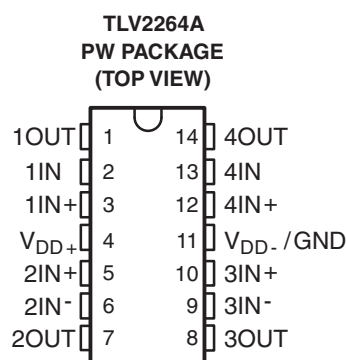
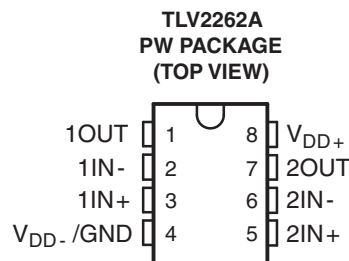


## Advanced LinCMOS™ RAIL-TO-RAIL OPERATIONAL AMPLIFIERS

### FEATURES

- Qualified for Automotive Applications
- 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<sub>A</sub> = 25°C
- Wide Supply Voltage Range . . . 2.7 V to 8 V
- Macromodel Included



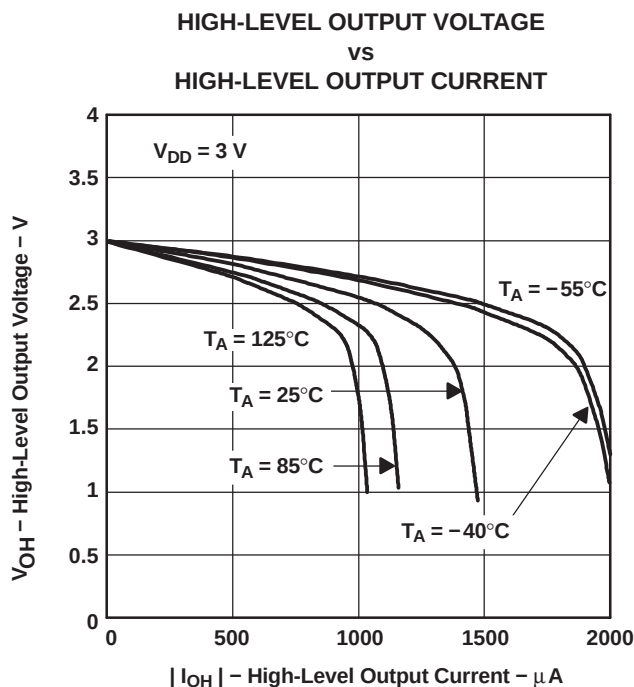
### DESCRIPTION

The TLV2262 and TLV2264 are dual and quad low voltage operational amplifiers from Texas Instruments. Both devices exhibit rail-to-rail output performance for increased dynamic range in single or split supply applications. The TLV226x family offers a compromise between the micropower TLV225x 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. This family is fully characterized at 3 V and 5 V and is optimized for low-voltage applications. 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.



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.

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Parts, PSpice are trademarks of MicroSim Corporation.



The TLV226x, 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 combined with 3-V operation, 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 TLV226xA family is available and has a maximum input offset voltage of 950  $\mu$ V.

The TLV2262/4 also makes great upgrades to the TLV2332/4 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 devices. 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.

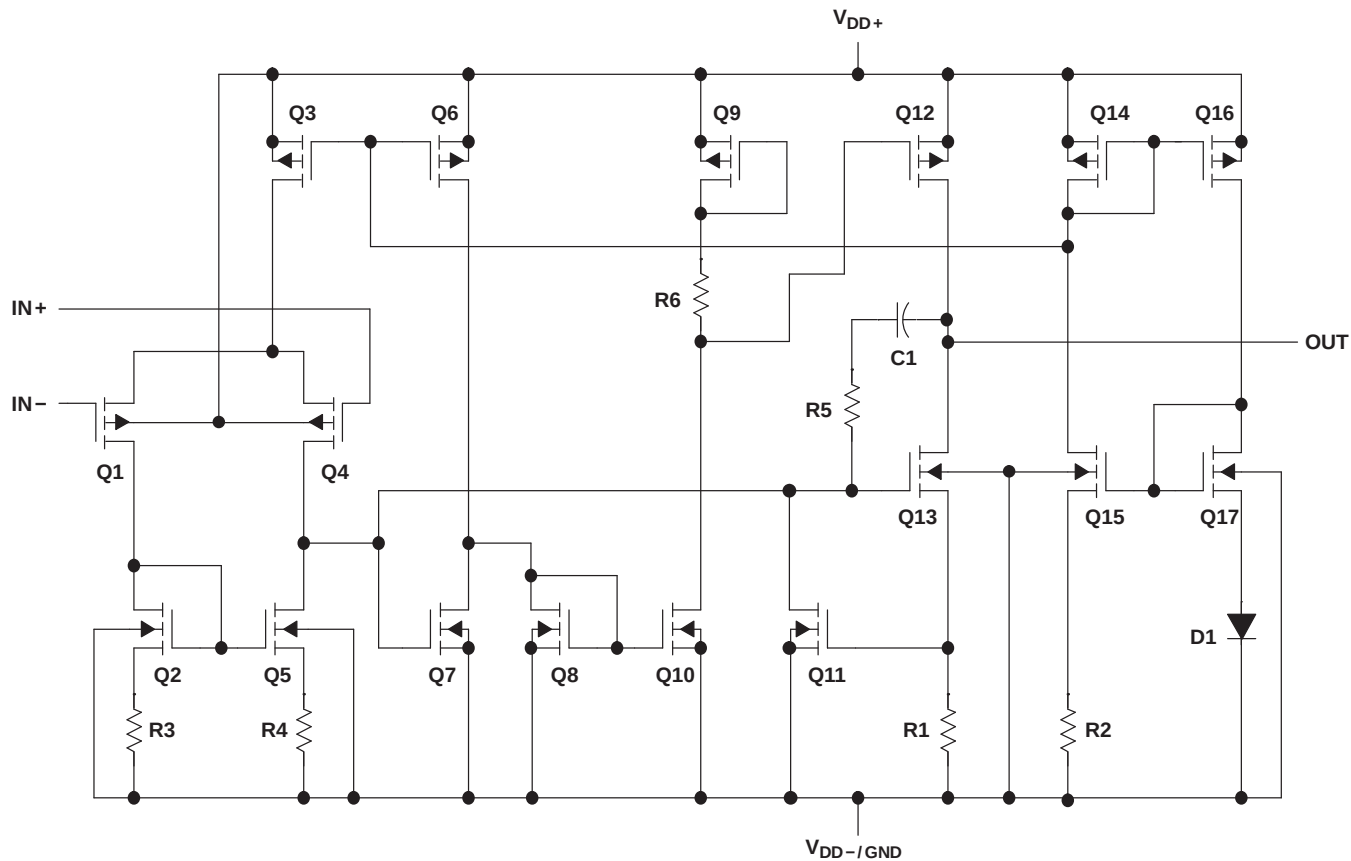
#### ORDERING INFORMATION<sup>(1)</sup>

| $T_A$          | PACKAGE <sup>(2)</sup> |              | ORDERABLE PART NUMBER | TOP-SIDE MARKING |
|----------------|------------------------|--------------|-----------------------|------------------|
| -40°C to 125°C | TSSOP – PW (8 pin)     | Reel of 2000 | TLV2262AQPWRQ1        | TQ262A           |
|                | TSSOP – PW (14 pin)    | Reel of 2000 | TLV2264AQPWRQ1        | P2264AQ          |

(1) 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 [www.ti.com](http://www.ti.com).

(2) Package drawings, thermal data, and symbolization are available at [www.ti.com/packaging](http://www.ti.com/packaging).

**EQUIVALENT SCHEMATIC (EACH AMPLIFIER)**



**Table 1. Actual Device Component Count**

| COMPONENT   | TLV2262 | TLV2264 |
|-------------|---------|---------|
| Transistors | 38      | 76      |
| Resistors   | 28      | 54      |
| Diodes      | 9       | 18      |
| Capacitors  | 3       | 6       |

**ABSOLUTE MAXIMUM RATINGS<sup>(1)</sup>**

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

|           |                                                                     |                                          |
|-----------|---------------------------------------------------------------------|------------------------------------------|
| $V_{DD}$  | Supply voltage <sup>(2)</sup>                                       | –0.3 V to 16 V                           |
| $V_{ID}$  | Differential input voltage <sup>(3)</sup>                           | $\pm V_{DD}$                             |
| $V_I$     | Input voltage range                                                 | $(V_{DD-} - 0.3 \text{ V})$ to $V_{DD+}$ |
| $I_I$     | Input current, any input                                            | $\pm 5 \text{ mA}$                       |
| $I_O$     | Output current                                                      | $\pm 50 \text{ mA}$                      |
|           | Total current into $V_{DD+}$                                        | $\pm 50 \text{ mA}$                      |
|           | Total current out of $V_{DD-}$                                      | $\pm 50 \text{ mA}$                      |
|           | Duration of short-circuit current (at or below) 25°C <sup>(4)</sup> | Unlimited                                |
| $P_D$     | Continuous total power dissipation                                  | See Dissipation Rating Table             |
| $T_A$     | Operating free-air temperature range                                | –40°C to 125°C                           |
| $T_{stg}$ | Storage temperature range                                           | –65°C to 150°C                           |

- (1) 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.
- (2) All voltage values, except differential voltages, are with respect to  $V_{DD-}$ .
- (3) Differential voltages are at the noninverting input with respect to the inverting input. Excessive current flows when input is brought below  $V_{DD-} - 0.3 \text{ V}$ .
- (4) 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 RATINGS**

| PACKAGE | $T_A \leq 25^\circ\text{C}$<br>POWER RATING | DERATING FACTOR<br>ABOVE $T_A = 25^\circ\text{C}$ | $T_A = 85^\circ\text{C}$<br>POWER RATING | $T_A = 125^\circ\text{C}$<br>POWER RATING |
|---------|---------------------------------------------|---------------------------------------------------|------------------------------------------|-------------------------------------------|
| PW-8    | 525 mW                                      | 4.2 mW/°C                                         | 273 mW                                   | 105 mW                                    |
| PW-14   | 700 mW                                      | 5.6 mW/°C                                         | 364 mW                                   | 140 mW                                    |

**RECOMMENDED OPERATING CONDITIONS**

|                                           | MIN       | MAX             | UNIT |
|-------------------------------------------|-----------|-----------------|------|
| $V_{DD\pm}$ Supply voltage <sup>(1)</sup> | 2.7       | 8               | V    |
| $V_I$ Input voltage                       | $V_{DD-}$ | $V_{DD+} - 1.3$ | V    |
| $V_{IC}$ Common-mode input voltage        | $V_{DD-}$ | $V_{DD+} - 1.3$ | V    |
| $T_A$ Operating free-air temperature      | –40       | 125             | °C   |

- (1) All voltage values, except differential voltages, are with respect to  $V_{DD-}$ .

## TLV2262A ELECTRICAL CHARACTERISTICS

 $V_{DD} = 3\text{ V}$ , over operating free-air temperature range (unless otherwise noted)

| PARAMETER         |                                                                      | TEST CONDITIONS                                                                           |                                       | T <sub>A</sub> | MIN | TYP              | MAX         | UNIT  |
|-------------------|----------------------------------------------------------------------|-------------------------------------------------------------------------------------------|---------------------------------------|----------------|-----|------------------|-------------|-------|
| V <sub>IO</sub>   | Input offset voltage                                                 | V <sub>DD±</sub> = ±1.5 V, V <sub>IC</sub> = 0, V <sub>O</sub> = 0, R <sub>S</sub> = 50 Ω |                                       | 25°C           |     | 300              | 950         | mV    |
|                   |                                                                      |                                                                                           |                                       | Full range     |     |                  | 1500        |       |
| α <sub>VIO</sub>  | Temperature coefficient of input offset voltage                      | V <sub>DD±</sub> = ±1.5 V, V <sub>IC</sub> = 0, V <sub>O</sub> = 0, R <sub>S</sub> = 50 Ω |                                       | 25°C to 125°C  |     | 2                |             | μV/°C |
|                   | Input offset voltage long-term drift <sup>(1)</sup>                  | V <sub>DD±</sub> = ±1.5 V, V <sub>IC</sub> = 0, V <sub>O</sub> = 0, R <sub>S</sub> = 50 Ω |                                       | 25°C           |     | 0.003            |             | μV/mo |
| I <sub>IO</sub>   | Input offset current                                                 | V <sub>DD±</sub> = ±1.5 V, V <sub>IC</sub> = 0, V <sub>O</sub> = 0, R <sub>S</sub> = 50 Ω |                                       | 25°C           |     | 0.5              | 60          | pA    |
|                   |                                                                      |                                                                                           |                                       | 125°C          |     |                  | 800         |       |
| I <sub>IB</sub>   | Input bias current                                                   | V <sub>DD±</sub> = ±1.5 V, V <sub>IC</sub> = 0, V <sub>O</sub> = 0, R <sub>S</sub> = 50 Ω |                                       | 25°C           |     | 1                | 60          | pA    |
|                   |                                                                      |                                                                                           |                                       | 125°C          |     |                  | 800         |       |
| V <sub>ICR</sub>  | Common-mode input voltage range                                      | R <sub>S</sub> = 50 Ω,  V <sub>IO</sub>   ≤ 5 mV                                          |                                       | 25°C           |     | 0 to 2           | −0.3 to 2.2 | V     |
|                   |                                                                      |                                                                                           |                                       | Full range     |     | 0 to 1.7         |             |       |
| V <sub>OH</sub>   | High-level output voltage                                            | I <sub>OH</sub> = −20 μA                                                                  |                                       | 25°C           |     | 2.99             |             | V     |
|                   |                                                                      | I <sub>OH</sub> = −100 μA                                                                 |                                       | 25°C           |     | 2.85             |             |       |
|                   |                                                                      |                                                                                           |                                       | Full range     |     | 2.82             |             |       |
|                   |                                                                      | I <sub>OH</sub> = −400 μA                                                                 |                                       | 25°C           |     | 2.7              |             |       |
|                   |                                                                      |                                                                                           |                                       | Full range     |     | 2.55             |             |       |
| V <sub>OL</sub>   | Low-level output voltage                                             | V <sub>IC</sub> = 1.5 V                                                                   | I <sub>OL</sub> = 50 μA               | 25°C           |     | 10               |             | mV    |
|                   |                                                                      |                                                                                           | I <sub>OL</sub> = 500 μA              | 25°C           |     | 100              | 150         |       |
|                   |                                                                      |                                                                                           |                                       | Full range     |     | 165              |             |       |
|                   |                                                                      |                                                                                           | I <sub>OL</sub> = 1 mA                | 25°C           |     | 200              | 300         |       |
|                   |                                                                      |                                                                                           |                                       | Full range     |     | 300              |             |       |
| A <sub>VD</sub>   | Large-signal differential voltage amplification                      | V <sub>IC</sub> = 1.5 V, V <sub>O</sub> = 1 V to 2 V                                      | R <sub>L</sub> = 50 kΩ <sup>(2)</sup> | 25°C           |     | 60               | 100         | V/mV  |
|                   |                                                                      |                                                                                           | R <sub>L</sub> = 1 MΩ <sup>(2)</sup>  | Full range     |     | 25               |             |       |
|                   |                                                                      |                                                                                           |                                       | 25°C           |     | 100              |             |       |
| r <sub>i(d)</sub> | Differential input resistance                                        |                                                                                           |                                       | 25°C           |     | 10 <sup>12</sup> |             | Ω     |
| r <sub>i(c)</sub> | Common-mode input resistance                                         |                                                                                           |                                       | 25°C           |     | 10 <sup>12</sup> |             | Ω     |
| C <sub>i(c)</sub> | Common-mode input capacitance                                        | f = 10 kHz                                                                                |                                       | 25°C           |     | 8                |             | pF    |
| Z <sub>O</sub>    | Closed-loop output impedance                                         | f = 100 kHz, A <sub>V</sub> = 10                                                          |                                       | 25°C           |     | 270              |             | Ω     |
| CMRR              | Common-mode rejection ratio                                          | V <sub>IC</sub> = 0 to 1.7 V, V <sub>O</sub> = 1.5 V, R <sub>S</sub> = 50 Ω               |                                       | 25°C           |     | 65               | 77          | dB    |
|                   |                                                                      |                                                                                           |                                       | Full range     |     | 60               |             |       |
| k <sub>SVR</sub>  | Supply voltage rejection ratio (ΔV <sub>DD</sub> /ΔV <sub>IO</sub> ) | V <sub>DD</sub> = 2.7 V to 8 V, V <sub>IC</sub> = V <sub>DD</sub> /2, No load             |                                       | 25°C           |     | 80               | 100         | dB    |
|                   |                                                                      |                                                                                           |                                       | Full range     |     | 80               |             |       |
| I <sub>DD</sub>   | Supply current                                                       | V <sub>O</sub> = 1.5 V, No load                                                           |                                       | 25°C           |     | 400              | 500         | μA    |
|                   |                                                                      |                                                                                           |                                       | Full range     |     | 500              |             |       |

(1) 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.

(2) Referenced to 1.5 V

**TLV2262A OPERATING CHARACTERISTICS**V<sub>DD</sub> = 3 V, over operating free-air temperature range (unless otherwise noted)

| PARAMETER          |                                             | TEST CONDITIONS                                                                                                                 |                     | T <sub>A</sub> | MIN  | TYP  | MAX | UNIT   |
|--------------------|---------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|---------------------|----------------|------|------|-----|--------|
| SR                 | Slew rate at unity gain                     | V <sub>O</sub> = 0.5 V to 1.7 V, R <sub>L</sub> = 50 kΩ <sup>(1)</sup> ,<br>C <sub>L</sub> = 100 pF <sup>(1)</sup>              |                     | 25°C           | 0.35 | 0.55 |     | V/μs   |
|                    |                                             |                                                                                                                                 |                     | Full range     | 0.25 |      |     |        |
| V <sub>n</sub>     | Equivalent input noise voltage              | f = 10 Hz                                                                                                                       |                     | 25°C           |      | 43   |     | nV/√Hz |
|                    |                                             | f = 1 kHz                                                                                                                       |                     | 25°C           |      | 12   |     |        |
| V <sub>N(PP)</sub> | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 1 Hz                                                                                                              |                     | 25°C           |      | 0.6  |     | μV     |
|                    |                                             | f = 0.1 Hz to 10 Hz                                                                                                             |                     | 25°C           |      | 1    |     |        |
| I <sub>n</sub>     | Equivalent input noise current              |                                                                                                                                 |                     | 25°C           |      | 0.6  |     | fA/√Hz |
| THD+N              | Total harmonic distortion plus noise        | V <sub>O</sub> = 0.5 V to 2.5 V, f = 20 kHz,<br>R <sub>L</sub> = 50 kΩ <sup>(1)</sup>                                           | A <sub>V</sub> = 1  | 25°C           |      | 0.03 |     | %      |
|                    |                                             |                                                                                                                                 | A <sub>V</sub> = 10 | 25°C           |      | 0.05 |     |        |
|                    | Gain-bandwidth product                      | f = 1 kHz, R <sub>L</sub> = 50 kΩ <sup>(1)</sup> , C <sub>L</sub> = 100 pF <sup>(1)</sup>                                       |                     | 25°C           |      | 0.67 |     | MHz    |
| B <sub>OM</sub>    | Maximum output-swing bandwidth              | V <sub>O(PP)</sub> = 1 V, A <sub>V</sub> = 1, R <sub>L</sub> = 50 kΩ <sup>(1)</sup> ,<br>C <sub>L</sub> = 100 pF <sup>(1)</sup> |                     | 25°C           |      | 395  |     | kHz    |
| t <sub>s</sub>     | Settling time                               | A <sub>V</sub> = –1, Step = 1 V to 2 V,<br>R <sub>L</sub> = 50 kΩ <sup>(1)</sup> , C <sub>L</sub> = 100 pF <sup>(1)</sup>       | To 0.1%             | 25°C           |      | 5.6  |     | μs     |
|                    |                                             |                                                                                                                                 | To 0.01%            | 25°C           |      | 12.5 |     |        |
| φ <sub>m</sub>     | Phase margin at unity gain                  | R <sub>L</sub> = 50 kΩ <sup>(1)</sup> , C <sub>L</sub> = 100 pF <sup>(1)</sup>                                                  |                     | 25°C           |      | 55   |     | °      |
| G <sub>m</sub>     | Gain margin                                 | R <sub>L</sub> = 50 kΩ <sup>(1)</sup> , C <sub>L</sub> = 100 pF <sup>(1)</sup>                                                  |                     | 25°C           |      | 11   |     | dB     |

(1) Referenced to 1.5 V

## TLV2262A ELECTRICAL CHARACTERISTICS

 $V_{DD} = 5\text{ V}$ , over operating free-air temperature range (unless otherwise noted)

| PARAMETER                                                                  | TEST CONDITIONS                                                                 | $T_A$                           | MIN        | TYP         | MAX  | UNIT                         |
|----------------------------------------------------------------------------|---------------------------------------------------------------------------------|---------------------------------|------------|-------------|------|------------------------------|
| $V_{IO}$ Input offset voltage                                              | $V_{DD\pm} = \pm 2.5\text{ V}$ , $V_{IC} = 0$ , $V_O = 0$ , $R_S = 50\ \Omega$  | 25°C                            |            | 300         | 950  | mV                           |
|                                                                            |                                                                                 | Full range                      |            |             | 1500 |                              |
| $\alpha_{VIO}$ Temperature coefficient of input offset voltage             | $V_{DD\pm} = \pm 2.5\text{ V}$ , $V_{IC} = 0$ , $V_O = 0$ , $R_S = 50\ \Omega$  | 25°C to 125°C                   |            | 2           |      | $\mu\text{V}/^\circ\text{C}$ |
| Input offset voltage long-term drift <sup>(1)</sup>                        | $V_{DD\pm} = \pm 2.5\text{ V}$ , $V_{IC} = 0$ , $V_O = 0$ , $R_S = 50\ \Omega$  | 25°C                            |            | 0.003       |      | $\mu\text{V}/\text{mo}$      |
| $I_{IO}$ Input offset current                                              | $V_{DD\pm} = \pm 2.5\text{ V}$ , $V_{IC} = 0$ , $V_O = 0$ , $R_S = 50\ \Omega$  | 25°C                            |            | 0.5         | 60   | pA                           |
|                                                                            |                                                                                 | 125°C                           |            |             | 800  |                              |
| $I_{IB}$ Input bias current                                                | $V_{DD\pm} = \pm 2.5\text{ V}$ , $V_{IC} = 0$ , $V_O = 0$ , $R_S = 50\ \Omega$  | 25°C                            |            | 1           | 60   | pA                           |
|                                                                            |                                                                                 | 125°C                           |            |             | 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 |      | V                            |
|                                                                            |                                                                                 | Full range                      | 0 to 3.5   |             |      |                              |
| $V_{OH}$ High-level output voltage                                         | $I_{OH} = -20\ \mu\text{A}$                                                     | 25°C                            |            | 4.99        |      | V                            |
|                                                                            |                                                                                 | 25°C                            | 4.85       | 4.94        |      |                              |
|                                                                            | $I_{OH} = -100\ \mu\text{A}$                                                    | Full range                      | 4.82       |             |      |                              |
|                                                                            |                                                                                 | 25°C                            | 4.7        | 4.85        |      |                              |
| $V_{OL}$ Low-level output voltage                                          | $V_{IC} = 2.5\text{ V}$                                                         | $I_{OL} = -400\ \mu\text{A}$    |            | 4.5         |      | V                            |
|                                                                            |                                                                                 | Full range                      | 4.5        |             |      |                              |
|                                                                            |                                                                                 | $I_{OL} = 50\ \mu\text{A}$      | 25°C       | 0.01        |      |                              |
|                                                                            |                                                                                 | $I_{OL} = 500\ \mu\text{A}$     | 25°C       | 0.09        | 0.15 |                              |
| $A_{VD}$ Large-signal differential voltage amplification                   | $V_{IC} = 2.5\text{ V}$ , $V_O = 1\text{ V to }4\text{ V}$                      | $R_L = 50\text{ k}\Omega^{(2)}$ | 25°C       | 80          | 170  | V/mV                         |
|                                                                            |                                                                                 | $R_L = 50\text{ k}\Omega^{(2)}$ | Full range | 50          |      |                              |
|                                                                            |                                                                                 | $R_L = 1\text{ M}\Omega^{(2)}$  | 25°C       | 550         |      |                              |
|                                                                            |                                                                                 | $R_L = 1\text{ M}\Omega^{(2)}$  | Full range |             |      |                              |
| $r_{i(d)}$ Differential input resistance                                   |                                                                                 | 25°C                            |            | $10^{12}$   |      | $\Omega$                     |
| $r_{i(c)}$ Common-mode input resistance                                    |                                                                                 | 25°C                            |            | $10^{12}$   |      | $\Omega$                     |
| $c_{i(c)}$ Common-mode input capacitance                                   | $f = 10\text{ kHz}$                                                             | 25°C                            |            | 8           |      | pF                           |
| $z_o$ Closed-loop output impedance                                         | $f = 100\text{ kHz}$ , $A_V = 10$                                               | 25°C                            |            | 240         |      | $\Omega$                     |
| 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          |      | dB                           |
|                                                                            |                                                                                 | Full range                      | 70         |             |      |                              |
| $k_{SVR}$ Supply voltage rejection ratio ( $\Delta V_{DD}/\Delta V_{IO}$ ) | $V_{DD} = 4.4\text{ V to }8\text{ V}$ , $V_{IC} = V_{DD}/2$ , No load           | 25°C                            | 80         | 95          |      | dB                           |
|                                                                            |                                                                                 | Full range                      | 80         |             |      |                              |
| $I_{DD}$ Supply current                                                    | $V_O = 2.5\text{ V}$ , No load                                                  | 25°C                            |            | 400         | 500  | $\mu\text{A}$                |
|                                                                            |                                                                                 | Full range                      |            |             | 500  |                              |

(1) 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.

(2) Referenced to 2.5 V

**TLV2262A OPERATING CHARACTERISTICS**V<sub>DD</sub> = 5 V, over operating free-air temperature range (unless otherwise noted)

| PARAMETER          |                                             | TEST CONDITIONS                                                                                                                 |                     | T <sub>A</sub> | MIN  | TYP   | MAX | UNIT   |
|--------------------|---------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|---------------------|----------------|------|-------|-----|--------|
| SR                 | Slew rate at unity gain                     | V <sub>O</sub> = 0.5 V to 3.5 V, R <sub>L</sub> = 50 kΩ <sup>(1)</sup> ,<br>C <sub>L</sub> = 100 pF <sup>(1)</sup>              |                     | 25°C           | 0.35 | 0.55  |     | V/μs   |
|                    |                                             |                                                                                                                                 |                     | Full range     | 0.25 |       |     |        |
| V <sub>n</sub>     | Equivalent input noise voltage              | f = 10 Hz                                                                                                                       |                     | 25°C           |      | 40    |     | nV/√Hz |
|                    |                                             | f = 1 kHz                                                                                                                       |                     | 25°C           |      | 12    |     |        |
| V <sub>N(PP)</sub> | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 1 Hz                                                                                                              |                     | 25°C           |      | 0.7   |     | μV     |
|                    |                                             | f = 0.1 Hz to 10 Hz                                                                                                             |                     | 25°C           |      | 1.3   |     |        |
| I <sub>n</sub>     | Equivalent input noise current              |                                                                                                                                 |                     | 25°C           |      | 0.6   |     | fA/√Hz |
| THD+N              | Total harmonic distortion plus noise        | V <sub>O</sub> = 0.5 V to 2.5 V, f = 20 kHz,<br>R <sub>L</sub> = 50 kΩ <sup>(1)</sup>                                           | A <sub>V</sub> = 1  | 25°C           |      | 0.017 |     | %      |
|                    |                                             |                                                                                                                                 | A <sub>V</sub> = 10 | 25°C           |      | 0.03  |     |        |
|                    | Gain-bandwidth product                      | f = 50 kHz, R <sub>L</sub> = 50 kΩ <sup>(1)</sup> , C <sub>L</sub> = 100 pF <sup>(1)</sup>                                      |                     | 25°C           |      | 0.71  |     | MHz    |
| B <sub>OM</sub>    | Maximum output-swing bandwidth              | V <sub>O(PP)</sub> = 2 V, A <sub>V</sub> = 1, R <sub>L</sub> = 50 kΩ <sup>(1)</sup> ,<br>C <sub>L</sub> = 100 pF <sup>(1)</sup> |                     | 25°C           |      | 185   |     | kHz    |
| t <sub>s</sub>     | Settling time                               | A <sub>V</sub> = –1, Step = 0.5 V to 2.5 V,<br>R <sub>L</sub> = 50 kΩ <sup>(1)</sup> , C <sub>L</sub> = 100 pF <sup>(1)</sup>   | To 0.1%             | 25°C           |      | 6.4   |     | μs     |
|                    |                                             |                                                                                                                                 | To 0.01%            | 25°C           |      | 14.1  |     |        |
| φ <sub>m</sub>     | Phase margin at unity gain                  | R <sub>L</sub> = 50 kΩ <sup>(1)</sup> , C <sub>L</sub> = 100 pF <sup>(1)</sup>                                                  |                     | 25°C           |      | 56    |     | °      |
| G <sub>m</sub>     | Gain margin                                 | R <sub>L</sub> = 50 kΩ <sup>(1)</sup> , C <sub>L</sub> = 100 pF <sup>(1)</sup>                                                  |                     | 25°C           |      | 11    |     | dB     |

(1) Referenced to 2.5 V



**TLV2264A ELECTRICAL CHARACTERISTICS**
 $V_{DD} = 3\text{ V}$ , over operating free-air temperature range (unless otherwise noted)

| PARAMETER      |                                                                  | TEST CONDITIONS                                                                                                                 | $T_A$         | MIN      | TYP         | MAX  | UNIT                         |
|----------------|------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|---------------|----------|-------------|------|------------------------------|
| $V_{IO}$       | Input offset voltage                                             | $V_{DD\pm} = \pm 1.5\text{ V}$ , $V_{IC} = 0$ , $V_O = 0$ , $R_S = 50\ \Omega$                                                  | 25°C          |          | 300         | 950  | mV                           |
|                |                                                                  |                                                                                                                                 | Full range    |          |             | 1500 |                              |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage                  | $V_{DD\pm} = \pm 1.5\text{ V}$ , $V_{IC} = 0$ , $V_O = 0$ , $R_S = 50\ \Omega$                                                  | 25°C to 125°C |          | 2           |      | $\mu\text{V}/^\circ\text{C}$ |
|                | Input offset voltage long-term drift <sup>(1)</sup>              | $V_{DD\pm} = \pm 1.5\text{ V}$ , $V_{IC} = 0$ , $V_O = 0$ , $R_S = 50\ \Omega$                                                  | 25°C          |          | 0.003       |      | $\mu\text{V}/\text{mo}$      |
| $I_{IO}$       | Input offset current                                             | $V_{DD\pm} = \pm 1.5\text{ V}$ , $V_{IC} = 0$ , $V_O = 0$ , $R_S = 50\ \Omega$                                                  | 25°C          |          | 0.5         | 60   | pA                           |
|                |                                                                  |                                                                                                                                 | 125°C         |          |             | 800  |                              |
| $I_{IB}$       | Input bias current                                               | $V_{DD\pm} = \pm 1.5\text{ V}$ , $V_{IC} = 0$ , $V_O = 0$ , $R_S = 50\ \Omega$                                                  | 25°C          |          | 1           | 60   | pA                           |
|                |                                                                  |                                                                                                                                 | 125°C         |          |             | 800  |                              |
| $V_{ICR}$      | Common-mode input voltage range                                  | $R_S = 50\ \Omega$ , $ V_{IO}  \leq 5\text{ mV}$                                                                                | 25°C          | 0 to 2   | –0.3 to 2.2 |      | V                            |
|                |                                                                  |                                                                                                                                 | Full range    | 0 to 1.7 |             |      |                              |
| $V_{OH}$       | High-level output voltage                                        | $I_{OH} = -20\ \mu\text{A}$<br>$I_{OH} = -100\ \mu\text{A}$<br>$I_{OH} = -400\ \mu\text{A}$                                     | 25°C          |          | 2.99        |      | V                            |
|                |                                                                  |                                                                                                                                 | 25°C          |          | 2.85        |      |                              |
|                |                                                                  |                                                                                                                                 | Full range    |          | 2.82        |      |                              |
|                |                                                                  |                                                                                                                                 | 25°C          |          | 2.7         |      |                              |
| $V_{OL}$       | Low-level output voltage                                         | $V_{IC} = 1.5\text{ V}$<br>$I_{OL} = 50\ \mu\text{A}$<br>$I_{OL} = 500\ \mu\text{A}$<br>$I_{OL} = 1\text{ mA}$                  | 25°C          |          | 10          |      | mV                           |
|                |                                                                  |                                                                                                                                 | 25°C          |          | 100         | 150  |                              |
|                |                                                                  |                                                                                                                                 | Full range    |          |             | 150  |                              |
|                |                                                                  |                                                                                                                                 | 25°C          |          | 200         | 300  |                              |
| $A_{VD}$       | Large-signal differential voltage amplification                  | $V_{IC} = 1.5\text{ V}$ , $V_O = 1\text{ V to }2\text{ V}$<br>$R_L = 50\text{ k}\Omega^{(2)}$<br>$R_L = 1\text{ M}\Omega^{(2)}$ | 25°C          |          | 60          | 100  | V/mV                         |
|                |                                                                  |                                                                                                                                 | Full range    |          | 25          |      |                              |
|                |                                                                  |                                                                                                                                 | 25°C          |          |             | 100  |                              |
|                |                                                                  |                                                                                                                                 | Full range    |          |             | 300  |                              |
| $r_{i(d)}$     | Differential input resistance                                    |                                                                                                                                 | 25°C          |          | $10^{12}$   |      | $\Omega$                     |
| $r_{i(c)}$     | Common-mode input resistance                                     |                                                                                                                                 | 25°C          |          | $10^{12}$   |      | $\Omega$                     |
| $c_{i(c)}$     | Common-mode input capacitance                                    | $f = 10\text{ kHz}$                                                                                                             | 25°C          |          | 8           |      | pF                           |
| $z_o$          | Closed-loop output impedance                                     | $f = 100\text{ kHz}$ , $A_V = 10$                                                                                               | 25°C          |          | 270         |      | $\Omega$                     |
| CMRR           | Common-mode rejection ratio                                      | $V_{IC} = 0\text{ to }1.7\text{ V}$ , $V_O = 1.5\text{ V}$ , $R_S = 50\ \Omega$                                                 | 25°C          |          | 65          | 77   | dB                           |
|                |                                                                  |                                                                                                                                 | Full range    |          | 60          |      |                              |
| $k_{SVR}$      | Supply voltage rejection ratio ( $\Delta V_{DD}/\Delta V_{IO}$ ) | $V_{DD} = 2.7\text{ V to }8\text{ V}$ , $V_{IC} = V_{DD}/2$ , No load                                                           | 25°C          |          | 80          | 100  | dB                           |
|                |                                                                  |                                                                                                                                 | Full range    |          | 80          |      |                              |
| $I_{DD}$       | Supply current                                                   | $V_O = 1.5\text{ V}$ , No load                                                                                                  | 25°C          |          | 0.8         | 1    | mA                           |
|                |                                                                  |                                                                                                                                 | Full range    |          |             | 1    |                              |

(1) 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.

(2) Referenced to 1.5 V

**TLV2264A OPERATING CHARACTERISTICS**V<sub>DD</sub> = 3 V, over operating free-air temperature range (unless otherwise noted)

| PARAMETER          |                                             | TEST CONDITIONS                                                                                                                 | T <sub>A</sub>      | MIN  | TYP  | MAX | UNIT   |
|--------------------|---------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|---------------------|------|------|-----|--------|
| SR                 | Slew rate at unity gain                     | V <sub>O</sub> = 0.5 V to 1.7 V, R <sub>L</sub> = 50 kΩ <sup>(1)</sup> ,<br>C <sub>L</sub> = 100 pF <sup>(1)</sup>              | 25°C                | 0.35 | 0.55 |     | V/μs   |
|                    |                                             |                                                                                                                                 | Full range          | 0.25 |      |     |        |
| V <sub>n</sub>     | Equivalent input noise voltage              | f = 10 Hz                                                                                                                       | 25°C                |      | 43   |     | nV/√Hz |
|                    |                                             | f = 1 kHz                                                                                                                       | 25°C                |      | 12   |     |        |
| V <sub>N(PP)</sub> | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 1 Hz                                                                                                              | 25°C                |      | 0.6  |     | μV     |
|                    |                                             | f = 0.1 Hz to 10 Hz                                                                                                             | 25°C                |      | 1    |     |        |
| I <sub>n</sub>     | Equivalent input noise current              |                                                                                                                                 | 25°C                |      | 0.6  |     | fA/√Hz |
| THD+N              | Total harmonic distortion plus noise        | V <sub>O</sub> = 0.5 V to 2.5 V, f = 20 kHz,<br>R <sub>L</sub> = 50 kΩ <sup>(1)</sup>                                           | A <sub>V</sub> = 1  | 25°C | 0.03 |     | %      |
|                    |                                             |                                                                                                                                 | A <sub>V</sub> = 10 | 25°C | 0.05 |     |        |
|                    | Gain-bandwidth product                      | f = 1 kHz, R <sub>L</sub> = 50 kΩ <sup>(1)</sup> , C <sub>L</sub> = 100 pF <sup>(1)</sup>                                       | 25°C                |      | 0.67 |     | MHz    |
| B <sub>OM</sub>    | Maximum output-swing bandwidth              | V <sub>O(PP)</sub> = 1 V, A <sub>V</sub> = 1, R <sub>L</sub> = 50 kΩ <sup>(1)</sup> ,<br>C <sub>L</sub> = 100 pF <sup>(1)</sup> | 25°C                |      | 395  |     | kHz    |
| t <sub>s</sub>     | Settling time                               | A <sub>V</sub> = –1, Step = 1 V to 2 V,<br>R <sub>L</sub> = 50 kΩ <sup>(1)</sup> , C <sub>L</sub> = 100 pF <sup>(1)</sup>       | To 0.1%             | 25°C | 5.6  |     | μs     |
|                    |                                             |                                                                                                                                 | To 0.01%            | 25°C | 12.5 |     |        |
| φ <sub>m</sub>     | Phase margin at unity gain                  | R <sub>L</sub> = 50 kΩ <sup>(1)</sup> , C <sub>L</sub> = 100 pF <sup>(1)</sup>                                                  | 25°C                |      | 55   |     | °      |
| G <sub>m</sub>     | Gain margin                                 | R <sub>L</sub> = 50 kΩ <sup>(1)</sup> , C <sub>L</sub> = 100 pF <sup>(1)</sup>                                                  | 25°C                |      | 11   |     | dB     |

(1) Referenced to 1.5 V

## TLV2264A ELECTRICAL CHARACTERISTICS

 $V_{DD} = 5\text{ V}$ , over operating free-air temperature range (unless otherwise noted)

| PARAMETER      |                                                                  | TEST CONDITIONS                                                                                                                 | $T_A$         | MIN      | TYP         | MAX  | UNIT                         |
|----------------|------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|---------------|----------|-------------|------|------------------------------|
| $V_{IO}$       | Input offset voltage                                             | $V_{DD\pm} = \pm 2.5\text{ V}$ , $V_{IC} = 0$ , $V_O = 0$ , $R_S = 50\ \Omega$                                                  | 25°C          |          | 300         | 950  | mV                           |
|                |                                                                  |                                                                                                                                 | Full range    |          |             | 1500 |                              |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage                  | $V_{DD\pm} = \pm 2.5\text{ V}$ , $V_{IC} = 0$ , $V_O = 0$ , $R_S = 50\ \Omega$                                                  | 25°C to 125°C |          | 2           |      | $\mu\text{V}/^\circ\text{C}$ |
|                | Input offset voltage long-term drift <sup>(1)</sup>              | $V_{DD\pm} = \pm 2.5\text{ V}$ , $V_{IC} = 0$ , $V_O = 0$ , $R_S = 50\ \Omega$                                                  | 25°C          |          | 0.003       |      | $\mu\text{V}/\text{mo}$      |
| $I_{IO}$       | Input offset current                                             | $V_{DD\pm} = \pm 2.5\text{ V}$ , $V_{IC} = 0$ , $V_O = 0$ , $R_S = 50\ \Omega$                                                  | 25°C          |          | 0.5         | 60   | pA                           |
|                |                                                                  |                                                                                                                                 | 125°C         |          |             | 800  |                              |
| $I_{IB}$       | Input bias current                                               | $V_{DD\pm} = \pm 2.5\text{ V}$ , $V_{IC} = 0$ , $V_O = 0$ , $R_S = 50\ \Omega$                                                  | 25°C          |          | 1           | 60   | pA                           |
|                |                                                                  |                                                                                                                                 | 125°C         |          |             | 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 |      | V                            |
|                |                                                                  |                                                                                                                                 | Full range    | 0 to 3.5 |             |      |                              |
| $V_{OH}$       | High-level output voltage                                        | $I_{OH} = -20\ \mu\text{A}$<br>$I_{OH} = -100\ \mu\text{A}$<br>$I_{OH} = -400\ \mu\text{A}$                                     | 25°C          |          | 4.99        |      | V                            |
|                |                                                                  |                                                                                                                                 | 25°C          |          | 4.85        | 4.94 |                              |
|                |                                                                  |                                                                                                                                 | Full range    |          | 4.82        |      |                              |
|                |                                                                  |                                                                                                                                 | 25°C          |          | 4.7         | 4.85 |                              |
| $V_{OL}$       | Low-level output voltage                                         | $V_{IC} = 2.5\text{ V}$<br>$I_{OL} = 50\ \mu\text{A}$<br>$I_{OL} = 500\ \mu\text{A}$<br>$I_{OL} = 1\text{ mA}$                  | 25°C          |          | 0.01        |      | V                            |
|                |                                                                  |                                                                                                                                 | 25°C          |          | 0.09        | 0.15 |                              |
|                |                                                                  |                                                                                                                                 | Full range    |          |             | 0.15 |                              |
|                |                                                                  |                                                                                                                                 | 25°C          |          | 0.2         | 0.3  |                              |
| $A_{VD}$       | Large-signal differential voltage amplification                  | $V_{IC} = 2.5\text{ V}$ , $V_O = 1\text{ V to }4\text{ V}$<br>$R_L = 50\text{ k}\Omega^{(2)}$<br>$R_L = 1\text{ M}\Omega^{(2)}$ | 25°C          |          | 80          | 170  | V/mV                         |
|                |                                                                  |                                                                                                                                 | Full range    |          | 50          |      |                              |
|                |                                                                  |                                                                                                                                 | 25°C          |          |             | 550  |                              |
|                |                                                                  |                                                                                                                                 | Full range    |          |             |      |                              |
| $r_{i(d)}$     | Differential input resistance                                    |                                                                                                                                 | 25°C          |          | $10^{12}$   |      | $\Omega$                     |
| $r_{i(c)}$     | Common-mode input resistance                                     |                                                                                                                                 | 25°C          |          | $10^{12}$   |      | $\Omega$                     |
| $C_{i(c)}$     | Common-mode input capacitance                                    | $f = 10\text{ kHz}$                                                                                                             | 25°C          |          | 8           |      | pF                           |
| $z_o$          | Closed-loop output impedance                                     | $f = 100\text{ kHz}$ , $A_V = 10$                                                                                               | 25°C          |          | 240         |      | $\Omega$                     |
| 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   | dB                           |
|                |                                                                  |                                                                                                                                 | Full range    |          | 70          |      |                              |
| $k_{SVR}$      | Supply voltage rejection ratio ( $\Delta V_{DD}/\Delta V_{IO}$ ) | $V_{DD} = 4.4\text{ V to }8\text{ V}$ , $V_{IC} = V_{DD}/2$ , No load                                                           | 25°C          |          | 80          | 95   | dB                           |
|                |                                                                  |                                                                                                                                 | Full range    |          | 80          |      |                              |
| $I_{DD}$       | Supply current                                                   | $V_O = 2.5\text{ V}$ , No load                                                                                                  | 25°C          |          | 0.8         | 1    | mA                           |
|                |                                                                  |                                                                                                                                 | Full range    |          |             | 1    |                              |

(1) 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.

(2) Referenced to 2.5 V

**TLV2264A OPERATING CHARACTERISTICS**V<sub>DD</sub> = 5 V, over operating free-air temperature range (unless otherwise noted)

| PARAMETER          |                                             | TEST CONDITIONS                                                                                                                 | T <sub>A</sub>              | MIN  | TYP   | MAX | UNIT   |
|--------------------|---------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|-----------------------------|------|-------|-----|--------|
| SR                 | Slew rate at unity gain                     | V <sub>O</sub> = 0.5 V to 3.5 V, R <sub>L</sub> = 50 kΩ <sup>(1)</sup> ,<br>C <sub>L</sub> = 100 pF <sup>(1)</sup>              | 25°C                        | 0.35 | 0.55  |     | V/μs   |
|                    |                                             |                                                                                                                                 | Full range                  | 0.25 |       |     |        |
| V <sub>n</sub>     | Equivalent input noise voltage              | f = 10 Hz                                                                                                                       | 25°C                        |      | 40    |     | nV/√Hz |
|                    |                                             | f = 1 kHz                                                                                                                       | 25°C                        |      | 12    |     |        |
| V <sub>N(PP)</sub> | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 1 Hz                                                                                                              | 25°C                        |      | 0.7   |     | μV     |
|                    |                                             | f = 0.1 Hz to 10 Hz                                                                                                             | 25°C                        |      | 1.3   |     |        |
| I <sub>n</sub>     | Equivalent input noise current              |                                                                                                                                 | 25°C                        |      | 0.6   |     | fA/√Hz |
| THD+N              | Total harmonic distortion plus noise        | V <sub>O</sub> = 0.5 V to 2.5 V, f = 20 kHz,<br>R <sub>L</sub> = 50 kΩ <sup>(1)</sup>                                           | A <sub>V</sub> = 1<br>25°C  |      | 0.017 |     | %      |
|                    |                                             |                                                                                                                                 | A <sub>V</sub> = 10<br>25°C |      | 0.03  |     |        |
|                    | Gain-bandwidth product                      | f = 50 kHz, R <sub>L</sub> = 50 kΩ <sup>(1)</sup> , C <sub>L</sub> = 100 pF <sup>(1)</sup>                                      | 25°C                        |      | 0.71  |     | MHz    |
| B <sub>OM</sub>    | Maximum output-swing bandwidth              | V <sub>O(PP)</sub> = 2 V, A <sub>V</sub> = 1, R <sub>L</sub> = 50 kΩ <sup>(1)</sup> ,<br>C <sub>L</sub> = 100 pF <sup>(1)</sup> | 25°C                        |      | 185   |     | kHz    |
| t <sub>s</sub>     | Settling time                               | A <sub>V</sub> = –1, Step = 0.5 V to 2.5 V,<br>R <sub>L</sub> = 50 kΩ <sup>(1)</sup> , C <sub>L</sub> = 100 pF <sup>(1)</sup>   | To 0.1%<br>25°C             |      | 6.4   |     | μs     |
|                    |                                             |                                                                                                                                 | To 0.01%<br>25°C            |      | 14.1  |     |        |
| φ <sub>m</sub>     | Phase margin at unity gain                  | R <sub>L</sub> = 50 kΩ <sup>(1)</sup> , C <sub>L</sub> = 100 pF <sup>(1)</sup>                                                  | 25°C                        |      | 56    |     | °      |
| G <sub>m</sub>     | Gain margin                                 | R <sub>L</sub> = 50 kΩ <sup>(1)</sup> , C <sub>L</sub> = 100 pF <sup>(1)</sup>                                                  | 25°C                        |      | 11    |     | dB     |

(1) Referenced to 2.5 V

## TYPICAL CHARACTERISTICS

For all curves where  $V_{DD} = 5\text{ V}$ , all loads are referenced to 2.5 V. For all curves where  $V_{DD} = 3\text{ V}$ , all loads are referenced to 1.5 V. Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

**Table of Graphs**

|                 |                                                 |                              | FIGURE     |
|-----------------|-------------------------------------------------|------------------------------|------------|
| $V_{IO}$        | Input offset voltage                            | Distribution                 | 2–5        |
|                 |                                                 | vs Common-mode voltage       | 6, 7       |
| $\alpha_{VIO}$  | Input offset voltage temperature coefficient    | Distribution                 | 8–11       |
| $I_{IB}/I_{IO}$ | Input bias and input offset currents            | vs Free-air temperature      | 12         |
| $V_I$           | Input voltage                                   | vs Supply voltage            | 13         |
|                 |                                                 | vs Free-air temperature      | 14         |
| $V_{OH}$        | High-level output voltage                       | vs High-level output current | 15, 18     |
| $V_{OL}$        | Low-level output voltage                        | vs Low-level output current  | 16, 17, 19 |
| $V_{O(PP)}$     | Maximum peak-to-peak output voltage             | vs Frequency                 | 20         |
| $I_{OS}$        | Short-circuit output current                    | vs Supply voltage            | 21         |
|                 |                                                 | vs Free-air temperature      | 22         |
| $V_{ID}$        | Differential input voltage                      | vs Output voltage            | 23, 24     |
| $A_{VD}$        | Differential voltage amplification              | vs Load resistance           | 25         |
| $A_{VD}$        | Large-signal differential voltage amplification | vs Frequency                 | 26, 27     |
|                 |                                                 | vs Free-air temperature      | 28, 29     |
| $z_o$           | Output impedance                                | vs Frequency                 | 30, 31     |
| CMRR            | Common-mode rejection ratio                     | vs Frequency                 | 32         |
|                 |                                                 | vs Free-air temperature      | 33         |
| $k_{SVR}$       | Supply-voltage rejection ratio                  | vs Frequency                 | 34, 35     |
|                 |                                                 | vs Free-air temperature      | 36, 37     |
| $I_{DD}$        | Supply current                                  | vs Free-air temperature      | 38, 39     |
| SR              | Slew rate                                       | vs Load capacitance          | 40         |
|                 |                                                 | vs Free-air temperature      | 41         |
| $V_O$           | Inverting large-signal pulse response           |                              | 42, 43     |
| $V_O$           | Voltage-follower large-signal pulse response    |                              | 44, 45     |
| $V_O$           | Inverting small-signal pulse response           |                              | 46, 47     |
| $V_O$           | Voltage-follower small-signal pulse response    |                              | 48, 49     |
| $V_n$           | Equivalent input noise voltage                  | vs Frequency                 | 50, 51     |
|                 | Input noise voltage                             | Over a 10-second period      | 52         |
|                 | Integrated noise voltage                        | vs Frequency                 | 53         |
| THD+N           | Total harmonic distortion plus noise            | vs Frequency                 | 54         |
|                 | Gain-bandwidth product                          | vs Supply voltage            | 55         |
|                 |                                                 | vs Free-air temperature      | 56         |
| $\phi_m$        | Phase margin                                    | vs Frequency                 | 26, 27     |
|                 |                                                 | vs Load capacitance          | 57         |
| $G_m$           | Gain margin                                     | vs Load capacitance          | 58         |
| $B_1$           | Unity-gain bandwidth                            | vs Load capacitance          | 59         |
|                 | Overestimation of phase margin                  | vs Load capacitance          | 60         |

**DISTRIBUTION OF TLV2262  
INPUT OFFSET VOLTAGE**

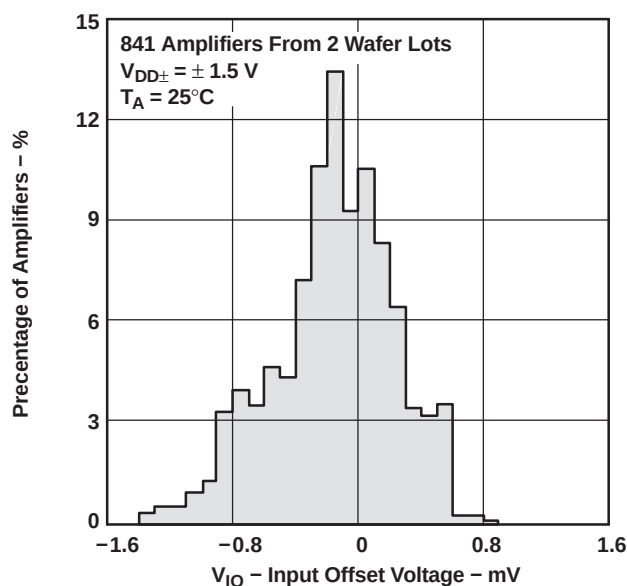


Figure 2.

**DISTRIBUTION OF TLV2262  
INPUT OFFSET VOLTAGE**

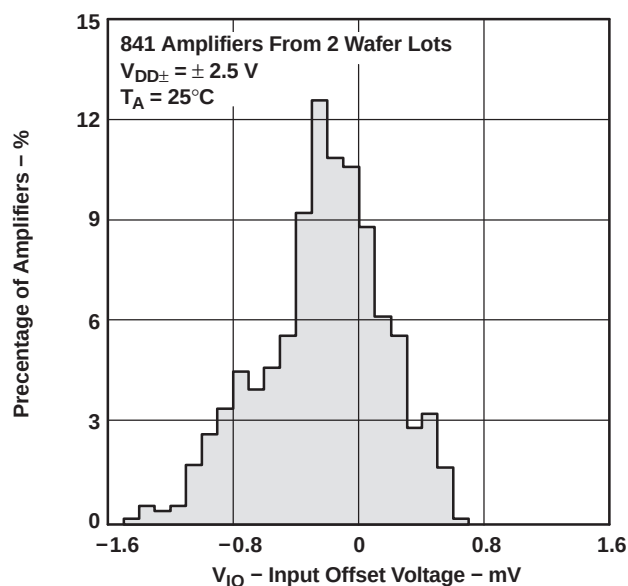


Figure 3.

**DISTRIBUTION OF TLV2264  
INPUT OFFSET VOLTAGE**

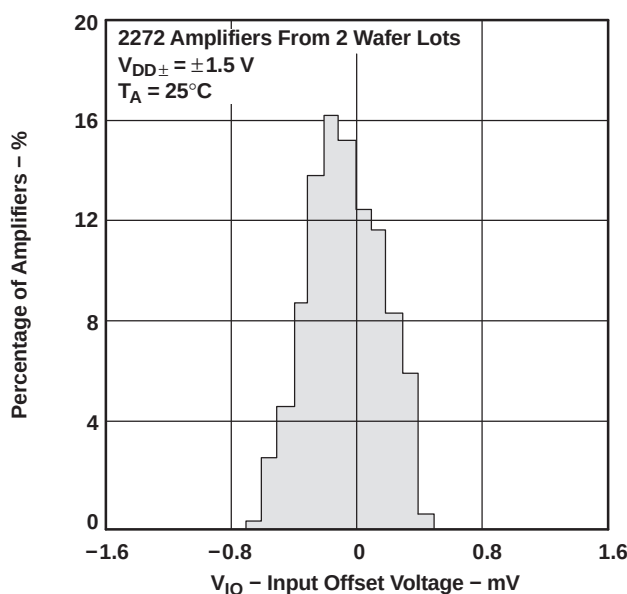


Figure 4.

**DISTRIBUTION OF TLV2264  
INPUT OFFSET VOLTAGE**

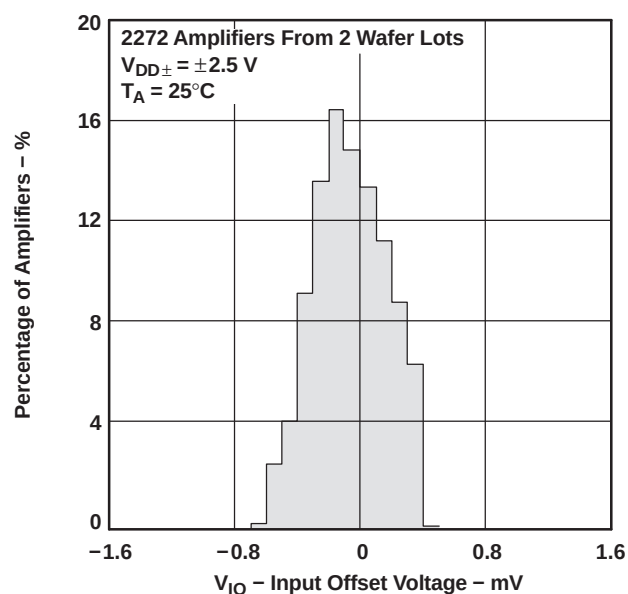


Figure 5.

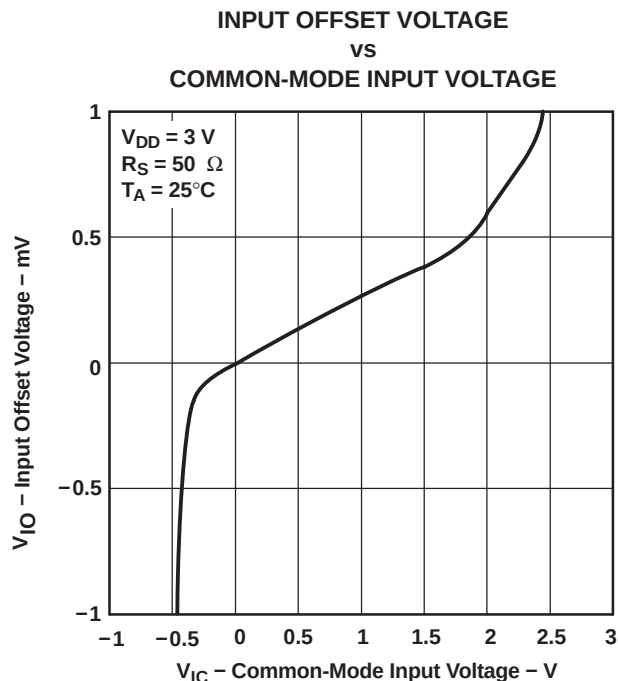


Figure 6.

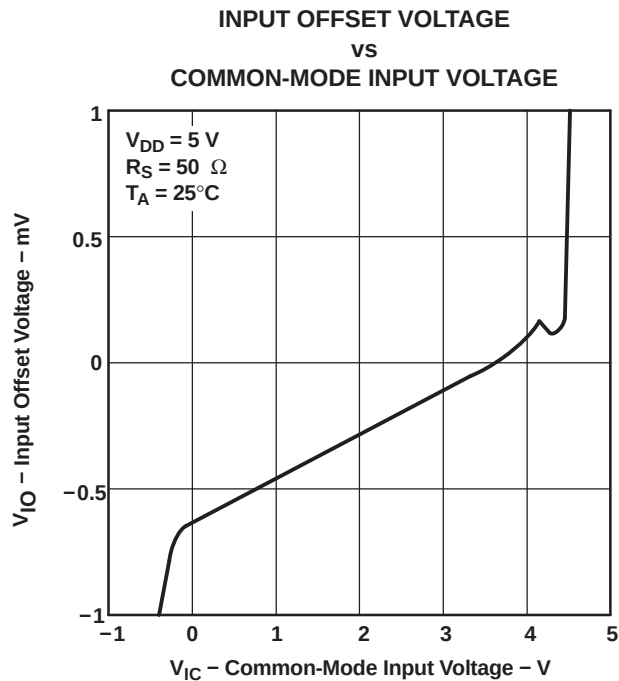


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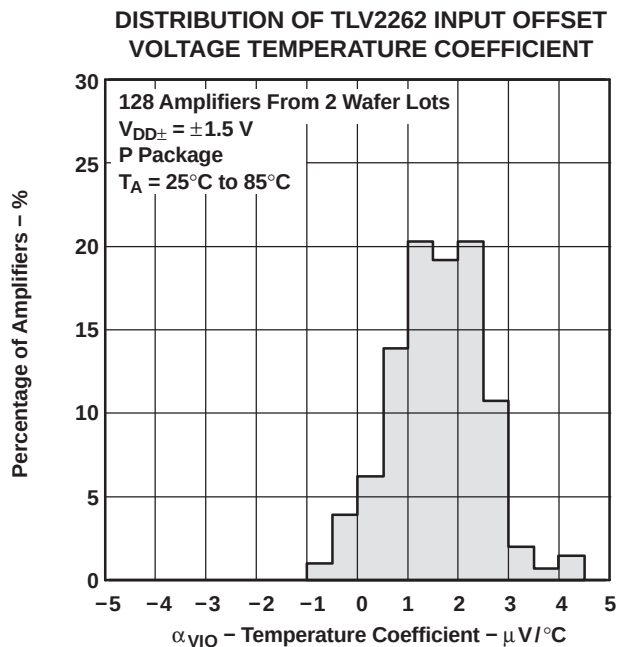


Figure 8.

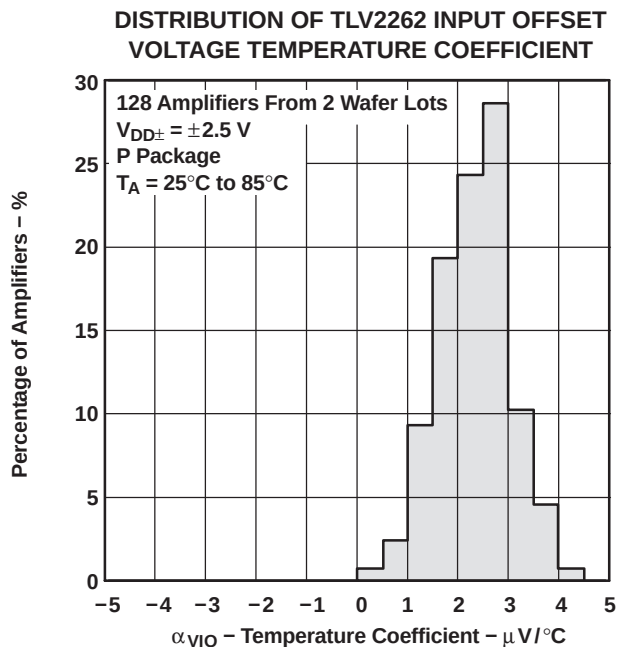


Figure 9.

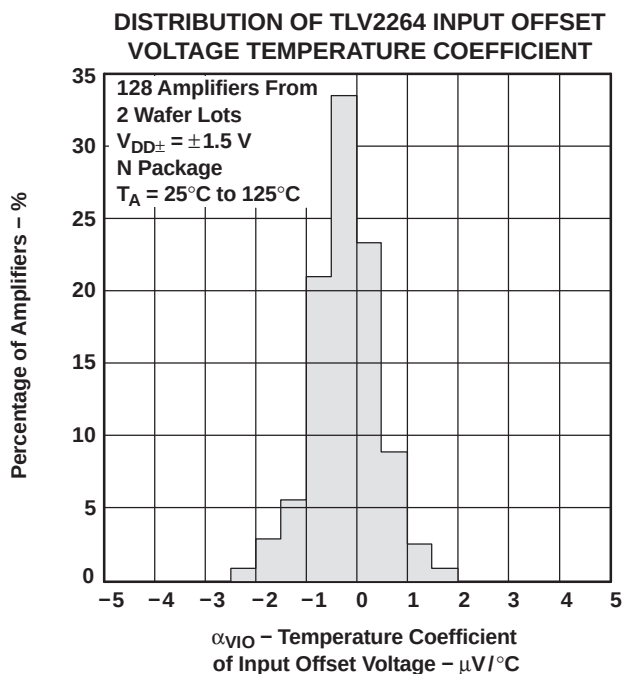


Figure 10.

INPUT BIAS AND INPUT OFFSET CURRENTS

VS

FREE-AIR TEMPERATURE

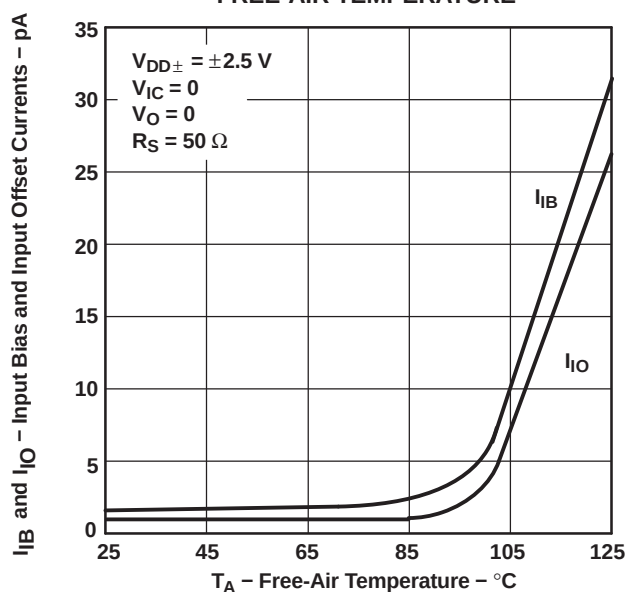


Figure 12.

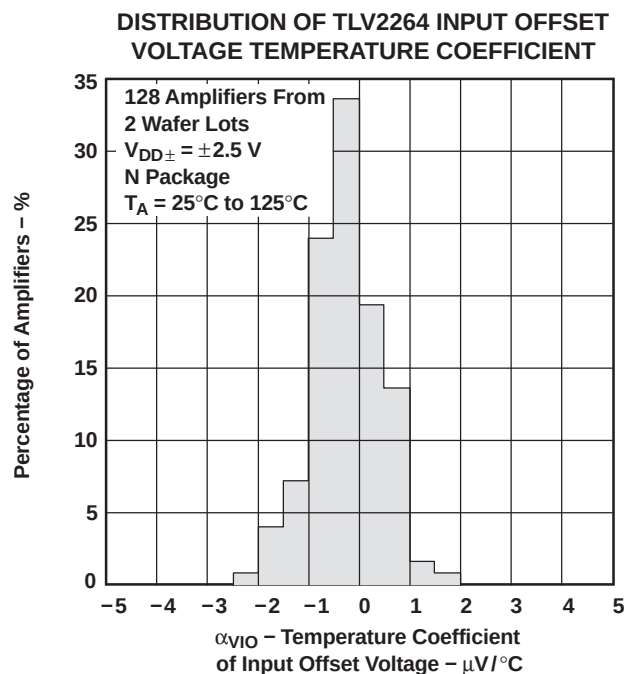


Figure 11.

INPUT VOLTAGE

VS

SUPPLY VOLTAGE

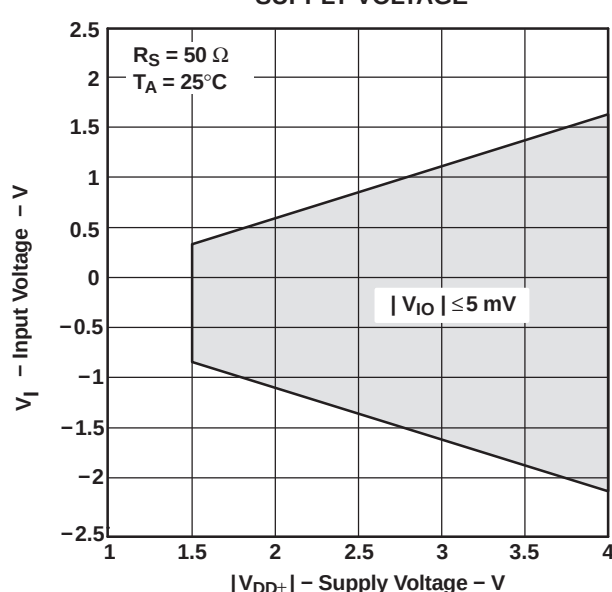


Figure 13.



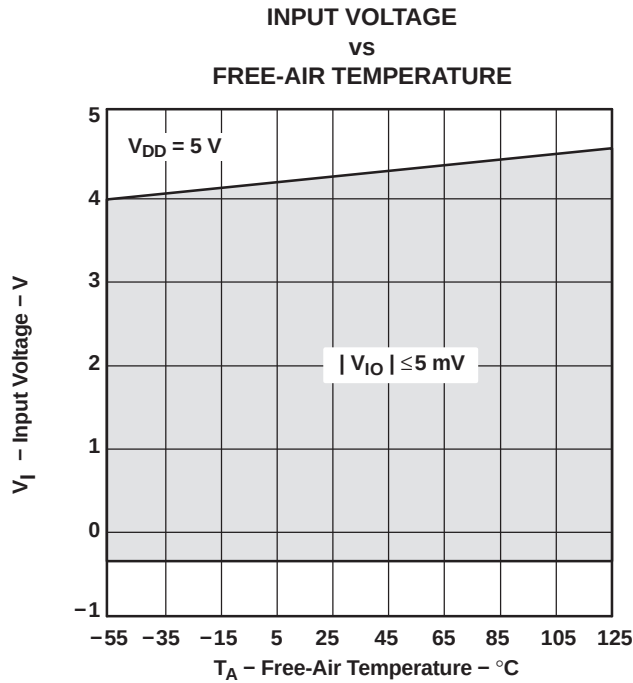


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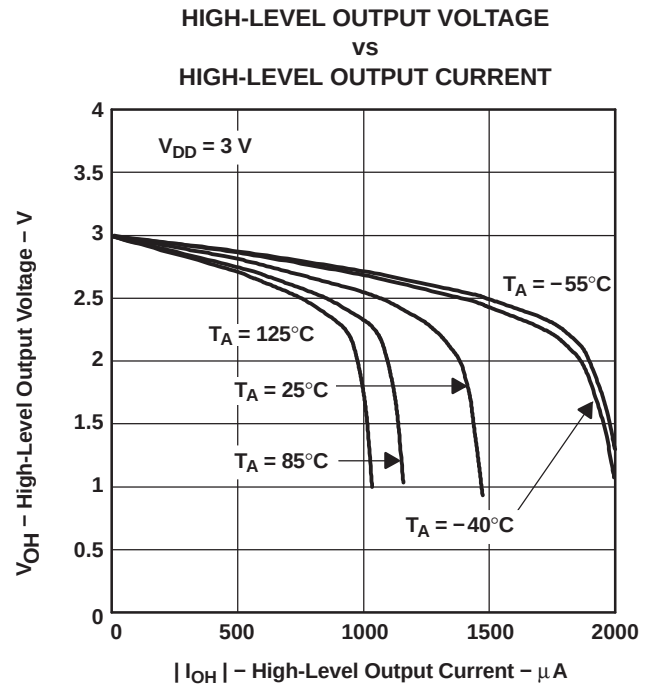


Figure 15.

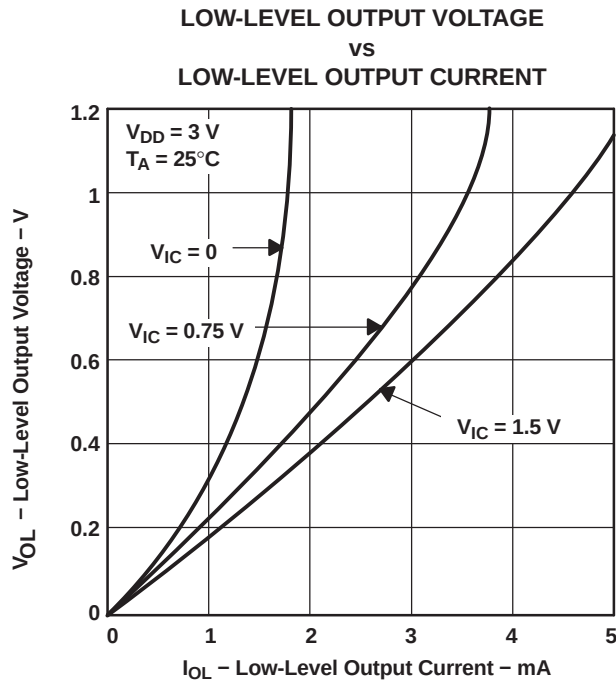


Figure 16.

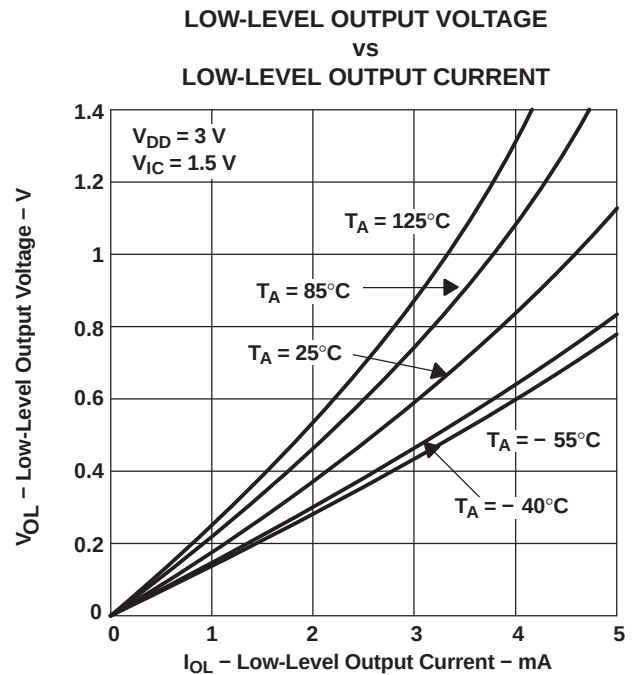
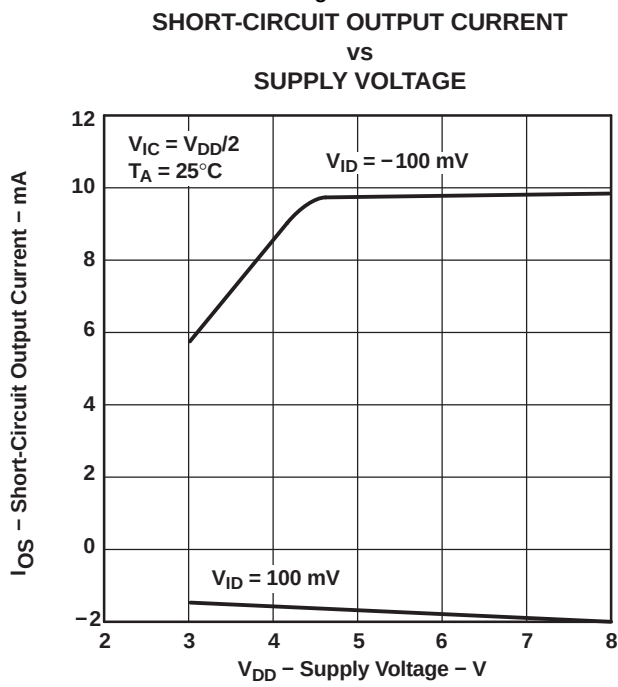
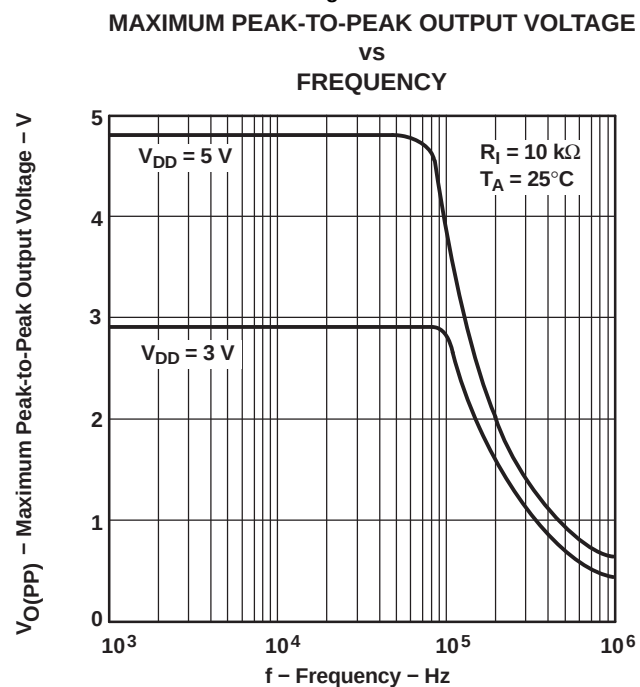
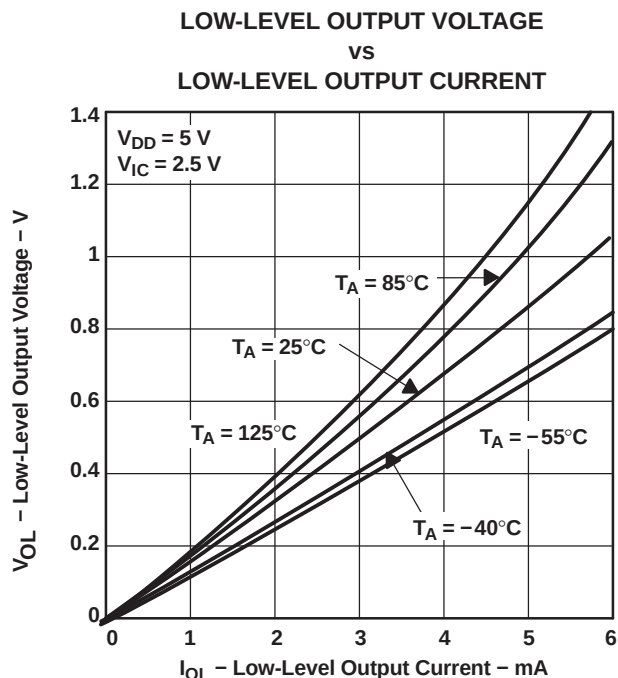
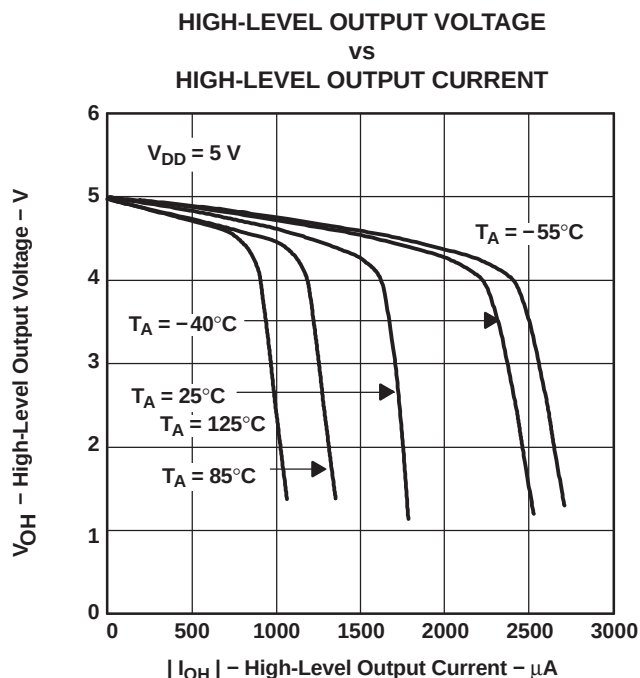


Figure 17.



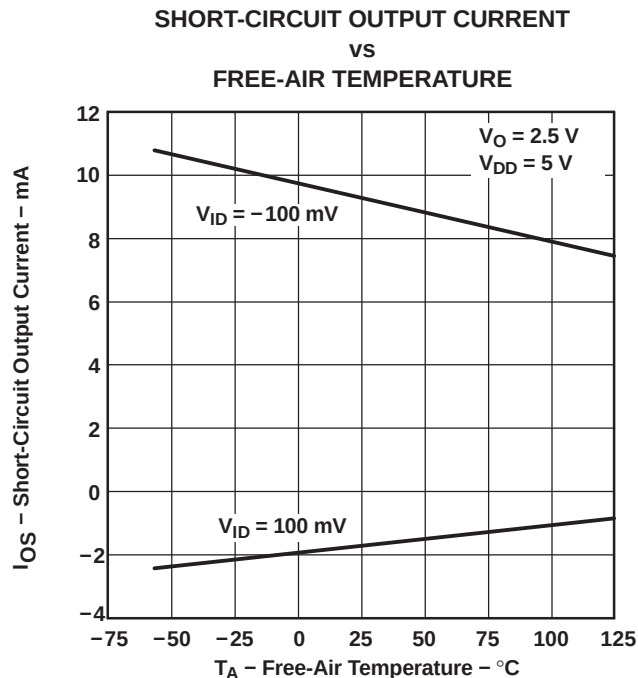


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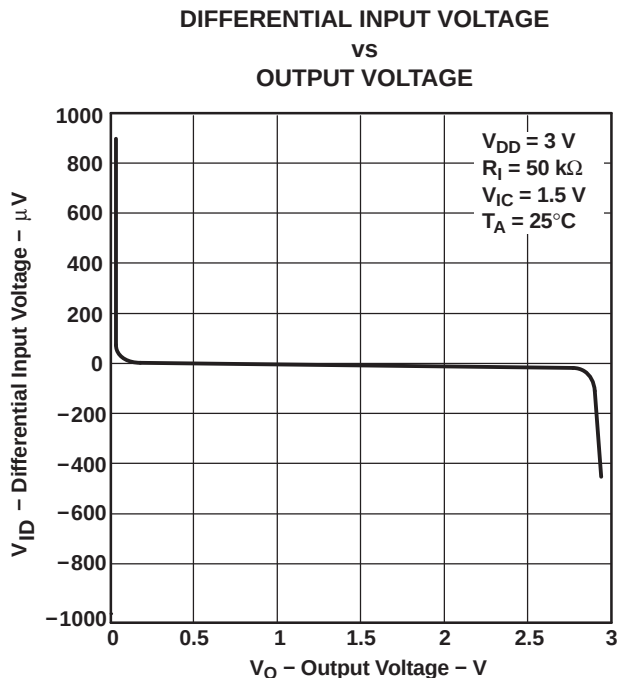


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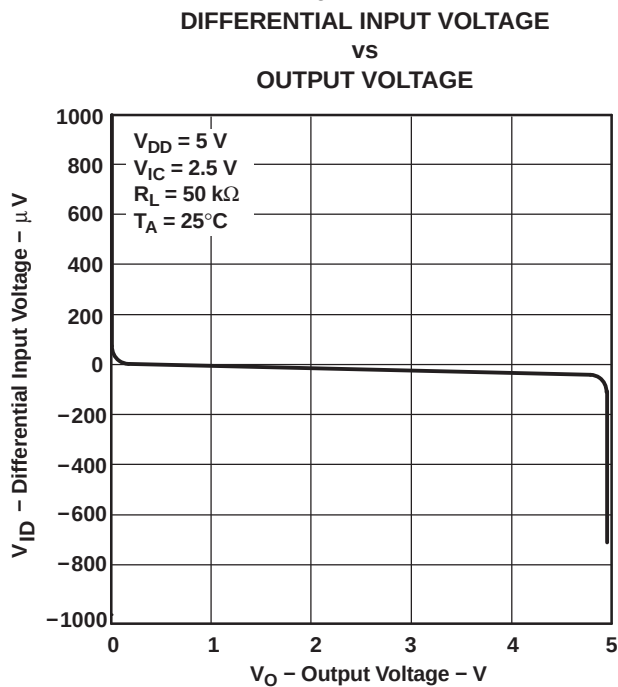


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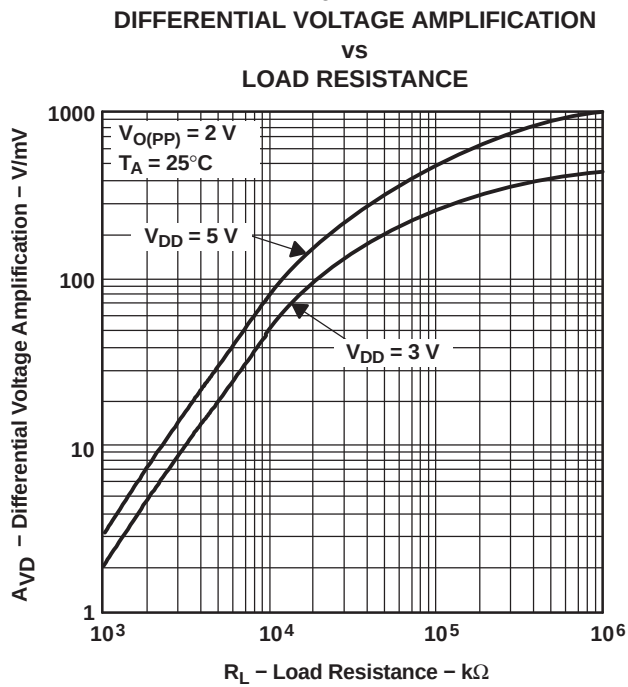


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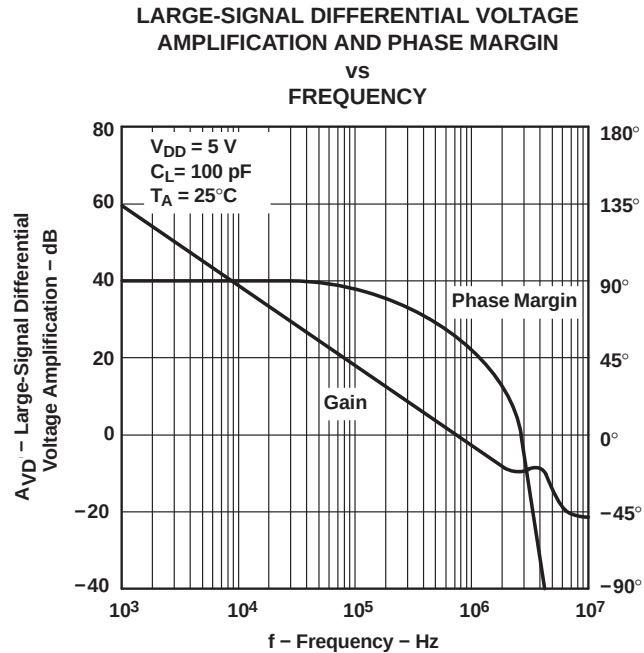


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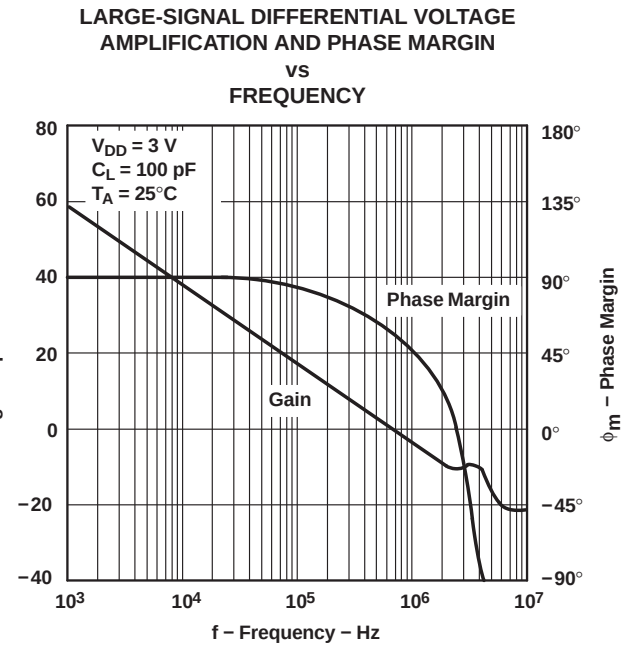


Figure 27.

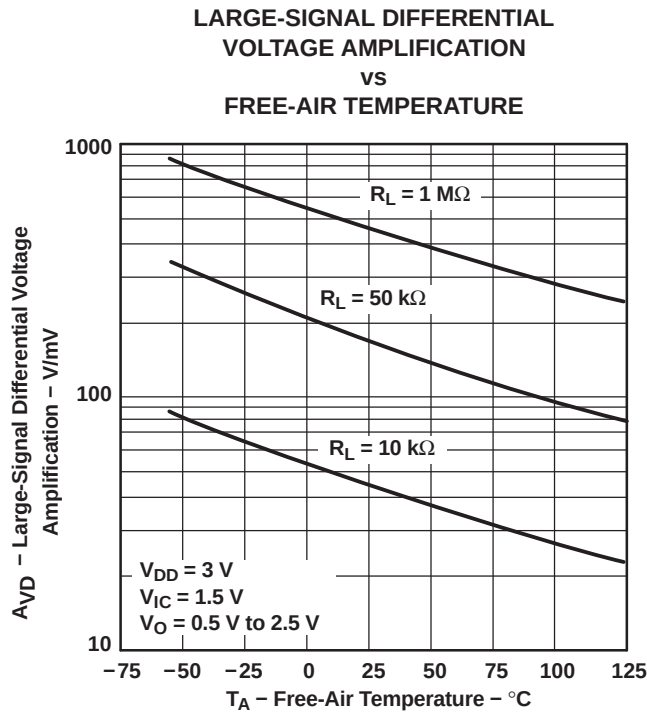


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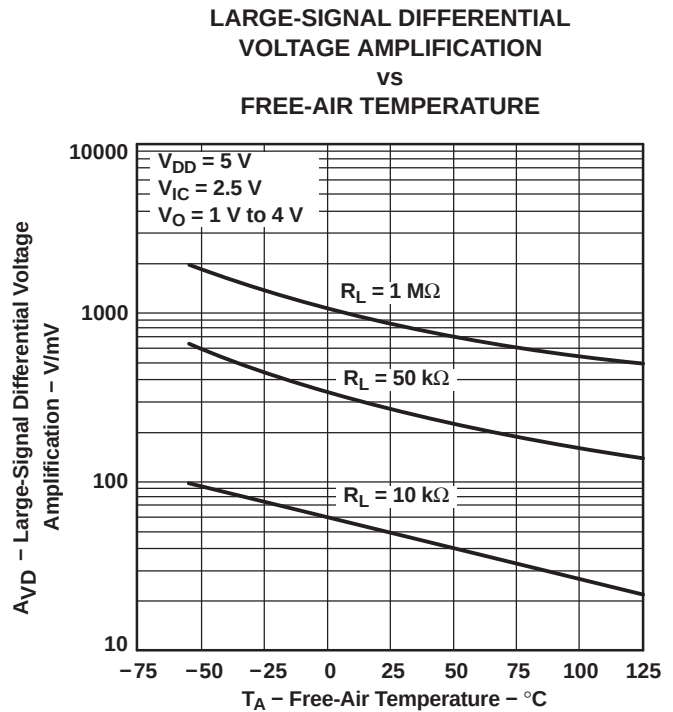


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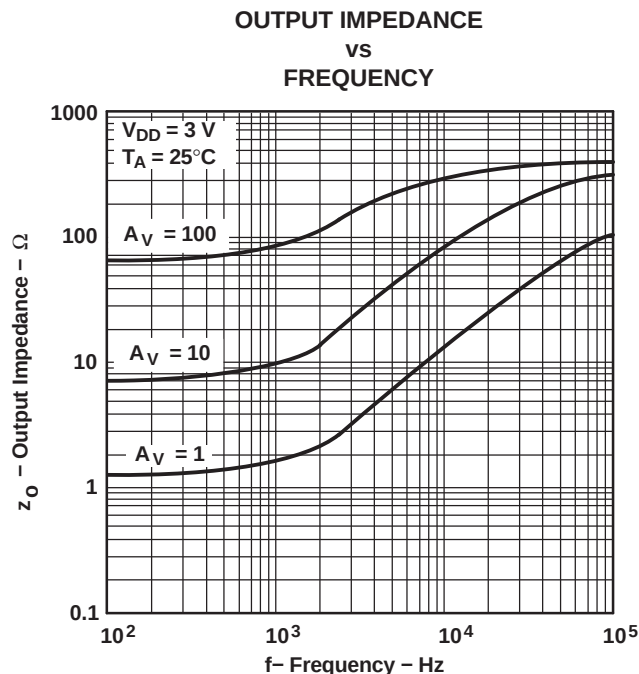


Figure 30.

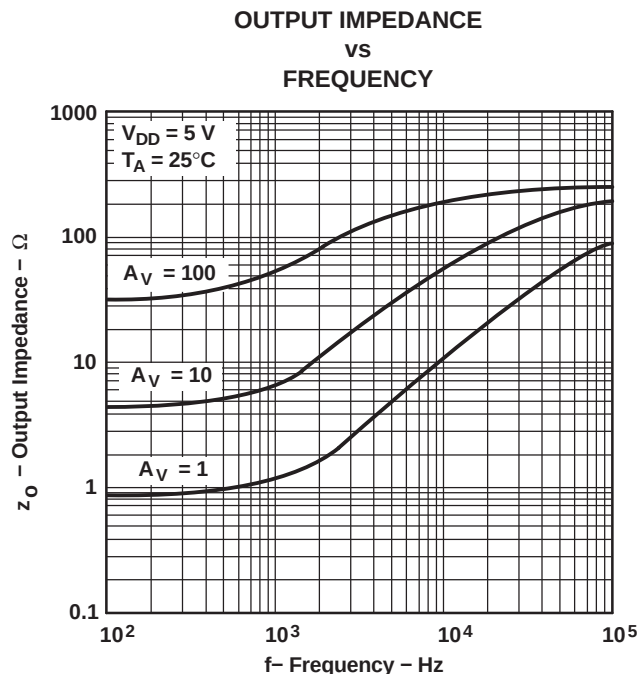


Figure 31.

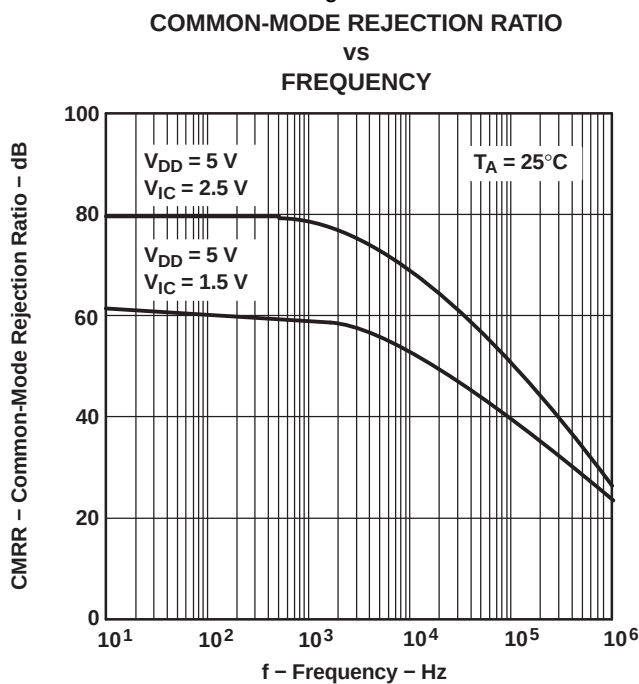


Figure 32.

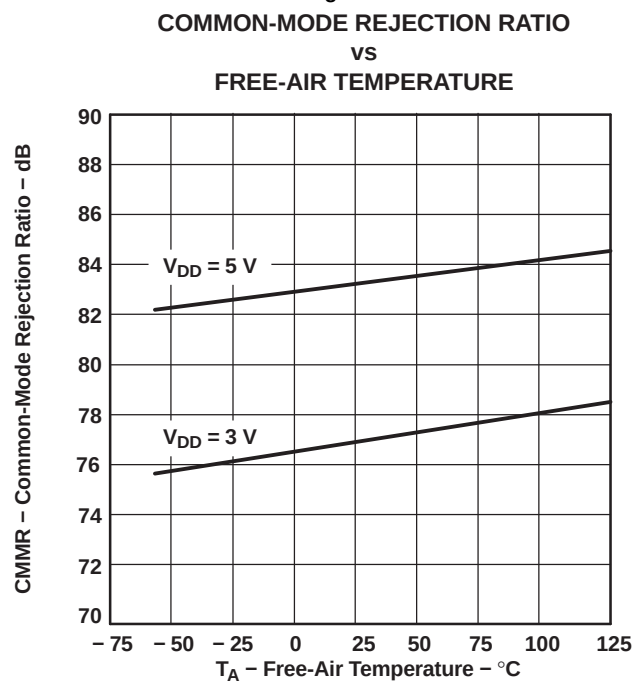
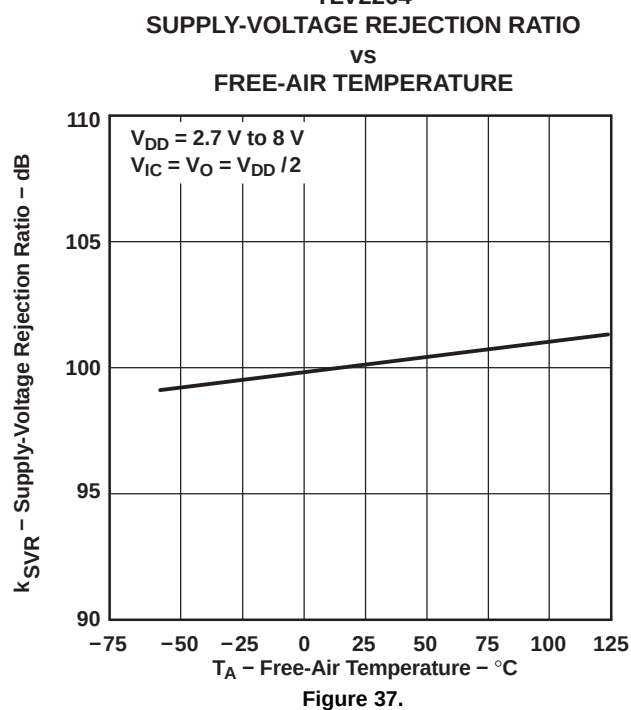
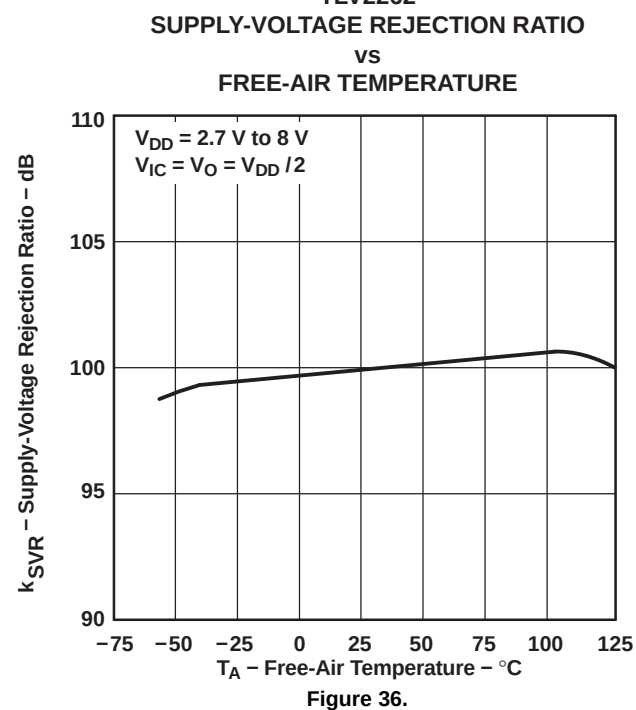
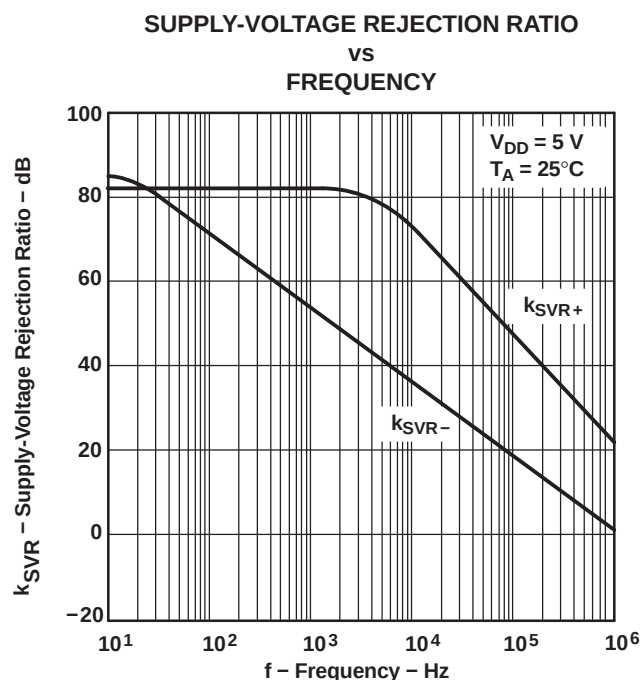
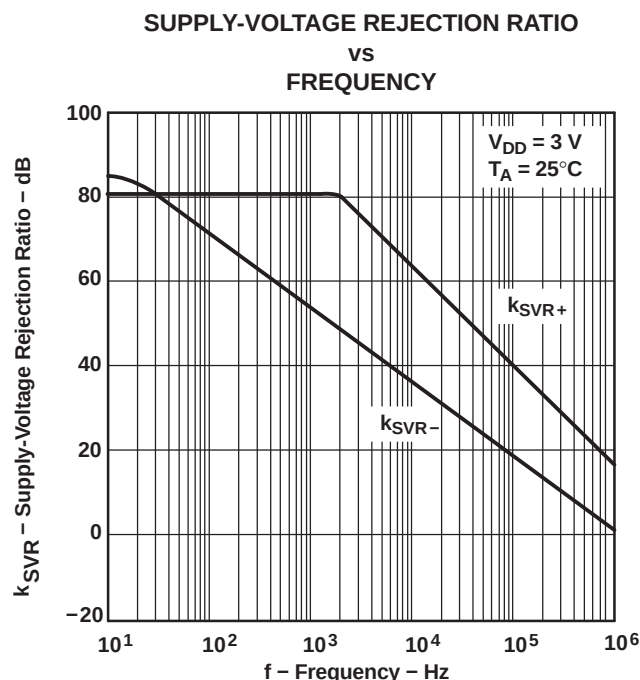


Figure 33.



**TLV2262  
SUPPLY CURRENT  
VS  
FREE-AIR TEMPERATURE**

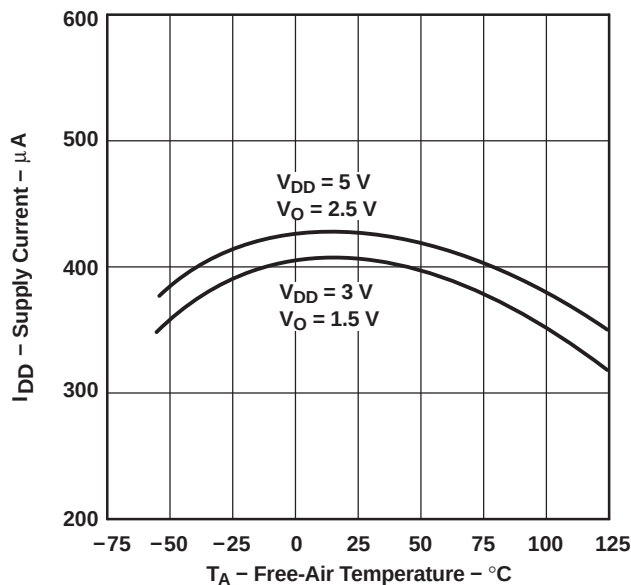


Figure 38.

**TLV2264  
SUPPLY CURRENT  
VS  
FREE-AIR TEMPERATURE**

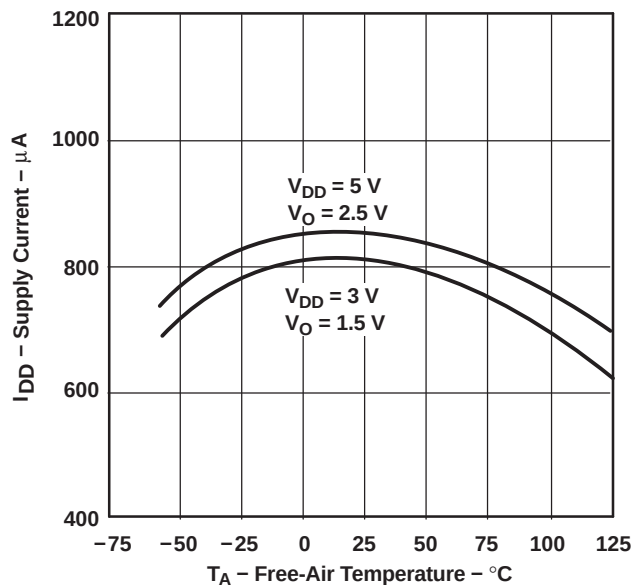


Figure 39.

**SLEW RATE  
VS  
LOAD CAPACITANCE**

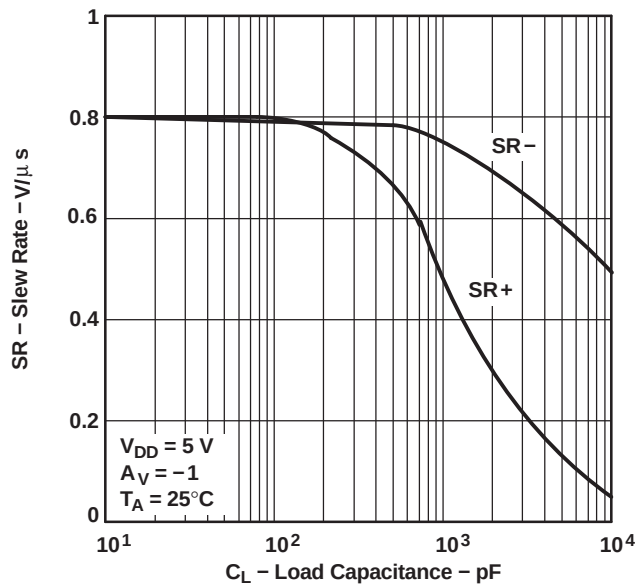


Figure 40.

**SLEW RATE  
VS  
FREE-AIR TEMPERATURE**

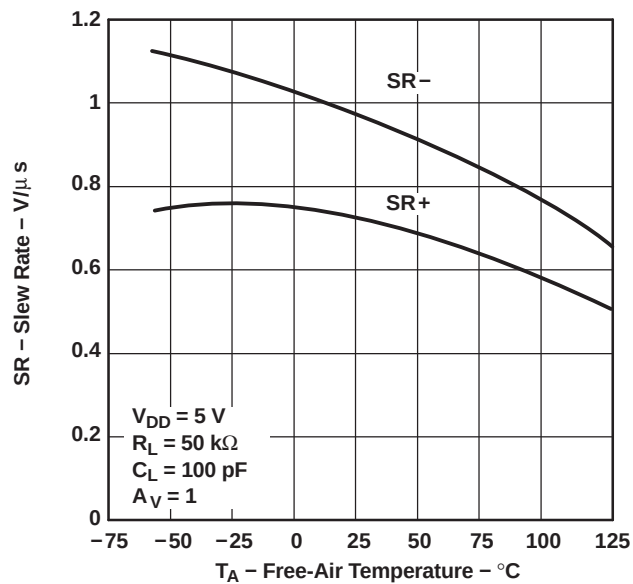


Figure 41.

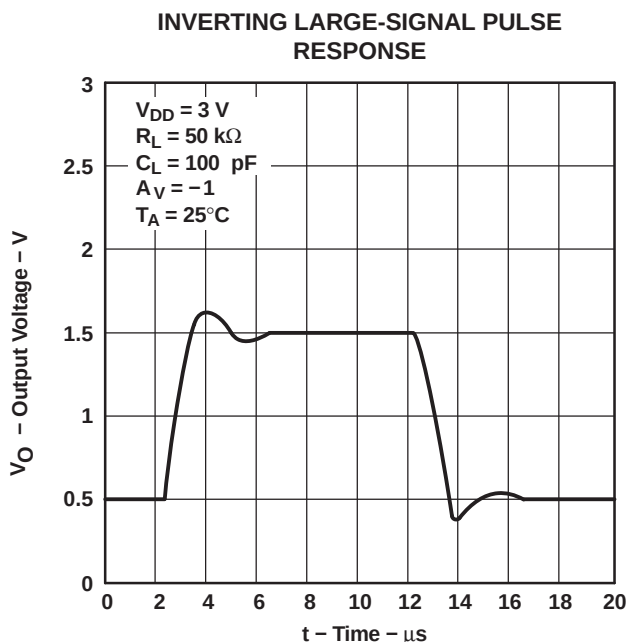


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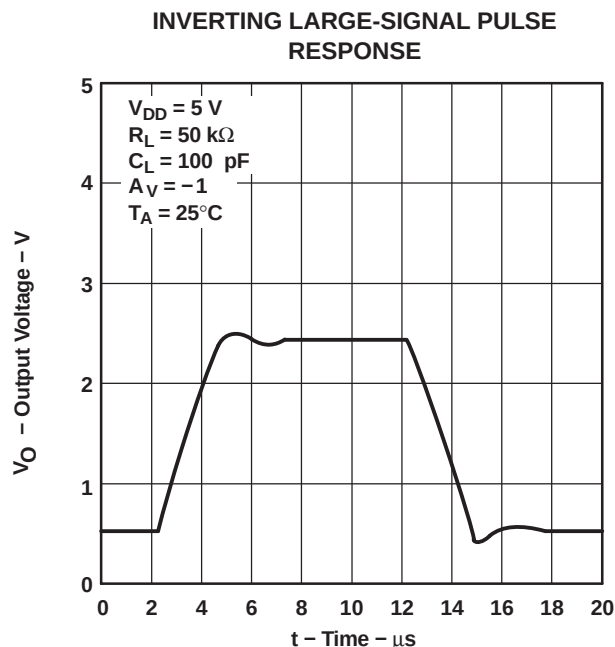


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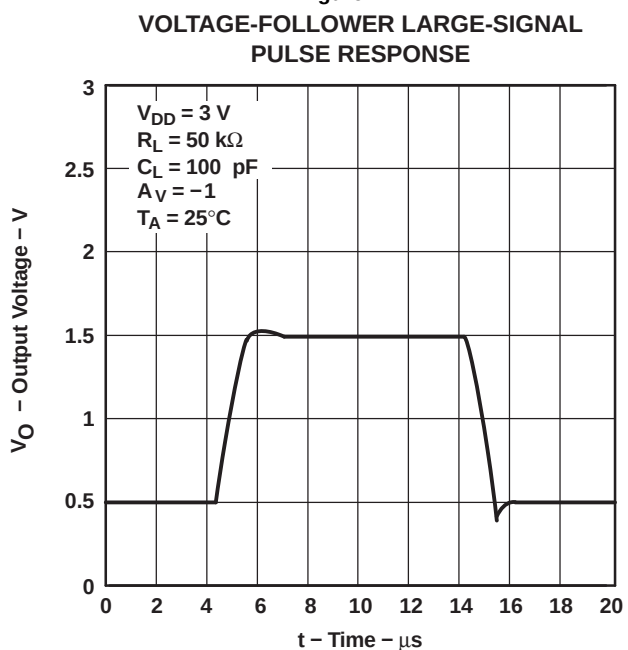


Figure 44.

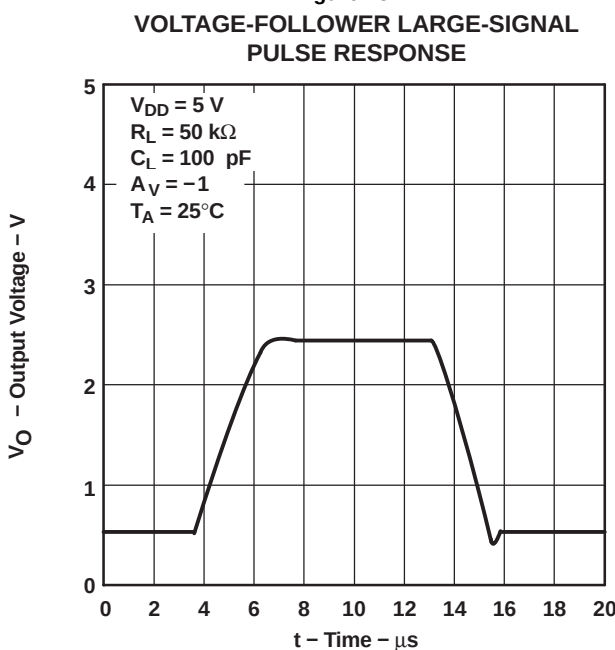


Figure 45.



**INVERTING SMALL-SIGNAL  
PULSE RESPONSE**

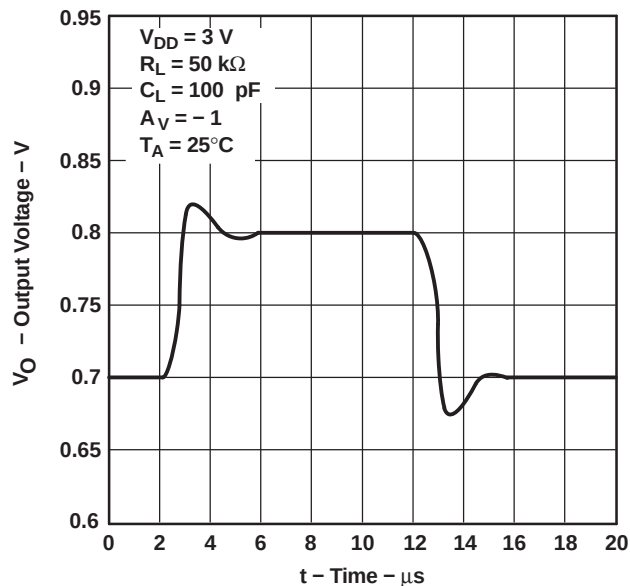


Figure 46.

**INVERTING SMALL-SIGNAL  
PULSE RESPONSE**

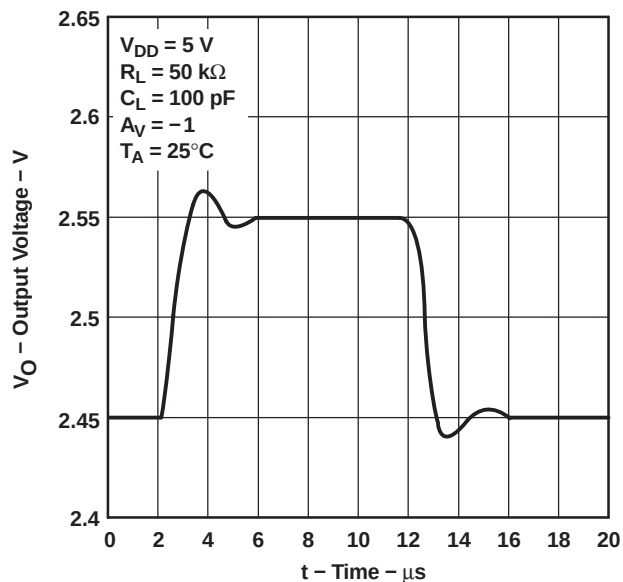


Figure 47.

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

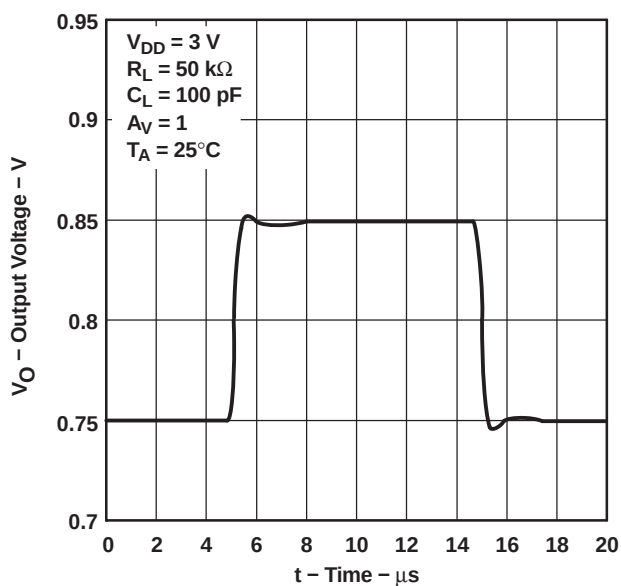


Figure 48.

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

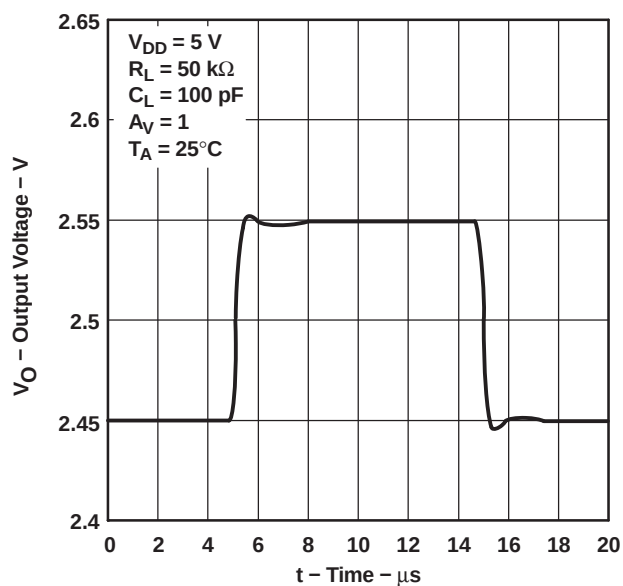


Figure 49.

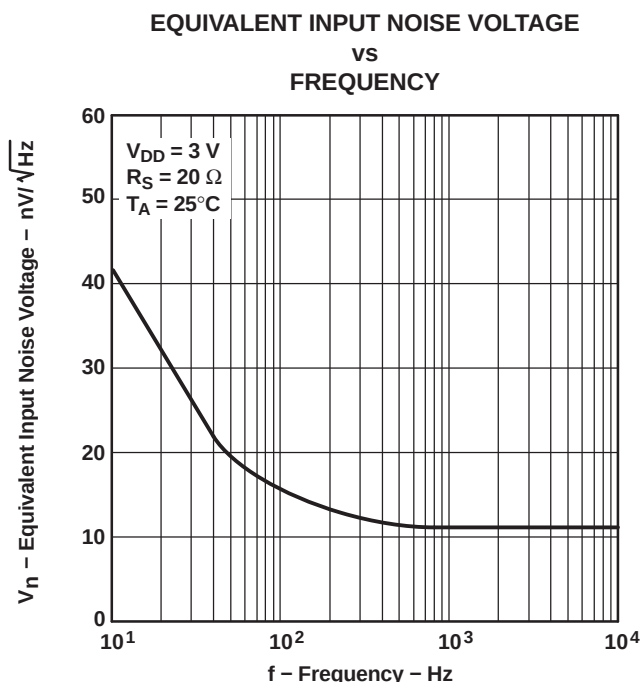


Figure 50.

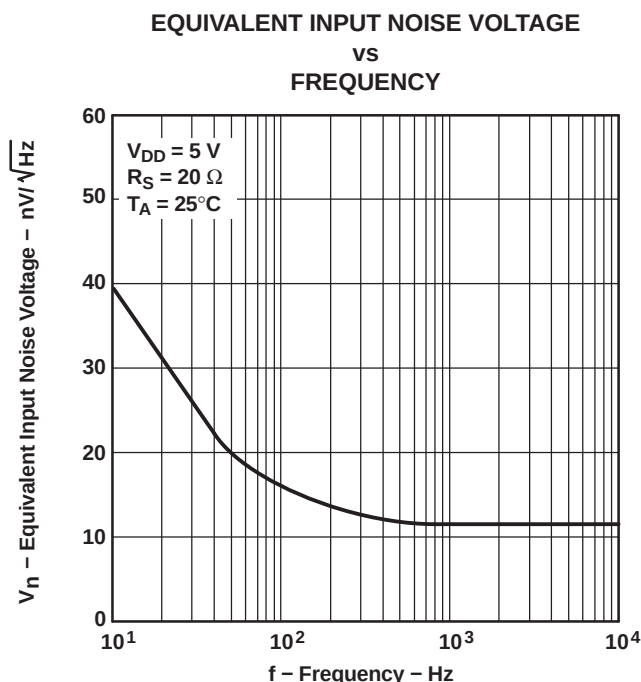


Figure 51.

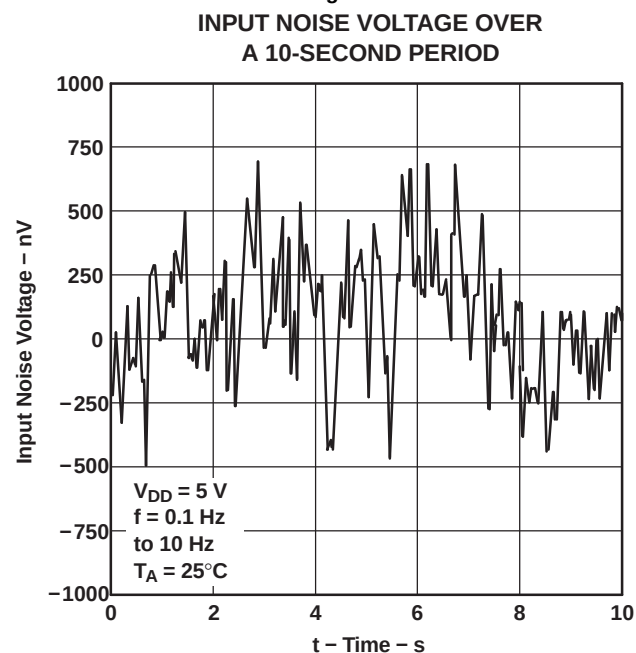


Figure 52.

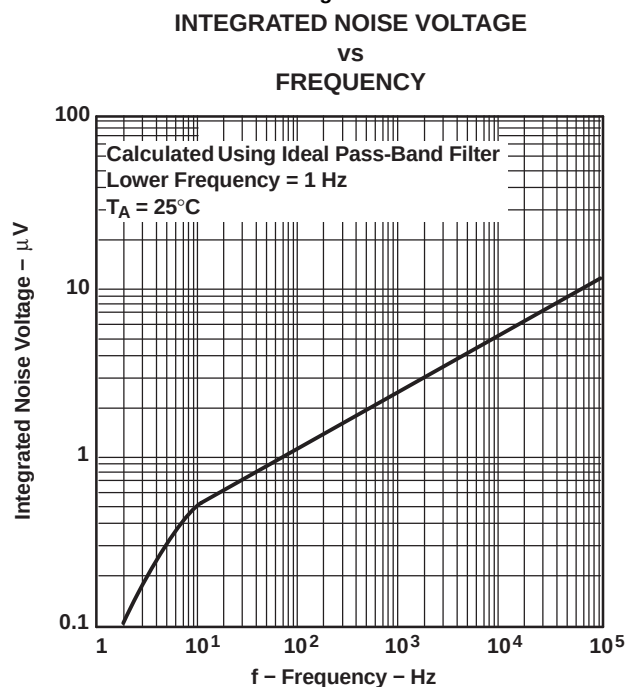
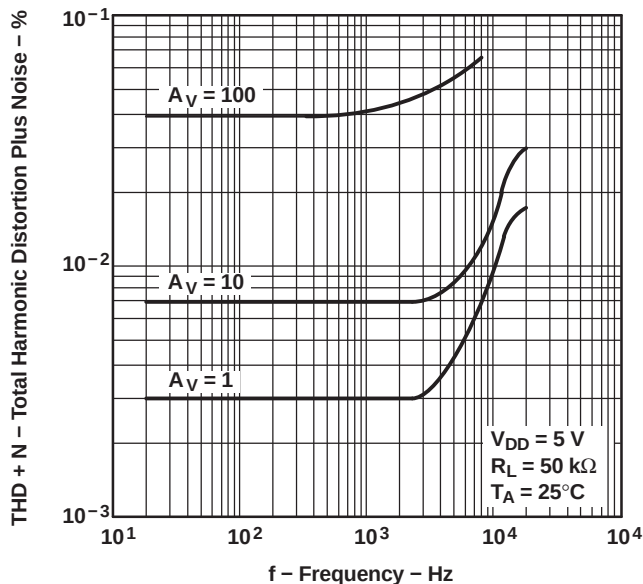
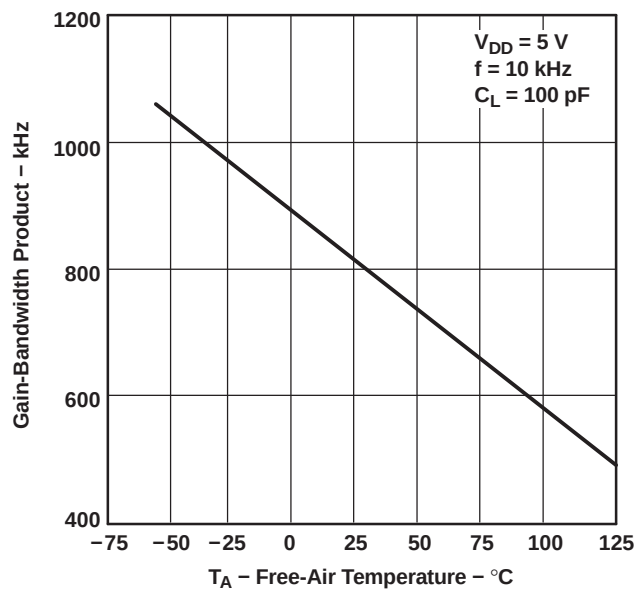


Figure 53.

**TOTAL HARMONIC DISTORTION PLUS NOISE  
VS  
FREQUENCY**

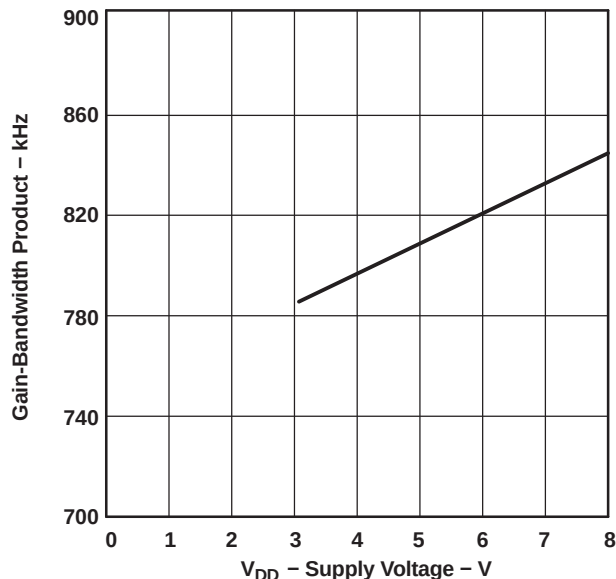


**Figure 54.**  
**GAIN-BANDWIDTH PRODUCT  
VS  
FREE-AIR TEMPERATURE**



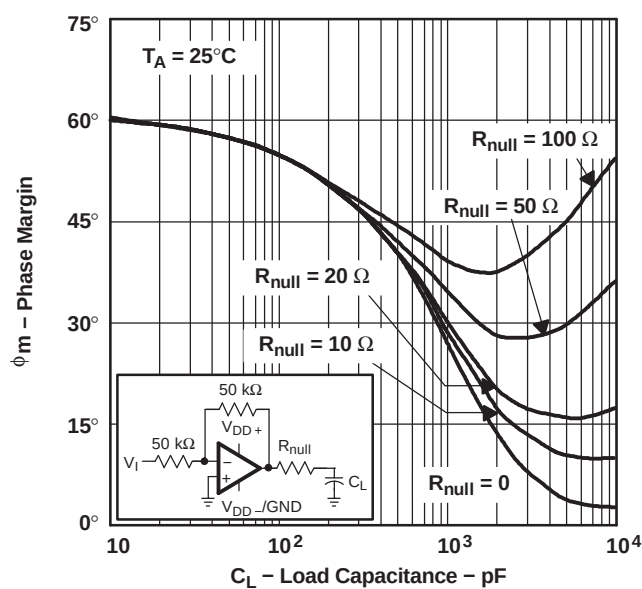
**Figure 56.**

**GAIN-BANDWIDTH PRODUCT  
VS  
SUPPLY VOLTAGE**



**Figure 55.**

**PHASE MARGIN  
VS  
LOAD CAPACITANCE**



**Figure 57.**

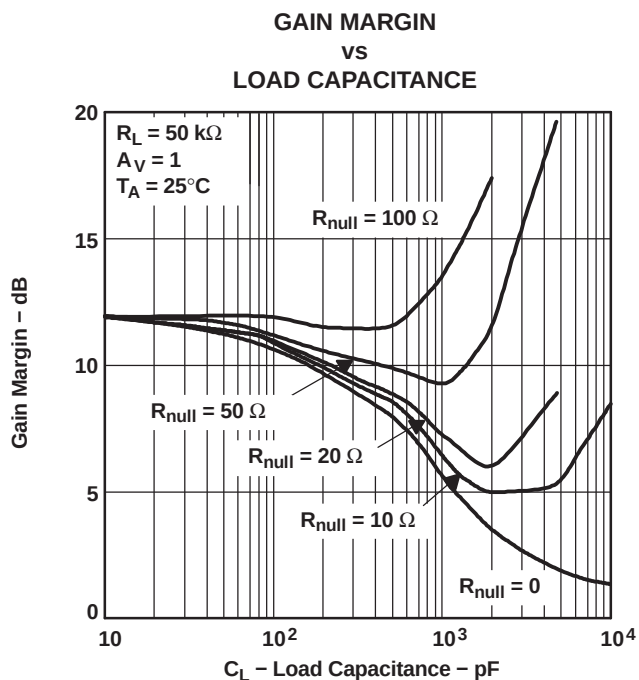


Figure 58.

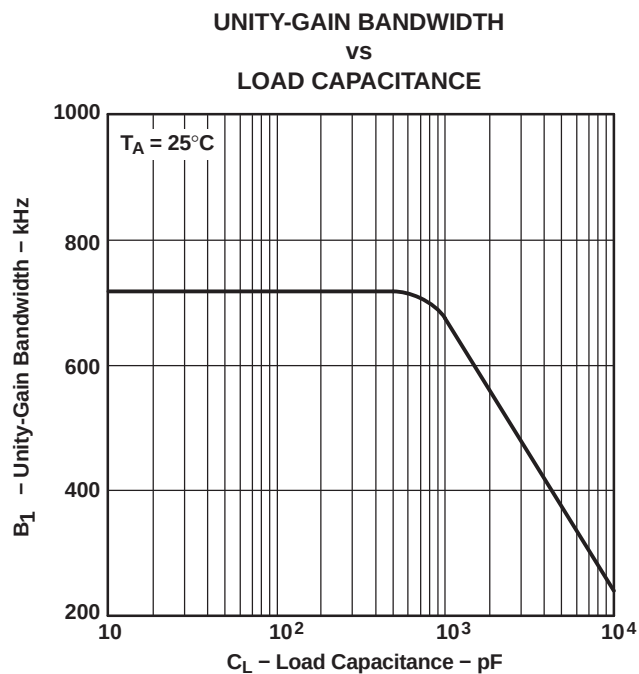
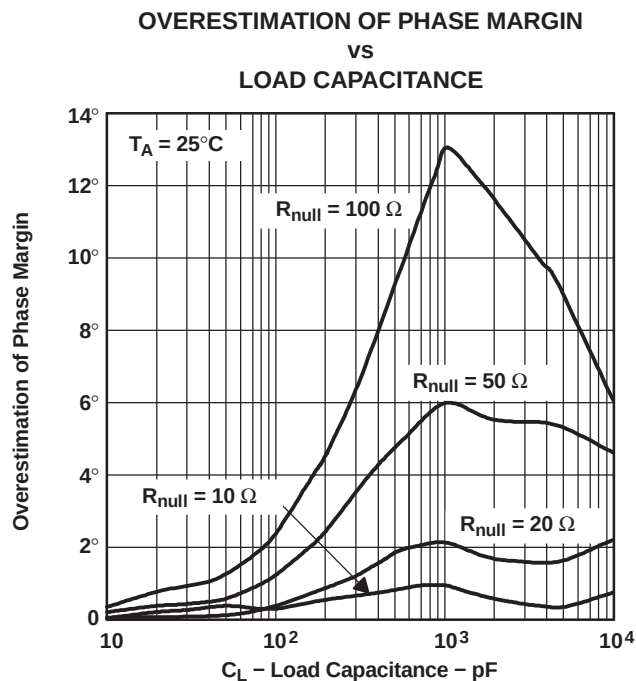


Figure 59.



NOTE: See application information.

Figure 60.

## APPLICATION INFORMATION

### Driving Large Capacitive Loads

The TLV226x is designed to drive larger capacitive loads than most CMOS operational amplifiers. Figure 51 and Figure 52 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 61) improves the gain and phase margins when driving large capacitive loads. Figure 51 and Figure 52 show the effects of adding series resistances of 10  $\Omega$ , 20  $\Omega$ , 50  $\Omega$ , and 100  $\Omega$ . 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.

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

Where :

$\Delta\theta_{m1}$  = improvement in phase margin

UGBW = unity-gain bandwidth frequency

$R_{null}$  = output series resistance

$C_L$  = load capacitance

(1)

The unity-gain bandwidth (UGBW) frequency decreases as the capacitive load increases (see Figure 53). To use Equation 1, UGBW must be approximated from Figure 53.

Using Equation 1 alone overestimates the improvement in phase margin as illustrated in Figure 60. The overestimation is caused by the decrease in the frequency of the pole associated with the load, 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.

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

Where :

F = factor reducing frequency of pole

$g_m$  = small-signal output transconductance (typically  $4.83 \times 10^{-3}$  mhos)

$R_{null}$  = output series resistance

(2)

For the TLV226x, 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 (see 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 1 to better approximate the improvement in phase margin.

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

Where :

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

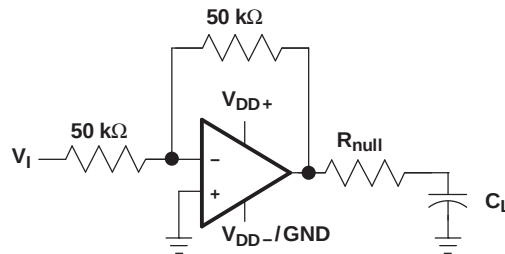
UGBW = unity-gain bandwidth frequency

F = factor from equation (2)

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

(3)

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 61. Series-Resistance Circuit**

## Macromodel Information

Macromodel information provided was derived using Microsim Parts™, the model generation software used with Microsim PSpice™. The Boyle macromodel<sup>(1)</sup> and subcircuit in [Figure 62](#) are generated using the TLV226x 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

(1) 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).

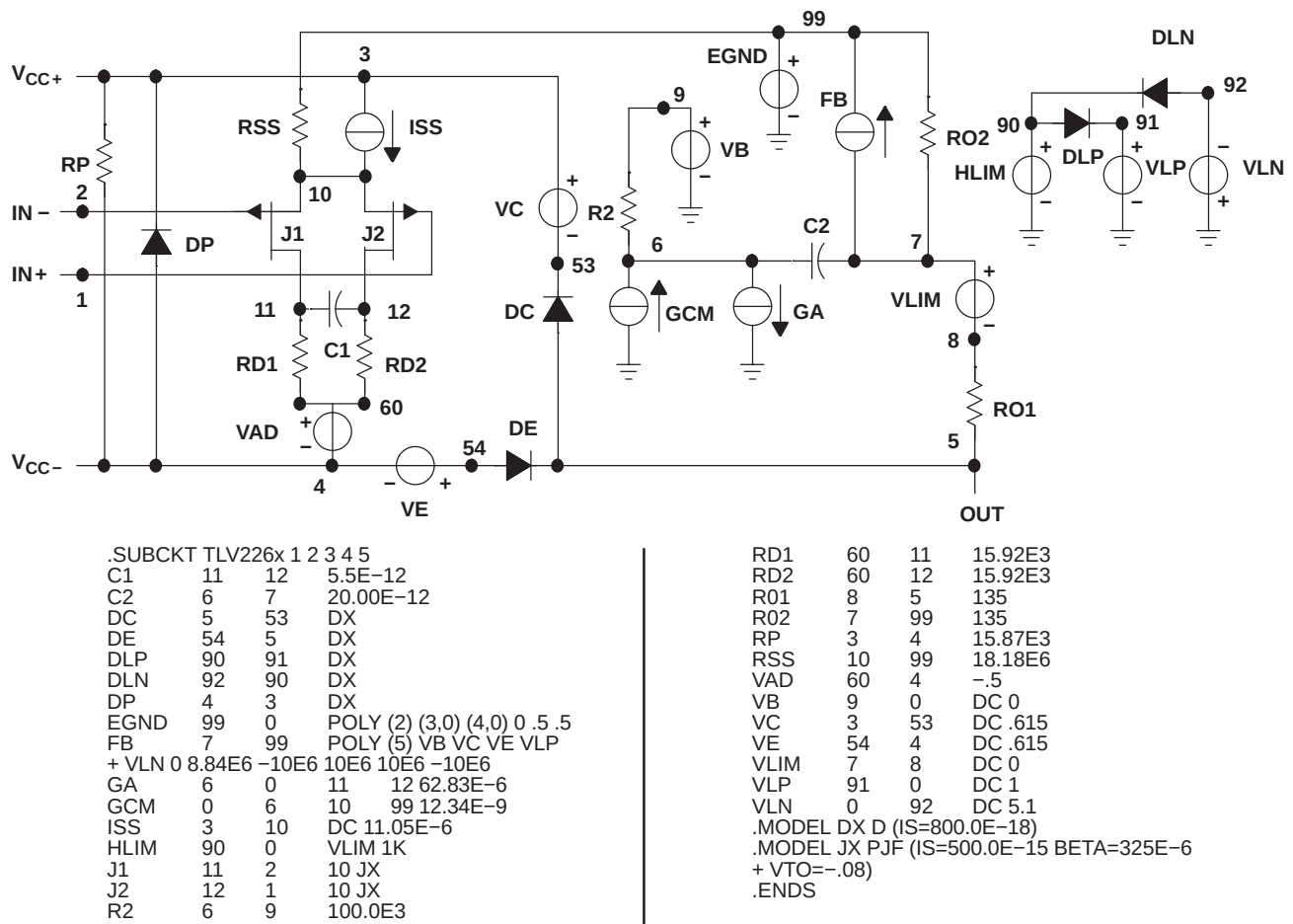


Figure 62. Boyle Macromodel and Subcircuit

## PACKAGING INFORMATION

| Orderable Device | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package<br>Qty | Eco Plan<br>(2)            | Lead/Ball Finish<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples                 |
|------------------|---------------|--------------|--------------------|------|----------------|----------------------------|-------------------------|----------------------|--------------|-------------------------|-------------------------|
| TLV2262AQPWRQ1   | ACTIVE        | TSSOP        | PW                 | 8    | 2000           | Green (RoHS<br>& no Sb/Br) | NIPDAU                  | Level-1-260C-UNLIM   | -40 to 125   | TQ262A                  | <a href="#">Samples</a> |
| TLV2264AQPWRQ1   | ACTIVE        | TSSOP        | PW                 | 14   | 2000           | Green (RoHS<br>& no Sb/Br) | NIPDAU                  | Level-1-260C-UNLIM   | -40 to 125   | P2264AQ                 | <a href="#">Samples</a> |

(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) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

**RoHS Exempt:** TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

**Green:** TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

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

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

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

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

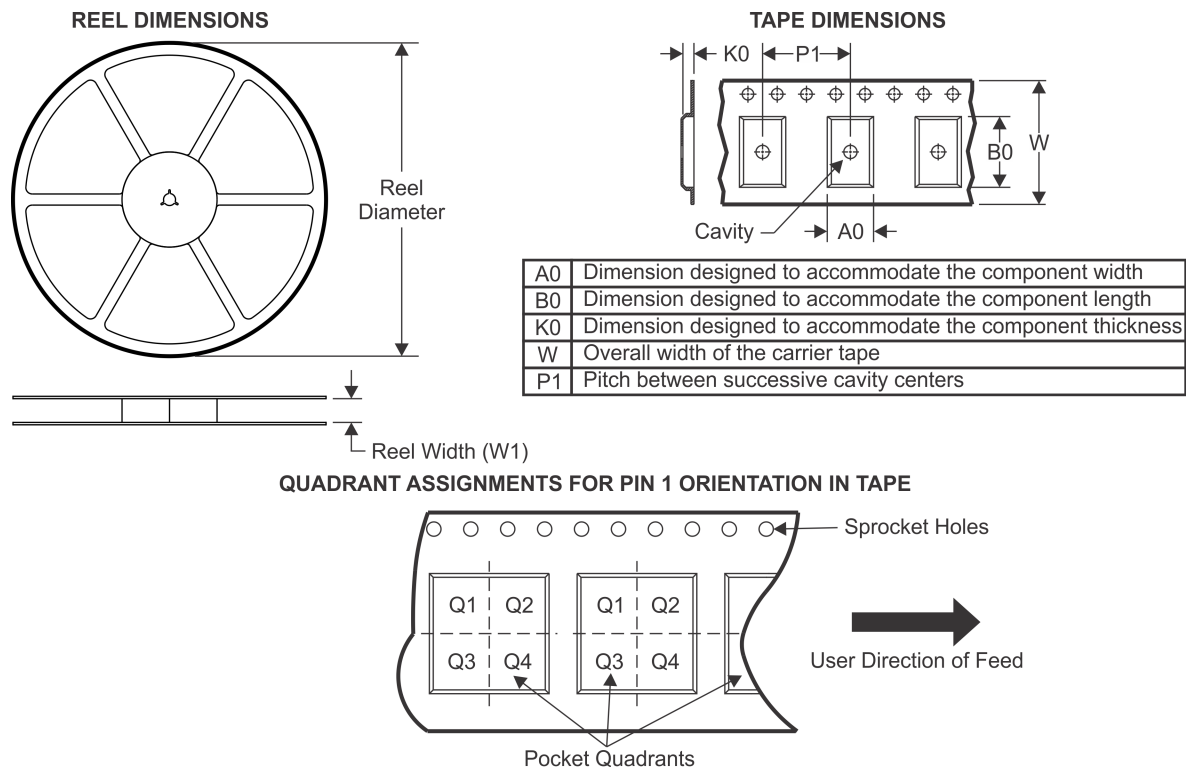


**OTHER QUALIFIED VERSIONS OF TLV2262A-Q1, TLV2264A-Q1 :**

- Catalog: [TLV2262A](#), [TLV2264A](#)
- Military: [TLV2262AM](#), [TLV2264AM](#)

**NOTE:** Qualified Version Definitions:

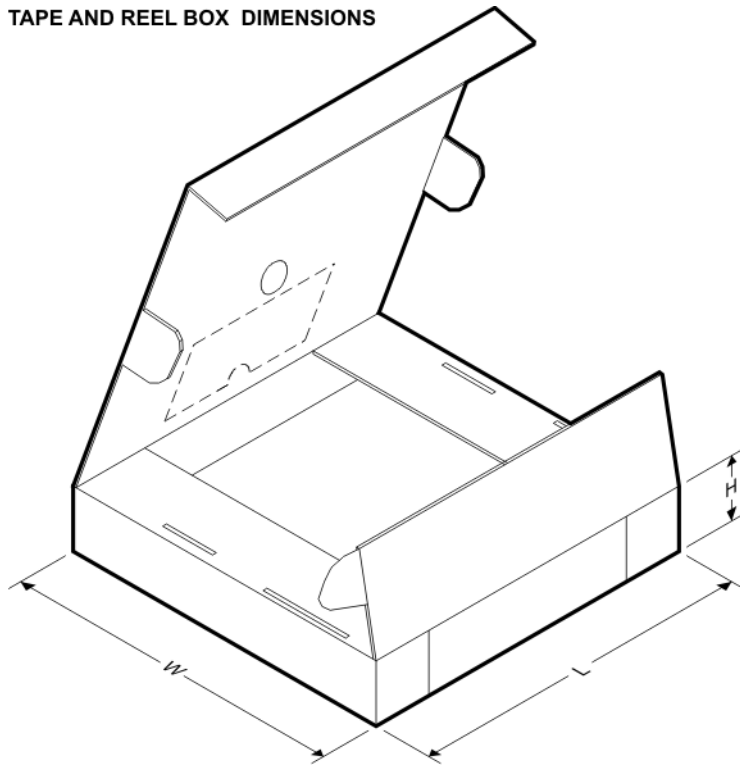
- Catalog - TI's standard catalog product
- Military - QML certified for Military and Defense Applications

**TAPE AND REEL INFORMATION**


\*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 |
|----------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TLV2262AQPWRQ1 | TSSOP        | PW              | 8    | 2000 | 330.0              | 12.4               | 7.0     | 3.6     | 1.6     | 8.0     | 12.0   | Q1            |
| TLV2264AQPWRQ1 | TSSOP        | PW              | 14   | 2000 | 330.0              | 12.4               | 6.9     | 5.6     | 1.6     | 8.0     | 12.0   | Q1            |

## TAPE AND REEL BOX DIMENSIONS

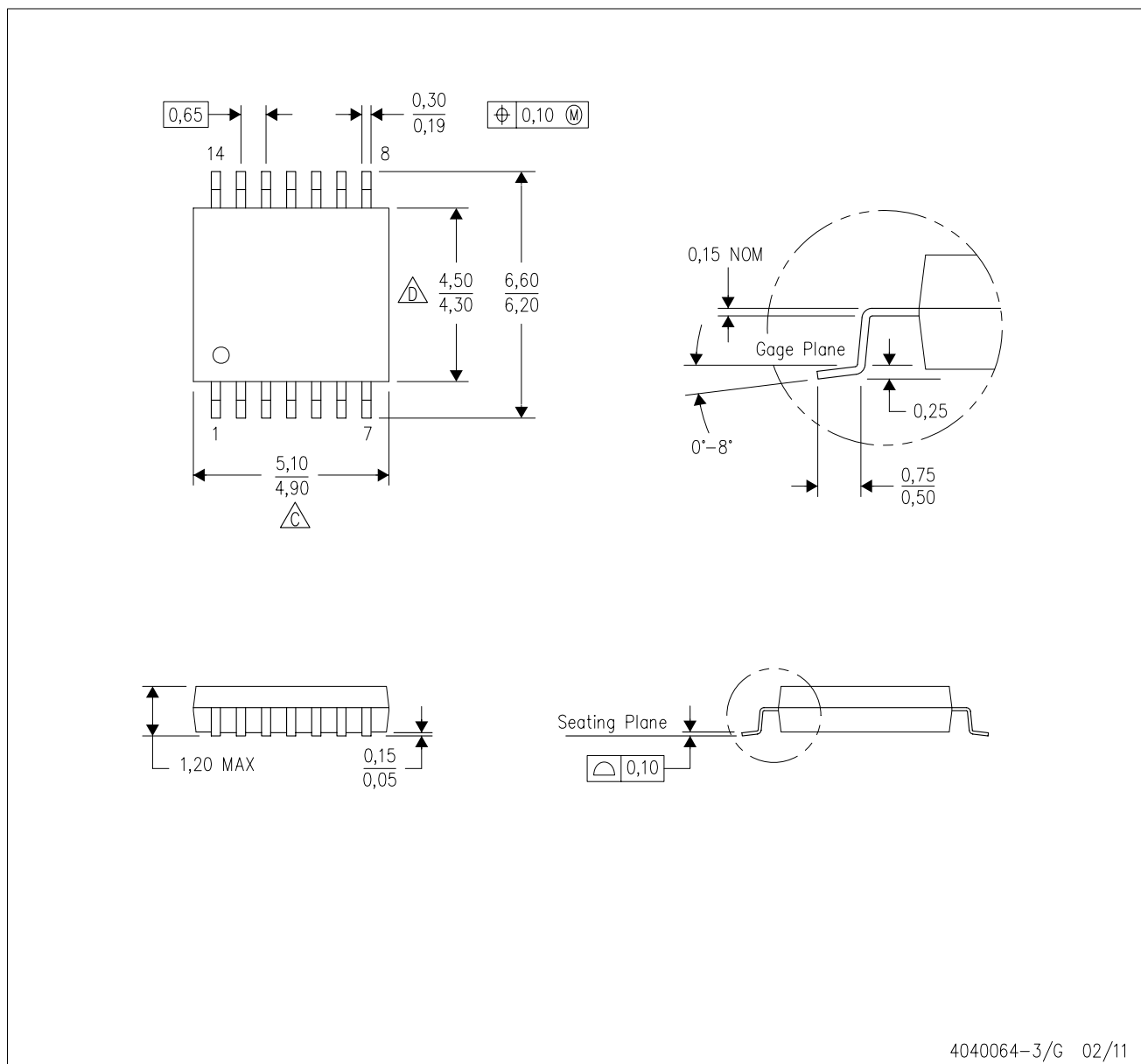


\*All dimensions are nominal

| Device         | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|----------------|--------------|-----------------|------|------|-------------|------------|-------------|
| TLV2262AQPWRQ1 | TSSOP        | PW              | 8    | 2000 | 367.0       | 367.0      | 35.0        |
| TLV2264AQPWRQ1 | TSSOP        | PW              | 14   | 2000 | 367.0       | 367.0      | 35.0        |

PW (R-PDSO-G14)

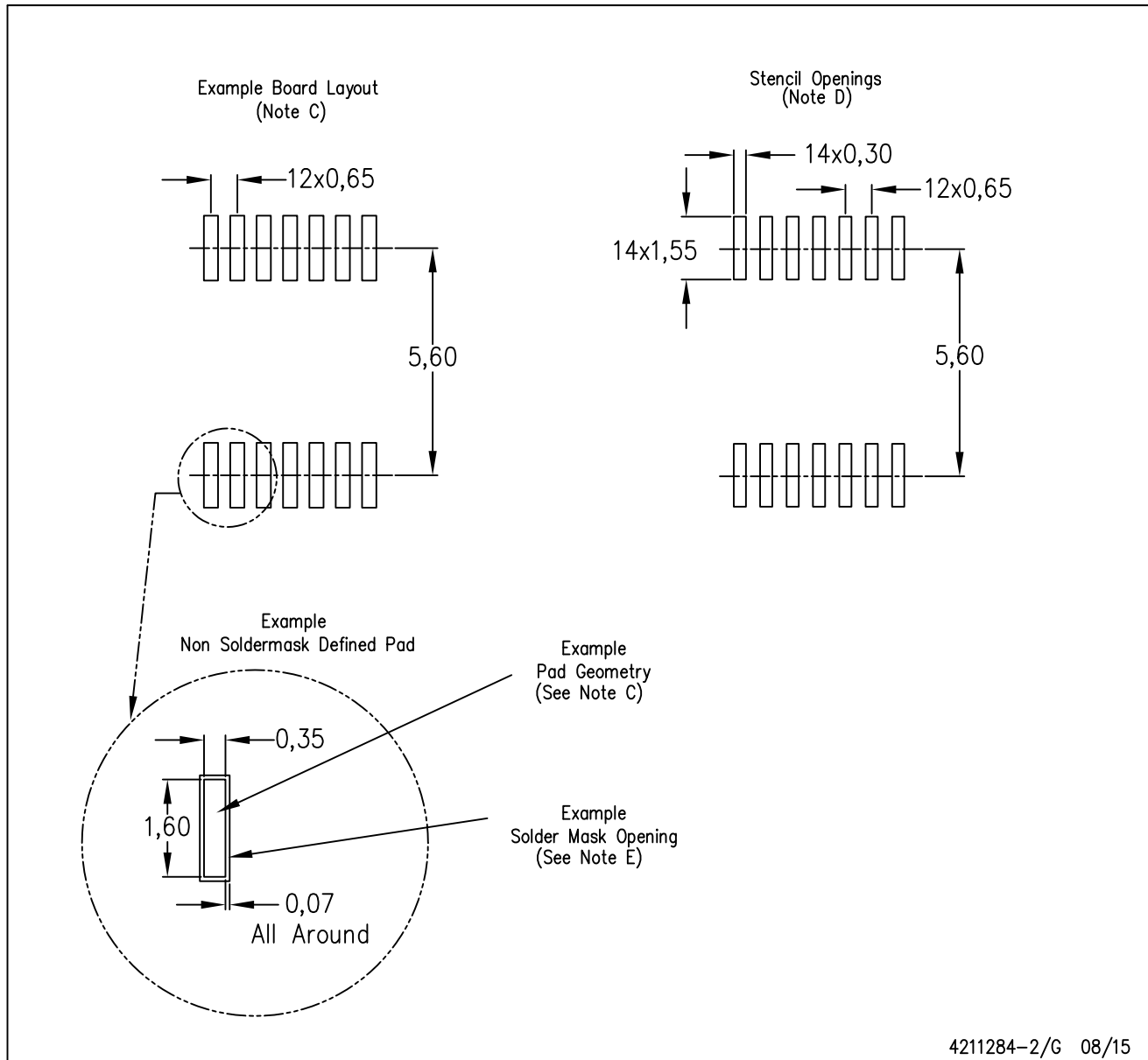
PLASTIC SMALL OUTLINE



4040064-3/G 02/11

PW (R-PDSO-G14)

PLASTIC SMALL OUTLINE



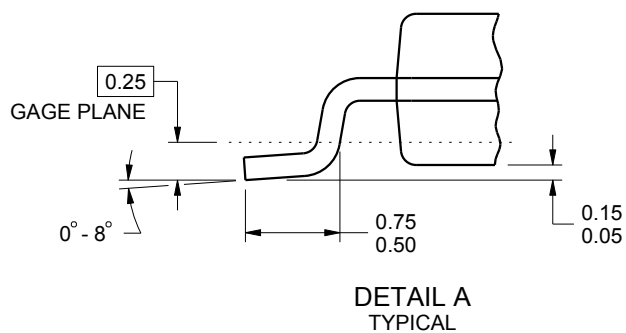
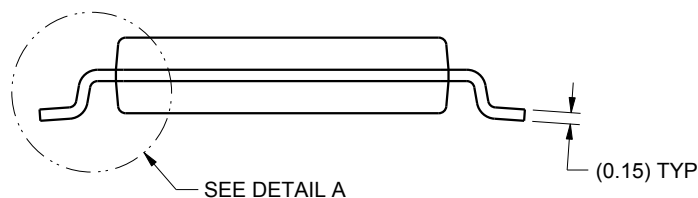
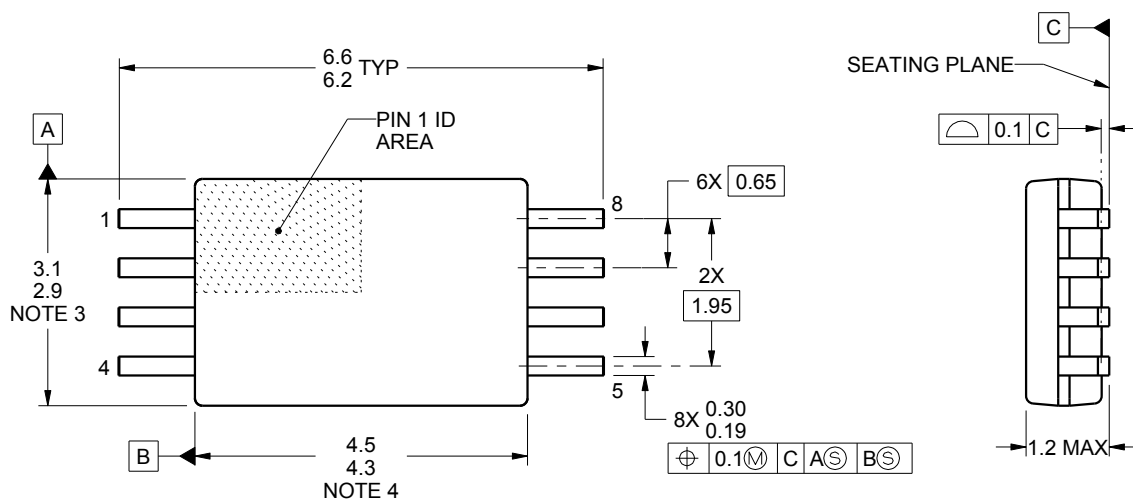
- NOTES:
- All linear dimensions are in millimeters.
  - This drawing is subject to change without notice.
  - Publication IPC-7351 is recommended for alternate designs.
  - Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
  - Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.



## PACKAGE OUTLINE

## TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



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NOTES:

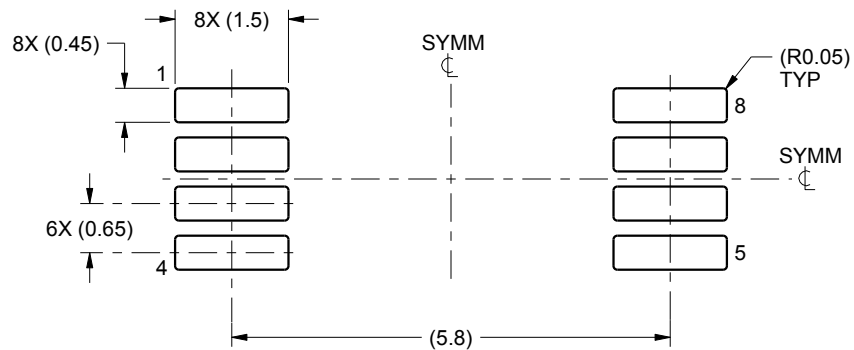
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or 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.

# EXAMPLE BOARD LAYOUT

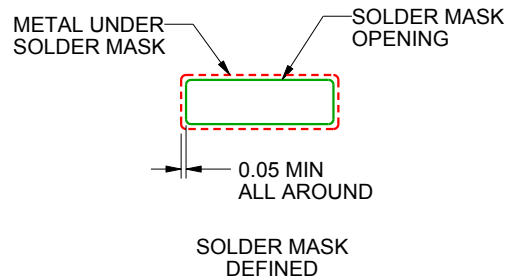
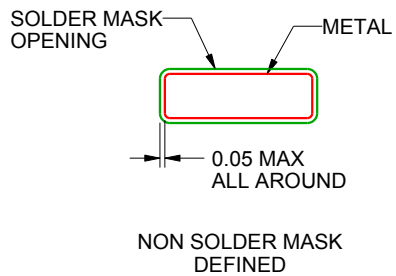
PW0008A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE  
SCALE:10X



SOLDER MASK DETAILS  
NOT TO SCALE

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NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

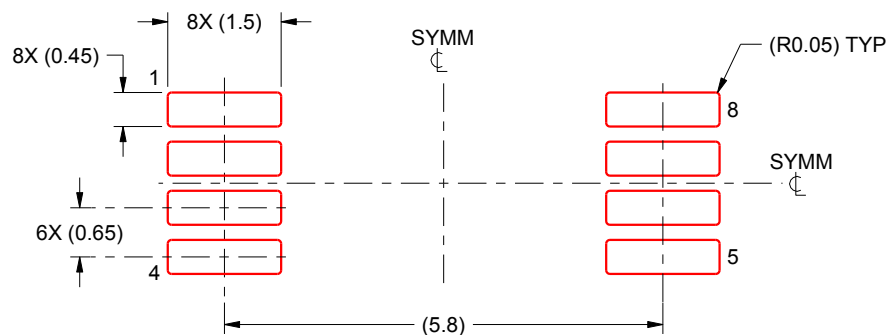
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

## EXAMPLE STENCIL DESIGN

PW0008A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



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

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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.



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