

# TLC225x Advanced LinCMOS™ RAIL-TO-RAIL VERY LOW-POWER OPERATIONAL AMPLIFIERS

SLOS176A – FEBRUARY 1997 – REVISED JULY 1999

- **Output Swing Includes Both Supply Rails**
- **Low Noise . . . 19 nV/√Hz Typ at f = 1 kHz**
- **Low Input Bias Current . . . 1 pA Typ**
- **Fully Specified for Both Single-Supply and Split-Supply Operation**
- **Very Low Power . . . 35 μA Per Channel Typ**
- **Common-Mode Input Voltage Range Includes Negative Rail**
- **Low Input Offset Voltage**  
850 μV Max at T<sub>A</sub> = 25°C (TLC225xA)
- **Macromodel Included**
- **Performance Upgrades for the TS27L2/L4 and TLC27L2/L4**
- **Available in Q-Temp Automotive HighRel Automotive Applications Configuration Control / Print Support Qualification to Automotive Standards**

## description

The TLC2252 and TLC2254 are dual and quadruple operational amplifiers from Texas Instruments. Both devices exhibit rail-to-rail output performance for increased dynamic range in single- or split-supply applications. The TLC225x family consumes only 35 μA of supply current per channel. This micropower operation makes them good choices for battery-powered applications. The noise performance has been dramatically improved over previous generations of CMOS amplifiers. Looking at Figure 1, the TLC225x has a noise level of 19 nV/√Hz at 1kHz; four times lower than competitive micropower solutions.

The TLC225x amplifiers, exhibiting high input impedance and low noise, are excellent for small-signal conditioning for high-impedance sources, such as piezoelectric transducers. Because of the micropower dissipation levels, these devices work well in hand-held monitoring and remote-sensing applications. In addition, the rail-to-rail output feature with single or split supplies makes this family a great choice when interfacing with analog-to-digital converters (ADCs). For precision applications, the TLC225xA family is available and has a maximum input offset voltage of 850 μV. This family is fully characterized at 5 V and ±5 V.

The TLC2252/4 also makes great upgrades to the TLC27L2/L4 or TS27L2/L4 in standard designs. They offer increased output dynamic range, lower noise voltage, and lower input offset voltage. This enhanced feature set allows them to be used in a wider range of applications. For applications that require higher output drive and wider input voltage ranges, see the TLV2432 and TLV2442 devices. If the 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.

EQUIVALENT INPUT NOISE VOLTAGE  
VS  
FREQUENCY

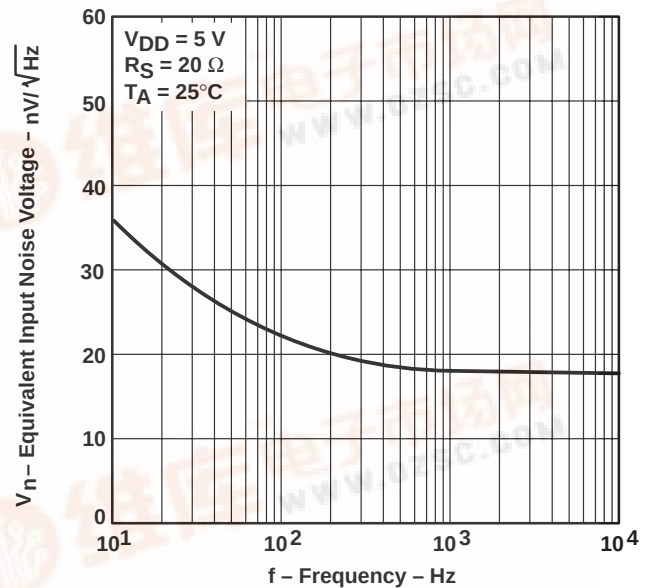


Figure 1

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



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**TLC2252 AVAILABLE OPTIONS**

| T <sub>A</sub> | V <sub>IO</sub> max<br>AT 25°C | PACKAGED DEVICES         |                         |                        |                       |                |                            |
|----------------|--------------------------------|--------------------------|-------------------------|------------------------|-----------------------|----------------|----------------------------|
|                |                                | SMALL<br>OUTLINE†<br>(D) | CHIP<br>CARRIER<br>(FK) | CERAMIC<br>DIP<br>(JG) | PLASTIC<br>DIP<br>(P) | TSSOP‡<br>(PW) | CERAMIC<br>FLATPACK<br>(U) |
| 0°C to 70°C    | 1500 µV                        | TLC2252CD                | —                       | —                      | TLC2252CP             | TLC2252CPWLE   | —                          |
| –40°C to 85°C  | 850 µV                         | TLC2252AID               | —                       | —                      | TLC2252AIP            | TLC2252AIPWLE  | —                          |
|                | 1500 µV                        | TLC2252ID                | —                       | —                      | TLC2252IP             | —              | —                          |
| –40°C to 125°C | 850 µV                         | TLC2252AQD               | —                       | —                      | —                     | —              | —                          |
|                | 1500 µV                        | TLC2252QD                | —                       | —                      | —                     | —              | —                          |
| –55°C to 125°C | 850 µV                         | —                        | TLC2252AMFK             | TLC2252AMJG            | —                     | —              | TLC2252AMU                 |
|                | 1500 µV                        | —                        | TLC2252MFK              | TLC2252MJG             | —                     | —              | TLC2252MU                  |

† The D packages are available taped and reeled. Add R suffix to device type (e.g., TLC2262CDR).

‡ The PW package is available only left-ended taped and reeled.

§ Chip forms are tested at 25°C only.

**TLC2254 AVAILABLE OPTIONS**

| T <sub>A</sub> | V <sub>IO</sub> max<br>AT 25°C | PACKAGED DEVICES         |                         |                       |                    |                |                            |
|----------------|--------------------------------|--------------------------|-------------------------|-----------------------|--------------------|----------------|----------------------------|
|                |                                | SMALL<br>OUTLINE†<br>(D) | CHIP<br>CARRIER<br>(FK) | CERAMIC<br>DIP<br>(J) | PLASTIC DIP<br>(N) | TSSOP‡<br>(PW) | CERAMIC<br>FLATPACK<br>(W) |
| 0°C to 70°C    | 1500 µV                        | TLC2254CD                | —                       | —                     | TLC2254CN          | TLC2254CPWLE   | —                          |
| –40°C to 85°C  | 850 µV                         | TLC2254AID               | —                       | —                     | TLC2254AIN         | TLC2254AIPWLE  | —                          |
|                | 1500 µV                        | TLC2254ID                | —                       | —                     | TLC2254IN          | —              | —                          |
| –40°C to 125°C | 850 µV                         | TLC2254AQD               | —                       | —                     | —                  | —              | —                          |
|                | 1500 µV                        | TLC2254QD                | —                       | —                     | —                  | —              | —                          |
| –55°C to 125°C | 850 µV                         | —                        | TLC2254AMFK             | TLC2254AMJ            | —                  | —              | TLC2254AMW                 |
|                | 1500 µV                        | —                        | TLC2254MFK              | TLC2254MJ             | —                  | —              | TLC2254MW                  |

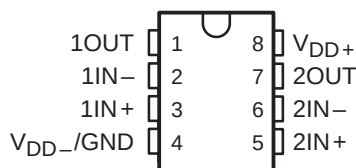
† The D packages are available taped and reeled. Add R suffix to the device type (e.g., TLC2254CDR).

‡ The PW package is available only left-end taped and reeled. Chips are tested at 25°C.

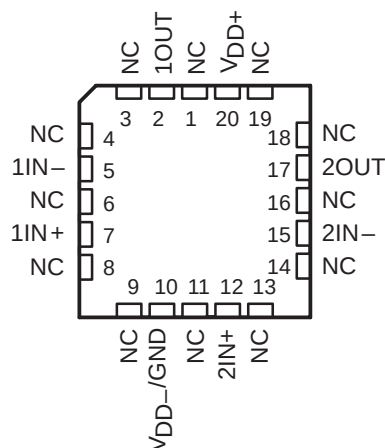
§ Chip forms are tested at 25°C only.

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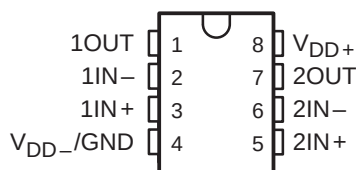
**TLC2252C, TLC2252AC**  
**TLC2252I, TLC2252AI**  
**TLC2252Q, TLC2252AQ**  
**D, P, OR PW PACKAGE**  
**(TOP VIEW)**



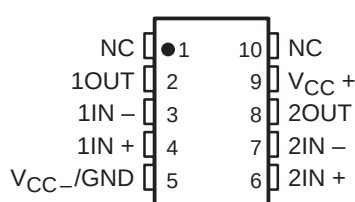
**TLC2252M, TLC2252AM . . . FK PACKAGE**  
**(TOP VIEW)**



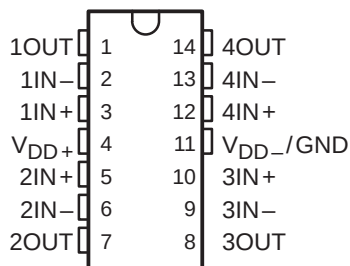
**TLC2252M, TLC2252AM . . . JG PACKAGE**  
**(TOP VIEW)**



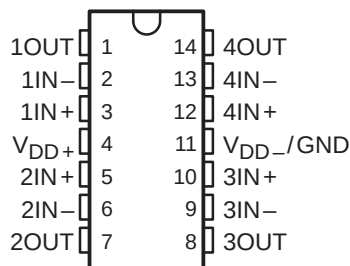
**TLC2262M, TLC2252AM . . . U PACKAGE**  
**(TOP VIEW)**



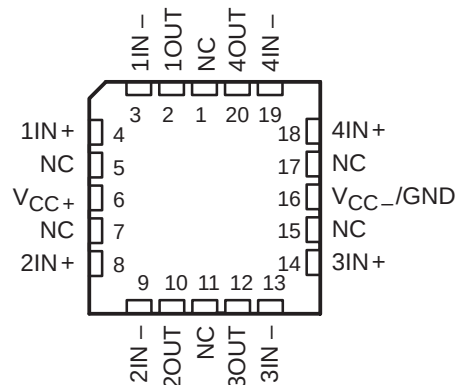
**TLC2254C, TLC2254AC**  
**TLC2254I, TLC2254AI**  
**TLC2254Q, TLC2254AQ**  
**D, N, OR PW PACKAGE**  
**(TOP VIEW)**



**TLC2254M, TLC2254AM**  
**J OR W PACKAGE**  
**(TOP VIEW)**

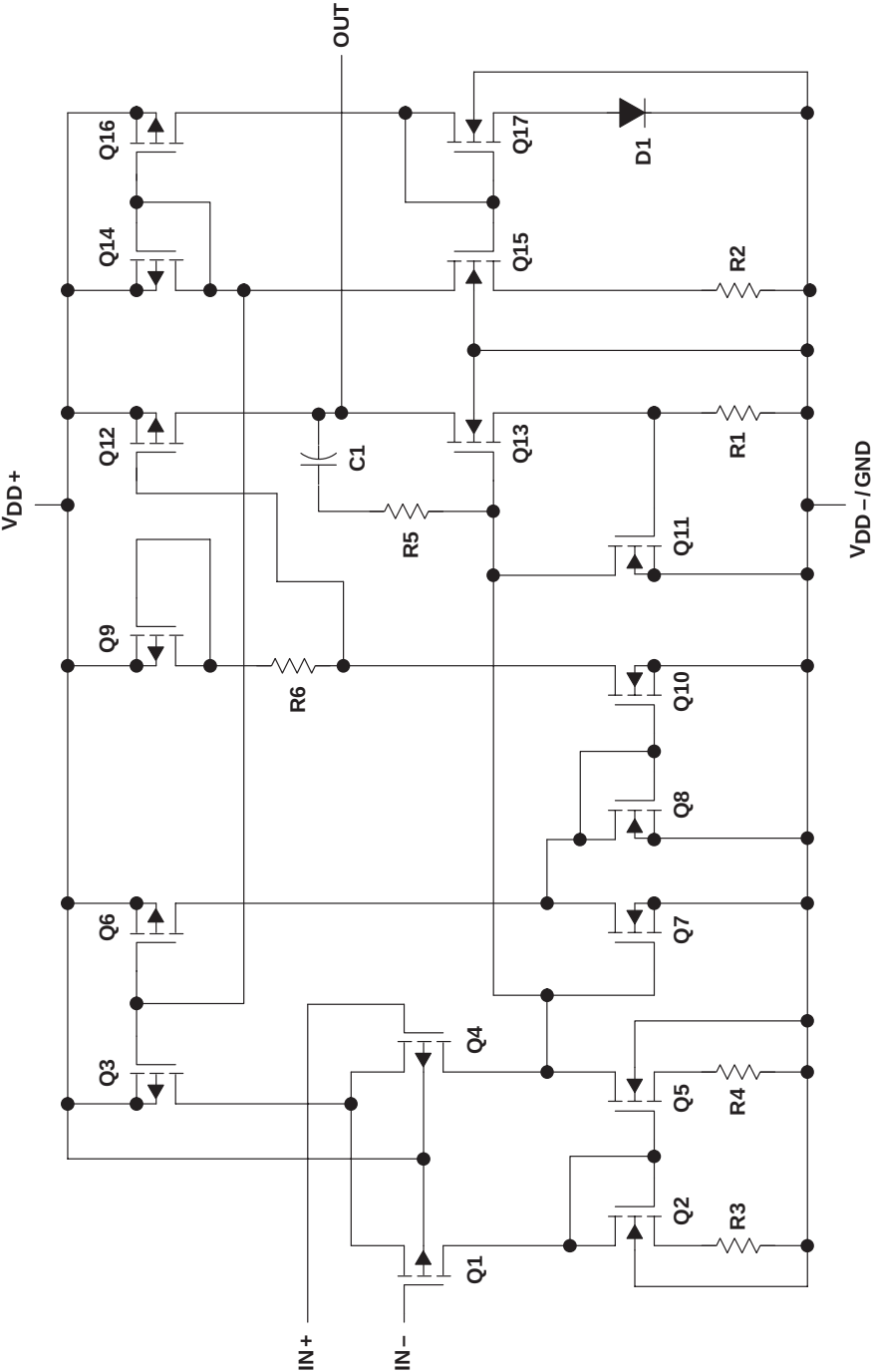


**TLC2254M, TLC2254AM**  
**FK PACKAGE**  
**(TOP VIEW)**



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equivalent schematic (each amplifier)



| ACTUAL DEVICE COMPONENT COUNT† |         |         |
|--------------------------------|---------|---------|
| COMPONENT                      | TLC2252 | TLC2254 |
| Transistors                    | 38      | 76      |
| Resistors                      | 30      | 56      |
| Diodes                         | 9       | 18      |
| Capacitors                     | 3       | 6       |

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

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**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)<sup>†</sup>**

|                                                                   |                              |
|-------------------------------------------------------------------|------------------------------|
| Supply voltage, $V_{DD+}$ (see Note 1)                            | 8 V                          |
| Supply voltage, $V_{DD-}$ (see Note 1)                            | –8 V                         |
| Differential input voltage, $V_{ID}$ (see Note 2)                 | ±16 V                        |
| Input voltage, $V_I$ (any input, see Note 1)                      | ±8 V                         |
| Input current, $I_I$ (each input)                                 | ±5 mA                        |
| Output current, $I_O$                                             | ±50 mA                       |
| Total current into $V_{DD+}$                                      | ±50 mA                       |
| Total current out of $V_{DD-}$                                    | ±50 mA                       |
| Duration of short-circuit current at (or below) 25°C (see Note 3) | unlimited                    |
| Continuous total dissipation                                      | See Dissipation Rating Table |
| Operating free-air temperature range, $T_A$ : C suffix            | 0°C to 70°C                  |
| I suffix                                                          | –40°C to 85°C                |
| Q suffix                                                          | –40°C to 125°C               |
| M suffix                                                          | –55°C to 125°C               |
| Storage temperature range, $T_{stg}$                              | –65°C to 150°C               |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds      | 260°C                        |

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

- NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between  $V_{DD+}$  and  $V_{DD-}$ .  
2. Differential voltages are at  $IN+$  with respect to  $IN-$ . Excessive current flows when input is brought below  $V_{DD-} - 0.3$  V.  
3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.

**DISSIPATION RATING TABLE**

| PACKAGE | $T_A \leq 25^\circ\text{C}$<br>POWER RATING | DERATING FACTOR<br>ABOVE $T_A = 25^\circ\text{C}$ | $T_A = 70^\circ\text{C}$<br>POWER RATING | $T_A = 85^\circ\text{C}$<br>POWER RATING | $T_A = 125^\circ\text{C}$<br>POWER RATING |
|---------|---------------------------------------------|---------------------------------------------------|------------------------------------------|------------------------------------------|-------------------------------------------|
| D–8     | 724 mW                                      | 5.8 mW/°C                                         | 464 mW                                   | 377 mW                                   | 144 mW                                    |
| D–14    | 950 mW                                      | 7.6 mW/°C                                         | 608 mW                                   | 450 mW                                   | 190 mW                                    |
| FK      | 1375 mW                                     | 11.0 mW/°C                                        | 880 mW                                   | 715 mW                                   | 275 mW                                    |
| J       | 1375 mW                                     | 11.0 mW/°C                                        | 880 mW                                   | 715 mW                                   | 275 mW                                    |
| JG      | 1050 mW                                     | 8.4 mW/°C                                         | 672 mW                                   | 546 mW                                   | 275 mW                                    |
| N       | 1150 mW                                     | 9.2 mW/°C                                         | 736 mW                                   | 736 mW                                   | —                                         |
| P       | 1000 mW                                     | 8.0 mW/°C                                         | 640 mW                                   | 520 mW                                   | —                                         |
| PW–8    | 525 mW                                      | 4.2 mW/°C                                         | 336 mW                                   | 273 mW                                   | —                                         |
| PW–14   | 700 mW                                      | 5.6 mW/°C                                         | 448 mW                                   | 448 mW                                   | —                                         |
| U       | 700 mW                                      | 5.5 mW/°C                                         | 246 mW                                   | 330 mW                                   | 150 mW                                    |
| W       | 700 mW                                      | 5.5 mW/°C                                         | 246 mW                                   | 330 mW                                   | 150 mW                                    |

**recommended operating conditions**

|                                       | C SUFFIX  |                 | I SUFFIX  |                 | Q SUFFIX  |                 | M SUFFIX  |                 | UNIT |
|---------------------------------------|-----------|-----------------|-----------|-----------------|-----------|-----------------|-----------|-----------------|------|
|                                       | MIN       | MAX             | MIN       | MAX             | MIN       | MAX             | MIN       | MAX             |      |
| Supply voltage, $V_{DD\pm}$           | ±2.2      | ±8              | ±2.2      | ±8              | ±2.2      | ±8              | ±2.2      | ±8              | V    |
| Input voltage range, $V_I$            | $V_{DD-}$ | $V_{DD+} - 1.5$ | $V_{DD-}$ | $V_{DD+} - 1.5$ | $V_{DD-}$ | $V_{DD+} - 1.5$ | $V_{DD-}$ | $V_{DD+} - 1.5$ | V    |
| Common-mode input voltage, $V_{IC}$   | $V_{DD-}$ | $V_{DD+} - 1.5$ | $V_{DD-}$ | $V_{DD+} - 1.5$ | $V_{DD-}$ | $V_{DD+} - 1.5$ | $V_{DD-}$ | $V_{DD+} - 1.5$ | V    |
| Operating free-air temperature, $T_A$ | 0         | 70              | –40       | 85              | –40       | 125             | –55       | 125             | °C   |

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

| PARAMETER                                                                  | TEST CONDITIONS                                                                        | $T_A$ †                             | TLC2252C |             |      | UNIT                         |
|----------------------------------------------------------------------------|----------------------------------------------------------------------------------------|-------------------------------------|----------|-------------|------|------------------------------|
|                                                                            |                                                                                        |                                     | MIN      | TYP         | MAX  |                              |
| $V_{IO}$ Input offset voltage                                              | $V_{IC} = 0$ ,<br>$V_O = 0$ ,<br>$V_{DD} \pm \pm 2.5\text{ V}$ ,<br>$R_S = 50\ \Omega$ | 25°C                                |          | 200         | 1500 | $\mu\text{V}$                |
|                                                                            |                                                                                        | Full range                          |          |             | 1750 |                              |
| $\alpha_{VIO}$ Temperature coefficient of input offset voltage             |                                                                                        | 25°C to 70°C                        |          | 0.5         |      | $\mu\text{V}/^\circ\text{C}$ |
| Input offset voltage long-term drift (see Note 4)                          |                                                                                        | 25°C                                |          | 0.003       |      | $\mu\text{V}/\text{mo}$      |
| $I_{IO}$ Input offset current                                              |                                                                                        | 25°C                                |          | 0.5         |      | $\text{pA}$                  |
|                                                                            |                                                                                        | Full range                          |          |             | 100  |                              |
| $I_{IB}$ Input bias current                                                |                                                                                        | 25°C                                |          | 1           |      | $\text{pA}$                  |
|                                                                            |                                                                                        | Full range                          |          |             | 100  |                              |
| $V_{ICR}$ Common-mode input voltage range                                  | $R_S = 50\ \Omega$ ,<br>$ V_{IO}  \leq 5\text{ mV}$                                    | 25°C                                | 0 to 4   | –0.3 to 4.2 |      | $\text{V}$                   |
|                                                                            |                                                                                        | Full range                          | 0 to 3.5 |             |      |                              |
| $V_{OH}$ High-level output voltage                                         | $I_{OH} = -20\ \mu\text{A}$                                                            | 25°C                                |          | 4.98        |      | $\text{V}$                   |
|                                                                            | $I_{OH} = -75\ \mu\text{A}$                                                            | 25°C                                |          | 4.9         | 4.94 |                              |
|                                                                            | Full range                                                                             |                                     |          | 4.8         |      |                              |
|                                                                            | $I_{OH} = -150\ \mu\text{A}$                                                           | 25°C                                |          | 4.8         | 4.88 |                              |
| $V_{OL}$ Low-level output voltage                                          | $V_{IC} = 2.5\text{ V}$ , $I_{OL} = 50\ \mu\text{A}$                                   | 25°C                                |          | 0.01        |      | $\text{V}$                   |
|                                                                            | $V_{IC} = 2.5\text{ V}$ , $I_{OL} = 500\ \mu\text{A}$                                  | 25°C                                |          | 0.09        | 0.15 |                              |
|                                                                            | Full range                                                                             |                                     |          |             | 0.15 |                              |
|                                                                            | $V_{IC} = 2.5\text{ V}$ , $I_{OL} = 1\text{ mA}$                                       | 25°C                                |          | 0.2         | 0.3  |                              |
|                                                                            | Full range                                                                             |                                     |          |             | 0.3  |                              |
|                                                                            | $V_{IC} = 2.5\text{ V}$ , $I_{OL} = 4\text{ mA}$                                       | 25°C                                |          | 0.7         | 1    |                              |
|                                                                            | Full range                                                                             |                                     |          |             | 1.2  |                              |
| $A_{VD}$ Large-signal differential voltage amplification                   | $V_{IC} = 2.5\text{ V}$ ,<br>$V_O = 1\text{ V to }4\text{ V}$                          | $R_L = 100\text{ k}\Omega^\ddagger$ | 25°C     | 100         | 350  | $\text{V}/\text{mV}$         |
|                                                                            |                                                                                        | Full range                          |          | 10          |      |                              |
|                                                                            |                                                                                        | $R_L = 1\text{ M}\Omega^\ddagger$   | 25°C     |             | 1700 |                              |
| $r_{id}$ Differential input resistance                                     |                                                                                        | 25°C                                |          | $10^{12}$   |      | $\Omega$                     |
| $r_{ic}$ Common-mode input resistance                                      |                                                                                        | 25°C                                |          | $10^{12}$   |      | $\Omega$                     |
| $c_{ic}$ Common-mode input capacitance                                     | $f = 10\text{ kHz}$ , P package                                                        | 25°C                                |          | 8           |      | $\text{pF}$                  |
| $z_o$ Closed-loop output impedance                                         | $f = 25\text{ kHz}$ , $A_V = 10$                                                       | 25°C                                |          | 200         |      | $\Omega$                     |
| $\text{CMRR}$ Common-mode rejection ratio                                  | $V_{IC} = 0\text{ to }2.7\text{ V}$ ,<br>$V_O = 2.5\text{ V}$ ,<br>$R_S = 50\ \Omega$  | 25°C                                |          | 70          | 83   | $\text{dB}$                  |
|                                                                            |                                                                                        | Full range                          |          | 70          |      |                              |
| $k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{DD}/\Delta V_{IO}$ ) | $V_{DD} = 4.4\text{ V to }16\text{ V}$ ,<br>$V_{IC} = V_{DD}/2$ , No load              | 25°C                                |          | 80          | 95   | $\text{dB}$                  |
|                                                                            |                                                                                        | Full range                          |          | 80          |      |                              |
| $I_{DD}$ Supply current                                                    | $V_O = 2.5\text{ V}$ , No load                                                         | 25°C                                |          | 70          | 125  | $\mu\text{A}$                |
|                                                                            |                                                                                        | Full range                          |          |             | 150  |                              |

† Full range is 0°C to 70°C.

‡ Referenced to 2.5 V

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

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

| PARAMETER              |                                             | TEST CONDITIONS                                                                                                 |                                                             | T <sub>A</sub> <sup>†</sup> | TLC2252C |      |        | UNIT |
|------------------------|---------------------------------------------|-----------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------|-----------------------------|----------|------|--------|------|
|                        |                                             |                                                                                                                 |                                                             |                             | MIN      | TYP  | MAX    |      |
| SR                     | Slew rate at unity gain                     | V <sub>O</sub> = 1.5 V to 3.5 V, R <sub>L</sub> = 100 kΩ <sup>‡</sup> ,<br>C <sub>L</sub> = 100 pF <sup>‡</sup> |                                                             | 25°C                        | 0.07     | 0.12 | V/μs   |      |
|                        |                                             |                                                                                                                 |                                                             | Full range                  | 0.05     |      |        |      |
| V <sub>n</sub>         | Equivalent input noise voltage              | f = 10 Hz                                                                                                       |                                                             | 25°C                        | 36       |      | nV/√Hz |      |
|                        |                                             | f = 1 kHz                                                                                                       |                                                             | 25°C                        | 19       |      |        |      |
| 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                        | 1.1      |      |        |      |
| 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,<br>f = 10 kHz,<br>R <sub>L</sub> = 50 kΩ <sup>‡</sup>                          | A <sub>V</sub> = 1                                          | 25°C                        | 0.2%     |      |        |      |
|                        |                                             |                                                                                                                 | A <sub>V</sub> = 10                                         |                             | 1%       |      |        |      |
| Gain-bandwidth product |                                             | f = 10 kHz,<br>C <sub>L</sub> = 100 pF <sup>‡</sup>                                                             | R <sub>L</sub> = 50 kΩ <sup>‡</sup> ,                       | 25°C                        | 0.2      |      | MHz    |      |
| B <sub>OM</sub>        | Maximum output-swing bandwidth              | V <sub>O(PP)</sub> = 2 V,<br>R <sub>L</sub> = 50 kΩ <sup>‡</sup> ,                                              | A <sub>V</sub> = 1,<br>C <sub>L</sub> = 100 pF <sup>‡</sup> | 25°C                        | 30       |      | kHz    |      |
| φ <sub>m</sub>         | Phase margin at unity gain                  | R <sub>L</sub> = 50 kΩ <sup>‡</sup> ,                                                                           | C <sub>L</sub> = 100 pF <sup>‡</sup>                        | 25°C                        | 63°      |      |        |      |
| Gain margin            |                                             |                                                                                                                 |                                                             | 25°C                        | 15       |      | dB     |      |

$^\dagger$  Full range is 0°C to 70°C.

$^\ddagger$  Referenced to 2.5 V

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

| PARAMETER                                                                       | TEST CONDITIONS                                          | $T_A^\dagger$          | TLC2252C   |             |      | UNIT             |
|---------------------------------------------------------------------------------|----------------------------------------------------------|------------------------|------------|-------------|------|------------------|
|                                                                                 |                                                          |                        | MIN        | TYP         | MAX  |                  |
| $V_{IO}$ Input offset voltage                                                   | $V_{IC} = 0, V_O = 0, R_S = 50 \Omega$                   | 25°C                   |            | 200         | 1500 | $\mu V$          |
|                                                                                 |                                                          | Full range             |            |             | 1750 |                  |
| $\alpha_{VIO}$ Temperature coefficient of input offset voltage                  |                                                          | 25°C to 70°C           |            | 0.5         |      | $\mu V/^\circ C$ |
| Input offset voltage long-term drift (see Note 4)                               |                                                          | 25°C                   |            | 0.003       |      | $\mu V/mo$       |
| $I_{IO}$ Input offset current                                                   |                                                          | 25°C                   |            | 0.5         |      | pA               |
|                                                                                 |                                                          | Full range             |            |             | 100  |                  |
| $I_{IB}$ Input bias current                                                     |                                                          | 25°C                   |            | 1           |      | pA               |
|                                                                                 |                                                          | Full range             |            |             | 100  |                  |
| $V_{ICR}$ Common-mode input voltage range                                       | $ V_{IO}  \leq 5$ mV, $R_S = 50 \Omega$                  | 25°C                   | –5 to 4    | –5.3 to 4.2 |      | V                |
|                                                                                 |                                                          | Full range             | –5 to 3.5  |             |      |                  |
| $V_{OM+}$ Maximum positive peak output voltage                                  | $I_O = -20 \mu A$                                        | 25°C                   |            | 4.98        |      | V                |
|                                                                                 | $I_O = -100 \mu A$                                       | 25°C                   |            | 4.9         | 4.93 |                  |
|                                                                                 |                                                          | Full range             |            | 4.7         |      |                  |
|                                                                                 | $I_O = -200 \mu A$                                       | 25°C                   |            | 4.8         | 4.86 |                  |
| $V_{OM-}$ Maximum negative peak output voltage                                  | $V_{IC} = 0, I_O = 50 \mu A$                             | 25°C                   |            | –4.99       |      | V                |
|                                                                                 | $V_{IC} = 0, I_O = 500 \mu A$                            | 25°C                   | –4.85      | –4.91       |      |                  |
|                                                                                 |                                                          | Full range             | –4.85      |             |      |                  |
|                                                                                 | $V_{IC} = 0, I_O = 1$ mA                                 | 25°C                   | –4.7       | –4.8        |      |                  |
|                                                                                 |                                                          | Full range             | –4.7       |             |      |                  |
|                                                                                 | $V_{IC} = 0, I_O = 4$ mA                                 | 25°C                   | –4         | –4.3        |      |                  |
|                                                                                 |                                                          | Full range             | –3.8       |             |      |                  |
|                                                                                 |                                                          |                        |            |             |      |                  |
| $A_{VD}$ Large-signal differential voltage amplification                        | $V_O = \pm 4$ V                                          | $R_L = 100$ k $\Omega$ | 25°C       | 45          | 650  | V/mV             |
|                                                                                 |                                                          |                        | Full range | 10          |      |                  |
|                                                                                 |                                                          | $R_L = 1$ M $\Omega$   | 25°C       |             | 3000 |                  |
| $r_{id}$ Differential input resistance                                          |                                                          | 25°C                   |            | $10^{12}$   |      | $\Omega$         |
| $r_{ic}$ Common-mode input resistance                                           |                                                          | 25°C                   |            | $10^{12}$   |      | $\Omega$         |
| $c_{ic}$ Common-mode input capacitance                                          | $f = 10$ kHz, P package                                  | 25°C                   |            | 8           |      | pF               |
| $z_o$ Closed-loop output impedance                                              | $f = 25$ kHz, $A_V = 10$                                 | 25°C                   |            | 190         |      | $\Omega$         |
| CMRR Common-mode rejection ratio                                                | $V_{IC} = -5$ V to 2.7 V, $V_O = 0, R_S = 50 \Omega$     | 25°C                   |            | 75          | 88   | dB               |
|                                                                                 |                                                          | Full range             |            | 75          |      |                  |
| $k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{DD\pm} / \Delta V_{IO}$ ) | $V_{DD\pm} = 2.2$ V to $\pm 8$ V, $V_{IC} = 0$ , No load | 25°C                   |            | 80          | 95   | dB               |
|                                                                                 |                                                          | Full range             |            | 80          |      |                  |
| $I_{DD}$ Supply current                                                         | $V_O = 0$ , No load                                      | 25°C                   |            | 80          | 125  | $\mu A$          |
|                                                                                 |                                                          | Full range             |            |             | 150  |                  |

$^\dagger$  Full range is 0°C to 70°C.

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



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

| PARAMETER              |                                             | TEST CONDITIONS                                                   |                                                | T <sub>A</sub> † | TLC2252C |      |        | UNIT |
|------------------------|---------------------------------------------|-------------------------------------------------------------------|------------------------------------------------|------------------|----------|------|--------|------|
|                        |                                             |                                                                   |                                                |                  | MIN      | TYP  | MAX    |      |
| SR                     | Slew rate at unity gain                     | V <sub>O</sub> = ±1.9 V,<br>C <sub>L</sub> = 100 pF               | R <sub>L</sub> = 100 kΩ,                       | 25°C             | 0.07     | 0.12 | V/μs   |      |
|                        |                                             |                                                                   |                                                | Full range       | 0.05     |      |        |      |
| V <sub>n</sub>         | Equivalent input noise voltage              | f = 10 Hz                                                         |                                                | 25°C             | 38       |      | nV/√Hz |      |
|                        |                                             | f = 1 kHz                                                         |                                                | 25°C             | 19       |      |        |      |
| V <sub>N(PP)</sub>     | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 1 Hz                                                |                                                | 25°C             | 0.8      |      | μV     |      |
|                        |                                             | f = 0.1 Hz to 10 Hz                                               |                                                | 25°C             | 1.1      |      |        |      |
| I <sub>n</sub>         | Equivalent input noise current              |                                                                   |                                                | 25°C             | 0.6      |      | fA/√Hz |      |
| THD + N                | Total harmonic distortion pulse duration    | V <sub>O</sub> = ±2.3 V,<br>f = 10 kHz,<br>R <sub>L</sub> = 50 kΩ | A <sub>V</sub> = 1                             | 25°C             | 0.2%     |      |        |      |
|                        |                                             |                                                                   | A <sub>V</sub> = 10                            |                  | 1%       |      |        |      |
| Gain-bandwidth product |                                             | f = 10 kHz,<br>C <sub>L</sub> = 100 pF                            | R <sub>L</sub> = 50 kΩ,                        | 25°C             | 0.21     |      | MHz    |      |
| B <sub>OM</sub>        | Maximum output-swing bandwidth              | V <sub>O(PP)</sub> = 4.6 V,<br>R <sub>L</sub> = 50 kΩ,            | A <sub>V</sub> = 1,<br>C <sub>L</sub> = 100 pF | 25°C             | 14       |      | kHz    |      |
| φ <sub>m</sub>         | Phase margin at unity gain                  | R <sub>L</sub> = 50 kΩ,                                           | C <sub>L</sub> = 100 pF                        | 25°C             | 63°      |      |        |      |
| Gain margin            |                                             |                                                                   |                                                | 25°C             | 15       |      | dB     |      |

$^\dagger$  Full range is 0°C to 70°C.

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

| PARAMETER                                                                  | TEST CONDITIONS                                                                         | $T_A$ †                             | TLC2254C   |             |      | UNIT                         |
|----------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|-------------------------------------|------------|-------------|------|------------------------------|
|                                                                            |                                                                                         |                                     | MIN        | TYP         | MAX  |                              |
| $V_{IO}$ Input offset voltage                                              | $V_{IC} = 0$ ,<br>$V_O = 0$ ,<br>$V_{DD\pm} = \pm 2.5\text{ V}$ ,<br>$R_S = 50\ \Omega$ | 25°C                                |            | 200         | 1500 | $\mu\text{V}$                |
|                                                                            |                                                                                         | Full range                          |            |             | 1750 |                              |
| $\alpha_{VIO}$ Temperature coefficient of input offset voltage             |                                                                                         | 25°C to 70°C                        |            | 0.5         |      | $\mu\text{V}/^\circ\text{C}$ |
| Input offset voltage long-term drift (see Note 4)                          |                                                                                         | 25°C                                |            | 0.003       |      | $\mu\text{V}/\text{mo}$      |
| $I_{IO}$ Input offset current                                              |                                                                                         | 25°C                                |            | 0.5         |      | $\text{pA}$                  |
|                                                                            |                                                                                         | Full range                          |            |             | 100  |                              |
| $I_{IB}$ Input bias current                                                |                                                                                         | 25°C                                |            | 1           |      | $\text{pA}$                  |
|                                                                            |                                                                                         | Full range                          |            |             | 100  |                              |
| $V_{ICR}$ Common-mode input voltage range                                  | $R_S = 50\ \Omega$ ,<br>$ V_{IO}  \leq 5\text{ mV}$                                     | 25°C                                | 0 to 4     | –0.3 to 4.2 |      | $\text{V}$                   |
|                                                                            |                                                                                         | Full range                          | 0 to 3.5   |             |      |                              |
| $V_{OH}$ High-level output voltage                                         | $I_{OH} = -20\ \mu\text{A}$                                                             | 25°C                                |            | 4.98        |      | $\text{V}$                   |
|                                                                            | $I_{OH} = -75\ \mu\text{A}$                                                             | 25°C                                |            | 4.9         | 4.94 |                              |
|                                                                            |                                                                                         | Full range                          |            | 4.8         |      |                              |
|                                                                            | $I_{OH} = -150\ \mu\text{A}$                                                            | 25°C                                |            | 4.8         | 4.88 |                              |
| $V_{OL}$ Low-level output voltage                                          | $V_{IC} = 2.5\text{ V}$ , $I_{OL} = 50\ \mu\text{A}$                                    | 25°C                                |            | 0.01        |      | $\text{V}$                   |
|                                                                            | $V_{IC} = 2.5\text{ V}$ , $I_{OL} = 500\ \mu\text{A}$                                   | 25°C                                |            | 0.09        | 0.15 |                              |
|                                                                            |                                                                                         | Full range                          |            |             | 0.15 |                              |
|                                                                            | $V_{IC} = 2.5\text{ V}$ , $I_{OL} = 1\text{ mA}$                                        | 25°C                                |            | 0.2         | 0.3  |                              |
|                                                                            |                                                                                         | Full range                          |            |             | 0.3  |                              |
|                                                                            | $V_{IC} = 2.5\text{ V}$ , $I_{OL} = 4\text{ mA}$                                        | 25°C                                |            | 0.7         | 1    |                              |
|                                                                            |                                                                                         | Full range                          |            |             | 1.2  |                              |
| $A_{VD}$ Large-signal differential voltage amplification                   | $V_{IC} = 2.5\text{ V}$ ,<br>$V_O = 1\text{ V to }4\text{ V}$                           | $R_L = 100\text{ k}\Omega^\ddagger$ | 25°C       | 100         | 350  | $\text{V/mV}$                |
|                                                                            |                                                                                         |                                     | Full range | 10          |      |                              |
|                                                                            |                                                                                         | $R_L = 1\text{ M}\Omega^\ddagger$   | 25°C       |             | 1700 |                              |
| $r_{i(d)}$ 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                                   | $f = 10\text{ kHz}$ , N package                                                         | 25°C                                |            | 8           |      | $\text{pF}$                  |
| $z_o$ Closed-loop output impedance                                         | $f = 25\text{ kHz}$ , $A_V = 10$                                                        | 25°C                                |            | 200         |      | $\Omega$                     |
| $\text{CMRR}$ Common-mode rejection ratio                                  | $V_{IC} = 0\text{ to }2.7\text{ V}$ , $V_O = 2.5\text{ V}$ ,<br>$R_S = 50\ \Omega$      | 25°C                                | 70         | 83          |      | $\text{dB}$                  |
|                                                                            |                                                                                         | Full range                          | 70         |             |      |                              |
| $k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{DD}/\Delta V_{IO}$ ) | $V_{DD} = 4.4\text{ V to }16\text{ V}$ ,<br>$V_{IC} = V_{DD}/2$ , No load               | 25°C                                | 80         | 95          |      | $\text{dB}$                  |
|                                                                            |                                                                                         | Full range                          | 80         |             |      |                              |
| $I_{DD}$ Supply current (four amplifiers)                                  | $V_O = 2.5\text{ V}$ , No load                                                          | 25°C                                |            | 140         | 250  | $\mu\text{A}$                |
|                                                                            |                                                                                         | Full range                          |            |             | 300  |                              |

† Full range is 0°C to 70°C.

‡ Referenced to 2.5 V

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

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

| PARAMETER              |                                             | TEST CONDITIONS                                                                                                   |                                                             | T <sub>A</sub> <sup>†</sup> | TLC2254C |      |        | UNIT |
|------------------------|---------------------------------------------|-------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------|-----------------------------|----------|------|--------|------|
|                        |                                             |                                                                                                                   |                                                             |                             | MIN      | TYP  | MAX    |      |
| SR                     | Slew rate at unity gain                     | V <sub>O</sub> = 1.4 V to 2.6 V    R <sub>L</sub> = 100 kΩ <sup>‡</sup> ,<br>C <sub>L</sub> = 100 pF <sup>‡</sup> |                                                             | 25°C                        | 0.07     | 0.12 | V/μs   |      |
|                        |                                             |                                                                                                                   |                                                             | Full range                  | 0.05     |      |        |      |
| V <sub>n</sub>         | Equivalent input noise voltage              | f = 10 Hz                                                                                                         |                                                             | 25°C                        | 36       |      | nV/√Hz |      |
|                        |                                             | f = 1 kHz                                                                                                         |                                                             | 25°C                        | 19       |      |        |      |
| 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                        | 1.1      |      |        |      |
| 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,<br>f = 10 kHz,<br>R <sub>L</sub> = 50 kΩ <sup>‡</sup>                            | A <sub>V</sub> = 1                                          | 25°C                        | 0.2%     |      |        |      |
|                        |                                             |                                                                                                                   | A <sub>V</sub> = 10                                         |                             | 1%       |      |        |      |
| Gain-bandwidth product |                                             | f = 10 kHz,<br>C <sub>L</sub> = 100 pF <sup>‡</sup>                                                               | R <sub>L</sub> = 50 kΩ <sup>‡</sup> ,                       | 25°C                        | 0.2      |      | MHz    |      |
| B <sub>OM</sub>        | Maximum output-swing bandwidth              | V <sub>O(PP)</sub> = 2 V,<br>R <sub>L</sub> = 50 kΩ <sup>‡</sup> ,                                                | A <sub>V</sub> = 1,<br>C <sub>L</sub> = 100 pF <sup>‡</sup> | 25°C                        | 30       |      | kHz    |      |
| φ <sub>m</sub>         | Phase margin at unity gain                  | R <sub>L</sub> = 50 kΩ <sup>‡</sup> ,                                                                             | C <sub>L</sub> = 100 pF <sup>‡</sup>                        | 25°C                        | 63°      |      |        |      |
|                        | Gain margin                                 |                                                                                                                   |                                                             | 25°C                        | 15       |      | dB     |      |

$^\dagger$  Full range is 0°C to 70°C.

$^\ddagger$  Referenced to 2.5 V

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

| PARAMETER                                                                       | TEST CONDITIONS                                              | $T_A^\dagger$          | TLC2254C   |             |      | UNIT             |
|---------------------------------------------------------------------------------|--------------------------------------------------------------|------------------------|------------|-------------|------|------------------|
|                                                                                 |                                                              |                        | MIN        | TYP         | MAX  |                  |
| $V_{IO}$ Input offset voltage                                                   | $V_{IC} = 0, V_O = 0, R_S = 50 \Omega$                       | 25°C                   |            | 200         | 1500 | $\mu V$          |
|                                                                                 |                                                              | Full range             |            |             | 1750 |                  |
| $\alpha_{VIO}$ Temperature coefficient of input offset voltage                  |                                                              | 25°C to 70°C           |            | 0.5         |      | $\mu V/^\circ C$ |
| Input offset voltage long-term drift (see Note 4)                               |                                                              | 25°C                   |            | 0.003       |      | $\mu V/mo$       |
| $I_{IO}$ Input offset current                                                   |                                                              | 25°C                   |            | 0.5         |      | pA               |
|                                                                                 |                                                              | Full range             |            |             | 100  |                  |
| $I_{IB}$ Input bias current                                                     |                                                              | 25°C                   |            | 1           |      | pA               |
|                                                                                 |                                                              | Full range             |            |             | 100  |                  |
| $V_{ICR}$ Common-mode input voltage range                                       | $ V_{IO}  \leq 5$ mV, $R_S = 50 \Omega$                      | 25°C                   | –5 to 4    | –5.3 to 4.2 |      | V                |
|                                                                                 |                                                              | Full range             | –5 to 3.5  |             |      |                  |
| $V_{OM+}$ Maximum positive peak output voltage                                  | $I_O = -20 \mu A$                                            | 25°C                   |            | 4.98        |      | V                |
|                                                                                 | $I_O = -100 \mu A$                                           | 25°C                   |            | 4.9         | 4.93 |                  |
|                                                                                 |                                                              | Full range             |            | 4.7         |      |                  |
|                                                                                 | $I_O = -200 \mu A$                                           | 25°C                   |            | 4.8         | 4.86 |                  |
| $V_{OM-}$ Maximum negative peak output voltage                                  | $V_{IC} = 0, I_O = 50 \mu A$                                 | 25°C                   |            | –4.99       |      | V                |
|                                                                                 | $V_{IC} = 0, I_O = 500 \mu A$                                | 25°C                   | –4.85      | –4.91       |      |                  |
|                                                                                 |                                                              | Full range             | –4.85      |             |      |                  |
|                                                                                 | $V_{IC} = 0, I_O = 1$ mA                                     | 25°C                   | –4.7       | –4.8        |      |                  |
|                                                                                 |                                                              | Full range             | –4.7       |             |      |                  |
|                                                                                 | $V_{IC} = 0, I_O = 4$ mA                                     | 25°C                   | –4         | –4.3        |      |                  |
|                                                                                 |                                                              | Full range             | –3.8       |             |      |                  |
| $A_{VD}$ Large-signal differential voltage amplification                        | $V_O = \pm 4$ V                                              | $R_L = 100$ k $\Omega$ | 25°C       | 40          | 150  | V/mV             |
|                                                                                 |                                                              |                        | Full range | 10          |      |                  |
|                                                                                 |                                                              | $R_L = 1$ M $\Omega$   | 25°C       |             | 3000 |                  |
| $r_{i(d)}$ 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 kHz, N package                                        | 25°C                   |            | 8           |      | pF               |
| $z_o$ Closed-loop output impedance                                              | f = 25 kHz, $A_V = 10$                                       | 25°C                   |            | 190         |      | $\Omega$         |
| CMRR Common-mode rejection ratio                                                | $V_{IC} = -5$ V to 2.7 V, $V_O = 0, R_S = 50 \Omega$         | 25°C                   | 75         | 88          |      | dB               |
|                                                                                 |                                                              | Full range             | 75         |             |      |                  |
| $k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{DD\pm} / \Delta V_{IO}$ ) | $V_{DD\pm} = \pm 2.2$ V to $\pm 8$ V, $V_{IC} = 0$ , No load | 25°C                   | 80         | 95          |      | dB               |
|                                                                                 |                                                              | Full range             | 80         |             |      |                  |
| $I_{DD}$ Supply current (four amplifiers)                                       | $V_O = 0$ , No load                                          | 25°C                   |            | 160         | 250  | $\mu A$          |
|                                                                                 |                                                              | Full range             |            |             | 300  |                  |

$^\dagger$  Full range is 0°C to 70°C.

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

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

| PARAMETER              |                                             | TEST CONDITIONS                                                           |                                             | T <sub>A</sub> <sup>†</sup> | TLC2254C |      |     | UNIT   |
|------------------------|---------------------------------------------|---------------------------------------------------------------------------|---------------------------------------------|-----------------------------|----------|------|-----|--------|
|                        |                                             |                                                                           |                                             |                             | MIN      | TYP  | MAX |        |
| SR                     | Slew rate at unity gain                     | V <sub>O</sub> = ±1.9 V, R <sub>L</sub> = 100 kΩ, C <sub>L</sub> = 100 pF |                                             | 25°C                        | 0.07     | 0.12 |     | V/μs   |
|                        |                                             |                                                                           |                                             | Full range                  | 0.05     |      |     |        |
| V <sub>n</sub>         | Equivalent input noise voltage              | f = 10 Hz                                                                 |                                             | 25°C                        | 38       |      |     | nV/√Hz |
|                        |                                             | f = 1 kHz                                                                 |                                             | 25°C                        | 19       |      |     |        |
| V <sub>N(PP)</sub>     | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 1 Hz                                                        |                                             | 25°C                        | 0.8      |      |     | μV     |
|                        |                                             | f = 0.1 Hz to 10 Hz                                                       |                                             | 25°C                        | 1.1      |      |     |        |
| 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> = ± 2.3 V, f = 20 kHz, R <sub>L</sub> = 50 kΩ              | A <sub>V</sub> = 1                          | 25°C                        | 0.2%     |      |     |        |
|                        |                                             |                                                                           | A <sub>V</sub> = 10                         |                             | 1%       |      |     |        |
| Gain-bandwidth product |                                             | f = 10 kHz, C <sub>L</sub> = 100 pF                                       | R <sub>L</sub> = 50 kΩ,                     | 25°C                        | 0.21     |      |     | MHz    |
| B <sub>OM</sub>        | Maximum output-swing bandwidth              | V <sub>O(PP)</sub> = 4.6 V, R <sub>L</sub> = 50 kΩ,                       | A <sub>V</sub> = 1, C <sub>L</sub> = 100 pF | 25°C                        | 14       |      |     | kHz    |
| φ <sub>m</sub>         | Phase margin at unity gain                  | R <sub>L</sub> = 50 kΩ,                                                   | C <sub>L</sub> = 100 pF                     | 25°C                        | 63°      |      |     |        |
| Gain margin            |                                             |                                                                           |                                             |                             | 25°C     | 15   |     |        |

<sup>†</sup> Full range is 0°C to 70°C.

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

| PARAMETER                                                                  | TEST CONDITIONS                                                                    | $T_A$ †                             | TLC2252I   |             |      | TLC2252AI |             |      | UNIT                         |
|----------------------------------------------------------------------------|------------------------------------------------------------------------------------|-------------------------------------|------------|-------------|------|-----------|-------------|------|------------------------------|
|                                                                            |                                                                                    |                                     | MIN        | TYP         | MAX  | MIN       | TYP         | MAX  |                              |
| $V_{IO}$ Input offset voltage                                              | $V_{DD} = \pm 2.5\text{ V}$ , $V_O = 0$ ,<br>$V_{IC} = 0$ , $R_S = 50\ \Omega$     | 25°C                                |            | 200         | 1500 |           | 200         | 850  | $\mu\text{V}$                |
|                                                                            |                                                                                    | Full range                          |            |             | 1750 |           |             | 1000 |                              |
| $\alpha_{VIO}$ Temperature coefficient of input offset voltage             |                                                                                    | 25°C to 85°C                        |            | 0.5         |      |           | 0.5         |      | $\mu\text{V}/^\circ\text{C}$ |
| Input offset voltage long-term drift (see Note 4)                          |                                                                                    | 25°C                                |            | 0.003       |      |           | 0.003       |      | $\mu\text{V}/\text{mo}$      |
| $I_{IO}$ Input offset current                                              |                                                                                    | 25°C                                |            | 0.5         |      |           | 0.5         |      | pA                           |
|                                                                            |                                                                                    | Full range                          |            |             | 1000 |           |             | 1000 |                              |
| $I_{IB}$ Input bias current                                                |                                                                                    | 25°C                                |            | 1           |      |           | 1           |      | pA                           |
|                                                                            |                                                                                    | Full range                          |            |             | 1000 |           |             | 1000 |                              |
| $V_{ICR}$ Common-mode input voltage range                                  | $R_S = 50\ \Omega$ , $ V_{IO}  \leq 5\text{ mV}$                                   | 25°C                                | 0 to 4     | –0.3 to 4.2 |      | 0 to 4    | –0.3 to 4.2 |      | V                            |
|                                                                            |                                                                                    | Full range                          | 0 to 3.5   |             |      | 0 to 3.5  |             |      |                              |
| $V_{OH}$ High-level output voltage                                         | $I_{OH} = -20\ \mu\text{A}$                                                        | 25°C                                |            | 4.98        |      |           | 4.98        |      | V                            |
|                                                                            | $I_{OH} = -75\ \mu\text{A}$                                                        | 25°C                                |            | 4.9         | 4.94 |           | 4.9         | 4.94 |                              |
|                                                                            |                                                                                    | Full range                          |            | 4.8         |      |           | 4.8         |      |                              |
|                                                                            | $I_{OH} = -150\ \mu\text{A}$                                                       | 25°C                                |            | 4.8         | 4.88 |           | 4.8         | 4.88 |                              |
| $V_{OL}$ Low-level output voltage                                          | $V_{IC} = 2.5\text{ V}$ , $I_{OL} = 50\ \mu\text{A}$                               | 25°C                                |            | 0.01        |      |           | 0.01        |      | V                            |
|                                                                            | $V_{IC} = 2.5\text{ V}$ , $I_{OL} = 500\ \mu\text{A}$                              | 25°C                                |            | 0.09        | 0.15 |           | 0.09        | 0.15 |                              |
|                                                                            |                                                                                    | Full range                          |            |             | 0.15 |           |             | 0.15 |                              |
|                                                                            | $V_{IC} = 2.5\text{ V}$ , $I_{OL} = 4\text{ mA}$                                   | 25°C                                |            | 0.8         | 1    |           | 0.7         | 1    |                              |
|                                                                            |                                                                                    | Full range                          |            |             | 1.2  |           |             | 1.2  |                              |
|                                                                            |                                                                                    |                                     |            |             |      |           |             |      |                              |
| $A_{VD}$ Large-signal differential voltage amplification                   | $V_{IC} = 2.5\text{ V}$ ,<br>$V_O = 1\text{ V to }4\text{ V}$                      | $R_L = 100\text{ k}\Omega^\ddagger$ | 25°C       | 100         | 350  |           | 100         | 350  | V/mV                         |
|                                                                            |                                                                                    |                                     | Full range | 10          |      |           | 10          |      |                              |
|                                                                            |                                                                                    | $R_L = 1\text{ M}\Omega^\ddagger$   | 25°C       |             | 1700 |           |             | 1700 |                              |
| $r_{id}$ Differential input resistance                                     |                                                                                    | 25°C                                |            | $10^{12}$   |      |           | $10^{12}$   |      | $\Omega$                     |
| $r_{ic}$ Common-mode input resistance                                      |                                                                                    | 25°C                                |            | $10^{12}$   |      |           | $10^{12}$   |      | $\Omega$                     |
| $C_{ic}$ Common-mode input capacitance                                     | $f = 10\text{ kHz}$ , P package                                                    | 25°C                                |            | 8           |      |           | 8           |      | pF                           |
| $z_o$ Closed-loop output impedance                                         | $f = 25\text{ kHz}$ , $A_V = 10$                                                   | 25°C                                |            | 200         |      |           | 200         |      | $\Omega$                     |
| CMRR Common-mode rejection ratio                                           | $V_{IC} = 0\text{ to }2.7\text{ V}$ , $V_O = 2.5\text{ V}$ ,<br>$R_S = 50\ \Omega$ | 25°C                                |            | 70          | 83   |           | 70          | 83   | dB                           |
|                                                                            |                                                                                    | Full range                          |            | 70          |      |           | 70          |      |                              |
| $k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{DD}/\Delta V_{IO}$ ) | $V_{DD} = 4.4\text{ V to }16\text{ V}$ ,<br>$V_{IC} = V_{DD}/2$ , No load          | 25°C                                |            | 80          | 95   |           | 80          | 95   | dB                           |
|                                                                            |                                                                                    | Full range                          |            | 80          |      |           | 80          |      |                              |
| $I_{DD}$ Supply current                                                    | $V_O = 2.5\text{ V}$ , No load                                                     | 25°C                                |            | 70          | 125  |           | 70          | 125  | $\mu\text{A}$                |
|                                                                            |                                                                                    | Full range                          |            |             | 150  |           |             | 150  |                              |

† Full range is –40°C to 125°C.

‡ Referenced to 2.5 V

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

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

| PARAMETER          |                                             | TEST CONDITIONS                                                                                                    |                                                              | T <sub>A</sub> <sup>†</sup> | TLC2252I |      |     | TLC2252AI |      |     | UNIT   |
|--------------------|---------------------------------------------|--------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------|-----------------------------|----------|------|-----|-----------|------|-----|--------|
|                    |                                             |                                                                                                                    |                                                              |                             | MIN      | TYP  | MAX | MIN       | TYP  | MAX |        |
| SR                 | Slew rate at unity gain                     | V <sub>O</sub> = 1.5 V to 3.5 V,<br>R <sub>L</sub> = 100 kΩ <sup>‡</sup> ,<br>C <sub>L</sub> = 100 pF <sup>‡</sup> |                                                              | 25°C                        | 0.07     | 0.12 |     | 0.07      | 0.12 |     | V/μs   |
|                    |                                             |                                                                                                                    |                                                              | Full range                  | 0.05     |      |     | 0.05      |      |     |        |
| V <sub>n</sub>     | Equivalent input noise voltage              | f = 10 Hz                                                                                                          |                                                              | 25°C                        | 36       |      |     | 36        |      |     | nV/√Hz |
|                    |                                             | f = 1 kHz                                                                                                          |                                                              | 25°C                        | 19       |      |     | 19        |      |     |        |
| V <sub>N(PP)</sub> | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 1 Hz                                                                                                 |                                                              | 25°C                        | 0.7      |      |     | 0.7       |      |     | μV     |
|                    |                                             | f = 0.1 Hz to 10 Hz                                                                                                |                                                              | 25°C                        | 1.1      |      |     | 1.1       |      |     |        |
| I <sub>n</sub>     | Equivalent input noise current              |                                                                                                                    |                                                              | 25°C                        | 0.6      |      |     | 0.6       |      |     | fA/√Hz |
| THD + N            | Total harmonic distortion plus noise        | V <sub>O</sub> = 0.5 V to 2.5 V,<br>f = 10 kHz,<br>R <sub>L</sub> = 50 kΩ <sup>‡</sup>                             | A <sub>V</sub> = 1                                           | 25°C                        | 0.2%     |      |     | 0.2%      |      |     |        |
|                    |                                             |                                                                                                                    | A <sub>V</sub> = 10                                          |                             | 1%       |      |     | 1%        |      |     |        |
|                    | Gain-bandwidth product                      | f = 50 kHz,<br>C <sub>L</sub> = 100 pF <sup>‡</sup>                                                                | R <sub>L</sub> = 50 kΩ <sup>‡</sup> ,                        | 25°C                        | 0.2      |      |     | 0.2       |      |     | MHz    |
| B <sub>OM</sub>    | Maximum output-swing bandwidth              | V <sub>O(PP)</sub> = 2 V,<br>R <sub>L</sub> = 50 kΩ <sup>‡</sup> ,                                                 | A <sub>V</sub> = 1,<br>R <sub>L</sub> = 50 kΩ <sup>‡</sup> , | 25°C                        | 30       |      |     | 30        |      |     | kHz    |
| φ <sub>m</sub>     | Phase margin at unity gain                  | R <sub>L</sub> = 50 kΩ <sup>‡</sup> ,<br>C <sub>L</sub> = 100 pF <sup>‡</sup>                                      |                                                              | 25°C                        | 63°      |      |     | 63°       |      |     |        |
|                    | Gain margin                                 |                                                                                                                    |                                                              | 25°C                        | 15       |      |     | 15        |      |     | dB     |

$^\dagger$  Full range is  $-40^\circ\text{C}$  to  $125^\circ\text{C}$ .

$^\ddagger$  Referenced to 2.5 V

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

| PARAMETER                                                                       | TEST CONDITIONS                                         | $T_A$ †            | TLC2252I   |             |       | TLC2252AI |             |       | UNIT             |
|---------------------------------------------------------------------------------|---------------------------------------------------------|--------------------|------------|-------------|-------|-----------|-------------|-------|------------------|
|                                                                                 |                                                         |                    | MIN        | TYP         | MAX   | MIN       | TYP         | MAX   |                  |
| $V_{IO}$ Input offset voltage                                                   | $V_{IC} = 0, V_O = 0, R_S = 50 \Omega$                  | 25°C               |            | 200         | 1500  |           | 200         | 850   | $\mu V$          |
|                                                                                 |                                                         | Full range         |            |             | 1750  |           |             | 1000  |                  |
| $\alpha_{VIO}$ Temperature coefficient of input offset voltage                  |                                                         | 25°C to 85°C       |            | 0.5         |       |           | 0.5         |       | $\mu V/^\circ C$ |
| Input offset voltage long-term drift (see Note 4)                               |                                                         | 25°C               |            | 0.003       |       |           | 0.003       |       | $\mu V/mo$       |
| $I_{IO}$ Input offset current                                                   |                                                         | 25°C               |            | 0.5         |       |           | 0.5         |       | pA               |
|                                                                                 |                                                         | Full range         |            |             | 1000  |           |             | 1000  |                  |
| $I_{IB}$ Input bias current                                                     |                                                         | 25°C               |            | 1           |       |           | 1           |       | pA               |
|                                                                                 |                                                         | Full range         |            |             | 1000  |           |             | 1000  |                  |
| $V_{ICR}$ Common-mode input voltage range                                       | $R_S = 50 \Omega,  V_{IO}  \leq 5 mV$                   | 25°C               | –5 to 4    | –5.3 to 4.2 |       | –5 to 4   | –5.3 to 4.2 |       | V                |
|                                                                                 |                                                         | Full range         | –5 to 3.5  |             |       | –5 to 3.5 |             |       |                  |
| $V_{OM+}$ Maximum positive peak output voltage                                  | $I_O = -20 \mu A$                                       | 25°C               |            | 4.98        |       |           | 4.98        |       | V                |
|                                                                                 | $I_O = -100 \mu A$                                      | 25°C               |            | 4.9         | 4.93  |           | 4.9         | 4.93  |                  |
|                                                                                 |                                                         | Full range         |            | 4.7         |       |           | 4.7         |       |                  |
|                                                                                 | $I_O = -200 \mu A$                                      | 25°C               |            | 4.8         | 4.86  |           | 4.8         | 4.86  |                  |
| $V_{OM-}$ Maximum negative peak output voltage                                  | $V_{IC} = 0, I_O = 50 \mu A$                            | 25°C               |            | –4.99       |       |           | –4.99       |       | V                |
|                                                                                 | $V_{IC} = 0, I_O = 500 \mu A$                           | 25°C               |            | –4.85       | –4.91 |           | –4.85       | –4.91 |                  |
|                                                                                 |                                                         | Full range         |            | –4.85       |       |           | –4.85       |       |                  |
|                                                                                 | $V_{IC} = 0, I_O = 4 mA$                                | 25°C               |            | –4          | –4.3  |           | –4          | –4.3  |                  |
|                                                                                 |                                                         | Full range         |            | –3.8        |       |           | –3.8        |       |                  |
|                                                                                 |                                                         |                    |            |             |       |           |             |       |                  |
| $A_{VD}$ Large-signal differential voltage amplification                        | $V_O = \pm 4 V$                                         | $R_L = 50 k\Omega$ | 25°C       | 40          | 150   |           | 40          | 150   | V/mV             |
|                                                                                 |                                                         |                    | Full range | 10          |       |           | 10          |       |                  |
|                                                                                 |                                                         | $R_L = 1 M\Omega$  | 25°C       |             | 3000  |           |             | 3000  |                  |
| $r_{id}$ Differential input resistance                                          |                                                         | 25°C               |            | $10^{12}$   |       |           | $10^{12}$   |       | $\Omega$         |
| $r_{ic}$ Common-mode input resistance                                           |                                                         | 25°C               |            | $10^{12}$   |       |           | $10^{12}$   |       | $\Omega$         |
| $c_{ic}$ Common-mode input capacitance                                          | $f = 10 kHz, P$ package                                 | 25°C               |            | 8           |       |           | 8           |       | pF               |
| $z_o$ Closed-loop output impedance                                              | $f = 25 kHz, A_V = 10$                                  | 25°C               |            | 190         |       |           | 190         |       | $\Omega$         |
| CMRR Common-mode rejection ratio                                                | $V_{IC} = -5 V$ to 2.7 V, $V_O = 0, R_S = 50 \Omega$    | 25°C               | 75         | 88          |       | 75        | 88          |       | dB               |
|                                                                                 |                                                         | Full range         | 75         |             |       | 75        |             |       |                  |
| $k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{DD\pm} / \Delta V_{IO}$ ) | $V_{DD} = 4.4 V$ to 16 V, $V_{IC} = V_{DD}/2$ , No load | 25°C               | 80         | 95          |       | 80        | 95          |       | dB               |
|                                                                                 |                                                         | Full range         | 80         |             |       | 80        |             |       |                  |
| $I_{DD}$ Supply current                                                         | $V_O = 2.5 V, No$ load                                  | 25°C               |            | 80          | 125   |           | 80          | 125   | $\mu A$          |
|                                                                                 |                                                         | Full range         |            |             | 150   |           |             | 150   |                  |

† Full range is –40°C to 125°C.

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



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

| PARAMETER              |                                             | TEST CONDITIONS                                                                                    |                         | T <sub>A</sub> <sup>†</sup> | TLC2252I |      |     | TLC2252AI |      |     | UNIT   |
|------------------------|---------------------------------------------|----------------------------------------------------------------------------------------------------|-------------------------|-----------------------------|----------|------|-----|-----------|------|-----|--------|
|                        |                                             |                                                                                                    |                         |                             | MIN      | TYP  | MAX | MIN       | TYP  | MAX |        |
| SR                     | Slew rate at unity gain                     | V <sub>O</sub> = ±1.9 V, R <sub>L</sub> = 100 kΩ,<br>C <sub>L</sub> = 100 pF                       |                         | 25°C                        | 0.07     | 0.12 |     | 0.07      | 0.12 |     | V/μs   |
|                        |                                             |                                                                                                    |                         | Full range                  | 0.05     |      |     | 0.05      |      |     |        |
| V <sub>n</sub>         | Equivalent input noise voltage              | f = 10 Hz                                                                                          |                         | 25°C                        | 38       |      |     | 38        |      |     | nV/√Hz |
|                        |                                             | f = 1 kHz                                                                                          |                         | 25°C                        | 19       |      |     | 19        |      |     |        |
| V <sub>N(PP)</sub>     | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 1 Hz                                                                                 |                         | 25°C                        | 0.8      |      |     | 0.8       |      |     | μV     |
|                        |                                             | f = 0.1 Hz to 10 Hz                                                                                |                         | 25°C                        | 1.1      |      |     | 1.1       |      |     |        |
| I <sub>n</sub>         | Equivalent input noise current              |                                                                                                    |                         | 25°C                        | 0.6      |      |     | 0.6       |      |     | fA/√Hz |
| THD + N                | Total harmonic distortion plus noise        | V <sub>O</sub> = ±2.3 V,<br>R <sub>L</sub> = 50 kΩ,<br>f = 10 kHz                                  | A <sub>V</sub> = 1      | 25°C                        | 0.2%     |      |     | 0.2%      |      |     |        |
|                        |                                             |                                                                                                    | A <sub>V</sub> = 10     |                             | 1%       |      |     | 1%        |      |     |        |
| Gain-bandwidth product |                                             | f = 10 kHz,<br>C <sub>L</sub> = 100 pF                                                             | R <sub>L</sub> = 50 kΩ, | 25°C                        | 0.21     |      |     | 0.21      |      |     | MHz    |
| B <sub>OM</sub>        | Maximum output-swing bandwidth              | V <sub>O(PP)</sub> = 4.6 V, A <sub>V</sub> = 1,<br>R <sub>L</sub> = 50 kΩ, C <sub>L</sub> = 100 pF |                         | 25°C                        | 14       |      |     | 14        |      |     | kHz    |
| φ <sub>m</sub>         | Phase margin at unity gain                  | R <sub>L</sub> = 50 kΩ, C <sub>L</sub> = 100 pF                                                    |                         | 25°C                        | 63°      |      |     | 63°       |      |     |        |
| Gain margin            |                                             |                                                                                                    |                         | 25°C                        | 15       |      |     | 15        |      |     | dB     |

$^\dagger$  Full range is  $-40^\circ\text{C}$  to  $125^\circ\text{C}$ .

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

| PARAMETER                                                                  | TEST CONDITIONS                                                                        | $T_A^\dagger$                       | TLC2254I   |             |      | TLC2254AI |             |      | UNIT                         |
|----------------------------------------------------------------------------|----------------------------------------------------------------------------------------|-------------------------------------|------------|-------------|------|-----------|-------------|------|------------------------------|
|                                                                            |                                                                                        |                                     | MIN        | TYP         | MAX  | MIN       | TYP         | MAX  |                              |
| $V_{IO}$ Input offset voltage                                              | $V_{DD} \pm \pm 2.5\text{ V}$ ,<br>$V_{IC} = 0$ ,<br>$V_O = 0$ ,<br>$R_S = 50\ \Omega$ | 25°C                                |            | 200         | 1500 |           | 200         | 850  | $\mu\text{V}$                |
|                                                                            |                                                                                        | Full range                          |            |             | 1750 |           |             | 1000 |                              |
| $\alpha_{VIO}$ Temperature coefficient of input offset voltage             |                                                                                        | 25°C to 125°C                       |            | 0.5         |      |           | 0.5         |      | $\mu\text{V}/^\circ\text{C}$ |
| Input offset voltage long-term drift (see Note 4)                          |                                                                                        | 25°C                                |            | 0.003       |      |           | 0.003       |      | $\mu\text{V}/\text{mo}$      |
| $I_{IO}$ Input offset current                                              |                                                                                        | 25°C                                |            | 0.5         |      |           | 0.5         |      | $\text{pA}$                  |
|                                                                            |                                                                                        | Full range                          |            |             | 1000 |           |             | 1000 |                              |
| $I_{IB}$ Input bias current                                                |                                                                                        | 25°C                                |            | 1           |      |           | 1           |      | $\text{pA}$                  |
|                                                                            |                                                                                        | Full range                          |            |             | 1000 |           |             | 1000 |                              |
| $V_{ICR}$ Common-mode input voltage range                                  | $R_S = 50\ \Omega$ , $ V_{IO}  \leq 5\text{ mV}$                                       | 25°C                                | 0 to 4     | –0.3 to 4.2 |      | 0 to 4    | –0.3 to 4.2 |      | $\text{V}$                   |
|                                                                            |                                                                                        | Full range                          | 0 to 3.5   |             |      | 0 to 3.5  |             |      |                              |
| $V_{OH}$ High-level output voltage                                         | $I_{OH} = -20\ \mu\text{A}$                                                            | 25°C                                |            | 4.98        |      |           | 4.98        |      | $\text{V}$                   |
|                                                                            | $I_{OH} = -75\ \mu\text{A}$                                                            | 25°C                                | 4.9        | 4.94        |      | 4.9       | 4.94        |      |                              |
|                                                                            |                                                                                        | Full range                          | 4.8        |             |      | 4.8       |             |      |                              |
|                                                                            | $I_{OH} = -150\ \mu\text{A}$                                                           | 25°C                                | 4.8        | 4.88        |      | 4.8       | 4.88        |      |                              |
| $V_{OL}$ Low-level output voltage                                          | $V_{IC} = 2.5\text{ V}$ , $I_{OL} = 50\ \mu\text{A}$                                   | 25°C                                |            | 0.01        |      |           | 0.01        |      | $\text{V}$                   |
|                                                                            | $V_{IC} = 2.5\text{ V}$ , $I_{OL} = 500\ \mu\text{A}$                                  | 25°C                                |            | 0.09        | 0.15 |           | 0.09        | 0.15 |                              |
|                                                                            |                                                                                        | Full range                          |            |             | 0.15 |           |             | 0.15 |                              |
|                                                                            | $V_{IC} = 2.5\text{ V}$ , $I_{OL} = 4\text{ mA}$                                       | 25°C                                |            | 0.8         | 1    |           | 0.7         | 1    |                              |
|                                                                            |                                                                                        | Full range                          |            |             | 1.2  |           |             | 1.2  |                              |
| $A_{VD}$ Large-signal differential voltage amplification                   | $V_{IC} = 2.5\text{ V}$ ,<br>$V_O = 1\text{ V to }4\text{ V}$                          | $R_L = 100\text{ k}\Omega^\ddagger$ | 25°C       | 100         | 350  |           | 100         | 350  | $\text{V/mV}$                |
|                                                                            |                                                                                        |                                     | Full range | 10          |      |           | 10          |      |                              |
|                                                                            |                                                                                        | $R_L = 1\text{ M}\Omega^\ddagger$   | 25°C       |             | 1700 |           |             | 1700 |                              |
| $r_{i(d)}$ Differential input resistance                                   |                                                                                        | 25°C                                |            | $10^{12}$   |      |           | $10^{12}$   |      | $\Omega$                     |
| $r_{i(c)}$ Common-mode input resistance                                    |                                                                                        | 25°C                                |            | $10^{12}$   |      |           | $10^{12}$   |      | $\Omega$                     |
| $C_{i(c)}$ Common-mode input capacitance                                   | $f = 10\text{ kHz}$ , N package                                                        | 25°C                                |            | 8           |      |           | 8           |      | $\text{pF}$                  |
| $z_o$ Closed-loop output impedance                                         | $f = 25\text{ kHz}$ , $A_V = 10$                                                       | 25°C                                |            | 200         |      |           | 200         |      | $\Omega$                     |
| $\text{CMRR}$ Common-mode rejection ratio                                  | $V_{IC} = 0\text{ to }2.7\text{ V}$ , $V_O = 2.5\text{ V}$ ,<br>$R_S = 50\ \Omega$     | 25°C                                | 70         | 83          |      | 70        | 83          |      | $\text{dB}$                  |
|                                                                            |                                                                                        | Full range                          | 70         |             |      | 70        |             |      |                              |
| $k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{DD}/\Delta V_{IO}$ ) | $V_{DD} = 4.4\text{ V to }16\text{ V}$ ,<br>$V_{IC} = V_{DD}/2$ , No load              | 25°C                                | 80         | 95          |      | 80        | 95          |      | $\text{dB}$                  |
|                                                                            |                                                                                        | Full range                          | 80         |             |      | 80        |             |      |                              |
| $I_{DD}$ Supply current (four amplifiers)                                  | $V_O = 2.5\text{ V}$ , No load                                                         | 25°C                                |            | 140         | 250  |           | 140         | 250  | $\mu\text{A}$                |
|                                                                            |                                                                                        | Full range                          |            |             | 300  |           |             | 300  |                              |

$^\dagger$  Full range is  $-40^\circ\text{C}$  to  $125^\circ\text{C}$ .

$^\ddagger$  Referenced to 2.5 V

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

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

| PARAMETER          |                                             | TEST CONDITIONS                                                                                                    |                                                             | T <sub>A</sub> <sup>†</sup> | TLC2254I |      |     | TLC2254AI |      |     | UNIT   |
|--------------------|---------------------------------------------|--------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------|-----------------------------|----------|------|-----|-----------|------|-----|--------|
|                    |                                             |                                                                                                                    |                                                             |                             | MIN      | TYP  | MAX | MIN       | TYP  | MAX |        |
| SR                 | Slew rate at unity gain                     | V <sub>O</sub> = 1.4 V to 2.6 V,<br>R <sub>L</sub> = 100 kΩ <sup>‡</sup> ,<br>C <sub>L</sub> = 100 pF <sup>‡</sup> |                                                             | 25°C                        | 0.07     | 0.12 |     | 0.07      | 0.12 |     | V/μs   |
|                    |                                             |                                                                                                                    |                                                             | Full range                  | 0.05     |      |     | 0.05      |      |     |        |
| V <sub>n</sub>     | Equivalent input noise voltage              | f = 10 Hz                                                                                                          |                                                             | 25°C                        | 36       |      |     | 36        |      |     | nV/√Hz |
|                    |                                             | f = 1 kHz                                                                                                          |                                                             | 25°C                        | 19       |      |     | 19        |      |     |        |
| V <sub>N(PP)</sub> | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 1 Hz                                                                                                 |                                                             | 25°C                        | 0.7      |      |     | 0.7       |      |     | μV     |
|                    |                                             | f = 0.1 Hz to 10 Hz                                                                                                |                                                             | 25°C                        | 1.1      |      |     | 1.1       |      |     |        |
| I <sub>n</sub>     | Equivalent input noise current              |                                                                                                                    |                                                             | 25°C                        | 0.6      |      |     | 0.6       |      |     | fA/√Hz |
| THD + N            | Total harmonic distortion plus noise        | V <sub>O</sub> = 0.5 V to 2.5 V,<br>f = 20 kHz,<br>R <sub>L</sub> = 50 kΩ <sup>‡</sup>                             | A <sub>V</sub> = 1                                          | 25°C                        | 0.2%     |      |     | 0.2%      |      |     |        |
|                    |                                             |                                                                                                                    | A <sub>V</sub> = 10                                         |                             | 1%       |      |     | 1%        |      |     |        |
|                    | Gain-bandwidth product                      | f = 50 kHz,<br>C <sub>L</sub> = 100 pF <sup>‡</sup>                                                                | R <sub>L</sub> = 50 kΩ <sup>‡</sup> ,                       | 25°C                        | 0.2      |      |     | 0.2       |      |     | MHz    |
| B <sub>OM</sub>    | Maximum output-swing bandwidth              | V <sub>O(PP)</sub> = 2 V,<br>R <sub>L</sub> = 50 kΩ <sup>‡</sup> ,                                                 | A <sub>V</sub> = 1,<br>C <sub>L</sub> = 100 pF <sup>‡</sup> | 25°C                        | 30       |      |     | 30        |      |     | kHz    |
| φ <sub>m</sub>     | Phase margin at unity gain                  | R <sub>L</sub> = 50 kΩ <sup>‡</sup> ,                                                                              | C <sub>L</sub> = 100 pF <sup>‡</sup>                        | 25°C                        | 63°      |      |     | 63°       |      |     |        |
|                    | Gain margin                                 |                                                                                                                    |                                                             | 25°C                        | 15       |      |     | 15        |      |     | dB     |

$^\dagger$  Full range is  $-40^\circ\text{C}$  to  $125^\circ\text{C}$ .

$^\ddagger$  Referenced to 2.5 V

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

| PARAMETER                                                                     | TEST CONDITIONS                                                     | $T_A$ †                | TLC2254I   |             |       | TLC2254AI |             |       | UNIT             |
|-------------------------------------------------------------------------------|---------------------------------------------------------------------|------------------------|------------|-------------|-------|-----------|-------------|-------|------------------|
|                                                                               |                                                                     |                        | MIN        | TYP         | MAX   | MIN       | TYP         | MAX   |                  |
| $V_{IO}$ Input offset voltage                                                 | $V_{IC} = 0, V_O = 0, R_S = 50 \Omega$                              | 25°C                   |            | 200         | 1500  |           | 200         | 850   | $\mu V$          |
|                                                                               |                                                                     | Full range             |            |             | 1750  |           |             | 1000  |                  |
| $\alpha_{VIO}$ Temperature coefficient of input offset voltage                |                                                                     | 25°C to 125°C          |            | 0.5         |       |           | 0.5         |       | $\mu V/^\circ C$ |
| Input offset voltage long-term drift (see Note 4)                             |                                                                     | 25°C                   |            | 0.003       |       |           | 0.003       |       | $\mu V/mo$       |
| $I_{IO}$ Input offset current                                                 |                                                                     | 25°C                   |            | 0.5         |       |           | 0.5         |       | pA               |
|                                                                               |                                                                     | Full range             |            |             | 1000  |           |             | 1000  |                  |
| $I_{IB}$ Input bias current                                                   |                                                                     | 25°C                   |            | 1           |       |           | 1           |       | pA               |
|                                                                               |                                                                     | Full range             |            |             | 1000  |           |             | 1000  |                  |
| $V_{ICR}$ Common-mode input voltage range                                     | $R_S = 50 \Omega,  V_{IO}  \leq 5$ mV                               | 25°C                   | –5 to 4    | –5.3 to 4.2 |       | –5 to 4   | –5.3 to 4.2 |       | V                |
|                                                                               |                                                                     | Full range             | –5 to 3.5  |             |       | –5 to 3.5 |             |       |                  |
| $V_{OM+}$ Maximum positive peak output voltage                                | $I_O = -20 \mu A$                                                   | 25°C                   |            | 4.98        |       |           | 4.98        |       | V                |
|                                                                               | $I_O = -100 \mu A$                                                  | 25°C                   |            | 4.9         | 4.93  |           | 4.9         | 4.93  |                  |
|                                                                               |                                                                     | Full range             |            | 4.7         |       |           | 4.7         |       |                  |
|                                                                               | $I_O = -200 \mu A$                                                  | 25°C                   |            | 4.8         | 4.86  |           | 4.8         | 4.86  |                  |
| $V_{OM-}$ Maximum negative peak output voltage                                | $V_{IC} = 0, I_O = 50 \mu A$                                        | 25°C                   |            | –4.99       |       |           | –4.99       |       | V                |
|                                                                               | $V_{IC} = 0, I_O = 500 \mu A$                                       | 25°C                   |            | –4.85       | –4.91 |           | –4.85       | –4.91 |                  |
|                                                                               |                                                                     | Full range             |            | –4.85       |       |           | –4.85       |       |                  |
|                                                                               | $V_{IC} = 0, I_O = 4$ mA                                            | 25°C                   |            | –4          | –4.3  |           | –4          | –4.3  |                  |
|                                                                               |                                                                     | Full range             |            | –3.8        |       |           | –3.8        |       |                  |
|                                                                               |                                                                     |                        |            |             |       |           |             |       |                  |
| $A_{VD}$ Large-signal differential voltage amplification                      | $V_O = \pm 4$ V                                                     | $R_L = 100$ k $\Omega$ | 25°C       | 40          | 150   |           | 40          | 150   | V/mV             |
|                                                                               |                                                                     |                        | Full range | 10          |       |           | 10          |       |                  |
|                                                                               |                                                                     | $R_L = 1$ M $\Omega$   | 25°C       |             | 3000  |           |             | 3000  |                  |
| $r_{i(d)}$ Differential input resistance                                      |                                                                     | 25°C                   |            | $10^{12}$   |       |           | $10^{12}$   |       | $\Omega$         |
| $r_{i(c)}$ Common-mode input resistance                                       |                                                                     | 25°C                   |            | $10^{12}$   |       |           | $10^{12}$   |       | $\Omega$         |
| $c_{i(c)}$ Common-mode input capacitance                                      | $f = 10$ kHz, N package                                             | 25°C                   |            | 8           |       |           | 8           |       | pF               |
| $z_o$ Closed-loop output impedance                                            | $f = 25$ kHz, $A_V = 10$                                            | 25°C                   |            | 190         |       |           | 190         |       | $\Omega$         |
| CMRR Common-mode rejection ratio                                              | $V_{IC} = -5$ V to 2.7 V, $V_O = 0, R_S = 50 \Omega$                | 25°C                   |            | 75          | 88    |           | 75          | 88    | dB               |
|                                                                               |                                                                     | Full range             |            | 75          |       |           | 75          |       |                  |
| $k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{DD\pm}/\Delta V_{IO}$ ) | $V_{DD\pm} = \pm 2.2$ V to $\pm 8$ V, $V_{IC} = V_{DD}/2$ , No load | 25°C                   |            | 80          | 95    |           | 80          | 95    | dB               |
|                                                                               |                                                                     | Full range             |            | 80          |       |           | 80          |       |                  |
| $I_{DD}$ Supply current (four amplifiers)                                     | $V_O = 0$ , No load                                                 | 25°C                   |            | 160         | 250   |           | 160         | 250   | $\mu A$          |
|                                                                               |                                                                     | Full range             |            |             | 300   |           |             | 300   |                  |

† Full range is –40°C to 125°C.

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

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

| PARAMETER   |                                             | TEST CONDITIONS                                                                  |                                      | $T_A^\dagger$ | TLC2254I |      |     | TLC2254AI |      |     | UNIT                   |
|-------------|---------------------------------------------|----------------------------------------------------------------------------------|--------------------------------------|---------------|----------|------|-----|-----------|------|-----|------------------------|
|             |                                             |                                                                                  |                                      |               | MIN      | TYP  | MAX | MIN       | TYP  | MAX |                        |
| SR          | Slew rate at unity gain                     | $V_O = \pm 1.9\text{ V}$ ,<br>$C_L = 100\text{ pF}$                              | $R_L = 100\text{ k}\Omega$ ,         | 25°C          | 0.07     | 0.12 |     | 0.07      | 0.12 |     | V/ $\mu\text{s}$       |
|             |                                             |                                                                                  |                                      | Full range    | 0.05     |      |     | 0.05      |      |     |                        |
| $V_n$       | Equivalent input noise voltage              | $f = 10\text{ Hz}$                                                               |                                      | 25°C          |          | 38   |     |           | 38   |     | nV/ $\sqrt{\text{Hz}}$ |
|             |                                             | $f = 1\text{ kHz}$                                                               |                                      | 25°C          |          | 19   |     |           | 19   |     |                        |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | $f = 0.1\text{ Hz to }1\text{ Hz}$                                               |                                      | 25°C          |          | 0.8  |     |           | 0.8  |     | $\mu\text{V}$          |
|             |                                             | $f = 0.1\text{ Hz to }10\text{ Hz}$                                              |                                      | 25°C          |          | 1.1  |     |           | 1.1  |     |                        |
| $I_n$       | Equivalent input noise current              |                                                                                  |                                      | 25°C          |          | 0.6  |     |           | 0.6  |     | fA/ $\sqrt{\text{Hz}}$ |
| THD + N     | Total harmonic distortion plus noise        | $V_O = \pm 2.3\text{ V}$ ,<br>$R_L = 50\text{ k}\Omega$ ,<br>$f = 20\text{ kHz}$ | $A_V = 1$                            | 25°C          |          | 0.2% |     |           | 0.2% |     |                        |
|             |                                             |                                                                                  | $A_V = 10$                           |               |          | 1%   |     |           | 1%   |     |                        |
|             | Gain-bandwidth product                      | $f = 10\text{ kHz}$ ,<br>$C_L = 100\text{ pF}$                                   | $R_L = 50\text{ k}\Omega$ ,          | 25°C          |          | 0.21 |     |           | 0.21 |     | MHz                    |
| BOM         | Maximum output-swing bandwidth              | $V_{O(PP)} = 4.6\text{ V}$ ,<br>$R_L = 50\text{ k}\Omega$ ,                      | $A_V = 1$ ,<br>$C_L = 100\text{ pF}$ | 25°C          |          | 14   |     |           | 14   |     | kHz                    |
| $\phi_m$    | Phase margin at unity gain                  | $R_L = 50\text{ k}\Omega$ ,                                                      | $C_L = 100\text{ pF}$                | 25°C          |          | 63°  |     |           | 63°  |     |                        |
|             | Gain margin                                 |                                                                                  |                                      | 25°C          |          | 15   |     |           | 15   |     | dB                     |

$^\dagger$  Full range is  $-40^\circ\text{C}$  to  $125^\circ\text{C}$ .

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

| PARAMETER                                                                  | TEST CONDITIONS                                                            | $T_A^\dagger$ | TLC2252Q<br>TLC2252M |             |      | TLC2252AQ<br>TLC2252AM |             |      | UNIT                         |
|----------------------------------------------------------------------------|----------------------------------------------------------------------------|---------------|----------------------|-------------|------|------------------------|-------------|------|------------------------------|
|                                                                            |                                                                            |               | MIN                  | TYP         | MAX  | MIN                    | TYP         | MAX  |                              |
| $V_{IO}$ Input offset voltage                                              | $V_{DD} = \pm 2.5\text{ V}, V_{IC} = 0, V_O = 0, R_S = 50\ \Omega$         | 25°C          |                      | 200         | 1500 |                        | 200         | 850  | $\mu\text{V}$                |
|                                                                            |                                                                            | Full range    |                      |             | 1750 |                        |             | 1000 |                              |
| $\alpha_{VIO}$ Temperature coefficient of input offset voltage             |                                                                            | 25°C to 125°C |                      | 0.5         |      |                        | 0.5         |      | $\mu\text{V}/^\circ\text{C}$ |
| Input offset voltage long-term drift (see Note 4)                          |                                                                            | 25°C          |                      | 0.003       |      |                        | 0.003       |      | $\mu\text{V}/\text{mo}$      |
| $I_{IO}$ Input offset current                                              |                                                                            | 25°C          |                      | 0.5         |      |                        | 0.5         |      | $\text{pA}$                  |
|                                                                            |                                                                            | Full range    |                      |             | 500  |                        |             | 500  |                              |
| $I_{IB}$ Input bias current                                                |                                                                            | 25°C          |                      | 1           |      |                        | 1           |      | $\text{pA}$                  |
|                                                                            |                                                                            | Full range    |                      |             | 500  |                        |             | 500  |                              |
| $V_{ICR}$ Common-mode input voltage range                                  | $R_S = 50\ \Omega,  V_{IO}  \leq 5\text{ mV}$                              | 25°C          | 0 to 4               | –0.3 to 4.2 |      | 0 to 4                 | –0.3 to 4.2 |      | $\text{V}$                   |
|                                                                            |                                                                            | Full range    | 0 to 3.5             |             |      | 0 to 3.5               |             |      |                              |
| $V_{OH}$ High-level output voltage                                         | $I_{OH} = -20\ \mu\text{A}$                                                | 25°C          |                      | 4.98        |      |                        | 4.98        |      | $\text{V}$                   |
|                                                                            | $I_{OH} = -75\ \mu\text{A}$                                                | 25°C          | 4.9                  | 4.94        |      | 4.9                    | 4.94        |      |                              |
|                                                                            |                                                                            | Full range    | 4.8                  |             |      | 4.8                    |             |      |                              |
|                                                                            | $I_{OH} = -150\ \mu\text{A}$                                               | 25°C          | 4.8                  | 4.88        |      | 4.8                    | 4.88        |      |                              |
| $V_{OL}$ Low-level output voltage                                          | $V_{IC} = 2.5\text{ V}, I_{OL} = 50\ \mu\text{A}$                          | 25°C          |                      | 0.01        |      |                        | 0.01        |      | $\text{V}$                   |
|                                                                            | $V_{IC} = 2.5\text{ V}, I_{OL} = 500\ \mu\text{A}$                         | 25°C          |                      | 0.09        | 0.15 |                        | 0.09        | 0.15 |                              |
|                                                                            |                                                                            | Full range    |                      |             | 0.15 |                        |             | 0.15 |                              |
|                                                                            | $V_{IC} = 2.5\text{ V}, I_{OL} = 4\text{ mA}$                              | 25°C          |                      | 0.8         | 1    |                        | 0.7         | 1    |                              |
|                                                                            |                                                                            | Full range    |                      |             | 1.2  |                        |             | 1.2  |                              |
| $A_{VD}$ Large-signal differential voltage amplification                   | $V_{IC} = 2.5\text{ V}, V_O = 1\text{ V to }4\text{ V}$                    | 25°C          | 100                  | 350         |      | 100                    | 350         |      | $\text{V}/\text{mV}$         |
|                                                                            |                                                                            | Full range    | 10                   |             |      | 10                     |             |      |                              |
|                                                                            |                                                                            | 25°C          |                      | 1700        |      |                        | 1700        |      |                              |
| $r_{id}$ Differential input resistance                                     |                                                                            | 25°C          |                      | $10^{12}$   |      |                        | $10^{12}$   |      | $\Omega$                     |
| $r_{ic}$ Common-mode input resistance                                      |                                                                            | 25°C          |                      | $10^{12}$   |      |                        | $10^{12}$   |      | $\Omega$                     |
| $C_{ic}$ Common-mode input capacitance                                     | $f = 10\text{ kHz}, f = 10\text{ kHz}$                                     | 25°C          |                      | 8           |      |                        | 8           |      | $\text{pF}$                  |
| $z_o$ Closed-loop output impedance                                         | $f = 25\text{ kHz}, A_V = 10$                                              | 25°C          |                      | 200         |      |                        | 200         |      | $\Omega$                     |
| $\text{CMRR}$ Common-mode rejection ratio                                  | $V_{IC} = 0\text{ to }2.7\text{ V}, V_O = 2.5\text{ V}, R_S = 50\ \Omega$  | 25°C          | 70                   | 83          |      | 70                     | 83          |      | $\text{dB}$                  |
|                                                                            |                                                                            | Full range    | 70                   |             |      | 70                     |             |      |                              |
| $k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{DD}/\Delta V_{IO}$ ) | $V_{DD} = 4.4\text{ V to }16\text{ V}, V_{IC} = V_{DD}/2, \text{ No load}$ | 25°C          | 80                   | 95          |      | 80                     | 95          |      | $\text{dB}$                  |
|                                                                            |                                                                            | Full range    | 80                   |             |      | 80                     |             |      |                              |
| $I_{DD}$ Supply current                                                    | $V_O = 2.5\text{ V}, \text{ No load}$                                      | 25°C          |                      | 70          | 125  |                        | 70          | 125  | $\mu\text{A}$                |
|                                                                            |                                                                            | Full range    |                      |             | 150  |                        |             | 150  |                              |

$^\dagger$  Full range is  $-40^\circ\text{C}$  to  $125^\circ\text{C}$  for Q suffix,  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for M suffix.

$^\ddagger$  Referenced to 2.5 V

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

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

| PARAMETER          |                                             | TEST CONDITIONS                                                                                                    |                                                             | T <sub>A</sub> <sup>†</sup> | TLC2252Q<br>TLC2252M |      |     | TLC2252AQ<br>TLC2252AM |      |     | UNIT   |
|--------------------|---------------------------------------------|--------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------|-----------------------------|----------------------|------|-----|------------------------|------|-----|--------|
|                    |                                             |                                                                                                                    |                                                             |                             | MIN                  | TYP  | MAX | MIN                    | TYP  | MAX |        |
| SR                 | Slew rate at unity gain                     | V <sub>O</sub> = 0.5 V to 3.5 V,<br>R <sub>L</sub> = 100 kΩ <sup>‡</sup> ,<br>C <sub>L</sub> = 100 pF <sup>‡</sup> |                                                             | 25°C                        | 0.07                 | 0.12 |     | 0.07                   | 0.12 |     | V/μs   |
|                    |                                             |                                                                                                                    |                                                             | Full range                  | 0.05                 |      |     | 0.05                   |      |     |        |
| V <sub>n</sub>     | Equivalent input noise voltage              | f = 10 Hz                                                                                                          |                                                             | 25°C                        | 36                   |      |     | 36                     |      |     | nV/√Hz |
|                    |                                             | f = 1 kHz                                                                                                          |                                                             | 25°C                        | 19                   |      |     | 19                     |      |     |        |
| V <sub>N(PP)</sub> | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 1 Hz                                                                                                 |                                                             | 25°C                        | 0.7                  |      |     | 0.7                    |      |     | μV     |
|                    |                                             | f = 0.1 Hz to 10 Hz                                                                                                |                                                             | 25°C                        | 1.1                  |      |     | 1.1                    |      |     |        |
| I <sub>n</sub>     | Equivalent input noise current              |                                                                                                                    |                                                             | 25°C                        | 0.6                  |      |     | 0.6                    |      |     | fA√Hz  |
| THD + N            | Total harmonic distortion plus noise        | V <sub>O</sub> = 0.5 V to 2.5 V,<br>f = 10 kHz,<br>R <sub>L</sub> = 50 kΩ <sup>‡</sup>                             | A <sub>V</sub> = 1                                          | 25°C                        | 0.2%                 |      |     | 0.2%                   |      |     |        |
|                    |                                             |                                                                                                                    | A <sub>V</sub> = 10                                         |                             | 1%                   |      |     | 1%                     |      |     |        |
|                    | Gain-bandwidth product                      | f = 50 kHz,<br>C <sub>L</sub> = 100 pF <sup>‡</sup>                                                                |                                                             | 25°C                        | 0.2                  |      |     | 0.2                    |      |     | MHz    |
| B <sub>OM</sub>    | Maximum output-swing bandwidth              | V <sub>O(PP)</sub> = 2 V,<br>R <sub>L</sub> = 50 kΩ <sup>‡</sup> ,                                                 | A <sub>V</sub> = 1,<br>C <sub>L</sub> = 100 pF <sup>‡</sup> | 25°C                        | 30                   |      |     | 30                     |      |     | kHz    |
| φ <sub>m</sub>     | Phase margin at unity gain                  | R <sub>L</sub> = 50 kΩ <sup>‡</sup> ,<br>C <sub>L</sub> = 100 pF <sup>‡</sup>                                      |                                                             | 25°C                        | 63°                  |      |     | 63°                    |      |     |        |
|                    | Gain margin                                 |                                                                                                                    |                                                             | 25°C                        | 15                   |      |     | 15                     |      |     | dB     |

† Full range is – 40°C to 125°C for Q suffix, – 55°C to 125°C for M suffix.

‡ Referenced to 2.5 V

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

| PARAMETER        |                                                                       | TEST CONDITIONS                                                            |                         | T <sub>A</sub> <sup>†</sup> | TLC2252Q<br>TLC2252M |             |                  | TLC2252AQ<br>TLC2252AM |       |     | UNIT |
|------------------|-----------------------------------------------------------------------|----------------------------------------------------------------------------|-------------------------|-----------------------------|----------------------|-------------|------------------|------------------------|-------|-----|------|
|                  |                                                                       |                                                                            |                         |                             | MIN                  | TYP         | MAX              | MIN                    | TYP   | MAX |      |
| V <sub>IO</sub>  | Input offset voltage                                                  | V <sub>IC</sub> = 0, V <sub>O</sub> = 0,<br>R <sub>S</sub> = 50 Ω          |                         | 25°C                        | 200                  | 1500        | 200              | 850                    | μV    |     |      |
|                  | Full range                                                            |                                                                            |                         | 1750                        |                      | 1000        |                  |                        |       |     |      |
| αV <sub>IO</sub> | Temperature coefficient of input offset voltage                       |                                                                            |                         | 25°C to 125°C               | 0.5                  |             | 0.5              |                        | μV/°C |     |      |
|                  | Input offset voltage long-term drift (see Note 4)                     |                                                                            |                         | 25°C                        | 0.003                |             | 0.003            |                        | μV/mo |     |      |
| I <sub>IO</sub>  | Input offset current                                                  |                                                                            |                         | 25°C                        | 0.5                  |             | 0.5              |                        | pA    |     |      |
|                  |                                                                       |                                                                            |                         | Full range                  | 500                  |             | 500              |                        |       |     |      |
| I <sub>IB</sub>  | Input bias current                                                    |                                                                            |                         | 25°C                        | 1                    |             | 1                |                        | pA    |     |      |
|                  |                                                                       |                                                                            |                         | Full range                  | 500                  |             | 500              |                        |       |     |      |
| V <sub>ICR</sub> | Common-mode input voltage range                                       | R <sub>S</sub> = 50 Ω,  V <sub>IO</sub>   ≤5 mV                            |                         | 25°C                        | -5 to 4              | -5.3 to 4.2 | -5 to 4          | -5.3 to 4.2            | V     |     |      |
|                  |                                                                       |                                                                            |                         | Full range                  | -5 to 3.5            |             | -5 to 3.5        |                        |       |     |      |
| V <sub>OM+</sub> | Maximum positive peak output voltage                                  | I <sub>O</sub> = -20 μA                                                    |                         | 25°C                        | 4.98                 |             | 4.98             |                        | V     |     |      |
|                  |                                                                       | I <sub>O</sub> = -100 μA                                                   |                         | 25°C                        | 4.9                  | 4.93        | 4.9              | 4.93                   |       |     |      |
|                  |                                                                       |                                                                            |                         | Full range                  | 4.7                  |             | 4.7              |                        |       |     |      |
|                  |                                                                       | I <sub>O</sub> = -200 μA                                                   |                         | 25°C                        | 4.8                  | 4.86        | 4.8              | 4.86                   |       |     |      |
| V <sub>OM-</sub> | Maximum negative peak output voltage                                  | V <sub>IC</sub> = 0, I <sub>O</sub> = 50 μA                                |                         | 25°C                        | -4.99                |             | -4.99            |                        | V     |     |      |
|                  |                                                                       | V <sub>IC</sub> = 0, I <sub>O</sub> = 500 μA                               |                         | 25°C                        | -4.85                | -4.91       | -4.85            | -4.91                  |       |     |      |
|                  |                                                                       |                                                                            |                         | Full range                  | -4.85                |             | -4.85            |                        |       |     |      |
|                  |                                                                       | V <sub>IC</sub> = 0, I <sub>O</sub> = 4 mA                                 |                         | 25°C                        | -4                   | -4.3        | -4               | -4.3                   |       |     |      |
|                  |                                                                       |                                                                            |                         | Full range                  | -3.8                 |             | -3.8             |                        |       |     |      |
|                  |                                                                       |                                                                            |                         |                             |                      |             |                  |                        |       |     |      |
| A <sub>VD</sub>  | Large-signal differential voltage amplification                       | V <sub>O</sub> = ±4 V                                                      | R <sub>L</sub> = 100 kΩ | 25°C                        | 40                   | 150         | 40               | 150                    | V/mV  |     |      |
|                  |                                                                       |                                                                            |                         | Full range                  | 10                   |             | 10               |                        |       |     |      |
|                  |                                                                       |                                                                            | R <sub>L</sub> = 1 MΩ   | 25°C                        | 3000                 |             | 3000             |                        |       |     |      |
| r <sub>id</sub>  | Differential input resistance                                         |                                                                            |                         | 25°C                        | 10 <sup>12</sup>     |             | 10 <sup>12</sup> |                        | Ω     |     |      |
| r <sub>ic</sub>  | Common-mode input resistance                                          |                                                                            |                         | 25°C                        | 10 <sup>12</sup>     |             | 10 <sup>12</sup> |                        | Ω     |     |      |
| c <sub>ic</sub>  | Common-mode input capacitance                                         | f = 10 kHz,                                                                | P package               | 25°C                        | 8                    |             | 8                |                        | pF    |     |      |
| z <sub>o</sub>   | Closed-loop output impedance                                          | f = 25 kHz,                                                                | A <sub>V</sub> = 10     | 25°C                        | 190                  |             | 190              |                        | Ω     |     |      |
| CMRR             | Common-mode rejection ratio                                           | V <sub>IC</sub> = -5 V to 2.7 V, V <sub>O</sub> = 0, R <sub>S</sub> = 50 Ω |                         | 25°C                        | 75                   | 88          | 75               | 88                     | dB    |     |      |
|                  |                                                                       |                                                                            |                         | Full range                  | 75                   |             | 75               |                        |       |     |      |
| k <sub>SVR</sub> | Supply-voltage rejection ratio (ΔV <sub>DD±</sub> /ΔV <sub>IO</sub> ) | V <sub>DD</sub> = ±2.2 V to ±8 V, V <sub>IC</sub> = 0, No load             |                         | 25°C                        | 80                   | 95          | 80               | 95                     | dB    |     |      |
|                  |                                                                       |                                                                            |                         | Full range                  | 80                   |             | 80               |                        |       |     |      |
| I <sub>DD</sub>  | Supply current                                                        | V <sub>O</sub> = 2.5 V, No load                                            |                         | 25°C                        | 80                   | 125         | 80               | 125                    | μA    |     |      |
|                  |                                                                       |                                                                            |                         | Full range                  | 150                  |             | 150              |                        |       |     |      |

† Full range is -40°C to 125°C for Q suffix, -55°C to 125°C for M suffix.

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



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

| PARAMETER   | TEST CONDITIONS                             | $T_A$ †                                                                                           | TLC2252Q<br>TLC2252M |                    |      | TLC2252AQ<br>TLC2252AM |      |     | UNIT                   |
|-------------|---------------------------------------------|---------------------------------------------------------------------------------------------------|----------------------|--------------------|------|------------------------|------|-----|------------------------|
|             |                                             |                                                                                                   | MIN                  | TYP                | MAX  | MIN                    | TYP  | MAX |                        |
| SR          | Slew rate at unity gain                     | $V_O = \pm 2\text{ V}$ ,<br>$C_L = 100\text{ pF}$<br>$R_L = 100\text{ k}\Omega$                   | 25°C                 | 0.07               | 0.12 | 0.07                   | 0.12 |     | V/ $\mu\text{s}$       |
|             |                                             |                                                                                                   |                      | Full range<br>0.05 |      | 0.05                   |      |     |                        |
| $V_n$       | Equivalent input noise voltage              | $f = 10\text{ Hz}$                                                                                | 25°C                 | 38                 |      | 38                     |      |     | nV/ $\sqrt{\text{Hz}}$ |
|             |                                             | $f = 1\text{ kHz}$                                                                                | 25°C                 | 19                 |      | 19                     |      |     |                        |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | $f = 0.1\text{ Hz to }1\text{ Hz}$                                                                | 25°C                 | 0.8                |      | 0.8                    |      |     | $\mu\text{V}$          |
|             |                                             | $f = 0.1\text{ Hz to }10\text{ Hz}$                                                               | 25°C                 | 1.1                |      | 1.1                    |      |     |                        |
| $I_n$       | Equivalent input noise current              |                                                                                                   | 25°C                 | 0.6                |      | 0.6                    |      |     | fA/ $\sqrt{\text{Hz}}$ |
| THD + N     | Total harmonic distortion plus noise        | $V_O = \pm 2.3\text{ V}$ ,<br>$R_L = 50\text{ k}\Omega$ ,<br>$f = 10\text{ kHz}$                  | 25°C                 | $A_V = 1$<br>0.2%  |      | 0.2%                   |      |     |                        |
|             |                                             |                                                                                                   |                      | $A_V = 10$<br>1%   |      | 1%                     |      |     |                        |
|             | Gain-bandwidth product                      | $f = 10\text{ kHz}$ ,<br>$C_L = 100\text{ pF}$<br>$R_L = 50\text{ k}\Omega$                       | 25°C                 | 0.21               |      | 0.21                   |      |     | MHz                    |
| BOM         | Maximum output-swing bandwidth              | $V_{O(PP)} = 4.6\text{ V}$ ,<br>$R_L = 50\text{ k}\Omega$ ,<br>$C_L = 100\text{ pF}$<br>$A_V = 1$ | 25°C                 | 14                 |      | 14                     |      |     | kHz                    |
| $\phi_m$    | Phase margin at unity gain                  | $R_L = 50\text{ k}\Omega$ ,<br>$C_L = 100\text{ pF}$                                              | 25°C                 | 63°                |      | 63°                    |      |     |                        |
|             | Gain margin                                 |                                                                                                   | 25°C                 | 15                 |      | 15                     |      |     | dB                     |

† Full range is – 40°C to 125°C for Q suffix, – 55°C to 125°C for M suffix.

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

| PARAMETER                          |                                                                      | TEST CONDITIONS                                                                              |                                                 | T <sub>A</sub> <sup>†</sup>                          | TLC2254Q<br>TLC2254M                 |          |                  | TLC2254AQ<br>TLC2254AM |       |     | UNIT |
|------------------------------------|----------------------------------------------------------------------|----------------------------------------------------------------------------------------------|-------------------------------------------------|------------------------------------------------------|--------------------------------------|----------|------------------|------------------------|-------|-----|------|
|                                    |                                                                      |                                                                                              |                                                 |                                                      | MIN                                  | TYP      | MAX              | MIN                    | TYP   | MAX |      |
| V <sub>IO</sub>                    | Input offset voltage                                                 | V <sub>DD±</sub> = ±2.5 V, V <sub>IC</sub> = 0,<br>V <sub>O</sub> = 0, R <sub>S</sub> = 50 Ω |                                                 | 25°C                                                 | 200                                  | 1500     |                  | 200                    | 850   | μV  |      |
|                                    | Full range                                                           |                                                                                              |                                                 |                                                      | 1750                                 |          | 1000             |                        |       |     |      |
| αV <sub>IO</sub>                   | Temperature coefficient of input offset voltage                      |                                                                                              |                                                 | 25°C to 125°C                                        | 0.5                                  |          | 0.5              |                        | μV/°C |     |      |
|                                    | Input offset voltage long-term drift (see Note 4)                    |                                                                                              |                                                 | 25°C                                                 | 0.003                                |          | 0.003            |                        | μV/mo |     |      |
| I <sub>IO</sub>                    | Input offset current                                                 |                                                                                              |                                                 | 25°C                                                 | 0.5                                  |          | 0.5              |                        | pA    |     |      |
|                                    |                                                                      |                                                                                              |                                                 | 125°C                                                | 500                                  |          | 500              |                        |       |     |      |
| I <sub>IB</sub>                    | Input bias current                                                   |                                                                                              |                                                 | 25°C                                                 | 1                                    |          | 1                |                        | pA    |     |      |
|                                    |                                                                      |                                                                                              |                                                 | 125°C                                                | 500                                  |          | 500              |                        |       |     |      |
| 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 4                                               | –0.3 to 4.2                          |          | 0 to 4           | –0.3 to 4.2            | V     |     |      |
|                                    |                                                                      |                                                                                              | Full range                                      | 0 to 3.5                                             |                                      | 0 to 3.5 |                  |                        |       |     |      |
| V <sub>OH</sub>                    | High-level output voltage                                            | I <sub>OH</sub> = –20 μA                                                                     | 25°C                                            | 4.98                                                 |                                      | 4.98     |                  | V                      |       |     |      |
|                                    |                                                                      | I <sub>OH</sub> = –75 μA                                                                     | 25°C                                            | 4.9                                                  | 4.94                                 | 4.9      | 4.94             |                        |       |     |      |
|                                    |                                                                      |                                                                                              | Full range                                      | 4.8                                                  |                                      | 4.8      |                  |                        |       |     |      |
|                                    |                                                                      | I <sub>OH</sub> = –150 μA                                                                    | 25°C                                            | 4.8                                                  | 4.88                                 | 4.8      | 4.88             |                        |       |     |      |
| V <sub>OL</sub>                    | Low-level output voltage                                             | V <sub>IC</sub> = 2.5 V, I <sub>OL</sub> = 50 μA                                             | 25°C                                            | 0.01                                                 |                                      | 0.01     |                  | V                      |       |     |      |
|                                    |                                                                      | V <sub>IC</sub> = 2.5 V, I <sub>OL</sub> = 500 μA                                            | 25°C                                            | 0.09                                                 | 0.15                                 | 0.09     | 0.15             |                        |       |     |      |
|                                    |                                                                      |                                                                                              | Full range                                      | 0.15                                                 |                                      | 0.15     |                  |                        |       |     |      |
|                                    |                                                                      | V <sub>IC</sub> = 2.5 V, I <sub>OL</sub> = 4 mA                                              | 25°C                                            | 0.8                                                  | 1                                    | 0.7      | 1                |                        |       |     |      |
|                                    |                                                                      |                                                                                              | Full range                                      | 1.2                                                  |                                      | 1.2      |                  |                        |       |     |      |
|                                    |                                                                      | A <sub>VD</sub>                                                                              | Large-signal differential voltage amplification | V <sub>IC</sub> = 2.5 V, V <sub>O</sub> = 1 V to 4 V | R <sub>L</sub> = 100 kΩ <sup>‡</sup> | 25°C     | 100              |                        | 350   | 100 | 350  |
|                                    | Full range                                                           |                                                                                              |                                                 |                                                      | 10                                   |          | 10               |                        |       |     |      |
| R <sub>L</sub> = 1 MΩ <sup>‡</sup> | 25°C                                                                 |                                                                                              |                                                 |                                                      | 1700                                 |          | 1700             |                        |       |     |      |
| r <sub>i(d)</sub>                  | Differential input resistance                                        |                                                                                              |                                                 | 25°C                                                 | 10 <sup>12</sup>                     |          | 10 <sup>12</sup> |                        | Ω     |     |      |
| r <sub>i(c)</sub>                  | Common-mode input resistance                                         |                                                                                              |                                                 | 25°C                                                 | 10 <sup>12</sup>                     |          | 10 <sup>12</sup> |                        | Ω     |     |      |
| c <sub>i(c)</sub>                  | Common-mode input capacitance                                        | f = 10 kHz,                                                                                  | N package                                       | 25°C                                                 | 8                                    |          | 8                |                        | pF    |     |      |
| z <sub>o</sub>                     | Closed-loop output impedance                                         | f = 25 kHz,                                                                                  | A <sub>V</sub> = 10                             | 25°C                                                 | 200                                  |          | 200              |                        | Ω     |     |      |
| CMRR                               | Common-mode rejection ratio                                          | V <sub>IC</sub> = 0 to 2.7 V, V <sub>O</sub> = 2.5 V, R <sub>S</sub> = 50 Ω                  |                                                 | 25°C                                                 | 70                                   | 83       | 70               | 83                     | dB    |     |      |
|                                    |                                                                      |                                                                                              |                                                 | Full range                                           | 70                                   |          | 70               |                        |       |     |      |
| k <sub>SVR</sub>                   | Supply-voltage rejection ratio (ΔV <sub>DD</sub> /ΔV <sub>IO</sub> ) | V <sub>DD</sub> = 4.4 V to 16 V, V <sub>IC</sub> = V <sub>DD</sub> /2, No load               |                                                 | 25°C                                                 | 80                                   | 95       | 80               | 95                     | dB    |     |      |
|                                    |                                                                      |                                                                                              |                                                 | Full range                                           | 80                                   |          | 80               |                        |       |     |      |
| I <sub>DD</sub>                    | Supply current (four amplifiers)                                     | V <sub>O</sub> = 2.5 V, No load                                                              |                                                 | 25°C                                                 | 140                                  | 250      | 140              | 250                    | μA    |     |      |
|                                    |                                                                      |                                                                                              |                                                 | Full range                                           | 300                                  |          | 300              |                        |       |     |      |

† Full range is  $-40^\circ\text{C}$  to  $125^\circ\text{C}$  for Q suffix,  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for M suffix.

‡ Referenced to 2.5 V

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

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

| PARAMETER   |                                             | TEST CONDITIONS                                                                                                     | $T_A$ †    | TLC2254Q<br>TLC2254M |      |     | TLC2254AQ<br>TLC2254AM |      |     | UNIT                   |
|-------------|---------------------------------------------|---------------------------------------------------------------------------------------------------------------------|------------|----------------------|------|-----|------------------------|------|-----|------------------------|
|             |                                             |                                                                                                                     |            | MIN                  | TYP  | MAX | MIN                    | TYP  | MAX |                        |
| SR          | Slew rate at unity gain                     | $V_O = 0.5\text{ V to }3.5\text{ V}$ ,<br>$R_L = 100\text{ k}\Omega^\ddagger$ ,<br>$C_L = 100\text{ pF}^\ddagger$   | 25°C       | 0.07                 | 0.12 |     | 0.07                   | 0.12 |     | V/ $\mu\text{s}$       |
|             |                                             |                                                                                                                     | Full range | 0.05                 |      |     | 0.05                   |      |     |                        |
| $V_n$       | Equivalent input noise voltage              | $f = 10\text{ Hz}$                                                                                                  | 25°C       |                      | 36   |     |                        | 36   |     | nV/ $\sqrt{\text{Hz}}$ |
|             |                                             | $f = 1\text{ kHz}$                                                                                                  | 25°C       |                      | 19   |     |                        | 19   |     |                        |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | $f = 0.1\text{ Hz to }1\text{ Hz}$                                                                                  | 25°C       |                      | 0.7  |     |                        | 0.7  |     | $\mu\text{V}$          |
|             |                                             | $f = 0.1\text{ Hz to }10\text{ Hz}$                                                                                 | 25°C       |                      | 1.1  |     |                        | 1.1  |     |                        |
| $I_n$       | Equivalent input noise current              |                                                                                                                     | 25°C       |                      | 0.6  |     |                        | 0.6  |     | fA/ $\sqrt{\text{Hz}}$ |
| THD + N     | Total harmonic distortion plus noise        | $V_O = 0.5\text{ V to }2.5\text{ V}$ ,<br>$f = 20\text{ kHz}$ ,<br>$R_L = 50\text{ k}\Omega^\ddagger$               | 25°C       |                      | 0.2% |     |                        | 0.2% |     |                        |
|             |                                             |                                                                                                                     |            |                      | 1%   |     |                        | 1%   |     |                        |
|             | Gain-bandwidth product                      | $f = 50\text{ kHz}$ ,<br>$C_L = 100\text{ pF}^\ddagger$                                                             | 25°C       |                      | 0.2  |     |                        | 0.2  |     | MHz                    |
| $B_{OM}$    | Maximum output-swing bandwidth              | $V_{O(PP)} = 2\text{ V}$ ,<br>$R_L = 50\text{ k}\Omega^\ddagger$ ,<br>$A_V = 1$ ,<br>$C_L = 100\text{ pF}^\ddagger$ | 25°C       |                      | 30   |     |                        | 30   |     | kHz                    |
| $\phi_m$    | Phase margin at unity gain                  | $R_L = 50\text{ k}\Omega^\ddagger$ ,<br>$C_L = 100\text{ pF}^\ddagger$                                              | 25°C       |                      | 63°  |     |                        | 63°  |     |                        |
|             | Gain margin                                 |                                                                                                                     | 25°C       |                      | 15   |     |                        | 15   |     | dB                     |

† Full range is – 40°C to 125°C for Q suffix, – 55°C to 125°C for M suffix.

‡ Referenced to 2.5 V

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

| PARAMETER             |                                                                       | TEST CONDITIONS                                                                        |                                                 | T <sub>A</sub> <sup>†</sup> | TLC2254Q<br>TLC2254M    |             |                  | TLC2254AQ<br>TLC2254AM |       |     | UNIT |
|-----------------------|-----------------------------------------------------------------------|----------------------------------------------------------------------------------------|-------------------------------------------------|-----------------------------|-------------------------|-------------|------------------|------------------------|-------|-----|------|
|                       |                                                                       |                                                                                        |                                                 |                             | MIN                     | TYP         | MAX              | MIN                    | TYP   | MAX |      |
| V <sub>IO</sub>       | Input offset voltage                                                  | V <sub>IC</sub> = 0,    V <sub>O</sub> = 0,<br>R <sub>S</sub> = 50 Ω                   |                                                 | 25°C                        | 200                     | 1500        | 200              | 850                    | μV    |     |      |
|                       | Full range                                                            |                                                                                        |                                                 | 1750                        |                         | 1000        |                  |                        |       |     |      |
| α <sub>VIO</sub>      | Temperature coefficient of input offset voltage                       |                                                                                        |                                                 | 25°C to 125°C               | 0.5                     |             | 0.5              |                        | μV/°C |     |      |
|                       | Input offset voltage long-term drift (see Note 4)                     |                                                                                        |                                                 | 25°C                        | 0.003                   |             | 0.003            |                        | μV/mo |     |      |
| I <sub>IO</sub>       | Input offset current                                                  |                                                                                        |                                                 | 25°C                        | 0.5                     |             | 0.5              |                        | pA    |     |      |
|                       |                                                                       |                                                                                        |                                                 | 125°C                       | 500                     |             | 500              |                        |       |     |      |
| I <sub>IB</sub>       | Input bias current                                                    |                                                                                        |                                                 | 25°C                        | 1                       |             | 1                |                        | pA    |     |      |
|                       |                                                                       |                                                                                        |                                                 | 125°C                       | 500                     |             | 500              |                        |       |     |      |
| V <sub>ICR</sub>      | Common-mode input voltage range                                       | R <sub>S</sub> = 50 Ω,     V <sub>IO</sub>   ≤ 5 mV                                    |                                                 | 25°C                        | -5 to 4                 | -5.3 to 4.2 | -5 to 4          | -5.3 to 4.2            | V     |     |      |
|                       |                                                                       |                                                                                        |                                                 | Full range                  | -5 to 3.5               |             | -5 to 3.5        |                        |       |     |      |
| V <sub>OM+</sub>      | Maximum positive peak output voltage                                  | I <sub>O</sub> = -20 μA                                                                |                                                 | 25°C                        | 4.98                    |             | 4.98             |                        | V     |     |      |
|                       |                                                                       | I <sub>O</sub> = -100 μA                                                               |                                                 | 25°C                        | 4.9                     | 4.93        | 4.9              | 4.93                   |       |     |      |
|                       |                                                                       |                                                                                        |                                                 | Full range                  | 4.7                     |             | 4.7              |                        |       |     |      |
|                       |                                                                       | I <sub>O</sub> = -200 μA                                                               |                                                 | 25°C                        | 4.8                     | 4.86        | 4.8              | 4.86                   |       |     |      |
| V <sub>OM-</sub>      | Maximum negative peak output voltage                                  | V <sub>IC</sub> = 0,    I <sub>O</sub> = 50 μA                                         |                                                 | 25°C                        | -4.99                   |             | -4.99            |                        | V     |     |      |
|                       |                                                                       | V <sub>IC</sub> = 0,    I <sub>O</sub> = 500 μA                                        |                                                 | 25°C                        | -4.85                   | -4.91       | -4.85            | -4.91                  |       |     |      |
|                       |                                                                       |                                                                                        |                                                 | Full range                  | -4.85                   |             | -4.85            |                        |       |     |      |
|                       |                                                                       | V <sub>IC</sub> = 0,    I <sub>O</sub> = 4 mA                                          |                                                 | 25°C                        | -4                      | -4.3        | -4               | -4.3                   |       |     |      |
|                       |                                                                       |                                                                                        |                                                 | Full range                  | -3.8                    |             | -3.8             |                        |       |     |      |
|                       |                                                                       | A <sub>VD</sub>                                                                        | Large-signal differential voltage amplification | V <sub>O</sub> = ±4 V       | R <sub>L</sub> = 100 kΩ | 25°C        | 40               | 150                    |       |     | 40   |
|                       | Full range                                                            |                                                                                        |                                                 |                             | 10                      |             | 10               |                        |       |     |      |
| R <sub>L</sub> = 1 MΩ | 25°C                                                                  |                                                                                        |                                                 |                             | 3000                    |             | 3000             |                        |       |     |      |
| r <sub>i(d)</sub>     | Differential input resistance                                         |                                                                                        |                                                 | 25°C                        | 10 <sup>12</sup>        |             | 10 <sup>12</sup> |                        | Ω     |     |      |
| r <sub>i(c)</sub>     | Common-mode input resistance                                          |                                                                                        |                                                 | 25°C                        | 10 <sup>12</sup>        |             | 10 <sup>12</sup> |                        | Ω     |     |      |
| c <sub>i(c)</sub>     | Common-mode input capacitance                                         | f = 10 kHz,    N package                                                               |                                                 | 25°C                        | 8                       |             | 8                |                        | pF    |     |      |
| z <sub>o</sub>        | Closed-loop output impedance                                          | f = 25 kHz,    A <sub>V</sub> = 10                                                     |                                                 | 25°C                        | 190                     |             | 190              |                        | Ω     |     |      |
| CMRR                  | Common-mode rejection ratio                                           | V <sub>IC</sub> = -5 V to 2.7 V,<br>V <sub>O</sub> = 0,    R <sub>S</sub> = 50 Ω       |                                                 | 25°C                        | 75                      | 88          | 75               | 88                     | dB    |     |      |
|                       |                                                                       |                                                                                        |                                                 | Full range                  | 75                      |             | 75               |                        |       |     |      |
| k <sub>SVR</sub>      | Supply-voltage rejection ratio (ΔV <sub>DD±</sub> /ΔV <sub>IO</sub> ) | V <sub>DD±</sub> = ±2.2 V to ±8 V,<br>V <sub>IC</sub> = V <sub>DD</sub> /2,    No load |                                                 | 25°C                        | 80                      | 95          | 80               | 95                     | dB    |     |      |
|                       |                                                                       |                                                                                        |                                                 | Full range                  | 80                      |             | 80               |                        |       |     |      |
| I <sub>DD</sub>       | Supply current (four amplifiers)                                      | V <sub>O</sub> = 0,    No load                                                         |                                                 | 25°C                        | 160                     | 250         | 160              | 250                    | μA    |     |      |
|                       |                                                                       |                                                                                        |                                                 | Full range                  | 300                     |             | 300              |                        |       |     |      |

$^\dagger$  Full range is -40°C to 125°C for Q suffix, -55°C to 125°C for M suffix.

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

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

| PARAMETER          |                                             | TEST CONDITIONS                                                   |                                                | T <sub>A</sub> <sup>†</sup> | TLC2254Q<br>TLC2254M |      |      | TLC2254AQ<br>TLC2254AM |      |     | UNIT   |
|--------------------|---------------------------------------------|-------------------------------------------------------------------|------------------------------------------------|-----------------------------|----------------------|------|------|------------------------|------|-----|--------|
|                    |                                             |                                                                   |                                                |                             | MIN                  | TYP  | MAX  | MIN                    | TYP  | MAX |        |
| SR                 | Slew rate at unity gain                     | V <sub>O</sub> = ±2 V,<br>C <sub>L</sub> = 100 pF                 | R <sub>L</sub> = 100 kΩ,                       | 25°C                        | 0.07                 | 0.12 |      | 0.07                   | 0.12 |     | V/μs   |
|                    |                                             |                                                                   |                                                | Full range                  | 0.05                 |      | 0.05 |                        |      |     |        |
| V <sub>n</sub>     | Equivalent input noise voltage              | f = 10 Hz                                                         |                                                | 25°C                        | 38                   |      |      | 38                     |      |     | nV/√Hz |
|                    |                                             | f = 1 kHz                                                         |                                                | 25°C                        | 19                   |      |      | 19                     |      |     |        |
| V <sub>N(PP)</sub> | Peak-to-peak equivalent input noise voltage | f = 0.1 Hz to 1 Hz                                                |                                                | 25°C                        | 0.8                  |      |      | 0.8                    |      |     | μV     |
|                    |                                             | f = 0.1 Hz to 10 Hz                                               |                                                | 25°C                        | 1.1                  |      |      | 1.1                    |      |     |        |
| I <sub>n</sub>     | Equivalent input noise current              |                                                                   |                                                | 25°C                        | 0.6                  |      |      | 0.6                    |      |     | fA/√Hz |
| THD + N            | Total harmonic distortion plus noise        | V <sub>O</sub> = ±2.3 V,<br>R <sub>L</sub> = 50 kΩ,<br>f = 20 kHz | A <sub>V</sub> = 1                             | 25°C                        | 0.2%                 |      |      | 0.2%                   |      |     |        |
|                    |                                             |                                                                   | A <sub>V</sub> = 10                            |                             | 1%                   |      |      | 1%                     |      |     |        |
|                    | Gain-bandwidth product                      | f = 10 kHz,<br>C <sub>L</sub> = 100 pF                            | R <sub>L</sub> = 50 kΩ,                        | 25°C                        | 0.21                 |      |      | 0.21                   |      |     | MHz    |
| B <sub>OM</sub>    | Maximum output-swing bandwidth              | V <sub>O(PP)</sub> = 4.6 V,<br>R <sub>L</sub> = 50 kΩ,            | A <sub>V</sub> = 1,<br>C <sub>L</sub> = 100 pF | 25°C                        | 14                   |      |      | 14                     |      |     | kHz    |
| φ <sub>m</sub>     | Phase margin at unity gain                  | R <sub>L</sub> = 50 kΩ,                                           | C <sub>L</sub> = 100 pF                        | 25°C                        | 63°                  |      |      | 63°                    |      |     |        |
|                    | Gain margin                                 |                                                                   |                                                | 25°C                        | 15                   |      |      | 15                     |      |     | dB     |

† Full range is – 40°C to 125°C for Q suffix, – 55°C to 125°C for M suffix.

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**TYPICAL CHARACTERISTICS**

**Table of Graphs**

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

## TYPICAL CHARACTERISTICS

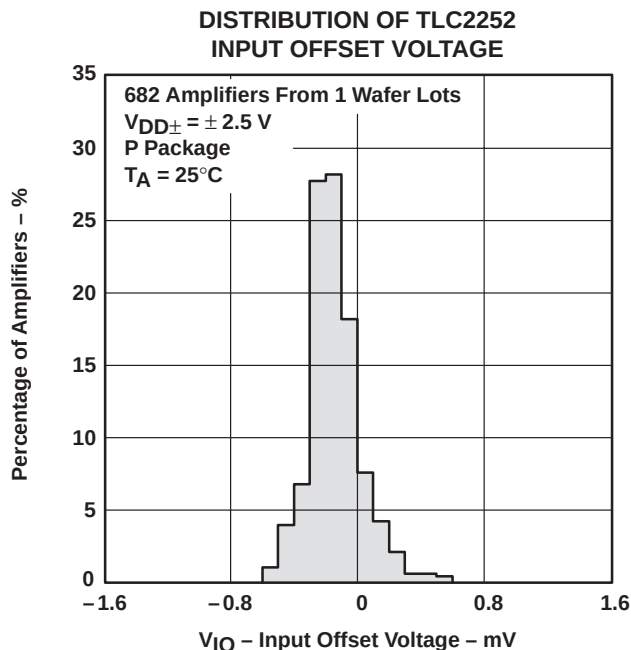


Figure 2

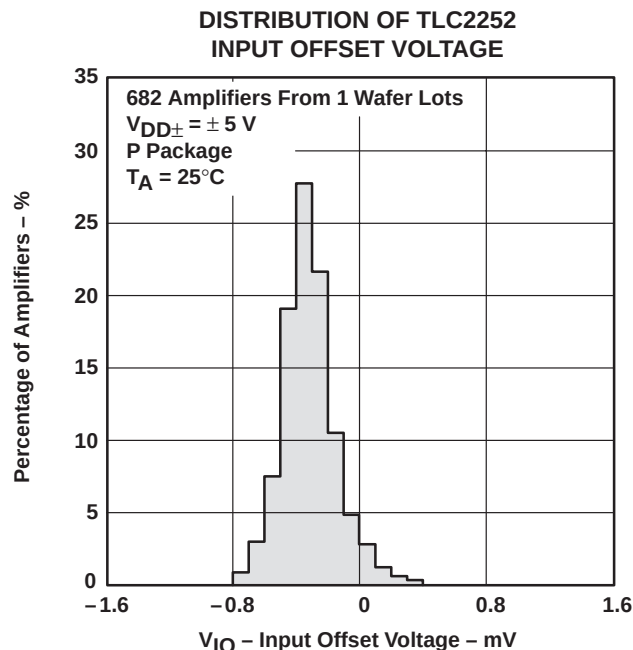


Figure 3

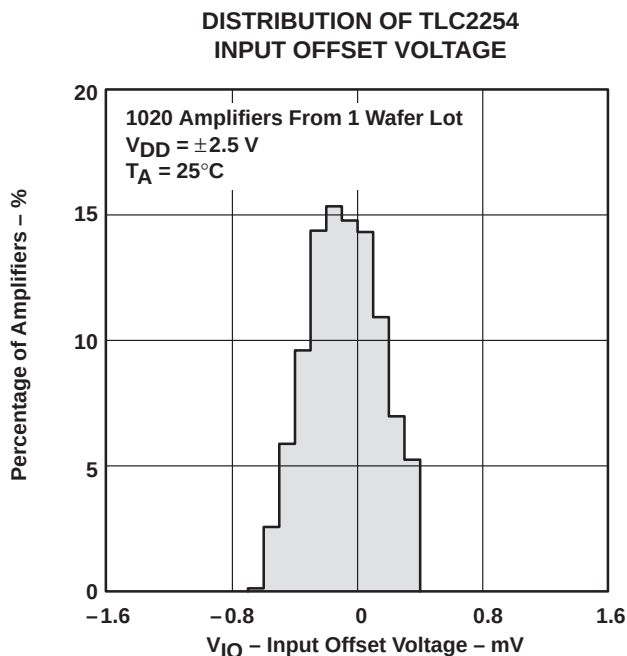


Figure 4

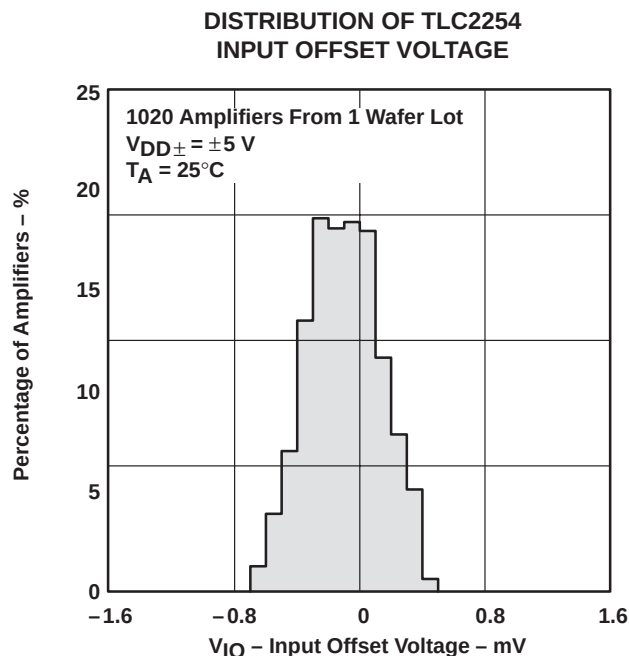
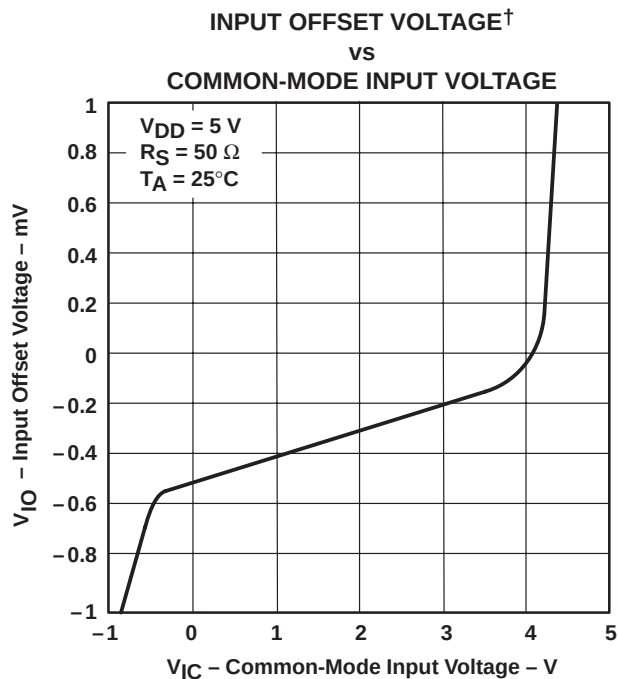


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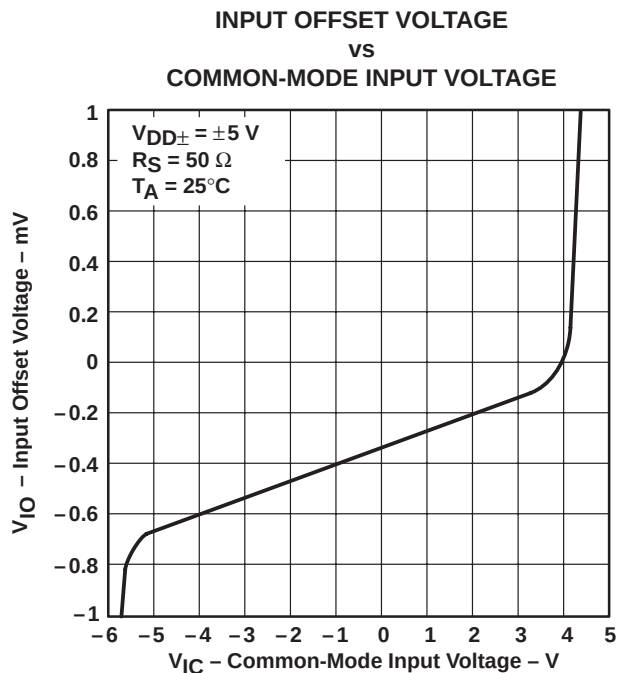
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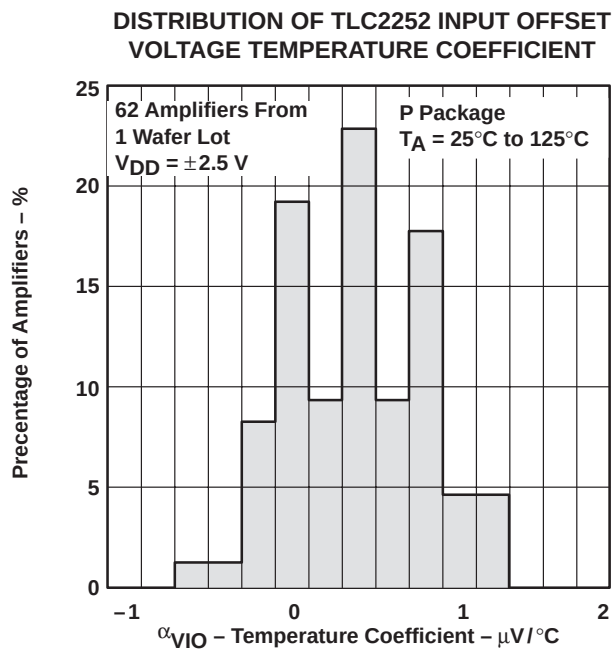
**TYPICAL CHARACTERISTICS**



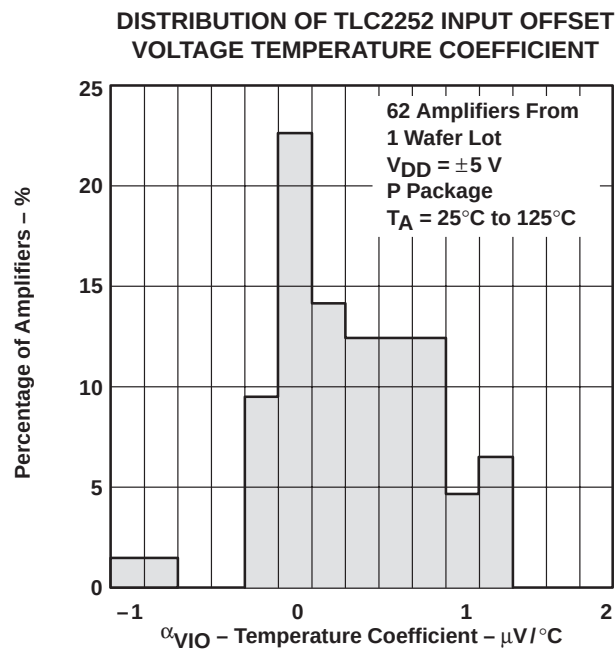
**Figure 6**



**Figure 7**



**Figure 8**



**Figure 9**

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



## TYPICAL CHARACTERISTICS

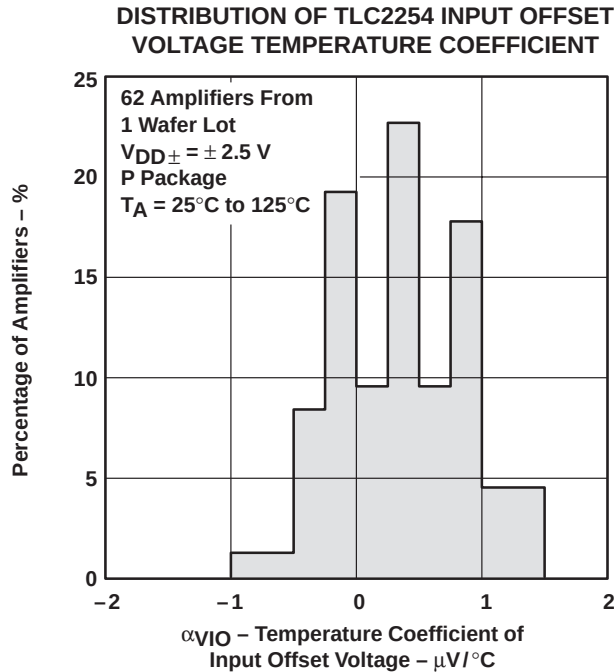


Figure 10

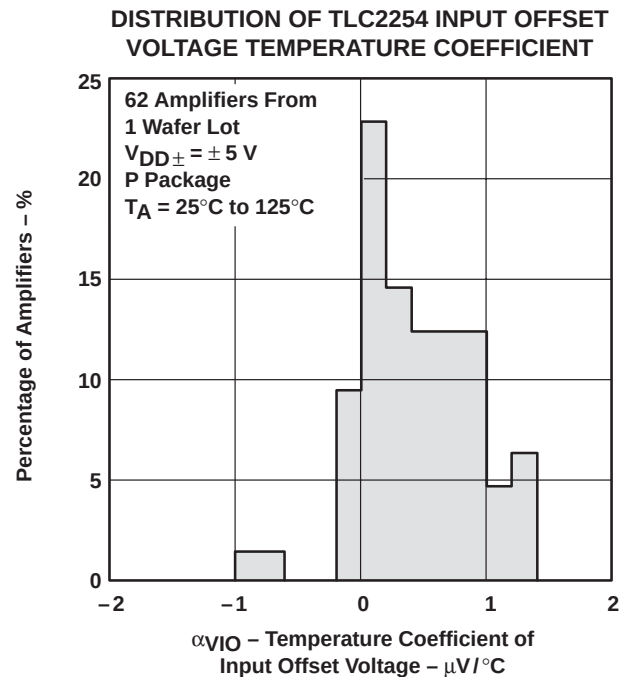


Figure 11

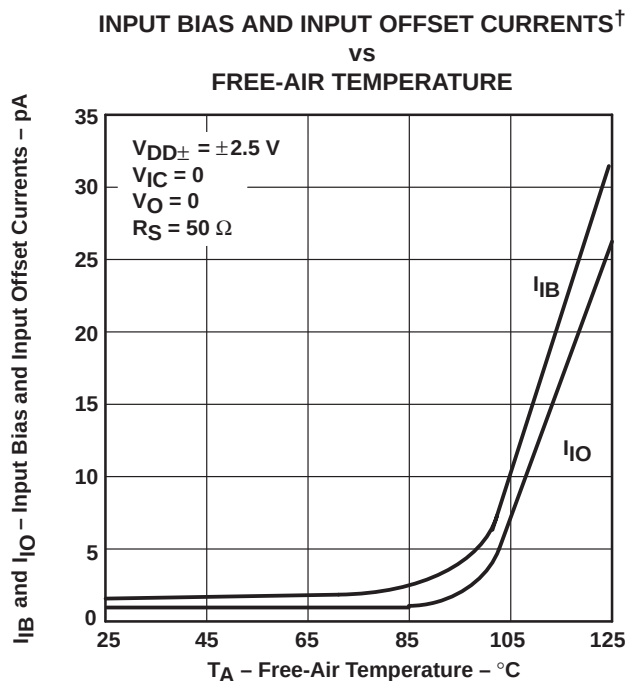


Figure 12

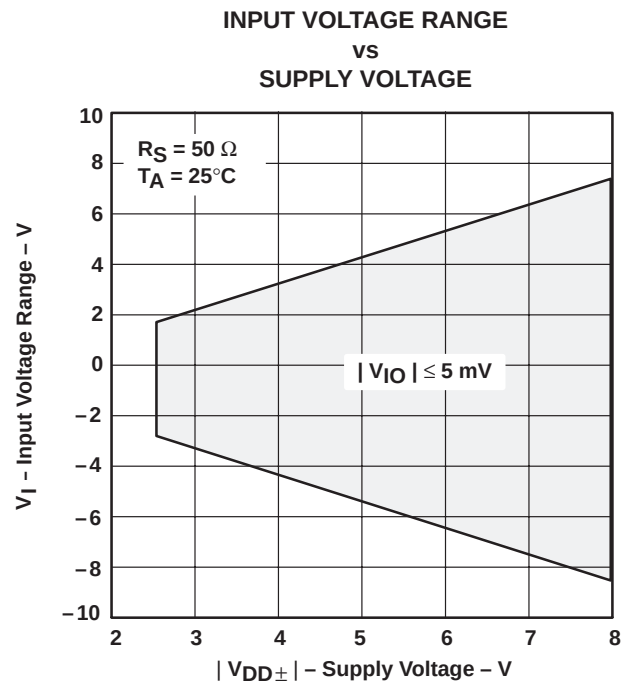
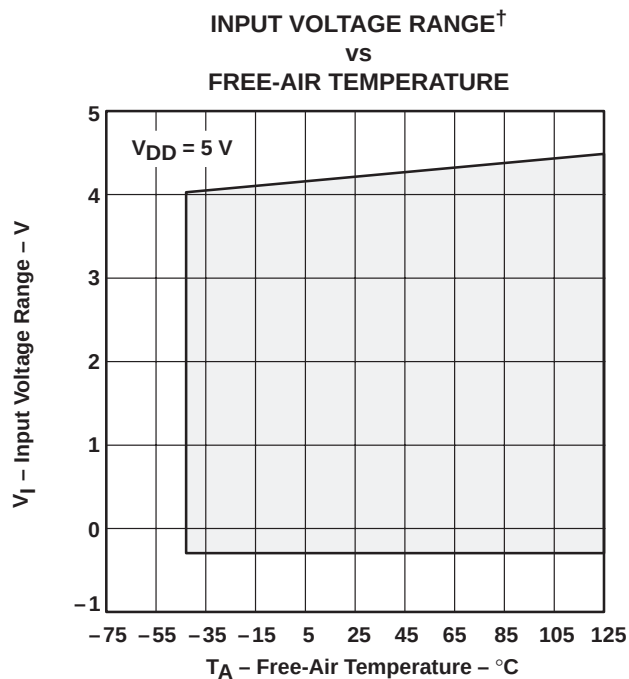


Figure 13

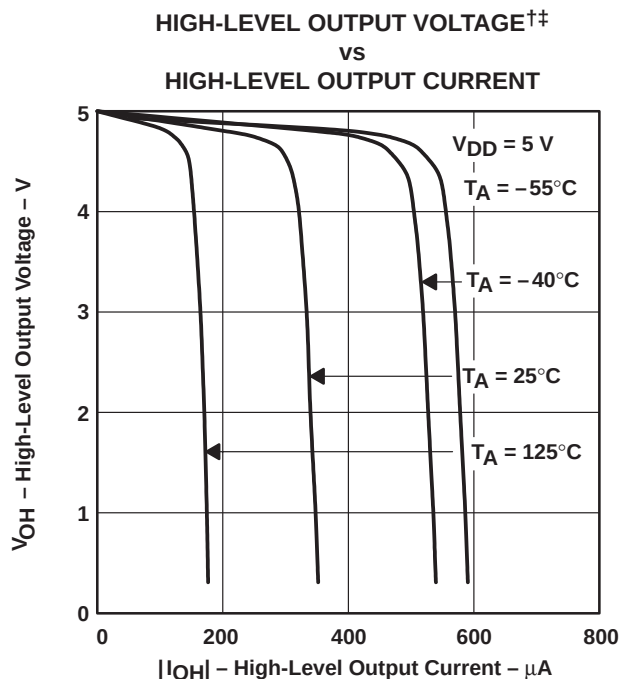
† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

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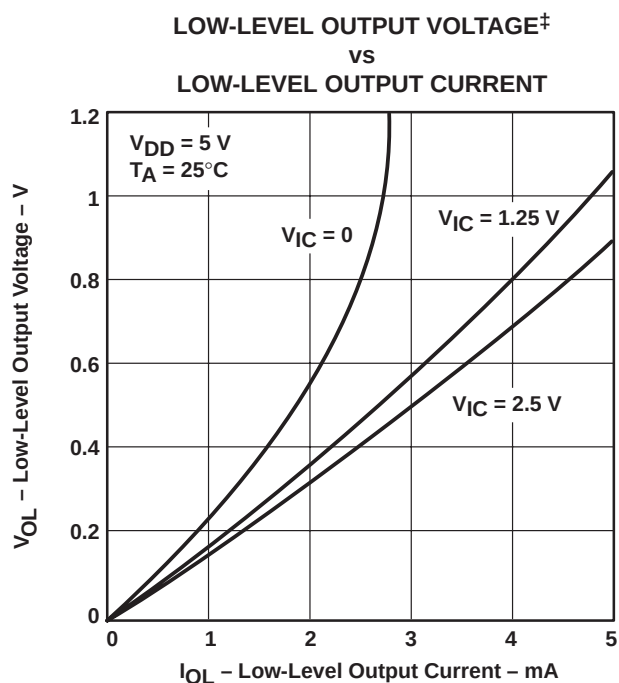
**TYPICAL CHARACTERISTICS**



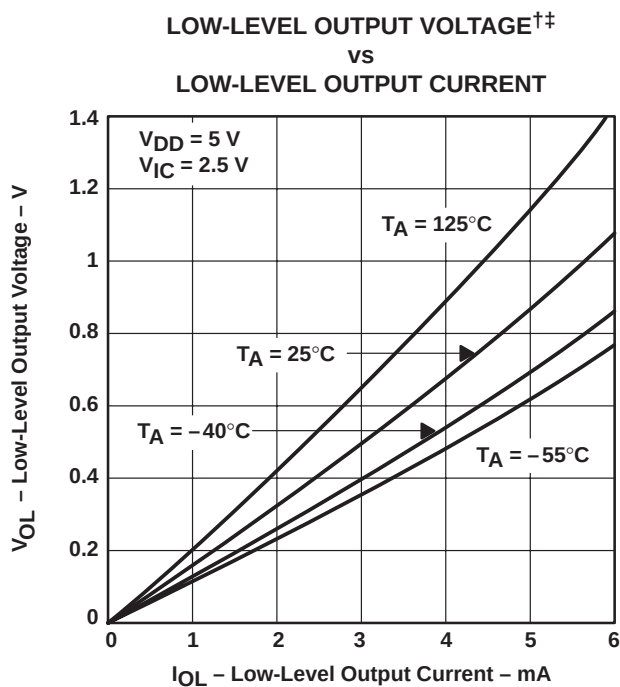
**Figure 14**



**Figure 15**



**Figure 16**

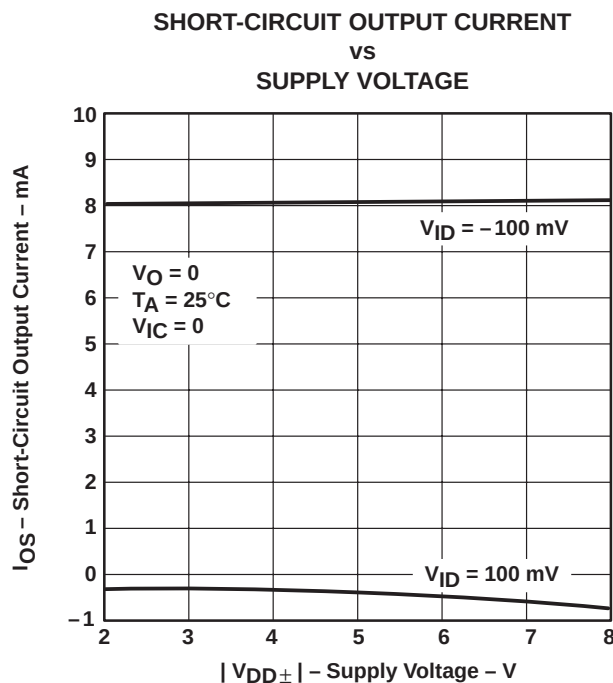
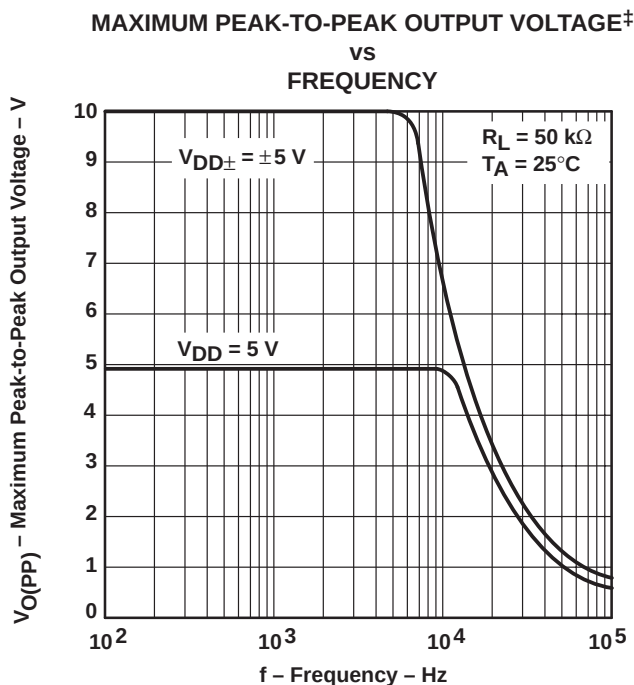
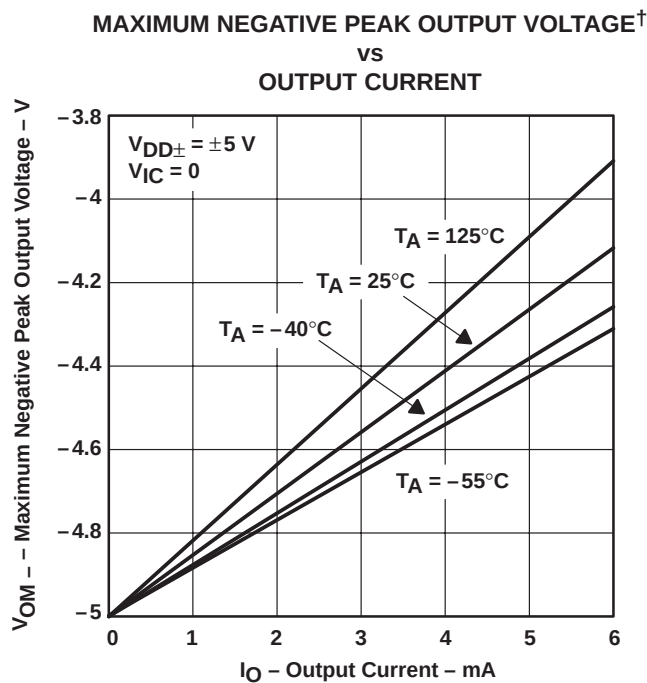
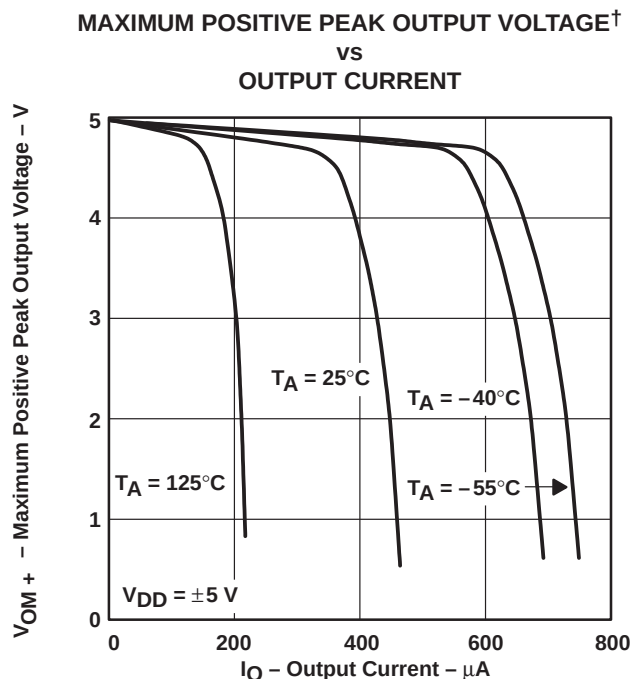


**Figure 17**

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

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

## TYPICAL CHARACTERISTICS



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

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

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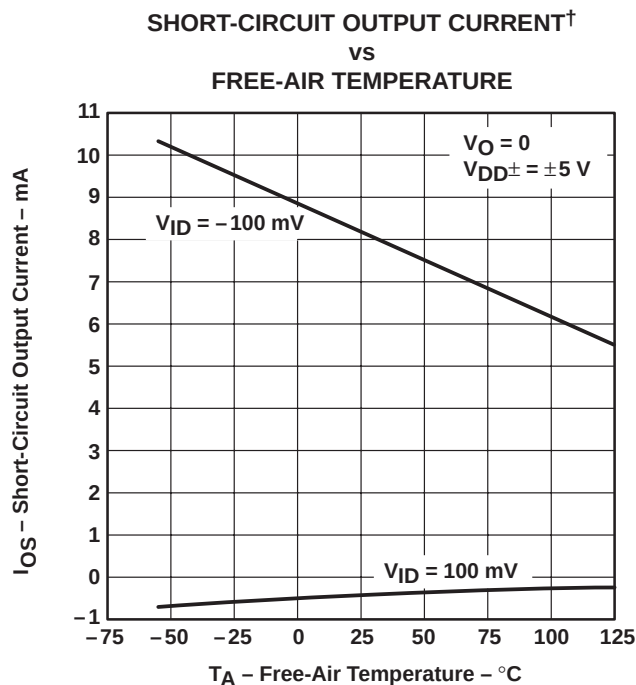


Figure 22

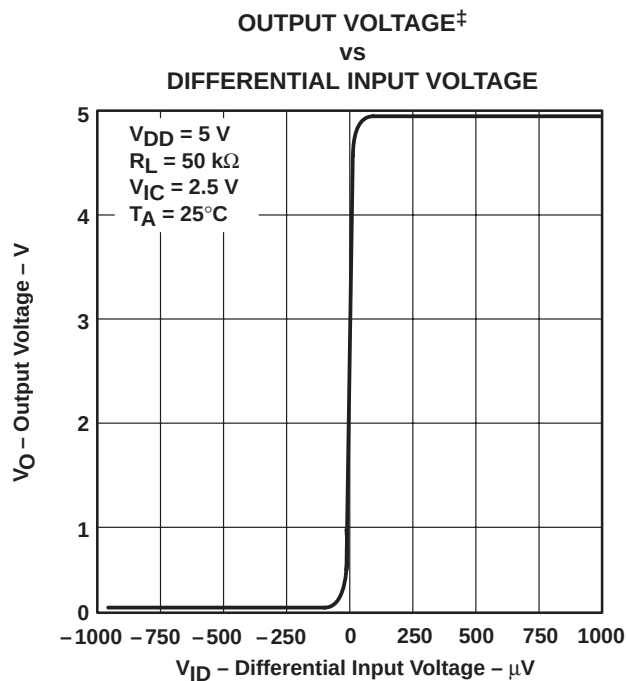


Figure 23

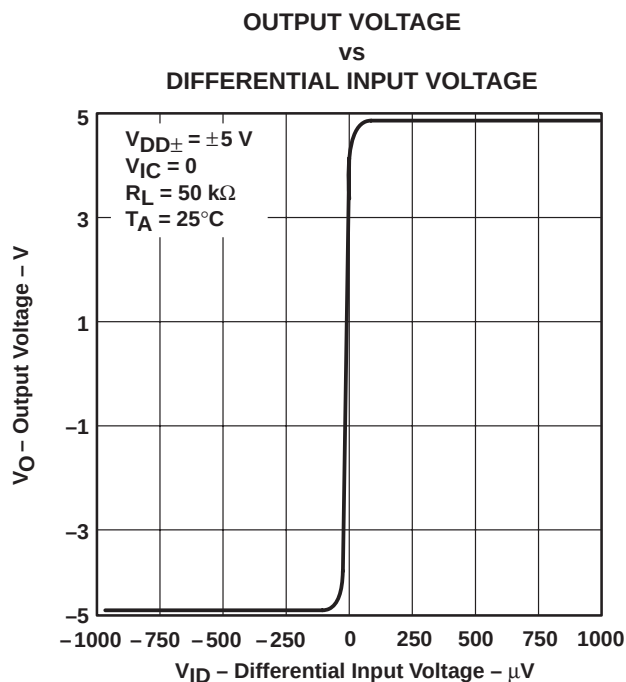


Figure 24

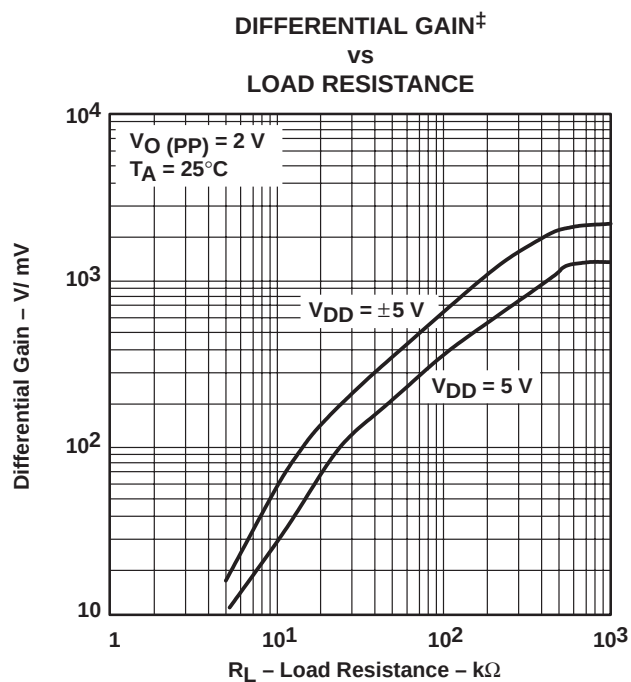


Figure 25

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

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

## TYPICAL CHARACTERISTICS

### LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE MARGIN†

VS  
FREQUENCY

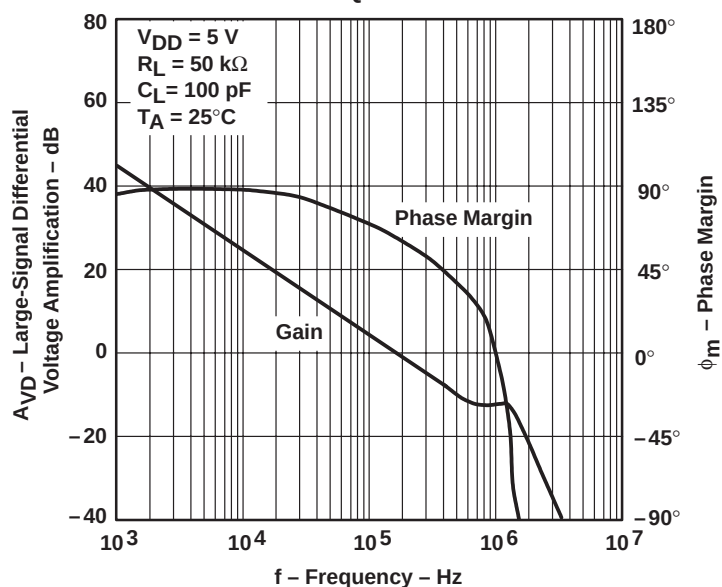


Figure 26

### LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE MARGIN

VS  
FREQUENCY

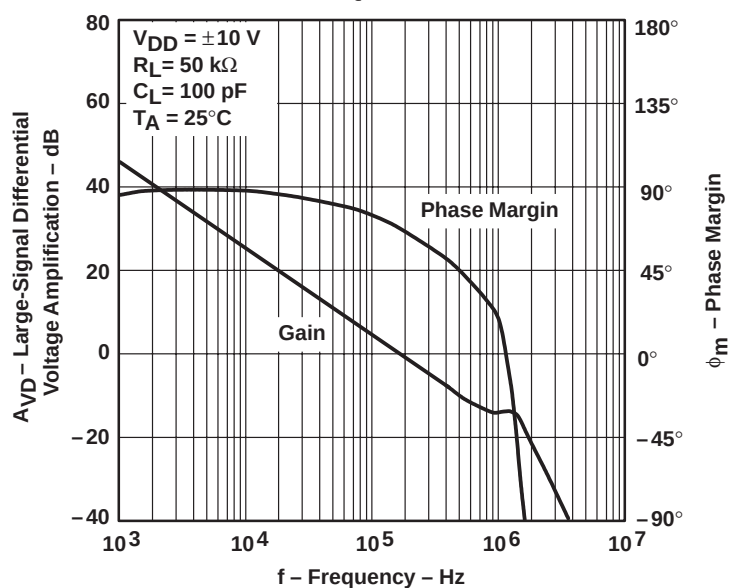


Figure 27

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

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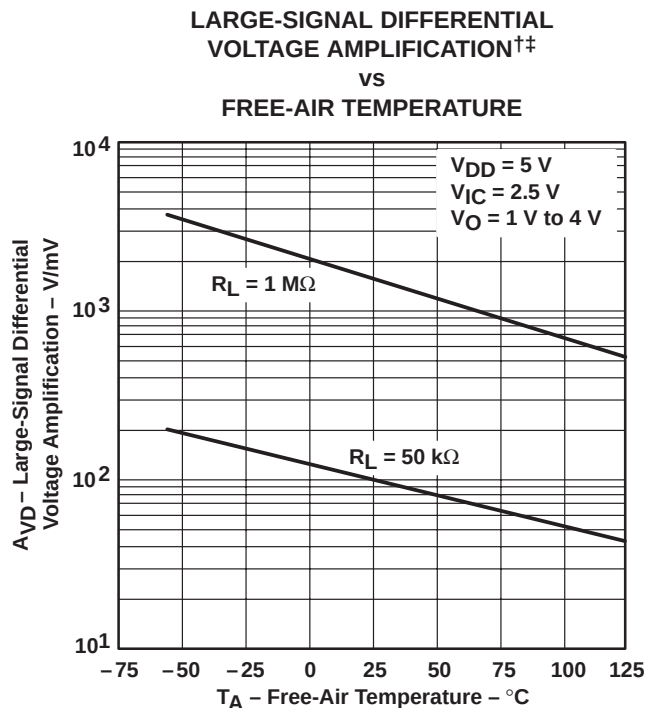


Figure 28

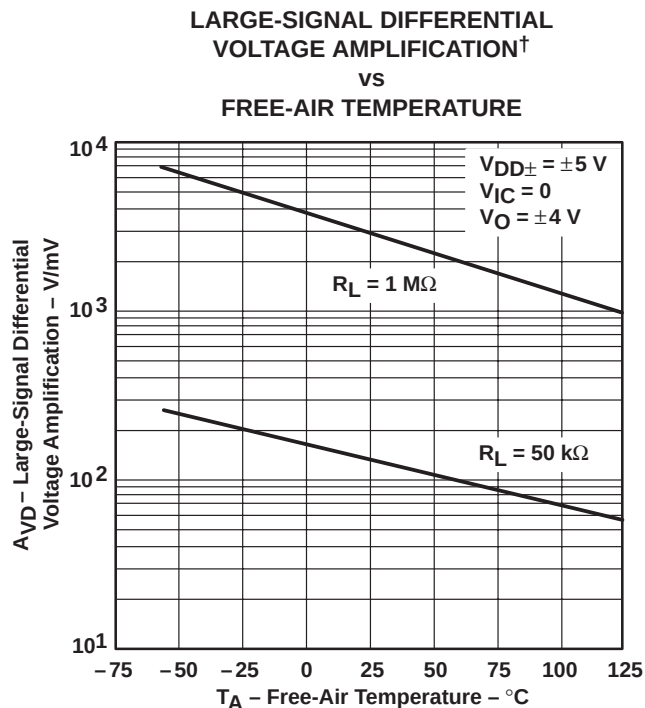


Figure 29

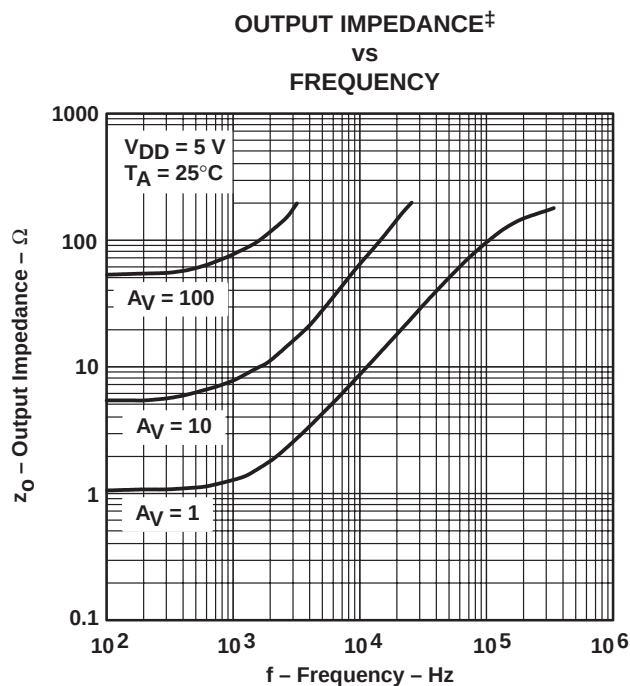


Figure 30

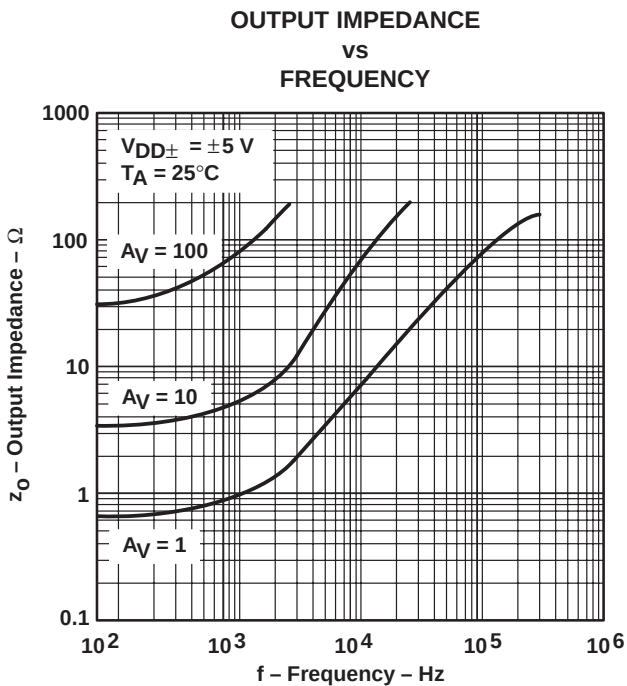


Figure 31

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

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

## TYPICAL CHARACTERISTICS

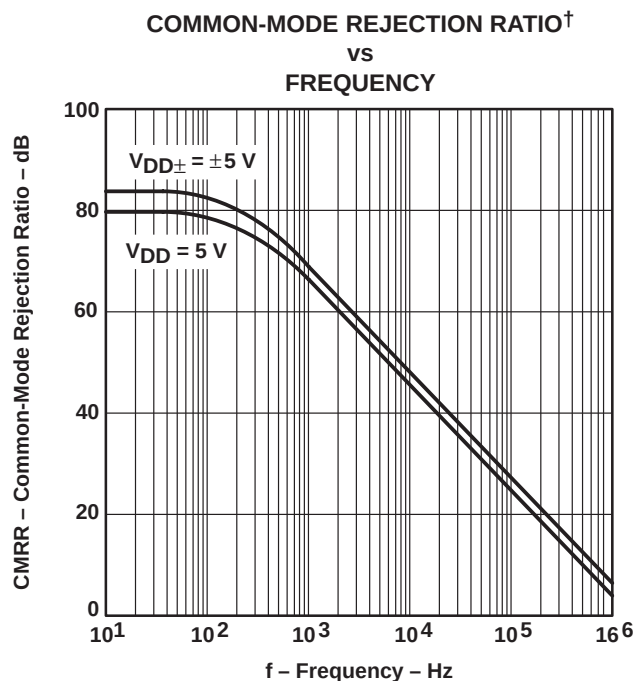


Figure 32

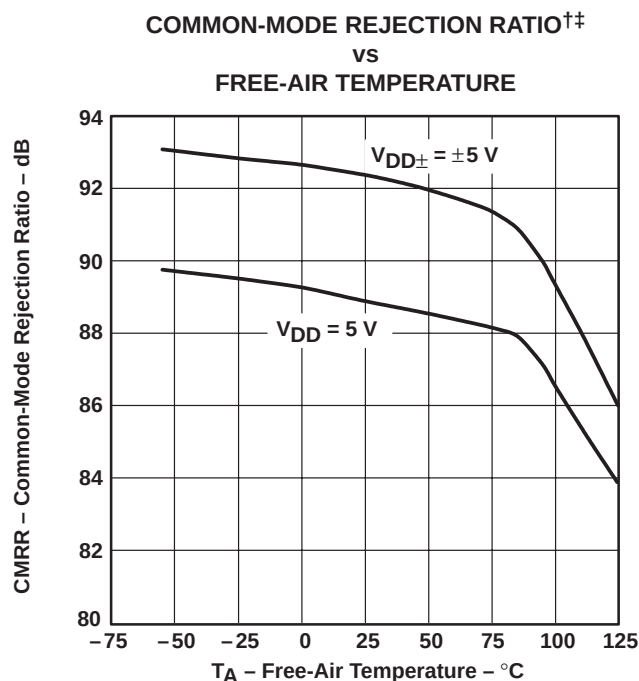


Figure 33

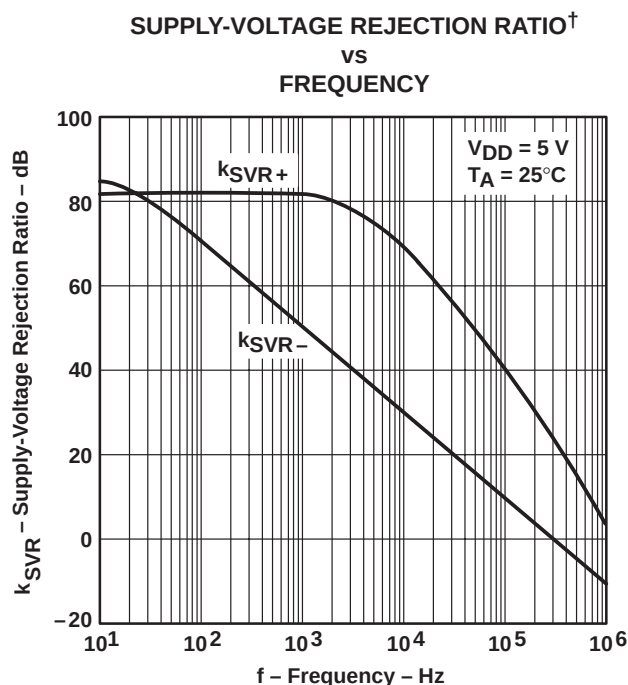


Figure 34

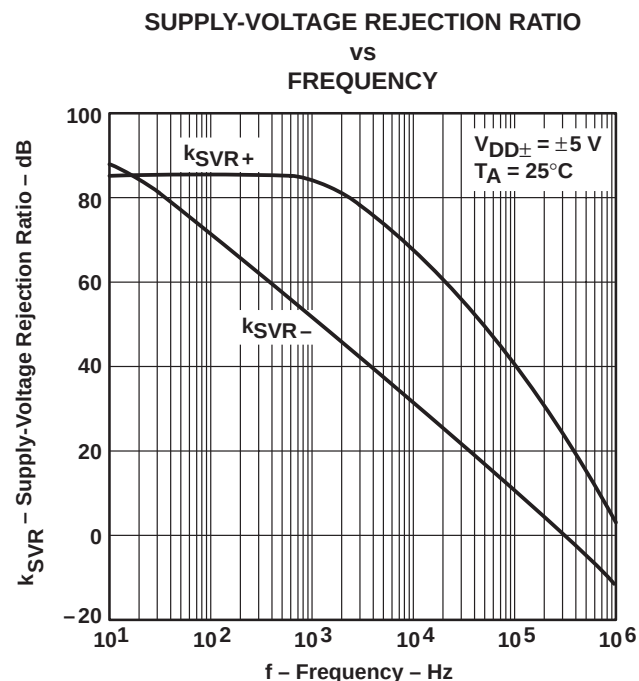


Figure 35

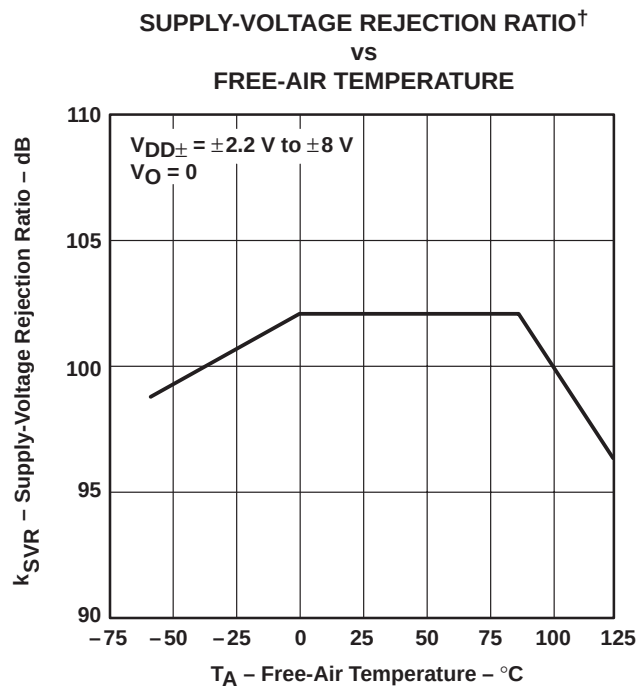
<sup>†</sup> For curves where  $V_{DD} = 5\text{ V}$ , all loads are referenced to 2.5 V.

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

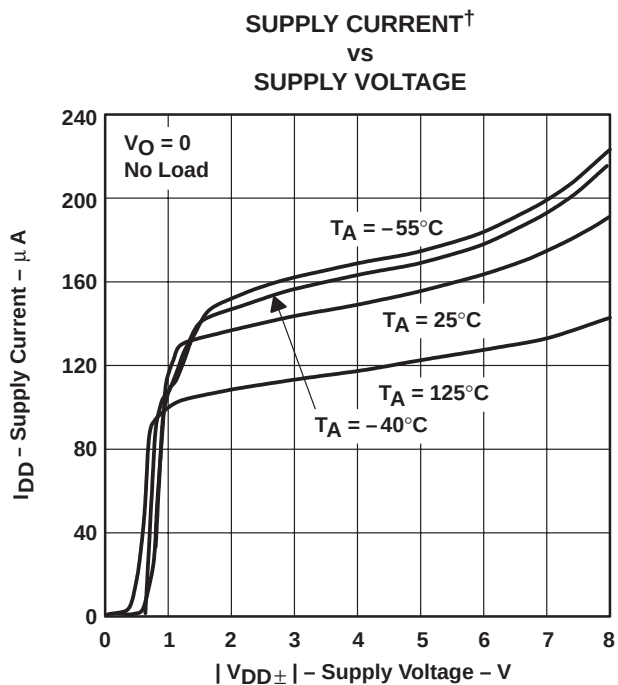
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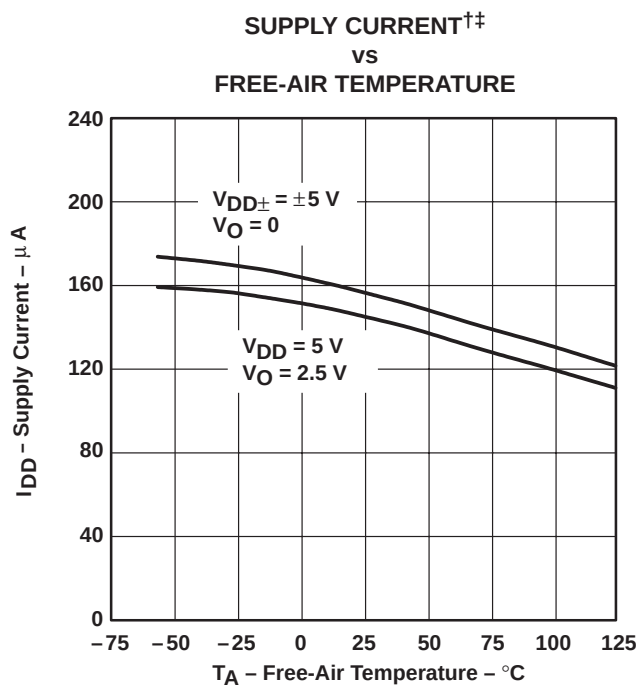
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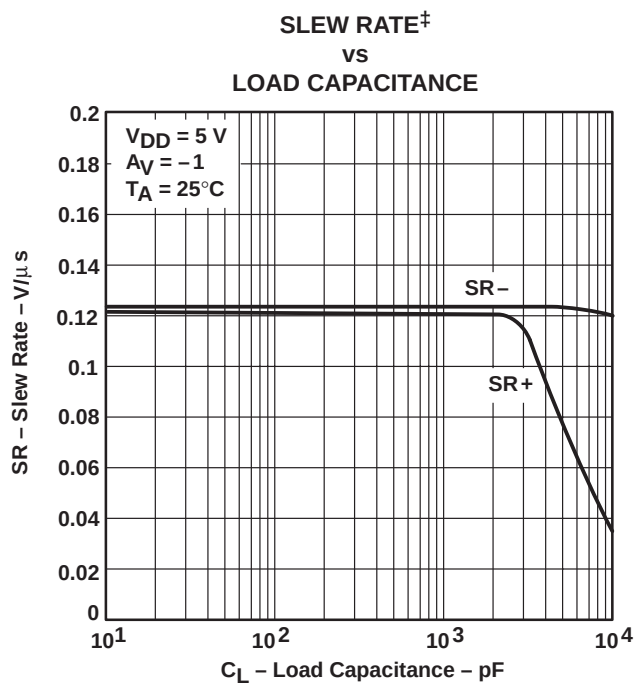
**Figure 36**



**Figure 37**



**Figure 38**



**Figure 39**

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

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



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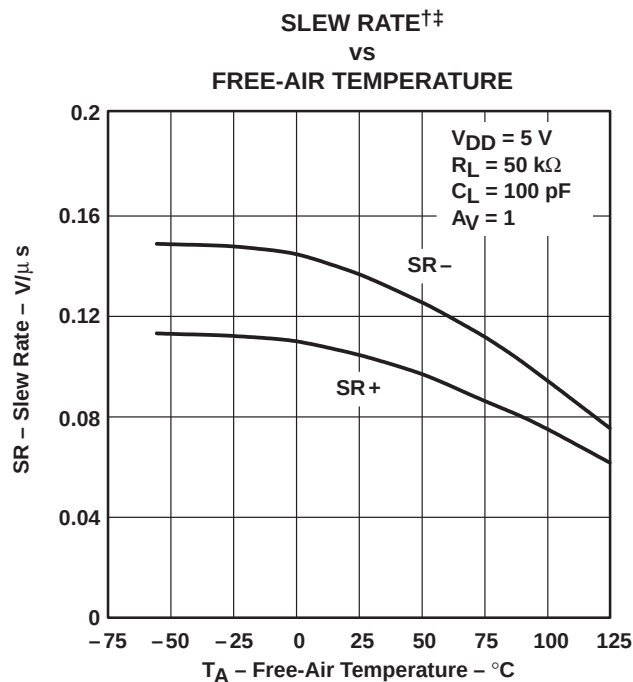


Figure 40

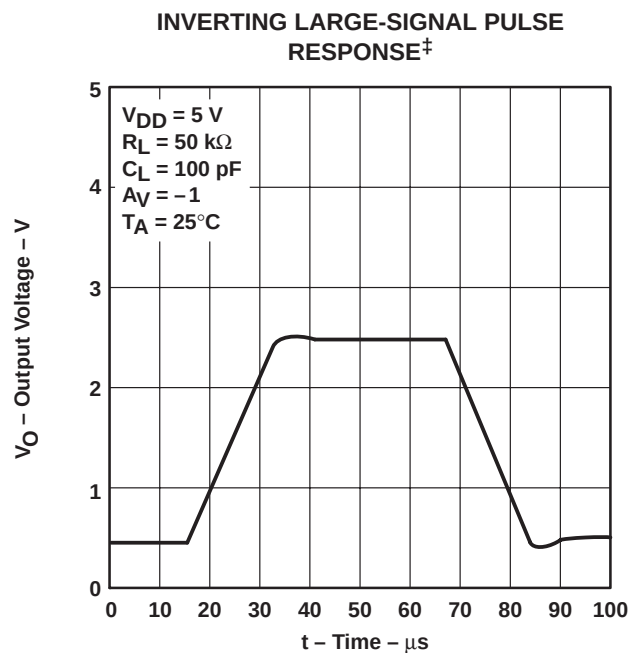


Figure 41

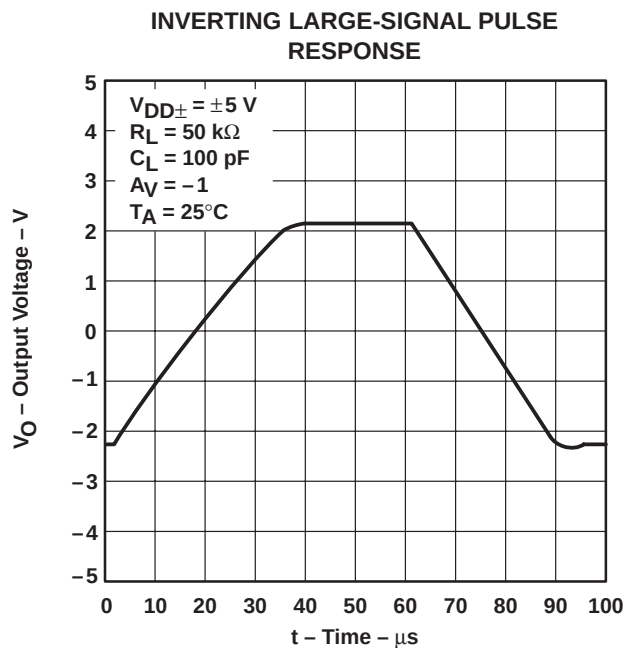


Figure 42

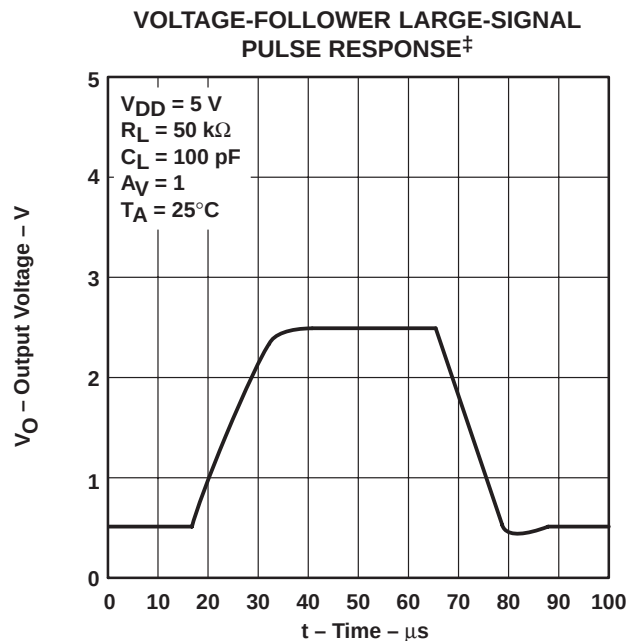


Figure 43

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

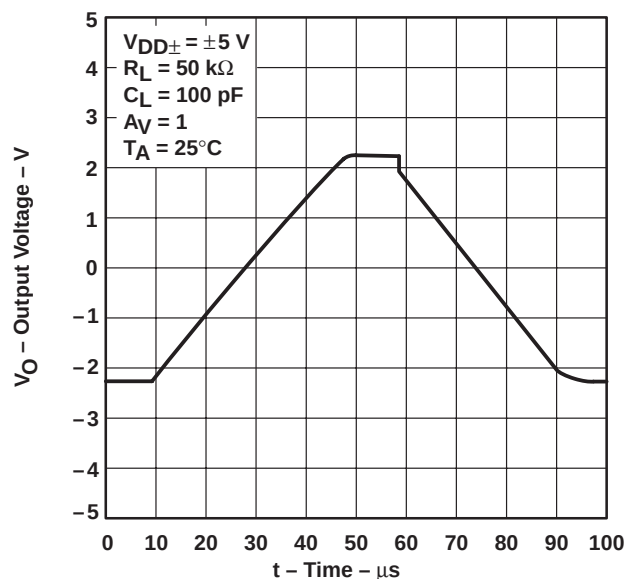
<sup>‡</sup> For curves where  $V_{DD} = 5\text{ V}$ , all loads are referenced to 2.5 V.

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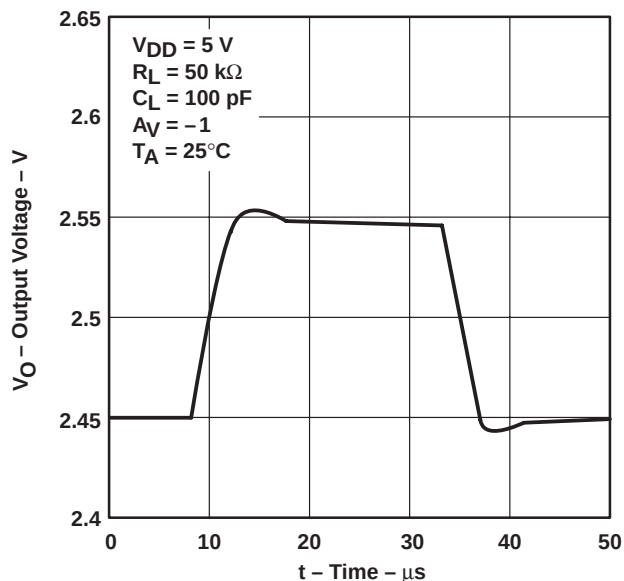
**TYPICAL CHARACTERISTICS**

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



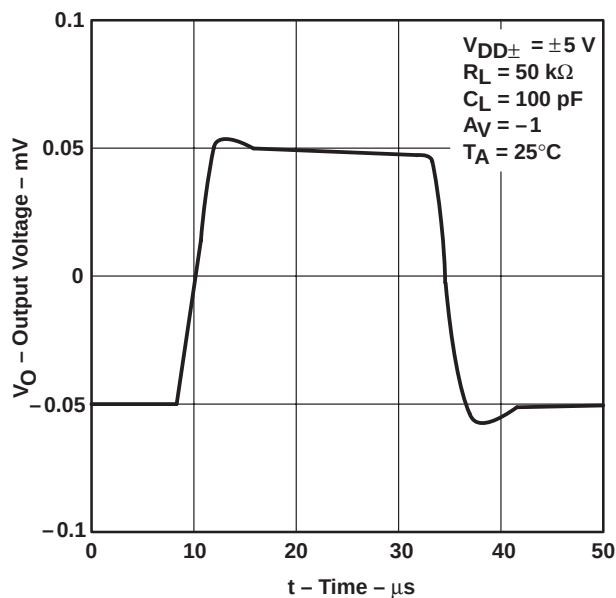
**Figure 44**

**INVERTING SMALL-SIGNAL PULSE RESPONSE†**



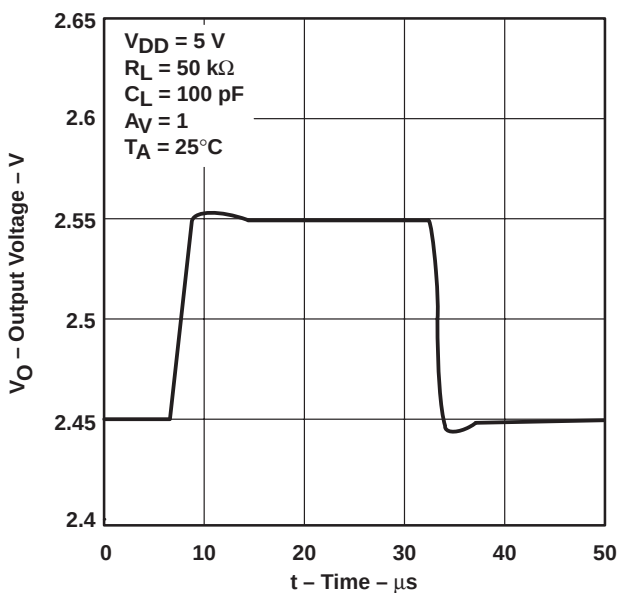
**Figure 45**

**INVERTING SMALL-SIGNAL PULSE RESPONSE**



**Figure 46**

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



**Figure 47**

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

## TYPICAL CHARACTERISTICS

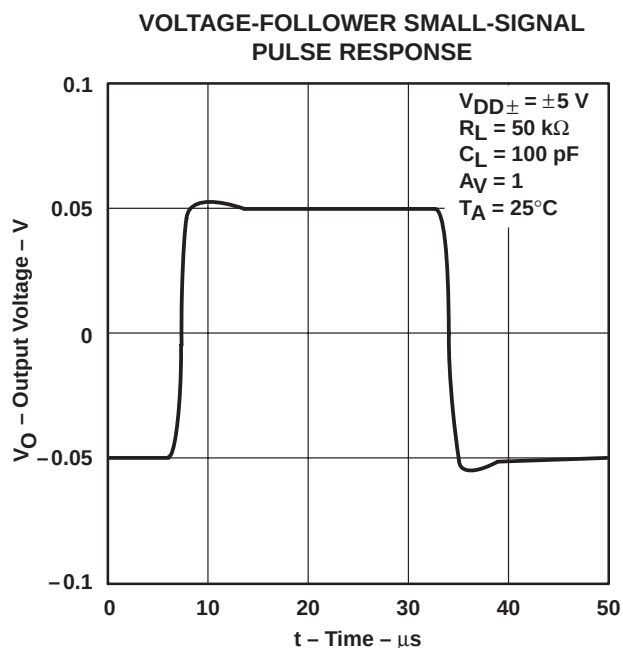


Figure 48

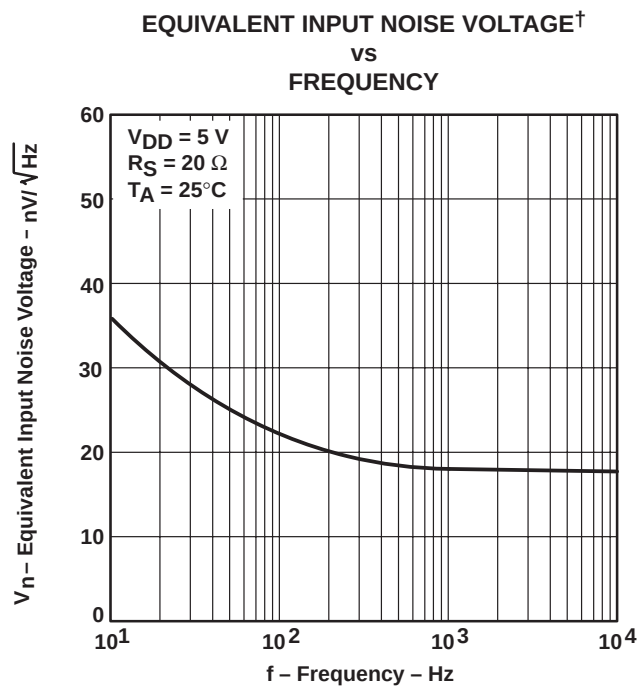


Figure 49

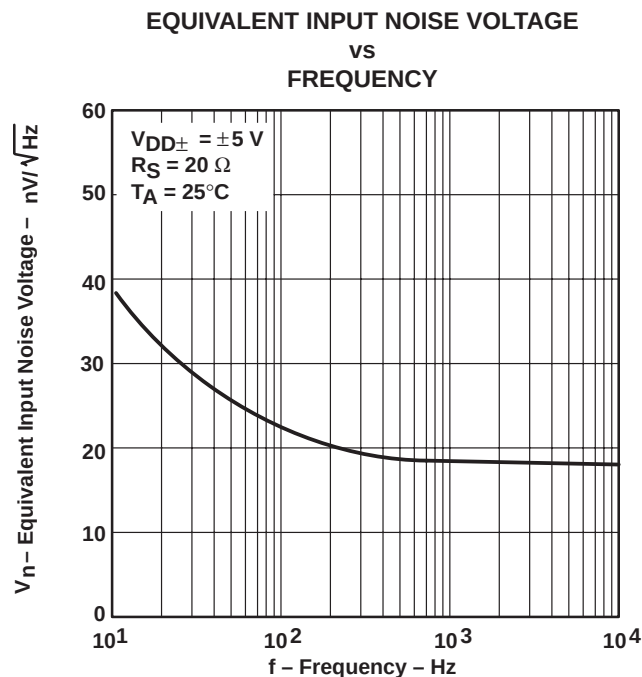


Figure 50

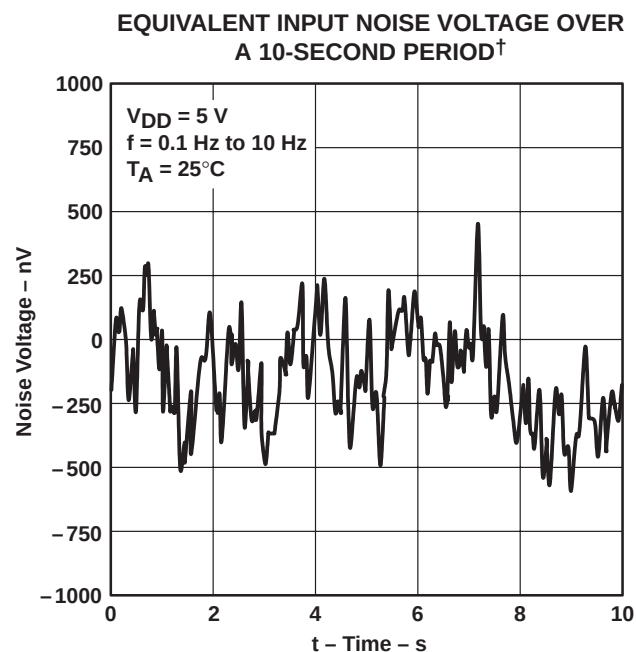


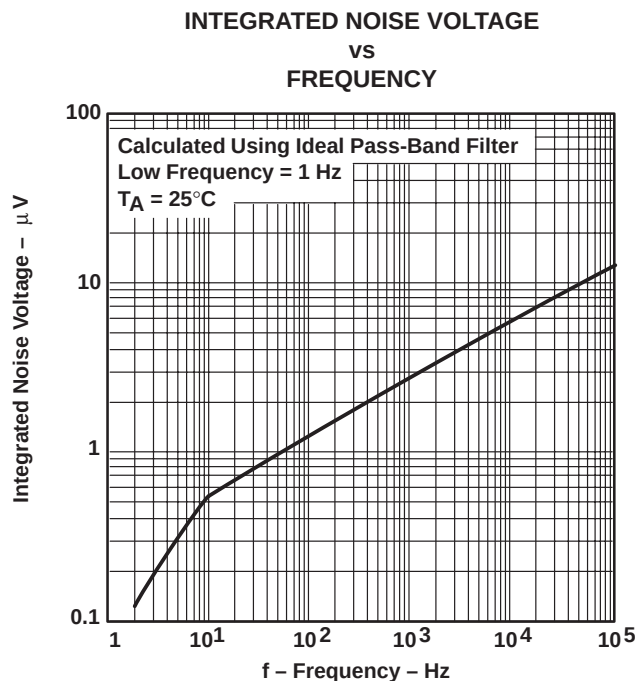
Figure 51

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

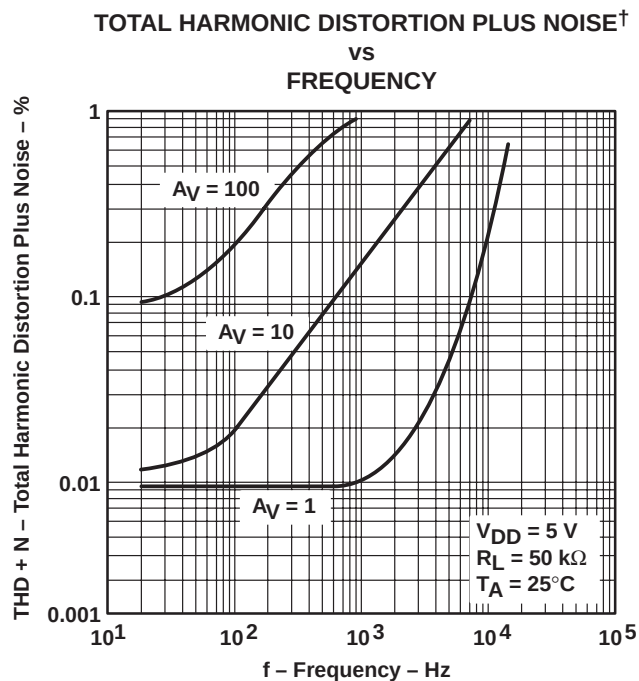
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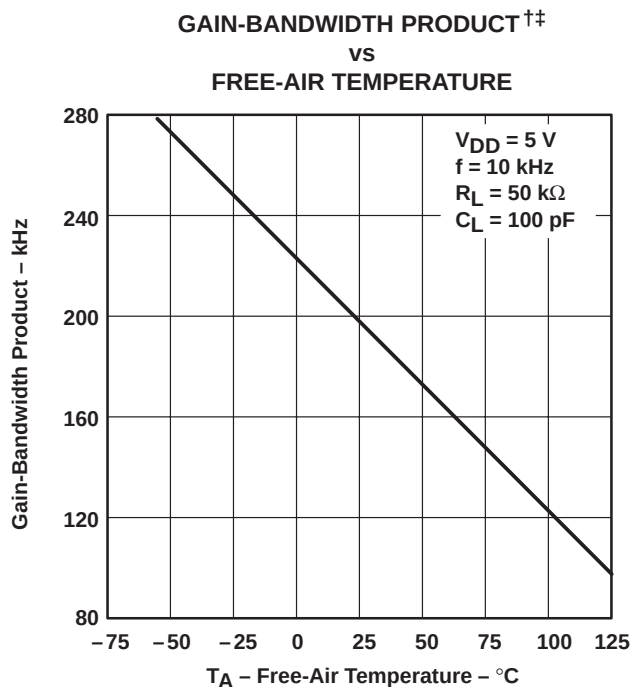
**TYPICAL CHARACTERISTICS**



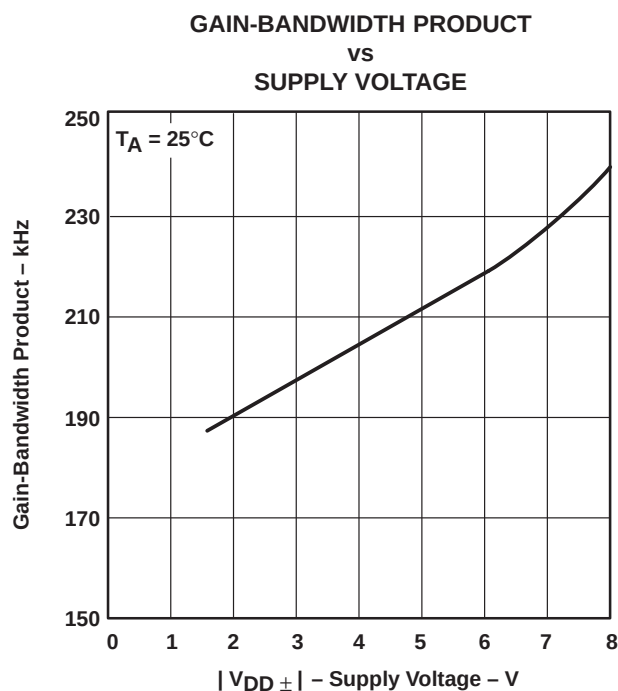
**Figure 52**



**Figure 53**



**Figure 54**



**Figure 55**

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

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

## TYPICAL CHARACTERISTICS

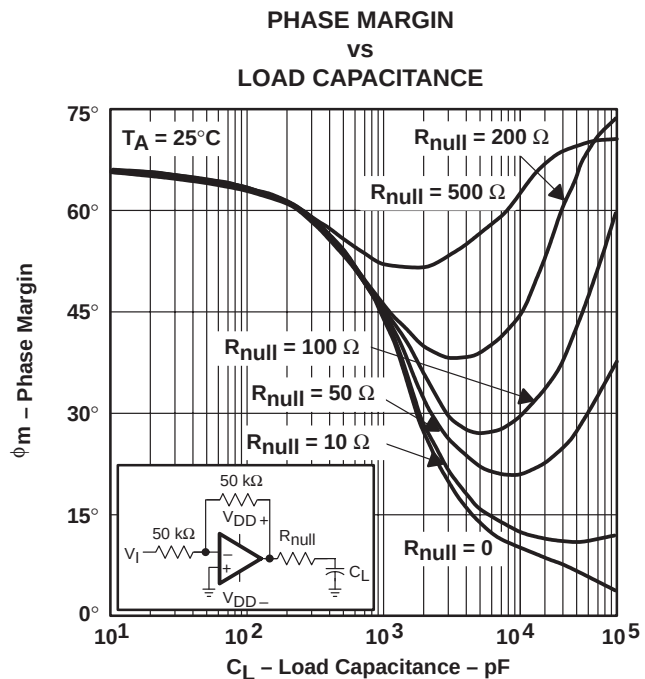


Figure 56

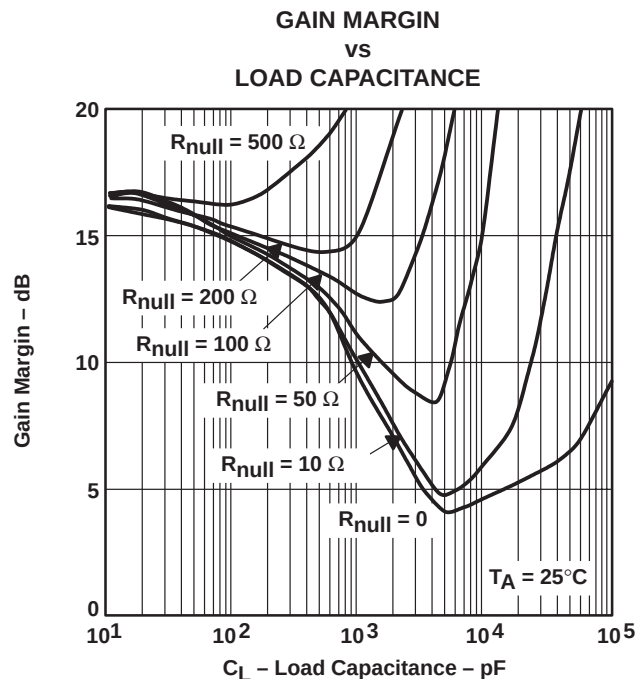


Figure 57

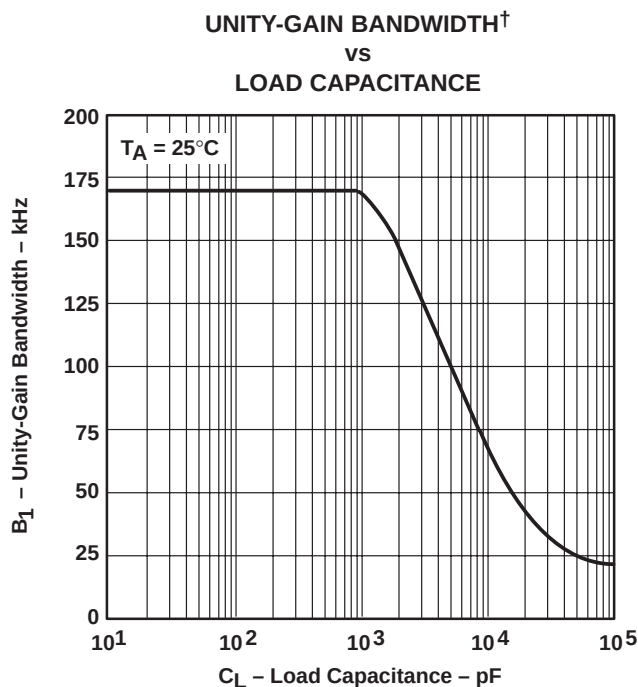


Figure 58

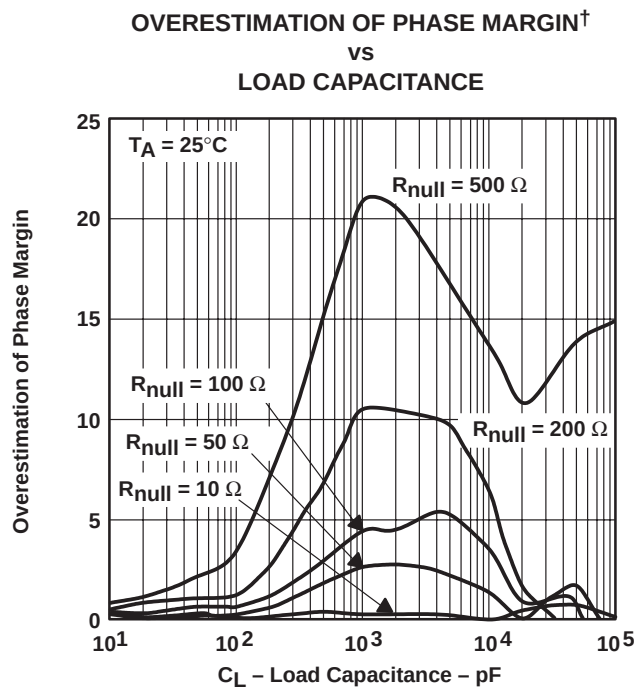


Figure 59

† See application information

## APPLICATION INFORMATION

### driving large capacitive loads

The TLC225x is designed to drive larger capacitive loads than most CMOS operational amplifiers. Figure 56 and Figure 57 illustrate its ability to drive loads up to 1000 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 60) improves the gain and phase margins when driving large capacitive loads. Figure 56 and Figure 57 show the effects of adding series resistances of 10  $\Omega$ , 50  $\Omega$ , 100  $\Omega$ , 200  $\Omega$ , and 500  $\Omega$ . 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.

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

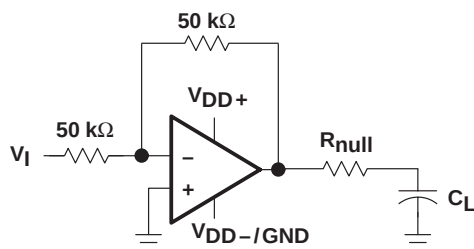
where :

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

The unity-gain bandwidth (UGBW) frequency decreases as the capacitive load increases (see Figure 58). To use equation 1, UGBW must be approximated from Figure 58.

Using equation 1 alone overestimates the improvement in phase margin, as illustrated in Figure 59. The overestimation is caused by the decrease in the frequency of the pole associated with the load, thus providing additional phase shift and reducing the overall improvement in phase margin.

Using Figure 60, with equation 1 enables the designer to choose the appropriate output series resistance to optimize the design of circuits driving large capacitance loads.



**Figure 60. Series-Resistance Circuit**

## APPLICATION INFORMATION

### macromodel information

Macromodel information provided was derived using Microsim *Parts*™, the model generation software used with Microsim *PSpice*™. The Boyle macromodel (see Note 5) and subcircuit in Figure 61 are generated using the TLC225x typical electrical and operating characteristics at  $T_A = 25^\circ\text{C}$ . Using this information, output simulations of the following key parameters can be generated to a tolerance of 20% (in most cases):

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

NOTE 5: 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).

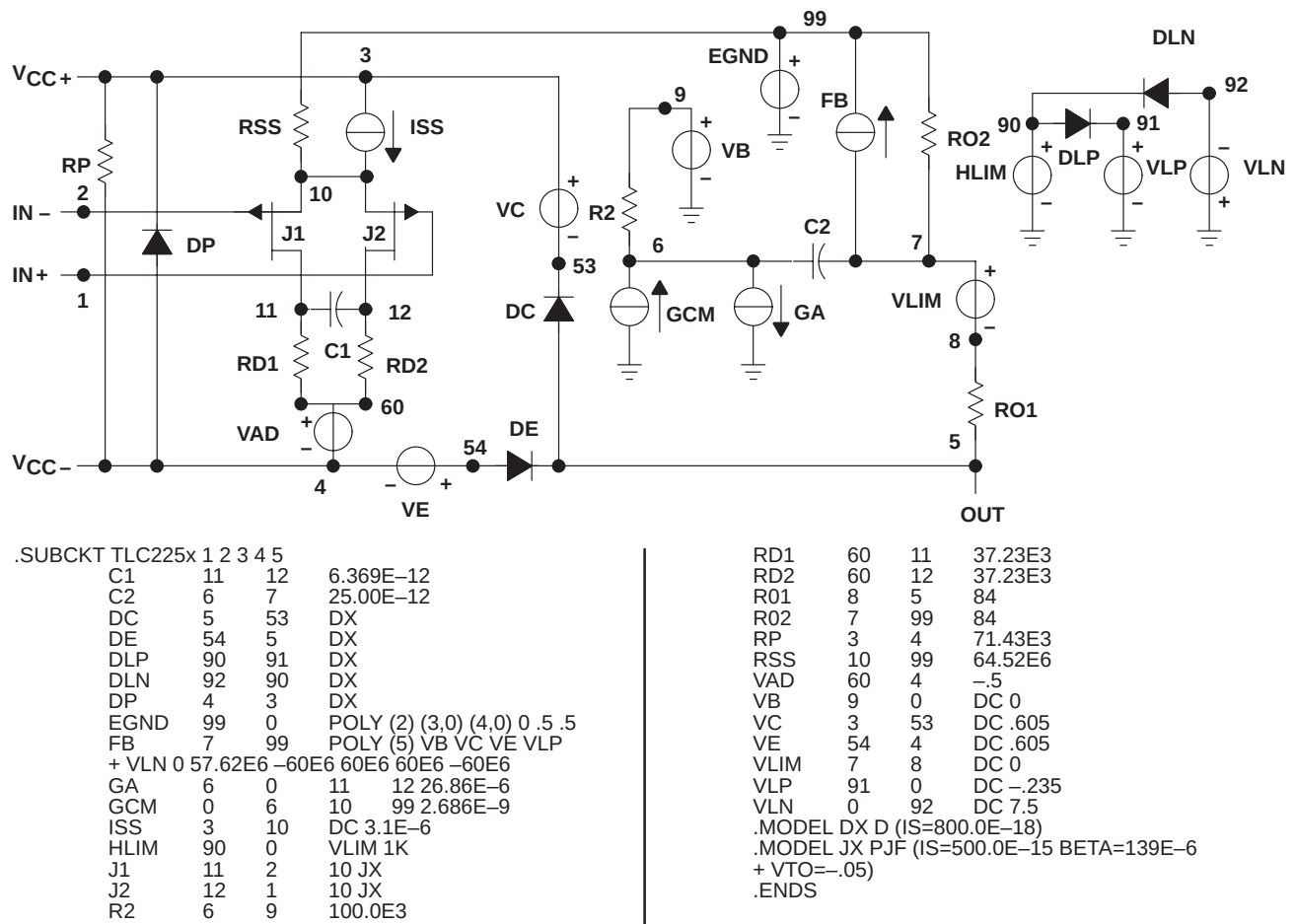


Figure 61. Boyle Macromodel and Subcircuit

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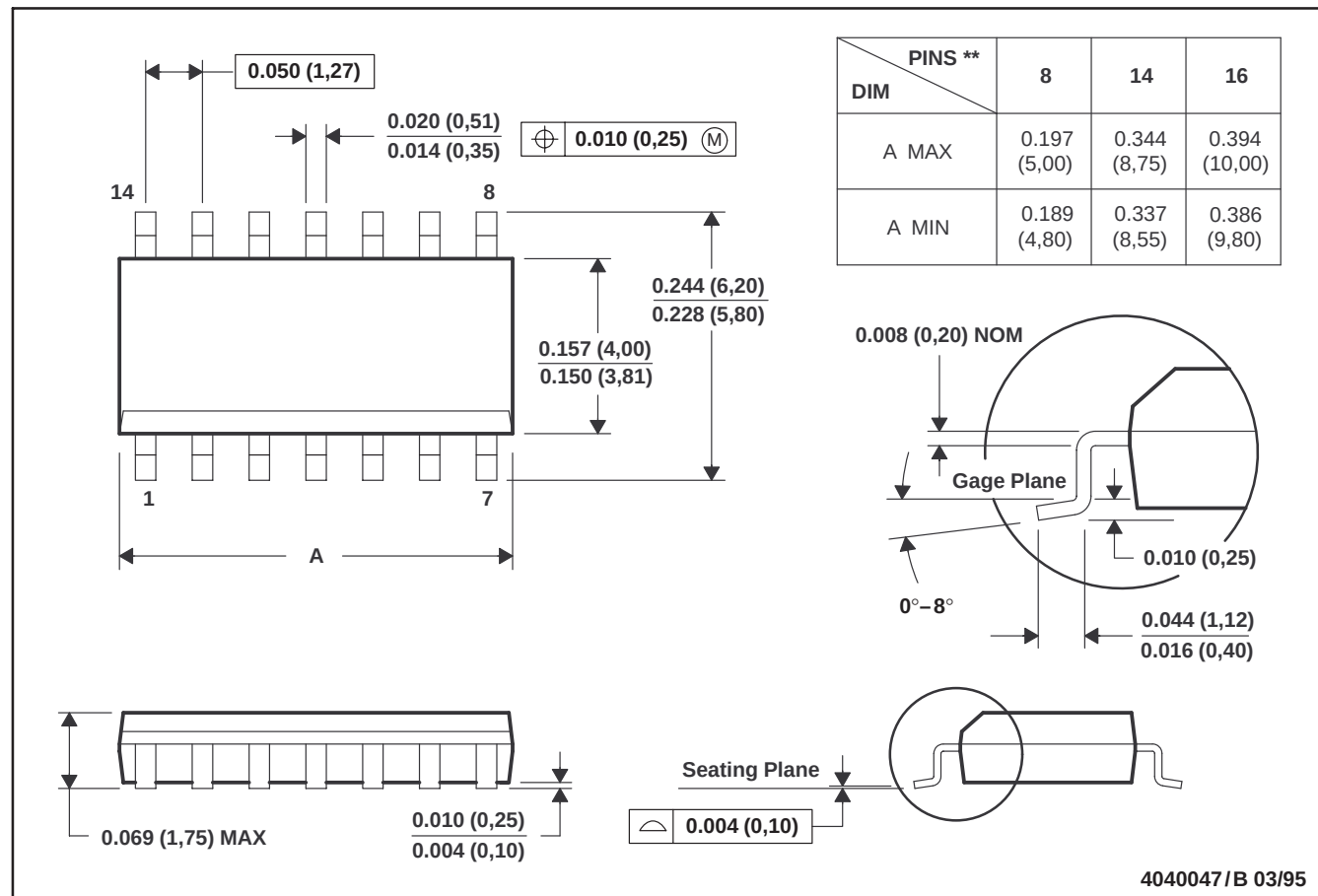
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**MECHANICAL INFORMATION**

**D (R-PDSO-G\*\*)**

**PLASTIC SMALL-OUTLINE PACKAGE**

14 PIN SHOWN



- NOTES:
- A. All linear dimensions are in inches (millimeters).
  - B. This drawing is subject to change without notice.
  - C. Body dimensions do not include mold flash or protrusion, not to exceed 0.006 (0,15).
  - D. Four center pins are connected to die mount pad.
  - E. Falls within JEDEC MS-012



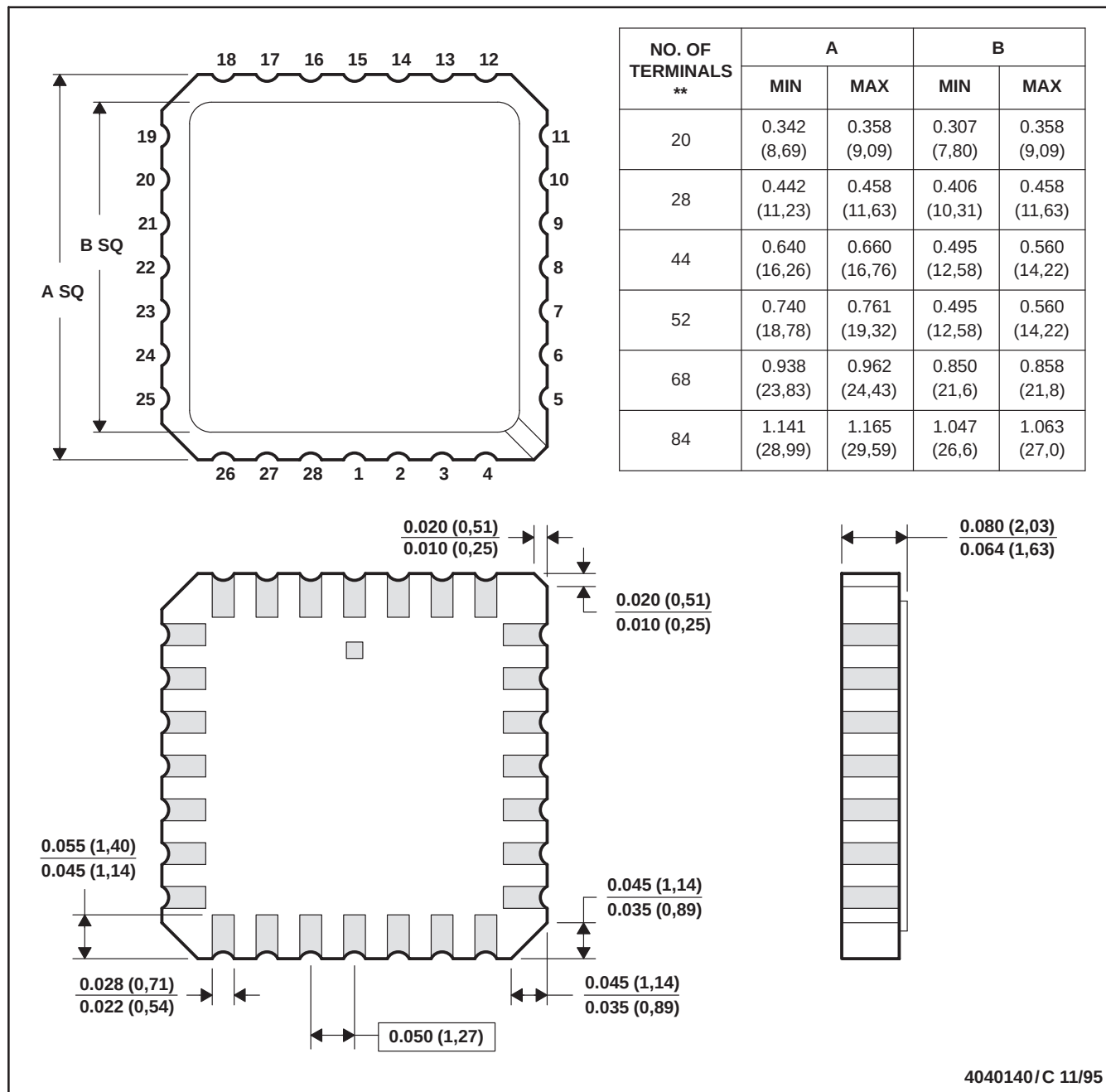
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**MECHANICAL INFORMATION**

**FK (S-CQCC-N\*\*)**

**LEADLESS CERAMIC CHIP CARRIER**

**28 TERMINAL SHOWN**



- NOTES: A. All linear dimensions are in inches (millimeters).  
 B. This drawing is subject to change without notice.  
 C. This package can be hermetically sealed with a metal lid.  
 D. The terminals are gold plated.  
 E. Falls within JEDEC MS-004

TLC225x, TLC225xA

Advanced LinCMOS™ RAIL-TO-RAIL

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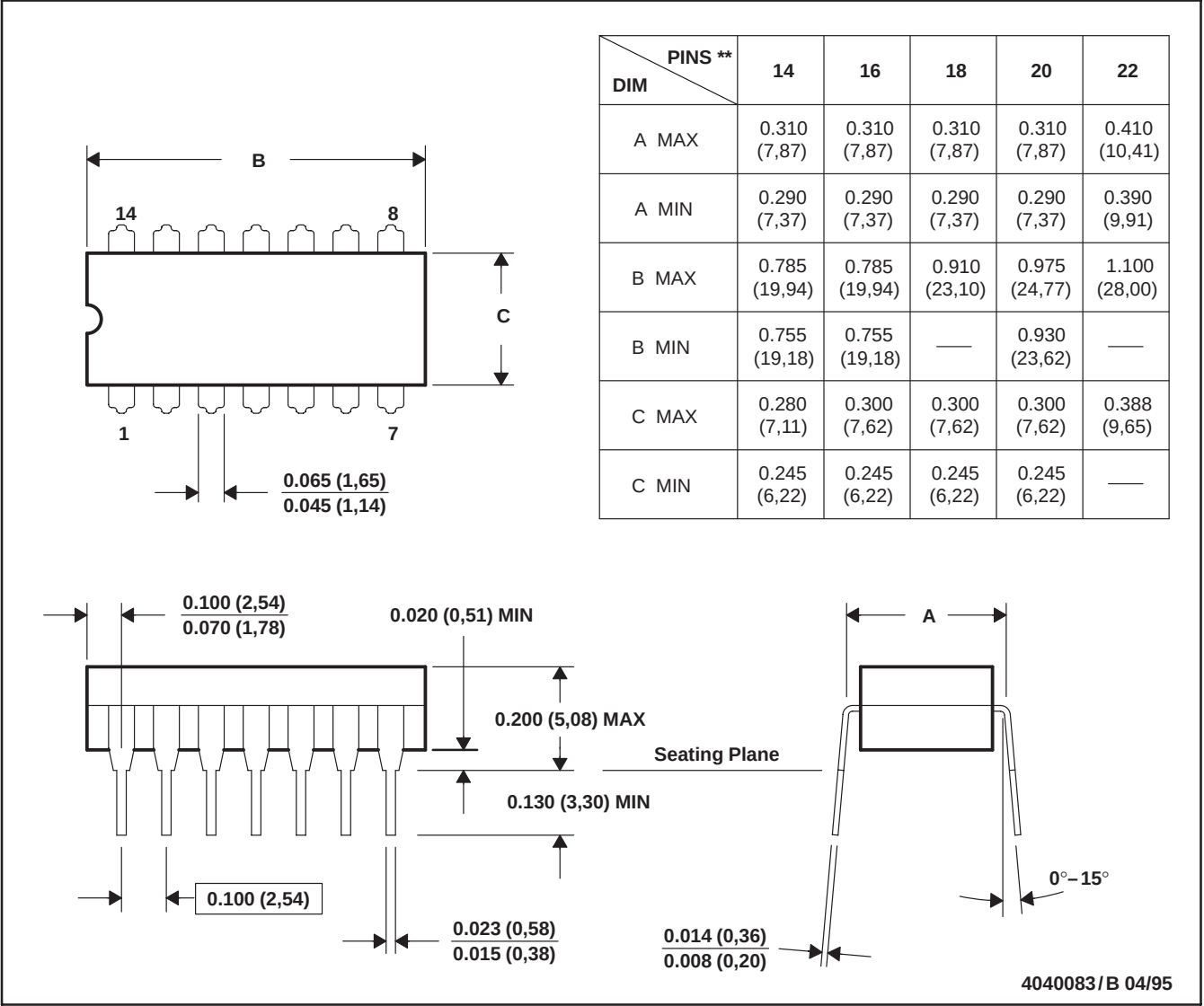
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MECHANICAL INFORMATION

J (R-GDIP-T\*\*)

CERAMIC DUAL-IN-LINE PACKAGE

14 PIN SHOWN

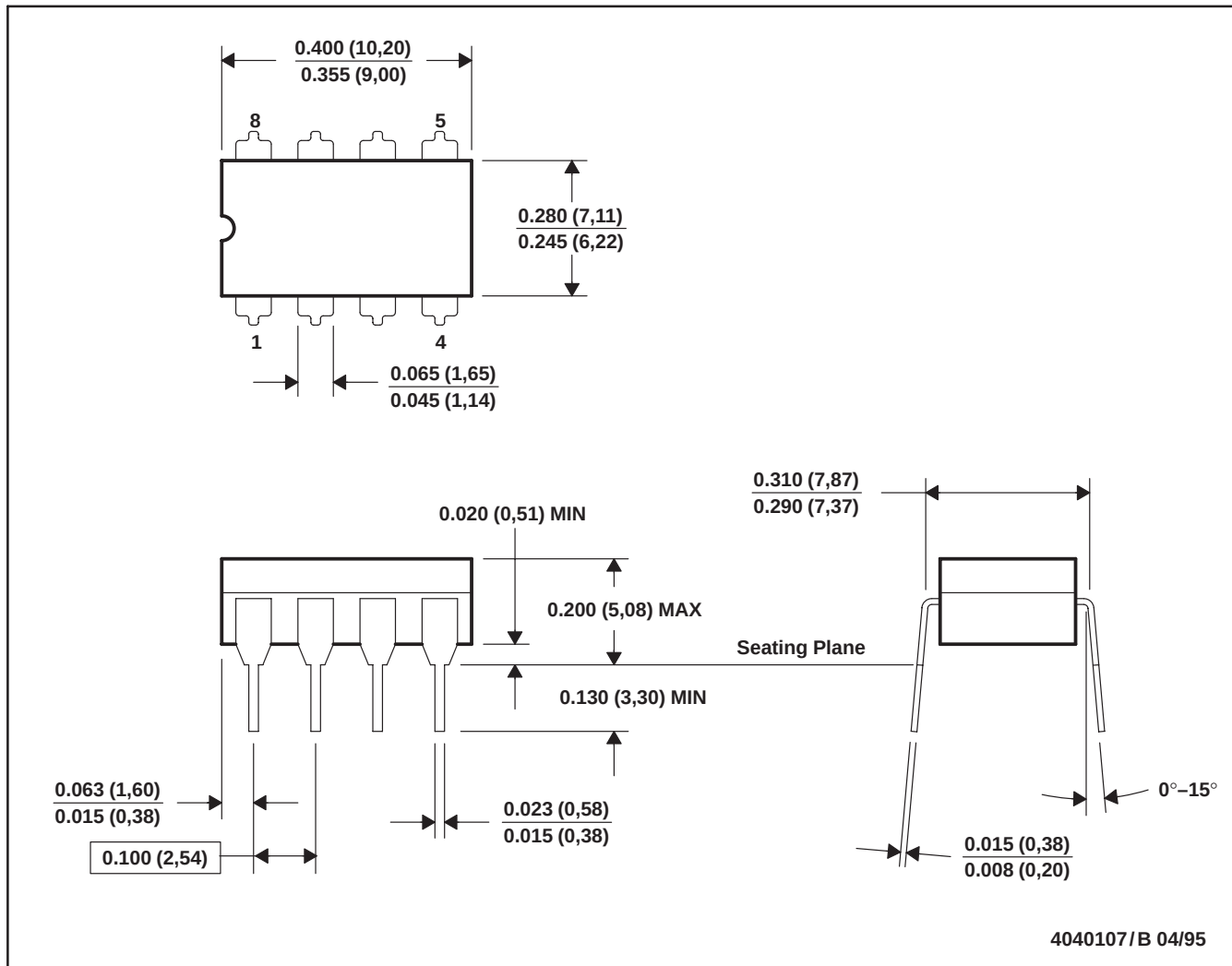


- NOTES:
- A. All linear dimensions are in inches (millimeters).
  - B. This drawing is subject to change without notice.
  - C. This package can be hermetically sealed with a ceramic lid using glass frit.
  - D. Index point is provided on cap for terminal identification only on press ceramic glass frit seal only.
  - E. Falls within MIL-STD-1835 GDIP1-T14, GDIP1-T16, GDIP1-T18, GDIP1-T20, and GDIP1-T22

## MECHANICAL INFORMATION

JG (R-GDIP-T8)

CERAMIC DUAL-IN-LINE PACKAGE



- NOTES:
- A. All linear dimensions are in inches (millimeters).
  - B. This drawing is subject to change without notice.
  - C. This package can be hermetically sealed with a ceramic lid using glass frit.
  - D. Index point is provided on cap for terminal identification only on press ceramic glass frit seal only
  - E. Falls within MIL-STD-1835 GDIP1-T8

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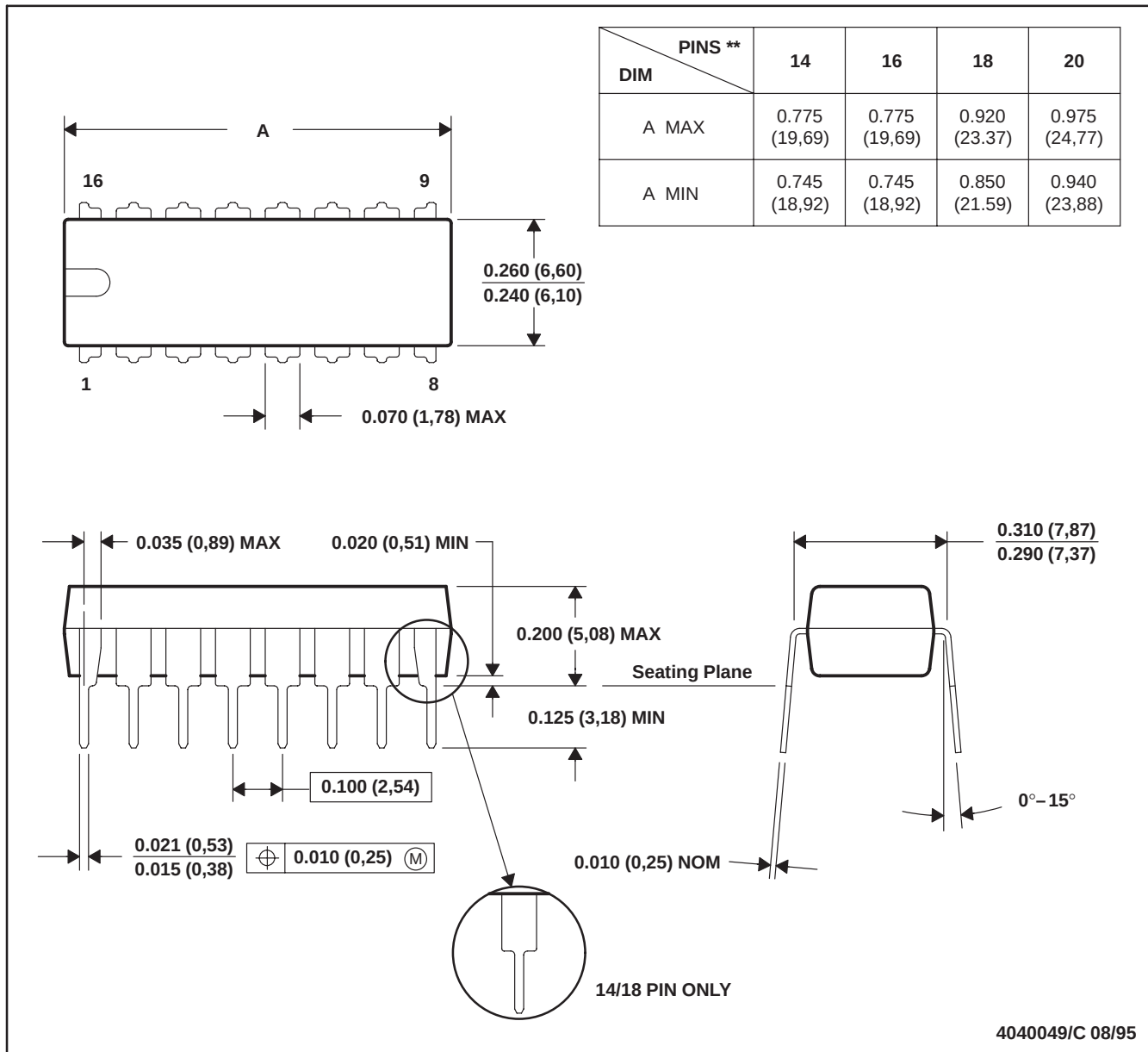
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**MECHANICAL INFORMATION**

**N (R-PDIP-T\*\*)**

**PLASTIC DUAL-IN-LINE PACKAGE**

16 PIN SHOWN



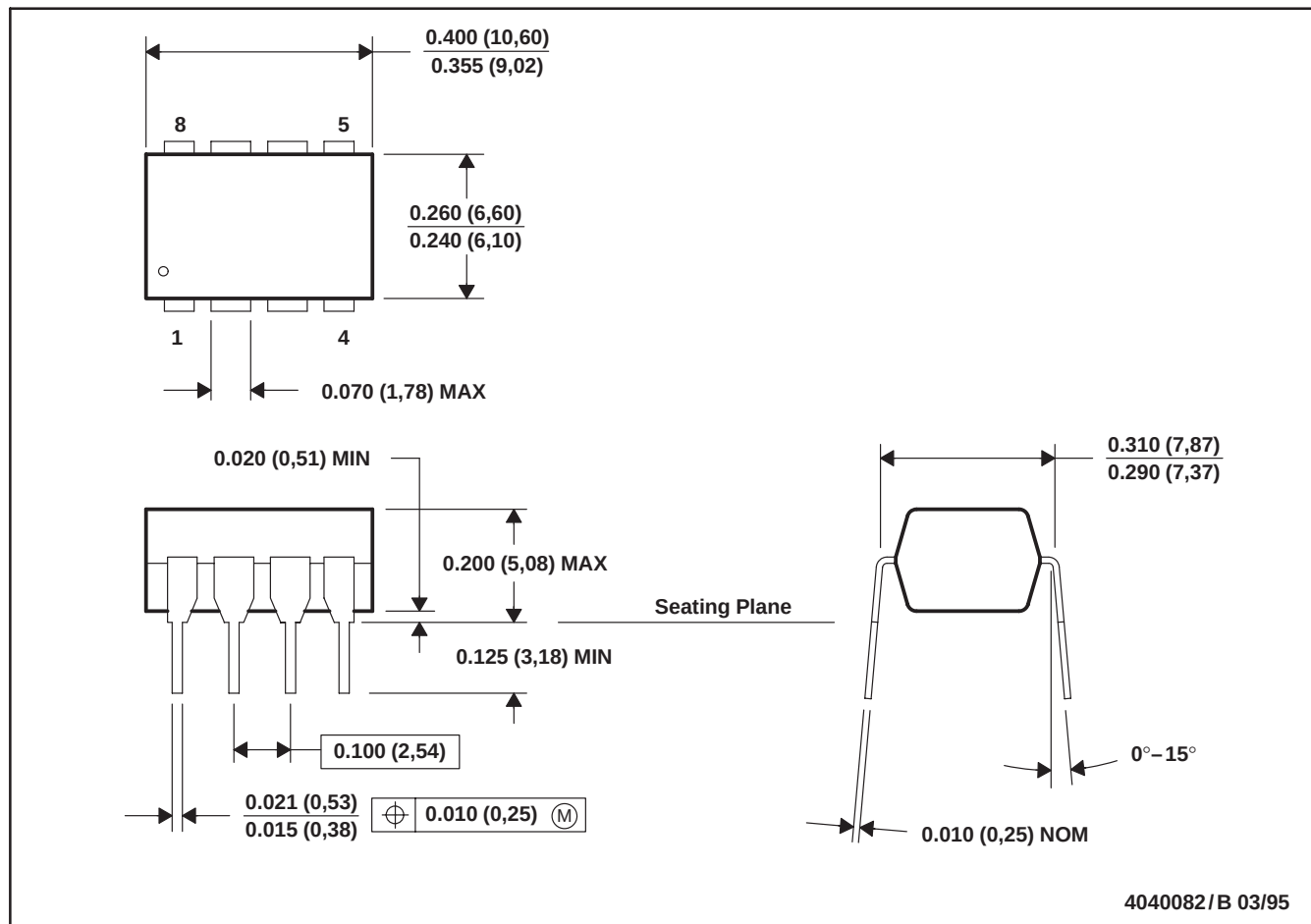
- NOTES: A. All linear dimensions are in inches (millimeters).  
 B. This drawing is subject to change without notice.  
 C. Falls within JEDEC MS-001 (20 pin package is shorter than MS-001.)

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## MECHANICAL INFORMATION

P (R-PDIP-T8)

PLASTIC DUAL-IN-LINE PACKAGE



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

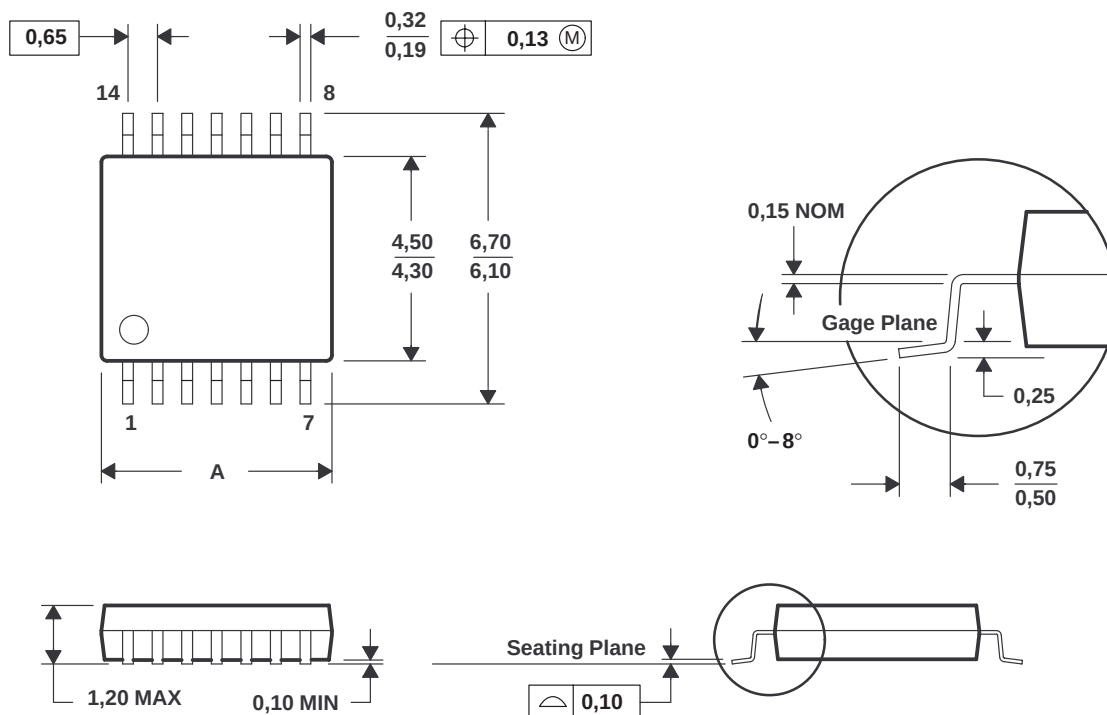
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**MECHANICAL INFORMATION**

**PW (R-PDSO-G\*\*)**

**PLASTIC SMALL-OUTLINE PACKAGE**

14 PIN SHOWN



| PINS ** | 8    | 14   | 16   | 20   | 24   | 28   |
|---------|------|------|------|------|------|------|
| DIM     |      |      |      |      |      |      |
| A MAX   | 3,10 | 5,10 | 5,10 | 6,60 | 7,90 | 9,80 |
| A MIN   | 2,90 | 4,90 | 4,90 | 6,40 | 7,70 | 9,60 |

4040064/D 10/95

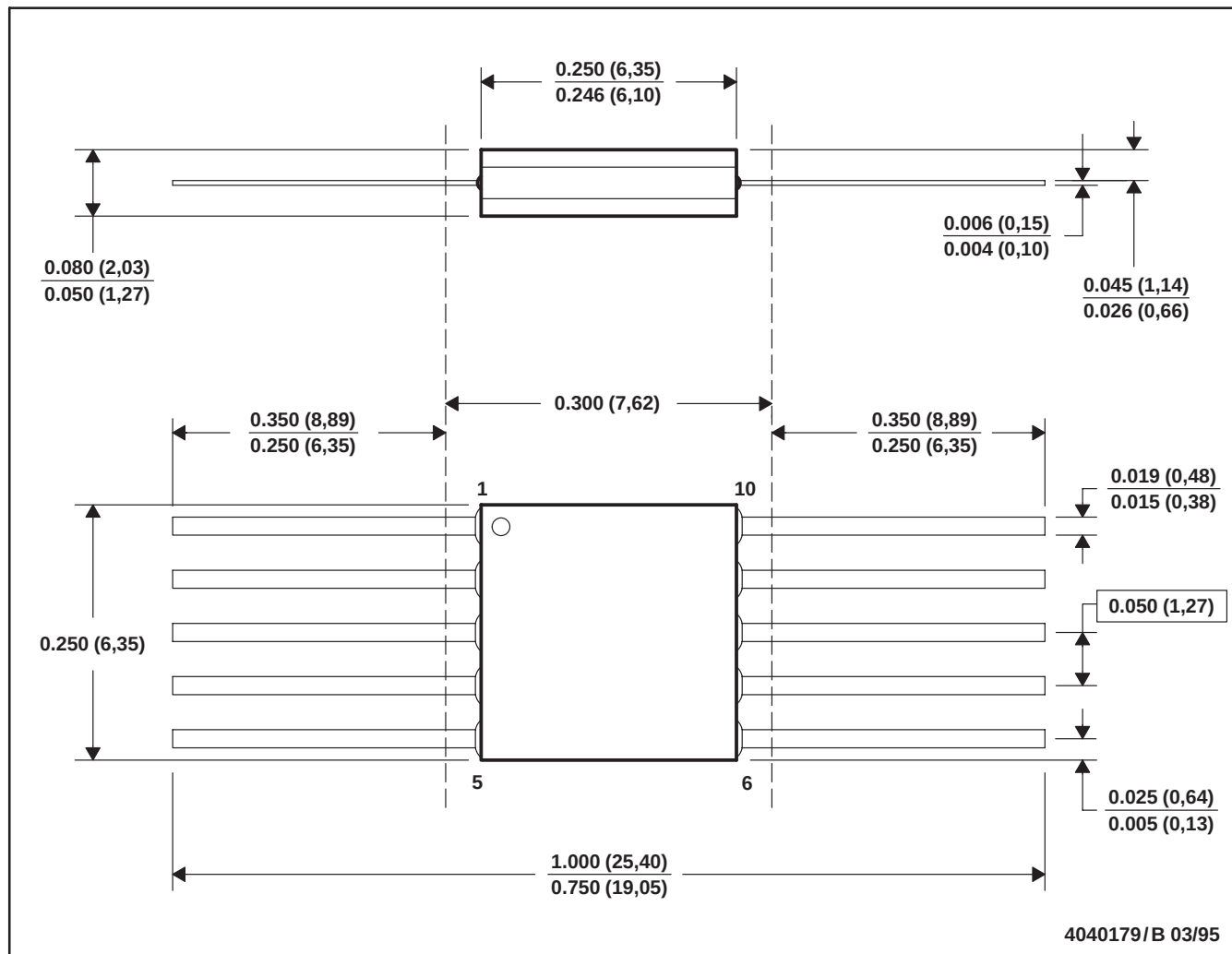
- NOTES: A. All linear dimensions are in millimeters.  
 B. This drawing is subject to change without notice.  
 C. Body dimensions do not include mold flash or protrusion not to exceed 0,15.  
 D. Falls within JEDEC MO-153

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## MECHANICAL INFORMATION

U (S-GDFP-F10)

CERAMIC DUAL FLATPACK



- NOTES: A. All linear dimensions are in inches (millimeters).  
 B. This drawing is subject to change without notice.  
 C. This package can be hermetically sealed with a ceramic lid using glass frit.  
 D. Index point is provided on cap for terminal identification only.  
 E. Falls within MIL STD 1835 GDFP1-F10 and JEDEC MO-092AA

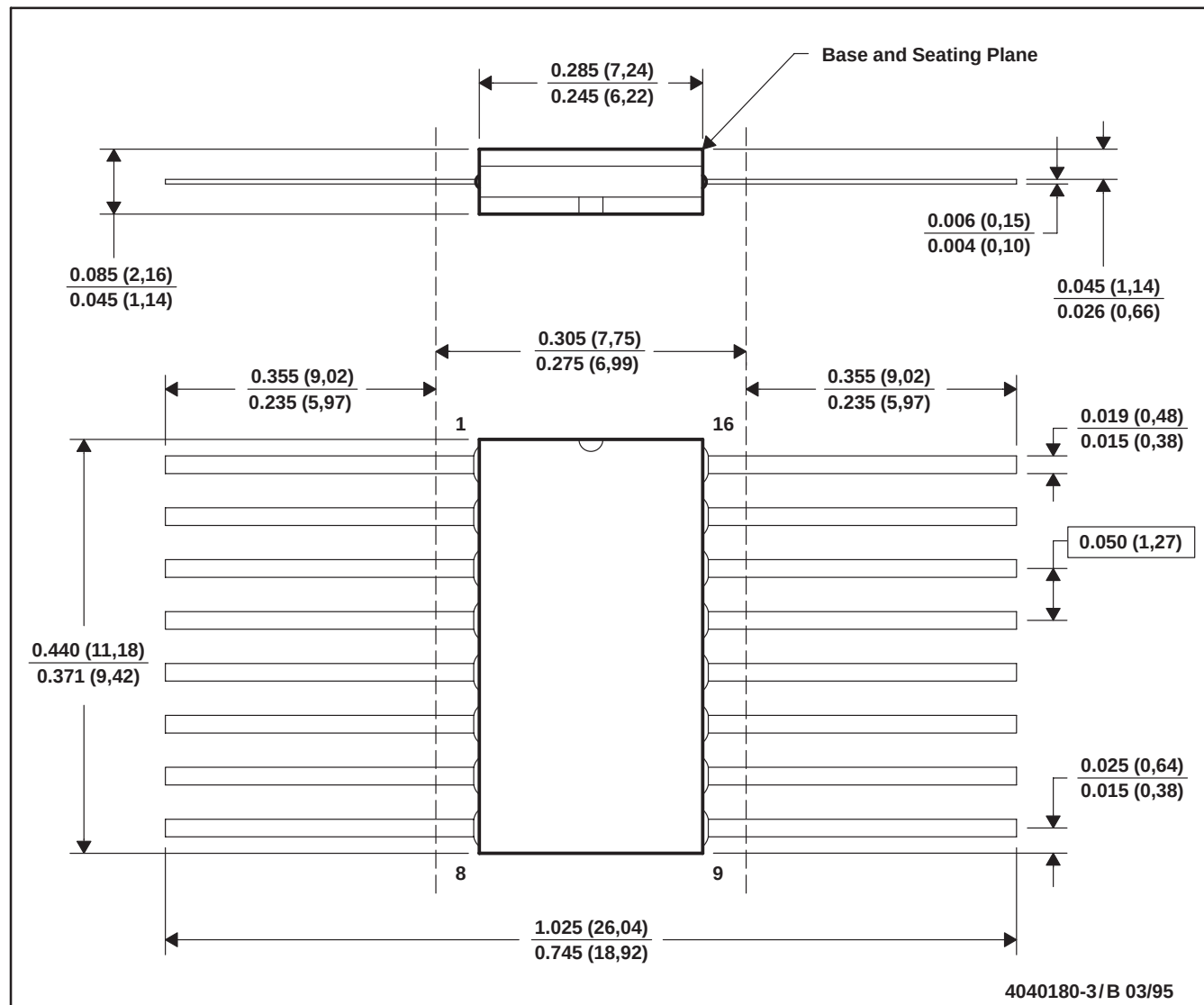
**TLC225x, TLC225xA**  
**Advanced LinCMOS™ RAIL-TO-RAIL**  
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**MECHANICAL INFORMATION**

**W (R-GDFP-F16)**

**CERAMIC DUAL FLATPACK**



- NOTES: A. All linear dimensions are in inches (millimeters).  
 B. This drawing is subject to change without notice.  
 C. This package can be hermetically sealed with a ceramic lid using glass frit.  
 D. Index point is provided on cap for terminal identification only.  
 E. Falls within MIL-STD-1835 GDFP1-F16 and JEDEC MO-092AC



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