- **Qualified for Automotive Applications**
- **High Slew Rate . . . 10.5 V/μs Typ**
- **High-Gain Bandwidth . . . 5.1 MHz Typ**
- **Supply Voltage Range 2.5 V to 5.5 V**
- **Rail-to-Rail Output**
- **360-μV Input Offset Voltage**
- **Low Distortion Driving 600-Ω . . . 0.005% THD+N**
- **1-mA Supply Current (Per Channel)**
- **17-nV/√Hz Input Noise Voltage**
- **2-pA Input Bias Current**
- **Characterized From $T_A$ = –40°C to 125°C**
- **Available in MSOP and SOT-23 Packages**
- **Micropower Shutdown Mode . . . $I_{DD}$ < 1 μA**

## description

The TLV277x CMOS operational amplifier family combines high slew rate and bandwidth, rail-to-rail output swing, high output drive, and excellent dc-precision. The device provides 10.5 V/μs of slew rate and 5.1 MHz of bandwidth while only consuming 1 mA of supply current per channel. This ac-performance is much higher than current competitive CMOS amplifiers. The rail-to-rail output swing and high output drive make these devices a good choice for driving the analog input or reference of analog-to-digital converters. These devices also have low distortion while driving a 600-Ω load for use in telecom systems.

These amplifiers have a 360-μV input offset voltage, a 17 nV/√Hz input noise voltage, and a 2-pA input bias current for measurement, medical, and industrial applications. The TLV277x family is also specified across an extended temperature range (–40°C to 125°C), making it useful for automotive systems.

These devices operate from a 2.5-V to 5.5-V single supply voltage and are characterized at 2.7 V and 5 V. The single-supply operation and low power consumption make these devices a good solution for portable applications. The following table lists the packages available.

**FAMILY PACKAGE TABLE**

| DEVICE | NUMBER OF CHANNELS | PACKAGE TYPES | | | SHUTDOWN | UNIVERSAL EVM BOARD |
|---|---|---|---|---|---|---|
| | | SOIC | TSSOP | SOT-23 | | |
| TLV2770 | 1 | 8 | — | — | Yes | See the EVM Selection Guide (SLOU060) |
| TLV2771 | 1 | 8 | — | 5 | — | |
| TLV2772 | 2 | 8 | 8 | — | — | |
| TLV2773 | 2 | 14 | — | — | Yes | |
| TLV2774 | 4 | 14 | 14 | — | — | |
| TLV2775 | 4 | 16 | 16 | — | Yes | |

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.

**A SELECTION OF SINGLE-SUPPLY OPERATIONAL AMPLIFIER PRODUCTS†**

| DEVICE | $V_{DD}$ (V) | BW (MHz) | SLEW RATE (V/μs) | $I_{DD}$ (per channel) (μA) | RAIL-TO-RAIL |
|---|---|---|---|---|---|
| TLV277x | 2.5 – 6 | 5.1 | 10.5 | 1000 | O |
| TLV247x | 2.7 – 6 | 2.8 | 1.5 | 600 | I/O |
| TLV245x | 2.7 – 6 | 0.22 | 0.11 | 23 | I/O |
| TLV246x | 2.7 – 6 | 6.4 | 1.6 | 550 | I/O |

† All specifications measured at 5 V.

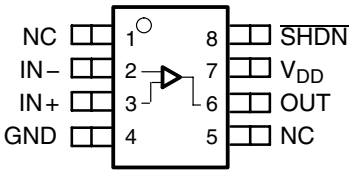
## ORDERING INFORMATION†

| $T_A$ | $V_{IO}$max AT 25°C (mV) | PACKAGE‡ | | ORDERABLE PART NUMBER | TOP-SIDE MARKING |
|---|---|---|---|---|---|
| –40°C to 125°C | 2.5 | SOIC (D) | Tape and reel | TLV2770QDRQ1§ | |
| | 1.6 | SOIC (D) | Tape and reel | TLV2770AQDRQ1§ | |
| | 2.5 | SOT-23 (DBV) | Tape and reel | TLV2771QDBVRQ1 | VBPQ |
| | 2.5 | SOIC (D) | Tape and reel | TLV2771QDRQ1§ | |
| | 1.6 | SOIC (D) | Tape and reel | TLV2771AQDRQ1§ | |
| | 2.5 | SOIC (D) | Tape and reel | TLV2772QDRQ1 | TLV2772QI |
| | | TSSOP (PW) | Tape and reel | TLV2772QPWRQ1 | TLV2772QI |
| | 1.6 | SOIC (D) | Tape and reel | TLV2772AQDRQ1 | TLV2772AQ |
| | | TSSOP (PW) | Tape and reel | TLV2772AQPWRQ1 | TLV2772AQ |
| | 2.5 | SOIC (D) | Tape and reel | TLV2773QDRQ1§ | |
| | 1.6 | SOIC (D) | Tape and reel | TLV2773AQDRQ1§ | |
| | 2.7 | SOIC (D) | Tape and reel | TLV2774QDRQ1§ | |
| | | TSSOP (PW) | Tape and reel | TLV2774QPWRQ1§ | |
| | 2.1 | SOIC (D) | Tape and reel | TLV2774AQDRQ1§ | |
| | | TSSOP (PW) | Tape and reel | TLV2774AQPWRQ1§ | |
| | 2.7 | SOIC (D) | Tape and reel | TLV2775QDRQ1§ | |
| | | TSSOP (PW) | Tape and reel | TLV2775QPWRQ1§ | |
| | 2.1 | SOIC (D) | Tape and reel | TLV2775AQDRQ1§ | |
| | | TSSOP (PW) | Tape and reel | TLV2775AQPWRQ1§ | |

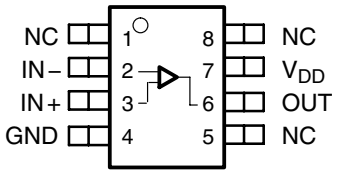
† For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI web site at http://www.ti.com.
‡ Package drawings, thermal data, and symbolization are available at http://www.ti.com/packaging.
§ Product Preview

## TLV277x PACKAGE PINOUTS

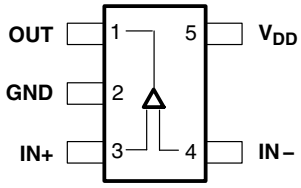
**TLV2770†**
**D PACKAGE**
**(TOP VIEW)**



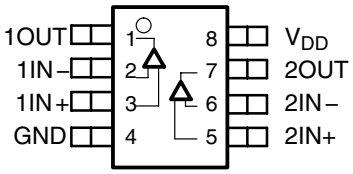

**TLV2771†**
**D PACKAGE**
**(TOP VIEW)**



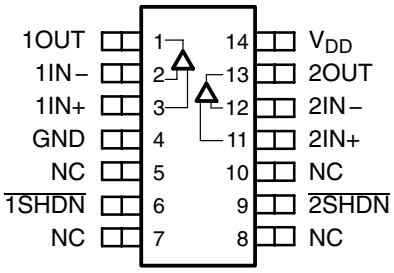

**TLV2771**
**DBV PACKAGE**
**(TOP VIEW)**



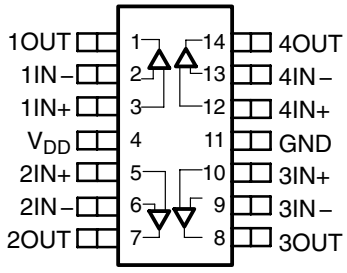

**TLV2772**
**D OR PW PACKAGE**
**(TOP VIEW)**



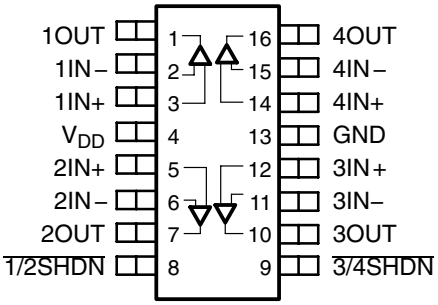

**TLV2773†**
**D PACKAGE**
**(TOP VIEW)**




**TLV2774†**
**D OR PW PACKAGE**
**(TOP VIEW)**




**TLV2775†**
**D OR PW PACKAGE**
**(TOP VIEW)**




NC – No internal connection

† This device is in the Product Preview stage of development. Contact your local Texas Instruments sales office for availability.

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

Supply voltage, $V_{DD}$ (see Note 1) . . . . . 7 V
Differential input voltage, $V_{ID}$ (see Note 2) . . . . . $\pm V_{DD}$
Input voltage range, $V_I$ (any input, see Note 1) . . . . . –0.3 V to $V_{DD}$
Input current, $I_I$ (any input) . . . . . ±4 mA
Output current, $I_O$ . . . . . ±50 mA
Total current into $V_{DD+}$ . . . . . ±50 mA
Total current out of GND . . . . . ±50 mA
Duration of short-circuit current (at or below) 25°C (see Note 3) . . . . . Unlimited
Continuous total power dissipation . . . . . See Dissipation Rating Table
Operating free-air temperature range, $T_A$: Q suffix . . . . . –40°C to 125°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.

NOTES: 1. All voltage values, except differential voltages, are with respect to GND.
2. Differential voltages are at the noninverting input with respect to the inverting input. Excessive current flows when input is brought below GND – 0.3 V.
3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.

**ESD RATING TABLE**

| | | | |
|---|---|---|---|
| ESD rating | Human Body Model (4) | 2 (H1C) | kV |
| | Charged-Device Model (4) | 1 (C5) | |
| | Machine Model (4) | 150 (M2) | V |
| | Machine Model (5) | 100 (M1) | V |

NOTE 4: ESD protection level per AEC Q100 Classification TLV2771QDBVRQ1
NOTE 5: ESD protection level per AEC Q100 Classification TLV2772QPWRG4Q1

**DISSIPATION RATING TABLE**

| PACKAGE | $T_A \le 25°C$ POWER RATING | DERATING FACTOR ABOVE $T_A = 25°C$ | $T_A = 70°C$ POWER RATING | $T_A = 85°C$ POWER RATING | $T_A = 125°C$ POWER RATING |
|---|---|---|---|---|---|
| D | 725 mW | 5.8 mW/°C | 464 mW | 377 mW | 145 mW |
| DBV | 437 mW | 3.5 mW/°C | 280 mW | 227 mW | 87 mW |
| PW | 700 mW | 5.6 mW/°C | 448 mW | 364 mW | 140 mW |

## recommended operating conditions

| | Q SUFFIX | | UNIT |
|---|---|---|---|
| | MIN | MAX | |
| Supply voltage, $V_{DD}$ | 2.5 | 6 | V |
| Input voltage range, $V_I$ | GND | $V_{DD+} - 1.3$ | V |
| Common-mode input voltage, $V_{IC}$ | GND | $V_{DD+} - 1.3$ | V |
| Operating free-air temperature, $T_A$ | –40 | 125 | °C |

## electrical characteristics at specified free-air temperature, $V_{DD}$ = 2.7 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLV2771-Q1 | | | UNIT |
|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC}$ = 0, $V_O$ = 0, $R_S$ = 50 Ω, $V_{DD}$ = ±1.35 V, No load | 25°C | | 0.48 | 2.5 | mV |
| | | | Full range | | 0.53 | 2.7 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | $V_{IC}$ = 0, $V_O$ = 0, $R_S$ = 50 Ω | 25°C to 125°C | | 2 | | µV/°C |
| $I_{IO}$ | Input offset current | | 25°C | | 1 | 60 | pA |
| | | | Full range | | 2 | 125 | |
| $I_{IB}$ | Input bias current | | 25°C | | 2 | 60 | pA |
| | | | Full range | | 6 | 350 | |
| $V_{OH}$ | High-level output voltage | $I_{OH}$ = –0.675 mA | 25°C | | 2.6 | | V |
| | | | Full range | | 2.5 | | |
| | | $I_{OH}$ = –2.2 mA | 25°C | | 2.4 | | |
| | | | Full range | | 2.1 | | |
| $V_{OL}$ | Low-level output voltage | $V_{IC}$ = 1.35 V, $I_{OL}$ = 0.675 mA | 25°C | | 0.1 | | V |
| | | | Full range | | 0.2 | | |
| | | $V_{IC}$ = 1.35 V, $I_{OL}$ = 2.2 mA | 25°C | | 0.21 | | |
| | | | Full range | | 0.6 | | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_{IC}$ = 1.35 V, $R_L$ = 10 kΩ‡, $V_O$ = 0.6 V to 2.1 V | 25°C | 20 | 380 | | V/mV |
| | | | Full range | 13 | | | |
| $r_{i(d)}$ | Differential input resistance | | 25°C | | $10^{12}$ | | Ω |
| $c_{i(c)}$ | Common-mode input capacitance | f = 10 kHz | 25°C | | 8 | | pF |
| $z_o$ | Closed-loop output impedance | f = 100 kHz, $A_V$ = 10 | 25°C | | 25 | | Ω |
| CMRR | Common-mode rejection ratio | $V_{IC}$ = 0 to 1.5 V, $V_O$ = $V_{DD}$/2, $R_S$ = 50 Ω | 25°C | 60 | 84 | | dB |
| | | | Full range | 60 | 82 | | |
| $k_{SVR}$ | Supply voltage rejection ratio ($\Delta V_{DD}$ /$\Delta V_{IO}$) | $V_{DD}$ = 2.7 V to 5 V, $V_{IC}$ = $V_{DD}$/2, No load | 25°C | 70 | 89 | | dB |
| | | | Full range | 70 | 84 | | |
| $I_{DD}$ | Supply current (per channel) | $V_O$ = $V_{DD}$/2, No load | 25°C | | 1 | 2 | mA |
| | | | Full range | | | 2 | |

† Full range is –40°C to 125°C for Q level part.
‡ Referenced to 1.35 V

## operating characteristics at specified free-air temperature, $V_{DD}$ = 2.7 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$† | TLV2771-Q1 | | | UNIT |
|---|---|---|---|---|---|---|---|---|
| | | | | | MIN | TYP | MAX | |
| SR | Slew rate at unity gain | $V_{O(PP)}$ = 0.8 V, $C_L$ = 100 pF, $R_L$ = 10 kΩ | | 25°C | 5 | 9 | | V/μs |
| | | | | Full range | 4.7 | 6 | | |
| $V_n$ | Equivalent input noise voltage | f = 1 kHz | | 25°C | | 21 | | nV/√Hz |
| | | f = 10 kHz | | 25°C | | 17 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 1 Hz | | 25°C | | 0.33 | | μV |
| | | f = 0.1 Hz to 10 Hz | | 25°C | | 0.86 | | μV |
| $I_n$ | Equivalent input noise current | f = 100 Hz | | 25°C | | 0.6 | | fA/√Hz |
| THD + N | Total harmonic distortion plus noise | $R_L$ = 600 Ω, f = 1 kHz | $A_V$ = 1 | 25°C | | 0.0085% | | |
| | | | $A_V$ = 10 | | | 0.025% | | |
| | | | $A_V$ = 100 | | | 0.12% | | |
| | Gain-bandwidth product | f = 10 kHz, $R_L$ = 600 Ω, $C_L$ = 100 pF | | 25°C | | 4.8 | | MHz |
| $t_s$ | Settling time | $A_V$ = –1, Step = 0.85 V to 1.85 V, $R_L$ = 600 Ω, $C_L$ = 100 pF | 0.1% | 25°C | | 0.186 | | μs |
| | | | 0.01% | 25°C | | 3.92 | | |
| $\phi_m$ | Phase margin at unity gain | $R_L$ = 600 Ω, $C_L$ = 100 pF | | 25°C | | 46° | | |
| | Gain margin | | | 25°C | | 12 | | dB |

† Full range is –40°C to 125°C.

## electrical characteristics at specified free-air temperature, $V_{DD}$ = 5 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$† | TLV2771-Q1 | | | UNIT |
|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{IC}$ = 0, No load<br>$V_O$ = 0, $R_S$ = 50 Ω, $V_{DD}$ = ±2.5 V | 25°C | | 0.5 | 2.5 | mV |
| | | | Full range | | 0.6 | 2.7 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | $V_{IC}$ = 0, $V_O$ = 0, $R_S$ = 50 Ω, $V_{DD}$ = ±2.5 V | 25°C to 125°C | | 2 | | μV/°C |
| $I_{IO}$ | Input offset current | | 25°C | | 1 | 60 | pA |
| | | | Full range | | 2 | 125 | |
| $I_{IB}$ | Input bias current | | 25°C | | 2 | 60 | pA |
| | | | Full range | | 6 | 350 | |
| $V_{OH}$ | High-level output voltage | $I_{OH}$ = –1.3 mA | 25°C | | 4.9 | | V |
| | | | Full range | | 4.8 | | |
| | | $I_{OH}$ = –4.2 mA | 25°C | | 4.7 | | |
| | | | Full range | | 4.4 | | |
| $V_{OL}$ | Low-level output voltage | $V_{IC}$ = 2.5 V, $I_{OL}$ = 1.3 mA | 25°C | | 0.1 | | V |
| | | | Full range | | 0.2 | | |
| | | $V_{IC}$ = 2.5 V, $I_{OL}$ = 4.2 mA | 25°C | | 0.21 | | |
| | | | Full range | | 0.6 | | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_{IC}$ = 2.5 V, $R_L$ = 10 kΩ‡, $V_O$ = 1 V to 4 V | 25°C | 20 | 450 | | V/mV |
| | | | Full range | 13 | | | |
| $r_{i(d)}$ | Differential input resistance | | 25°C | | $10^{12}$ | | Ω |
| $c_{i(c)}$ | Common-mode input capacitance | f = 10 kHz | 25°C | | 8 | | pF |
| $z_o$ | Closed-loop output impedance | f = 100 kHz, $A_V$ = 10 | 25°C | | 20 | | Ω |
| CMRR | Common-mode rejection ratio | $V_{IC}$ = 0 to 3.7 V,<br>$V_O$ = $V_{DD}$/2, $R_S$ = 50 Ω | 25°C | 60 | 96 | | dB |
| | | | Full range | 60 | 93 | | |
| $k_{SVR}$ | Supply voltage rejection ratio ($\Delta V_{DD}$ /$\Delta V_{IO}$) | $V_{DD}$ = 2.7 V to 5 V,<br>$V_{IC}$ = $V_{DD}$/2, No load | 25°C | 70 | 89 | | dB |
| | | | Full range | 70 | 84 | | |
| $I_{DD}$ | Supply current (per channel) | $V_O$ = $V_{DD}$/2, No load | 25°C | | 1 | 2 | mA |
| | | | Full range | | | 2 | |

† Full range is – 40°C to 125°C for Q level part.
‡ Referenced to 2.5 V

### operating characteristics at specified free-air temperature, $V_{DD}$ = 5 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$† | TLV2771-Q1 | | | UNIT |
|---|---|---|---|---|---|---|---|---|
| | | | | | MIN | TYP | MAX | |
| SR | Slew rate at unity gain | $V_{O(PP)}$ = 1.5 V, $C_L$ = 100 pF, $R_L$ = 10 kΩ | | 25°C | 5 | 10.5 | | V/μs |
| | | | | Full range | 4.7 | 6 | | |
| $V_n$ | Equivalent input noise voltage | f = 1 kHz | | 25°C | | 17 | | nV/√Hz |
| | | f = 10 kHz | | 25°C | | 12 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 1 Hz | | 25°C | | 0.33 | | μV |
| | | f = 0.1 Hz to 10 Hz | | 25°C | | 0.86 | | μV |
| $I_n$ | Equivalent input noise current | f = 100 Hz | | 25°C | | 0.6 | | fA/√Hz |
| THD + N | Total harmonic distortion plus noise | $R_L$ = 600 Ω, f = 1 kHz | $A_V$ = 1 | 25°C | | 0.005% | | |
| | | | $A_V$ = 10 | | | 0.016% | | |
| | | | $A_V$ = 100 | | | 0.095% | | |
| | Gain-bandwidth product | f = 10 kHz, $R_L$ = 600 Ω, $C_L$ = 100 pF | | 25°C | | 5.1 | | MHz |
| $t_s$ | Settling time | $A_V$ = –1, Step = 1.5 V to 3.5 V, $R_L$ = 600 Ω, $C_L$ = 100 pF | 0.1% | 25°C | | 0.134 | | μs |
| | | | 0.01% | 25°C | | 1.97 | | |
| $\phi_m$ | Phase margin at unity gain | $R_L$ = 600 Ω, $C_L$ = 100 pF | | 25°C | | 46° | | |
| | Gain margin | | | 25°C | | 12 | | dB |

† Full range is –40°C to 125°C.

## electrical characteristics at specified free-air temperature, $V_{DD}$ = 2.7 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$† | TLV2772-Q1 | | | TLV2772A-Q1 | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{DD}$ = ±1.35 V, $V_{IC}$ = 0, $R_S$ = 50 Ω | $V_O$ = 0, | 25°C | | 0.44 | 2.5 | | 0.44 | 1.6 | mV |
| | | | | Full range | | 0.47 | 2.7 | | 0.47 | 1.9 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | 25°C to 125°C | | 2 | | | 2 | | µV/°C |
| $I_{IO}$ | Input offset current | | | 25°C | | 1 | 60 | | 1 | 60 | pA |
| | | | | Full range | | 2 | 125 | | 2 | 125 | |
| $I_{IB}$ | Input bias current | | | 25°C | | 2 | 60 | | 2 | 60 | pA |
| | | | | Full range | | 6 | 350 | | 6 | 350 | |
| $V_{ICR}$ | Common-mode input voltage range | CMRR > 60 dB, | $R_S$ = 50 Ω | 25°C | 0 to 1.4 | −0.3 to 1.7 | | 0 to 1.4 | −0.3 to 1.7 | | V |
| | | | | Full range | 0 to 1.4 | −0.3 to 1.7 | | 0 to 1.4 | −0.3 to 1.7 | | |
| $V_{OH}$ | High-level output voltage | $I_{OH}$ = −0.675 mA | | 25°C | | 2.6 | | | 2.6 | | V |
| | | | | Full range | 2.45 | | | 2.45 | | | |
| | | $I_{OH}$ = −2.2 mA | | 25°C | | 2.4 | | | 2.4 | | |
| | | | | Full range | 2.1 | | | 2.1 | | | |
| $V_{OL}$ | Low-level output voltage | $V_{IC}$ = 1.35 V, | $I_{OL}$ = 0.675 mA | 25°C | | 0.1 | | | 0.1 | | V |
| | | | | Full range | | | 0.2 | | | 0.2 | |
| | | $V_{IC}$ = 1.35 V, | $I_{OL}$ = 2.2 mA | 25°C | | 0.21 | | | 0.21 | | |
| | | | | Full range | | | 0.6 | | | 0.6 | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_{IC}$ = 1.35 V, $V_O$ = 0.6 V to 2.1 V | $R_L$ = 10 kΩ,‡ | 25°C | 20 | 380 | | 20 | 380 | | V/mV |
| | | | | Full range | 13 | | | 13 | | | |
| $r_{i(d)}$ | Differential input resistance | | | 25°C | | $10^{12}$ | | | $10^{12}$ | | Ω |
| $c_{i(c)}$ | Common-mode input capacitance | f = 10 kHz, | | 25°C | | 8 | | | 8 | | pF |
| $z_o$ | Closed-loop output impedance | f = 100 kHz, | $A_V$ = 10 | 25°C | | 25 | | | 25 | | Ω |
| CMRR | Common-mode rejection ratio | $V_{IC}$ = $V_{ICR}$ (min), $R_S$ = 50 Ω | $V_O$ = 1.5 V, | 25°C | 60 | 84 | | 60 | 84 | | dB |
| | | | | Full range | 60 | 82 | | 60 | 82 | | |
| $k_{SVR}$ | Supply voltage rejection ratio ($\Delta V_{DD}$ /$\Delta V_{IO}$) | $V_{DD}$ = 2.7 V to 5 V, No load | $V_{IC}$ = $V_{DD}$/2, | 25°C | 70 | 89 | | 70 | 89 | | dB |
| | | | | Full range | 70 | 84 | | 70 | 84 | | |
| $I_{DD}$ | Supply current (per channel) | $V_O$ = 1.5 V, | No load | 25°C | | 1 | 2 | | 1 | 2 | mA |
| | | | | Full range | | | 2 | | | 2 | |

† Full range is –40°C to 125°C for Q level part.
‡ Referenced to 1.35 V

## operating characteristics at specified free-air temperature, $V_{DD}$ = 2.7 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$† | TLV2772-Q1 | | | TLV2772A-Q1 | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR | Slew rate at unity gain | $V_{O(PP)}$ = 0.8 V, $C_L$ = 100 pF, $R_L$ = 10 kΩ | | 25°C | 5 | 9 | | 5 | 9 | | V/μs |
| | | | | Full range | 4.7 | 6 | | 4.7 | 6 | | |
| $V_n$ | Equivalent input noise voltage | f = 1 kHz | | 25°C | | 21 | | | 21 | | nV/√Hz |
| | | f = 10 kHz | | 25°C | | 17 | | | 17 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 1 Hz | | 25°C | | 0.33 | | | 0.33 | | μV |
| | | f = 0.1 Hz to 10 Hz | | 25°C | | 0.86 | | | 0.86 | | μV |
| $I_n$ | Equivalent input noise current | f = 100 Hz | | 25°C | | 0.6 | | | 0.6 | | fA/√Hz |
| THD + N | Total harmonic distortion plus noise | $R_L$ = 600 Ω, f = 1 kHz | $A_V$ = 1 | 25°C | | 0.0085% | | | 0.0085% | | |
| | | | $A_V$ = 10 | | | 0.025% | | | 0.025% | | |
| | | | $A_V$ = 100 | | | 0.12% | | | 0.12% | | |
| | Gain-bandwidth product | f = 10 kHz, $R_L$ = 600 Ω, $C_L$ = 100 pF | | 25°C | | 4.8 | | | 4.8 | | MHz |
| $t_s$ | Settling time | $A_V$ = –1, Step = 0.85 V to 1.85 V, $R_L$ = 600 Ω, $C_L$ = 100 pF | 0.1% | 25°C | | 0.186 | | | 0.186 | | μs |
| | | | 0.01% | 25°C | | 3.92 | | | 3.92 | | |
| $\phi_m$ | Phase margin at unity gain | $R_L$ = 600 Ω, $C_L$ = 100 pF | | 25°C | | 46° | | | 46° | | |
| | Gain margin | | | 25°C | | 12 | | | 12 | | dB |

† Full range is –40°C to 125°C for Q level part.

## electrical characteristics at specified free-air temperature, $V_{DD}$ = 5 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$† | TLV2772-Q1 | | | TLV2772A-Q1 | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_{DD}$ = ±2.5 V, $V_{IC}$ = 0, | $V_O$ = 0, $R_S$ = 50 Ω | 25°C | | 0.36 | 2.5 | | 0.36 | 1.6 | mV |
| | | | | Full range | | 0.4 | 2.7 | | 0.4 | 1.9 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | | 25°C to 125°C | | 2 | | | 2 | | µV/°C |
| $I_{IO}$ | Input offset current | | | 25°C | | 1 | 60 | | 1 | 60 | pA |
| | | | | Full range | | 2 | 125 | | 2 | 125 | |
| $I_{IB}$ | Input bias current | | | 25°C | | 2 | 60 | | 2 | 60 | pA |
| | | | | Full range | | 6 | 350 | | 6 | 350 | |
| $V_{ICR}$ | Common-mode input voltage range | CMRR > 60 dB, | $R_S$ = 50 Ω | 25°C | 0 to 3.7 | −0.3 to 3.8 | | 0 to 3.7 | −0.3 to 3.8 | | V |
| | | | | Full range | 0 to 3.7 | −0.3 to 3.8 | | 0 to 3.7 | −0.3 to 3.8 | | |
| $V_{OH}$ | High-level output voltage | $I_{OH}$ = −1.3 mA | | 25°C | | 4.9 | | | 4.9 | | V |
| | | | | Full range | 4.8 | | | 4.8 | | | |
| | | $I_{OH}$ = −4.2 mA | | 25°C | | 4.7 | | | 4.7 | | |
| | | | | Full range | 4.4 | | | 4.4 | | | |
| $V_{OL}$ | Low-level output voltage | $V_{IC}$ = 2.5 V, | $I_{OL}$ = 1.3 mA | 25°C | | 0.1 | | | 0.1 | | V |
| | | | | Full range | | | 0.2 | | | 0.2 | |
| | | $V_{IC}$ = 2.5 V, | $I_{OL}$ = 4.2 mA | 25°C | | 0.21 | | | 0.21 | | |
| | | | | Full range | | | 0.6 | | | 0.6 | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_{IC}$ = 2.5 V, $V_O$ = 1 V to 4 V | $R_L$ = 10 kΩ,‡ | 25°C | 20 | 450 | | 20 | 450 | | V/mV |
| | | | | Full range | 13 | | | 13 | | | |
| $r_{i(d)}$ | Differential input resistance | | | 25°C | | $10^{12}$ | | | $10^{12}$ | | Ω |
| $c_{i(c)}$ | Common-mode input capacitance | f = 10 kHz, | | 25°C | | 8 | | | 8 | | pF |
| $z_o$ | Closed-loop output impedance | f = 100 kHz, | $A_V$ = 10 | 25°C | | 20 | | | 20 | | Ω |
| CMRR | Common-mode rejection ratio | $V_{IC}$ = $V_{ICR}$ (min), $R_S$ = 50 Ω | $V_O$ = 3.7 V, | 25°C | 60 | 96 | | 60 | 96 | | dB |
| | | | | Full range | 60 | 93 | | 60 | 93 | | |
| $k_{SVR}$ | Supply voltage rejection ratio ($\Delta V_{DD}$ /$\Delta V_{IO}$) | $V_{DD}$ = 2.7 V to 5 V, No load | $V_{IC}$ = $V_{DD}$/2, | 25°C | 70 | 89 | | 70 | 89 | | dB |
| | | | | Full range | 70 | 84 | | 70 | 84 | | |
| $I_{DD}$ | Supply current (per channel) | $V_O$ = 1.5 V, | No load | 25°C | | 1 | 2 | | 1 | 2 | mA |
| | | | | Full range | | | 2 | | | 2 | |

† Full range is –40°C to 125°C for Q level part.
‡ Referenced to 2.5 V

## operating characteristics at specified free-air temperature, $V_{DD}$ = 5 V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$† | TLV2772-Q1 | | | TLV2772A-Q1 | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR | Slew rate at unity gain | $V_{O(PP)}$ = 1.5 V, $C_L$ = 100 pF, $R_L$ = 10 kΩ | | 25°C | 5 | 10.5 | | 5 | 10.5 | | V/μs |
| | | | | Full range | 4.7 | 6 | | 4.7 | 6 | | |
| $V_n$ | Equivalent input noise voltage | f = 1 kHz | | 25°C | | 17 | | | 17 | | nV/√Hz |
| | | f = 10 kHz | | 25°C | | 12 | | | 12 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 1 Hz | | 25°C | | 0.33 | | | 0.33 | | μV |
| | | f = 0.1 Hz to 10 Hz | | 25°C | | 0.86 | | | 0.86 | | μV |
| $I_n$ | Equivalent input noise current | f = 100 Hz | | 25°C | | 0.6 | | | 0.6 | | fA/√Hz |
| THD + N | Total harmonic distortion plus noise | $R_L$ = 600 Ω, f = 1 kHz | $A_V$ = 1 | 25°C | | 0.005% | | | 0.005% | | |
| | | | $A_V$ = 10 | | | 0.016% | | | 0.016% | | |
| | | | $A_V$ = 100 | | | 0.095% | | | 0.095% | | |
| | Gain-bandwidth product | f = 10 kHz, $R_L$ = 600 Ω, $C_L$ = 100 pF | | 25°C | | 5.1 | | | 5.1 | | MHz |
| $t_s$ | Settling time | $A_V$ = –1, Step = 1.5 V to 3.5 V, $R_L$ = 600 Ω, $C_L$ = 100 pF | 0.1% | 25°C | | 0.134 | | | 0.134 | | μs |
| | | | 0.01% | 25°C | | 1.97 | | | 1.97 | | |
| $\phi_m$ | Phase margin at unity gain | $R_L$ = 600 Ω, $C_L$ = 100 pF | | 25°C | | 46° | | | 46° | | |
| | Gain margin | | | 25°C | | 12 | | | 12 | | dB |

† Full range is –40°C to 125°C for Q level part.

## TYPICAL CHARACTERISTICS

### Table of Graphs

| | | | FIGURE |
|---|---|---|---|
| $V_{IO}$ | Input offset voltage | Distribution<br>vs Common-mode input voltage<br>Distribution | 1, 2<br>3, 4<br>5, 6 |
| $I_{IB}/I_{IO}$ | Input bias and input offset currents | vs Free-air temperature | 7 |
| $V_{OH}$ | High-level output voltage | vs High-level output current | 8, 9 |
| $V_{OL}$ | Low-level output voltage | vs Low-level output current | 10, 11 |
| $V_{O(PP)}$ | Maximum peak-to-peak output voltage | vs Frequency | 12, 13 |
| $I_{OS}$ | Short-circuit output current | vs Supply voltage<br>vs Free-air temperature | 14<br>15 |
| $V_O$ | Output voltage | vs Differential input voltage | 16 |
| $A_{VD}$ | Large-signal differential voltage amplification and phase margin | vs Frequency | 17, 18 |
| $A_{VD}$ | Differential voltage amplification | vs Load resistance<br>vs Free-air temperature | 19<br>20, 21 |
| $z_o$ | Output impedance | vs Frequency | 22, 23 |
| CMRR | Common-mode rejection ratio | vs Frequency<br>vs Free-air temperature | 24<br>25 |
| $k_{SVR}$ | Supply-voltage rejection ratio | vs Frequency | 26, 27 |
| $I_{DD}$ | Supply current (per channel) | vs Supply voltage | 28 |
| SR | Slew rate | vs Load capacitance<br>vs Free-air temperature | 29<br>30 |
| $V_O$ | Voltage-follower small-signal pulse response | | 31, 32 |
| $V_O$ | Voltage-follower large-signal pulse response | | 33, 34 |
| $V_O$ | Inverting small-signal pulse response | | 35, 36 |
| $V_O$ | Inverting large-signal pulse response | | 37, 38 |
| $V_n$ | Equivalent input noise voltage | vs Frequency | 39, 40 |
| | Noise voltage (referred to input) | Over a 10-second period | 41 |
| THD + N | Total harmonic distortion plus noise | vs Frequency | 42, 43 |
| | Gain-bandwidth product | vs Supply voltage | 44 |
| $B_1$ | Unity-gain bandwidth | vs Load capacitance | 45 |
| $\phi_m$ | Phase margin | vs Load capacitance | 46 |
| | Gain margin | vs Load capacitance | 47 |
| | Amplifier with shutdown pulse turnon/off characteristics | | 48–50 |
| | Supply current with shutdown pulse turnon/off characteristics | | 51–53 |
| | Shutdown supply current | vs Free-air temperature | 54 |
| | Shutdown forward/reverse isolation | vs Frequency | 55, 56 |

## TYPICAL CHARACTERISTICS

**DISTRIBUTION OF TLV2772
INPUT OFFSET VOLTAGE**

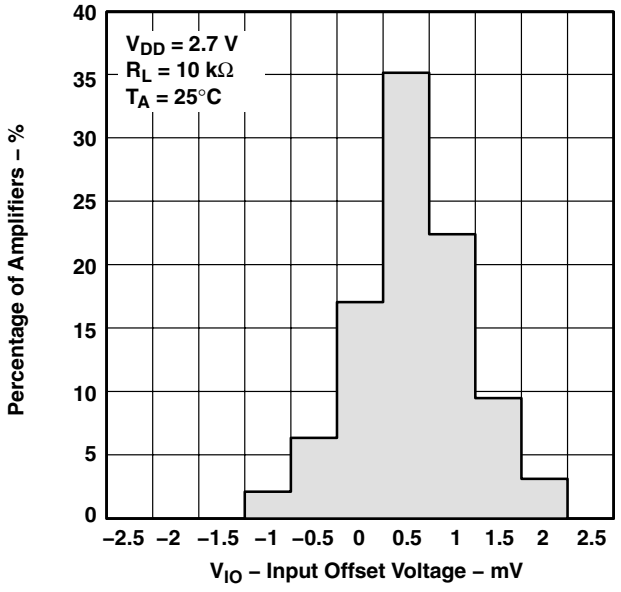



Figure 1

**DISTRIBUTION OF TLV2772
INPUT OFFSET VOLTAGE**

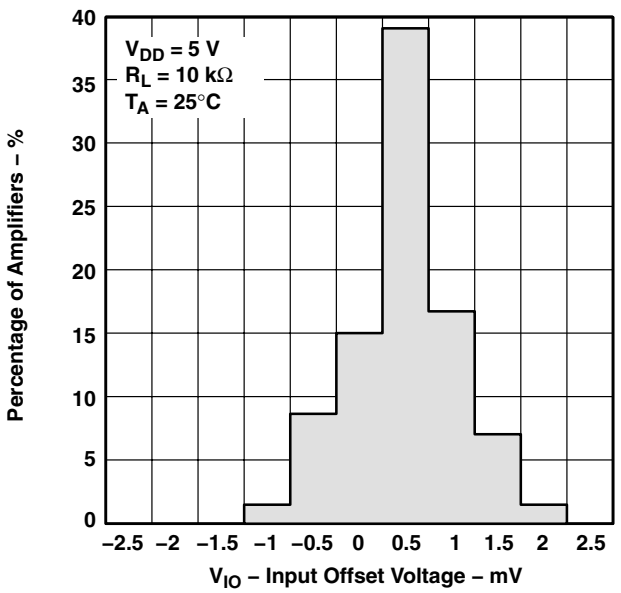



Figure 2

**INPUT OFFSET VOLTAGE
vs
COMMON-MODE INPUT VOLTAGE**

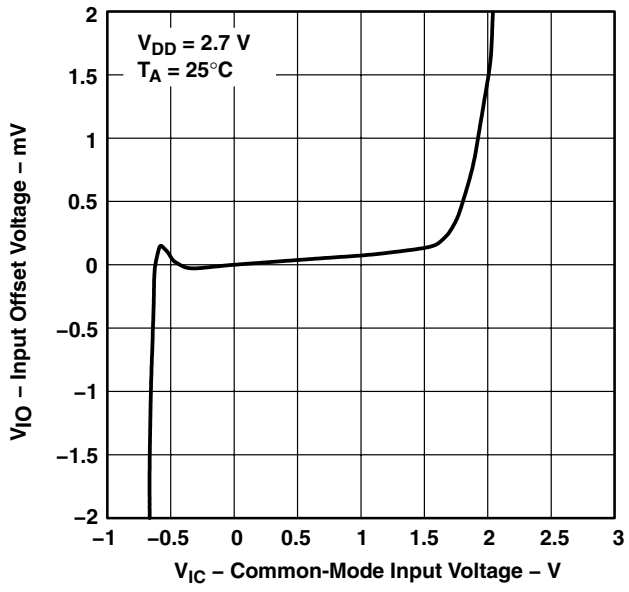



Figure 3

**INPUT OFFSET VOLTAGE
vs
COMMON-MODE INPUT VOLTAGE**

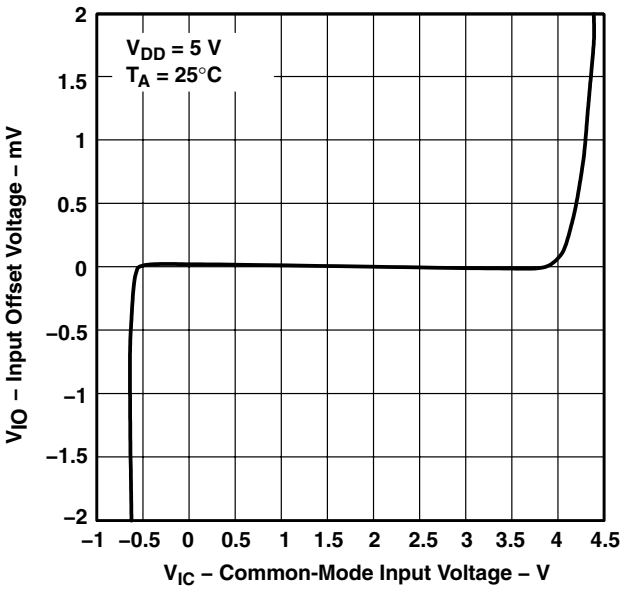



Figure 4

## TYPICAL CHARACTERISTICS

**DISTRIBUTION OF TLV2772
INPUT OFFSET VOLTAGE**

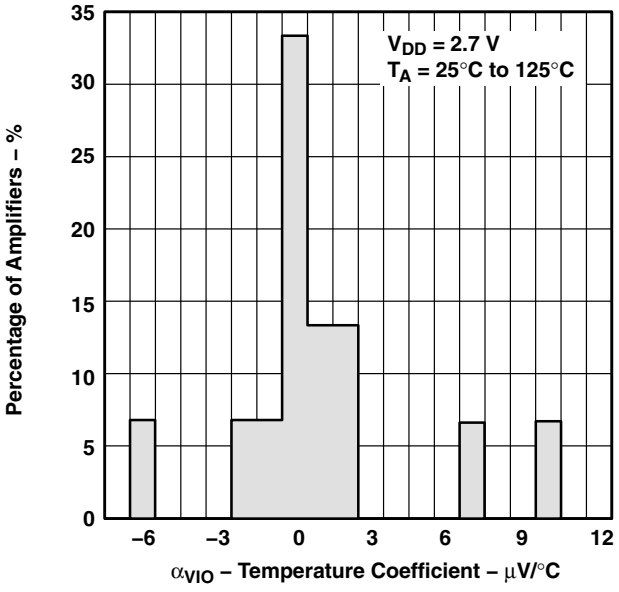



Figure 5

**DISTRIBUTION OF TLV2772
INPUT OFFSET VOLTAGE**

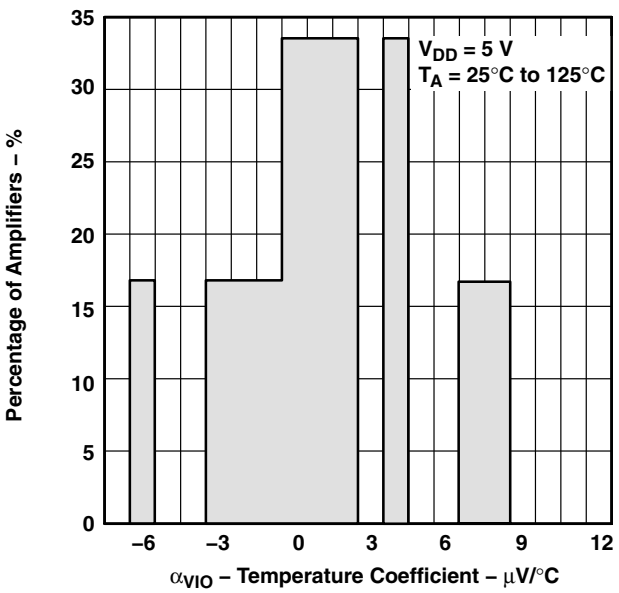



Figure 6

**INPUT BIAS AND OFFSET CURRENT
vs
FREE-AIR TEMPERATURE**

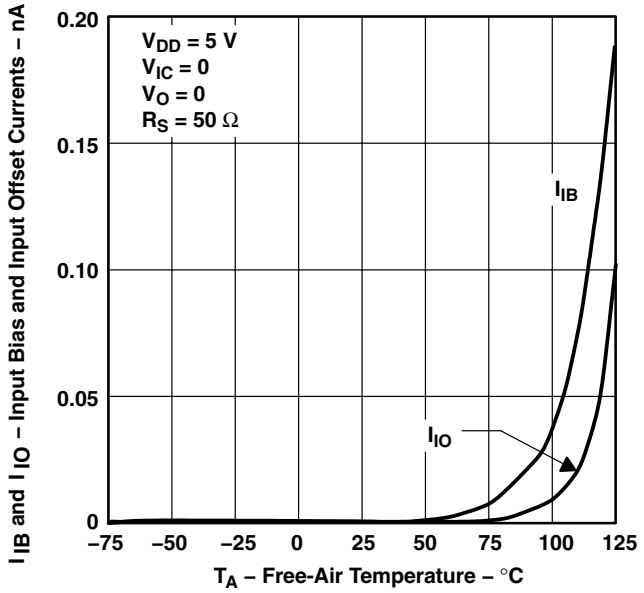



Figure 7

**HIGH-LEVEL OUTPUT VOLTAGE
vs
HIGH-LEVEL OUTPUT CURRENT**

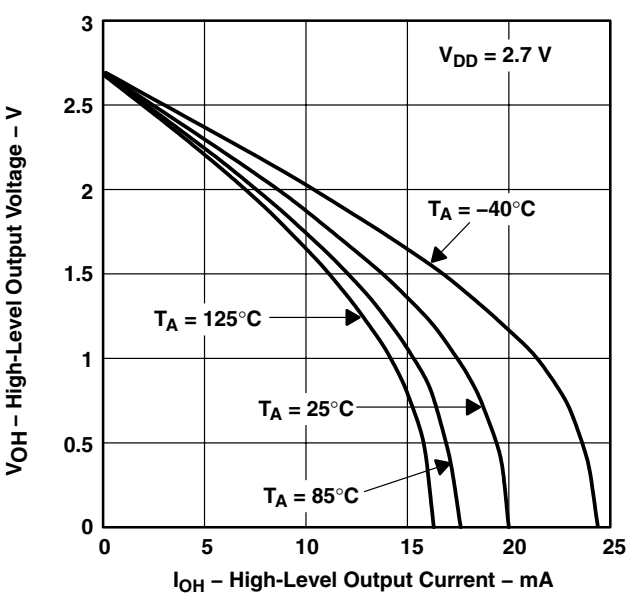



Figure 8

## TYPICAL CHARACTERISTICS

**HIGH-LEVEL OUTPUT VOLTAGE vs HIGH-LEVEL OUTPUT CURRENT**

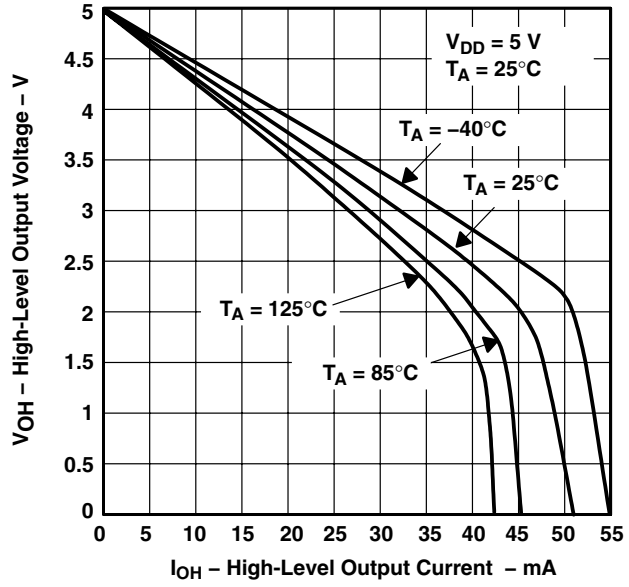



Figure 9

**LOW-LEVEL OUTPUT VOLTAGE vs LOW-LEVEL OUTPUT CURRENT**

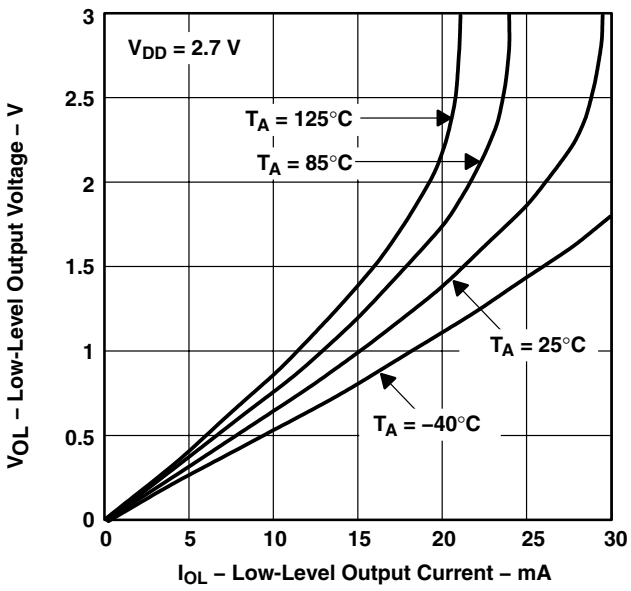



Figure 10

**LOW-LEVEL OUTPUT VOLTAGE vs LOW-LEVEL OUTPUT CURRENT**

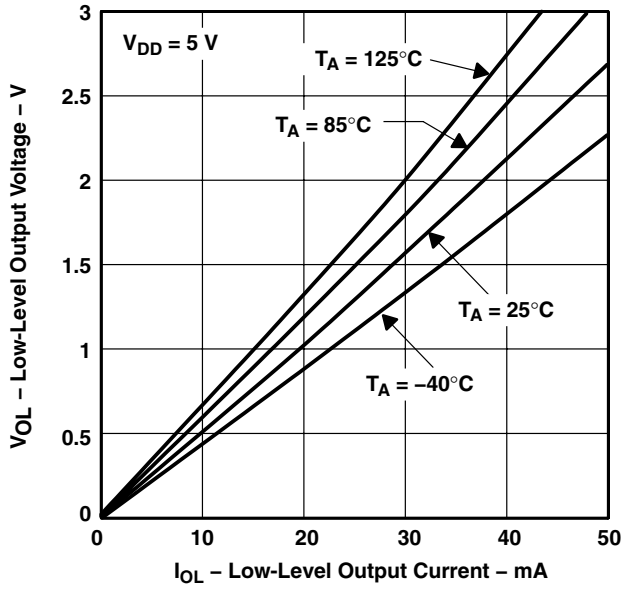



Figure 11

**MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE vs FREQUENCY**

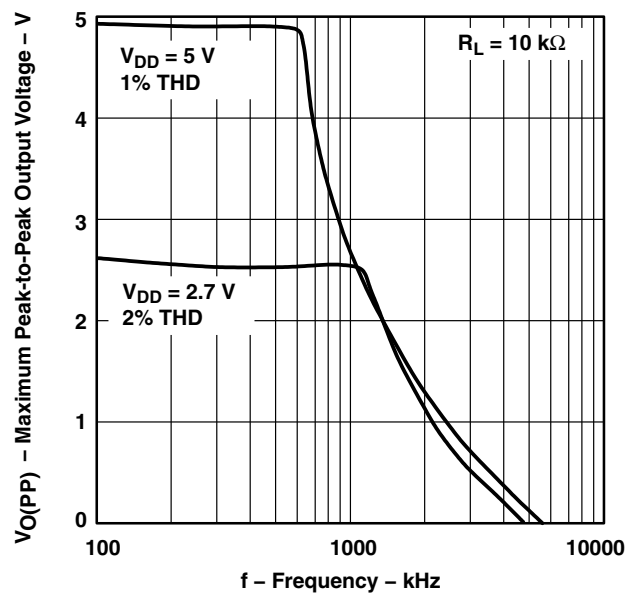



Figure 12

## TYPICAL CHARACTERISTICS

**MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE vs FREQUENCY**

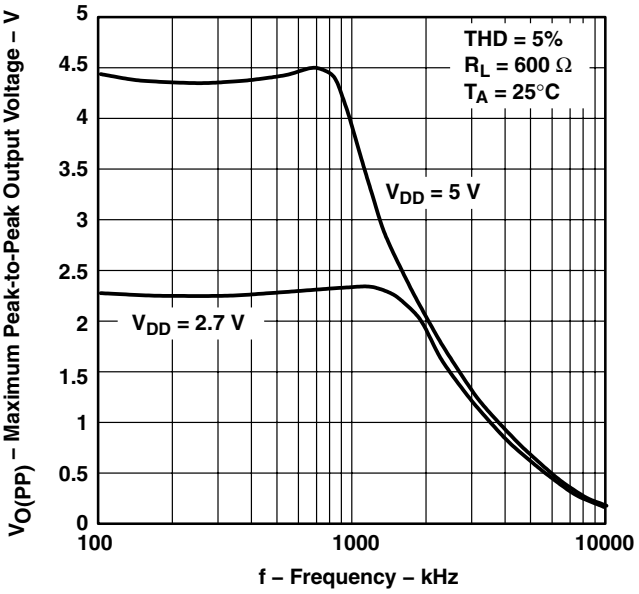



Figure 13

**SHORT-CIRCUIT OUTPUT CURRENT vs SUPPLY VOLTAGE**

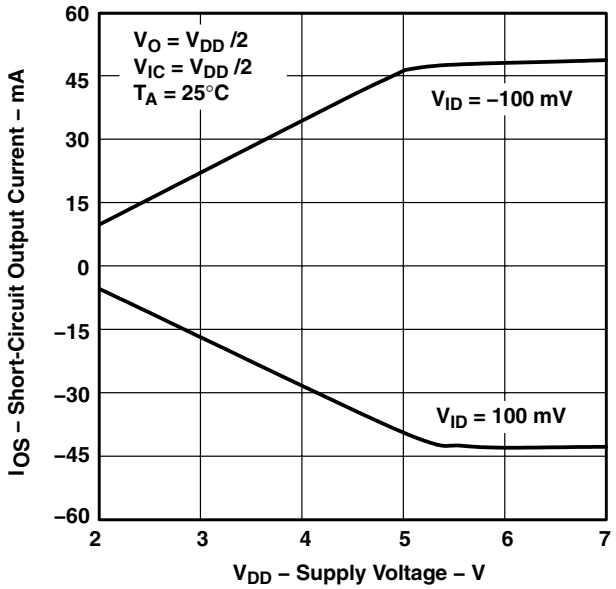



Figure 14

**SHORT-CIRCUIT OUTPUT CURRENT vs FREE-AIR TEMPERATURE**

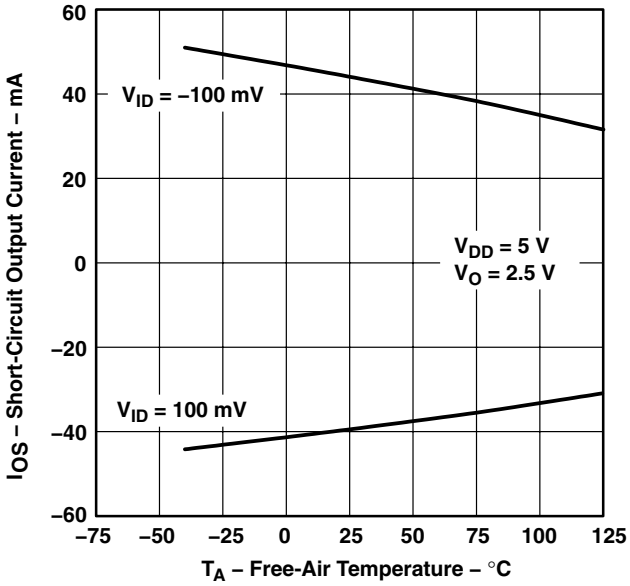



Figure 15

**OUTPUT VOLTAGE vs DIFFERENTIAL INPUT VOLTAGE**

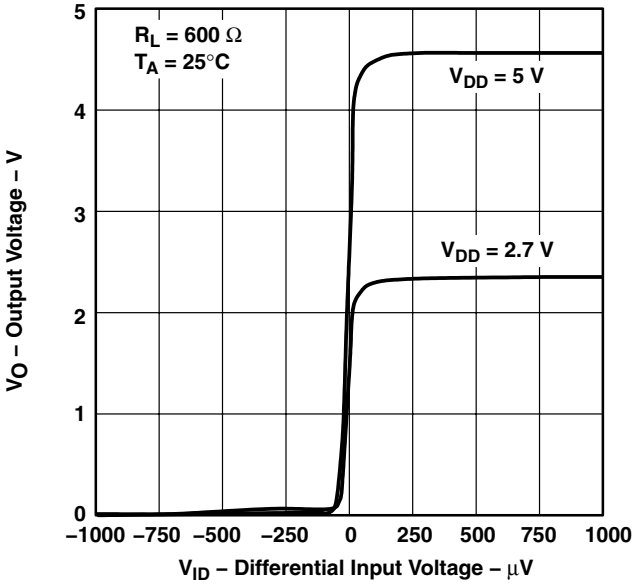



Figure 16

## TYPICAL CHARACTERISTICS

**LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE MARGIN vs FREQUENCY**

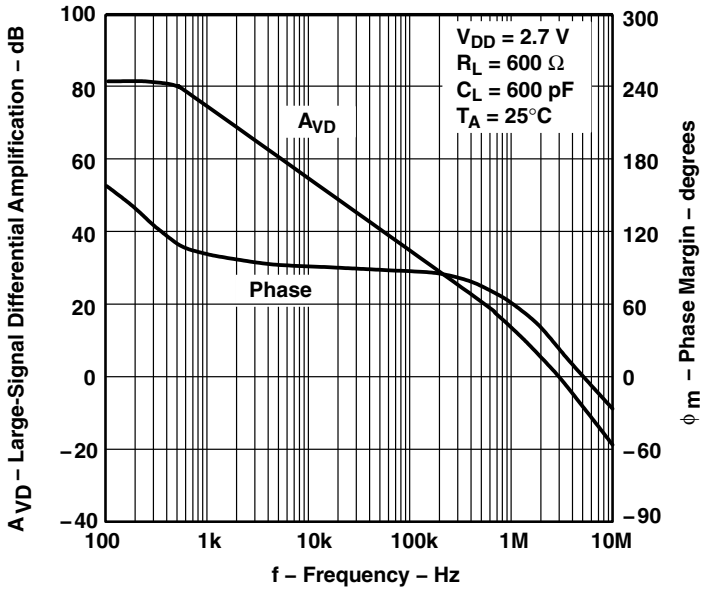



Figure 17

**LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE MARGIN vs FREQUENCY**

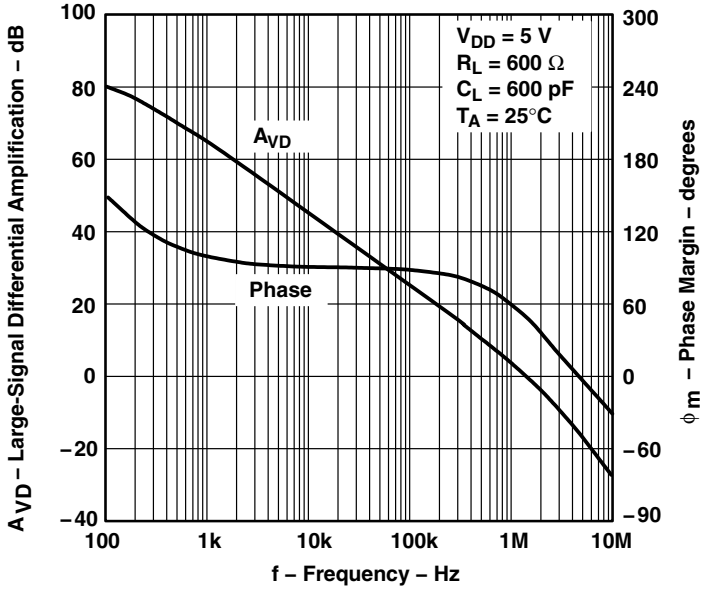



Figure 18

## TYPICAL CHARACTERISTICS

**DIFFERENTIAL VOLTAGE AMPLIFICATION vs LOAD RESISTANCE**

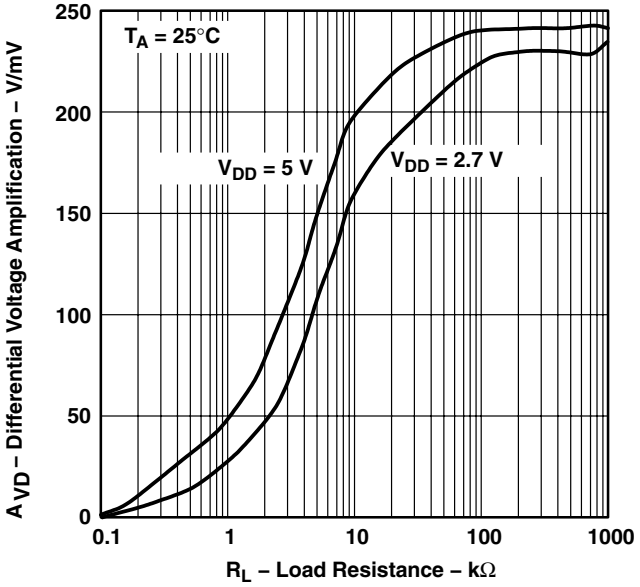



Figure 19

**DIFFERENTIAL VOLTAGE AMPLIFICATION vs FREE-AIR TEMPERATURE**

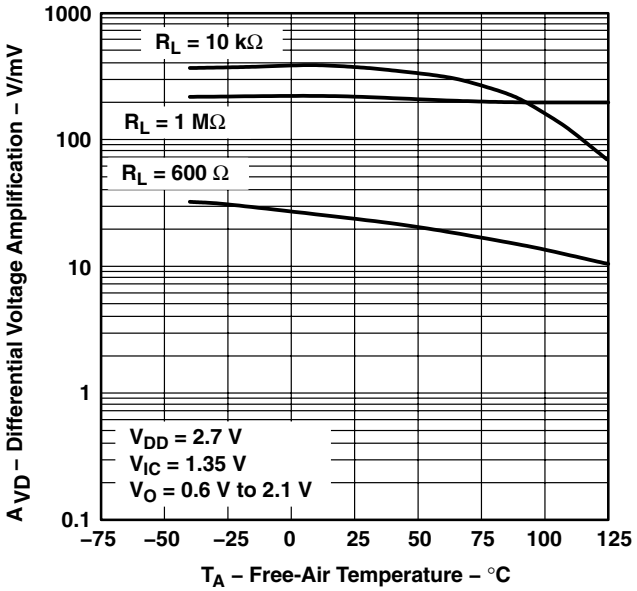



Figure 20

**DIFFERENTIAL VOLTAGE AMPLIFICATION vs FREE-AIR TEMPERATURE**

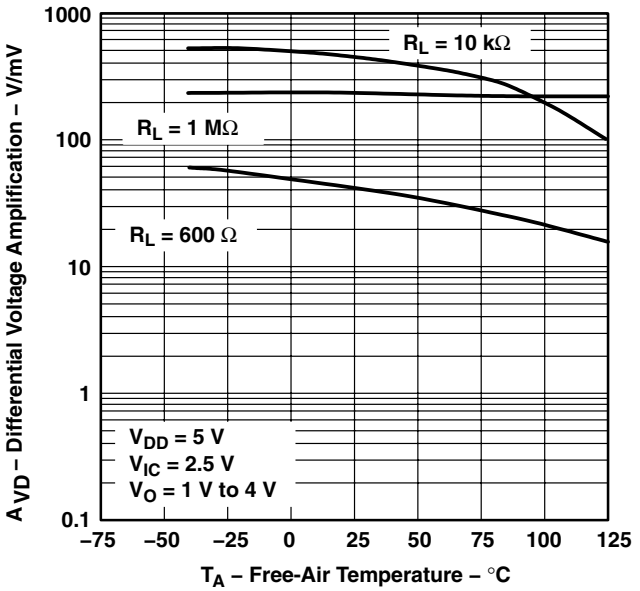



Figure 21

**OUTPUT IMPEDANCE vs FREQUENCY**

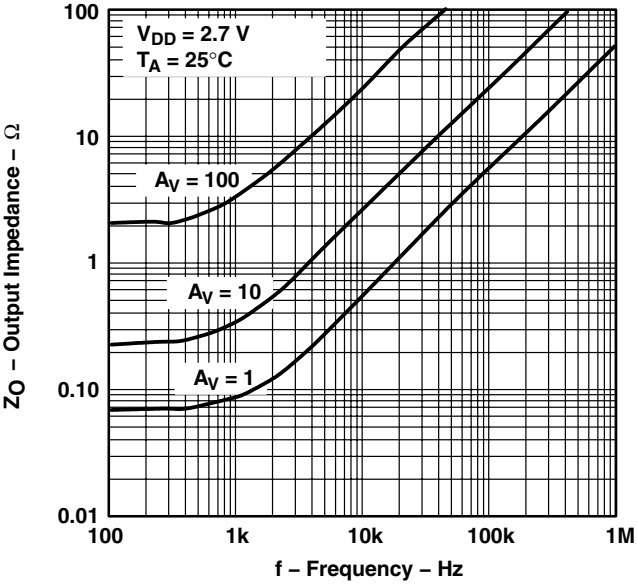



Figure 22

## TYPICAL CHARACTERISTICS

**OUTPUT IMPEDANCE vs FREQUENCY**

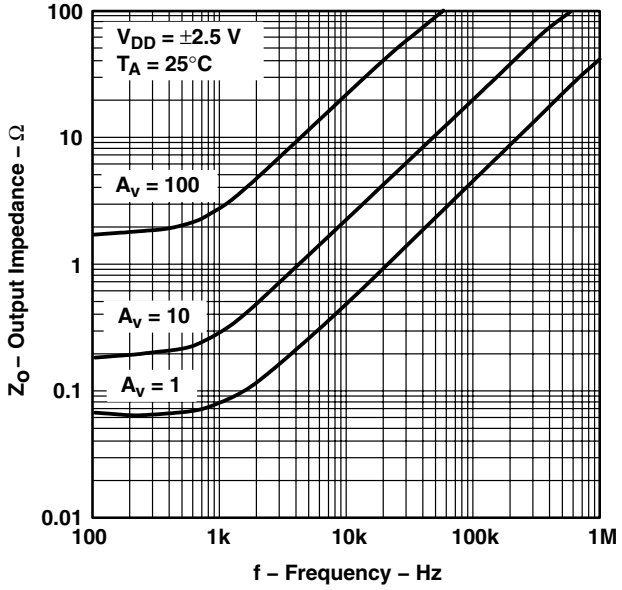



Figure 23

**COMMON-MODE REJECTION RATIO vs FREQUENCY**

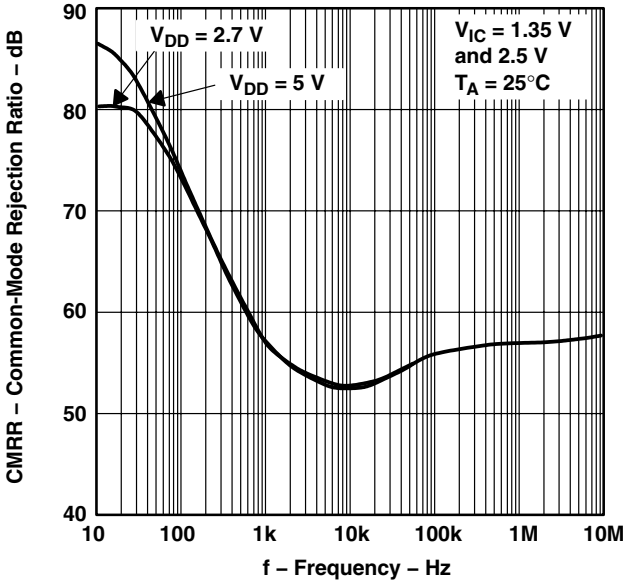



Figure 24

**COMMON-MODE REJECTION RATIO vs FREE-AIR TEMPERATURE**

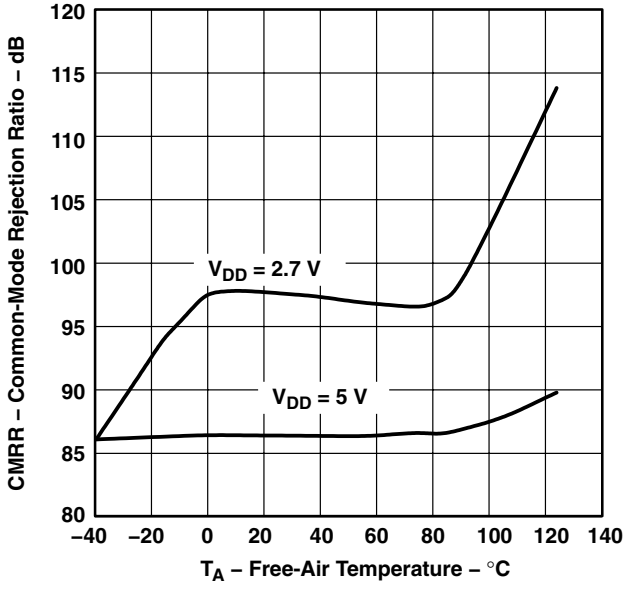



Figure 25

**SUPPLY-VOLTAGE REJECTION RATIO vs FREQUENCY**

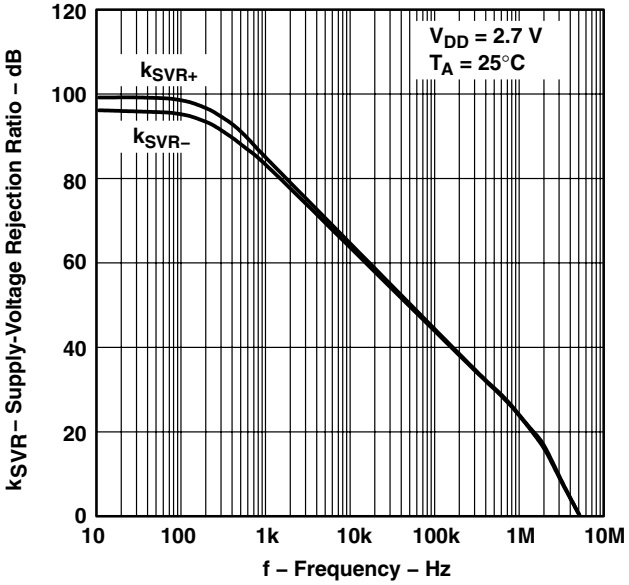



Figure 26

## TYPICAL CHARACTERISTICS

**SUPPLY VOLTAGE REJECTION RATIO vs FREQUENCY**

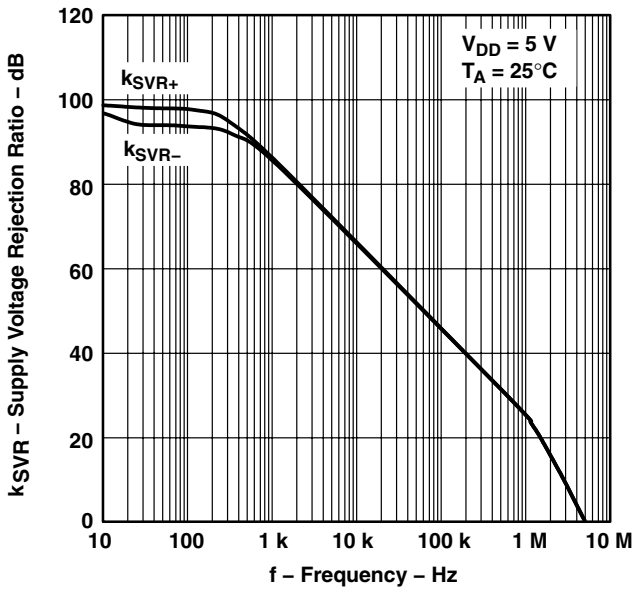



Figure 27

**SUPPLY CURRENT (PER CHANNEL) vs SUPPLY VOLTAGE**

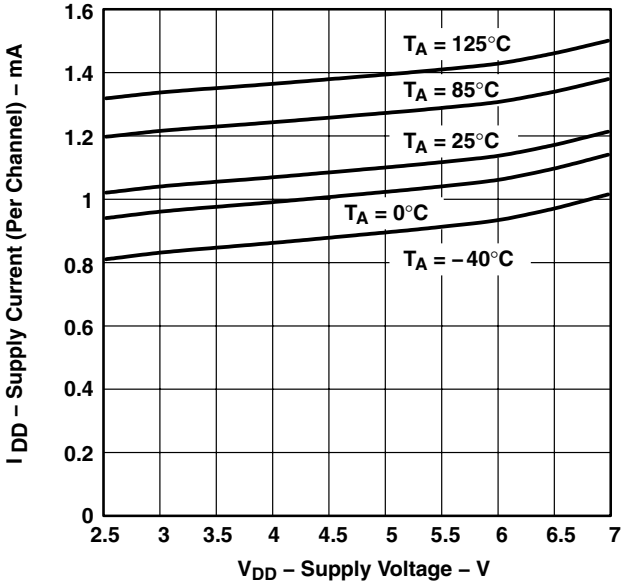



Figure 28

**SLEW RATE vs LOAD CAPACITANCE**

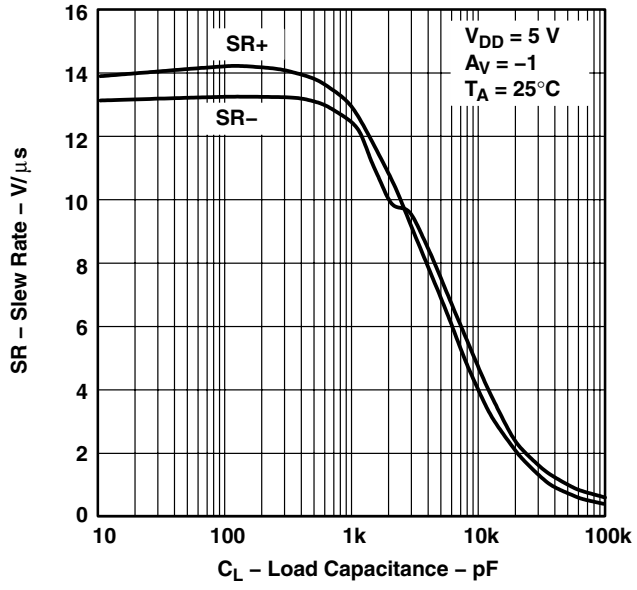



Figure 29

**SLEW RATE vs FREE-AIR TEMPERATURE**

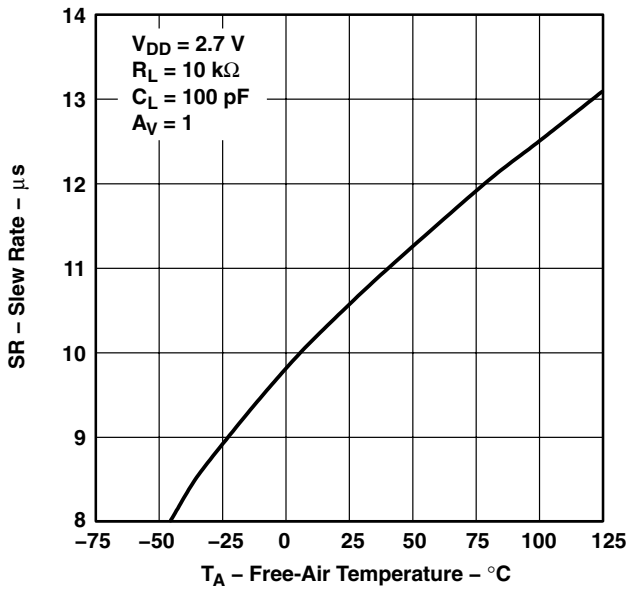



Figure 30

## TYPICAL CHARACTERISTICS

**VOLTAGE-FOLLOWER
SMALL-SIGNAL PULSE RESPONSE**

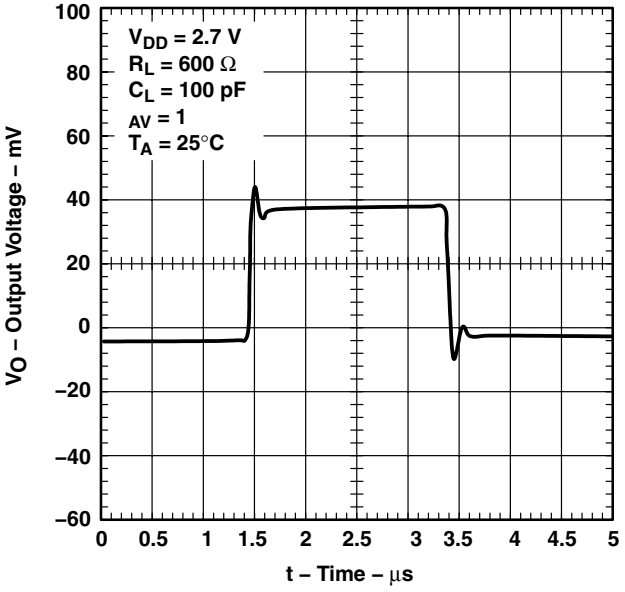



**Figure 31**

**VOLTAGE-FOLLOWER
SMALL-SIGNAL PULSE RESPONSE**

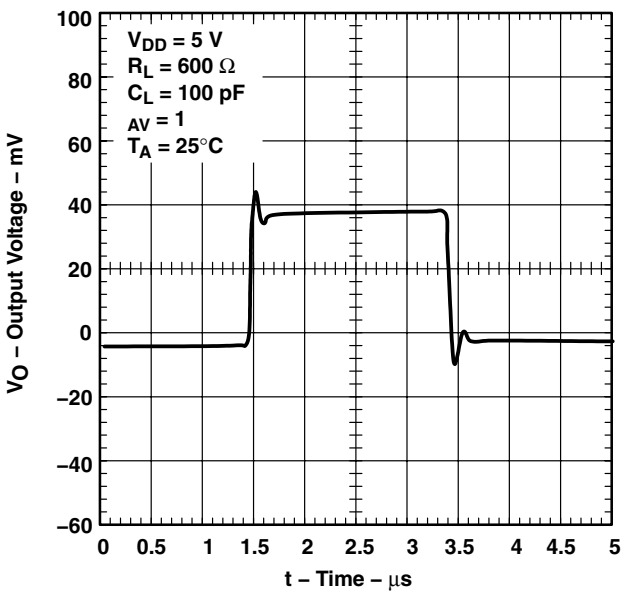



**Figure 32**

**VOLTAGE-FOLLOWER
LARGE-SIGNAL PULSE RESPONSE**

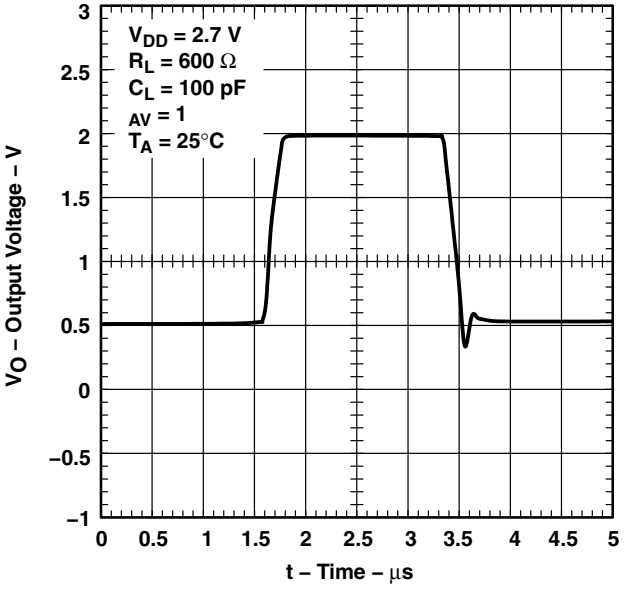



**Figure 33**

**VOLTAGE-FOLLOWER
LARGE-SIGNAL PULSE RESPONSE**

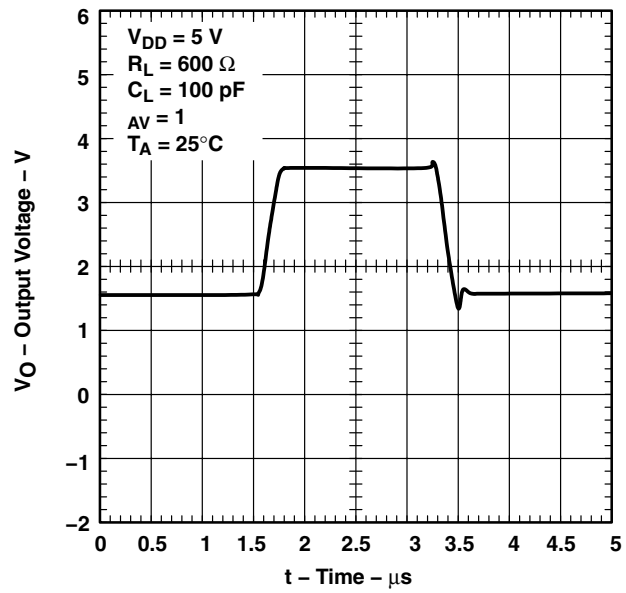



**Figure 34**

## TYPICAL CHARACTERISTICS

**INVERTING SMALL-SIGNAL PULSE RESPONSE**

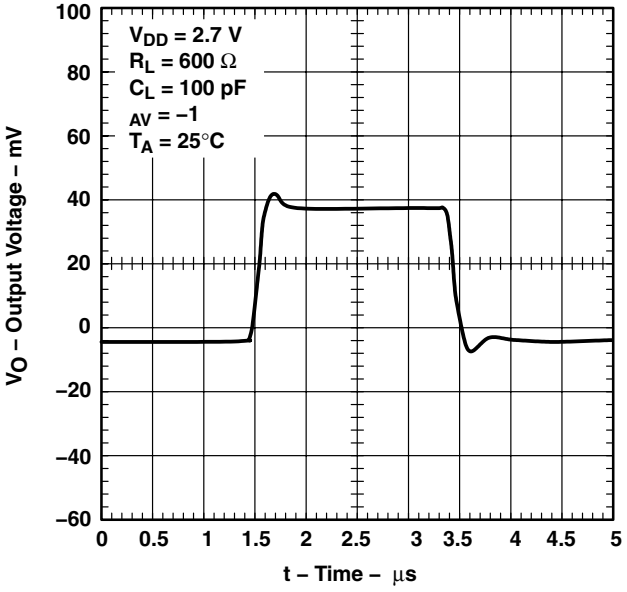



Figure 35

**INVERTING SMALL-SIGNAL PULSE RESPONSE**

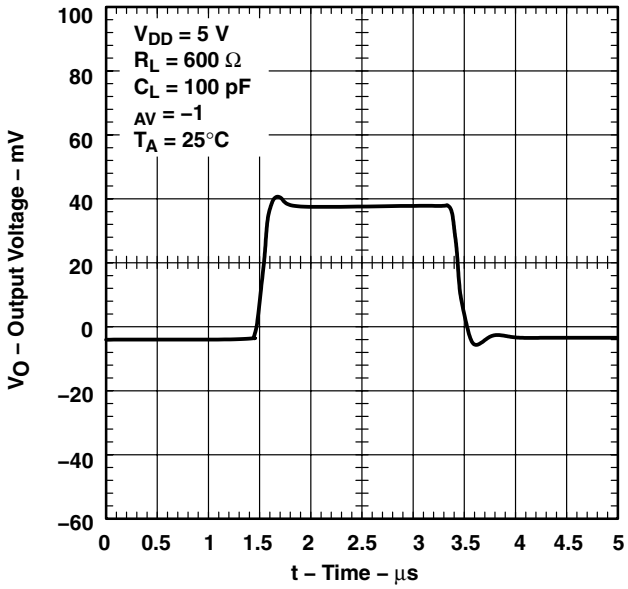



Figure 36

**INVERTING LARGE-SIGNAL PULSE RESPONSE**

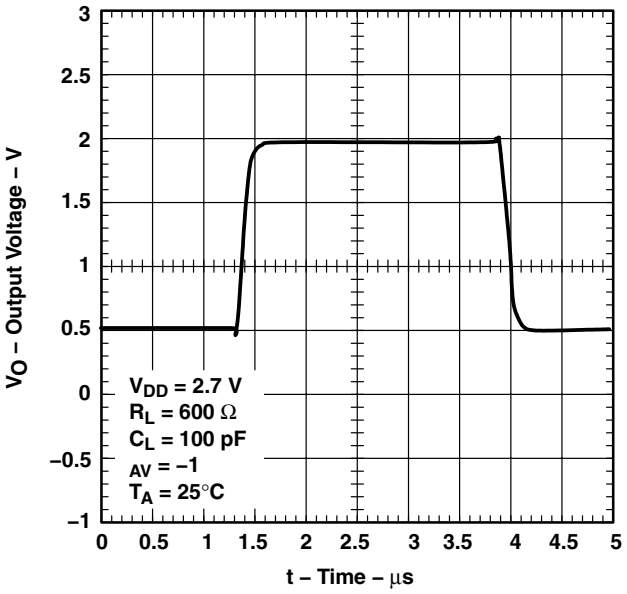



Figure 37

**INVERTING LARGE-SIGNAL PULSE RESPONSE**

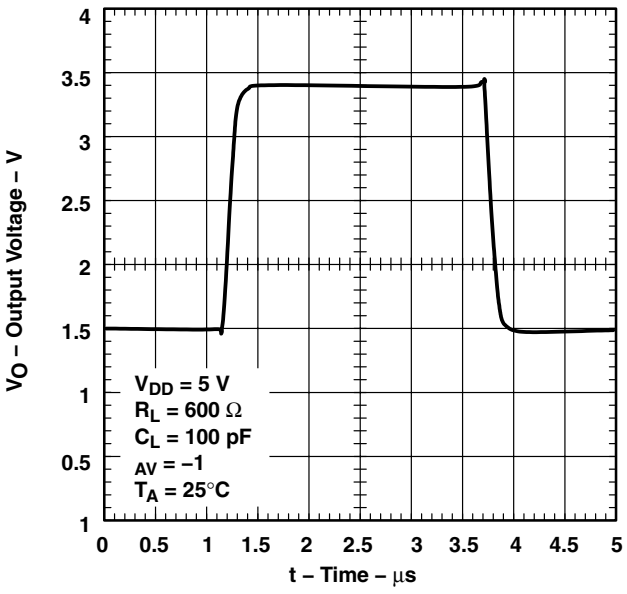



Figure 38

## TYPICAL CHARACTERISTICS

**EQUIVALENT INPUT NOISE VOLTAGE vs FREQUENCY**

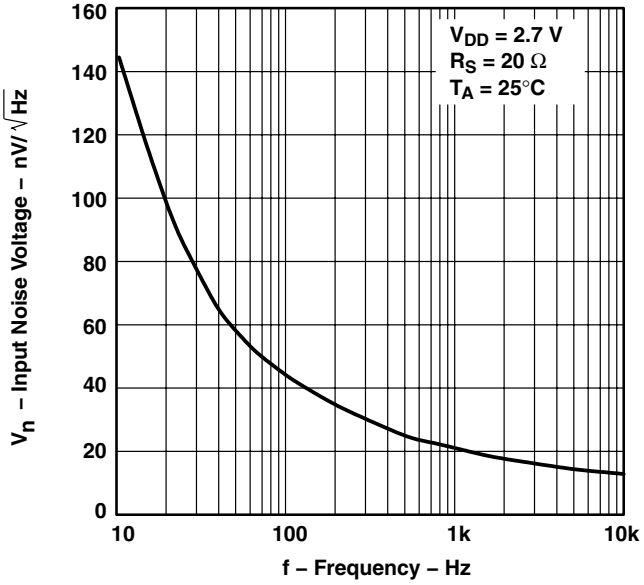



Figure 39

**EQUIVALENT INPUT NOISE VOLTAGE vs FREQUENCY**

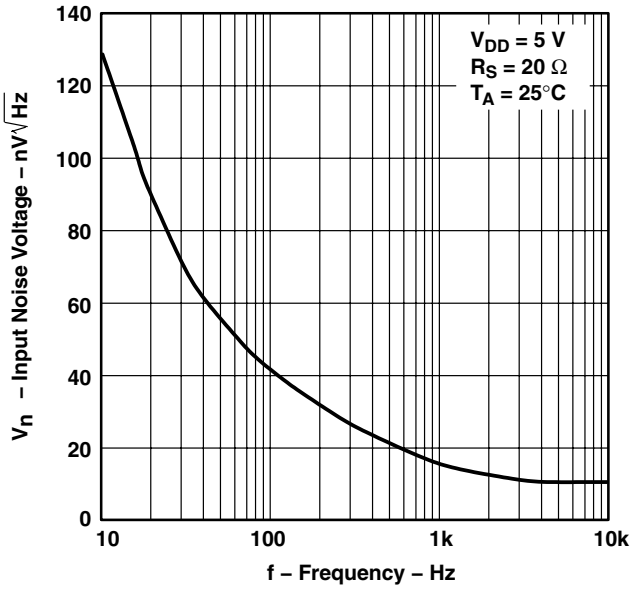



Figure 40

**NOISE VOLTAGE OVER A 10 SECOND PERIOD**

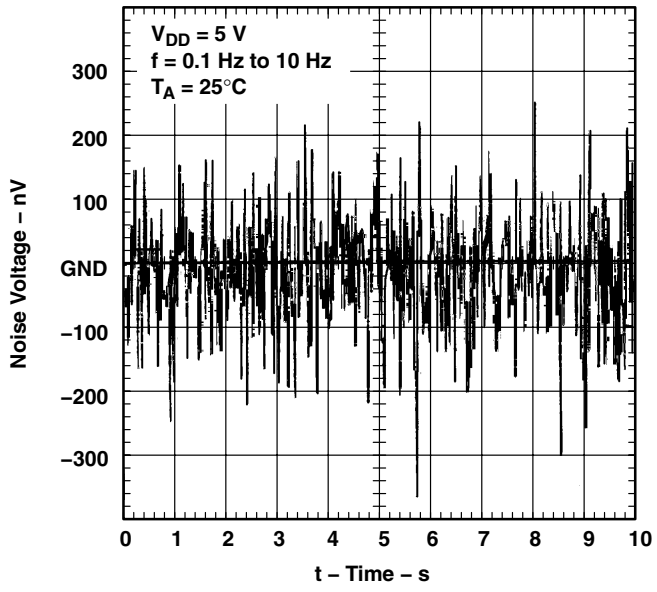



Figure 41

## TYPICAL CHARACTERISTICS

**TOTAL HARMONIC DISTORTION PLUS NOISE vs FREQUENCY**

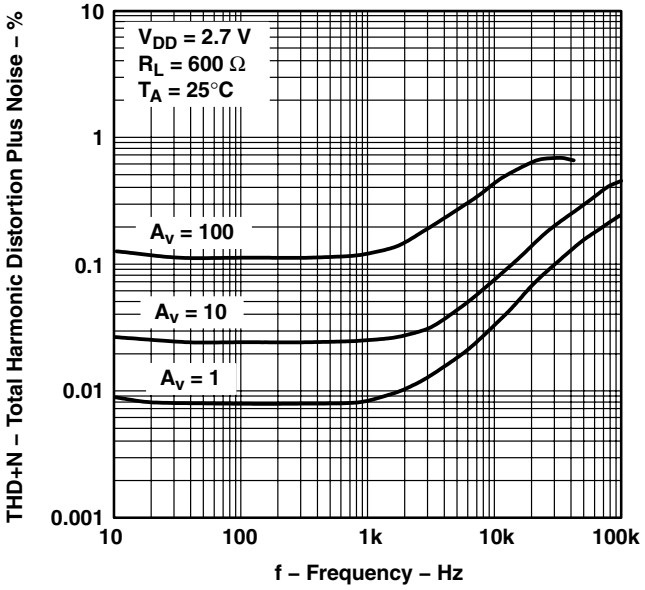



Figure 42

**TOTAL HARMONIC DISTORTION PLUS NOISE vs FREQUENCY**

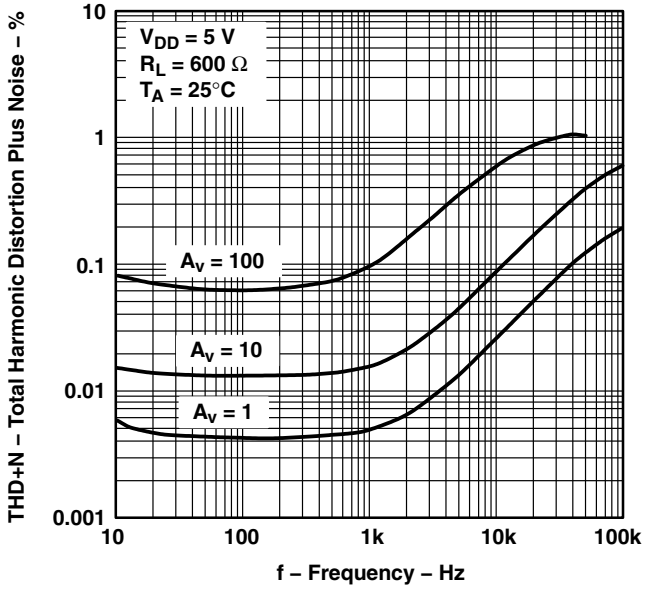



Figure 43

**GAIN-BANDWIDTH PRODUCT vs SUPPLY VOLTAGE**

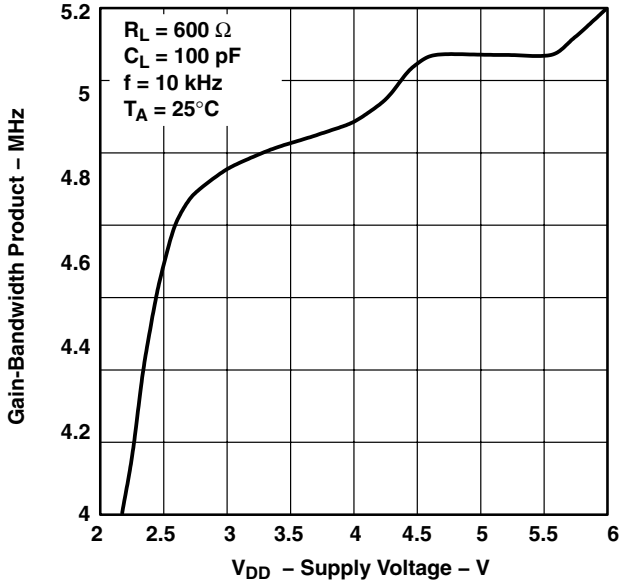



Figure 44

**UNITY-GAIN BANDWIDTH vs LOAD CAPACITANCE**

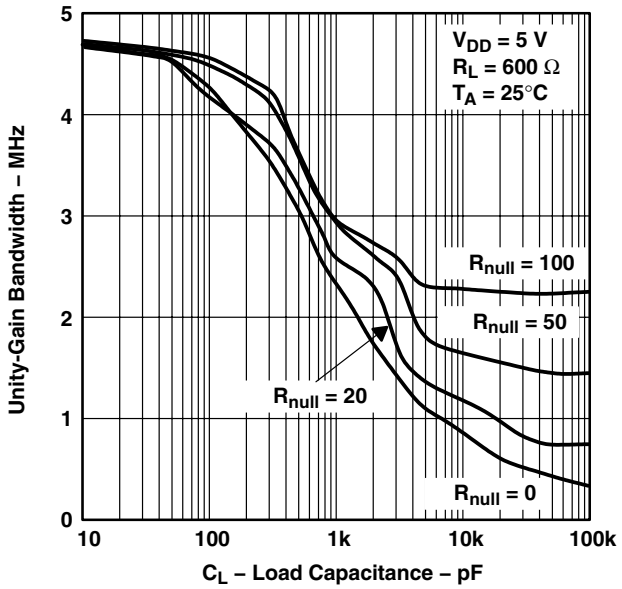



Figure 45

## TYPICAL CHARACTERISTICS

**PHASE MARGIN vs LOAD CAPACITANCE**

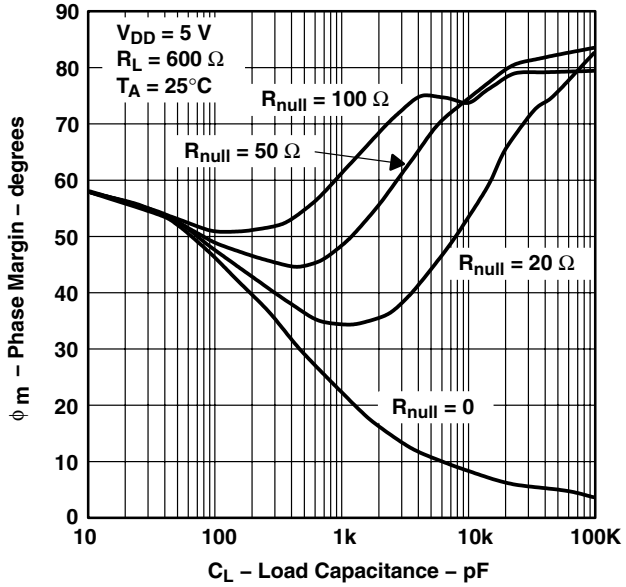



Figure 46

**GAIN MARGIN vs LOAD CAPACITANCE**

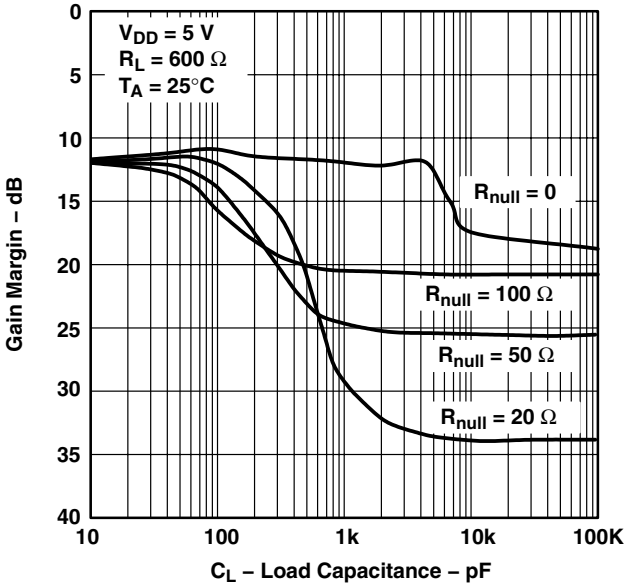



Figure 47

**TLV2770 AMPLIFIER WITH SHUTDOWN PULSE TURNON/OFF CHARACTERISTICS**

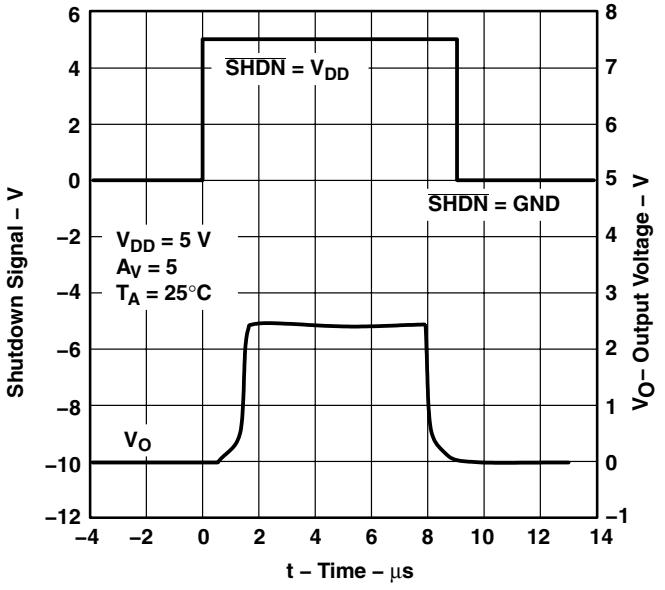



Figure 48

**TLV2773 AMPLIFIER WITH SHUTDOWN PULSE TURNON/OFF CHARACTERISTICS**

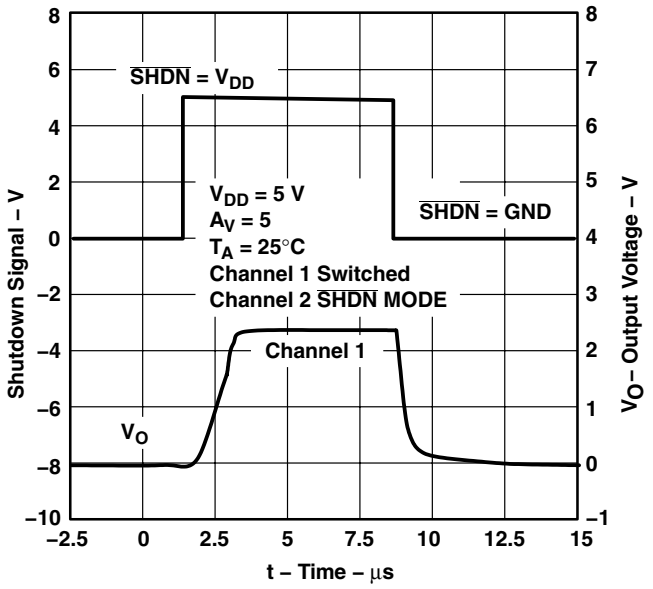



Figure 49

## TYPICAL CHARACTERISTICS

TLV2775 – CHANNEL 1
AMPLIFIER WITH SHUTDOWN PULSE
TURNON/OFF CHARACTERISTICS

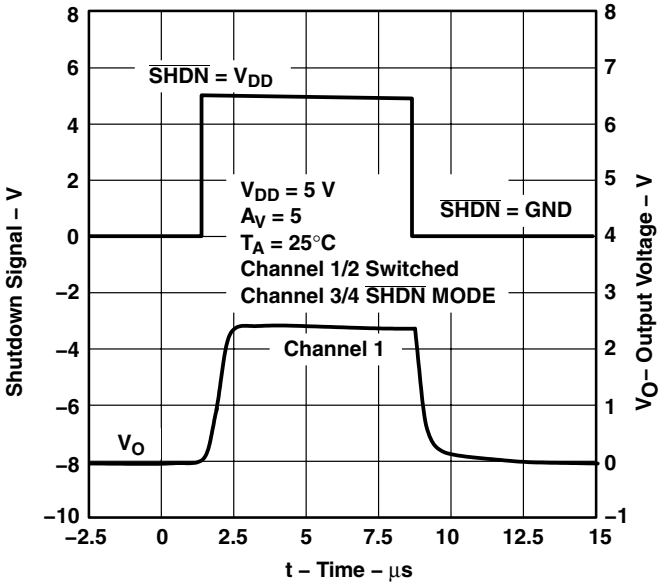



Figure 50

TLV2770
SUPPLY CURRENT WITH SHUTDOWN PULSE
TURNON/OFF CHARACTERISTICS

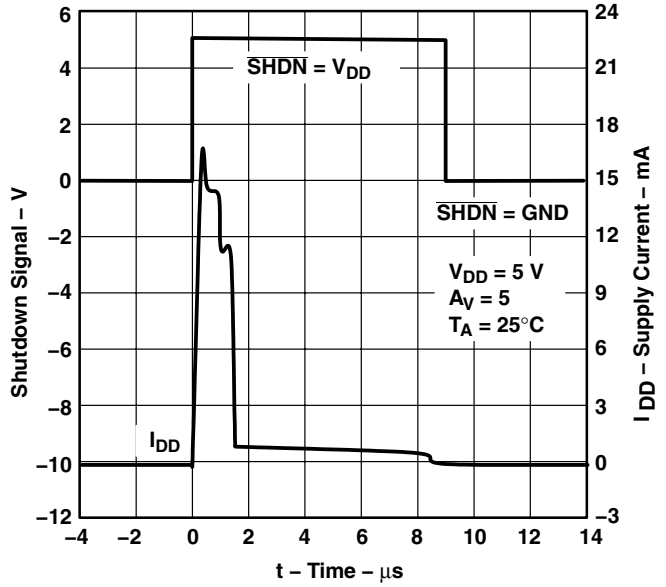



Figure 51

TLV2773
SUPPLY CURRENT WITH SHUTDOWN PULSE
TURNON/OFF CHARACTERISTICS

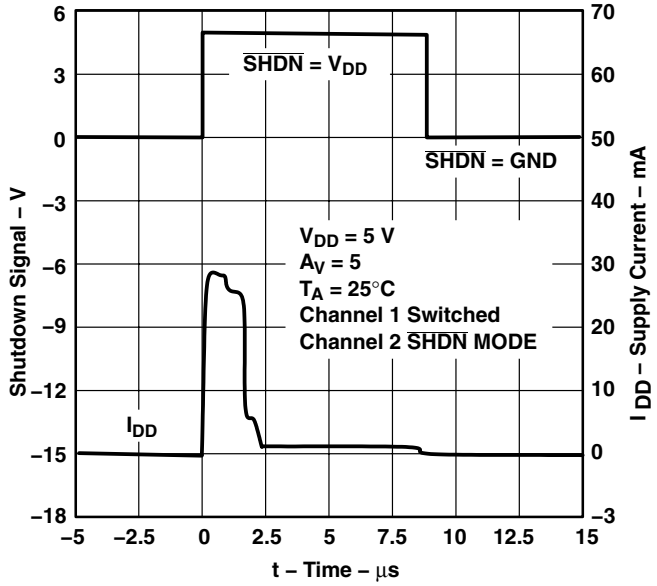



Figure 52

TLV2775
SUPPLY CURRENT WITH SHUTDOWN PULSE
TURNON/OFF CHARACTERISTICS

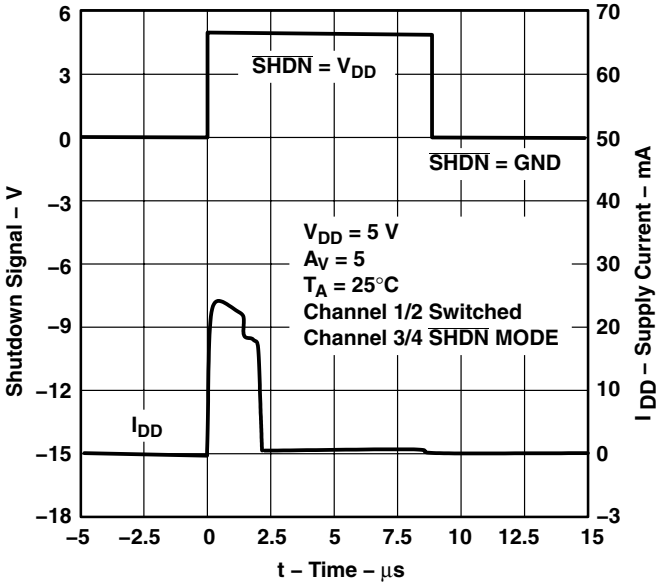



Figure 53

## TYPICAL CHARACTERISTICS

**SHUTDOWN SUPPLY CURRENT vs FREE-AIR TEMPERATURE**

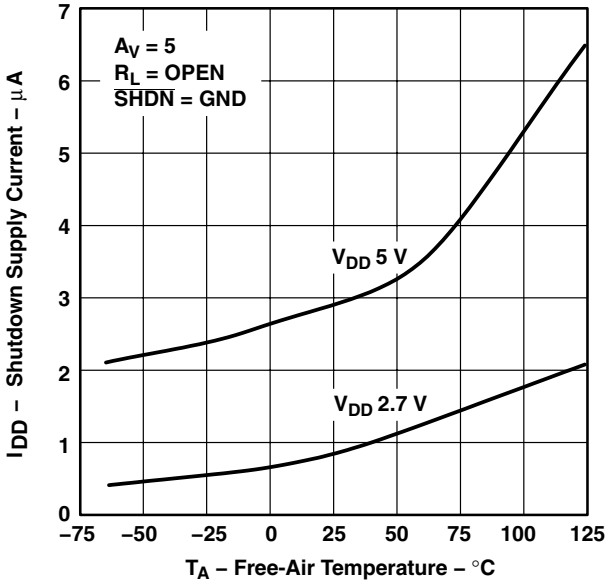



Figure 54

**TLV2770**
**SHUTDOWN FORWARD ISOLATION vs FREQUENCY**

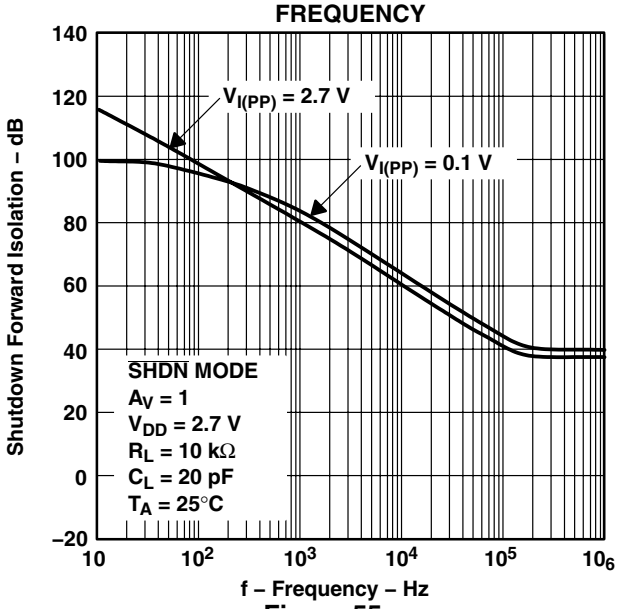



Figure 55

**TLV2770**
**SHUTDOWN REVERSE ISOLATION vs FREQUENCY**

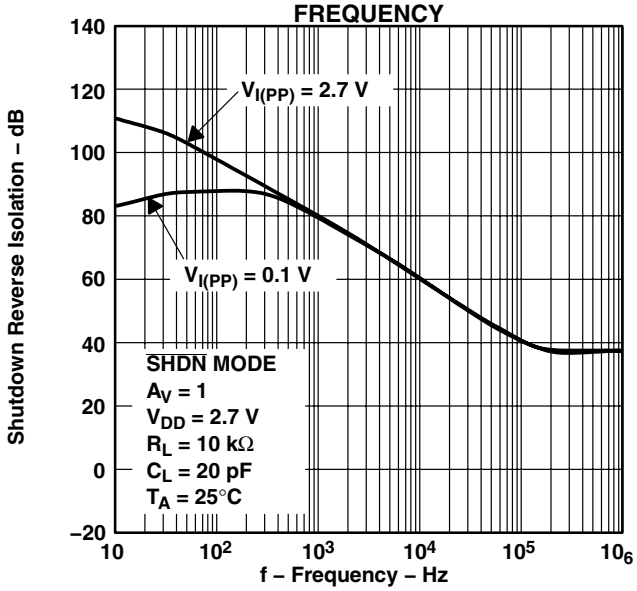



Figure 56

## PARAMETER MEASUREMENT INFORMATION

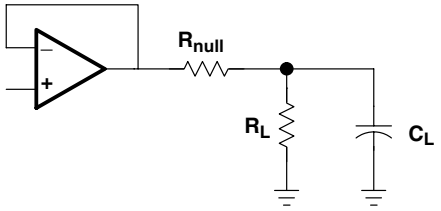



**Figure 57**

### 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 58. A minimum value of 20 Ω should work well for most applications.

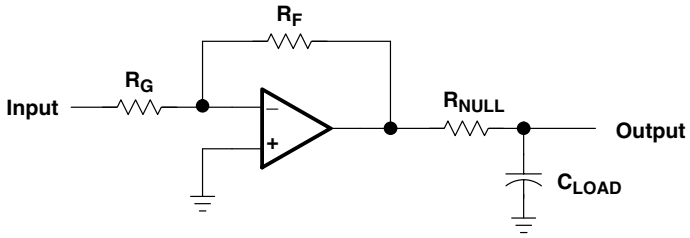
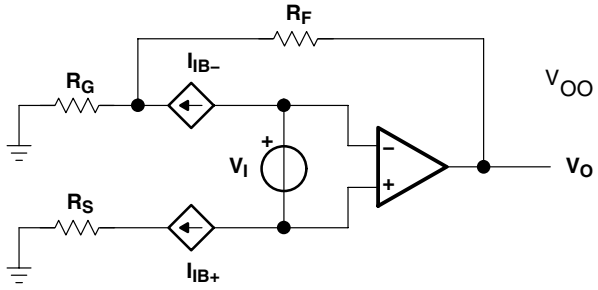



**Figure 58. Driving a Capacitive Load**

## APPLICATION INFORMATION

### 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:

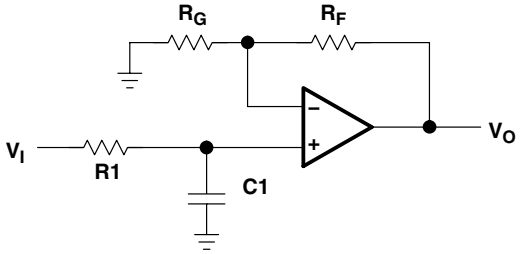



$$V_{OO} = V_{IO}\left(1 + \left(\frac{R_F}{R_G}\right)\right) \pm I_{IB+} R_S \left(1 + \left(\frac{R_F}{R_G}\right)\right) \pm I_{IB-} R_F$$

**Figure 59. Output Offset Voltage Model**

### 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 60).

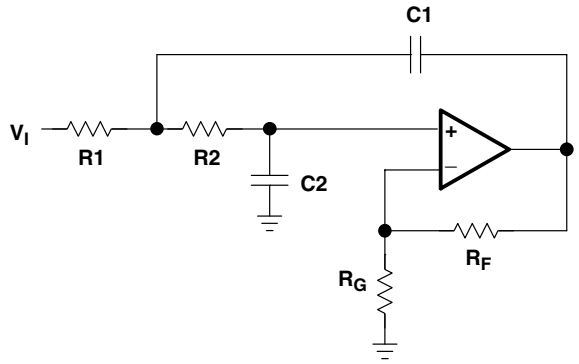



$$f_{-3dB} = \frac{1}{2\pi R1C1}$$

$$\frac{V_O}{V_I} = \left(1 + \frac{R_F}{R_G}\right)\left(\frac{1}{1 + sR1C1}\right)$$

**Figure 60. 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.




**R1 = R2 = R**
**C1 = C2 = C**
**Q = Peaking Factor**
**(Butterworth Q = 0.707)**

$$f_{-3dB} = \frac{1}{2\pi RC}$$

$$R_G = \frac{R_F}{\left(2 - \frac{1}{Q}\right)}$$

**Figure 61. 2-Pole Low-Pass Sallen-Key Filter**

## APPLICATION INFORMATION

### using the TLV2772 as an accelerometer interface

The schematic, shown in Figure 62, shows the ACH04-08-05 interfaced to the TLV1544 10-bit analog-to-digital converter (ADC).

The ACH04-08-05 is a shock sensor designed to convert mechanical acceleration into electrical signals. The sensor contains three piezoelectric sensing elements oriented to simultaneously measure acceleration in three orthogonal, linear axes (x, y, z). The operating frequency is 0.5 Hz to 5 kHz. The output is buffered with an internal JFET and has a typical output voltage of 1.80 mV/g for the x and y axis and 1.35 mV/g for the z axis.

Amplification and frequency shaping of the shock sensor output is done by the TLV2772 rail-to-rail operational amplifier. The TLV2772 is ideal for this application as it offers high input impedance, good slew rate, and excellent dc precision. The rail-to-rail output swing and high output drive are perfect for driving the analog input of the TLV1544 ADC.

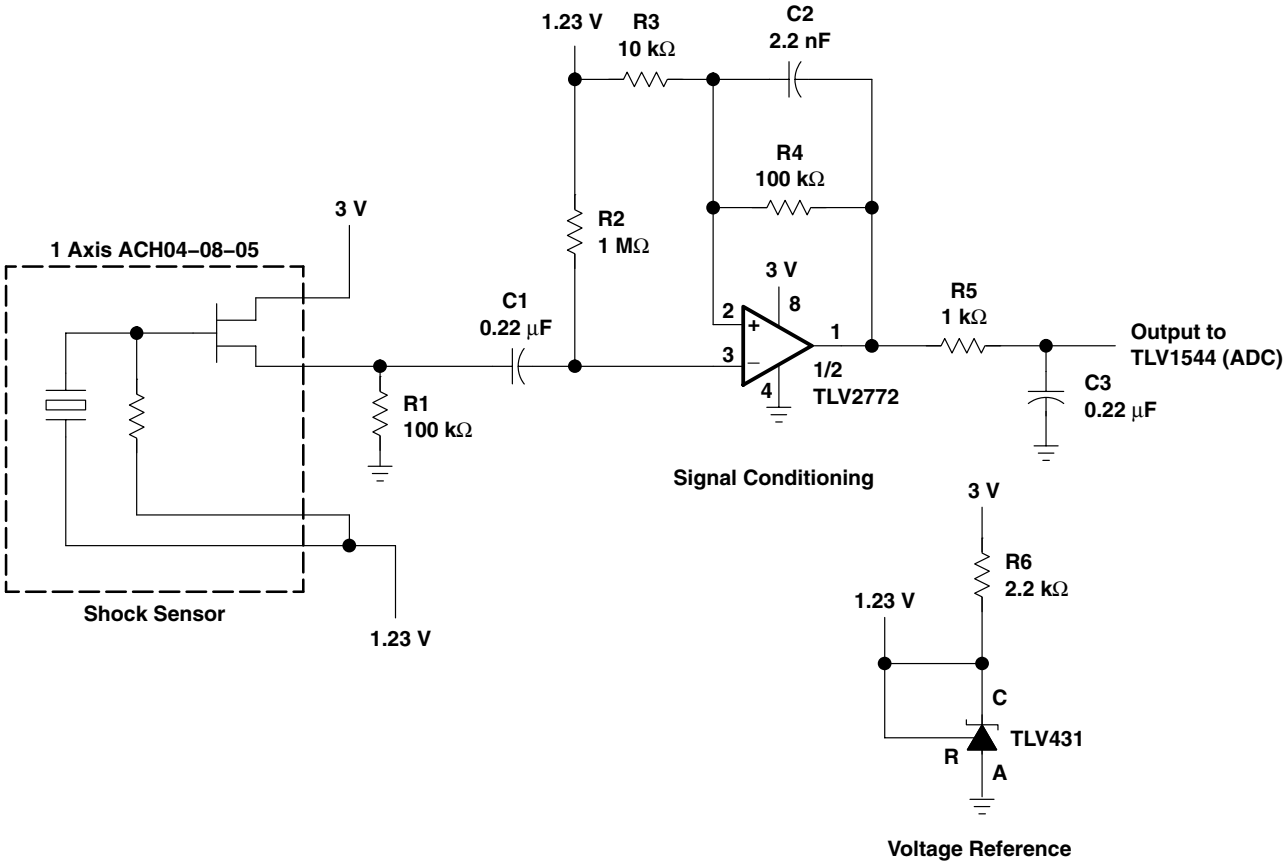



**Figure 62. Accelerometer Interface Schematic**

The sensor signal must be amplified and frequency-shaped to provide a signal the ADC can properly convert into the digital domain. Figure 62 shows the topology used in this application for one axis of the sensor. This system is powered from a single 3-V supply. Configuring the TLV431 with a 2.2-kΩ resistor produces a reference voltage of 1.23 V. This voltage is used to bias the operational amplifier and the internal JFETs in the shock sensor.

## APPLICATION INFORMATION

### gain calculation

Since the TLV2772 is capable of rail-to-rail output using a 3-V supply, $V_O$ = 0 (min) to 3 V (max). With no signal from the sensor, nominal $V_O$ = reference voltage = 1.23 V. Therefore, the maximum negative swing from nominal is 0 V – 1.23 V = –1.23 V and the maximum positive swing is 3 V – 1.23 V = 1.77 V. By modeling the shock sensor as a low impedance voltage source with output of 2.25 mV/g (max) in the x and y axis and 1.7 mV/g (max) in the z axis, the gain of the circuit is calculated by equation 1.

$$\text{Gain} = \frac{\text{Output Swing}}{\text{Sensor Signal} \times \text{Acceleration}} \quad (1)$$

To avoid saturation of the operational amplifier, the gain calculations are based on the maximum negative swing of –1.23 V and the maximum sensor output of 2.25 mV/g (x and y axis) and 1.70 mV/g (z axis).

$$\text{Gain (x, y)} = \frac{-1.23\ \text{V}}{2.25\ \text{mV/g} \times -50\ \text{g}} = 10.9 \quad (2)$$

and

$$\text{Gain (z)} = \frac{-1.23\ \text{V}}{1.70\ \text{mV/g} \times -50\ \text{g}} = 14.5 \quad (3)$$

By selecting R3 = 10 kΩ and R4 = 100 kΩ, in the x and y channels, a gain of 11 is realized. By selecting R3 = 7.5 kΩ and R4 = 100 kΩ, in the z channel, a gain of 14.3 is realized. The schematic shows the configuration for either the x- or y-axis.

### bandwidth calculation

To calculate the component values for the frequency shaping characteristics of the signal conditioning circuit, 1 Hz and 500 Hz are selected as the minimum required 3-dB bandwidth.

To minimize the value of the input capacitor (C1) required to set the lower cutoff frequency requires a large value resistor for R2 is required. A 1-MΩ resistor is used in this example. To set the lower cutoff frequency, the required capacitor value for C1 is:

$$C1 = \frac{1}{2\pi f_{LOW} R_2} = 0.159\ \mu\text{F} \quad (4)$$

Using a value of 0.22 μF, a more common value of capacitor, the lower cutoff frequency is 0.724 Hz.

To minimize the phase shift in the feedback loop caused by the input capacitance of the TLV2772, it is best to minimize the value of the feedback resistor R4. However, to reduce the required capacitance in the feedback loop a large value for R4 is required. Therefore, a compromise for the value of R4 must be made. In this circuit, a value of 100 kΩ has been selected. To set the upper cutoff frequency, the required capacitor value for C2 is:

$$C2 = \frac{1}{2\pi f_{HIGH} R_4} = 3.18\ \mu\text{F} \quad (5)$$

Using a 2.2-nF capacitor, the upper cutoff frequency is 724 Hz.

R5 and C3 also cause the signal response to roll off. Therefore, it is beneficial to design this roll-off point to begin at the upper cutoff frequency. Assuming a value of 1 kΩ for R5, the value for C3 is calculated to be 0.22 μF.

## APPLICATION INFORMATION

### circuit layout considerations

To achieve the levels of high performance of the TLV277x, 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-μF tantalum capacitor in parallel with a 0.1-μF 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-μF ceramic capacitor should always be used on the supply terminal of every amplifier. In addition, the 0.1-μF 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.

## APPLICATION INFORMATION

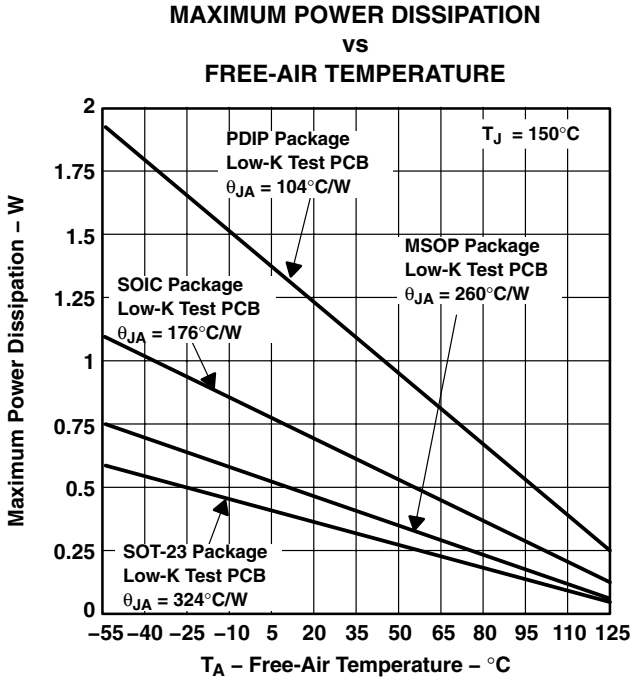
### general power dissipation considerations

For a given $\theta_{JA}$, the maximum power dissipation is shown in Figure 63 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 TLV277x IC (watts)
$T_{MAX}$ = Absolute maximum junction temperature (150°C)
$T_A$ = Free-ambient air temperature (°C)
$\theta_{JA} = \theta_{JC} + \theta_{CA}$
$\theta_{JC}$ = Thermal coefficient from junction-to-case
$\theta_{CA}$ = 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 63.**

## APPLICATION INFORMATION

### shutdown function

Three members of the TLV277x family (TLV2770/3/5) have a shutdown terminal for conserving battery life in portable applications. When the shutdown terminal is tied low, the supply current is reduced to 0.8 μA/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 needs to be taken to ensure that parasitic leakage current at the shutdown terminal does not inadvertently place the operational amplifier into shutdown. The shutdown terminal threshold is always referenced to $V_{DD}/2$. Therefore, when operating the device with split supply voltages (e.g. ±2.5 V), the shutdown terminal needs to be pulled to $V_{DD}–$ (not GND) to disable the operational amplifier.

The amplifier's output with a shutdown pulse is shown in Figure 48 through Figure 50. The amplifier is powered with a single 5-V supply and configured as a noninverting configuration with a gain of 5. The amplifier turnon and turnoff times are measured from the 50% point of the shutdown pulse to the 50% point of the output waveform. The times for the single, dual, and quad are listed in the data tables. The *bump* on the rising edge of the TLV2770 output waveform is due to the start-up circuit on the bias generator. For the dual and quad (TLV2773/5), this *bump* is attributed to the bias generator's start-up circuit as well as the crosstalk between the other channel(s), which are in shutdown.

Figure 55 and Figure 56 show the amplifier's forward and reverse isolation in shutdown. The operational amplifier is powered by ±1.35-V supplies and configured as a voltage follower ($A_V$ = 1). The isolation performance is plotted across frequency for both 0.1-$V_{PP}$ and 2.7-$V_{PP}$ input signals. During normal operation, the amplifier would not be able to handle a 2.7-$V_{PP}$ input signal with a supply voltage of ±1.35 V since it exceeds the common-mode input voltage range ($V_{ICR}$). However, this curve illustrates that the amplifier remains in shutdown even under a worst case scenario.

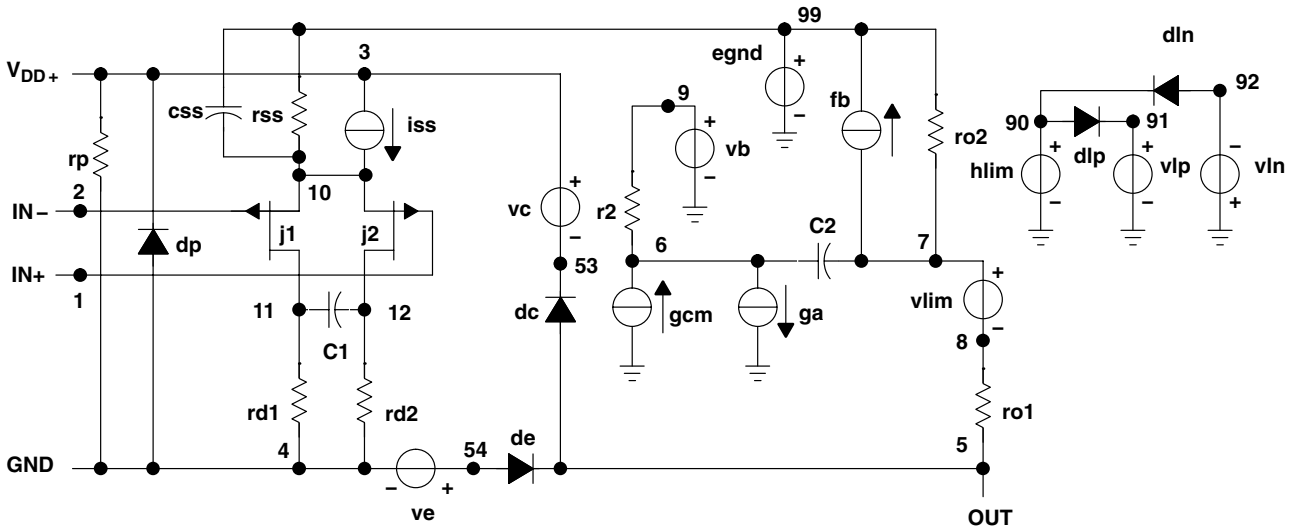
## APPLICATION INFORMATION

### macromodel information

Macromodel information provided was derived using Microsim *Parts*™ Release 8, the model generation software used with Microsim *PSpice*™. The Boyle macromodel (see Note 4) and subcircuit in Figure 64 are generated using the TLV2772 typical electrical and operating characteristics at $T_A$ = 25°C. Using this information, output simulations of the following key parameters can be generated to a tolerance of 20% (in most cases):

- Maximum positive output voltage swing
- Maximum negative output voltage swing
- Slew rate
- Quiescent power dissipation
- Input bias current
- Open-loop voltage amplification
- Unity-gain frequency
- Common-mode rejection ratio
- Phase margin
- DC output resistance
- AC output resistance
- Short-circuit output current limit

NOTE 6: G. R. Boyle, B. M. Cohn, D. O. Pederson, and J. E. Solomon, “Macromodeling of Integrated Circuit Operational Amplifiers”, *IEEE Journal of Solid-State Circuits,* SC-9, 353 (1974).




```
* TLV2772 operational amplifier macromodel subcircuit
* created using Parts release 8.0 on 12/12/97 at 10:08
* Parts is a MicroSim product.
*
* connections:   noninverting input
*                |  inverting input
*                |  |  positive power supply
*                |  |  |  negative power supply
*                |  |  |  |  output
*                |  |  |  |  |
.subckt TLV2772  1  2  3  4  5
*
c1      11   12   2.8868E-12
c2      6    7    10.000E–12
css     10   99   2.6302E–12
dc      5    53   dy
de      54   5    dy
dlp     90   91   dx
dln     92   90   dx
dp      4    3    dx
egnd    99   0    poly(2) (3,0) (4,0) 0 .5 .5
fb      7    99   poly(5) vb vc ve vlp vln 0
                  15.513E6 –1E3 1E3 16E6 –16E6
ga      6    0    11   12   188.50E–6
gcm     0    6    10   99   9.4472E–9
iss     3    10   dc     145.50E–6
hlim    90   0    vlim 1K
j1      11   2    10 jx1
j2      12   1    10 jx2
r2      6    9    100.00E3
rd1     4    11   5.3052E3
rd2     4    12   5.3052E3
ro1     8    5    17.140
ro2     7    99   17.140
rp      3    4    4.5455E3
rss     10   99   1.3746E6
vb      9    0    dc 0
vc      3    53   dc .82001
ve      54   4    dc .82001
vlim    7    8    dc 0
vlp     91   0    dc 47
vln     0    92   dc 47
.model  dx   D(Is=800.00E–18)
.model  dy   D(Is=800.00E–18 Rs=1m Cjo=10p)
.model  jx1  PJF(Is=2.2500E–12 Beta=244.20E–6
             + Vto=–.99765)
.model  jx2  PJF(Is=1.7500E–12 Beta=244.20E–6
             + Vto=–1.002350)
.ends
*$
```

**Figure 64. Boyle Macromodel and Subcircuit**

*PSpice* and *Parts* are trademarks of MicroSim Corporation.

## PACKAGING INFORMATION

| Orderable part number | Status (1) | Material type (2) | Package \| Pins | Package qty \| Carrier | RoHS (3) | Lead finish/ Ball material (4) | MSL rating/ Peak reflow (5) | Op temp (°C) | Part marking (6) |
|---|---|---|---|---|---|---|---|---|---|
| TLV2771QDBVRQ1 | Active | Production | SOT-23 (DBV) \| 5 | 3000 \| LARGE T&R | Yes | Call TI | Level-1-260C-UNLIM | -40 to 125 | VBPQ |
| TLV2771QDBVRQ1.A | Active | Production | SOT-23 (DBV) \| 5 | 3000 \| LARGE T&R | Yes | Call TI | Level-1-260C-UNLIM | -40 to 125 | VBPQ |
| TLV2772AQDRQ1 | Active | Production | SOIC (D) \| 8 | 2500 \| LARGE T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 2772AQ |
| TLV2772AQDRQ1.A | Active | Production | SOIC (D) \| 8 | 2500 \| LARGE T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 2772AQ |
| TLV2772AQPWRG4Q1 | Active | Production | TSSOP (PW) \| 8 | 2000 \| LARGE T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 2772AQ |
| TLV2772AQPWRG4Q1.A | Active | Production | TSSOP (PW) \| 8 | 2000 \| LARGE T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 2772AQ |
| TLV2772QDRG4Q1 | Active | Production | SOIC (D) \| 8 | 2500 \| LARGE T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 2772Q1 |
| TLV2772QDRG4Q1.A | Active | Production | SOIC (D) \| 8 | 2500 \| LARGE T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 2772Q1 |
| TLV2772QPWRG4Q1 | Active | Production | TSSOP (PW) \| 8 | 2000 \| LARGE T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 2772Q1 |
| TLV2772QPWRG4Q1.A | Active | Production | TSSOP (PW) \| 8 | 2000 \| LARGE T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 2772Q1 |
| TLV2772QPWRQ1 | Active | Production | TSSOP (PW) \| 8 | 2000 \| LARGE T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 2772Q1 |
| TLV2772QPWRQ1.A | Active | Production | TSSOP (PW) \| 8 | 2000 \| LARGE T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 2772Q1 |

(1) **Status:** For more details on status, see our product life cycle.

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

(4) **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

**OTHER QUALIFIED VERSIONS OF TLV2771-Q1, TLV2772-Q1, TLV2772A-Q1 :**

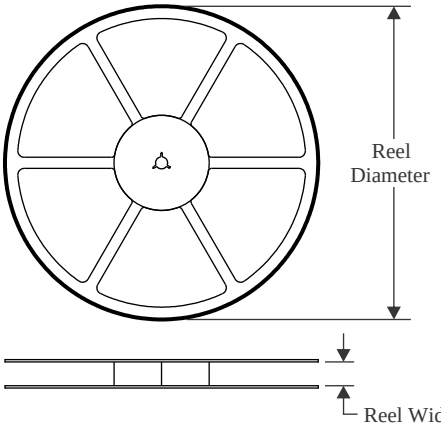
- Catalog : TLV2771, TLV2772, TLV2772A
- Enhanced Product : TLV2772A-EP
- Military : TLV2772AM

NOTE: Qualified Version Definitions:

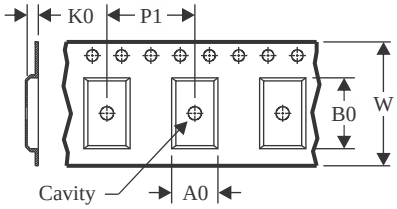
- Catalog - TI's standard catalog product
- Enhanced Product - Supports Defense, Aerospace and Medical Applications
- Military - QML certified for Military and Defense Applications

## TAPE AND REEL INFORMATION

**REEL DIMENSIONS**

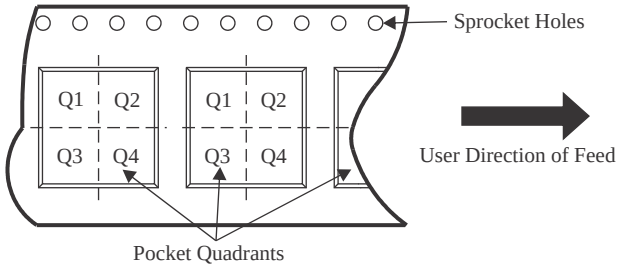



**TAPE DIMENSIONS**




| | |
|---|---|
| A0 | Dimension designed to accommodate the component width |
| B0 | Dimension designed to accommodate the component length |
| K0 | Dimension designed to accommodate the component thickness |
| W | Overall width of the carrier tape |
| P1 | Pitch between successive cavity centers |

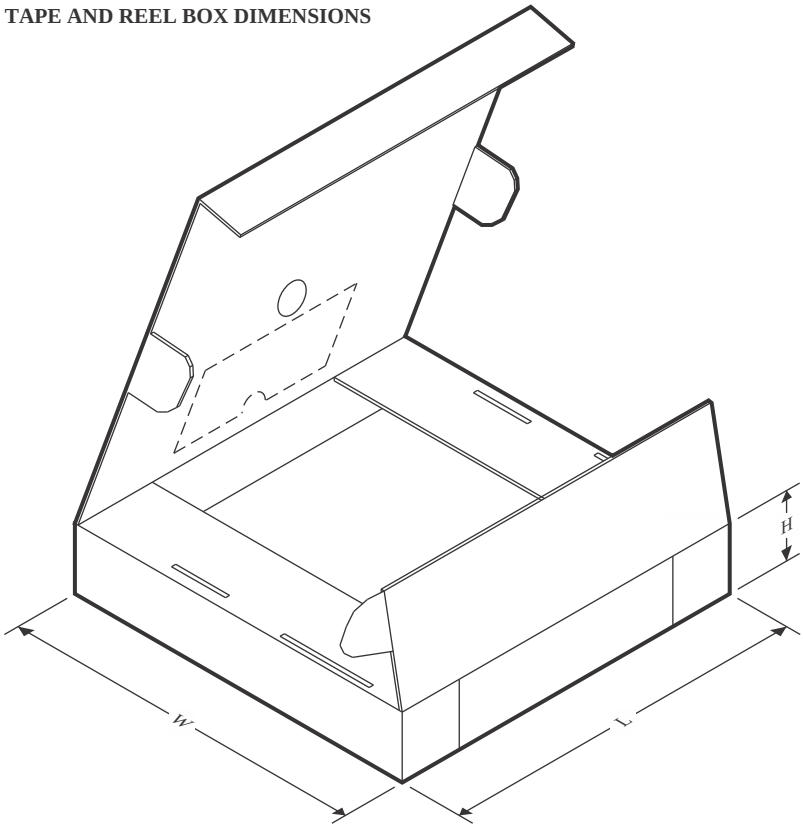
**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**




*All dimensions are nominal

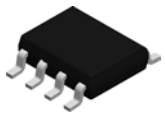
| Device | Package Type | Package Drawing | Pins | SPQ | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TLV2771QDBVRQ1 | SOT-23 | DBV | 5 | 3000 | 180.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TLV2772AQPWRG4Q1 | TSSOP | PW | 8 | 2000 | 330.0 | 12.4 | 7.0 | 3.6 | 1.6 | 8.0 | 12.0 | Q1 |
| TLV2772QPWRG4Q1 | TSSOP | PW | 8 | 2000 | 330.0 | 12.4 | 7.0 | 3.6 | 1.6 | 8.0 | 12.0 | Q1 |
| TLV2772QPWRQ1 | TSSOP | PW | 8 | 2000 | 330.0 | 12.4 | 7.0 | 3.6 | 1.6 | 8.0 | 12.0 | Q1 |

TAPE AND REEL BOX DIMENSIONS




*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---|---|---|---|---|---|---|---|
| TLV2771QDBVRQ1 | SOT-23 | DBV | 5 | 3000 | 210.0 | 185.0 | 35.0 |
| TLV2772AQPWRG4Q1 | TSSOP | PW | 8 | 2000 | 353.0 | 353.0 | 32.0 |
| TLV2772QPWRG4Q1 | TSSOP | PW | 8 | 2000 | 353.0 | 353.0 | 32.0 |
| TLV2772QPWRQ1 | TSSOP | PW | 8 | 2000 | 353.0 | 353.0 | 32.0 |

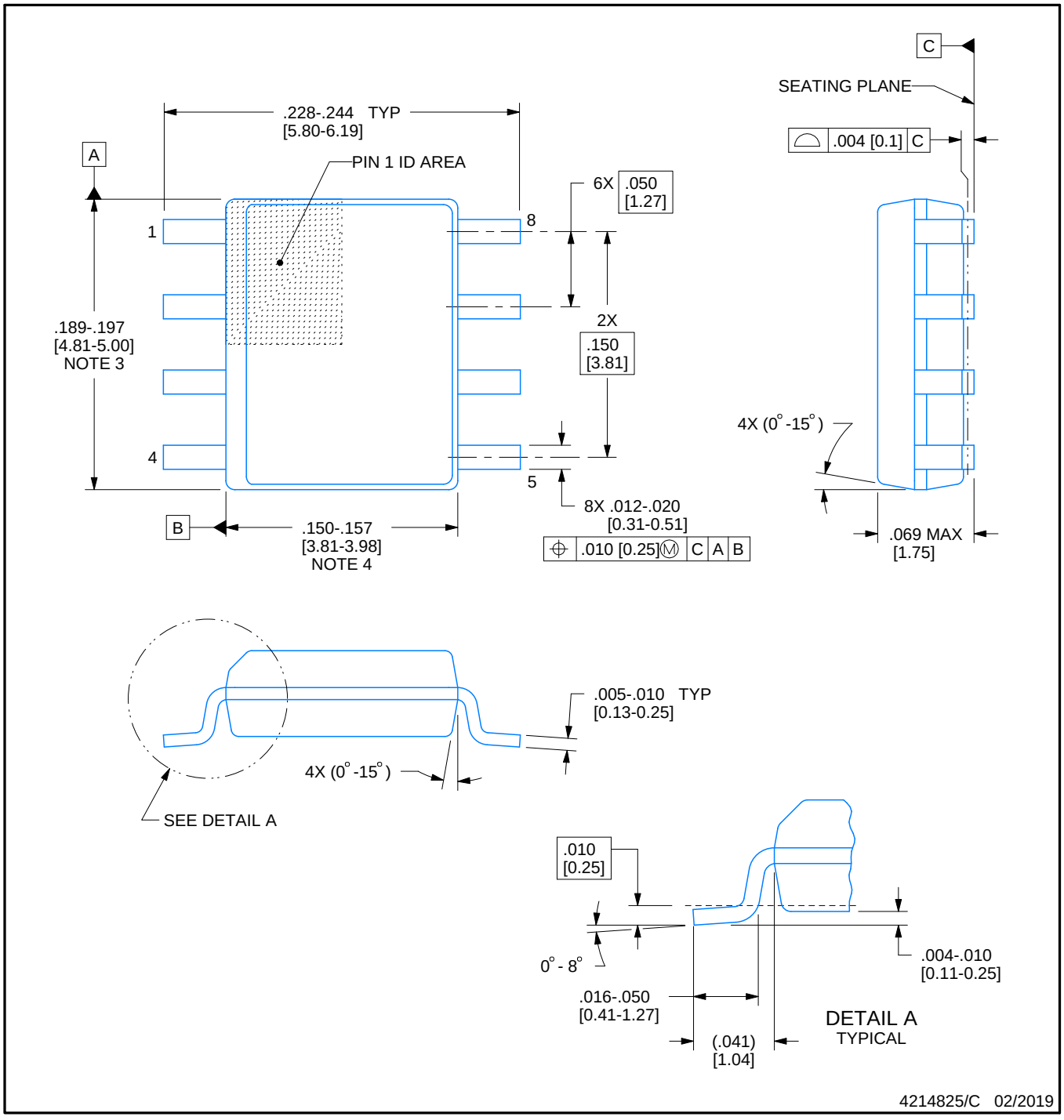


# PACKAGE OUTLINE

## D0008A

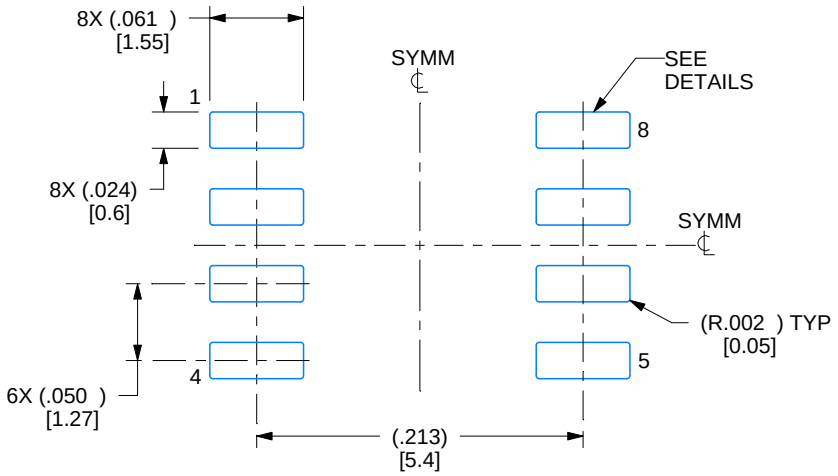
## SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT

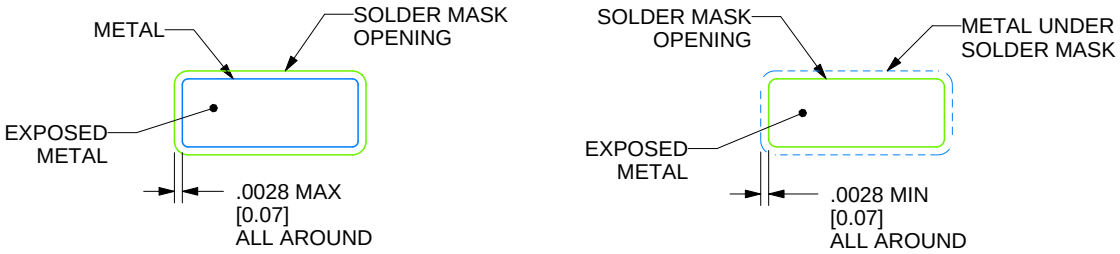



NOTES:

1. Linear dimensions are in inches [millimeters]. Dimensions in parenthesis are for reference only. Controlling dimensions are in inches. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed .006 [0.15] per side.
4. This dimension does not include interlead flash.
5. Reference JEDEC registration MS-012, variation AA.




LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:8X




SOLDER MASK DETAILS

4214825/C 02/2019

NOTES: (continued)

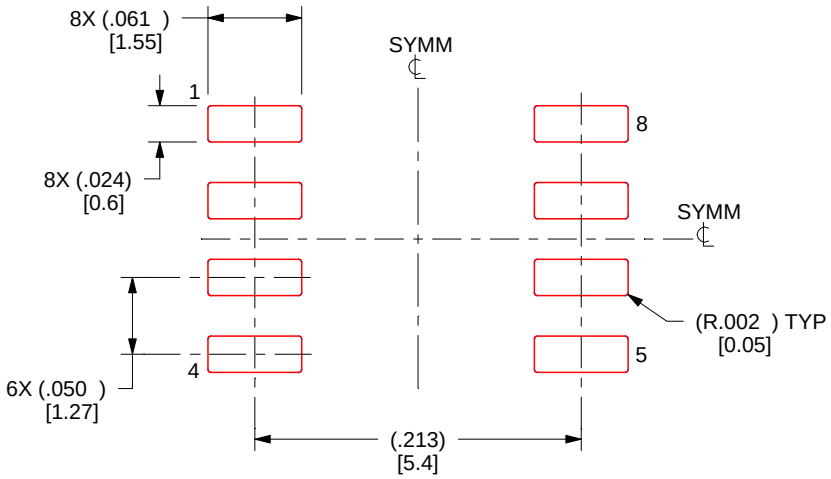
6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

# EXAMPLE STENCIL DESIGN

## D0008A

## SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT




SOLDER PASTE EXAMPLE
BASED ON .005 INCH [0.125 MM] THICK STENCIL
SCALE:8X

4214825/C 02/2019

NOTES: (continued)

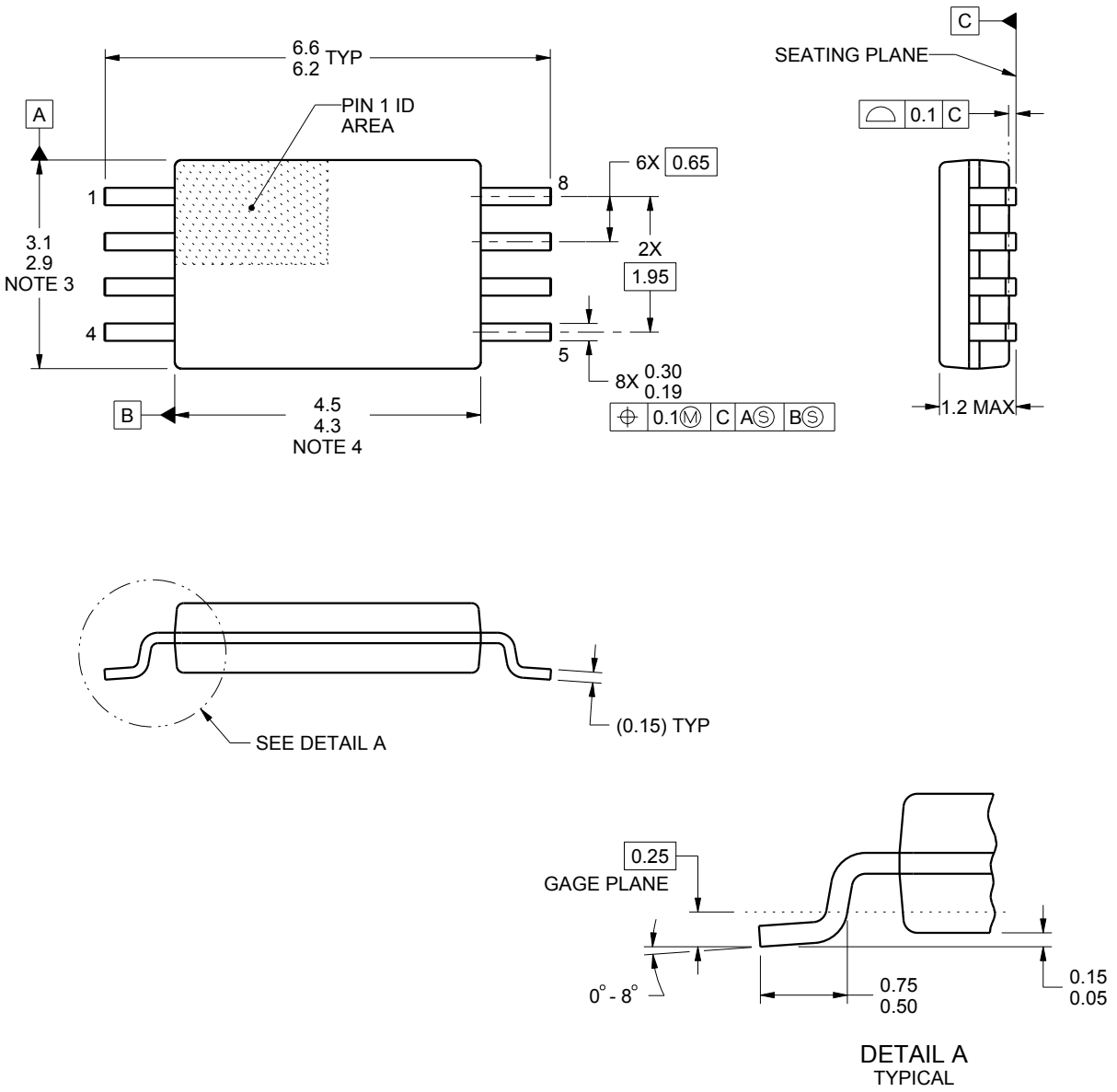
8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

# PACKAGE OUTLINE

## PW0008A

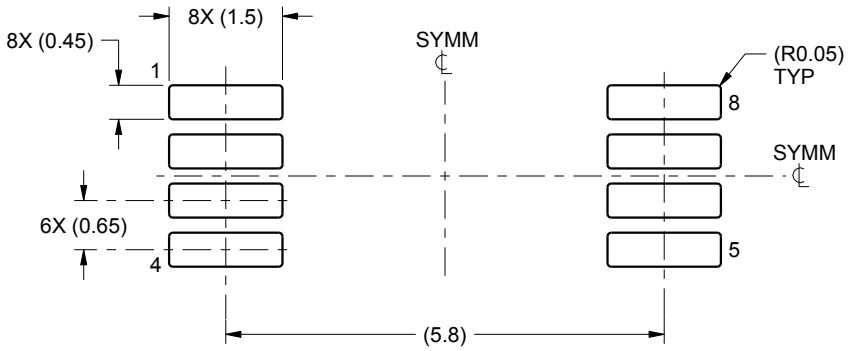
## TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE

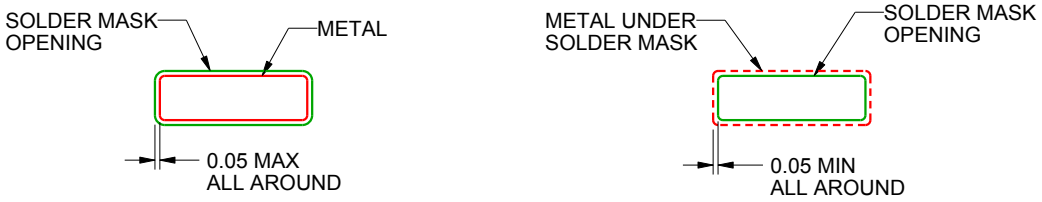



NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
5. Reference JEDEC registration MO-153, variation AA.




LAND PATTERN EXAMPLE
SCALE:10X

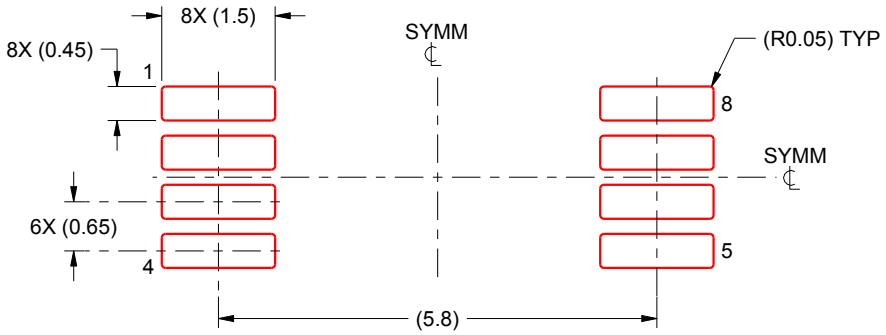



SOLDER MASK DETAILS
NOT TO SCALE

4221848/A 02/2015

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.




SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:10X

4221848/A 02/2015

NOTES: (continued)

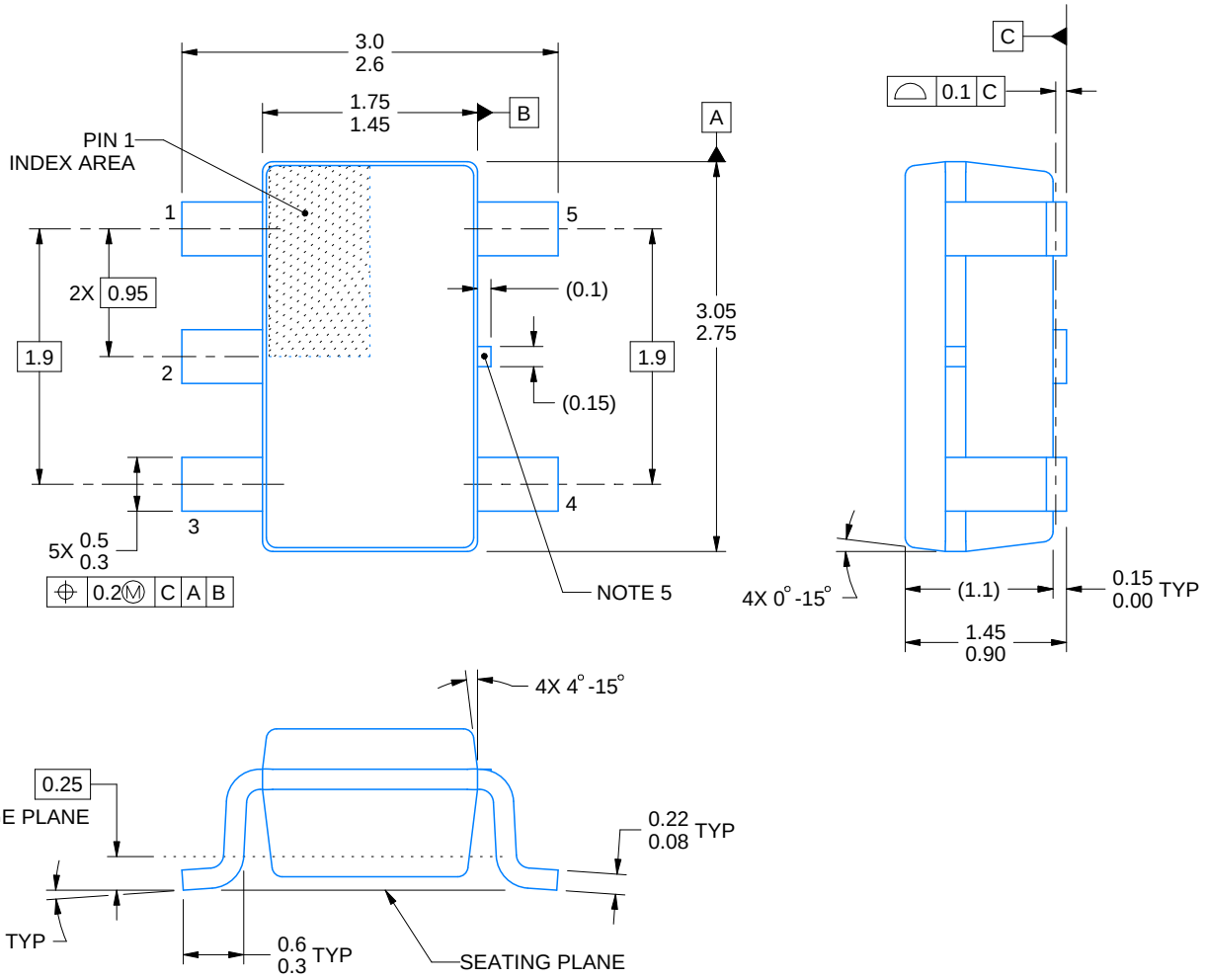
8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

# PACKAGE OUTLINE

## DBV0005A

## SOT-23 - 1.45 mm max height

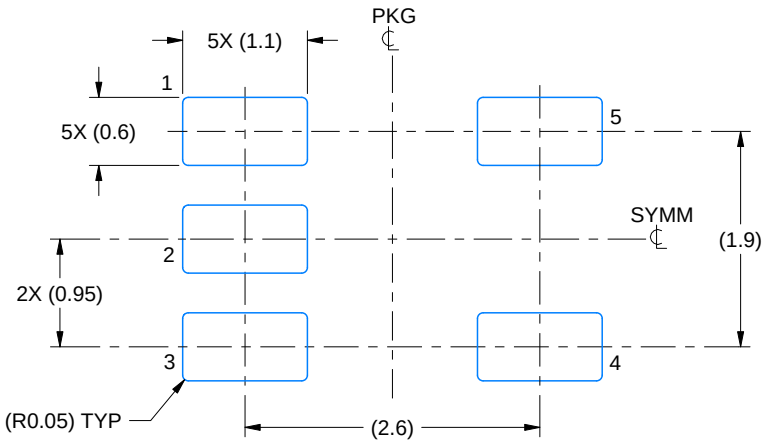
SMALL OUTLINE TRANSISTOR



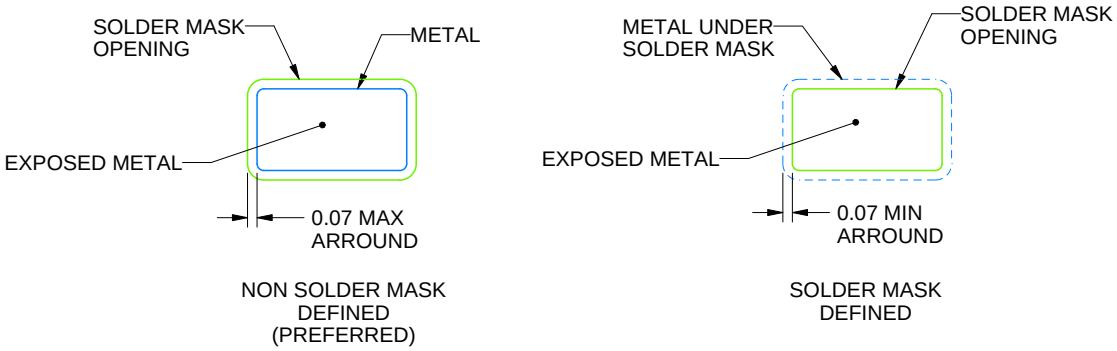

4214839/K 08/2024

NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Refernce JEDEC MO-178.
4. Body dimensions do not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.25 mm per side.
5. Support pin may differ or may not be present.




LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:15X

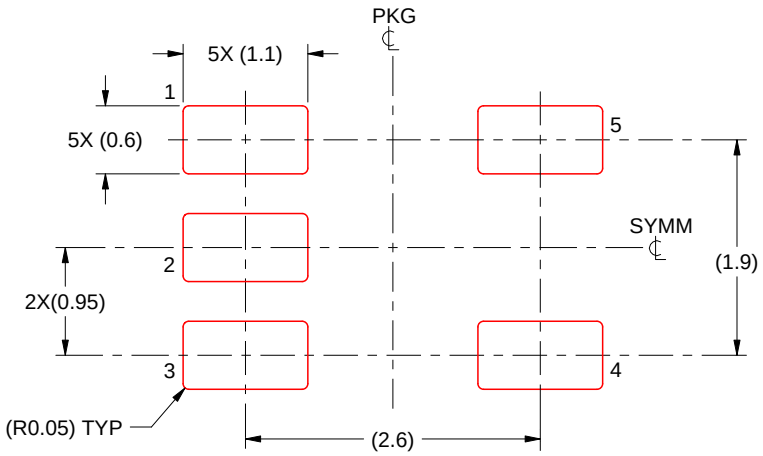



SOLDER MASK DETAILS

4214839/K 08/2024

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.




SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:15X

4214839/K 08/2024

NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

# IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you fully indemnify TI and its representatives against any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI’s products are provided subject to TI’s Terms of Sale, TI’s General Quality Guidelines, or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI’s provision of these resources does not expand or otherwise alter TI’s applicable warranties or warranty disclaimers for TI products. Unless TI explicitly designates a product as custom or customer-specified, TI products are standard, catalog, general purpose devices.

TI objects to and rejects any additional or different terms you may propose.



Last updated 10/2025