

## 150mA Low Dropout Voltage Regulator

### FEATURES

- 5.0V and 3.3V at 150mA Output
- Accurate: 0.5% for SPX2950A/SPX2951A
- Very Low Quiescent Current
- Low Dropout Voltage: 300mV at 150mA
- Extremely Tight Load and Line Regulation
- Very Low Temperature Coefficient
- Current & Thermal Limiting
- Need Only 1 $\mu$ F for Stability
- Offered in TO-92 (SPX2950) and SOIC (SPX2951)
- Direct Replacement for LP2950/LP2951

### SPX2951 versions only

- Error Flag Warns of Output Dropout
- Logic-Controlled Electronic Shutdown
- Output Programmable From 1.24 to 30V

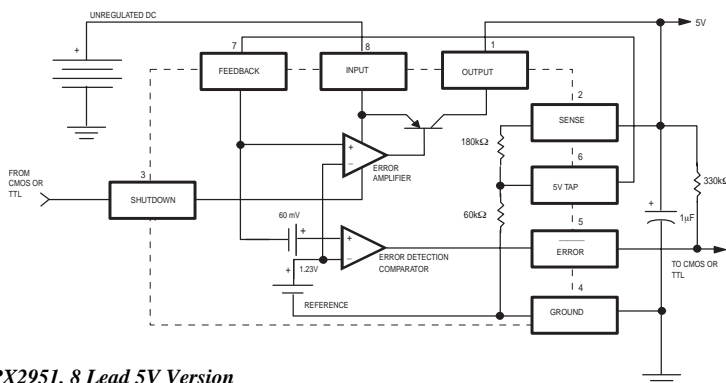
### APPLICATIONS

- Battery Powered Systems
- Cordless Telephones
- Radio Control Systems
- Portable/Palm Top/Notebook Computers
- Portable Consumer Equipment
- Portable Instrumentation
- Avionics
- SMPS Post-Regulator
- Voltage Reference
- Automotive Electronics

### DESCRIPTION

The SPX2950 and SPX2951 are low power voltage regulators. These devices are an excellent choice for use in battery-powered applications such as cordless telephones, radio control systems, and portable computers. The SPX2950 and SPX2951 feature low quiescent current and low dropout voltage (typ. 20mV at 100 $\mu$ A and 300mV at 150mA). This includes a tight initial tolerance of (0.5% for SPX2950A/SPX2951A), extremely good load and line regulation (0.05% typ.), and very low output temperature coefficient (20ppm/ $^{\circ}$ C typ.), making the SPX2950/SPX2951 useful as a low-power voltage reference.

The error flag output feature is used as a power-on reset for warning of a low output voltage, due to a falling voltage. The logic compatible shutdown feature enables the regulator to be switched ON and OFF. The SPX2950 is offered in a 3-pin TO-92 package compatible with other 5.0V, 3.3V regulators. The SPX2951 is available in an 8-lead SOIC package.



*Block Diagram of SPX2951, 8 Lead 5V Version*

## ABSOLUTE MAXIMUM RATINGS

Power Dissipation ..... Internally Limited  
 Lead Temp. (Soldering, 5 Seconds) ..... 260°C  
 Storage Temperature Range ..... -65°C to +150°C  
 Operating Junction Temperature Range ..... -40°C to +125°C  
 Input Supply Voltage ..... -0.3V to +30V

Feedback Input Voltage ..... -1.5V to +30V  
 Shutdown Input Voltage ..... -0.3V to +30V  
 Error Comparator Output ..... -0.3V to +30V  
 ESD Rating ..... 2kV Min

## ELECTRICAL CHARACTERISTICS

Electrical characteristics at  $V_{IN} = V_O + 1V$ ,  $I_L = 100\mu A$ ,  $C_L = 1\mu F$  (note 2)  $T_A = 25^\circ C$ , unless otherwise specified. Boldface applies over the full operating temperature range.

PARAMETER	CONDITIONS	MIN	TYP	MAX	MIN	TYP	MAX	UNITS
		SPX2950AC SPX2951AC			SPX2950C SPX2951C			
3.3V Version								
Output Voltage	T <sub>J</sub> =25°C -25°C≤T <sub>J</sub> ≤85°C Full Operating Temperature	3.284 3.267 3.260	3.3 3.3 3.3	3.317 3.333 3.340	3.267 3.251 3.324	3.3 3.3 3.3	3.333 3.350 3.366	V
Output Voltage	100μA≤ I <sub>L</sub> ≤150mA T <sub>J</sub> ≤T <sub>JMAX</sub>	3.254	3.3	3.346	3.221	3.3	3.379	V
5.0V Version								
Output Voltage	T <sub>J</sub> =25°C -25°C≤T <sub>J</sub> ≤85°C Full Operating Temperature	4.975 4.950 4.940	5.0 5.0 5.0	5.025 5.050 5.060	4.950 4.925 4.900	5.0 5.0 5.0	5.050 5.075 5.100	V
Output Voltage	100μA≤I <sub>L</sub> ≤150mA T <sub>J</sub> ≤T <sub>JMAX</sub>	4.925	5.0	5.075	4.880	5.0	5.120	V
All Voltage Options								
Output Voltage Temperature Coefficient	(Note1)		20	100		50	150	ppm/°C
Line Regulation (Note 3)	V <sub>O</sub> +1V ≤ V <sub>IN</sub> ≤ 30V (Note 4)		0.03	0.1		0.04	0.2	%
Load Regulation (Note 3)	100μA≤I <sub>L</sub> ≤150mA		0.04	0.1		0.1	0.2	%
Dropout Voltage (Note5)	I <sub>L</sub> =100μA		20	80		20	80	mV
	I <sub>L</sub> =100mA		270	450		270	450	mV
	I <sub>L</sub> =150mA		300	500		300	500	mV
Ground Current	I <sub>L</sub> =100μA		150	170		150	170	μA
	I <sub>L</sub> =100mA		3	6		3	6	mA
	I <sub>L</sub> =150mA		5	8		5	8	mA
Current Limit	V <sub>OUT</sub> =0		230			230		mA
Thermal Regulation			0.05	0.2		0.05	0.2	%/W
Output Noise, 10Hz to 100kHz	C <sub>L</sub> =1μF C <sub>L</sub> =200μF C <sub>L</sub> =3.3μF, Bypass=0.01μF from pin 7 to pin1 (SPX2951)		430 160 100			430 160 100		μVrms μVrms μVrms
8-Pin Version only		SPX2951AC			SPX2951C			
Reference Voltage		1.220	1.235	1.250	1.210	1.235	1.260	V
Reference Voltage	Over Temperature (Note 6)	1.190		1.270	1.185		1.285	V
Feedback Pin Bias Current			40	60		40	60	nA
Reference Voltage Temperature Coefficient			20			50		ppm/°C
Feedback Pin Bias Current Temperature Coefficient			0.1			0.1		nA/°C

## ELECTRICAL CHARACTERISTICS: Continued

Electrical characteristics at  $V_{IN} = V_O + 1V$ ,  $I_L = 100\mu A$ ,  $C_L = 1\mu F$  (note 2)  $T_A = 25^\circ C$ , unless otherwise specified. **Boldface** applies over the full operating temperature range.

PARAMETER	CONDITIONS	MIN	TYP	MAX	MIN	TYP	MAX	UNITS
<b>Error Comparator</b>								
Output Leakage Current	$V_{OH} = 30V$		0.01	1		0.01	1	$\mu A$
Output Low Voltage	$V_{IN} = V_O - 0.5V$ $I_{OL} = 400\mu A$		150	250		150	250	mV
Upper Threshold Voltage	(Note 7)	40	60		40	60		mV
Lower Threshold Voltage	(Note 7)		75	95		75	95	mV
Hysteresis	(Note 7)		15			15		mV
<b>Shutdown Input</b>								
Input Logic Voltage	Low (Regulator ON) High (Regulator OFF)	2.0	1.3	0.7	2.0	1.3	0.7	V V
Shutdown Pin Input Current	$V_S = 2.4V$ $V_S = 30V$		30 400	50 800		30 400	50 800	$\mu A$ $\mu A$
Regulator Output Current in Shutdown	(Note 8)		3	10		3	10	$\mu A$

**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 are guaranteed for  $T_J = 25^\circ C$ ,  $V_{IN} = V_O + 1V$ ,  $I_L = 100\mu A$  and  $C_L = 1\mu F$ . Additional conditions for the 8-pin versions are feedback tied to 5V tap and output tied to output sense ( $V_{OUT} = 5V$ ) and  $V_{SHUTDOWN} \leq 0.8V$ .

**Note 3:** 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 4:** Line regulation for the SPX2951 is tested at  $I_L = 1mA$ . See typical performance characteristics for line regulation versus temperature and load current.

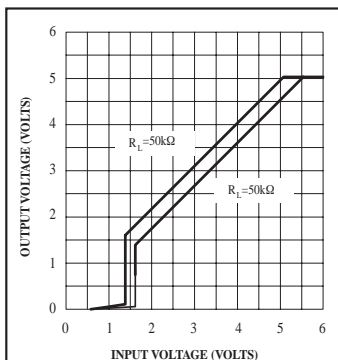
**Note 5:** Dropout voltage is defined as the input to output differential at which the output voltage drops 100mV below its nominal value measured at 1V differential. At very low values of programmed output voltage, the minimum input supply voltage of 2V ( 2.3V over temperature) must be taken into account.

**Note 6:**  $V_{REF} \leq V_{OUT} \leq (V_{IN} - 1V)$ ,  $2.3 \leq V_{IN} \leq 30V$ ,  $100\mu A \leq I_L \leq 150mA$ ,  $T_J \leq T_{JMAX}$ .

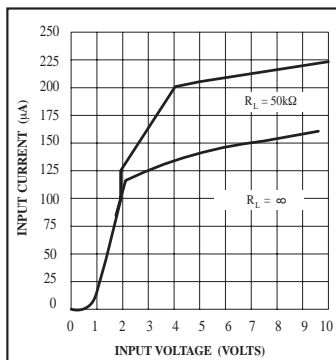
**Note 7:** Comparator thresholds are expressed in terms of a voltage differential at the feedback terminal below the nominal reference voltage measured at 6V input. To express these thresholds in terms of output voltage change, multiply by the error amplifier gain =  $V_{OUT}/V_{REF} = (R_1 + R_2)/R_2$ . For example, at a programmed output voltage of 5V, the error output is guaranteed to go low when the output drops by  $95mV \times 5V/1.235 = 384mV$ . 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 8:**  $V_{SHUTDOWN} \geq 2V$ ,  $V_{IN} \leq 30V$ ,  $V_{OUT} = 0$ , Feedback pin tied to 5V/ 3.3V tap.

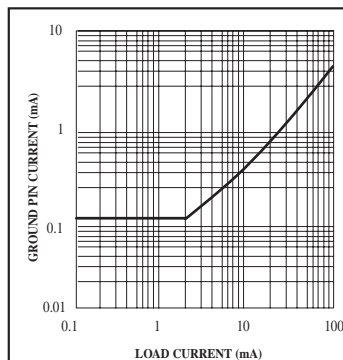
# TYPICAL PREFORMANCE CHARACTERISTICS



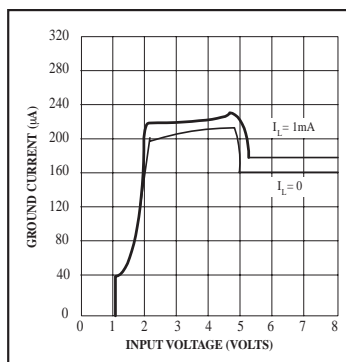
Dropout Characteristics



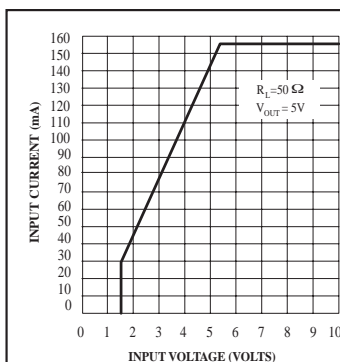
Input Current



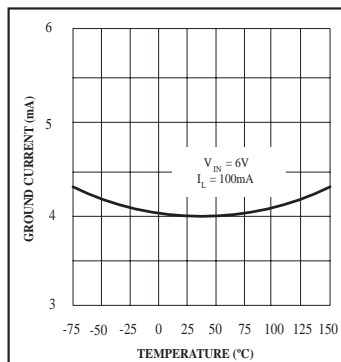
Quiescent Current



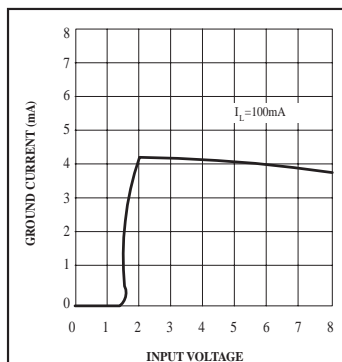
Ground Current



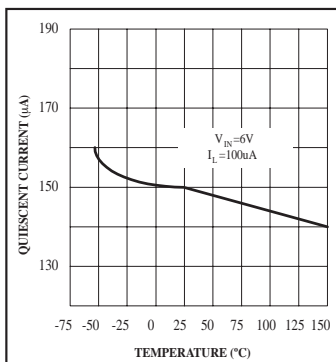
Input Current



Ground Current

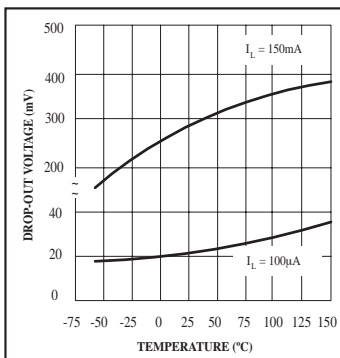


Ground Current

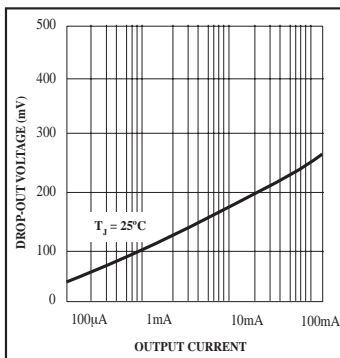


Quiescent Current

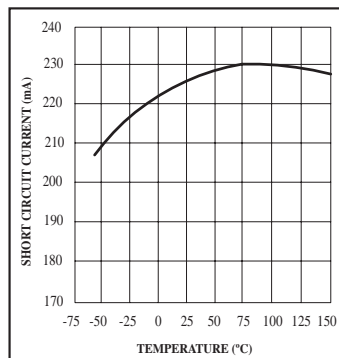
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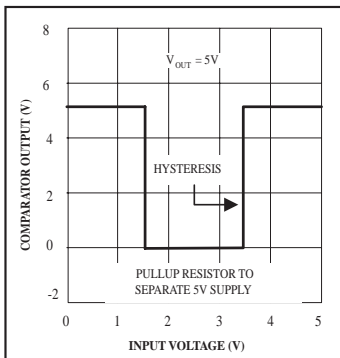
Drop-Out Voltage



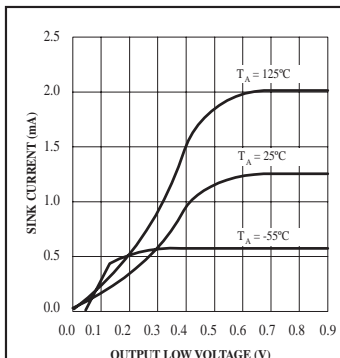
Drop-Out Voltage



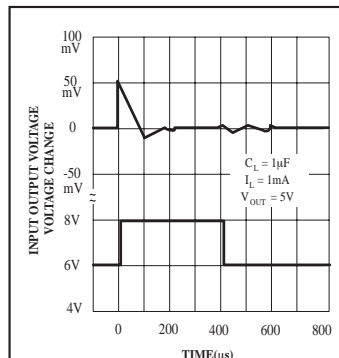
Short Circuit Current



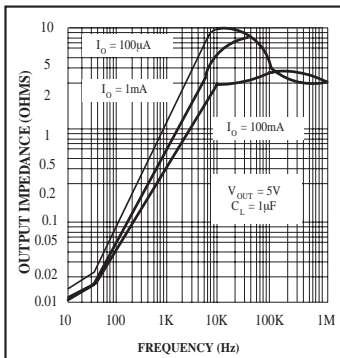
Error Comparator Output



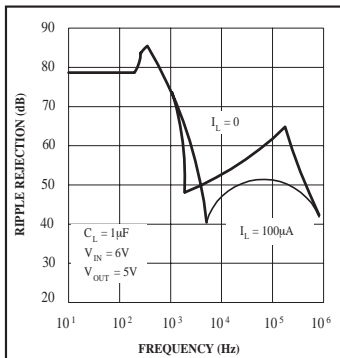
SPX2951 Comparator Sink Current



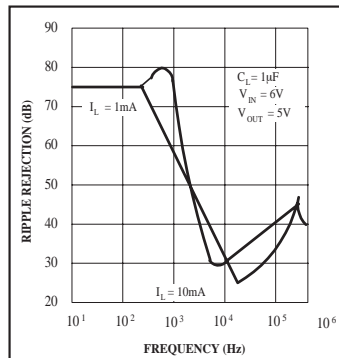
Line Transient Response



Output Impedance

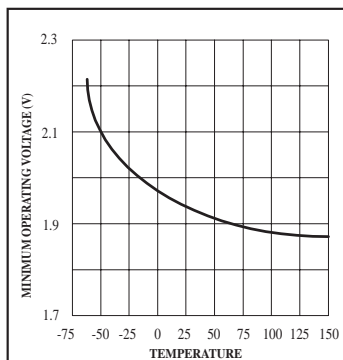


Ripple Rejection

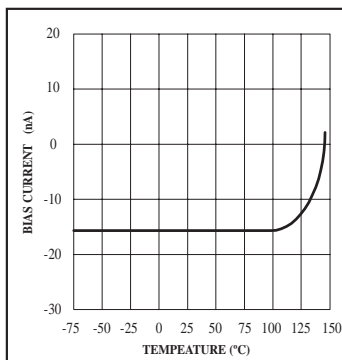


Ripple Rejection

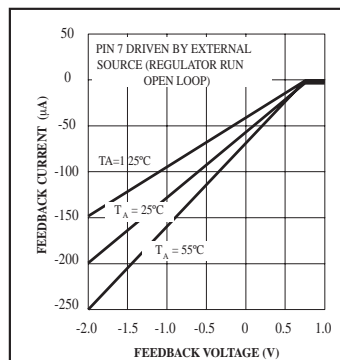
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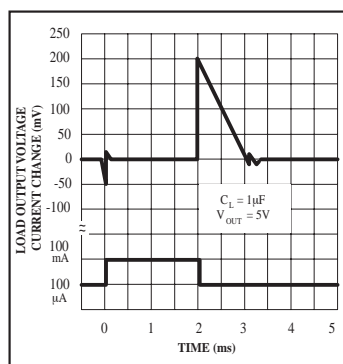
SPX2951 Minimum Operating Voltage



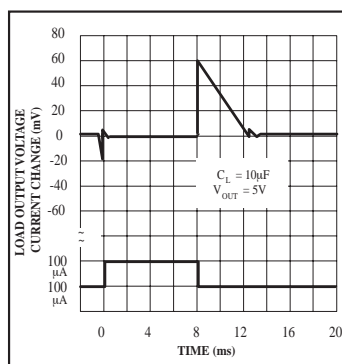
SPX2951 Feedback Bias Current



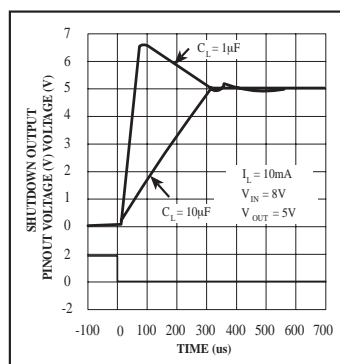
SPX2951 Feedback Pin Current



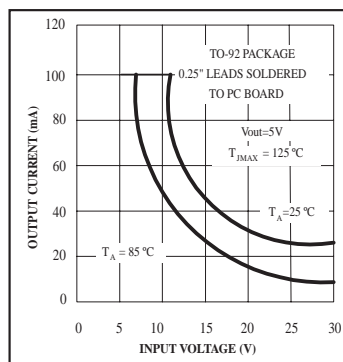
Load Transient Response



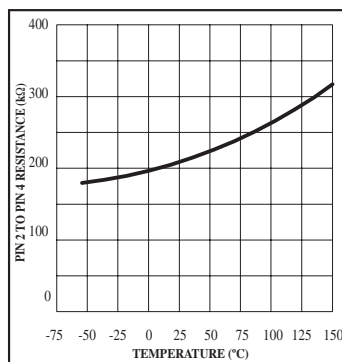
Load Transient Response



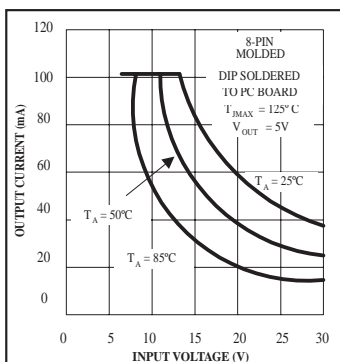
Enable Transient



SPX2950 Maximum Rated Output

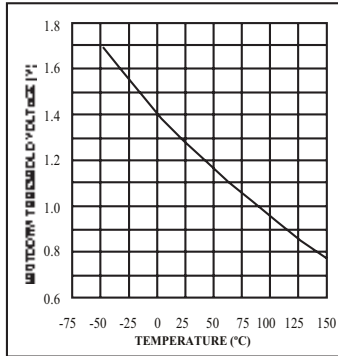


SPX2951 Divider Resistance

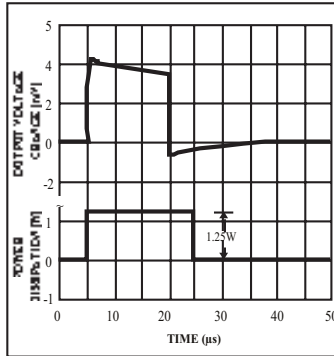


SPX2950 Maximum Rated Output Current

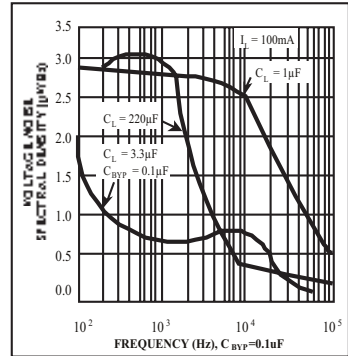
## TYPICAL APPLICATIONS:



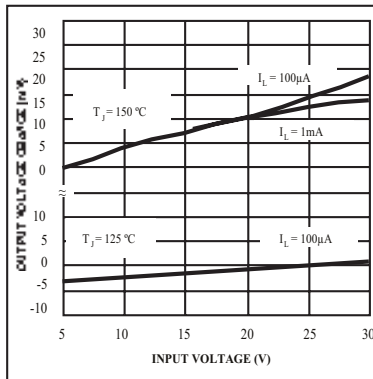
Shutdown Threshold Voltage



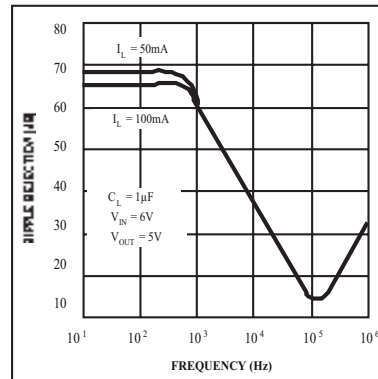
Thermal Response



Output Noise



Line Regulation



Ripple Rejection

## APPLICATION HINTS

### EXTERNAL CAPACITORS

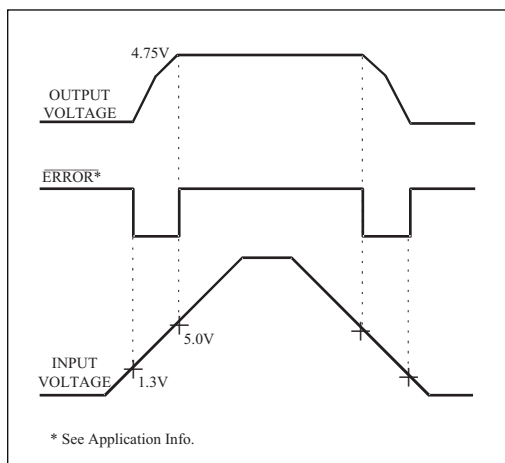
The stability of the SPX2950/SPX2951 requires a  $1\mu\text{F}$  or greater capacitor between output and ground. Oscillation could occur without this capacitor. Most types of tantalum or aluminum electrolytic works fine here. For operations below  $-25^{\circ}\text{C}$  solid tantalum is recommended since the many aluminum types have electrolytes that freeze at about  $-30^{\circ}\text{C}$ . The ESR of about  $5\Omega$  or less and resonant frequency above  $500\text{kHz}$  are the most important parameters in the value of the capacitor. The capacitors value may be increased without limit.

At lower values of output current, less output capacitance is required for stability. For the currents below  $10\text{mA}$  the value of the capacitor can be reduced to  $0.33\mu\text{F}$  and  $0.1\mu\text{F}$  for  $1\text{mA}$ . More output capacitance is needed for the 8-pin version at voltages below  $5\text{V}$  since it runs the error amplifier at lower gain. At worst case  $3.3\mu\text{F}$  or greater must be used for the condition of  $150\text{mA}$  load at  $1.23\text{V}$  output.

The SPX2950/51 unlike other low dropout regulators will remain stable and in regulation with no load in addition to the internal voltage divider. This feature is especially important in applications like CMOS RAM keep-alive. When setting the output voltage of the SPX2950/51 version with external resistors, a minimum load of  $1\mu\text{A}$  is recommended

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 then a  $1\mu\text{F}$  tantalum or aluminum electrolytic capacitor should be placed from the input to the ground.

Instability can occur if there is stray capacitance to the SPX2951 feedback terminal (pin 7). This could cause more problems when using a higher value of external resistors to set the output voltage. This problem can be fixed by adding a  $100\text{pF}$  capacitor between output and feedback and increasing the output capacitor to at least  $3.3\mu\text{F}$ .



**Fig. 1 ERROR Output Timing**

### ERROR DETECTION COMPARATOR OUTPUT

The comparator produces a logic low output whenever the SPX2951 output falls out of regulation by more than around  $5\%$ . This is around  $60\text{mV}$  offset divided by the  $1.235$  reference voltage. This trip level remains  $5\%$  below normal regardless of the programmed output voltage of the regulator.

Figure 1 shows the timing diagram depicting the ERROR signal and the regulator output voltage as the SPX2951 input is ramped up and down. The ERROR signal becomes low at around  $1.3\text{V}$  input, and goes high around  $5\text{V}$  input (input voltage at which  $V_{\text{OUT}} = 4.75$ ). Since the SPX2951's dropout voltage is load dependent, the input voltage trip point (around  $5\text{V}$ ) will vary with the load current. The output voltage trip point (approx.  $4.75\text{V}$ ) does not vary with load.

The error comparator has an open-collector output, which requires an external pull-up resistor. Depending on the system requirements the resistor may be returned to  $5\text{V}$  output or other supply voltage. In determining the value of this resistor, note that the output is rated to sink  $400\mu\text{A}$ , this value adds to battery drain in a low battery condition. Suggested values range from  $100\text{K}$  to  $1\text{M}\Omega$ . If the output is unused this resistor is not required.



## PROGRAMMING THE OUTPUT VOLTAGE OF SPX2951

The SPX2951 may be pin-strapped for 5V using its internal voltage divider by tying Pin 1 (output) to Pin 2 (sense) and Pin 7 (feedback) to Pin 6 (5V Tap). Also, 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. Refer to the below equation for the programming of the output voltage:

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

The  $V_{REF}$  is 1.235 and  $I_{FB}$  is the feedback bias current, nominally -20nA. The minimum recommended load current of 1  $\mu$ A forces an upper limit of 1.2M $\Omega$  on value of  $R_2$ . If no load is presented the  $I_{FB}$  produces an error of typically 2% in  $V_{OUT}$  which may be eliminated at room temperature by trimming  $R_1$ . To improve the accuracy choose the value of  $R_2 = 100k$  this reduces the error by 0.17% and increases the resistor program current by 12 $\mu$ A. Since the SPX2951 typically draws 60 $\mu$ A at no load with Pin 2 open-circuited this is a small price to pay.

## REDUCING OUTPUT NOISE

It may be an advantage to reduce the AC noise present at the output. One way 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 SPX2950 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<sub>RMS</sub> for a 100kHz 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 choose 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<sub>RMS</sub> for a 100kHz 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

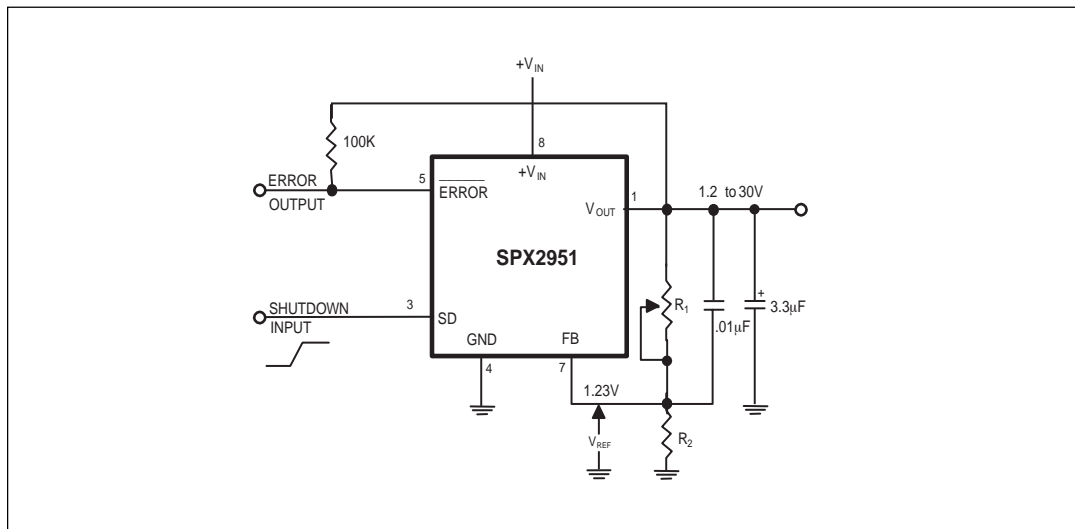


Figure 2. Adjustable Regulator

## TYPICAL APPLICATIONS: (Continued)

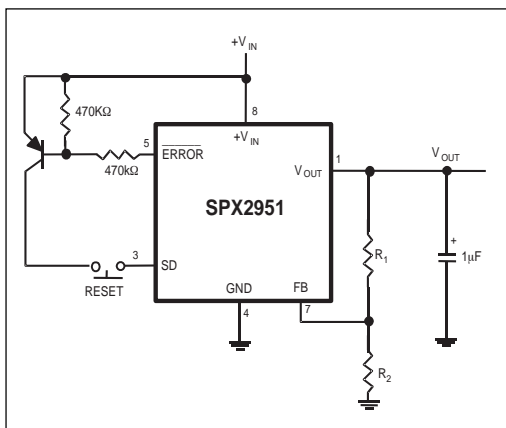


Figure 3. Latch Off When Error Flag Occurs

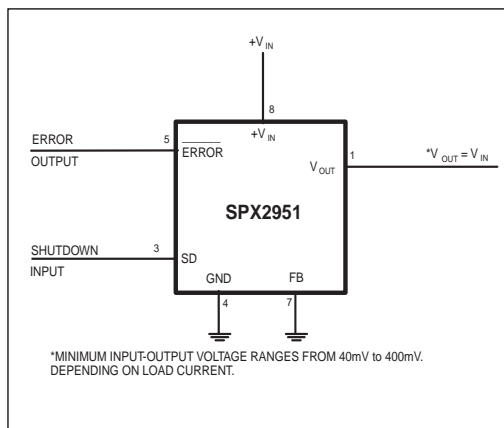


Figure 4. Wide Input Voltage Range Current Limiter

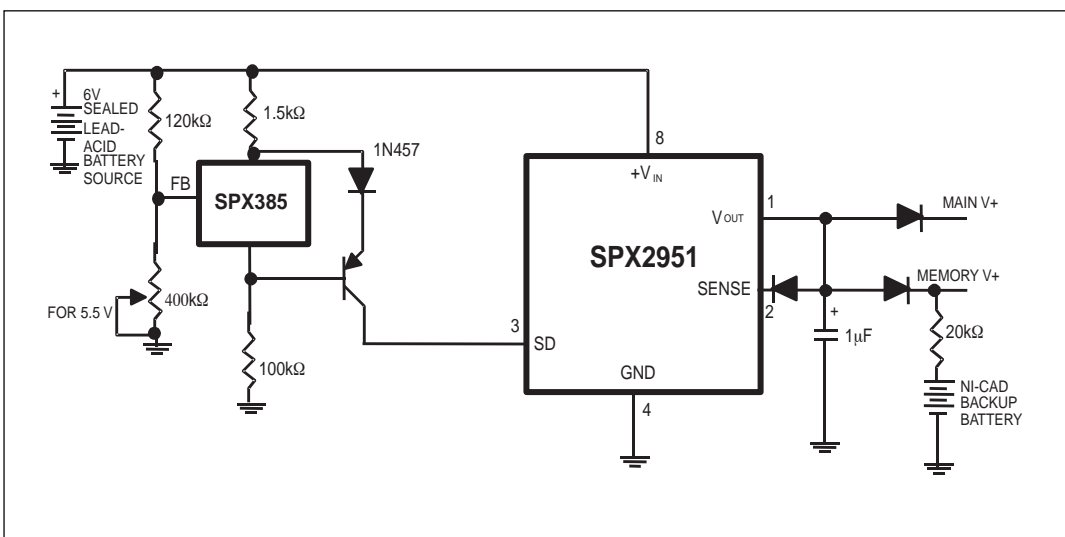


Figure 5. Low Battery Disconnect

## TYPICAL APPLICATIONS: (Continued)

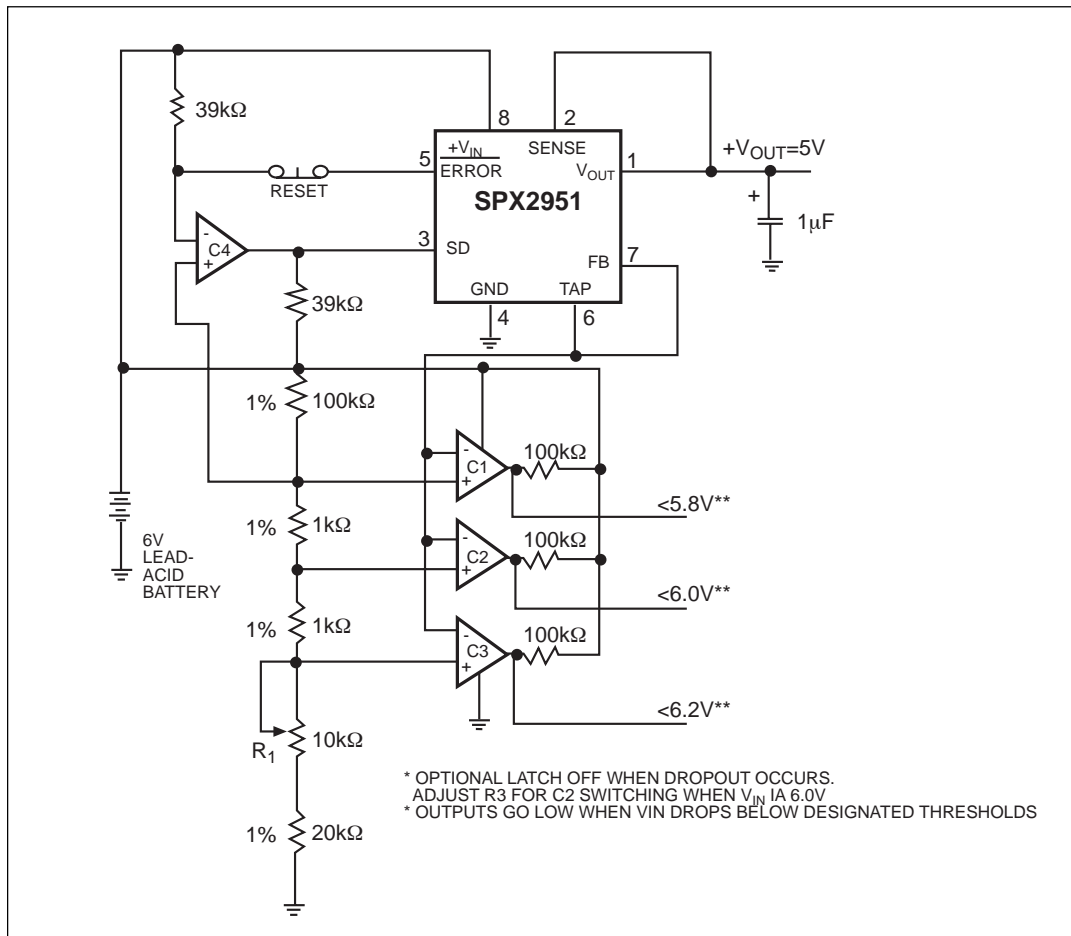


Figure 6. Regulator with State-of-Charge Indicator

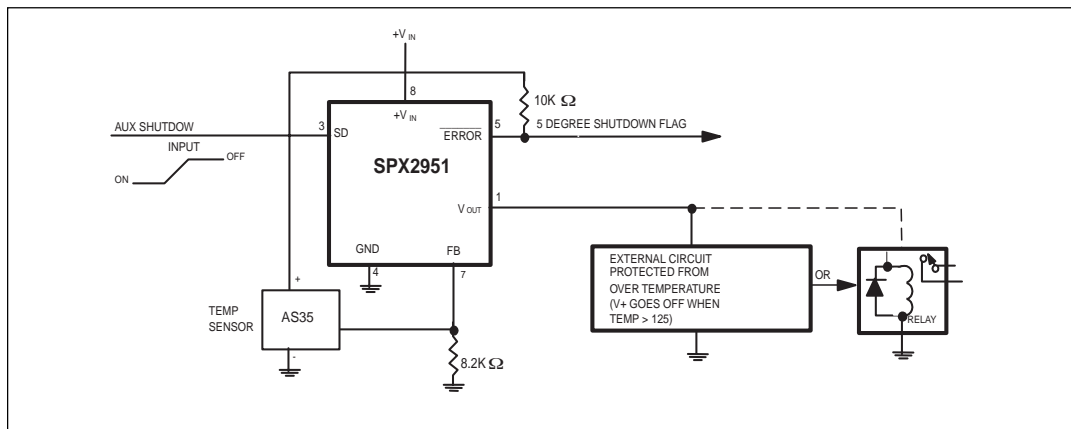


Figure 7. System Over Temperature Protection

## TYPICAL APPLICATIONS: (Continued)

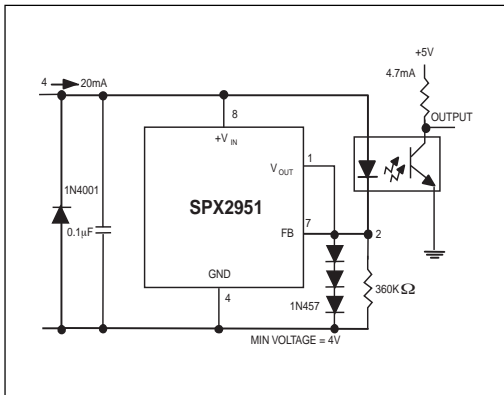


Figure 8. Open Circuit Detector for 4mA to 20mA Current Loop

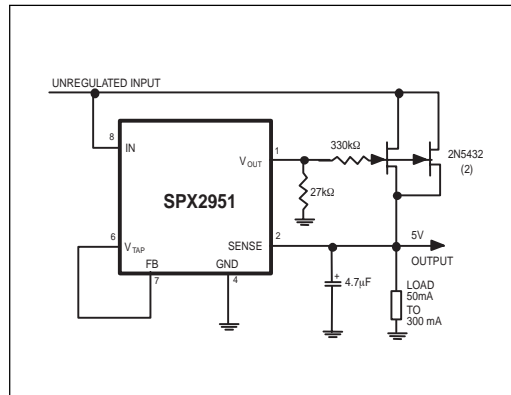


Figure 9. 300mA Regulator with 0.75V

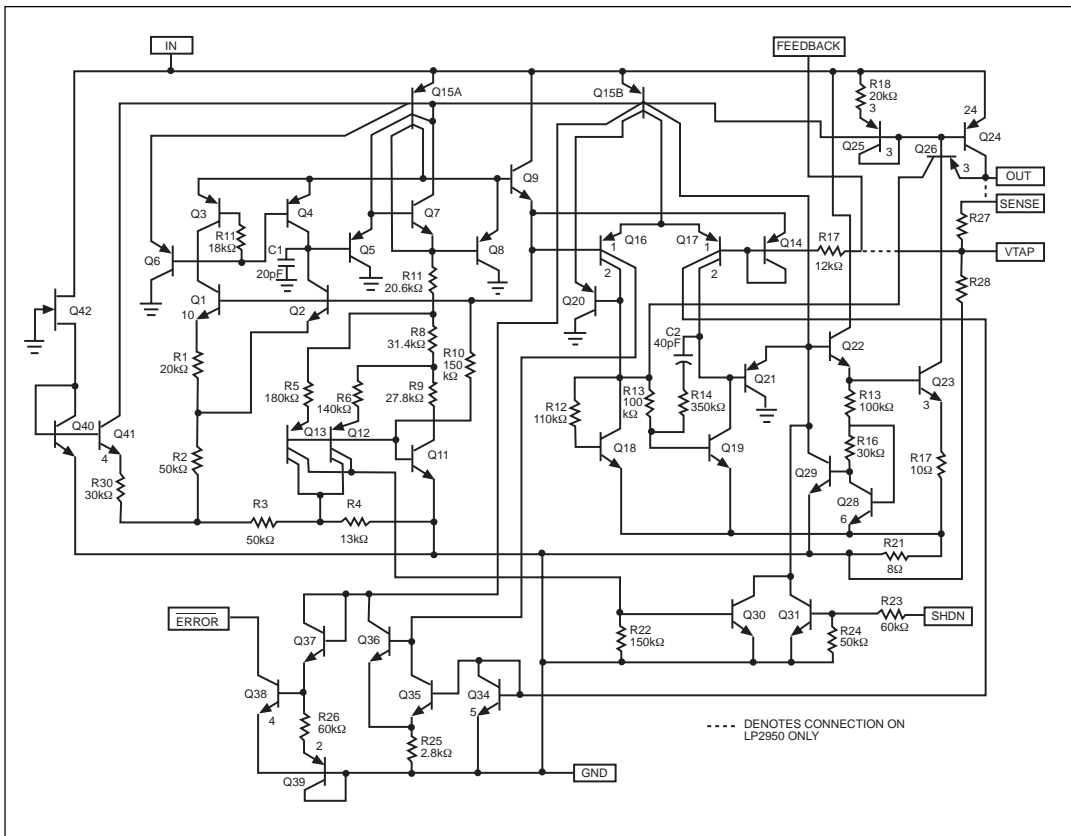
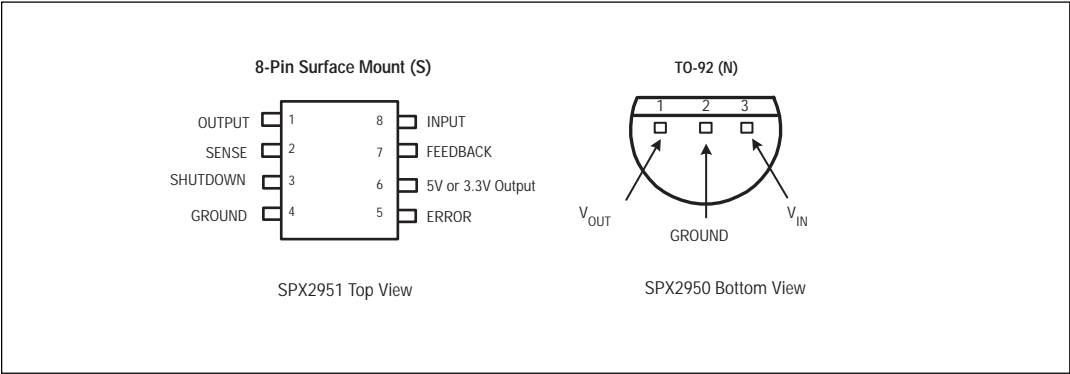


Figure 10. Schematic Diagram

PACKAGE DIAGRAM



ORDERING INFORMATION

Ordering No.	Accuracy	Output Voltage	Packages
SPX2950ACN-3.3	0.5%	3.3V	3-Pin TO-92
SPX2950ACN-5.0	0.5%	5.0V	3-Pin TO-92
SPX2950CN-3.3	1%	3.3V	3-Pin TO-92
SPX2950CN-5.0	1%	5.0V	3-Pin TO-92
SPX2951ACS-3.3	0.5%	3.3V	8-Pin SOIC
SPX2951ACS-5.0	0.5%	5.0V	8-Pin SOIC
SPX2951CS-3.3	1%	3.3V	8-Pin SOIC
SPX2951CS-5.0	1%	5.0V	8-Pin SOIC



SIGNAL PROCESSING EXCELLENCE

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