Fast Transient Response Using Small Output Capacitor (10 μF)
- 200-mA Low-Dropout Voltage Regulator
- Available in 1.5-V, 1.8-V, 2.5-V, 3-V and 3.3-V
- Dropout Voltage Down to 170 mV at 200 mA (TPS7433)
- 3% Tolerance Over Specified Conditions
- 8-Pin SOIC Package
- Thermal Shutdown Protection

**description**

This device is designed to have a fast transient response and be stable with 1-μF capacitors. This combination provides high performance at a reasonable cost.

Because the PMOS device behaves as a low-value resistor, the dropout voltage is very low (typically 170 mV at an output current of 200-mA for the TPS7433). This LDO family also features a sleep mode; applying a TTL high signal to EN (enable) shuts down the regulator, reducing the quiescent current to less than 1 μA at TJ = 25°C.

The TPS74xx is offered in 1.5-V, 1.8-V, 2.5-V, 3-V, and 3.3-V. Output voltage tolerance is specified as a maximum of 3% over line, load, and temperature ranges. The TPS74xx family is available in 8 pin SOIC package.

**TPS7433 Dropout Voltage vs Junction Temperature**

![Graph showing dropout voltage vs junction temperature for TPS7433]

**TPS7418 Load Transient Response**

![Graph showing load transient response for TPS7418]

Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.
AVAILABLE OPTIONS

<table>
<thead>
<tr>
<th>℃</th>
<th>OUTPUT VOLTAGE (V)</th>
<th>PACKAGED DEVICES</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.3</td>
<td>TYP</td>
<td>TPS7433D</td>
</tr>
<tr>
<td>3</td>
<td>SOIC (D)</td>
<td>TPS7430D</td>
</tr>
<tr>
<td>2.5</td>
<td>TPS7425D</td>
<td></td>
</tr>
<tr>
<td>1.8</td>
<td>TPS7418D</td>
<td></td>
</tr>
<tr>
<td>1.5</td>
<td>TPS7415D</td>
<td></td>
</tr>
</tbody>
</table>

The D package is available taped and reeled. Add an R suffix to the device type (e.g., TPS7433DR).

† See application information section for capacitor selection details.

Figure 1. Typical Application Configuration
Terminal Functions

<table>
<thead>
<tr>
<th>TERMINAL</th>
<th>NAME</th>
<th>NO.</th>
<th>I/O</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN</td>
<td>1</td>
<td>I</td>
<td>Enable input</td>
<td></td>
</tr>
<tr>
<td>GND</td>
<td>6</td>
<td></td>
<td>Regulator ground</td>
<td></td>
</tr>
<tr>
<td>IN</td>
<td>4, 5</td>
<td>I</td>
<td>Input voltage</td>
<td></td>
</tr>
<tr>
<td>NC</td>
<td>2, 3</td>
<td></td>
<td>Not connected</td>
<td></td>
</tr>
<tr>
<td>OUT</td>
<td>7</td>
<td>O</td>
<td>Regulated output voltage</td>
<td></td>
</tr>
<tr>
<td>SENSE</td>
<td>8</td>
<td>I</td>
<td>Sense</td>
<td></td>
</tr>
</tbody>
</table>

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Input voltage range, $V_I$ ........................................... $-0.3 \text{ V to } 8 \text{ V}$
Voltage range at EN ........................................... $-0.3 \text{ V to } V_I + 0.3 \text{ V}$
Peak output current ........................................... Internally limited
Continuous total power dissipation .................................. See dissipation rating tables
Operating virtual junction temperature range, $T_J$ .......................... $-40 \degree \text{C to } 125 \degree \text{C}$
Storage temperature range, $T_{stg}$ .................................. $-65 \degree \text{C to } 150 \degree \text{C}$

† Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

‡ All voltage values are with respect to network terminal ground.

Dissipation Rating Table 1 – Free-Air Temperatures

<table>
<thead>
<tr>
<th>PACKAGE</th>
<th>AIR FLOW (CFM)</th>
<th>$T_A &lt; 25\degree \text{C}$</th>
<th>DERATING FACTOR ABOVE $T_A = 25\degree \text{C}$</th>
<th>$T_A = 70\degree \text{C}$</th>
<th>$T_A = 85\degree \text{C}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>0</td>
<td>568 mW</td>
<td>5.68 mW/°C</td>
<td>312 mW</td>
<td>227 mW</td>
</tr>
<tr>
<td></td>
<td>250</td>
<td>904 mW</td>
<td>9.04 mW/°C</td>
<td>497 mW</td>
<td>361 mW</td>
</tr>
</tbody>
</table>

Recommended Operating Conditions

<table>
<thead>
<tr>
<th>MIN</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5</td>
<td>7</td>
<td>V</td>
</tr>
<tr>
<td>0</td>
<td>200</td>
<td>mA</td>
</tr>
<tr>
<td>-40</td>
<td>125</td>
<td>°C</td>
</tr>
</tbody>
</table>

§ To calculate the minimum input voltage for your maximum output current, use the following equation: $V_I(\text{min}) = V_O(\text{max}) + V_D(\text{max load})$.

NOTE 1: Continuous current and operating junction temperature are limited by internal protection circuitry, but it is not recommended that the device operate under conditions beyond those specified in this table for extended periods of time.
### SLVS212 – DECEMBER 1999

#### 200-mA LOW-DROPOUT VOLTAGE REGULATORS

**FAST-TRANSIENT-RESPONSE USING SMALL OUTPUT CAPACITOR**

**TPS7415, TPS7418, TPS7425, TPS7430, TPS7433**

**Electrical Characteristics**

V<sub>i</sub> = V<sub>O</sub>(typ) + 1 V, I<sub>O</sub> = 1 mA, EN = 0 V, C<sub>O</sub> = 1 μF (unless otherwise noted)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>TEST CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output voltage (10 μA to 200 mA load) (see Note 2)</td>
<td>TPS7415</td>
<td>2.5 V &lt; V&lt;sub&gt;i&lt;/sub&gt; &lt; 7 V</td>
<td>T&lt;sub&gt;J&lt;/sub&gt; = 25°C</td>
<td>1.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>T&lt;sub&gt;J&lt;/sub&gt; = -40°C to 125°C</td>
<td>1.455</td>
<td>1.545</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TPS7418</td>
<td>2.8 V &lt; V&lt;sub&gt;i&lt;/sub&gt; &lt; 7 V</td>
<td>T&lt;sub&gt;J&lt;/sub&gt; = 25°C</td>
<td>1.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>T&lt;sub&gt;J&lt;/sub&gt; = -40°C to 125°C</td>
<td>1.746</td>
<td>1.854</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TPS7425</td>
<td>3.5 V &lt; V&lt;sub&gt;i&lt;/sub&gt; &lt; 7 V</td>
<td>T&lt;sub&gt;J&lt;/sub&gt; = 25°C</td>
<td>2.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>T&lt;sub&gt;J&lt;/sub&gt; = -40°C to 125°C</td>
<td>2.425</td>
<td>2.575</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TPS7430</td>
<td>4.0 V &lt; V&lt;sub&gt;i&lt;/sub&gt; &lt; 7 V</td>
<td>T&lt;sub&gt;J&lt;/sub&gt; = 25°C</td>
<td>3.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>T&lt;sub&gt;J&lt;/sub&gt; = -40°C to 125°C</td>
<td>2.910</td>
<td>3.090</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TPS7433</td>
<td>4.3 V &lt; V&lt;sub&gt;i&lt;/sub&gt; &lt; 7 V</td>
<td>T&lt;sub&gt;J&lt;/sub&gt; = 25°C</td>
<td>3.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>T&lt;sub&gt;J&lt;/sub&gt; = -40°C to 125°C</td>
<td>3.201</td>
<td>3.399</td>
<td></td>
</tr>
<tr>
<td>Quiescent current (GND current) (See Note 2)</td>
<td></td>
<td>I&lt;sub&gt;O&lt;/sub&gt; = 1 mA, EN = 0 V</td>
<td>T&lt;sub&gt;J&lt;/sub&gt; = 25°C</td>
<td>80</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>T&lt;sub&gt;J&lt;/sub&gt; = -40°C to 125°C</td>
<td>115</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>I&lt;sub&gt;O&lt;/sub&gt; = 100 mA, EN = 0 V</td>
<td>T&lt;sub&gt;J&lt;/sub&gt; = 25°C</td>
<td>550</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>T&lt;sub&gt;J&lt;/sub&gt; = -40°C to 125°C</td>
<td>850</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>I&lt;sub&gt;O&lt;/sub&gt; = 200 mA, EN = 0 V</td>
<td>T&lt;sub&gt;J&lt;/sub&gt; = 25°C</td>
<td>1300</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>T&lt;sub&gt;J&lt;/sub&gt; = -40°C to 125°C</td>
<td>1500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output voltage line regulation (ΔV&lt;sub&gt;O&lt;/sub&gt;/V&lt;sub&gt;O&lt;/sub&gt;) (see Notes 2 and 3)</td>
<td></td>
<td>V&lt;sub&gt;O&lt;/sub&gt; + 1 V &lt; V&lt;sub&gt;i&lt;/sub&gt; ≤ 7 V, T&lt;sub&gt;J&lt;/sub&gt; = 25°C</td>
<td>V&lt;sub&gt;O&lt;/sub&gt; = 1.5 V</td>
<td>0.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Load regulation</td>
<td></td>
<td>BW = 300 Hz to 50 kHz, T&lt;sub&gt;J&lt;/sub&gt; = 25°C</td>
<td>C&lt;sub&gt;O&lt;/sub&gt; = 1 μF</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output noise voltage</td>
<td></td>
<td>V&lt;sub&gt;O&lt;/sub&gt; = 0 V</td>
<td>500</td>
<td>750</td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>Thermal shutdown junction temperature</td>
<td></td>
<td>T&lt;sub&gt;J&lt;/sub&gt; = 25°C</td>
<td>150</td>
<td></td>
<td></td>
<td>°C</td>
</tr>
<tr>
<td>Standby current</td>
<td></td>
<td>2.5 V &lt; V&lt;sub&gt;i&lt;/sub&gt; &lt; 7 V, T&lt;sub&gt;J&lt;/sub&gt; = 25°C</td>
<td>EN = V&lt;sub&gt;i&lt;/sub&gt;</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High level enable input voltage</td>
<td></td>
<td>2.5 V &lt; V&lt;sub&gt;i&lt;/sub&gt; &lt; 7 V, T&lt;sub&gt;J&lt;/sub&gt; = -40°C to 125°C</td>
<td>EN = V&lt;sub&gt;i&lt;/sub&gt;</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low level enable input voltage</td>
<td></td>
<td>EN = V&lt;sub&gt;i&lt;/sub&gt;</td>
<td>2</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Input current (EN)</td>
<td></td>
<td>EN = 0 V</td>
<td>-1</td>
<td>1</td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>Power supply ripple rejection (see Note 2)</td>
<td></td>
<td>f = 100 Hz, C&lt;sub&gt;O&lt;/sub&gt; = 1 μF, T&lt;sub&gt;J&lt;/sub&gt; = 25°C</td>
<td>55</td>
<td></td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td>Dropout voltage (see Note 4)</td>
<td></td>
<td>I&lt;sub&gt;O&lt;/sub&gt; = 200 mA, T&lt;sub&gt;J&lt;/sub&gt; = 25°C</td>
<td>TPS7430</td>
<td>180</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>I&lt;sub&gt;O&lt;/sub&gt; = 200 mA, T&lt;sub&gt;J&lt;/sub&gt; = -40°C to 125°C</td>
<td>TPS7430</td>
<td>350</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>I&lt;sub&gt;O&lt;/sub&gt; = 200 mA, T&lt;sub&gt;J&lt;/sub&gt; = 25°C</td>
<td>TPS7433</td>
<td>170</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>I&lt;sub&gt;O&lt;/sub&gt; = 200 mA, T&lt;sub&gt;J&lt;/sub&gt; = -40°C to 125°C</td>
<td>TPS7433</td>
<td>315</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**

2. Minimum IN operating voltage is 2.5 V or V<sub>O</sub>(typ) + 1 V, whichever is greater. Maximum IN voltage 7 V.

3. If V<sub>O</sub> = 1.5 V then V<sub>imax</sub> = 7 V, V<sub>imin</sub> = 2.5 V.

4. IN voltage equals V<sub>O</sub>(typ) – 100 mV; TPS7430 and TPS7433 dropout limited by input voltage range limitations (i.e., TPS7430 input voltage needs to drop to 2.9 V for purpose of this test).

\[
\text{Line Reg. (mV)} = \left(\% / \text{V}\right) \times \frac{V<sub>O</sub>(V<sub>imax</sub> - 2.5 \text{ V})}{100} \times 1000
\]

If V<sub>O</sub> ≥ 2.5 V then V<sub>imax</sub> = 7 V, V<sub>imin</sub> = V<sub>O</sub> + 1 V:

\[
\text{Line Reg. (mV)} = \left(\% / \text{V}\right) \times \frac{V<sub>O</sub>(V<sub>imax</sub> - (V<sub>O</sub> + 1 \text{ V}))}{100} \times 1000
\]
Table of Graphs

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>FIGURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_O$</td>
<td>Output voltage vs Output current</td>
<td>2, 3, 4</td>
</tr>
<tr>
<td></td>
<td>vs Junction temperature</td>
<td>5, 6</td>
</tr>
<tr>
<td>Ground current</td>
<td>vs Junction temperature</td>
<td>7, 8</td>
</tr>
<tr>
<td>Power supply ripple rejection</td>
<td>vs Frequency</td>
<td>12</td>
</tr>
<tr>
<td>Output noise</td>
<td>vs Frequency</td>
<td>9</td>
</tr>
<tr>
<td>$Z_O$</td>
<td>Output impedance vs Frequency</td>
<td>10</td>
</tr>
<tr>
<td>$V_DO$</td>
<td>Dropout voltage vs Junction temperature</td>
<td>11</td>
</tr>
<tr>
<td>Line transient response</td>
<td>vs Frequency</td>
<td>13, 15</td>
</tr>
<tr>
<td>Load transient response</td>
<td>vs Frequency</td>
<td>14, 16</td>
</tr>
<tr>
<td>Output voltage</td>
<td>vs Time</td>
<td>17</td>
</tr>
<tr>
<td>(Stability) Equivalent series resistance (ESR)</td>
<td>vs Output current</td>
<td>19</td>
</tr>
</tbody>
</table>

**TYPICAL CHARACTERISTICS**

**TPS7418**

**OUTPUT VOLTAGE VS OUTPUT CURRENT**

$V_I = 2.8 \, V$
$T_A = 25°C$

**TPS7433**

**OUTPUT VOLTAGE VS OUTPUT CURRENT**

$V_I = 4.3 \, V$
$T_A = 25°C$
TPS7415, TPS7418, TPS7425, TPS7430, TPS7433
FAST-TRANSIENT-RESPONSE USING SMALL OUTPUT CAPACITOR
200-mA LOW-DROPOUT VOLTAGE REGULATORS
SLVS212 – DECEMBER 1999

TYPICAL CHARACTERISTICS

**TPS7425**
**OUTPUT VOLTAGE vs OUTPUT CURRENT**

![Graph](image1)

**TPS7418**
**OUTPUT VOLTAGE vs JUNCTION TEMPERATURE**

![Graph](image2)

**TPS7433**
**OUTPUT VOLTAGE vs JUNCTION TEMPERATURE**

![Graph](image3)

**TPS7418**
**GROUND CURRENT vs JUNCTION TEMPERATURE**

![Graph](image4)
TYPICAL CHARACTERISTICS

TPS7433
GROUND CURRENT
VS
JUNCTION TEMPERATURE

Output Spectral Noise Density
VS
FREQUENCY

OUTPUT IMPEDANCE
VS
FREQUENCY

TPS7430
DROPOUT VOLTAGE
VS
JUNCTION TEMPERATURE

TPS7415, TPS7418, TPS7425, TPS7430, TPS7433
FAST-TRANSIENT-RESPONSE USING SMALL OUTPUT CAPACITOR
200-mA LOW-DROPOUT VOLTAGE REGULATORS
SLVS212 – DECEMBER 1999

Figure 8

Figure 9

Figure 10

Figure 11
TPS7415, TPS7418, TPS7425, TPS7430, TPS7433
FAST TRANSIENT RESPONSE USING SMALL OUTPUT CAPACITOR
200-mA LOW-DROPOUT VOLTAGE REGULATORS
SLVS212 – DECEMBER 1999

TYPICAL CHARACTERISTICS

RIPPLE REJECTION

vs

FREQUENCY

Figure 12

Figure 13

Figure 14

TPS7418

LINE TRANSIENT RESPONSE

LOAD TRANSIENT RESPONSE

Texas Instruments

POST OFFICE BOX 655303 • DALLAS, TEXAS 75265
TPS7415, TPS7418, TPS7425, TPS7430, TPS7433
FAST-TRANSIENT-RESPONSE USING SMALL OUTPUT CAPACITOR
200-mA LOW-DROPOUT VOLTAGE REGULATORS
SLVS212 – DECEMBER 1999

TYPICAL CHARACTERISTICS

Figure 15  
TPS7433 LINE TRANSIENT RESPONSE

Figure 16  
TPS7433 LOAD TRANSIENT RESPONSE

Figure 17  
TPS7433 OUTPUT VOLTAGE vs TIME (AT STARTUP)
Figure 18. Test Circuit for Typical Regions of Stability (Figure 19)

Figure 19

† ESR refers to the total series resistance, including the ESR of the capacitor, any series resistance added externally, and PWB trace resistance to CO.
APPLICATION INFORMATION

The TPS74xx family includes five voltage regulators (1.5 V, 1.8 V, 2.5 V, 3 V, and 3.3 V).

minimum load requirements

The TPS74xx family is stable even at zero load; no minimum load is required for operation.

SENSE terminal connection

The SENSE terminal must be connected to the regulator output for proper functioning of the regulator. Normally, this connection should be as short as possible; however, the connection can be made near a critical circuit (remote sense) to improve performance at that point. Internally, SENSE connects to a high-impedance wide-bandwidth amplifier through a resistor-divider network and noise pickup feeds through to the regulator output. Routing the SENSE connection to minimize/avoid noise pickup is essential. Adding an RC network between SENSE and OUT to filter noise is not recommended because it can cause the regulator to oscillate.

external capacitor requirements

An input capacitor is not usually required; however, a ceramic bypass capacitor (1 µF or larger) improves load transient response and noise rejection if the TPS74xx is located more than a few inches from the power supply. A higher-capacitance electrolytic capacitor may be necessary if large (hundreds of milliamps) load transients with fast rise times are anticipated.

Like all low dropout regulators, the TPS74xx requires an output capacitor connected between OUT and GND to stabilize the internal control loop. The minimum recommended capacitance value is 1 µF and the ESR (equivalent series resistance) must be at least 300 mΩ. Solid tantalum electrolytic and aluminum electrolytic are all suitable, provided they meet the requirements described previously.

regulator protection

The TPS74xx PMOS-pass transistor has a built-in back diode that conducts reverse currents when the input voltage drops below the output voltage (e.g., during power down). Current is conducted from the output to the input and is not internally limited. When extended reverse voltage is anticipated, external limiting may be appropriate.

Figure 20. Typical Application Circuit
regulator protection (continued)

The TPS74xx also features internal current limiting and thermal protection. During normal operation, the TPS74xx limits output current to approximately 500 mA. When current limiting engages, the output voltage scales back linearly until the overcurrent condition ends. While current limiting is designed to prevent gross device failure, care should be taken not to exceed the power dissipation ratings of the package. If the temperature of the device exceeds 150°C (typ), thermal-protection circuitry shuts it down. Once the device has cooled below 130°C (typ), regulator operation resumes.

power dissipation and junction temperature

Specified regulator operation is assured to a junction temperature of 125°C; the maximum junction temperature should be restricted to 125°C under normal operating conditions. This restriction limits the power dissipation the regulator can handle in any given application. To ensure the junction temperature is within acceptable limits, calculate the maximum allowable dissipation, \( P_D(\text{max}) \), and the actual dissipation, \( P_D \), which must be less than or equal to \( P_D(\text{max}) \).

The maximum-power-dissipation limit is determined using the following equation:

\[
P_D(\text{max}) = \frac{T_{\text{J max}} - T_A}{R_{\text{JA}}}
\]

Where

- \( T_{\text{J max}} \) is the maximum allowable junction temperature.
- \( R_{\text{JA}} \) is the thermal resistance junction-to-ambient for the package, i.e., 172°C/W for the 8-terminal SOIC.
- \( T_A \) is the ambient temperature.

The regulator dissipation is calculated using:

\[
P_D = (V_I - V_O) \times I_O
\]

Power dissipation resulting from quiescent current is negligible. Excessive power dissipation will trigger the thermal protection circuit.
MECHANICAL DATA

D (R-PDSO-G**)
14 PIN SHOWN

NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion, not to exceed 0.006 (0.15).
D. Four center pins are connected to die mount pad.
E. Falls within JEDEC MS-012
IMPORTANT NOTICE

Texas Instruments and its subsidiaries (TI) reserve the right to make changes to their products or to discontinue any product or service without notice, and advise customers to obtain the latest version of relevant information to verify, before placing orders, that information being relied on is current and complete. All products are sold subject to the terms and conditions of sale supplied at the time of order acknowledgement, including those pertaining to warranty, patent infringement, and limitation of liability.

TI warrants performance of its semiconductor products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are utilized to the extent TI deems necessary to support this warranty. Specific testing of all parameters of each device is not necessarily performed, except those mandated by government requirements.

CERTAIN APPLICATIONS USING SEMICONDUCTOR PRODUCTS MAY INVOLVE POTENTIAL RISKS OF DEATH, PERSONAL INJURY, OR SEVERE PROPERTY OR ENVIRONMENTAL DAMAGE (“CRITICAL APPLICATIONS”). TI SEMICONDUCTOR PRODUCTS ARE NOT DESIGNED, AUTHORIZED, OR WARRANTED TO BE SUITABLE FOR USE IN LIFE-SUPPORT DEVICES OR SYSTEMS OR OTHER CRITICAL APPLICATIONS. INCLUSION OF TI PRODUCTS IN SUCH APPLICATIONS IS UNDERSTOOD TO BE FULLY AT THE CUSTOMER’S RISK.

In order to minimize risks associated with the customer’s applications, adequate design and operating safeguards must be provided by the customer to minimize inherent or procedural hazards.

TI assumes no liability for applications assistance or customer product design. TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right of TI covering or relating to any combination, machine, or process in which such semiconductor products or services might be or are used. TI's publication of information regarding any third party’s products or services does not constitute TI's approval, warranty or endorsement thereof.

Copyright © 1999, Texas Instruments Incorporated