

# TLE202x, TLE202xA, TLE202xB, TLE202xY EXCALIBUR HIGH-SPEED LOW-POWER PRECISION OPERATIONAL AMPLIFIERS

SLOS191D – FEBRUARY 1997 – REVISED NOVEMBER 2010

- Supply Current . . . 300  $\mu$ A Max
- High Unity-Gain Bandwidth . . . 2 MHz Typ
- High Slew Rate . . . 0.45 V/ $\mu$ s Min
- Supply-Current Change Over Military Temp Range . . . 10  $\mu$ A Typ at  $V_{CC} \pm \pm 15$  V
- Specified for Both 5-V Single-Supply and  $\pm 15$ -V Operation
- Phase-Reversal Protection
- High Open-Loop Gain . . . 6.5 V/ $\mu$ V (136 dB) Typ
- Low Offset Voltage . . . 100  $\mu$ V Max
- Offset Voltage Drift With Time 0.005  $\mu$ V/mo Typ
- Low Input Bias Current . . . 50 nA Max
- Low Noise Voltage . . . 19 nV/ $\sqrt{\text{Hz}}$  Typ

## description

The TLE202x, TLE202xA, and TLE202xB devices are precision, high-speed, low-power operational amplifiers using a new Texas Instruments Excalibur process. These devices combine the best features of the OP21 with highly improved slew rate and unity-gain bandwidth.

The complementary bipolar Excalibur process utilizes isolated vertical pnp transistors that yield dramatic improvement in unity-gain bandwidth and slew rate over similar devices.

The addition of a bias circuit in conjunction with this process results in extremely stable parameters with both time and temperature. This means that a precision device remains a precision device even with changes in temperature and over years of use.

This combination of excellent dc performance with a common-mode input voltage range that includes the negative rail makes these devices the ideal choice for low-level signal conditioning applications in either single-supply or split-supply configurations. In addition, these devices offer phase-reversal protection circuitry that eliminates an unexpected change in output states when one of the inputs goes below the negative supply rail.

A variety of available options includes small-outline and chip-carrier versions for high-density systems applications.

The C-suffix devices are characterized for operation from 0°C to 70°C. The I-suffix devices are characterized for operation from –40°C to 85°C. The M-suffix devices are characterized for operation over the full military temperature range of –55°C to 125°C.



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

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## TLE2021 AVAILABLE OPTIONS

| T <sub>A</sub>       | V <sub>IO</sub> max<br>AT 25°C | PACKAGED DEVICES                     |                           |                           |                           |                         |                            | CHIP<br>FORM <sup>§</sup><br>(Y) |
|----------------------|--------------------------------|--------------------------------------|---------------------------|---------------------------|---------------------------|-------------------------|----------------------------|----------------------------------|
|                      |                                | SMALL<br>OUTLINE <sup>†</sup><br>(D) | SSOP <sup>‡</sup><br>(DB) | CHIP<br>CARRIER<br>(FK)   | CERAMIC DIP<br>(JG)       | PLASTIC DIP<br>(P)      | TSSOP <sup>‡</sup><br>(PW) |                                  |
| 0°C to<br>70°C       | 200 µV<br>500 µV               | TLE2021ACD<br>TLE2021CD              | TLE2021CDBLE              | —                         | —                         | TLE2021ACP<br>TLE2021CP | —<br>TLE2021CPWLE          | —<br>TLE2021Y                    |
| –40°C<br>to<br>85°C  | 200 µV<br>500 µV               | TLE2021AID<br>TLE2021ID              | —                         | —                         | —                         | TLE2021AIP<br>TLE2021IP | —                          | —                                |
| –55°C<br>to<br>125°C | 100 µV<br>500 µV               | —<br>TLE2021MD                       | —                         | TLE2021BMFK<br>TLE2021MFK | TLE2021BMJG<br>TLE2021MJG | —<br>TLE2021MP          | —                          | —                                |

<sup>†</sup> The D packages are available taped and reeled. To order a taped and reeled part, add the suffix R (e.g., TLE2021CDR).

<sup>‡</sup> The DB and PW packages are only available left-end taped and reeled.

<sup>§</sup> Chip forms are tested at 25°C only.

## TLE2022 AVAILABLE OPTIONS

| T <sub>A</sub>       | V <sub>IO</sub> max<br>AT 25°C | PACKAGED DEVICES                      |                           |                                |                                          |                              |                            | CHIP<br>FORM <sup>§</sup><br>(Y) |
|----------------------|--------------------------------|---------------------------------------|---------------------------|--------------------------------|------------------------------------------|------------------------------|----------------------------|----------------------------------|
|                      |                                | SMALL<br>OUTLINE <sup>†</sup><br>(D)  | SSOP <sup>‡</sup><br>(DB) | CHIP<br>CARRIER<br>(FK)        | CERAMIC<br>DIP<br>(JG)                   | PLASTIC<br>DIP<br>(P)        | TSSOP <sup>‡</sup><br>(PW) |                                  |
| 0°C<br>to<br>70°C    | 150 µV<br>300 µV<br>500 µV     | TLE2022BCD<br>TLE2022ACD<br>TLE2022CD | —<br>—<br>TLE2022CDBLE    | —                              | —                                        | —<br>TLE2022ACP<br>TLE2022CP | —<br>—<br>TLE2022CPWLE     | —<br>—<br>TLE2022Y               |
| –40°C<br>to<br>85°C  | 150 µV<br>300 µV<br>500 µV     | TLE2022BID<br>TLE2022AID<br>TLE2022ID | —                         | —                              | —                                        | —<br>TLE2022AIP<br>TLE2022IP | —                          | —                                |
| –55°C<br>to<br>125°C | 150 µV<br>300 µV<br>500 µV     | —<br>TLE2022AMD<br>TLE2022MD          | —                         | —<br>TLE2022AMFK<br>TLE2022MFK | TLE2022BMJG<br>TLE2022AMJG<br>TLE2022MJG | —<br>TLE2022AMP<br>TLE2022MP | —                          | —                                |

<sup>†</sup> The D packages are available taped and reeled. To order a taped and reeled part, add the suffix R (e.g., TLE2022CDR).

<sup>‡</sup> The DB and PW packages are only available left-end taped and reeled.

<sup>§</sup> Chip forms are tested at 25°C only.

## TLE2024 AVAILABLE OPTIONS

| T <sub>A</sub> | V <sub>IO</sub> max<br>AT 25°C | PACKAGED DEVICES                         |                                          |                                       |                                       | CHIP<br>FORM <sup>§</sup><br>(Y) |
|----------------|--------------------------------|------------------------------------------|------------------------------------------|---------------------------------------|---------------------------------------|----------------------------------|
|                |                                | SMALL<br>OUTLINE<br>(DW)                 | CHIP<br>CARRIER<br>(FK)                  | CERAMIC<br>DIP<br>(J)                 | PLASTIC<br>DIP<br>(N)                 |                                  |
| 0°C to 70°C    | 500 µV<br>750 µV<br>1000 µV    | TLE2024BCDW<br>TLE2024ACDW<br>TLE2024CDW | —                                        | —                                     | TLE2024BCN<br>TLE2024ACN<br>TLE2024CN | —<br>—<br>TLE2024Y               |
| –40°C to 85°C  | 500 µV<br>750 µV<br>1000 µV    | TLE2024BIDW<br>TLE2024AIDW<br>TLE2024IDW | —                                        | —                                     | TLE2024BIN<br>TLE2024AIN<br>TLE2024IN | —                                |
| –55°C to 125°C | 500 µV<br>750 µV<br>1000 µV    | TLE2024BMDW<br>TLE2024AMDW<br>TLE2024MDW | TLE2024BMFK<br>TLE2024AMFK<br>TLE2024MFK | TLE2024BMJ<br>TLE2024AMJ<br>TLE2024MJ | TLE2024BMN<br>TLE2024AMN<br>TLE2024MN | —                                |

<sup>§</sup> Chip forms are tested at 25°C only.

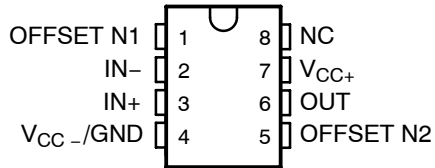


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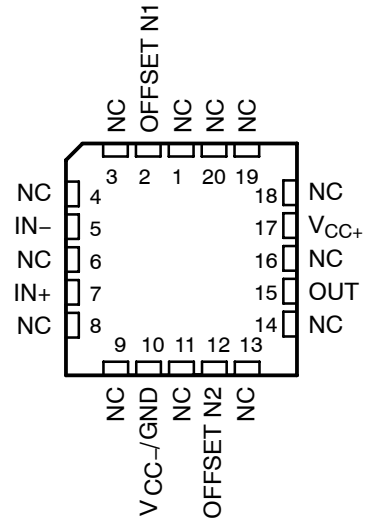
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**TLE2021**  
**D, DB, JG, P, OR PW PACKAGE**  
**(TOP VIEW)**

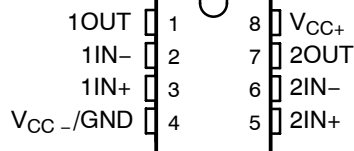


NC – No internal connection

**TLE2021**  
**FK PACKAGE**  
**(TOP VIEW)**

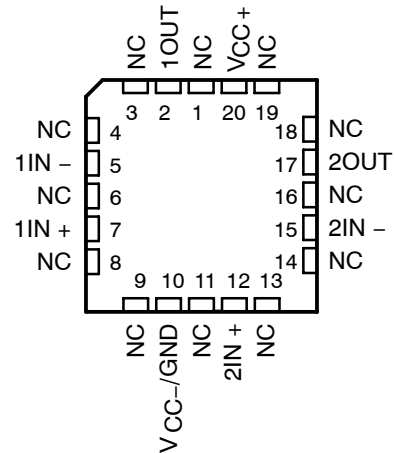


**D, DB, JG, P, OR PW PACKAGE**  
**(TOP VIEW)**

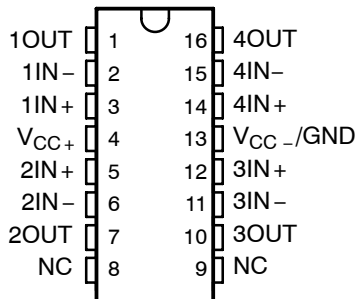


NC – No internal connection

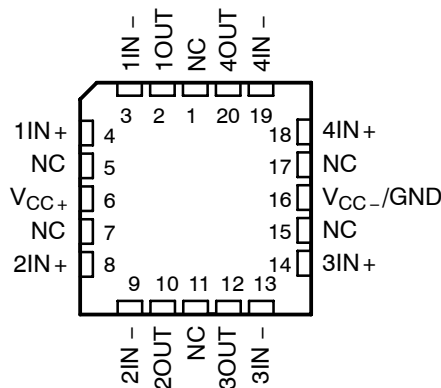
**FK PACKAGE**  
**(TOP VIEW)**



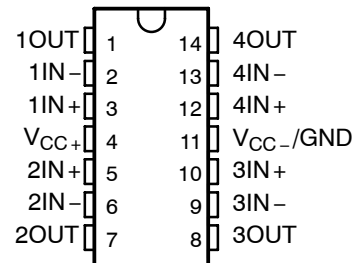
**DW PACKAGE**  
**(TOP VIEW)**



**FK PACKAGE**  
**(TOP VIEW)**



**J OR N PACKAGE**  
**(TOP VIEW)**



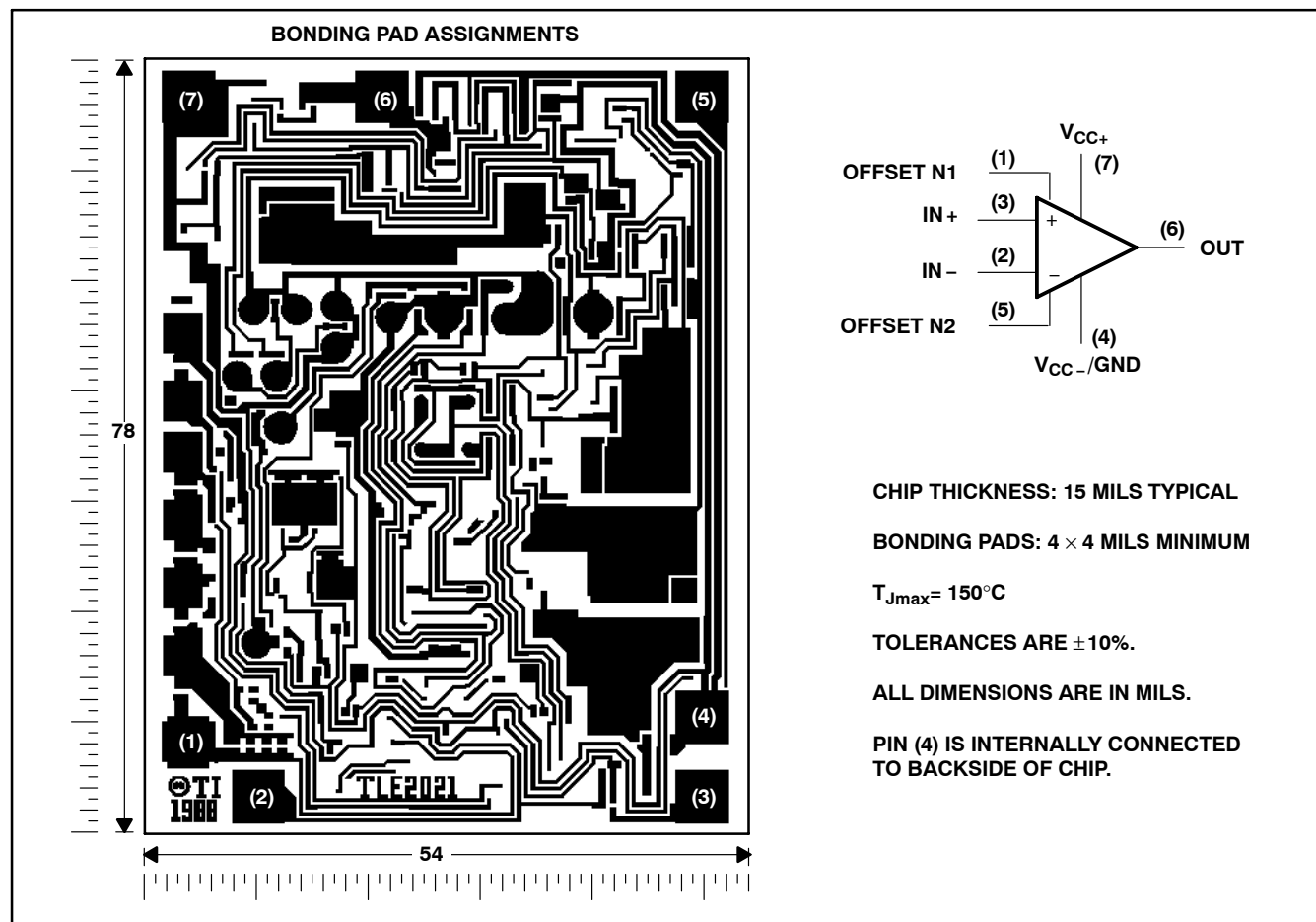
NC – No internal connection

# TLE202x, TLE202xA, TLE202xB, TLE202xY EXCALIBUR HIGH-SPEED LOW-POWER PRECISION OPERATIONAL AMPLIFIERS

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## TLE2021Y chip information

This chip, when properly assembled, display characteristics similar to the TLE2021. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. This chip may be mounted with conductive epoxy or a gold-silicon preform.

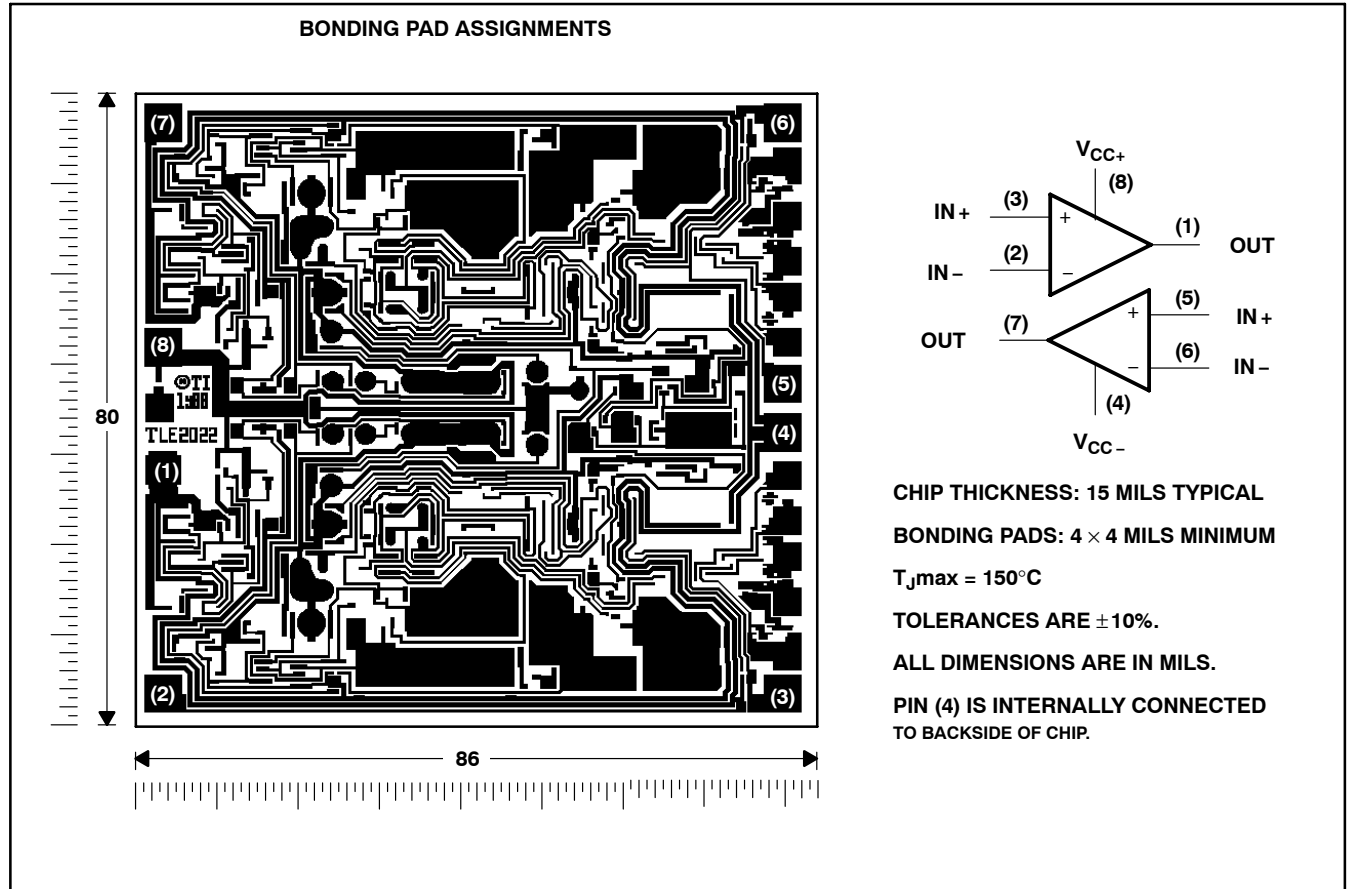


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## TLE2022Y chip information

This chip, when properly assembled, displays characteristics similar to TLE2022. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. This chip may be mounted with conductive epoxy or a gold-silicon preform.



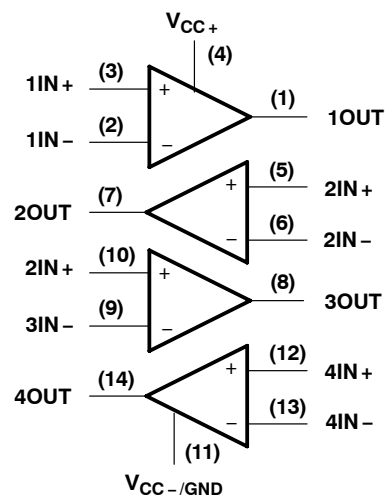
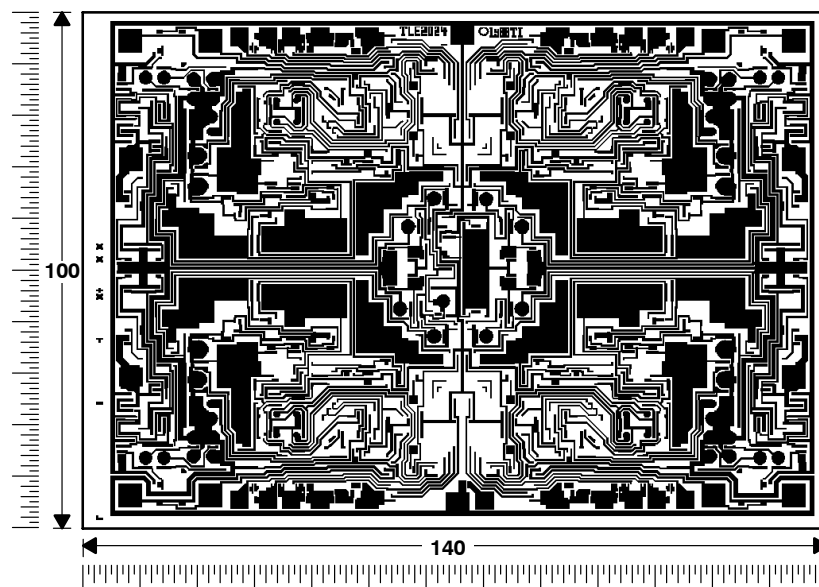
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## TLE2024Y chip information

This chip, when properly assembled, displays characteristics similar to the TLE2024. Thermal compression or ultrasonic bonding may be used on the doped aluminum-bonding pads. This chip may be mounted with conductive epoxy or a gold-silicon preform.

**BONDING PAD ASSIGNMENTS**



CHIP THICKNESS: 15 MILS TYPICAL

BONDING PADS:  $4 \times 4$  MILS MINIMUM

$T_{Jmax} = 150^{\circ}\text{C}$

TOLERANCES ARE  $\pm 10\%$ .

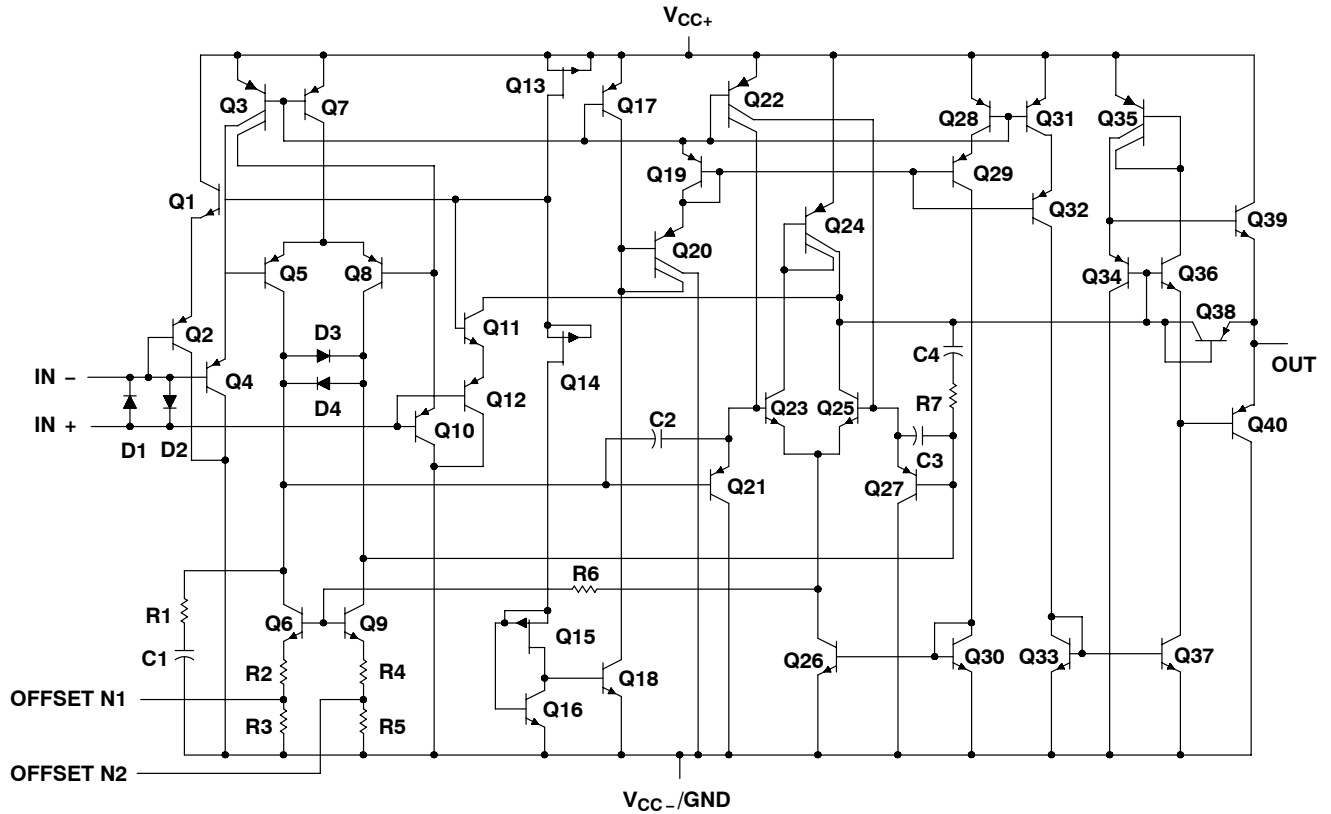
ALL DIMENSIONS ARE IN MILS.

PIN (11) IS INTERNALLY CONNECTED  
TO BACKSIDE OF CHIP.

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equivalent schematic (each amplifier)



| ACTUAL DEVICE COMPONENT COUNT |         |         |         |
|-------------------------------|---------|---------|---------|
| COMPONENT                     | TLE2021 | TLE2022 | TLE2024 |
| Transistors                   | 40      | 80      | 160     |
| Resistors                     | 7       | 14      | 28      |
| Diodes                        | 4       | 8       | 16      |
| Capacitors                    | 4       | 8       | 16      |

# TLE202x, TLE202xA, TLE202xB, TLE202xY

## EXCALIBUR HIGH-SPEED LOW-POWER PRECISION

### OPERATIONAL AMPLIFIERS

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

|                                                                                       |                              |
|---------------------------------------------------------------------------------------|------------------------------|
| Supply voltage, $V_{CC+}$ (see Note 1)                                                | 20 V                         |
| Supply voltage, $V_{CC-}$ (see Note 1)                                                | –20 V                        |
| Differential input voltage, $V_{ID}$ (see Note 2)                                     | $\pm 0.6$ V                  |
| Input voltage range, $V_I$ (any input, see Note 1)                                    | $\pm V_{CC}$                 |
| Input current, $I_I$ (each input)                                                     | $\pm 1$ mA                   |
| Output current, $I_O$ (each output): TLE2021                                          | $\pm 20$ mA                  |
| TLE2022                                                                               | $\pm 30$ mA                  |
| TLE2024                                                                               | $\pm 40$ mA                  |
| Total current into $V_{CC+}$                                                          | 80 mA                        |
| Total current out of $V_{CC-}$                                                        | 80 mA                        |
| Duration of short-circuit current at (or below) 25°C (see Note 3)                     | unlimited                    |
| Continuous total power dissipation                                                    | See Dissipation Rating Table |
| Operating free-air temperature range, $T_A$ : C suffix                                | 0°C to 70°C                  |
| I suffix                                                                              | –40°C to 85°C                |
| M suffix                                                                              | –55°C to 125°C               |
| Storage temperature range, $T_{stg}$                                                  | –65°C to 150°C               |
| Case temperature for 60 seconds, $T_C$ : FK package                                   | 260°C                        |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D, DP, P, or PW package | 260°C                        |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package              | 300°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  $V_{CC+}$  and  $V_{CC-}$ .
2. Differential voltages are at  $IN+$  with respect to  $IN-$ . Excessive current flows if a differential input voltage in excess of approximately  $\pm 600$  mV is applied between the inputs unless some limiting resistance is used.
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     | 725 mW                                      | 5.8 mW/°C                                         | 464 mW                                   | 377 mW                                   | 145 mW                                    |
| DB–8    | 525 mW                                      | 4.2 mW/°C                                         | 336 mW                                   | —                                        | —                                         |
| DW–16   | 1025 mW                                     | 8.2 mW/°C                                         | 656 mW                                   | 533 mW                                   | 205 mW                                    |
| FK      | 1375 mW                                     | 11.0 mW/°C                                        | 880 mW                                   | 715 mW                                   | 275 mW                                    |
| J–14    | 1375 mW                                     | 11.0 mW/°C                                        | 880 mW                                   | 715 mW                                   | 275 mW                                    |
| JG–8    | 1050 mW                                     | 8.4 mW/°C                                         | 672 mW                                   | 546 mW                                   | 210 mW                                    |
| N–14    | 1150 mW                                     | 9.2 mW/°C                                         | 736 mW                                   | 598 mW                                   | 230 mW                                    |
| P–8     | 1000 mW                                     | 8.0 mW/°C                                         | 640 mW                                   | 520 mW                                   | 200 mW                                    |
| PW–8    | 525 mW                                      | 4.2 mW/°C                                         | 336 mW                                   | —                                        | —                                         |

#### recommended operating conditions

|                                       |                        | C SUFFIX |          | I SUFFIX |          | M SUFFIX |          | UNIT |
|---------------------------------------|------------------------|----------|----------|----------|----------|----------|----------|------|
|                                       |                        | MIN      | MAX      | MIN      | MAX      | MIN      | MAX      |      |
| Supply voltage, $V_{CC}$              |                        | $\pm 2$  | $\pm 20$ | $\pm 2$  | $\pm 20$ | $\pm 2$  | $\pm 20$ | V    |
| Common-mode input voltage, $V_{IC}$   | $V_{CC} = \pm 5$ V     | 0        | 3.5      | 0        | 3.2      | 0        | 3.2      | V    |
|                                       | $V_{CC\pm} = \pm 15$ V | –15      | 13.5     | –15      | 13.2     | –15      | 13.2     |      |
| Operating free-air temperature, $T_A$ |                        | 0        | 70       | –40      | 85       | –55      | 125      | °C   |



**TLE2021 electrical characteristics at specified free-air temperature,  $V_{CC} = 5\text{ V}$  (unless otherwise noted)**

| PARAMETER        |                                                                      | TEST CONDITIONS                                               | T <sub>A</sub> <sup>†</sup> | TLE2021C   |            |      | TLE2021AC |            |      | TLE2021BC |            |      | UNIT  |
|------------------|----------------------------------------------------------------------|---------------------------------------------------------------|-----------------------------|------------|------------|------|-----------|------------|------|-----------|------------|------|-------|
|                  |                                                                      |                                                               |                             | MIN        | TYP        | MAX  | MIN       | TYP        | MAX  | MIN       | TYP        | MAX  |       |
| V <sub>IO</sub>  | Input offset voltage                                                 | V <sub>IC</sub> = 0, R <sub>S</sub> = 50 Ω                    | 25°C                        | 120        |            | 600  | 100       |            | 300  | 80        |            | 200  | μV    |
|                  |                                                                      |                                                               | Full range                  |            |            | 850  |           |            | 600  |           |            | 300  |       |
| α <sub>VIO</sub> | Temperature coefficient of input offset voltage                      |                                                               | Full range                  | 2          |            |      | 2         |            |      | 2         |            |      | μV/°C |
|                  | Input offset voltage long-term drift (see Note 4)                    |                                                               | 25°C                        | 0.005      |            |      | 0.005     |            |      | 0.005     |            |      | μV/mo |
| I <sub>IO</sub>  | Input offset current                                                 |                                                               | 25°C                        | 0.2        |            | 6    | 0.2       |            | 6    | 0.2       |            | 6    | nA    |
|                  |                                                                      |                                                               | Full range                  |            |            | 10   |           |            | 10   |           |            | 10   |       |
| I <sub>IB</sub>  | Input bias current                                                   |                                                               | 25°C                        | 25         |            | 70   | 25        |            | 70   | 25        |            | 70   | nA    |
|                  |                                                                      |                                                               | Full range                  |            |            | 90   |           |            | 90   |           |            | 90   |       |
| V <sub>ICR</sub> | Common-mode input voltage range                                      | R <sub>S</sub> = 50 Ω                                         | 25°C                        | 0 to 3.5   | – 0.3 to 4 |      | 0 to 3.5  | – 0.3 to 4 |      | 0 to 3.5  | – 0.3 to 4 |      | V     |
|                  |                                                                      |                                                               | Full range                  | 0 to 3.5   |            |      | 0 to 3.5  |            |      | 0 to 3.5  |            |      |       |
| V <sub>OH</sub>  | High-level output voltage                                            | R <sub>L</sub> = 10 kΩ                                        | 25°C                        | 4          | 4.3        |      | 4         | 4.3        |      | 4         | 4.3        |      | V     |
|                  |                                                                      |                                                               | Full range                  | 3.9        |            |      | 3.9       |            |      | 3.9       |            |      |       |
| V <sub>OL</sub>  | Low-level output voltage                                             |                                                               | 25°C                        | 0.7        |            | 0.8  | 0.7       |            | 0.8  | 0.7       |            | 0.8  | V     |
|                  |                                                                      |                                                               | Full range                  |            |            | 0.85 |           |            | 0.85 |           |            | 0.85 |       |
| A <sub>VD</sub>  | Large-signal differential voltage amplification                      | V <sub>O</sub> = 1.4 V to 4 V, R <sub>L</sub> = 10 kΩ         | 25°C                        | 0.3        | 1.5        |      | 0.3       | 1.5        |      | 0.3       | 1.5        |      | V/μV  |
|                  |                                                                      |                                                               | Full range                  | 0.3        |            |      | 0.3       |            |      | 0.3       |            |      |       |
| CMRR             | Common-mode rejection ratio                                          | V <sub>IC</sub> = V <sub>ICRmin</sub> , R <sub>S</sub> = 50 Ω | 25°C                        | 85         | 110        |      | 85        | 110        |      | 85        | 110        |      | dB    |
|                  |                                                                      |                                                               | Full range                  | 80         |            |      | 80        |            |      | 80        |            |      |       |
| k <sub>SVR</sub> | Supply-voltage rejection ratio (ΔV <sub>CC</sub> /ΔV <sub>IO</sub> ) | V <sub>CC</sub> = 5 V to 30 V                                 | 25°C                        | 105        | 120        |      | 105       | 120        |      | 105       | 120        |      | dB    |
|                  |                                                                      |                                                               | Full range                  | 100        |            |      | 100       |            |      | 100       |            |      |       |
| I <sub>CC</sub>  | Supply current                                                       | V <sub>O</sub> = 2.5 V, No load                               | 25°C                        | 200        | 300        |      | 200       | 300        |      | 200       | 300        |      | μA    |
|                  |                                                                      |                                                               | Full range                  |            |            | 300  |           |            | 300  |           |            | 300  |       |
| ΔI <sub>CC</sub> | Supply-current change over operating temperature range               |                                                               |                             | Full range | 5          |      |           | 5          |      |           | 5          |      | μA    |

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

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 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.

**TLE2021 electrical characteristics at specified free-air temperature,  $V_{CC} = \pm 15\text{ V}$  (unless otherwise noted)**

| PARAMETER                                                                  | TEST CONDITIONS                                    | $T_A^\dagger$ | TLE2021C    |             |     | TLE2021AC   |             |     | TLE2021BC   |             |     | UNIT                         |
|----------------------------------------------------------------------------|----------------------------------------------------|---------------|-------------|-------------|-----|-------------|-------------|-----|-------------|-------------|-----|------------------------------|
|                                                                            |                                                    |               | MIN         | TYP         | MAX | MIN         | TYP         | MAX | MIN         | TYP         | MAX |                              |
| $V_{IO}$ Input offset voltage                                              | $V_{IC} = 0, R_S = 50\ \Omega$                     | 25°C          |             | 120         | 500 |             | 80          | 200 |             | 40          | 100 | $\mu\text{V}$                |
|                                                                            |                                                    | Full range    |             |             | 750 |             |             | 500 |             |             | 200 |                              |
| $\alpha_{VIO}$ Temperature coefficient of input offset voltage             |                                                    | Full range    |             | 2           |     |             | 2           |     |             | 2           |     | $\mu\text{V}/^\circ\text{C}$ |
| Input offset voltage long-term drift (see Note 4)                          |                                                    | 25°C          |             | 0.006       |     |             | 0.006       |     |             | 0.006       |     | $\mu\text{V}/\text{mo}$      |
| $I_{IO}$ Input offset current                                              |                                                    | 25°C          |             | 0.2         | 6   |             | 0.2         | 6   |             | 0.2         | 6   | $\text{nA}$                  |
|                                                                            |                                                    | Full range    |             |             | 10  |             |             | 10  |             |             | 10  |                              |
| $I_{IB}$ Input bias current                                                |                                                    | 25°C          |             | 25          | 70  |             | 25          | 70  |             | 25          | 70  | $\text{nA}$                  |
|                                                                            |                                                    | Full range    |             |             | 90  |             |             | 90  |             |             | 90  |                              |
| $V_{ICR}$ Common-mode input voltage range                                  | $R_S = 50\ \Omega$                                 | 25°C          | –15 to 13.5 | –15.3 to 14 |     | –15 to 13.5 | –15.3 to 14 |     | –15 to 13.5 | –15.3 to 14 |     | $\text{V}$                   |
|                                                                            |                                                    | Full range    | –15 to 13.5 |             |     | –15 to 13.5 |             |     | –15 to 13.5 |             |     |                              |
| $V_{OM+}$ Maximum positive peak output voltage swing                       | $R_L = 10\ \text{k}\Omega$                         | 25°C          | 14          | 14.3        |     | 14          | 14.3        |     | 14          | 14.3        |     | $\text{V}$                   |
|                                                                            |                                                    | Full range    | 13.9        |             |     | 13.9        |             |     | 13.9        |             |     |                              |
| $V_{OM-}$ Maximum negative peak output voltage swing                       |                                                    | 25°C          | –13.7       | –14.1       |     | –13.7       | –14.1       |     | –13.7       | –14.1       |     | $\text{V}$                   |
|                                                                            |                                                    | Full range    | –13.7       |             |     | –13.7       |             |     | –13.7       |             |     |                              |
| $A_{VD}$ Large-signal differential voltage amplification                   | $V_O = \pm 10\text{ V}, R_L = 10\ \text{k}\Omega$  | 25°C          | 1           | 6.5         |     | 1           | 6.5         |     | 1           | 6.5         |     | $\text{V}/\mu\text{V}$       |
|                                                                            |                                                    | Full range    | 1           |             |     | 1           |             |     | 1           |             |     |                              |
| CMRR Common-mode rejection ratio                                           | $V_{IC} = V_{ICR}\text{ min}, R_S = 50\ \Omega$    | 25°C          | 100         | 115         |     | 100         | 115         |     | 100         | 115         |     | $\text{dB}$                  |
|                                                                            |                                                    | Full range    | 96          |             |     | 96          |             |     | 96          |             |     |                              |
| $k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{CC}/\Delta V_{IO}$ ) | $V_{CC\pm} = \pm 2.5\text{ V to } \pm 15\text{ V}$ | 25°C          | 105         | 120         |     | 105         | 120         |     | 105         | 120         |     | $\text{dB}$                  |
|                                                                            |                                                    | Full range    | 100         |             |     | 100         |             |     | 100         |             |     |                              |
| $I_{CC}$ Supply current                                                    | $V_O = 0, \text{ No load}$                         | 25°C          |             | 240         | 350 |             | 240         | 350 |             | 240         | 350 | $\mu\text{A}$                |
|                                                                            |                                                    | Full range    |             |             | 350 |             |             | 350 |             |             | 350 |                              |
| $\Delta I_{CC}$ Supply-current change over operating temperature range     |                                                    | Full range    |             | 6           |     |             | 6           |     |             | 6           |     | $\mu\text{A}$                |

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

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 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.

**TLE2022 electrical characteristics at specified free-air temperature,  $V_{CC} = 5\text{ V}$  (unless otherwise noted)**

| PARAMETER        |                                                                       | TEST CONDITIONS                                               | T <sub>A</sub> <sup>†</sup> | TLE2022C |           |          | TLE2022AC |          |           | TLE2022BC |           |      | UNIT  |
|------------------|-----------------------------------------------------------------------|---------------------------------------------------------------|-----------------------------|----------|-----------|----------|-----------|----------|-----------|-----------|-----------|------|-------|
|                  |                                                                       |                                                               |                             | MIN      | TYP       | MAX      | MIN       | TYP      | MAX       | MIN       | TYP       | MAX  |       |
| V <sub>IO</sub>  | Input offset voltage                                                  | V <sub>IC</sub> = 0, R <sub>S</sub> = 50 Ω                    | 25°C                        | 600      |           |          | 400       |          |           | 250       |           |      | μV    |
|                  |                                                                       |                                                               | Full range                  | 800      |           |          | 550       |          |           | 400       |           |      |       |
| αV <sub>IO</sub> | Temperature coefficient of input offset voltage                       |                                                               | Full range                  | 2        |           |          | 2         |          |           | 2         |           |      | μV/°C |
|                  | Input offset voltage long-term drift (see Note 4)                     |                                                               | 25°C                        | 0.005    |           |          | 0.005     |          |           | 0.005     |           |      | μV/mo |
| I <sub>IO</sub>  | Input offset current                                                  |                                                               | 25°C                        | 0.5 6    |           |          | 0.4 6     |          |           | 0.3 6     |           |      | nA    |
|                  |                                                                       |                                                               | Full range                  | 10       |           |          | 10        |          |           | 10        |           |      |       |
| I <sub>IB</sub>  | Input bias current                                                    |                                                               | 25°C                        | 35 70    |           |          | 33 70     |          |           | 30 70     |           |      | nA    |
|                  |                                                                       |                                                               | Full range                  | 90       |           |          | 90        |          |           | 90        |           |      |       |
| V <sub>ICR</sub> | Common-mode input voltage range                                       | R <sub>S</sub> = 50 Ω                                         | 25°C                        | 0 to 3.5 | −0.3 to 4 | 0 to 3.5 | −0.3 to 4 | 0 to 3.5 | −0.3 to 4 | 0 to 3.5  | −0.3 to 4 | V    |       |
|                  |                                                                       |                                                               | Full range                  | 0 to 3.5 |           | 0 to 3.5 |           | 0 to 3.5 |           |           |           |      |       |
| V <sub>OH</sub>  | High-level output voltage                                             | R <sub>L</sub> = 10 kΩ                                        | 25°C                        | 4        | 4.3       | 4        | 4.3       | 4        | 4.3       | 4         | 4.3       | V    |       |
|                  |                                                                       |                                                               | Full range                  | 3.9      |           | 3.9      |           | 3.9      |           |           |           |      |       |
| V <sub>OL</sub>  | Low-level output voltage                                              |                                                               | 25°C                        | 0.7      | 0.8       | 0.7      | 0.8       | 0.7      | 0.8       | 0.7       | 0.8       | V    |       |
|                  |                                                                       |                                                               | Full range                  | 0.85     |           | 0.85     |           | 0.85     |           |           |           |      |       |
| A <sub>VD</sub>  | Large-signal differential voltage amplification                       | V <sub>O</sub> = 1.4 V to 4 V, R <sub>L</sub> = 10 kΩ         | 25°C                        | 0.3      | 1.5       | 0.4      | 1.5       | 0.5      | 1.5       |           |           | V/μV |       |
|                  |                                                                       |                                                               | Full range                  | 0.3      |           | 0.4      |           | 0.5      |           |           |           |      |       |
| CMRR             | Common-mode rejection ratio                                           | V <sub>IC</sub> = V <sub>ICRmin</sub> , R <sub>S</sub> = 50 Ω | 25°C                        | 85       | 100       | 87       | 102       | 90       | 105       |           |           | dB   |       |
|                  |                                                                       |                                                               | Full range                  | 80       |           | 82       |           | 85       |           |           |           |      |       |
| k <sub>SVR</sub> | Supply-voltage rejection ratio (ΔV <sub>CC</sub> ±/ΔV <sub>IO</sub> ) | V <sub>CC</sub> = 5 V to 30 V                                 | 25°C                        | 100      | 115       | 103      | 118       | 105      | 120       |           |           | dB   |       |
|                  |                                                                       |                                                               | Full range                  | 95       |           | 98       |           | 100      |           |           |           |      |       |
| I <sub>CC</sub>  | Supply current                                                        | V <sub>O</sub> = 2.5 V, No load                               | 25°C                        | 450      | 600       | 450      | 600       | 450      | 600       |           |           | μA   |       |
|                  |                                                                       |                                                               | Full range                  | 600      |           | 600      |           | 600      |           |           |           |      |       |
| ΔI <sub>CC</sub> | Supply current change over operating temperature range                |                                                               | Full range                  | 7        |           | 7        |           | 7        |           |           | μA        |      |       |

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

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 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.

**TLE2022 electrical characteristics at specified free-air temperature,  $V_{CC} = \pm 15$  V (unless otherwise noted)**

| PARAMETER                                                                     | TEST CONDITIONS                        | $T_A^\dagger$ | TLE2022C    |             |       | TLE2022AC   |             |       | TLE2022BC   |             |       | UNIT             |
|-------------------------------------------------------------------------------|----------------------------------------|---------------|-------------|-------------|-------|-------------|-------------|-------|-------------|-------------|-------|------------------|
|                                                                               |                                        |               | MIN         | TYP         | MAX   | MIN         | TYP         | MAX   | MIN         | TYP         | MAX   |                  |
| $V_{IO}$ Input offset voltage                                                 | $V_{IC} = 0, R_S = 50 \Omega$          | 25°C          |             | 150         | 500   |             | 120         | 300   |             | 70          | 150   | $\mu V$          |
|                                                                               |                                        | Full range    |             |             | 700   |             |             | 450   |             |             | 300   |                  |
| $\alpha_{VIO}$ Temperature coefficient of input offset voltage                |                                        | Full range    |             | 2           |       |             | 2           |       |             | 2           |       | $\mu V/^\circ C$ |
| Input offset voltage long-term drift (see Note 4)                             |                                        | 25°C          |             | 0.006       |       |             | 0.006       |       |             | 0.006       |       | $\mu V/mo$       |
| $I_{IO}$ Input offset current                                                 |                                        | 25°C          |             | 0.5         | 6     |             | 0.4         | 6     |             | 0.3         | 6     | nA               |
|                                                                               |                                        | Full range    |             |             | 10    |             |             | 10    |             |             | 10    |                  |
| $I_{IB}$ Input bias current                                                   |                                        | 25°C          |             | 35          | 70    |             | 33          | 70    |             | 30          | 70    | nA               |
|                                                                               |                                        | Full range    |             |             | 90    |             |             | 90    |             |             | 90    |                  |
| $V_{ICR}$ Common-mode input voltage range                                     | $R_S = 50 \Omega$                      | 25°C          | –15 to 13.5 | –15.3 to 14 |       | –15 to 13.5 | –15.3 to 14 |       | –15 to 13.5 | –15.3 to 14 |       | V                |
|                                                                               |                                        | Full range    | –15 to 13.5 |             |       | –15 to 13.5 |             |       | –15 to 13.5 |             |       |                  |
| $V_{OM+}$ Maximum positive peak output voltage swing                          | $R_L = 10 k\Omega$                     | 25°C          |             | 14          | 14.3  |             | 14          | 14.3  |             | 14          | 14.3  | V                |
|                                                                               |                                        | Full range    |             | 13.9        |       |             | 13.9        |       |             | 13.9        |       |                  |
| $V_{OM-}$ Maximum negative peak output voltage swing                          |                                        | 25°C          |             | –13.7       | –14.1 |             | –13.7       | –14.1 |             | –13.7       | –14.1 | V                |
|                                                                               |                                        | Full range    |             | –13.7       |       |             | –13.7       |       |             | –13.7       |       |                  |
| $A_{VD}$ Large-signal differential voltage amplification                      | $V_O = \pm 10$ V, $R_L = 10 k\Omega$   | 25°C          |             | 0.8         | 4     |             | 1           | 7     |             | 1.5         | 10    | V/ $\mu V$       |
|                                                                               |                                        | Full range    |             | 0.8         |       |             | 1           |       |             | 1.5         |       |                  |
| CMRR Common-mode rejection ratio                                              | $V_{IC} = V_{ICRmin}, R_S = 50 \Omega$ | 25°C          |             | 95          | 106   |             | 97          | 109   |             | 100         | 112   | dB               |
|                                                                               |                                        | Full range    |             | 91          |       |             | 93          |       |             | 96          |       |                  |
| $k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{CC\pm}/\Delta V_{IO}$ ) | $V_{CC\pm} = \pm 2.5$ V to $\pm 15$ V  | 25°C          |             | 100         | 115   |             | 103         | 118   |             | 105         | 120   | dB               |
|                                                                               |                                        | Full range    |             | 95          |       |             | 98          |       |             | 100         |       |                  |
| $I_{CC}$ Supply current                                                       | $V_O = 0$ , No load                    | 25°C          |             | 550         | 700   |             | 550         | 700   |             | 550         | 700   | $\mu A$          |
|                                                                               |                                        | Full range    |             |             | 700   |             |             | 700   |             |             | 700   |                  |
| $\Delta I_{CC}$ Supply current change over operating temperature range        |                                        | Full range    |             | 9           |       |             | 9           |       |             | 9           |       | $\mu A$          |

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

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 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.

**TLE2024 electrical characteristics at specified free-air temperature,  $V_{CC} = 5\text{ V}$  (unless otherwise noted)**

| PARAMETER        |                                                                      | TEST CONDITIONS                                                    | T <sub>A</sub> <sup>†</sup> | TLE2024C   |           |          | TLE2024AC  |          |           | TLE2024BC  |           |      | UNIT  |
|------------------|----------------------------------------------------------------------|--------------------------------------------------------------------|-----------------------------|------------|-----------|----------|------------|----------|-----------|------------|-----------|------|-------|
|                  |                                                                      |                                                                    |                             | MIN        | TYP       | MAX      | MIN        | TYP      | MAX       | MIN        | TYP       | MAX  |       |
| V <sub>IO</sub>  | Input offset voltage                                                 | V <sub>IC</sub> = 0,                      R <sub>S</sub> = 50 Ω    | 25°C                        | 1100       |           |          | 850        |          |           | 600        |           |      | μV    |
|                  |                                                                      |                                                                    | Full range                  | 1300       |           |          | 1050       |          |           | 800        |           |      |       |
| α <sub>VIO</sub> | Temperature coefficient of input offset voltage                      |                                                                    | Full range                  | 2          |           |          | 2          |          |           | 2          |           |      | μV/°C |
|                  | Input offset voltage long-term drift (see Note 4)                    |                                                                    | 25°C                        | 0.005      |           |          | 0.005      |          |           | 0.005      |           |      | μV/mo |
| I <sub>IO</sub>  | Input offset current                                                 |                                                                    | 25°C                        | 0.6      6 |           |          | 0.5      6 |          |           | 0.4      6 |           |      | nA    |
|                  |                                                                      |                                                                    | Full range                  | 10         |           |          | 10         |          |           | 10         |           |      |       |
| I <sub>IB</sub>  | Input bias current                                                   |                                                                    | 25°C                        | 45      70 |           |          | 40      70 |          |           | 35      70 |           |      | nA    |
|                  |                                                                      |                                                                    | Full range                  | 90         |           |          | 90         |          |           | 90         |           |      |       |
| V <sub>ICR</sub> | Common-mode input voltage range                                      | R <sub>S</sub> = 50 Ω                                              | 25°C                        | 0 to 3.5   | –0.3 to 4 | 0 to 3.5 | –0.3 to 4  | 0 to 3.5 | –0.3 to 4 | 0 to 3.5   | –0.3 to 4 | V    |       |
|                  |                                                                      |                                                                    | Full range                  | 0 to 3.5   |           | 0 to 3.5 |            | 0 to 3.5 |           |            |           |      |       |
| V <sub>OH</sub>  | High-level output voltage                                            | R <sub>L</sub> = 10 kΩ                                             | 25°C                        | 3.9        | 4.2       | 3.9      | 4.2        | 4        | 4.3       |            |           | V    |       |
|                  |                                                                      |                                                                    | Full range                  | 3.7        |           | 3.7      |            | 3.8      |           |            |           |      |       |
| V <sub>OL</sub>  | Low-level output voltage                                             |                                                                    | 25°C                        |            | 0.7       | 0.8      |            | 0.7      | 0.8       |            | 0.7       | 0.8  | V     |
|                  |                                                                      |                                                                    | Full range                  |            | 0.95      |          |            | 0.95     |           | 0.95       |           |      |       |
| A <sub>VD</sub>  | Large-signal differential voltage amplification                      | V <sub>O</sub> = 1.4 V to 4 V,      R <sub>L</sub> = 10 kΩ         | 25°C                        | 0.2        | 1.5       | 0.3      | 1.5        | 0.4      | 1.5       |            |           | V/μV |       |
|                  |                                                                      |                                                                    | Full range                  | 0.1        |           | 0.1      |            | 0.1      |           |            |           |      |       |
| CMRR             | Common-mode rejection ratio                                          | V <sub>IC</sub> = V <sub>ICRmin</sub> ,      R <sub>S</sub> = 50 Ω | 25°C                        | 80         | 90        | 82       | 92         | 85       | 95        |            |           | dB   |       |
|                  |                                                                      |                                                                    | Full range                  | 80         |           | 82       |            | 85       |           |            |           |      |       |
| k <sub>SVR</sub> | Supply-voltage rejection ratio (ΔV <sub>CC</sub> /ΔV <sub>IO</sub> ) | V <sub>CC</sub> = 5 V to 30 V                                      | 25°C                        | 98         | 112       | 100      | 115        | 103      | 117       |            |           | dB   |       |
|                  |                                                                      |                                                                    | Full range                  | 93         |           | 95       |            | 98       |           |            |           |      |       |
| I <sub>CC</sub>  | Supply current                                                       | V <sub>O</sub> = 2.5 V,                      No load               | 25°C                        | 800        | 1200      | 800      | 1200       | 800      | 1200      |            |           | μA   |       |
|                  |                                                                      |                                                                    | Full range                  |            | 1200      |          | 1200       |          | 1200      |            |           |      |       |
| ΔI <sub>CC</sub> | Supply current change over operating temperature range               |                                                                    | Full range                  |            | 15        |          | 15         |          | 15        |            | μA        |      |       |

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

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 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.

**TLE2024 electrical characteristics at specified free-air temperature,  $V_{CC} = \pm 15$  V (unless otherwise noted)**

| PARAMETER                                                                     | TEST CONDITIONS                                    | $T_A^\dagger$ | TLE2024C     |              |      | TLE2024AC    |              |      | TLE2024BC    |              |      | UNIT             |
|-------------------------------------------------------------------------------|----------------------------------------------------|---------------|--------------|--------------|------|--------------|--------------|------|--------------|--------------|------|------------------|
|                                                                               |                                                    |               | MIN          | TYP          | MAX  | MIN          | TYP          | MAX  | MIN          | TYP          | MAX  |                  |
| $V_{IO}$ Input offset voltage                                                 | $V_{IC} = 0, \quad R_S = 50 \, \Omega$             | 25°C          |              |              | 1000 |              |              | 750  |              |              | 500  | $\mu V$          |
|                                                                               |                                                    | Full range    |              |              | 1200 |              |              | 950  |              |              | 700  |                  |
| $\alpha_{VIO}$ Temperature coefficient of input offset voltage                |                                                    | Full range    |              | 2            |      |              | 2            |      |              | 2            |      | $\mu V/^\circ C$ |
| Input offset voltage long-term drift (see Note 4)                             |                                                    | 25°C          |              | 0.006        |      |              | 0.006        |      |              | 0.006        |      | $\mu V/mo$       |
| $I_{IO}$ Input offset current                                                 |                                                    | 25°C          |              | 0.6          | 6    |              | 0.5          | 6    |              | 0.4          | 6    | nA               |
|                                                                               |                                                    | Full range    |              |              | 10   |              |              | 10   |              |              | 10   |                  |
| $I_{IB}$ Input bias current                                                   |                                                    | 25°C          |              | 50           | 70   |              | 45           | 70   |              | 40           | 70   | nA               |
|                                                                               |                                                    | Full range    |              |              | 90   |              |              | 90   |              |              | 90   |                  |
| $V_{ICR}$ Common-mode input voltage range                                     | $R_S = 50 \, \Omega$                               | 25°C          | – 15 to 13.5 | – 15.3 to 14 |      | – 15 to 13.5 | – 15.3 to 14 |      | – 15 to 13.5 | – 15.3 to 14 |      | V                |
|                                                                               |                                                    | Full range    | – 15 to 13.5 |              |      | – 15 to 13.5 |              |      | – 15 to 13.5 |              |      |                  |
| $V_{OM+}$ Maximum positive peak output voltage swing                          | $R_L = 10 \, k\Omega$                              | 25°C          | 13.8         | 14.1         |      | 13.9         | 14.2         |      | 14           | 14.3         |      | V                |
|                                                                               |                                                    | Full range    | 13.7         |              |      | 13.8         |              |      | 13.9         |              |      |                  |
| $V_{OM-}$ Maximum negative peak output voltage swing                          |                                                    | 25°C          | – 13.7       | – 14.1       |      | – 13.7       | – 14.1       |      | – 13.7       | – 14.1       |      | V                |
|                                                                               |                                                    | Full range    | – 13.6       |              |      | – 13.6       |              |      | – 13.6       |              |      |                  |
| $A_{VD}$ Large-signal differential voltage amplification                      | $V_O = \pm 10 \, V, \quad R_L = 10 \, k\Omega$     | 25°C          | 0.4          | 2            |      | 0.8          | 4            |      | 1            | 7            |      | V/ $\mu V$       |
|                                                                               |                                                    | Full range    | 0.4          |              |      | 0.8          |              |      | 1            |              |      |                  |
| CMRR Common-mode rejection ratio                                              | $V_{IC} = V_{ICRmin}, \quad R_S = 50 \, \Omega$    | 25°C          | 92           | 102          |      | 94           | 105          |      | 97           | 108          |      | dB               |
|                                                                               |                                                    | Full range    | 88           |              |      | 90           |              |      | 93           |              |      |                  |
| $k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{CC\pm}/\Delta V_{IO}$ ) | $V_{CC\pm} = \pm 2.5 \, V \text{ to } \pm 15 \, V$ | 25°C          | 98           | 112          |      | 100          | 115          |      | 103          | 117          |      | dB               |
|                                                                               |                                                    | Full range    | 93           |              |      | 95           |              |      | 98           |              |      |                  |
| $I_{CC}$ Supply current                                                       | $V_O = 0, \quad \text{No load}$                    | 25°C          |              | 1050         | 1400 |              | 1050         | 1400 |              | 1050         | 1400 | $\mu A$          |
|                                                                               |                                                    | Full range    |              |              | 1400 |              |              | 1400 |              |              | 1400 |                  |
| $\Delta I_{CC}$ Supply current change over operating temperature range        |                                                    | Full range    |              | 20           |      |              | 20           |      |              | 20           |      | $\mu A$          |

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

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 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.

**TLE2021 electrical characteristics at specified free-air temperature,  $V_{CC} = 5\text{ V}$  (unless otherwise noted)**

| PARAMETER        |                                                                      | TEST CONDITIONS                                               | T <sub>A</sub> <sup>†</sup> | TLE2021I |           |          | TLE2021AI |          |           | TLE2021BI |       |     | UNIT |
|------------------|----------------------------------------------------------------------|---------------------------------------------------------------|-----------------------------|----------|-----------|----------|-----------|----------|-----------|-----------|-------|-----|------|
|                  |                                                                      |                                                               |                             | MIN      | TYP       | MAX      | MIN       | TYP      | MAX       | MIN       | TYP   | MAX |      |
| V <sub>IO</sub>  | Input offset voltage                                                 | V <sub>IC</sub> = 0, R <sub>S</sub> = 50 Ω                    | 25°C                        | 120      | 600       | 100      | 300       | 80       | 200       | μV        |       |     |      |
|                  |                                                                      |                                                               | Full range                  | 950      |           |          | 600       |          |           |           | 300   |     |      |
| α <sub>VIO</sub> | Temperature coefficient of input offset voltage                      |                                                               | Full range                  | 2        |           |          | 2         |          |           | 2         | μV/°C |     |      |
|                  | Input offset voltage long-term drift (see Note 4)                    |                                                               | 25°C                        | 0.005    |           |          | 0.005     |          |           | 0.005     | μV/mo |     |      |
| I <sub>IO</sub>  | Input offset current                                                 |                                                               | 25°C                        | 0.2      | 6         | 0.2      | 6         | 0.2      | 6         | nA        |       |     |      |
|                  |                                                                      |                                                               | Full range                  | 10       |           |          | 10        |          |           |           | 10    |     |      |
| I <sub>IB</sub>  | Input bias current                                                   |                                                               | 25°C                        | 25       | 70        | 25       | 70        | 25       | 70        | nA        |       |     |      |
|                  |                                                                      |                                                               | Full range                  | 90       |           |          | 90        |          |           |           | 90    |     |      |
| V <sub>ICR</sub> | Common-mode input voltage range                                      | R <sub>S</sub> = 50 Ω                                         | 25°C                        | 0 to 3.5 | –0.3 to 4 | 0 to 3.5 | –0.3 to 4 | 0 to 3.5 | –0.3 to 4 | V         |       |     |      |
|                  |                                                                      |                                                               | Full range                  | 0 to 3.2 |           | 0 to 3.2 |           | 0 to 3.2 |           |           |       |     |      |
| V <sub>OH</sub>  | High-level output voltage                                            | R <sub>L</sub> = 10 kΩ                                        | 25°C                        | 4        | 4.3       | 4        | 4.3       | 4        | 4.3       | V         |       |     |      |
|                  |                                                                      |                                                               | Full range                  | 3.9      |           |          | 3.9       |          |           |           |       |     |      |
| V <sub>OL</sub>  | Low-level output voltage                                             |                                                               | 25°C                        | 0.7      | 0.8       | 0.7      | 0.8       | 0.7      | 0.8       | V         |       |     |      |
|                  |                                                                      |                                                               | Full range                  | 0.9      |           |          | 0.9       |          |           |           | 0.9   |     |      |
| A <sub>VD</sub>  | Large-signal differential voltage amplification                      | V <sub>O</sub> = 1.4 V to 4 V, R <sub>L</sub> = 10 kΩ         | 25°C                        | 0.3      | 1.5       | 0.3      | 1.5       | 0.3      | 1.5       | V/μV      |       |     |      |
|                  |                                                                      |                                                               | Full range                  | 0.25     |           |          | 0.25      |          |           |           |       |     |      |
| CMRR             | Common-mode rejection ratio                                          | V <sub>IC</sub> = V <sub>ICR</sub> min, R <sub>S</sub> = 50 Ω | 25°C                        | 85       | 110       | 85       | 110       | 85       | 110       | dB        |       |     |      |
|                  |                                                                      |                                                               | Full range                  | 80       |           |          | 80        |          |           |           |       |     |      |
| k <sub>SVR</sub> | Supply-voltage rejection ratio (ΔV <sub>CC</sub> /ΔV <sub>IO</sub> ) | V <sub>CC</sub> = 5 V to 30 V                                 | 25°C                        | 105      | 120       | 105      | 120       | 105      | 120       | dB        |       |     |      |
|                  |                                                                      |                                                               | Full range                  | 100      |           |          | 100       |          |           |           |       |     |      |
| I <sub>CC</sub>  | Supply current                                                       | V <sub>O</sub> = 2.5 V, No load                               | 25°C                        | 200      | 300       | 200      | 300       | 200      | 300       | μA        |       |     |      |
|                  |                                                                      |                                                               | Full range                  | 300      |           |          | 300       |          |           |           |       |     |      |
| ΔI <sub>CC</sub> | Supply-current change over operating temperature range               |                                                               | Full range                  | 6        |           |          | 6         |          |           | 6         | μA    |     |      |

$^\dagger$  Full range is  $-40^\circ\text{C}$  to  $85^\circ\text{C}$ .

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 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.

**TLE2021 electrical characteristics at specified free-air temperature,  $V_{CC} = \pm 15\text{ V}$  (unless otherwise noted)**

| PARAMETER                                                                  | TEST CONDITIONS                                    | $T_A^\dagger$ | TLE2021I     |              |        | TLE2021AI    |              |        | TLE2021BI    |              |        | UNIT                         |
|----------------------------------------------------------------------------|----------------------------------------------------|---------------|--------------|--------------|--------|--------------|--------------|--------|--------------|--------------|--------|------------------------------|
|                                                                            |                                                    |               | MIN          | TYP          | MAX    | MIN          | TYP          | MAX    | MIN          | TYP          | MAX    |                              |
| $V_{IO}$ Input offset voltage                                              | $V_{IC} = 0, R_S = 50\ \Omega$                     | 25°C          |              | 120          | 500    |              | 80           | 200    |              | 40           | 100    | $\mu\text{V}$                |
|                                                                            |                                                    | Full range    |              |              | 850    |              |              | 500    |              |              | 200    |                              |
| $\alpha_{VIO}$ Temperature coefficient of input offset voltage             |                                                    | Full range    |              | 2            |        |              | 2            |        |              | 2            |        | $\mu\text{V}/^\circ\text{C}$ |
| Input offset voltage long-term drift (see Note 4)                          |                                                    | 25°C          |              | 0.006        |        |              | 0.006        |        |              | 0.006        |        | $\mu\text{V}/\text{mo}$      |
| $I_{IO}$ Input offset current                                              |                                                    | 25°C          |              | 0.2          | 6      |              | 0.2          | 6      |              | 0.2          | 6      | nA                           |
|                                                                            |                                                    | Full range    |              |              | 10     |              |              | 10     |              |              | 10     |                              |
| $I_{IB}$ Input bias current                                                |                                                    | 25°C          |              | 25           | 70     |              | 25           | 70     |              | 25           | 70     | nA                           |
|                                                                            |                                                    | Full range    |              |              | 90     |              |              | 90     |              |              | 90     |                              |
| $V_{ICR}$ Common-mode input voltage range                                  | $R_S = 50\ \Omega$                                 | 25°C          | – 15 to 13.5 | – 15.3 to 14 |        | – 15 to 13.5 | – 15.3 to 14 |        | – 15 to 13.5 | – 15.3 to 14 |        | V                            |
|                                                                            |                                                    | Full range    | – 15 to 13.2 |              |        | – 15 to 13.2 |              |        | – 15 to 13.2 |              |        |                              |
| $V_{OM+}$ Maximum positive peak output voltage swing                       | $R_L = 10\ \text{k}\Omega$                         | 25°C          |              | 14           | 14.3   |              | 14           | 14.3   |              | 14           | 14.3   | V                            |
|                                                                            |                                                    | Full range    |              |              | 13.9   |              |              | 13.9   |              |              | 13.9   |                              |
| $V_{OM-}$ Maximum negative peak output voltage swing                       |                                                    | 25°C          |              | – 13.7       | – 14.1 |              | – 13.7       | – 14.1 |              | – 13.7       | – 14.1 | V                            |
|                                                                            |                                                    | Full range    |              |              | – 13.6 |              |              | – 13.6 |              |              | – 13.6 |                              |
| $A_{VD}$ Large-signal differential voltage amplification                   | $V_O = 10\text{ V}, R_L = 10\ \text{k}\Omega$      | 25°C          |              | 1            | 6.5    |              | 1            | 6.5    |              | 1            | 6.5    | $\text{V}/\mu\text{V}$       |
|                                                                            |                                                    | Full range    |              |              | 0.75   |              |              | 0.75   |              |              | 0.75   |                              |
| CMRR Common-mode rejection ratio                                           | $V_{IC} = V_{ICR\text{ min}}, R_S = 50\ \Omega$    | 25°C          |              | 100          | 115    |              | 100          | 115    |              | 100          | 115    | dB                           |
|                                                                            |                                                    | Full range    |              |              | 96     |              |              | 96     |              |              | 96     |                              |
| $k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{CC}/\Delta V_{IO}$ ) | $V_{CC\pm} = \pm 2.5\text{ V to } \pm 15\text{ V}$ | 25°C          |              | 105          | 120    |              | 105          | 120    |              | 105          | 120    | dB                           |
|                                                                            |                                                    | Full range    |              |              | 100    |              |              | 100    |              |              | 100    |                              |
| $I_{CC}$ Supply current                                                    | $V_O = 0\text{ V}, \text{ No load}$                | 25°C          |              | 240          | 350    |              | 240          | 350    |              | 240          | 350    | $\mu\text{A}$                |
|                                                                            |                                                    | Full range    |              |              | 350    |              |              | 350    |              |              | 350    |                              |
| $\Delta I_{CC}$ Supply-current change over operating temperature range     |                                                    | Full range    |              | 7            |        |              | 7            |        |              | 7            |        | $\mu\text{A}$                |

$^\dagger$  Full range is – 40°C to 85°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 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.

**TLE2022 electrical characteristics at specified free-air temperature,  $V_{CC} = 5\text{ V}$  (unless otherwise noted)**

| PARAMETER        |                                                                       | TEST CONDITIONS                                                                    | T <sub>A</sub> <sup>†</sup> | TLE2022I       |                 |     | TLE2022AI      |                 |            | TLE2022BI      |                 |      | UNIT  |
|------------------|-----------------------------------------------------------------------|------------------------------------------------------------------------------------|-----------------------------|----------------|-----------------|-----|----------------|-----------------|------------|----------------|-----------------|------|-------|
|                  |                                                                       |                                                                                    |                             | MIN            | TYP             | MAX | MIN            | TYP             | MAX        | MIN            | TYP             | MAX  |       |
| V <sub>IO</sub>  | Input offset voltage                                                  | V <sub>IC</sub> = 0,                      R <sub>S</sub> = 50 Ω                    | 25°C                        | 600            |                 |     | 400            |                 |            | 250            |                 |      | μV    |
|                  |                                                                       |                                                                                    | Full range                  | 800            |                 |     | 550            |                 |            | 400            |                 |      |       |
| α <sub>VIO</sub> | Temperature coefficient of input offset voltage                       |                                                                                    | Full range                  | 2              |                 |     | 2              |                 |            | 2              |                 |      | μV/°C |
|                  | Input offset voltage long-term drift (see Note 4)                     |                                                                                    | 25°C                        | 0.005          |                 |     | 0.005          |                 |            | 0.005          |                 |      | μV/mo |
| I <sub>IO</sub>  | Input offset current                                                  |                                                                                    | 25°C                        | 0.5    6       |                 |     | 0.4    6       |                 |            | 0.3    6       |                 |      | nA    |
|                  |                                                                       |                                                                                    | Full range                  | 10             |                 |     | 10             |                 |            | 10             |                 |      |       |
| I <sub>IB</sub>  | Input bias current                                                    |                                                                                    | 25°C                        | 35    70       |                 |     | 33    70       |                 |            | 30    70       |                 |      | nA    |
|                  |                                                                       |                                                                                    | Full range                  | 90             |                 |     | 90             |                 |            | 90             |                 |      |       |
| V <sub>ICR</sub> | Common-mode input voltage range                                       | R <sub>S</sub> = 50 Ω                                                              | 25°C                        | 0<br>to<br>3.5 | −0.3<br>to<br>4 |     | 0<br>to<br>3.5 | −0.3<br>to<br>4 |            | 0<br>to<br>3.5 | −0.3<br>to<br>4 | V    |       |
|                  |                                                                       |                                                                                    | Full range                  | 0<br>to<br>3.2 |                 |     | 0<br>to<br>3.2 |                 |            | 0<br>to<br>3.2 |                 |      |       |
| V <sub>OH</sub>  | High-level output voltage                                             | R <sub>L</sub> = 10 kΩ                                                             | 25°C                        | 4              | 4.3             |     | 4              | 4.3             |            | 4              | 4.3             | V    |       |
|                  |                                                                       |                                                                                    | Full range                  | 3.9            |                 |     | 3.9            |                 |            | 3.9            |                 |      |       |
| V <sub>OL</sub>  | Low-level output voltage                                              |                                                                                    | 25°C                        |                | 0.7             | 0.8 |                | 0.7             | 0.8        |                | 0.7             | 0.8  | V     |
|                  |                                                                       |                                                                                    | Full range                  |                |                 | 0.9 |                |                 | 0.9        |                |                 | 0.9  |       |
| A <sub>VD</sub>  | Large-signal differential voltage amplification                       | V <sub>O</sub> = 1.4 V to 4 V,    R <sub>L</sub> = 10 kΩ                           | 25°C                        | 0.3            | 1.5             |     | 0.4            | 1.5             |            | 0.5            | 1.5             | V/μV |       |
|                  |                                                                       |                                                                                    | Full range                  | 0.2            |                 |     | 0.2            |                 |            | 0.2            |                 |      |       |
| CMRR             | Common-mode rejection ratio                                           | V <sub>IC</sub> = V <sub>ICRmin</sub> ,                      R <sub>S</sub> = 50 Ω | 25°C                        | 85             | 100             |     | 87             | 102             |            | 90             | 105             | dB   |       |
|                  |                                                                       |                                                                                    | Full range                  | 80             |                 |     | 82             |                 |            | 85             |                 |      |       |
| k <sub>SVR</sub> | Supply-voltage rejection ratio (ΔV <sub>CC±</sub> /ΔV <sub>IO</sub> ) | V <sub>CC</sub> = 5 V to 30 V                                                      | 25°C                        | 100            | 115             |     | 103            | 118             |            | 105            | 120             | dB   |       |
|                  |                                                                       |                                                                                    | Full range                  | 95             |                 |     | 98             |                 |            | 100            |                 |      |       |
| I <sub>CC</sub>  | Supply current                                                        | V <sub>O</sub> = 2.5 V,                      No load                               | 25°C                        |                | 450    600      |     | 450    600     |                 | 450    600 |                | 450    600      | μA   |       |
|                  |                                                                       |                                                                                    | Full range                  |                |                 | 600 |                |                 | 600        |                |                 |      | 600   |
| ΔI <sub>CC</sub> | Supply current change over operating temperature range                |                                                                                    | Full range                  |                | 15              |     | 15             |                 | 15         |                | μA              |      |       |

$^\dagger$  Full range is  $-40^\circ\text{C}$  to  $85^\circ\text{C}$ .

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 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.

**TLE2022 electrical characteristics at specified free-air temperature,  $V_{CC} = \pm 15\text{ V}$  (unless otherwise noted)**

| PARAMETER                                                                     | TEST CONDITIONS                                   | $T_A^\dagger$ | TLE2022I     |              |        | TLE2022AI    |              |        | TLE2022BI    |              |        | UNIT                         |
|-------------------------------------------------------------------------------|---------------------------------------------------|---------------|--------------|--------------|--------|--------------|--------------|--------|--------------|--------------|--------|------------------------------|
|                                                                               |                                                   |               | MIN          | TYP          | MAX    | MIN          | TYP          | MAX    | MIN          | TYP          | MAX    |                              |
| $V_{IO}$ Input offset voltage                                                 | $V_{IC} = 0, R_S = 50\ \Omega$                    | 25°C          |              | 150          | 500    |              | 120          | 300    |              | 70           | 150    | $\mu\text{V}$                |
|                                                                               |                                                   | Full range    |              |              | 700    |              |              | 450    |              |              | 300    |                              |
| $\alpha_{VIO}$ Temperature coefficient of input offset voltage                |                                                   | Full range    |              | 2            |        |              | 2            |        |              | 2            |        | $\mu\text{V}/^\circ\text{C}$ |
| Input offset voltage long-term drift (see Note 4)                             |                                                   | 25°C          |              | 0.006        |        |              | 0.006        |        |              | 0.006        |        | $\mu\text{V}/\text{mo}$      |
| $I_{IO}$ Input offset current                                                 |                                                   | 25°C          |              | 0.5          | 6      |              | 0.4          | 6      |              | 0.3          | 6      | nA                           |
|                                                                               |                                                   | Full range    |              |              | 10     |              |              | 10     |              |              | 10     |                              |
| $I_{IB}$ Input bias current                                                   |                                                   | 25°C          |              | 35           | 70     |              | 33           | 70     |              | 30           | 70     | nA                           |
|                                                                               |                                                   | Full range    |              |              | 90     |              |              | 90     |              |              | 90     |                              |
| $V_{ICR}$ Common-mode input voltage range                                     | $R_S = 50\ \Omega$                                | 25°C          | – 15 to 13.5 | – 15.3 to 14 |        | – 15 to 13.5 | – 15.3 to 14 |        | – 15 to 13.5 | – 15.3 to 14 |        | V                            |
|                                                                               |                                                   | Full range    | – 15 to 13.2 |              |        | – 15 to 13.2 |              |        | – 15 to 13.2 |              |        |                              |
| $V_{OM+}$ Maximum positive peak output voltage swing                          | $R_L = 10\ \text{k}\Omega$                        | 25°C          |              | 14           | 14.3   |              | 14           | 14.3   |              | 14           | 14.3   | V                            |
|                                                                               |                                                   | Full range    |              |              | 13.9   |              |              | 13.9   |              |              | 13.9   |                              |
| $V_{OM-}$ Maximum negative peak output voltage swing                          |                                                   | 25°C          |              | – 13.7       | – 14.1 |              | – 13.7       | – 14.1 |              | – 13.7       | – 14.1 | V                            |
|                                                                               |                                                   | Full range    |              |              | – 13.6 |              |              | – 13.6 |              |              | – 13.6 |                              |
| $A_{VD}$ Large-signal differential voltage amplification                      | $V_O = \pm 10\text{ V}, R_L = 10\ \text{k}\Omega$ | 25°C          |              | 0.8          | 4      |              | 1            | 7      |              | 1.5          | 10     | $\text{V}/\mu\text{V}$       |
|                                                                               |                                                   | Full range    |              |              | 0.8    |              |              | 1      |              |              | 1.5    |                              |
| CMRR Common-mode rejection ratio                                              | $V_{IC} = V_{ICRmin}, R_S = 50\ \Omega$           | 25°C          |              | 95           | 106    |              | 97           | 109    |              | 100          | 112    | dB                           |
|                                                                               |                                                   | Full range    |              |              | 91     |              |              | 93     |              |              | 96     |                              |
| $k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{CC\pm}/\Delta V_{IO}$ ) | $V_{CC} = \pm 2.5\text{ V to } \pm 15\text{ V}$   | 25°C          |              | 100          | 115    |              | 103          | 118    |              | 105          | 120    | dB                           |
|                                                                               |                                                   | Full range    |              |              | 95     |              |              | 98     |              |              | 100    |                              |
| $I_{CC}$ Supply current                                                       | $V_O = 0, \text{ No load}$                        | 25°C          |              | 550          | 700    |              | 550          | 700    |              | 550          | 700    | $\mu\text{A}$                |
|                                                                               |                                                   | Full range    |              |              | 700    |              |              | 700    |              |              | 700    |                              |
| $\Delta I_{CC}$ Supply current change over operating temperature range        |                                                   | Full range    |              | 30           |        |              | 30           |        |              | 30           |        | $\mu\text{A}$                |

$^\dagger$  Full range is  $-40^\circ\text{C}$  to  $85^\circ\text{C}$ .

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 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.

**TLE2024 electrical characteristics at specified free-air temperature,  $V_{CC} = 5\text{ V}$  (unless otherwise noted)**

| PARAMETER        |                                                                       | TEST CONDITIONS                                                                    | T <sub>A</sub> <sup>†</sup> | TLE2024I                                |                                         |     | TLE2024AI  |                                         |     | TLE2024BI  |      |     | UNIT  |
|------------------|-----------------------------------------------------------------------|------------------------------------------------------------------------------------|-----------------------------|-----------------------------------------|-----------------------------------------|-----|------------|-----------------------------------------|-----|------------|------|-----|-------|
|                  |                                                                       |                                                                                    |                             | MIN                                     | TYP                                     | MAX | MIN        | TYP                                     | MAX | MIN        | TYP  | MAX |       |
| V <sub>IO</sub>  | Input offset voltage                                                  | V <sub>IC</sub> = 0,                      R <sub>S</sub> = 50 Ω                    | 25°C                        | 1100                                    |                                         |     | 850        |                                         |     | 600        |      |     | μV    |
|                  |                                                                       |                                                                                    | Full range                  | 1300                                    |                                         |     | 1050       |                                         |     | 800        |      |     |       |
| α <sub>VIO</sub> | Temperature coefficient of input offset voltage                       |                                                                                    | Full range                  | 2                                       |                                         |     | 2          |                                         |     | 2          |      |     | μV/°C |
|                  | Input offset voltage long-term drift (see Note 4)                     |                                                                                    | 25°C                        | 0.005                                   |                                         |     | 0.005      |                                         |     | 0.005      |      |     | μV/mo |
| I <sub>IO</sub>  | Input offset current                                                  |                                                                                    | 25°C                        | 0.6      6                              |                                         |     | 0.5      6 |                                         |     | 0.4      6 |      |     | nA    |
|                  |                                                                       |                                                                                    | Full range                  | 10                                      |                                         |     | 10         |                                         |     | 10         |      |     |       |
| I <sub>IB</sub>  | Input bias current                                                    |                                                                                    | 25°C                        | 45      70                              |                                         |     | 40      70 |                                         |     | 35      70 |      |     | nA    |
|                  |                                                                       |                                                                                    | Full range                  | 90                                      |                                         |     | 90         |                                         |     | 90         |      |     |       |
| V <sub>ICR</sub> | Common-mode input voltage range                                       | R <sub>S</sub> = 50 Ω                                                              | 25°C                        | 0      –0.3<br>to      to<br>3.5      4 | 0      –0.3<br>to      to<br>3.5      4 |     |            | 0      –0.3<br>to      to<br>3.5      4 |     |            | V    |     |       |
|                  |                                                                       |                                                                                    | Full range                  | 0<br>to<br>3.2                          | 0<br>to<br>3.2                          |     |            | 0<br>to<br>3.2                          |     |            |      |     |       |
| V <sub>OM+</sub> | Maximum positive peak output voltage swing                            | R <sub>L</sub> = 10 kΩ                                                             | 25°C                        | 3.9      4.2                            | 3.9      4.2                            |     |            | 4      4.3                              |     |            | V    |     |       |
|                  |                                                                       |                                                                                    | Full range                  | 3.7                                     | 3.7                                     |     |            | 3.8                                     |     |            |      |     |       |
| V <sub>OM–</sub> | Maximum negative peak output voltage swing                            |                                                                                    | 25°C                        | 0.7      0.8                            | 0.7      0.8                            |     |            | 0.7      0.8                            |     |            | V    |     |       |
|                  |                                                                       |                                                                                    | Full range                  | 0.95                                    | 0.95                                    |     |            | 0.95                                    |     |            |      |     |       |
| A <sub>VD</sub>  | Large-signal differential voltage amplification                       | V <sub>O</sub> = 1.4 V to 4 V,      R <sub>L</sub> = 10 kΩ                         | 25°C                        | 0.2      1.5                            | 0.3      1.5                            |     |            | 0.4      1.5                            |     |            | V/μV |     |       |
|                  |                                                                       |                                                                                    | Full range                  | 0.1                                     | 0.1                                     |     |            | 0.1                                     |     |            |      |     |       |
| CMRR             | Common-mode rejection ratio                                           | V <sub>IC</sub> = V <sub>ICR</sub> min,                      R <sub>S</sub> = 50 Ω | 25°C                        | 80      90                              | 82      92                              |     |            | 85      95                              |     |            | dB   |     |       |
|                  |                                                                       |                                                                                    | Full range                  | 80                                      | 82                                      |     |            | 85                                      |     |            |      |     |       |
| k <sub>SVR</sub> | Supply-voltage rejection ratio (ΔV <sub>CC±</sub> /ΔV <sub>IO</sub> ) | V <sub>CC±</sub> = ±2.5 V to ±15 V                                                 | 25°C                        | 98      112                             | 100      115                            |     |            | 103      117                            |     |            | dB   |     |       |
|                  |                                                                       |                                                                                    | Full range                  | 93                                      | 95                                      |     |            | 98                                      |     |            |      |     |       |
| I <sub>CC</sub>  | Supply current                                                        | V <sub>O</sub> = 0,                      No load                                   | 25°C                        | 800      1200                           | 800      1200                           |     |            | 800      1200                           |     |            | μA   |     |       |
|                  |                                                                       |                                                                                    | Full range                  | 1200                                    | 1200                                    |     |            | 1200                                    |     |            |      |     |       |
| ΔI <sub>CC</sub> | Supply current change over operating temperature range                |                                                                                    |                             | Full range                              | 30                                      | 30  |            |                                         | 30  |            |      | μA  |       |

$^\dagger$  Full range is  $-40^\circ\text{C}$  to  $85^\circ\text{C}$ .

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 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.

**TLE2024 electrical characteristics at specified free-air temperature,  $V_{CC} = \pm 15\text{ V}$  (unless otherwise noted)**

| PARAMETER                                                                     | TEST CONDITIONS                                    | $T_A^\dagger$ | TLE2024I    |             |      | TLE2024AI   |             |      | TLE2024BI   |             |      | UNIT                         |
|-------------------------------------------------------------------------------|----------------------------------------------------|---------------|-------------|-------------|------|-------------|-------------|------|-------------|-------------|------|------------------------------|
|                                                                               |                                                    |               | MIN         | TYP         | MAX  | MIN         | TYP         | MAX  | MIN         | TYP         | MAX  |                              |
| $V_{IO}$ Input offset voltage                                                 | $V_{IC} = 0, R_S = 50\ \Omega$                     | 25°C          |             |             | 1000 |             |             | 750  |             |             | 500  | $\mu\text{V}$                |
|                                                                               |                                                    | Full range    |             |             | 1200 |             |             | 950  |             |             | 700  |                              |
| $\alpha_{VIO}$ Temperature coefficient of input offset voltage                |                                                    | Full range    |             | 2           |      |             | 2           |      |             | 2           |      | $\mu\text{V}/^\circ\text{C}$ |
| Input offset voltage long-term drift (see Note 4)                             |                                                    | 25°C          |             | 0.006       |      |             | 0.006       |      |             | 0.006       |      | $\mu\text{V}/\text{mo}$      |
| $I_{IO}$ Input offset current                                                 |                                                    | 25°C          |             | 0.6         | 6    |             | 0.5         | 6    |             | 0.4         | 6    | nA                           |
|                                                                               |                                                    | Full range    |             |             | 10   |             |             | 10   |             |             | 10   |                              |
| $I_{IB}$ Input bias current                                                   |                                                    | 25°C          |             | 50          | 70   |             | 45          | 70   |             | 40          | 70   | nA                           |
|                                                                               |                                                    | Full range    |             |             | 90   |             |             | 90   |             |             | 90   |                              |
| $V_{ICR}$ Common-mode input voltage range                                     | $R_S = 50\ \Omega$                                 | 25°C          | –15 to 13.5 | –15.3 to 14 |      | –15 to 13.5 | –15.3 to 14 |      | –15 to 13.5 | –15.3 to 14 |      | V                            |
|                                                                               |                                                    | Full range    | –15 to 13.2 |             |      | –15 to 13.2 |             |      | –15 to 13.2 |             |      |                              |
| $V_{OM+}$ Maximum positive peak output voltage swing                          | $R_L = 10\ \text{k}\Omega$                         | 25°C          | 13.8        | 14.1        |      | 13.9        | 14.2        |      | 14          | 14.3        |      | V                            |
|                                                                               |                                                    | Full range    | 13.7        |             |      | 13.7        |             |      | 13.8        |             |      |                              |
| $V_{OM-}$ Maximum negative peak output voltage swing                          | $R_L = 10\ \text{k}\Omega$                         | 25°C          | –13.7       | –14.1       |      | –13.7       | –14.1       |      | –13.7       | –14.1       |      | V                            |
|                                                                               |                                                    | Full range    | –13.6       |             |      | –13.6       |             |      | –13.6       |             |      |                              |
| $A_{VD}$ Large-signal differential voltage amplification                      | $V_O = \pm 10\text{ V}, R_L = 10\ \text{k}\Omega$  | 25°C          | 0.4         | 2           |      | 0.8         | 4           |      | 1           | 7           |      | $\text{V}/\mu\text{V}$       |
|                                                                               |                                                    | Full range    | 0.4         |             |      | 0.8         |             |      | 1           |             |      |                              |
| CMRR Common-mode rejection ratio                                              | $V_{IC} = V_{ICRmin}, R_S = 50\ \Omega$            | 25°C          | 92          | 102         |      | 94          | 105         |      | 97          | 108         |      | dB                           |
|                                                                               |                                                    | Full range    | 88          |             |      | 90          |             |      | 93          |             |      |                              |
| $k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{CC\pm}/\Delta V_{IO}$ ) | $V_{CC\pm} = \pm 2.5\text{ V to } \pm 15\text{ V}$ | 25°C          | 98          | 112         |      | 100         | 115         |      | 103         | 117         |      | dB                           |
|                                                                               |                                                    | Full range    | 93          |             |      | 95          |             |      | 98          |             |      |                              |
| $I_{CC}$ Supply current                                                       | $V_O = 0, \text{ No load}$                         | 25°C          |             | 1050        | 1400 |             | 1050        | 1400 |             | 1050        | 1400 | $\mu\text{A}$                |
|                                                                               |                                                    | Full range    |             |             | 1400 |             |             | 1400 |             |             | 1400 |                              |
| $\Delta I_{CC}$ Supply current change over operating temperature range        |                                                    | Full range    |             | 50          |      |             | 50          |      |             | 50          |      | $\mu\text{A}$                |

$^\dagger$  Full range is –40°C to 85°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 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.

**TLE2021 electrical characteristics at specified free-air temperature,  $V_{CC} = 5\text{ V}$  (unless otherwise noted)**

| PARAMETER        |                                                                       | TEST CONDITIONS                                                          | T <sub>A</sub> <sup>†</sup> | TLE2021M |       |        | TLE2021BM |       |        | UNIT  |    |
|------------------|-----------------------------------------------------------------------|--------------------------------------------------------------------------|-----------------------------|----------|-------|--------|-----------|-------|--------|-------|----|
|                  |                                                                       |                                                                          |                             | MIN      | TYP   | MAX    | MIN       | TYP   | MAX    |       |    |
| V <sub>IO</sub>  | Input offset voltage                                                  | V <sub>IC</sub> = 0,                      R <sub>S</sub> = 50 Ω          | 25°C                        |          | 120   | 600    |           | 80    | 200    | μV    |    |
|                  |                                                                       |                                                                          | Full range                  |          | 1100  |        |           | 300   |        |       |    |
| α <sub>VIO</sub> | Temperature coefficient of input offset voltage                       |                                                                          | Full range                  |          | 2     |        |           | 2     |        | μV/°C |    |
|                  | Input offset voltage long-term drift (see Note 4)                     |                                                                          | 25°C                        |          | 0.005 |        |           | 0.005 |        | μV/mo |    |
| I <sub>IO</sub>  | Input offset current                                                  |                                                                          | 25°C                        |          | 0.2   |        |           | 0.2   |        |       | nA |
|                  |                                                                       |                                                                          | Full range                  |          | 10    |        |           | 10    |        |       |    |
| I <sub>IB</sub>  | Input bias current                                                    |                                                                          | 25°C                        |          | 25    |        |           | 25    |        |       | nA |
|                  |                                                                       |                                                                          | Full range                  |          | 90    |        |           | 90    |        |       |    |
| V <sub>ICR</sub> | Common-mode input voltage range                                       | R <sub>S</sub> = 50 Ω                                                    | 25°C                        | 0        | –0.3  |        | 0         | –0.3  |        | V     |    |
|                  |                                                                       |                                                                          | Full range                  |          | 0     | to 3.2 |           | 0     | to 3.2 |       |    |
| V <sub>OH</sub>  | High-level output voltage                                             | R <sub>L</sub> = 10 kΩ                                                   | 25°C                        | 4        | 4.3   |        | 4         | 4.3   |        | V     |    |
|                  |                                                                       |                                                                          | Full range                  |          | 3.8   |        | 3.8       |       |        |       |    |
| V <sub>OL</sub>  | Low-level output voltage                                              |                                                                          | 25°C                        |          | 0.7   |        | 0.8       | 0.7   |        | 0.8   | V  |
|                  |                                                                       |                                                                          | Full range                  |          | 0.95  |        | 0.95      |       |        |       |    |
| A <sub>VD</sub>  | Large-signal differential voltage amplification                       | V <sub>O</sub> = 1.4 V to 4 V,    R <sub>L</sub> = 10 kΩ                 | 25°C                        | 0.3      | 1.5   |        | 0.3       | 1.5   |        | V/μV  |    |
|                  |                                                                       |                                                                          | Full range                  |          | 0.1   |        | 0.1       |       |        |       |    |
| CMRR             | Common-mode rejection ratio                                           | V <sub>IC</sub> = V <sub>ICRmin</sub> ,            R <sub>S</sub> = 50 Ω | 25°C                        | 85       | 110   |        | 85        | 110   |        | dB    |    |
|                  |                                                                       |                                                                          | Full range                  |          | 80    |        | 80        |       |        |       |    |
| k <sub>SVR</sub> | Supply-voltage rejection ratio (ΔV <sub>CC±</sub> /ΔV <sub>IO</sub> ) | V <sub>CC</sub> = 5 V to 30 V                                            | 25°C                        | 105      | 120   |        | 105       | 120   |        | dB    |    |
|                  |                                                                       |                                                                          | Full range                  |          | 100   |        | 100       |       |        |       |    |
| I <sub>CC</sub>  | Supply current                                                        | V <sub>O</sub> = 2.5 V,                      No load                     | 25°C                        |          | 170   | 230    |           | 170   | 230    | μA    |    |
|                  |                                                                       |                                                                          | Full range                  |          | 230   |        | 230       |       |        |       |    |
| ΔI <sub>CC</sub> | Supply current change over operating temperature range                |                                                                          | Full range                  |          | 9     |        | 9         |       |        | μA    |    |

$^\dagger$  Full range is –55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 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.

**TLE2021 electrical characteristics at specified free-air temperature,  $V_{CC} = \pm 15$  V (unless otherwise noted)**

| PARAMETER                                                                     | TEST CONDITIONS                                 | $T_A^\dagger$ | TLE2021M    |             |     | TLE2021BM   |             |     | UNIT             |
|-------------------------------------------------------------------------------|-------------------------------------------------|---------------|-------------|-------------|-----|-------------|-------------|-----|------------------|
|                                                                               |                                                 |               | MIN         | TYP         | MAX | MIN         | TYP         | MAX |                  |
| $V_{IO}$ Input offset voltage                                                 | $V_{IC} = 0, \quad R_S = 50 \, \Omega$          | 25°C          | 120         | 500         |     | 40          | 100         |     | $\mu V$          |
|                                                                               |                                                 | Full range    |             | 1000        |     |             | 200         |     |                  |
| $\alpha_{VIO}$ Temperature coefficient of input offset voltage                |                                                 | Full range    | 2           |             |     | 2           |             |     | $\mu V/^\circ C$ |
| Input offset voltage long-term drift (see Note 4)                             |                                                 | 25°C          | 0.006       |             |     | 0.006       |             |     | $\mu V/mo$       |
| $I_{IO}$ Input offset current                                                 |                                                 | 25°C          | 0.2         | 6           |     | 0.2         | 6           |     | nA               |
|                                                                               |                                                 | Full range    |             | 10          |     |             | 10          |     |                  |
| $I_{IB}$ Input bias current                                                   | $R_S = 50 \, \Omega$                            | 25°C          | 25          | 70          |     | 25          | 70          |     | nA               |
|                                                                               |                                                 | Full range    |             | 90          |     |             | 90          |     |                  |
| $V_{ICR}$ Common-mode input voltage range                                     | $R_S = 50 \, \Omega$                            | 25°C          | –15 to 13.5 | –15.3 to 14 |     | –15 to 13.5 | –15.3 to 14 |     | V                |
|                                                                               |                                                 | Full range    | –15 to 13.2 |             |     | –15 to 13.2 |             |     |                  |
| $V_{OM+}$ Maximum positive peak output voltage swing                          | $R_L = 10 \, k\Omega$                           | 25°C          | 14          | 14.3        |     | 14          | 14.3        |     | V                |
|                                                                               |                                                 | Full range    | 13.8        |             |     | 13.8        |             |     |                  |
| $V_{OM-}$ Maximum negative peak output voltage swing                          |                                                 | 25°C          | –13.7       | –14.1       |     | –13.7       | –14.1       |     | V                |
|                                                                               |                                                 | Full range    | –13.6       |             |     | –13.6       |             |     |                  |
| $A_{VD}$ Large-signal differential voltage amplification                      | $V_O = \pm 10$ V, $R_L = 10 \, k\Omega$         | 25°C          | 1           | 6.5         |     | 1           | 6.5         |     | V/ $\mu V$       |
|                                                                               |                                                 | Full range    | 0.5         |             |     | 0.5         |             |     |                  |
| CMRR Common-mode rejection ratio                                              | $V_{IC} = V_{ICRmin}, \quad R_S = 50 \, \Omega$ | 25°C          | 100         | 115         |     | 100         | 115         |     | dB               |
|                                                                               |                                                 | Full range    | 96          |             |     | 96          |             |     |                  |
| $k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{CC\pm}/\Delta V_{IO}$ ) | $V_{CC\pm} = \pm 2.5$ V to $\pm 15$ V           | 25°C          | 105         | 120         |     | 105         | 120         |     | dB               |
|                                                                               |                                                 | Full range    | 100         |             |     | 100         |             |     |                  |
| $I_{CC}$ Supply current                                                       | $V_O = 0, \quad \text{No load}$                 | 25°C          | 200         | 300         |     | 200         | 300         |     | $\mu A$          |
|                                                                               |                                                 | Full range    |             | 300         |     |             | 300         |     |                  |
| $\Delta I_{CC}$ Supply current change over operating temperature range        |                                                 | Full range    | 10          |             |     | 10          |             |     | $\mu A$          |

$^\dagger$  Full range is  $-55^\circ C$  to  $125^\circ C$ .

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 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.

**TLE2022 electrical characteristics at specified free-air temperature,  $V_{CC} = 5\text{ V}$  (unless otherwise noted)**

| PARAMETER                                         |                                                                       | TEST CONDITIONS                                                          | T <sub>A</sub> <sup>†</sup> | TLE2022M   |                                                          |                                                          | TLE2022AM |            |                                                          | TLE2022BM |      |     | UNIT  |
|---------------------------------------------------|-----------------------------------------------------------------------|--------------------------------------------------------------------------|-----------------------------|------------|----------------------------------------------------------|----------------------------------------------------------|-----------|------------|----------------------------------------------------------|-----------|------|-----|-------|
|                                                   |                                                                       |                                                                          |                             | MIN        | TYP                                                      | MAX                                                      | MIN       | TYP        | MAX                                                      | MIN       | TYP  | MAX |       |
| V <sub>IO</sub>                                   | Input offset voltage                                                  | V <sub>IC</sub> = 0,                      R <sub>S</sub> = 50 Ω          | 25°C                        | 600        |                                                          |                                                          | 400       |            |                                                          | 250       |      |     | μV    |
|                                                   |                                                                       |                                                                          | Full range                  | 800        |                                                          |                                                          | 550       |            |                                                          | 400       |      |     |       |
| α <sub>VIO</sub>                                  | Temperature coefficient of input offset voltage                       |                                                                          | Full range                  | 2          |                                                          |                                                          | 2         |            |                                                          | 2         |      |     | μV/°C |
| Input offset voltage long-term drift (see Note 4) |                                                                       |                                                                          | 25°C                        | 0.005      |                                                          |                                                          | 0.005     |            |                                                          | 0.005     |      |     | μV/mo |
| I <sub>IO</sub>                                   | Input offset current                                                  |                                                                          | 25°C                        | 0.5    6   |                                                          |                                                          | 0.4    6  |            |                                                          | 0.3    6  |      |     | nA    |
|                                                   |                                                                       |                                                                          | Full range                  | 10         |                                                          |                                                          | 10        |            |                                                          | 10        |      |     |       |
| I <sub>IB</sub>                                   | Input bias current                                                    |                                                                          | 25°C                        | 35    70   |                                                          |                                                          | 33    70  |            |                                                          | 30    70  |      |     | nA    |
|                                                   |                                                                       |                                                                          | Full range                  | 90         |                                                          |                                                          | 90        |            |                                                          | 90        |      |     |       |
| V <sub>ICR</sub>                                  | Common-mode input voltage range                                       |                                                                          | R <sub>S</sub> = 50 Ω       | 25°C       | 0            –0.3<br>to            to<br>3.5           4 | 0            –0.3<br>to            to<br>3.5           4 |           |            | 0            –0.3<br>to            to<br>3.5           4 |           |      | V   |       |
|                                                   |                                                                       |                                                                          |                             | Full range | 0            to<br>3.2                                   | 0            to<br>3.2                                   |           |            | 0            to<br>3.2                                   |           |      |     |       |
| V <sub>OH</sub>                                   | High-level output voltage                                             | R <sub>L</sub> = 10 kΩ                                                   | 25°C                        | 4    4.3   | 4    4.3                                                 |                                                          |           | 4    4.3   |                                                          |           | V    |     |       |
|                                                   |                                                                       |                                                                          | Full range                  | 3.8        | 3.8                                                      |                                                          |           | 3.8        |                                                          |           |      |     |       |
| V <sub>OL</sub>                                   | Low-level output voltage                                              |                                                                          | 25°C                        | 0.7    0.8 | 0.7    0.8                                               |                                                          |           | 0.7    0.8 |                                                          |           | V    |     |       |
|                                                   |                                                                       |                                                                          | Full range                  | 0.95       | 0.95                                                     |                                                          |           | 0.95       |                                                          |           |      |     |       |
| A <sub>VD</sub>                                   | Large-signal differential voltage amplification                       | V <sub>O</sub> = 1.4 V to 4 V,    R <sub>L</sub> = 10 kΩ                 | 25°C                        | 0.3    1.5 | 0.4    1.5                                               |                                                          |           | 0.5    1.5 |                                                          |           | V/μV |     |       |
|                                                   |                                                                       |                                                                          | Full range                  | 0.1        | 0.1                                                      |                                                          |           | 0.1        |                                                          |           |      |     |       |
| CMRR                                              | Common-mode rejection ratio                                           | V <sub>IC</sub> = V <sub>ICR</sub> min,            R <sub>S</sub> = 50 Ω | 25°C                        | 85    100  | 87    102                                                |                                                          |           | 90    105  |                                                          |           | dB   |     |       |
|                                                   |                                                                       |                                                                          | Full range                  | 80         | 82                                                       |                                                          |           | 85         |                                                          |           |      |     |       |
| k <sub>SVR</sub>                                  | Supply-voltage rejection ratio (ΔV <sub>CC±</sub> /ΔV <sub>IO</sub> ) | V <sub>CC</sub> = 5 V to 30 V                                            | 25°C                        | 100    115 | 103    118                                               |                                                          |           | 105    120 |                                                          |           | dB   |     |       |
|                                                   |                                                                       |                                                                          | Full range                  | 95         | 98                                                       |                                                          |           | 100        |                                                          |           |      |     |       |
| I <sub>CC</sub>                                   | Supply current                                                        | V <sub>O</sub> = 2.5 V,                      No load                     | 25°C                        | 450    600 | 450    600                                               |                                                          |           | 450    600 |                                                          |           | μA   |     |       |
|                                                   |                                                                       |                                                                          | Full range                  | 600        | 600                                                      |                                                          |           | 600        |                                                          |           |      |     |       |
| ΔI <sub>CC</sub>                                  | Supply current change over operating temperature range                |                                                                          | Full range                  | 37         | 37                                                       |                                                          |           | 37         |                                                          |           | μA   |     |       |

$^\dagger$  Full range is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$ .

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 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.

**TLE2022 electrical characteristics at specified free-air temperature,  $V_{CC} = \pm 15$  V (unless otherwise noted)**

| PARAMETER                                                                     | TEST CONDITIONS                        | $T_A^\dagger$ | TLE2022M     |              |        | TLE2022AM    |              |        | TLE2022BM    |              |        | UNIT              |
|-------------------------------------------------------------------------------|----------------------------------------|---------------|--------------|--------------|--------|--------------|--------------|--------|--------------|--------------|--------|-------------------|
|                                                                               |                                        |               | MIN          | TYP          | MAX    | MIN          | TYP          | MAX    | MIN          | TYP          | MAX    |                   |
| $V_{IO}$ Input offset voltage                                                 | $V_{IC} = 0, R_S = 50 \Omega$          | 25°C          |              | 150          | 500    |              | 120          | 300    |              | 70           | 150    | $\mu V$           |
|                                                                               |                                        | Full range    |              |              | 700    |              |              | 450    |              |              | 300    |                   |
| $^{\circ}V_{IO}$ Temperature coefficient of input offset voltage              |                                        | Full range    |              | 2            |        |              | 2            |        |              | 2            |        | $\mu V/^{\circ}C$ |
| Input offset voltage long-term drift (see Note 4)                             |                                        | 25°C          |              | 0.006        |        |              | 0.006        |        |              | 0.006        |        | $\mu V/mo$        |
| $I_{IO}$ Input offset current                                                 |                                        | 25°C          |              | 0.5          | 6      |              | 0.4          | 6      |              | 0.3          | 6      | nA                |
|                                                                               |                                        | Full range    |              |              | 10     |              |              | 10     |              |              | 10     |                   |
| $I_{IB}$ Input bias current                                                   |                                        | 25°C          |              | 35           | 70     |              | 33           | 70     |              | 30           | 70     | nA                |
|                                                                               |                                        | Full range    |              |              | 90     |              |              | 90     |              |              | 90     |                   |
| $V_{ICR}$ Common-mode input voltage range                                     | $R_S = 50 \Omega$                      | 25°C          | – 15 to 13.5 | – 15.3 to 14 |        | – 15 to 13.5 | – 15.3 to 14 |        | – 15 to 13.5 | – 15.3 to 14 |        | V                 |
|                                                                               |                                        | Full range    | – 15 to 13.2 |              |        | – 15 to 13.2 |              |        | – 15 to 13.2 |              |        |                   |
| $V_{OM+}$ Maximum positive peak output voltage swing                          | $R_L = 10 k\Omega$                     | 25°C          |              | 14           | 14.3   |              | 14           | 14.3   |              | 14           | 14.3   | V                 |
|                                                                               |                                        | Full range    |              | 13.9         |        |              | 13.9         |        |              | 13.9         |        |                   |
| $V_{OM-}$ Maximum negative peak output voltage swing                          |                                        | 25°C          |              | – 13.7       | – 14.1 |              | – 13.7       | – 14.1 |              | – 13.7       | – 14.1 | V                 |
|                                                                               |                                        | Full range    |              | – 13.6       |        |              | – 13.6       |        |              | – 13.6       |        |                   |
| $A_{VD}$ Large-signal differential voltage amplification                      | $V_O = \pm 10$ V, $R_L = 10 k\Omega$   | 25°C          |              | 0.8          | 4      |              | 1            | 7      |              | 1.5          | 10     | $V/\mu V$         |
|                                                                               |                                        | Full range    |              | 0.8          |        |              | 1            |        |              | 1.5          |        |                   |
| CMRR Common-mode rejection ratio                                              | $V_{IC} = V_{ICRmin}, R_S = 50 \Omega$ | 25°C          |              | 95           | 106    |              | 97           | 109    |              | 100          | 112    | dB                |
|                                                                               |                                        | Full range    |              | 91           |        |              | 93           |        |              | 96           |        |                   |
| $k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{CC\pm}/\Delta V_{IO}$ ) | $V_{CC\pm} = \pm 2.5$ V to $\pm 15$ V  | 25°C          |              | 100          | 115    |              | 103          | 118    |              | 105          | 120    | dB                |
|                                                                               |                                        | Full range    |              | 95           |        |              | 98           |        |              | 100          |        |                   |
| $I_{CC}$ Supply current                                                       | $V_O = 0,$ No load                     | 25°C          |              | 550          | 700    |              | 550          | 700    |              | 550          | 700    | $\mu A$           |
|                                                                               |                                        | Full range    |              |              | 700    |              |              | 700    |              |              | 700    |                   |
| $\Delta I_{CC}$ Supply current change over operating temperature range        |                                        | Full range    |              | 60           |        |              | 60           |        |              | 60           |        | $\mu A$           |

$^\dagger$  Full range is –55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 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.

**TLE2024 electrical characteristics at specified free-air temperature,  $V_{CC} = 5\text{ V}$  (unless otherwise noted)**

| PARAMETER        |                                                                       | TEST CONDITIONS                                                                    | T <sub>A</sub> <sup>†</sup> | TLE2024M                                |     |     | TLE2024AM                               |     |     | TLE2024BM                               |     |     | UNIT  |
|------------------|-----------------------------------------------------------------------|------------------------------------------------------------------------------------|-----------------------------|-----------------------------------------|-----|-----|-----------------------------------------|-----|-----|-----------------------------------------|-----|-----|-------|
|                  |                                                                       |                                                                                    |                             | MIN                                     | TYP | MAX | MIN                                     | TYP | MAX | MIN                                     | TYP | MAX |       |
| V <sub>IO</sub>  | Input offset voltage                                                  | V <sub>IC</sub> = 0,                      R <sub>S</sub> = 50 Ω                    | 25°C                        | 1100                                    |     |     | 850                                     |     |     | 600                                     |     |     | μV    |
|                  |                                                                       |                                                                                    | Full range                  | 1300                                    |     |     | 1050                                    |     |     | 800                                     |     |     |       |
| α <sub>VIO</sub> | Temperature coefficient of input offset voltage                       |                                                                                    | Full range                  | 2                                       |     |     | 2                                       |     |     | 2                                       |     |     | μV/°C |
|                  | Input offset voltage long-term drift (see Note 4)                     |                                                                                    | 25°C                        | 0.005                                   |     |     | 0.005                                   |     |     | 0.005                                   |     |     | μV/mo |
| I <sub>IO</sub>  | Input offset current                                                  |                                                                                    | 25°C                        | 0.6      6                              |     |     | 0.5      6                              |     |     | 0.4      6                              |     |     | nA    |
|                  |                                                                       |                                                                                    | Full range                  | 10                                      |     |     | 10                                      |     |     | 10                                      |     |     |       |
| I <sub>IB</sub>  | Input bias current                                                    |                                                                                    | 25°C                        | 45      70                              |     |     | 40      70                              |     |     | 35      70                              |     |     | nA    |
|                  |                                                                       |                                                                                    | Full range                  | 90                                      |     |     | 90                                      |     |     | 90                                      |     |     |       |
| V <sub>ICR</sub> | Common-mode input voltage range                                       | R <sub>S</sub> = 50 Ω                                                              | 25°C                        | 0      –0.3<br>to      to<br>3.5      4 |     |     | 0      –0.3<br>to      to<br>3.5      4 |     |     | 0      –0.3<br>to      to<br>3.5      4 |     |     | V     |
|                  |                                                                       |                                                                                    | Full range                  | 0<br>to<br>3.2                          |     |     | 0<br>to<br>3.2                          |     |     | 0<br>to<br>3.2                          |     |     |       |
| V <sub>OM+</sub> | Maximum positive peak output voltage swing                            | R <sub>L</sub> = 10 kΩ                                                             | 25°C                        | 3.9      4.2                            |     |     | 3.9      4.2                            |     |     | 4      4.3                              |     |     | V     |
|                  |                                                                       |                                                                                    | Full range                  | 3.7                                     |     |     | 3.7                                     |     |     | 3.8                                     |     |     |       |
| V <sub>OM–</sub> | Maximum negative peak output voltage swing                            |                                                                                    | 25°C                        | 0.7      0.8                            |     |     | 0.7      0.8                            |     |     | 0.7      0.8                            |     |     | V     |
|                  |                                                                       |                                                                                    | Full range                  | 0.95                                    |     |     | 0.95                                    |     |     | 0.95                                    |     |     |       |
| A <sub>VD</sub>  | Large-signal differential voltage amplification                       | V <sub>O</sub> = 1.4 V to 4 V,                      R <sub>L</sub> = 10 kΩ         | 25°C                        | 0.2      1.5                            |     |     | 0.3      1.5                            |     |     | 0.4      1.5                            |     |     | V/μV  |
|                  |                                                                       |                                                                                    | Full range                  | 0.1                                     |     |     | 0.1                                     |     |     | 0.1                                     |     |     |       |
| CMRR             | Common-mode rejection ratio                                           | V <sub>IC</sub> = V <sub>ICRmin</sub> ,                      R <sub>S</sub> = 50 Ω | 25°C                        | 80      90                              |     |     | 82      92                              |     |     | 85      95                              |     |     | dB    |
|                  |                                                                       |                                                                                    | Full range                  | 80                                      |     |     | 82                                      |     |     | 85                                      |     |     |       |
| k <sub>SVR</sub> | Supply-voltage rejection ratio (ΔV <sub>CC±</sub> /ΔV <sub>IO</sub> ) | V <sub>CC±</sub> = ±2.5 V to ±15 V                                                 | 25°C                        | 98      112                             |     |     | 100      115                            |     |     | 103      117                            |     |     | dB    |
|                  |                                                                       |                                                                                    | Full range                  | 93                                      |     |     | 95                                      |     |     | 98                                      |     |     |       |
| I <sub>CC</sub>  | Supply current                                                        | V <sub>O</sub> = 0,                      No load                                   | 25°C                        | 800      1200                           |     |     | 800      1200                           |     |     | 800      1200                           |     |     | μA    |
|                  |                                                                       |                                                                                    | Full range                  | 1200                                    |     |     | 1200                                    |     |     | 1200                                    |     |     |       |
| ΔI <sub>CC</sub> | Supply current change over operating temperature range                |                                                                                    | Full range                  | 50                                      |     |     | 50                                      |     |     | 50                                      |     |     | μA    |

$^\dagger$  Full range is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$ .

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 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.

**TLE2024 electrical characteristics at specified free-air temperature,  $V_{CC} = \pm 15\text{ V}$  (unless otherwise noted)**

| PARAMETER                                                                     | TEST CONDITIONS                                    | $T_A^\dagger$ | TLE2024M    |             |      | TLE2024AM   |             |      | TLE2024BM   |             |      | UNIT                         |
|-------------------------------------------------------------------------------|----------------------------------------------------|---------------|-------------|-------------|------|-------------|-------------|------|-------------|-------------|------|------------------------------|
|                                                                               |                                                    |               | MIN         | TYP         | MAX  | MIN         | TYP         | MAX  | MIN         | TYP         | MAX  |                              |
| $V_{IO}$ Input offset voltage                                                 | $V_{IC} = 0, R_S = 50\ \Omega$                     | 25°C          |             |             | 1000 |             |             | 750  |             |             | 500  | $\mu\text{V}$                |
|                                                                               |                                                    | Full range    |             |             | 1200 |             |             | 950  |             |             | 700  |                              |
| $\alpha_{VIO}$ Temperature coefficient of input offset voltage                |                                                    | Full range    |             | 2           |      |             | 2           |      |             | 2           |      | $\mu\text{V}/^\circ\text{C}$ |
| Input offset voltage long-term drift (see Note 4)                             |                                                    | 25°C          |             | 0.006       |      |             | 0.006       |      |             | 0.006       |      | $\mu\text{V}/\text{mo}$      |
| $I_{IO}$ Input offset current                                                 |                                                    | 25°C          |             | 0.6         | 6    |             | 0.5         | 6    |             | 0.4         | 6    | nA                           |
|                                                                               |                                                    | Full range    |             |             | 10   |             |             | 10   |             |             | 10   |                              |
| $I_{IB}$ Input bias current                                                   |                                                    | 25°C          |             | 50          | 70   |             | 45          | 70   |             | 40          | 70   | nA                           |
|                                                                               |                                                    | Full range    |             |             | 90   |             |             | 90   |             |             | 90   |                              |
| $V_{ICR}$ Common-mode input voltage range                                     | $R_S = 50\ \Omega$                                 | 25°C          | –15 to 13.5 | –15.3 to 14 |      | –15 to 13.5 | –15.3 to 14 |      | –15 to 13.5 | –15.3 to 14 |      | V                            |
|                                                                               |                                                    | Full range    | –15 to 13.2 |             |      | –15 to 13.2 |             |      | –15 to 13.2 |             |      |                              |
| $V_{OM+}$ Maximum positive peak output voltage swing                          | $R_L = 10\ \text{k}\Omega$                         | 25°C          | 13.8        | 14.1        |      | 13.9        | 14.2        |      | 14          | 14.3        |      | V                            |
|                                                                               |                                                    | Full range    | 13.7        |             |      | 13.7        |             |      | 13.8        |             |      |                              |
| $V_{OM-}$ Maximum negative peak output voltage swing                          | $R_L = 10\ \text{k}\Omega$                         | 25°C          | –13.7       | –14.1       |      | –13.7       | –14.1       |      | –13.7       | –14.1       |      | V                            |
|                                                                               |                                                    | Full range    | –13.6       |             |      | –13.6       |             |      | –13.6       |             |      |                              |
| $A_{VD}$ Large-signal differential voltage amplification                      | $V_O = \pm 10\text{ V}, R_L = 10\ \text{k}\Omega$  | 25°C          | 0.4         | 2           |      | 0.8         | 4           |      | 1           | 7           |      | $\text{V}/\mu\text{V}$       |
|                                                                               |                                                    | Full range    | 0.4         |             |      | 0.8         |             |      | 1           |             |      |                              |
| CMRR Common-mode rejection ratio                                              | $V_{IC} = V_{ICRmin}, R_S = 50\ \Omega$            | 25°C          | 92          | 102         |      | 94          | 105         |      | 97          | 108         |      | dB                           |
|                                                                               |                                                    | Full range    | 88          |             |      | 90          |             |      | 93          |             |      |                              |
| $k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{CC\pm}/\Delta V_{IO}$ ) | $V_{CC\pm} = \pm 2.5\text{ V to } \pm 15\text{ V}$ | 25°C          | 98          | 112         |      | 100         | 115         |      | 103         | 117         |      | dB                           |
|                                                                               |                                                    | Full range    | 93          |             |      | 95          |             |      | 98          |             |      |                              |
| $I_{CC}$ Supply current                                                       | $V_O = 0, \text{ No load}$                         | 25°C          |             | 1050        | 1400 |             | 1050        | 1400 |             | 1050        | 1400 | $\mu\text{A}$                |
|                                                                               |                                                    | Full range    |             |             | 1400 |             |             | 1400 |             |             | 1400 |                              |
| $\Delta I_{CC}$ Supply current change over operating temperature range        |                                                    | Full range    |             | 85          |      |             | 85          |      |             | 85          |      | $\mu\text{A}$                |

$^\dagger$  Full range is –55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 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.

**TLE2021 operating characteristics,  $V_{CC} = 5\text{ V}$ ,  $T_A = 25^\circ\text{C}$**

| PARAMETER          |                                                  | TEST CONDITIONS                              | T <sub>A</sub> | C SUFFIX |     |     | I SUFFIX |     |     | M SUFFIX |     |     | UNIT  |
|--------------------|--------------------------------------------------|----------------------------------------------|----------------|----------|-----|-----|----------|-----|-----|----------|-----|-----|-------|
|                    |                                                  |                                              |                | MIN      | TYP | MAX | MIN      | TYP | MAX | MIN      | TYP | MAX |       |
| SR                 | Slew rate at unity gain                          | V <sub>O</sub> = 1 V to 3 V,    See Figure 1 | 25°C           | 0.5      |     |     | 0.5      |     |     | 0.5      |     |     | V/μs  |
| V <sub>n</sub>     | Equivalent input noise voltage<br>(see Figure 2) | f = 10 Hz                                    | 25°C           | 21    50 |     |     | 21    50 |     |     | 21       |     |     | nV/Hz |
|                    |                                                  | f = 1 kHz                                    | 25°C           | 17    30 |     |     | 17    30 |     |     | 17       |     |     |       |
| V <sub>N(PP)</sub> | Peak-to-peak equivalent input<br>noise voltage   | f = 0.1 to 1 Hz                              | 25°C           | 0.16     |     |     | 0.16     |     |     | 0.16     |     |     | μV    |
|                    |                                                  | f = 0.1 to 10 Hz                             | 25°C           | 0.47     |     |     | 0.47     |     |     | 0.47     |     |     |       |
| I <sub>n</sub>     | Equivalent input noise current                   |                                              | 25°C           | 0.09     |     |     | 0.09     |     |     | 0.9      |     |     | pA/Hz |
| B <sub>1</sub>     | Unity-gain bandwidth                             | See Figure 3                                 | 25°C           | 1.2      |     |     | 1.2      |     |     | 1.2      |     |     | MHz   |
| φ <sub>m</sub>     | Phase margin at unity gain                       | See Figure 3                                 | 25°C           | 42°      |     |     | 42°      |     |     | 42°      |     |     |       |

**TLE2021 operating characteristics at specified free-air temperature,  $V_{CC} = \pm 15\text{ V}$**

| PARAMETER          |                                                  | TEST CONDITIONS                             | T <sub>A</sub> <sup>†</sup> | C SUFFIX |      |     | I SUFFIX |      |     | M SUFFIX |      |       | UNIT |
|--------------------|--------------------------------------------------|---------------------------------------------|-----------------------------|----------|------|-----|----------|------|-----|----------|------|-------|------|
|                    |                                                  |                                             |                             | MIN      | TYP  | MAX | MIN      | TYP  | MAX | MIN      | TYP  | MAX   |      |
| SR                 | Slew rate at unity gain                          | V <sub>O</sub> = 1V to 3 V,    See Figure 1 | 25°C                        | 0.45     | 0.65 |     | 0.45     | 0.65 |     | 0.45     | 0.65 | V/μs  |      |
|                    |                                                  |                                             | Full range                  | 0.45     |      |     | 0.42     |      |     | 0.45     |      |       |      |
| V <sub>n</sub>     | Equivalent input noise voltage<br>(see Figure 2) | f = 10 Hz                                   | 25°C                        |          | 19   | 50  |          | 19   | 50  |          | 19   | nV/Hz |      |
|                    |                                                  | f = 1 kHz                                   | 25°C                        |          | 15   | 30  |          | 15   | 30  |          | 15   |       |      |
| V <sub>N(PP)</sub> | Peak-to-peak equivalent input<br>noise voltage   | f = 0.1 to 1 Hz                             | 25°C                        |          | 0.16 |     |          | 0.16 |     |          | 0.16 | μV    |      |
|                    |                                                  | f = 0.1 to 10 Hz                            | 25°C                        |          | 0.47 |     |          | 0.47 |     |          | 0.47 |       |      |
| I <sub>n</sub>     | Equivalent input noise current                   |                                             | 25°C                        |          | 0.09 |     |          | 0.09 |     |          | 0.09 | pA/Hz |      |
| B <sub>1</sub>     | Unity-gain bandwidth                             | See Figure 3                                | 25°C                        |          | 2    |     |          | 2    |     |          | 2    | MHz   |      |
| φ <sub>m</sub>     | Phase margin at unity gain                       | See Figure 3                                | 25°C                        |          | 46°  |     |          | 46°  |     |          | 46°  |       |      |

<sup>†</sup> Full range is 0°C to 70°C for the C-suffix devices, –40°C to 85°C for the I-suffix devices, and –55°C to 125°C for the M-suffix devices.

**TLE2022 operating characteristics,  $V_{CC} = 5\text{ V}$ ,  $T_A = 25^\circ\text{C}$**

| PARAMETER   |                                               | TEST CONDITIONS                                 | C SUFFIX |            |     | I SUFFIX |            |     | M SUFFIX |            |     | UNIT                         |
|-------------|-----------------------------------------------|-------------------------------------------------|----------|------------|-----|----------|------------|-----|----------|------------|-----|------------------------------|
|             |                                               |                                                 | MIN      | TYP        | MAX | MIN      | TYP        | MAX | MIN      | TYP        | MAX |                              |
| SR          | Slew rate at unity gain                       | $V_O = 1\text{ V to }3\text{ V}$ , See Figure 1 |          | 0.5        |     |          | 0.5        |     |          | 0.5        |     | $\text{V}/\mu\text{s}$       |
| $V_n$       | Equivalent input noise voltage (see Figure 2) | $f = 10\text{ Hz}$                              |          | 21         | 50  |          | 21         | 50  |          | 21         |     | $\text{nV}/\sqrt{\text{Hz}}$ |
|             |                                               | $f = 1\text{ kHz}$                              |          | 17         | 30  |          | 17         | 30  |          | 17         |     |                              |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage   | $f = 0.1\text{ to }1\text{ Hz}$                 |          | 0.16       |     |          | 0.16       |     |          | 0.16       |     | $\mu\text{V}$                |
|             |                                               | $f = 0.1\text{ to }10\text{ Hz}$                |          | 0.47       |     |          | 0.47       |     |          | 0.47       |     |                              |
| $I_n$       | Equivalent input noise current                |                                                 |          | 0.1        |     |          | 0.1        |     |          | 0.1        |     | $\text{pA}/\sqrt{\text{Hz}}$ |
| $B_1$       | Unity-gain bandwidth                          | See Figure 3                                    |          | 1.7        |     |          | 1.7        |     |          | 1.7        |     | MHz                          |
| $\phi_m$    | Phase margin at unity gain                    | See Figure 3                                    |          | $47^\circ$ |     |          | $47^\circ$ |     |          | $47^\circ$ |     |                              |

**TLE2022 operating characteristics at specified free-air temperature,  $V_{CC} = \pm 15\text{ V}$**

| PARAMETER   |                                               | TEST CONDITIONS                        | $T_A$              | C SUFFIX† |            |     | I SUFFIX† |            |     | M SUFFIX† |            |     | UNIT                         |
|-------------|-----------------------------------------------|----------------------------------------|--------------------|-----------|------------|-----|-----------|------------|-----|-----------|------------|-----|------------------------------|
|             |                                               |                                        |                    | MIN       | TYP        | MAX | MIN       | TYP        | MAX | MIN       | TYP        | MAX |                              |
| SR          | Slew rate at unity gain                       | $V_O = \pm 10\text{ V}$ , See Figure 1 | $25^\circ\text{C}$ | 0.45      | 0.65       |     | 0.45      | 0.65       |     | 0.45      | 0.65       |     | $\text{V}/\mu\text{s}$       |
|             |                                               |                                        | Full range         | 0.45      |            |     | 0.42      |            |     | 0.4       |            |     |                              |
| $V_n$       | Equivalent input noise voltage (see Figure 2) | $f = 10\text{ Hz}$                     | $25^\circ\text{C}$ |           | 19         | 50  |           | 19         | 50  |           | 19         |     | $\text{nV}/\sqrt{\text{Hz}}$ |
|             |                                               | $f = 1\text{ kHz}$                     | $25^\circ\text{C}$ |           | 15         | 30  |           | 15         | 30  |           | 15         |     |                              |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage   | $f = 0.1\text{ to }1\text{ Hz}$        | $25^\circ\text{C}$ |           | 0.16       |     |           | 0.16       |     |           | 0.16       |     | $\mu\text{V}$                |
|             |                                               | $f = 0.1\text{ to }10\text{ Hz}$       | $25^\circ\text{C}$ |           | 0.47       |     |           | 0.47       |     |           | 0.47       |     |                              |
| $I_n$       | Equivalent input noise current                |                                        | $25^\circ\text{C}$ |           | 0.1        |     |           | 0.1        |     |           | 0.1        |     | $\text{pA}/\sqrt{\text{Hz}}$ |
| $B_1$       | Unity-gain bandwidth                          | See Figure 3                           | $25^\circ\text{C}$ |           | 2.8        |     |           | 2.8        |     |           | 2.8        |     | MHz                          |
| $\phi_m$    | Phase margin at unity gain                    | See Figure 3                           | $25^\circ\text{C}$ |           | $52^\circ$ |     |           | $52^\circ$ |     |           | $52^\circ$ |     |                              |

† Full range is  $0^\circ\text{C}$  to  $70^\circ\text{C}$  for the C-suffix devices,  $-40^\circ\text{C}$  to  $85^\circ\text{C}$  for the I suffix devices and  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for the I-suffix devices.

**TLE2024 operating characteristics,  $V_{CC} = 5\text{ V}$ ,  $T_A = 25^\circ\text{C}$**

| PARAMETER          |                                               | TEST CONDITIONS                           | C SUFFIX |     |     | I SUFFIX |     |     | M SUFFIX |     |     | UNIT   |
|--------------------|-----------------------------------------------|-------------------------------------------|----------|-----|-----|----------|-----|-----|----------|-----|-----|--------|
|                    |                                               |                                           | MIN      | TYP | MAX | MIN      | TYP | MAX | MIN      | TYP | MAX |        |
| SR                 | Slew rate at unity gain                       | V <sub>O</sub> = 1 V to 3 V, See Figure 1 | 0.5      |     |     | 0.5      |     |     | 0.5      |     |     | V/μs   |
| V <sub>n</sub>     | Equivalent input noise voltage (see Figure 2) | f = 10 Hz                                 | 21       |     |     | 21       |     |     | 21       |     |     | nV/√Hz |
|                    |                                               | f = 1 kHz                                 | 17       |     |     | 17       |     |     | 17       |     |     |        |
| V <sub>N(PP)</sub> | Peak-to-peak equivalent input noise voltage   | f = 0.1 to 1 Hz                           | 0.16     |     |     | 0.16     |     |     | 0.16     |     |     | μV     |
|                    |                                               | f = 0.1 to 10 Hz                          | 0.47     |     |     | 0.47     |     |     | 0.47     |     |     |        |
| I <sub>n</sub>     | Equivalent input noise current                |                                           | 0.1      |     |     | 0.1      |     |     | 0.1      |     |     | pA/√Hz |
| B <sub>1</sub>     | Unity-gain bandwidth                          | See Figure 3                              | 1.7      |     |     | 1.7      |     |     | 1.7      |     |     | MHz    |
| φ <sub>m</sub>     | Phase margin at unity gain                    | See Figure 3                              | 47°      |     |     | 47°      |     |     | 47°      |     |     |        |

**TLE2024 operating characteristics at specified free-air temperature,  $V_{CC} = \pm 15\text{ V}$  (unless otherwise noted)**

| PARAMETER          |                                                  | TEST CONDITIONS                         | T <sub>A</sub> | C SUFFIX† |     |     | I SUFFIX† |     |     | M SUFFIX† |     |     | UNIT   |
|--------------------|--------------------------------------------------|-----------------------------------------|----------------|-----------|-----|-----|-----------|-----|-----|-----------|-----|-----|--------|
|                    |                                                  |                                         |                | MIN       | TYP | MAX | MIN       | TYP | MAX | MIN       | TYP | MAX |        |
| SR                 | Slew rate at unity gain                          | V <sub>O</sub> = ±10 V,    See Figure 1 | 25°C           | 0.45      | 0.7 |     | 0.45      | 0.7 |     | 0.45      | 0.7 |     | V/μs   |
|                    |                                                  |                                         | Full range     | 0.45      |     |     | 0.42      |     |     | 0.4       |     |     |        |
| V <sub>n</sub>     | Equivalent input noise voltage<br>(see Figure 2) | f = 10 Hz                               | 25°C           | 19        |     | 50  | 19        |     | 50  | 19        |     |     | nV/√Hz |
|                    |                                                  | f = 1 kHz                               | 25°C           | 15        |     | 30  | 15        |     | 30  | 15        |     |     |        |
| V <sub>N(PP)</sub> | Peak-to-peak equivalent input noise<br>voltage   | f = 0.1 to 1 Hz                         | 25°C           | 0.16      |     |     | 0.16      |     |     | 0.16      |     |     | μV     |
|                    |                                                  | f = 0.1 to 10 Hz                        | 25°C           | 0.47      |     |     | 0.47      |     |     | 0.47      |     |     |        |
| I <sub>n</sub>     | Equivalent input noise current                   |                                         | 25°C           | 0.1       |     |     | 0.1       |     |     | 0.1       |     |     | pA/√Hz |
| B <sub>1</sub>     | Unity-gain bandwidth                             | See Figure 3                            | 25°C           | 2.8       |     |     | 2.8       |     |     | 2.8       |     |     | MHz    |
| φ <sub>m</sub>     | Phase margin at unity gain                       | See Figure 3                            | 25°C           | 52°       |     |     | 52°       |     |     | 52°       |     |     |        |

† Full range is  $0^\circ\text{C}$  to  $70^\circ\text{C}$  for the C-suffix devices,  $-40^\circ\text{C}$  to  $85^\circ\text{C}$  for the I suffix devices and  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for the I-suffix devices.

# TLE202x, TLE202xA, TLE202xB, TLE202xY

## EXCALIBUR HIGH-SPEED LOW-POWER PRECISION

### OPERATIONAL AMPLIFIERS

SLOS191D – FEBRUARY 1997 – REVISED NOVEMBER 2010

#### TLE2021Y electrical characteristics at $V_{CC} = 5\text{ V}$ , $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER                                                                     | TEST CONDITIONS                                               | TLE2021Y |                  |     | UNIT                    |
|-------------------------------------------------------------------------------|---------------------------------------------------------------|----------|------------------|-----|-------------------------|
|                                                                               |                                                               | MIN      | TYP              | MAX |                         |
| $V_{IO}$ Input offset voltage                                                 | $V_{IC} = 0$ , $R_S = 50\ \Omega$                             |          | 150              |     | $\mu\text{V}$           |
| Input offset voltage long-term drift (see Note 4)                             |                                                               |          | 0.005            |     | $\mu\text{V}/\text{mo}$ |
| $I_{IO}$ Input offset current                                                 |                                                               |          | 0.5              |     | nA                      |
| $I_{IB}$ Input bias current                                                   |                                                               |          | 35               |     | nA                      |
| $V_{ICR}$ Common-mode input voltage range                                     | $R_S = 50\ \Omega$                                            |          | – 0.3<br>to<br>4 |     | V                       |
| $V_{OH}$ Maximum high-level output voltage                                    | $R_L = 10\ \text{k}\Omega$                                    |          | 4.3              |     | V                       |
| $V_{OL}$ Maximum low-level output voltage                                     |                                                               |          | 0.7              |     | V                       |
| $A_{VD}$ Large-signal differential voltage amplification                      | $V_O = 1.4\text{ to }4\text{ V}$ , $R_L = 10\ \text{k}\Omega$ |          | 1.5              |     | $\text{V}/\mu\text{V}$  |
| CMRR Common-mode rejection ratio                                              | $V_{IC} = V_{ICR}\text{ min}$ , $R_S = 50\ \Omega$            |          | 100              |     | dB                      |
| $k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{CC\pm}/\Delta V_{IO}$ ) | $V_{CC} = 5\text{ V to }30\text{ V}$                          |          | 115              |     | dB                      |
| $I_{CC}$ Supply current                                                       | $V_O = 2.5\text{ V}$ , No load                                |          | 400              |     | $\mu\text{A}$           |

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 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.

#### TLE2021Y operating characteristics at $V_{CC} = 5\text{ V}$ , $T_A = 25^\circ\text{C}$

| PARAMETER                                               | TEST CONDITIONS                  | TLE2021Y |      |     | UNIT                         |
|---------------------------------------------------------|----------------------------------|----------|------|-----|------------------------------|
|                                                         |                                  | MIN      | TYP  | MAX |                              |
| SR Slew rate at unity gain                              | $V_O = 1\text{ V to }3\text{ V}$ |          | 0.5  |     | $\text{V}/\mu\text{s}$       |
| $V_n$ Equivalent input noise voltage                    | $f = 10\text{ Hz}$               |          | 21   |     | $\text{nV}/\sqrt{\text{Hz}}$ |
|                                                         | $f = 1\text{ kHz}$               |          | 17   |     |                              |
| $V_{N(PP)}$ Peak-to-peak equivalent input noise voltage | $f = 0.1\text{ to }1\text{ Hz}$  |          | 0.16 |     | $\mu\text{V}$                |
|                                                         | $f = 0.1\text{ to }10\text{ Hz}$ |          | 0.47 |     |                              |
| $I_n$ Equivalent input noise current                    |                                  |          | 0.1  |     | $\text{pA}/\sqrt{\text{Hz}}$ |
| $B_1$ Unity-gain bandwidth                              |                                  |          | 1.7  |     | MHz                          |
| $\phi_m$ Phase margin at unity gain                     |                                  |          | 47°  |     |                              |

# TLE202x, TLE202xA, TLE202xB, TLE202xY EXCALIBUR HIGH-SPEED LOW-POWER PRECISION OPERATIONAL AMPLIFIERS

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## TLE2022Y electrical characteristics, $V_{CC} = 5\text{ V}$ , $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER                                                                       | TEST CONDITIONS                                               | TLE2022Y |                  |     | UNIT                    |
|---------------------------------------------------------------------------------|---------------------------------------------------------------|----------|------------------|-----|-------------------------|
|                                                                                 |                                                               | MIN      | TYP              | MAX |                         |
| $V_{IO}$ Input offset voltage                                                   | $V_{IC} = 0$ , $R_S = 50\ \Omega$                             |          | 150              | 600 | $\mu\text{V}$           |
| Input offset voltage long-term drift (see Note 4)                               |                                                               |          | 0.005            |     | $\mu\text{V}/\text{mo}$ |
| $I_{IO}$ Input offset current                                                   |                                                               |          | 0.5              |     | nA                      |
| $I_{IB}$ Input bias current                                                     |                                                               |          | 35               |     | nA                      |
| $V_{ICR}$ Common-mode input voltage range                                       | $R_S = 50\ \Omega$                                            |          | – 0.3<br>to<br>4 |     | V                       |
| $V_{OH}$ Maximum high-level output voltage                                      | $R_L = 10\ \text{k}\Omega$                                    |          | 4.3              |     | V                       |
| $V_{OL}$ Maximum low-level output voltage                                       |                                                               |          | 0.7              |     | V                       |
| $A_{VD}$ Large-signal differential voltage amplification                        | $V_O = 1.4\text{ to }4\text{ V}$ , $R_L = 10\ \text{k}\Omega$ |          | 1.5              |     | $\text{V}/\mu\text{V}$  |
| CMRR Common-mode rejection ratio                                                | $V_{IC} = V_{ICR}\text{ min}$ , $R_S = 50\ \Omega$            |          | 100              |     | dB                      |
| $k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{CC\pm} / \Delta V_{IO}$ ) | $V_{CC} = 5\text{ V to }30\text{ V}$                          |          | 115              |     | dB                      |
| $I_{CC}$ Supply current                                                         | $V_O = 2.5\text{ V}$ , No load                                |          | 450              |     | $\mu\text{A}$           |

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 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.

## TLE2022Y operating characteristics, $V_{CC} = 5\text{ V}$ , $T_A = 25^\circ\text{C}$

| PARAMETER                                               | TEST CONDITIONS                                 | TLE2022Y |      |     | UNIT                         |
|---------------------------------------------------------|-------------------------------------------------|----------|------|-----|------------------------------|
|                                                         |                                                 | MIN      | TYP  | MAX |                              |
| SR Slew rate at unity gain                              | $V_O = 1\text{ V to }3\text{ V}$ , See Figure 1 |          | 0.5  |     | $\text{V}/\mu\text{s}$       |
| $V_n$ Equivalent input noise voltage (see Figure 2)     | $f = 10\text{ Hz}$                              |          | 21   |     | $\text{nV}/\sqrt{\text{Hz}}$ |
|                                                         | $f = 1\text{ kHz}$                              |          | 17   |     |                              |
| $V_{N(PP)}$ Peak-to-peak equivalent input noise voltage | $f = 0.1\text{ to }1\text{ Hz}$                 |          | 0.16 |     | $\mu\text{V}$                |
|                                                         | $f = 0.1\text{ to }10\text{ Hz}$                |          | 0.47 |     |                              |
| $I_n$ Equivalent input noise current                    |                                                 |          | 0.1  |     | $\text{pA}/\sqrt{\text{Hz}}$ |
| $B_1$ Unity-gain bandwidth                              | See Figure 3                                    |          | 1.7  |     | MHz                          |
| $\phi_m$ Phase margin at unity gain                     | See Figure 3                                    |          | 47°  |     |                              |

# TLE202x, TLE202xA, TLE202xB, TLE202xY

## EXCALIBUR HIGH-SPEED LOW-POWER PRECISION

### OPERATIONAL AMPLIFIERS

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#### TLE2024Y electrical characteristics, $V_{CC} = 5\text{ V}$ , $T_A = 25^\circ\text{C}$ (unless otherwise noted)

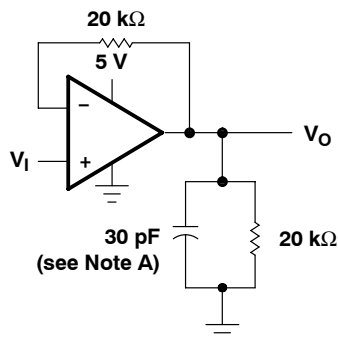
| PARAMETER                                                                  | TEST CONDITIONS                                                 | TLE2024Y |                 |     | UNIT                    |
|----------------------------------------------------------------------------|-----------------------------------------------------------------|----------|-----------------|-----|-------------------------|
|                                                                            |                                                                 | MIN      | TYP             | MAX |                         |
| Input offset voltage long-term drift (see Note 4)                          |                                                                 |          | 0.005           |     | $\mu\text{V}/\text{mo}$ |
| $I_{IO}$ Input offset current                                              | $V_{IC} = 0$ , $R_S = 50\ \Omega$                               |          | 0.6             |     | nA                      |
| $I_{IB}$ Input bias current                                                |                                                                 |          | 45              |     | nA                      |
| $V_{ICR}$ Common-mode input voltage range                                  | $R_S = 50\ \Omega$                                              |          | -0.3<br>to<br>4 |     | V                       |
| $V_{OH}$ High-level output voltage                                         | $R_L = 10\ \text{k}\Omega$                                      |          | 4.2             |     | V                       |
| $V_{OL}$ Low-level output voltage                                          |                                                                 |          | 0.7             |     | V                       |
| $A_{VD}$ Large-signal differential voltage amplification                   | $V_O = 1.4\text{ V to }4\text{ V}$ , $R_L = 10\ \text{k}\Omega$ |          | 1.5             |     | $\text{V}/\mu\text{V}$  |
| CMRR Common-mode rejection ratio                                           | $V_{IC} = V_{ICRmin}$ , $R_S = 50\ \Omega$                      |          | 90              |     | dB                      |
| $k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{CC}/\Delta V_{IO}$ ) | $V_{CC} = 5\text{ V to }30\text{ V}$                            |          | 112             |     | dB                      |
| $I_{CC}$ Supply current                                                    | $V_O = 2.5\text{ V}$ , No load                                  |          | 800             |     | $\mu\text{A}$           |

NOTE 4. Typical values are based on the input offset voltage shift observed through 168 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.

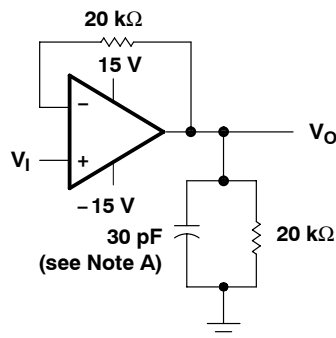
#### TLE2024Y operating characteristics, $V_{CC} = 5\text{ V}$ , $T_A = 25^\circ\text{C}$

| PARAMETER                                               | TEST CONDITIONS                                 | TLE2024Y |      |     | UNIT                         |
|---------------------------------------------------------|-------------------------------------------------|----------|------|-----|------------------------------|
|                                                         |                                                 | MIN      | TYP  | MAX |                              |
| SR Slew rate at unity gain                              | $V_O = 1\text{ V to }3\text{ V}$ , See Figure 1 |          | 0.5  |     | $\text{V}/\mu\text{s}$       |
| $V_n$ Equivalent input noise voltage (see Figure 2)     | $f = 10\text{ Hz}$                              |          | 21   |     | $\text{nV}/\sqrt{\text{Hz}}$ |
|                                                         | $f = 1\text{ kHz}$                              |          | 17   |     |                              |
| $V_{N(PP)}$ Peak-to-peak equivalent input noise voltage | $f = 0.1\text{ to }1\text{ Hz}$                 |          | 0.16 |     | $\mu\text{V}$                |
|                                                         | $f = 0.1\text{ to }10\text{ Hz}$                |          | 0.47 |     |                              |
| $I_n$ Equivalent input noise current                    |                                                 |          | 0.1  |     | $\text{pA}/\sqrt{\text{Hz}}$ |
| $B_1$ Unity-gain bandwidth                              | See Figure 3                                    |          | 1.7  |     | MHz                          |
| $\phi_m$ Phase margin at unity gain                     | See Figure 3                                    |          | 47°  |     |                              |

## PARAMETER MEASUREMENT INFORMATION



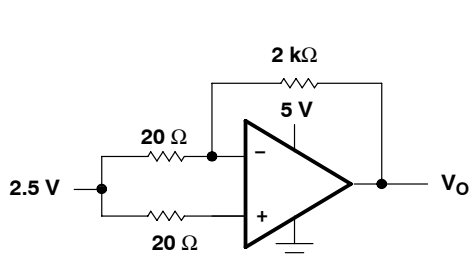
(a) SINGLE SUPPLY



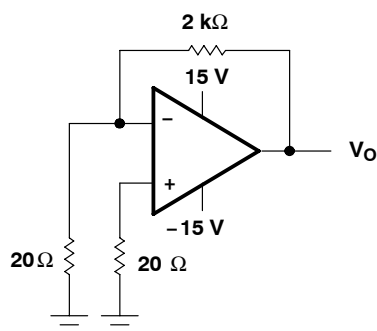
(b) SPLIT SUPPLY

NOTE A: C<sub>L</sub> includes fixture capacitance.

**Figure 1. Slew-Rate Test Circuit**

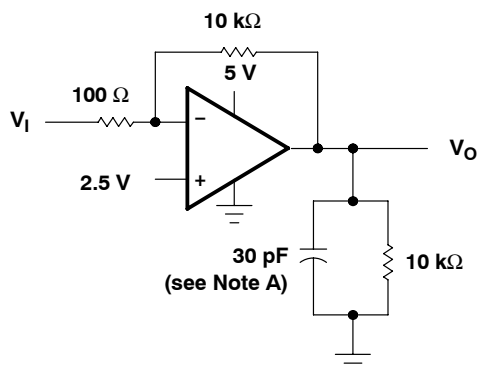


(a) SINGLE SUPPLY

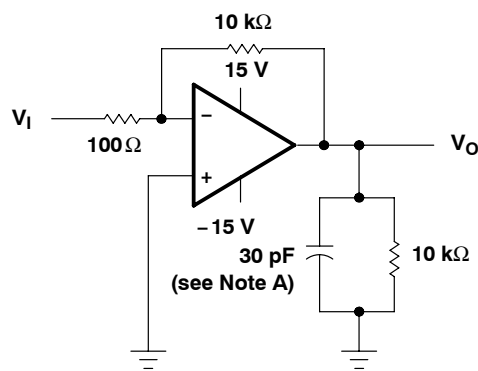


(b) SPLIT SUPPLY

**Figure 2. Noise-Voltage Test Circuit**



(a) SINGLE SUPPLY



(b) SPLIT SUPPLY

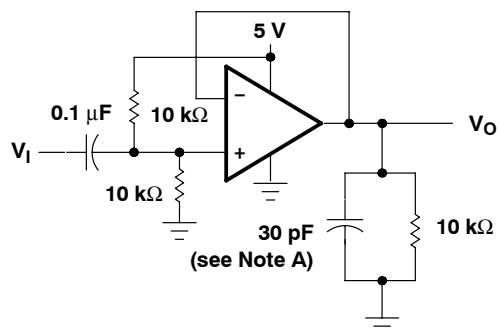
NOTE A: C<sub>L</sub> includes fixture capacitance.

**Figure 3. Unity-Gain Bandwidth and Phase-Margin Test Circuit**

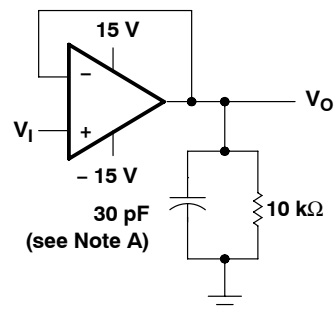
# TLE202x, TLE202xA, TLE202xB, TLE202xY EXCALIBUR HIGH-SPEED LOW-POWER PRECISION OPERATIONAL AMPLIFIERS

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## PARAMETER MEASUREMENT INFORMATION



(a) SINGLE SUPPLY



(b) SPLIT SUPPLY

NOTE A:  $C_L$  includes fixture capacitance.

Figure 4. Small-Signal Pulse-Response Test Circuit

## typical values

Typical values presented in this data sheet represent the median (50% point) of device parametric performance.

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## TYPICAL CHARACTERISTICS

**Table of Graphs**

|             |                                                 |                                                                     | FIGURE                     |
|-------------|-------------------------------------------------|---------------------------------------------------------------------|----------------------------|
| $V_{IO}$    | Input offset voltage                            | Distribution                                                        | 5, 6, 7                    |
| $I_{IB}$    | Input bias current                              | vs Common-mode input voltage<br>vs Free-air temperature             | 8, 9, 10<br>11, 12, 13     |
| $I_I$       | Input current                                   | vs Differential input voltage                                       | 14                         |
| $V_{OM}$    | Maximum peak output voltage                     | vs Output current<br>vs Free-air temperature                        | 15, 16, 17<br>18           |
| $V_{OH}$    | High-level output voltage                       | vs High-level output current<br>vs Free-air temperature             | 19, 20<br>21               |
| $V_{OL}$    | Low-level output voltage                        | vs Low-level output current<br>vs Free-air temperature              | 22<br>23                   |
| $V_{O(PP)}$ | Maximum peak-to-peak output voltage             | vs Frequency                                                        | 24, 25                     |
| $A_{VD}$    | Large-signal differential voltage amplification | vs Frequency<br>vs Free-air temperature                             | 26<br>27, 28, 29           |
| $I_{OS}$    | Short-circuit output current                    | vs Supply voltage<br>vs Free-air temperature                        | 30 – 33<br>34 – 37         |
| $I_{CC}$    | Supply current                                  | vs Supply voltage<br>vs Free-air temperature                        | 38, 39, 40<br>41, 42, 43   |
| CMRR        | Common-mode rejection ratio                     | vs Frequency                                                        | 44, 45, 46                 |
| SR          | Slew rate                                       | vs Free-air temperature                                             | 47, 48, 49                 |
|             | Voltage-follower small-signal pulse response    |                                                                     | 50, 51                     |
|             | Voltage-follower large-signal pulse response    |                                                                     | 52 – 57                    |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage     | 0.1 to 1 Hz<br>0.1 to 10 Hz                                         | 58<br>59                   |
| $V_n$       | Equivalent input noise voltage                  | vs Frequency                                                        | 60                         |
| $B_1$       | Unity-gain bandwidth                            | vs Supply voltage<br>vs Free-air temperature                        | 61, 62<br>63, 64           |
| $\phi_m$    | Phase margin                                    | vs Supply voltage<br>vs Load capacitance<br>vs Free-air temperature | 65, 66<br>67, 68<br>69, 70 |
|             | Phase shift                                     | vs Frequency                                                        | 26                         |

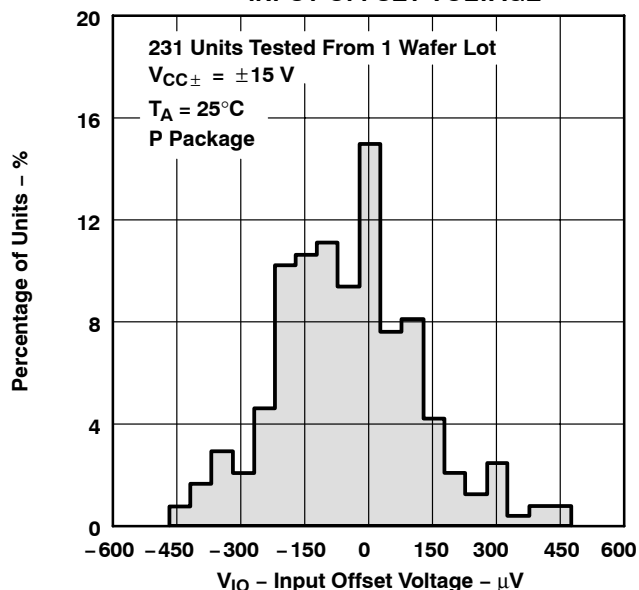


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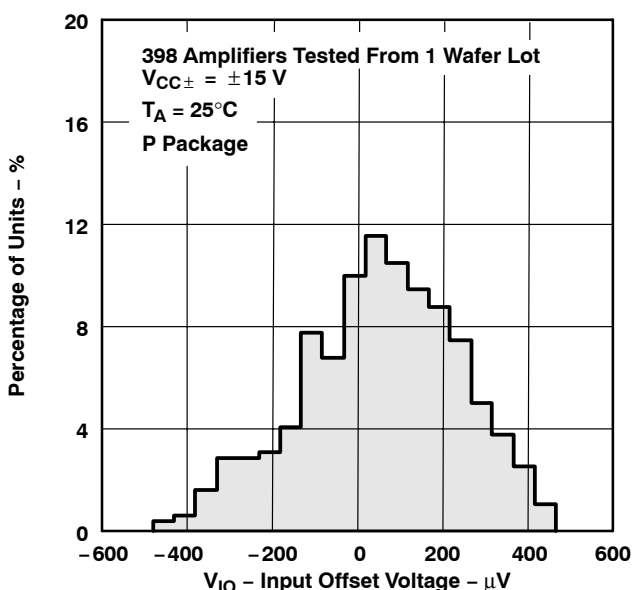
## TYPICAL CHARACTERISTICS

**DISTRIBUTION OF TLE2021  
INPUT OFFSET VOLTAGE**



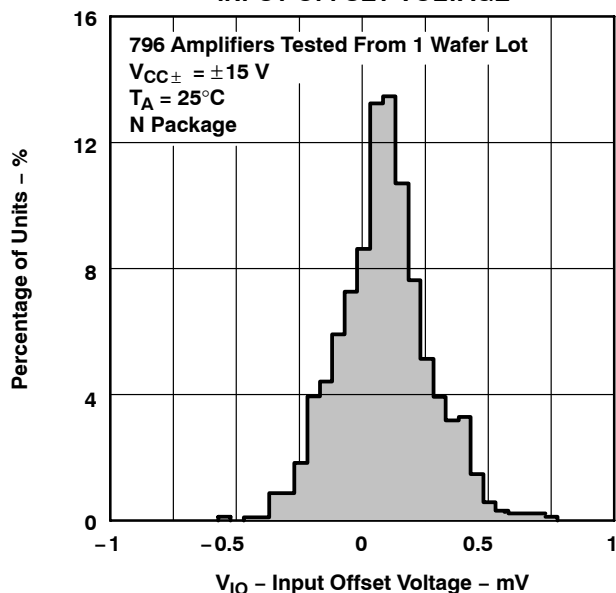
**Figure 5**

**DISTRIBUTION OF TLE2022  
INPUT OFFSET VOLTAGE**



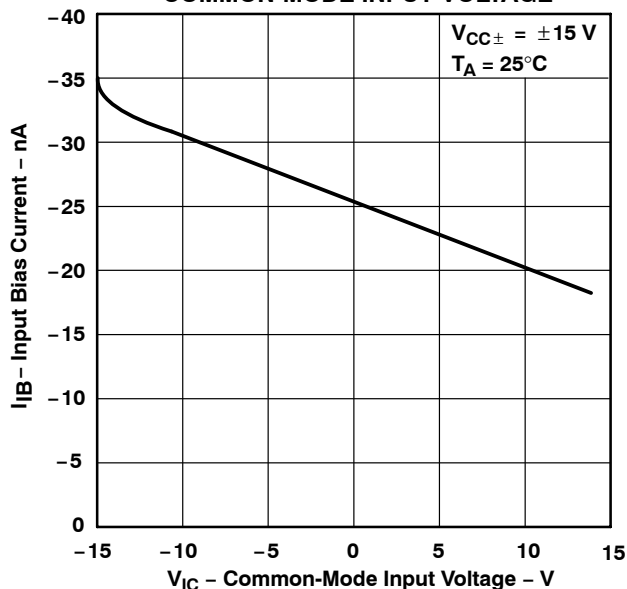
**Figure 6**

**DISTRIBUTION OF TLE2024  
INPUT OFFSET VOLTAGE**



**Figure 7**

**TLE2021  
INPUT BIAS CURRENT  
vs  
COMMON-MODE INPUT VOLTAGE**



**Figure 8**

# TLE202x, TLE202xA, TLE202xB, TLE202xY EXCALIBUR HIGH-SPEED LOW-POWER PRECISION OPERATIONAL AMPLIFIERS

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## TYPICAL CHARACTERISTICS

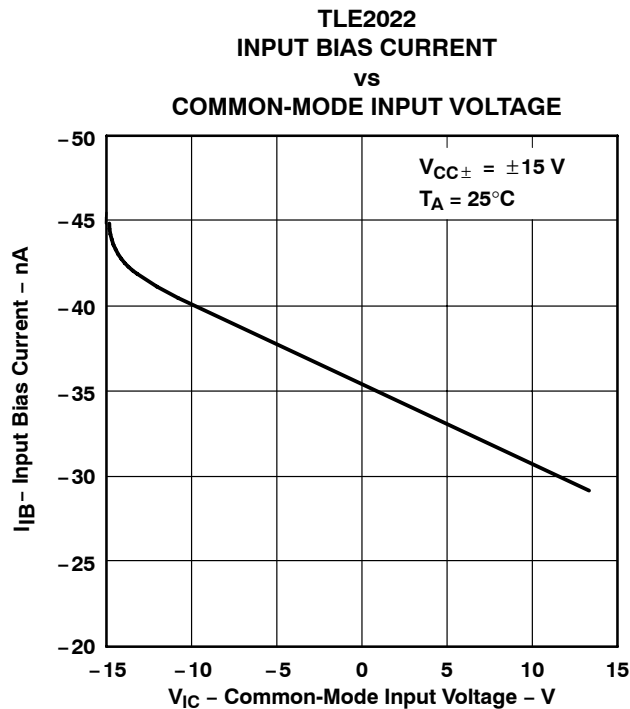


Figure 9

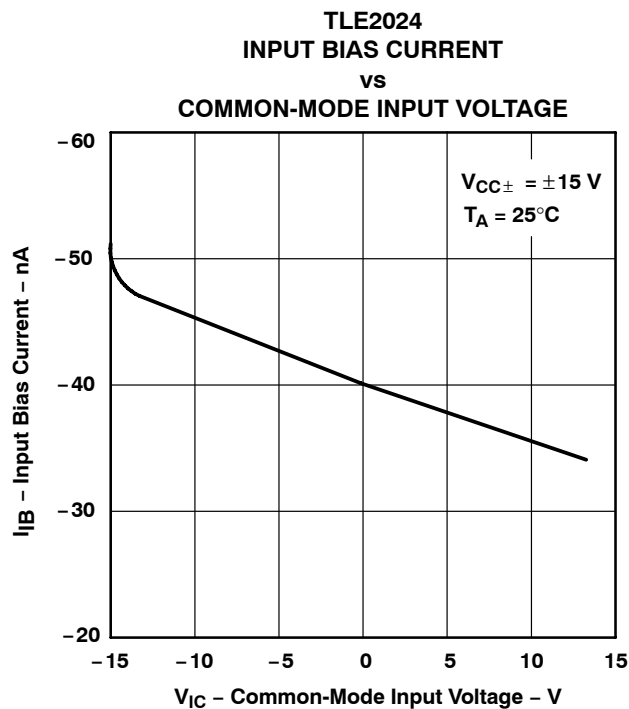


Figure 10

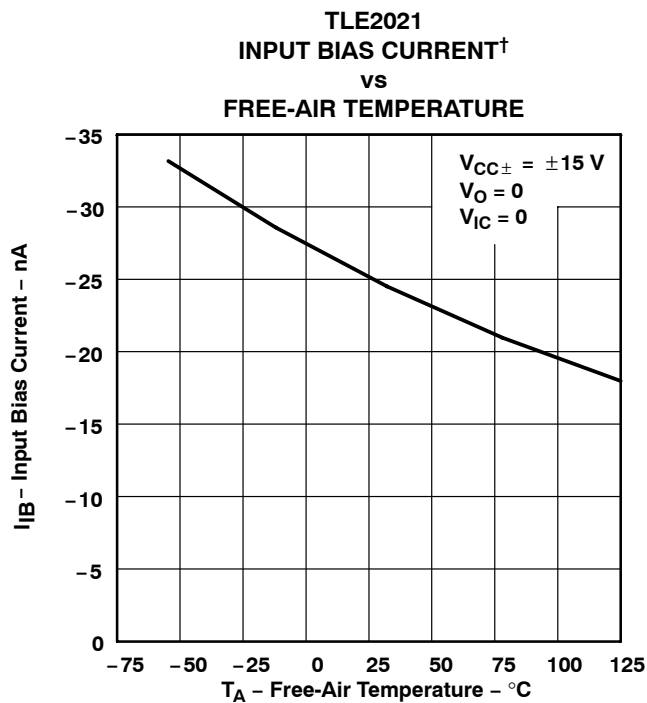


Figure 11

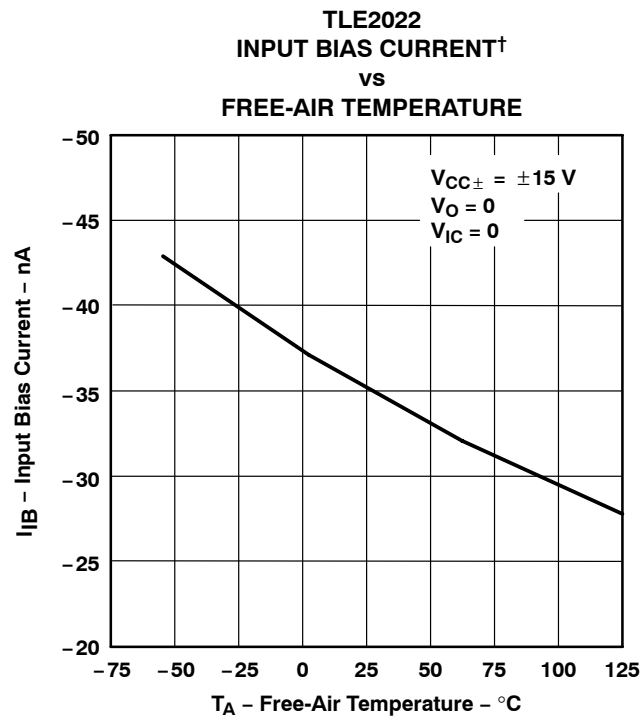


Figure 12

† 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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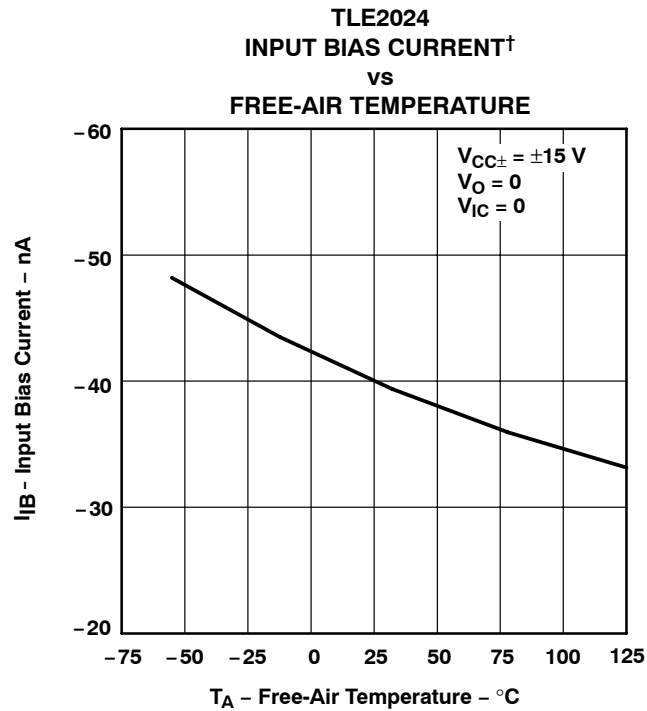


Figure 13

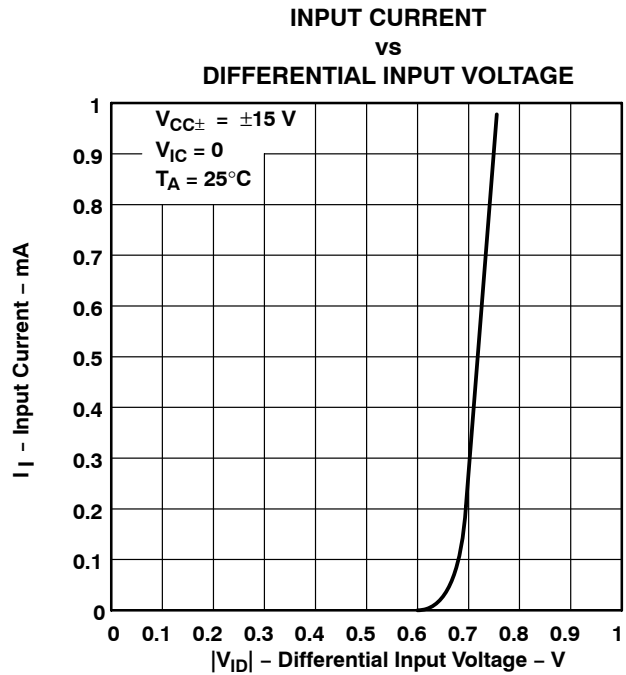


Figure 14

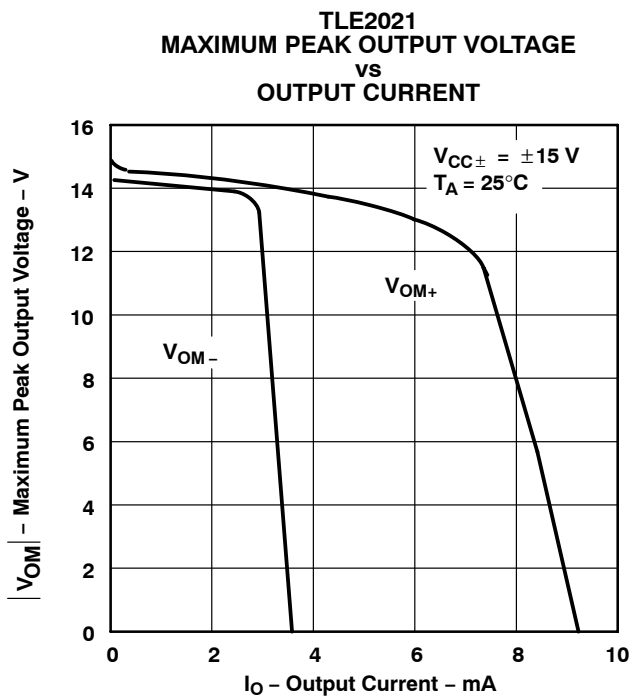


Figure 15

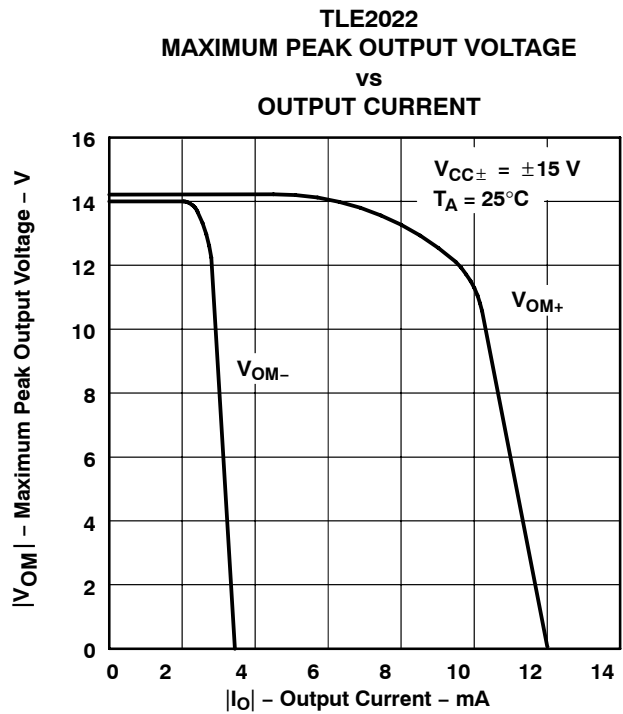


Figure 16

<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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## TYPICAL CHARACTERISTICS

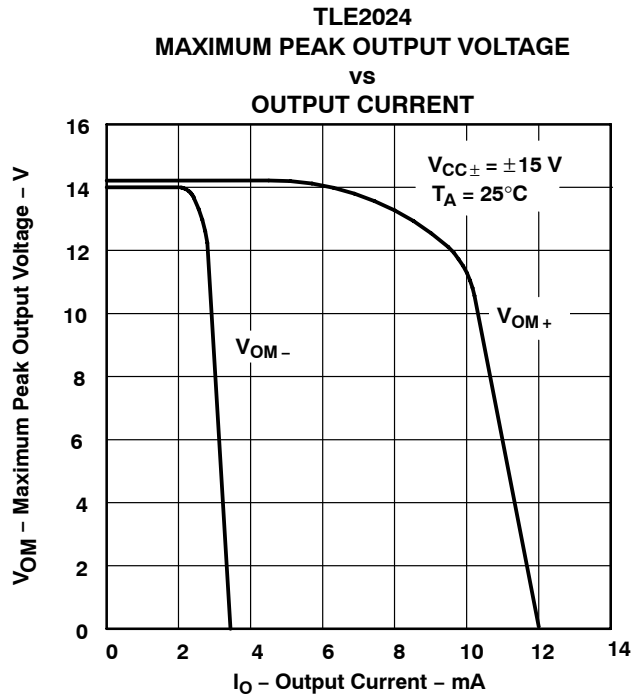


Figure 17

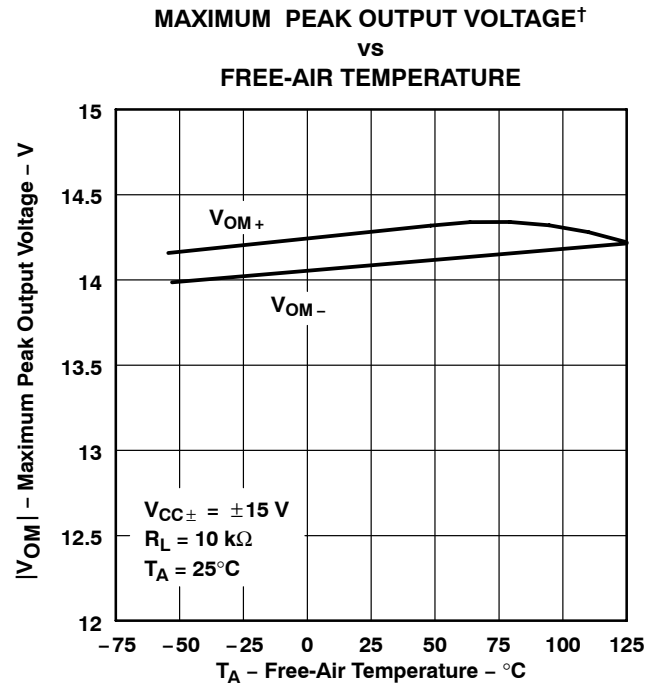


Figure 18

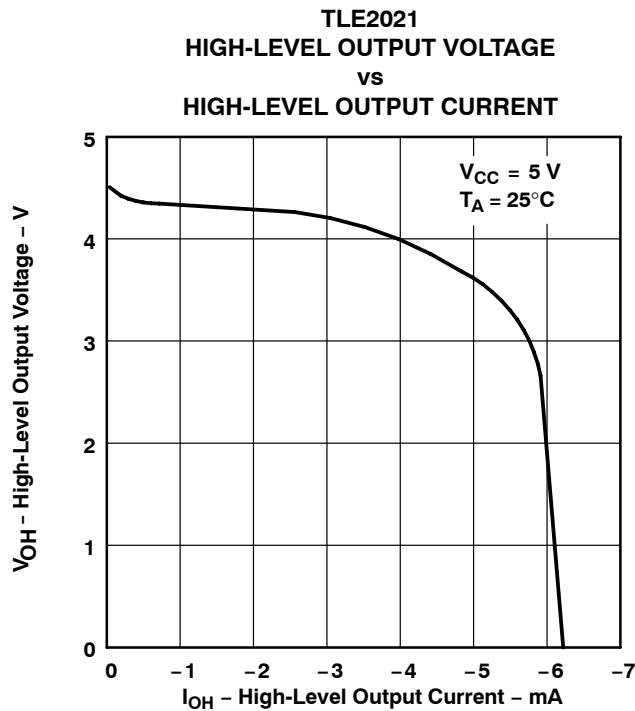


Figure 19

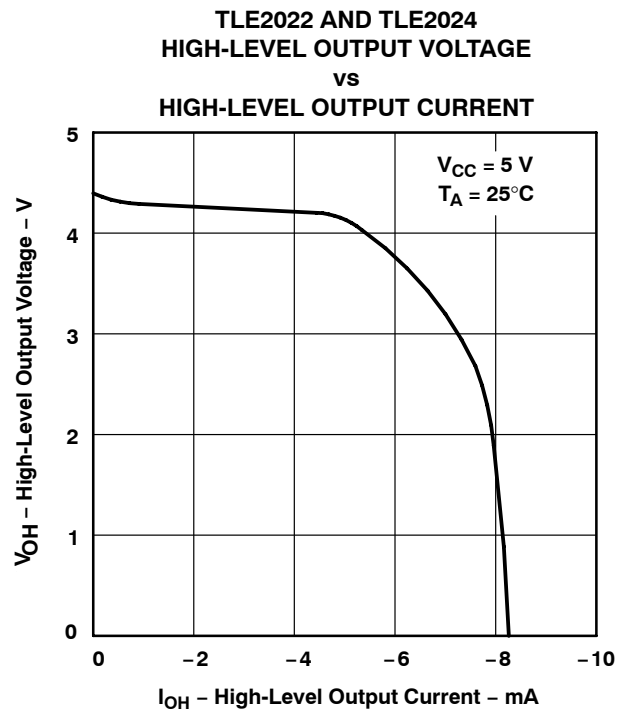


Figure 20

† 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

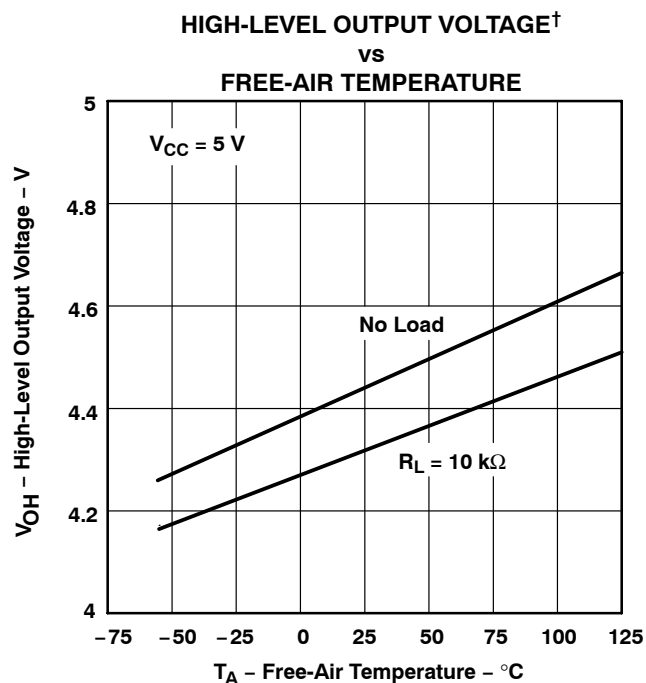


Figure 21

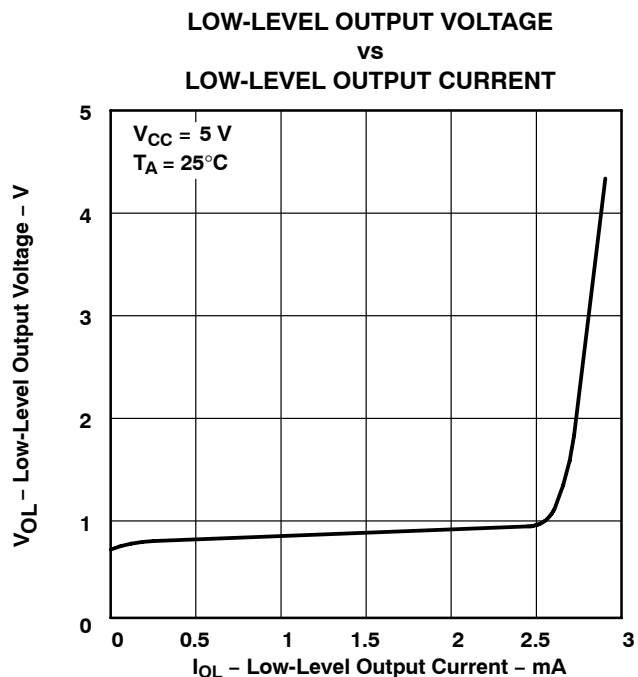


Figure 22

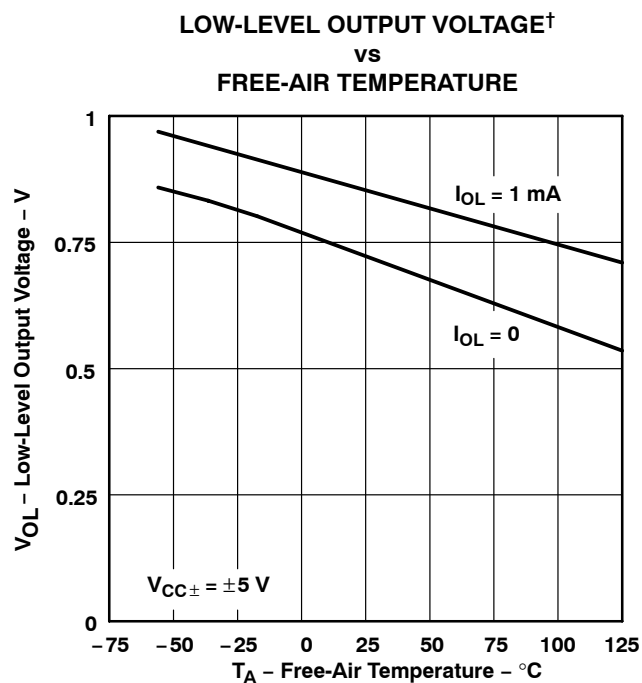


Figure 23

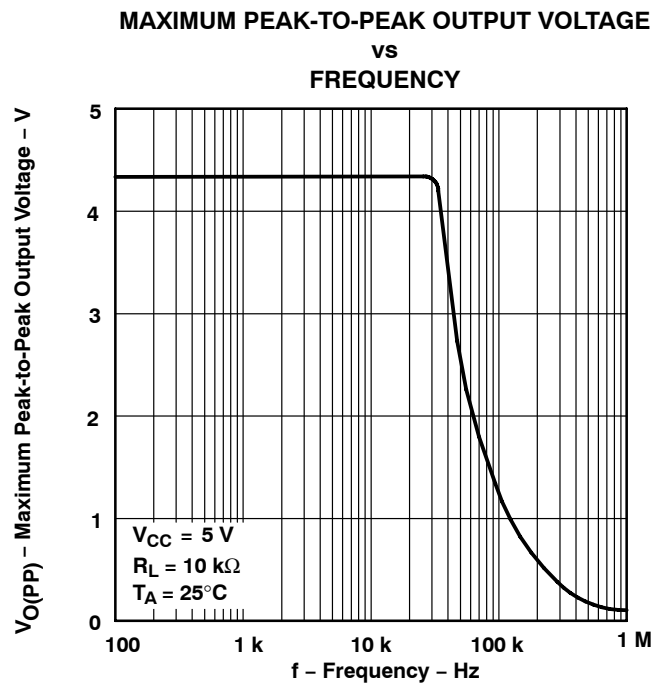


Figure 24

<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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## TYPICAL CHARACTERISTICS

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

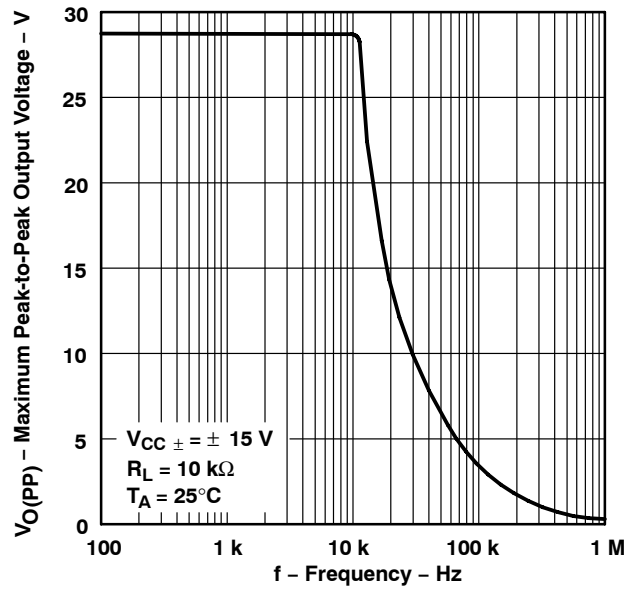


Figure 25

### LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT vs FREQUENCY

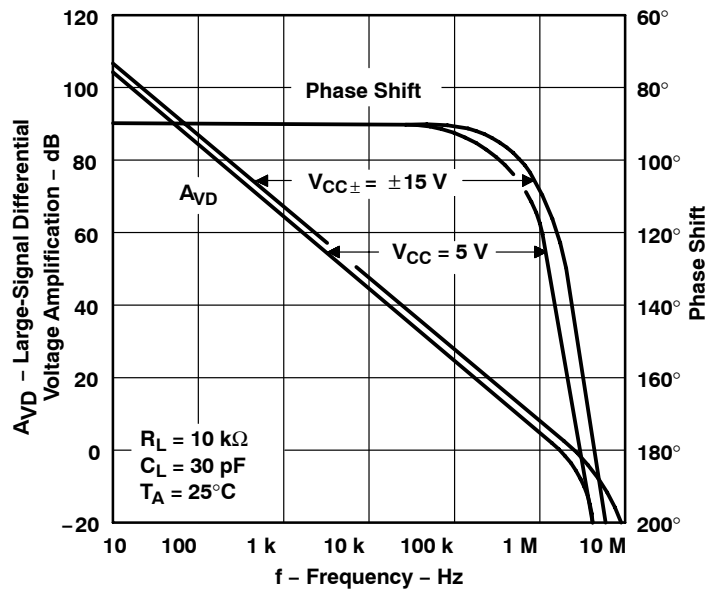


Figure 26

# TLE202x, TLE202xA, TLE202xB, TLE202xY EXCALIBUR HIGH-SPEED LOW-POWER PRECISION OPERATIONAL AMPLIFIERS

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## TYPICAL CHARACTERISTICS

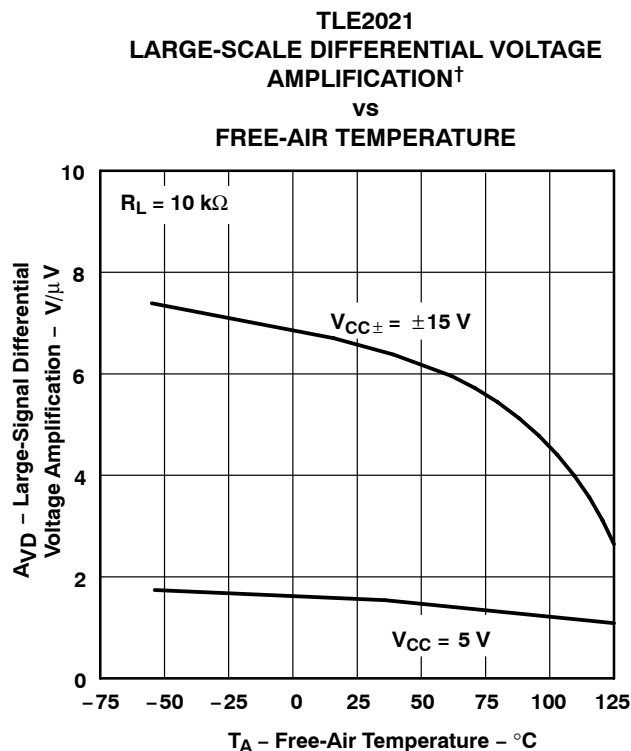


Figure 27

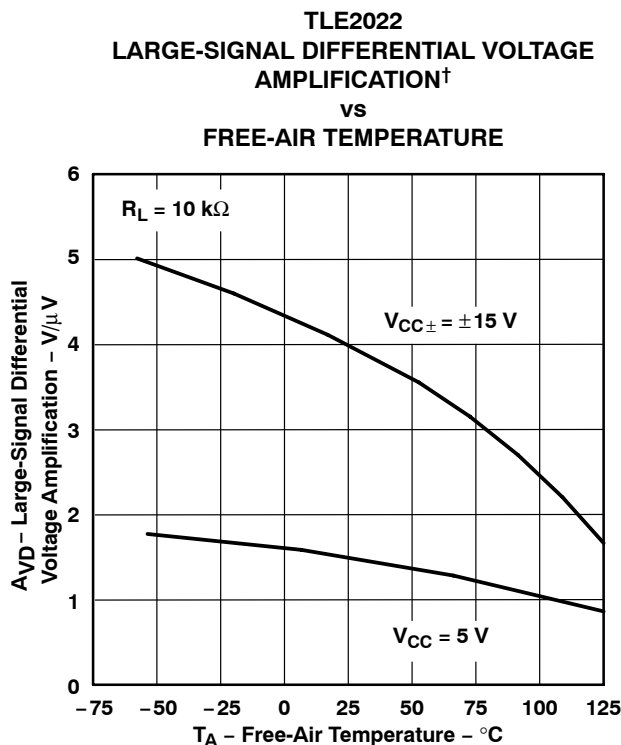


Figure 28

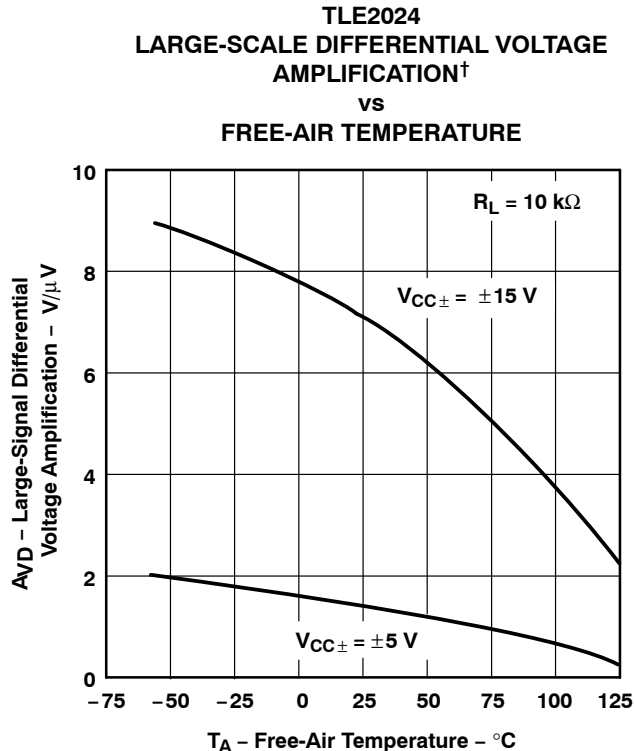


Figure 29

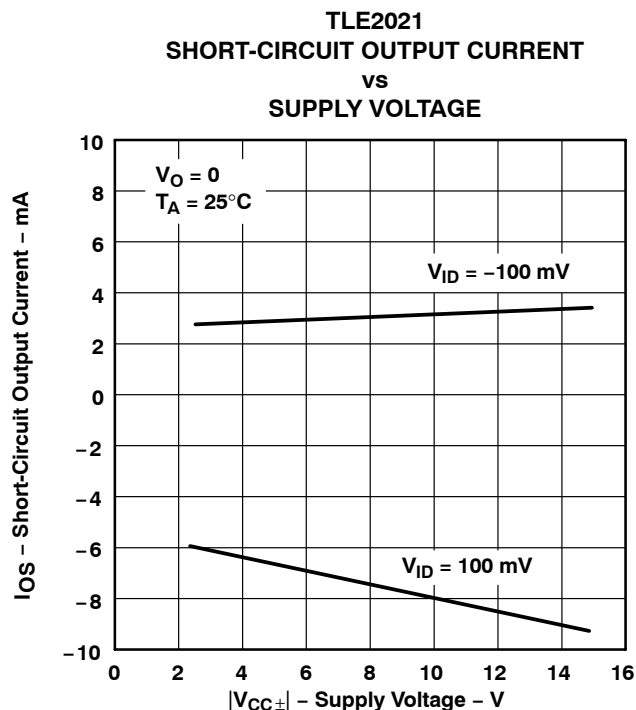


Figure 30

<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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## TYPICAL CHARACTERISTICS

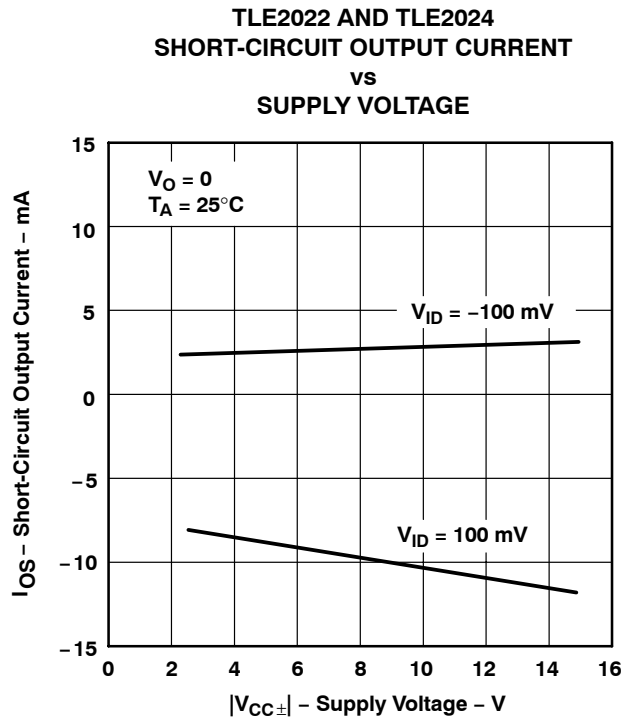


Figure 31

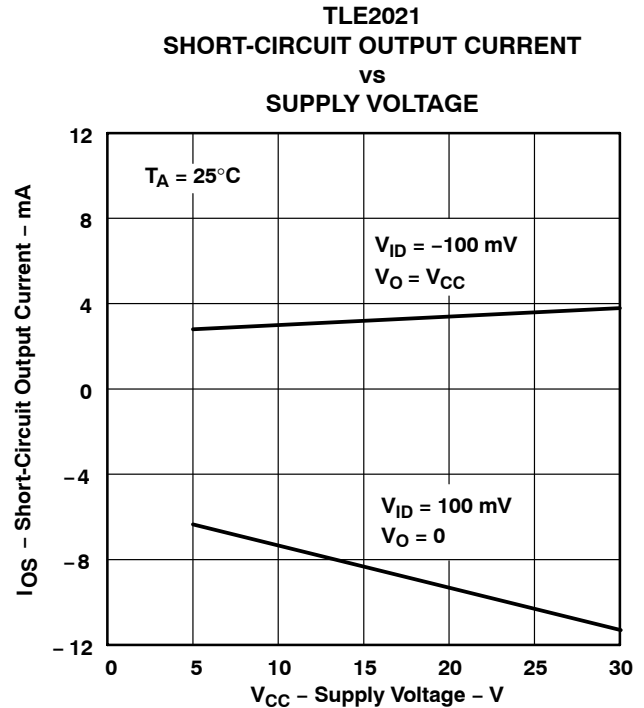


Figure 32

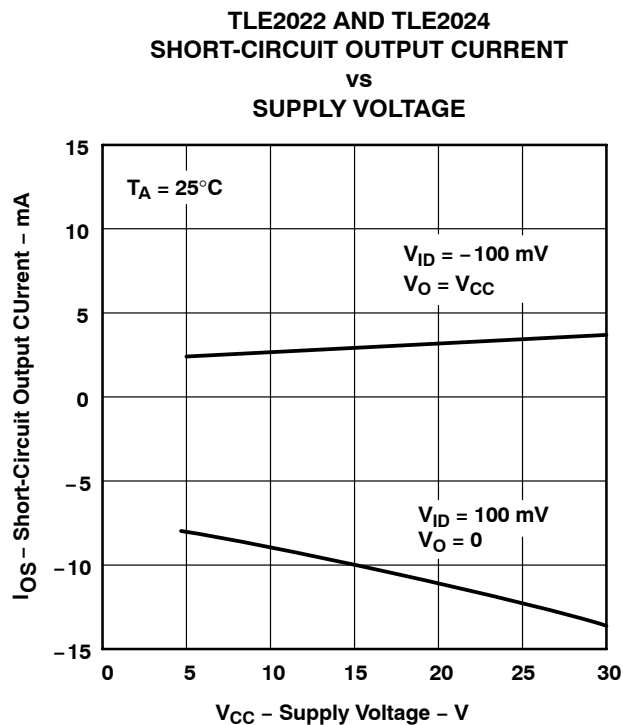


Figure 33

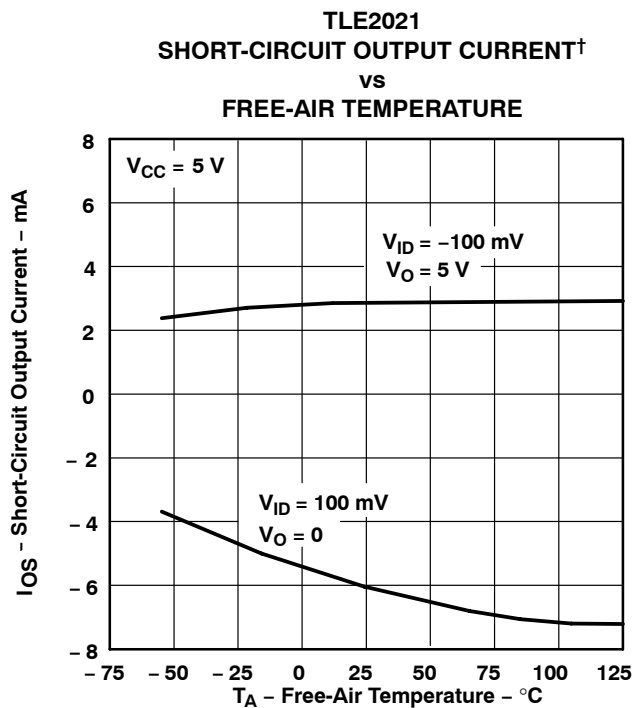


Figure 34

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

# TLE202x, TLE202xA, TLE202xB, TLE202xY EXCALIBUR HIGH-SPEED LOW-POWER PRECISION OPERATIONAL AMPLIFIERS

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## TYPICAL CHARACTERISTICS

**TLE2022 AND TLE2024**  
**SHORT-CIRCUIT OUTPUT CURRENT†**  
vs  
**FREE-AIR TEMPERATURE**

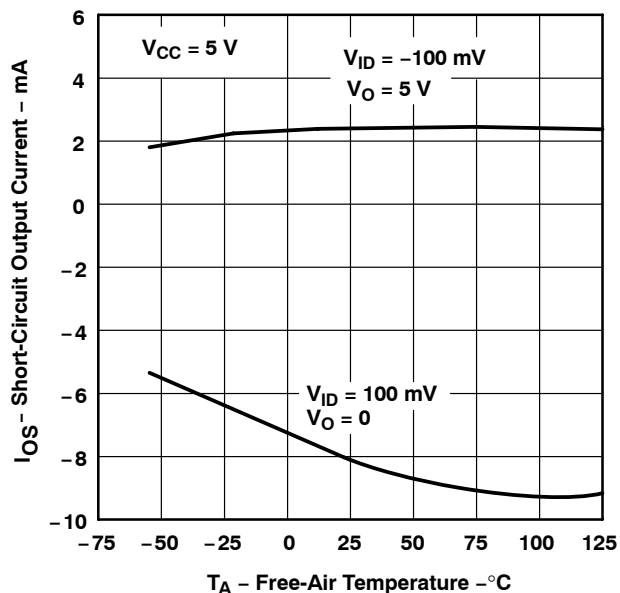


Figure 35

**TLE2021**  
**SHORT-CIRCUIT OUTPUT CURRENT†**  
vs  
**FREE-AIR TEMPERATURE**

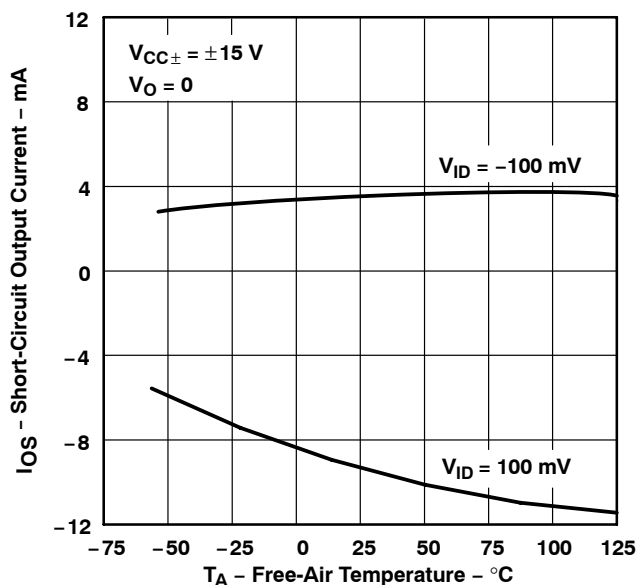


Figure 36

**TLE2022 AND TLE2024**  
**SHORT-CIRCUIT OUTPUT CURRENT†**  
vs  
**FREE-AIR TEMPERATURE**

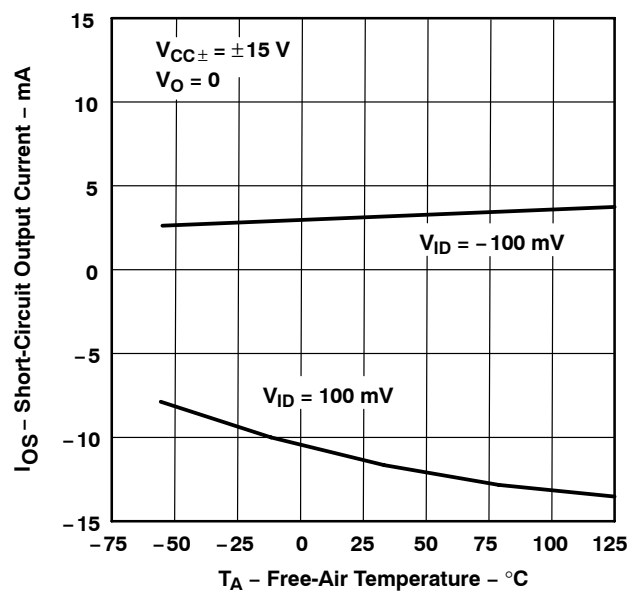


Figure 37

**TLE2021**  
**SUPPLY CURRENT**  
vs  
**SUPPLY VOLTAGE**

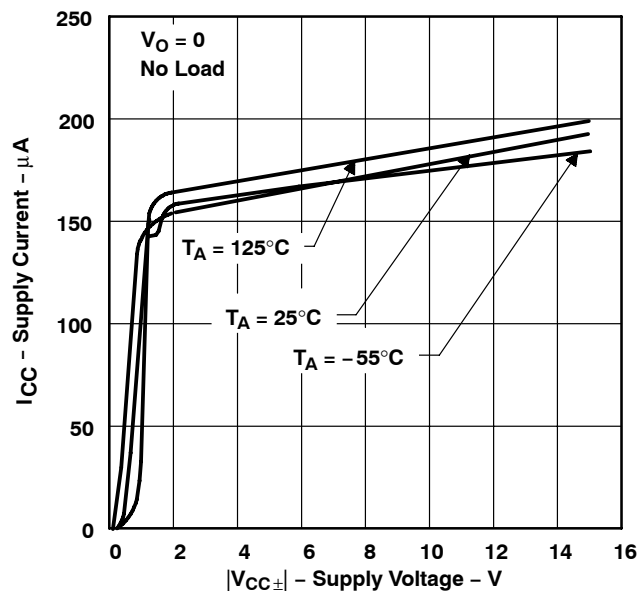


Figure 38

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

# TLE202x, TLE202xA, TLE202xB, TLE202xY EXCALIBUR HIGH-SPEED LOW-POWER PRECISION OPERATIONAL AMPLIFIERS

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## TYPICAL CHARACTERISTICS

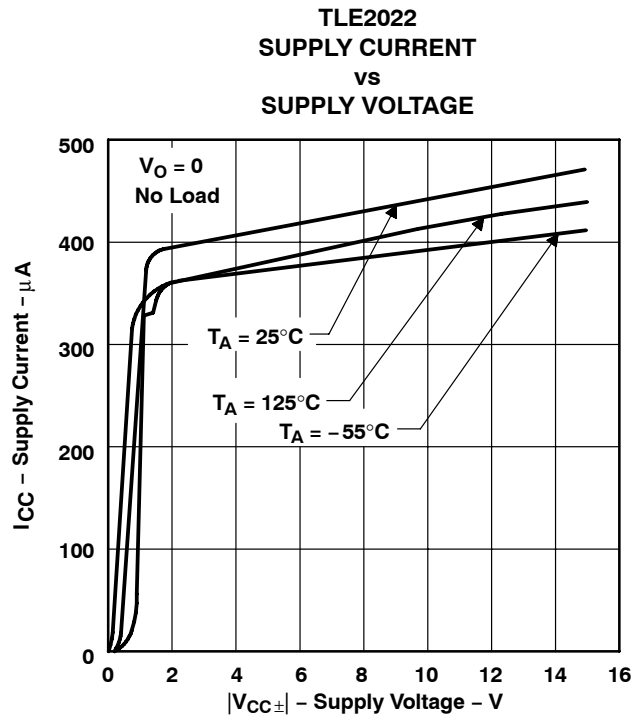


Figure 39

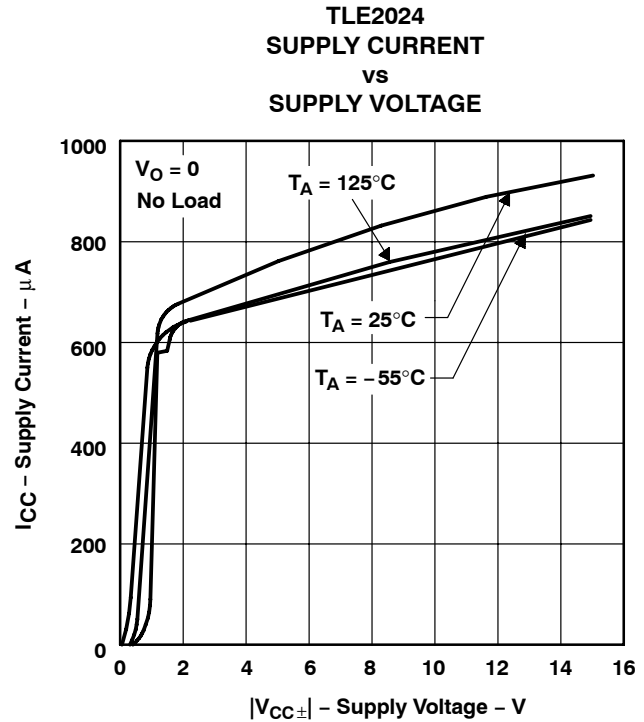


Figure 40

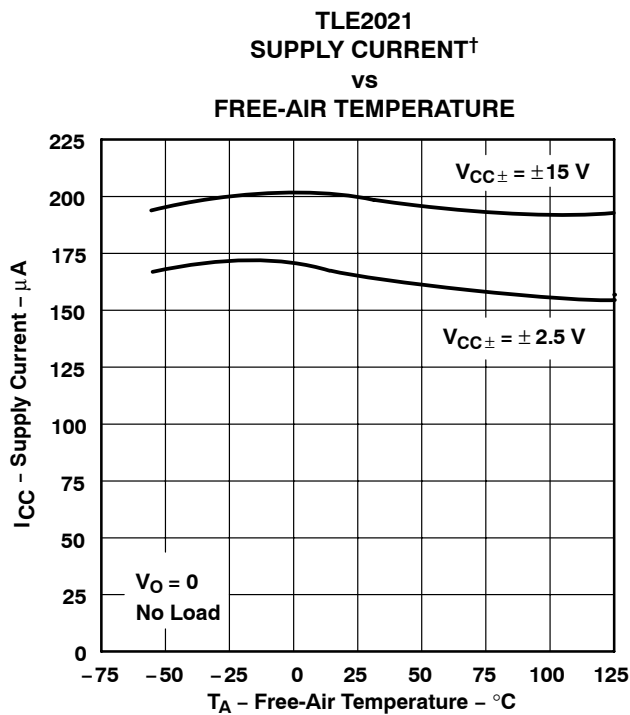


Figure 41

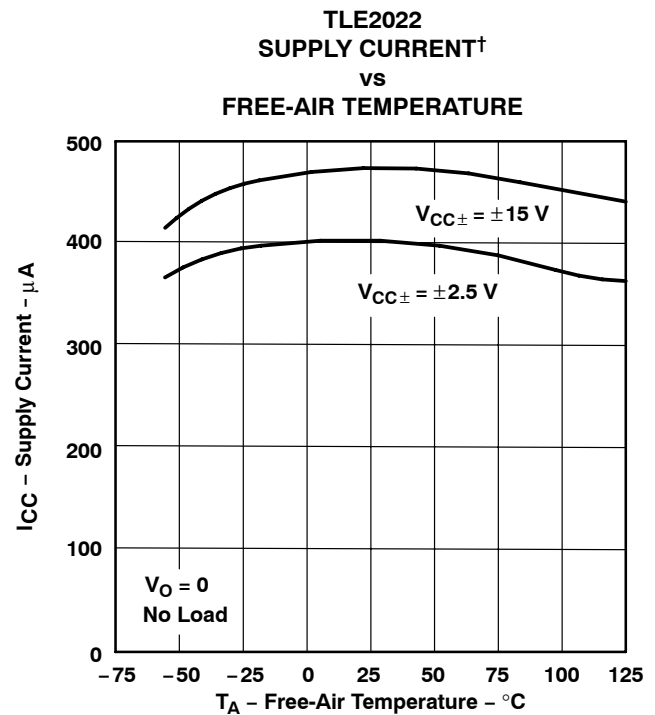


Figure 42

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

# TLE202x, TLE202xA, TLE202xB, TLE202xY EXCALIBUR HIGH-SPEED LOW-POWER PRECISION OPERATIONAL AMPLIFIERS

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## TYPICAL CHARACTERISTICS

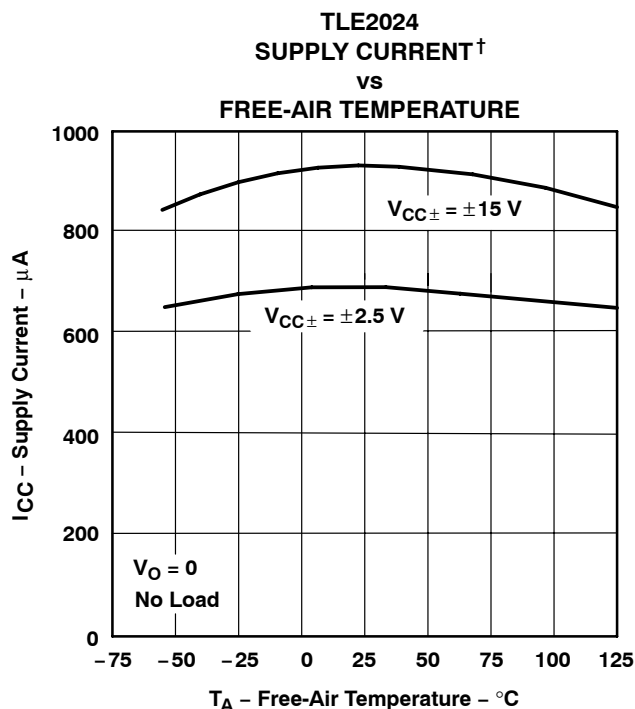


Figure 43

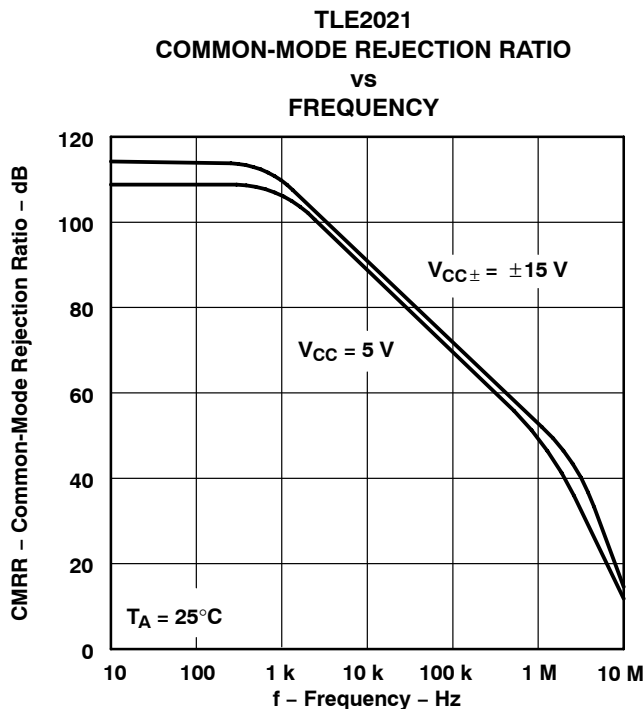


Figure 44

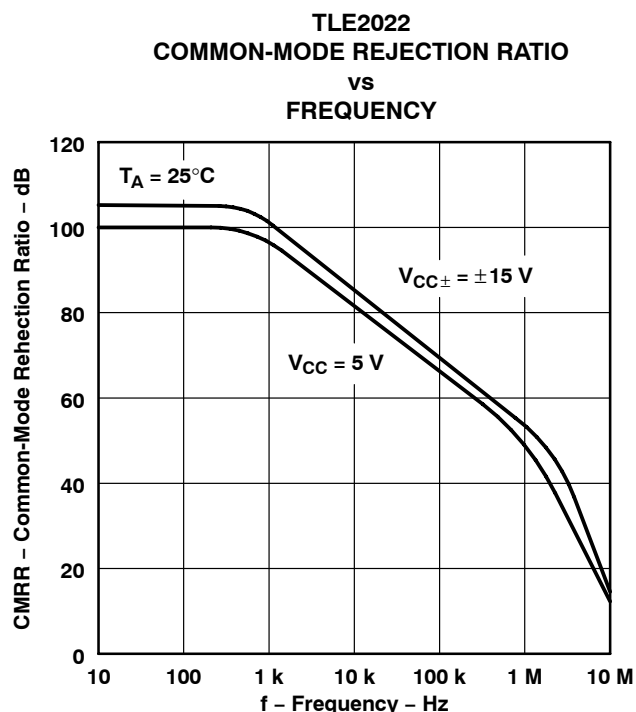


Figure 45

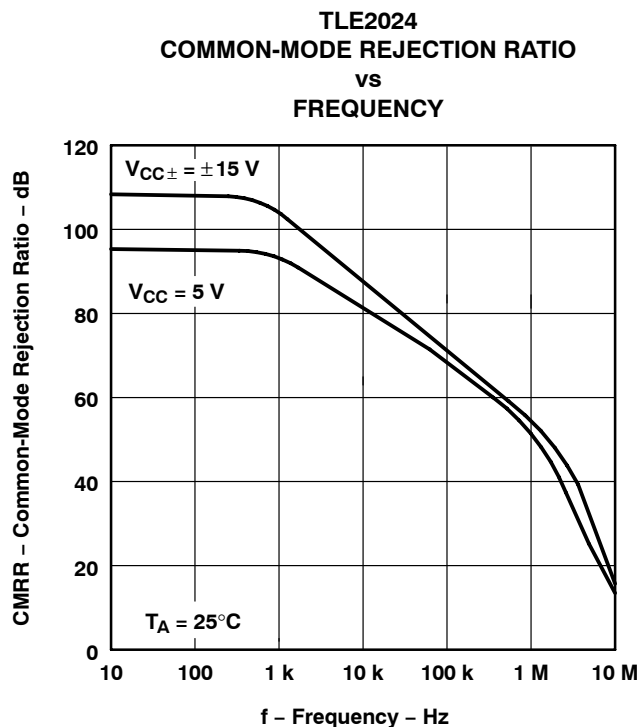


Figure 46

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

# TLE202x, TLE202xA, TLE202xB, TLE202xY EXCALIBUR HIGH-SPEED LOW-POWER PRECISION OPERATIONAL AMPLIFIERS

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## TYPICAL CHARACTERISTICS

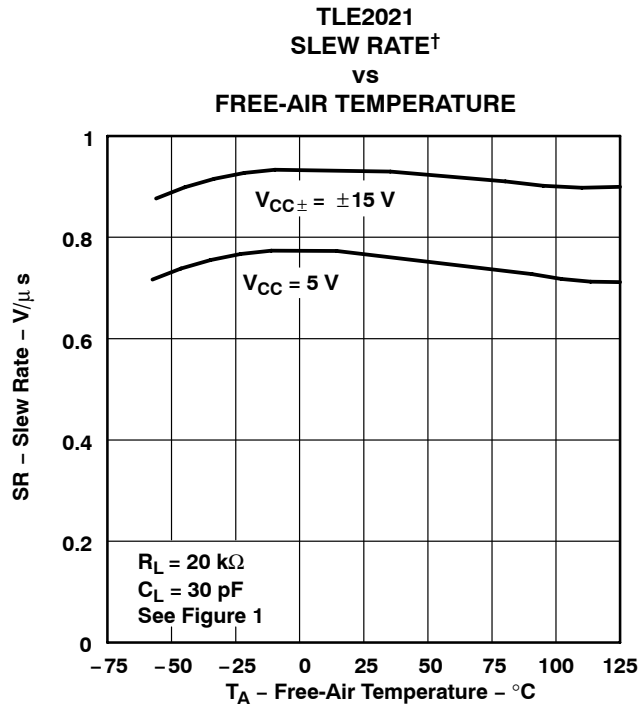


Figure 47

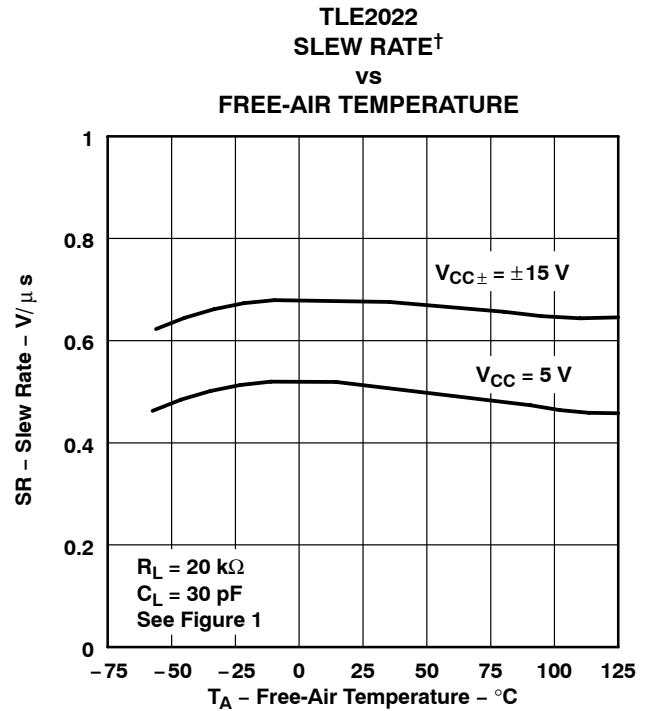


Figure 48

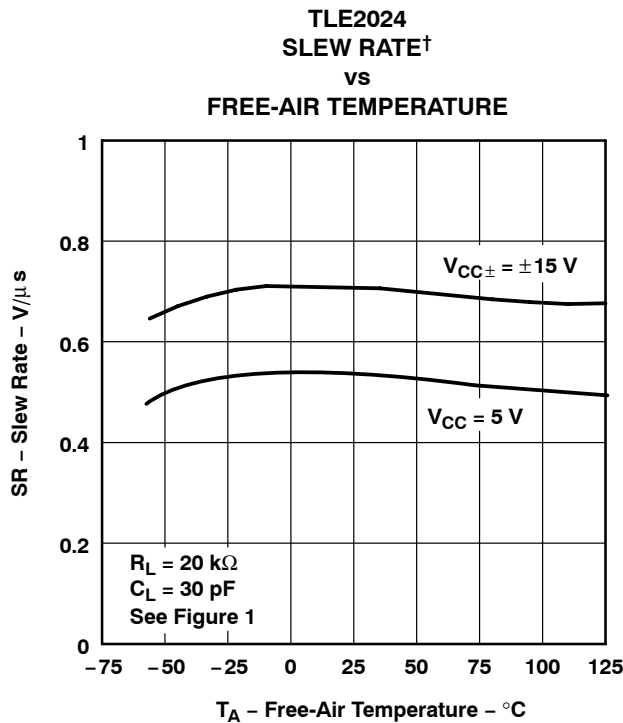


Figure 49

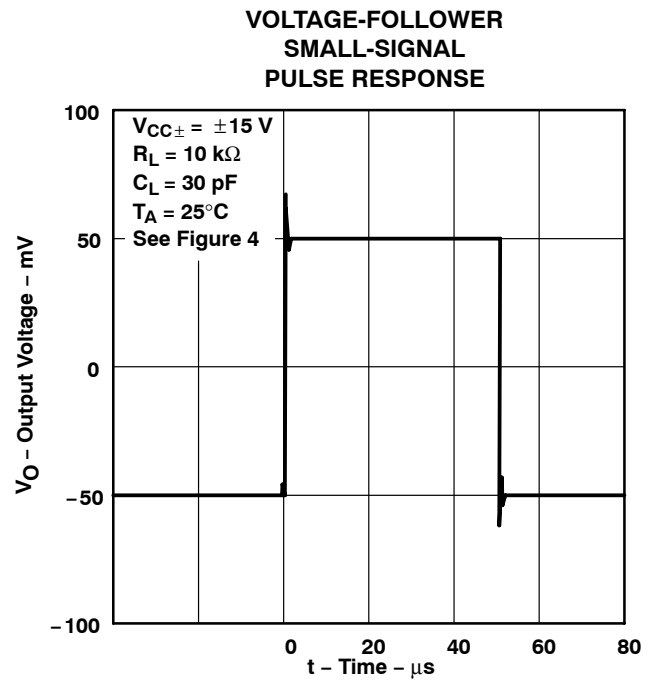


Figure 50

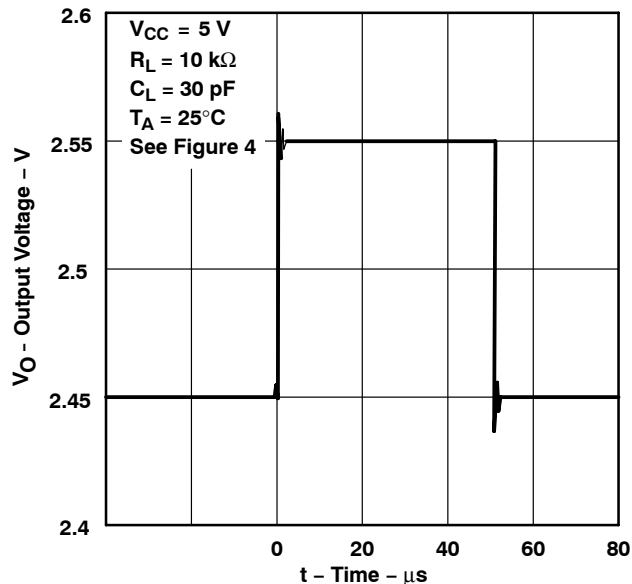
<sup>†</sup> Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

# TLE202x, TLE202xA, TLE202xB, TLE202xY EXCALIBUR HIGH-SPEED LOW-POWER PRECISION OPERATIONAL AMPLIFIERS

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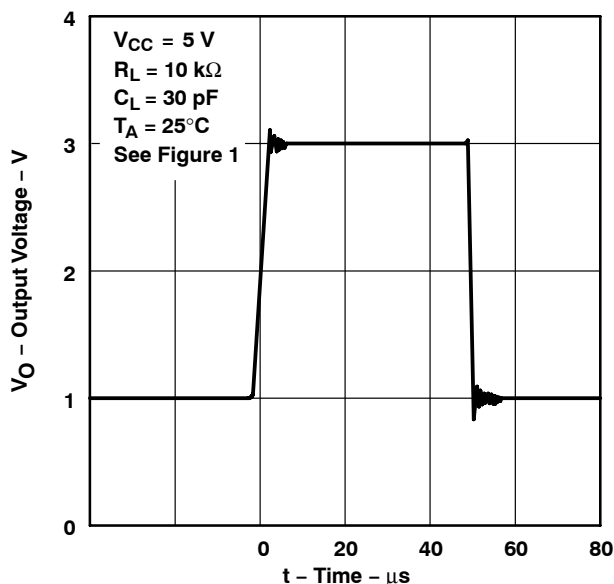
## TYPICAL CHARACTERISTICS

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



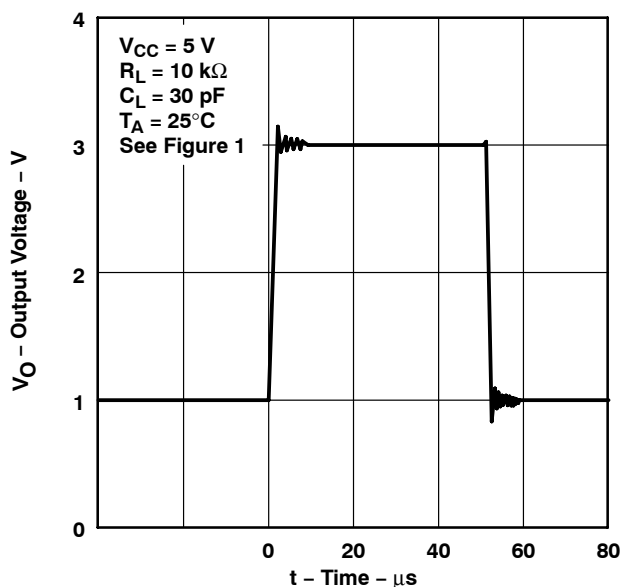
**Figure 51**

**TLE2021  
VOLTAGE-FOLLOWER LARGE-SIGNAL  
PULSE RESPONSE**



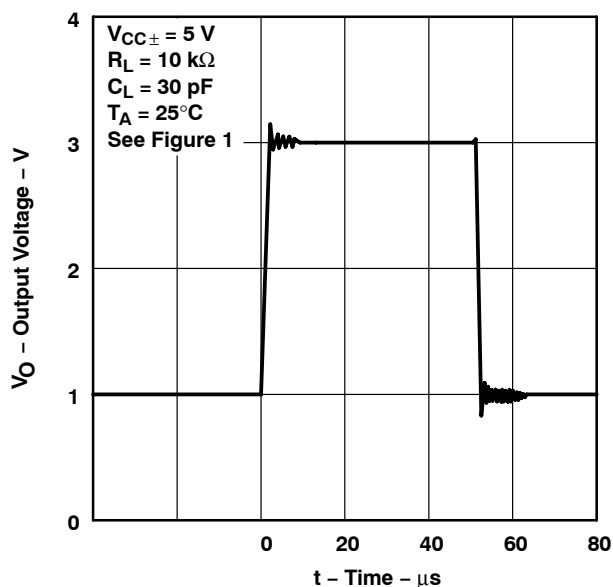
**Figure 52**

**TLE2022  
VOLTAGE-FOLLOWER LARGE-SIGNAL  
PULSE RESPONSE**



**Figure 53**

**TLE2024  
VOLTAGE-FOLLOWER LARGE-SCALE  
PULSE RESPONSE**



**Figure 54**

# TLE202x, TLE202xA, TLE202xB, TLE202xY EXCALIBUR HIGH-SPEED LOW-POWER PRECISION OPERATIONAL AMPLIFIERS

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## TYPICAL CHARACTERISTICS

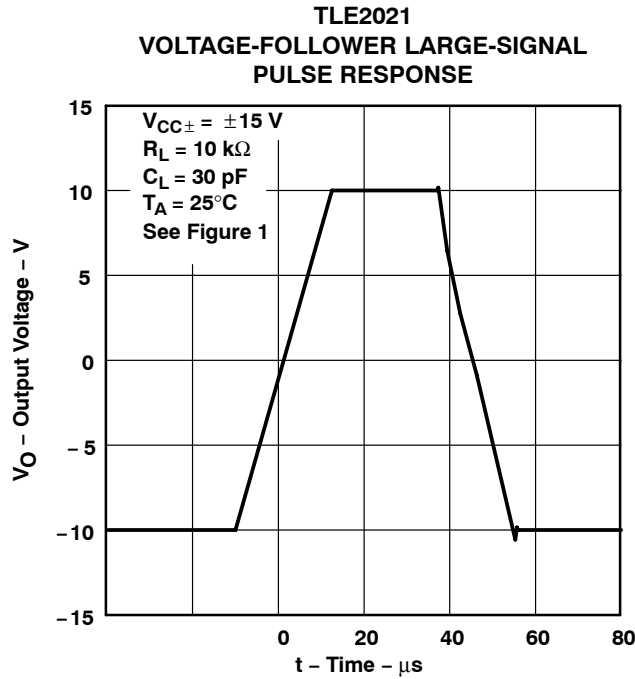


Figure 55

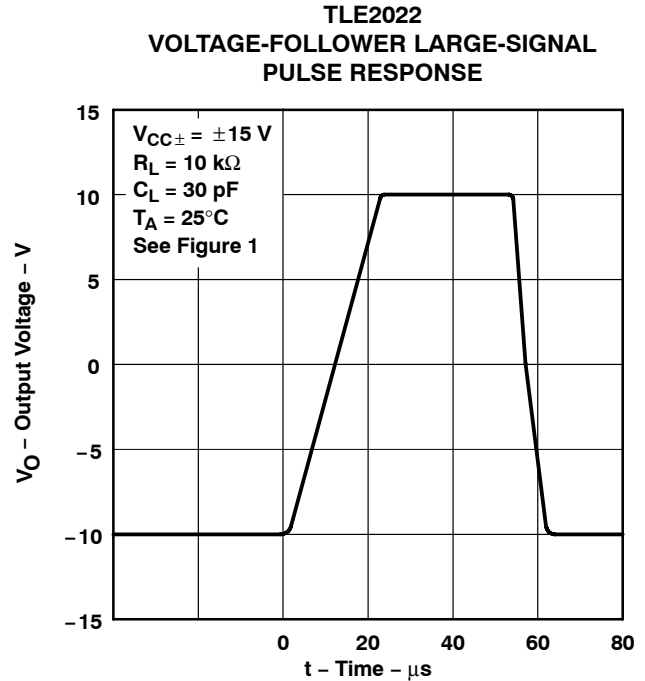


Figure 56

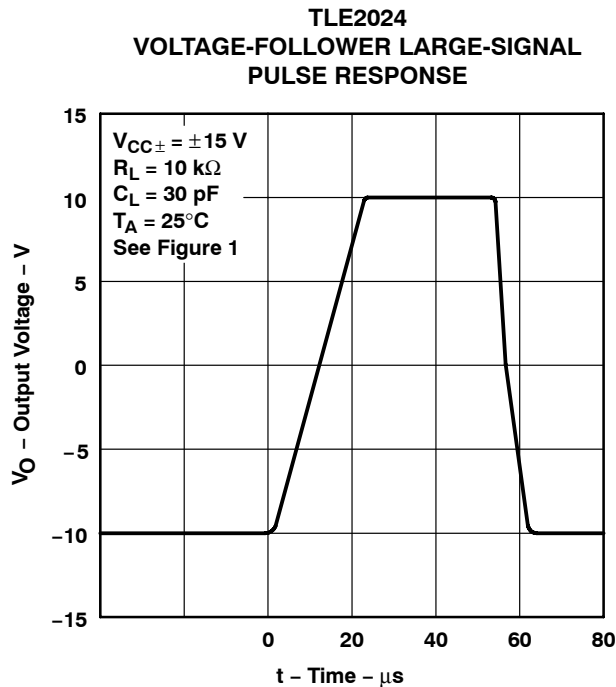


Figure 57

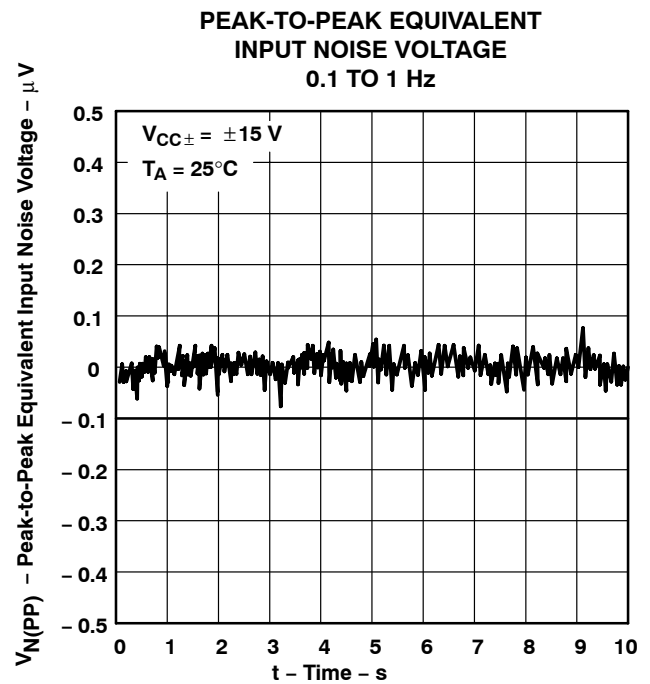


Figure 58

# TLE202x, TLE202xA, TLE202xB, TLE202xY EXCALIBUR HIGH-SPEED LOW-POWER PRECISION OPERATIONAL AMPLIFIERS

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## TYPICAL CHARACTERISTICS

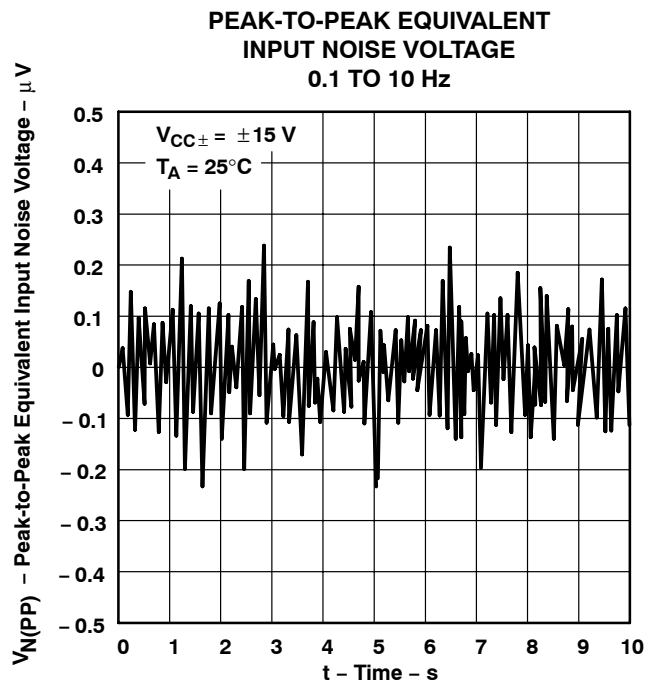


Figure 59

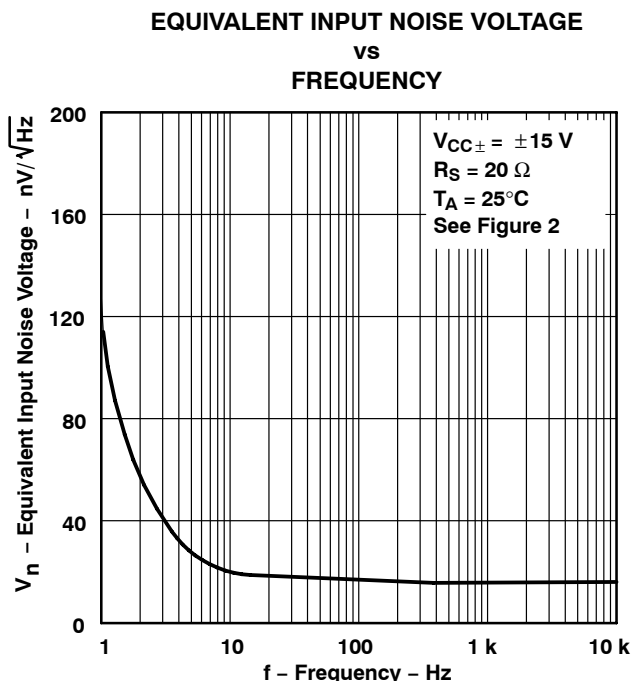


Figure 60

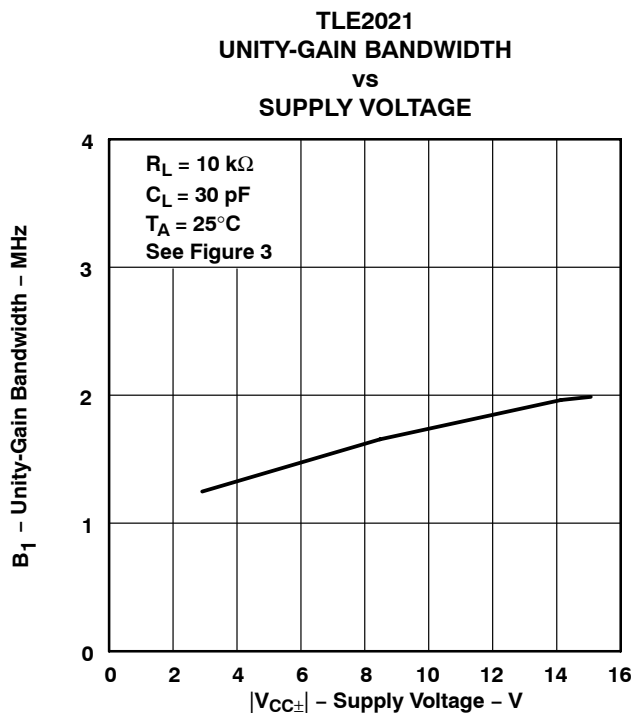


Figure 61

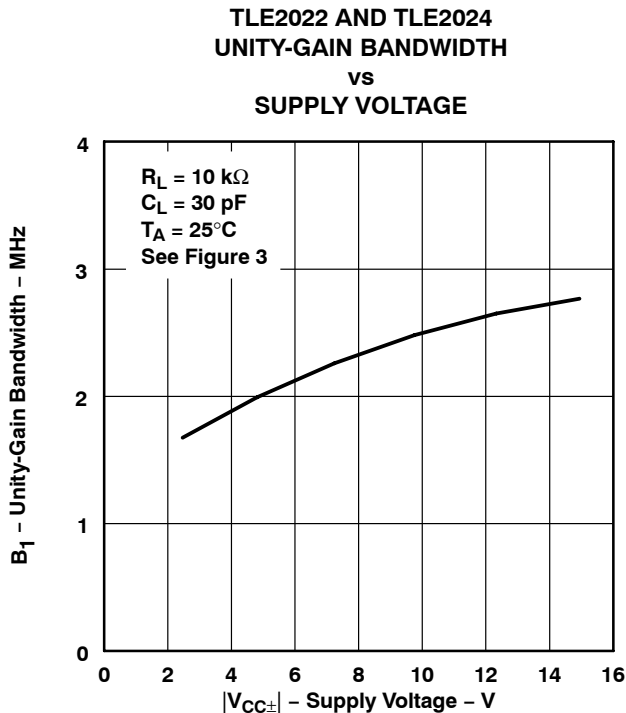


Figure 62

# TLE202x, TLE202xA, TLE202xB, TLE202xY EXCALIBUR HIGH-SPEED LOW-POWER PRECISION OPERATIONAL AMPLIFIERS

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## TYPICAL CHARACTERISTICS

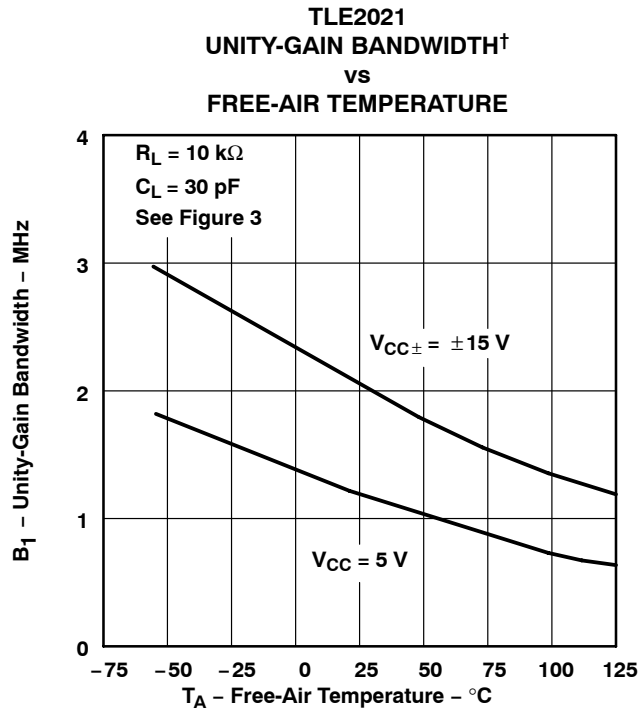


Figure 63

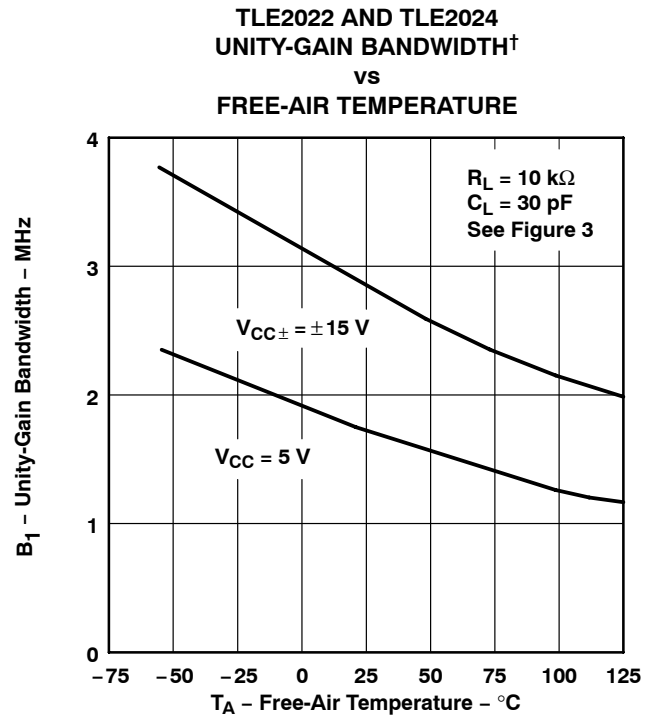


Figure 64

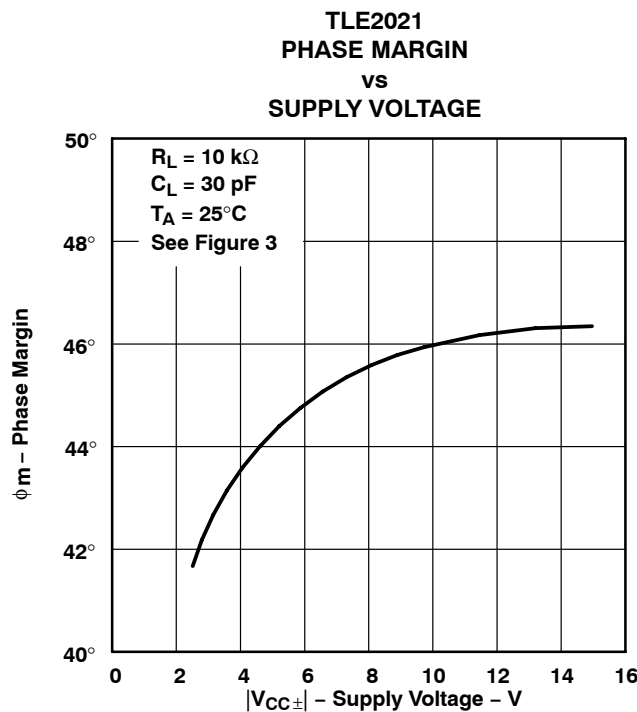


Figure 65

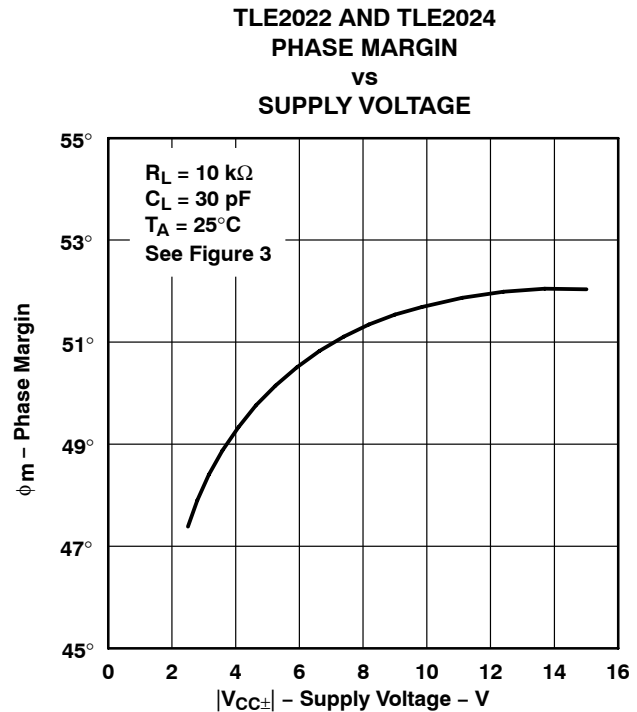


Figure 66

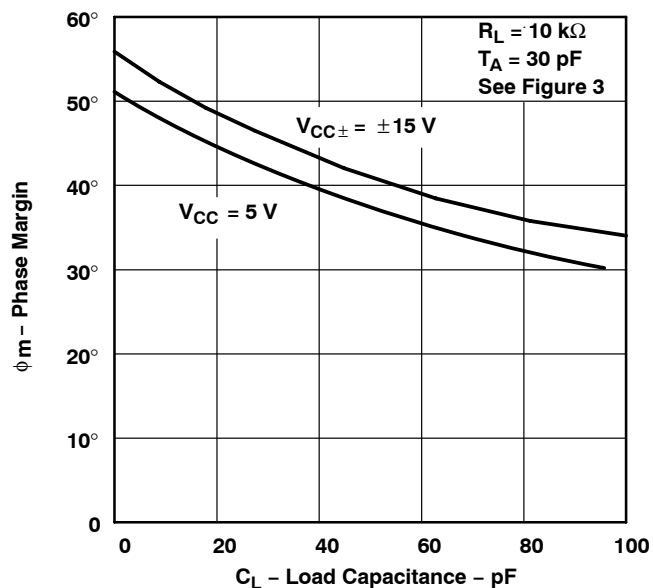
† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

# TLE202x, TLE202xA, TLE202xB, TLE202xY EXCALIBUR HIGH-SPEED LOW-POWER PRECISION OPERATIONAL AMPLIFIERS

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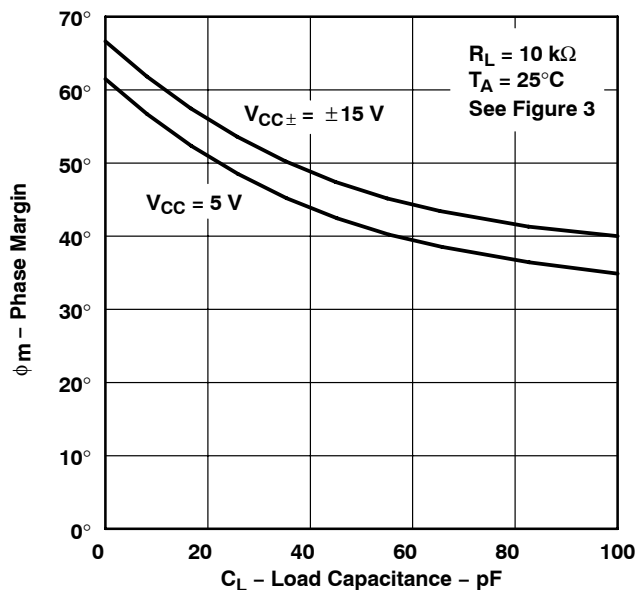
## TYPICAL CHARACTERISTICS

**TLE2021  
PHASE MARGIN  
vs  
LOAD CAPACITANCE**



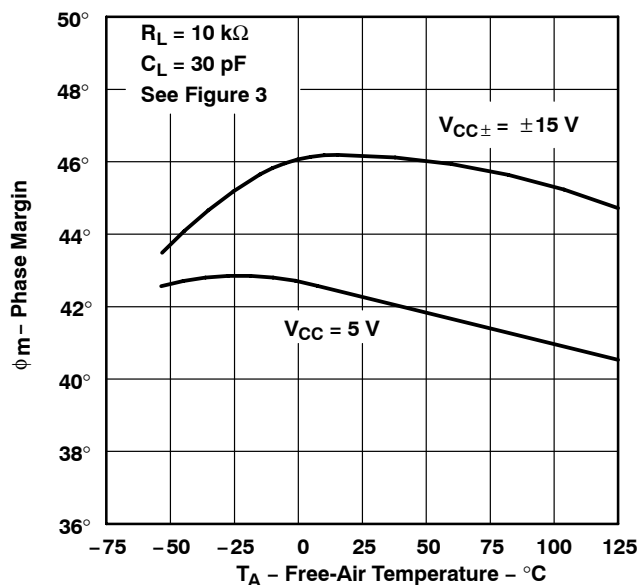
**Figure 67**

**TLE2022 AND TLE2024  
PHASE MARGIN  
vs  
LOAD CAPACITANCE**



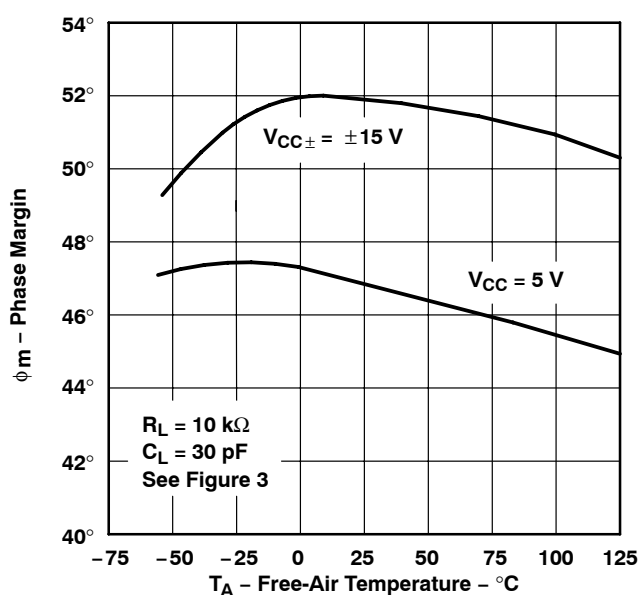
**Figure 68**

**TLE2021  
PHASE MARGIN†  
vs  
FREE-AIR TEMPERATURE**



**Figure 69**

**TLE2022 AND TLE2024  
PHASE MARGIN†  
vs  
FREE-AIR TEMPERATURE**



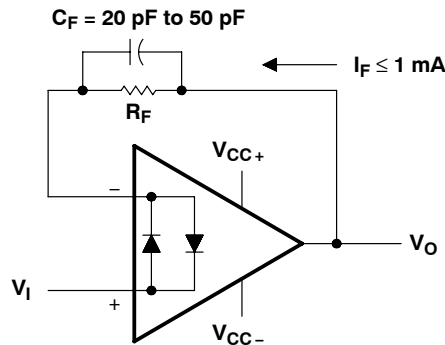
**Figure 70**

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

## APPLICATION INFORMATION

### voltage-follower applications

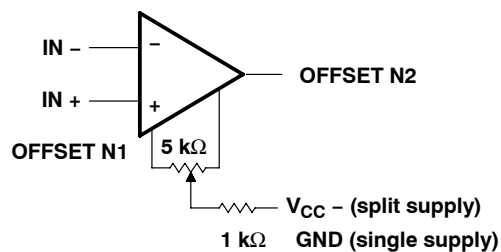
The TLE202x circuitry includes input-protection diodes to limit the voltage across the input transistors; however, no provision is made in the circuit to limit the current if these diodes are forward biased. This condition can occur when the device is operated in the voltage-follower configuration and driven with a fast, large-signal pulse. It is recommended that a feedback resistor be used to limit the current to a maximum of 1 mA to prevent degradation of the device. This feedback resistor forms a pole with the input capacitance of the device. For feedback resistor values greater than 10 k $\Omega$ , this pole degrades the amplifier phase margin. This problem can be alleviated by adding a capacitor (20 pF to 50 pF) in parallel with the feedback resistor (see Figure 71).



**Figure 71. Voltage Follower**

### Input offset voltage nulling

The TLE202x series offers external null pins that further reduce the input offset voltage. The circuit in Figure 72 can be connected as shown if this feature is desired. When external nulling is not needed, the null pins may be left disconnected.



**Figure 72. Input Offset Voltage Null Circuit**

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## APPLICATION INFORMATION

### macromodel information

Macromodel information provided was derived using Microsim *Parts*™, the model generation software used with Microsim *PSpice*™. The Boyle macromodel (see Note 5) and subcircuit in Figure 73, Figure 74, and Figure 75 were generated using the TLE202x typical electrical and operating characteristics at 25°C. Using this information, output simulations of the following key parameters can be generated to a tolerance of 20% (in most cases):

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

NOTE 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).

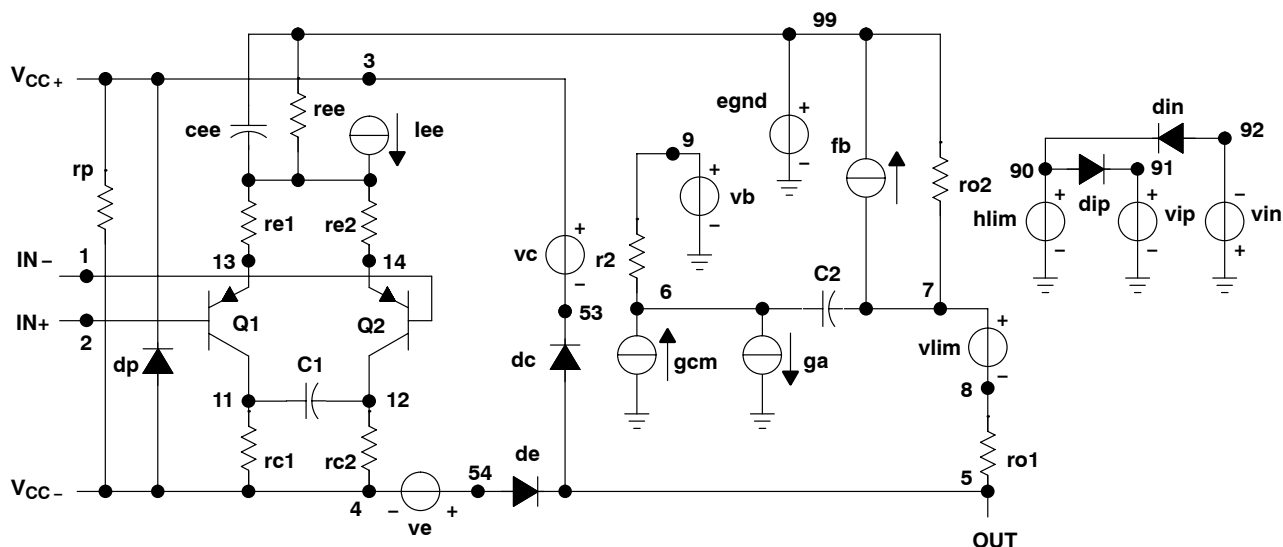


Figure 73. Boyle Subcircuit

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

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```
.SUBCKT TLE2021 1 2 3 4 5
*
c1 11 12 6.244E-12
c2 6 7 13.4E-12
c3 87 0 10.64E-9
cpsr 85 86 15.9E-9
dcm+ 81 82 dx
dcm- 83 81 dx
dc 5 53 dx
de 54 5 dx
dlp 90 91 dx
dln 92 90 dx
dp 4 3 dx
ecmr 84 99 (2 99) 1
egnd 99 0 poly(2) (3,0) (4,0) 0 .5 .5
epsr 85 0 poly(1) (3,4) -60E-6 2.0E-6
ense 89 2 poly(1) (88,0) 120E-6 1
fb 7 99 poly(6) vb vc ve vlp vln vpsr 0 547.3E6
+ -50E7 50E7 50E7 -50E7 547E6
ga 6 0 11 12 188.5E-6
gcm 0 6 10 99 335.2E-12
gpsr 85 86 (85,86) 100E-6
grc1 4 11 (4,11) 1.885E-4
grc2 4 12 (4,12) 1.885E-4
gre1 13 10 (13,10) 6.82E-4
gre2 14 10 (14,10) 6.82E-4
hlim 90 0 vlim 1k

hcmr 80 1 poly(2) vcm+ vcm- 0 1E2 1E2
irp 3 4 185E-6
iee 3 10 dc 15.67E-6
iio 2 0 2E-9
ii 88 0 1E-21
q1 11 89 13 qx
q2 12 80 14 qx
R2 6 9 100.0E3
rcm 84 81 1K
ree 10 99 14.76E6
rn1 87 0 2.55E8
rn2 87 88 11.67E3
ro1 8 5 62
ro2 7 99 63
vcm+ 82 99 13.3
vcm- 83 99 -14.6
vb 9 0 dc 0
vc 3 53 dc 1.300
ve 54 4 dc 1.500
vlim 7 8 dc 0
vlp 91 0 dc 3.600
vln 0 92 dc 3.600
vpsr 0 86 dc 0
.model dx d(is=800.0E-18)
.model qx pnp(is=800.0E-18 bf=270)
.ends
```

**Figure 74. Boyle Macromodel for the TLE2021**

```
.SUBCKT TLE2022 1 2 3 4 5
*
c1 11 12 6.814E-12
c2 6 7 20.00E-12
dc 5 53 dx
de 54 5 dx
dlp 90 91 dx
dln 92 90 dx
dp 4 3 dx
egnd 99 0 poly(2) (3,0) (4,0) 0 .5 .5
fb 7 99 poly(5) vb vc ve vlp vln 0
+ 45.47E6 -50E6 50E6 50E6 -50E6
ga 6 0 11 12 377.9E-6
gcm 0 6 10 99 7.84E-10
iee 3 10 DC 18.07E-6
hlim 90 0 vlim 1k
q1 11 2 13 qx
q2 12 1 14 qx
r2 6 9 100.0E3

rc1 4 11 2.842E3
rc2 4 12 2.842E3
ge1 13 10 (10,13) 31.299E-3
ge2 14 10 (10,14) 31.299E-3
ree 10 99 11.07E6
ro1 8 5 250
ro2 7 99 250
rp 3 4 137.2E3
vb 9 0 dc 0
vc 3 53 dc 1.300
ve 54 4 dc 1.500
vlim 7 8 dc 0
vlp 91 0 dc 3
vln 0 92 dc 3
.model dx d(is=800.0E-18)
.model qx pnp(is=800.0E-18 bf=257.1)
.ends
```

**Figure 75. Boyle Macromodel for the TLE2022**



## PACKAGING INFORMATION

| Orderable Device | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package<br>Qty | Eco Plan<br>(2)     | Lead finish/<br>Ball material<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5)                 | Samples                 |
|------------------|---------------|--------------|--------------------|------|----------------|---------------------|--------------------------------------|----------------------|--------------|-----------------------------------------|-------------------------|
| 5962-9088101MPA  | LIFEBUY       | CDIP         | JG                 | 8    | 50             | Non-RoHS<br>& Green | SNPB                                 | N / A for Pkg Type   | -55 to 125   | 9088101MPA<br>TLE2021M                  |                         |
| 5962-9088102M2A  | ACTIVE        | LCCC         | FK                 | 20   | 55             | Non-RoHS<br>& Green | SNPB                                 | N / A for Pkg Type   | -55 to 125   | 5962-<br>9088102M2A<br>TLE2022MFKB      | <a href="#">Samples</a> |
| 5962-9088102MPA  | ACTIVE        | CDIP         | JG                 | 8    | 50             | Non-RoHS<br>& Green | SNPB                                 | N / A for Pkg Type   | -55 to 125   | 9088102MPA<br>TLE2022M                  | <a href="#">Samples</a> |
| 5962-9088103M2A  | ACTIVE        | LCCC         | FK                 | 20   | 55             | Non-RoHS<br>& Green | SNPB                                 | N / A for Pkg Type   | -55 to 125   | 5962-<br>9088103M2A<br>TLE2024MFKB      | <a href="#">Samples</a> |
| 5962-9088103MCA  | ACTIVE        | CDIP         | J                  | 14   | 25             | Non-RoHS<br>& Green | SNPB                                 | N / A for Pkg Type   | -55 to 125   | 5962-9088103MC<br>A<br>TLE2024MJB       | <a href="#">Samples</a> |
| 5962-9088104Q2A  | LIFEBUY       | LCCC         | FK                 | 20   | 55             | Non-RoHS<br>& Green | SNPB                                 | N / A for Pkg Type   | -55 to 125   | 5962-<br>9088104Q2A<br>TLE2021<br>AMFKB |                         |
| 5962-9088104QPA  | LIFEBUY       | CDIP         | JG                 | 8    | 50             | Non-RoHS<br>& Green | SNPB                                 | N / A for Pkg Type   | -55 to 125   | 9088104QPA<br>TLE2021AM                 |                         |
| 5962-9088105Q2A  | ACTIVE        | LCCC         | FK                 | 20   | 55             | Non-RoHS<br>& Green | SNPB                                 | N / A for Pkg Type   | -55 to 125   | 5962-<br>9088105Q2A<br>TLE2022A<br>MFKB | <a href="#">Samples</a> |
| 5962-9088105QPA  | ACTIVE        | CDIP         | JG                 | 8    | 50             | Non-RoHS<br>& Green | SNPB                                 | N / A for Pkg Type   | -55 to 125   | 9088105QPA<br>TLE2022AM                 | <a href="#">Samples</a> |
| 5962-9088106Q2A  | ACTIVE        | LCCC         | FK                 | 20   | 55             | Non-RoHS<br>& Green | SNPB                                 | N / A for Pkg Type   | -55 to 125   | 5962-<br>9088106Q2A<br>TLE2024A<br>MFKB | <a href="#">Samples</a> |
| 5962-9088106QCA  | LIFEBUY       | CDIP         | J                  | 14   | 25             | Non-RoHS<br>& Green | SNPB                                 | N / A for Pkg Type   | -55 to 125   | 5962-9088106QC<br>A<br>TLE2024AMJB      |                         |
| 5962-9088107Q2A  | LIFEBUY       | LCCC         | FK                 | 20   | 55             | Non-RoHS<br>& Green | SNPB                                 | N / A for Pkg Type   | -55 to 125   | 5962-<br>9088107Q2A<br>TLE2021          |                         |

| Orderable Device | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package<br>Qty | Eco Plan<br>(2)     | Lead finish/<br>Ball material<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5)                 | Samples                 |
|------------------|---------------|--------------|--------------------|------|----------------|---------------------|--------------------------------------|----------------------|--------------|-----------------------------------------|-------------------------|
|                  |               |              |                    |      |                |                     |                                      |                      |              | BMFKB                                   |                         |
| 5962-9088107QPA  | LIFEBUY       | CDIP         | JG                 | 8    | 50             | Non-RoHS<br>& Green | SNPB                                 | N / A for Pkg Type   | -55 to 125   | 9088107QPA<br>TLE2021BM                 |                         |
| 5962-9088108Q2A  | ACTIVE        | LCCC         | FK                 | 20   | 55             | Non-RoHS<br>& Green | SNPB                                 | N / A for Pkg Type   | -55 to 125   | 5962-<br>9088108Q2A<br>TLE2022B<br>MFKB | <a href="#">Samples</a> |
| 5962-9088108QPA  | ACTIVE        | CDIP         | JG                 | 8    | 50             | Non-RoHS<br>& Green | SNPB                                 | N / A for Pkg Type   | -55 to 125   | 9088108QPA<br>TLE2022BM                 | <a href="#">Samples</a> |
| 5962-9088109Q2A  | ACTIVE        | LCCC         | FK                 | 20   | 55             | Non-RoHS<br>& Green | SNPB                                 | N / A for Pkg Type   | -55 to 125   | 5962-<br>9088109Q2A<br>TLE2024<br>BMFKB | <a href="#">Samples</a> |
| 5962-9088109QCA  | ACTIVE        | CDIP         | J                  | 14   | 25             | Non-RoHS<br>& Green | SNPB                                 | N / A for Pkg Type   | -55 to 125   | 5962-9088109QC<br>A<br>TLE2024BMJB      | <a href="#">Samples</a> |
| TLE2021ACDR      | ACTIVE        | SOIC         | D                  | 8    | 2500           | RoHS & Green        | NIPDAU                               | Level-1-260C-UNLIM   |              | 2021AC                                  | <a href="#">Samples</a> |
| TLE2021ACP       | LIFEBUY       | PDIP         | P                  | 8    | 50             | RoHS & Green        | NIPDAU                               | N / A for Pkg Type   |              | TLE2021AC                               |                         |
| TLE2021AIDR      | ACTIVE        | SOIC         | D                  | 8    | 2500           | RoHS & Green        | NIPDAU                               | Level-1-260C-UNLIM   |              | 2021AI                                  | <a href="#">Samples</a> |
| TLE2021AIP       | LIFEBUY       | PDIP         | P                  | 8    | 50             | RoHS & Green        | NIPDAU                               | N / A for Pkg Type   |              | TLE2021AI                               |                         |
| TLE2021AMFKB     | LIFEBUY       | LCCC         | FK                 | 20   | 55             | Non-RoHS<br>& Green | SNPB                                 | N / A for Pkg Type   | -55 to 125   | 5962-<br>9088104Q2A<br>TLE2021<br>AMFKB |                         |
| TLE2021AMJGB     | LIFEBUY       | CDIP         | JG                 | 8    | 50             | Non-RoHS<br>& Green | SNPB                                 | N / A for Pkg Type   | -55 to 125   | 9088104QPA<br>TLE2021AM                 |                         |
| TLE2021BMFKB     | LIFEBUY       | LCCC         | FK                 | 20   | 55             | Non-RoHS<br>& Green | SNPB                                 | N / A for Pkg Type   |              | 5962-<br>9088107Q2A<br>TLE2021<br>BMFKB |                         |
| TLE2021BMJG      | LIFEBUY       | CDIP         | JG                 | 8    | 50             | Non-RoHS<br>& Green | SNPB                                 | N / A for Pkg Type   | -55 to 125   | TLE2021<br>BMJG                         |                         |
| TLE2021BMJGB     | LIFEBUY       | CDIP         | JG                 | 8    | 50             | Non-RoHS<br>& Green | SNPB                                 | N / A for Pkg Type   |              | 9088107QPA<br>TLE2021BM                 |                         |
| TLE2021CD        | LIFEBUY       | SOIC         | D                  | 8    | 75             | RoHS & Green        | NIPDAU                               | Level-1-260C-UNLIM   | 0 to 70      | 2021C                                   |                         |

| Orderable Device | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package<br>Qty | Eco Plan<br>(2)     | Lead finish/<br>Ball material<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5)                 | Samples                 |
|------------------|---------------|--------------|--------------------|------|----------------|---------------------|--------------------------------------|----------------------|--------------|-----------------------------------------|-------------------------|
| TLE2021CDG4      | LIFEBUY       | SOIC         | D                  | 8    | 75             | RoHS & Green        | NIPDAU                               | Level-1-260C-UNLIM   | 0 to 70      | 2021C                                   |                         |
| TLE2021CDR       | ACTIVE        | SOIC         | D                  | 8    | 2500           | RoHS & Green        | NIPDAU                               | Level-1-260C-UNLIM   | 0 to 70      | 2021C                                   | <a href="#">Samples</a> |
| TLE2021CP        | LIFEBUY       | PDIP         | P                  | 8    | 50             | RoHS & Green        | NIPDAU                               | N / A for Pkg Type   | 0 to 70      | TLE2021CP                               |                         |
| TLE2021CPE4      | LIFEBUY       | PDIP         | P                  | 8    | 50             | RoHS & Green        | NIPDAU                               | N / A for Pkg Type   | 0 to 70      | TLE2021CP                               |                         |
| TLE2021ID        | LIFEBUY       | SOIC         | D                  | 8    | 75             | RoHS & Green        | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | 2021I                                   |                         |
| TLE2021IDG4      | LIFEBUY       | SOIC         | D                  | 8    | 75             | RoHS & Green        | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | 2021I                                   |                         |
| TLE2021IDR       | ACTIVE        | SOIC         | D                  | 8    | 2500           | RoHS & Green        | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | 2021I                                   | <a href="#">Samples</a> |
| TLE2021IP        | LIFEBUY       | PDIP         | P                  | 8    | 50             | RoHS & Green        | NIPDAU                               | N / A for Pkg Type   | -40 to 85    | TLE2021IP                               |                         |
| TLE2021MD        | LIFEBUY       | SOIC         | D                  | 8    | 75             | RoHS & Green        | NIPDAU                               | Level-1-260C-UNLIM   | -55 to 125   | 2021M                                   |                         |
| TLE2021MDG4      | LIFEBUY       | SOIC         | D                  | 8    | 75             | RoHS & Green        | NIPDAU                               | Level-1-260C-UNLIM   |              | 2021M                                   |                         |
| TLE2021MJG       | LIFEBUY       | CDIP         | JG                 | 8    | 50             | Non-RoHS<br>& Green | SNPB                                 | N / A for Pkg Type   | -55 to 125   | TLE2021MJG                              |                         |
| TLE2021MJGB      | LIFEBUY       | CDIP         | JG                 | 8    | 50             | Non-RoHS<br>& Green | SNPB                                 | N / A for Pkg Type   | -55 to 125   | 9088101MPA<br>TLE2021M                  |                         |
| TLE2022ACD       | LIFEBUY       | SOIC         | D                  | 8    | 75             | RoHS & Green        | NIPDAU                               | Level-1-260C-UNLIM   | 0 to 70      | 2022AC                                  |                         |
| TLE2022ACDG4     | LIFEBUY       | SOIC         | D                  | 8    | 75             | RoHS & Green        | NIPDAU                               | Level-1-260C-UNLIM   | 0 to 70      | 2022AC                                  |                         |
| TLE2022ACDR      | ACTIVE        | SOIC         | D                  | 8    | 2500           | RoHS & Green        | NIPDAU                               | Level-1-260C-UNLIM   |              | 2022AC                                  | <a href="#">Samples</a> |
| TLE2022ACP       | LIFEBUY       | PDIP         | P                  | 8    | 50             | RoHS & Green        | NIPDAU                               | N / A for Pkg Type   |              | TLE2022AC                               |                         |
| TLE2022AIDR      | ACTIVE        | SOIC         | D                  | 8    | 2500           | RoHS & Green        | NIPDAU                               | Level-1-260C-UNLIM   |              | 2022AI                                  | <a href="#">Samples</a> |
| TLE2022AIP       | LIFEBUY       | PDIP         | P                  | 8    | 50             | RoHS & Green        | NIPDAU                               | N / A for Pkg Type   |              | TLE2022AI                               |                         |
| TLE2022AMDR      | ACTIVE        | SOIC         | D                  | 8    | 2500           | RoHS & Green        | NIPDAU                               | Level-1-260C-UNLIM   | -55 to 125   | 2022AM                                  | <a href="#">Samples</a> |
| TLE2022AMDRG4    | ACTIVE        | SOIC         | D                  | 8    | 2500           | RoHS & Green        | NIPDAU                               | Level-1-260C-UNLIM   |              | 2022AM                                  | <a href="#">Samples</a> |
| TLE2022AMFKB     | ACTIVE        | LCCC         | FK                 | 20   | 55             | Non-RoHS<br>& Green | SNPB                                 | N / A for Pkg Type   | -55 to 125   | 5962-<br>9088105Q2A<br>TLE2022A<br>MFKB | <a href="#">Samples</a> |
| TLE2022AMJGB     | ACTIVE        | CDIP         | JG                 | 8    | 50             | Non-RoHS<br>& Green | SNPB                                 | N / A for Pkg Type   | -55 to 125   | 9088105QPA<br>TLE2022AM                 | <a href="#">Samples</a> |
| TLE2022BMFKB     | ACTIVE        | LCCC         | FK                 | 20   | 55             | Non-RoHS<br>& Green | SNPB                                 | N / A for Pkg Type   | -55 to 125   | 5962-<br>9088108Q2A                     | <a href="#">Samples</a> |

| Orderable Device | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package<br>Qty | Eco Plan<br>(2)     | Lead finish/<br>Ball material<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5)                 | Samples                 |
|------------------|---------------|--------------|--------------------|------|----------------|---------------------|--------------------------------------|----------------------|--------------|-----------------------------------------|-------------------------|
|                  |               |              |                    |      |                |                     |                                      |                      |              | TLE2022B<br>MFKB                        |                         |
| TLE2022BMJGB     | ACTIVE        | CDIP         | JG                 | 8    | 50             | Non-RoHS<br>& Green | SNPB                                 | N / A for Pkg Type   | -55 to 125   | 9088108QPA<br>TLE2022BM                 | <a href="#">Samples</a> |
| TLE2022CD        | LIFEBUY       | SOIC         | D                  | 8    | 75             | RoHS & Green        | NIPDAU                               | Level-1-260C-UNLIM   |              | 2022C                                   |                         |
| TLE2022CDR       | ACTIVE        | SOIC         | D                  | 8    | 2500           | RoHS & Green        | NIPDAU                               | Level-1-260C-UNLIM   | 0 to 70      | 2022C                                   | <a href="#">Samples</a> |
| TLE2022CP        | LIFEBUY       | PDIP         | P                  | 8    | 50             | RoHS & Green        | NIPDAU                               | N / A for Pkg Type   |              | TLE2022CP                               |                         |
| TLE2022CPE4      | LIFEBUY       | PDIP         | P                  | 8    | 50             | RoHS & Green        | NIPDAU                               | N / A for Pkg Type   |              | TLE2022CP                               |                         |
| TLE2022ID        | LIFEBUY       | SOIC         | D                  | 8    | 75             | RoHS & Green        | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | 2022I                                   |                         |
| TLE2022IDG4      | LIFEBUY       | SOIC         | D                  | 8    | 75             | RoHS & Green        | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | 2022I                                   |                         |
| TLE2022IDR       | ACTIVE        | SOIC         | D                  | 8    | 2500           | RoHS & Green        | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | 2022I                                   | <a href="#">Samples</a> |
| TLE2022IP        | LIFEBUY       | PDIP         | P                  | 8    | 50             | RoHS & Green        | NIPDAU                               | N / A for Pkg Type   |              | TLE2022IP                               |                         |
| TLE2022IPE4      | LIFEBUY       | PDIP         | P                  | 8    | 50             | RoHS & Green        | NIPDAU                               | N / A for Pkg Type   |              | TLE2022IP                               |                         |
| TLE2022MDR       | ACTIVE        | SOIC         | D                  | 8    | 2500           | RoHS & Green        | NIPDAU                               | Level-1-260C-UNLIM   | -55 to 125   | 2022M                                   | <a href="#">Samples</a> |
| TLE2022MDRG4     | ACTIVE        | SOIC         | D                  | 8    | 2500           | RoHS & Green        | NIPDAU                               | Level-1-260C-UNLIM   |              | 2022M                                   | <a href="#">Samples</a> |
| TLE2022MFKB      | ACTIVE        | LCCC         | FK                 | 20   | 55             | Non-RoHS<br>& Green | SNPB                                 | N / A for Pkg Type   | -55 to 125   | 5962-<br>9088102M2A<br>TLE2022MFKB      | <a href="#">Samples</a> |
| TLE2022MJG       | ACTIVE        | CDIP         | JG                 | 8    | 50             | Non-RoHS<br>& Green | SNPB                                 | N / A for Pkg Type   | -55 to 125   | TLE2022MJG                              | <a href="#">Samples</a> |
| TLE2022MJGB      | ACTIVE        | CDIP         | JG                 | 8    | 50             | Non-RoHS<br>& Green | SNPB                                 | N / A for Pkg Type   | -55 to 125   | 9088102MPA<br>TLE2022M                  | <a href="#">Samples</a> |
| TLE2024ACDWR     | ACTIVE        | SOIC         | DW                 | 16   | 2000           | RoHS & Green        | NIPDAU                               | Level-1-260C-UNLIM   |              | TLE2024AC                               | <a href="#">Samples</a> |
| TLE2024ACN       | LIFEBUY       | PDIP         | N                  | 14   | 25             | RoHS & Green        | NIPDAU                               | N / A for Pkg Type   |              | TLE2024ACN                              |                         |
| TLE2024AIDW      | LIFEBUY       | SOIC         | DW                 | 16   | 40             | RoHS & Green        | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | TLE2024AI                               |                         |
| TLE2024AIN       | LIFEBUY       | PDIP         | N                  | 14   | 25             | RoHS & Green        | NIPDAU                               | N / A for Pkg Type   |              | TLE2024AIN                              |                         |
| TLE2024AMFKB     | ACTIVE        | LCCC         | FK                 | 20   | 55             | Non-RoHS<br>& Green | SNPB                                 | N / A for Pkg Type   | -55 to 125   | 5962-<br>9088106Q2A<br>TLE2024A<br>MFKB | <a href="#">Samples</a> |

| Orderable Device | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package<br>Qty | Eco Plan<br>(2)     | Lead finish/<br>Ball material<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5)                 | Samples                 |
|------------------|---------------|--------------|--------------------|------|----------------|---------------------|--------------------------------------|----------------------|--------------|-----------------------------------------|-------------------------|
| TLE2024AMJB      | LIFEBUY       | CDIP         | J                  | 14   | 25             | Non-RoHS<br>& Green | SNPB                                 | N / A for Pkg Type   | -55 to 125   | 5962-9088106QC<br>A<br>TLE2024AMJB      |                         |
| TLE2024BMDWR     | ACTIVE        | SOIC         | DW                 | 16   | 2000           | RoHS & Green        | NIPDAU                               | Level-1-260C-UNLIM   | -55 to 125   | TLE2024BM                               | <a href="#">Samples</a> |
| TLE2024BMFKB     | ACTIVE        | LCCC         | FK                 | 20   | 55             | Non-RoHS<br>& Green | SNPB                                 | N / A for Pkg Type   | -55 to 125   | 5962-<br>9088109Q2A<br>TLE2024<br>BMFKB | <a href="#">Samples</a> |
| TLE2024BMJ       | LIFEBUY       | CDIP         | J                  | 14   | 25             | Non-RoHS<br>& Green | SNPB                                 | N / A for Pkg Type   | -55 to 125   | TLE2024BMJ                              |                         |
| TLE2024BMJB      | ACTIVE        | CDIP         | J                  | 14   | 25             | Non-RoHS<br>& Green | SNPB                                 | N / A for Pkg Type   | -55 to 125   | 5962-9088109QC<br>A<br>TLE2024BMJB      | <a href="#">Samples</a> |
| TLE2024CDWR      | ACTIVE        | SOIC         | DW                 | 16   | 2000           | RoHS & Green        | NIPDAU                               | Level-1-260C-UNLIM   |              | TLE2024C                                | <a href="#">Samples</a> |
| TLE2024CN        | LIFEBUY       | PDIP         | N                  | 14   | 25             | RoHS & Green        | NIPDAU                               | N / A for Pkg Type   |              | TLE2024CN                               |                         |
| TLE2024CNE4      | LIFEBUY       | PDIP         | N                  | 14   | 25             | RoHS & Green        | NIPDAU                               | N / A for Pkg Type   |              | TLE2024CN                               |                         |
| TLE2024IDW       | LIFEBUY       | SOIC         | DW                 | 16   | 40             | RoHS & Green        | NIPDAU                               | Level-1-260C-UNLIM   |              | TLE2024I                                |                         |
| TLE2024IN        | LIFEBUY       | PDIP         | N                  | 14   | 25             | RoHS & Green        | NIPDAU                               | N / A for Pkg Type   |              | TLE2024IN                               |                         |
| TLE2024MFKB      | ACTIVE        | LCCC         | FK                 | 20   | 55             | Non-RoHS<br>& Green | SNPB                                 | N / A for Pkg Type   | -55 to 125   | 5962-<br>9088103M2A<br>TLE2024MFKB      | <a href="#">Samples</a> |
| TLE2024MJB       | ACTIVE        | CDIP         | J                  | 14   | 25             | Non-RoHS<br>& Green | SNPB                                 | N / A for Pkg Type   | -55 to 125   | 5962-9088103MC<br>A<br>TLE2024MJB       | <a href="#">Samples</a> |

<sup>(1)</sup> The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

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

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

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

**OBsolete:** TI has discontinued the production of the device.

<sup>(2)</sup> **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

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

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

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

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

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

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

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

**OTHER QUALIFIED VERSIONS OF TLE2021, TLE2021A, TLE2021AM, TLE2021M, TLE2022, TLE2022A, TLE2022AM, TLE2022M, TLE2024, TLE2024A, TLE2024AM, TLE2024M :**

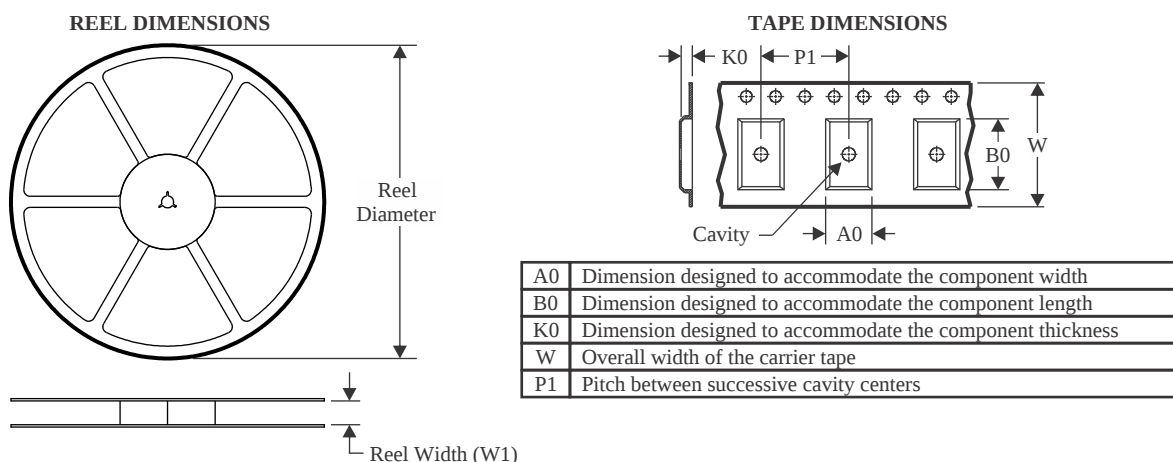
- Catalog : [TLE2021A](#), [TLE2021](#), [TLE2022A](#), [TLE2022](#), [TLE2024A](#), [TLE2024](#)
- Automotive : [TLE2021-Q1](#), [TLE2021A-Q1](#), [TLE2021A-Q1](#), [TLE2021-Q1](#), [TLE2022-Q1](#), [TLE2022A-Q1](#), [TLE2022A-Q1](#), [TLE2022-Q1](#), [TLE2024-Q1](#), [TLE2024-Q1](#)
- Enhanced Product : [TLE2021-EP](#), [TLE2021A-EP](#), [TLE2021A-EP](#), [TLE2021-EP](#), [TLE2022-EP](#), [TLE2022A-EP](#), [TLE2022A-EP](#), [TLE2022-EP](#), [TLE2024-EP](#), [TLE2024A-EP](#), [TLE2024A-EP](#), [TLE2024-EP](#)
- Military : [TLE2021M](#), [TLE2021AM](#), [TLE2022M](#), [TLE2022AM](#), [TLE2024M](#), [TLE2024AM](#)

NOTE: Qualified Version Definitions:

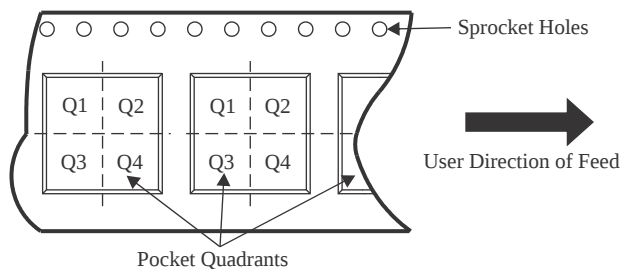
- Catalog - TI's standard catalog product
- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects
- Enhanced Product - Supports Defense, Aerospace and Medical Applications

- Military - QML certified for Military and Defense Applications

## TAPE AND REEL INFORMATION



### QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



\*All dimensions are nominal

| Device        | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|---------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TLE2021ACDR   | SOIC         | D               | 8    | 2500 | 330.0              | 12.4               | 6.4     | 5.2     | 2.1     | 8.0     | 12.0   | Q1            |
| TLE2021AIDR   | SOIC         | D               | 8    | 2500 | 330.0              | 12.4               | 6.4     | 5.2     | 2.1     | 8.0     | 12.0   | Q1            |
| TLE2021CDR    | SOIC         | D               | 8    | 2500 | 330.0              | 12.4               | 6.4     | 5.2     | 2.1     | 8.0     | 12.0   | Q1            |
| TLE2021IDR    | SOIC         | D               | 8    | 2500 | 330.0              | 12.4               | 6.4     | 5.2     | 2.1     | 8.0     | 12.0   | Q1            |
| TLE2022ACDR   | SOIC         | D               | 8    | 2500 | 330.0              | 12.4               | 6.4     | 5.2     | 2.1     | 8.0     | 12.0   | Q1            |
| TLE2022AIDR   | SOIC         | D               | 8    | 2500 | 330.0              | 12.4               | 6.4     | 5.2     | 2.1     | 8.0     | 12.0   | Q1            |
| TLE2022AMDR   | SOIC         | D               | 8    | 2500 | 330.0              | 12.4               | 6.4     | 5.2     | 2.1     | 8.0     | 12.0   | Q1            |
| TLE2022AMDRG4 | SOIC         | D               | 8    | 2500 | 330.0              | 12.5               | 6.4     | 5.2     | 2.1     | 8.0     | 12.0   | Q1            |
| TLE2022CDR    | SOIC         | D               | 8    | 2500 | 330.0              | 12.4               | 6.4     | 5.2     | 2.1     | 8.0     | 12.0   | Q1            |
| TLE2022IDR    | SOIC         | D               | 8    | 2500 | 330.0              | 12.4               | 6.4     | 5.2     | 2.1     | 8.0     | 12.0   | Q1            |
| TLE2022MDR    | SOIC         | D               | 8    | 2500 | 330.0              | 12.4               | 6.4     | 5.2     | 2.1     | 8.0     | 12.0   | Q1            |
| TLE2024ACDWR  | SOIC         | DW              | 16   | 2000 | 330.0              | 16.4               | 10.75   | 10.7    | 2.7     | 12.0    | 16.0   | Q1            |
| TLE2024CDWR   | SOIC         | DW              | 16   | 2000 | 330.0              | 16.4               | 10.75   | 10.7    | 2.7     | 12.0    | 16.0   | Q1            |

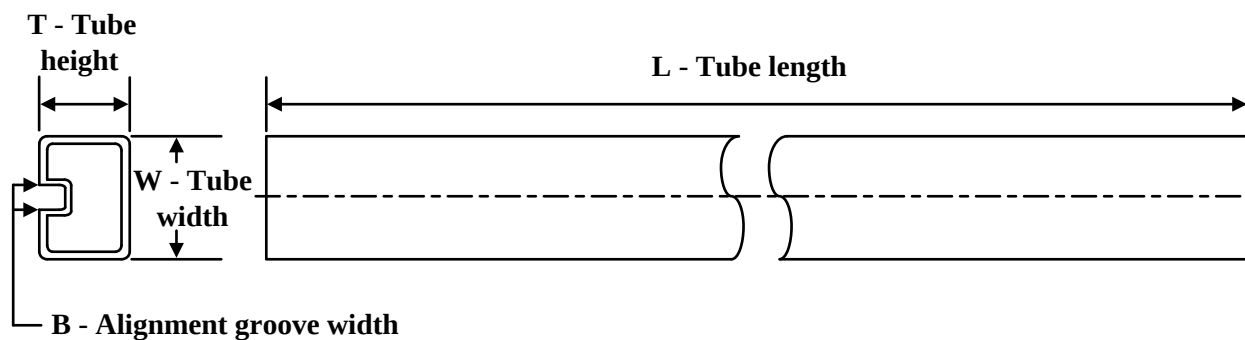
## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

| Device        | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|---------------|--------------|-----------------|------|------|-------------|------------|-------------|
| TLE2021ACDR   | SOIC         | D               | 8    | 2500 | 340.5       | 338.1      | 20.6        |
| TLE2021AIDR   | SOIC         | D               | 8    | 2500 | 340.5       | 338.1      | 20.6        |
| TLE2021CDR    | SOIC         | D               | 8    | 2500 | 340.5       | 338.1      | 20.6        |
| TLE2021IDR    | SOIC         | D               | 8    | 2500 | 340.5       | 338.1      | 20.6        |
| TLE2022ACDR   | SOIC         | D               | 8    | 2500 | 340.5       | 338.1      | 20.6        |
| TLE2022AIDR   | SOIC         | D               | 8    | 2500 | 340.5       | 338.1      | 20.6        |
| TLE2022AMDR   | SOIC         | D               | 8    | 2500 | 350.0       | 350.0      | 43.0        |
| TLE2022AMDRG4 | SOIC         | D               | 8    | 2500 | 340.5       | 338.1      | 20.6        |
| TLE2022CDR    | SOIC         | D               | 8    | 2500 | 340.5       | 338.1      | 20.6        |
| TLE2022IDR    | SOIC         | D               | 8    | 2500 | 340.5       | 338.1      | 20.6        |
| TLE2022MDR    | SOIC         | D               | 8    | 2500 | 350.0       | 350.0      | 43.0        |
| TLE2024ACDWR  | SOIC         | DW              | 16   | 2000 | 350.0       | 350.0      | 43.0        |
| TLE2024CDWR   | SOIC         | DW              | 16   | 2000 | 350.0       | 350.0      | 43.0        |

## TUBE



\*All dimensions are nominal

| Device          | Package Name | Package Type | Pins | SPQ | L (mm) | W (mm) | T (μm) | B (mm) |
|-----------------|--------------|--------------|------|-----|--------|--------|--------|--------|
| 5962-9088102M2A | FK           | LCCC         | 20   | 55  | 506.98 | 12.06  | 2030   | NA     |
| 5962-9088103M2A | FK           | LCCC         | 20   | 55  | 506.98 | 12.06  | 2030   | NA     |
| 5962-9088104Q2A | FK           | LCCC         | 20   | 55  | 506.98 | 12.06  | 2030   | NA     |
| 5962-9088105Q2A | FK           | LCCC         | 20   | 55  | 506.98 | 12.06  | 2030   | NA     |
| 5962-9088106Q2A | FK           | LCCC         | 20   | 55  | 506.98 | 12.06  | 2030   | NA     |
| 5962-9088107Q2A | FK           | LCCC         | 20   | 55  | 506.98 | 12.06  | 2030   | NA     |
| 5962-9088108Q2A | FK           | LCCC         | 20   | 55  | 506.98 | 12.06  | 2030   | NA     |
| 5962-9088109Q2A | FK           | LCCC         | 20   | 55  | 506.98 | 12.06  | 2030   | NA     |
| TLE2021ACP      | P            | PDIP         | 8    | 50  | 506    | 13.97  | 11230  | 4.32   |
| TLE2021AIP      | P            | PDIP         | 8    | 50  | 506    | 13.97  | 11230  | 4.32   |
| TLE2021AMFKB    | FK           | LCCC         | 20   | 55  | 506.98 | 12.06  | 2030   | NA     |
| TLE2021BMFKB    | FK           | LCCC         | 20   | 55  | 506.98 | 12.06  | 2030   | NA     |
| TLE2021CD       | D            | SOIC         | 8    | 75  | 505.46 | 6.76   | 3810   | 4      |
| TLE2021CD       | D            | SOIC         | 8    | 75  | 507    | 8      | 3940   | 4.32   |
| TLE2021CDG4     | D            | SOIC         | 8    | 75  | 505.46 | 6.76   | 3810   | 4      |
| TLE2021CDG4     | D            | SOIC         | 8    | 75  | 507    | 8      | 3940   | 4.32   |
| TLE2021CP       | P            | PDIP         | 8    | 50  | 506    | 13.97  | 11230  | 4.32   |
| TLE2021CPE4     | P            | PDIP         | 8    | 50  | 506    | 13.97  | 11230  | 4.32   |
| TLE2021ID       | D            | SOIC         | 8    | 75  | 505.46 | 6.76   | 3810   | 4      |
| TLE2021ID       | D            | SOIC         | 8    | 75  | 507    | 8      | 3940   | 4.32   |
| TLE2021IDG4     | D            | SOIC         | 8    | 75  | 507    | 8      | 3940   | 4.32   |
| TLE2021IDG4     | D            | SOIC         | 8    | 75  | 505.46 | 6.76   | 3810   | 4      |
| TLE2021IP       | P            | PDIP         | 8    | 50  | 506    | 13.97  | 11230  | 4.32   |
| TLE2021MD       | D            | SOIC         | 8    | 75  | 505.46 | 6.76   | 3810   | 4      |
| TLE2021MDG4     | D            | SOIC         | 8    | 75  | 505.46 | 6.76   | 3810   | 4      |
| TLE2022ACD      | D            | SOIC         | 8    | 75  | 505.46 | 6.76   | 3810   | 4      |
| TLE2022ACD      | D            | SOIC         | 8    | 75  | 507    | 8      | 3940   | 4.32   |
| TLE2022ACDG4    | D            | SOIC         | 8    | 75  | 507    | 8      | 3940   | 4.32   |
| TLE2022ACDG4    | D            | SOIC         | 8    | 75  | 505.46 | 6.76   | 3810   | 4      |

| Device       | Package Name | Package Type | Pins | SPQ | L (mm) | W (mm) | T (μm) | B (mm) |
|--------------|--------------|--------------|------|-----|--------|--------|--------|--------|
| TLE2022ACP   | P            | PDIP         | 8    | 50  | 506    | 13.97  | 11230  | 4.32   |
| TLE2022AIP   | P            | PDIP         | 8    | 50  | 506    | 13.97  | 11230  | 4.32   |
| TLE2022AMFKB | FK           | LCCC         | 20   | 55  | 506.98 | 12.06  | 2030   | NA     |
| TLE2022BMFKB | FK           | LCCC         | 20   | 55  | 506.98 | 12.06  | 2030   | NA     |
| TLE2022CD    | D            | SOIC         | 8    | 75  | 507    | 8      | 3940   | 4.32   |
| TLE2022CD    | D            | SOIC         | 8    | 75  | 505.46 | 6.76   | 3810   | 4      |
| TLE2022CP    | P            | PDIP         | 8    | 50  | 506    | 13.97  | 11230  | 4.32   |
| TLE2022CPE4  | P            | PDIP         | 8    | 50  | 506    | 13.97  | 11230  | 4.32   |
| TLE2022ID    | D            | SOIC         | 8    | 75  | 505.46 | 6.76   | 3810   | 4      |
| TLE2022ID    | D            | SOIC         | 8    | 75  | 507    | 8      | 3940   | 4.32   |
| TLE2022IDG4  | D            | SOIC         | 8    | 75  | 505.46 | 6.76   | 3810   | 4      |
| TLE2022IDG4  | D            | SOIC         | 8    | 75  | 507    | 8      | 3940   | 4.32   |
| TLE2022IP    | P            | PDIP         | 8    | 50  | 506    | 13.97  | 11230  | 4.32   |
| TLE2022IPE4  | P            | PDIP         | 8    | 50  | 506    | 13.97  | 11230  | 4.32   |
| TLE2022MFKB  | FK           | LCCC         | 20   | 55  | 506.98 | 12.06  | 2030   | NA     |
| TLE2024ACN   | N            | PDIP         | 14   | 25  | 506    | 13.97  | 11230  | 4.32   |
| TLE2024AIDW  | DW           | SOIC         | 16   | 40  | 506.98 | 12.7   | 4826   | 6.6    |
| TLE2024AIN   | N            | PDIP         | 14   | 25  | 506    | 13.97  | 11230  | 4.32   |
| TLE2024AMFKB | FK           | LCCC         | 20   | 55  | 506.98 | 12.06  | 2030   | NA     |
| TLE2024BMFKB | FK           | LCCC         | 20   | 55  | 506.98 | 12.06  | 2030   | NA     |
| TLE2024CN    | N            | PDIP         | 14   | 25  | 506    | 13.97  | 11230  | 4.32   |
| TLE2024CNE4  | N            | PDIP         | 14   | 25  | 506    | 13.97  | 11230  | 4.32   |
| TLE2024IDW   | DW           | SOIC         | 16   | 40  | 506.98 | 12.7   | 4826   | 6.6    |
| TLE2024IN    | N            | PDIP         | 14   | 25  | 506    | 13.97  | 11230  | 4.32   |
| TLE2024MFKB  | FK           | LCCC         | 20   | 55  | 506.98 | 12.06  | 2030   | NA     |

## GENERIC PACKAGE VIEW

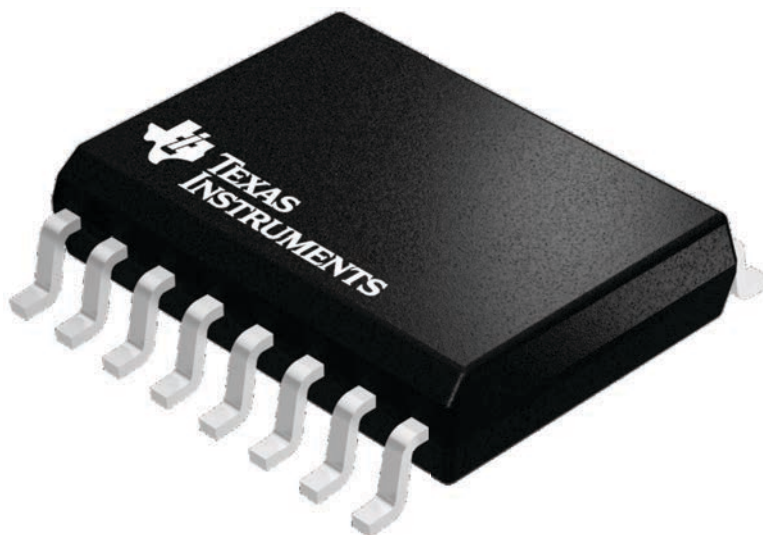
**DW 16**

**SOIC - 2.65 mm max height**

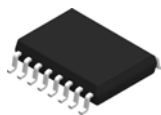
7.5 x 10.3, 1.27 mm pitch

SMALL OUTLINE INTEGRATED CIRCUIT

This image is a representation of the package family, actual package may vary.  
Refer to the product data sheet for package details.



4224780/A

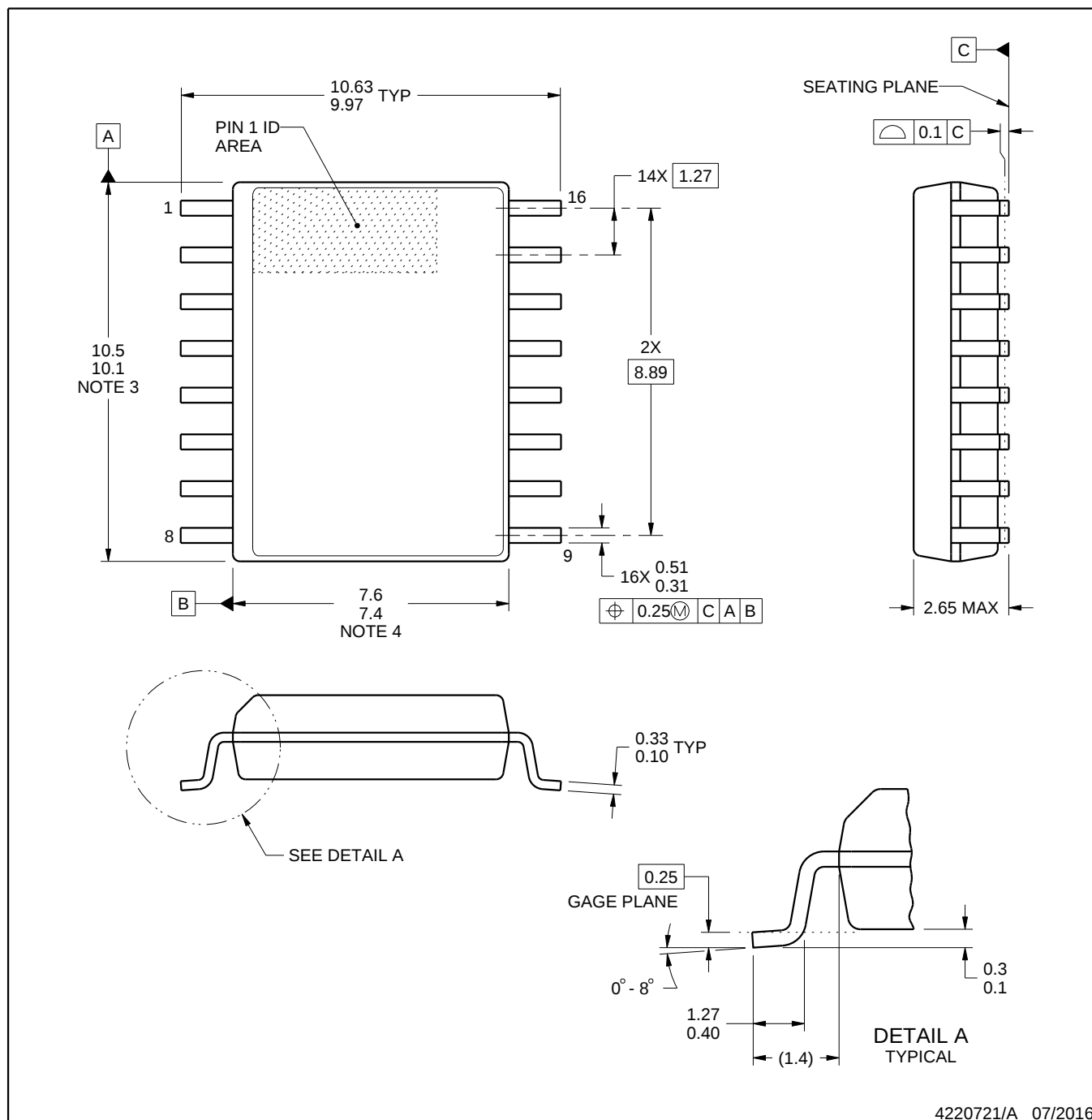


DW0016A

# PACKAGE OUTLINE

## SOIC - 2.65 mm max height

SOIC



4220721/A 07/2016

### NOTES:

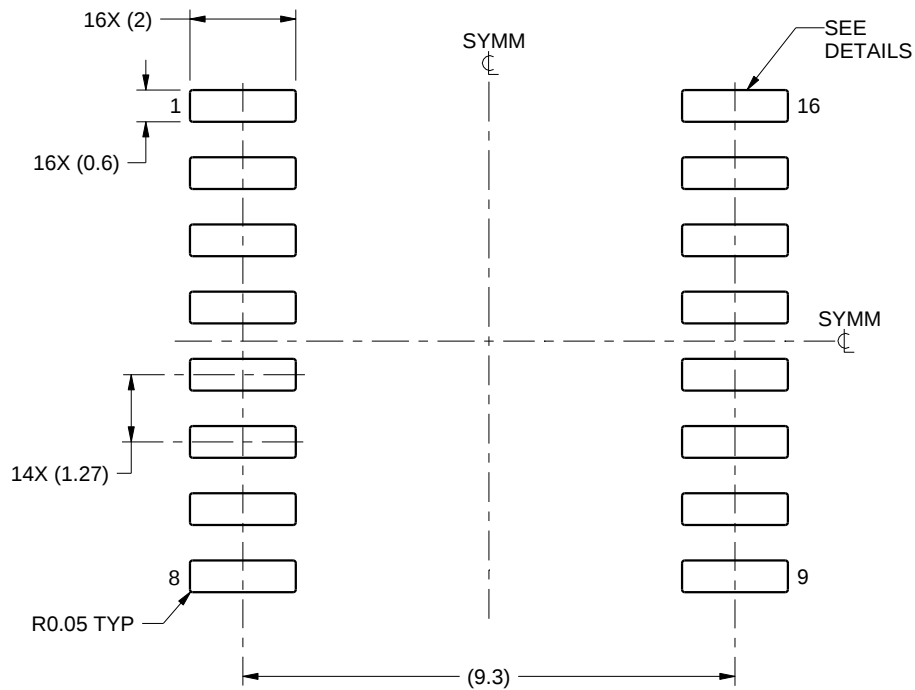
1. All linear dimensions are in millimeters. Dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm, per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm, per side.
5. Reference JEDEC registration MS-013.

# EXAMPLE BOARD LAYOUT

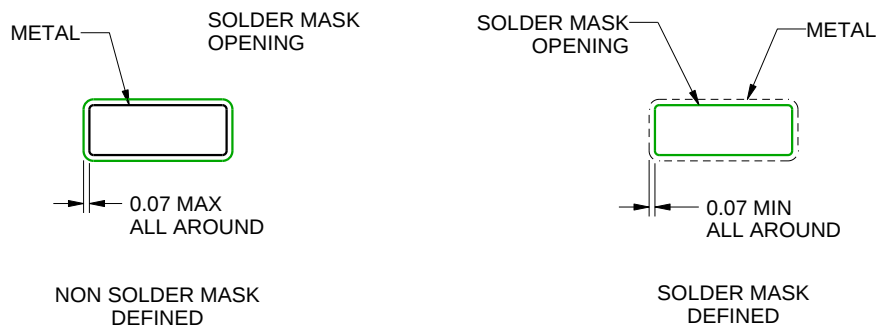
DW0016A

SOIC - 2.65 mm max height

SOIC



LAND PATTERN EXAMPLE  
SCALE:7X



SOLDER MASK DETAILS

4220721/A 07/2016

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

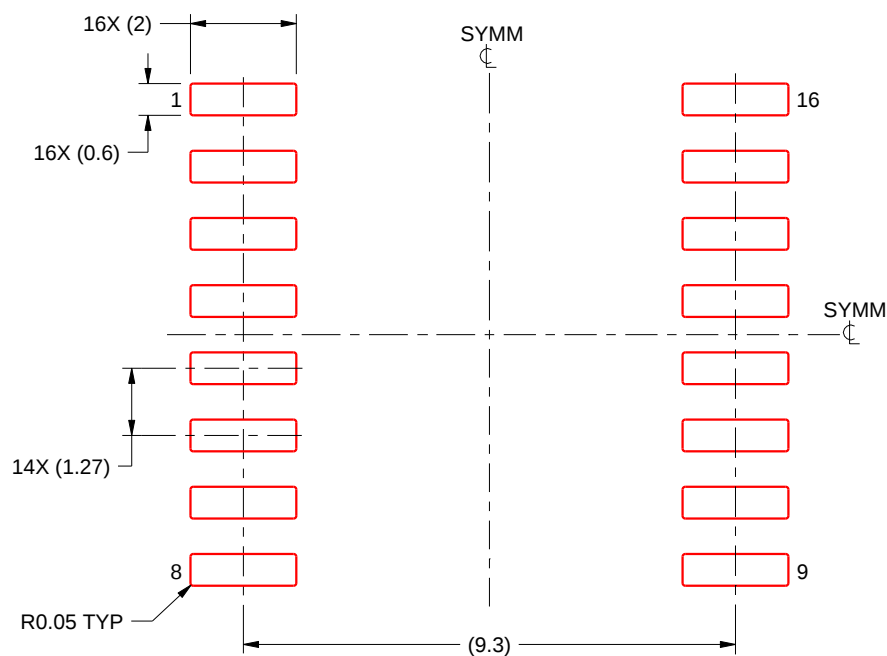
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

## EXAMPLE STENCIL DESIGN

DW0016A

SOIC - 2.65 mm max height

SOIC



SOLDER PASTE EXAMPLE  
BASED ON 0.125 mm THICK STENCIL  
SCALE:7X

4220721/A 07/2016

NOTES: (continued)

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

## GENERIC PACKAGE VIEW

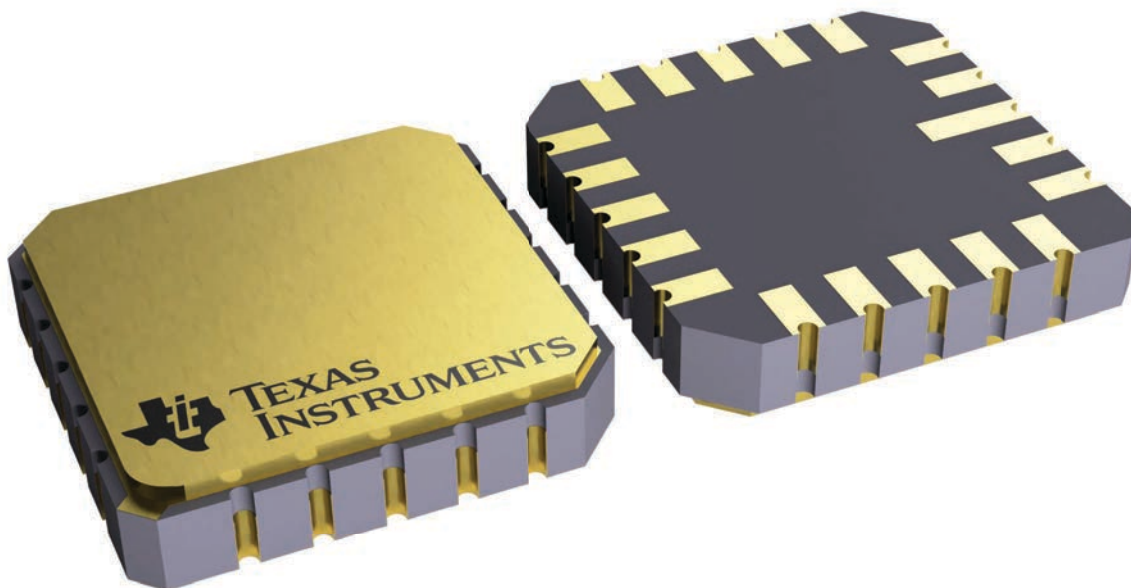
**FK 20**

**LCCC - 2.03 mm max height**

8.89 x 8.89, 1.27 mm pitch

LEADLESS CERAMIC CHIP CARRIER

This image is a representation of the package family, actual package may vary.  
Refer to the product data sheet for package details.



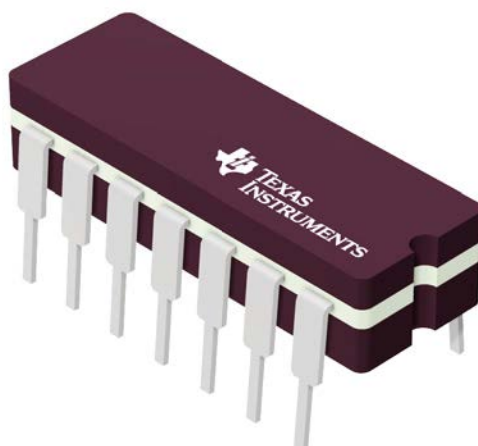
4229370VA\

**J 14**

## GENERIC PACKAGE VIEW

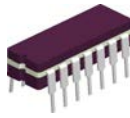
**CDIP - 5.08 mm max height**

CERAMIC DUAL IN LINE PACKAGE

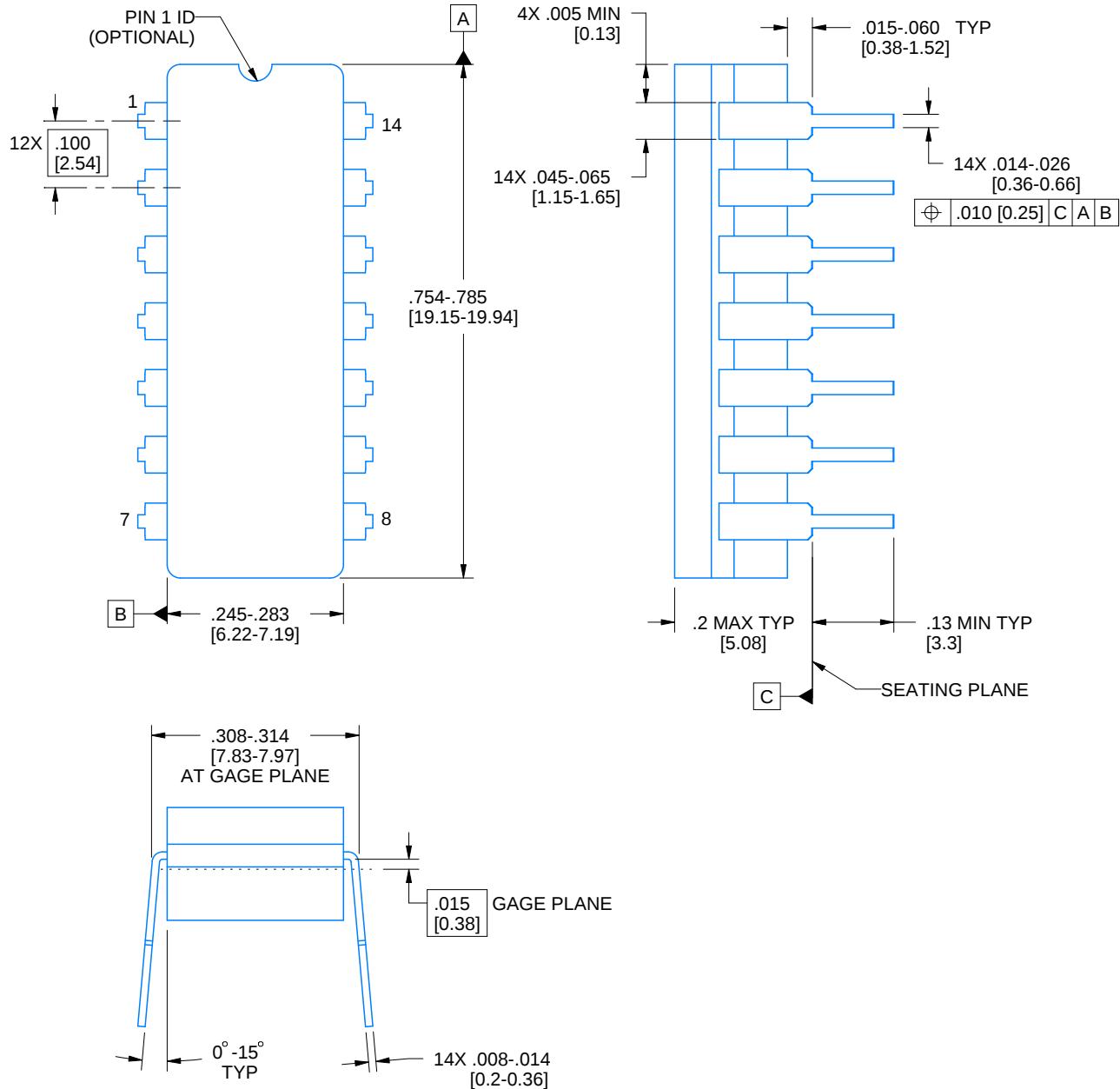


Images above are just a representation of the package family, actual package may vary.  
Refer to the product data sheet for package details.

4040083-5/G

**J0014A****PACKAGE OUTLINE****CDIP - 5.08 mm max height**

CERAMIC DUAL IN LINE PACKAGE



4214771/A 05/2017

**NOTES:**

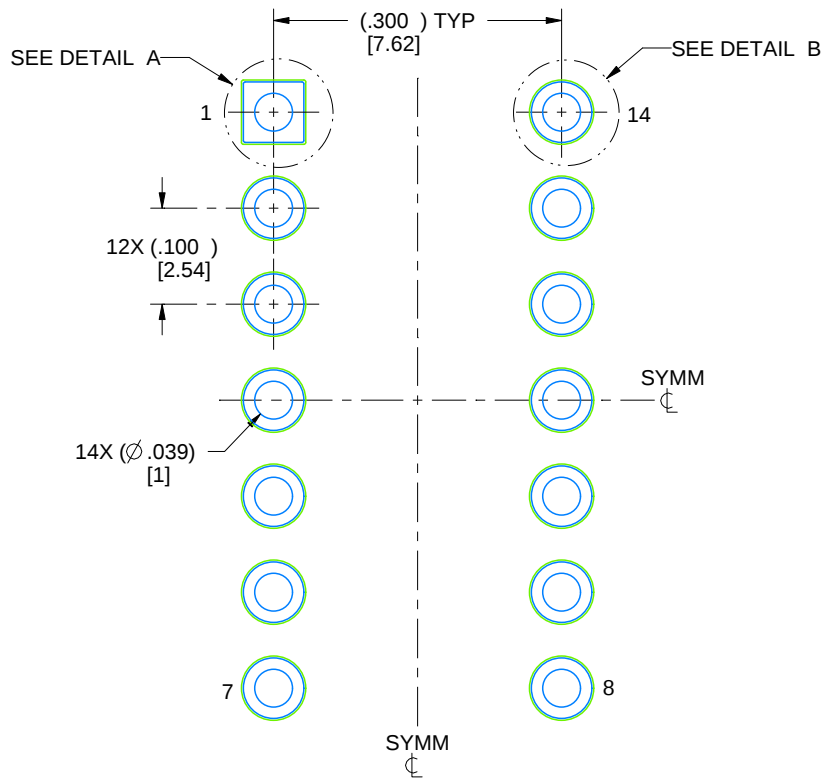
1. All controlling linear dimensions are in inches. Dimensions in brackets are in millimeters. Any dimension in brackets or parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This package is hermetically sealed with a ceramic lid using glass frit.
4. Index point is provided on cap for terminal identification only and on press ceramic glass frit seal only.
5. Falls within MIL-STD-1835 and GDIP1-T14.

# EXAMPLE BOARD LAYOUT

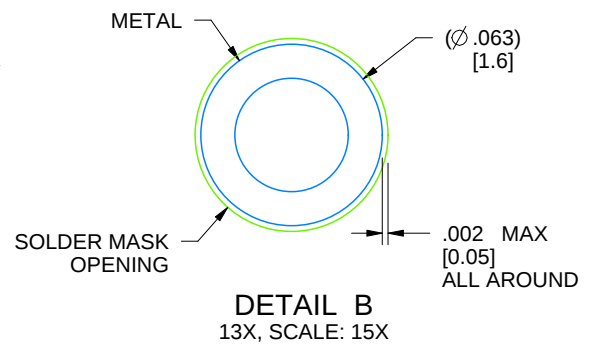
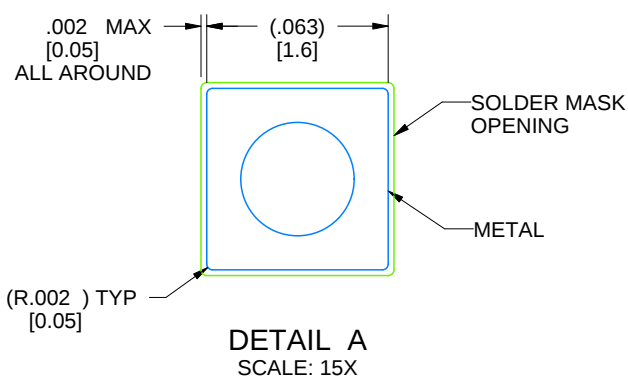
J0014A

CDIP - 5.08 mm max height

CERAMIC DUAL IN LINE PACKAGE



LAND PATTERN EXAMPLE  
NON-SOLDER MASK DEFINED  
SCALE: 5X



4214771/A 05/2017



## PACKAGE OUTLINE

**SOIC - 1.75 mm max height**

SMALL OUTLINE INTEGRATED CIRCUIT

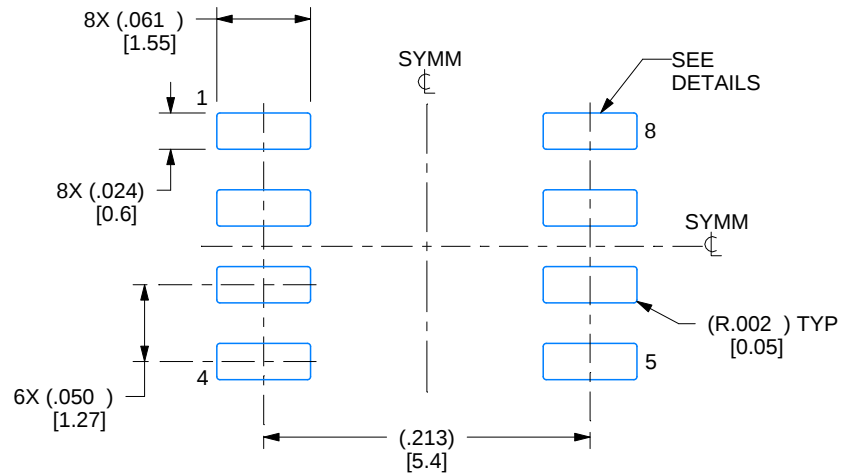


1. Linear dimensions are in inches [millimeters]. Dimensions in parenthesis are for reference only. Controlling dimensions are in inches. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate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

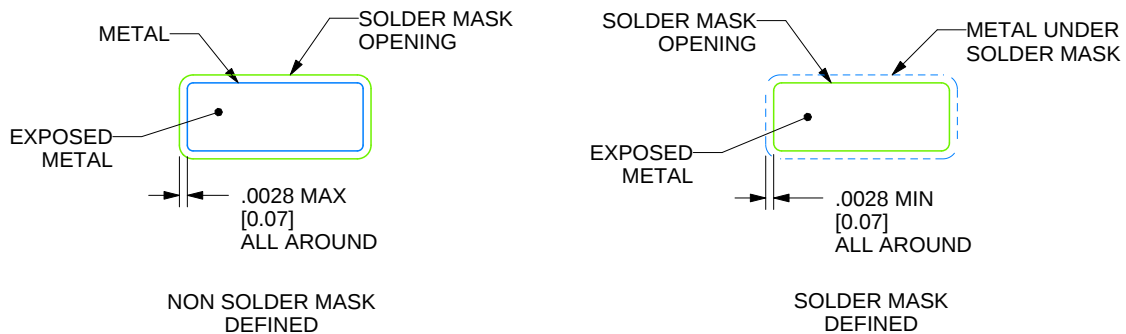
**D0008A**

**SOIC - 1.75 mm max height**

SMALL OUTLINE INTEGRATED CIRCUIT



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:8X



## SOLDER MASK DETAILS

4214825/C 02/2019

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

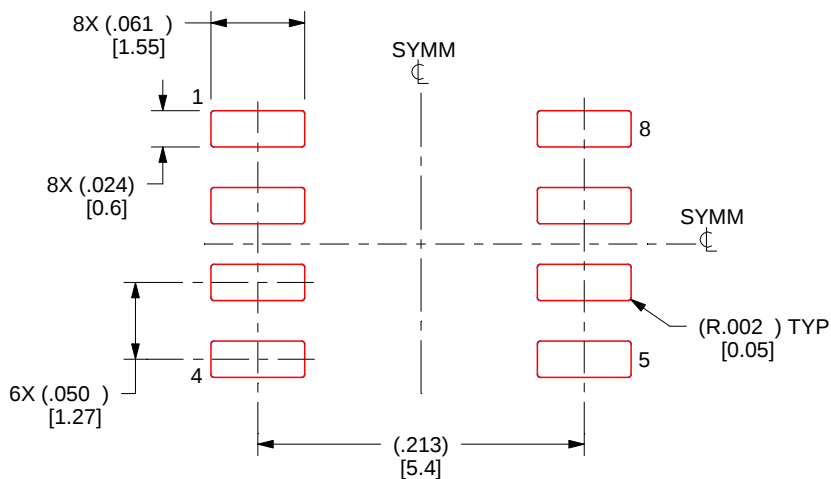
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

## EXAMPLE STENCIL DESIGN

D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



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

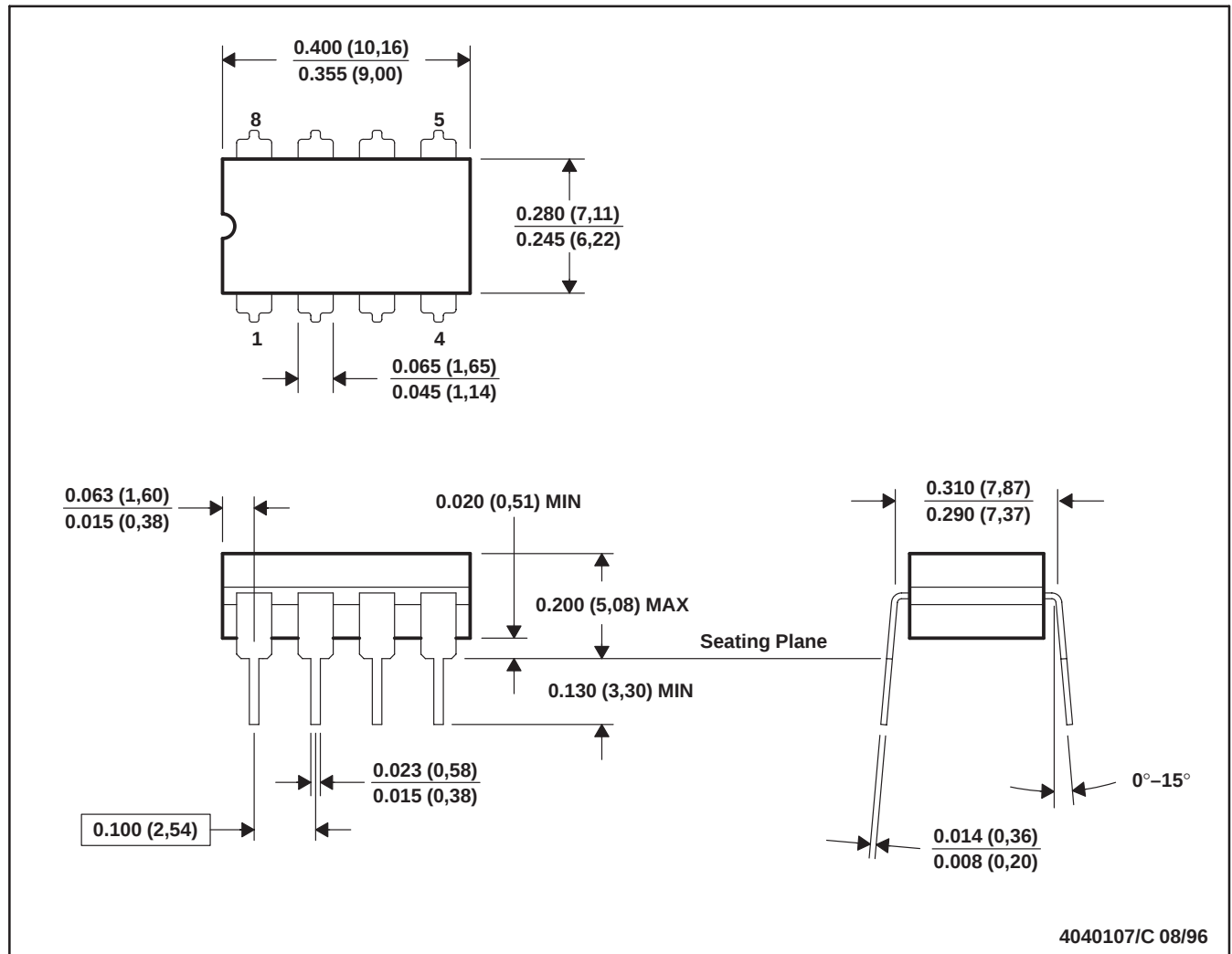
4214825/C 02/2019

NOTES: (continued)

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

## JG (R-GDIP-T8)

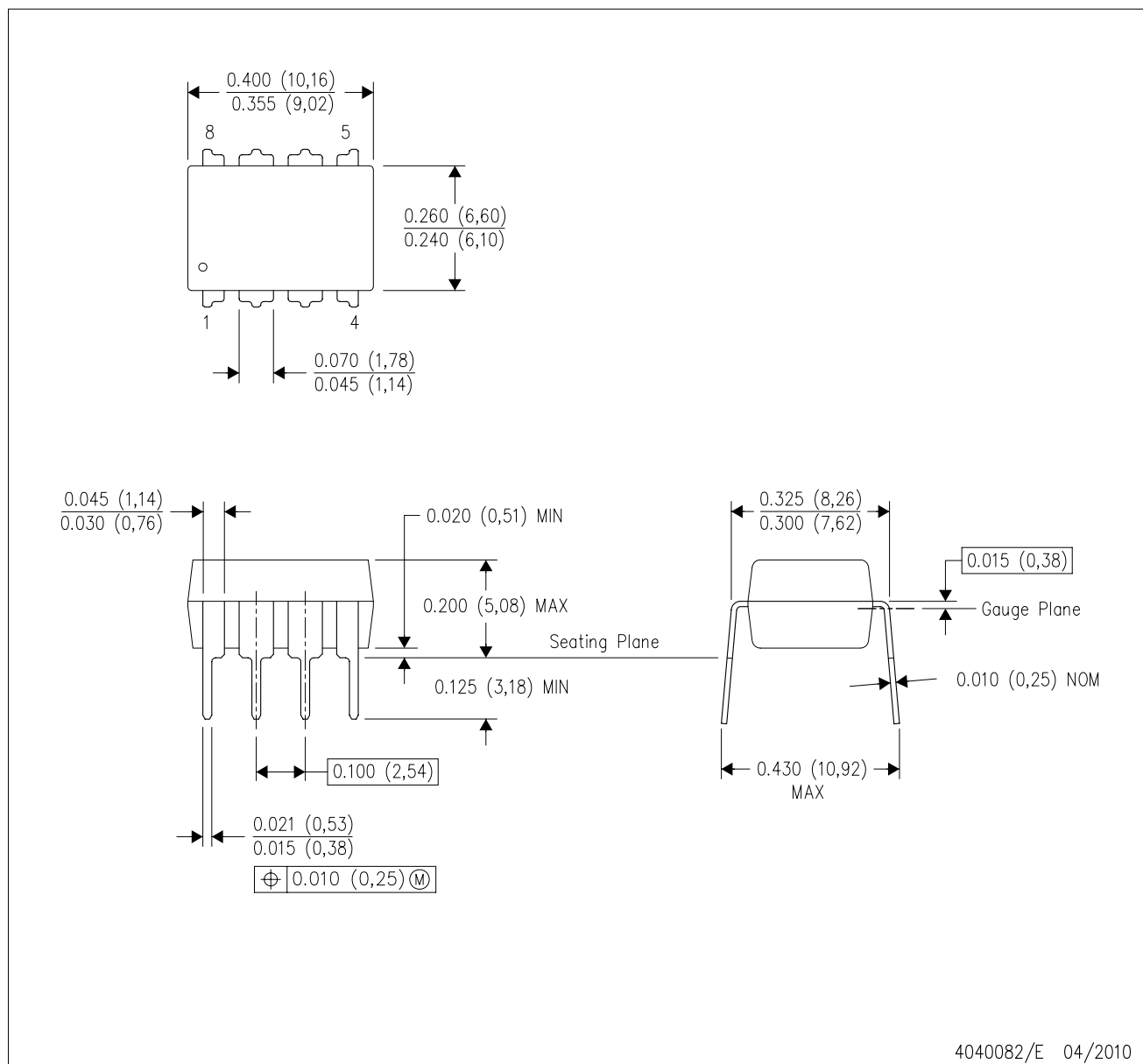
## CERAMIC DUAL-IN-LINE



- 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.  
 E. Falls within MIL STD 1835 GDIP1-T8

P (R-PDIP-T8)

PLASTIC DUAL-IN-LINE PACKAGE

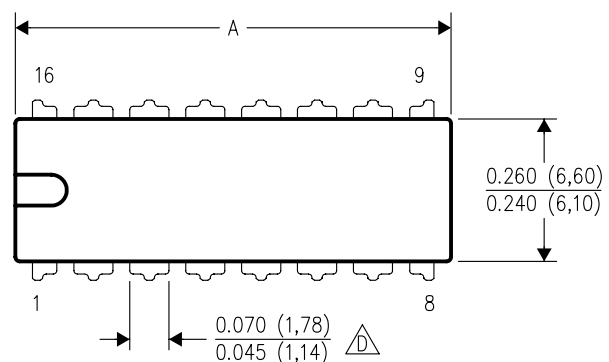


- NOTES:
- A. All linear dimensions are in inches (millimeters).
  - B. This drawing is subject to change without notice.
  - C. Falls within JEDEC MS-001 variation BA.

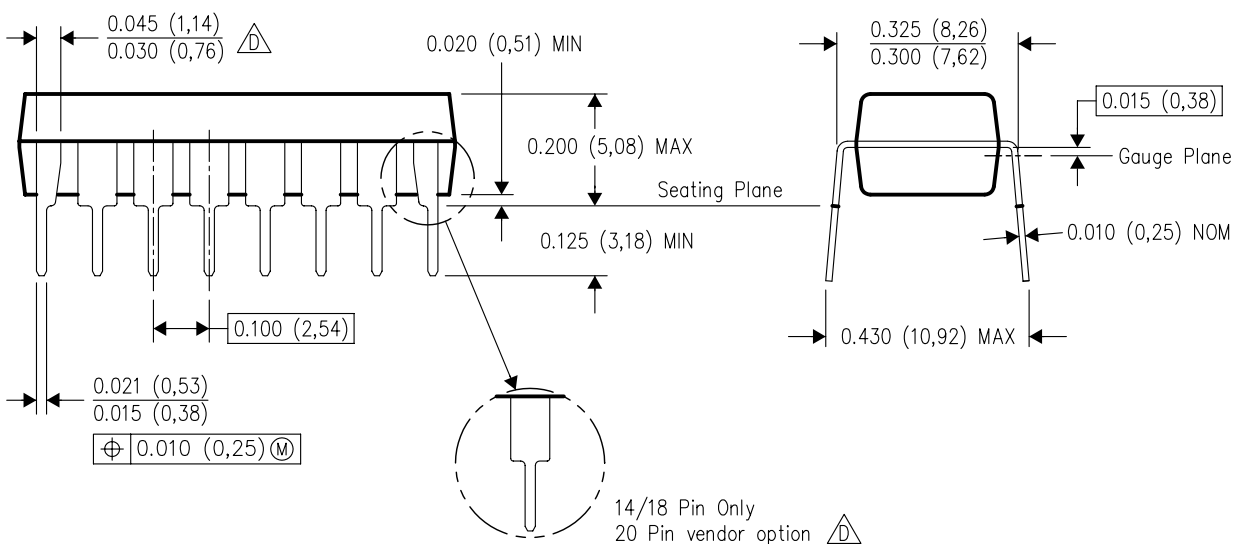
N (R-PDIP-T\*\*)

16 PINS SHOWN

## PLASTIC DUAL-IN-LINE PACKAGE



| PINS **<br>DIM      | 14               | 16               | 18               | 20               |
|---------------------|------------------|------------------|------------------|------------------|
| A MAX               | 0.775<br>(19,69) | 0.775<br>(19,69) | 0.920<br>(23,37) | 1.060<br>(26,92) |
| A MIN               | 0.745<br>(18,92) | 0.745<br>(18,92) | 0.850<br>(21,59) | 0.940<br>(23,88) |
| MS-001<br>VARIATION | AA               | BB               | AC               | AD               |



4040049/E 12/2002

NOTES:

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

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