FEATURES
- 5.0V and 3.3V Versions at 100mA Output
- Very Low Quiescent Current
- Low Dropout Voltage: 380mV at 100mA
- Extremely Tight Load and Line Regulation
- Very Low Temperature Coefficient
- Current & Thermal Limiting
- Need Only 1 µF for Stability
- Offered in Lead Free, RoHS Compliant Packages:
  TO-92 (LP2950) & SOIC (LP2951)
- Direct Replacement For LP2950/LP2951

LP2951 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
- SMPS Post-Regulator
- Voltage Reference
- Automotive Electronics

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 feature low quiescent current and low dropout voltage (typ. 50mV at light load and 380 mV at 100mA). This includes a tight initial tolerance (0.5% typ.), extremely good load and line regulation (0.05% typ.), and very low output temperature coefficient (20 ppm/°C typ.), making the LP2950/LP2951 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 input voltage. The logic-compatible shutdown feature enables the regulator to be switched ON and OFF. The LP2950 is offered in a 3-pin TO-92 package compatible with other 5V, 3.3V regulators. The LP2951 is available in an 8-lead SOIC package.

Block diagram of LP2951
### 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

$V_{IN}=6V$, $I_O=100\mu A$, $C_{OUT}=1\mu F$ (Note 2) $T_A=25C$, unless otherwise noted.

#### 3.3 V Versions

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>CONDITIONS</th>
<th>LP2950AC Min.</th>
<th>LP2950AC Typ.</th>
<th>LP2950C Min.</th>
<th>LP2950C Typ.</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output Voltage</td>
<td>$T_J=25^\circ C$</td>
<td>3.284</td>
<td>3.3</td>
<td>3.17</td>
<td>3.267</td>
<td>3.3</td>
</tr>
<tr>
<td></td>
<td>$-25^\circ C \leq T_J \leq 85^\circ C$</td>
<td>3.267</td>
<td>3.3</td>
<td>3.333</td>
<td>3.251</td>
<td>3.3</td>
</tr>
<tr>
<td></td>
<td>Full Operating Temperature</td>
<td>3.260</td>
<td>3.3</td>
<td>3.340</td>
<td>3.234</td>
<td>3.3</td>
</tr>
<tr>
<td>Output Voltage</td>
<td>$100\mu A \leq I_L \leq 100 mA$</td>
<td>3.254</td>
<td>3.3</td>
<td>3.346</td>
<td>3.221</td>
<td>3.3</td>
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#### 5 V Versions

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<tr>
<th>PARAMETER</th>
<th>CONDITIONS</th>
<th>LP2951AC Min.</th>
<th>LP2951AC Typ.</th>
<th>LP2951C Min.</th>
<th>LP2951C Typ.</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output Voltage</td>
<td>$T_J=25^\circ C$</td>
<td>4.975</td>
<td>5.0</td>
<td>5.025</td>
<td>4.950</td>
<td>5.0</td>
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<tr>
<td></td>
<td>$-25^\circ C \leq T_J \leq 85^\circ C$</td>
<td>4.950</td>
<td>5.0</td>
<td>5.050</td>
<td>4.925</td>
<td>5.0</td>
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<tr>
<td></td>
<td>Full Operating Temperature</td>
<td>4.940</td>
<td>5.0</td>
<td>5.060</td>
<td>4.909</td>
<td>5.0</td>
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<tr>
<td>Output Voltage</td>
<td>$100\mu A \leq I_L \leq 100 mA$</td>
<td>4.925</td>
<td>5.0</td>
<td>5.075</td>
<td>4.880</td>
<td>5.0</td>
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#### All Voltage Options

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<th>PARAMETER</th>
<th>CONDITIONS</th>
<th>LP2950AC Min.</th>
<th>LP2950AC Typ.</th>
<th>LP2950C Min.</th>
<th>LP2950C Typ.</th>
<th>UNITS</th>
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<tbody>
<tr>
<td>Output Voltage Temperature Coefficient</td>
<td>(Note 1)</td>
<td>20</td>
<td>120</td>
<td>250</td>
<td>150</td>
<td>ppm/°C</td>
</tr>
<tr>
<td>Line Regulation (Note 3)</td>
<td>$6V \leq V_{IN} \leq 30V$ (Note 4)</td>
<td>0.05</td>
<td>0.1</td>
<td>0.04</td>
<td>0.2</td>
<td>%</td>
</tr>
<tr>
<td>Load Regulation (Note 3)</td>
<td>$100\mu A \leq I_L \leq 100 mA$</td>
<td>0.04</td>
<td>0.1</td>
<td>0.1</td>
<td>0.2</td>
<td>%</td>
</tr>
<tr>
<td>Dropout Voltage (Note 5)</td>
<td>$I_L=100\mu A$</td>
<td>50</td>
<td>80</td>
<td>50</td>
<td>80</td>
<td>mV</td>
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<tr>
<td></td>
<td>$I_L=100 mA$</td>
<td>380</td>
<td>450</td>
<td>380</td>
<td>450</td>
<td>mV</td>
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<tr>
<td>Ground Current</td>
<td>$I_L=100\mu A$</td>
<td>150</td>
<td>170</td>
<td>150</td>
<td>170</td>
<td>μA</td>
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<tr>
<td></td>
<td>$I_L=100 mA$</td>
<td>8</td>
<td>12</td>
<td>8</td>
<td>12</td>
<td>mA</td>
</tr>
<tr>
<td>Current Limit</td>
<td>$V_{OUT}=0$</td>
<td>150</td>
<td>200</td>
<td>150</td>
<td>200</td>
<td>mA</td>
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<tr>
<td>Thermal Regulation</td>
<td>$T_{J}=25^\circ C$</td>
<td>0.05</td>
<td>0.2</td>
<td>0.05</td>
<td>0.2</td>
<td>%/W</td>
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<tr>
<td>Output Noise, 10Hz to 100KHz</td>
<td>$C_L=1\mu F$</td>
<td>430</td>
<td>430</td>
<td>μV rms</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$C_L=200\mu F$</td>
<td>160</td>
<td>160</td>
<td>μV rms</td>
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<tr>
<td></td>
<td>$C_L=3.3\mu F, Bypass = 0.01\mu F$ from Pin 7 to Pin 1 (LP2951)</td>
<td>100</td>
<td>100</td>
<td>μV rms</td>
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#### 8-Pin Versions only

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<th>PARAMETER</th>
<th>CONDITIONS</th>
<th>LP2951AC</th>
<th>LP2951C</th>
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<tbody>
<tr>
<td>Reference Voltage</td>
<td>$T_J=25^\circ C$</td>
<td>1.220</td>
<td>1.235</td>
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<td></td>
<td>Over Temperature (Note 6)</td>
<td>1.190</td>
<td>1.270</td>
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<tr>
<td>Feedback Pin Bias Current</td>
<td>$I_B=40\mu A$</td>
<td>40</td>
<td>60</td>
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The product (or products) being manufactured and may not be shipped. (OBS)
### LP2950/51

#### PARAMETER CONDITIONS (Note 2) LP2951AC Min. Typ. Max. LP2951C Min. Typ. Max. UNITS

<table>
<thead>
<tr>
<th>8-Pin Versions only (Note 2)</th>
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<tbody>
<tr>
<td>Reference Voltage Temperature Coefficient</td>
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<tr>
<td>Feedback Pin Bias Current Temperature Coefficient</td>
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<th>Error Comparator</th>
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<tbody>
<tr>
<td>Output Leakage Current</td>
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<tr>
<td>VOUT = 30V</td>
<td>0.01</td>
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<tr>
<td>Output Low Voltage</td>
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</tr>
<tr>
<td>VOUT = 4.5V</td>
<td>150</td>
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<tr>
<td>Upper Threshold Voltage</td>
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<td>(Note 7)</td>
<td>40</td>
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<tr>
<td>Lower Threshold Voltage</td>
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<tr>
<td>(Note 7)</td>
<td>75</td>
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<tr>
<td>Hysteresis</td>
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<td>(Note 7)</td>
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<table>
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<th>Shutdown Input</th>
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<tbody>
<tr>
<td>Input logic Voltage</td>
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<tr>
<td>Low (Regulator ON)</td>
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<tr>
<td>High (Regulator OFF)</td>
<td></td>
</tr>
<tr>
<td>Shut down Pin Input Current</td>
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</tr>
<tr>
<td>VREF = 2.4V</td>
<td>30</td>
</tr>
<tr>
<td>VREF = 30V</td>
<td>675</td>
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<tr>
<td>Regulator Output Current in Shutdown</td>
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<tr>
<td>(Note 8)</td>
<td>3</td>
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<tr>
<td>Thermal Resistance θJA</td>
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<tr>
<td>8 Pin SOIC</td>
<td>128.4</td>
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<tr>
<td>3 Pin TO-92</td>
<td>131.9</td>
</tr>
</tbody>
</table>

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 TJ = 25°C, VIN = 6V, ILOAD = 100μA and C1 = 1μF. Additional conditions for the 8-pin versions are feedback tied to 5V tap and output tied to output sense (VOUT = 5V) and VSHUTDOWN ≤ 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 ILOAD = 1mA. For ILOAD = 100μA and TJ = 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 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: VOUT ≤ VREF ≤ (VIN - 1V), 2.3 ≤ VREF ≤ 30V, 100μA ≤ ILOAD ≤ 100mA, TJ ≤ TjMAX.

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 = VOUT/VREF = (R1 + R2)/R2. For example, at a programmed output voltage of 5V, the error output is guaranteed to go low when the output drops by 95 mV x 5V/1.235 = 384 mV. Thresholds remain constant as a percent of VOUT as VOUT is varied, with the dropout warning occurring at typically 5% below nominal, 7.5% guaranteed.

Note 8: VSHUTDOWN ≥ 2V, VIN ≤ 30V, VOUT = 0, Feedback pin tied to 5V Tap.

Note 9: All typical values are not guaranteed. The value could vary from lot to lot.
LP2950/ LP2951

TYPICAL PERFORMANCE CHARACTERISTIC

LP2950 obsolete

Dropout Characteristics

Input Current

Quiescent Current

Ground Current

Input Current

Ground Current

Ground Current

Quiescent Current

The product(s) mentioned in this data sheet are no longer being manufactured and may not be ordered (OBS).
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

![Drop-Out Voltage](image1)

Drop-Out Voltage

![Drop-Out Voltage](image2)

Drop-Out Voltage

![Short Circuit Current](image3)

Short Circuit Current

![Error Comparator Output](image4)

Error Comparator Output

![LP2951 Comparator Sink Current](image5)

LP2951 Comparator Sink Current

![Line Transient Response](image6)

Line Transient Response

![Output Impedance](image7)

Output Impedance

![Ripple Rejection](image8)

Ripple Rejection

![Ripple Rejection](image9)

Ripple Rejection

---

Note: The product mentioned in this data sheet are no longer being manufactured and may not be reordered. (OBS)
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

LP2951 Minimum Operating Voltage

LP2951 Feedback Bias Current

LP2951 Feedback Pin Current

Load Transient Response

Enable Transient

LP2950 Maximum Rated Output

LP2951 Divider Resistance

LP2950 Maximum Rated Output Current
TYPICAL APPLICATIONS

Shutdown Threshold Voltage

Thermal Response

Output Noise

Line Regulation

Ripple Rejection

BLOCK DIAGRAM

TO-92 package obsolete

8-Pin Surface Mount (S)

TO-92 (N)

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APPLICATION HINTS
EXTERNAL CAPACITORS
LP2950 obsolete

The stability of the LP2950/LP2951 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 520µ less and resonant frequency above 50kHz 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 3.3 µF or greater must be used for the condition of 100mA 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 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 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 100µF capacitor between 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 VOUT = 4.75V). 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 400µA, this value adds battery drain in a low battery condition. Suggested values range from 100kΩ to 1MΩ. If the output is caused 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 (source) 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 20V 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:

\[ V_{OUT} = V_{REF} \times (1 + \frac{R_1}{R_2}) = \frac{I_{FB}}{R_1} \]

The VREF is 1.235 and I_FB is the feedback bias current, nominally -20mA. The minimum recommended load current of 1µA forces an upper limit of 1.25mV bias at R2. If no load is presented the I_FB produces an error of typically 25µA. VOUT which may be eliminated at room temperature by trimming R2 to improve the accuracy. The choice of the value of R2 = 100kΩ reduces the error by 0.17% and increases the resistor program current by 0.2µA. Since the LP2951 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 LP2950 but is relatively inefficient, as increasing the capacitor from 1µF to 220 µF only decreases the noise from 430µV to 160µV for a 100kHz bandwidth at 5V output. Noise could also be reduced fourfold by a bypass capacitor across R1, since it reduces the high frequency gain from 4 to unity. Pick

\[ C_{BYPASS} = \frac{1}{2 \pi R_1} > 200 \text{Hz} \]

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 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

Figure 3. Latch Off When Error Flag Occurs

Figure 4. Wide Input Voltage Range Current Limiter

The product (or products) mentioned in this data sheet are no longer being manufactured and may not be ordered (OBS).
TYPICAL APPLICATIONS (continued)

Figure 5. Low Battery disconnect

Figure 6. Regulator with State-of Charge Indicator

* OPTIONAL LATCH OFF WHEN DROPOUT OCCURS. ADJUST R3 FOR C2 SWITCHING WHEN VDS > 6.0V
* OUTPUTS GO LOW WHEN VDS DROPS BELOW DESIGNATED THRESHOLDS

The product (or products) mentioned in this data sheet are no longer being manufactured and may not be ordered (OBS).
Figure 7. System Over Temperature Protection

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

Figure 9. 300mA Regulator with 0.75V

TYPICAL APPLICATIONS (continued)
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The product (or products) mentioned in this data sheet are no longer being manufactured and may not be ordered (OBS).
The product (or products) mentioned in this data sheet are no longer being manufactured (OBS).
NOTE: For more information about part numbers, as well as the most up-to-date ordering information and additional information on environmental rating, go to [www.maxlinear.com/LP2950](http://www.maxlinear.com/LP2950) and [www.maxlinear.com/LP2951](http://www.maxlinear.com/LP2951).

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