July 1999

LP2950-xx/LP2951-xx

100mA Low Dropout Voltage Regulators

Product Description

The LP2950-xx and LP2951-xx are micropower voltage regulators with very low quiescent current (75 µA typ.) and very low dropout voltage (typ. 40 mV at light loads and 380 mV at 100 mA). This includes a tight initial tolerance of 0.5% typ., extremely good load and line regulation of 0.05% typ., and very low output temperature coefficient, making the LP2950-xx/LP2951-xx useful as a low-power voltage reference. They are ideally suited for use in battery-powered systems. Furthermore, the quiescent current of the LP2950-xx/LP2951-xx increases only slightly in dropout, prolonging battery life.

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 –xx volt output (depending on the version), or programmed from 1.24V to 29V with an external pair of resistors.

The LP2950-xx is available in the popular 3-pin TO-92 package compatible with other fixed regulator. The 8-pin LP2951-xx is available in plastic packages.

Features

- 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 only 1 µ F capacitance for stability

LP2951-xx versions only

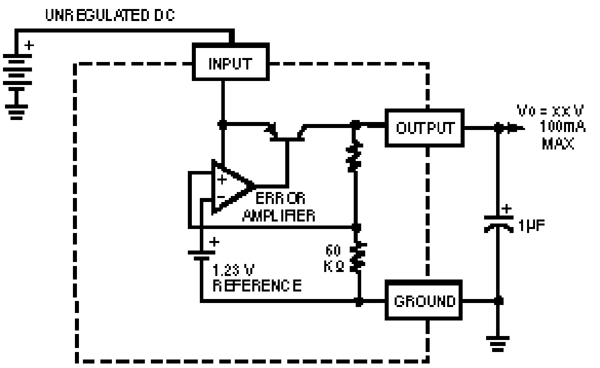
- Error Flag warns of output dropout
- Logic-Controlled electronic shutdown
- Output programmable from 1.24 to 29V

Applications

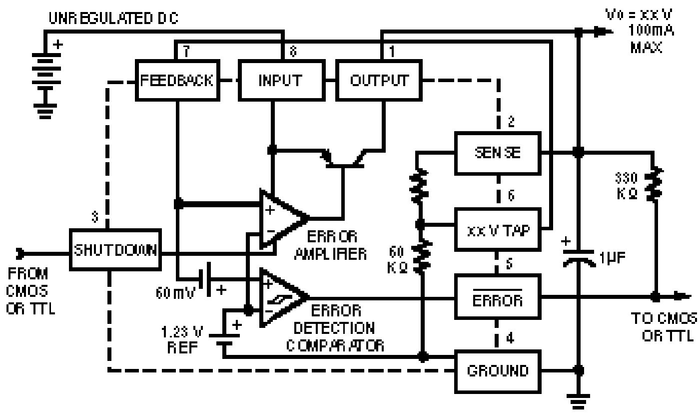
- Battery powered systems
- Cordless telephones
- Radio control systems
- Portable/Palm top/Notebook computers
- Portable consumer equipment
- Portable instrumentation
- Avionics
- Automotive electronics
- SMPS Post-Regulator
- Voltage reference

Block Diagram and Typical Applications

LP2950 - xx



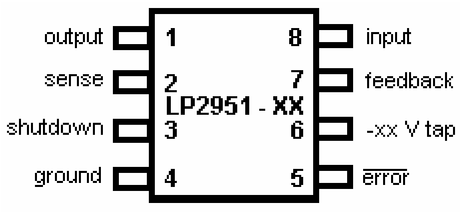
LP2951 - xx



Absolute Maximum Ratings

Power Dissipation	Internally Limited
Lead Temperature (Soldering, 5 seconds)	260°C
Storage Temperature Range	-65°C to+150°C
Operating Junction Temperature Range	-55°C to +150°C
Input Supply Voltage	-0.3 to +30V
Feedback Input Voltage	-1.5 to +30V
Shutdown Input Voltage	-0.3 to +30V
Error Comparator Output	-0.3 to +30V

Pin Connection
LP2951 - xx



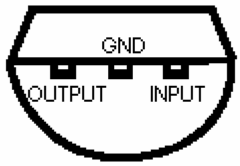
Top View

Device Selection Guide

Device	Vout Volts	Package	Temperature range(℃)
LP2950Z-2.85	2.85*	TO-92	-40 — 125
LP2950D-2.85	2.85*	TO-252	
LP2951M-2.85	2.85*	SOP8	
LP2950Z-3.0	3.0	TO-92	
LP2950D-3.0	3.0	TO-252	
LP2951M-3.0	3.0	SOP8	
LP2950Z-3.3	3.3	TO-92	
LP2950D-3.3	3.3	TO-252	
LP2951M-3.3	3.3	SOP8	
LP2950Z-5.0	5.0	TO-92	
LP2950D-5.0	5.0	TO-252	
LP2951M-5.0	5.0	SOP8	

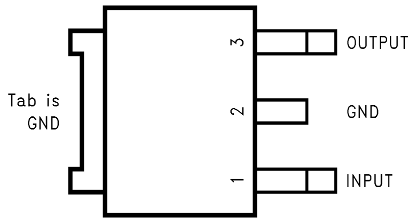
* - Other versions are also available
V_{out} = 2.0V to 5.0V. Please consult factory for more information

TO-92 Plastic Package
(LP2950 – xx only)



Bottom View

TO-252-2L Plastic Package
(LP2950 – xx only)



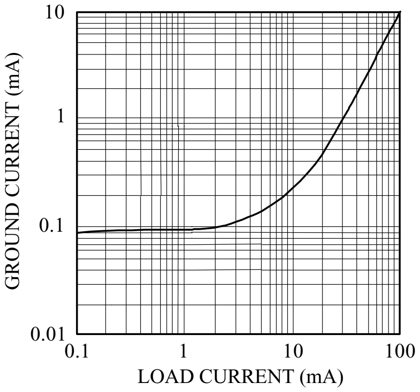
ELECTRICAL CHARACTERISTICS (at T_a =25℃, V_{in}=15V; unless otherwise noted)

Parameter	Conditions (Note 2)	Min	Typ	Max	Units
Output Voltage	-25°C≤T_J≤85°C Full Operating Temperature	0.985 |V_0| 0.98 |V_0|	V_0	1.015 |V_0| 1.02 |V_0|	V
Output Voltage	100µA ≤ I_L ≤ 100mA, T_J ≤ T_{JMAX}	0.976|V_0|	V_0	1.024 |V_0|	
Output Voltage Temperature Coefficient	(Note 1)		50	150	ppm/°C
Line Regulation (Note 3)	V_0 + 1V ≤ V_{in} ≤ 30V (Note 4)		0.04	0.4	%
Load Regulation (Note 3)	100µA ≤ I_L ≤ 100mA		0.1	0.3	%
Dropout Voltage (Note 5)	I_L=100 µA I_L=100 mA		50 380	80 450	mV
Ground Current	I_L=100 µA I_L=100 mA		75 8	120 12	µA mA
Dropout Ground Current	V_{in}=V_0 - 0.5V, I_L=100 µA		110	170	µA
Current Limit	Vout=0		160	200	mA
Thermal Regulation			0.05	0.2	%/W
Output Noise, 10Hz to 100KHz	C_L=1µF C_L=200µF C_L=3.3µF (Bypass=0.01 µF pins 7 to 1 (LP2951-XX))		430 160 100		µV rms
8-pin Versions only					
Reference Voltage		1.21	1.235	1.26	V
Reference Voltage	Over Temperature (Note 6)	1.185		1.285	
Feedback Pin Bias Current			20	40	nA
Reference Voltage Temperature Coefficient	(Note 7)		50		ppm/°C
Feedback Pin Bias Current Temperature Coefficient			0.1		nA/°C
Error Comparator					
Output Leakage Current	Voh=30V		0.01	1.0	µA
Output Low Voltage	Vin=4.5V, I_{OL}=400 µA		150	250	mV
Upper Threshold Voltage	(Note 8)	40	60		
Lower Threshold Voltage	(Note 8)		75	95	
Hysteresis	(Note 8)		15		
Shutdown Input					
Input Logic Voltage	Low (Regulator ON) High (Regulator OFF)	2	1.3	0.7	V
Shut down Pin Input Current	V_S=2.4V V_S=30V		30 450	50 600	µA
Regulator Output Current in Shutdown	(Note 9)				
	V_{OUT} = 5.0 V		3	10	
	3.3V ≤ V_{OUT} < 5.0 V			20	
	2.0V ≤ V_{OUT} < 3.3 V			30	

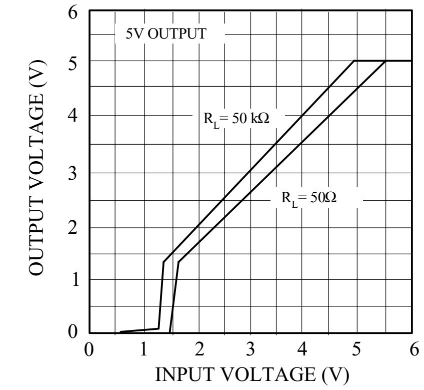
Note 1: Output or reference voltage temperature coefficients defined as the worst case voltage change divided by the total temperature range.
Note 2: Unless otherwise specified all limits guaranteed for T_J = 25°C, Vin = V_0 + 1V, I_L = 100µA and C_L = 1µF. Additional conditions for the 8-pin versions are feedback tied to -XX V tap and output tied to output Sense (V_{out} = XX V) and $V_{shutdown}$ ≤ 0.8 V
Note 3: Regulations 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 4: Line regulation for LP2951-XX is tested at 150°C for I_L = 1mA. For I_L = 100µA 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 5: Dropout voltage is defined as the input to output differential at which the output voltage drops 100mV below its nominal value measured at 1V differential. At very low values of programmed output voltage, the min. input supply voltage of 2V (2.3V over temperature) must be taken into account
Note 6: Vref ≤ Vout ≤ (Vin - 1V), 2.3V ≤ Vin ≤ 30V, 100µA ≤ I_L ≤ 100mA, T_J ≤ T_{JMAX}
Note 7: Output or reference voltage temperature coefficient is defined as the worst case voltage change divided by the total temperature range
Note 8: Comparator thresholds are expressed in terms of a voltage differential at the feedback terminal below the nominal reference voltage measured at V_0 + 1V input. To express these thresholds in terms of output voltage change, multiply by the error amplifier gain = V_{out}/V_{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 95mV x 5V/1.235V=384mV. Thresholds remain constant as a percent of Vout as Vout is varied , with the dropout warning occurring at typically 5% below nominal, 7.5% guaranteed.
Note 9: $V_{shutdown}$ ≥ 2V, Vin ≤ 30V, Vout = 0, Feed-back pin tied to -XX V Tap.

TYPICAL PERFORMANCE CHARACTERISTICS

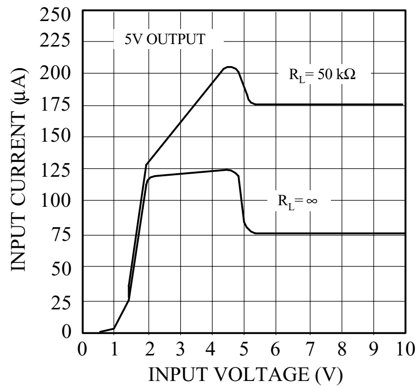
Quiescent Current



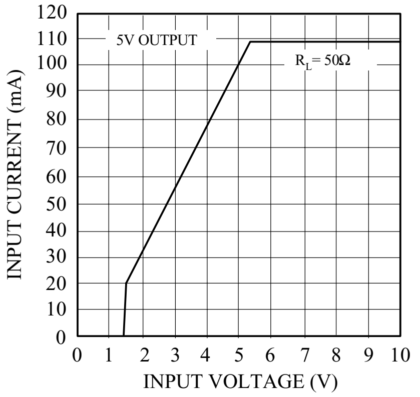
Dropout Characteristics



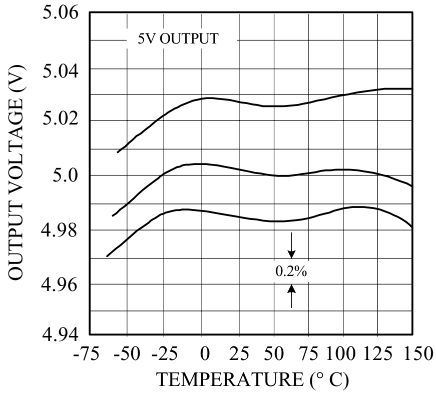
Input Current



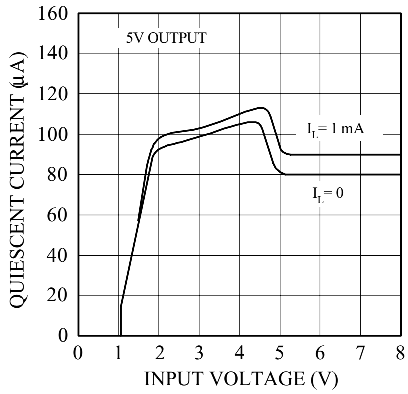
Input Current



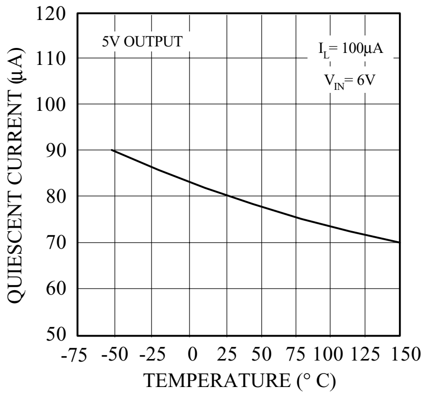
Temperature Drift of 3 Representative Units



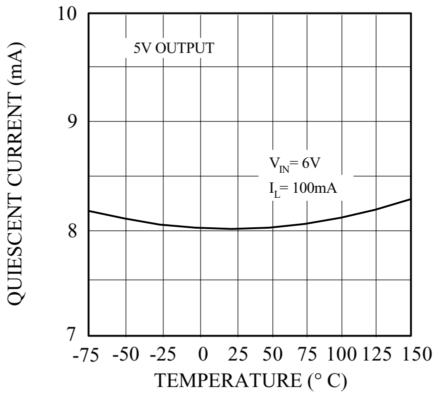
Quiescent Current



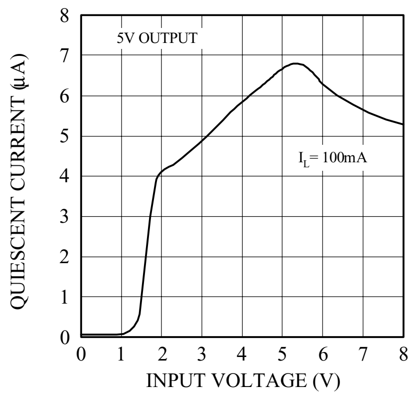
Quiescent Current



Quiescent Current

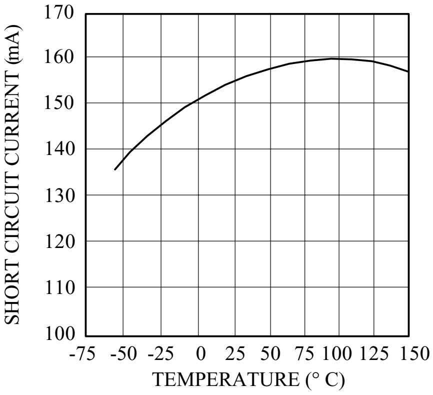


Quiescent Current

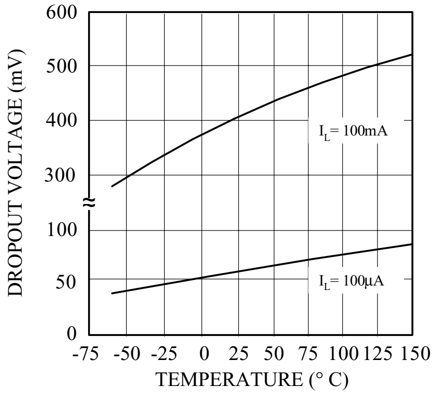


TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

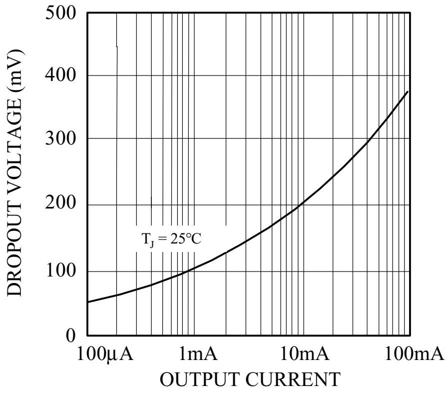
Short Circuit Current



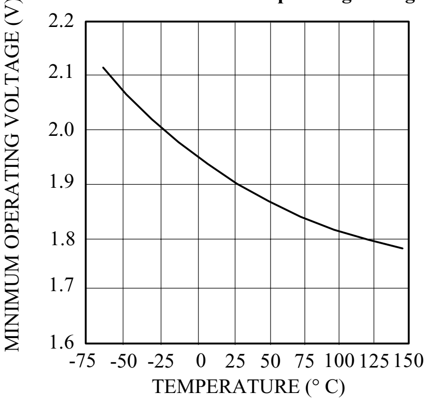
Dropout Voltage



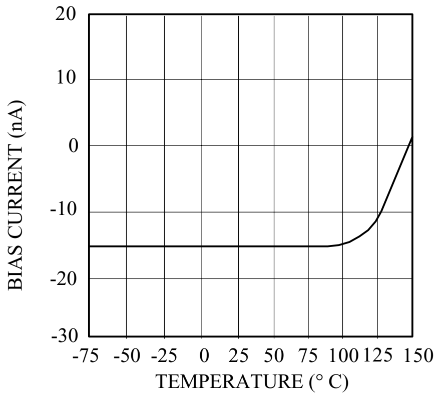
Dropout Voltage



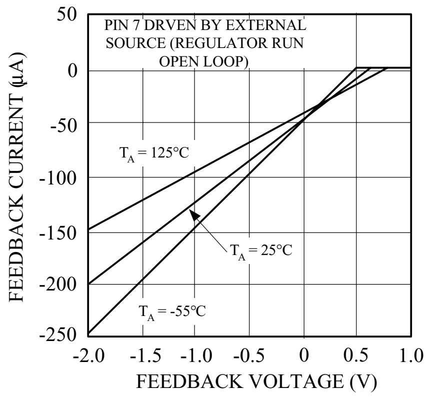
LP2951 Minimum Operating Voltage



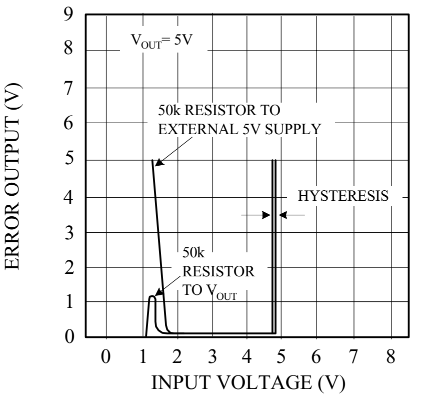
LP2951 Feedback Bias Current



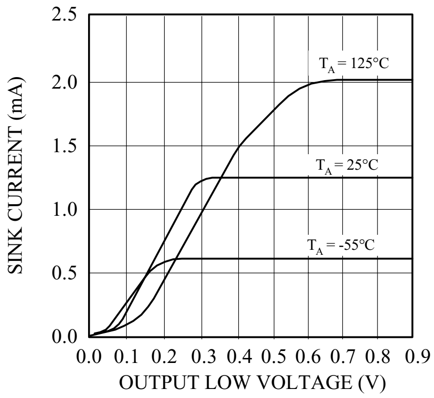
LP2951 Feedback Pin Current



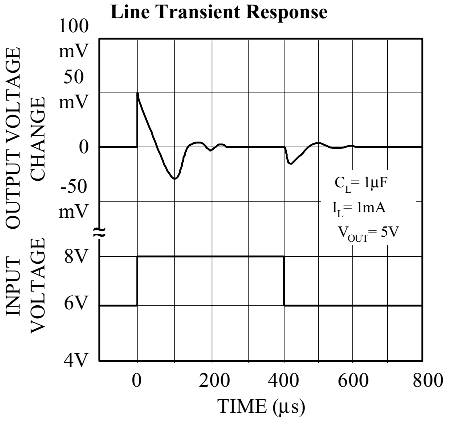
LP2951 Error Comparator Output



LP2951 Comparator Sink Current

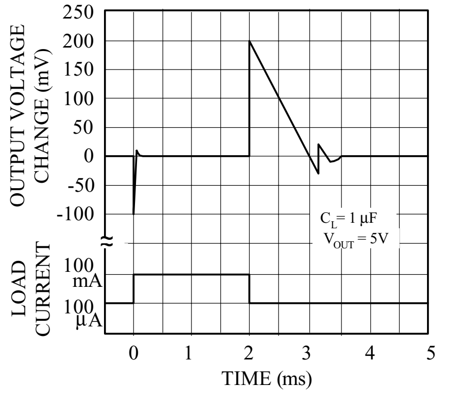


Line Transient Response

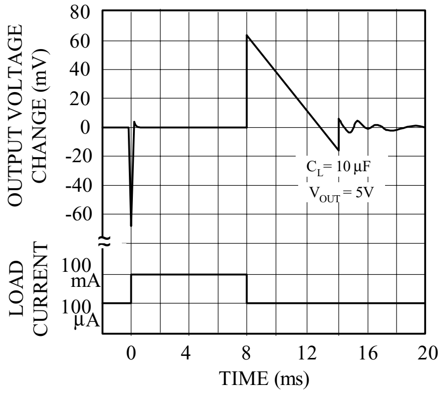


TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

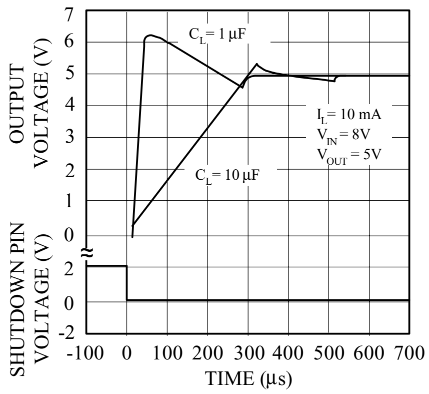
Load Transient Response



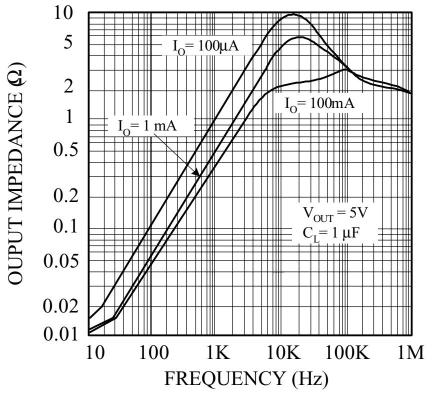
Load Transient Response



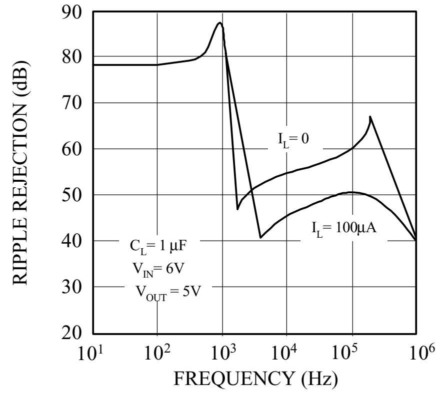
LP2951 Enable Transient



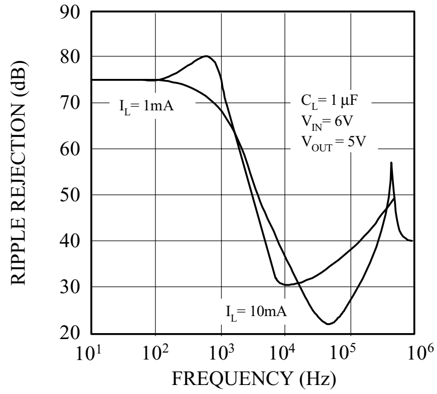
Output Impedance



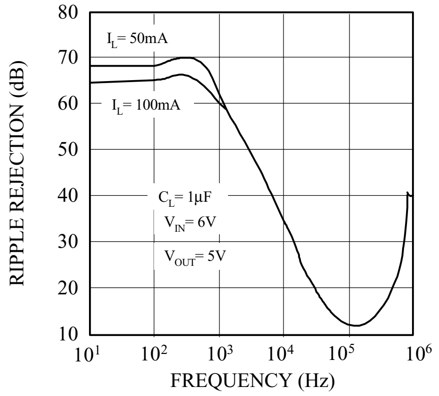
Ripple Rejection



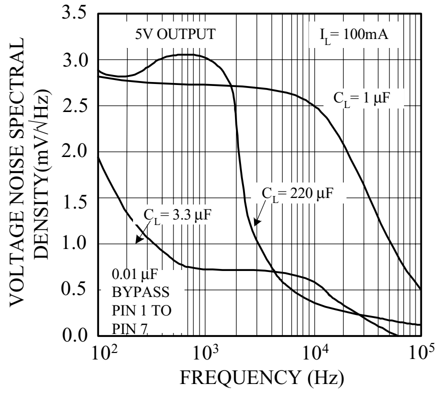
Ripple Rejection



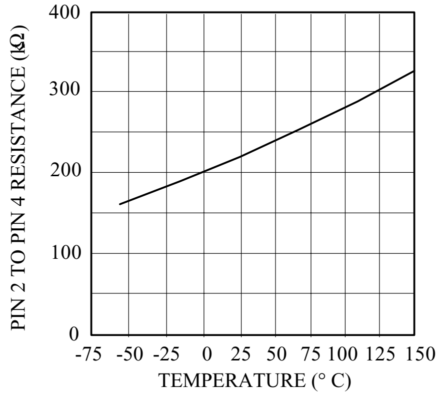
Ripple Rejection



LP2951 Output Noise

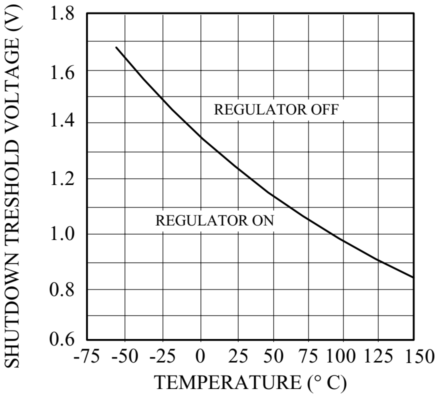


LP2951 Divider Resistance

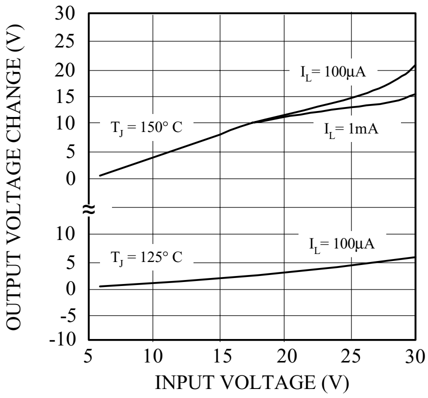


TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

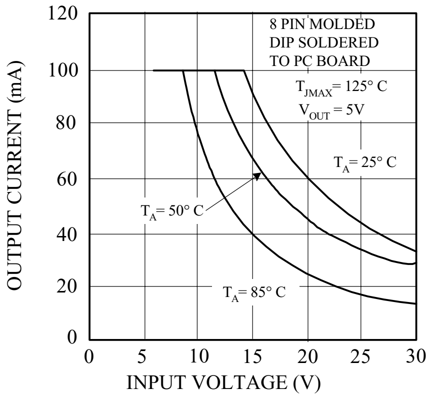
Shutdown Treshold Voltage



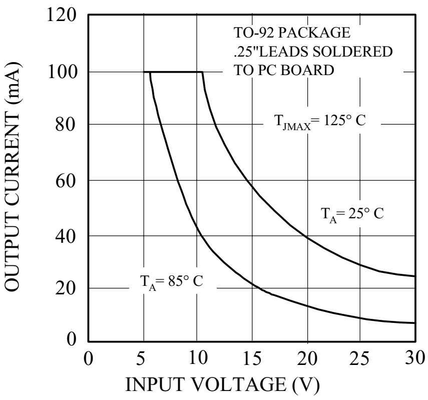
Line Regulation



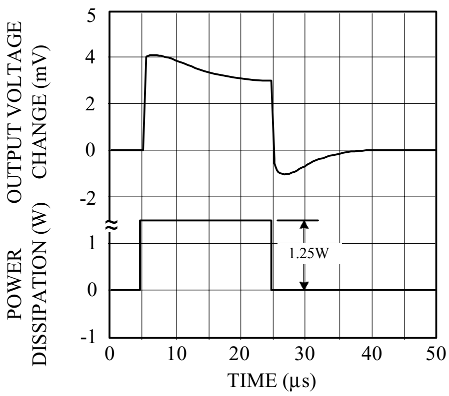
LP2951 Maximum Rated Output Current



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)

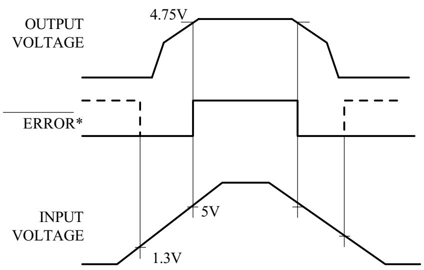


FIGURE 1. ERROR Output Timing

*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.

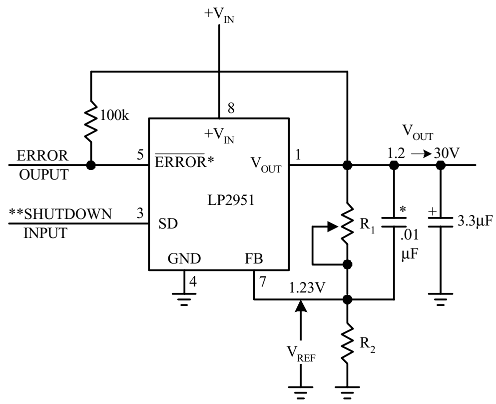


FIGURE 2. Adjustable Regulator

*See Application Hints.

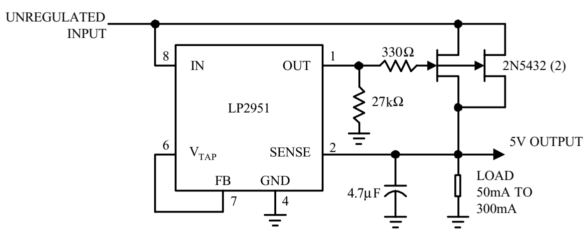
$V_{out} = V_{REF} \times (1 + R_1/ R_2)$

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

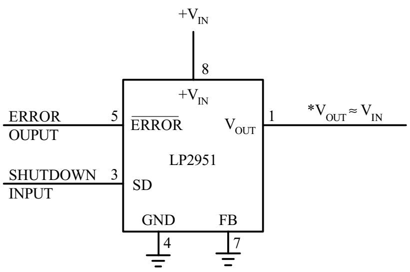
Note: Pins 2 and 6 are left open.

TYPICAL APPLICATIONS

300 mA Regulator with 0.75 Dropout



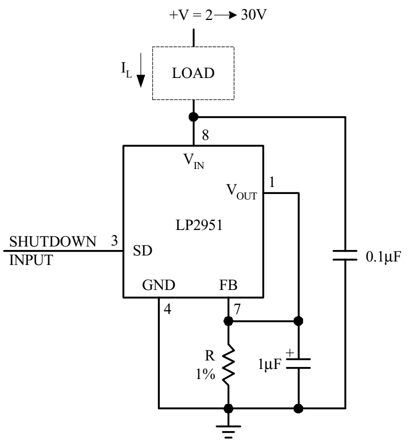
Wide Input Voltage Range Current Limiter



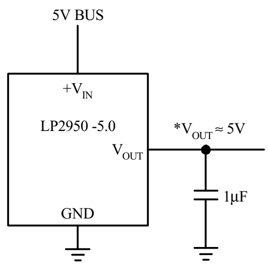
*Minimum Input-Output voltage ranges from 40mV to 400mV, depending on load current. Current limit is typically 160 mA

TYPICAL APPLICATIONS (Continued)

Low Drift Current Source

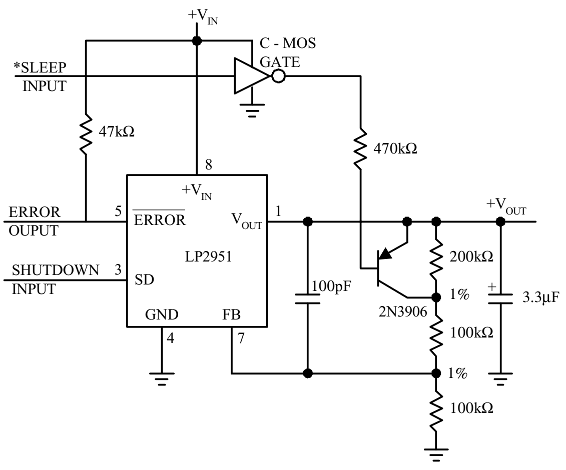


5Volt Current Limiter

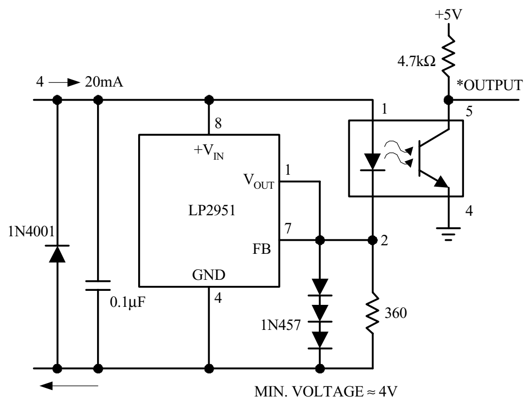


*Minimum Input-Output voltage ranges from 40mV to 400mV, depending on load current. Current limit is typically 160 mA

5V Regulator with 2.5V Sleep Function

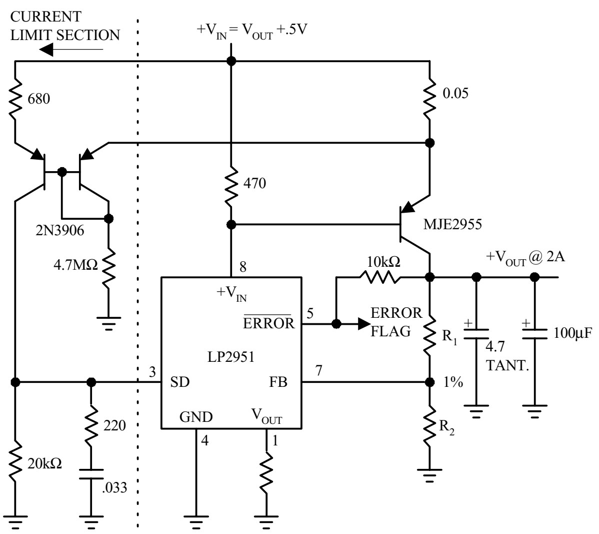


Open Circuit Detector for 4 to 20mA Current Loop



TYPICAL APPLICATIONS (Continued)

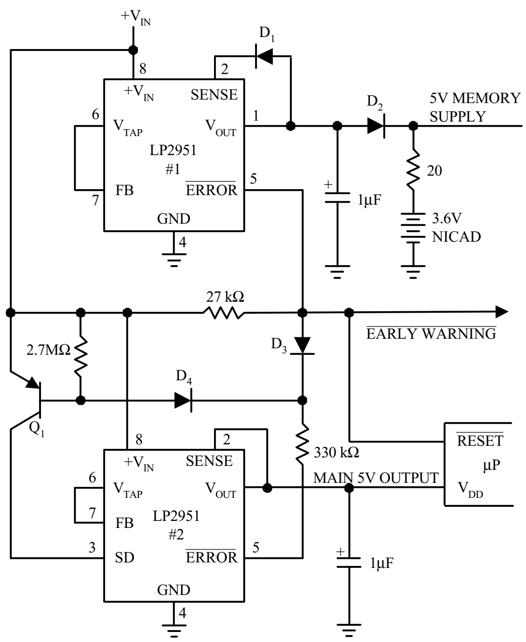
2 Ampere Low Dropout Regulator



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.

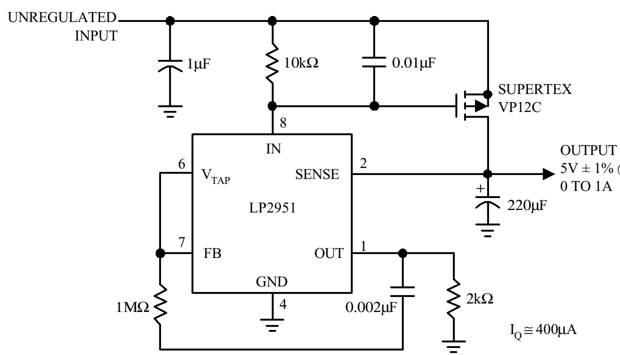
Regulator with Early Warning and Auxiliary Output



- 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