



180 mA Low Dropout Voltage Regulators

FEATURES

- 3.0V, 3.3V and 5.0V Fixed Output Voltages
- Very Low Quiescent Current
- Low Dropout Voltage
- Extremely Tight Load And Line Regulation
- Very Low Temperature Coefficient
- Needs Only 1 μ F For Stability
- Current & Thermal Limiting
- Unregulated DC Input Can Withstand -20V Reverse Battery And +60V Positive Transients
- Similar Replacement For LP2950/LP2951 Sockets

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

SPX2975 SO-8 versions only

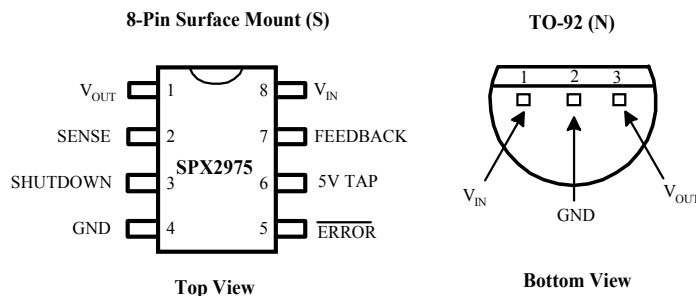
- Error Flag Warns Of Output Dropout
- Logic- Controlled Electronic Shutdown
- Output Programmable from 1.24 to 29V

PRODUCT DESCRIPTION

The SPX2975 is a low power voltage regulator. This device is an excellent choice for use in battery-powered applications such as cordless telephones, radio control systems, and portable computers. The SPX2975 features very low quiescent current and very low dropout voltage (Typ. 50mV at light load and 380 mV at 180 mA). This includes a tight initial tolerance of 0.5% typ., extremely good load and line regulation 0.05% typ. and very low output temperature coefficient, making the SPX2975 useful as a low-power voltage reference. Other additional key features include higher output current (150mA), positive transient protection up to 60V (Load dump), and the ability to survive an unregulated input voltage transient of -20V below ground (reverse battery).

The error flag output feature is used as power-on reset for warning of a low output voltage, due to falling voltage input of batteries. Another feature is the logic-compatible shutdown input which enables the regulator to be switched on and off. The SPX2975 is offered in a 3-pin TO-92 package compatible with other 5V regulators. The SPX2975 is available in 8-pin plastic, SO-8 packages.

PIN CONNECTIONS



ABSOLUTE MAXIMUM RATINGS

Power Dissipation.....	Internally Limited
Lead Temp. (Soldering, 5 Seconds)	260°C
Storage Temperature Range	-65° to +150°C
Operating Junction Temperature Range (Note 10)	
SPX2975.....	-55° to +150°C
SPX2975AC/SPX2975C	-40° to +125°C

Input Supply Voltage (Survival)	-20V to +60V
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

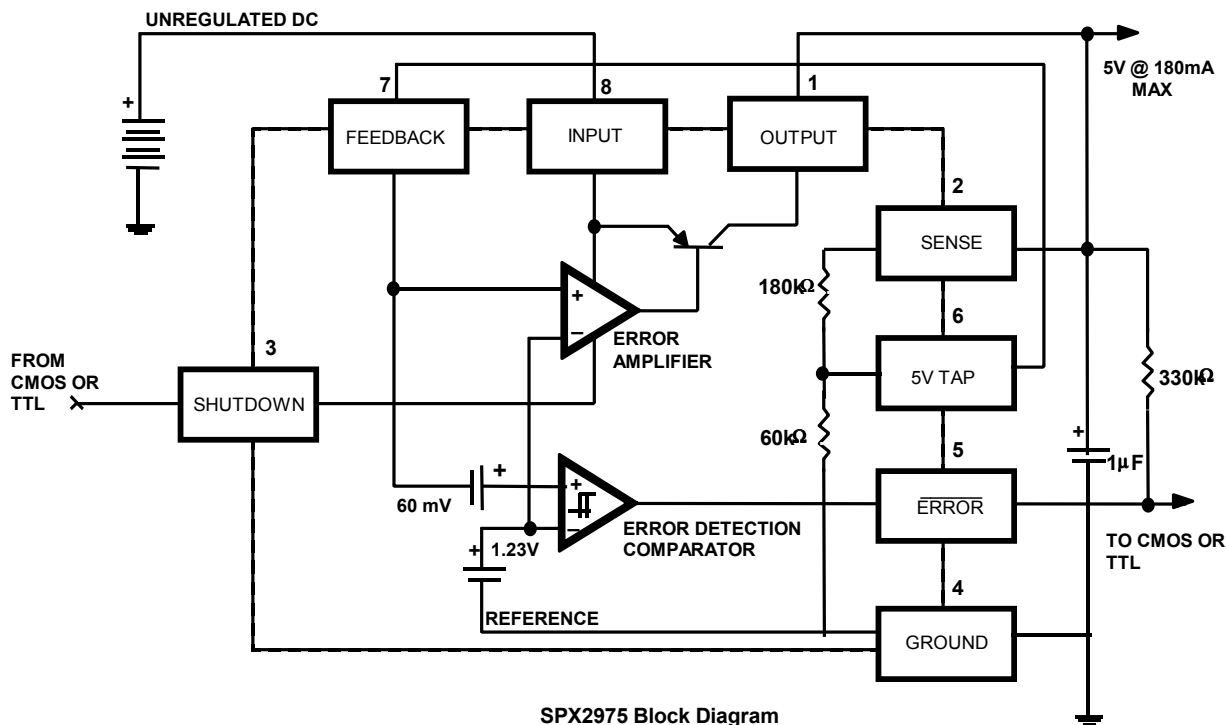
ELECTRICAL CHARACTERISTICS at $V_S=15V$, $T_A=25^\circ C$, unless otherwise specified. **Boldface** apply over the full operating temperature range.

PARAMETER	CONDITIONS (Note 2)	SPX2975AC			SPX2975C			UNITS	
		Min	Typ	Max	Min	Typ	Max		
Output Voltage	$T_J = 25^\circ C$ $-25^\circ C \leq T_J \leq 85^\circ C$ $-40^\circ C \leq T_J \leq +125^\circ C$	3.2835 3.267 3.2608	3.3	3.3165 3.333 3.3396	3.267 3.2505 3.2604	3.3	3.333 3.695 3.3396	V	
Output Voltage	$100 \mu A \leq I_L \leq 180 \text{ mA}$ $T_J \leq T_{JMAX}$	3.2505	3.3	3.3495	3.201	3.3	3.399	V	
Output Voltage	$T_J = 25^\circ C$ $-25^\circ C \leq T_J \leq 85^\circ C$ $-40^\circ C \leq T_J \leq +125^\circ C$	4.975 4.95 4.94	5.0	5.025 5.050 5.06	4.95 4.925 4.90	5.0	5.05 5.075 5.10	V	
Output Voltage	$100 \mu A \leq I_L \leq 180 \text{ mA}$ $T_J \leq T_{JMAX}$	4.925	5.0	5.075	4.85	5.0	5.15	V	
Output Voltage Temperature Coefficient	(Note 1)		20			50		ppm/°C	
Line Regulation (Note 3)	$6V \leq V_{IN} \leq 30V$ (Note 4)		0.03	0.1		0.04	0.2	%	
Load Regulation (Note 3)	$100 \mu A \leq I_L \leq 180 \text{ mA}$		0.04	0.1		0.1	0.2	%	
Dropout Voltage (Note 5)	$I_L = 100 \mu A$ $I_L = 100 \text{ mA}$ $I_L = 180 \text{ mA}$		50 380 450	80 450 500		50 380 450	80 450 500	mV	
Ground Current	$I_L = 100 \mu A$ $I_L = 100 \text{ mA}$ $I_L = 180 \text{ mA}$		150 8 18	170 12 22		150 8 18	170 12 22	μA mA mA	
Current Limit	$V_{OUT} = 0$		130	200		130	200	mA	
Thermal Regulation			0.05	0.2		0.05	0.2	%/W	
Output Noise, 10Hz to 100kHz	$C_L = 1 \mu F$ $C_L = 200 \mu F$ $C_L = 13.3 \mu F$ (Bypass = 0.01 μF pins 7 to 1 (SPX2975))		430 160 100			430 160 100		μV rms	
8-Pin Versions Only			SPX2975AC			SPX2975C			
Reference Voltage		1.22	1.235	1.25	1.21	1.23	1.26	V	
Reference Voltage	Over Temperature (Note 6)	1.19		1.27	1.18		1.28	V	
Feedback Pin Bias Current			40	60		40	60	nA	
Reference Voltage Temperature Coefficient	(Note 7)		20			50		ppm/°C	
Feedback Pin Bias Current Temperature Coefficient			0.1			0.1		nA/°C	
Output Leakage Current	$V_{OH} = 30V$		0.01	1		0.01	1	μA	
Output Low Voltage	$V_{IN} = 4.5V$ $I_{OL} = 400 \mu A$		150	250		150	250	mV	
Upper Threshold Voltage	(Note 8)	40	60		40	60		mV	
Lower Threshold Voltage	(Note 8)		75	95		75	95	mV	
Hysteresis	(Note 8)		15			15		mV	

PARAMETER	CONDITIONS (Note 2)	SPX2975AC			SPX2975C			UNITS
		Min	Typ	Max	Min Max	Typ		
Input Logic Voltage	Low (Regulator ON) High (Regulator OFF)	2	1.3	0.7	2	1.3	0.7	V
Shut Down Pin Input Current	$V_S = 2.4V$ $V_S = 30V$		30 675	50 800		30 675	50 800	μA
Regulator Output Current in Shutdown	(Note 9)		3	10		3	10	μA

- 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 $T_J = 25^\circ C$, $V_{IN} = 6V$, $I_L = 100\mu A$ 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 SPX2975 is tested at $150^\circ C$ for $I_L = 1mA$. For $I_L = 100\mu A$ and $T_J = 125^\circ C$, 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 minimum input supply voltage of 2V (2.3V over temperature) must be taken into account.
- Note 6:** $V_{REF} \leq V_{OUT} \leq (V_{IN} - 1V)$, $2.3 \leq V_{IN} \leq 30V$, $100\mu A \leq I_L \leq 100mA$, $T_J \leq T_{JMAX}$.
- 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 Tap.
- Note 9:** All typical values are not guaranteed. The value could vary from lot to lot.
- Note 10:** The junction -to-ambient thermal resistance of the TO-92 package is $180^\circ C/W$ with 0.4" leads and $160^\circ C/W$ with 0.25" leads to a PC board. The thermal resistance of the 8-Pin DIP package is $105^\circ C/W$ junction-to-ambient when soldered directly to a PC board. Junction-to-ambient thermal resistance for the SOIC (S) package is $160^\circ C/W$.

BLOCK DIAGRAM



APPLICATION HINTS

EXTERNAL CAPACITORS

The stability of the SPX2975 requires a 1.0μF 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°C solid tantalum is recommended since the many aluminum types have electrolytes that freeze at about -30°C. The ESR of about 5Ω or less and resonant frequency above 500kHz 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 10mA the value of the capacitor can be reduced to 0.33μF and 0.1μF for 1mA. More output capacitance is needed for the 8-pin version at voltages below 5V since it runs the error amplifier at lower gain. At worst case 3.3μF or greater must be used for the condition of 10mA load at 1.23V output.

The SPX2975, 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 SPX2975, a minimum load of 1μA 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 1μA tantalum or aluminum electrolytic capacitor should be placed from the input to the ground.

Instability can occur if there is stray capacitance to the SPX2975 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 pF capacitor between output and feedback and increasing the output capacitor to at least 3.3μF.

ERROR DETECTION COMPARATOR OUTPUT

The Comparator produces a logic low output whenever the SPX2975 output falls out of regulation by more than around 5%. This is around 60mV 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 SPX2975 input is ramped up and down. The ERROR signal becomes low at around 1.3V input, and goes high around 5V input (input voltage at which $V_{out} = 4.75$). Since the SPX2975 dropout voltage is load dependent, the input voltage trip point (around 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 pull-up resistor. Depending on the system requirements the resistor may be returned to 5V output or other supply voltage. In determining the value of this resistor, note that the output is rated to sink 400μA, this value adds to battery drain in a low battery condition. Suggested values range from 100K to 1MΩ. If the output is unused this resistor is not required.

PROGRAMMING THE OUTPUT VOLTAGE OF SPX2975

The SPX2975 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:

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

The V_{ref} is 1.235 and I_{FB} is the feedback bias current, nominally -20nA. The minimum recommended load current of 1μA forces an upper limit of 1.2 MΩ 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 12μA. Since the SPX2975 typically draws 60μA at no load with Pin 2 open-circuited this is a small price to pay

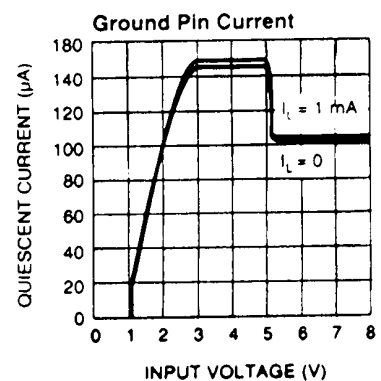
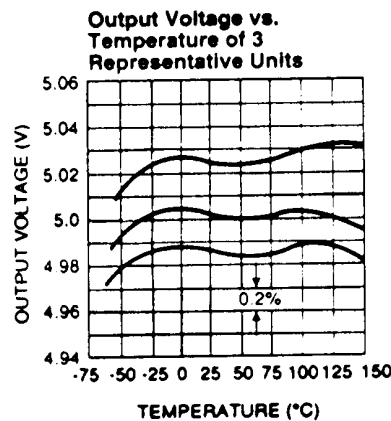
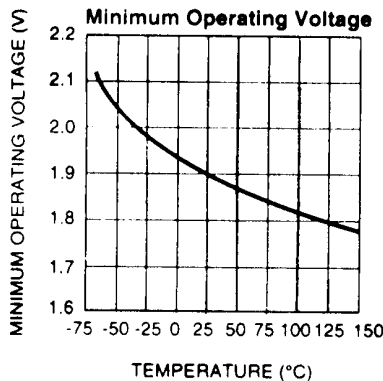
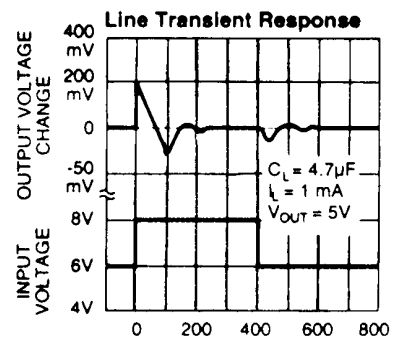
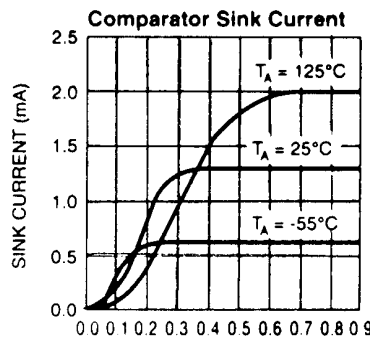
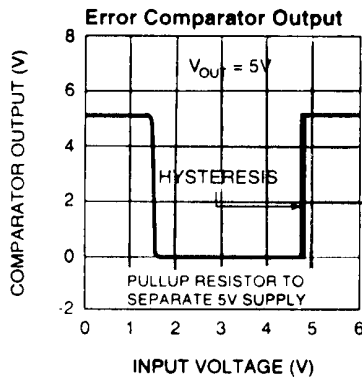
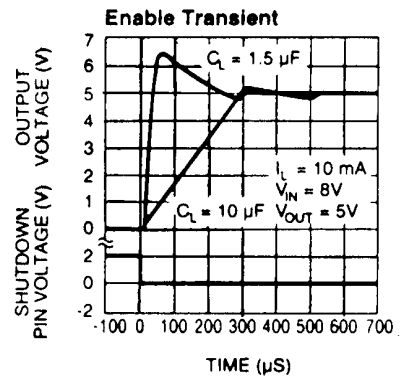
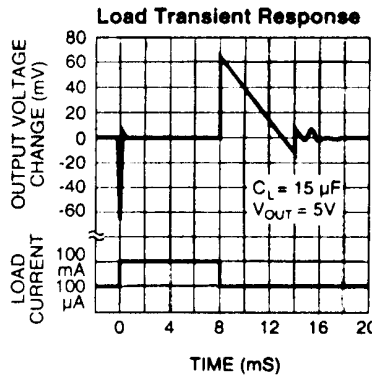
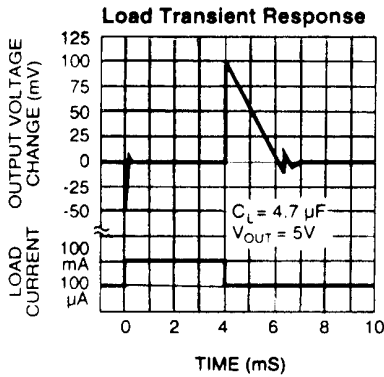
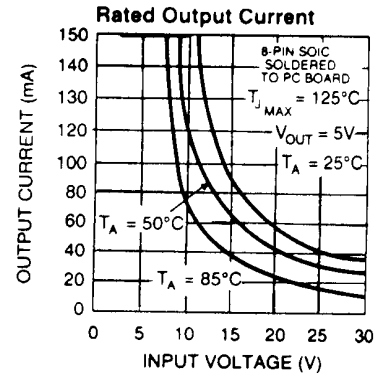
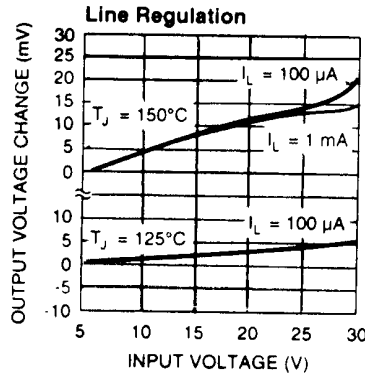
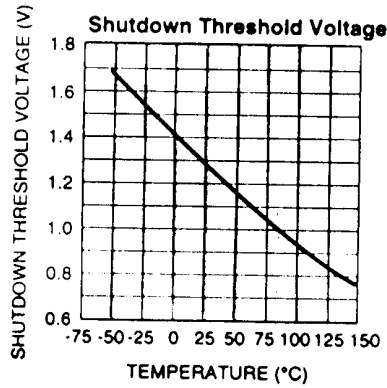
REDUCING OUTPUT NOISE

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 SPX2975 but is relatively inefficient, as increasing the capacitor from 1μF to 220μF only decreases the noise from 430μV to 160μV rms 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

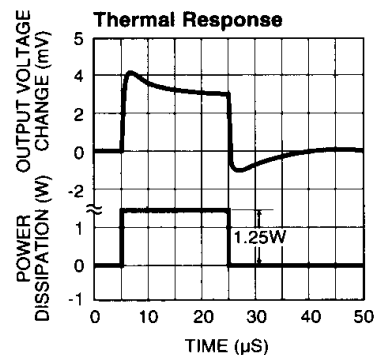
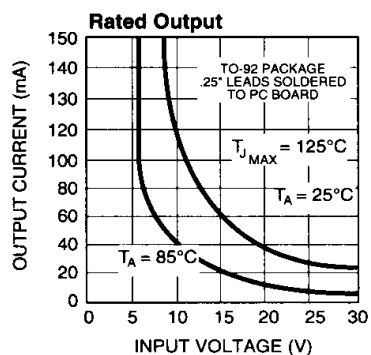
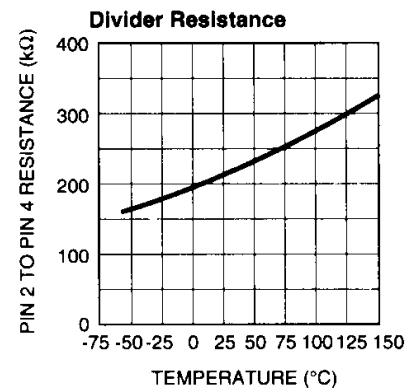
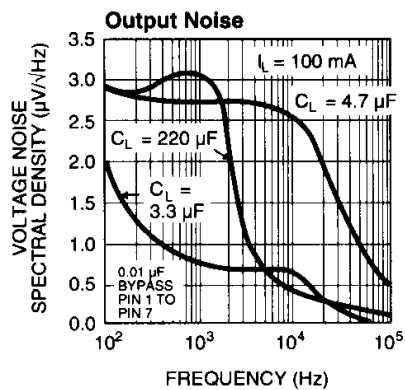
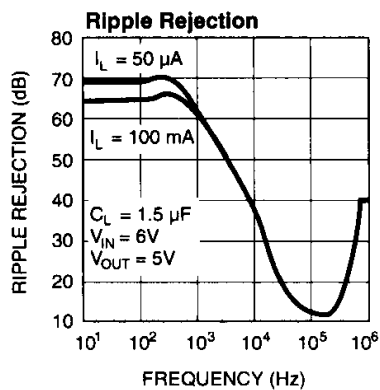
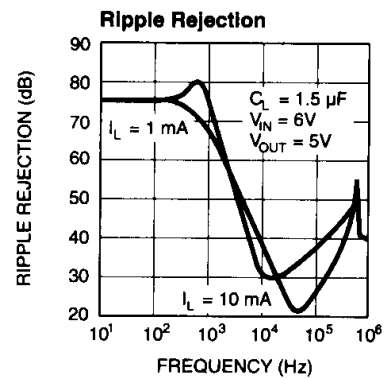
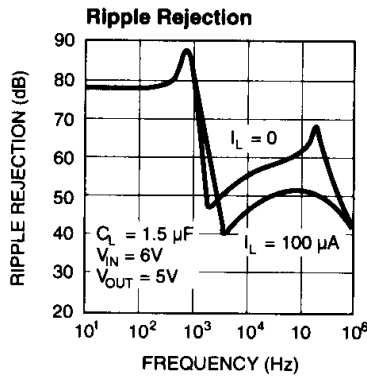
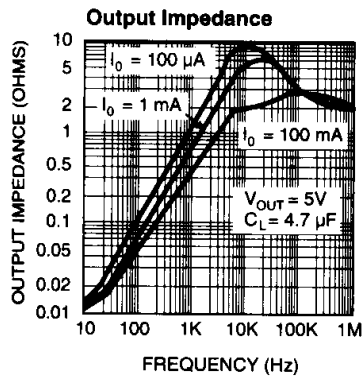
$$C_{BYPASS} \cong 1 / 2\pi R_1 \times 200 \text{ Hz}$$

or choose 0.01μF. When doing this, the output capacitor must be increased to 3.3μF to maintain stability. These changes reduce the output noise from 430μV to 100μV_{RMS} 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.

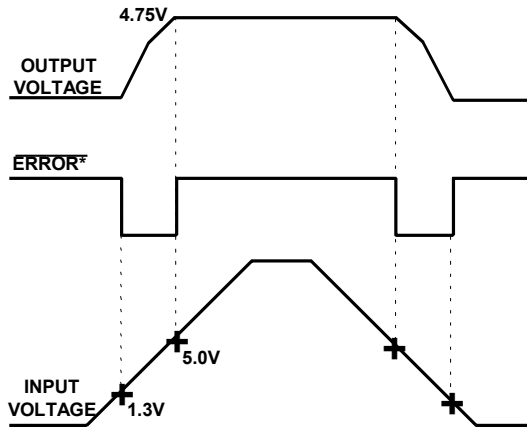
TYPICAL PERFORMANCE CHARACTERISTICS



TYPICAL PERFORMANCE CHARACTERISTICS (continued)



TYPICAL APPLICATIONS



* See Application

Figure 1. ERROR Output Timing

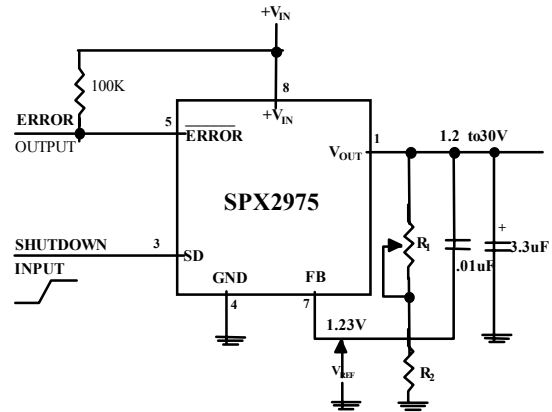
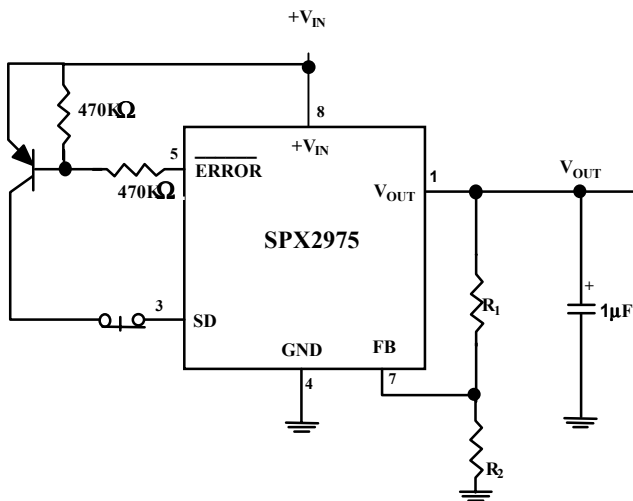
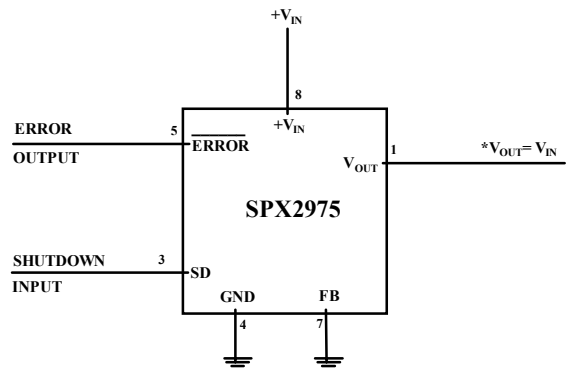


Figure 2. Adjustable Regulator



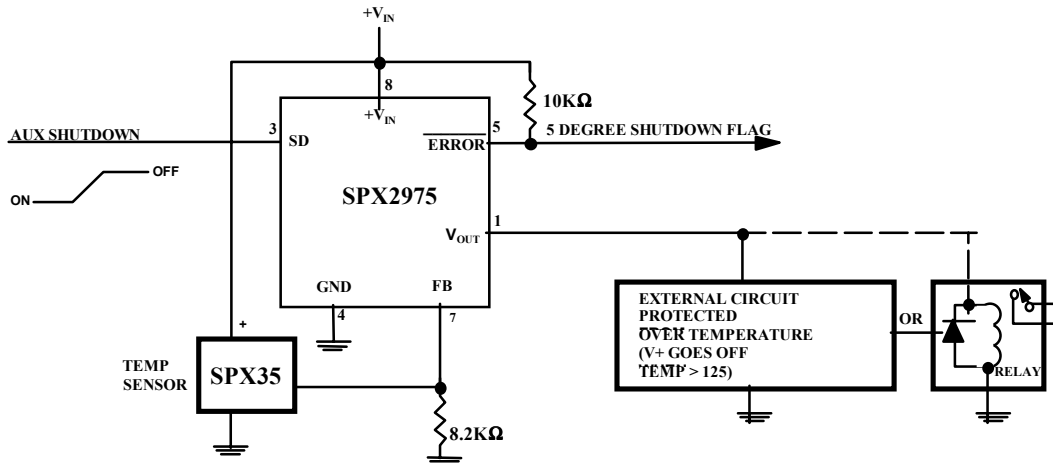
Latch Off When Error Flag Occurs



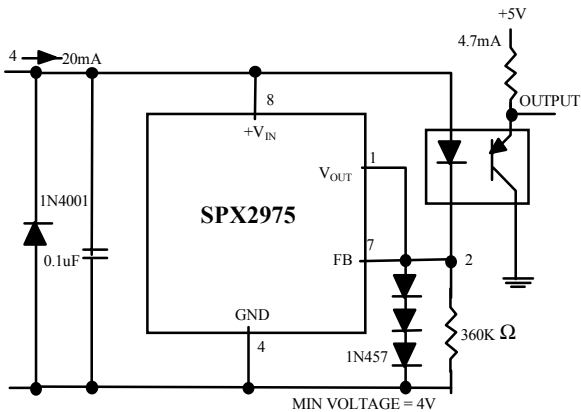
MINIMUM INPUT-OUTPUT VOLTAGE RANGES FROM 4mV to 400mV.
 EPENDING ON LOAD CURRENT, CURRENT LIMIT IS TYPICALLY 160mA

Wide Input Voltage Range Current Limiter

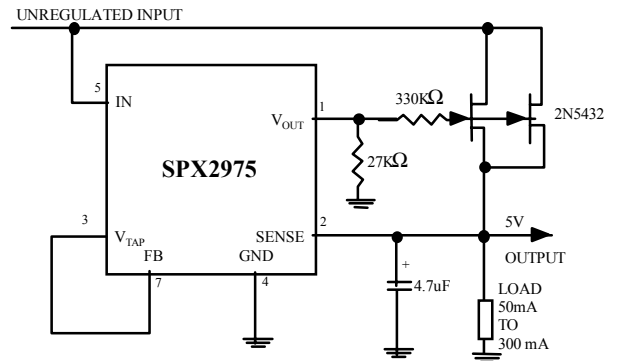
TYPICAL APPLICATIONS (continued)



System Over Temperature Protection Circuit



Open Circuit Detector for 4mA to 20mA Current Loop



300 mA Regulator with 0.75 Dropout

ORDERING INFORMATION

Ordering No.	Precision	Output Voltage	Packages
SPX2975N-3.0	1%	3.0V	3 Lead TO-92
SPX2975N-3.3	1%	3.3V	3 Lead TO-92
SPX2975N-5.0	1%	5.0V	3 Lead TO-92
SPX2975ACN-3.0	0.5%	3.0V	3 Lead TO-92
SPX2975ACN-3.3	0.5%	3.3V	3 Lead TO-92
SPX2975ACN-5.0	0.5%	5.0V	3 Lead TO-92
SPX2975CP-3.0	1%	3.0V	8 Lead SOIC
SPX2975CP-3.3	1%	3.3V	8 Lead SOIC
SPX2975CP-5.0	1%	5.0V	8 Lead SOIC
SPX2975ACP-3.0	0.5%	3.0V	8 Lead SOIC
SPX2975ACP-3.3	0.5%	3.3V	8 Lead SOIC
SPX2975ACP-5.0	0.5%	5.0V	8 Lead SOIC



SIGNAL PROCESSING EXCELLENCE

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