRW# 042294

*DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTUSIONS.
MOLD FLASH OR PROTUSIONS SHALL NOT EXCEED 0.010" (0.254mm)