National Semiconductor

March 2005

# LP2952/LP2952A/LP2953/LP2953A
# Adjustable Micropower Low-Dropout Voltage Regulators

## General Description

The LP2952 and LP2953 are micropower voltage regulators with very low quiescent current (130 µA typical at 1 mA load) and very low dropout voltage (typ. 60 mV at light load and 470 mV at 250 mA load current). They are ideally suited for battery-powered systems. Furthermore, the quiescent current increases only slightly at dropout, which prolongs battery life.

The LP2952 and LP2953 retain all the desirable characteristics of the LP2951, but offer increased output current, additional features, and an improved shutdown function.

The internal crowbar pulls the output down quickly when the shutdown is activated.

The error flag goes low if the output voltage drops out of regulation.

Reverse battery protection is provided.

The internal voltage reference is made available for external use, providing a low-T.C. reference with very good line and load regulation.

The parts are available in DIP and surface mount packages.

## Features

- Output voltage adjusts from 1.23V to 29V
- Guaranteed 250 mA output current
- Extremely low quiescent current
- Low dropout voltage
- Extremely tight line and load regulation
- Very low temperature coefficient
- Current and thermal limiting
- Reverse battery protection
- 50 mA (typical) output pulldown crowbar
- 5V and 3.3V versions available

## LP2953 Versions Only

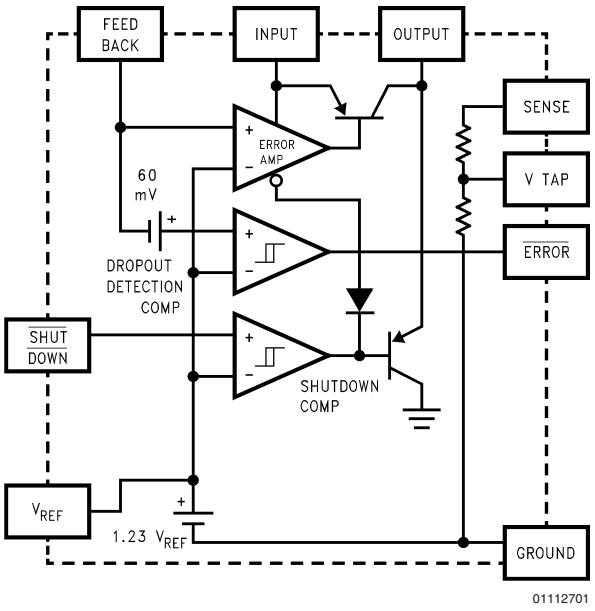
- Auxiliary comparator included with CMOS/TTL compatible output levels. Can be used for fault detection, low input line detection, etc.

## Applications

- High-efficiency linear regulator
- Regulator with under-voltage shutdown
- Low dropout battery-powered regulator
- Snap-ON/Snap-OFF regulator

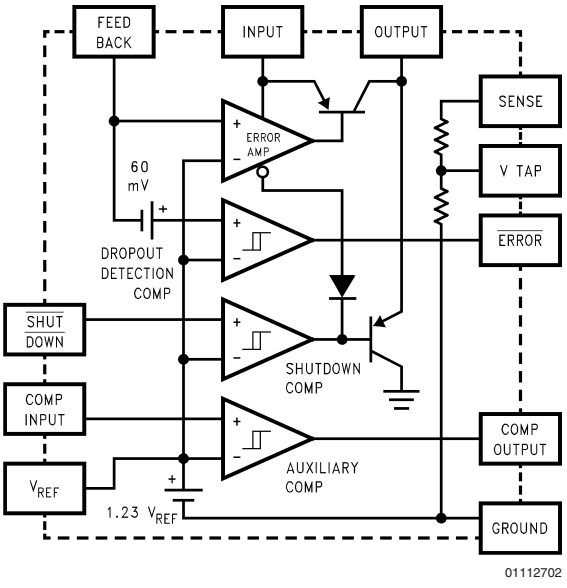
## Block Diagrams

**LP2952**




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**LP2953**

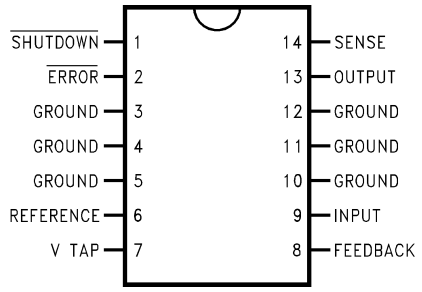



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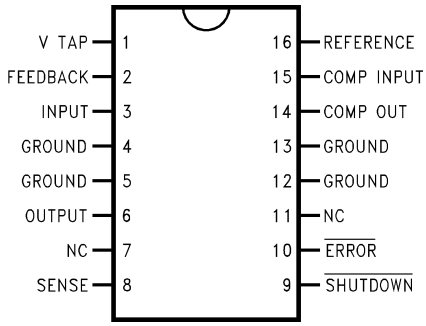
## Pinout Drawings

**LP2952**
**14-Pin DIP**



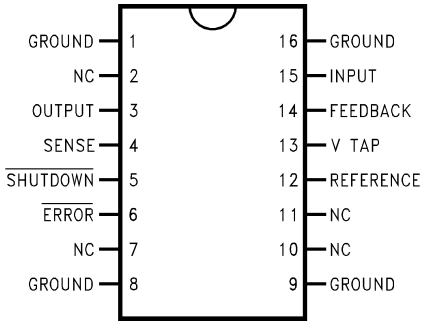

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**LP2953**
**16-Pin DIP**



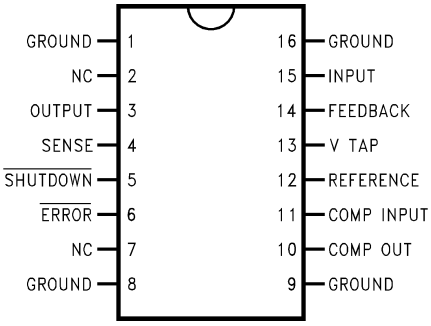

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**LP2952**
**16-Pin SO**




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**LP2953**
**16-Pin SO**




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## Ordering Information

**LP2952**

| Order Number | Temp. Range ($T_J$) °C | Package | NSC Drawing Number |
|---|---|---|---|
| LP2952IN, LP2952AIN, LP2952IN-3.3, LP2952AIN-3.3 | –40 to +125 | 14-Pin Molded DIP | N14A |
| LP2952IM, LP2952AIM, LP2952IM-3.3, LP2952AIM-3.3 | –40 to +125 | 16-Pin Surface Mount | M16A |

**LP2953**

| Order Number | Temp. Range ($T_J$) °C | Package | NSC Drawing Number |
|---|---|---|---|
| LP2953IN, LP2953AIN, LP2953IN-3.3, LP2953AIN-3.3 | –40 to +125 | 16-Pin Molded DIP | N16A |
| LP2953IM, LP2953AIM, LP2953IM-3.3, LP2953AIM-3.3 | –40 to +125 | 16-Pin Surface Mount | M16A |
| LP2953AMJ/883 5962-9233601MEA LP2953AMJ-QMLV 5962-9233601VEA | –55 to +150 | 16-Pin Ceramic DIP | J16A |
| LP2953AMWG/883 5962-9233601QXA LP2953AMWG-QMLV 5962-9233601VXA | –55 to +150 | 16-Pin Ceramic Surface Mount | WG16A |

## Absolute Maximum Ratings (Note 1)

**If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.**

| | |
|---|---|
| Storage Temperature Range | $-65^{\circ}C \le T_A \le +150^{\circ}C$ |
| Operating Temperature Range | |
| LP2952I, LP2953I, LP2952AI, LP2953AI, LP2952I-3.3, LP2953I-3.3, LP2952AI-3.3, LP2953AI-3.3 | $-40^{\circ}C \le T_J \le +125^{\circ}C$ |
| LP2953AM | $-55^{\circ}C \le T_A \le +125^{\circ}C$ |
| Lead Temp. (Soldering, 5 seconds) | 260˚C |
| Power Dissipation (Note 2) | Internally Limited |
| Maximum Junction Temperature | |
| LP2952I, LP2953I, LP2952AI, LP2953AI, LP2952I-3.3, LP2953I-3.3, LP2952AI-3.3, LP2953AI-3.3 | +125˚C |
| LP2953AM | +150˚C |
| Input Supply Voltage | −20V to +30V |
| Feedback Input Voltage (Note 3) | −0.3V to +5V |
| Comparator Input Voltage (Note 4) | −0.3V to +30V |
| Shutdown Input Voltage (Note 4) | −0.3V to +30V |
| Comparator Output Voltage (Note 4) | −0.3V to +30V |
| ESD Rating (Note 15) | 2 kV |

## Electrical Characteristics

Limits in standard typeface are for $T_J$ = 25˚C, **bold typeface** applies over the full operating temperature range. Limits are guaranteed by production testing or correlation techniques using standard Statistical Quality Control (SQC) methods. Unless otherwise specified: $V_{IN} = V_O(NOM) + 1V$, $I_L$ = 1 mA, $C_L$ = 2.2 µF for 5V parts and 4.7µF for 3.3V parts. Feedback pin is tied to V Tap pin, Output pin is tied to Output Sense pin.

### 3.3V Versions

| Symbol | Parameter | Conditions | Typical | LP2952AI-3.3, LP2953AI-3.3 | | LP2952I-3.3, LP2953I-3.3 | | Units |
|---|---|---|---|---|---|---|---|---|
| | | | | Min | Max | Min | Max | |
| $V_O$ | Output Voltage | | 3.3 | 3.284<br>**3.260** | 3.317<br>**3.340** | 3.267<br>**3.234** | 3.333<br>**3.366** | V |
| | | 1 mA ≤ $I_L$ ≤ 250 mA | 3.3 | **3.254** | **3.346** | **3.221** | **3.379** | |

### 5V Versions

| Symbol | Parameter | Conditions | Typical | LP2952AI, LP2953AI, LP2953AM (Note 17) | | LP2952I, LP2953I | | Units |
|---|---|---|---|---|---|---|---|---|
| | | | | Min | Max | Min | Max | |
| $V_O$ | Output Voltage | | 5.0 | 4.975<br>**4.940** | 5.025<br>**5.060** | 4.950<br>**4.900** | 5.050<br>**5.100** | V |
| | | 1 mA ≤ $I_L$ ≤ 250 mA | 5.0 | **4.930** | **5.070** | **4.880** | **5.120** | |

## All Voltage Options

## Electrical Characteristics

Limits in standard typeface are for $T_J$ = 25˚C, **bold typeface** applies over the full operating temperature range. Limits are guaranteed by production testing or correlation techniques using standard Statistical Quality Control (SQC) methods. Unless otherwise specified: $V_{IN} = V_O(NOM) + 1V$, $I_L$ = 1 mA, $C_L$ = 2.2 µF for 5V parts and 4.7µF for 3.3V parts. Feedback pin is tied to V Tap pin, Output pin is tied to Output Sense pin.

| Symbol | Parameter | Conditions | Typical | LP2952AI, LP2953AI, LP2952AI-3.3, LP2953AI-3.3, LP2953AM (Notes 16, 17) | | LP2952I, LP2953I, LP2952I-3.3, LP2953I-3.3 | | Units |
|---|---|---|---|---|---|---|---|---|
| | | | | Min | Max | Min | Max | |
| **REGULATOR** | | | | | | | | |
| $\frac{\Delta V_O}{\Delta T}$ | Output Voltage Temp. Coefficient | (Note 5) | **20** | | **100** | | **150** | ppm/˚C |
| $\frac{\Delta V_O}{V_O}$ | Output Voltage Line Regulation | $V_{IN} = V_O(NOM) + 1V$ to 30V | 0.03 | | 0.1<br>**0.2** | | 0.2<br>**0.4** | % |

## All Voltage Options (Continued)

## Electrical Characteristics (Continued)

Limits in standard typeface are for $T_J$ = 25˚C, **bold typeface** applies over the full operating temperature range. Limits are guaranteed by production testing or correlation techniques using standard Statistical Quality Control (SQC) methods. Unless otherwise specified: $V_{IN} = V_O(NOM) + 1V$, $I_L$ = 1 mA, $C_L$ = 2.2 µF for 5V parts and 4.7µF for 3.3V parts. Feedback pin is tied to V Tap pin, Output pin is tied to Output Sense pin.

| Symbol | Parameter | Conditions | Typical | LP2952AI, LP2953AI, LP2952AI-3.3, LP2953AI-3.3, LP2953AM (Notes 16, 17) | | LP2952I, LP2953I, LP2952I-3.3, LP2953I-3.3 | | Units |
|---|---|---|---|---|---|---|---|---|
| | | | | Min | Max | Min | Max | |
| $\frac{\Delta V_O}{V_O}$ | Output Voltage Load Regulation (Note 6) | $I_L$ = 1 mA to 250 mA | 0.04 | | 0.16 | | 0.20 | % |
| | | $I_L$ = 0.1 mA to 1 mA | | | **0.20** | | **0.30** | |
| $V_{IN}–V_O$ | Dropout Voltage (Note 7) | $I_L$ = 1 mA | 60 | | 100 | | 100 | mV |
| | | | | | **150** | | **150** | |
| | | $I_L$ = 50 mA | 240 | | 300 | | 300 | |
| | | | | | **420** | | **420** | |
| | | $I_L$ = 100 mA | 310 | | 400 | | 400 | |
| | | | | | **520** | | **520** | |
| | | $I_L$ = 250 mA | 470 | | 600 | | 600 | |
| | | | | | **800** | | **800** | |
| $I_{GND}$ | Ground Pin Current (Note 8) | $I_L$ = 1 mA | 130 | | 170 | | 170 | µA |
| | | | | | **200** | | **200** | |
| | | $I_L$ = 50 mA | 1.1 | | 2 | | 2 | mA |
| | | | | | **2.5** | | **2.5** | |
| | | $I_L$ = 100 mA | 4.5 | | 6 | | 6 | |
| | | | | | **8** | | **8** | |
| | | $I_L$ = 250 mA | 21 | | 28 | | 28 | |
| | | | | | **33** | | **33** | |
| $I_{GND}$ | Ground Pin Current at Dropout | $V_{IN} = V_O(NOM) –0.5V$ | 165 | | 210 | | 210 | µA |
| | | $I_L$ = 100 µA | | | **240** | | **240** | |
| $I_{GND}$ | Ground Pin Current at Shutdown (Note 8) | $V_{SHUTDOWN} \leq 1.1V$ | 105 | | 140 | | 140 | µA |
| $I_{LIMIT}$ | Current Limit | $V_{OUT}$ = 0 | 380 | | 500 | | 500 | mA |
| | | | | | **530** | | **530** | |
| $\frac{\Delta V_O}{\Delta Pd}$ | Thermal Regulation | (Note 10) | 0.05 | | 0.2 | | 0.2 | %/W |
| $e_n$ | Output Noise Voltage (10 Hz to 100 kHz) $I_L$ = 100 mA | $C_L$ = 4.7 µF | 400 | | | | | µV RMS |
| | | $C_L$ = 33 µF | 260 | | | | | |
| | | $C_L$ = 33 µF (Note 11) | 80 | | | | | |
| $V_{REF}$ | Reference Voltage | (Note 12) | 1.230 | 1.215 | 1.245 | 1.205 | 1.255 | V |
| | | | | **1.205** | **1.255** | **1.190** | **1.270** | |
| $\frac{\Delta V_{REF}}{V_{REF}}$ | Reference Voltage Line Regulation | $V_{IN} = 2.5V$ to $V_O(NOM) + 1V$ | 0.03 | | 0.1 | | 0.2 | % |
| | | $V_{IN} = V_O(NOM) + 1V$ to 30V (Note 13) | | | **0.2** | | **0.4** | |
| $\frac{\Delta V_{REF}}{V_{REF}}$ | Reference Voltage Load Regulation | $I_{REF}$ = 0 to 200 µA | 0.25 | | 0.4 | | 0.8 | % |
| | | | | | **0.6** | | **1.0** | |
| $\frac{\Delta V_{REF}}{\Delta T}$ | Reference Voltage Temp. Coefficient | (Note 5) | **20** | | | | | ppm/˚C |

## All Voltage Options (Continued)

## Electrical Characteristics (Continued)

Limits in standard typeface are for $T_J$ = 25˚C, **bold typeface** applies over the full operating temperature range. Limits are guaranteed by production testing or correlation techniques using standard Statistical Quality Control (SQC) methods. Unless otherwise specified: $V_{IN} = V_O$(NOM) + 1V, $I_L$ = 1 mA, $C_L$ = 2.2 µF for 5V parts and 4.7µF for 3.3V parts. Feedback pin is tied to V Tap pin, Output pin is tied to Output Sense pin.

| Symbol | Parameter | Conditions | | Typical | LP2952AI, LP2953AI, LP2952AI-3.3, LP2953AI-3.3, LP2953AM (Notes 16, 17) | | LP2952I, LP2953I, LP2952I-3.3, LP2953I-3.3 | | Units |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Min | Max | Min | Max | |
| $I_B$(FB) | Feedback Pin Bias Current | | | 20 | | 40<br>**60** | | 40<br>**60** | nA |
| $I_O$(SINK) | Output "OFF" Pulldown Current | (Note 9) | | | 30<br>**20** | | 30<br>**20** | | mA |
| **DROPOUT DETECTION COMPARATOR** | | | | | | | | | |
| $I_{OH}$ | Output "HIGH" Leakage | $V_{OH}$ = 30V | | 0.01 | | 1<br>**2** | | 1<br>**2** | µA |
| $V_{OL}$ | Output "LOW" Voltage | $V_{IN} = V_O$(NOM) – 0.5V<br>$I_O$(COMP) = 400 µA | | 150 | | 250<br>**400** | | 250<br>**400** | mV |
| $V_{THR}$ (MAX) | Upper Threshold Voltage | (Note 14) | | –60 | –80<br>**–95** | –35<br>**–25** | –80<br>**–95** | –35<br>**–25** | mV |
| $V_{THR}$ (MIN) | Lower Threshold Voltage | (Note 14) | | –85 | –110<br>**–160** | –55<br>**–40** | –110<br>**–160** | –55<br>**–40** | mV |
| HYST | Hysteresis | (Note 14) | | 15 | | | | | mV |
| **$\overline{\text{SHUTDOWN}}$ INPUT** (Note 15) | | | | | | | | | |
| $V_{OS}$ | Input Offset Voltage | (Referred to $V_{REF}$) | | ±3 | –7.5<br>**–10** | 7.5<br>**10** | –7.5<br>**–10** | 7.5<br>**10** | mV |
| HYST | Hysteresis | | | 6 | | | | | mV |
| $I_B$ | Input Bias Current | $V_{IN}$(S/D) = 0V to 5V | | 10 | –30<br>**–50** | 30<br>**50** | –30<br>**–50** | –30<br>**50** | nA |
| | | | LP2953AM | 10 | –30<br>**–75** | 30<br>**75** | | | |
| **AUXILIARY COMPARATOR (LP2953 Only)** | | | | | | | | | |
| $V_{OS}$ | Input Offset Voltage | (Referred to $V_{REF}$) | | ±3 | –7.5<br>**–10** | 7.5<br>**10** | –7.5<br>**–10** | 7.5<br>**10** | mV |
| | | | LP2953AM | ±3 | –7.5<br>**–12** | 7.5<br>**12** | | | |
| HYST | Hysteresis | | | 6 | | | | | mV |
| $I_B$ | Input Bias Current | $V_{IN}$(COMP) = 0V to 5V | | 10 | –30<br>**–50** | 30<br>**50** | –30<br>**–50** | 30<br>**50** | nA |
| | | | LP2953AM | 10 | –30<br>**–75** | 30<br>**75** | | | |
| $I_{OH}$ | Output "HIGH" Leakage | $V_{OH}$ = 30V<br>$V_{IN}$(COMP) = 1.3V | | 0.01 | | 1<br>**2** | | 1<br>**2** | µA |
| | | | LP2953AM | 0.01 | | 1<br>**2.2** | | | |
| $V_{OL}$ | Output "LOW" Voltage | $V_{IN}$(COMP) = 1.1V<br>$I_O$(COMP) = 400 µA | | 150 | | 250<br>**400** | | 250<br>**400** | mV |
| | | | LP2953AM | 150 | | 250<br>**420** | | | |

## All Voltage Options (Continued)

## Electrical Characteristics (Continued)

**Note 1:** Absolute maximum ratings indicate limits beyond which damage to the component may occur. Electrical specifications do not apply when operating the device outside of its rated operating conditions.

**Note 2:** The maximum allowable power dissipation is a function of the maximum junction temperature, $T_J$(MAX), the junction-to-ambient thermal resistance, $\theta_{J-A}$, and the ambient temperature, $T_A$. The maximum allowable power dissipation at any ambient temperature is calculated using the equation for P(MAX),

$$P\ (MAX) = \frac{T_J(MAX) - T_A}{\theta_{J-A}}.$$

.

Exceeding the maximum allowable power dissipation will cause excessive die temperature, and the regulator will go into thermal shutdown. See APPLICATION HINTS for additional information on heatsinking and thermal resistance.

**Note 3:** When used in dual-supply systems where the regulator load is returned to a negative supply, the output voltage must be diode-clamped to ground.

**Note 4:** May exceed the input supply voltage.

**Note 5:** Output or reference voltage temperature coefficient is defined as the worst case voltage change divided by the total temperature range.

**Note 6:** Load regulation is measured at constant junction temperature using low duty cycle pulse testing. Two separate tests are performed, one for the range of 100 µA to 1 mA and one for the 1 mA to 250 mA range. Changes in output voltage due to heating effects are covered by the thermal regulation specification.

**Note 7:** Dropout voltage is defined as the input to output differential at which the output voltage drops 100 mV below the value measured with a 1V differential. At very low values of programmed output voltage, the input voltage minimum of 2V (2.3V over temperature) must be observed.

**Note 8:** Ground pin current is the regulator quiescent current. The total current drawn from the source is the sum of the ground pin current, output load current, and current through the external resistive divider (if used).

**Note 9:** $V_{SHUTDOWN} \leq 1.1V$, $V_{OUT} = V_O$(NOM).

**Note 10:** Thermal regulation is the change in output voltage at a time T after a change in power dissipation, excluding load or line regulation effects. Specifications are for a 200 mA load pulse at $V_{IN} = V_O$(NOM)+15V (3W pulse) for T = 10 ms.

**Note 11:** Connect a 0.1 µF capacitor from the output to the feedback pin.

**Note 12:** $V_{REF} \leq V_{OUT} \leq (V_{IN} - 1V)$, $2.3V \leq V_{IN} \leq 30V$, $100\ \mu A \leq I_L \leq 250$ mA.

**Note 13:** Two separate tests are performed, one covering $2.5V \leq V_{IN} \leq V_O$(NOM)+1V and the other test for $V_O$(NOM)+1V $\leq V_{IN} \leq 30V$.

**Note 14:** Comparator thresholds are expressed in terms of a voltage differential at the Feedback terminal below the nominal reference voltage measured at$V_{IN} = V_O$(NOM) + 1V. To express these thresholds in terms of output voltage change, multiply by the Error amplifier gain, which is $V_{OUT}/V_{REF}$ = (R1 + R2)/R2(refer to *Figure 4*).

**Note 15:** Human body model, 200 pF discharged through 1.5 kΩ.

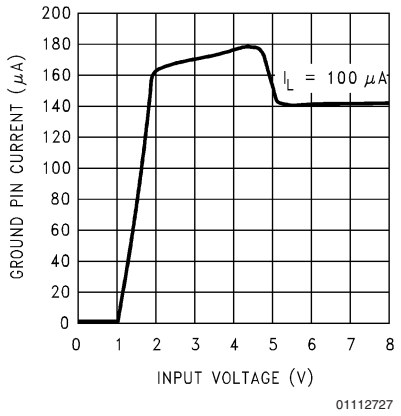
**Note 16:** Drive $\overline{\text{Shutdown}}$ pin with TTL or CMOS-low level to shut regulator OFF, high level to turn regulator ON.

**Note 17:** A military RETS specification is available upon request. For more information on military products, please refer to the Mil-Aero web page at http://www.national.com/appinfo/milaero/index.html.

# Typical Performance Characteristics

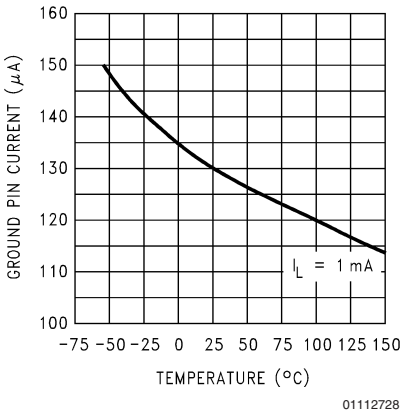
Unless otherwise specified: $V_{IN}$ = 6V, $I_L$ = 1 mA, $C_L$ = 2.2 µF, $V_{SD}$ = 3V, $T_A$ = 25˚C, $V_{OUT}$ = 5V.

**Quiescent Current**



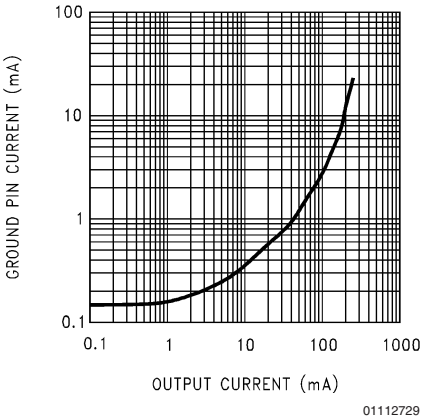

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**Quiescent Current**



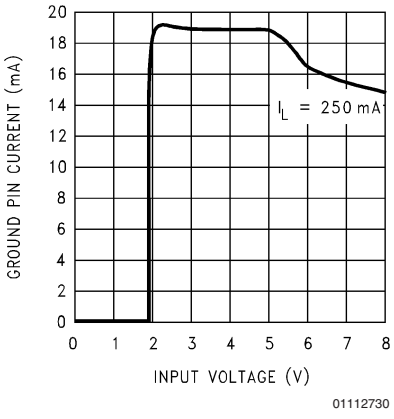

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**Ground Pin Current vs Load**



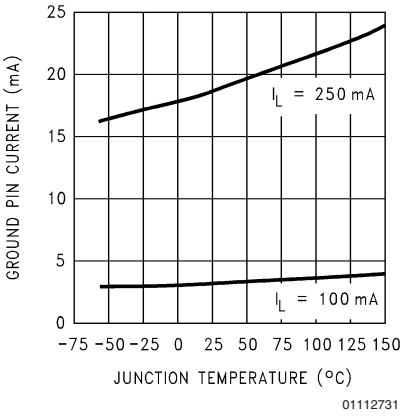

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**Ground Pin Current**



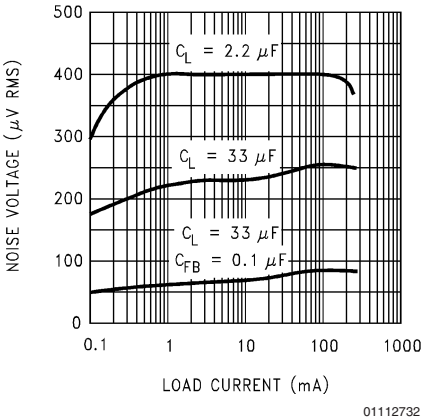

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**Ground Pin Current**




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**Output Noise Voltage**

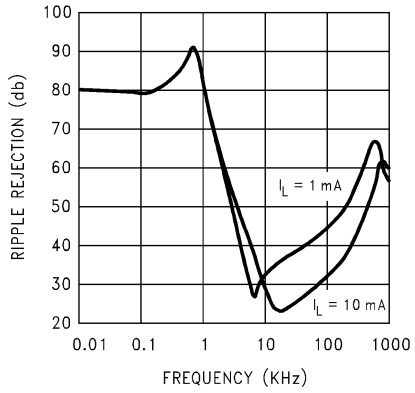



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## Typical Performance Characteristics

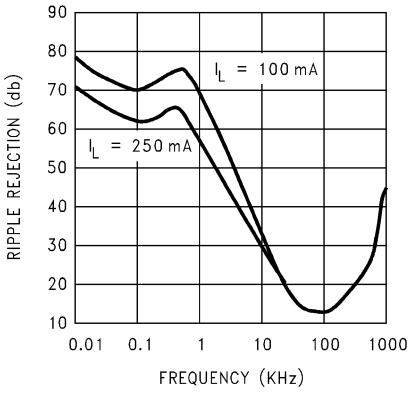
Unless otherwise specified: $V_{IN}$ = 6V, $I_L$ = 1 mA, $C_L$ = 2.2 µF, $V_{SD}$ = 3V, $T_A$ = 25˚C, $V_{OUT}$ = 5V. (Continued)

**Ripple Rejection**



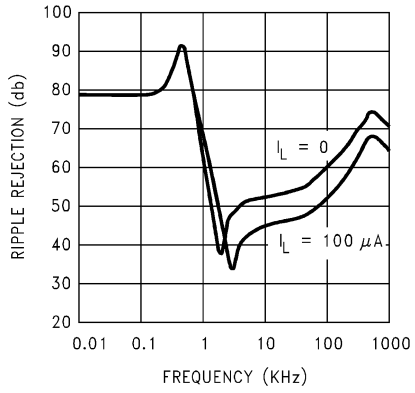

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**Ripple Rejection**



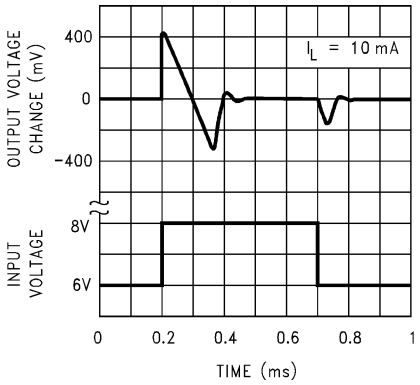

01112734

**Ripple Rejection**



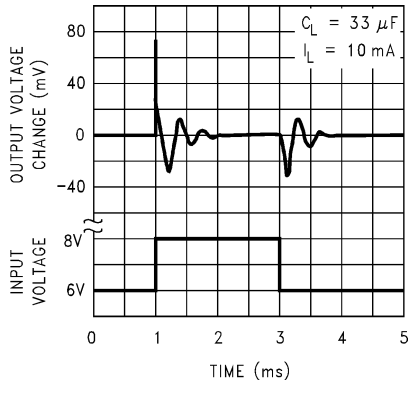

01112735

**Line Transient Response**



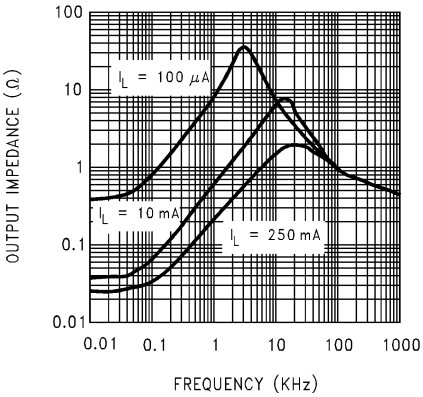

01112736

**Line Transient Response**




01112737

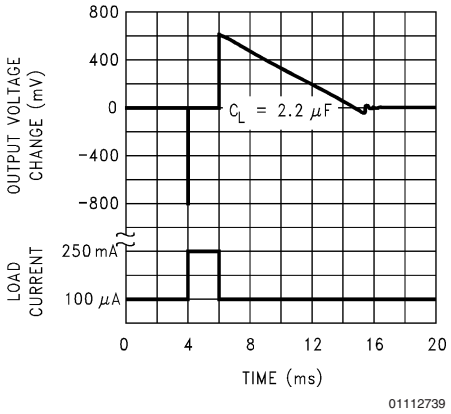
**Output Impedance**




01112738

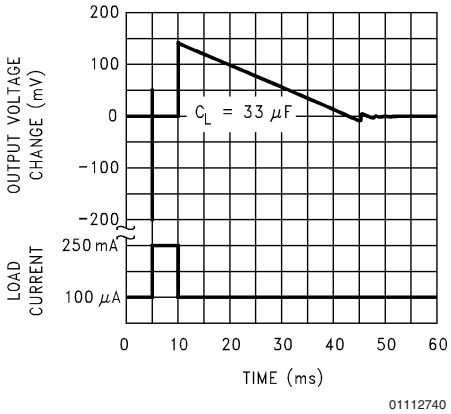
## Typical Performance Characteristics Unless otherwise specified: $V_{IN}$ = 6V, $I_L$ = 1 mA, $C_L$ = 2.2 µF, $V_{SD}$ = 3V, $T_A$ = 25˚C, $V_{OUT}$ = 5V. (Continued)

**Load Transient Response**



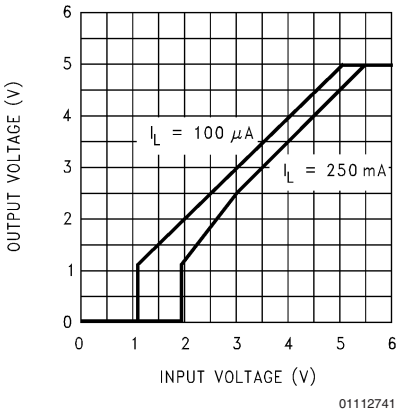

01112739

**Load Transient Response**



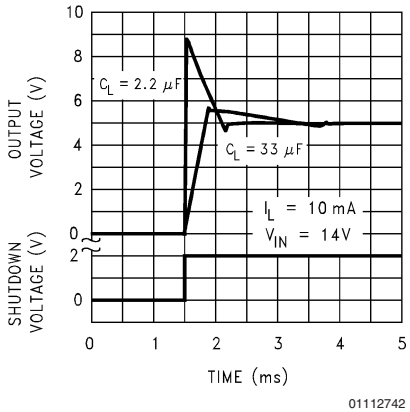

01112740

**Dropout Characteristics**



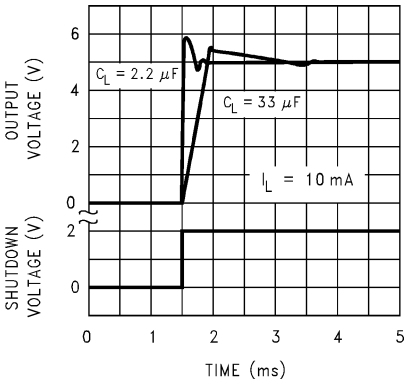

01112741

**Enable Transient**



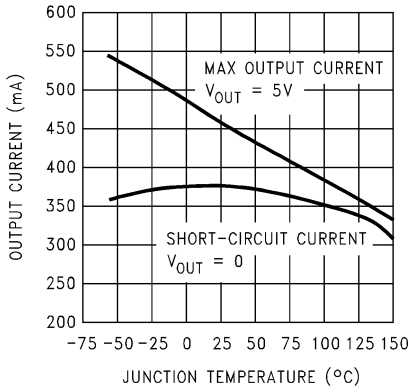

01112742

**Enable Transient**




01112743

**Short-Circuit Output Current and Maximum Output Current**

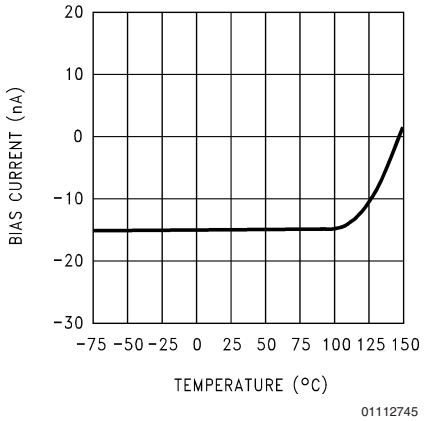



01112744

## Typical Performance Characteristics

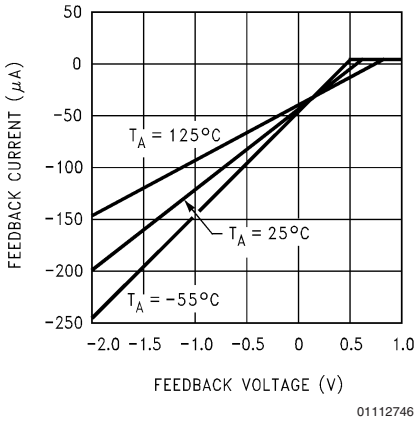
Unless otherwise specified: $V_{IN}$ = 6V, $I_L$ = 1 mA, $C_L$ = 2.2 µF, $V_{SD}$ = 3V, $T_A$ = 25˚C, $V_{OUT}$ = 5V. (Continued)

**Feedback Bias Current**



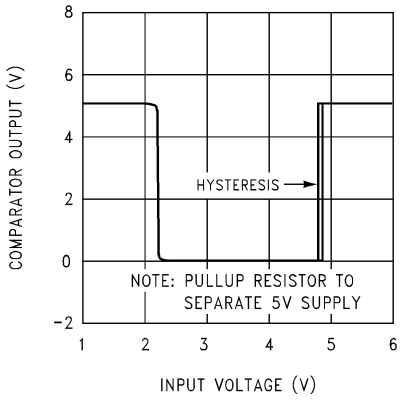

01112745

**Feedback Pin Current**



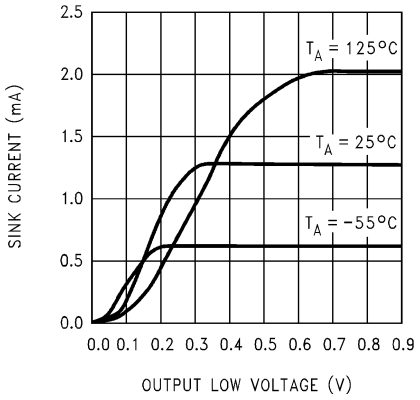

01112746

**Error Output**



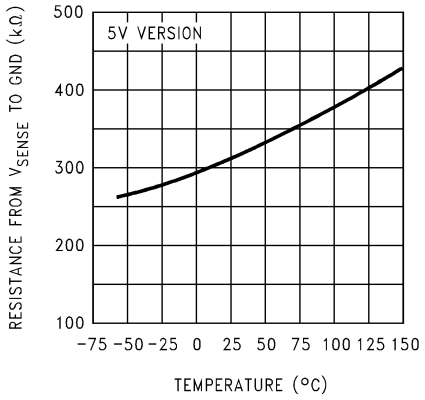

01112747

**Comparator Sink Current**



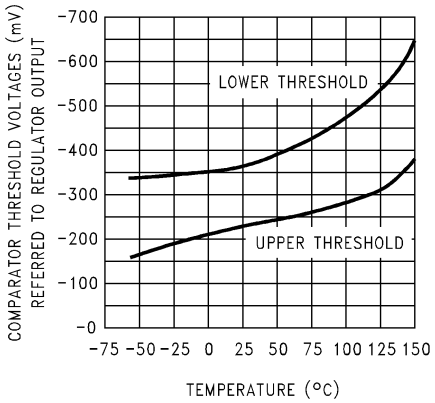

01112748

**Divider Resistance**




01112749

**Dropout Detection Comparator Threshold Voltages**

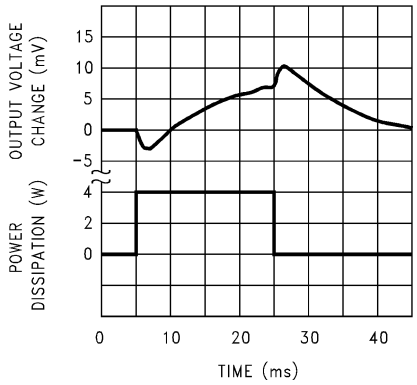



01112750

## Typical Performance Characteristics

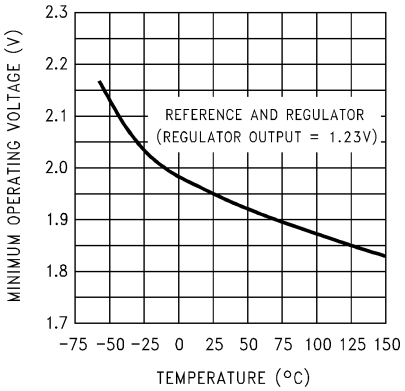
Unless otherwise specified: $V_{IN}$ = 6V, $I_L$ = 1 mA, $C_L$ = 2.2 µF, $V_{SD}$ = 3V, $T_A$ = 25˚C, $V_{OUT}$ = 5V. (Continued)

**Thermal Regulation**



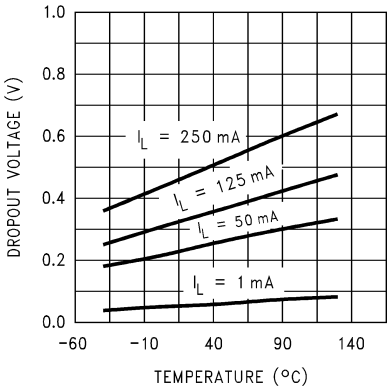

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**Minimum Operating Voltage**



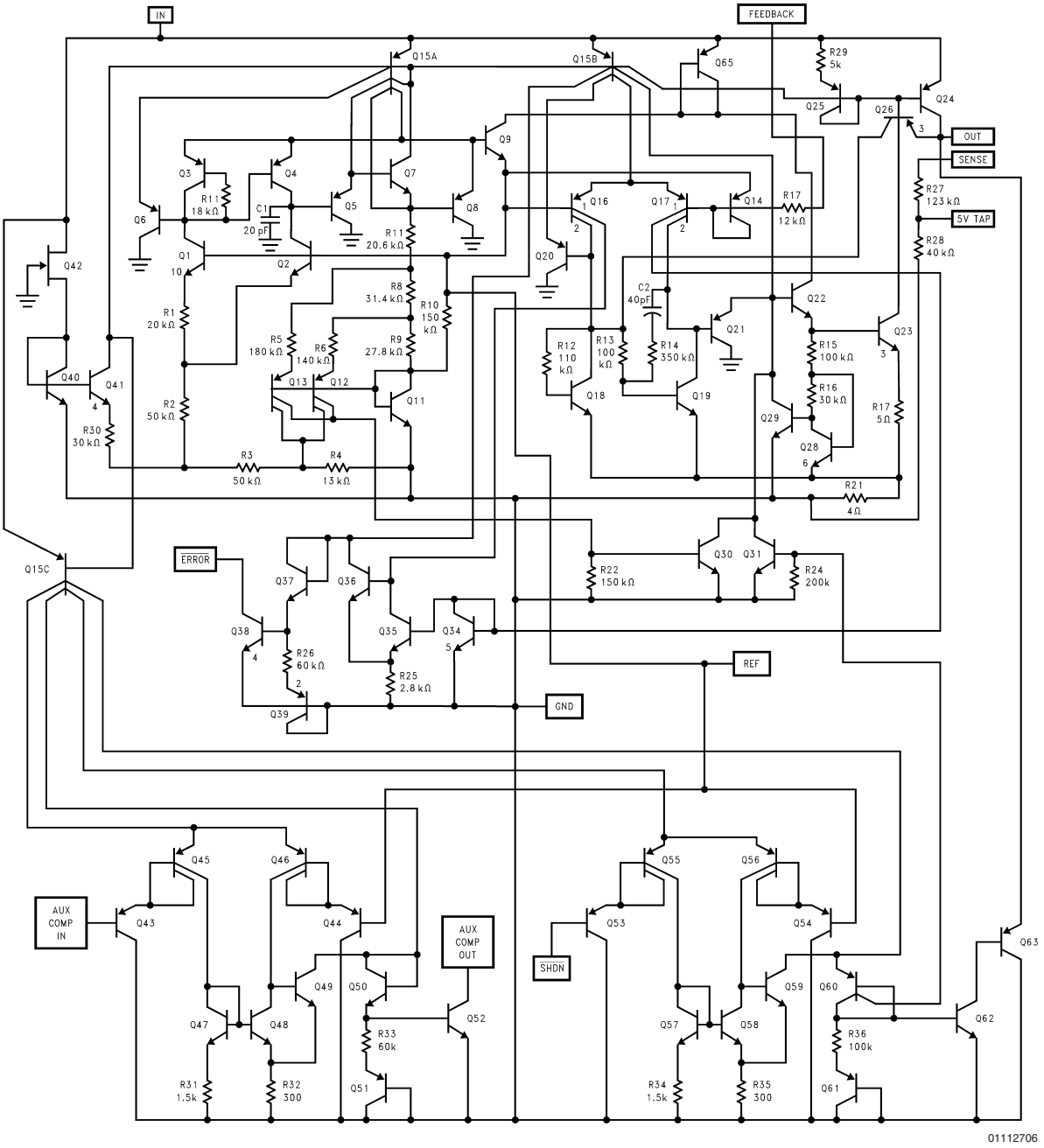

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**Dropout Voltage**




01112753

## Schematic Diagram




## Application Hints

**HEATSINK REQUIREMENTS (Industrial Temperature Range Devices)**

The maximum allowable power dissipation for the LP2952/LP2953 is limited by the maximum junction temperature (+125˚C) and the external factors that determine how quickly heat flows away from the part: the *ambient temperature* and the *junction-to-ambient thermal resistance* for the specific application.

The industrial temperature range (–40˚C ≤ $T_J$ ≤ +125˚C) parts are manufactured in plastic DIP and surface mount packages which contain a copper lead frame that allows heat to be effectively conducted away from the die, through the ground pins of the IC, and into the copper of the PC board. Details on heatsinking using PC board copper are covered later.

To determine if a heatsink is required, the maximum power dissipated by the regulator, P(max), must be calculated. It is important to remember that if the regulator is powered from a transformer connected to the AC line, the **maximum specified AC input voltage** must be used (since this produces the maximum DC input voltage to the regulator). *Figure 1* shows the voltages and currents which are present in the circuit. The formula for calculating the power dissipated in the regulator is also shown in *Figure 1*:

## Application Hints (Continued)

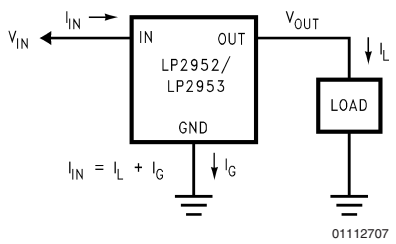



**FIGURE 1. $P_{TOTAL} = (V_{IN} - V_{OUT})\, I_L + (V_{IN})\, I_G$ Current/Voltage Diagram**

The next parameter which must be calculated is the maximum allowable temperature rise, $T_R$(max). This is calculated by using the formula:

$$T_R(\text{max}) = T_J(\text{max}) - T_A(\text{max})\theta_{(J-A)} = T_R(\text{max})/P(\text{max})$$

where: $T_J$(max) is the maximum allowable junction temperature

$T_A$(max) is the maximum ambient temperature

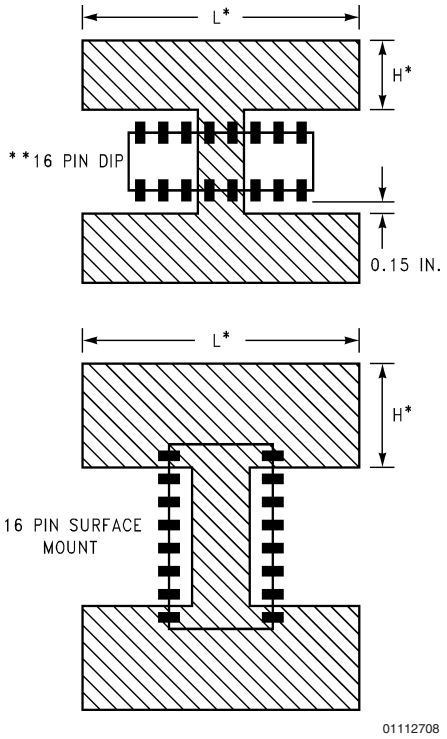
Using the calculated values for $T_R$(max) and P(max), the required value for junction-to-ambient thermal resistance, $\theta_{(J-A)}$, can now be found:

The heatsink is made using the PC board copper. The heat is conducted from the die, through the lead frame (inside the part), and out the pins which are soldered to the PC board. The pins used for heat conduction are given in *Table 1*.

**TABLE 1. Heat Conducting Pins**

| Part | Package | Pins |
|---|---|---|
| LP2952IN, LP2952AIN, LP2952IN-3.3, LP2952AIN-3.3 | 14-Pin DIP | 3, 4, 5, 10, 11, 12 |
| LP2953IN, LP2953AIN, LP2953IN-3.3, LP2953AIN-3.3 | 16-Pin DIP | 4, 5, 12, 13 |
| LP2952IM, LP2952AIM, LP2952IM-3.3, LP2952AIM-3.3, LP2953IM, LP2953AIM, LP2953IM-3.3, LP2953AIM-3.3 | 16-Pin Surface Mount | 1, 8, 9, 16 |

*Figure 2* shows copper patterns which may be used to dissipate heat from the LP2952 and LP2953. *Table 2* shows some values of junction-to-ambient thermal resistance ($\theta_{J-A}$) for values of L and W for 1 oz. copper.




* For best results, use L = 2H

** 14-Pin DIP is similar, refer to *Table 1* for pins designated for heatsinking.

**FIGURE 2. Copper Heatsink Patterns**

**TABLE 2. Thermal Resistance for Various Copper Heatsink Patterns**

| Package | L (in.) | H (in.) | $\theta_{J-A}$ (°C/W) |
|---|---|---|---|
| 16-Pin DIP | 1 | 0.5 | 70 |
| | 2 | 1 | 60 |
| | 3 | 1.5 | 58 |
| | 4 | 0.19 | 66 |
| | 6 | 0.19 | 66 |
| 14-Pin DIP | 1 | 0.5 | 65 |
| | 2 | 1 | 51 |
| | 3 | 1.5 | 49 |
| Surface Mount | 1 | 0.5 | 83 |
| | 2 | 1 | 70 |
| | 3 | 1.5 | 67 |
| | 6 | 0.19 | 69 |
| | 4 | 0.19 | 71 |
| | 2 | 0.19 | 73 |

**HEATSINK REQUIREMENTS (Military Temperature Range Devices)**

The maximum allowable power dissipation for the LP2953AMJ is limited by the maximum junction temperature (+150˚C) and the two parameters that determine how quickly heat flows away from the die: *the ambient temperature and the junction-to-ambient thermal resistance of the part*.

## Application Hints (Continued)

The military temperature range (−55˚C ≤ $T_J$ ≤+150˚C) parts are manufactured in ceramic DIP packages which contain a KOVAR lead frame (unlike the industrial parts, which have a copper lead frame). The KOVAR material is necessary to attain the hermetic seal required in military applications.

The KOVAR lead frame does not conduct heat as well as copper, which means that the PC board copper can not be used to significantly reduce the overall junction-to-ambient thermal resistance in applications using the LP2953AMJ part.

The power dissipation calculations for military applications are done exactly the same as was detailed in the previous section, with one important exception: the value for $\theta_{(J-A)}$, the junction-to-ambient thermal resistance, is fixed at 95˚C/W and can not be changed by adding copper foil patterns to the PC board. This leads to an important fact: The *maximum allowable power dissipation in any application using the LP2953AMJ is dependent only on the ambient temperature:*

$$P(max) = T_{R(max)} / \theta_{(J-A)}$$

$$P(max) = \frac{T_{J(max)} - T_{A(max)}}{\theta_{(J-A)}}$$

$$P(max) = \frac{150 - T_{A(max)}}{95}$$

*Figure 3* shows a graph of maximum allowable power dissipation vs. ambient temperature for the LP2953AMJ, made using the 95˚C/W value for $\theta_{(J-A)}$ and assuming a maximum junction temperature of 150˚C (caution: the *maximum* ambient temperature which will be reached in a given application must always be used to calculate maximum allowable power dissipation).

### EXTERNAL CAPACITORS

A 2.2 µF (or greater) capacitor is required between the output pin and ground to assure stability when the output is set to 5V. Without this capacitor, the part will oscillate. Most type of tantalum or aluminum electrolytics will work here. Film types will work, but are more expensive. Many aluminum electrolytics contain electrolytes which freeze at –30˚C, which requires the use of solid tantalums below –25˚C. The important parameters of the capacitor are an ESR of about 5Ω or less and a resonant frequency above 500 kHz (the ESR may increase by a factor of **20** or **30** as the temperature is reduced from 25˚C to –30˚C). 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 0.68 µF for currents below 10 mA or 0.22 µF for currents below 1 mA.

Programming the output for voltages below 5V runs the error amplifier at lower gains requiring *more* output capacitance for stability. At 3.3V output, a minimum of 4.7 µF is required. For the worst-case condition of 1.23V output and 250 mA of load current, a 6.8 µF (or larger) capacitor should be used.

A 1 µF capacitor should be placed from the input pin to ground if there is more than 10 inches of wire between the input and the AC filter capacitor or if a battery input is used.

Stray capacitance to the Feedback terminal can cause instability. This problem is most likely to appear when using high value external resistors to set the output voltage. Adding a 100 pF capacitor between the Output and Feedback pins and increasing the output capacitance to 6.8 µF (or greater) will cure the problem.

### MINIMUM LOAD

When setting the output voltage using an external resistive divider, a minimum current of 1 µA is recommended through the resistors to provide a minimum load.

It should be noted that a minimum load current is specified in several of the electrical characteristic test conditions, so this value must be used to obtain correlation on these tested limits.

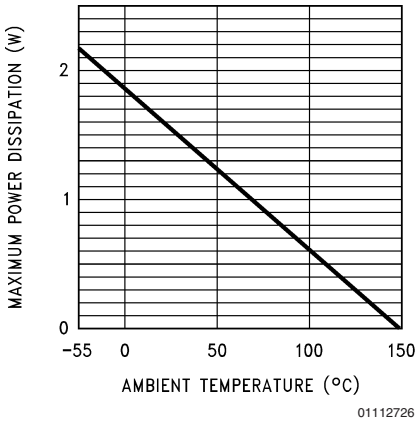



**FIGURE 3. Power Derating Curve for LP2953AMJ**

### PROGRAMMING THE OUTPUT VOLTAGE

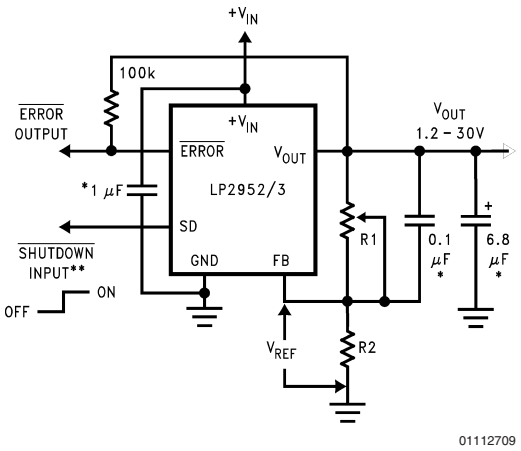
The regulator may be pin-strapped for 5V operation using its internal resistive divider by tying the Output and Sense pins together and also tying the Feedback and 5V Tap pins together.

Alternatively, it may be programmed for any voltage between the 1.23V reference and the 30V maximum rating using an external pair of resistors (see *Figure 4*). The complete equation for the output voltage is:

$$V_{OUT} = V_{REF} \times \left(1 + \frac{R1}{R2}\right) + (I_{FB} \times R1)$$

where $V_{REF}$ is the 1.23V reference and $I_{FB}$ is the Feedback pin bias current (–20 nA typical). The minimum recommended load current of 1 µA sets an upper limit of 1.2 MΩ on the value of R2 in cases where the regulator must work with no load (see **MINIMUM LOAD** ). $I_{FB}$ will produce a typical 2% error in $V_{OUT}$ which can be eliminated at room temperature by trimming R1. For better accuracy, choosing R2 = 100 kΩ will reduce this error to 0.17% while increasing the resistor program current to 12 µA. Since the typical quiescent current is 120 µA, this added current is negligible.

## Application Hints (Continued)

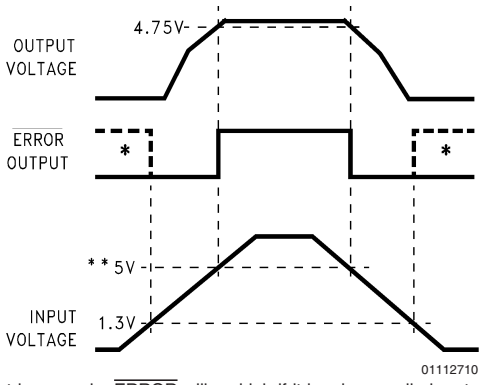



* See Application Hints

** Drive with TTL-low to shut down

**FIGURE 4. Adjustable Regulator**

down the error flag voltage using equal-value resistors (10 kΩ suggested) to ensure a low-level logic signal during any fault condition, while still allowing a valid high logic level during normal operation.




* In shutdown mode, $\overline{\text{ERROR}}$ will go high if it has been pulled up to an external supply. To avoid this invalid response, pull up to regulator output.

** Exact value depends on dropout voltage. (See Application Hints)

**FIGURE 5. $\overline{\text{ERROR}}$ Output Timing**

### DROPOUT VOLTAGE

The dropout voltage of the regulator is defined as the minimum input-to-output voltage differential required for the output voltage to stay within 100 mV of the output voltage measured with a 1V differential. The dropout voltage is independent of the programmed output voltage.

### DROPOUT DETECTION COMPARATOR

This comparator produces a logic "LOW" whenever the output falls out of regulation by more than about 5%. This figure results from the comparator's built-in offset of 60 mV divided by the 1.23V reference (refer to block diagrams on page 1). The 5% low trip level remains constant regardless of the programmed output voltage. An out-of-regulation condition can result from low input voltage, current limiting, or thermal limiting.

*Figure 5* gives a timing diagram showing the relationship between the output voltage, the $\overline{\text{ERROR}}$ output, and input voltage as the input voltage is ramped up and down to a regulator programmed for 5V output. The $\overline{\text{ERROR}}$ signal becomes low at about 1.3V input. It goes high at about 5V input, where the output equals 4.75V. Since the dropout voltage is load dependent, the **input** voltage trip points will vary with load current. The **output** voltage trip point does not vary.

The comparator has an open-collector output which requires an external pull-up resistor. This resistor may be connected to the regulator output or some other supply voltage. Using the regulator output prevents an invalid "HIGH" on the comparator output which occurs if it is pulled up to an external voltage while the regulator input voltage is reduced below 1.3V. In selecting a value for the pull-up resistor, note that while the output can sink 400 μA, this current adds to battery drain. Suggested values range from 100 kΩ to 1 MΩ. This resistor is not required if the output is unused.

When $V_{IN} \leq 1.3V$, the error flag pin becomes a high impedance, allowing the error flag voltage to rise to its pull-up voltage. Using $V_{OUT}$ as the pull-up voltage (rather than an external 5V source) will keep the error flag voltage below 1.2V (typical) in this condition. The user may wish to divide

### OUTPUT ISOLATION

The regulator output can be left connected to an active voltage source (such as a battery) with the regulator input power shut off, **as long as the regulator ground pin is connected to ground.** If the ground pin is left floating, **damage to the regulator can occur** if the output is pulled up by an external voltage source.

### REDUCING OUTPUT NOISE

In reference applications it may be advantageous to reduce the AC noise present on the output. One method is to reduce regulator bandwidth by increasing output capacitance. This is relatively inefficient, since large increases in capacitance are required to get significant improvement.

Noise can be reduced more effectively by a bypass capacitor placed across R1 (refer to *Figure 4*). The formula for selecting the capacitor to be used is:

$$C_B = \frac{1}{2\pi\ R1 \times 20\ Hz}$$

This gives a value of about 0.1 μF. When this is used, the output capacitor must be 6.8 μF (or greater) to maintain stability. The 0.1 μF capacitor reduces the high frequency gain of the circuit to unity, lowering the output noise from 260 μV to 80 μV using a 10 Hz to 100 kHz bandwidth. Also, noise is no longer proportional to the output voltage, so improvements are more pronounced at high output voltages.

### AUXILIARY COMPARATOR (LP2953 only)

The LP2953 contains an auxiliary comparator whose inverting input is connected to the 1.23V reference. The auxiliary comparator has an open-collector output whose electrical characteristics are similar to the dropout detection comparator. The non-inverting input and output are brought out for external connections.

## Application Hints (Continued)

### SHUTDOWN INPUT

A logic-level signal will shut off the regulator output when a "LOW" (<1.2V) is applied to the Shutdown input.

To prevent possible mis-operation, the Shutdown input must be actively terminated. If the input is driven from open-collector logic, a pull-up resistor (20 kΩ to 100 kΩ recommended) should be connected from the Shutdown input to the regulator input.

If the Shutdown input is driven from a source that actively pulls high and low (like an op-amp), the pull-up resistor is not required, but may be used.

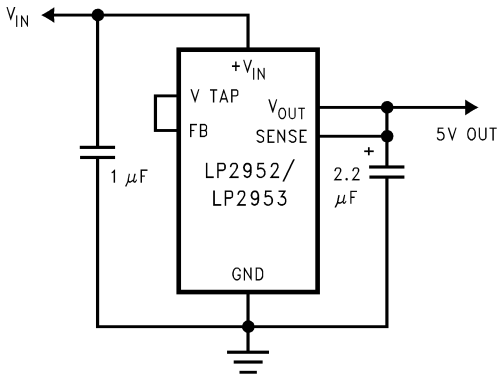
If the shutdown function is not to be used, the cost of the pull-up resistor can be saved by simply tying the Shutdown input directly to the regulator input.

**IMPORTANT:** Since the Absolute Maximum Ratings state that the Shutdown input can not go more than 0.3V below ground, the reverse-battery protection feature which protects the regulator input is sacrificed if the Shutdown input is tied directly to the regulator input.

If reverse-battery protection is required in an application, *the pull-up resistor between the Shutdown input and the regulator input must be used.*

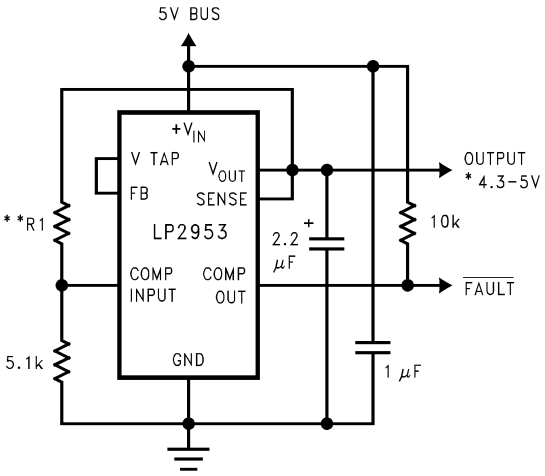
## Typical Applications

**Basic 5V Regulator**




01112715

**5V Current Limiter with Load Fault Indicator**

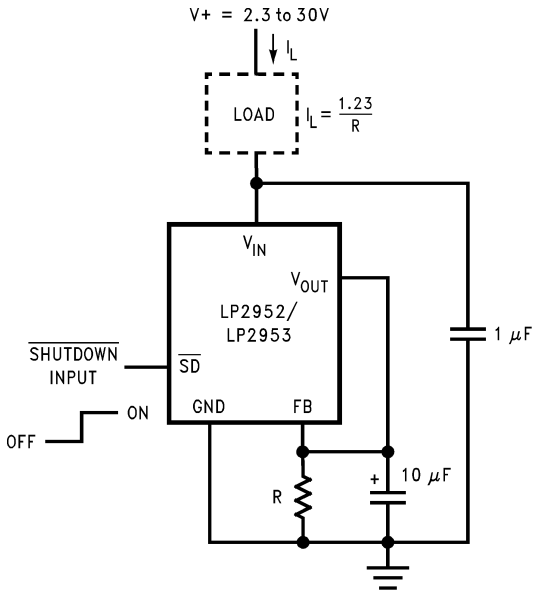



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* Output voltage equals $+V_{IN}$ minum dropout voltage, which varies with output current. Current limits at a maximum of 380 mA (typical).

** Select R1 so that the comparator input voltage is 1.23V at the output voltage which corresponds to the desired fault current value.

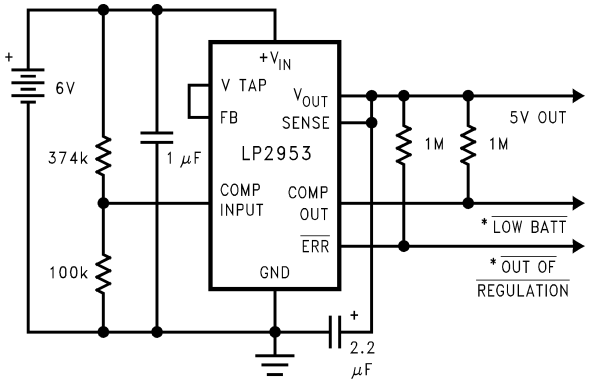
**Low T.C. Current Sink**




01112717

## Typical Applications (Continued)

**5V Regulator with Error Flags for LOW BATTERY and OUT OF REGULATION**

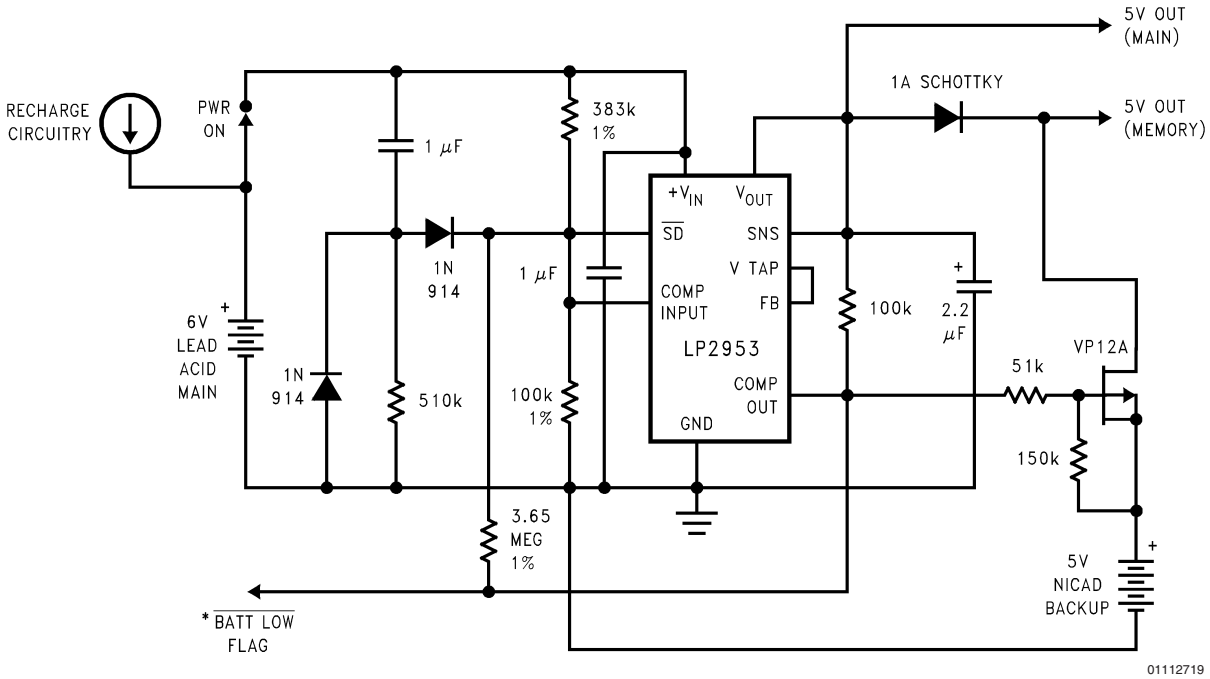



* Connect to Logic or μP control inputs.

LOW BATT flag warns the user that the battery has discharged down to about 5.8V, giving the user time to recharge the battery or power down some hardware with high power requirements. The output is still in regulation at this time.

OUT OF REGULATION flag indicates when the battery is almost completely discharged, and can be used to initiate a power-down sequence.

**5V Battery Powered Supply with Backup and Low Battery Flag**



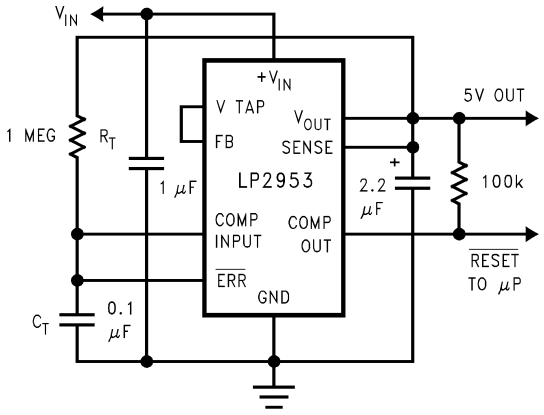

The circuit switches to the NI-CAD backup battery when the main battery voltage drops below about 5.6V, and returns to the main battery when its voltage is recharged to about 6V.

The 5V MAIN output powers circuitry which requires no backup, and the 5V MEMORY output powers critical circuitry which can not be allowed to lose power.

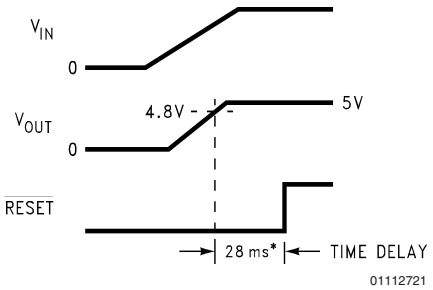
* The $\overline{\text{BATTERY LOW}}$ flag goes low whenever the circuit switches to the NI-CAD backup battery.

## Typical Applications (Continued)

### 5V Regulator with Timed Power-On Reset

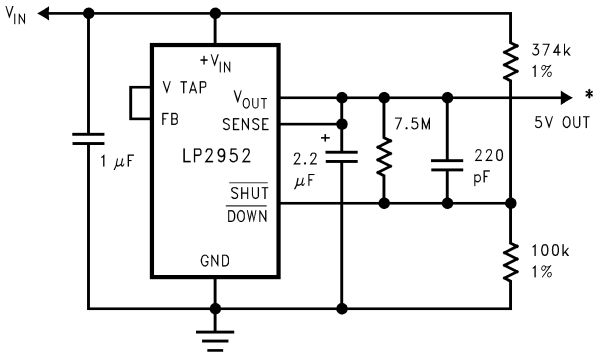



### Timing Diagram for Timed Power-On Reset



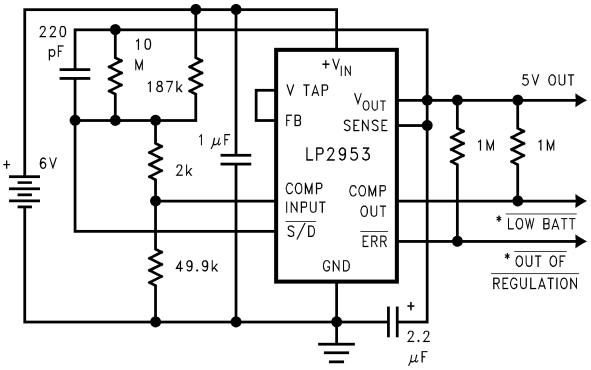

* $R_T$ = 1 MEG, $C_T$ = 0.1 μF

### 5V Regulator with Snap-On/Snap-Off Feature and Hysteresis




* Turns ON at $V_{IN}$ = 5.87V
Turns OFF at $V_{IN}$ = 5.64V
(for component values shown)

### 5V Regulator with Error Flags for LOW BATTERY and OUT OF REGULATION with SNAP-ON/SNAP-OFF Output




* Connect to Logic or μP control inputs.

OUTPUT has SNAP-ON/SNAP-OFF feature.

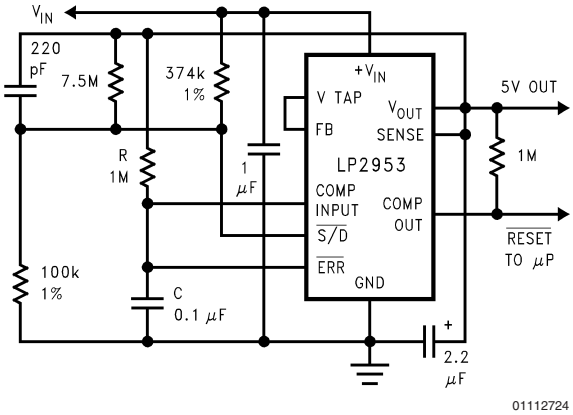
LOW BATT flag warns the user that the battery has discharged down to about 5.8V, giving the user time to recharge the battery or shut down hardware with high power requirements. The output is still in regulation at this time.

OUT OF REGULATION flag goes low if the output goes below about 4.7V, which could occur from a load fault.

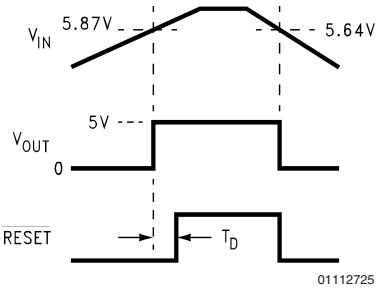
OUTPUT has SNAP-ON/SNAP-OFF feature. Regulator snaps ON at about 5.7V input, and OFF at about 5.6V.

## Typical Applications (Continued)

**5V Regulator with Timed Power-On Reset, Snap-On/Snap-Off Feature and Hysteresis**




**Timing Diagram**

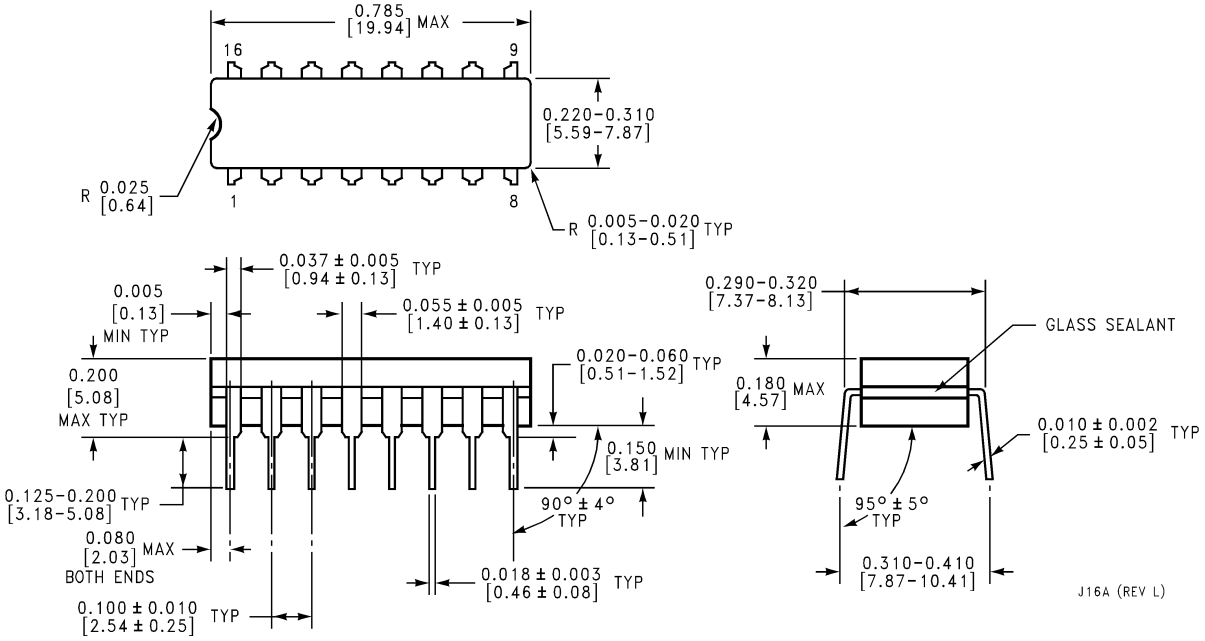



Td = (0.28) RC = 28 ms for components shown.

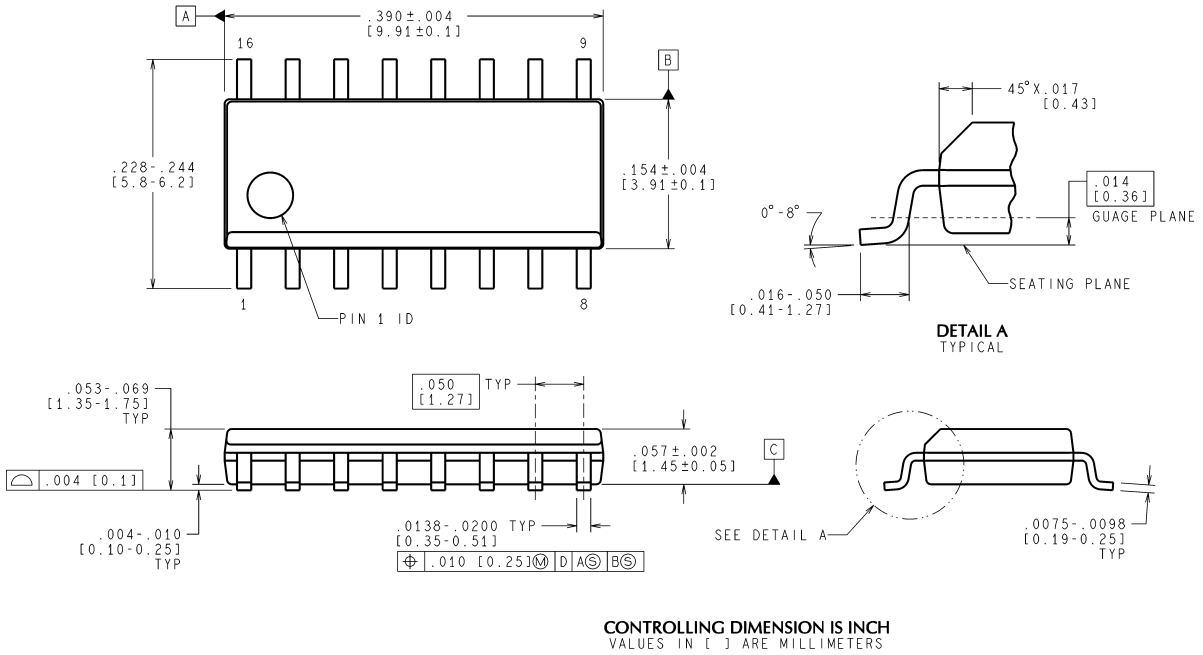
**FIGURE 6.**

## Physical Dimensions inches (millimeters)

unless otherwise noted

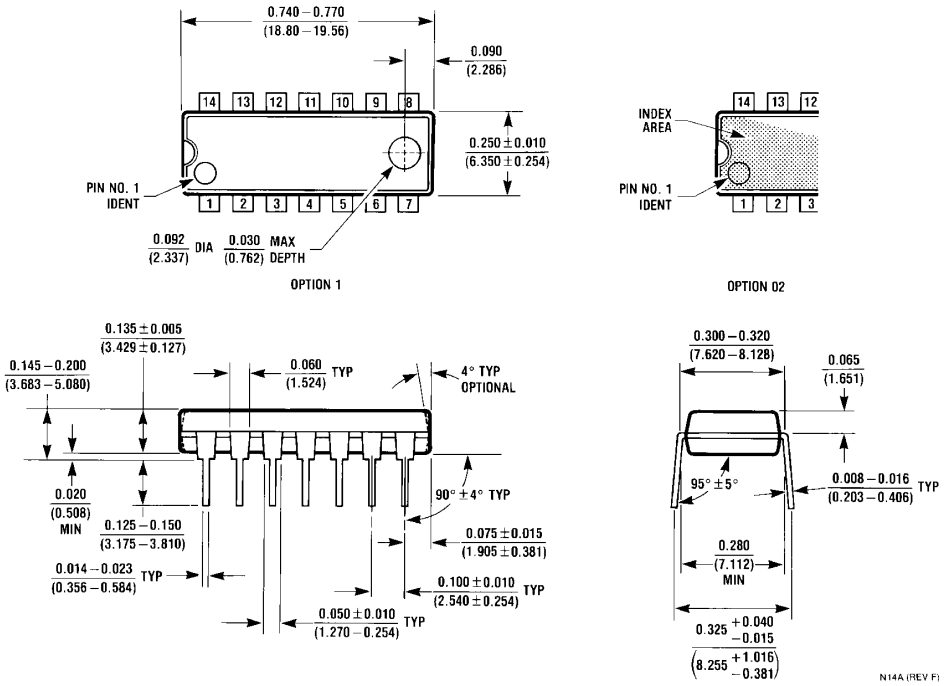



**16-Pin Ceramic DIP**
**Order Number LP2953AMJ/883, 5962-9233601MEA, LP2953AMJ-QMLV, 5962-9233601VEA**
**NS Package Number J16A**

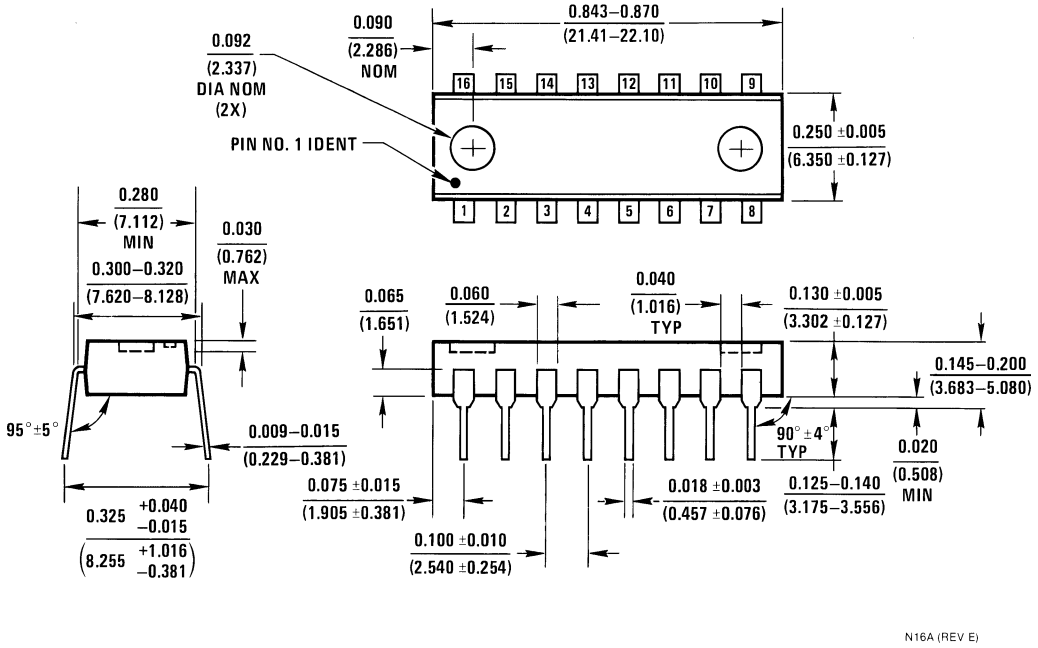



**16-Pin Surface Mount**
**Order Number LP2952IM, LP2952AIM, LP2952IM-3.3, LP2952AIM-3.3,**
**LP2953IM, LP2953AIM, LP2953IM-3.3 or LP2953AIM-3.3**
**NS Package Number M16A**

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

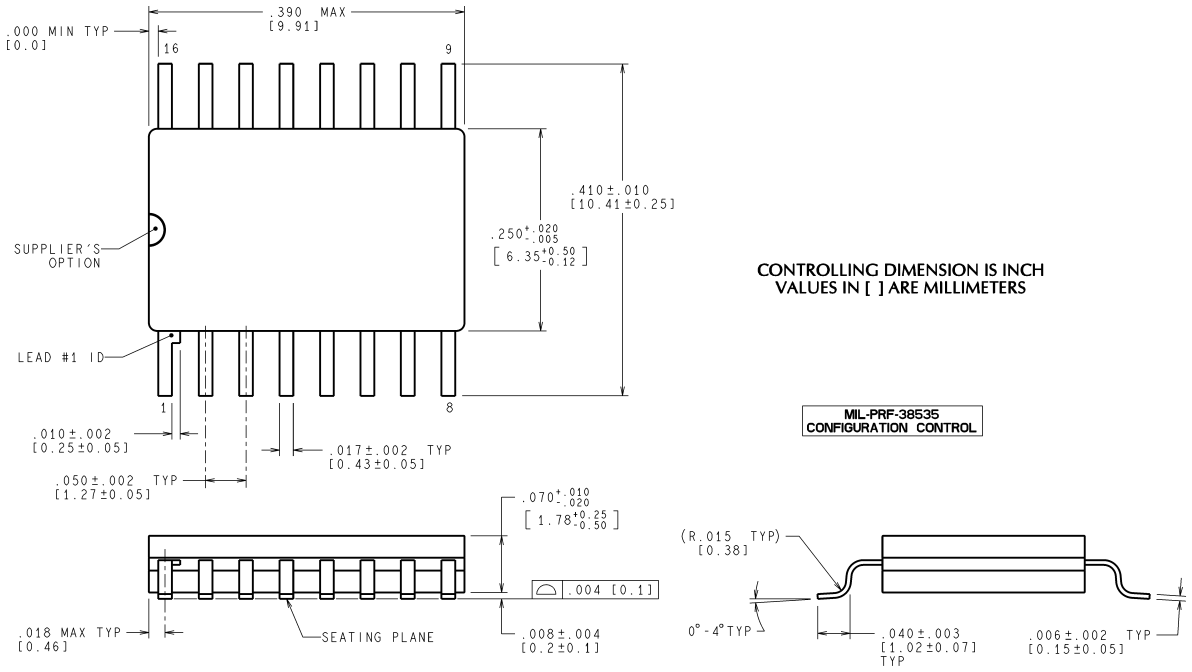



**14-Pin Molded DIP**
**Order Number LP2952IN, LP2952AIN, LP2952IN-3.3 or LP2952AIN-3.3**
**NS Package Number N14A**




**16-Pin Molded DIP**
**Order Number LP2953IN, LP2953AIN, LP2953IN-3.3 or LP2953AIN-3.3**
**NS Package Number N16A**

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




WG16A (Rev D)

**16-Pin Ceramic Surface-Mount**
**Order Number LP2953AMWG/883, 5962-9233601QXA, LP2953AMWG-QMLV, 5962-9233601VXA**
**NS Package Number WG16A**

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