

TLC226x-Q1, TLC226xA-Q1 Advanced LinCMOS™ RAIL-TO-RAIL OPERATIONAL AMPLIFIERS

SGLS189A – OCTOBER 2003 – REVISED JULY 2004

- Qualification in Accordance With AEC-Q100†
- Qualified for Automotive Applications
- Customer-Specific Configuration Control Can Be Supported Along With Major-Change Approval
- ESD Protection Exceeds 2000 V Per MIL-STD-883, Method 3015; Exceeds 200 V Using Machine Model (C = 200 pF, R = 0)
- Output Swing includes Both Supply Rails
- Low Noise . . . 12 nV/√Hz Typ at f = 1 kHz
- Low Input Bias Current . . . 1 pA Typ
- Fully Specified for Both Single-Supply and Split-Supply Operation
- Low Power . . . 500 μA Max
- Common-Mode Input Voltage Range Includes Negative Rail
- Low Input Offset Voltage
950 μV Max at T_A = 25°C (TLC2262A)
- Macromodel Included
- Performance Upgrade for the TS27M2/M4 and TLC27M2/M4

† Contact factory for details. Q100 qualification data available on request.

description

The TLC2262 and TLC2264 are dual and quadruple operational amplifiers from Texas Instruments. Both devices exhibit rail-to-rail output performance for increased dynamic range in single- or split-supply applications. The TLC226x family offers a compromise between the micropower TLC225x and the ac performance of the TLC227x. It has low supply current for battery-powered applications, while still having adequate ac performance for applications that demand it. The noise performance has been dramatically improved over previous generations of CMOS amplifiers. Figure 1 depicts the low level of noise voltage for this CMOS amplifier, which has only 200 μA (typ) of supply current per amplifier.

The TLC226x, exhibiting high input impedance and low noise, are excellent for small-signal conditioning for high-impedance sources, such as piezoelectric transducers. Because of the micropower dissipation levels, these devices work well in hand-held monitoring and remote-sensing applications. In addition, the rail-to-rail output feature with single or split supplies makes this family a great choice when interfacing with analog-to-digital converters (ADCs). For precision applications, the TLC226xA family is available and has a maximum input offset voltage of 950 μV. This family is fully characterized at 5 V and ±5 V.

EQUIVALENT INPUT NOISE VOLTAGE
vs
FREQUENCY

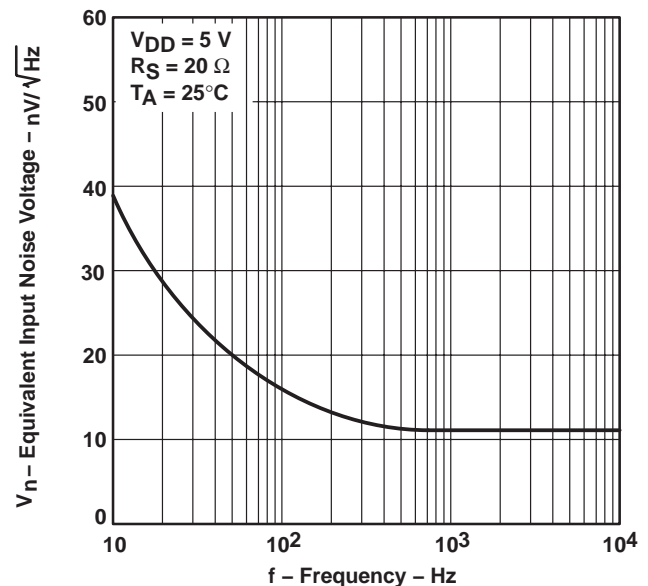


Figure 1

For precision applications, the rail-to-rail output feature with single or split supplies makes this family a great choice when interfacing with analog-to-digital converters (ADCs). For precision applications, the TLC226xA family is available and has a maximum input offset voltage of 950 μV. This family is fully characterized at 5 V and ±5 V.



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description (continued)

The TLC2262/4 also makes great upgrades to the TLC27M2/L4 or TS27M2/L4 in standard designs. They offer increased output dynamic range, lower noise voltage and lower input offset voltage. This enhanced feature set allows them to be used in a wider range of applications. For applications that require higher output drive and wider input voltage range, see the TLV2432 and TLV2442. If your design requires single amplifiers, please see the TLV2211/21/31 family. These devices are single rail-to-rail operational amplifiers in the SOT-23 package. Their small size and low power consumption, make them ideal for high density, battery-powered equipment.

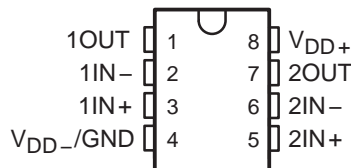
ORDERING INFORMATION

| T _A | V _{IO} max AT 25°C | PACKAGE† | | ORDERABLE PART NUMBER | TOP-SIDE MARKING |
|----------------|--------------------------------|------------|---------------|--------------------------|---------------------|
| -40°C to 125°C | 950 μV | SOIC (D) | Tape and reel | TLC2262AQDRQ1‡ | 2262AQ1 |
| | 2.5 mV | SOIC (D) | Tape and reel | TLC2262QDRQ1‡ | 2262Q1 |
| | 950 μV | TSSOP (PW) | Tape and reel | TLC2262AQPWRQ1‡ | 2262AQ1 |
| | 2.5 mV | TSSOP (PW) | Tape and reel | TLC2262QPWRQ1‡ | 2262Q1 |
| | 950 μV | SOIC (D) | Tape and reel | TLC2264AQDRQ1 | 2264AQ1 |
| | 2.5 mV | SOIC (D) | Tape and reel | TLC2264QDRQ1 | 2264Q1 |
| | 950 μV | TSSOP (PW) | Tape and reel | TLC2264AQPWRQ1 | 2264AQ1 |
| | 2.5 mV | TSSOP (PW) | Tape and reel | TLC2264QPWRQ1 | 2264Q1 |

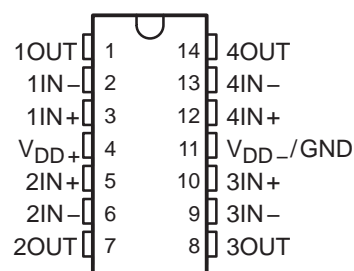
† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.

‡ Product Preview.

TLC2262, TLC2262A
D OR PW PACKAGE
(TOP VIEW)



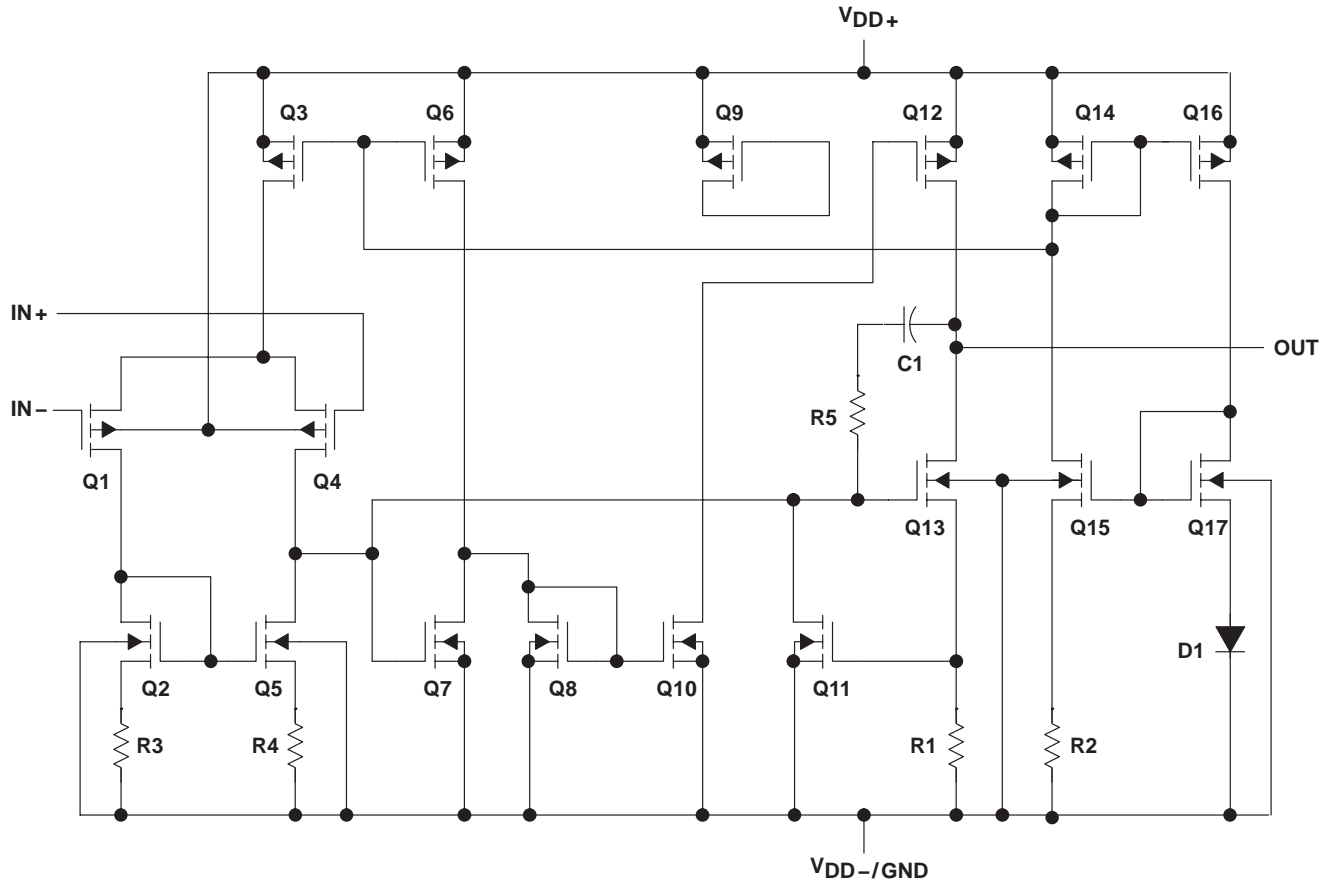
TLC2264, TLC2264A
D OR PW PACKAGE
(TOP VIEW)



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equivalent schematic (each amplifier)



| ACTUAL DEVICE COMPONENT COUNT† | | |
|--------------------------------|---------|---------|
| COMPONENT | TLC2262 | TLC2264 |
| Transistors | 38 | 76 |
| Resistors | 28 | 56 |
| Diodes | 9 | 18 |
| Capacitors | 3 | 6 |

† Includes both amplifiers and all ESD, bias, and trim circuitry

TLC226x-Q1, TLC226xA-Q1

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

| | |
|---|--------------------------------|
| Supply voltage, V_{DD+} (see Note 1) | 8 V |
| Supply voltage, V_{DD-} (see Note 1) | -8 V |
| Differential input voltage, V_{ID} (see Note 2) | ± 16 V |
| Input voltage, V_I (any input, see Note 1) | $V_{DD-} - 0.3$ V to V_{DD+} |
| Input current, I_I (each input) | ± 5 mA |
| Output current, I_O | ± 50 mA |
| Total current into V_{DD+} | ± 50 mA |
| Total current out of V_{DD-} | ± 50 mA |
| Duration of short-circuit current at (or below) 25°C (see Note 3) | unlimited |
| Continuous total 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: D or PW package | 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 the midpoint between V_{DD+} and V_{DD-} .
 2. Differential voltages are at $IN+$ with respect to $IN-$. Excessive current flows if input is brought below $V_{DD-} - 0.3$ 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.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ POWER RATING | DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$ | $T_A = 70^\circ\text{C}$ POWER RATING | $T_A = 85^\circ\text{C}$ POWER RATING | $T_A = 125^\circ\text{C}$ POWER RATING |
|---------|---|---|--|--|---|
| D-8 | 725 mW | 5.8 mW/°C | 464 mW | 377 mW | 145 mW |
| D-14 | 950 mW | 7.6 mW/°C | 608 mW | 494 mW | 190 mW |
| PW-14 | 750 mW | 6.0 mW/°C | 480 mW | 389 mW | 150 mW |

recommended operating conditions

| | MIN | MAX | UNIT |
|---------------------------------------|-----------|-----------------|------|
| Supply voltage, $V_{DD\pm}$ | ± 2.2 | ± 8 | V |
| Input voltage range, V_I | V_{DD-} | $V_{DD+} - 1.5$ | V |
| Common-mode input voltage, V_{IC} | V_{DD-} | $V_{DD+} - 1.5$ | V |
| Operating free-air temperature, T_A | -40 | 125 | °C |



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TLC2262 electrical characteristics at specified free-air temperature, $V_{DD} = 5\text{ V}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_A † | TLC2262-Q1 | | | TLC2262A-Q1 | | | UNIT |
|--|--|-------------------------------------|------------|-------------|------|-------------|-------------|------------------------------|---------------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| V_{IO} Input offset voltage | $V_{DD} \pm \pm 2.5\text{ V}$, $V_{IC} = 0$, $V_O = 0$, $R_S = 50\ \Omega$ | 25°C | 300 | 2500 | | 300 | 950 | μV | |
| | | Full range | | | 3000 | | 1500 | | |
| α_{VIO} Temperature coefficient of input offset voltage | | Full range | 5 | | | 5 | | $\mu\text{V}/^\circ\text{C}$ | |
| Input offset voltage long-term drift (see Note 4) | | 25°C | 0.003 | | | 0.003 | | $\mu\text{V}/\text{mo}$ | |
| I_{IO} Input offset current | | 25°C | 0.5 | | | 0.5 | | pA | |
| | | 125°C | | 800 | | 800 | | | |
| I_{IB} Input bias current | | 25°C | 1 | | | 1 | | pA | |
| | | 125°C | | 800 | | 800 | | | |
| V_{ICR} Common-mode input voltage range | $R_S = 50\ \Omega$, $ V_{IO} \leq 5\text{ mV}$ | 25°C | 0 to 4 | -0.3 to 4.2 | | 0 to 4 | -0.3 to 4.2 | V | |
| | | Full range | 0 to 3.5 | | | 0 to 3.5 | | | |
| V_{OH} High-level output voltage | $I_{OH} = -20\ \mu\text{A}$ | 25°C | | 4.99 | | | 4.99 | V | |
| | | 25°C | 4.85 | 4.94 | | 4.85 | 4.94 | | |
| | | Full range | 4.82 | | | 4.82 | | | |
| | | 25°C | 4.7 | 4.85 | | 4.7 | 4.85 | | |
| V_{OL} Low-level output voltage | $V_{IC} = 2.5\text{ V}$, $I_{OL} = 50\ \mu\text{A}$ | 25°C | | 0.01 | | | 0.01 | V | |
| | | 25°C | 0.09 | 0.15 | | 0.09 | 0.15 | | |
| | | Full range | | 0.15 | | | 0.15 | | |
| | | 25°C | 0.8 | 1 | | 0.7 | 1 | | |
| A_{VD} Large-signal differential voltage amplification | $V_{IC} = 2.5\text{ V}$, $V_O = 1\text{ V to }4\text{ V}$ | $R_L = 50\ \text{k}\Omega^\ddagger$ | 25°C | 80 | 100 | | 80 | 170 | V/mV |
| | | | Full range | 50 | | | 50 | | |
| | | $R_L = 1\ \text{M}\Omega^\ddagger$ | 25°C | | 550 | | | 550 | |
| | | | Full range | | 1.2 | | | 1.2 | |
| $r_{i(d)}$ Differential input resistance | | 25°C | | 10^{12} | | | 10^{12} | Ω | |
| $r_{i(c)}$ Common-mode input resistance | | 25°C | | 10^{12} | | | 10^{12} | Ω | |
| $c_{i(c)}$ Common-mode input capacitance | $f = 10\ \text{kHz}$, P package | 25°C | | 8 | | | 8 | pF | |
| z_o Closed-loop output impedance | $f = 100\ \text{kHz}$, $A_V = 10$ | 25°C | | 240 | | | 240 | Ω | |
| CMRR Common-mode rejection ratio | $V_{IC} = 0\text{ to }2.7\text{ V}$, $V_O = 2.5\text{ V}$, $R_S = 50\ \Omega$ | 25°C | 70 | 83 | | 70 | 83 | dB | |
| | | Full range | 70 | | | 70 | | | |
| k_{SVR} Supply-voltage rejection ratio ($\Delta V_{DD}/\Delta V_{IO}$) | $V_{DD} = 4.4\text{ V to }16\text{ V}$, $V_{IC} = V_{DD}/2$, No load | 25°C | 80 | 95 | | 80 | 95 | dB | |
| | | Full range | 80 | | | 80 | | | |
| I_{DD} Supply current | $V_O = 2.5\text{ V}$, No load | 25°C | | 400 | 500 | | 400 | 500 | μA |
| | | Full range | | | 500 | | | 500 | |

† Full range is -40°C to 125°C for Q suffix.

‡ Referenced to 2.5 V

NOTE 4: Typical values are based on the input offset voltage shift observed through 500 hours of operating life test at $T_A = 150^\circ\text{C}$ extrapolated to $T_A = 25^\circ\text{C}$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.



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TLC2262 operating characteristics at specified free-air temperature, $V_{DD} = 5\text{ V}$

| PARAMETER | TEST CONDITIONS | T_A † | TLC2262-Q1 | | | TLC2262A-Q1 | | | UNIT |
|-------------|--|--------------------------------------|------------|--------|-----|-------------|--------|------------------------|------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR | Slew rate at unity gain $V_O = 0.5\text{ V to }3.5\text{ V}$, $R_L = 50\text{ k}\Omega$ ‡, $C_L = 100\text{ pF}$ ‡ | 25°C | 0.35 | 0.55 | | 0.35 | 0.55 | V/ μs | |
| | | Full range | 0.25 | | | 0.25 | | | |
| V_n | Equivalent input noise voltage | f = 10 Hz | | 40 | | | 40 | nV/ $\sqrt{\text{Hz}}$ | |
| | | f = 1 kHz | | 12 | | | 12 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 1 Hz | | 0.7 | | | 0.7 | μV | |
| | | f = 0.1 Hz to 10 Hz | | 1.3 | | | 1.3 | | |
| I_n | Equivalent input noise current | 25°C | | 0.6 | | | 0.6 | fA/ $\sqrt{\text{Hz}}$ | |
| THD + N | Total harmonic distortion plus noise $V_O = 0.5\text{ V to }2.5\text{ V}$, f = 20 kHz, $R_L = 50\text{ k}\Omega$ ‡ | $A_V = 1$ | | 0.017% | | | 0.017% | | |
| | | $A_V = 10$ | | 0.03% | | | 0.03% | | |
| | Gain-bandwidth product f = 50 kHz, $C_L = 100\text{ pF}$ ‡ | $R_L = 50\text{ k}\Omega$ ‡, 25°C | | 0.82 | | | 0.82 | MHz | |
| BOM | Maximum output-swing bandwidth $V_O(PP) = 2\text{ V}$, $R_L = 50\text{ k}\Omega$ ‡, $A_V = 1$, $C_L = 100\text{ pF}$ ‡ | 25°C | | 185 | | | 185 | kHz | |
| t_s | Settling time $A_V = -1$, Step = 0.5 V to 2.5 V, $R_L = 50\text{ k}\Omega$ ‡, $C_L = 100\text{ pF}$ ‡ | To 0.1% | | 6.4 | | | 6.4 | μs | |
| | | To 0.01% | | 14.1 | | | 14.1 | | |
| ϕ_m | Phase margin at unity gain $R_L = 50\text{ k}\Omega$ ‡, $C_L = 100\text{ pF}$ ‡ | 25°C | | 56° | | | 56° | | |
| | | 25°C | | 11 | | | 11 | | dB |

† Full range is -40°C to 125°C for Q suffix.

‡ Referenced to 2.5 V

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TLC2262 electrical characteristics at specified free-air temperature, $V_{DD\pm} = \pm 5\text{ V}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T _A † | TLC2262-Q1 | | | TLC2262A-Q1 | | | UNIT |
|--|--|------------------------|------------------|-----------|------|------------------|-------------|-------|------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| V _{IO} Input offset voltage | V _{IC} = 0, V _O = 0, R _S = 50 Ω | 25°C | 300 | 2500 | | 300 | 950 | μV | |
| | | Full range | | | 3000 | | 1500 | | |
| α _{VIO} Temperature coefficient of input offset voltage | | Full range | 5 | | | 5 | | μV/°C | |
| Input offset voltage long-term drift (see Note 4) | | 25°C | 0.003 | | | 0.003 | | μV/mo | |
| I _{IO} Input offset current | | 25°C | 0.5 | | | 0.5 | | pA | |
| | | 125°C | | 800 | | 800 | | | |
| I _{IB} Input bias current | 25°C | 1 | | | 1 | | pA | | |
| | 125°C | | 800 | | 800 | | | | |
| V _{ICR} Common-mode input voltage range | R _S = 50 Ω, V _{IO} ≤ 5 mV | 25°C | -5 to 4 | -5.3 to 4 | | -5 to 4 | -5.3 to 4.2 | V | |
| | | Full range | -5 to 3.5 | | | -5 to 3.5 | | | |
| V _{OM+} Maximum positive peak output voltage | I _O = -20 μA | 25°C | 4.99 | | | 4.99 | | V | |
| | | 25°C | 4.85 | 4.94 | | 4.85 | 4.94 | | |
| | | Full range | 4.82 | | | 4.82 | | | |
| | | 25°C | 4.7 | 4.85 | | 4.7 | 4.85 | | |
| V _{OM-} Maximum negative peak output voltage | I _O = -100 μA | 25°C | -4.99 | | | -4.99 | | V | |
| | | 25°C | -4.85 | -4.91 | | -4.85 | -4.91 | | |
| | | Full range | -4.85 | | | -4.85 | | | |
| | | 25°C | -4 | -4.3 | | -4 | -4.3 | | |
| V _{OM-} Maximum negative peak output voltage | I _O = -400 μA | 25°C | -4.99 | | | -4.99 | | V | |
| | | 25°C | -4.85 | -4.91 | | -4.85 | -4.91 | | |
| | | Full range | -4.85 | | | -4.85 | | | |
| | | 25°C | -4 | -4.3 | | -4 | -4.3 | | |
| A _{VD} Large-signal differential voltage amplification | V _O = ±4 V | R _L = 50 kΩ | 25°C | 80 | 200 | | 80 | 200 | V/mV |
| | | | Full range | 50 | | | 50 | | |
| | | R _L = 1 MΩ | 25°C | 1000 | | | 1000 | | |
| r _{i(d)} Differential input resistance | | 25°C | 10 ¹² | | | 10 ¹² | Ω | | |
| r _{i(c)} Common-mode input resistance | | 25°C | 10 ¹² | | | 10 ¹² | Ω | | |
| c _{i(c)} Common-mode input capacitance | f = 10 kHz, P package | 25°C | 8 | | | 8 | pF | | |
| z _o Closed-loop output impedance | f = 100 kHz, A _V = 10 | 25°C | 220 | | | 220 | Ω | | |
| CMRR Common-mode rejection ratio | V _{IC} = -5 V to 2.7 V, V _O = 0, R _S = 50 Ω | 25°C | 75 | 88 | | 75 | 88 | dB | |
| | | Full range | 75 | | | 75 | | | |
| k _{SVR} Supply-voltage rejection ratio (ΔV _{DD±} /ΔV _{IO}) | V _{DD} = 4.4 V to 16 V, V _{IC} = V _{DD} /2, No load | 25°C | 80 | 95 | | 80 | 95 | dB | |
| | | Full range | 80 | | | 80 | | | |
| I _{DD} Supply current | V _O = 0, No load | 25°C | 425 | 500 | | 425 | 500 | μA | |
| | | Full range | | 500 | | | 500 | | |

† Full range is -40°C to 125°C for Q suffix.

NOTE 4: Typical values are based on the input offset voltage shift observed through 500 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.



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TLC2262 operating characteristics at specified free-air temperature, $V_{DD\pm} = \pm 5\text{ V}$

| PARAMETER | TEST CONDITIONS | T_A † | TLC2262-Q1 | | | TLC2262A-Q1 | | | UNIT | |
|-------------|---|--------------------------------------|------------|------------|--------|-------------|--------|--------|------------------|------------------------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | | |
| SR | Slew rate at unity gain $V_O = \pm 2\text{ V}$, $C_L = 100\text{ pF}$ | $R_L = 50\text{ k}\Omega$ | 25°C | 0.35 | 0.55 | | 0.35 | 0.55 | V/ μs | |
| | | | Full range | 0.25 | | | 0.25 | | | |
| V_n | Equivalent input noise voltage | | 25°C | 43 | | | 43 | | | nV/ $\sqrt{\text{Hz}}$ |
| | | | 25°C | 12 | | | 12 | | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | | 25°C | 0.8 | | | 0.8 | | | μV |
| | | | 25°C | 1.3 | | | 1.3 | | | |
| I_n | Equivalent input noise current | | 25°C | 0.6 | | | 0.6 | | | fA/ $\sqrt{\text{Hz}}$ |
| THD + N | Total harmonic distortion plus noise $V_O = \pm 2.3\text{ V}$, $R_L = 50\text{ k}\Omega$, $f = 20\text{ kHz}$ | $A_V = 1$ | 25°C | 0.014% | | | 0.014% | | | |
| | | | | $A_V = 10$ | 0.024% | | | 0.024% | | |
| | Gain-bandwidth product $f = 10\text{ kHz}$, $C_L = 100\text{ pF}$ | $R_L = 50\text{ k}\Omega$ | 25°C | 0.73 | | | 0.73 | | | MHz |
| BOM | Maximum output-swing bandwidth $V_{O(PP)} = 4.6\text{ V}$, $R_L = 50\text{ k}\Omega$, | $A_V = 1$, $C_L = 100\text{ pF}$ | 25°C | 85 | | | 85 | | | kHz |
| t_s | Settling time $A_V = -1$, Step = -2.3 V to 2.3 V , $R_L = 50\text{ k}\Omega$, $C_L = 100\text{ pF}$ | To 0.1% | 25°C | 7.1 | | | 7.1 | | | μs |
| | | To 0.01% | | 16.5 | | | 16.5 | | | |
| ϕ_m | Phase margin at unity gain $R_L = 50\text{ k}\Omega$, | $C_L = 100\text{ pF}$ | 25°C | 57° | | | 57° | | | |
| | | | 25°C | 11 | | | 11 | | | |

† Full range is -40°C to 125°C for Q suffix.

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TLC2264 electrical characteristics at specified free-air temperature, $V_{DD} = 5\text{ V}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_A † | TLC2264-Q1 | | | TLC2264A-Q1 | | | UNIT |
|--|---|-------------------------------------|------------|-------------|------|-------------|-------------|------------------------------|---------------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| V_{IO} Input offset voltage | | 25°C | | 300 | 2500 | | 300 | 950 | μV |
| | | Full range | | | 3000 | | | 1500 | |
| α_{VIO} Temperature coefficient of input offset voltage | | Full range | | 2 | | | 2 | $\mu\text{V}/^\circ\text{C}$ | |
| Input offset voltage long-term drift (see Note 4) | $V_{DD\pm} = \pm 2.5\text{ V}$, $V_O = 0$, $V_{IC} = 0$, $R_S = 50\ \Omega$ | 25°C | | 0.003 | | | 0.003 | $\mu\text{V}/\text{mo}$ | |
| I_{IO} Input offset current | | 25°C | | 0.5 | | | 0.5 | pA | |
| | | 125°C | | | 800 | | 800 | | |
| I_{IB} Input bias current | | 25°C | | 1 | | | 1 | pA | |
| | | 125°C | | | 800 | | 800 | | |
| V_{ICR} Common-mode input voltage range | $R_S = 50\ \Omega$, $ V_{IO} \leq 5\text{ mV}$ | 25°C | 0 to 4 | -0.3 to 4.2 | | 0 to 4 | -0.3 to 4.2 | V | |
| | | Full range | 0 to 3.5 | | | 0 to 3.5 | | | |
| V_{OH} High-level output voltage | $I_{OH} = -20\ \mu\text{A}$ | 25°C | | 4.99 | | | 4.99 | V | |
| | | 25°C | 4.85 | 4.94 | | 4.85 | 4.94 | | |
| | | Full range | 4.82 | | | 4.82 | | | |
| | | 25°C | 4.7 | 4.85 | | 4.7 | 4.85 | | |
| V_{OL} Low-level output voltage | $V_{IC} = 2.5\text{ V}$, $I_{OL} = 50\ \mu\text{A}$ | 25°C | | 0.01 | | | 0.01 | V | |
| | | 25°C | 0.09 | 0.15 | | 0.09 | 0.15 | | |
| | | Full range | | 0.15 | | | 0.15 | | |
| | | 25°C | 0.8 | 1 | | 0.7 | 1 | | |
| A_{VD} Large-signal differential voltage amplification | $V_{IC} = 2.5\text{ V}$, $V_O = 1\text{ V to }4\text{ V}$ | $R_L = 50\ \text{k}\Omega^\ddagger$ | 25°C | 80 | 100 | | 80 | 170 | V/mV |
| | | | Full range | 50 | | | 50 | | |
| | | $R_L = 1\ \text{M}\Omega^\ddagger$ | 25°C | | 550 | | | 550 | |
| | | | Full range | | | 1.2 | | | |
| $r_{i(d)}$ Differential input resistance | | 25°C | | 10^{12} | | | 10^{12} | Ω | |
| $r_{i(c)}$ Common-mode input resistance | | 25°C | | 10^{12} | | | 10^{12} | Ω | |
| $c_{i(c)}$ Common-mode input capacitance | $f = 10\ \text{kHz}$, N package | 25°C | | 8 | | | 8 | pF | |
| z_o Closed-loop output impedance | $f = 100\ \text{kHz}$, $A_V = 10$ | 25°C | | 240 | | | 240 | Ω | |
| CMRR Common-mode rejection ratio | $V_{IC} = 0\text{ to }2.7\text{ V}$, $V_O = 2.5\text{ V}$, $R_S = 50\ \Omega$ | 25°C | 70 | 83 | | 70 | 83 | dB | |
| | | Full range | 70 | | | 70 | | | |
| k_{SVR} Supply-voltage rejection ratio ($\Delta V_{DD}/\Delta V_{IO}$) | $V_{DD} = 4.4\text{ V to }16\text{ V}$, | 25°C | 80 | 95 | | 80 | 95 | dB | |
| I_{DD} Supply current (four amplifiers) | $V_O = 2.5\text{ V}$, No load | 25°C | | 0.8 | 1 | | 0.8 | 1 | mA |
| | | Full range | | | 1 | | | 1 | |

† Full range is -40°C to 125°C for Q suffix.

‡ Referenced to 2.5 V

NOTE 4: Typical values are based on the input offset voltage shift observed through 500 hours of operating life test at $T_A = 150^\circ\text{C}$ extrapolated to $T_A = 25^\circ\text{C}$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.



TLC226x-Q1, TLC226xA-Q1
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OPERATIONAL AMPLIFIERS

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TLC2264 operating characteristics at specified free-air temperature, $V_{DD} = 5\text{ V}$

| PARAMETER | TEST CONDITIONS | T_A † | TLC2264-Q1 | | | TLC2264A-Q1 | | | UNIT | |
|-------------|---|---|------------|------|-----|-------------|------|------------------|------------------------|---------------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | | |
| SR | Slew rate at unity gain $V_O = 0.5\text{ V to }3.5\text{ V}, R_L = 50\text{ k}\Omega^\ddagger, C_L = 100\text{ pF}^\ddagger$ | 25°C | 0.35 | 0.55 | | 0.35 | 0.55 | V/ μs | | |
| | | Full range | 0.25 | | | 0.25 | | | | |
| V_n | Equivalent input noise voltage | f = 10 Hz | 40 | | | 40 | | | nV/ $\sqrt{\text{Hz}}$ | |
| | | f = 1 kHz | 12 | | | 12 | | | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 1 Hz | 0.7 | | | 0.7 | | | μV | |
| | | f = 0.1 Hz to 10 Hz | 1.3 | | | 1.3 | | | | |
| I_n | Equivalent input noise current | 25°C | 0.6 | | | 0.6 | | | fA/ $\sqrt{\text{Hz}}$ | |
| THD + N | Total harmonic distortion plus noise $V_O = 0.5\text{ V to }2.5\text{ V}, f = 20\text{ kHz}, R_L = 50\text{ k}\Omega^\ddagger$ | $A_V = 1$ | 0.017% | | | 0.017% | | | | |
| | | $A_V = 10$ | 0.03% | | | 0.03% | | | | |
| | Gain-bandwidth product | f = 50 kHz, $C_L = 100\text{ pF}^\ddagger$ | 0.71 | | | 0.71 | | | MHz | |
| BOM | Maximum output-swing bandwidth | $V_{O(PP)} = 2\text{ V}, R_L = 50\text{ k}\Omega^\ddagger$ | 185 | | | 185 | | | kHz | |
| t_s | Settling time | $A_V = -1, \text{ Step} = 0.5\text{ V to }2.5\text{ V}, R_L = 50\text{ k}\Omega^\ddagger, C_L = 100\text{ pF}^\ddagger$ | To 0.1% | 6.4 | | | 6.4 | | | μs |
| | | | To 0.01% | 14.1 | | | 14.1 | | | |
| ϕ_m | Phase margin at unity gain | $R_L = 50\text{ k}\Omega^\ddagger, C_L = 100\text{ pF}^\ddagger$ | 56° | | | 56° | | | | |
| | Gain margin | | 11 | | | 11 | | | | dB |

† Full range is -40°C to 125°C for Q suffix.

‡ Referenced to 2.5 V



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TLC2264 electrical characteristics at specified free-air temperature, $V_{DD\pm} = \pm 5\text{ V}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T _A † | TLC2264-Q1 | | | TLC2264A-Q1 | | | UNIT | |
|--|--|------------------------|------------|------------------|-----------|-------------|------------------|-------|-------|--|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | | |
| V _{IO} Input offset voltage | V _{IC} = 0, V _O = 0, R _S = 50 Ω | 25°C | 300 | 2500 | | 300 | 950 | μV | | |
| | | Full range | | | 3000 | | 1500 | | | |
| αV _{IO} Temperature coefficient of input offset voltage | | Full range | | 2 | | | 2 | μV/°C | | |
| Input offset voltage long-term drift (see Note 4) | | 25°C | | 0.003 | | | 0.003 | μV/mo | | |
| I _{IO} Input offset current | | 25°C | | 0.5 | | | 0.5 | pA | | |
| | | 125°C | | | 800 | | 800 | | | |
| I _B Input bias current | | 25°C | | 1 | | | 1 | pA | | |
| | | 125°C | | | 800 | | 800 | | | |
| V _{ICR} Common-mode input voltage range | R _S = 50 Ω, V _{IO} ≤ 5 mV | 25°C | -5 to 4 | -5.3 to 4.2 | | -5 to 4 | -5.3 to 4.2 | V | | |
| | | Full range | | | -5 to 3.5 | | -5 to 3.5 | | | |
| V _{OM+} Maximum positive peak output voltage | I _O = -20 μA | 25°C | | 4.99 | | | 4.99 | V | | |
| | | 25°C | | 4.85 | 4.94 | | 4.85 | | 4.94 | |
| | | Full range | | 4.82 | | | 4.82 | | | |
| | | 25°C | | 4.7 | 4.85 | | 4.7 | | 4.85 | |
| V _{OM-} Maximum negative peak output voltage | I _O = -400 μA | 25°C | | -4.99 | | | -4.99 | V | | |
| | | 25°C | | -4.85 | -4.91 | | -4.85 | | -4.91 | |
| | | Full range | | -4.85 | | | -4.85 | | | |
| | | 25°C | | -4 | -4.3 | | -4 | | -4.3 | |
| A _{VD} Large-signal differential voltage amplification | V _O = ±4 V | R _L = 50 kΩ | 25°C | 80 | 200 | | 80 | 200 | V/mV | |
| | | | Full range | | 50 | | | 50 | | |
| | | R _L = 1 MΩ | 25°C | | 1000 | | | 1000 | | |
| | | | Full range | | | | | | | |
| r _{i(d)} Differential input resistance | | 25°C | | 10 ¹² | | | 10 ¹² | Ω | | |
| r _{i(c)} Common-mode input resistance | | 25°C | | 10 ¹² | | | 10 ¹² | Ω | | |
| c _{i(c)} Common-mode input capacitance | f = 10 kHz, N package | 25°C | | 8 | | | 8 | pF | | |
| z _O Closed-loop output impedance | f = 100 kHz, A _V = 10 | 25°C | | 220 | | | 220 | Ω | | |
| CMRR Common-mode rejection ratio | V _{IC} = -5 V to 2.7 V, V _O = 0, R _S = 50 Ω | 25°C | 75 | 88 | | 75 | 88 | dB | | |
| | | Full range | | 75 | | | 75 | | | |
| k _{SVR} Supply-voltage rejection ratio (ΔV _{DD±} /ΔV _{IO}) | V _{DD±} = ±2.2 V to ±8 V, V _{IC} = V _{DD} /2, No load | 25°C | 80 | 95 | | 80 | 95 | dB | | |
| | | Full range | | 80 | | | 80 | | | |
| I _{DD} Supply current (four amplifiers) | V _O = 0, No load | 25°C | | 0.85 | 1 | | 0.85 | 1 | mA | |
| | | Full range | | | 1 | | | 1 | | |

† Full range is -40°C to 125°C for Q suffix.

NOTE 4: Typical values are based on the input offset voltage shift observed through 500 hours of operating life test at T_A = 150°C extrapolated to T_A = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.



TLC226x-Q1, TLC226xA-Q1
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TLC2264 operating characteristics at specified free-air temperature, $V_{DD\pm} = \pm 5\text{ V}$

| PARAMETER | TEST CONDITIONS | T_A † | TLC2264-Q1 | | | TLC2264A-Q1 | | | UNIT |
|-------------|---|---|------------|------|--------|-------------|--------|------------------------|------------------------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR | Slew rate at unity gain $V_O = \pm 2\text{ V}$, $C_L = 100\text{ pF}$ $R_L = 50\text{ k}\Omega$ | 25°C | 0.35 | 0.55 | | 0.35 | 0.55 | | V/ μ s |
| | | Full range | 0.25 | | | 0.25 | | | |
| V_n | Equivalent input noise voltage | f = 10 Hz | | 43 | | | 43 | | nV/ $\sqrt{\text{Hz}}$ |
| | | f = 1 kHz | 25°C | | 12 | | 12 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 1 Hz | 25°C | | 0.8 | | 0.8 | | μ V |
| | | f = 0.1 Hz to 10 Hz | 25°C | | 1.3 | | 1.3 | | |
| I_n | Equivalent input noise current | 25°C | | 0.6 | | 0.6 | | fA/ $\sqrt{\text{Hz}}$ | |
| THD + N | Total harmonic distortion plus noise $V_O = \pm 2.3\text{ V}$, $R_L = 50\text{ k}\Omega$, f = 20 kHz | $A_V = 1$ | 25°C | | 0.014% | | 0.014% | | |
| | | $A_V = 10$ | | | 0.024% | | 0.024% | | |
| | Gain-bandwidth product | f = 10 kHz, $C_L = 100\text{ pF}$ $R_L = 50\text{ k}\Omega$ | 25°C | | 0.73 | | 0.73 | | MHz |
| BOM | Maximum output-swing bandwidth | $V_{O(PP)} = 4.6\text{ V}$, $R_L = 50\text{ k}\Omega$ | 25°C | | 70 | | 70 | | kHz |
| t_s | Settling time | $A_V = -1$, Step = -2.3 V to 2.3 V, $R_L = 50\text{ k}\Omega$, $C_L = 100\text{ pF}$ | To 0.1% | 25°C | | 7.1 | | 7.1 | μ s |
| | | | To 0.01% | | | 16.5 | | 16.5 | |
| ϕ_m | Phase margin at unity gain | $R_L = 50\text{ k}\Omega$, $C_L = 100\text{ pF}$ | 25°C | | 57° | | 57° | | |
| | Gain margin | | 25°C | | 11 | | 11 | | dB |

† Full range is -40°C to 125°C for Q suffix.



TYPICAL CHARACTERISTICS

Table of Graphs

| | | | FIGURE |
|-----------------|---|--|------------------|
| V_{IO} | Input offset voltage | Distribution vs Common-mode input voltage | 2 – 5 6, 7 |
| α_{VIO} | Input offset voltage temperature coefficient | Distribution | 8 – 11 |
| I_{IB}/I_{IO} | Input bias and input offset currents | vs Free-air temperature | 12 |
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| V_{OH} | High-level output voltage | vs High-level output current | 15 |
| V_{OL} | Low-level output voltage | vs Low-level output current | 16, 17 |
| V_{OM+} | Maximum positive output voltage | vs Output current | 18 |
| V_{OM-} | Maximum negative output voltage | vs Output current | 19 |
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| | Differential gain | vs Load resistance | 25 |
| A_{VD} | Large-signal differential voltage amplification | vs Frequency vs Free-air temperature | 26, 27 28, 29 |
| z_o | Output impedance | vs Frequency | 30, 31 |
| $CMRR$ | Common-mode rejection ratio | vs Frequency vs Free-air temperature | 32 33 |
| k_{SVR} | Supply-voltage rejection ratio | vs Frequency vs Free-air temperature | 34, 35 36 |
| I_{DD} | Supply current | vs Supply voltage vs Free-air temperature | 37, 38 39, 40 |
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| | Voltage-follower small-signal pulse response | | 49, 50 |
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| | Noise voltage (referred to input) | Over a 10-second period | 53 |
| | Integrated noise voltage | vs Frequency | 54 |
| $THD + N$ | Total harmonic distortion plus noise | vs Frequency | 55 |
| | Gain-bandwidth product | vs Supply voltage vs Free-air temperature | 56 57 |
| ϕ_m | Phase margin | vs Frequency vs Load capacitance | 26, 27 58 |
| | Gain margin | vs Load capacitance | 59 |
| B_1 | Unity-gain bandwidth | vs Load capacitance | 60 |
| | Overestimation of phase margin | vs Load capacitance | 61 |

TYPICAL CHARACTERISTICS

**DISTRIBUTION OF TLC2262
 INPUT OFFSET VOLTAGE**

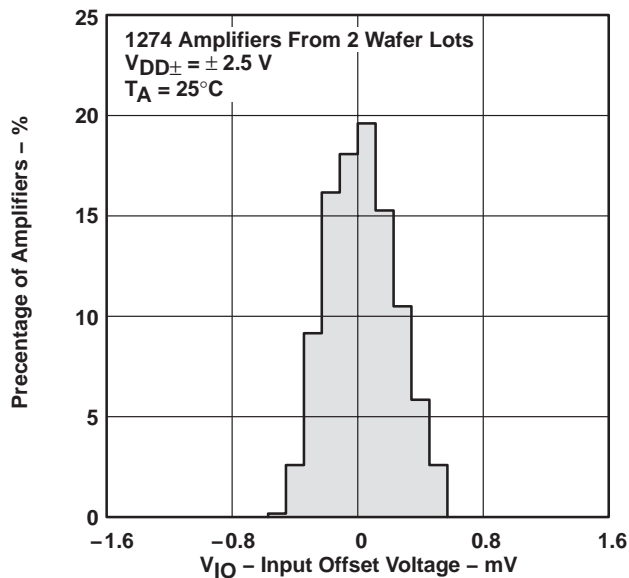


Figure 2

**DISTRIBUTION OF TLC2262
 INPUT OFFSET VOLTAGE**

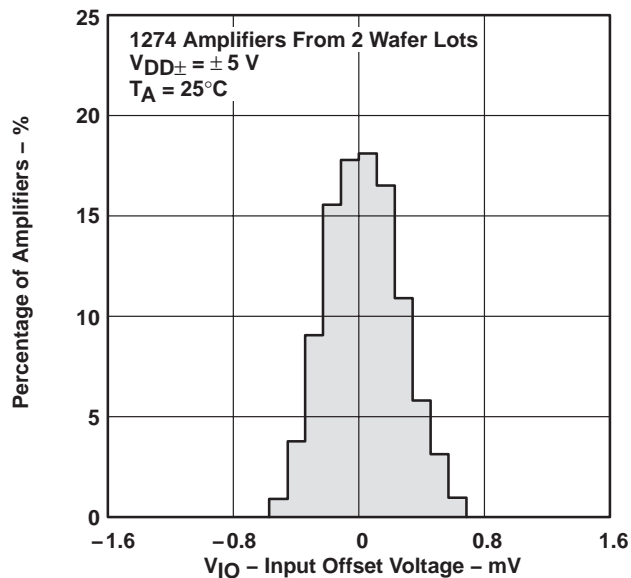


Figure 3

**DISTRIBUTION OF TLC2264
 INPUT OFFSET VOLTAGE**

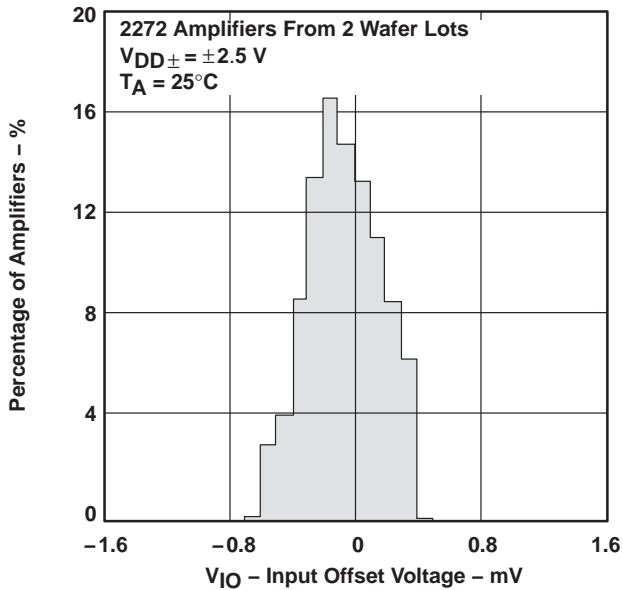


Figure 4

**DISTRIBUTION OF TLC2264
 INPUT OFFSET VOLTAGE**

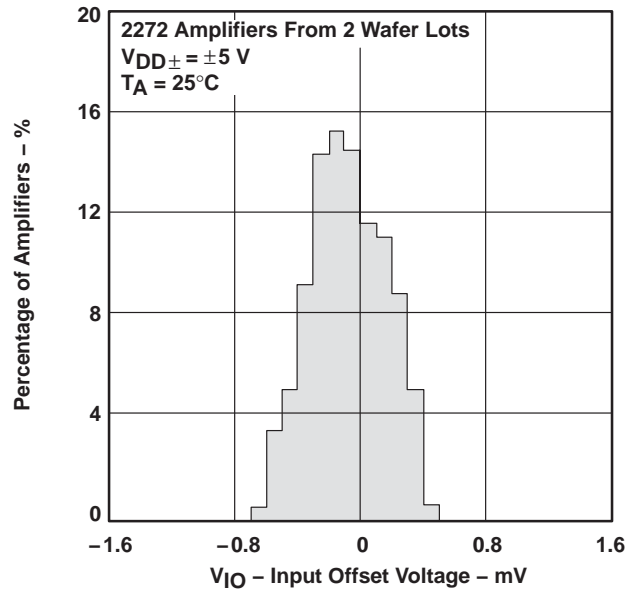


Figure 5

TYPICAL CHARACTERISTICS

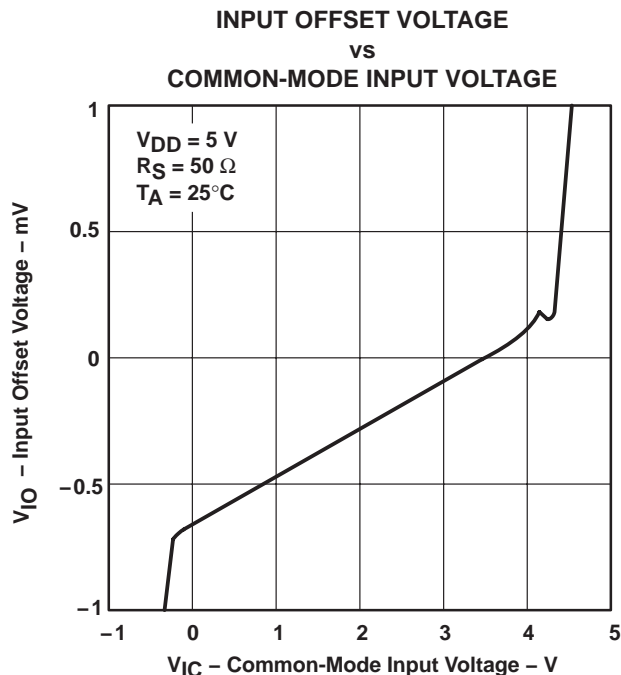


Figure 6

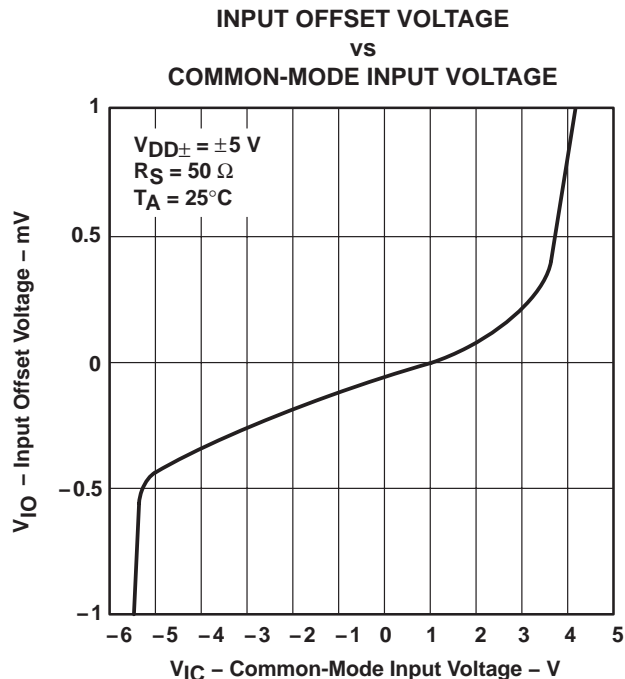


Figure 7

† For curves where $V_{DD} = 5\text{ V}$, all loads are referenced to 2.5 V.

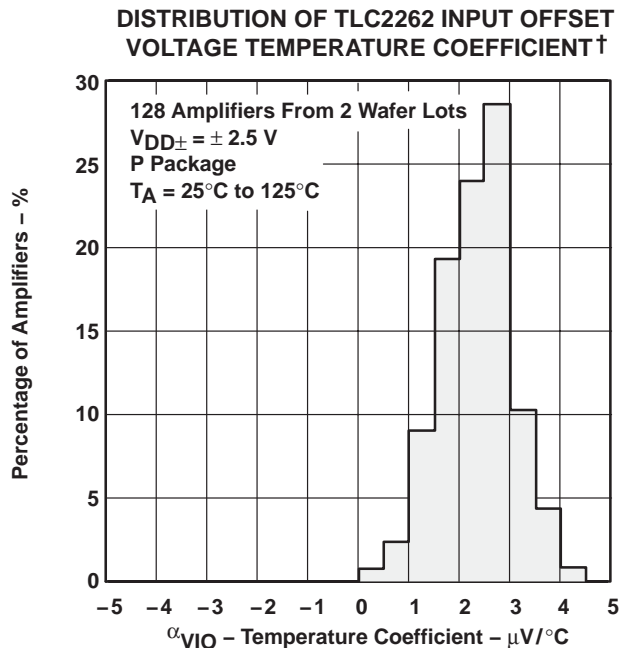


Figure 8

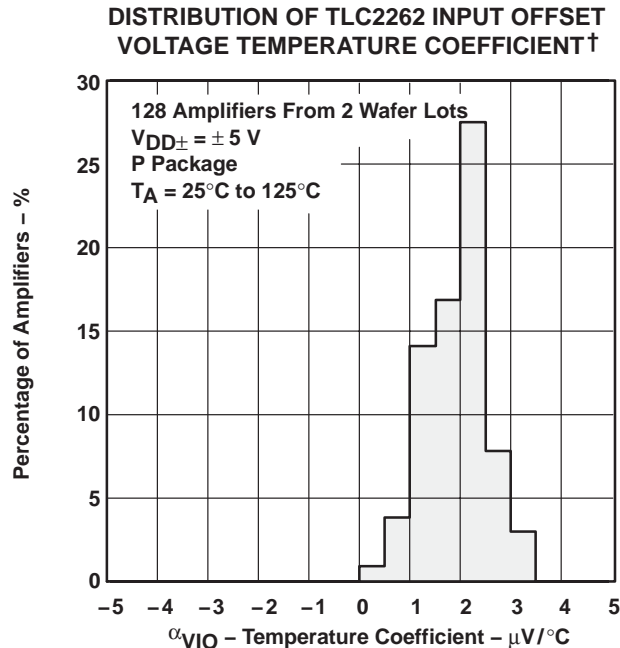


Figure 9

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS

DISTRIBUTION OF TLC2264 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT†

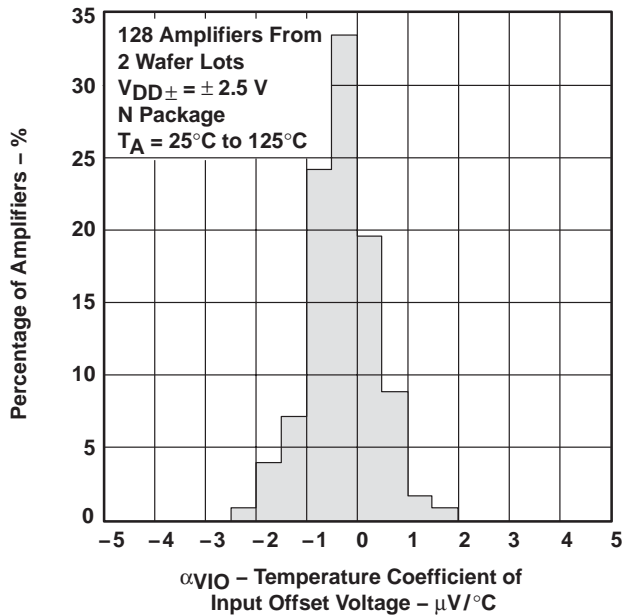


Figure 10

DISTRIBUTION OF TLC2264 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT†

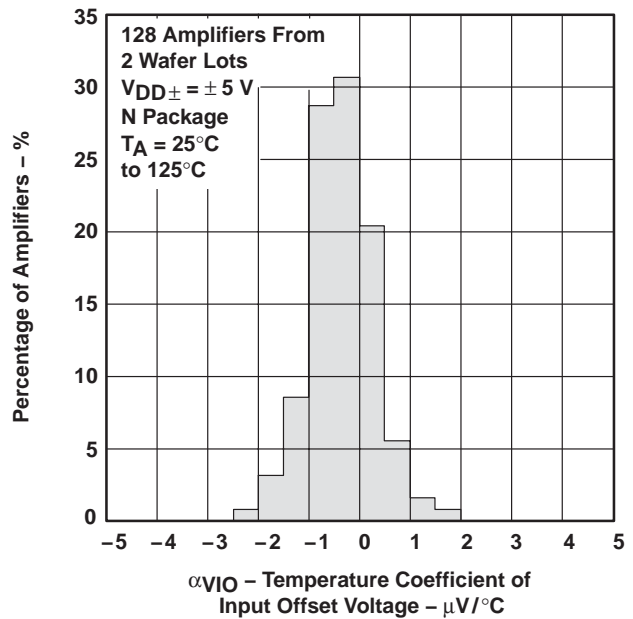


Figure 11

INPUT BIAS AND INPUT OFFSET CURRENTS†
vs
FREE-AIR TEMPERATURE

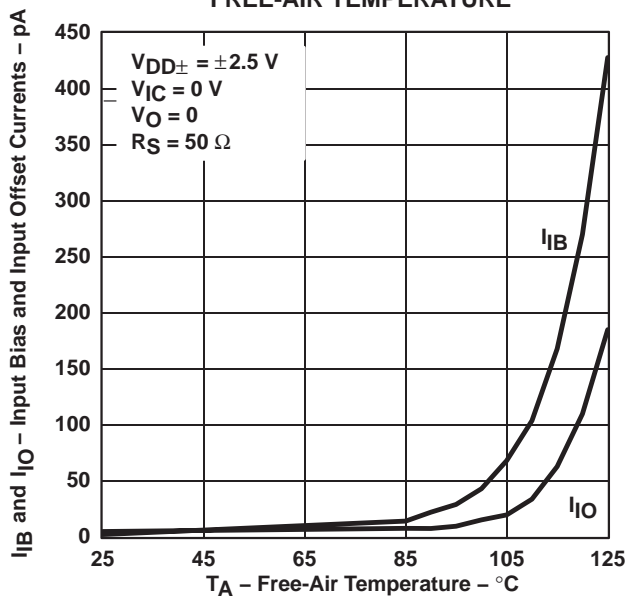


Figure 12

INPUT VOLTAGE RANGE
vs
SUPPLY VOLTAGE

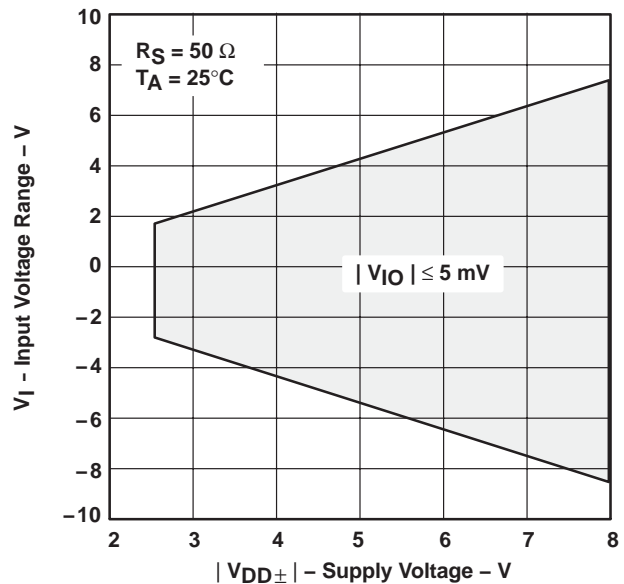


Figure 13

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS

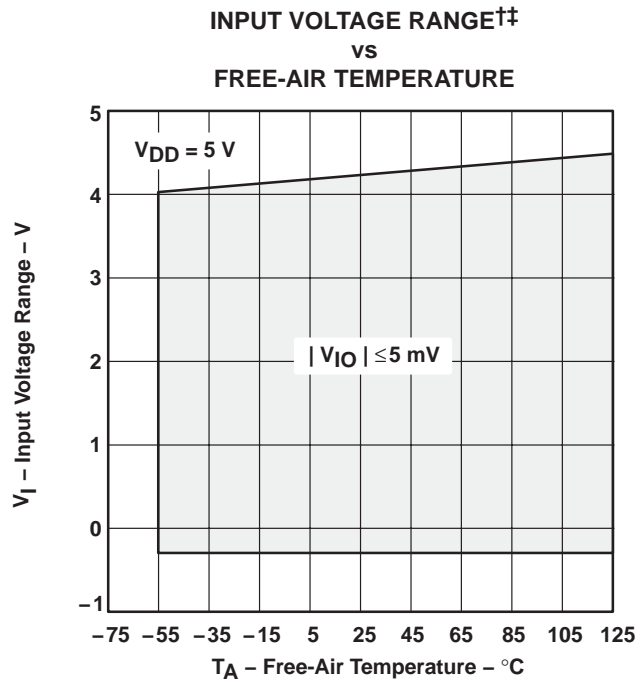


Figure 14

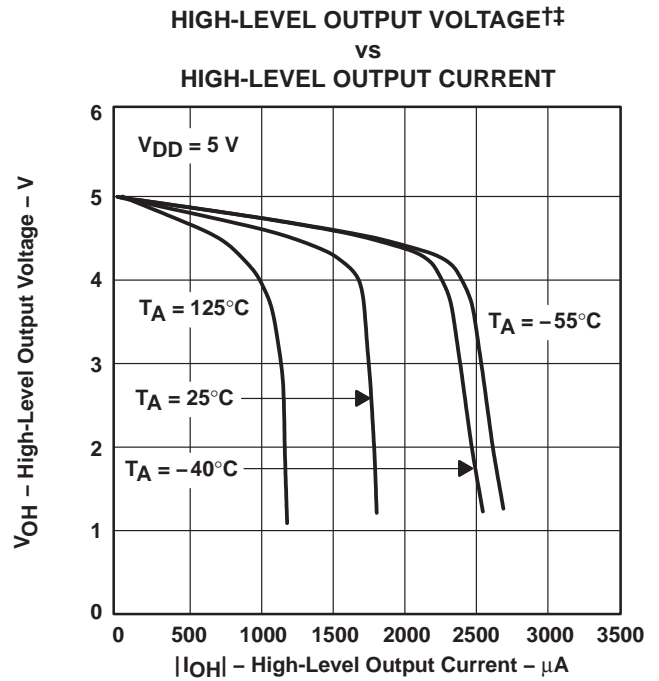


Figure 15

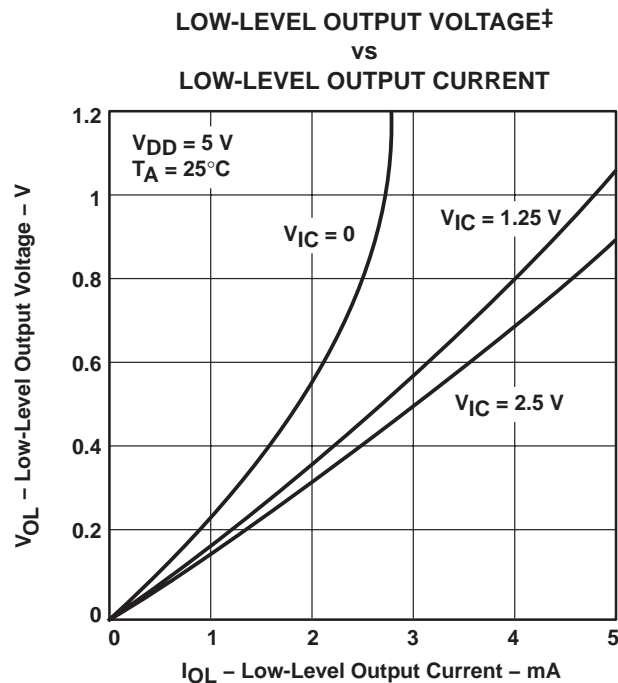


Figure 16

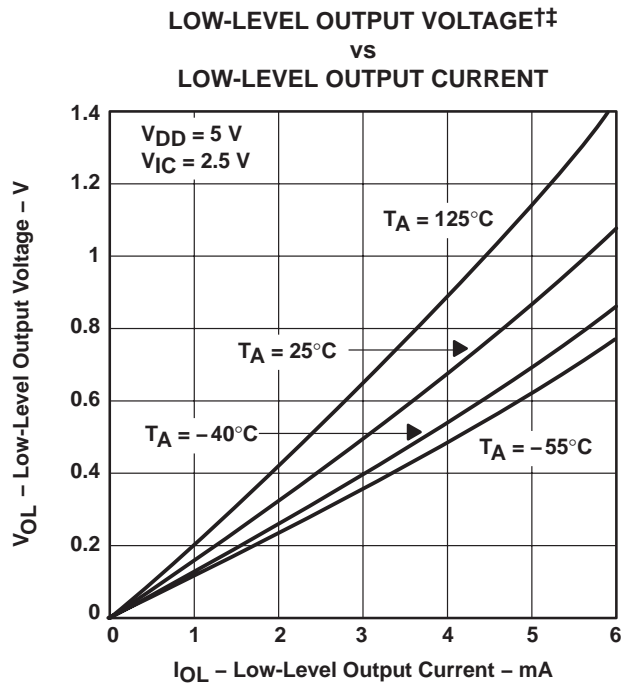


Figure 17

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

†† For curves where $V_{DD} = 5\text{ V}$, all loads are referenced to 2.5 V.

TYPICAL CHARACTERISTICS

**MAXIMUM POSITIVE OUTPUT VOLTAGE†
 vs
 OUTPUT CURRENT**

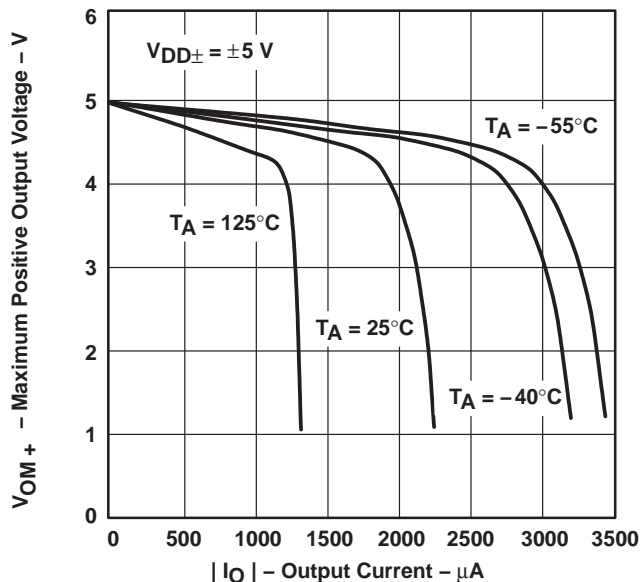


Figure 18

**MAXIMUM NEGATIVE OUTPUT VOLTAGE†
 vs
 OUTPUT CURRENT**

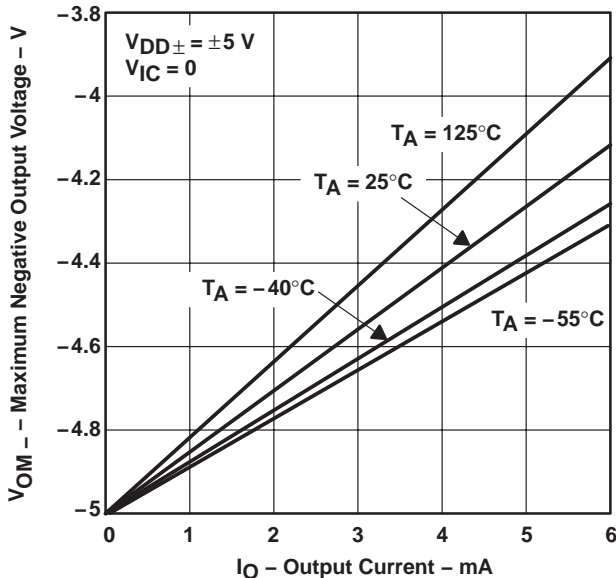


Figure 19

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

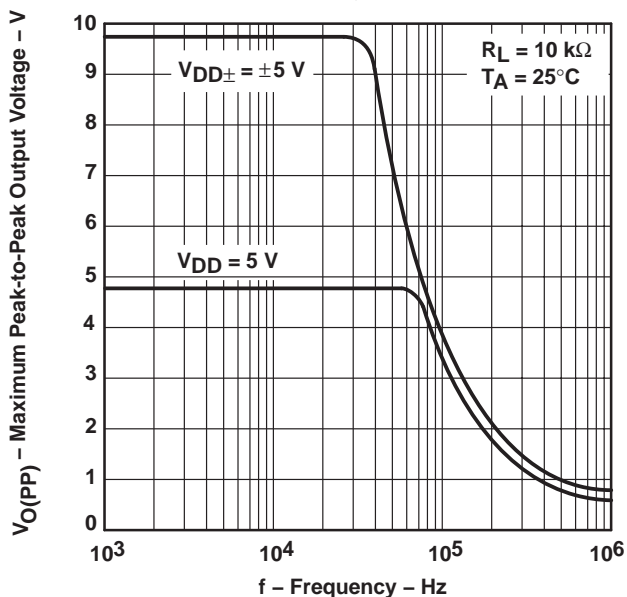


Figure 20

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

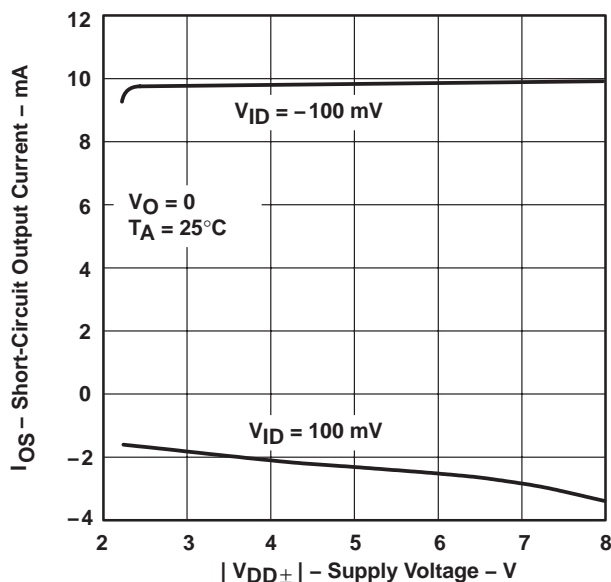


Figure 21

‡ For curves where $V_{DD} = 5\text{ V}$, all loads are referenced to 2.5 V.

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS

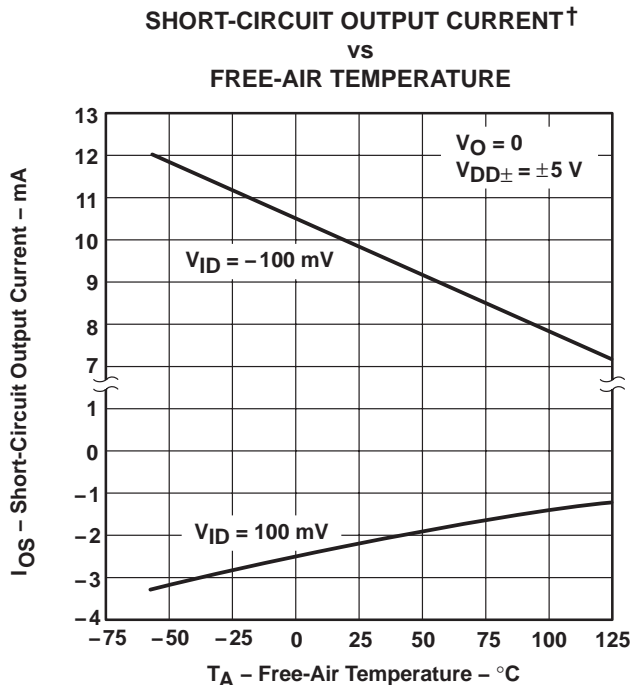


Figure 22

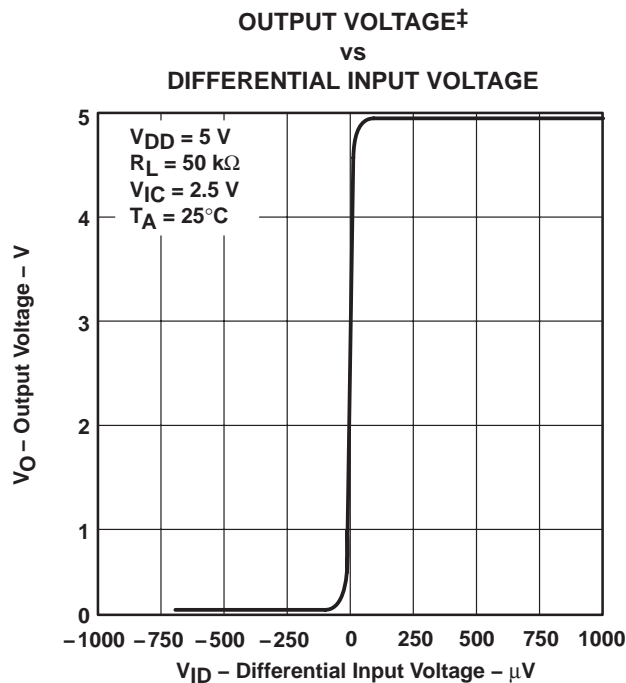


Figure 23

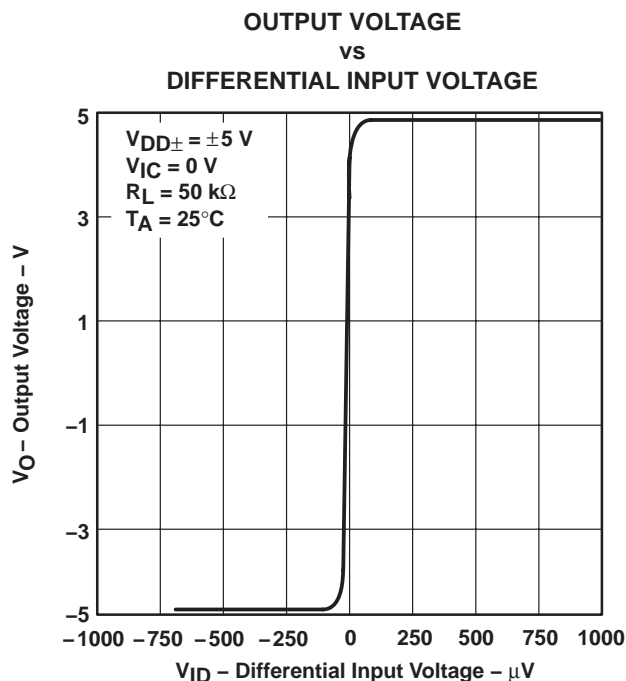


Figure 24

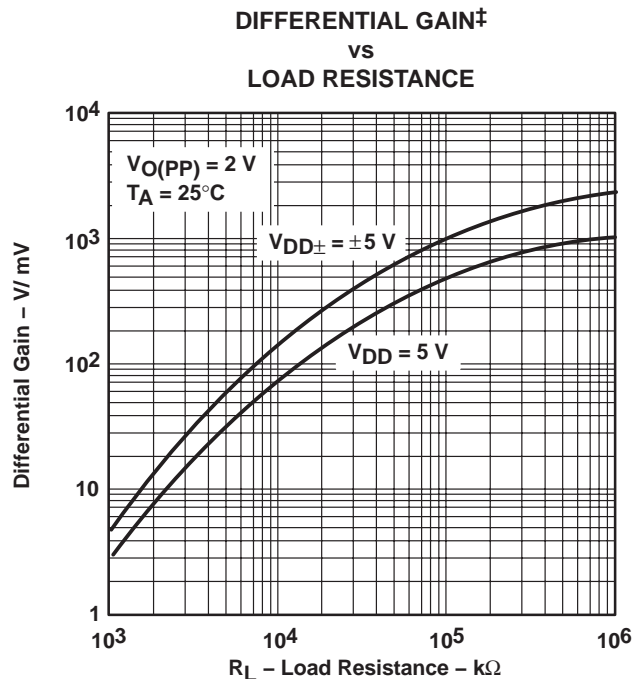


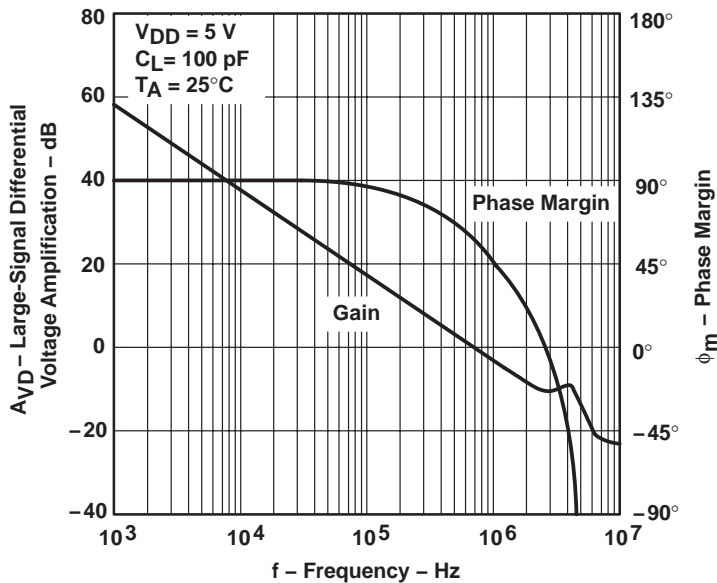
Figure 25

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

‡ For curves where $V_{DD} = 5 \text{ V}$, all loads are referenced to 2.5 V.

TYPICAL CHARACTERISTICS

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



† For curves where $V_{DD} = 5\text{ V}$, all loads are referenced to 2.5 V.

Figure 26

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

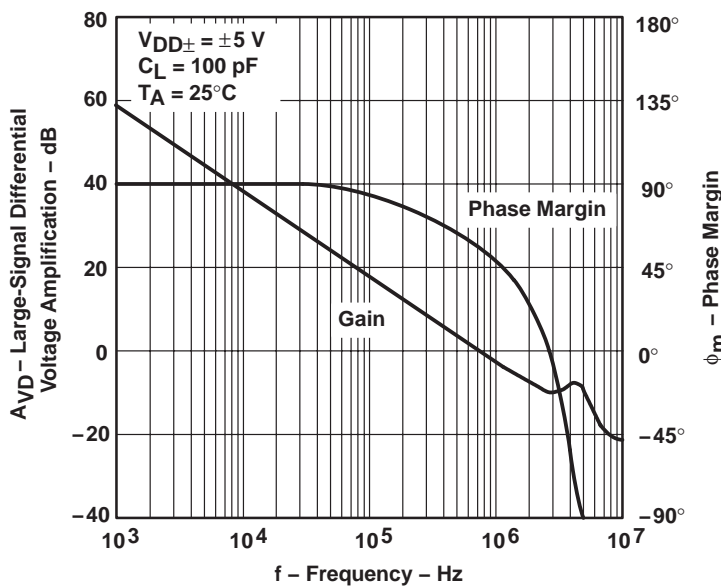


Figure 27

TYPICAL CHARACTERISTICS

LARGE-SIGNAL DIFFERENTIAL
 VOLTAGE AMPLIFICATION†‡
 vs
 FREE-AIR TEMPERATURE

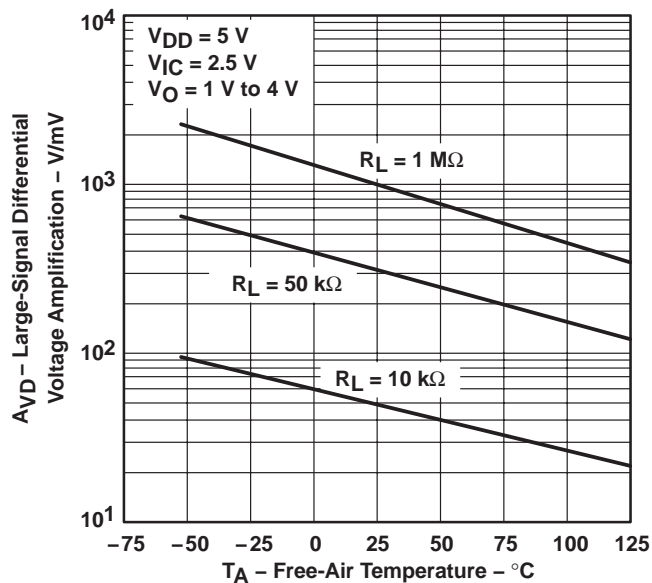


Figure 28

LARGE-SIGNAL DIFFERENTIAL
 VOLTAGE AMPLIFICATION†
 vs
 FREE-AIR TEMPERATURE

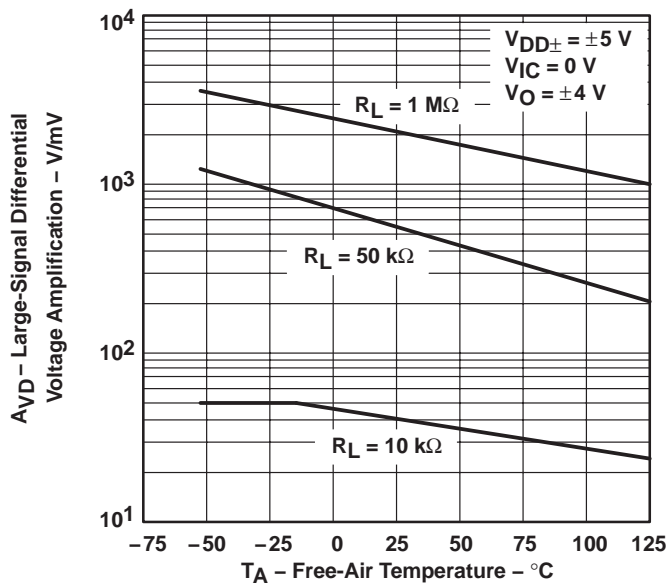


Figure 29

OUTPUT IMPEDANCE‡
 vs
 FREQUENCY

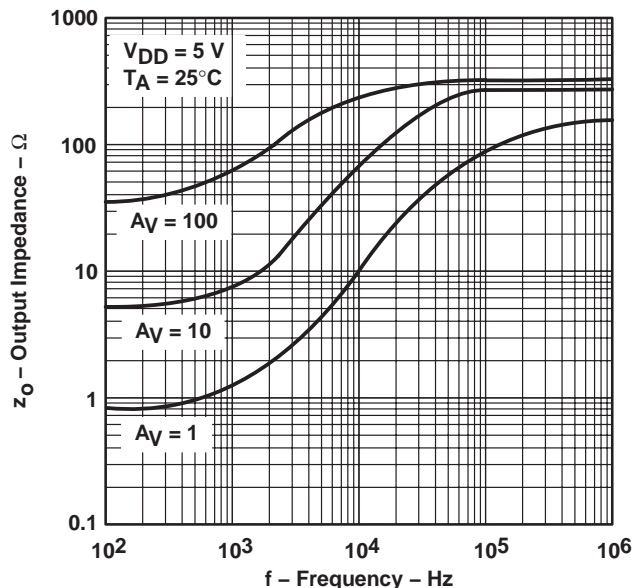


Figure 30

OUTPUT IMPEDANCE
 vs
 FREQUENCY

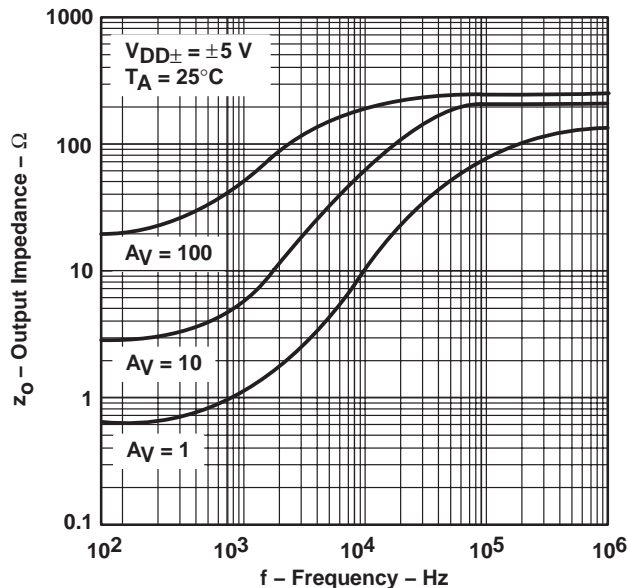


Figure 31

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

‡ For curves where $V_{DD} = 5\text{ V}$, all loads are referenced to 2.5 V.

TYPICAL CHARACTERISTICS

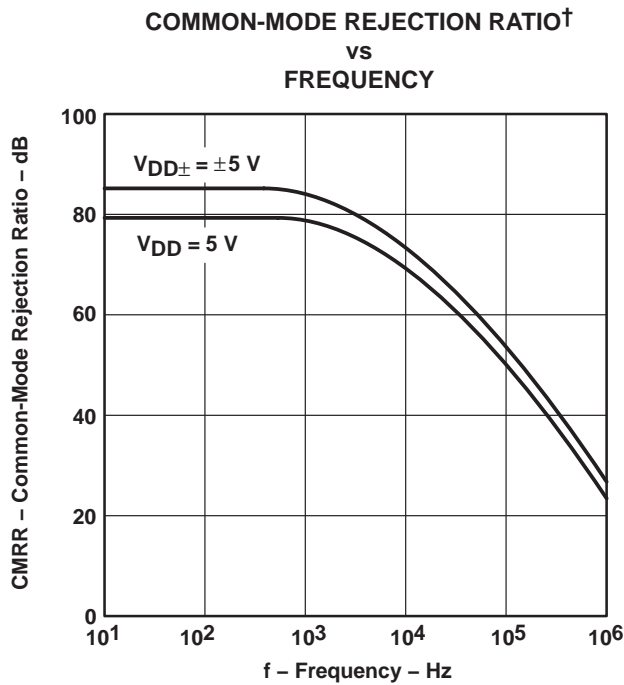


Figure 32

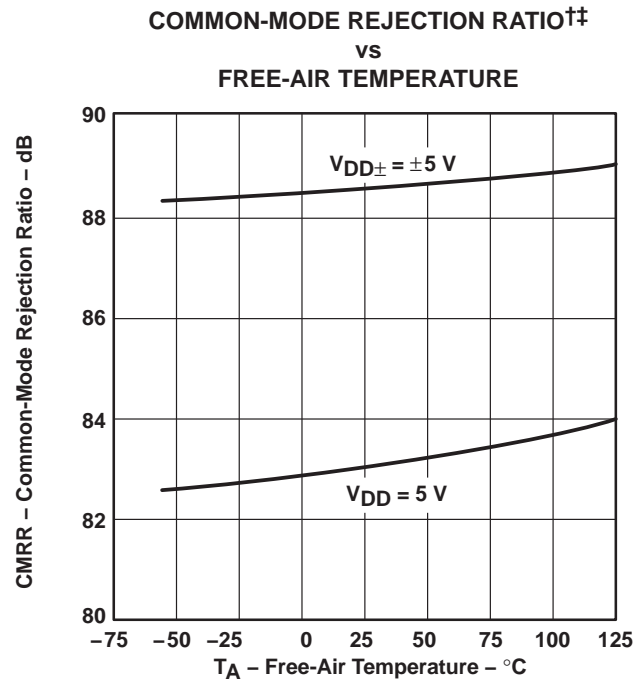


Figure 33

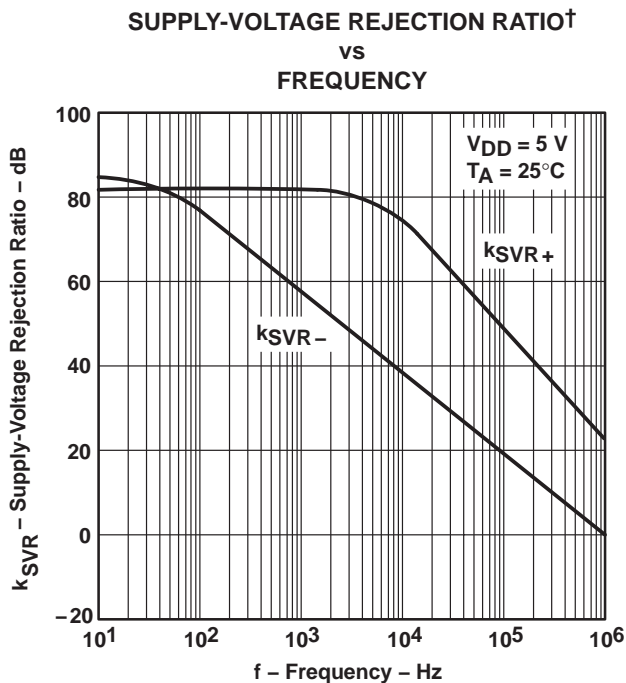


Figure 34

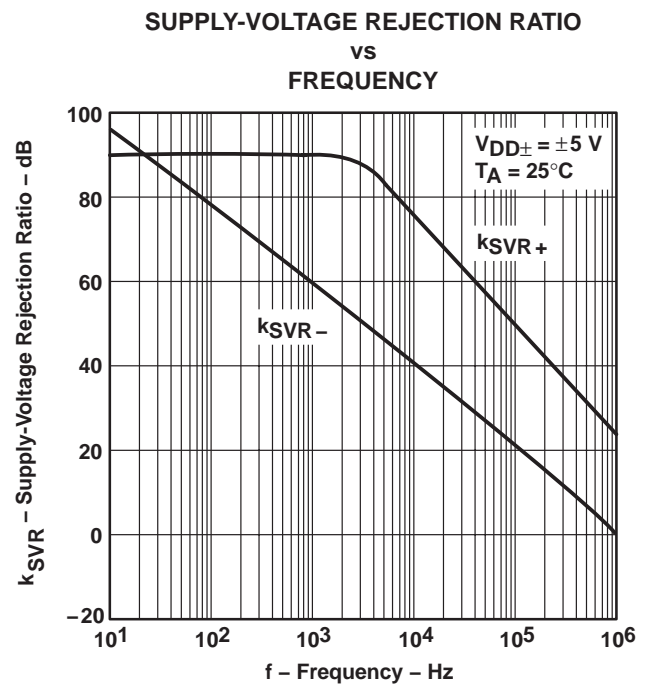
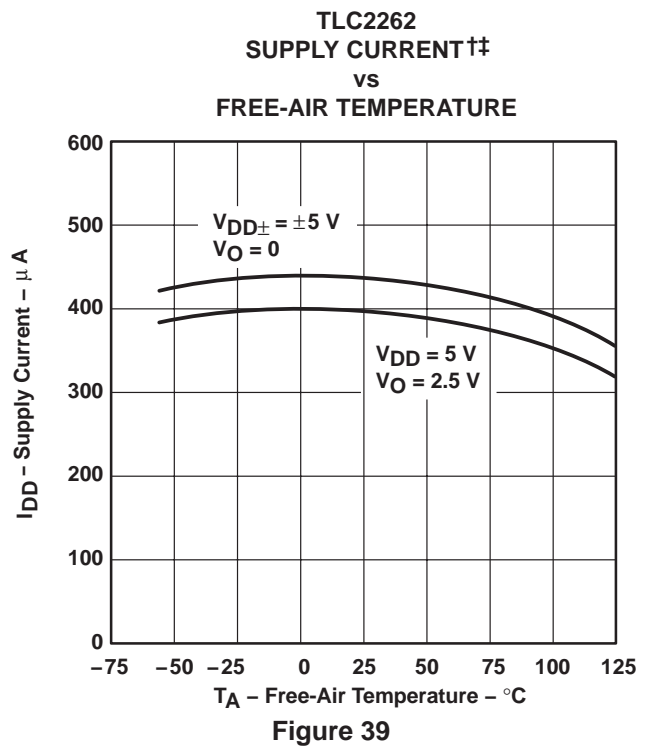
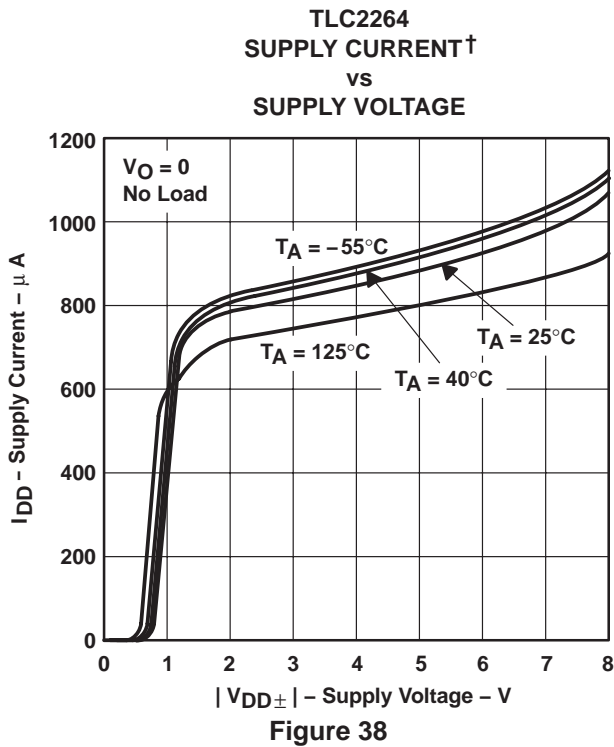
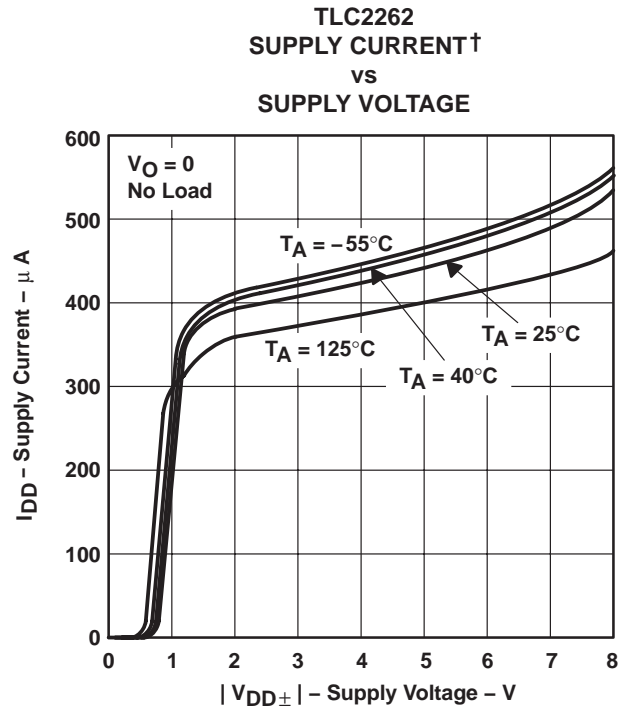
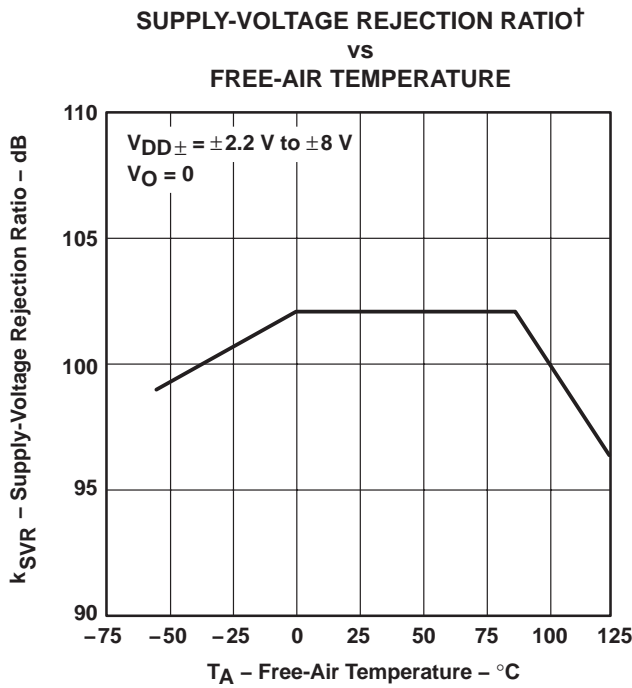


Figure 35

† For curves where $V_{DD} = 5\text{ V}$, all loads are referenced to 2.5 V.

‡ Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS



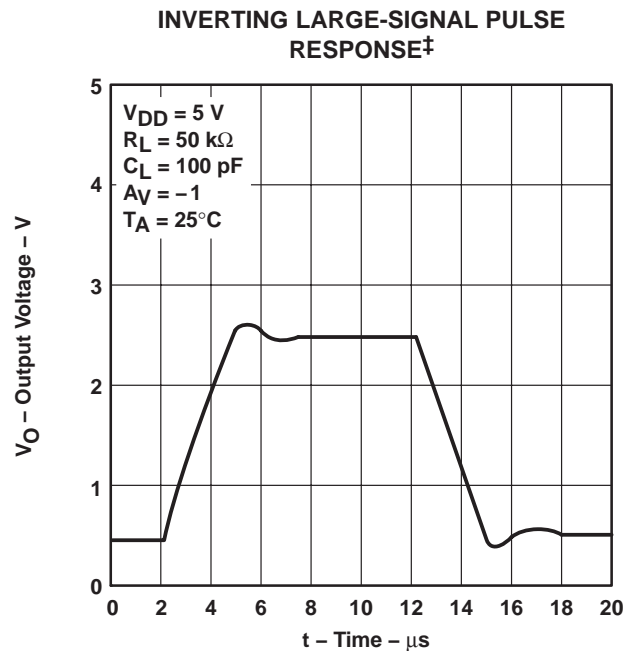
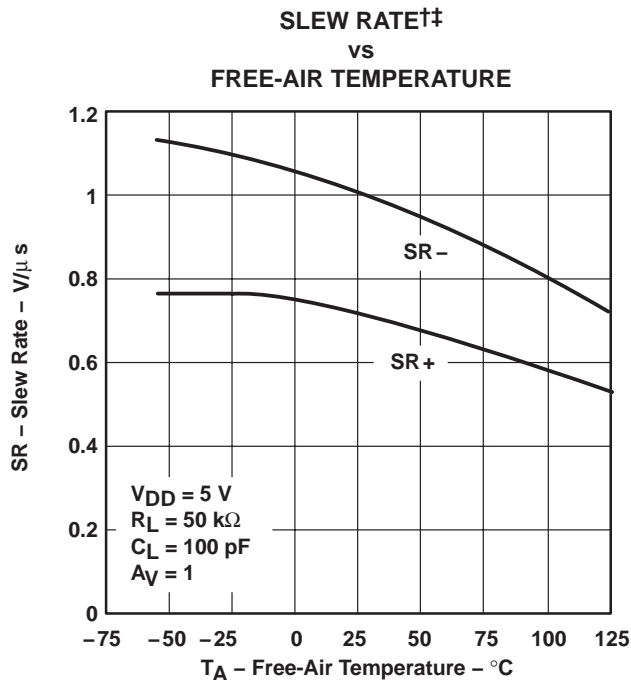
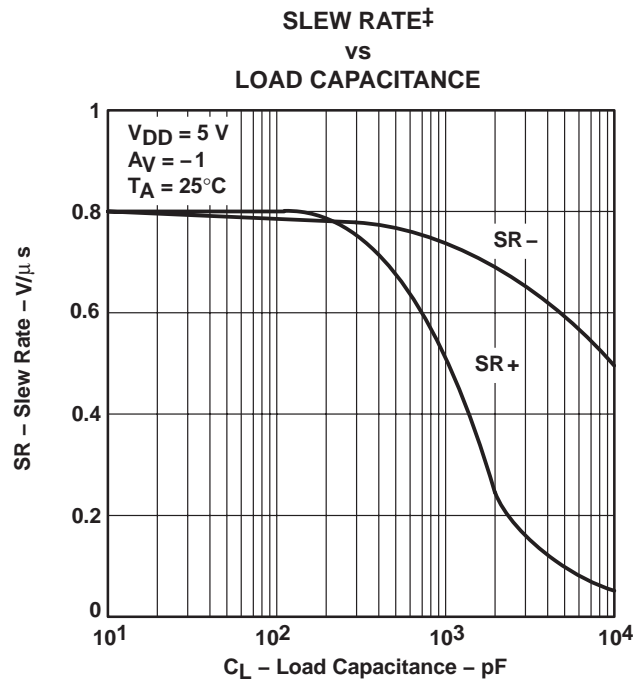
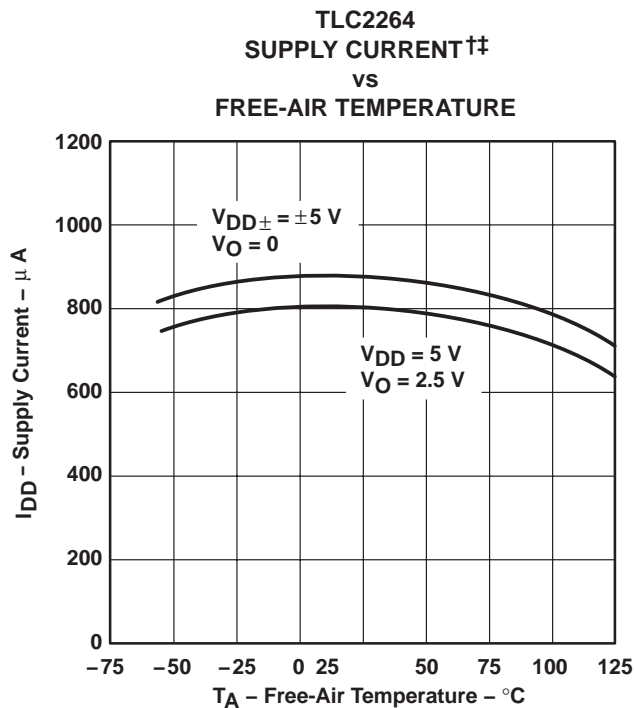
† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

‡ For curves where $V_{DD} = 5\text{ V}$, all loads are referenced to 2.5 V.

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TYPICAL CHARACTERISTICS



† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

‡ For curves where $V_{DD} = 5\text{ V}$, all loads are referenced to 2.5 V.

TYPICAL CHARACTERISTICS

INVERTING LARGE-SIGNAL PULSE RESPONSE

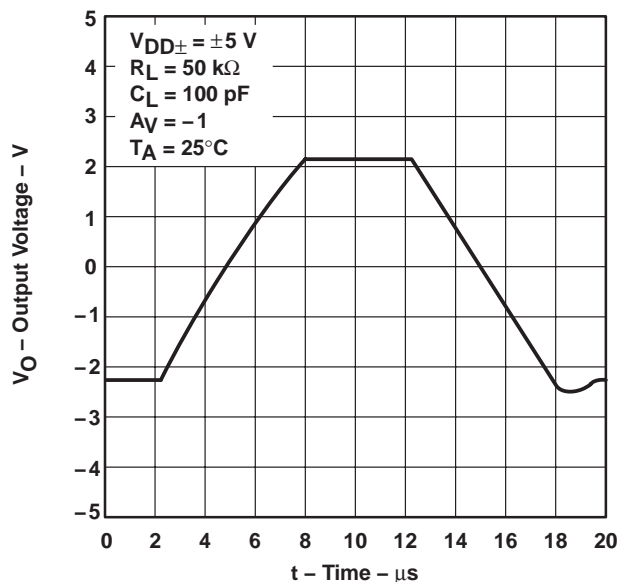


Figure 44

VOLTAGE-FOLLOWER LARGE-SIGNAL PULSE RESPONSE†

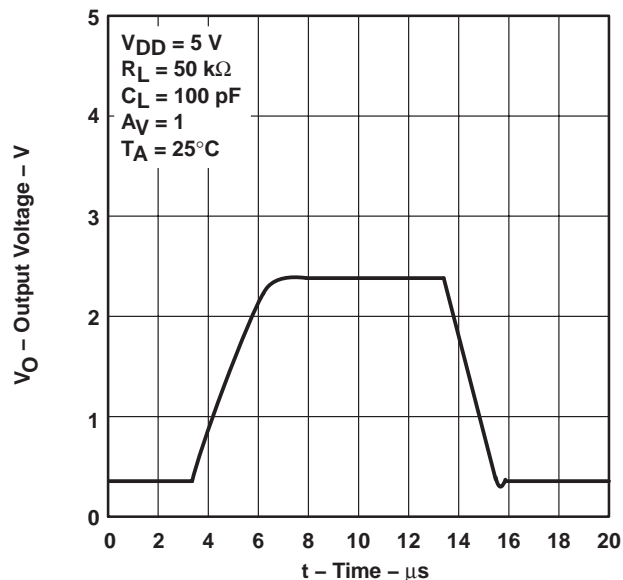


Figure 45

VOLTAGE-FOLLOWER LARGE-SIGNAL PULSE RESPONSE

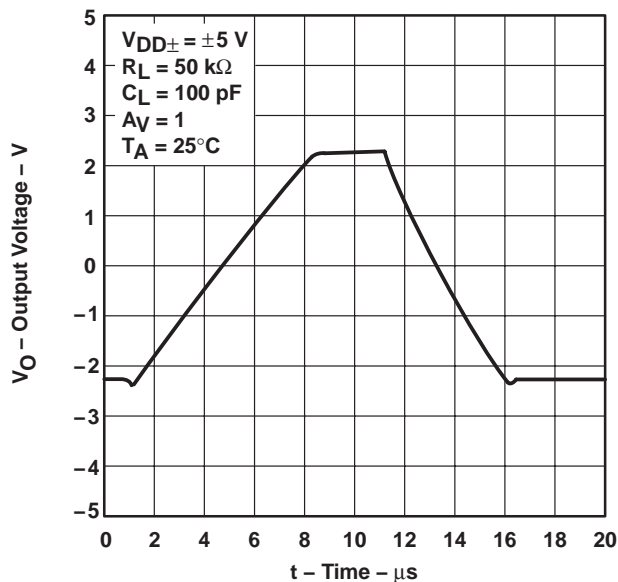


Figure 46

INVERTING SMALL-SIGNAL PULSE RESPONSE†

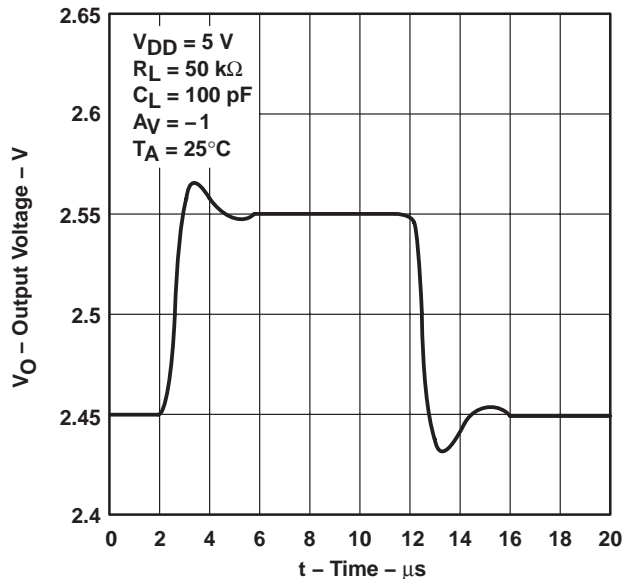


Figure 47

† For curves where $V_{DD} = 5\text{ V}$, all loads are referenced to 2.5 V.

TYPICAL CHARACTERISTICS

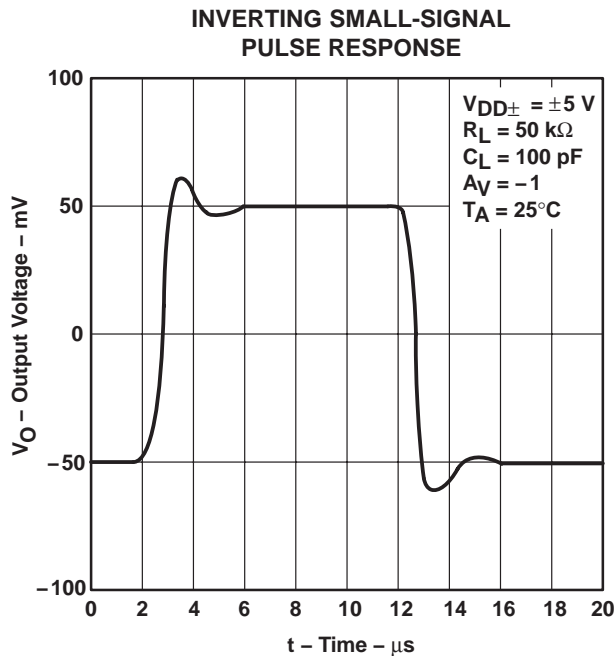


Figure 48

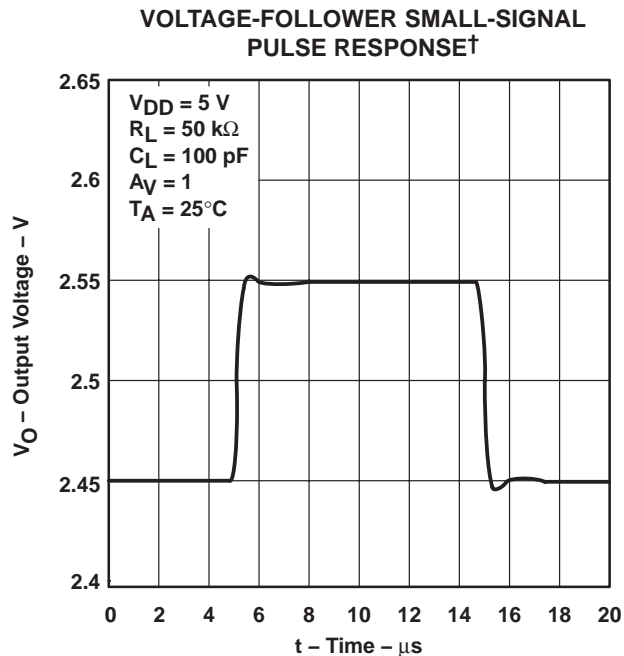


Figure 49

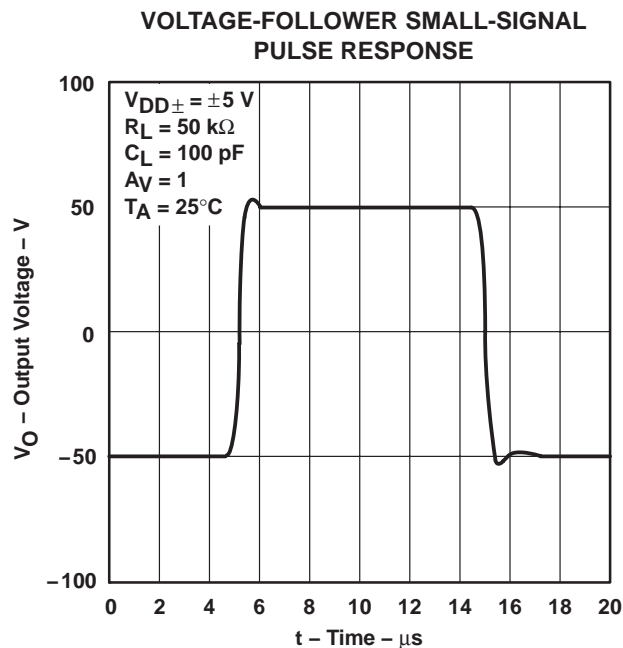


Figure 50

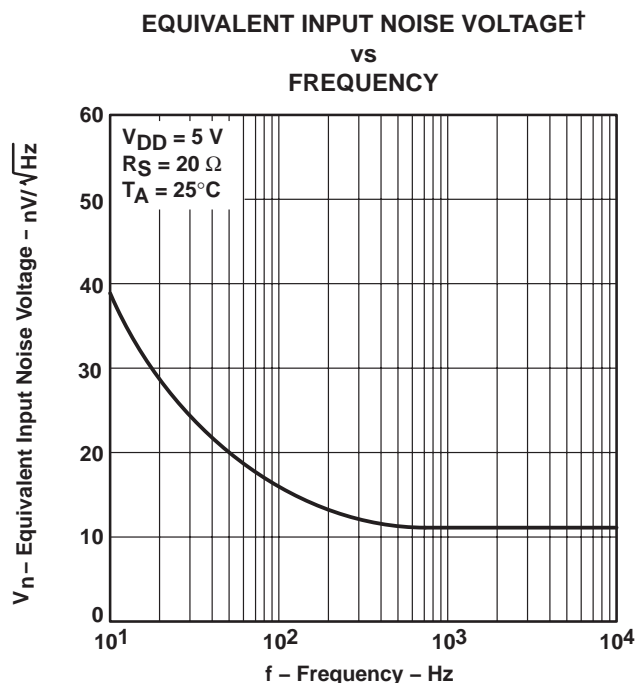


Figure 51

† For curves where $V_{DD} = 5\text{ V}$, all loads are referenced to 2.5 V.

TYPICAL CHARACTERISTICS

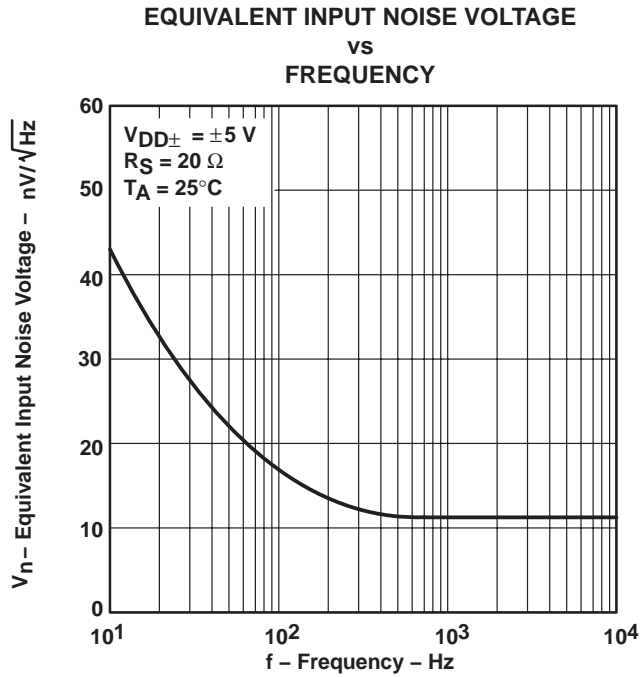


Figure 52

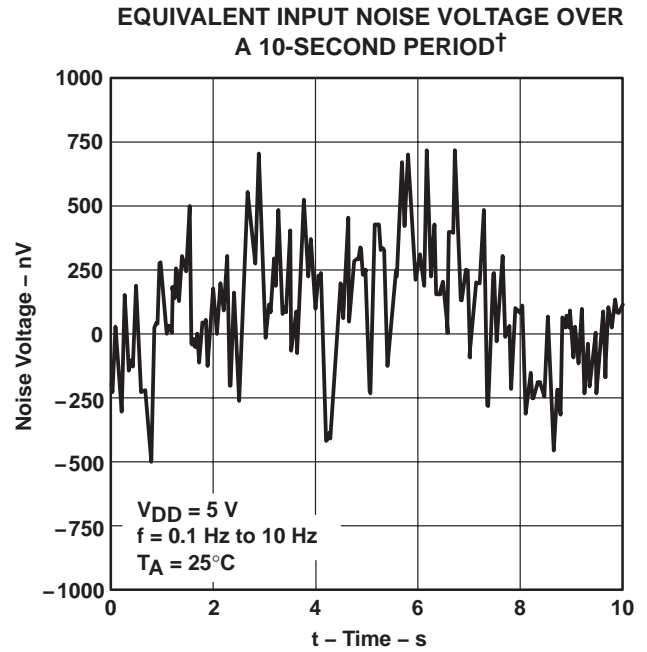


Figure 53

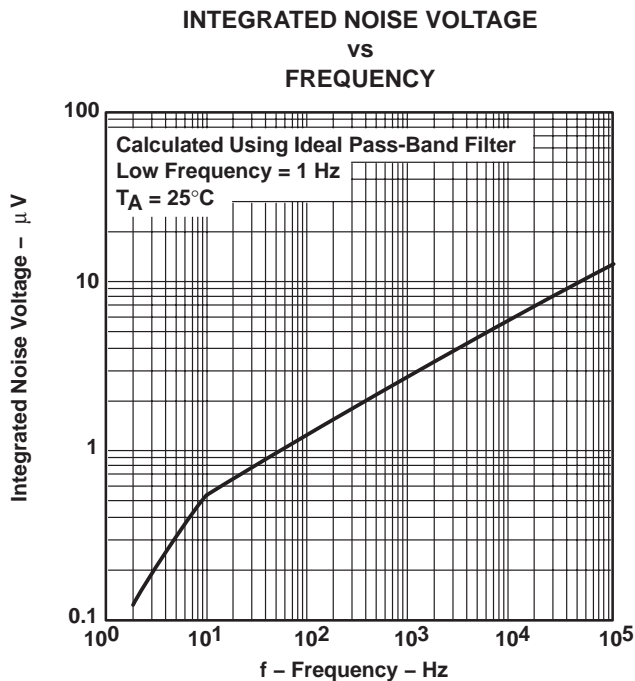


Figure 54

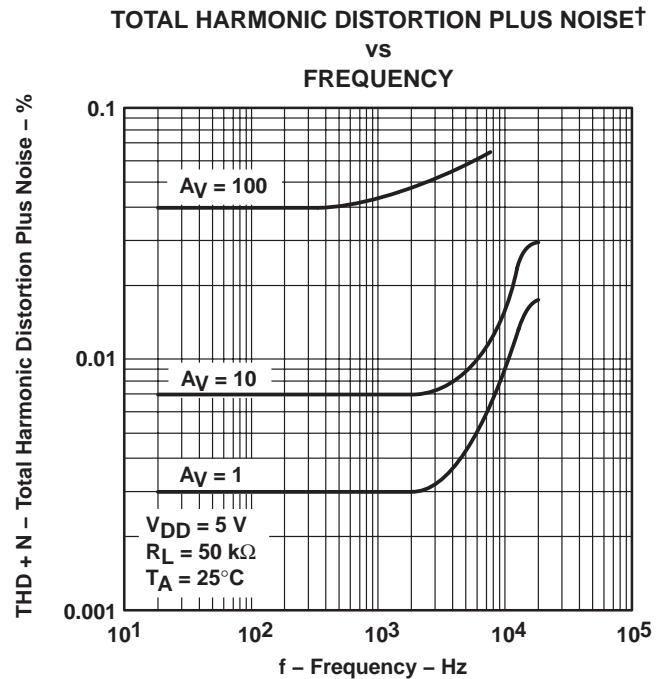


Figure 55

† For curves where $V_{DD} = 5 V$, all loads are referenced to 2.5 V.

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TYPICAL CHARACTERISTICS

GAIN-BANDWIDTH PRODUCT
vs
SUPPLY VOLTAGE

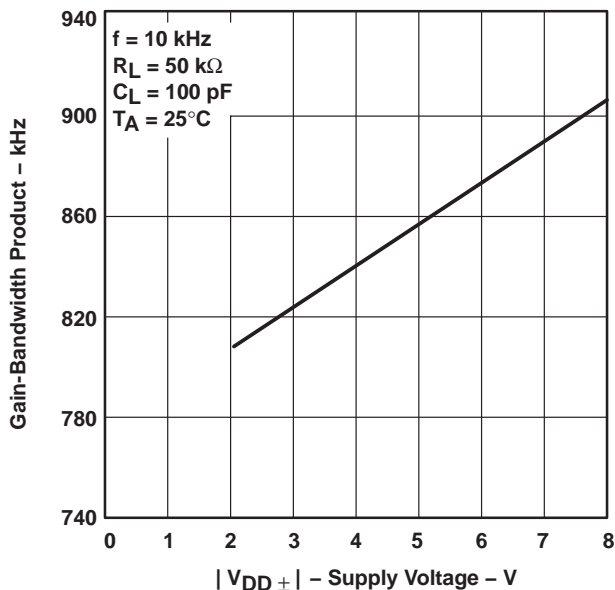


Figure 56

GAIN-BANDWIDTH PRODUCT††
vs
FREE-AIR TEMPERATURE

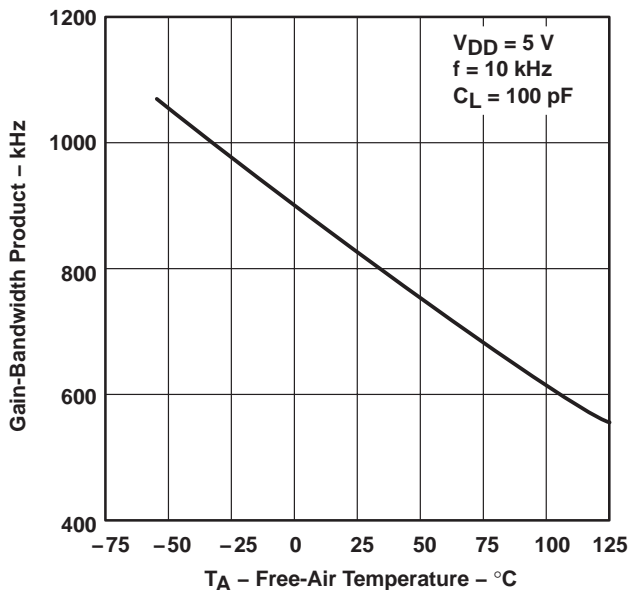


Figure 57

PHASE MARGIN
vs
LOAD CAPACITANCE

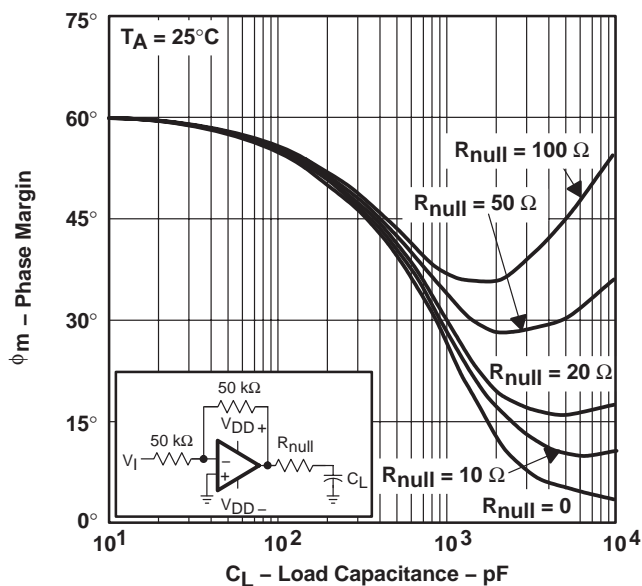


Figure 58

GAIN MARGIN
vs
LOAD CAPACITANCE

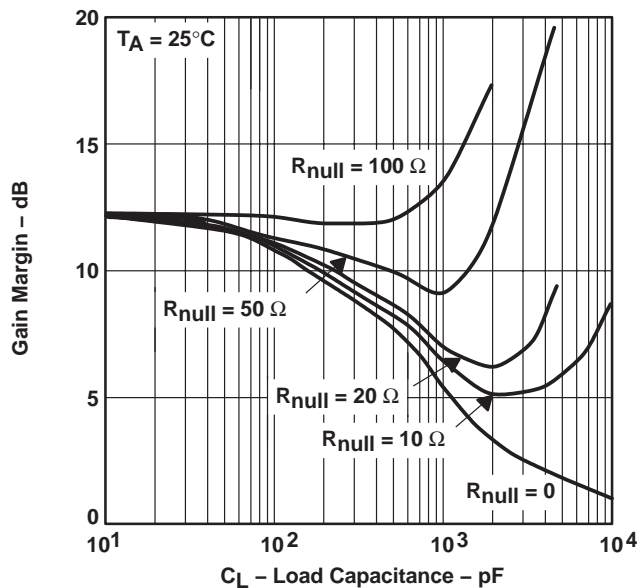


Figure 59

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

†† For curves where $V_{DD} = 5\text{ V}$, all loads are referenced to 2.5 V.

TYPICAL CHARACTERISTICS

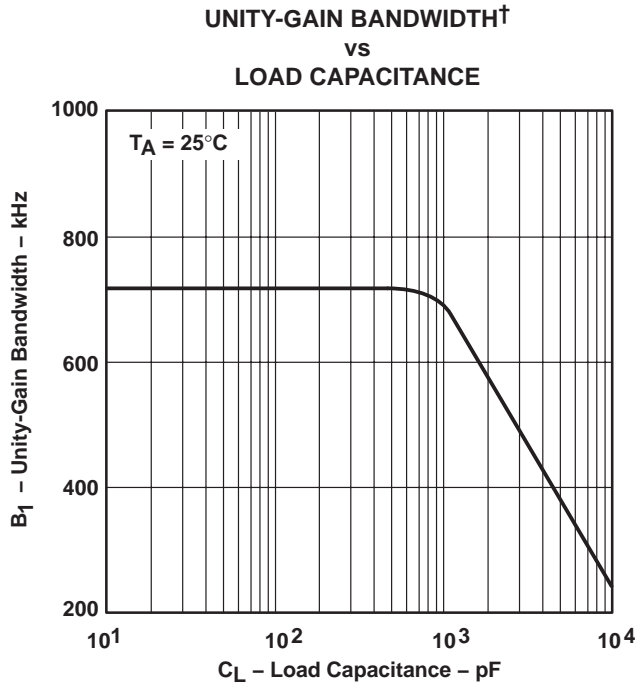


Figure 60

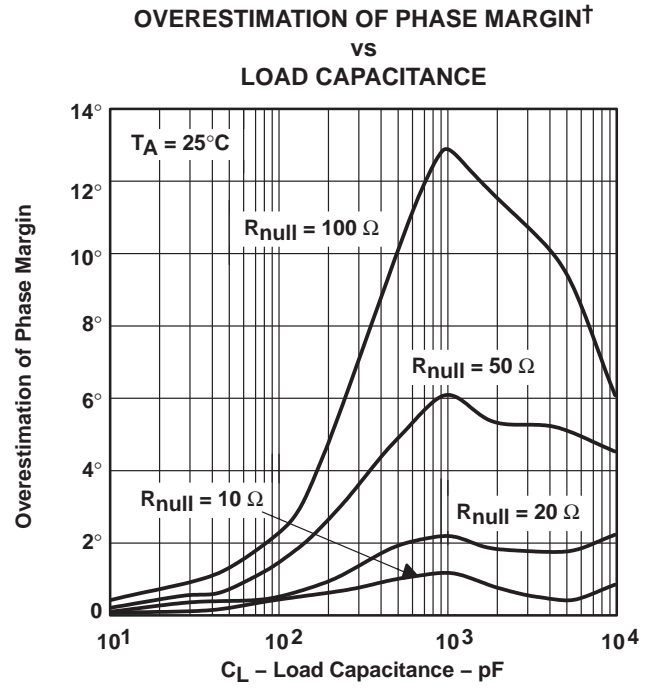


Figure 61

† See application information

APPLICATION INFORMATION

driving large capacitive loads

The TLC226x is designed to drive larger capacitive loads than most CMOS operational amplifiers. Figure 58 and Figure 59 illustrate its ability to drive loads greater than 400 pF while maintaining good gain and phase margins ($R_{null} = 0$).

A smaller series resistor (R_{null}) at the output of the device (see Figure 62) improves the gain and phase margins when driving large capacitive loads. Figure 58 and Figure 59 show the effects of adding series resistances of 10 Ω , 20 Ω , 50 Ω , and 100 Ω . The addition of this series resistor has two effects: the first is that it adds a zero to the transfer function and the second is that it reduces the frequency of the pole associated with the output load in the transfer function.

The zero introduced to the transfer function is equal to the series resistance times the load capacitance. To calculate the improvement in phase margin, equation 1 can be used.

$$\Delta\theta_{m1} = \tan^{-1} \left(2 \times \pi \times \text{UGBW} \times R_{null} \times C_L \right) \tag{1}$$

Where :

- $\Delta\theta_{m1}$ = improvement in phase margin
- UGBW = unity-gain bandwidth frequency
- R_{null} = output series resistance
- C_L = load capacitance

The unity-gain bandwidth (UGBW) frequency decreases as the capacitive load increases (see Figure 60). To use equation 1, UGBW must be approximated from Figure 60.

Using equation 1 alone overestimates the improvement in phase margin, as illustrated in Figure 61. The overestimation is caused by the decrease in the frequency of the pole associated with the load, thus providing additional phase shift and reducing the overall improvement in phase margin. The pole associated with the load is reduced by the factor calculated in equation 2.

$$F = \frac{1}{1 + g_m \times R_{null}} \tag{2}$$

Where :

- F = factor reducing frequency of pole
- g_m = small-signal output transconductance (typically 4.83×10^{-3} mhos)
- R_{null} = output series resistance

For the TLC226x, the pole associated with the load is typically 7 MHz with 100-pF load capacitance. This value varies inversely with C_L : at $C_L = 10$ pF, use 70 MHz, at $C_L = 1000$ pF, use 700 kHz, and so on.

Reducing the pole associated with the load introduces phase shift, thereby reducing phase margin. This results in an error in the increase in phase margin expected by considering the zero alone (equation 1). Equation 3 approximates the reduction in phase margin due to the movement of the pole associated with the load. The result of this equation can be subtracted from the result of the equation in equation 1 to better approximate the improvement in phase margin.

APPLICATION INFORMATION

driving large capacitive loads (continued)

$$\Delta\theta_{m2} = \tan^{-1} \left[\frac{UGBW}{(F \times P_2)} \right] - \tan^{-1} \left(\frac{UGBW}{P_2} \right) \quad (3)$$

Where :

$\Delta\theta_{m2}$ = reduction in phase margin

UGBW = unity-gain bandwidth frequency

F = factor from equation 2

P_2 = unadjusted pole (70 MHz @10 pF, 7 MHz @100 pF, etc.)

Using these equations with Figure 60 and Figure 61 enables the designer to choose the appropriate output series resistance to optimize the design of circuits driving large capacitive loads.

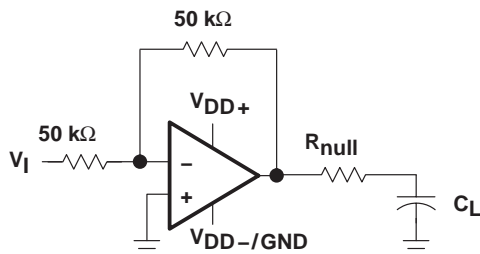


Figure 62. Series-Resistance Circuit

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APPLICATION INFORMATION

macromodel information

Macromodel information provided was derived using Microsim *Parts*™, the model generation software used with Microsim *PSpice*™. The Boyle macromodel (see Note 5) and subcircuit in Figure 63 are generated using the TLC226x typical electrical and operating characteristics at $T_A = 25^\circ\text{C}$. 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 4: 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).

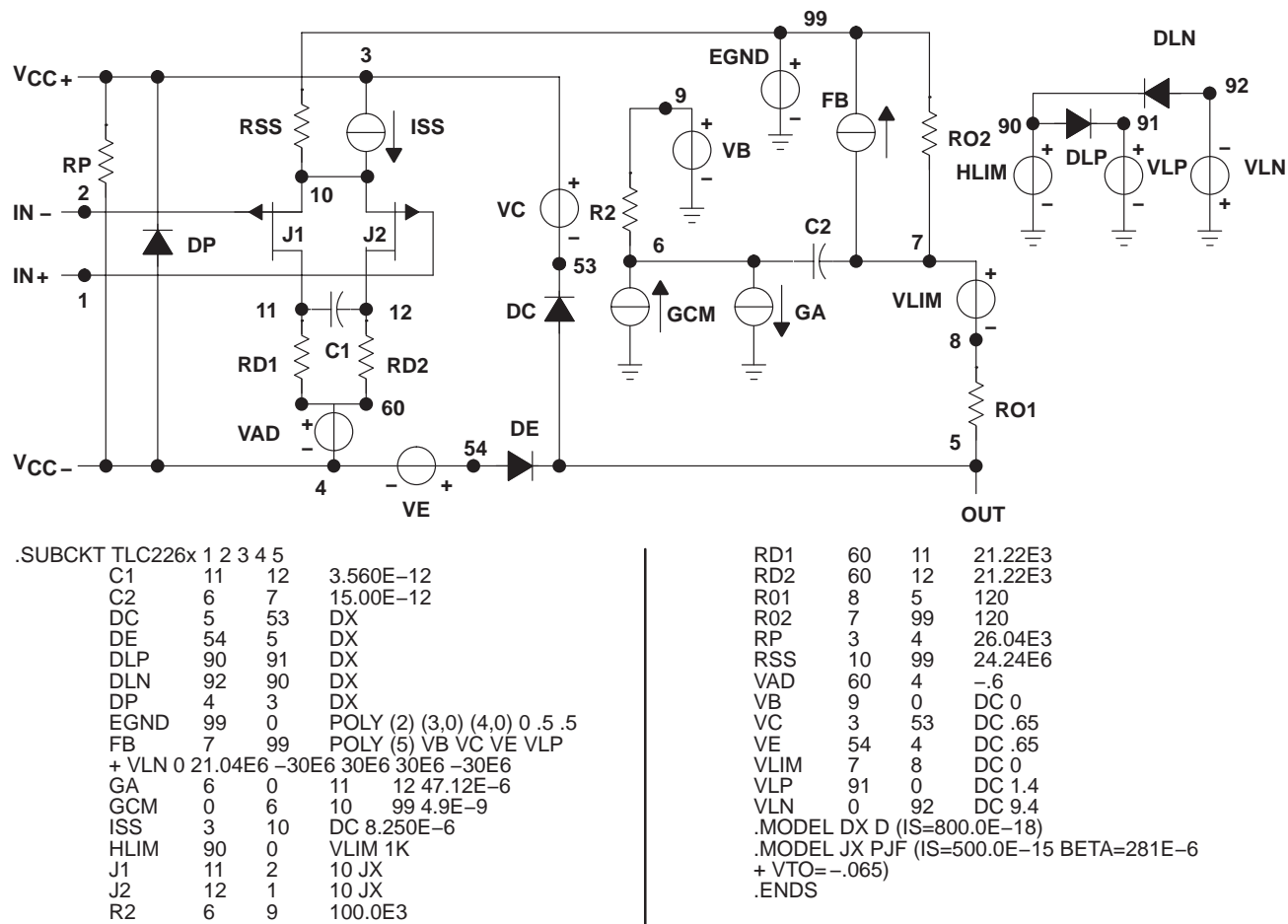


Figure 63. Boyle Macromodel and Subcircuit

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PACKAGING INFORMATION

| Orderable Device | Status ⁽¹⁾ | Package Type | Package Drawing | Pins | Package Qty | Eco Plan ⁽²⁾ | Lead/Ball Finish | MSL Peak Temp ⁽³⁾ |
|------------------|-----------------------|--------------|-----------------|------|-------------|-------------------------|------------------|------------------------------|
| TLC2264AQPWRQ1 | ACTIVE | TSSOP | PW | 14 | 2000 | None | CU NIPDAU | Level-1-250C-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 - May not be currently available - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

None: Not yet available Lead (Pb-Free).

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.

Green (RoHS & no Sb/Br): TI defines "Green" to mean "Pb-Free" and in addition, uses package materials that do not contain halogens, including bromine (Br) or antimony (Sb) above 0.1% of total product weight.

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

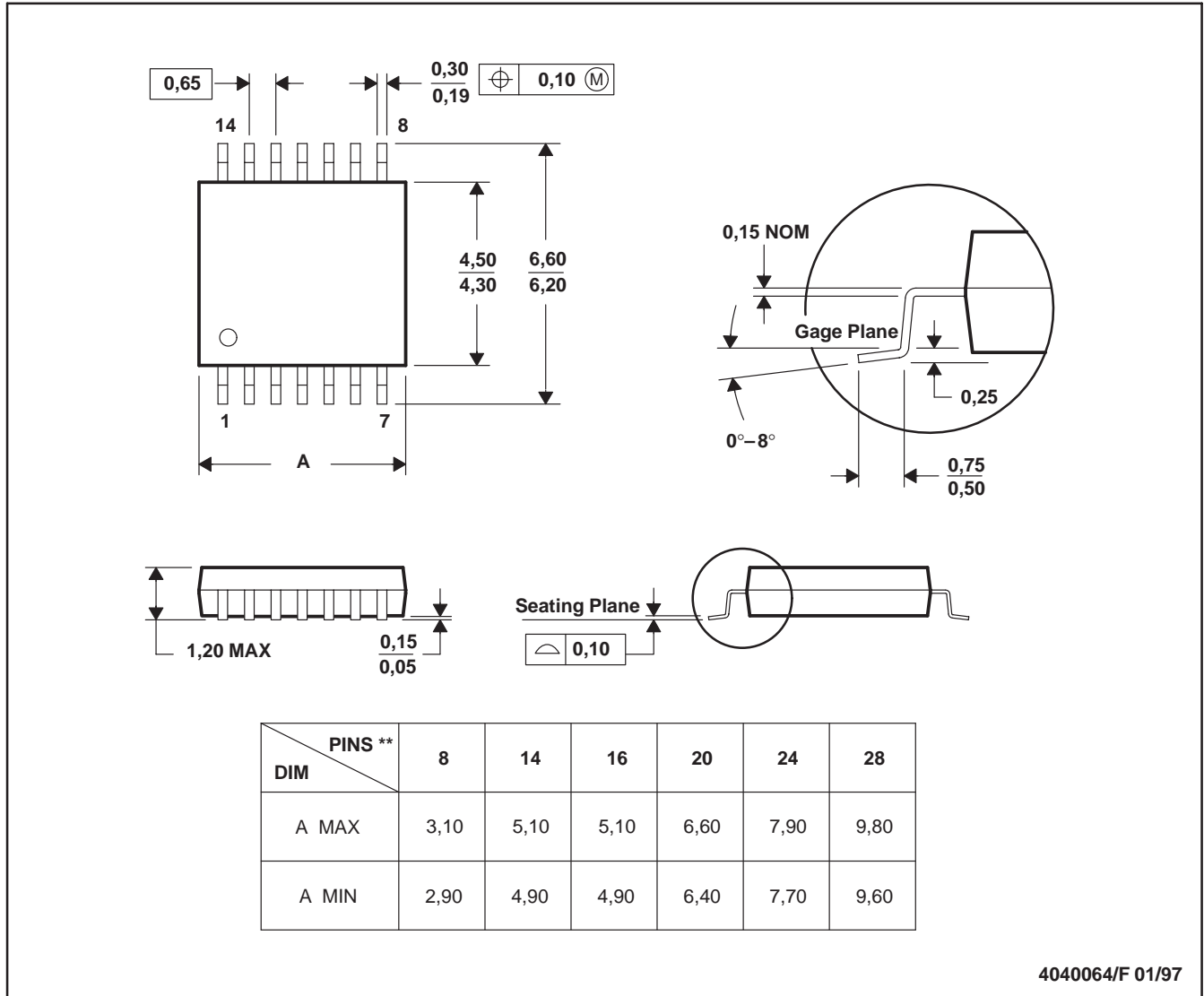
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PW (R-PDSO-G**)

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

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