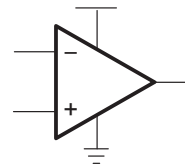


TLV2370, TLV2371, TLV2372, TLV2373, TLV2374, TLV2375 FAMILY OF 550- μ A/Ch 3-MHz RAIL-TO-RAIL INPUT/OUTPUT OPERATIONAL AMPLIFIERS WITH SHUTDOWN

SLOS270D – MARCH 2001 – REVISED JANUARY 2005

- Rail-To-Rail Input/Output
- Wide Bandwidth . . . 3 MHz
- High Slew Rate . . . 2.4 V/ μ s
- Supply Voltage Range . . . 2.7 V to 16 V
- Supply Current . . . 550 μ A/Channel
- Low Power Shutdown Mode
 $I_{DD}(SHDN)$. . . 25 μ A/Channel
- Input Noise Voltage . . . 39 nV/ $\sqrt{\text{Hz}}$
- Input Bias Current . . . 1 pA
- Specified Temperature Range
–40°C to 125°C . . . Industrial Grade
- Ultrasmall Packaging
5 or 6 Pin SOT-23 (TLV2370/1)
8 or 10 Pin MSOP (TLV2372/3)

Operational Amplifier



description

The TLV237x single supply operational amplifiers provide rail-to-rail input and output capability. The TLV237x takes the minimum operating supply voltage down to 2.7 V over the extended industrial temperature range while adding the rail-to-rail output swing feature. The TLV237x also provides 3-MHz bandwidth from only 550 μ A. The maximum recommended supply voltage is 16 V, which allows the devices to be operated from (± 8 V supplies down to ± 1.35 V) a variety of rechargeable cells.

The CMOS inputs enable use in high-impedance sensor interfaces, with the lower voltage operation making an ideal alternative for the TLC227x in battery-powered applications. The rail-to-rail input stage further increases its versatility. The TLV237x is the seventh member of a rapidly growing number of RRIO products available from TI, and it is the first to allow operation up to 16-V rails with good ac performance.

All members are available in PDIP and SOIC with the singles in the small SOT-23 package, duals in the MSOP, and quads in the TSSOP package.

The 2.7-V operation makes the TLV237x compatible with Li-Ion powered systems and the operating supply voltage range of many micro-power microcontrollers available today including TI's MSP430.

SELECTION OF SIGNAL AMPLIFIER PRODUCTS†

| DEVICE | V _{DD} (V) | V _{IO} (μ V) | I _q /Ch (μ A) | I _{IB} (pA) | GBW (MHz) | SR (V/ μ s) | SHUTDOWN | RAIL-TO-RAIL | SINGLES/DUALS/QUADS |
|---------|---------------------|----------------------------|-------------------------------|----------------------|-----------|-----------------|----------|--------------|---------------------|
| TLV237x | 2.7–16 | 500 | 550 | 1 | 3 | 2.4 | Yes | I/O | S/D/Q |
| TLC227x | 4–16 | 300 | 1100 | 1 | 2.2 | 3.6 | — | O | D/Q |
| TLV27x | 2.7–16 | 500 | 550 | 1 | 3 | 2.4 | — | O | S/D/Q |
| TLC27x | 3–16 | 1100 | 675 | 1 | 1.7 | 3.6 | — | — | S/D/Q |
| TLV246x | 2.7–6 | 150 | 550 | 1300 | 6.4 | 1.6 | Yes | I/O | S/D/Q |
| TLV247x | 2.7–6 | 250 | 600 | 2 | 2.8 | 1.5 | Yes | I/O | S/D/Q |
| TLV244x | 2.7–10 | 300 | 725 | 1 | 1.8 | 1.4 | — | O | D/Q |

† Typical values measured at 5 V, 25°C



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.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

 **TEXAS
INSTRUMENTS**

WWW.TI.COM
POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

Copyright © 2001–2005, Texas Instruments Incorporated

TLV2370, TLV2371, TLV2372, TLV2373, TLV2374, TLV2375 FAMILY OF 550- μ A/Ch 3-MHz RAIL-TO-RAIL INPUT/OUTPUT OPERATIONAL AMPLIFIERS WITH SHUTDOWN

SLOS270D – MARCH 2001 – REVISED JANUARY 2005

FAMILY PACKAGE TABLE(1)

| DEVICE | NUMBER OF CHANNELS | PACKAGE TYPES | | | | | SHUTDOWN | UNIVERSAL EVM BOARD |
|---------|--------------------|---------------|------|--------|-------|------|----------|---|
| | | PDIP | SOIC | SOT-23 | TSSOP | MSOP | | |
| TLV2370 | 1 | 8 | 8 | 6 | — | — | Yes | Refer to the EVM Selection Guide (Lit# SLOU060) |
| TLV2371 | 1 | 8 | 8 | 5 | — | — | — | |
| TLV2372 | 2 | 8 | 8 | — | — | 8 | — | |
| TLV2373 | 2 | 14 | 14 | — | — | 10 | Yes | |
| TLV2374 | 4 | 14 | 14 | — | 14 | — | — | |
| TLV2375 | 4 | 16 | 16 | — | 16 | — | Yes | |

TLV2370 and TLV2371 AVAILABLE OPTIONS(1)

| T _A | V _{IO} MAX AT 25°C | PACKAGED DEVICES | | | |
|----------------|-----------------------------|--------------------------------|----------------------------|--------------|------------------------|
| | | SMALL OUTLINE (D) [†] | SOT-23 | | PLASTIC DIP (P) |
| | | | (DBV) [‡] | SYMBOL | |
| -40°C to 125°C | 4.5 mV | TLV2370ID TLV2371ID | TLV2370IDBV TLV2371IDBV | VBFI VBGI | TLV2370IP TLV2371IP |

[†] This package is available taped and reeled. To order this packaging option, add an R suffix to the part number (e.g., TLV2370IDR).

[‡] This package is only available taped and reeled. For standard quantities (3,000 pieces per reel), add an R suffix (e.g., TLV2370IDBVR). For smaller quantities (250 pieces per mini-reel), add a T suffix to the part number (e.g., TLV2370IDBVT).

TLV2372 AND TLV2373 AVAILABLE OPTIONS(1)

| T _A | V _{IO} MAX AT 25°C | PACKAGED DEVICES | | | | | | |
|----------------|-----------------------------|--------------------------------|--------------------|----------|--------------------|----------|-----------------|-----------------|
| | | SMALL OUTLINE (D) [§] | MSOP | | | | PLASTIC DIP (N) | PLASTIC DIP (P) |
| | | | (DGK) [§] | SYMBOL | (DGS) [§] | SYMBOL | | |
| -40°C to 125°C | 4.5 mV | TLV2372ID TLV2373ID | TLV2372IDGK — | APG — | — TLV2373IDGS | — API | — TLV2373IN | TLV2372IP — |

[§] This package is available taped and reeled. To order this packaging option, add an R suffix to the part number (e.g., TLV2372IDR).

TLV2374 and TLV2375 AVAILABLE OPTIONS(1)

| T _A | V _{IO} MAX AT 25°C | PACKAGED DEVICES | | |
|----------------|-----------------------------|--------------------------------|------------------------|--------------------------|
| | | SMALL OUTLINE (D) [¶] | PLASTIC DIP (N) | TSSOP (PW) [¶] |
| -40°C to 125°C | 4.5 mV | TLV2374ID TLV2375ID | TLV2374IN TLV2375IN | TLV2374IPW TLV2375IPW |

[¶] This package is available taped and reeled. To order this packaging option, add an R suffix to the part number (e.g., TLV2374IDR).

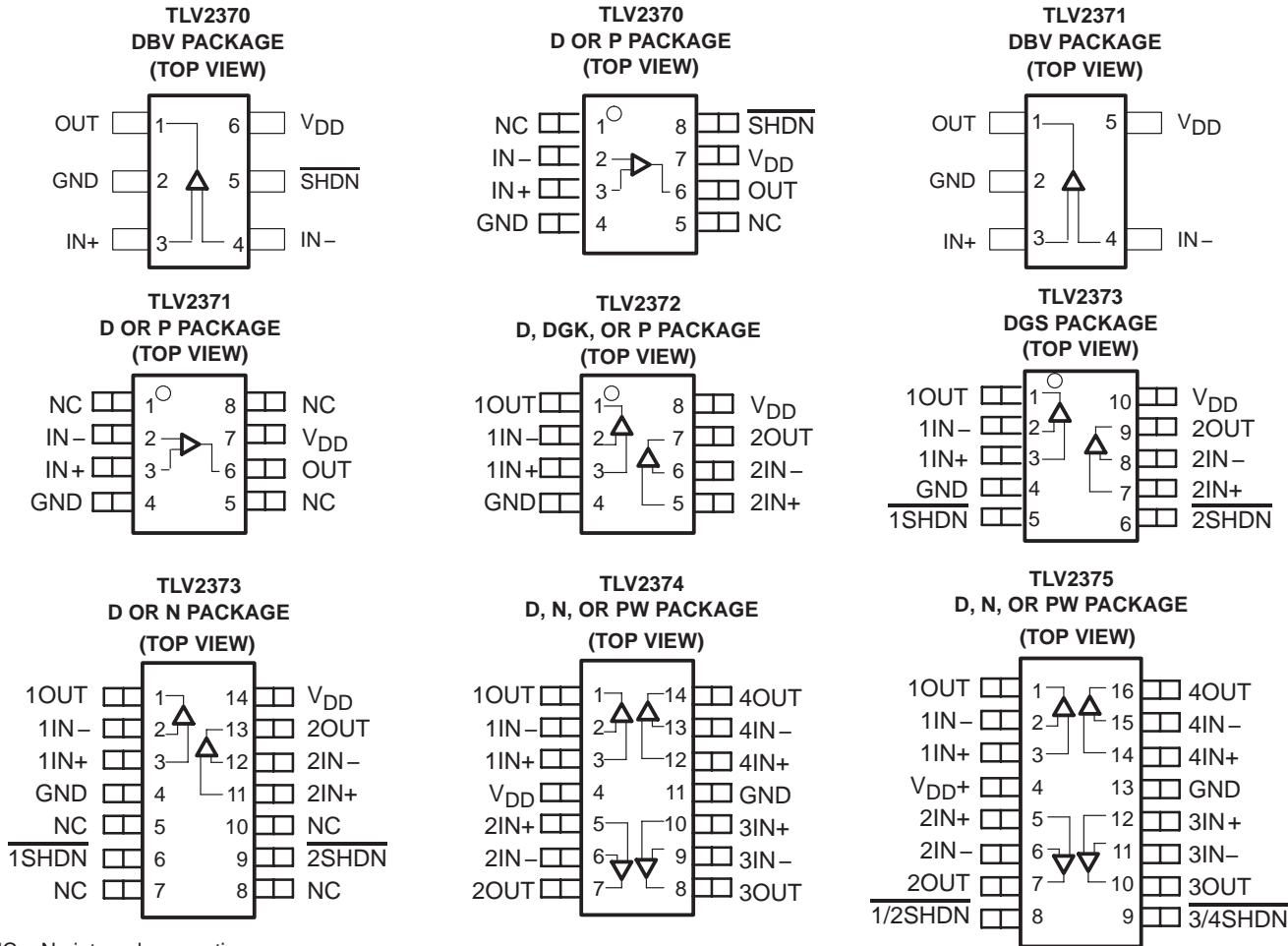
- For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI website at www.ti.com.



TLV2370, TLV2371, TLV2372, TLV2373, TLV2374, TLV2375 FAMILY OF 550- μ A/Ch 3-MHz RAIL-TO-RAIL INPUT/OUTPUT OPERATIONAL AMPLIFIERS WITH SHUTDOWN

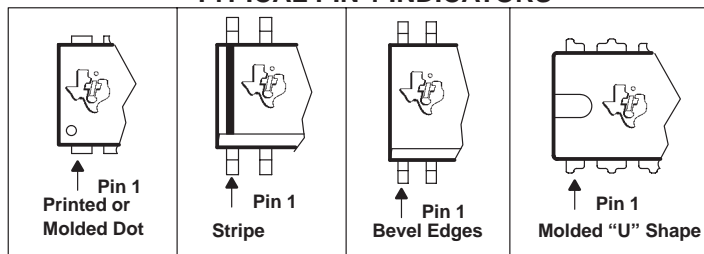
SLOS270D – MARCH 2001 – REVISED JANUARY 2005

TLV237x PACKAGE PINOUTS(1)



NC – No internal connection

TYPICAL PIN 1 INDICATORS



NOTE: (1) If there is not a Pin 1 indicator, turn device to enable reading the symbol from the left to right. Pin 1 is at the lower left corner of the device.

TLV2370, TLV2371, TLV2372, TLV2373, TLV2374, TLV2375 FAMILY OF 550- μ A/Ch 3-MHz RAIL-TO-RAIL INPUT/OUTPUT OPERATIONAL AMPLIFIERS WITH SHUTDOWN

SLOS270D – MARCH 2001 – REVISED JANUARY 2005

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

| | |
|--|------------------------------|
| Supply voltage, V_{DD} (see Note 1) | 16.5 V |
| Differential input voltage, V_{ID} | $\pm V_{DD}$ |
| Input voltage range, V_I (see Note 1) | -0.2 V to $V_{DD} + 0.2$ V |
| Input current range, I_I | ± 10 mA |
| Output current range, I_O | ± 100 mA |
| Continuous total power dissipation | See Dissipation Rating Table |
| Operating free-air temperature range, T_A : I-suffix | -40°C to 125°C |
| Maximum junction temperature, T_J | 150°C |
| Storage temperature range, T_{stg} | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°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.

NOTE: All voltage values, except differential voltages, are with respect to GND.

DISSIPATION RATING TABLE

| PACKAGE | θ_{JC} (°C/W) | θ_{JA} (°C/W) | $T_A \leq 25^\circ\text{C}$ POWER RATING |
|------------|-------------------------|-------------------------|---|
| D (8) | 38.3 | 176 | 710 mW |
| D (14) | 26.9 | 122.3 | 1022 mW |
| D (16) | 25.7 | 114.7 | 1090 mW |
| DBV (5) | 55 | 324.1 | 385 mW |
| DBV (6) | 55 | 294.3 | 425 mW |
| DGK (8) | 54.23 | 259.96 | 481 mW |
| DGS (10) | 54.1 | 257.71 | 485 mW |
| N (14, 16) | 32 | 78 | 1600 mW |
| P (8) | 41 | 104 | 1200 mW |
| PW (14) | 29.3 | 173.6 | 720 mW |
| PW (16) | 28.7 | 161.4 | 774 mW |

recommended operating conditions

| | | MIN | MAX | UNIT |
|--|---------------|------------|----------|------|
| Supply voltage, V_{DD} | Single supply | 2.7 | 16 | V |
| | Split supply | ± 1.35 | ± 8 | |
| Common-mode input voltage range, V_{ICR} | | 0 | V_{DD} | V |
| Operating free-air temperature, T_A | I-suffix | -40 | 125 | °C |
| Turnon voltage level, $V_{(ON)}$, relative to GND pin voltage | | | 2 | V |
| Turnoff voltage level, $V_{(OFF)}$, relative to GND pin voltage | | 0.8 | | V |



TLV2370, TLV2371, TLV2372, TLV2373, TLV2374, TLV2375
FAMILY OF 550- μ A/Ch 3-MHz RAIL-TO-RAIL INPUT/OUTPUT
OPERATIONAL AMPLIFIERS WITH SHUTDOWN

SLOS270D – MARCH 2001 – REVISED JANUARY 2005

electrical characteristics at specified free-air temperature, $V_{DD} = 2.7\text{ V}$, 5 V , and 15 V (unless otherwise noted)

dc performance

| PARAMETER | | TEST CONDITIONS | | T_A | MIN | TYP | MAX | UNIT |
|----------------|---|--|-------------------------|------------|-----|-----|-----|------------------------------|
| V_{IO} | Input offset voltage | $V_{IC} = V_{DD}/2$, $R_S = 50\ \Omega$ | $V_O = V_{DD}/2$, | 25°C | | 2 | 4.5 | mV |
| | | | | Full range | | | 6 | |
| α_{VIO} | Offset voltage drift | | | 25°C | | 2 | | $\mu\text{V}/^\circ\text{C}$ |
| CMRR | Common-mode rejection ratio | $V_{IC} = 0\text{ to }V_{DD}$, $R_S = 50\ \Omega$ | $V_{DD} = 2.7\text{ V}$ | 25°C | 50 | 68 | dB | |
| | | | | Full range | 49 | | | |
| | | $V_{IC} = 0\text{ to }V_{DD}-1.35\text{V}$, $R_S = 50\ \Omega$ | $V_{DD} = 2.7\text{ V}$ | 25°C | 56 | 70 | | |
| | | | | Full range | 54 | | | |
| | | $V_{IC} = 0\text{ to }V_{DD}$, $R_S = 50\ \Omega$, | $V_{DD} = 5\text{ V}$ | 25°C | 55 | 72 | | |
| | | | | Full range | 54 | | | |
| | | $V_{IC} = 0\text{ to }V_{DD}-1.35\text{V}$, $R_S = 50\ \Omega$, | $V_{DD} = 5\text{ V}$ | 25°C | 67 | 80 | | |
| | | | | Full range | 64 | | | |
| | | $V_{IC} = 0\text{ to }V_{DD}$, $R_S = 50\ \Omega$, | $V_{DD} = 15\text{ V}$ | 25°C | 64 | 82 | | |
| | | | | Full range | 63 | | | |
| | | $V_{IC} = 0\text{ to }V_{DD}-1.35\text{V}$, $R_S = 50\ \Omega$, | $V_{DD} = 15\text{ V}$ | 25°C | 67 | 84 | | |
| | | | | Full range | 66 | | | |
| A_{VD} | Large-signal differential voltage amplification | $V_{O(PP)} = V_{DD}/2$, $R_L = 10\text{ k}\Omega$ | $V_{DD} = 2.7\text{ V}$ | 25°C | 98 | 106 | dB | |
| | | | | Full range | 76 | | | |
| | | | $V_{DD} = 5\text{ V}$ | 25°C | 100 | 110 | | |
| | | | | Full range | 86 | | | |
| | | | $V_{DD} = 15\text{ V}$ | 25°C | 81 | 83 | | |
| | | | | Full range | 79 | | | |

input characteristics

| PARAMETER | | TEST CONDITIONS | | T_A | MIN | TYP | MAX | UNIT |
|------------|-------------------------------|--|-----------------------|-------|-----|------|------|------------|
| I_{IO} | Input offset current | $V_{DD} = 15\text{ V}$, $V_O = V_{DD}/2$ | $V_{IC} = V_{DD}/2$, | 25°C | | 1 | 60 | pA |
| | | | | 70°C | | | 100 | |
| | | | | 125°C | | | 1000 | |
| I_{IB} | Input bias current | $V_{DD} = 15\text{ V}$, $V_O = V_{DD}/2$ | $V_{IC} = V_{DD}/2$, | 25°C | | 1 | 60 | pA |
| | | | | 70°C | | | 100 | |
| | | | | 125°C | | | 1000 | |
| $r_{i(d)}$ | Differential input resistance | | | 25°C | | 1000 | | G Ω |
| C_{IC} | Common-mode input capacitance | $f = 21\text{ kHz}$ | | 25°C | | 8 | | pF |



TLV2370, TLV2371, TLV2372, TLV2373, TLV2374, TLV2375
FAMILY OF 550- μ A/Ch 3-MHz RAIL-TO-RAIL INPUT/OUTPUT
OPERATIONAL AMPLIFIERS WITH SHUTDOWN

SLOS270D – MARCH 2001 – REVISED JANUARY 2005

electrical characteristics at specified free-air temperature, $V_{DD} = 2.7\text{ V}$, 5 V , and 15 V (unless otherwise noted) (continued)

output characteristics

| PARAMETER | TEST CONDITIONS | T_A | MIN | TYP | MAX | UNIT |
|------------------------------------|--|-------------------------|------------|-------|-------|------|
| V_{OH} High-level output voltage | $V_{IC} = V_{DD}/2$, $I_{OH} = -1\text{ mA}$ | $V_{DD} = 2.7\text{ V}$ | 25°C | 2.55 | 2.58 | V |
| | | | Full range | 2.48 | | |
| | | $V_{DD} = 5\text{ V}$ | 25°C | 4.9 | 4.93 | |
| | | | Full range | 4.85 | | |
| | | $V_{DD} = 15\text{ V}$ | 25°C | 14.92 | 14.96 | |
| | | | Full range | 14.9 | | |
| | $V_{IC} = V_{DD}/2$, $I_{OH} = -5\text{ mA}$ | $V_{DD} = 2.7\text{ V}$ | 25°C | 1.9 | 2 | |
| | | | Full range | 1.6 | | |
| | | $V_{DD} = 5\text{ V}$ | 25°C | 4.6 | 4.68 | |
| | | | Full range | 4.5 | | |
| | | $V_{DD} = 15\text{ V}$ | 25°C | 14.7 | 14.8 | |
| | | | Full range | 14.6 | | |
| V_{OL} Low-level output voltage | $V_{IC} = V_{DD}/2$, $I_{OL} = 1\text{ mA}$ | $V_{DD} = 2.7\text{ V}$ | 25°C | 0.1 | 0.15 | V |
| | | | Full range | | 0.22 | |
| | | $V_{DD} = 5\text{ V}$ | 25°C | 0.05 | 0.1 | |
| | | | Full range | | 0.15 | |
| | | $V_{DD} = 15\text{ V}$ | 25°C | 0.05 | 0.08 | |
| | | | Full range | | 0.1 | |
| | $V_{IC} = V_{DD}/2$, $I_{OL} = 5\text{ mA}$ | $V_{DD} = 2.7\text{ V}$ | 25°C | 0.52 | 0.7 | |
| | | | Full range | | 1.1 | |
| | | $V_{DD} = 5\text{ V}$ | 25°C | 0.28 | 0.4 | |
| | | | Full range | | 0.5 | |
| | | $V_{DD} = 15\text{ V}$ | 25°C | 0.19 | 0.3 | |
| | | | Full range | | 0.35 | |
| I_O Output current | $V_{DD} = 2.7\text{ V}$, $V_O = 0.5\text{ V}$ from rail | Positive rail | 25°C | 4 | mA | |
| | | Negative rail | 25°C | 5 | | |
| | $V_{DD} = 5\text{ V}$, $V_O = 0.5\text{ V}$ from rail | Positive rail | 25°C | 7 | | |
| | | Negative rail | 25°C | 8 | | |
| | $V_{DD} = 15\text{ V}$, $V_O = 0.5\text{ V}$ from rail | Positive rail | 25°C | 16 | | |
| | | Negative rail | 25°C | 15 | | |

power supply

| PARAMETER | TEST CONDITIONS | T_A | MIN | TYP | MAX | UNIT |
|---|---|-------------------------|------------|-----|------|---------------|
| I_{DD} Supply current (per channel) | $V_O = V_{DD}/2$, | $V_{DD} = 2.7\text{ V}$ | 25°C | 470 | 560 | μA |
| | | $V_{DD} = 5\text{ V}$ | 25°C | 550 | 660 | |
| | | $V_{DD} = 15\text{ V}$ | 25°C | 750 | 900 | |
| | | | Full range | | 1200 | |
| PSRR Supply voltage rejection ratio ($\Delta V_{DD} / \Delta V_{IO}$) | $V_{DD} = 2.7\text{ V}$ to 15 V , No load | $V_{IC} = V_{DD}/2$, | 25°C | 70 | 80 | dB |
| | | Full range | | 65 | | |



TLV2370, TLV2371, TLV2372, TLV2373, TLV2374, TLV2375
FAMILY OF 550- μ A/Ch 3-MHz RAIL-TO-RAIL INPUT/OUTPUT
OPERATIONAL AMPLIFIERS WITH SHUTDOWN

SLOS270D – MARCH 2001 – REVISED JANUARY 2005

electrical characteristics at specified free-air temperature, $V_{DD} = 2.7\text{ V}$, 5 V , and 15 V (unless otherwise noted) (continued)

dynamic performance

| PARAMETER | | TEST CONDITIONS | | T_A | MIN | TYP | MAX | UNIT |
|-----------|-------------------------|--|---|--------------------|------|-----|-----|------------------------|
| UGBW | Unity gain bandwidth | $R_L = 2\text{ k}\Omega$, $C_L = 10\text{ pF}$ | $V_{DD} = 2.7\text{ V}$ | 25°C | 2.4 | | 3 | MHz |
| | | | $V_{DD} = 5\text{ V to }15\text{ V}$ | 25°C | | | | |
| SR | Slew rate at unity gain | $V_{O(PP)} = V_{DD}/2$, $C_L = 50\text{ pF}$, $R_L = 10\text{ k}\Omega$ | $V_{DD} = 2.7\text{ V}$ | 25°C | 1.4 | 2 | 1 | $\text{V}/\mu\text{s}$ |
| | | | | Full range | | | | |
| | | | $V_{DD} = 5\text{ V}$ | 25°C | 1.6 | 2.4 | 1.2 | $\text{V}/\mu\text{s}$ |
| | | | | Full range | | | | |
| | | | $V_{DD} = 15\text{ V}$ | 25°C | 1.9 | 2.1 | 1.4 | $\text{V}/\mu\text{s}$ |
| | | | | Full range | | | | |
| ϕ_m | Phase margin | $R_L = 2\text{ k}\Omega$, | $C_L = 100\text{ pF}$ | 25°C | 65° | | | |
| | Gain margin | $R_L = 2\text{ k}\Omega$, | $C_L = 10\text{ pF}$ | 25°C | 18 | | dB | |
| t_s | Settling time | $V_{DD} = 2.7\text{ V}$, $V_{(STEP)PP} = 1\text{ V}$, $A_V = -1$, $C_L = 10\text{ pF}$, $R_L = 2\text{ k}\Omega$ | 0.1% | 25°C | 2.9 | | 2 | μs |
| | | | $V_{DD} = 5\text{ V}, 15\text{ V}$, $V_{(STEP)PP} = 1\text{ V}$, $A_V = -1$, $C_L = 47\text{ pF}$, $R_L = 2\text{ k}\Omega$ | | 0.1% | | | |

noise/distortion performance

| PARAMETER | | TEST CONDITIONS | | T_A | MIN | TYP | MAX | UNIT |
|-----------|--------------------------------------|---|-------------|--------------------|-------|-----|------------------------------|------|
| THD + N | Total harmonic distortion plus noise | $V_{DD} = 2.7\text{ V}$, $V_{O(PP)} = V_{DD}/2\text{ V}$, $R_L = 2\text{ k}\Omega$, $f = 10\text{ kHz}$ | $A_V = 1$ | 25°C | 0.02% | | | |
| | | | $A_V = 10$ | | 0.05% | | | |
| | | | $A_V = 100$ | | 0.18% | | | |
| | | $V_{DD} = 5\text{ V}, 15\text{ V}$, $V_{O(PP)} = V_{DD}/2\text{ V}$, $R_L = 2\text{ k}\Omega$, $f = 10\text{ kHz}$ | $A_V = 1$ | 25°C | 0.02% | | | |
| | | | $A_V = 10$ | | 0.09% | | | |
| | | | $A_V = 100$ | | 0.5% | | | |
| V_n | Equivalent input noise voltage | $f = 1\text{ kHz}$ | | 25°C | 39 | | $\text{nV}/\sqrt{\text{Hz}}$ | |
| | | $f = 10\text{ kHz}$ | | | 35 | | | |
| I_n | Equivalent input noise current | $f = 1\text{ kHz}$ | | 25°C | 0.6 | | $\text{fA}/\sqrt{\text{Hz}}$ | |

shutdown characteristics

| PARAMETER | | TEST CONDITIONS | T_A | MIN | TYP | MAX | UNIT |
|-----------------------|---|---|--------------------|-----|-----|---------------|---------------|
| $I_{DD}(\text{SHDN})$ | Supply current in shutdown mode (TLV2370, TLV2373, TLV2375) (per channel) | $V_{DD} = 2.7\text{ V}, 5\text{ V}$, SHDN = 0 V | 25°C | 25 | 30 | 35 | μA |
| | | | Full range | | | | |
| | | $V_{DD} = 15\text{ V}$, SHDN = 0 V | 25°C | 40 | 45 | 50 | μA |
| | | | Full range | | | | |
| $t_{(on)}$ | Amplifier turnon time (see Note 2) | $R_L = 2\text{ k}\Omega$ | 25°C | 0.8 | | μs | |
| $t_{(off)}$ | Amplifier turnoff time (see Note 2) | | 25°C | 1 | | μs | |

NOTE: Disable time and enable time are defined as the interval between application of the logic signal to the SHDN terminal and the point at which the supply current has reached one half of its final value.



TLV2370, TLV2371, TLV2372, TLV2373, TLV2374, TLV2375
FAMILY OF 550- μ A/Ch 3-MHz RAIL-TO-RAIL INPUT/OUTPUT
OPERATIONAL AMPLIFIERS WITH SHUTDOWN

SLOS270D – MARCH 2001 – REVISED JANUARY 2005

TYPICAL CHARACTERISTICS

Table of Graphs

| | | | FIGURE |
|----------------|--|------------------------------|---------------|
| V_{IO} | Input offset voltage | vs Common-mode input voltage | 1, 2, 3 |
| CMRR | Common-mode rejection ratio | vs Frequency | 4 |
| | Input bias and offset current | vs Free-air temperature | 5 |
| V_{OL} | Low-level output voltage | vs Low-level output current | 6, 8, 10 |
| V_{OH} | High-level output voltage | vs High-level output current | 7, 9, 11 |
| $V_{O(PP)}$ | Peak-to-peak output voltage | vs Frequency | 12 |
| I_{DD} | Supply current | vs Supply voltage | 13 |
| PSRR | Power supply rejection ratio | vs Frequency | 14 |
| A_{VD} | Differential voltage gain & phase | vs Frequency | 15 |
| | Gain-bandwidth product | vs Free-air temperature | 16 |
| SR | Slew rate | vs Supply voltage | 17 |
| | | vs Free-air temperature | 18 |
| ϕ_m | Phase margin | vs Capacitive load | 19 |
| V_n | Equivalent input noise voltage | vs Frequency | 20 |
| | Voltage-follower large-signal pulse response | | 21, 22 |
| | Voltage-follower small-signal pulse response | | 23 |
| | Inverting large-signal response | | 24, 25 |
| | Inverting small-signal response | | 26 |
| | Crosstalk | vs Frequency | 27 |
| | Shutdown forward & reverse isolation | vs Frequency | 28 |
| $I_{DD(SHDN)}$ | Shutdown supply current | vs Supply voltage | 29 |
| $I_{DD(SHDN)}$ | Shutdown pin leakage current | vs Shutdown pin voltage | 30 |
| $I_{DD(SHDN)}$ | Shutdown supply current/output voltage | vs Time | 31, 32 |

TLV2370, TLV2371, TLV2372, TLV2373, TLV2374, TLV2375 FAMILY OF 550- μ A/Ch 3-MHz RAIL-TO-RAIL INPUT/OUTPUT OPERATIONAL AMPLIFIERS WITH SHUTDOWN

SLOS270D – MARCH 2001 – REVISED JANUARY 2005

TYPICAL CHARACTERISTICS

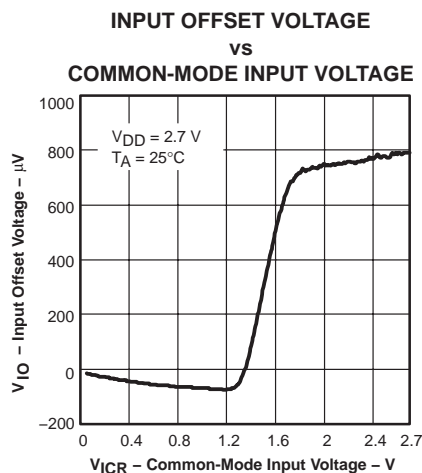


Figure 1

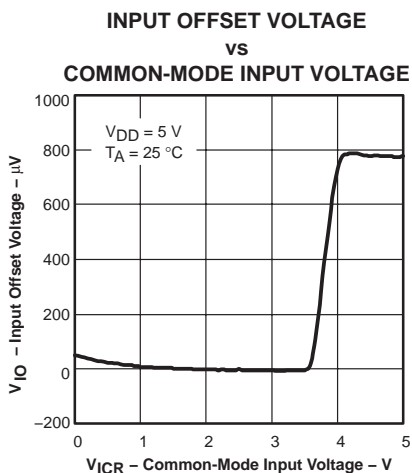


Figure 2

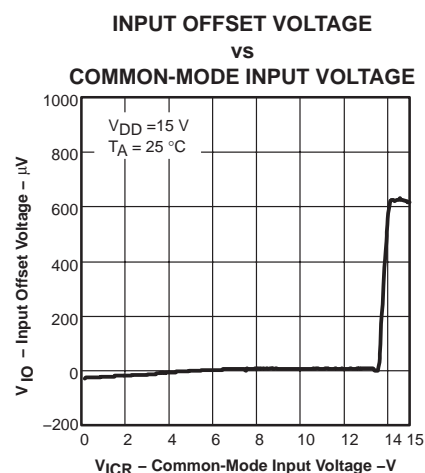


Figure 3

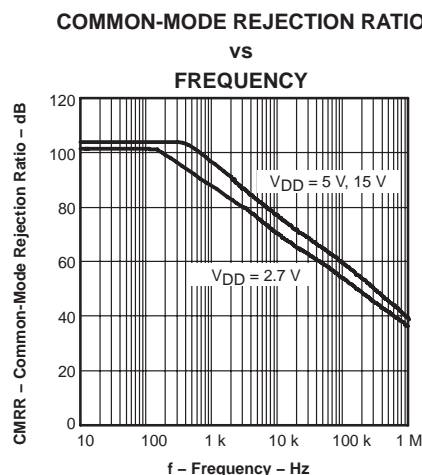


Figure 4

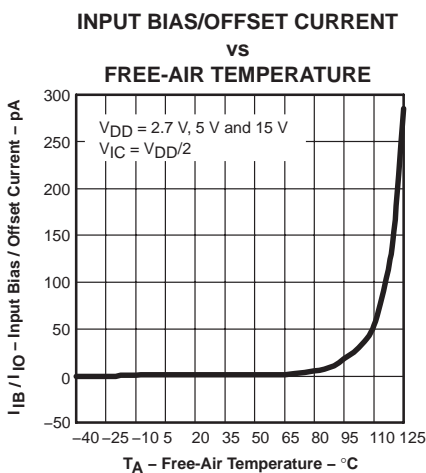


Figure 5

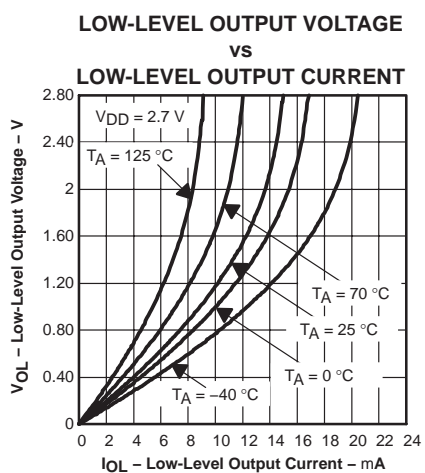


Figure 6

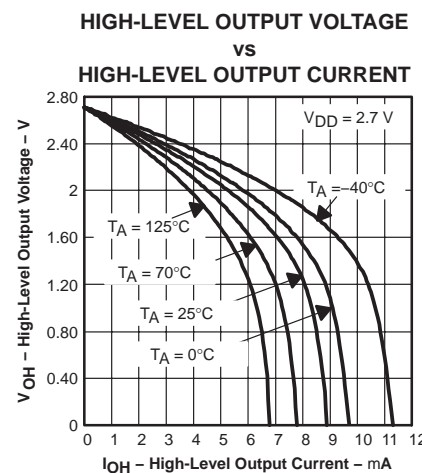


Figure 7

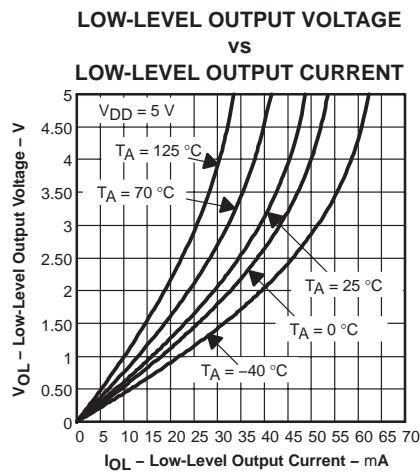


Figure 8

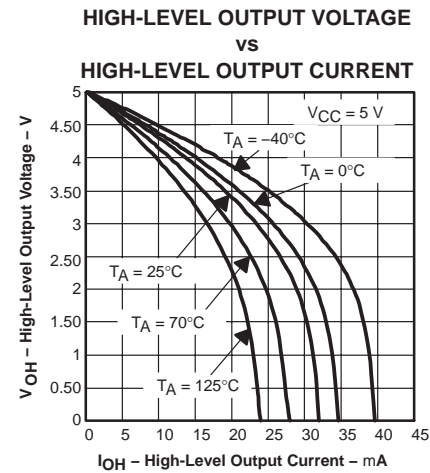


Figure 9

TLV2370, TLV2371, TLV2372, TLV2373, TLV2374, TLV2375 FAMILY OF 550- μ A/Ch 3-MHz RAIL-TO-RAIL INPUT/OUTPUT OPERATIONAL AMPLIFIERS WITH SHUTDOWN

SLOS270D – MARCH 2001 – REVISED JANUARY 2005

TYPICAL CHARACTERISTICS

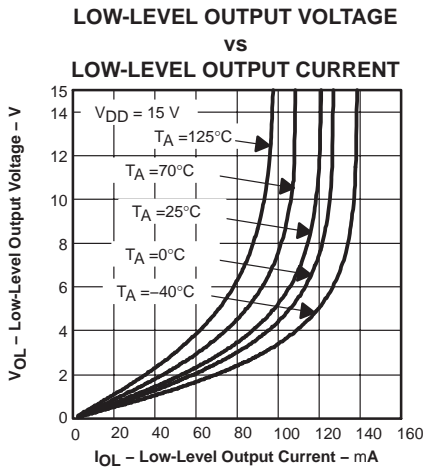


Figure 10

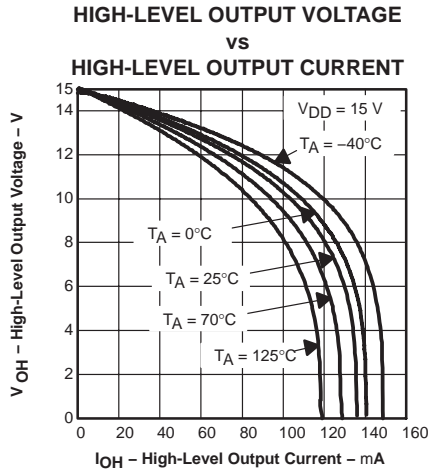


Figure 11

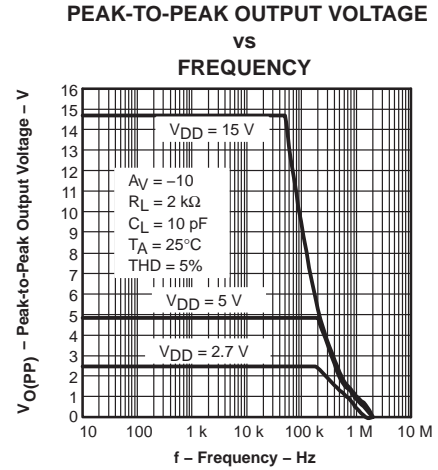


Figure 12

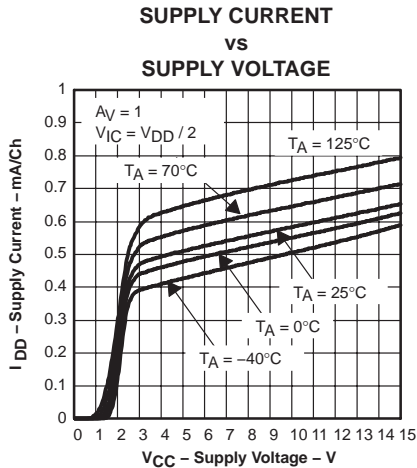


Figure 13

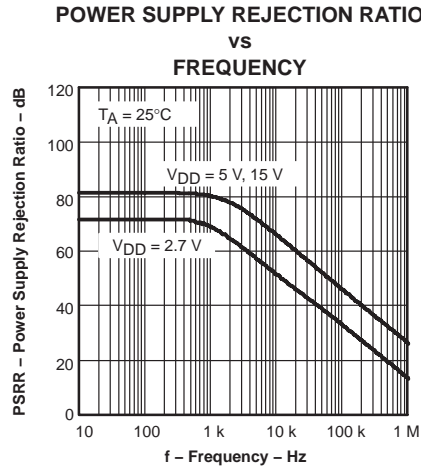


Figure 14

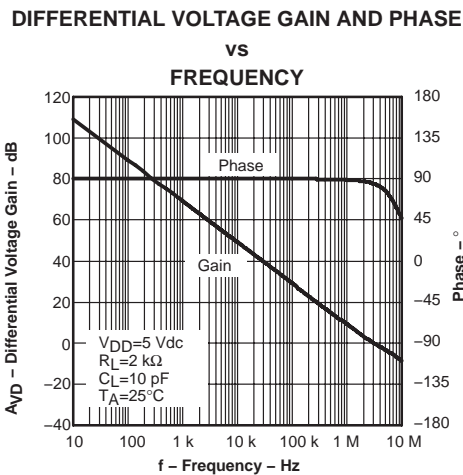


Figure 15

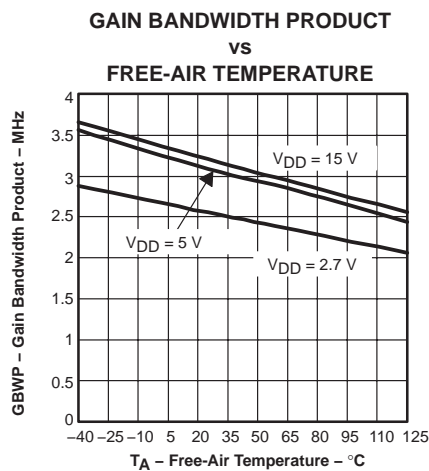


Figure 16



TLV2370, TLV2371, TLV2372, TLV2373, TLV2374, TLV2375 FAMILY OF 550- μ A/Ch 3-MHz RAIL-TO-RAIL INPUT/OUTPUT OPERATIONAL AMPLIFIERS WITH SHUTDOWN

SLOS270D – MARCH 2001 – REVISED JANUARY 2005

TYPICAL CHARACTERISTICS

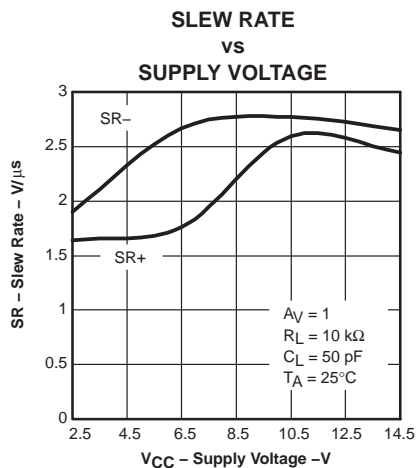


Figure 17

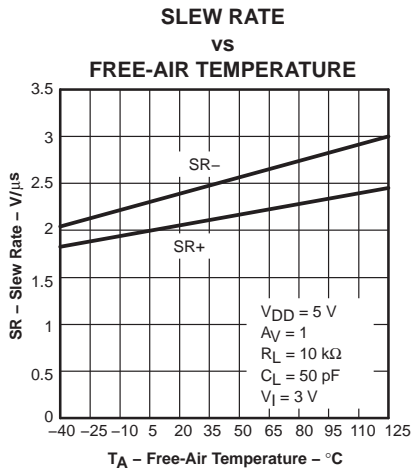


Figure 18

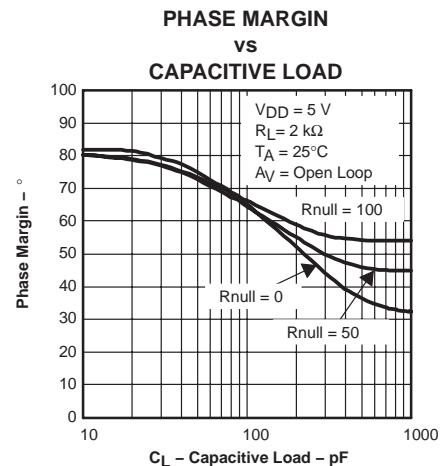


Figure 19

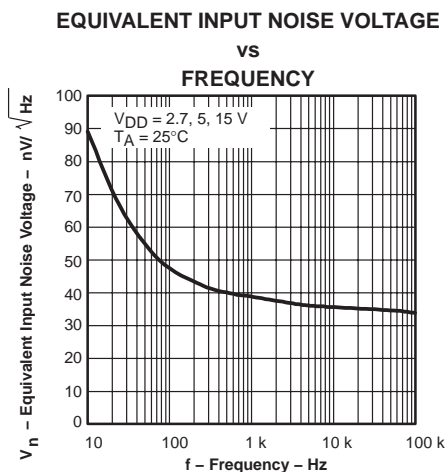


Figure 20

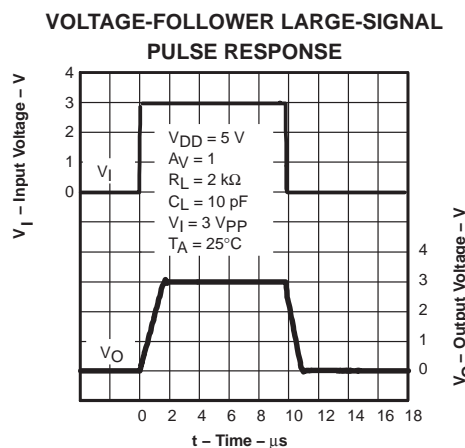


Figure 21

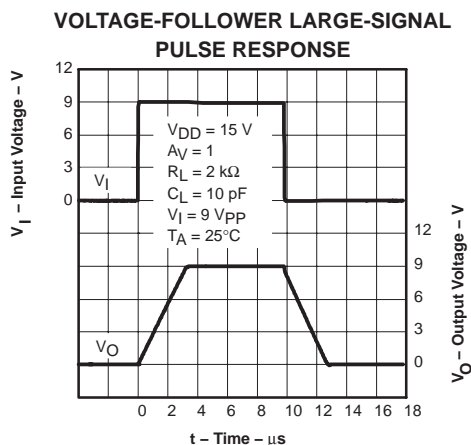


Figure 22

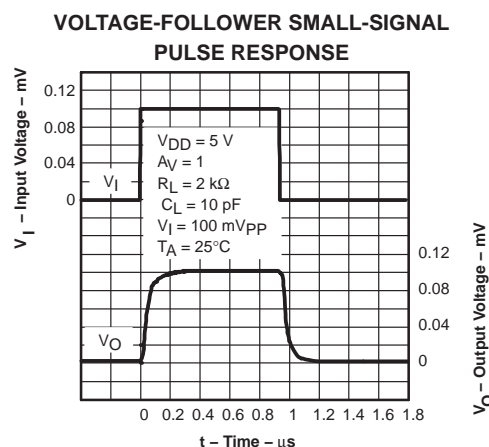


Figure 23

TLV2370, TLV2371, TLV2372, TLV2373, TLV2374, TLV2375 FAMILY OF 550- μ A/Ch 3-MHz RAIL-TO-RAIL INPUT/OUTPUT OPERATIONAL AMPLIFIERS WITH SHUTDOWN

SLOS270D – MARCH 2001 – REVISED JANUARY 2005

TYPICAL CHARACTERISTICS

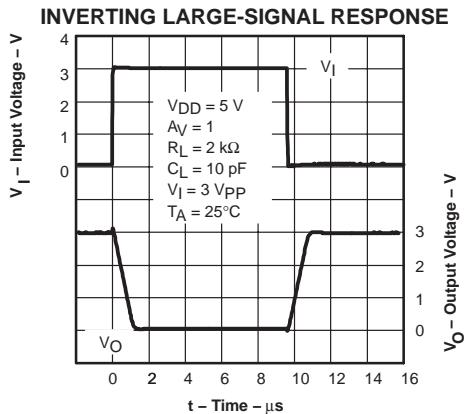


Figure 24

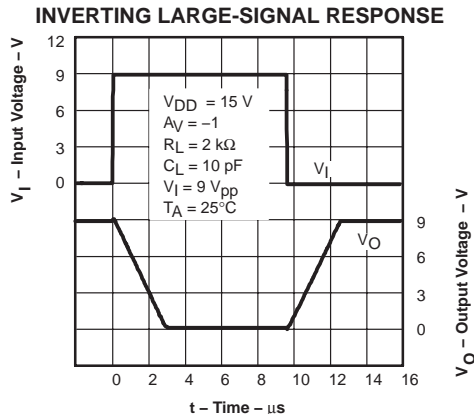


Figure 25

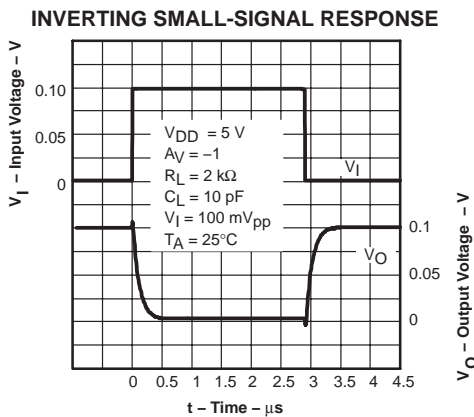


Figure 26

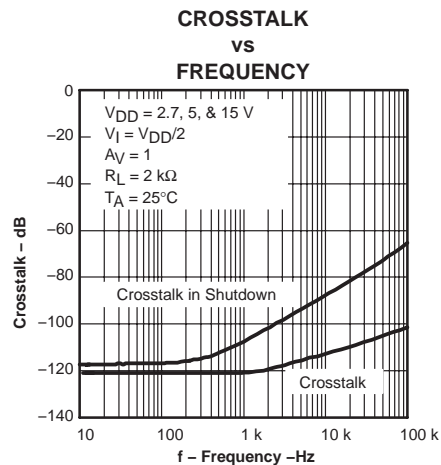


Figure 27

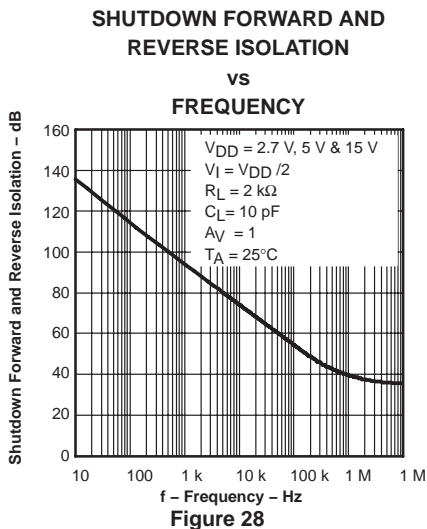


Figure 28

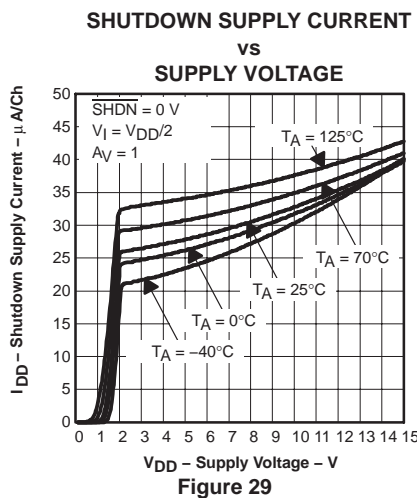


Figure 29

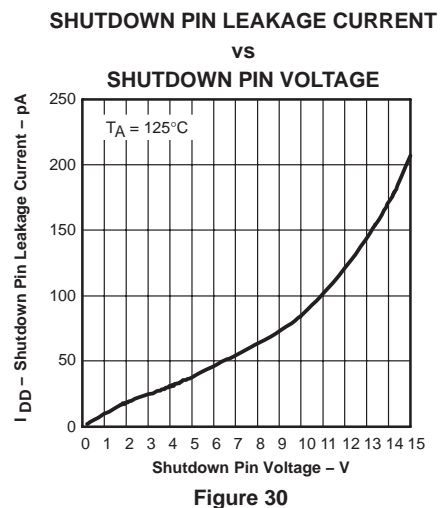


Figure 30

TLV2370, TLV2371, TLV2372, TLV2373, TLV2374, TLV2375
 FAMILY OF 550- μ A/Ch 3-MHz RAIL-TO-RAIL INPUT/OUTPUT
 OPERATIONAL AMPLIFIERS WITH SHUTDOWN

SLOS270D – MARCH 2001 – REVISED JANUARY 2005

TYPICAL CHARACTERISTICS

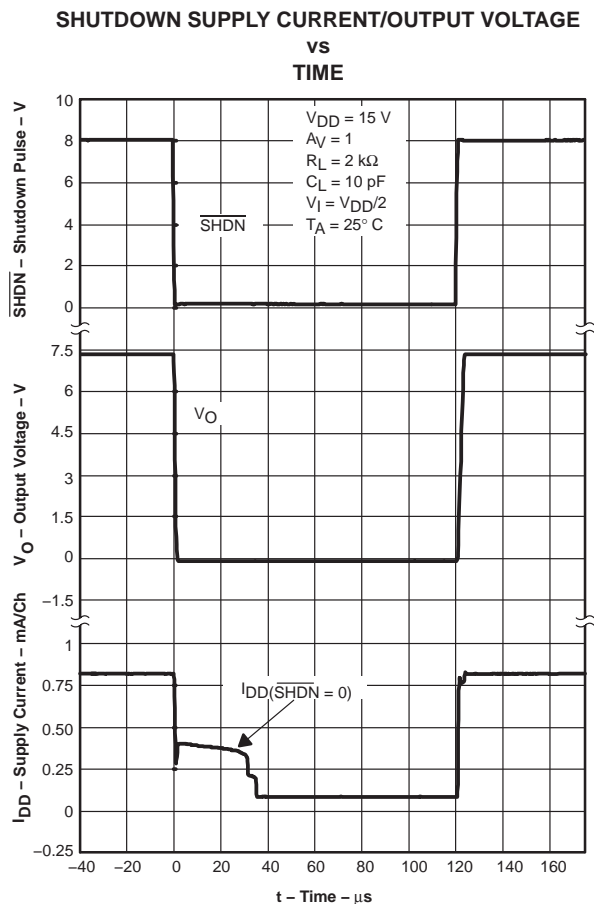


Figure 31

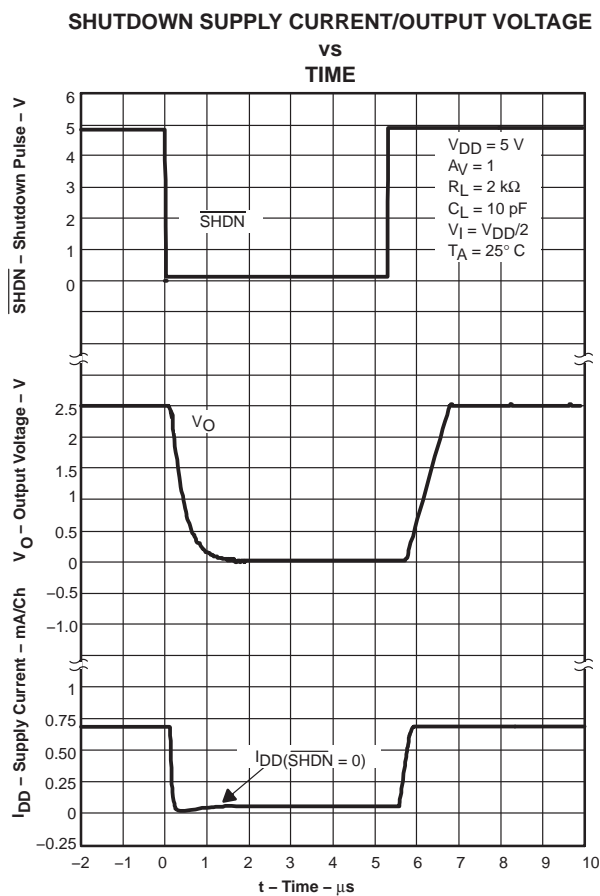


Figure 32

TLV2370, TLV2371, TLV2372, TLV2373, TLV2374, TLV2375 FAMILY OF 550- μ A/Ch 3-MHz RAIL-TO-RAIL INPUT/OUTPUT OPERATIONAL AMPLIFIERS WITH SHUTDOWN

SLOS270D – MARCH 2001 – REVISED JANUARY 2005

APPLICATION INFORMATION

rail-to-rail input operation

The TLV237x input stage consists of two differential transistor pairs, NMOS and PMOS, that operate together to achieve rail-to-rail input operation. The transition point between these two pairs can be seen in Figure 1, Figure 2, and Figure 3 for a 2.7-V, 5-V, and 15-V supply. As the common-mode input voltage approaches the positive supply rail, the input pair switches from the PMOS differential pair to the NMOS differential pair. This transition occurs approximately 1.35 V from the positive rail and results in a change in offset voltage due to different device characteristics between the NMOS and PMOS pairs. If the input signal to the device is large enough to swing between both rails, this transition results in a reduction in common-mode rejection ratio (CMRR). If the input signal does not swing between both rails, it is best to bias the signal in the region where only one input pair is active. This is the region in Figure 1 through Figure 3 where the offset voltage varies slightly across the input range and optimal CMRR can be achieved. This has the greatest impact when operating from a 2.7-V supply voltage.

driving a capacitive load

When the amplifier is configured in this manner, capacitive loading directly on the output decreases the device's phase margin leading to high frequency ringing or oscillations. Therefore, for capacitive loads of greater than 10 pF, it is recommended that a resistor be placed in series (R_{NULL}) with the output of the amplifier, as shown in Figure 33. A minimum value of 20 Ω should work well for most applications.

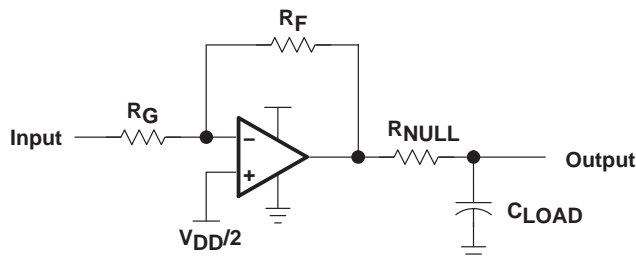


Figure 33. Driving a Capacitive Load

offset voltage

The output offset voltage, (V_{OO}) is the sum of the input offset voltage (V_{IO}) and both input bias currents (I_{IB}) times the corresponding gains. The following schematic and formula can be used to calculate the output offset voltage:

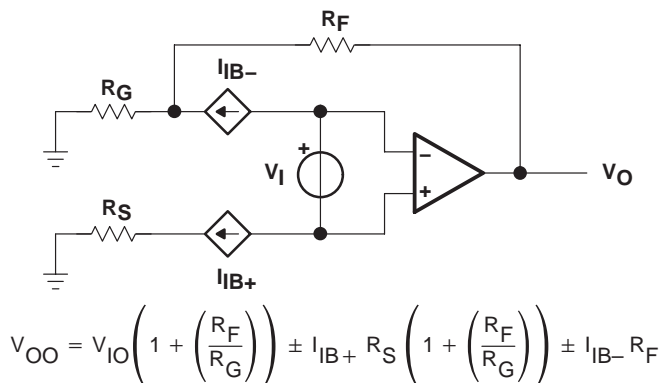


Figure 34. Output Offset Voltage Model

APPLICATION INFORMATION

general configurations

When receiving low-level signals, limiting the bandwidth of the incoming signals into the system is often required. The simplest way to accomplish this is to place an RC filter at the noninverting terminal of the amplifier (see Figure 35).

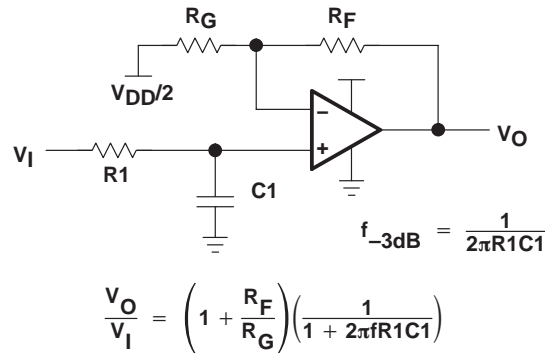


Figure 35. Single-Pole Low-Pass Filter

If even more attenuation is needed, a multiple pole filter is required. The Sallen-Key filter can be used for this task. For best results, the amplifier should have a bandwidth that is 8 to 10 times the filter frequency bandwidth. Failure to do this can result in phase shift of the amplifier.

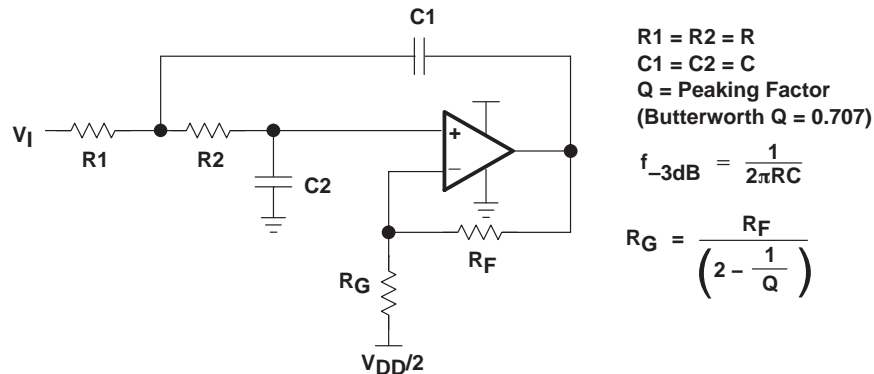


Figure 36. 2-Pole Low-Pass Sallen-Key Filter

TLV2370, TLV2371, TLV2372, TLV2373, TLV2374, TLV2375 FAMILY OF 550- μ A/Ch 3-MHz RAIL-TO-RAIL INPUT/OUTPUT OPERATIONAL AMPLIFIERS WITH SHUTDOWN

SLOS270D – MARCH 2001 – REVISED JANUARY 2005

APPLICATION INFORMATION

circuit layout considerations

To achieve the levels of high performance of the TLV237x, follow proper printed-circuit board design techniques. A general set of guidelines is given in the following.

- Ground planes—It is highly recommended that a ground plane be used on the board to provide all components with a low inductive ground connection. However, in the areas of the amplifier inputs and output, the ground plane can be removed to minimize the stray capacitance.
- Proper power supply decoupling—Use a 6.8- μ F tantalum capacitor in parallel with a 0.1- μ F ceramic capacitor on each supply terminal. It may be possible to share the tantalum among several amplifiers depending on the application, but a 0.1- μ F ceramic capacitor should always be used on the supply terminal of every amplifier. In addition, the 0.1- μ F capacitor should be placed as close as possible to the supply terminal. As this distance increases, the inductance in the connecting trace makes the capacitor less effective. The designer should strive for distances of less than 0.1 inches between the device power terminals and the ceramic capacitors.
- Sockets—Sockets can be used but are not recommended. The additional lead inductance in the socket pins will often lead to stability problems. Surface-mount packages soldered directly to the printed-circuit board is the best implementation.
- Short trace runs/compact part placements—Optimum high performance is achieved when stray series inductance has been minimized. To realize this, the circuit layout should be made as compact as possible, thereby minimizing the length of all trace runs. Particular attention should be paid to the inverting input of the amplifier. Its length should be kept as short as possible. This helps to minimize stray capacitance at the input of the amplifier.
- Surface-mount passive components—Using surface-mount passive components is recommended for high performance amplifier circuits for several reasons. First, because of the extremely low lead inductance of surface-mount components, the problem with stray series inductance is greatly reduced. Second, the small size of surface-mount components naturally leads to a more compact layout thereby minimizing both stray inductance and capacitance. If leaded components are used, it is recommended that the lead lengths be kept as short as possible.

shutdown function

Three members of the TLV237x family (TLV2370/3/5) have a shutdown terminal for conserving battery life in portable applications. When the shutdown terminal is tied low, the supply current is reduced to 25 μ A/channel, the amplifier is disabled, and the outputs are placed in a high impedance mode. To enable the amplifier, the shutdown terminal can either be left floating or pulled high. When the shutdown terminal is left floating, care should be taken to ensure that parasitic leakage current at the shutdown terminal does not inadvertently place the operational amplifier into shutdown.



TLV2370, TLV2371, TLV2372, TLV2373, TLV2374, TLV2375
FAMILY OF 550- μ A/Ch 3-MHz RAIL-TO-RAIL INPUT/OUTPUT
OPERATIONAL AMPLIFIERS WITH SHUTDOWN

SLOS270D – MARCH 2001 – REVISED JANUARY 2005

APPLICATION INFORMATION

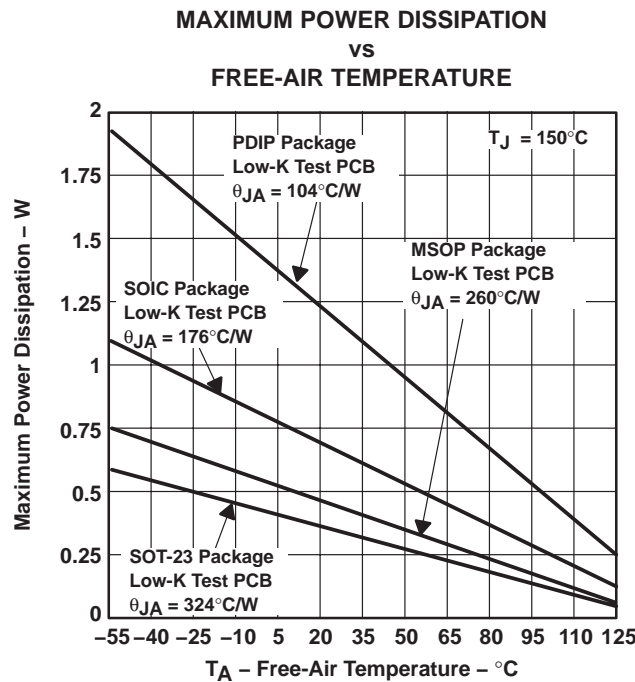
general power dissipation considerations

For a given θ_{JA} , the maximum power dissipation is shown in Figure 37 and is calculated by the following formula:

$$P_D = \left(\frac{T_{MAX} - T_A}{\theta_{JA}} \right)$$

Where:

- P_D = Maximum power dissipation of TLV237x IC (watts)
- T_{MAX} = Absolute maximum junction temperature (150°C)
- T_A = Free-ambient air temperature (°C)
- θ_{JA} = $\theta_{JC} + \theta_{CA}$
- θ_{JC} = Thermal coefficient from junction to case
- θ_{CA} = Thermal coefficient from case to ambient air (°C/W)



NOTE A: Results are with no air flow and using JEDEC Standard Low-K test PCB.

Figure 37. Maximum Power Dissipation vs Free-Air Temperature

PACKAGING INFORMATION

| Orderable Device | Status ⁽¹⁾ | Package Type | Package Drawing | Pins | Package Qty | Eco Plan ⁽²⁾ | Lead/Ball Finish | MSL Peak Temp ⁽³⁾ |
|------------------|-----------------------|--------------|-----------------|------|-------------|-------------------------|------------------|------------------------------|
| TLV2370ID | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2370IDBVR | ACTIVE | SOT-23 | DBV | 6 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2370IDBVRG4 | ACTIVE | SOT-23 | DBV | 6 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2370IDBVT | ACTIVE | SOT-23 | DBV | 6 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2370IDBVTG4 | ACTIVE | SOT-23 | DBV | 6 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2370IDG4 | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2370IDR | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2370IDRG4 | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2370IP | ACTIVE | PDIP | P | 8 | 50 | Pb-Free (RoHS) | CU NIPDAU | N / A for Pkg Type |
| TLV2370IPE4 | ACTIVE | PDIP | P | 8 | 50 | Pb-Free (RoHS) | CU NIPDAU | N / A for Pkg Type |
| TLV2371ID | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2371IDBVR | ACTIVE | SOT-23 | DBV | 5 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2371IDBVRG4 | ACTIVE | SOT-23 | DBV | 5 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2371IDBVT | ACTIVE | SOT-23 | DBV | 5 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2371IDBVTG4 | ACTIVE | SOT-23 | DBV | 5 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2371IDG4 | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2371IDR | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2371IDRG4 | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2371IP | ACTIVE | PDIP | P | 8 | 50 | Pb-Free (RoHS) | Call TI | N / A for Pkg Type |
| TLV2371IPE4 | ACTIVE | PDIP | P | 8 | 50 | Pb-Free (RoHS) | Call TI | N / A for Pkg Type |
| TLV2372ID | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2372IDG4 | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2372IDGK | ACTIVE | MSOP | DGK | 8 | 80 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2372IDGKG4 | ACTIVE | MSOP | DGK | 8 | 80 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2372IDGKR | ACTIVE | MSOP | DGK | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |

| Orderable Device | Status ⁽¹⁾ | Package Type | Package Drawing | Pins | Package Qty | Eco Plan ⁽²⁾ | Lead/Ball Finish | MSL Peak Temp ⁽³⁾ |
|------------------|-----------------------|--------------|-----------------|------|-------------|-------------------------|------------------|------------------------------|
| TLV2372IDGKRG4 | ACTIVE | MSOP | DGK | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2372IDR | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2372IDRG4 | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2372IP | ACTIVE | PDIP | P | 8 | 50 | Pb-Free (RoHS) | CU NIPDAU | N / A for Pkg Type |
| TLV2372IPE4 | ACTIVE | PDIP | P | 8 | 50 | Pb-Free (RoHS) | CU NIPDAU | N / A for Pkg Type |
| TLV2373ID | ACTIVE | SOIC | D | 14 | 50 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2373IDG4 | ACTIVE | SOIC | D | 14 | 50 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2373IDGS | ACTIVE | MSOP | DGS | 10 | 80 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2373IDGSG4 | ACTIVE | MSOP | DGS | 10 | 80 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2373IDGSR | ACTIVE | MSOP | DGS | 10 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2373IDGSRG4 | ACTIVE | MSOP | DGS | 10 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2373IDR | ACTIVE | SOIC | D | 14 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2373IDRG4 | ACTIVE | SOIC | D | 14 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2373IN | ACTIVE | PDIP | N | 14 | 25 | Pb-Free (RoHS) | CU NIPDAU | N / A for Pkg Type |
| TLV2373INE4 | ACTIVE | PDIP | N | 14 | 25 | Pb-Free (RoHS) | CU NIPDAU | N / A for Pkg Type |
| TLV2374ID | ACTIVE | SOIC | D | 14 | 50 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2374IDG4 | ACTIVE | SOIC | D | 14 | 50 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2374IDR | ACTIVE | SOIC | D | 14 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2374IDRG4 | ACTIVE | SOIC | D | 14 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2374IN | ACTIVE | PDIP | N | 14 | 25 | Pb-Free (RoHS) | CU NIPDAU | N / A for Pkg Type |
| TLV2374INE4 | ACTIVE | PDIP | N | 14 | 25 | Pb-Free (RoHS) | CU NIPDAU | N / A for Pkg Type |
| TLV2374IPW | ACTIVE | TSSOP | PW | 14 | 90 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2374IPWG4 | ACTIVE | TSSOP | PW | 14 | 90 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2374IPWR | ACTIVE | TSSOP | PW | 14 | 2000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2374IPWRG4 | ACTIVE | TSSOP | PW | 14 | 2000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2375D | PREVIEW | SOIC | D | 16 | | TBD | Call TI | Call TI |

| Orderable Device | Status ⁽¹⁾ | Package Type | Package Drawing | Pins | Package Qty | Eco Plan ⁽²⁾ | Lead/Ball Finish | MSL Peak Temp ⁽³⁾ |
|------------------|-----------------------|--------------|-----------------|------|-------------|-------------------------|------------------|------------------------------|
| TLV2375DR | PREVIEW | SOIC | D | 16 | | TBD | Call TI | Call TI |
| TLV2375ID | ACTIVE | SOIC | D | 16 | 40 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2375IDG4 | ACTIVE | SOIC | D | 16 | 40 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2375IDR | ACTIVE | SOIC | D | 16 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2375IDRG4 | ACTIVE | SOIC | D | 16 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2375IN | ACTIVE | PDIP | N | 16 | 25 | Pb-Free (RoHS) | CU NIPDAU | N / A for Pkg Type |
| TLV2375INE4 | ACTIVE | PDIP | N | 16 | 25 | Pb-Free (RoHS) | CU NIPDAU | N / A for Pkg Type |
| TLV2375IPW | ACTIVE | TSSOP | PW | 16 | 90 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2375IPWG4 | ACTIVE | TSSOP | PW | 16 | 90 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2375IPWR | ACTIVE | TSSOP | PW | 16 | 2000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLV2375IPWRG4 | ACTIVE | TSSOP | PW | 16 | 2000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |

⁽¹⁾ The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

OBSOLETE: TI has discontinued the production of the device.

⁽²⁾ Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

TBD: The Pb-Free/Green conversion plan has not been defined.

Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

⁽³⁾ MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

Important Information and Disclaimer:The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

P (R-PDIP-T8)

PLASTIC DUAL-IN-LINE



- NOTES: A. All linear dimensions are in inches (millimeters).
 B. This drawing is subject to change without notice.
 C. Falls within JEDEC MS-001

For the latest package information, go to http://www.ti.com/sc/docs/package/pkg_info.htm



N (R-PDIP-T**)

PLASTIC DUAL-IN-LINE PACKAGE

16 PINS SHOWN



4040049/E 12/2002

- NOTES:
- A. All linear dimensions are in inches (millimeters).
 - B. This drawing is subject to change without notice.
 - $\triangle C$ Falls within JEDEC MS-001, except 18 and 20 pin minimum body length (Dim A).
 - $\triangle D$ The 20 pin end lead shoulder width is a vendor option, either half or full width.

DBV (R-PDSO-G5)

PLASTIC SMALL-OUTLINE PACKAGE



- NOTES:
- A. All linear dimensions are in millimeters.
 - B. This drawing is subject to change without notice.
 - C. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
 - D. Falls within JEDEC MO-178 Variation AA.

DBV (R-PDSO-G6)

PLASTIC SMALL-OUTLINE PACKAGE



- NOTES:
- A. All linear dimensions are in millimeters.
 - B. This drawing is subject to change without notice.
 - C. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
 - D. Leads 1,2,3 may be wider than leads 4,5,6 for package orientation.
- $\triangle E$ Falls within JEDEC MO-178 Variation AB, except minimum lead width.

DGK (S-PDSO-G8)

PLASTIC SMALL-OUTLINE PACKAGE



4073329/E 05/06

- NOTES:
- A. All linear dimensions are in millimeters.
 - B. This drawing is subject to change without notice.
 - C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 per end.
 - D. Body width does not include interlead flash. Interlead flash shall not exceed 0.50 per side.
 - E. Falls within JEDEC MO-187 variation AA, except interlead flash.

DGS (S-PDSO-G10)

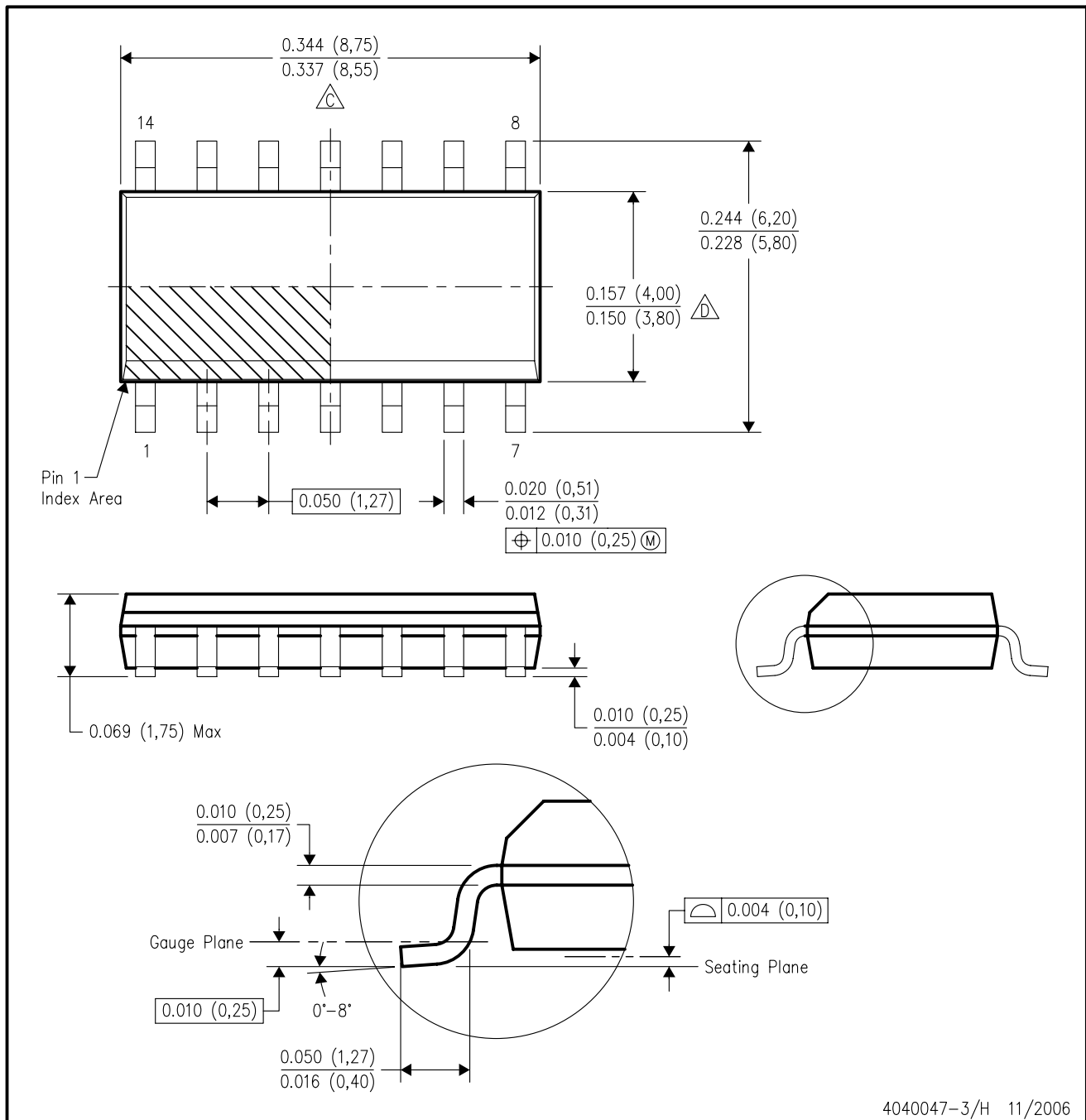
PLASTIC SMALL-OUTLINE PACKAGE



- NOTES:
- A. All linear dimensions are in millimeters.
 - B. This drawing is subject to change without notice.
 - C. Body dimensions do not include mold flash or protrusion.
 - D. Falls within JEDEC MO-187 variation BA.

D (R-PDSO-G14)

PLASTIC SMALL-OUTLINE PACKAGE



- NOTES:
- A. All linear dimensions are in inches (millimeters).
 - B. This drawing is subject to change without notice.
 - C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed .006 (0,15) per end.
 - D. Body width does not include interlead flash. Interlead flash shall not exceed .017 (0,43) per side.
 - E. Reference JEDEC MS-012 variation AB.

D (R-PDSO-G16)

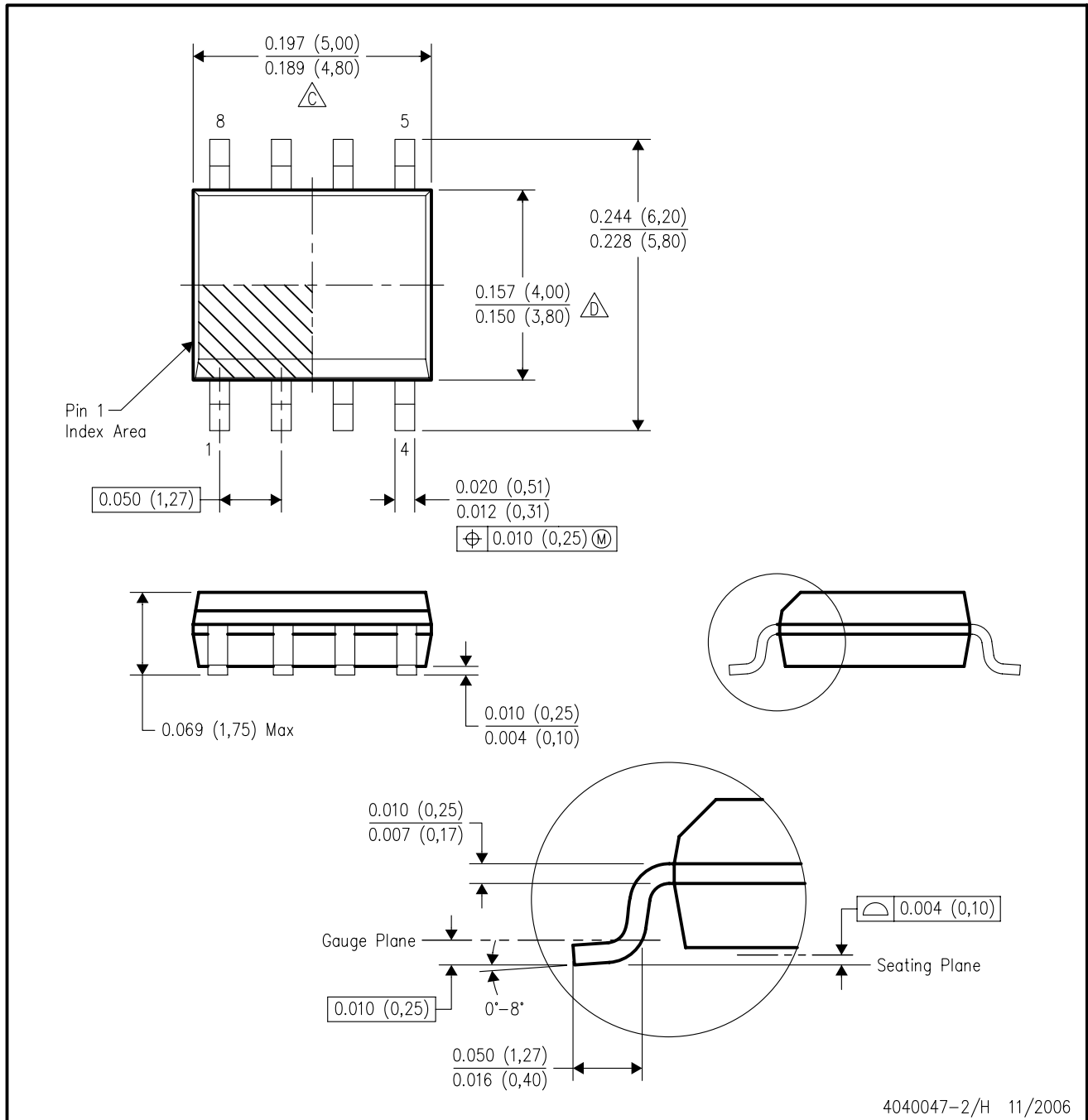
PLASTIC SMALL-OUTLINE PACKAGE



- NOTES:
- A. All linear dimensions are in inches (millimeters).
 - B. This drawing is subject to change without notice.
 - C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed .006 (0,15) per end.
 - D. Body width does not include interlead flash. Interlead flash shall not exceed .017 (0,43) per side.
 - E. Reference JEDEC MS-012 variation AC.

D (R-PDSO-G8)

PLASTIC SMALL-OUTLINE PACKAGE



- NOTES:
- A. All linear dimensions are in inches (millimeters).
 - B. This drawing is subject to change without notice.
 - C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed .006 (0,15) per end.
 - D. Body width does not include interlead flash. Interlead flash shall not exceed .017 (0,43) per side.
 - E. Reference JEDEC MS-012 variation AA.

PW (R-PDSO-G**)

PLASTIC SMALL-OUTLINE PACKAGE

14 PINS SHOWN



4040064/F 01/97

- NOTES: A. All linear dimensions are in millimeters.
 B. This drawing is subject to change without notice.
 C. Body dimensions do not include mold flash or protrusion not to exceed 0,15.
 D. Falls within JEDEC MO-153

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

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

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

| Products | | Applications | |
|--------------------|--|---------------------|--|
| Amplifiers | amplifier.ti.com | Audio | www.ti.com/audio |
| Data Converters | dataconverter.ti.com | Automotive | www.ti.com/automotive |
| DSP | dsp.ti.com | Broadband | www.ti.com/broadband |
| Interface | interface.ti.com | Digital Control | www.ti.com/digitalcontrol |
| Logic | logic.ti.com | Military | www.ti.com/military |
| Power Mgmt | power.ti.com | Optical Networking | www.ti.com/opticalnetwork |
| Microcontrollers | microcontroller.ti.com | Security | www.ti.com/security |
| Low Power Wireless | www.ti.com/lpw | Telephony | www.ti.com/telephony |
| | | Video & Imaging | www.ti.com/video |
| | | Wireless | www.ti.com/wireless |

Mailing Address: Texas Instruments
Post Office Box 655303 Dallas, Texas 75265