

# TLE202xM Excalibur, High-Speed, Low-Power, Precision, Operational Amplifiers

## 1 Features

- Supply current: 300 $\mu$ A, max
- High unity-gain bandwidth: 2MHz
- High slew rate: 0.65V/ $\mu$ s
- Supply-current change over military temperature range: 10 $\mu$ A at  $V_S = \pm 15$ V
- Specified for both 5V single-supply and  $\pm 15$ V operation
- Phase-reversal protection
- High open-loop gain: 6.5V/ $\mu$ V (136dB)
- Low offset voltage: 100 $\mu$ V, max
- Offset voltage drift with time: 0.005 $\mu$ V/mo
- Low input bias current: 50nA, max
- Low noise voltage: 19nV/ $\sqrt{\text{Hz}}$

## 2 Description

The TLE2021xM, TLE2022xM, and TLE2024xM (TLE202xM) 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 a highly improved slew rate and unity-gain bandwidth.

The complementary bipolar Excalibur process uses 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. Therefore, 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 an excellent 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 is less than the negative supply rail.

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

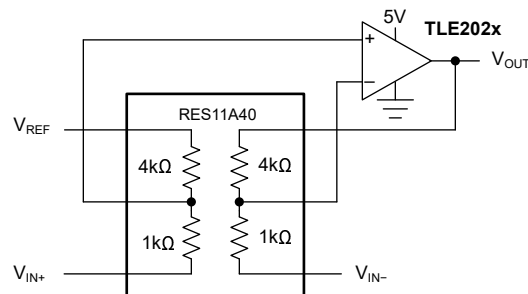
The M-suffix devices are characterized for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ .

### Device Information

| PART NUMBER <sup>(1)</sup> | CHANNEL COUNT | PACKAGE <sup>(2)</sup> |
|----------------------------|---------------|------------------------|
| TLE2021xM                  | Single        | FK (LCCC, 20)          |
|                            |               | JG (CDIP, 8)           |
| TLE2022xM                  | Dual          | FK (LCCC, 20)          |
|                            |               | JG (CDIP, 8)           |
| TLE2024xM                  | Quad          | FK (LCCC, 20)          |
|                            |               | J (CDIP, 14)           |

(1) See [Section 3](#).

(2) For more information, see [Section 11](#).



**Difference Amplifier Circuit With the RES11A**



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## 3 Device Comparison Tables

**Table 3-1. TLE2021xM Available Options**

| $T_A$           | PACKAGED DEVICES                       |                           |                           |
|-----------------|----------------------------------------|---------------------------|---------------------------|
|                 | $V_{IOmax}$<br>AT 25°C                 | CHIP<br>CARRIER<br>(FK))  | CERAMIC DIP<br>(JG)       |
| –55°C to +125°C | 100 $\mu\text{V}$<br>500 $\mu\text{V}$ | TLE2021BMFK<br>TLE2021MFK | TLE2021BMJG<br>TLE2021MJG |

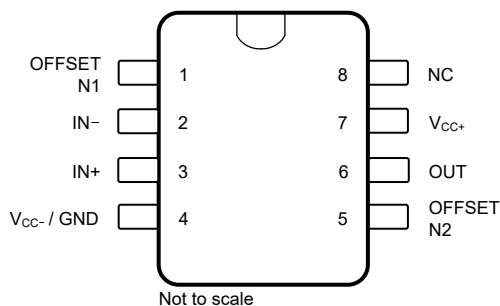
**Table 3-2. TLE2022xM Available Options**

| $T_A$           | PACKAGED DEVICES                                            |                                |                                          |
|-----------------|-------------------------------------------------------------|--------------------------------|------------------------------------------|
|                 | $V_{IOmax}$<br>AT 25°C                                      | CHIP<br>CARRIER<br>(FK))       | CERAMIC DIP<br>(JG)                      |
| –55°C to +125°C | 150 $\mu\text{V}$<br>300 $\mu\text{V}$<br>500 $\mu\text{V}$ | —<br>TLE2022AMFK<br>TLE2022MFK | TLE2022BMJG<br>TLE2022AMJG<br>TLE2022MJG |

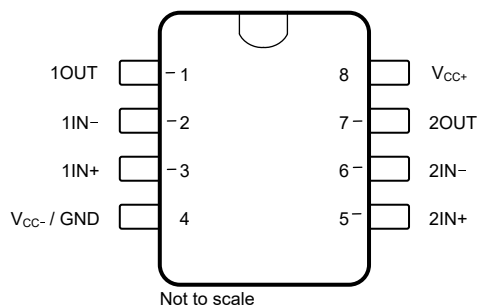
**Table 3-3. TLE2024xM Available Options**

| $T_A$           | PACKAGED DEVICES                                             |                                          |                                       |
|-----------------|--------------------------------------------------------------|------------------------------------------|---------------------------------------|
|                 | $V_{IOmax}$<br>AT 25°C                                       | CHIP<br>CARRIER<br>(FK))                 | CERAMIC DIP<br>(J)                    |
| –55°C to +125°C | 500 $\mu\text{V}$<br>750 $\mu\text{V}$<br>1000 $\mu\text{V}$ | TLE2024BMFK<br>TLE2024AMFK<br>TLE2024MFK | TLE2024BMJ<br>TLE2024AMJ<br>TLE2024MJ |

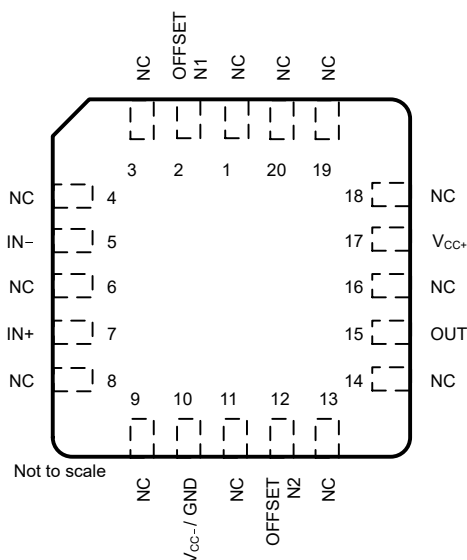
## 4 Pin Configuration and Functions



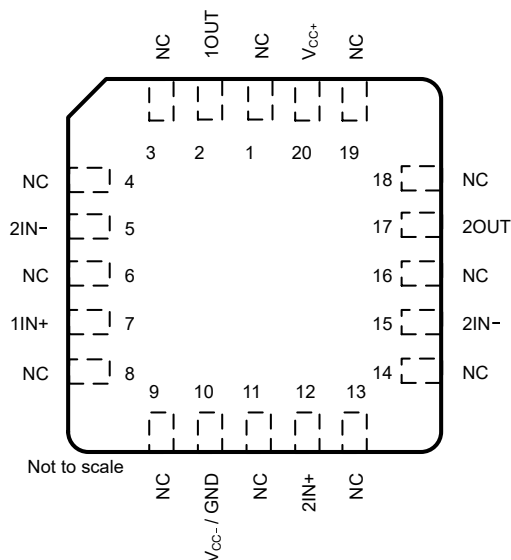
**Figure 4-1. TLE2021xM: JG Package, 8-Pin CDIP (Top View)**



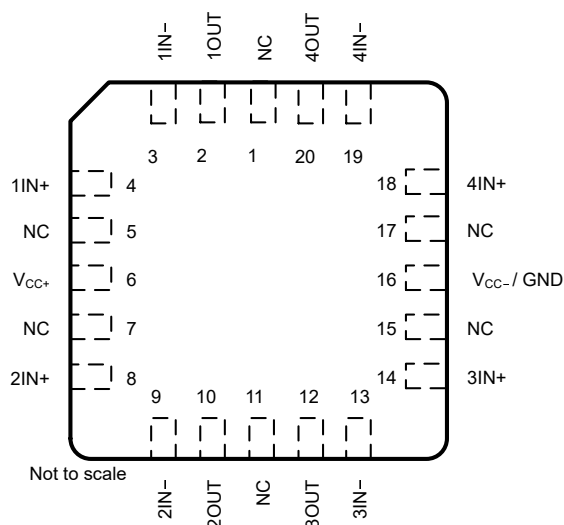
**Figure 4-2. TLE2022xM: JG Package, 8-Pin CDIP (Top View)**



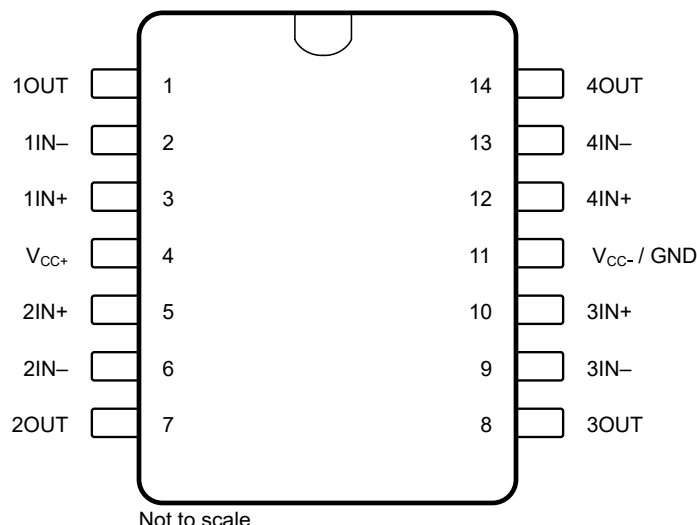
**Figure 4-3. TLE2021xM: FK Package, 20-Pin LCCC (Top View)**



**Figure 4-4. TLE2022xM: FK Package, 20-Pin LCCC (Top View)**



**Figure 4-5. TLE2024xM: FK Package, 20-Pin LCCC (Top View)**



**Figure 4-6. TLE2024xM: J Package, 14-Pin CDIP (Top View)**

## 5 Specifications

### 5.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted) <sup>(1)</sup>

|                                                                          |         | VALUE                          | UNIT |
|--------------------------------------------------------------------------|---------|--------------------------------|------|
| Supply voltage, $V_{CC+}$ <sup>(2)</sup>                                 |         | 20                             | V    |
| Supply voltage, $V_{CC-}$ <sup>(2)</sup>                                 |         | -20                            | V    |
| Differential input voltage, $V_{ID}$ <sup>(3)</sup>                      |         | $\pm 0.6$                      | V    |
| Input voltage range, $V_I$ (any input) <sup>(2)</sup>                    |         | $\pm V_{CC}$                   |      |
| Input current, $I_I$ (each input)                                        |         | $\pm 1$                        | mA   |
| Output current, $I_O$ (each output):                                     | TLE2021 | $\pm 20$                       | mA   |
|                                                                          | TLE2022 | $\pm 30$                       |      |
|                                                                          | TLE2024 | $\pm 40$                       |      |
| 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 <sup>(4)</sup>      |         | Unlimited                      |      |
| Continuous total power dissipation                                       |         | See <i>Dissipation Ratings</i> |      |
| Operating free-air temperature range, $T_A$                              |         | -55 to 125                     | °C   |
| Storage temperature range, $T_{stg}$                                     |         | -65 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 60 seconds: JG package |         | 300                            | °C   |

- (1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2) All voltage values, except differential voltages, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .
- (3) 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.
- (4) The output is able to be shorted to either supply. Limit temperature, supply voltages, or both to not exceed the maximum dissipation ratings.

### 5.2 Dissipation Ratings

| PACKAGE | $T_A \leq 25^\circ\text{C}$<br>POWER RATING | DERATING FACTOR<br>ABOVE $T_A = 25^\circ\text{C}$ | $T_A = 70^\circ\text{C}$<br>POWER RATING | $T_A = 85^\circ\text{C}$<br>POWER RATING | $T_A = 125^\circ\text{C}$<br>POWER RATING |
|---------|---------------------------------------------|---------------------------------------------------|------------------------------------------|------------------------------------------|-------------------------------------------|
| 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                                    |

### 5.3 Recommended Operating Conditions

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

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

## 5.4 Electrical Characteristics TLE2021xM, $V_{CC} = 5\text{ V}$

at specified free-air temperature and  $V_{CC} = 5\text{ V}$  (unless otherwise noted)

| PARAMETER       |                                                                  | TEST CONDITIONS                                             | $T_A$ <sup>(1)</sup> | TLE2021M |           |      | TLE2021BM |           |      | UNIT                         |
|-----------------|------------------------------------------------------------------|-------------------------------------------------------------|----------------------|----------|-----------|------|-----------|-----------|------|------------------------------|
|                 |                                                                  |                                                             |                      | MIN      | TYP       | MAX  | MIN       | TYP       | MAX  |                              |
| $V_{IO}$        | Input offset voltage                                             | $V_{IC} = 0, R_S = 50\ \Omega$                              | 25°C                 |          | 120       | 600  |           | 80        | 200  | $\mu\text{V}$                |
|                 |                                                                  |                                                             | Full range           |          |           | 1100 |           |           | 300  |                              |
| $\alpha_{VIO}$  | Temperature coefficient of input offset voltage                  |                                                             | Full range           |          | 2         |      |           | 2         |      | $\mu\text{V}/^\circ\text{C}$ |
|                 | Input offset voltage long-term drift <sup>(2)</sup>              |                                                             | 25°C                 |          | 0.005     |      |           | 0.005     |      | $\mu\text{V}/\text{mo}$      |
| $I_{IO}$        | Input offset current                                             |                                                             | 25°C                 |          | 0.2       | 6    |           | 0.2       | 6    | nA                           |
|                 |                                                                  |                                                             | Full range           |          |           | 10   |           |           | 10   |                              |
| $I_{IB}$        | Input bias current                                               |                                                             | 25°C                 |          | 25        | 70   |           | 25        | 70   | nA                           |
|                 |                                                                  |                                                             | Full range           |          |           | 90   |           |           | 90   |                              |
| $V_{ICR}$       | Common-mode input voltage range                                  | $R_S = 50\ \Omega$                                          | 25°C                 | 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  |           |      |                              |
| $V_{OH}$        | High-level output voltage                                        | $R_L = 10\text{ k}\Omega$                                   | 25°C                 | 4        | 4.3       |      | 4         | 4.3       |      | V                            |
|                 |                                                                  |                                                             | Full range           | 3.8      |           |      | 3.8       |           |      |                              |
| $V_{OL}$        | Low-level output voltage                                         |                                                             | 25°C                 |          | 0.7       | 0.8  |           | 0.7       | 0.8  | V                            |
|                 |                                                                  |                                                             | Full range           |          |           | 0.95 |           |           | 0.95 |                              |
| $A_{VD}$        | Large-signal differential voltage amplification                  | $V_O = 1.4\text{ V to }4\text{ V}, R_L = 10\text{ k}\Omega$ | 25°C                 | 0.3      | 1.5       |      | 0.3       | 1.5       |      | $\text{V}/\mu\text{V}$       |
|                 |                                                                  |                                                             | Full range           | 0.1      |           |      | 0.1       |           |      |                              |
| CMRR            | Common mode rejection ratio                                      | $V_{IC} = V_{ICRmin}, R_S = 50\ \Omega$                     | 25°C                 | 85       | 110       |      | 85        | 110       |      | dB                           |
|                 |                                                                  |                                                             | Full range           | 80       |           |      | 80        |           |      |                              |
| $k_{SVR}$       | Supply-voltage rejection ratio ( $\Delta V_{CC}/\Delta V_{IO}$ ) | $V_{CC} = 5\text{ V to }30\text{ V}$                        | 25°C                 | 105      | 120       |      | 105       | 120       |      | dB                           |
|                 |                                                                  |                                                             | Full range           | 100      |           |      | 100       |           |      |                              |
| $I_{CC}$        | Supply current                                                   | $V_O = 2.5\text{ V}, \text{ no load}$                       | 25°C                 |          | 170       | 230  |           | 170       | 230  | $\mu\text{A}$                |
|                 |                                                                  |                                                             | Full range           |          |           | 230  |           |           | 230  |                              |
| $\Delta I_{CC}$ | Supply-current change over operating temperature range           |                                                             | Full range           |          | 9         |      |           | 9         |      | $\mu\text{A}$                |

(1) Full range is  $-55^\circ\text{C}$  to  $+125^\circ\text{C}$ .

(2) 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.

## 5.5 Operating Characteristics TLE2021M, $V_{CC} = 5\text{ V}$

at  $T_A = 25^\circ\text{C}$  and  $V_{CC} = 5\text{ V}$  (unless otherwise noted)

| PARAMETER   |                                                                  | TEST CONDITIONS                                                   | $T_A$ | M SUFFIX |      |     | UNIT                         |
|-------------|------------------------------------------------------------------|-------------------------------------------------------------------|-------|----------|------|-----|------------------------------|
|             |                                                                  |                                                                   |       | MIN      | TYP  | MAX |                              |
| SR          | Slew rate at unity gain                                          | $V_O = 1\text{ V to }3\text{ V}$ , see <a href="#">Figure 6-1</a> | 25°C  |          | 0.5  |     | $\text{V}/\mu\text{s}$       |
| $V_n$       | Equivalent input noise voltage (see <a href="#">Figure 6-2</a> ) | $f = 10\text{ Hz}$                                                | 25°C  |          | 21   |     | $\text{nV}/\sqrt{\text{Hz}}$ |
|             |                                                                  | $f = 1\text{ kHz}$                                                | 25°C  |          | 17   |     |                              |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage                      | $f = 0.1\text{ Hz to }1\text{ Hz}$                                | 25°C  |          | 0.16 |     | $\mu\text{V}$                |
|             |                                                                  | $f = 0.1\text{ Hz to }10\text{ Hz}$                               | 25°C  |          | 0.47 |     |                              |
| $I_n$       | Equivalent input noise current                                   |                                                                   | 25°C  |          | 0.9  |     | $\text{pA}/\sqrt{\text{Hz}}$ |
| $B_1$       | Unity-gain bandwidth                                             | See <a href="#">Figure 6-3</a>                                    | 25°C  |          | 1.2  |     | MHz                          |
| $\Phi_m$    | Phase margin at unity gain                                       | See <a href="#">Figure 6-3</a>                                    | 25°C  |          | 42°  |     |                              |

## 5.6 Electrical Characteristics TLE2021xM, $V_{CC} = \pm 15\text{ V}$

at specified free-air temperature and  $V_{CC} = \pm 15\text{ V}$  (unless otherwise noted)

| PARAMETER       |                                                                  | TEST CONDITIONS                                  | $T_A$ <sup>(1)</sup> | TLE2021M    |             |      | TLE2021BM   |             |     | UNIT                         |
|-----------------|------------------------------------------------------------------|--------------------------------------------------|----------------------|-------------|-------------|------|-------------|-------------|-----|------------------------------|
|                 |                                                                  |                                                  |                      | MIN         | TYP         | MAX  | MIN         | TYP         | MAX |                              |
| $V_{IO}$        | Input offset voltage                                             | $V_{IC} = 0, R_S = 50\ \Omega$                   | 25°C                 |             | 120         | 500  |             | 40          | 100 | $\mu\text{V}$                |
|                 |                                                                  |                                                  | Full range           |             |             | 1000 |             |             | 200 |                              |
| $\alpha_{VIO}$  | Temperature coefficient of input offset voltage                  |                                                  | Full range           |             | 2           |      |             | 2           |     | $\mu\text{V}/^\circ\text{C}$ |
|                 | Input offset voltage long-term drift <sup>(2)</sup>              |                                                  | 25°C                 |             | 0.006       |      |             | 0.006       |     | $\mu\text{V}/\text{mo}$      |
| $I_{IO}$        | Input offset current                                             |                                                  | 25°C                 |             | 0.2         | 6    |             | 0.2         | 6   | nA                           |
|                 |                                                                  |                                                  | Full range           |             |             | 10   |             |             | 10  |                              |
| $I_{IB}$        | Input bias current                                               |                                                  | 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                       | $R_L = 10\text{ k}\Omega$                        | 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                  | $V_O = \pm 10\text{ V}, R_L = 10\text{ k}\Omega$ | 25°C                 | 1           | 6.5         |      | 1           | 6.5         |     | V/ $\mu\text{V}$             |
|                 |                                                                  |                                                  | Full range           | 0.5         |             |      | 0.5         |             |     |                              |
| $CMRR$          | Common mode rejection ratio                                      | $V_{IC} = V_{ICRmin}, R_S = 50\ \Omega$          | 25°C                 | 100         | 115         |      | 100         | 115         |     | dB                           |
|                 |                                                                  |                                                  | Full range           | 96          |             |      | 96          |             |     |                              |
| $k_{SVR}$       | Supply-voltage rejection ratio ( $\Delta V_{CC}/\Delta V_{IO}$ ) | $V_{CC} = \pm 2.5\text{ V to } \pm 15\text{ V}$  | 25°C                 | 105         | 120         |      | 105         | 120         |     | dB                           |
|                 |                                                                  |                                                  | Full range           | 100         |             |      | 100         |             |     |                              |
| $I_{CC}$        | Supply current                                                   | $V_O = 0, \text{ no load}$                       | 25°C                 |             | 200         | 300  |             | 200         | 300 | $\mu\text{A}$                |
|                 |                                                                  |                                                  | Full range           |             |             | 300  |             |             | 300 |                              |
| $\Delta I_{CC}$ | Supply-current change over operating temperature range           |                                                  | Full range           |             | 10          |      |             | 10          |     | $\mu\text{A}$                |

(1) Full range is  $-55^\circ\text{C}$  to  $+125^\circ\text{C}$ .

(2) 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.

## 5.7 Operating Characteristics TLE2021M, $V_{CC} = \pm 15\text{ V}$

at specified free-air temperature and  $V_{CC} = \pm 15\text{ V}$  (unless otherwise noted)

| PARAMETER   |                                                 | TEST CONDITIONS                                           | $T_A$ <sup>(1)</sup> | M SUFFIX |      |     | UNIT                   |
|-------------|-------------------------------------------------|-----------------------------------------------------------|----------------------|----------|------|-----|------------------------|
|             |                                                 |                                                           |                      | MIN      | TYP  | MAX |                        |
| $SR$        | Slew rate at unity gain                         | $V_O = 1\text{ V to } 3\text{ V}, \text{ see Figure 6-1}$ | 25°C                 | 0.45     | 0.65 |     | V/ $\mu\text{s}$       |
|             |                                                 |                                                           | Full range           | 0.42     |      |     |                        |
| $V_n$       | Equivalent input noise voltage (see Figure 6-2) | $f = 10\text{ Hz}$                                        | 25°C                 |          | 19   |     | nV/ $\sqrt{\text{Hz}}$ |
|             |                                                 | $f = 1\text{ kHz}$                                        | 25°C                 |          | 15   |     |                        |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage     | $f = 0.1\text{ Hz to } 1\text{ Hz}$                       | 25°C                 |          | 0.16 |     | $\mu\text{V}$          |
|             |                                                 | $f = 0.1\text{ Hz to } 10\text{ Hz}$                      | 25°C                 |          | 0.47 |     |                        |
| $I_n$       | Equivalent input noise current                  |                                                           | 25°C                 |          | 0.9  |     | pA/ $\sqrt{\text{Hz}}$ |
| $B_1$       | Unity-gain bandwidth                            | See Figure 6-3                                            | 25°C                 |          | 1.2  |     | MHz                    |
| $\phi_m$    | Phase margin at unity gain                      | See Figure 6-3                                            | 25°C                 |          | 46°  |     |                        |

(1) Full range is  $-55^\circ\text{C}$  to  $+125^\circ\text{C}$ .

## 5.8 Electrical Characteristics TLE2022xM, $V_{CC} = 5\text{ V}$

at specified free-air temperature and  $V_{CC} = 5\text{ V}$  (unless otherwise noted)

| PARAMETER        |                                                                      | TEST CONDITIONS                                               | T <sub>A</sub> <sup>(1)</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 <sup>(2)</sup>                  |                                                               | 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 |            |     | 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       | 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>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                    | 37         |           |          | 37         |          |           | 37         |     |      | μA    |

(1) Full range is  $-55^\circ\text{C}$  to  $+125^\circ\text{C}$ .

(2) 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.

## 5.9 Operating Characteristics TLE2022M, $V_{CC} = 5\text{ V}$

at  $T_A = 25^\circ\text{C}$  and  $V_{CC} = 5\text{ V}$  (unless otherwise noted)

| PARAMETER   |                                                                  | TEST CONDITIONS                                                   | $T_A$ | M SUFFIX |      |     | UNIT                         |
|-------------|------------------------------------------------------------------|-------------------------------------------------------------------|-------|----------|------|-----|------------------------------|
|             |                                                                  |                                                                   |       | MIN      | TYP  | MAX |                              |
| SR          | Slew rate at unity gain                                          | $V_O = 1\text{ V to }3\text{ V}$ , see <a href="#">Figure 6-1</a> | 25°C  |          | 0.5  |     | $\text{V}/\mu\text{s}$       |
| $V_n$       | Equivalent input noise voltage (see <a href="#">Figure 6-2</a> ) | $f = 10\text{ Hz}$                                                | 25°C  |          | 21   |     | $\text{nV}/\sqrt{\text{Hz}}$ |
|             |                                                                  | $f = 1\text{ kHz}$                                                | 25°C  |          | 17   |     |                              |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage                      | $f = 0.1\text{ Hz to }1\text{ Hz}$                                | 25°C  |          | 0.16 |     | $\mu\text{V}$                |
|             |                                                                  | $f = 0.1\text{ Hz to }10\text{ Hz}$                               | 25°C  |          | 0.47 |     |                              |
| $I_n$       | Equivalent input noise current                                   |                                                                   | 25°C  |          | 0.1  |     | $\text{pA}/\sqrt{\text{Hz}}$ |
| $B_1$       | Unity-gain bandwidth                                             | See <a href="#">Figure 6-3</a>                                    | 25°C  |          | 1.7  |     | MHz                          |
| $\phi_m$    | Phase margin at unity gain                                       | See <a href="#">Figure 6-3</a>                                    | 25°C  |          | 47°  |     |                              |

## 5.10 Electrical Characteristics TLE2022xM, $V_{CC} = \pm 15\text{ V}$

at specified free-air temperature and  $V_{CC} = \pm 15\text{ V}$  (unless otherwise noted)

| PARAMETER        |                                                                            | TEST<br>CONDITIONS                                               | T <sub>A</sub> <sup>(1)</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,<br>R <sub>S</sub> = 50 Ω                    | 25°C                          |            | 150            | 500            |           | 120            | 300            |           | 70             | 150            | μV   |
|                  |                                                                            |                                                                  | Full range                    |            |                | 700            |           |                | 450            |           |                | 300            |      |
| α <sub>VIO</sub> | Temperature coefficient<br>of input offset voltage                         |                                                                  | Full range                    |            | 2              |                |           | 2              |                |           | 2              | μV/°C          |      |
|                  | Input offset voltage<br>long-term drift <sup>(2)</sup>                     |                                                                  | 25°C                          |            | 0.006          |                |           | 0.006          |                |           | 0.006          | 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<br>voltage range                                         |                                                                  | R <sub>S</sub> = 50 Ω         | 25°C       | −15<br>to 13.5 | −15.3<br>to 14 |           | −15<br>to 13.5 | −15.3<br>to 14 |           | −15<br>to 13.5 | −15.3<br>to 14 | V    |
|                  |                                                                            |                                                                  |                               | Full range | −15<br>to 13.2 |                |           | −15<br>to 13.2 |                |           | −15<br>to 13.2 |                |      |
| V <sub>OM+</sub> | Maximum positive peak<br>output voltage swing                              | R <sub>L</sub> = 10 kΩ                                           | 25°C                          | 14         | 14.3           |                | 14        | 14.3           |                | 14        | 14.3           | V              |      |
|                  |                                                                            |                                                                  | Full range                    | 13.9       |                |                | 13.9      |                |                | 13.9      |                |                |      |
| V <sub>OM−</sub> | Maximum negative peak<br>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 <sub>VD</sub>  | Large-signal differential<br>voltage amplification                         | V <sub>O</sub> = ±10 V,<br>R <sub>L</sub> = 10 kΩ                | 25°C                          | 0.8        | 4              |                | 1         | 7              |                | 1.5       | 10             | V/μV           |      |
|                  |                                                                            |                                                                  | Full range                    | 0.8        |                |                | 1         |                |                | 1.5       |                |                |      |
| CMRR             | Common mode<br>rejection ratio                                             | V <sub>IC</sub> = V <sub>ICRmin</sub> ,<br>R <sub>S</sub> = 50 Ω | 25°C                          | 95         | 106            |                | 97        | 109            |                | 100       | 112            | dB             |      |
|                  |                                                                            |                                                                  | Full range                    | 91         |                |                | 93        |                |                | 96        |                |                |      |
| k <sub>SVR</sub> | Supply-voltage<br>rejection ratio<br>(ΔV <sub>CC</sub> /ΔV <sub>IO</sub> ) | V <sub>CC</sub> = ±2.5 V to<br>±15 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> = 0, no load                                      | 25°C                          |            | 550            | 700            |           | 550            | 700            |           | 550            | 700            | μA   |
|                  |                                                                            |                                                                  | Full range                    |            |                | 700            |           |                | 700            |           |                | 700            |      |
| ΔI <sub>CC</sub> | Supply-current change<br>over operating<br>temperature range               |                                                                  |                               | Full range |                | 60             |           |                | 60             |           |                | 60             | μA   |

(1) Full range is  $-55^\circ\text{C}$  to  $+125^\circ\text{C}$ .

(2) 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.

## 5.11 Operating Characteristics TLE2022M, $V_{CC} = \pm 15\text{ V}$

at specified free-air temperature and  $V_{CC} = \pm 15\text{ V}$  (unless otherwise noted)

| PARAMETER   |                                                                  | TEST CONDITIONS                                                     | $T_A$ <sup>(1)</sup> | M SUFFIX |      |     | UNIT                   |
|-------------|------------------------------------------------------------------|---------------------------------------------------------------------|----------------------|----------|------|-----|------------------------|
|             |                                                                  |                                                                     |                      | MIN      | TYP  | MAX |                        |
| SR          | Slew rate at unity gain                                          | $V_O = 1\text{ V}$ to $3\text{ V}$ , see <a href="#">Figure 6-1</a> | 25°C                 | 0.45     | 0.65 |     | V/ $\mu\text{s}$       |
|             |                                                                  |                                                                     | Full range           | 0.4      |      |     |                        |
| $V_n$       | Equivalent input noise voltage (see <a href="#">Figure 6-2</a> ) | $f = 10\text{ Hz}$                                                  | 25°C                 |          | 19   |     | nV/ $\sqrt{\text{Hz}}$ |
|             |                                                                  | $f = 1\text{ kHz}$                                                  | 25°C                 |          | 15   |     |                        |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage                      | $f = 0.1\text{ Hz}$ to $1\text{ Hz}$                                | 25°C                 |          | 0.16 |     | $\mu\text{V}$          |
|             |                                                                  | $f = 0.1\text{ Hz}$ to $10\text{ Hz}$                               | 25°C                 |          | 0.47 |     |                        |
| $I_n$       | Equivalent input noise current                                   |                                                                     | 25°C                 |          | 0.1  |     | pA/ $\sqrt{\text{Hz}}$ |
| $B_1$       | Unity-gain bandwidth                                             | See <a href="#">Figure 6-3</a>                                      | 25°C                 |          | 2.8  |     | MHz                    |
| $\phi_m$    | Phase margin at unity gain                                       | See <a href="#">Figure 6-3</a>                                      | 25°C                 |          | 52°  |     |                        |

(1) Full range is  $-55^\circ\text{C}$  to  $+125^\circ\text{C}$ .



## 5.12 Electrical Characteristics TLE2024xM, $V_{CC} = 5\text{ V}$

at specified free-air temperature and  $V_{CC} = 5\text{ V}$  (unless otherwise noted)

| PARAMETER        |                                                                      | TEST CONDITIONS                                               | T <sub>A</sub> <sup>(1)</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 <sup>(2)</sup>                  |                                                               | 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 |           |     | 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                          | 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                    | 50       |           |          | 50        |          |           | 50        |     |      | μA    |

(1) Full range is  $-55^\circ\text{C}$  to  $+125^\circ\text{C}$ .

(2) 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.

## 5.13 Operating Characteristics TLE2024M, $V_{CC} = 5\text{ V}$

at  $T_A = 25^\circ\text{C}$  and  $V_{CC} = 5\text{ V}$  (unless otherwise noted)

| PARAMETER   |                                                                  | TEST CONDITIONS                                                   | $T_A$ | M SUFFIX |      |     | UNIT                         |
|-------------|------------------------------------------------------------------|-------------------------------------------------------------------|-------|----------|------|-----|------------------------------|
|             |                                                                  |                                                                   |       | MIN      | TYP  | MAX |                              |
| SR          | Slew rate at unity gain                                          | $V_O = 1\text{ V to }3\text{ V}$ , see <a href="#">Figure 6-1</a> | 25°C  |          | 0.5  |     | $\text{V}/\mu\text{s}$       |
| $V_n$       | Equivalent input noise voltage (see <a href="#">Figure 6-2</a> ) | $f = 10\text{ Hz}$                                                | 25°C  |          | 21   |     | $\text{nV}/\sqrt{\text{Hz}}$ |
|             |                                                                  | $f = 1\text{ kHz}$                                                | 25°C  |          | 17   |     |                              |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage                      | $f = 0.1\text{ Hz to }1\text{ Hz}$                                | 25°C  |          | 0.16 |     | $\mu\text{V}$                |
|             |                                                                  | $f = 0.1\text{ Hz to }10\text{ Hz}$                               | 25°C  |          | 0.47 |     |                              |
| $I_n$       | Equivalent input noise current                                   |                                                                   | 25°C  |          | 0.1  |     | $\text{pA}/\sqrt{\text{Hz}}$ |
| $B_1$       | Unity-gain bandwidth                                             | See <a href="#">Figure 6-3</a>                                    | 25°C  |          | 1.7  |     | MHz                          |
| $\phi_m$    | Phase margin at unity gain                                       | See <a href="#">Figure 6-3</a>                                    | 25°C  |          | 47°  |     |                              |

## 5.14 Electrical Characteristics TLE2024xM, $V_{CC} = \pm 15\text{ V}$

at specified free-air temperature and  $V_{CC} = \pm 15\text{ V}$  (unless otherwise noted)

| PARAMETER        |                                                                      | TEST CONDITIONS                                                  | T <sub>A</sub> <sup>(1)</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,<br>R <sub>S</sub> = 50 Ω                    | 25°C                          |             |             | 1000 |             |             | 750  |             |             | 500   | μV   |
|                  |                                                                      |                                                                  | Full range                    |             |             | 1200 |             |             | 950  |             |             | 700   |      |
| α <sub>VIO</sub> | Temperature coefficient of input offset voltage                      |                                                                  | Full range                    |             | 2           |      |             | 2           |      |             | 2           | μV/°C |      |
|                  | Input offset voltage long-term drift <sup>(2)</sup>                  |                                                                  | 25°C                          |             | 0.006       |      |             | 0.006       |      |             | 0.006       | 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                          |             | 50          | 70   |             | 45          | 70   |             | 40          | 70    | nA   |
|                  |                                                                      |                                                                  | Full range                    |             |             | 90   |             |             | 90   |             |             | 90    |      |
| V <sub>ICR</sub> | Common-mode input voltage range                                      | R <sub>S</sub> = 50 Ω                                            | 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 <sub>OM+</sub> | Maximum positive peak output voltage swing                           | R <sub>L</sub> = 10 kΩ                                           | 25°C                          | 13.8        | 14.1        |      | 13.9        | 14.2        |      | 14          | 14.3        | V     |      |
|                  |                                                                      |                                                                  | Full range                    | 13.7        |             |      | 13.7        |             |      | 13.8        |             |       |      |
| V <sub>OM−</sub> | 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 <sub>VD</sub>  | Large-signal differential voltage amplification                      | V <sub>O</sub> = ±10 V,<br>R <sub>L</sub> = 10 kΩ                | 25°C                          | 0.4         | 2           |      | 0.8         | 4           |      | 1           | 7           | V/μV  |      |
|                  |                                                                      |                                                                  | Full range                    | 0.4         |             |      | 0.8         |             |      | 1           |             |       |      |
| CMRR             | Common mode rejection ratio                                          | V <sub>IC</sub> = V <sub>ICRmin</sub> ,<br>R <sub>S</sub> = 50 Ω | 25°C                          | 92          | 102         |      | 94          | 105         |      | 97          | 108         | dB    |      |
|                  |                                                                      |                                                                  | Full range                    | 88          |             |      | 90          |             |      | 93          |             |       |      |
| 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                          |             | 1050        | 1400 |             | 1050        | 1400 |             | 1050        | 1400  | μA   |
|                  |                                                                      |                                                                  | Full range                    |             |             | 1400 |             |             | 1400 |             |             | 1400  |      |
| ΔI <sub>CC</sub> | Supply-current change over operating temperature range               |                                                                  | Full range                    |             | 85          |      |             | 85          |      |             | 85          |       | μA   |

(1) Full range is  $-55^\circ\text{C}$  to  $+125^\circ\text{C}$ .

(2) 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.

## 5.15 Operating Characteristics TLE2024M, $V_{CC} = \pm 15\text{ V}$

at specified free-air temperature and  $V_{CC} = \pm 15\text{ V}$  (unless otherwise noted)

| PARAMETER   |                                                                  | TEST CONDITIONS                                                     | $T_A$ <sup>(1)</sup> | M SUFFIX |      |     | UNIT                   |
|-------------|------------------------------------------------------------------|---------------------------------------------------------------------|----------------------|----------|------|-----|------------------------|
|             |                                                                  |                                                                     |                      | MIN      | TYP  | MAX |                        |
| SR          | Slew rate at unity gain                                          | $V_O = 1\text{ V}$ to $3\text{ V}$ , see <a href="#">Figure 6-1</a> | 25°C                 | 0.45     | 0.7  |     | V/ $\mu\text{s}$       |
|             |                                                                  |                                                                     | Full range           | 0.42     |      |     |                        |
| $V_n$       | Equivalent input noise voltage (see <a href="#">Figure 6-2</a> ) | $f = 10\text{ Hz}$                                                  | 25°C                 |          | 19   |     | nV/ $\sqrt{\text{Hz}}$ |
|             |                                                                  | $f = 1\text{ kHz}$                                                  | 25°C                 |          | 15   |     |                        |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage                      | $f = 0.1\text{ Hz}$ to $1\text{ Hz}$                                | 25°C                 |          | 0.16 |     | $\mu\text{V}$          |
|             |                                                                  | $f = 0.1\text{ Hz}$ to $10\text{ Hz}$                               | 25°C                 |          | 0.47 |     |                        |
| $I_n$       | Equivalent input noise current                                   |                                                                     | 25°C                 |          | 0.1  |     | pA/ $\sqrt{\text{Hz}}$ |
| $B_1$       | Unity-gain bandwidth                                             | See <a href="#">Figure 6-3</a>                                      | 25°C                 |          | 2.8  |     | MHz                    |
| $\phi_m$    | Phase margin at unity gain                                       | See <a href="#">Figure 6-3</a>                                      | 25°C                 |          | 52°  |     |                        |

(1) Full range is  $-55^\circ\text{C}$  to  $+125^\circ\text{C}$ .

## 5.16 Typical Characteristics

**Table 5-1. Table of Graphs**

|             |                                                                 |                                                                     | FIGURE       |
|-------------|-----------------------------------------------------------------|---------------------------------------------------------------------|--------------|
| $V_{IO}$    | Input offset voltage                                            | Distribution                                                        | 4-1 to 4-3   |
| $I_{IB}$    | Input bias current                                              | vs Common-mode input voltage<br>vs Free-air temperature             | 4-4 to 4-9   |
| $I_I$       | Input current                                                   | vs Differential input voltage                                       | 4-10         |
| $V_{OM}$    | Maximum peak output voltage                                     | vs Output current<br>vs Free-air temperature                        | 4-11 to 4-14 |
| $V_{OH}$    | High-level output voltage                                       | vs High-level output current<br>vs Free-air temperature             | 4-15 to 4-17 |
| $V_{OL}$    | Low-level output voltage                                        | vs Low-level output current<br>vs Free-air temperature              | 4-18, 4-19   |
| $V_{O(PP)}$ | Maximum peak-to-peak output voltage                             | vs Frequency                                                        | 4-20, 4-21   |
| $A_{VD}$    | Large-signal differential voltage amplification and phase shift | vs Frequency                                                        | 4-22         |
|             | Large-signal differential voltage amplification                 | vs Free-air temperature                                             | 4-23 to 4-25 |
| $I_{OS}$    | Short-circuit output current                                    | vs Supply voltage<br>vs Free-air temperature                        | 4-26 to 4-33 |
| $I_{CC}$    | Supply current                                                  | vs Supply voltage<br>vs Free-air temperature                        | 4-34 to 4-39 |
| CMRR        | Common-mode rejection ratio                                     | vs Frequency                                                        | 4-40 to 4-42 |
| SR          | Slew rate                                                       | vs Free-air temperature                                             | 4-43 to 4-45 |
|             | Voltage-follower small-signal pulse response                    |                                                                     | 4-46, 4-47   |
|             | Voltage-follower large-signal pulse response                    |                                                                     | 4-48 to 4-53 |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage                     | 0.1Hz to 1Hz<br>0.1Hz to 10Hz                                       | 4-54, 4-55   |
| $V_n$       | Equivalent input noise voltage                                  | vs Frequency                                                        | 4-56         |
| $B_1$       | Unity-gain bandwidth                                            | vs Supply voltage<br>vs Free-air temperature                        | 4-57 to 4-60 |
| $\phi_m$    | Phase margin                                                    | vs Supply voltage<br>vs Load capacitance<br>vs Free-air temperature | 4-61 to 4-66 |
|             | Phase shift                                                     | vs Frequency                                                        | 4-22         |

## 5.16 Typical Characteristics (continued)

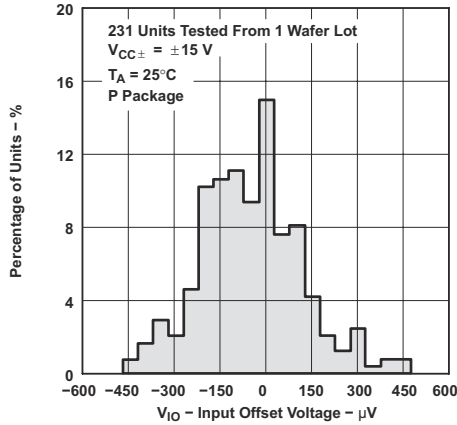


Figure 5-1. Distribution of TLE2021xM Input Offset Voltage

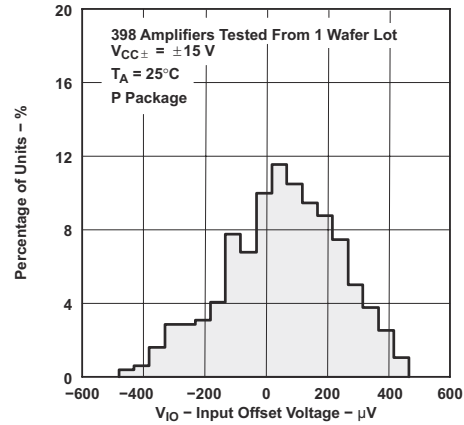


Figure 5-2. Distribution of TLE2022xM Input Offset Voltage

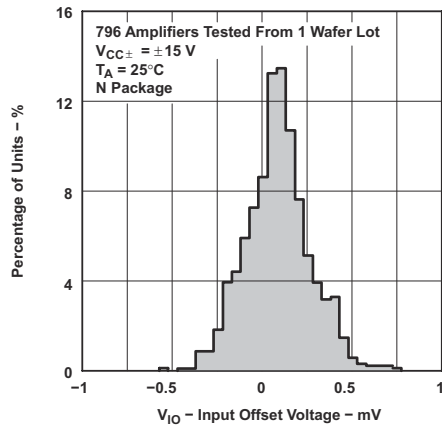


Figure 5-3. Distribution of TLE2024xM Input Offset Voltage

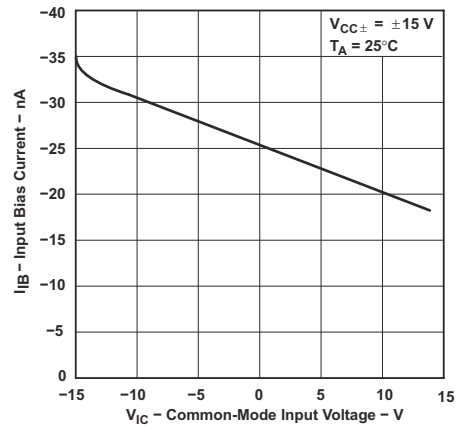


Figure 5-4. TLE2021xM Input Bias Current vs Common-Mode Input Voltage

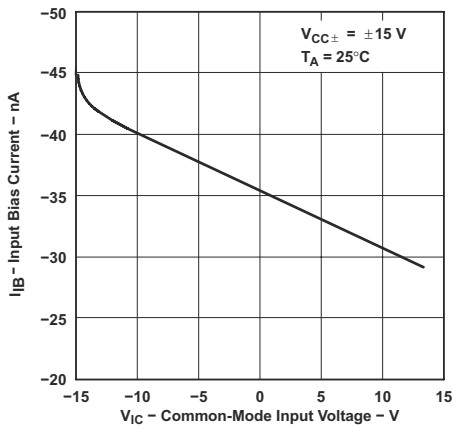


Figure 5-5. TLE2022xM Input Bias Current vs Common-Mode Input Voltage

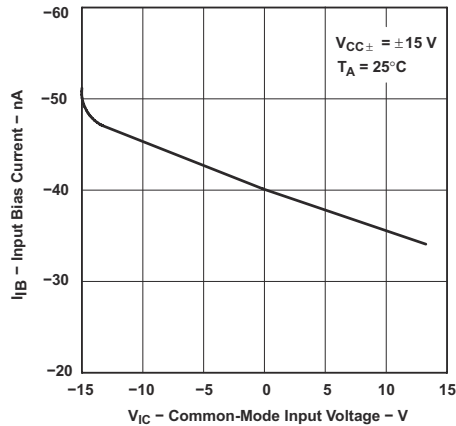
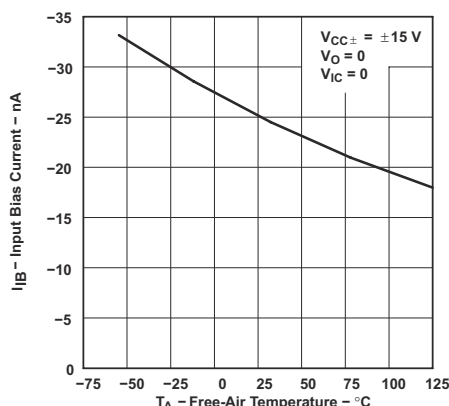


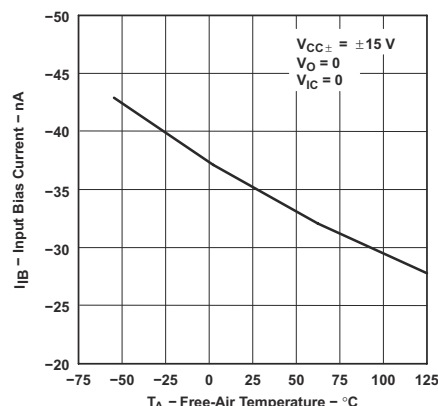
Figure 5-6. TLE2024xM Input Bias Current vs Common-Mode Input Voltage

## 5.16 Typical Characteristics (continued)



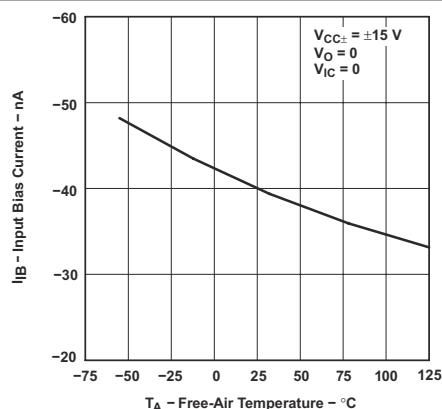
Data at high and low temperatures applicable only within rated operating free-air temperature ranges of the various devices

**Figure 5-7. TLE2021xM Input Bias Current vs Free-Air Temperature**



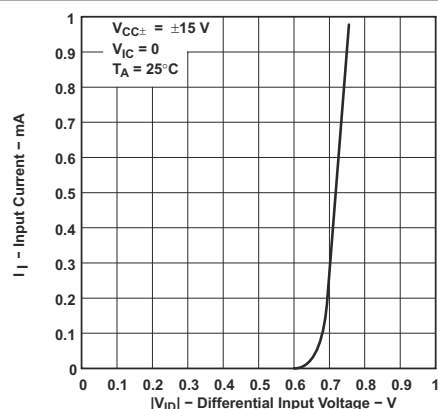
Data at high and low temperatures applicable only within rated operating free-air temperature ranges of the various devices

**Figure 5-8. TLE2022xM Input Bias Current vs Free-Air Temperature**

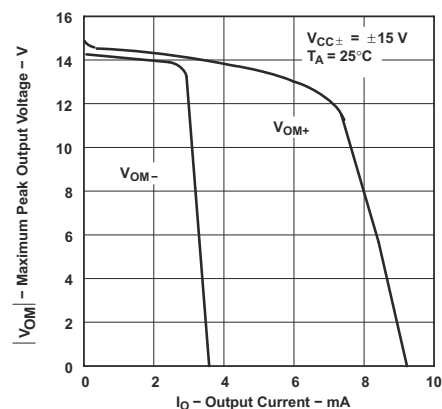


Data at high and low temperatures applicable only within rated operating free-air temperature ranges of the various devices

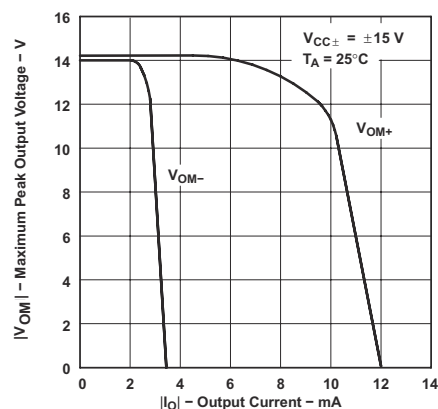
**Figure 5-9. TLE2024xM Input Bias Current vs Free-Air Temperature**



**Figure 5-10. Input Current vs Differential Input Voltage**



**Figure 5-11. TLE2021xM Maximum Peak Output Voltage vs Output Current**



**Figure 5-12. TLE2022xM Maximum Peak Output Voltage vs Output Current**

## 5.16 Typical Characteristics (continued)

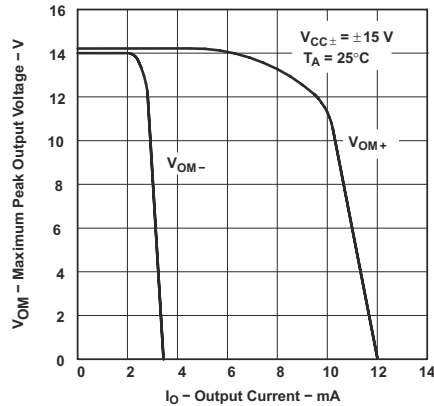
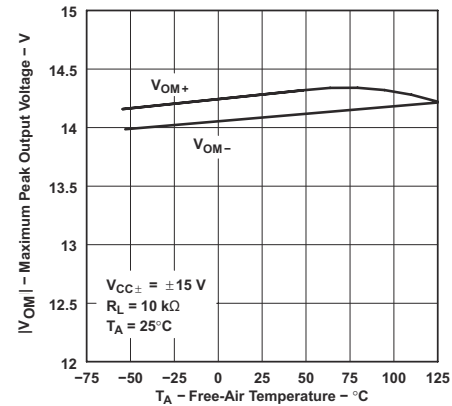


Figure 5-13. TLE2024xM Maximum Peak Output Voltage vs Output Current



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

Figure 5-14. Maximum Peak Output Voltage vs Free-Air Temperature

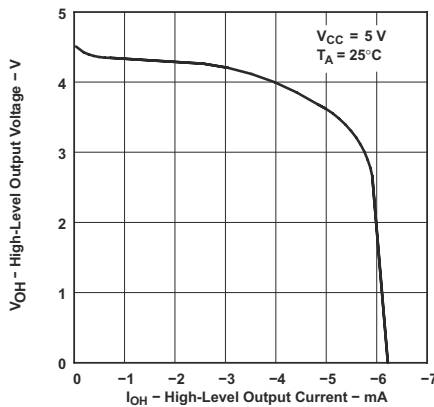


Figure 5-15. TLE2021xM High-Level Output Voltage vs High-Level Output Current

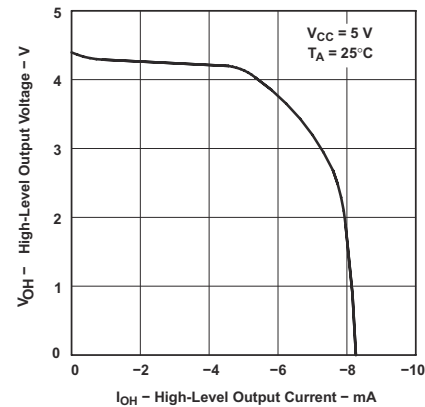
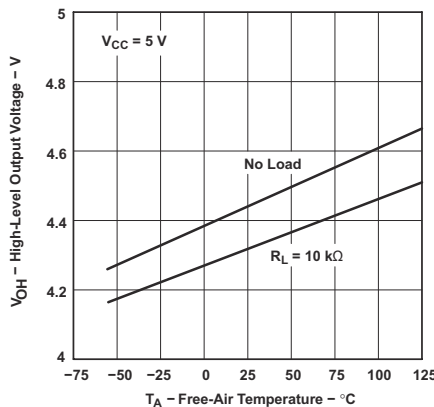


Figure 5-16. TLE2022xM and TLE2024xM High-Level Output Voltage vs High-Level Output Current



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

Figure 5-17. High-Level Output Voltage vs Free-Air Temperature

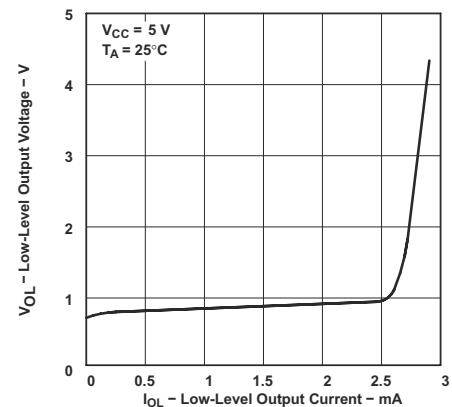
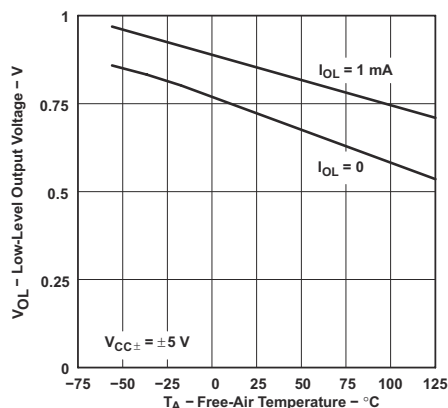


Figure 5-18. Low-Level Output Voltage vs Low-Level Output Current

## 5.16 Typical Characteristics (continued)



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

Figure 5-19. Low-Level Output Voltage vs Free-Air Temperature

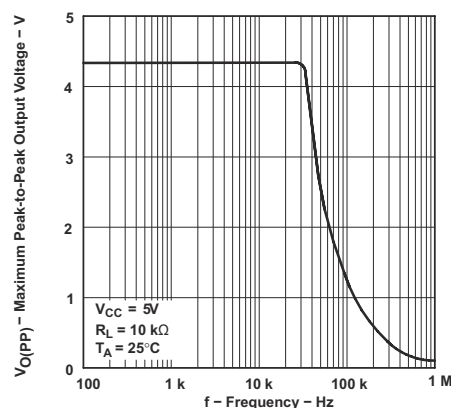


Figure 5-20. Maximum Peak-to-Peak Output Voltage Vs Frequency

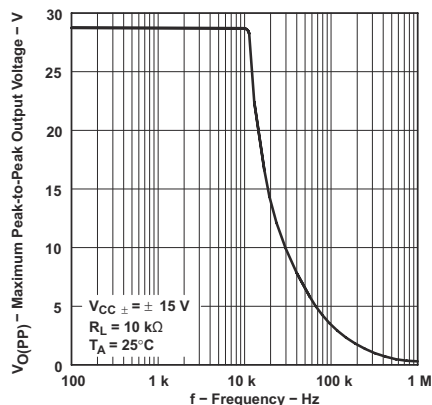


Figure 5-21. Maximum Peak-to-Peak Output Voltage vs Frequency

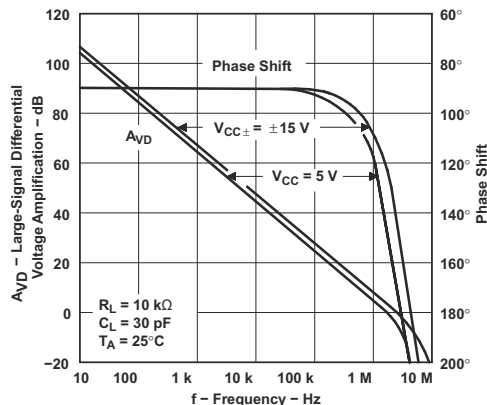
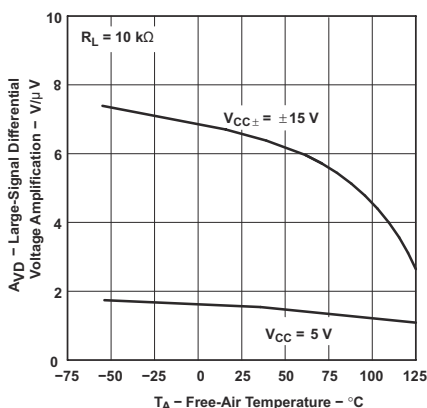
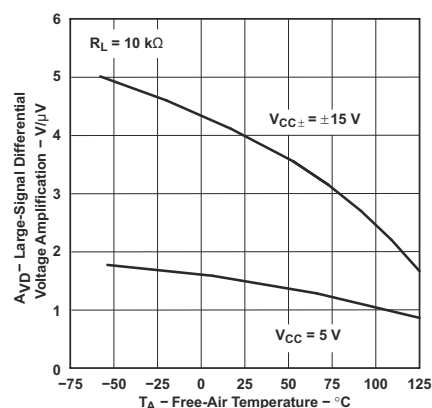


Figure 5-22. Large-Signal Differential Voltage Amplification and Phase Shift vs Frequency



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

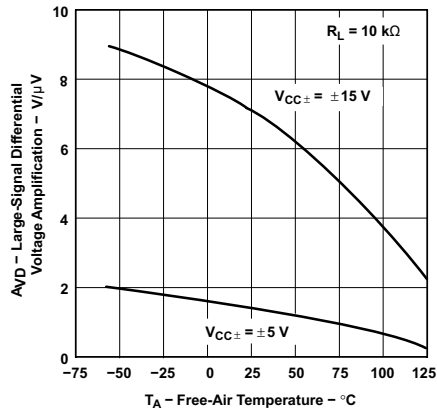
Figure 5-23. TLE2021xM Large-Scale Differential Voltage Amplification vs Free-Air Temperature



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

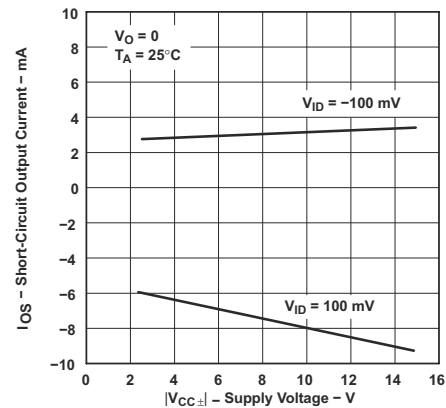
Figure 5-24. TLE2022xM Large-Signal Differential Voltage Amplification vs Free-Air Temperature

## 5.16 Typical Characteristics (continued)

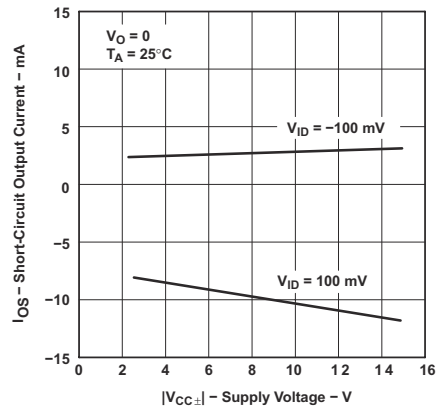


Data at high and low temperatures applicable only within rated operating free-air temperature ranges of the various devices

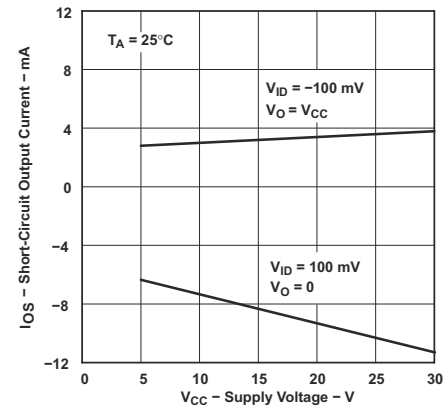
**Figure 5-25. TLE2024xM Large-Scale Differential Voltage Amplification vs Free-Air Temperature**



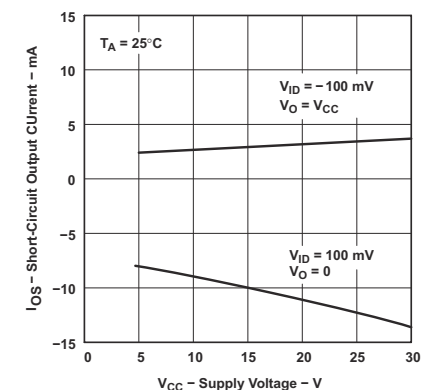
**Figure 5-26. TLE2021xM Short-Circuit Output Current vs Supply Voltage**



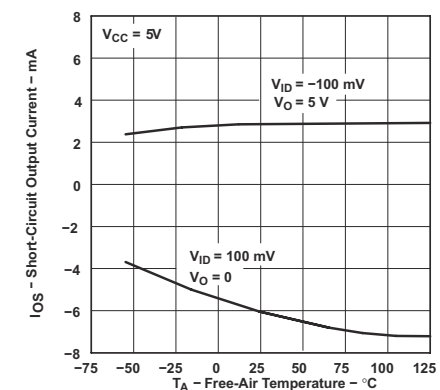
**Figure 5-27. TLE2022xM and TLE2024xM Short-Circuit Output Current vs Supply Voltage**



**Figure 5-28. TLE2021xM Short-Circuit Output Current vs Supply Voltage**



**Figure 5-29. TLE2022xM and TLE2024xM Short-Circuit Output Current vs Supply Voltage**

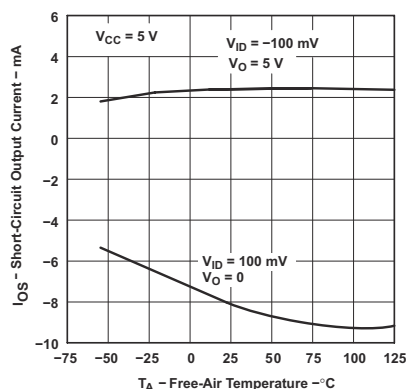


Data at high and low temperatures applicable only within rated operating free-air temperature ranges of the various devices

**Figure 5-30. TLE2021xM Short-Circuit Output Current vs Free-Air Temperature**

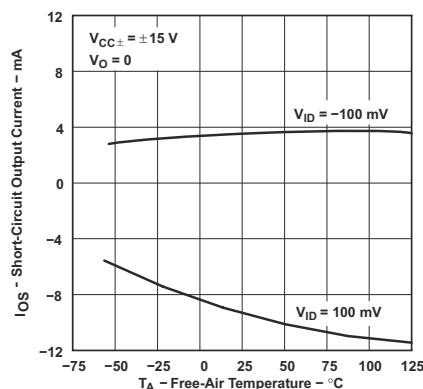


## 5.16 Typical Characteristics (continued)



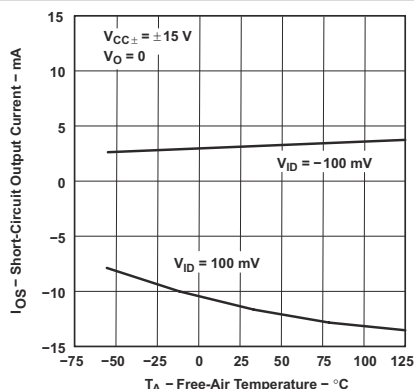
Data at high and low temperatures applicable only within rated operating free-air temperature ranges of the various devices

**Figure 5-31. TLE2022xM and TLE2024xM Short-Circuit Output Current vs Free-Air Temperature**



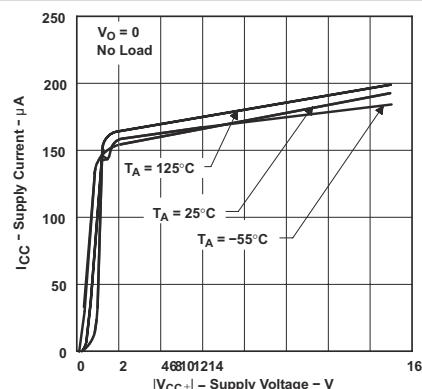
Data at high and low temperatures applicable only within rated operating free-air temperature ranges of the various devices

**Figure 5-32. TLE2021xM Short-Circuit Output Current vs Free-Air Temperature**

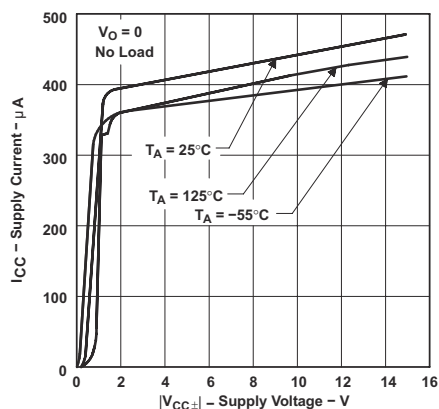


Data at high and low temperatures applicable only within rated operating free-air temperature ranges of the various devices

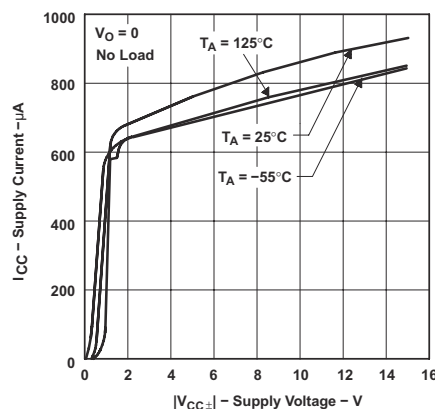
**Figure 5-33. TLE2022xM and TLE2024xM Short-Circuit Output Current vs Free-Air Temperature**



**Figure 5-34. TLE2021xM Supply Current vs Supply Voltage**

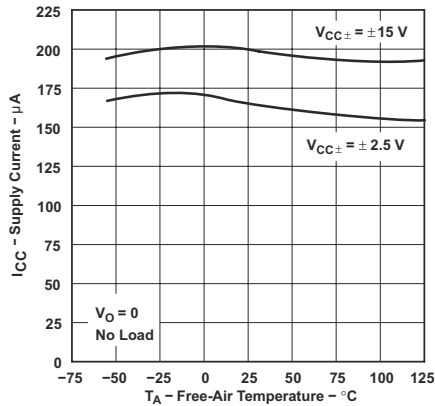


**Figure 5-35. TLE2022xM Supply Current vs Supply Voltage**



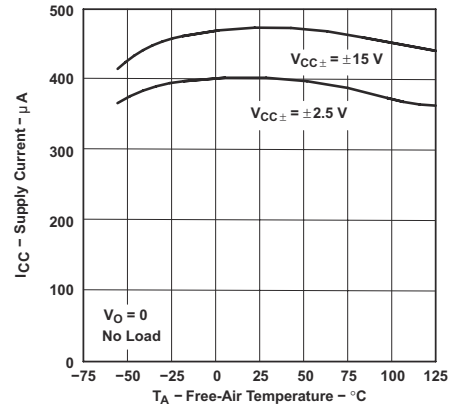
**Figure 5-36. TLE2024xM Supply Current vs Supply Voltage**

## 5.16 Typical Characteristics (continued)



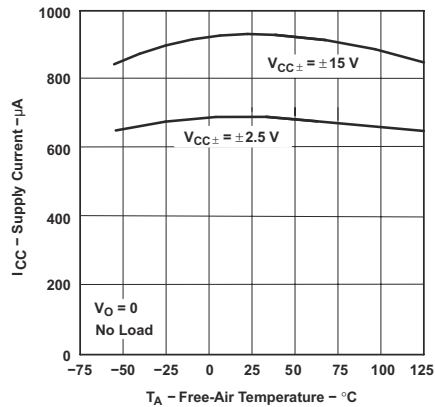
Data at high and low temperatures applicable only within rated operating free-air temperature ranges of the various devices

**Figure 5-37. TLE2021xM Supply Current vs Free-Air Temperature**



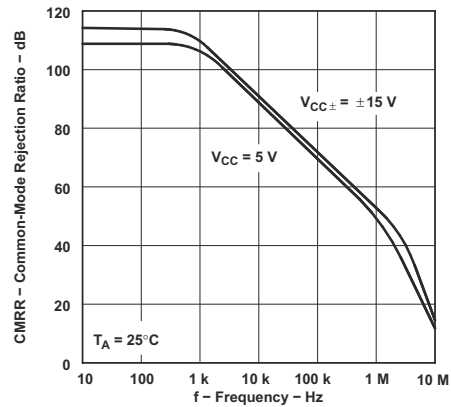
Data at high and low temperatures applicable only within rated operating free-air temperature ranges of the various devices

**Figure 5-38. TLE2022xM Supply Current vs Free-Air Temperature**

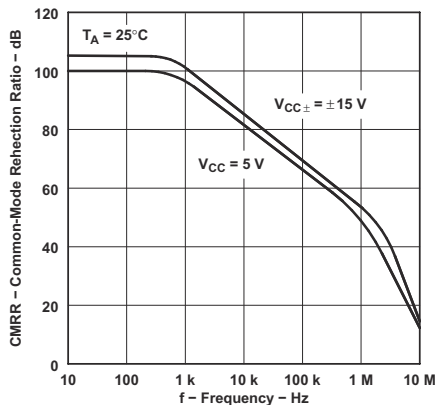


Data at high and low temperatures applicable only within rated operating free-air temperature ranges of the various devices

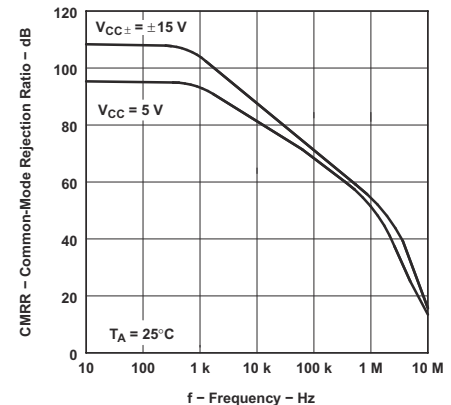
**Figure 5-39. TLE2024xM Supply Current vs Free-Air Temperature**



**Figure 5-40. TLE2021xM Common-Mode Rejection Ratio vs Frequency**

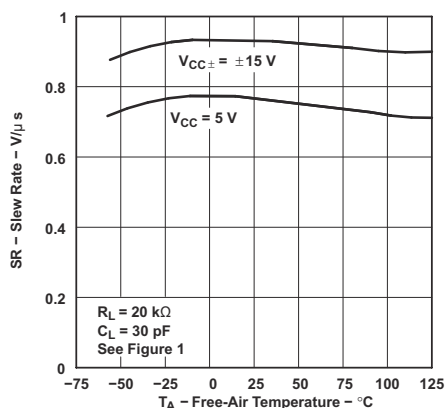


**Figure 5-41. TLE2022xM Common-Mode Rejection Ratio vs Frequency**



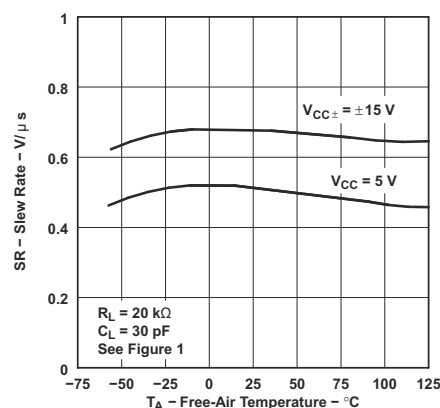
**Figure 5-42. TLE2024xM Common-Mode Rejection Ratio vs Frequency**

## 5.16 Typical Characteristics (continued)



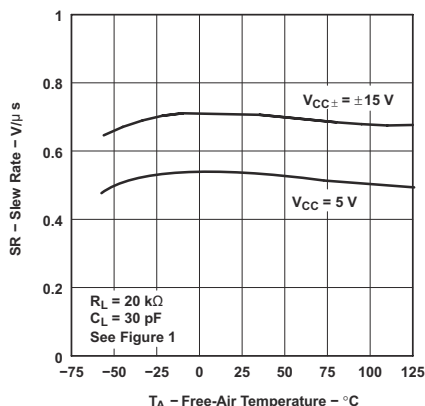
Data at high and low temperatures applicable only within rated operating free-air temperature ranges of the various devices

**Figure 5-43. TLE2021xM Slew Rate vs Free-Air Temperature**



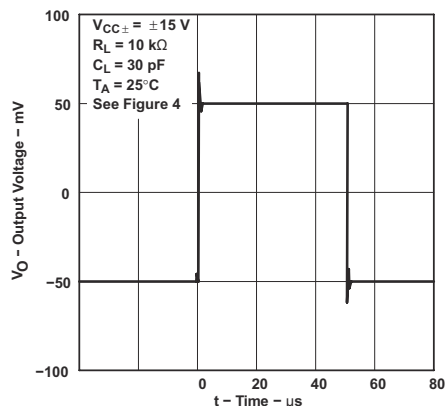
Data at high and low temperatures applicable only within rated operating free-air temperature ranges of the various devices

**Figure 5-44. TLE2022xM Slew Rate vs Free-Air Temperature**

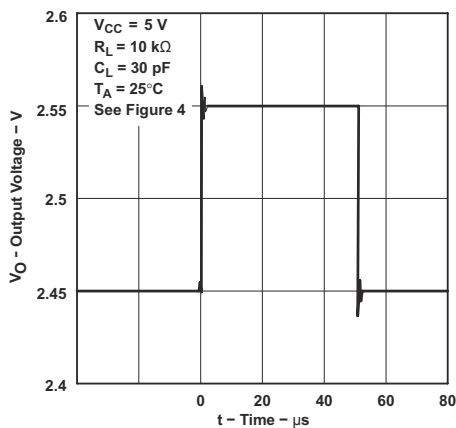


Data at high and low temperatures applicable only within rated operating free-air temperature ranges of the various devices

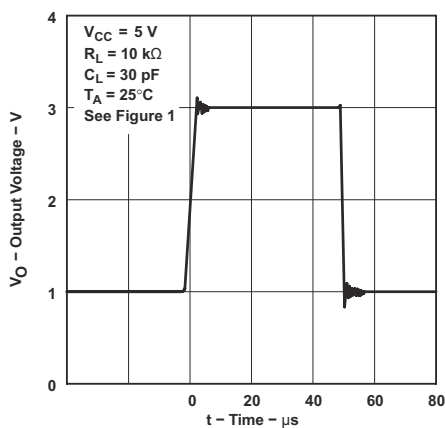
**Figure 5-45. TLE2024xM Slew Rate vs Free-Air Temperature**



**Figure 5-46. Voltage-Follower Small-Signal Pulse Response**

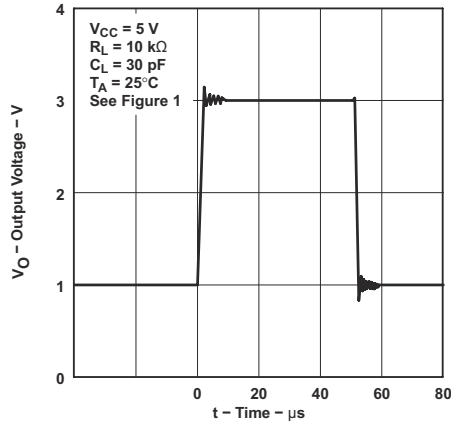


**Figure 5-47. Voltage-Follower Small-Signal Pulse Response**

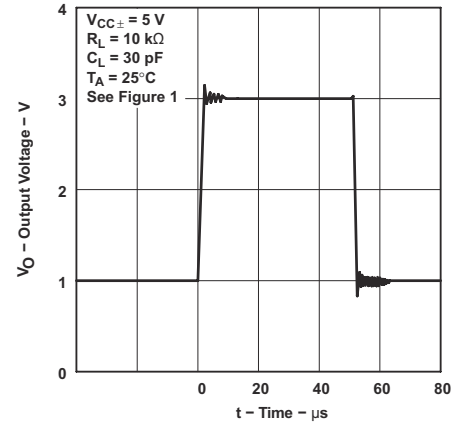


**Figure 5-48. TLE2021xM Voltage-Follower Large-Signal Pulse Response**

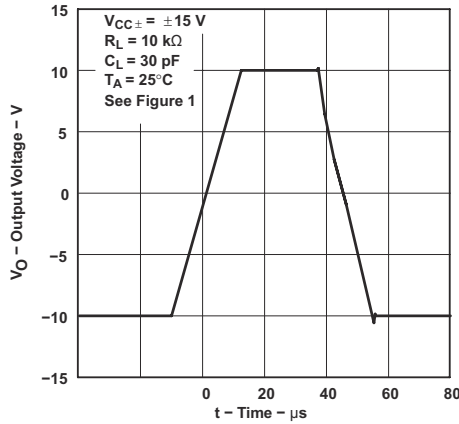
## 5.16 Typical Characteristics (continued)



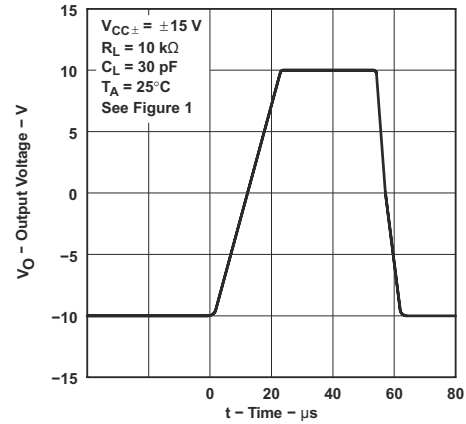
**Figure 5-49. TLE2022xM Voltage-Follower Large-Signal Pulse Response**



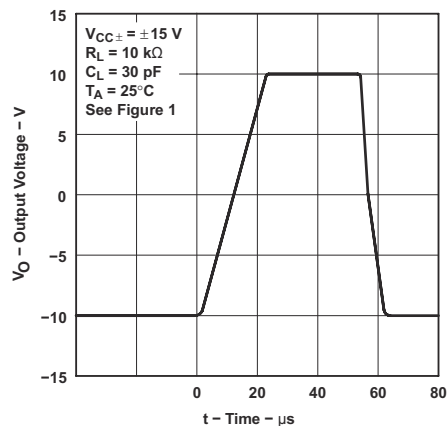
**Figure 5-50. TLE2024xM Voltage-Follower Large-Scale Pulse Response**



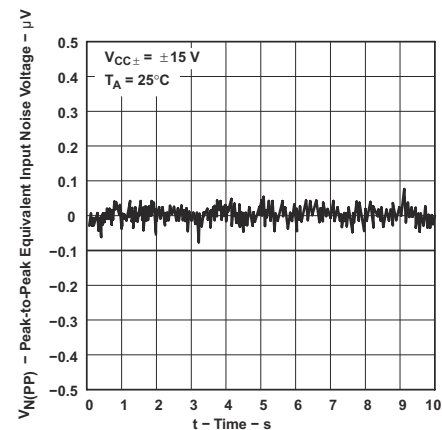
**Figure 5-51. TLE2021xM Voltage-Follower Large-Signal Pulse Response**



**Figure 5-52. TLE2022xM Voltage-Follower Large-Signal Pulse Response**

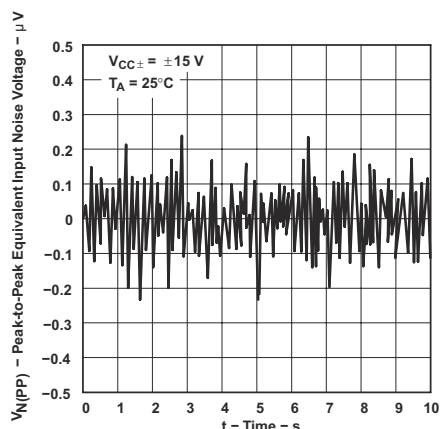


**Figure 5-53. TLE2024xM Voltage-Follower Large-Signal Pulse Response**

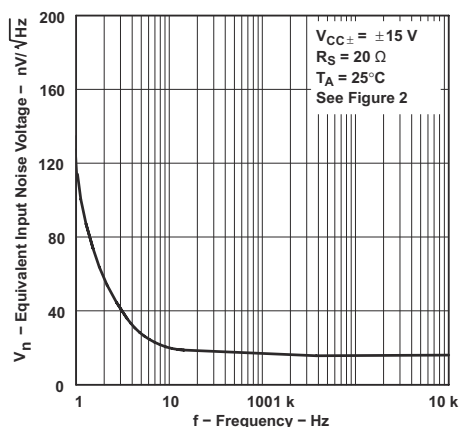


**Figure 5-54. Peak-to-Peak Equivalent Input Noise Voltage 0.1Hz to 1Hz**

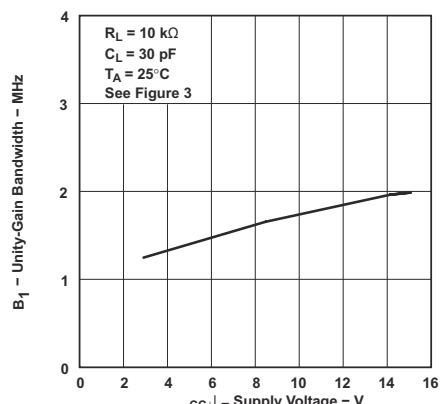
## 5.16 Typical Characteristics (continued)



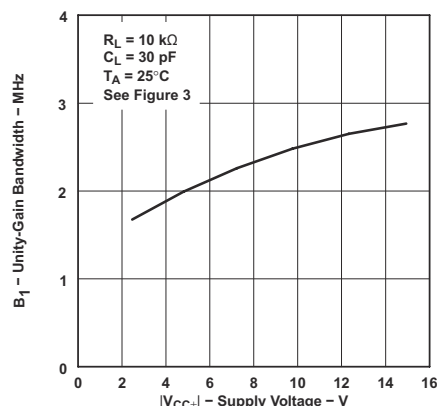
**Figure 5-55. Peak-to-Peak Equivalent Input Noise Voltage 0.1Hz to 10Hz**



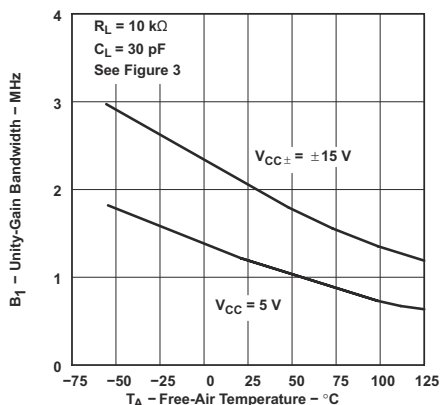
**Figure 5-56. Equivalent Input Noise Voltage vs Frequency**



**Figure 5-57. TLE2021xM Unity-Gain Bandwidth vs Supply Voltage**

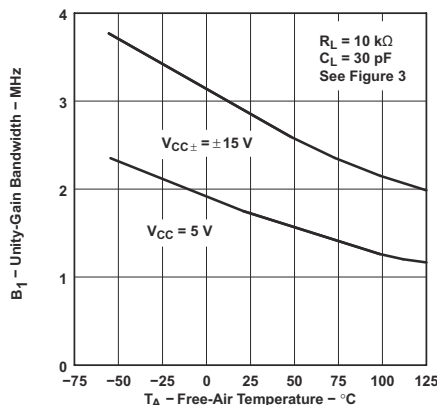


**Figure 5-58. TLE2022xM and TLE2024xM Unity-Gain Bandwidth vs Supply Voltage**



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

**Figure 5-59. TLE2021xM Unity-Gain Bandwidth vs Free-Air Temperature**



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

**Figure 5-60. TLE2022xM and TLE2024xM Unity-Gain Bandwidth vs Free-Air Temperature**

## 5.16 Typical Characteristics (continued)

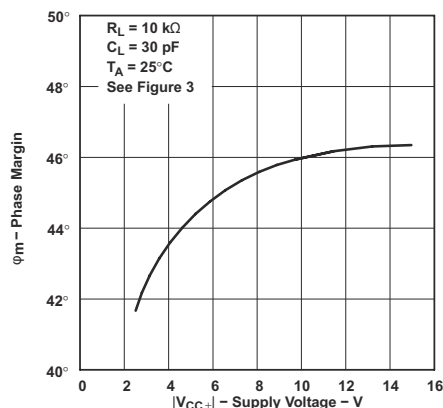


Figure 5-61. TLE2021xM Phase Margin vs Supply Voltage

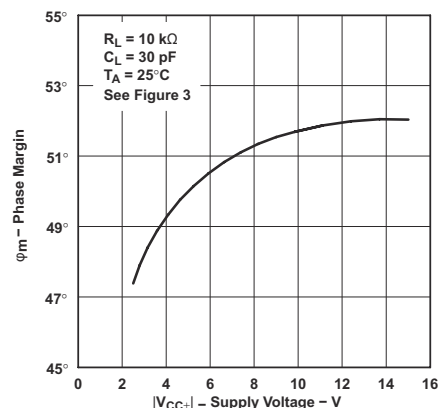


Figure 5-62. TLE2022xM and TLE2024xM Phase Margin vs Supply Voltage

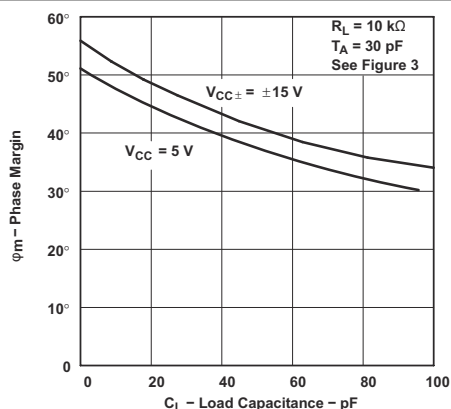


Figure 5-63. TLE2021xM Phase Margin vs Load Capacitance

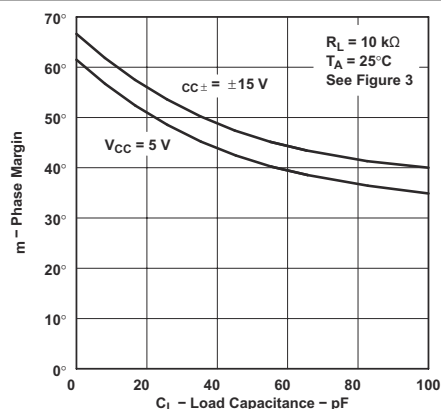
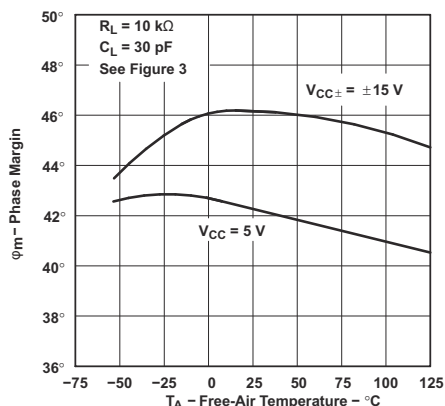
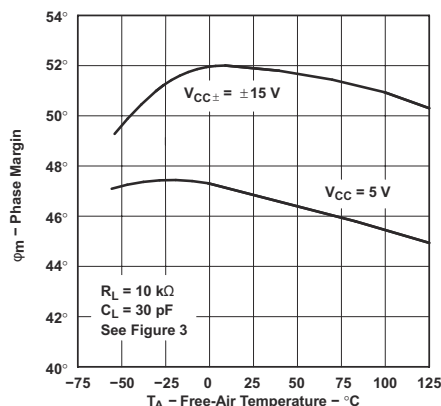


Figure 5-64. TLE2022xM and TLE2024xM Phase Margin vs Load Capacitance



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

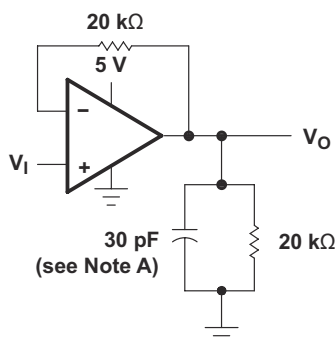
Figure 5-65. TLE2021xM Phase Margin vs Free-Air Temperature



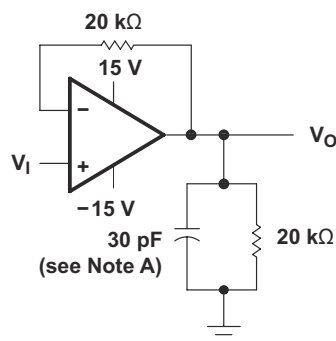
Data at high and low temperatures applicable only within rated operating free-air temperature ranges of the various devices

Figure 5-66. TLE2022xM and TLE2024xM Phase Margin vs Free-Air Temperature

## 6 Parameter Measurement Information



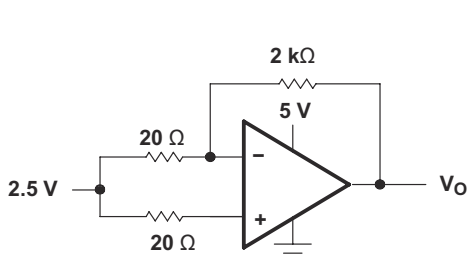
(a) SINGLE SUPPLY



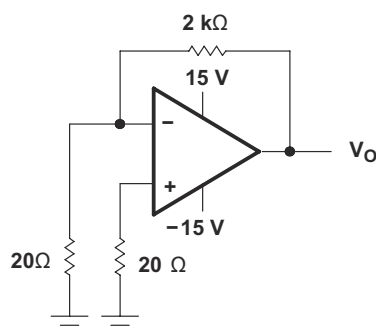
(b) SPLIT SUPPLY

A.  $C_L$  includes fixture capacitance.

Figure 6-1. Slew-Rate Test Circuit

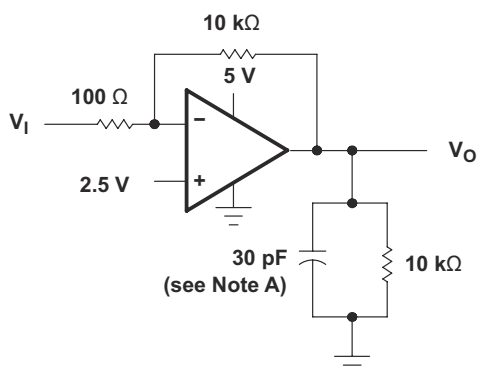


(a) SINGLE SUPPLY

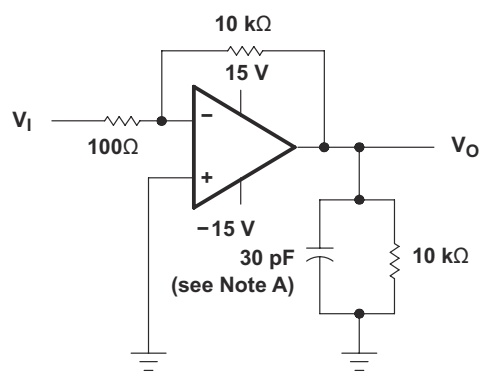


(b) SPLIT SUPPLY

Figure 6-2. Noise-Voltage Test Circuit



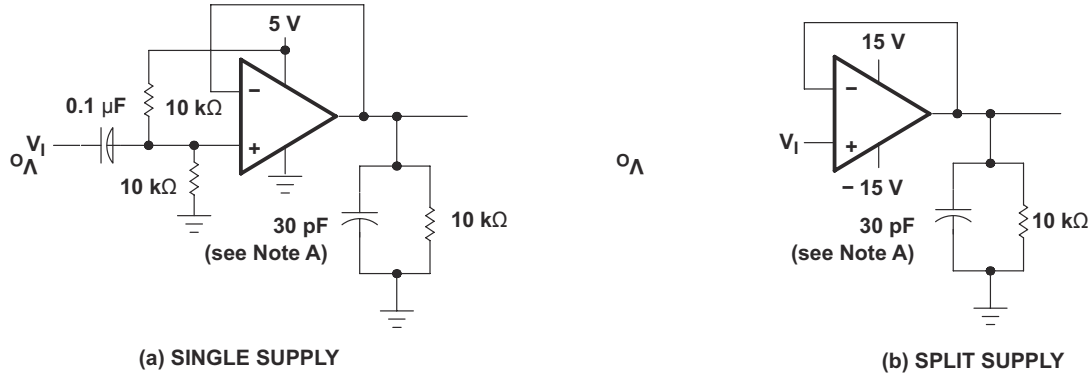
(a) SINGLE SUPPLY



(b) SPLIT SUPPLY

A.  $C_L$  includes fixture capacitance.

Figure 6-3. Unity-Gain Bandwidth and Phase-Margin Test Circuit



A.  $C_L$  includes fixture capacitance.

**Figure 6-4. Small-Signal Pulse-Response Test Circuit**

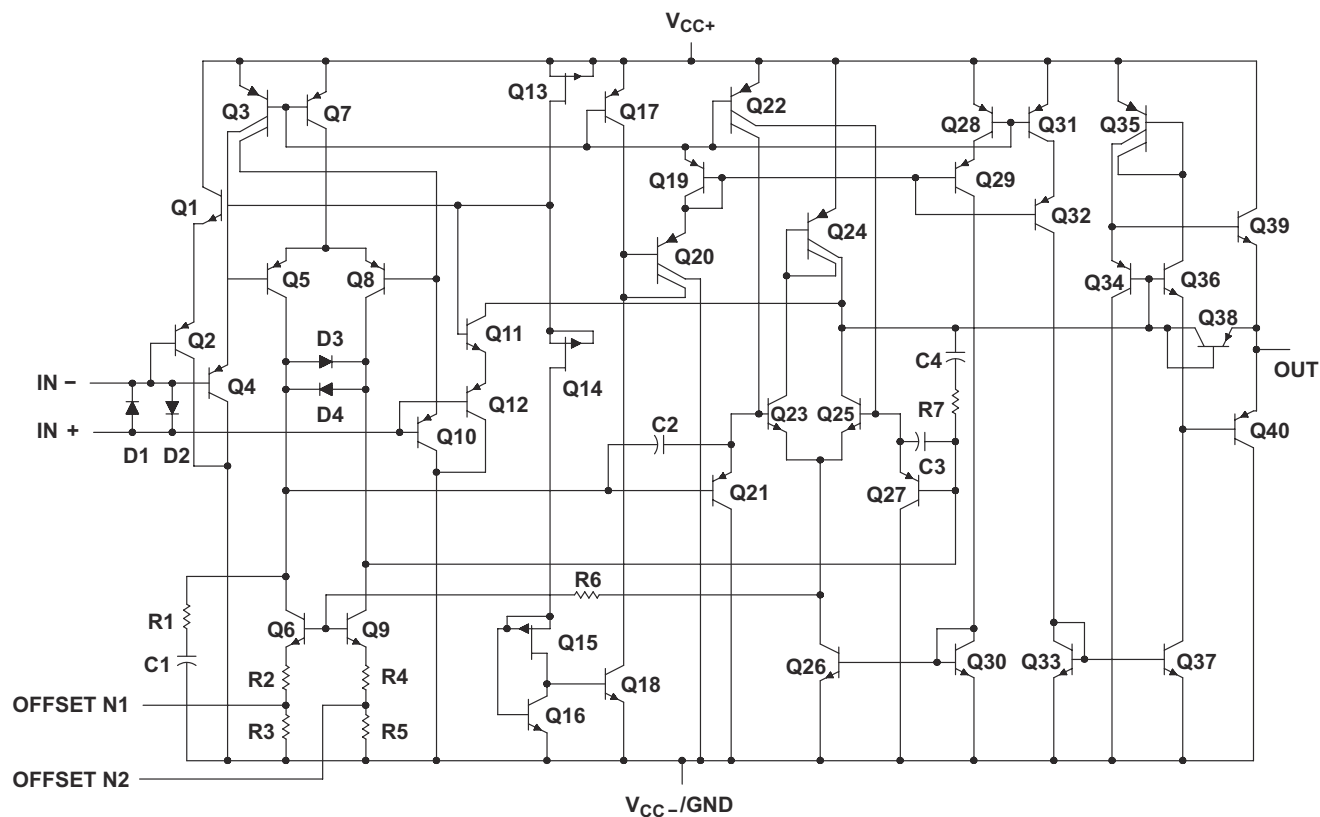
## 6.1 Typical Values

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



## 7 Detailed Description

### 7.1 Functional Block Diagram



**Figure 7-1. Equivalent Schematic (Each Amplifier)**

**Table 7-1. Actual Device Component Count**

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

## 8 Application and Implementation

### Note

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes, as well as validating and testing their design implementation to confirm system functionality.

### 8.1 Application Information

#### 8.1.1 Voltage-Follower Applications

The TLE202xM 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 sometimes occurs when the device is operated in the voltage-follower configuration and driven with a fast, large-signal pulse. Use a feedback resistor to limit the current to a maximum of 1mA 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 10kΩ, this pole degrades the amplifier phase margin. Figure 8-1 shows that to alleviate this problem, add a capacitor (20pF to 50pF) in parallel with the feedback resistor.

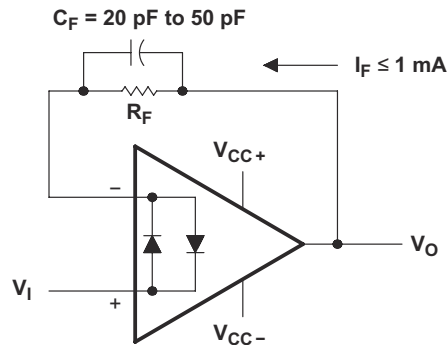


Figure 8-1. Voltage Follower

#### 8.1.2 Input Offset Voltage Null

The TLE202xM series offers external null pins that further reduce the input offset voltage. Figure 8-2 shows how to connect the circuit if this feature is desired. When external null is not needed, leave the null pins disconnected.

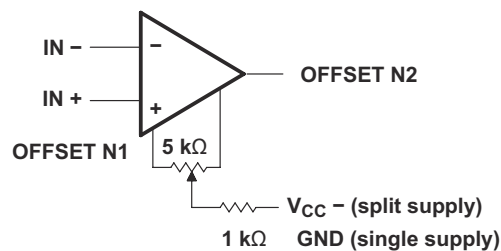


Figure 8-2. Input Offset Voltage Null Circuit

### 8.1.3 Macromodel Information

Macromodel information derived using Microsim Parts™, the model generation software used with PSpice™. The Boyle macromodel<sup>1</sup> (see subcircuit in Figure 8-3, Figure 8-4, and Figure 8-5) are generated using the TLE202x typical electrical and operating characteristics at 25°C. Using this information, output simulations of the following key parameters are 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

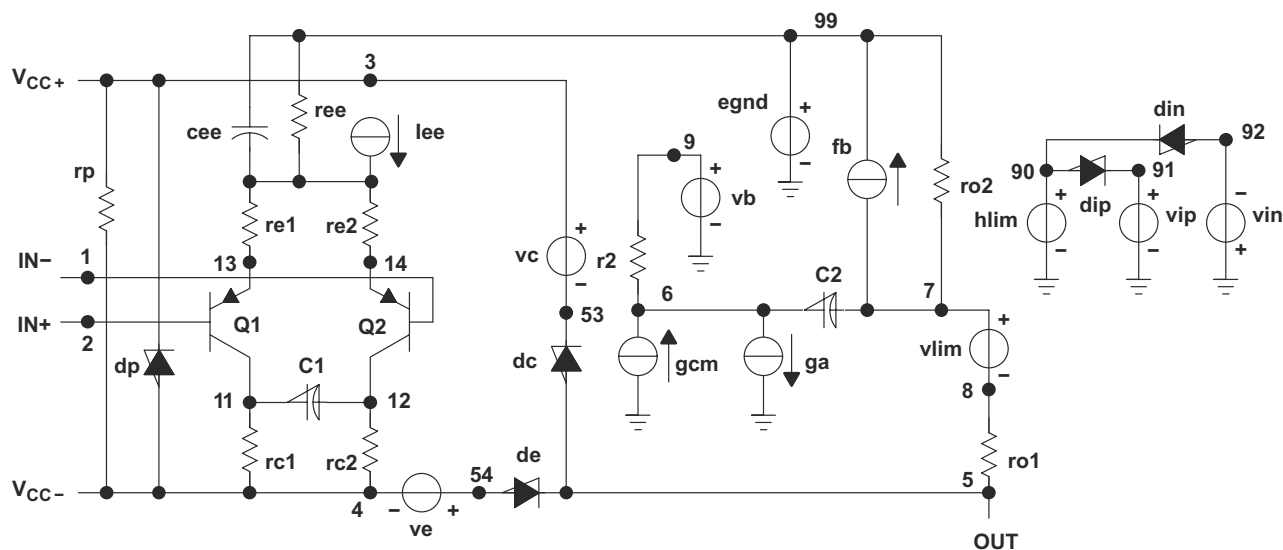


Figure 8-3. Boyle Subcircuit

<sup>1</sup> 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).

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <pre> .SUBCKT TLE2021 1 2 3 4 5 * c111126.244E      ! 12 c26713.4E         ! 12 c387010.64E       ! 9 cpsr858615.9E     ! 9 dcm+8182dx dcm! 8381dx dc553dx de545dx dlp9091dx dln9290dx dp43dx ecmr8499(2 99) 1 egnd990poly(2) (3,0) (4,0) 0 .5 .5 epsr850poly(1) (3,4)      ! 60E! 6 2.0E! 6 ense892poly(1) (88,0) 120E      ! 6 1 fb799poly(6) vb vc ve vlp vln vpsr 0 547.3E6 + ! 50E7 50E7 50E7 ! 50E7 547E6 ga6011 12 188.5E      ! 6 gcm0610 99 335.2E     ! 12 gpsr8586(85,86) 100E  ! 6 grc1411(4,11) 1.885E  ! 4 grc2412(4,12) 1.885E  ! 4 gre11310(13,10) 6.82E ! 4 gre21410(14,10) 6.82E ! 4 hlim900vlim 1k </pre> | <pre> hcmr801poly(2) vcm+ vcm      ! 0 1E2 1E2 irp34185E      ! 6 iee310dc 15.67E      ! 6 iio202E      ! 9 i18801E      ! 21 q1118913 qx q2128014 qx R269100.0E3 rcm 84811K ree109914.76E6 rn18702.55E8 rn2878811.67E3 ro18562 ro279963 vcm+829913.3 vcm! 8399      ! 14.6 vb90dc 0 vc353dc 1.300 ve544dc 1.500 vlim78dc 0 vlp910dc 3.600 vln092dc 3.600 vpsr086dc 0 .model dx d(is=800.0E! 18) .model qx pnp(is=800.0E! 18 bf=270) .ends </pre> |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**Figure 8-4. Boyle Macromodel for the TLE2021xM**

|                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                             |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <pre> .SUBCKT TLE2022 1 2 3 4 5 * c11112 6.814E      ! 12 c26720.00E         ! 12 dc553 dx de545 dx dlp9091 dx dln9290 dx dp43 dx egnd 990poly(2) (3,0) (4,0) 0 .5 .5 fb799poly(5) vb vc ve vlp vln 0 + 45.47E6      ! 50E6 50E6 50E6      ! 50E6 ga 6011 12 377.9E      ! 6 gcm 0610 99 7.84E      ! 10 iee310 DC 18.07E      ! 6 hlim 900 vlim 1k q1112 13 qx q2121 14 qx r269 100.0E3 </pre> | <pre> rc1411 2.842E3 rc2412 2.842E3 ge11310 (10,13) 31.299E      ! 3 ge21410 (10,14) 31.299E      ! 3 ree1099 11.07E6 ro185 250 ro2799 250 rp34 137.2E3 vb90 dc 0 vc353 dc 1.300 ve544 dc 1.500 vlim78 dc 0 vlp910 dc 3 vln092 dc 3 .model dxd(is=800.0E      ! 18) .model qxpnp(is=800.0E      ! 18 bf=257.1) .ends </pre> |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**Figure 8-5. Boyle Macromodel for the TLE2022xM**

## 9 Device and Documentation Support

TI offers an extensive line of development tools. Tools and software to evaluate the performance of the device, generate code, and develop solutions are listed below.

### 9.1 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on [ti.com](https://www.ti.com). Click on *Notifications* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

### 9.2 Support Resources

[TI E2E™ support forums](#) are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

Linked content is provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's [Terms of Use](#).

### 9.3 Trademarks

Microsim Parts™ and PSpice™ are trademarks of Cadence Design Systems, Inc..

TI E2E™ is a trademark of Texas Instruments.

All trademarks are the property of their respective owners.

### 9.4 Electrostatic Discharge Caution



This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

### 9.5 Glossary

[TI Glossary](#) This glossary lists and explains terms, acronyms, and definitions.

## 10 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

| Changes from Revision D (November 2010) to Revision E (July 2025)                                     | Page |
|-------------------------------------------------------------------------------------------------------|------|
| • Deleted obsolete Y-suffix device and associated content from data sheet.....                        | 1    |
| • Deleted DB and PW packages and associated content from data sheet.....                              | 1    |
| • Moved D, DW, N, and P devices and associated content to SLVSJD7.....                                | 1    |
| • Updated the numbering format for tables, figures, and cross-references throughout the document..... | 1    |
| • Added application circuit to <i>Description</i> .....                                               | 1    |

## 11 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

**PACKAGING INFORMATION**

| Orderable part number           | Status<br>(1) | Material type<br>(2) | Package   Pins | Package qty   Carrier | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6)                     |
|---------------------------------|---------------|----------------------|----------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|-----------------------------------------|
| <a href="#">5962-9088101MPA</a> | Active        | Production           | CDIP (JG)   8  | 50   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 9088101MPA<br>TLE2021M                  |
| <a href="#">5962-9088102M2A</a> | Active        | Production           | LCCC (FK)   20 | 55   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-<br>9088102M2A<br>TLE2022MFKB      |
| <a href="#">5962-9088102MPA</a> | Active        | Production           | CDIP (JG)   8  | 50   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 9088102MPA<br>TLE2022M                  |
| <a href="#">5962-9088103M2A</a> | Active        | Production           | LCCC (FK)   20 | 55   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-<br>9088103M2A<br>TLE2024MFKB      |
| <a href="#">5962-9088103MCA</a> | Active        | Production           | CDIP (J)   14  | 25   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-9088103MC<br>A<br>TLE2024MJB       |
| <a href="#">5962-9088104Q2A</a> | Active        | Production           | LCCC (FK)   20 | 55   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-<br>9088104Q2A<br>TLE2021<br>AMFKB |
| <a href="#">5962-9088104QPA</a> | Active        | Production           | CDIP (JG)   8  | 50   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 9088104QPA<br>TLE2021AM                 |
| <a href="#">5962-9088105Q2A</a> | Active        | Production           | LCCC (FK)   20 | 55   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-<br>9088105Q2A<br>TLE2022A<br>MFKB |
| <a href="#">5962-9088105QPA</a> | Active        | Production           | CDIP (JG)   8  | 50   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 9088105QPA<br>TLE2022AM                 |
| <a href="#">5962-9088106Q2A</a> | Active        | Production           | LCCC (FK)   20 | 55   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-<br>9088106Q2A<br>TLE2024A<br>MFKB |
| <a href="#">5962-9088106QCA</a> | Active        | Production           | CDIP (J)   14  | 25   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-9088106QC<br>A<br>TLE2024AMJB      |

| Orderable part number           | Status<br>(1) | Material type<br>(2) | Package   Pins | Package qty   Carrier | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6)                     |
|---------------------------------|---------------|----------------------|----------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|-----------------------------------------|
| <a href="#">5962-9088107Q2A</a> | Active        | Production           | LCCC (FK)   20 | 55   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-<br>9088107Q2A<br>TLE2021<br>BMFKB |
| <a href="#">5962-9088107QPA</a> | Active        | Production           | CDIP (JG)   8  | 50   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 9088107QPA<br>TLE2021BM                 |
| <a href="#">5962-9088108Q2A</a> | Active        | Production           | LCCC (FK)   20 | 55   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-<br>9088108Q2A<br>TLE2022B<br>MFKB |
| <a href="#">5962-9088108QPA</a> | Active        | Production           | CDIP (JG)   8  | 50   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 9088108QPA<br>TLE2022BM                 |
| <a href="#">5962-9088109Q2A</a> | Active        | Production           | LCCC (FK)   20 | 55   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-<br>9088109Q2A<br>TLE2024<br>BMFKB |
| <a href="#">5962-9088109QCA</a> | Active        | Production           | CDIP (J)   14  | 25   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-9088109QC<br>A<br>TLE2024BMJB      |
| <a href="#">TLE2021AMFKB</a>    | Active        | Production           | LCCC (FK)   20 | 55   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-<br>9088104Q2A<br>TLE2021<br>AMFKB |
| TLE2021AMFKB.A                  | Active        | Production           | LCCC (FK)   20 | 55   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-<br>9088104Q2A<br>TLE2021<br>AMFKB |
| <a href="#">TLE2021AMJGB</a>    | Active        | Production           | CDIP (JG)   8  | 50   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 9088104QPA<br>TLE2021AM                 |
| TLE2021AMJGB.A                  | Active        | Production           | CDIP (JG)   8  | 50   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 9088104QPA<br>TLE2021AM                 |
| <a href="#">TLE2021BMFKB</a>    | Active        | Production           | LCCC (FK)   20 | 55   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -            | 5962-<br>9088107Q2A<br>TLE2021<br>BMFKB |

| Orderable part number        | Status<br>(1) | Material type<br>(2) | Package   Pins | Package qty   Carrier | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6)                     |
|------------------------------|---------------|----------------------|----------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|-----------------------------------------|
| TLE2021BMFKB.A               | Active        | Production           | LCCC (FK)   20 | 55   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-<br>9088107Q2A<br>TLE2021<br>BMFKB |
| <a href="#">TLE2021BMJG</a>  | Active        | Production           | CDIP (JG)   8  | 50   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | TLE2021<br>BMJG                         |
| TLE2021BMJG.A                | Active        | Production           | CDIP (JG)   8  | 50   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | TLE2021<br>BMJG                         |
| <a href="#">TLE2021BMJGB</a> | Active        | Production           | CDIP (JG)   8  | 50   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -            | 9088107QPA<br>TLE2021BM                 |
| TLE2021BMJGB.A               | Active        | Production           | CDIP (JG)   8  | 50   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 9088107QPA<br>TLE2021BM                 |
| <a href="#">TLE2021MJG</a>   | Active        | Production           | CDIP (JG)   8  | 50   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | TLE2021MJG                              |
| TLE2021MJG.A                 | Active        | Production           | CDIP (JG)   8  | 50   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | TLE2021MJG                              |
| <a href="#">TLE2021MJGB</a>  | Active        | Production           | CDIP (JG)   8  | 50   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 9088101MPA<br>TLE2021M                  |
| TLE2021MJGB.A                | Active        | Production           | CDIP (JG)   8  | 50   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 9088101MPA<br>TLE2021M                  |
| <a href="#">TLE2022AMFKB</a> | Active        | Production           | LCCC (FK)   20 | 55   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-<br>9088105Q2A<br>TLE2022A<br>MFKB |
| TLE2022AMFKB.A               | Active        | Production           | LCCC (FK)   20 | 55   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-<br>9088105Q2A<br>TLE2022A<br>MFKB |
| <a href="#">TLE2022AMJGB</a> | Active        | Production           | CDIP (JG)   8  | 50   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 9088105QPA<br>TLE2022AM                 |
| TLE2022AMJGB.A               | Active        | Production           | CDIP (JG)   8  | 50   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 9088105QPA<br>TLE2022AM                 |
| <a href="#">TLE2022BMFKB</a> | Active        | Production           | LCCC (FK)   20 | 55   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-<br>9088108Q2A<br>TLE2022B<br>MFKB |



| Orderable part number        | Status<br>(1) | Material type<br>(2) | Package   Pins | Package qty   Carrier | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6)                     |
|------------------------------|---------------|----------------------|----------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|-----------------------------------------|
| TLE2022BMFKB.A               | Active        | Production           | LCCC (FK)   20 | 55   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-<br>9088108Q2A<br>TLE2022B<br>MFKB |
| <a href="#">TLE2022BMJGB</a> | Active        | Production           | CDIP (JG)   8  | 50   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 9088108QPA<br>TLE2022BM                 |
| TLE2022BMJGB.A               | Active        | Production           | CDIP (JG)   8  | 50   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 9088108QPA<br>TLE2022BM                 |
| <a href="#">TLE2022MFKB</a>  | Active        | Production           | LCCC (FK)   20 | 55   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-<br>9088102M2A<br>TLE2022MFKB      |
| TLE2022MFKB.A                | Active        | Production           | LCCC (FK)   20 | 55   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-<br>9088102M2A<br>TLE2022MFKB      |
| <a href="#">TLE2022MJG</a>   | Active        | Production           | CDIP (JG)   8  | 50   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | TLE2022MJG                              |
| TLE2022MJG.A                 | Active        | Production           | CDIP (JG)   8  | 50   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | TLE2022MJG                              |
| <a href="#">TLE2022MJGB</a>  | Active        | Production           | CDIP (JG)   8  | 50   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 9088102MPA<br>TLE2022M                  |
| TLE2022MJGB.A                | Active        | Production           | CDIP (JG)   8  | 50   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 9088102MPA<br>TLE2022M                  |
| <a href="#">TLE2024AMFKB</a> | Active        | Production           | LCCC (FK)   20 | 55   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-<br>9088106Q2A<br>TLE2024A<br>MFKB |
| TLE2024AMFKB.A               | Active        | Production           | LCCC (FK)   20 | 55   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-<br>9088106Q2A<br>TLE2024A<br>MFKB |
| <a href="#">TLE2024AMJB</a>  | Active        | Production           | CDIP (J)   14  | 25   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-9088106QC<br>A<br>TLE2024AMJB      |
| TLE2024AMJB.A                | Active        | Production           | CDIP (J)   14  | 25   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-9088106QC<br>A<br>TLE2024AMJB      |

| Orderable part number        | Status<br>(1) | Material type<br>(2) | Package   Pins | Package qty   Carrier | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6)                 |
|------------------------------|---------------|----------------------|----------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|-------------------------------------|
| <a href="#">TLE2024BMFKB</a> | Active        | Production           | LCCC (FK)   20 | 55   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-9088109Q2A<br>TLE2024<br>BMFKB |
| TLE2024BMFKB.A               | Active        | Production           | LCCC (FK)   20 | 55   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-9088109Q2A<br>TLE2024<br>BMFKB |
| <a href="#">TLE2024BMJ</a>   | Active        | Production           | CDIP (J)   14  | 25   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | TLE2024BMJ                          |
| TLE2024BMJ.A                 | Active        | Production           | CDIP (J)   14  | 25   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | TLE2024BMJ                          |
| <a href="#">TLE2024BMJB</a>  | Active        | Production           | CDIP (J)   14  | 25   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-9088109QC<br>A<br>TLE2024BMJB  |
| TLE2024BMJB.A                | Active        | Production           | CDIP (J)   14  | 25   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-9088109QC<br>A<br>TLE2024BMJB  |
| <a href="#">TLE2024MFKB</a>  | Active        | Production           | LCCC (FK)   20 | 55   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-9088103M2A<br>TLE2024MFKB      |
| TLE2024MFKB.A                | Active        | Production           | LCCC (FK)   20 | 55   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-9088103M2A<br>TLE2024MFKB      |
| <a href="#">TLE2024MJB</a>   | Active        | Production           | CDIP (J)   14  | 25   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-9088103MC<br>A<br>TLE2024MJB   |
| TLE2024MJB.A                 | Active        | Production           | CDIP (J)   14  | 25   TUBE             | No          | SNPB                                 | N/A for Pkg Type                  | -55 to 125   | 5962-9088103MC<br>A<br>TLE2024MJB   |

<sup>(1)</sup> **Status:** For more details on status, see our [product life cycle](#).

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

<sup>(3)</sup> **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

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

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

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

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

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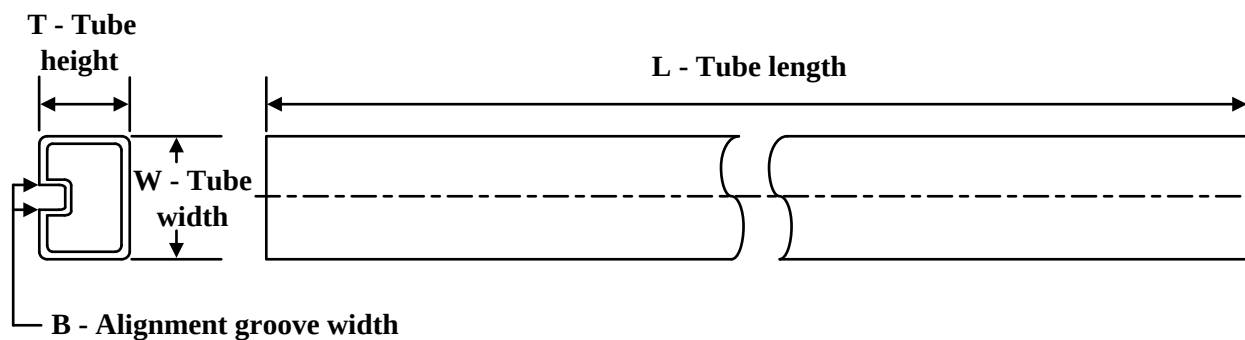
**OTHER QUALIFIED VERSIONS OF TLE2021AM, TLE2024AM, TLE2024M :**

- Catalog : [TLE2021A](#), [TLE2024A](#), [TLE2024](#)
- Automotive : [TLE2021A-Q1](#), [TLE2024-Q1](#)
- Enhanced Product : [TLE2021A-EP](#), [TLE2024A-EP](#), [TLE2024-EP](#)

**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

## TUBE

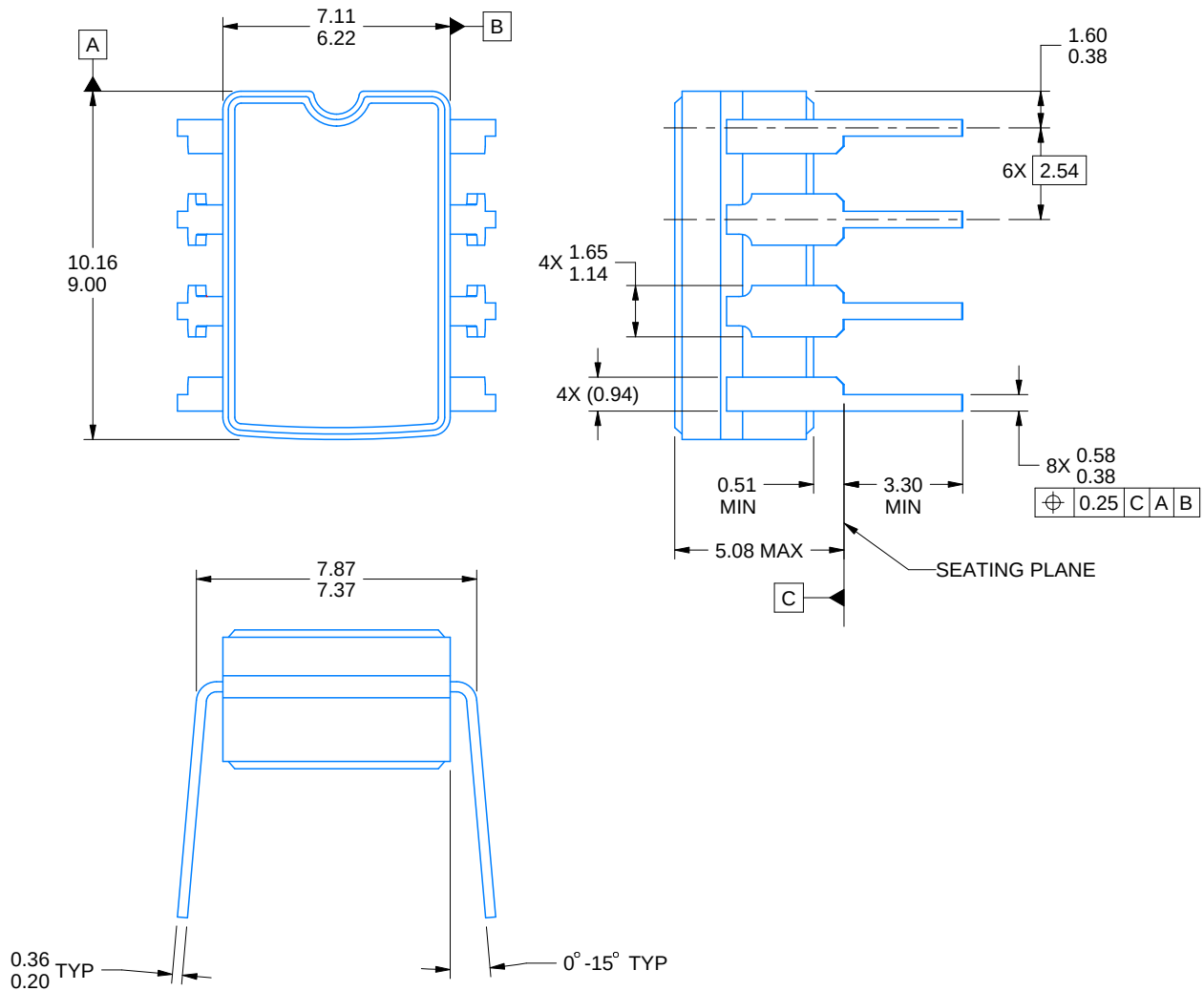


\*All dimensions are nominal

| 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     |
| TLE2021AMFKB    | FK           | LCCC         | 20   | 55  | 506.98 | 12.06  | 2030   | NA     |
| TLE2021AMFKB.A  | FK           | LCCC         | 20   | 55  | 506.98 | 12.06  | 2030   | NA     |
| TLE2021BMFKB    | FK           | LCCC         | 20   | 55  | 506.98 | 12.06  | 2030   | NA     |
| TLE2021BMFKB.A  | FK           | LCCC         | 20   | 55  | 506.98 | 12.06  | 2030   | NA     |
| TLE2022AMFKB    | FK           | LCCC         | 20   | 55  | 506.98 | 12.06  | 2030   | NA     |
| TLE2022AMFKB.A  | FK           | LCCC         | 20   | 55  | 506.98 | 12.06  | 2030   | NA     |
| TLE2022BMFKB    | FK           | LCCC         | 20   | 55  | 506.98 | 12.06  | 2030   | NA     |
| TLE2022BMFKB.A  | FK           | LCCC         | 20   | 55  | 506.98 | 12.06  | 2030   | NA     |
| TLE2022MFKB     | FK           | LCCC         | 20   | 55  | 506.98 | 12.06  | 2030   | NA     |
| TLE2022MFKB.A   | FK           | LCCC         | 20   | 55  | 506.98 | 12.06  | 2030   | NA     |
| TLE2024AMFKB    | FK           | LCCC         | 20   | 55  | 506.98 | 12.06  | 2030   | NA     |
| TLE2024AMFKB.A  | FK           | LCCC         | 20   | 55  | 506.98 | 12.06  | 2030   | NA     |
| TLE2024BMFKB    | FK           | LCCC         | 20   | 55  | 506.98 | 12.06  | 2030   | NA     |
| TLE2024BMFKB.A  | FK           | LCCC         | 20   | 55  | 506.98 | 12.06  | 2030   | NA     |
| TLE2024MFKB     | FK           | LCCC         | 20   | 55  | 506.98 | 12.06  | 2030   | NA     |
| TLE2024MFKB.A   | FK           | LCCC         | 20   | 55  | 506.98 | 12.06  | 2030   | NA     |

**JG0008A****PACKAGE OUTLINE****CDIP - 5.08 mm max height**

CERAMIC DUAL IN-LINE PACKAGE



4230036/A 09/2023

**NOTES:**

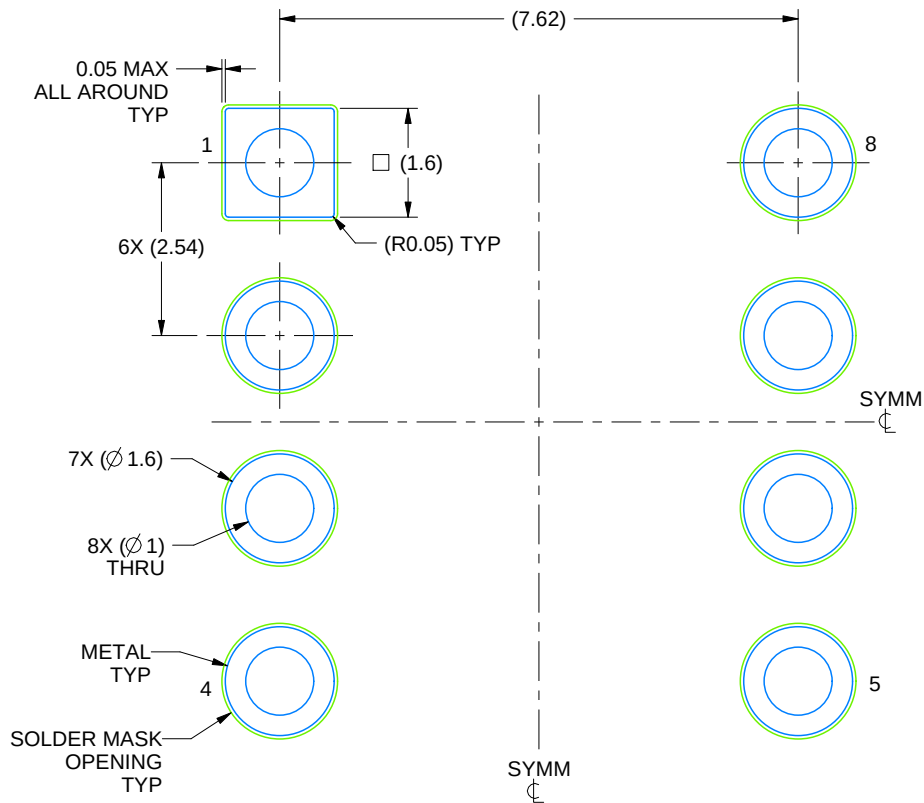
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This package can be hermetically sealed with a ceramic lid using glass frit.
4. Index point is provided on cap for terminal identification.
5. Falls within MIL STD 1835 GDIP1-T8

# EXAMPLE BOARD LAYOUT

JG0008A

CDIP - 5.08 mm max height

CERAMIC DUAL IN-LINE PACKAGE



LAND PATTERN EXAMPLE  
NON SOLDER MASK DEFINED  
SCALE: 9X

4230036/A 09/2023

## GENERIC PACKAGE VIEW

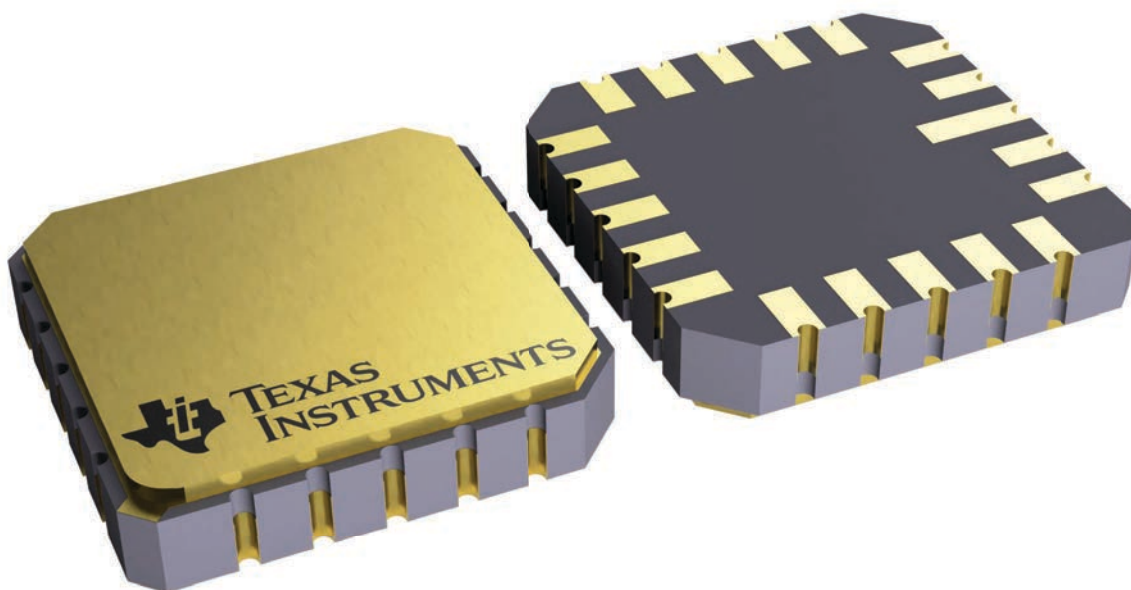
**FK 20**

**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.



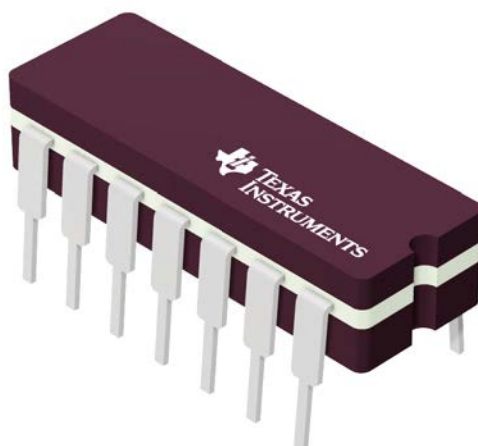
4229370VA\

**J 14**

## GENERIC PACKAGE VIEW

**CDIP - 5.08 mm max height**

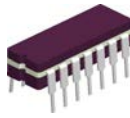
CERAMIC DUAL IN LINE PACKAGE



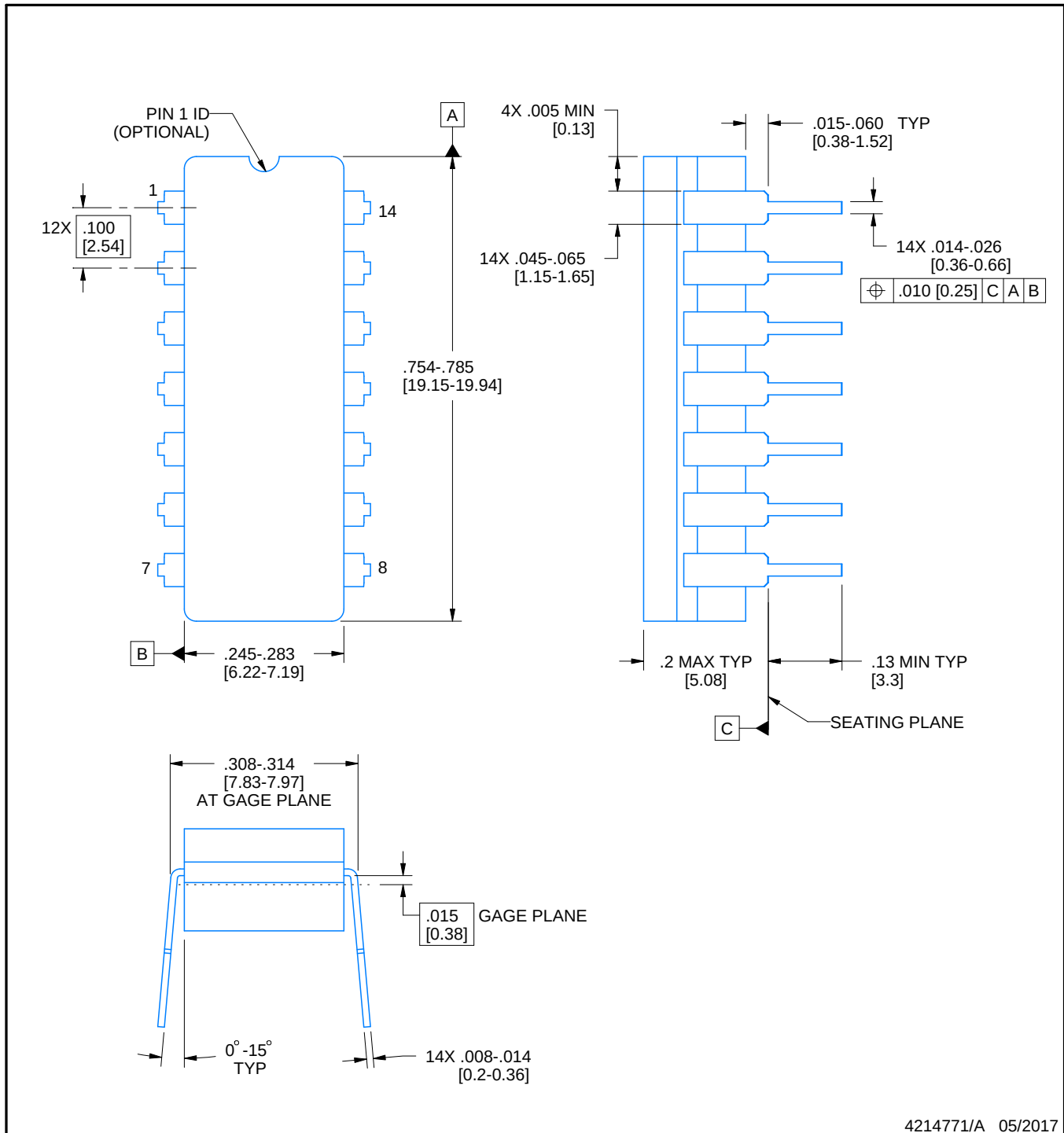
Images above are just a representation of the package family, actual package may vary.  
Refer to the product data sheet for package details.

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.



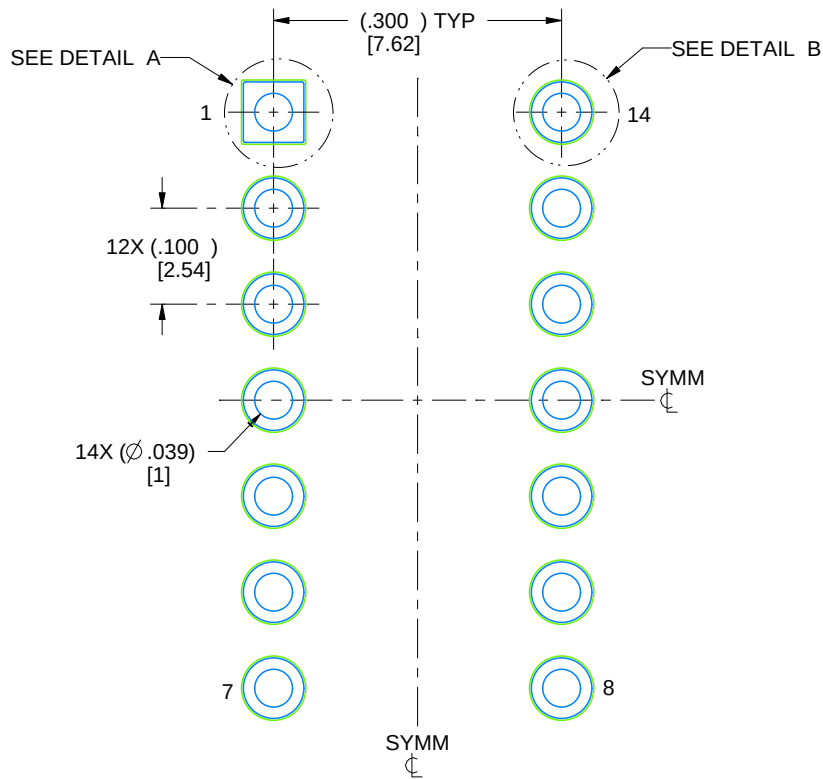
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# EXAMPLE BOARD LAYOUT

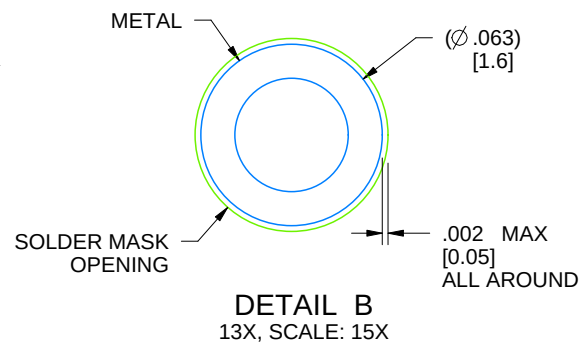
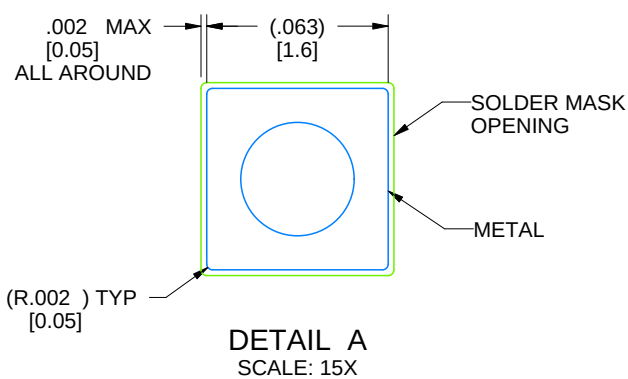
J0014A

CDIP - 5.08 mm max height

CERAMIC DUAL IN LINE PACKAGE



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



4214771/A 05/2017

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