



LP2950/LP2951

100 mA Low Dropout Voltage Regulators

FEATURES

- 5.0V, 3.3V and 3.0V Versions @ 100mA Output
- Very Low Quiescent Current
- Low Dropout Voltage
- Extremely Tight Load and Line Regulation
- Very Low Temperature Coefficient
- Current & Thermal Limiting
- Need Only 1 μ F for Stability
- Offered in TO-263 & SOIC
- Direct 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
- SMPS Post-Regulator
- Voltage Reference
- Automotive Electronics

LP2951 versions only

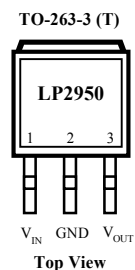
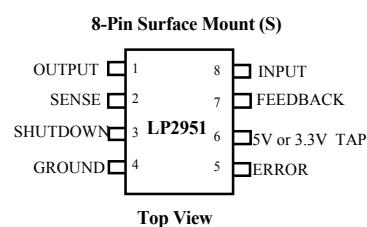
- Error Flag Warns of Output Dropout
- Logic-Controlled Electronic Shutdown
- Output Programmable From 1.24 to 29V

PRODUCT DESCRIPTION

The LP2950 and LP2951 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 LP2950 and LP2951 features low quiescent current and very low dropout voltage (Typ. 50mV at light load and 380 mV at 100mA). 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 LP2950/LP2951 useful as a low-power voltage reference.

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 LP2950 is offered in a 3-pin TO-263 package compatible with other 5V, 3.0V & 3.3V regulators. The LP2951 is also available in 8-pin plastic, SO-8 packages.

The regulator output voltage may be pin-strapped for 5.0V, 3.0V or 3.3V or programmed from 1.24V to 29V with an external pair of resistors. Look for SPX2950/51 for 150mA, for SPX2975 for 180mA and SPX2954 for 250mA.



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	
LP2951	-55°C to +150°C
LP2950AC/LP2950C	-40°C to +125°C
LP2951AC/LP2951C	-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

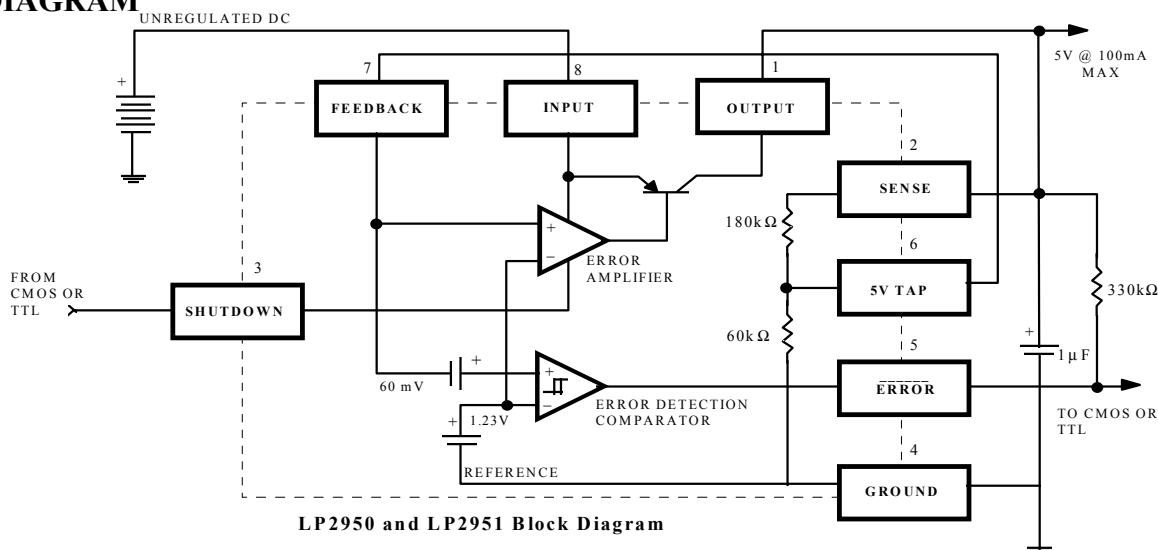
ELECTRICAL CHARACTERISTICS at $V_S=15V$, $T_a=25^\circ C$, unless otherwise noted.

PARAMETER	CONDITIONS (Note 2)	LP2951			LP2950AC LP2951AC			LP2950C LP2951C			UNITS	
		Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.		
3 V Versions												
Output Voltage	$T_J = 25^\circ C$ $-25^\circ C \leq T_J \leq 85^\circ C$ Full Operating Temperature	2.985	3.0	3.015	2.985	3.0	3.015	2.970	3.0	3.030	V	
Output Voltage	$100 \mu A \leq I_L \leq 100 mA$ $T_J \leq T_{JMAX}$	2.964		3.036	2.964	3.0	3.036	2.940	3.0	3.060	V	
Output Voltage	$100 \mu A \leq I_L \leq 100 mA$ $T_J \leq T_{JMAX}$	2.955	3.0	3.045	2.958	3.0	3.042	2.928	3.0	3.072	V	
3.3 V Versions												
Output Voltage	$T_J = 25^\circ C$ $-25^\circ C \leq T_J \leq 85^\circ C$ Full Operating Temperature	3.284	3.3	3.317	3.284	3.3	3.317	3.267	3.3	3.333	V	
Output Voltage	$100 \mu A \leq I_L \leq 100 mA$ $T_J \leq T_{JMAX}$	3.260		3.340	3.260	3.3	3.340	3.234	3.3	3.366	V	
Output Voltage	$100 \mu A \leq I_L \leq 100 mA$ $T_J \leq T_{JMAX}$	3.251	3.3	3.350	3.254	3.3	3.346	3.221	3.3	3.379	V	
5 V Versions												
Output Voltage	$T_J = 25^\circ C$ $-25^\circ C \leq T_J \leq 85^\circ C$ Full Operating Temperature	4.975	5.0	5.025	4.975	5.0	5.025	4.95	5.0	5.05	V	
Output Voltage	$100 \mu A \leq I_L \leq 100 mA$ $T_J \leq T_{JMAX}$	4.94		5.06	4.94	5.0	5.06	4.925	5.0	5.075	V	
Output Voltage	$100 \mu A \leq I_L \leq 100 mA$ $T_J \leq T_{JMAX}$	4.925	5.0	5.075	4.93	5.0	5.07	4.88	5.0	5.12	V	
All Voltage Options												
Output Voltage Temperature Coefficient	(Note 1)		20	120		20	120		50	120	ppm/°C	
Line Regulation (Note 3)	$6V \leq V_{in} \leq 30V$ (Note 4)		0.03	0.1		0.03	0.1		0.04	0.2	%	
Load Regulation (Note 3)	$100 \mu A \leq I_L \leq 100 mA$		0.04	0.1		0.04	0.1		0.1	0.2	%	
Dropout Voltage (Note 5)	$I_L = 100 \mu A$ $I_L = 100 mA$		50	80		50	80		50	80	mV	
Ground Current	$I_L = 100 \mu A$ $I_L = 100 mA$		150	170		150	170		150	170	μA mA	
Current Limit	$V_{OUT} = 0$		130	200		130	200		130	200	mA	
Thermal Regulation			0.05	0.2		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(LP2951))		430			430			430		μV rms μV rms μV rms	
			160			160			160			
			100			100			100			
8-Pin Versions only			LP2951			LP2951AC			LP2951C			
Reference Voltage		1.22	1.235	1.25	1.22	1.235	1.25	1.21	1.235	1.26	V	
Reference Voltage	Over Temperature (Note 6)	1.19		1.27	1.19		1.27	1.185		1.285	V	
Feedback Pin Bias Current			40	60		40	60		40	60	nA	

PARAMETER	CONDITIONS (Note 2)	LP2951			LP2950AC LP2951AC			LP2950C LP2951C			UNITS
		Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	
8-Pin Versions only (Continued)											
Reference Voltage Temperature Coefficient	(Note 7)		20			20			50		ppm/°C
Feedback Pin Bias Current Temperature Coefficient			0.1			0.1			0.1		nA/°C
Error Comparator											
Output Leakage Current	$V_{OH} = 30V$		0.01	1		0.01	1		0.01	1	μA
Output Low Voltage	$V_{IN} = 4.5V$ $I_{OL} = 400\mu A$		150	250		150	250		150	250	mV
Upper Threshold Voltage	(Note 8)	40	60		40	60		40	60		mV
Lower Threshold Voltage	(Note 8)		75	95		75	95		75	95	mV
Hysteresis	(Note 8)		15			15			15		mV
Shutdown Input											
Input logic Voltage	Low (Regulator ON) High (Regulator OFF)	2	1.3	0.6	2	1.3	0.7	2	1.3	0.7	V V
Shut down Pin Input Current	$V_S = 2.4V$ $V_S = 30V$		30 675	50 800		30 675	50 800		30 675	50 800	μA μA
Regulator Output Current in Shutdown	(Note 9)		3	10		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 LP2951 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 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:** $V_{REF} \leq V_{OUT} \leq (V_{IN} - 1V)$, $2.3 \leq V_{IN} \leq 30V$, $100\mu A \leq I_L \leq 100 mA$, $T_J \leq T_{JMAX}$.
- 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 $95 mV \times 5V/1.235 = 384 mV$. 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 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.

BLOCK DIAGRAM



APPLICATION HINTS EXTERNAL CAPACITORS

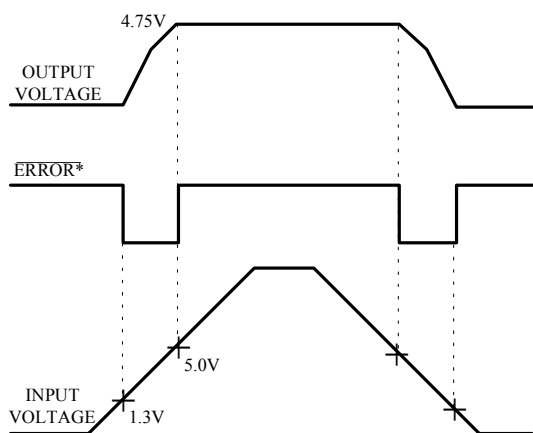
The stability of the LP2950/LP2951 requires a 1.0 μF or greater capacitor between output and ground. Oscillation could occur without this capacitor. Most types of tantalum or aluminum electrolytic works fine here. For operations below -25°C solid tantalum is recommended since the many aluminum types have electrolytes that freeze at about -30°C . The ESR of about $5\ \Omega$ or less and resonant frequency above 500 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 mA the value of the capacitor can be reduced to 0.33 μF and 0.1 μF for 1 mA. 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 3.3 μF or greater must be used for the condition of 100 mA load at 1.23V output.

The LP2950/51 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 LP2950/51 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 $1\ \mu\text{A}$ tantalum or aluminum electrolytic capacitor should be placed from the input to the ground.

Instability can occur if there is stray capacitance to the LP2951 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



* See Application Info.

Figure 1. ERROR Output Timing

output and feedback and increasing the output capacitor to at least 3.3 μF .

ERROR DETECTION COMPARATOR OUTPUT

The Comparator produces a logic low output whenever the LP2951 output falls out of regulation by more than around 5%. This is around 60 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 LP2951 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 $V_{\text{OUT}} = 4.75$). Since the LP2951's 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 $400\ \mu\text{A}$, this value adds to battery drain in a low battery condition. Suggested values range from 100K to $1\text{M}\Omega$. If the output is unused this resistor is not required.

PROGRAMMING THE OUTPUT VOLTAGE OF LP2951

The LP2951 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:

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

The V_{REF} is 1.235 and I_{FB} is the feedback bias current, nominally $-20\ \text{nA}$. The minimum recommended load current of $1\ \mu\text{A}$ forces an upper limit of 1.2 $\text{M}\Omega$ 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 $R_2 = 100\text{k}$ this reduces the error by 0.17% and increases the resistor program current by $12\ \mu\text{A}$. Since the LP2951 typically draws $60\ \mu\text{A}$ at no load with Pin 2 open-circuited this is a small price to pay

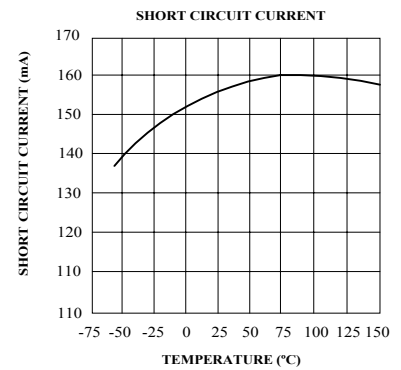
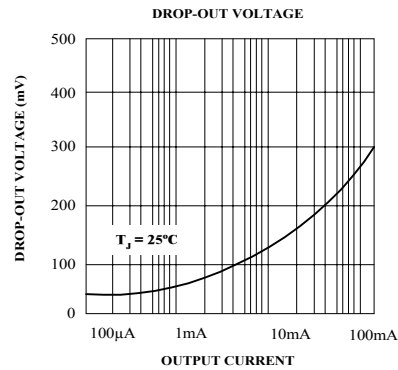
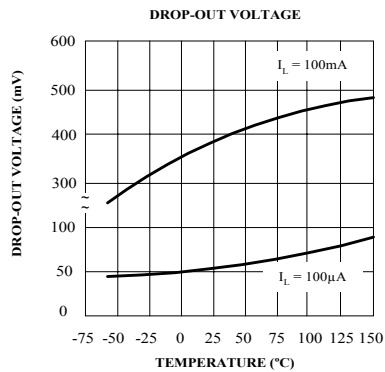
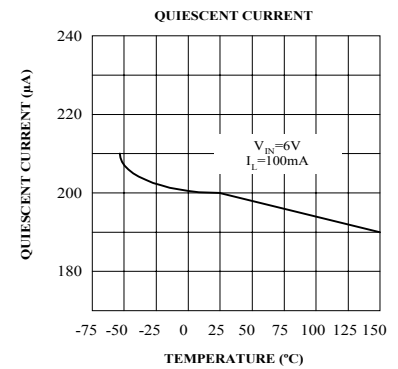
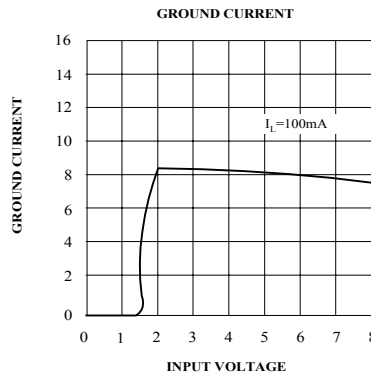
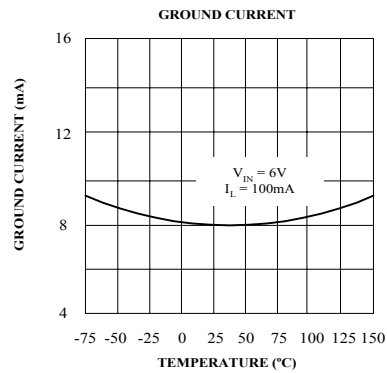
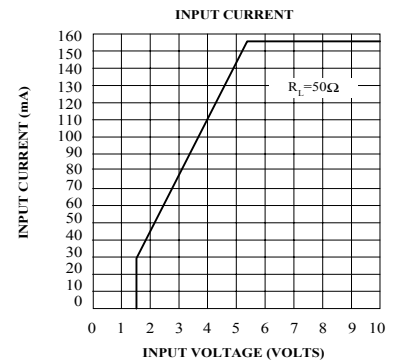
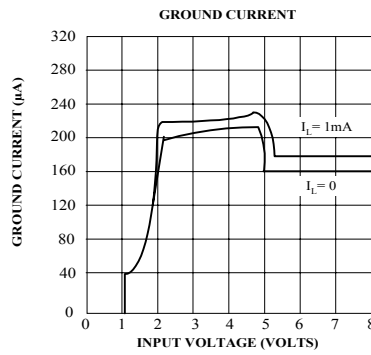
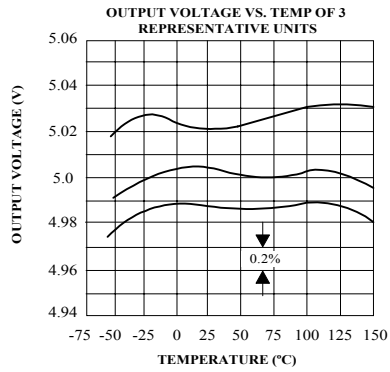
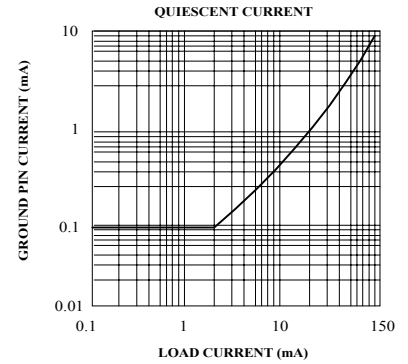
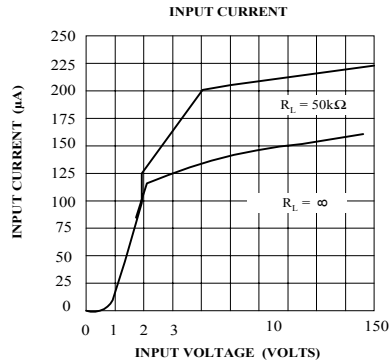
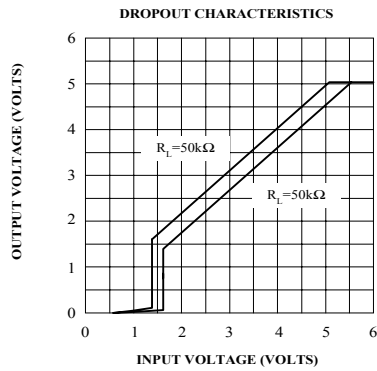
REDUCING OUTPUT NOISE

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 LP2950 but is relatively inefficient, as increasing the capacitor from $1\ \mu\text{F}$ to $220\ \mu\text{F}$ only decreases the noise from $430\ \mu\text{V}$ to $160\ \mu\text{V}_{\text{RMS}}$ 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

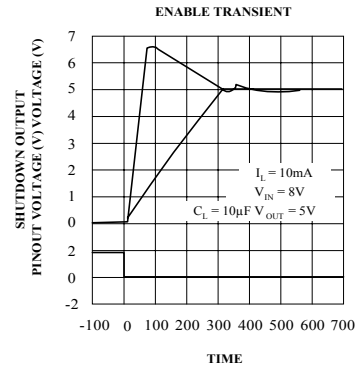
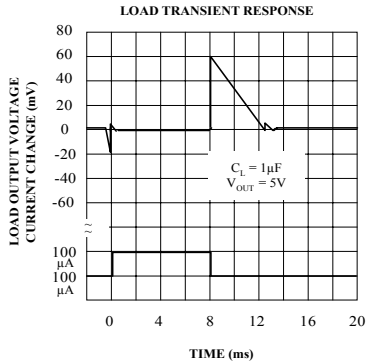
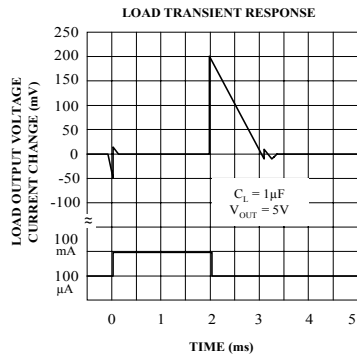
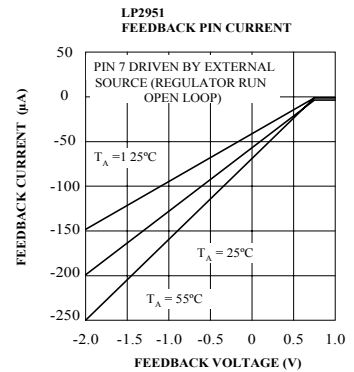
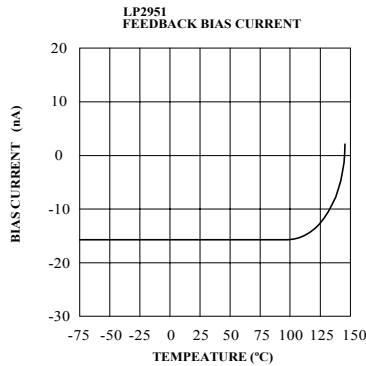
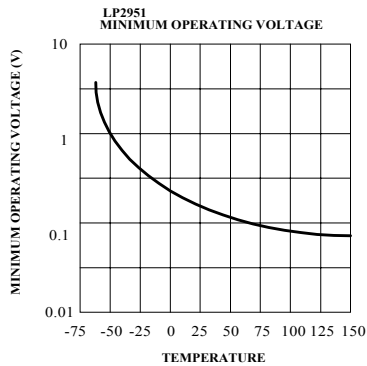
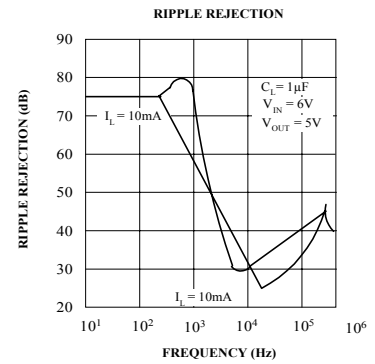
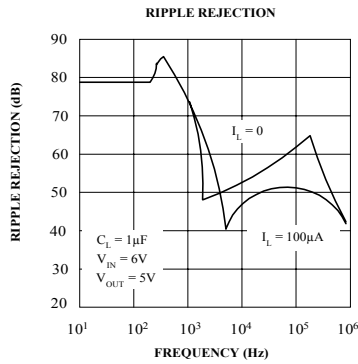
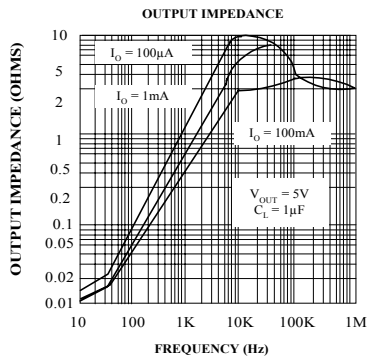
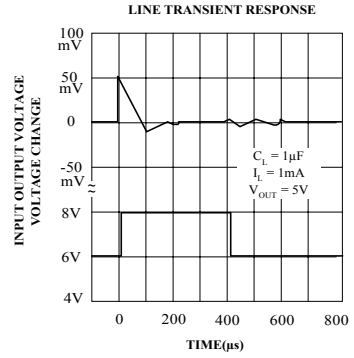
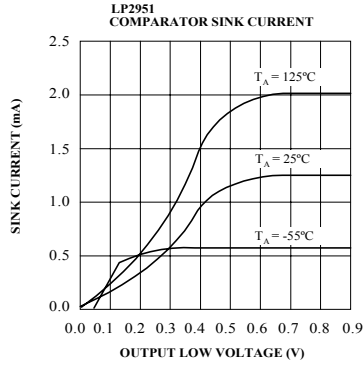
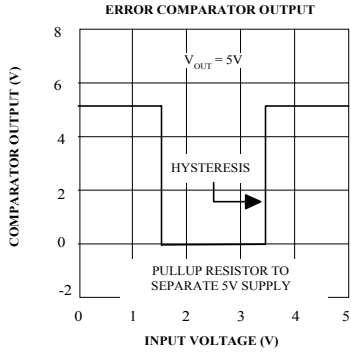
$$C_{\text{BYPASS}} \cong 1 / 2\pi R_1 \times 200\ \text{Hz}$$

or choose $0.01\ \mu\text{F}$. When doing this, the output capacitor must be increased to $3.3\ \mu\text{F}$ to maintain stability. These changes reduce the output noise from $430\ \mu\text{V}$ to $100\ \mu\text{V}_{\text{RMS}}$ 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.

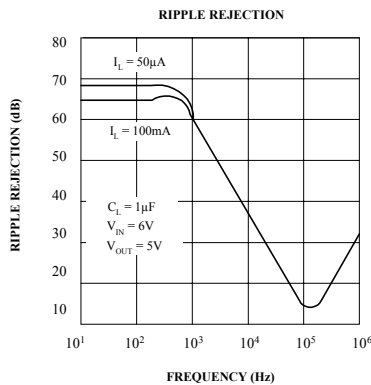
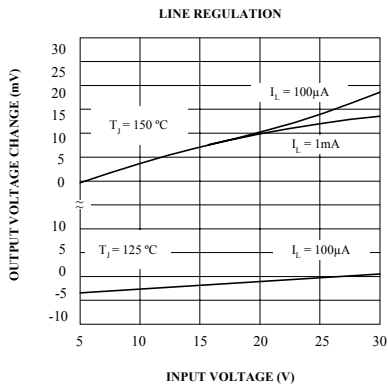
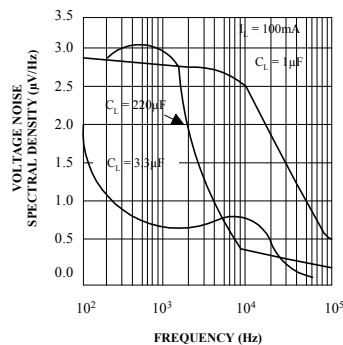
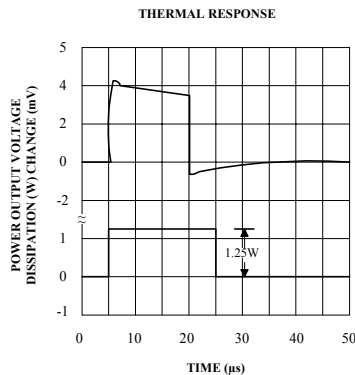
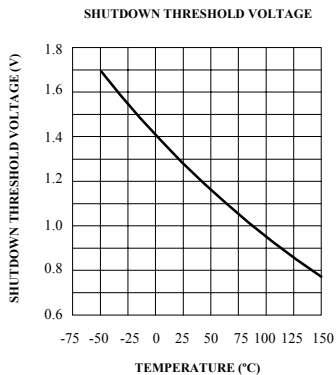
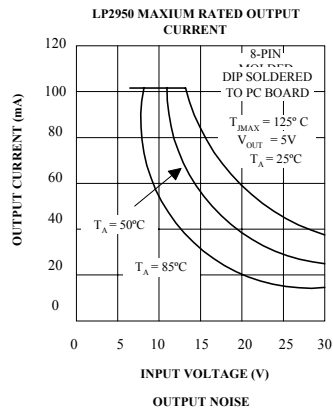
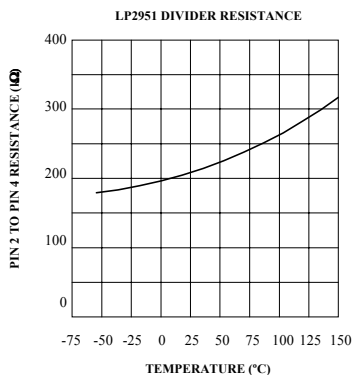
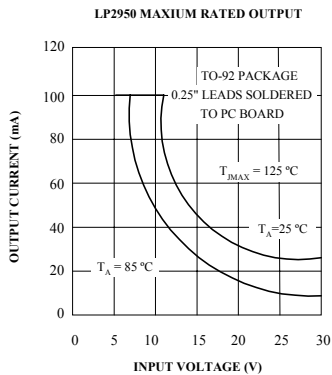
TYPICAL PERFORMANCE CHARACTERISTIC



TYPICAL PERFORMANCE CHARACTERISTICS (continued)



TYPICAL PERFORMANCE CHARACTERISTICS (continued)



TYPICAL APPLICATIONS

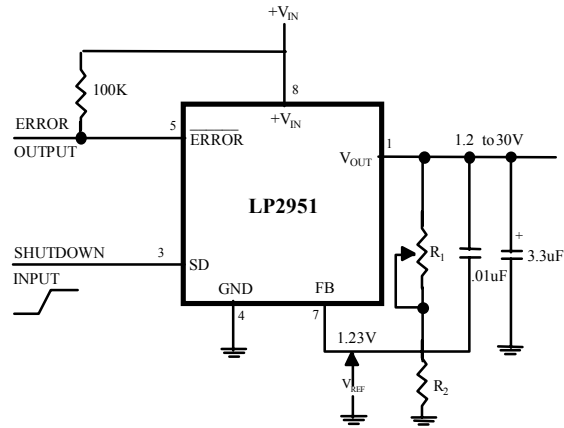


Figure 1. Adjustable Regulator

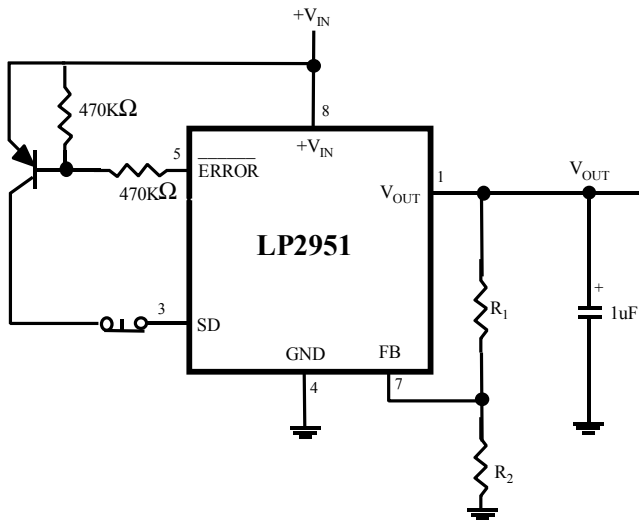
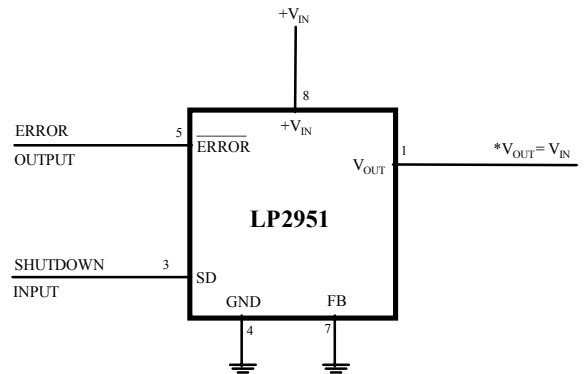


Fig.2 Latch Off When Error Flag Occurs



*MINIMUM INPUT-OUTPUT VOLTAGE RANGES FROM 4mV TO 400mV. DEPENDENT ON LOAD CURRENT. CURRENT LIMIT IS TYPICALLY 160mA

Fig.3 Wide Input Voltage Range Current Limiter

TYPICAL APPLICATIONS (continued)

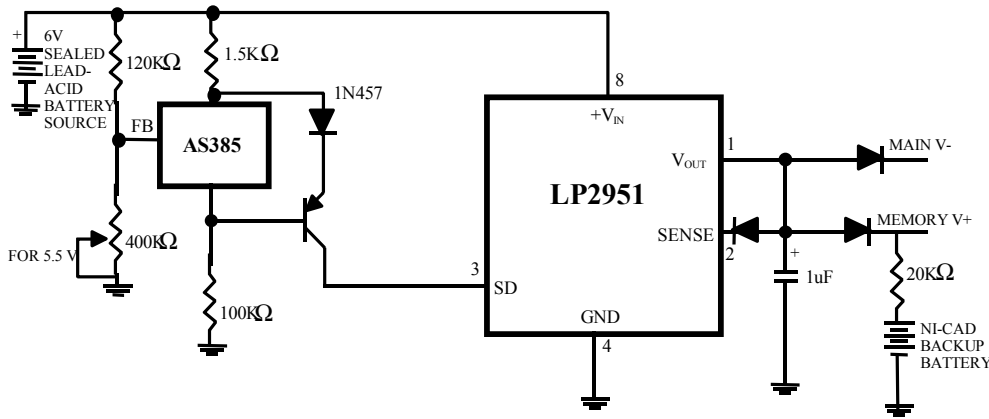


Fig.4 Low Battery Disconnect

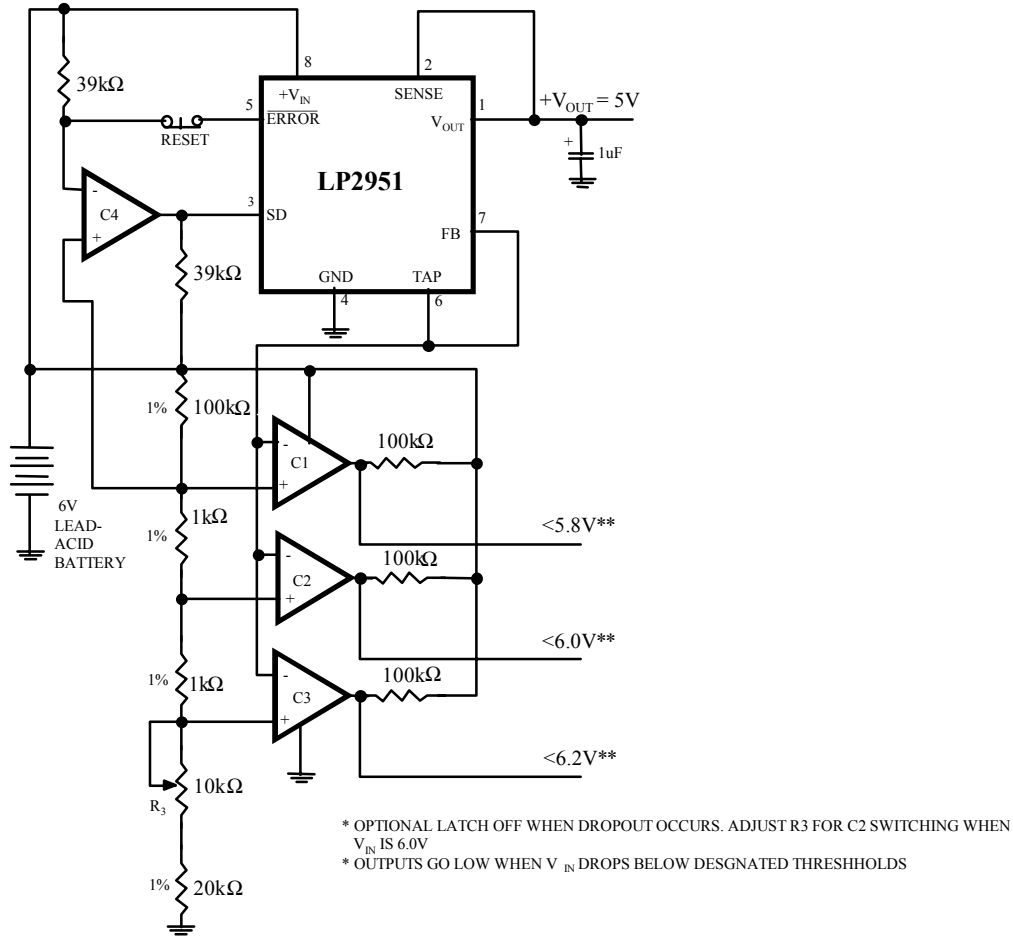


Fig. 5 Regulator with State-of-Charge Indicator

* OPTIONAL LATCH OFF WHEN DROPOUT OCCURS. ADJUST R₃ FOR C₂ SWITCHING WHEN V_{IN} IS 6.0V
 ** OUTPUTS GO LOW WHEN V_{IN} DROPS BELOW DESIGNATED THRESHOLDS

TYPICAL APPLICATIONS (continued)

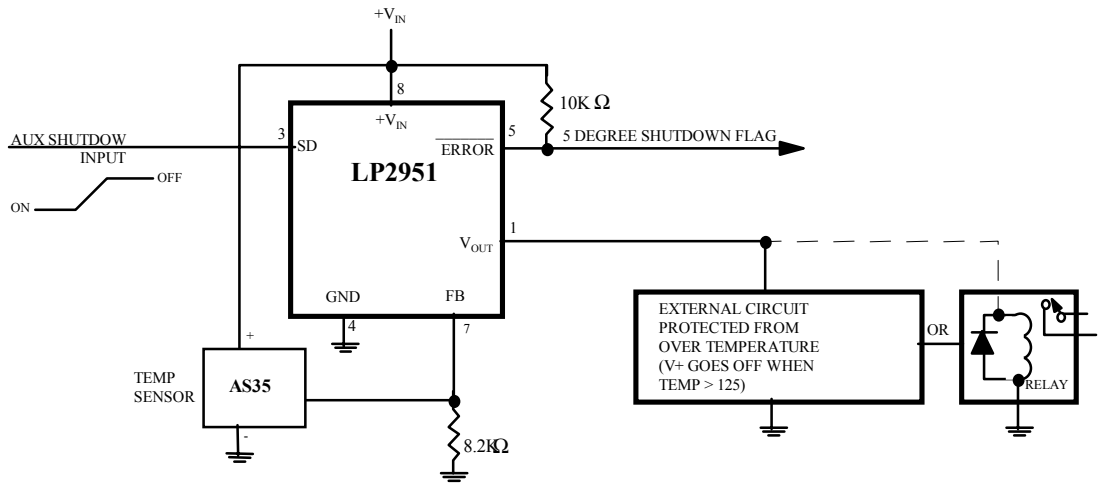


Fig 6. System Over Temperature Protection

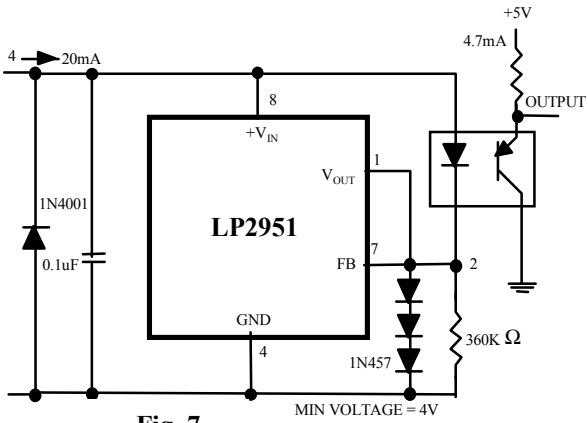


Fig. 7

Open Circuit Detector for 4mA to 20mA Current Loop

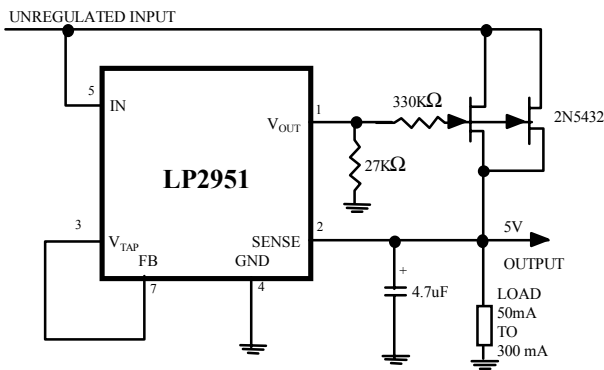
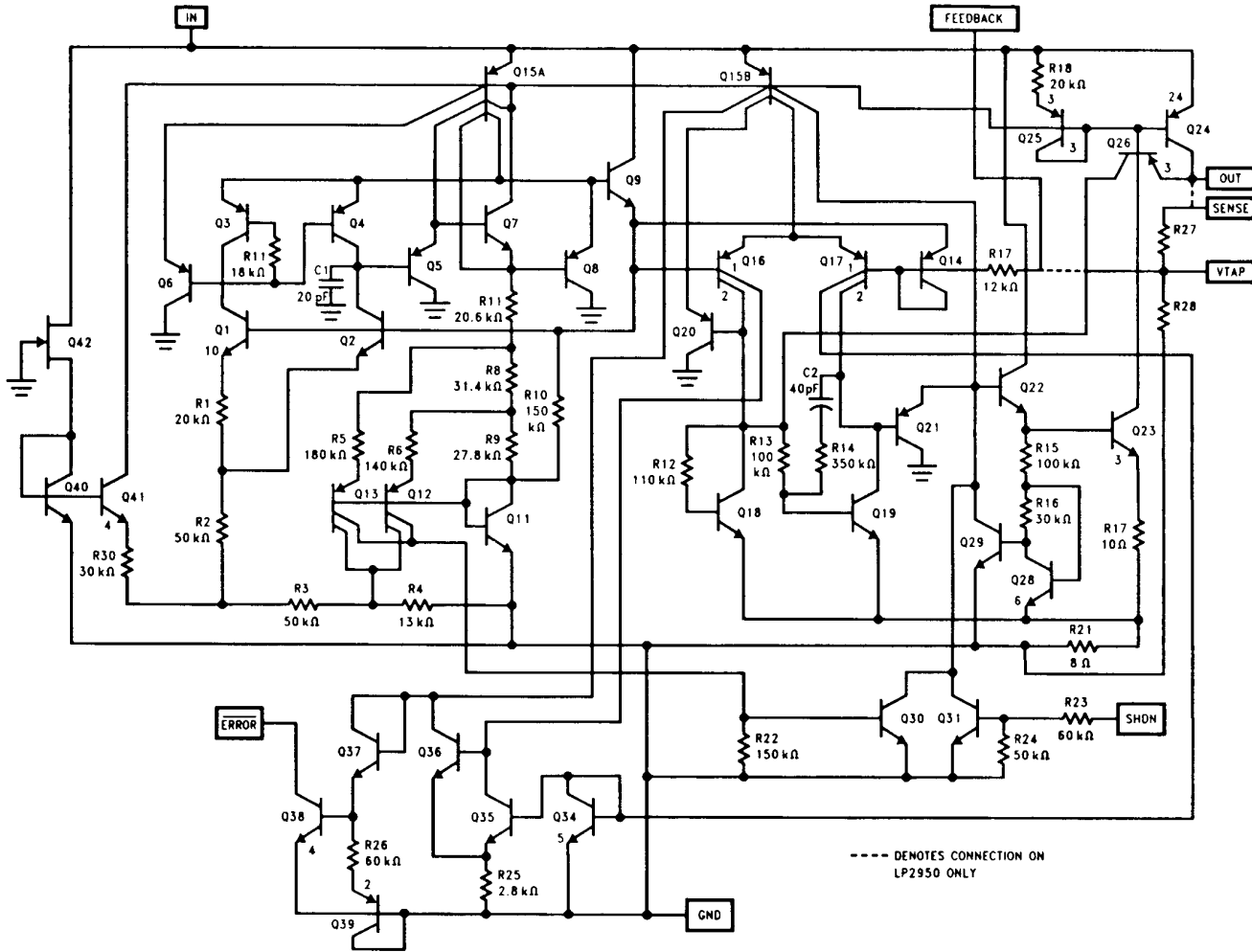


Fig 8. 300 mA Regulator with 0.75V

SCHEMATIC DIAGRAM



ORDERING INFORMATION

Ordering No.	Precision	Output Voltage	Packages
LP2950AS	1%	Adj	8 Lead SOIC
LP2950AS-3.0	1%	3.0V	8 Lead SOIC
LP2950AS-3.3	1%	3.3V	8 Lead SOIC
LP2950AS-5.0	1%	5.0V	8 Lead SOIC
LP2950CS	0.5%	Adj	8 Lead SOIC
LP2950CS-3.0	0.5%	3.0V	8 Lead SOIC
LP2950CS-3.3	0.5%	3.3V	8 Lead SOIC
LP2950CS-5.0	0.5%	5.0V	8 Lead SOIC
LP2950AT	1%	Adj	3 Lead TO-263
LP2950AT-3.0	1%	3.0V	3 Lead TO-263
LP2950AT-3.3	1%	3.3V	3 Lead TO-263
LP2950AT-5.0	1%	5.0V	3 Lead TO-263
LP2950CT	0.5%	Adj	3 Lead TO-263
LP2950CT-3.0	0.5%	3.0V	3 Lead TO-263
LP2950CT-3.3	0.5%	3.3V	3 Lead TO-263
LP2950CT-5.0	0.5%	5.0V	3 Lead TO-263



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