


## Ordering Information

| Package | Output Voltage |  |  | Temperature ( ${ }^{\circ} \mathrm{C}$ ) |
| :---: | :---: | :---: | :---: | :---: |
|  | 3.0 V | 3.3 V | 5.0V |  |
| TO-92 (Z) | $\begin{aligned} & \text { LP2950ACZ-3.0 } \\ & \text { LP2950CA-3.0 } \end{aligned}$ | $\begin{aligned} & \text { LP2950ACZ-3.3 } \\ & \text { LP2950CZ-3.3 } \end{aligned}$ | $\begin{aligned} & \text { LP2950ACZ-5.0 } \\ & \text { LP2950CZ-5.0 } \end{aligned}$ | $-40<\mathrm{T}_{\mathrm{J}}<125$ |
| N (N-08E) | $\begin{aligned} & \text { LP2951ACN-3.0 } \\ & \text { LP2951CN-3.0 } \end{aligned}$ | $\begin{aligned} & \text { LP2951ACN-3.3 } \\ & \text { LP2951CN-3.3 } \end{aligned}$ | $\begin{aligned} & \text { LP2951ACN } \\ & \text { LP2950CN } \end{aligned}$ | $-40<\mathrm{T}_{J}<125$ |
| M (M08A) | LP2951ACM-3.0 <br> LP2951CM-3.0 | LP2951ACM-3.3 <br> LP2951CM-3.3 | LP2951ACM <br> LP2951CM | $-40<\mathrm{T}_{\mathrm{J}}<125$ |
| MM (MUA08A) | LP2951ACMM-3.0 LP2951CMM-3.0 | LP2951ACMM-3.3 <br> LP2951CMM-3.3 | LP2951ACMM LP2951CMM | $-40<\mathrm{T}_{\mathrm{J}}<125$ |
| J (J08A) |  |  | LP2951ACJ <br> LP2951CJ <br> LP2951J <br> LP2951J/883 <br> 5926-3870501MPA | $-40<\mathrm{T}_{\mathrm{J}}<125$ $-55<T_{J}<150$ |
| H (H08C) |  |  | $\begin{aligned} & \text { LP2951H/883 } \\ & 5962-3870501 \mathrm{MGA} \end{aligned}$ | $-55<\mathrm{T}_{\mathrm{J}}<150$ |
| E (E20A) |  |  | $\begin{aligned} & \text { LP2951E/883 } \\ & 5962-3870501 \mathrm{M} 2 \mathrm{~A} \end{aligned}$ | $-55<\mathrm{T}_{\mathrm{J}}<150$ |

## For MM Package:

| Order Number | Package Marking |
| :--- | :--- |
| LP2951ACMM | LODA |
| LP2951CMM | LODB |
| LP2951ACMM-3.3 | LOCA |
| LP2951CMM-3.3 | LOCB |
| LP2951ACMM-3.0 | LOBA |
| LP2951CMM-3.0 | LOBB |

Absolute Maximum Ratings (Note 1)
If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.
Input Supply Voltage
-0.3 to +30 V
SHUTDOWN Input Voltage,
Error Comparator Output
Voltage, (Note 9)
FEEDBACK Input Voltage
(Note 9) (Note 10)
Power Dissipation
Junction Temperature ( $\mathrm{T}_{\mathrm{J}}$ )
,
$+150^{\circ} \mathrm{C}$
Ambient Storage Temperature
Soldering Dwell Time, Temperature

## Wave

Infrared
Vapor Phase ESD

4 seconds, $260^{\circ} \mathrm{C}$
10 seconds, $240^{\circ} \mathrm{C}$
75 seconds, $219^{\circ} \mathrm{C}$ TBD

Operating Ratings (Note 1)
Maximum Input Supply Voltage 30V
Junction Temperature Range
( $\mathrm{T}_{\mathrm{J}}$ ) (Note 8)
LP2951 $-55^{\circ}$ to $+150^{\circ} \mathrm{C}$
LP2950AC-XX, LP2950C-XX,
LP2951AC-XX, LP2951C-XX
$-40^{\circ}$ to $+125^{\circ} \mathrm{C}$

Electrical Characteristics (Note 2)

| Parameter | Conditions (Note 2) | LP2951 |  | $\begin{aligned} & \hline \text { LP2950AC-XX } \\ & \text { LP2951AC-XX } \end{aligned}$ |  |  | $\begin{aligned} & \text { LP2950C-XX } \\ & \text { LP2951C-XX } \end{aligned}$ |  |  | Units |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Typ | Tested Limit (Notes 3, 16) | Typ | Tested Limit (Note 3) | Design Limit (Note 4) | Typ | Tested Limit (Note 3) | Design Limit (Note 4) |  |


| Output Voltage | $\mathrm{T}_{\mathrm{J}}=25^{\circ} \mathrm{C}$ | 3.0 | $\begin{aligned} & 3.015 \\ & 2.985 \end{aligned}$ | 3.0 | $\begin{aligned} & \hline 3.015 \\ & 2.985 \end{aligned}$ |  | 3.0 | $\begin{aligned} & \hline 3.030 \\ & 2.970 \end{aligned}$ |  | $\begin{aligned} & \hline V_{\text {max }} \\ & V_{\text {min }} \end{aligned}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | $-25^{\circ} \mathrm{C} \leq \mathrm{T}_{J} \leq 80^{\circ} \mathrm{C}$ | 3.0 |  | 3.0 |  | $\begin{aligned} & \hline 3.030 \\ & 2.970 \end{aligned}$ | 3.0 |  | $\begin{aligned} & \hline 3.045 \\ & 2.955 \end{aligned}$ | $\begin{aligned} & \hline V_{\text {max }} \\ & V_{\text {min }} \end{aligned}$ |
|  | Full Operating Temperature Range | 3.0 | $\begin{aligned} & \hline 3.036 \\ & 2.964 \end{aligned}$ | 3.0 |  | $\begin{aligned} & \hline 3.036 \\ & 2.964 \end{aligned}$ | 3.0 |  | $\begin{aligned} & \hline 3.060 \\ & 2.940 \end{aligned}$ | $\begin{aligned} & \hline V_{\text {max }} \\ & V_{\text {min }} \end{aligned}$ |
| Output Voltage | $\begin{aligned} & 100 \mu \mathrm{~A} \leq \mathrm{I}_{\mathrm{L}} \leq 100 \mathrm{~mA} \\ & \mathrm{~T}_{\mathrm{J}} \leq \mathrm{T}_{\mathrm{JMAX}} \end{aligned}$ | 3.0 | $\begin{aligned} & 3.045 \\ & 2.955 \end{aligned}$ | 3.0 |  | $\begin{aligned} & \hline 3.042 \\ & 2.958 \end{aligned}$ | 3.0 |  | $\begin{aligned} & 3.072 \\ & 2.928 \end{aligned}$ | $\checkmark$ max <br> $V$ min |


| 3.3V VERSIONS (Note 17) |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Output Voltage | $\mathrm{T}_{\mathrm{J}}=25^{\circ} \mathrm{C}$ | 3.3 | $\begin{aligned} & 3.317 \\ & 3.284 \end{aligned}$ | 3.3 | $\begin{aligned} & 3.317 \\ & 3.284 \end{aligned}$ |  | 3.3 | $\begin{aligned} & 3.333 \\ & 3.267 \end{aligned}$ |  | $\begin{aligned} & \hline \mathrm{V} \text { max } \\ & \mathrm{V} \text { min } \end{aligned}$ |
|  | $-25^{\circ} \mathrm{C} \leq \mathrm{T}_{J} \leq 85^{\circ} \mathrm{C}$ | 3.3 |  | 3.3 |  | $\begin{aligned} & \hline 3.333 \\ & 3.267 \end{aligned}$ | 3.3 |  | $\begin{aligned} & 3.350 \\ & 3.251 \end{aligned}$ | $\begin{aligned} & \hline V_{\text {max }} \\ & V \text { min } \end{aligned}$ |
|  | Full Operating Temperature Range | 3.3 | $\begin{aligned} & 3.340 \\ & 3.260 \\ & \hline \end{aligned}$ | 3.3 |  | $\begin{aligned} & \hline 3.340 \\ & 3.260 \\ & \hline \end{aligned}$ | 3.3 |  | $\begin{aligned} & 3.366 \\ & 3.234 \end{aligned}$ | $\begin{aligned} & V_{\max } \\ & \mathrm{V} \text { min } \end{aligned}$ |
| Output Voltage | $\begin{aligned} & 100 \mu \mathrm{~A} \leq \mathrm{I}_{\mathrm{L}} \leq 100 \mathrm{~mA} \\ & \mathrm{~T}_{\mathrm{J}} \leq \mathrm{T}_{\text {JMAX }} \end{aligned}$ | 3.3 | $\begin{aligned} & 3.350 \\ & 3.251 \end{aligned}$ | 3.3 |  | $\begin{aligned} & \hline 3.346 \\ & 3.254 \end{aligned}$ | 3.3 |  | $\begin{aligned} & \hline 3.379 \\ & 3.221 \end{aligned}$ | $\begin{aligned} & \hline \mathrm{V} \text { max } \\ & \mathrm{V} \text { min } \end{aligned}$ |

## 5V VERSIONS (Note 17)

| Output Voltage | $\mathrm{T}_{\mathrm{J}}=25^{\circ} \mathrm{C}$ | 5.0 | $\begin{aligned} & \hline 5.025 \\ & 4.975 \end{aligned}$ | 5.0 | $\begin{aligned} & \hline 5.025 \\ & 4.975 \end{aligned}$ |  | 5.0 | $\begin{aligned} & \hline 5.05 \\ & 4.95 \end{aligned}$ |  | $\vee$ max <br> $V$ min |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | $-25^{\circ} \mathrm{C} \leq \mathrm{T}_{\mathrm{J}} \leq 85^{\circ} \mathrm{C}$ | 5.0 |  | 5.0 |  | $\begin{aligned} & \hline 5.05 \\ & 4.95 \end{aligned}$ | 5.0 |  | $\begin{aligned} & \hline 5.075 \\ & 4.925 \end{aligned}$ | $\begin{aligned} & \hline V_{\text {max }} \\ & V \text { min } \end{aligned}$ |
|  | Full Operating Temperature Range | 5.0 | $\begin{aligned} & \hline 5.06 \\ & 4.94 \end{aligned}$ | 5.0 |  | $\begin{aligned} & \hline 5.06 \\ & 4.94 \end{aligned}$ | 5.0 |  | $\begin{aligned} & 5.1 \\ & 4.9 \end{aligned}$ | $\begin{aligned} & \hline V_{\text {max }} \\ & V_{\text {min }} \end{aligned}$ |
| Output Voltage | $\begin{aligned} & 100 \mu \mathrm{~A} \leq \mathrm{I}_{\mathrm{L}} \leq 100 \mathrm{~mA} \\ & \mathrm{~T}_{\mathrm{J}} \leq \mathrm{T}_{\text {JMAX }} \end{aligned}$ | 5.0 | $\begin{aligned} & 5.075 \\ & 4.925 \end{aligned}$ | 5.0 |  | $\begin{aligned} & 5.075 \\ & 4.925 \\ & \hline \end{aligned}$ | 5.0 |  | $\begin{aligned} & 5.12 \\ & 4.88 \end{aligned}$ | $\begin{aligned} & \hline \mathrm{V} \text { max } \\ & V_{\text {min }} \end{aligned}$ |

ALL VOLTAGE OPTIONS

| Output Voltage <br> Temperature Coefficient | (Note 12) | $\mathbf{2 0}$ | $\mathbf{1 2 0}$ | $\mathbf{2 0}$ |  | $\mathbf{1 0 0}$ | $\mathbf{5 0}$ |  | $\mathbf{1 5 0}$ | $\mathrm{ppm} /{ }^{\circ} \mathrm{C}$ |
| :--- | :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Line Regulation <br> (Note 14) | $\left(\mathrm{V}_{\mathrm{NONM}}+1\right) \mathrm{V} \leq \mathrm{V}_{\text {in }} \leq 30 \mathrm{~V}$ <br> (Note 15) | 0.03 | 0.1 <br> $\mathbf{0 . 5}$ | 0.03 | 0.1 |  | 0.04 | 0.2 |  | $\% \max$ <br> $\% \max$ |
| Load Regulation <br> (Note 14) | $100 \mu \mathrm{~A} \leq \mathrm{I}_{\mathrm{L}} \leq 100 \mathrm{~mA}$ | 0.04 | 0.1 | 0.04 | 0.1 |  | $\mathbf{0 . 2}$ |  | 0.1 | 0.2 |

Electrical Characteristics (Note 2) (Continued)

| Parameter | Conditions <br> (Note 2) | LP2951 |  | $\begin{aligned} & \text { LP2950AC-XX } \\ & \text { LP2951AC-XX } \end{aligned}$ |  |  | $\begin{aligned} & \text { LP2950C-XX } \\ & \text { LP2951C-XX } \end{aligned}$ |  |  | Units |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Typ | Tested Limit (Notes 3, 16) | Typ | Tested Limit (Note 3) | Design Limit (Note 4) | Typ | Tested Limit (Note 3) | Design Limit (Note 4) |  |
| ALL VOLTAGE OPTIONS |  |  |  |  |  |  |  |  |  |  |
| Dropout Voltage (Note 5) | $\mathrm{I}_{\mathrm{L}}=100 \mu \mathrm{~A}$ | 50 | $\begin{gathered} 80 \\ 150 \end{gathered}$ | 50 | 80 | 150 | 50 | 80 | 150 | mV max $m V$ max |
|  | $\mathrm{I}_{\mathrm{L}}=100 \mathrm{~mA}$ | 380 | $\begin{aligned} & 450 \\ & 600 \end{aligned}$ | 380 | 450 | 600 | 380 | 450 | 600 | $m V$ max $m V$ max |
| Ground Current | $\mathrm{I}_{\mathrm{L}}=100 \mu \mathrm{~A}$ | 75 | $\begin{aligned} & \hline 120 \\ & 140 \end{aligned}$ | 75 | 120 | 140 | 75 | 120 | 140 | $\mu \mathrm{A}$ max $\mu \mathrm{A}$ max |
|  | $\mathrm{L}_{\mathrm{L}}=100 \mathrm{~mA}$ | 8 | $\begin{aligned} & \hline 12 \\ & 14 \end{aligned}$ | 8 | 12 | 14 | 8 | 12 | 14 | mA max mA max |
| Dropout <br> Ground Current | $\begin{aligned} & \mathrm{V}_{\text {in }}=\left(\mathrm{V}_{\mathrm{O}} \mathrm{NOM}-0.5\right) \mathrm{V} \\ & \mathrm{I}_{\mathrm{L}}=100 \mu \mathrm{~A} \end{aligned}$ | 110 | $\begin{aligned} & \hline 170 \\ & 200 \end{aligned}$ | 110 | 170 | 200 | 110 | 170 | 200 | $\mu \mathrm{A}$ max $\mu \mathrm{A}$ max |
| Current Limit | $\mathrm{V}_{\text {out }}=0$ | 160 | $\begin{aligned} & 200 \\ & 220 \end{aligned}$ | 160 | 200 | 220 | 160 | 200 | 220 | mA max mA max |
| Thermal Regulation | (Note 13) | 0.05 | 0.2 | 0.05 | 0.2 |  | 0.05 | 0.2 |  | \%/W max |
| Output Noise, 10 Hz to 100 KHz | $\mathrm{C}_{\mathrm{L}}=1 \mu \mathrm{~F}$ ( 5 V Only) | 430 |  | 430 |  |  | 430 |  |  | $\mu \mathrm{V}$ rms |
|  | $\mathrm{C}_{\mathrm{L}}=200 \mu \mathrm{~F}$ | 160 |  | 160 |  |  | 160 |  |  | $\mu \mathrm{V}$ rms |
|  | $\begin{aligned} & \hline \mathrm{C}_{\mathrm{L}}=3.3 \mu \mathrm{~F} \\ & \text { (Bypass }=0.01 \mu \mathrm{~F} \\ & \text { Pins } 7 \text { to } 1 \text { (LP2951)) } \\ & \hline \end{aligned}$ | 100 |  | 100 |  |  | 100 |  |  | $\mu \mathrm{V}$ rms |
| 8-PIN VERSIONS ONLY |  | LP2951 |  | LP2951AC-XX |  |  | LP2951C-XX |  |  |  |
| Reference <br> Voltage |  | 1.235 | $\begin{gathered} 1.25 \\ 1.26 \\ 1.22 \\ 1.2 \end{gathered}$ | 1.235 | $\begin{aligned} & 1.25 \\ & 1.22 \end{aligned}$ | $\begin{aligned} & 1.26 \\ & 1.2 \end{aligned}$ | 1.235 | $\begin{aligned} & 1.26 \\ & 1.21 \end{aligned}$ | $\begin{aligned} & 1.27 \\ & 1.2 \\ & \hline \end{aligned}$ | V max <br> V max <br> $\vee$ min <br> $\vee$ min |
| Reference <br> Voltage | (Note 7) |  | $\begin{aligned} & 1.27 \\ & 1.19 \end{aligned}$ |  |  | $\begin{aligned} & 1.27 \\ & 1.19 \end{aligned}$ |  |  | $\begin{aligned} & 1.285 \\ & 1.185 \end{aligned}$ | V max <br> V min |
| Feedback Pin Bias Current |  | 20 | $\begin{aligned} & 40 \\ & 60 \end{aligned}$ | 20 | 40 | 60 | 20 | 40 | 60 | nA max <br> nA max |
| Reference Voltage Temperature Coefficient | (Note 12) | 20 |  | 20 |  |  | 50 |  |  | ppm/ ${ }^{\circ} \mathrm{C}$ |
| Feedback Pin Bias Current Temperature Coefficient |  | 0.1 |  | 0.1 |  |  | 0.1 |  |  | nA/ ${ }^{\circ} \mathrm{C}$ |
| Error Comparator |  |  |  |  |  |  |  |  |  |  |
| Output Leakage Current | $\mathrm{V}_{\mathrm{OH}}=30 \mathrm{~V}$ | 0.01 | $\begin{aligned} & 1 \\ & 2 \end{aligned}$ | 0.01 | 1 | 2 | 0.01 | 1 | 2 | $\mu \mathrm{A}$ max $\mu \mathrm{A}$ max |
| Output Low <br> Voltage | $\begin{aligned} & \mathrm{V}_{\text {in }}=\left(\mathrm{V}_{\mathrm{O}} \mathrm{NOM}-0.5\right) \mathrm{V} \\ & \mathrm{I}_{\mathrm{OL}}=400 \mu \mathrm{~A} \end{aligned}$ | 150 | $\begin{aligned} & 250 \\ & 400 \end{aligned}$ | 150 | 250 | 400 | 150 | 250 | 400 | mV max <br> $m V$ max |
| Upper Threshold Voltage | (Note 6) | 60 | $\begin{aligned} & 40 \\ & 25 \end{aligned}$ | 60 | 40 | 25 | 60 | 40 | 25 | mV min mV min |
| Lower Threshold Voltage | (Note 6) | 75 | $\begin{gathered} 95 \\ 140 \\ \hline \end{gathered}$ | 75 | 95 | 140 | 75 | 95 | 140 | $m V$ max $m V$ max |
| Hysteresis | (Note 6) | 15 |  | 15 |  |  | 15 |  |  | mV |
| Shutdown Input |  |  |  |  |  |  |  |  |  |  |
| Input <br> Logic <br> Voltage | Low (Regulator ON) <br> High (Regulator OFF) | 1.3 | $\begin{aligned} & 0.6 \\ & 2.0 \end{aligned}$ | 1.3 |  | $\begin{aligned} & 0.7 \\ & 2.0 \end{aligned}$ | 1.3 |  | $\begin{aligned} & 0.7 \\ & 2.0 \end{aligned}$ | $V$ $V$ max $V$ min |

Electrical Characteristics (Note 2) (Continued)

| Parameter | Conditions (Note 2) | LP2951 |  | $\begin{aligned} & \text { LP2950AC-XX } \\ & \text { LP2951AC-XX } \end{aligned}$ |  |  | $\begin{aligned} & \text { LP2950C-XX } \\ & \text { LP2951C-XX } \end{aligned}$ |  |  | Units |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Typ | Tested Limit (Notes 3, 16) | Typ | Tested <br> Limit <br> (Note 3) | Design <br> Limit <br> (Note 4) | Typ | Tested <br> Limit <br> (Note 3) | Design <br> Limit <br> (Note 4) |  |
| Shutdown Input |  |  |  |  |  |  |  |  |  |  |
| Shutdown Pin Input Current | $\mathrm{V}_{\text {shutdown }}=2.4 \mathrm{~V}$ | 30 | $\begin{gathered} \hline 50 \\ 100 \end{gathered}$ | 30 | 50 | 100 | 30 | 50 | 100 | $\mu \mathrm{A} \max$ $\mu \mathrm{A}$ max |
|  | $\mathrm{V}_{\text {shutdown }}=30 \mathrm{~V}$ | 450 | $\begin{aligned} & 600 \\ & 750 \end{aligned}$ | 450 | 600 | 750 | 450 | 600 | 750 | $\mu \mathrm{A}$ max $\mu \mathrm{A}$ max |
| Regulator Output Current in Shutdown | (Note 11) | 3 | $\begin{aligned} & 10 \\ & 20 \end{aligned}$ | 3 | 10 | 20 | 3 | 10 | 20 | $\mu \mathrm{A}$ max $\mu \mathrm{A}$ max |

Note 1: Absolute Maximum Ratings are limits beyond which damage to the device may occur. Operating Ratings are conditions under which operation of the device is guaranteed. Operating Ratings do not imply guaranteed performance limits. For guaranteed performance limits and associated test conditions, see the Electrical Characteristics tables.

Note 2: Unless otherwise specified all limits guaranteed for $\mathrm{V}_{\mathrm{IN}}=\left(\mathrm{V}_{\mathrm{ONOM}}+1\right) \mathrm{V}, \mathrm{I}_{\mathrm{L}}=100 \mu \mathrm{~A}$ and $\mathrm{C}_{\mathrm{L}}=1 \mu \mathrm{~F}$ for 5 V versions and $2.2 \mu \mathrm{~F}$ for 3 V and 3.3 V versions. Limits appearing in boldface type apply over the entire junction temperature range for operation. Limits appearing in normal type apply for $\mathrm{T}_{\mathrm{A}}=\mathrm{T}_{J}=25^{\circ} \mathrm{C}$. Additional conditions for the 8 -pin versions are FEEDBACK tied to $\mathrm{V}_{\text {TAP }}$, OUTPUT tied to SENSE, and $\mathrm{V}_{\text {SHUTDOWN }} \leq 0.8 \mathrm{~V}$.
Note 3: Guaranteed and $100 \%$ production tested.
Note 4: Guaranteed but not $100 \%$ production tested. These limits are not used to calculate outgoing AQL levels.
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 1 V differential. At very low values of programmed output voltage, the minimum input supply voltage of 2 V ( 2.3 V over temperature) must be taken into account.
Note 6: Comparator thresholds are expressed in terms of a voltage differential at the Feedback terminal below the nominal reference voltage measured at
$\mathrm{V}_{\text {in }}=\left(\mathrm{V}_{\mathrm{O}} \mathrm{NOM}+1\right) \mathrm{V}$. To express these thresholds in terms of output voltage change, multiply by the error amplifier gain $=\mathrm{V}_{\text {out }} / \mathrm{V}_{\text {ref }}=(\mathrm{R} 1+\mathrm{R} 2) / \mathrm{R} 2$.
For example, at a programmed output voltage of 5 V , the Error output is guaranteed to go low when the output drops by $95 \mathrm{mV} \times 5 \mathrm{~V} / 1.235 \mathrm{~V}=384 \mathrm{mV}$.
Thresholds remain constant as a percent of $\mathrm{V}_{\text {out }}$ as $\mathrm{V}_{\text {out }}$ is varied, with the dropout warning occurring at typically $5 \%$ below nominal, $7.5 \%$ guaranteed.
Note 7: $\mathrm{V}_{\text {ref }} \leq \mathrm{V}_{\text {out }} \leq\left(\mathrm{V}_{\text {in }}-1 \mathrm{~V}\right), 2.3 \mathrm{~V} \leq \mathrm{V}_{\text {in }} \leq 30 \mathrm{~V}, 100 \mu \mathrm{~A} \leq \mathrm{I}_{\mathrm{L}} \leq 100 \mathrm{~mA}, \mathrm{~T}_{\mathrm{J}} \leq \mathrm{T}_{\mathrm{JMAX}}$.
Note 8: The junction-to-ambient thermal resistances are as follows: $180^{\circ} \mathrm{C} / \mathrm{W}$ and $160^{\circ} \mathrm{C} / \mathrm{W}$ for the TO-92 package with 0.40 inch and 0.25 inch leads to the printed circuit board (PCB) respectively, $105^{\circ} \mathrm{C} / \mathrm{W}$ for the molded plastic DIP (N), $130^{\circ} \mathrm{C} / \mathrm{W}$ for the ceramic DIP $(\mathrm{J}), 160^{\circ} \mathrm{C} / \mathrm{W}$ for the molded plastic SOP (M), 200 ${ }^{\circ} \mathrm{C} / \mathrm{W}$ for the molded plastic MSOP (MM), $160^{\circ} \mathrm{C} / \mathrm{W}$ for the metal can package $(\mathrm{H})$, and $180^{\circ} \mathrm{C} / \mathrm{W}$ for the leadless chip carrier (E). The above thermal resistances for the $\mathrm{N}, \mathrm{J}, \mathrm{M}$, $M M$, and E packages apply when the package is soldered directly to the PCB . Junction-to-case thermal resistances for the E and H packages are $24^{\circ} \mathrm{C} / \mathrm{W}$ and $20^{\circ} \mathrm{C} / \mathrm{W}$ respectively.
Note 9: May exceed input supply voltage.
Note 10: When used in dual-supply systems where the output terminal sees loads returned to a negative supply, the output voltage should be diode-clamped to ground.
Note 11: $\mathrm{V}_{\text {shutdown }} \geq 2 \mathrm{~V}, \mathrm{~V}_{\text {in }} \leq 30 \mathrm{~V}, \mathrm{~V}_{\text {out }}=0$, Feedback pin tied to $\mathrm{V}_{\text {TAP. }}$
Note 12: Output or reference voltage temperature coefficient is defined as the worst case voltage change divided by the total temperature range.
Note 13: Thermal regulation is defined as the change in output voltage at a time T after a change in power dissipation is applied, excluding load or line regulation effects. Specifications are for a 50 mA load pulse at $\mathrm{V}_{\mathrm{IN}}=30 \mathrm{~V}$ ( 1.25 W pulse) for $\mathrm{T}=10 \mathrm{~ms}$.
Note 14: 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 15: Line regulation for the LP2951 is tested at $150^{\circ} \mathrm{C}$ for $\mathrm{I}_{\mathrm{L}}=1 \mathrm{~mA}$. For $\mathrm{I}_{\mathrm{L}}=100 \mu \mathrm{~A}$ and $\mathrm{T}_{\mathrm{J}}=125^{\circ} \mathrm{C}$, line regulation is guaranteed by design to $0.2 \%$. See Typical Performance Characteristics for line regulation versus temperature and load current.
Note 16: A Military RETS spec is available on request. At time of printing, the LP2951 RETS spec complied with the boldface limits in this column. The LP2951H, E, or J may also be procured as Standard Military Drawing Spec \#5962-3870501MGA, M2A, or MPA.
Note 17: All LP2950 devices have the nominal output voltage coded as the last two digits of the part number. In the LP2951 products, the 3.0 V and 3.3 V versions are designated by the last two digits, but the 5 V version is denoted with no code at this location of the part number (refer to ordering information table).

## Typical Performance Characteristics




## Input Current






Quiescent Current


Quiescent Current


Typical Performance Characteristics (Continued)



## LP2951

Feedback Bias Current


LP2951
Feedback Pin Current


Line Transient Response


## Typical Performance Characteristics (Continued)







## 



LP2951 Divider Resistance


## Typical Performance Characteristics (Continued)




LP2951 Maximum Rated Output Current

input Voltage (v)

DS008546-56

LP2950 Maximum Rated Output Current


Thermal Response


## Application Hints

## external capacitors

A $1.0 \mu \mathrm{~F}$ (or greater) capacitor is required between the output and ground for stability at output voltages of 5 V or more. At lower output voltages, more capacitance is required ( $2.2 \mu \mathrm{~F}$ or more is recommended for 3 V and 3.3 V versions). Without this capacitor the part will oscillate. Most types of tantalum or aluminum electrolytics work fine here; even film types work but are not recommended for reasons of cost. Many aluminum electrolytics have electrolytes that freeze at about $-30^{\circ} \mathrm{C}$, so solid tantalums are recommended for operation below $-25^{\circ} \mathrm{C}$. The important parameters of the capacitor are an ESR of about $5 \Omega$ or less and a resonant frequency above 500 kHz . 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 $0.33 \mu \mathrm{~F}$ for currents below 10 mA or $0.1 \mu \mathrm{~F}$ for currents below 1 mA . Using the adjustable versions at voltages below 5 V runs the error amplifier at lower gains so that more output capacitance is needed. For the worst-case situation of a 100 mA load at 1.23 V output (Output shorted to Feedback) a $3.3 \mu \mathrm{~F}$ (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 versions with external resistors, a minimum load of $1 \mu \mathrm{~A}$ is recommended.

A $1 \mu \mathrm{~F}$ tantalum or aluminum electrolytic capacitor should be placed from the LP2950/LP2951 input to 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 high value external resistors to set the output voltage. Adding a 100 pF capacitor between Output and Feedback and increasing the output capacitor to at least $3.3 \mu \mathrm{~F}$ 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 4.75 V for a 5 V output or 11.4 V for a 12 V output. The out of regulation condition may be due either to low input voltage, current limiting, or thermal limiting. Figure 1 below gives a timing diagram depicting the $\overline{\text { ERROR }}$ signal and the regulated output voltage as the LP2951 input is ramped up and down. For 5 V versions, the ERROR signal becomes valid (low) at about 1.3 V input. It goes high at about 5 V input (the input voltage at which $\mathrm{V}_{\text {OUT }}=4.75$ ). Since the LP2951's dropout voltage is load-dependent (see

## Application Hints (Continued)

curve in typical performance characteristics), the input voltage trip point (about 5 V ) 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 while the output is rated to sink $400 \mu \mathrm{~A}$, this sink current adds to battery drain in a low battery condition. Suggested values range from 100 k to $1 \mathrm{M} \Omega$. 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 $\mathrm{V}_{\text {TAP }}$ pins together. Alternatively, it may be programmed for any output voltage between its 1.235 V reference and its 30 V maximum rating. As seen in Figure 2, an external pair of resistors is required.

${ }^{*}$ When $\mathrm{V}_{\mathrm{IN}} \leq 1.3 \mathrm{~V}$, the error flag pin becomes a high impedance, and the error flag voltage rises to its pull-up voltage. Using $\mathrm{V}_{\text {Out }}$ as the pull-up voltage (see Figure 2), rather than an external 5 V source, will keep the error flag voltage under 1.2 V (typ.) in this condition. The user may wish to divide down the error flag voltage using equal-value resistors ( $10 \mathrm{k} \Omega$ suggested), to ensure a low-level logic signal during any fault condition, while still allowing a valid high logic level during normal operation.

## FIGURE 1. ERROR Output Timing

The complete equation for the output voltage is

$$
V_{\text {OUT }}=V_{R E F} \cdot\left(1+\frac{R_{1}}{R_{2}}\right)+I_{F B} R_{1}
$$

where $\mathrm{V}_{\text {REF }}$ is the nominal 1.235 reference voltage and $\mathrm{I}_{\mathrm{FB}}$ is the feedback pin bias current, nominally -20 nA . The minimum recommended load current of $1 \mu \mathrm{~A}$ forces an upper limit of $1.2 \mathrm{M} \Omega$ on the value of $\mathrm{R}_{2}$, if the regulator must work
with no load (a condition often found in CMOS in standby) $\mathrm{I}_{\text {FB }}$ will produce a $2 \%$ typical error in $\mathrm{V}_{\text {OUt }}$ which may be eliminated at room temperature by trimming $R_{1}$. For better accuracy, choosing $R_{2}=100 \mathrm{k}$ reduces this error to $0.17 \%$ while increasing the resistor program current to $12 \mu \mathrm{~A}$. Since the LP2951 typically draws $60 \mu \mathrm{~A}$ at no load with Pin 2 open-circuited, this is a small price to pay.

## REDUCING OUTPUT NOISE

In reference applications it may be 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 noise can be reduced on the 3 lead LP2950 but is relatively inefficient, as increasing the capacitor from $1 \mu \mathrm{~F}$ to $220 \mu \mathrm{~F}$ only decreases the noise from $430 \mu \mathrm{~V}$ to $160 \mu \mathrm{~V}$ rms for a 100 kHz bandwidth at 5 V output. Noise can be reduced fourfold by a bypass capacitor accross $\mathrm{R}_{1}$, since it reduces the high frequency gain from 4 to unity. Pick

$$
\mathrm{C}_{\mathrm{BYPASS}} \cong \frac{1}{2 \pi \mathrm{R}_{1} \cdot 200 \mathrm{~Hz}}
$$

or about $0.01 \mu \mathrm{~F}$. When doing this, the output capacitor must be increased to $3.3 \mu \mathrm{~F}$ to maintain stability. These changes reduce the output noise from $430 \mu \mathrm{~V}$ to $100 \mu \mathrm{~V}$ rms for a 100 kHz bandwidth at 5 V output. With the bypass capacitor added, noise no longer scales with output voltage so that improvements are more dramatic at higher output voltages.


DS008546-7
*See Application Hints
$V_{\text {out }}=V_{\text {Ref }}\left(1+\frac{R_{1}}{R_{2}}\right)$
**Drive with TTL-high to shut down. Ground or leave open if shutdown feature is not to be used.
Note: Pins 2 and 6 are left open.
FIGURE 2. Adjustable Regulator

## Typical Applications



## Typical Applications (Continued)



Typical Applications (Continued)


DS008546-13
$V_{\text {out }}=1.23 \mathrm{~V}\left(1+\frac{\mathrm{R}_{1}}{\mathrm{R}_{2}}\right)$
For $5 \mathrm{~V}_{\text {out, }}$, use internal resistors. Wire pin 6 to 7 , \& wire pin 2 to $+\mathrm{V}_{\text {out }}$ Buss.


Open Circuit Detector for $\mathbf{4} \boldsymbol{\rightarrow} \mathbf{2 0} \mathbf{m A}$ Current Loop

*High input lowers $\mathrm{V}_{\text {out }}$ to 2.5 V

Typical Applications (Continued)


DS008546-16
*Optional Latch off when drop out occurs. Adjust R3 for C 2 Switching when $\mathrm{V}_{\text {in }}$ is 6.0 V .
**Outputs go low when $\mathrm{V}_{\text {in }}$ drops below designated thresholds.


DS008546-17
For values shown, Regulator shuts down when $\mathrm{V}_{\text {in }}<5.5 \mathrm{~V}$ and turns on again at 6.0 V . Current drain in disconnected mode is $\approx 150 \mu \mathrm{~A}$.
*Sets disconnect Voltage
**Sets disconnect Hysteresis

## Typical Applications (Continued)



[^0]Schematic Diagram

$\square$

Physical Dimensions inches (millimeters) unless otherwise noted


Order Number LP2951E/883 or 5962-3870501M2A NS Package Number E20A


Order Number LP2951H/883 or 5962-3870501MGA
NS Package Number H08C

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)


Surface Mount Package (M)
Order Number LP2951ACM, LP2951CM, LP2951ACM-3.0, LP2951CM-3.0, LP2951ACM-3.3 or LP2951CM-3.3

NS Package Number M08A

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)


Molded Dual-In-Line Package ( N )
Order Number LP2951ACN, LP2951CN, LP2951ACN-3.0,
LP2951CN-3.0, or LP2951ACN-3.3 or LP2951CN-3.3
NS Package Number N08E


Molded TO-92 Package (Z)
Order Number LP2950ACZ-3.0 or LP2950CZ-3.0, LP2950ACZ-3.3,
LP2950CZ-3.3, LP2950ACZ-5.0 or LP2950CZ-5.0
NS Package Number Z03A
LP2950/A-XX and LP2951/A-XX Series of Adjustable Micropower Voltage Regulators

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)


Surface Mount Package (MM)
Order Number LP2951ACMM, LP2951CMM, LP2951ACMM-3.0, LP2951CMM-3.0, LP2951ACMM-3.3 or LP2951CMM-3.3 NS Package Number MUA08A

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[^0]:    LM34 for $125^{\circ} \mathrm{F}$ Shutdown
    LM35 for $125^{\circ} \mathrm{C}$ Shutdown

