

# TL03x, TL03xA, TL03xY ENHANCED-JFET LOW-POWER LOW-OFFSET OPERATIONAL AMPLIFIERS

SLOS180B – FEBRUARY 1997 – REVISED FEBRUARY 1999

- Direct Upgrades for the TL06x Low-Power BiFETs
- Low Power Consumption . . . 6.5 mW/Channel Typ
- On-Chip Offset-Voltage Trimming for Improved DC Performance (1.5 mV, TL031A)
- Higher Slew Rate and Bandwidth Without Increased Power Consumption
- Available in TSSOP for Small Form-Factor Designs

## description

The TL03x series of JFET-input operational amplifiers offer improved dc and ac characteristics over the TL06x family of low-power BiFET operational amplifiers. On-chip zener trimming of offset voltage yields precision grades as low as 1.5 mV (TL031A) for greater accuracy in dc-coupled applications. Texas Instruments improved BiFET process and optimized designs also yield improved bandwidths and slew rates without increased power consumption. The TL03x devices are pin-compatible with the TL06x and can be used to upgrade existing circuits or for optimal performance in new designs.

BiFET operational amplifiers offer the inherently higher input impedance of the JFET-input transistors without sacrificing the output drive associated with bipolar amplifiers. This higher input impedance makes the TL3x amplifiers better suited for interfacing with high-impedance sensors or very low-level ac signals. These devices also feature inherently better ac response than bipolar or CMOS devices having comparable power consumption.

The TL03x family has been optimized for micropower operation, while improving on the performance of the TL06x series. Designers requiring significantly faster ac response should consider the Excalibur TLE206x family of low-power BiFET operational amplifiers.

Because BiFET operational amplifiers are designed for use with dual power supplies, care must be taken to observe common-mode input-voltage limits and output swing when operating from a single supply. DC biasing of the input signal is required and loads should be terminated to a virtual-ground node at midsupply. Texas Instruments TLE2426 integrated virtual-ground generator is useful when operating BiFET amplifiers from single supplies.

The TL03x devices are fully specified at  $\pm 15$  V and  $\pm 5$  V. For operation in low-voltage and/or single-supply systems, Texas Instruments LinCMOS families of operational amplifiers (TLC-prefix) are recommended. When moving from BiFET to CMOS amplifiers, particular attention should be paid to slew rate, bandwidth requirements, and output loading.

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



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

 **TEXAS  
INSTRUMENTS**

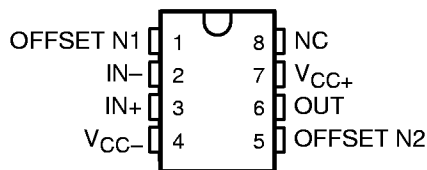
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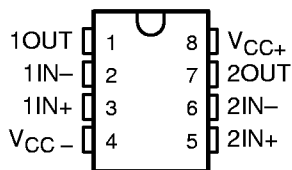
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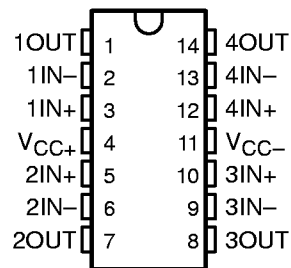
**TL031x, TL031Ax**  
D, JG, OR P PACKAGE  
(TOP VIEW)



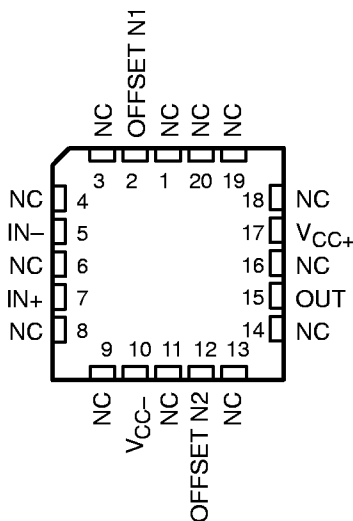
**TL032x, TL032Ax**  
D, JG, OR P PACKAGE  
(TOP VIEW)



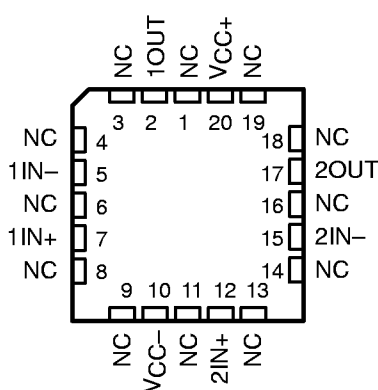
**TL034x, TL034Ax**  
D, J, N, OR PW PACKAGE  
(TOP VIEW)



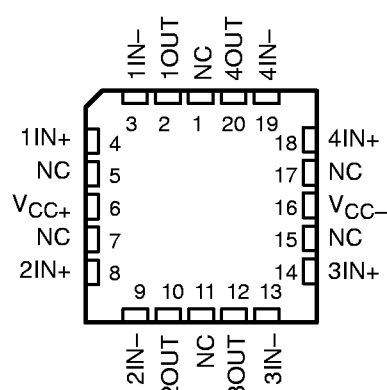
**TL031M, TL031AM**  
FK PACKAGE  
(TOP VIEW)



**TL032M, TL032AM**  
FK PACKAGE  
(TOP VIEW)



**TL034M, TL034AM**  
FK PACKAGE  
(TOP VIEW)



NC – No internal connection

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## AVAILABLE OPTIONS

| T <sub>A</sub> | V <sub>IO</sub> MAX<br>AT 25°C | PACKAGED DEVICES               |                                   |                       |                        |                       |                       |                | CHIP<br>FORM‡<br>(Y)       |
|----------------|--------------------------------|--------------------------------|-----------------------------------|-----------------------|------------------------|-----------------------|-----------------------|----------------|----------------------------|
|                |                                | SMALL<br>OUTLINE†<br>(D)       | CHIP<br>CARRIER<br>(FK)           | CERAMIC<br>DIP<br>(J) | CERAMIC<br>DIP<br>(JG) | PLASTIC<br>DIP<br>(N) | PLASTIC<br>DIP<br>(P) | TSSOP†<br>(PW) |                            |
| 0°C to 70°C    | 0.8 mV                         | TL031ACD<br>TL032ACD           | —                                 | —                     | —                      | —                     | TL031ACP<br>TL032ACP  | —              | TL031Y<br>TL032Y<br>TL034Y |
|                | 1.5 mV                         | TL031CD<br>TL032CD<br>TL034ACD | —                                 | —                     | —                      | TL034ACN              | TL031CP<br>TL032CP    | —              |                            |
|                | 4 mV                           | TL034CD                        | —                                 | —                     | —                      | TL034CN               | —                     | TL034CPW       |                            |
| –40°C to 85°C  | 0.8 mV                         | TL031AID<br>TL032AID           | —                                 | —                     | —                      | —                     | TL031AIP<br>TL032AIP  | —              | —                          |
|                | 1.5 mV                         | TL031ID<br>TL032ID<br>TL034AID | —                                 | —                     | —                      | TL034AIN              | TL031IP<br>TL032IP    | —              | —                          |
|                | 4 mV                           | TL034ID                        | —                                 | —                     | —                      | TL034IN               | —                     | —              | —                          |
| –55°C to 125°C | 0.8 mV                         | TL031AMD<br>TL032AMD           | TL031AMFK<br>TL032AMFK            | —                     | TL031AMJG<br>TL032AMJG | —                     | TL031AMP<br>TL032AMP  | —              | —                          |
|                | 1.5 mV                         | TL031MD<br>TL032MD<br>TL034AMD | TL031MFK<br>TL032MFK<br>TL034AMFK | TL034AMJ              | TL031MJG<br>TL032MJG   | TL034AMN              | TL031MP<br>TL032MP    | —              | —                          |
|                | 4 mV                           | TL034MD                        | TL034MFK                          | TL034MJ               | —                      | TL034MN               | —                     | —              | —                          |

† The D and PW packages are available taped and reeled and are indicated by adding an R suffix to device type (e.g., TL034CDR or TL034CPWR).

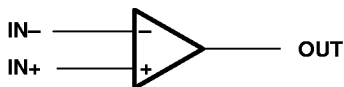
‡ Chip forms are tested at 25°C.



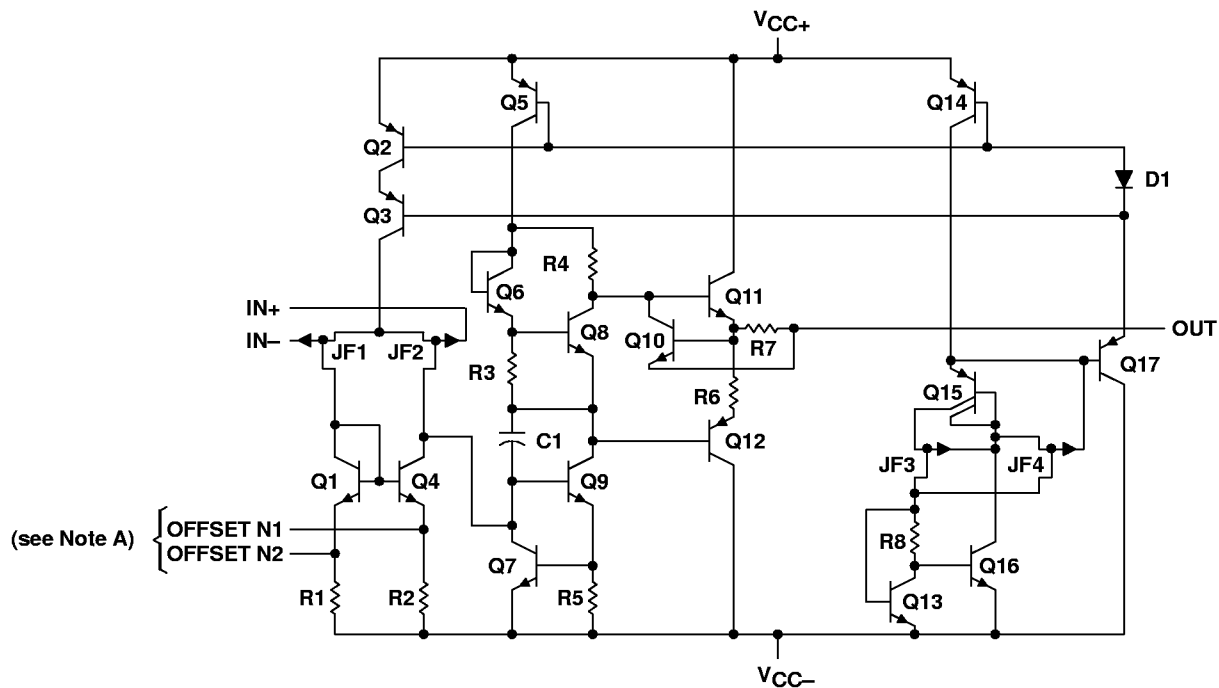
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symbol (each amplifier)



equivalent schematic (each amplifier)



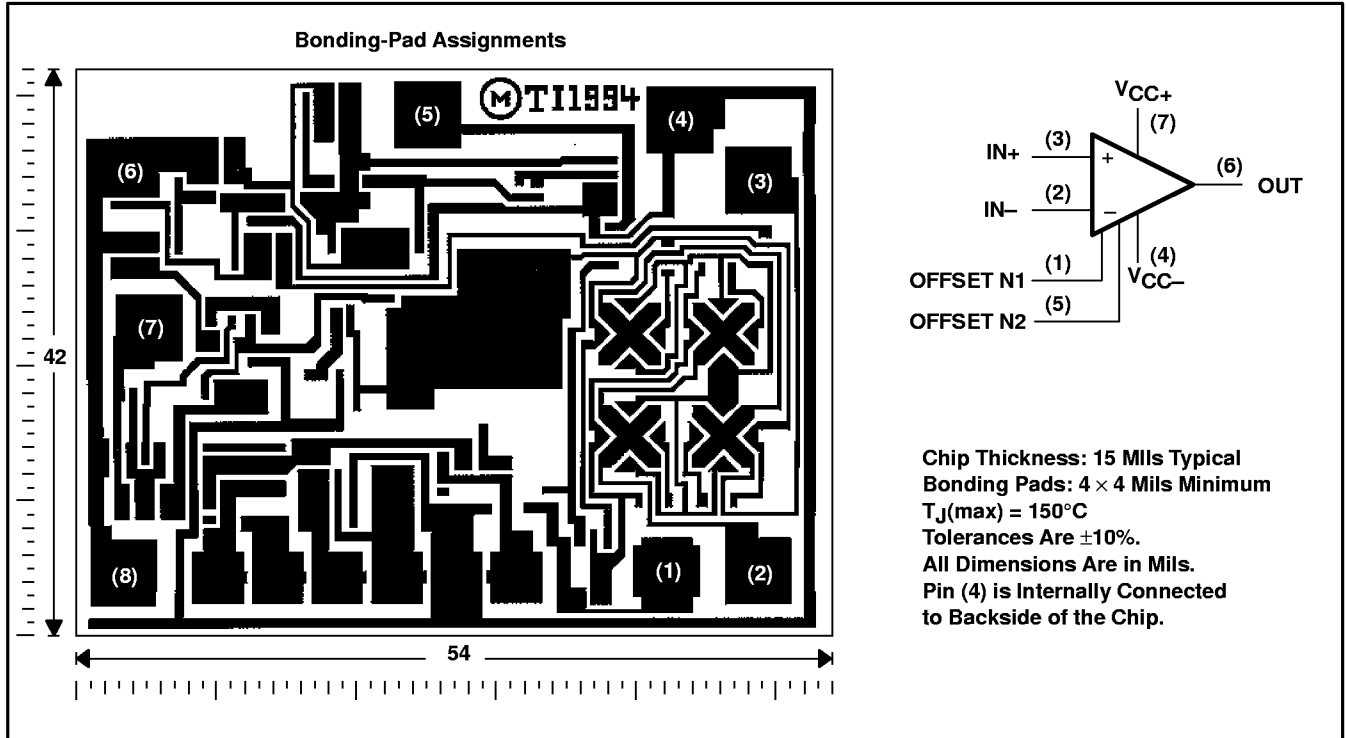
NOTE A: OFFSET N1 and OFFSET N2 are available only on the TL031.

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**TL031Y chip information**

This chip, when properly assembled, has characteristics similar to the TL031C. Thermal compression or ultrasonic bonding can be used on the doped-aluminum bonding pads. These chips can be mounted with conductive epoxy or a gold-silicon preform.

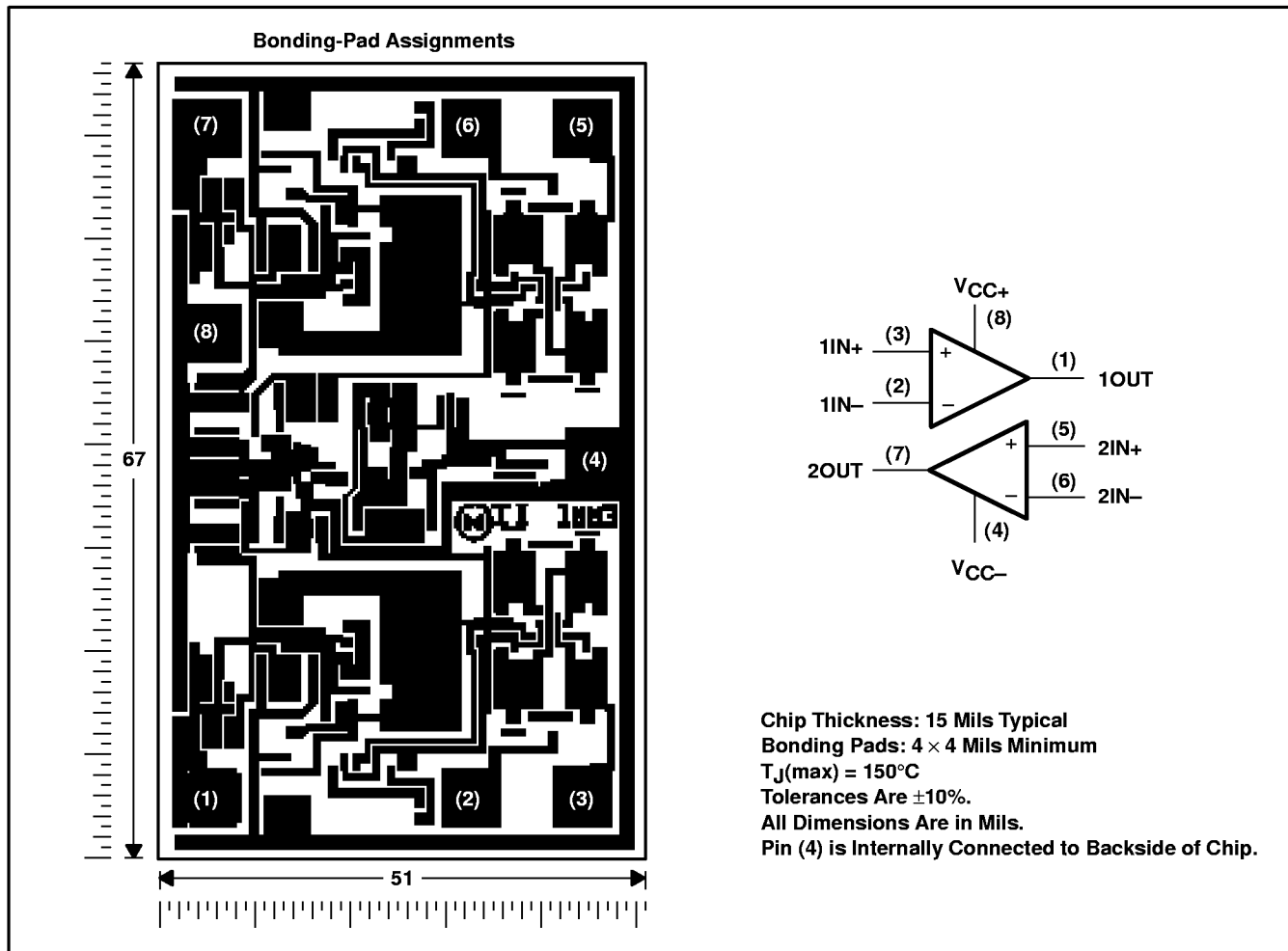


# TL03x, TL03xA, TL03xY ENHANCED-JFET LOW-POWER LOW-OFFSET OPERATIONAL AMPLIFIERS

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## TL032Y chip information

This chip, when properly assembled, has characteristics similar to the TL032C. Thermal compression or ultrasonic bonding can be used on the doped-aluminum bonding pads. These chips can be mounted with conductive epoxy or a gold-silicon preform.

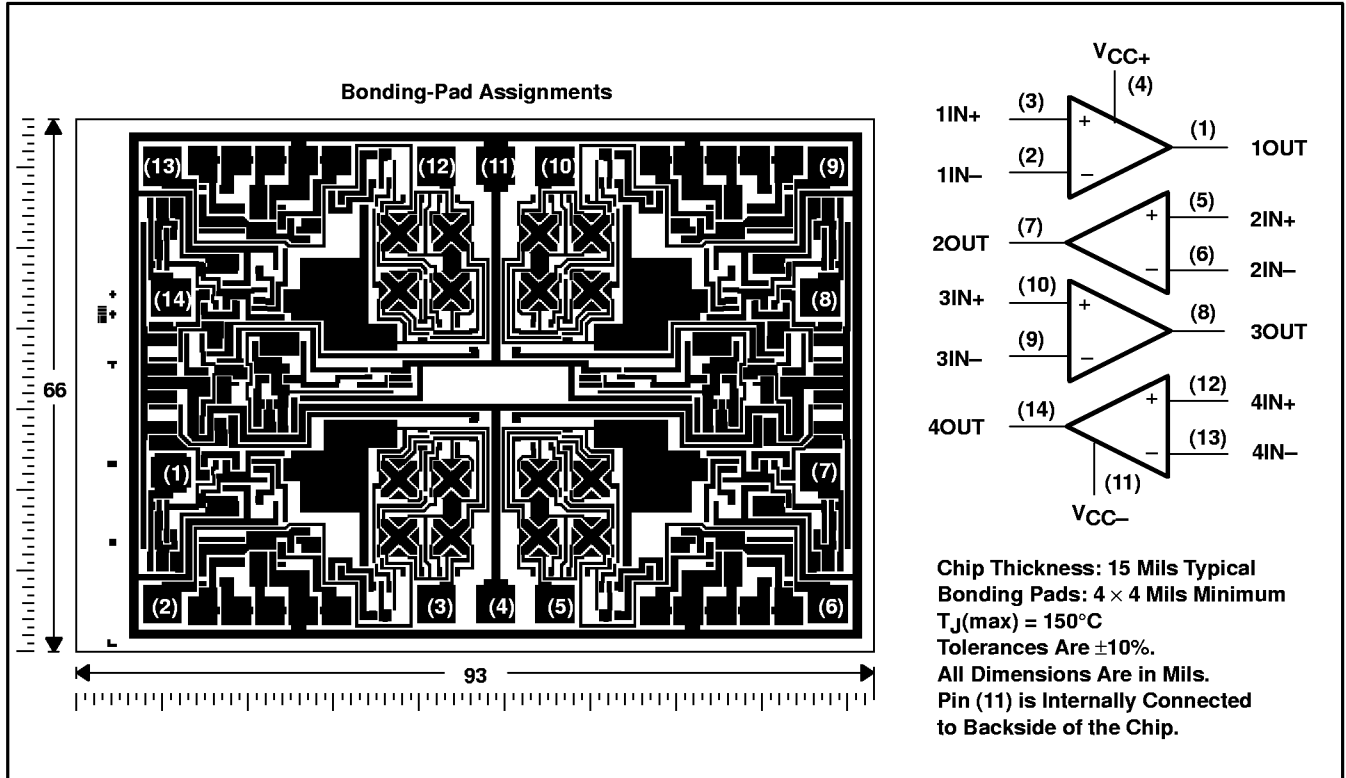


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**TL034Y chip information**

This chip, when properly assembled, has characteristics similar to the TL034C. Thermal compression or ultrasonic bonding can be used on the doped-aluminum bonding pads. These chips can be mounted with conductive epoxy or a gold-silicon preform.



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

|   |                              |
|---|------------------------------|
| Supply voltage, $V_{CC+}$ (see Note 1)  | 18 V                         |
| Supply voltage, $V_{CC-}$ (see Note 1)  | -18 V                        |
| Differential input voltage, $V_{ID}$ (see Note 2)                                     | $\pm 30$ V                   |
| Input voltage, $V_I$ (any input) (see Notes 1 and 3)                                  | $\pm 15$ V                   |
| Input current, $I_I$ (each input)   | $\pm 1$ mA                   |
| Output current, $I_O$ (each output)   | $\pm 40$ mA                  |
| Total current into $V_{CC+}$  | 160 mA                       |
| Total current out of $V_{CC-}$  | 160 mA                       |
| Duration of short-circuit current at (or below) 25°C (see Note 4)                     | Unlimited                    |
| Continuous total power dissipation  | See Dissipation Rating Table |
| Storage temperature range, $T_{stg}$  | -65°C to 150°C               |
| Case temperature for 60 seconds: FK package   | 260°C                        |
| Lead temperature 1,6 mm (1 /16 inch) from case for 10 seconds: D, N, P, or PW package | 260°C                        |
| Lead temperature 1,6 mm (1 /16 inch) from case for 60 seconds: J or JG package        | 300°C                        |

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

- NOTES:
1. All voltage values, except differential voltages, are with respect to the midpoint between  $V_{CC+}$  and  $V_{CC-}$ .
  2. Differential voltages are at  $IN+$  with respect to  $IN-$ .
  3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 V, whichever is less.
  4. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^\circ\text{C}$<br>POWER RATING | DERATING FACTOR<br>ABOVE $T_A = 25^\circ\text{C}$ | $T_A = 70^\circ\text{C}$<br>POWER RATING | $T_A = 85^\circ\text{C}$<br>POWER RATING | $T_A = 125^\circ\text{C}$<br>POWER RATING |
|---------|---|---|--|--|---|
| D       | 950 mW                                      | 7.6 mW/°C   | 608 mW                                   | 494 mW                                   | 190 mW                                    |
| FK      | 1375 mW                                     | 11.0 mW/°C  | 880 mW                                   | 715 mW                                   | 275 mW                                    |
| J       | 1375 mW                                     | 11.0 mW/°C  | 880 mW                                   | 715 mW                                   | 275 mW                                    |
| JG      | 1050 mW                                     | 8.4 mW/°C   | 672 mW                                   | 546 mW                                   | 210 mW                                    |
| N       | 1150 mW                                     | 9.2 mW/°C   | 736 mW                                   | 598 mW                                   | 230 mW                                    |
| P       | 1100 mW                                     | 8.0 mW/°C   | 640 mW                                   | 520 mW                                   | 200 mW                                    |
| PW      | 700 mW                                      | 5.6 mW/°C   | 448 mW                                   | N/A                                      | N/A                                       |

## recommended operating conditions

|                                       |                        | C SUFFIX |          | I SUFFIX |          | M SUFFIX |          | UNIT |
|---------------------------------------|------------------------|----------|----------|----------|----------|----------|----------|------|
|                                       |                        | MIN      | MAX      | MIN      | MAX      | MIN      | MAX      |      |
| Supply voltage, $V_{CC\pm}$           |                        | $\pm 5$  | $\pm 15$ | $\pm 5$  | $\pm 15$ | $\pm 5$  | $\pm 15$ | V    |
| Common-mode input voltage, $V_{IC}$   | $V_{CC\pm} = \pm 5$ V  | -1.5     | 4        | -1.5     | 4        | -1.5     | 4        | V    |
|                                       | $V_{CC\pm} = \pm 15$ V | -11.5    | 14       | -11.5    | 14       | -11.5    | 14       |      |
| Operating free-air temperature, $T_A$ |                        | 0        | 70       | -40      | 85       | -55      | 125      | °C   |





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**TL031C and TL031AC electrical characteristics at specified free-air temperature**

| PARAMETER  | TEST CONDITIONS   | T <sub>A</sub> | TL031C, TL031AC         |                  |             |                          |               |       | UNIT |
|--|---|----------------|-------------------------|------------------|-------------|--------------------------|---------------|-------|------|
|  |   |                | V <sub>CC±</sub> = ±5 V |                  |             | V <sub>CC±</sub> = ±15 V |               |       |      |
|  |   |                | MIN                     | TYP              | MAX         | MIN                      | TYP           | MAX   |      |
| V <sub>IO</sub> Input offset voltage   |   | TL031C         | 25°C                    | 0.54    3.5      |             | 0.5    1.5               |               | mV    |      |
|  |   |                | Full range†             |                  |             | 4.5    2.5               |               |       |      |
|  |   | TL031AC        | 25°C                    | 0.41    2.8      |             | 0.34    0.8              |               |       |      |
|  |   |                | Full range†             |                  |             | 3.8    1.8               |               |       |      |
| α <sub>VIO</sub> Temperature coefficient of input offset voltage                       | V <sub>O</sub> = 0, V <sub>IC</sub> = 0, R <sub>S</sub> = 50 Ω                    | TL031C         | 25°C to 70°C            | 7.1              |             | 5.9                      |               | μV/°C |      |
|  |   | TL031AC        | 25°C to 70°C            | 7.1              |             | 5.9    25                |               |       |      |
| Input offset voltage long-term drift‡  |   |                | 25°C                    | 0.04             |             | 0.04                     |               | μV/mo |      |
| I <sub>IO</sub> Input offset current   | V <sub>O</sub> = 0, V <sub>IC</sub> = 0, See Figure 5                             |                | 25°C                    | 1    100         |             | 1    100                 |               | pA    |      |
|  |   |                | 70°C                    | 9    200         |             | 12    200                |               |       |      |
| I <sub>IB</sub> Input bias current   | V <sub>O</sub> = 0, V <sub>IC</sub> = 0, See Figure 5                             |                | 25°C                    | 2    200         |             | 2    200                 |               | pA    |      |
|  |   |                | 70°C                    | 50    400        |             | 80    400                |               |       |      |
| V <sub>ICR</sub> Common-mode input voltage range                                       |   |                | 25°C                    | -1.5 to 4        | -3.4 to 5.4 | -11.5 to 14              | -13.4 to 15.4 | V     |      |
|  |   |                | Full range†             | -1.5 to .4       |             | -11.5 to 14              |               |       |      |
| V <sub>OM+</sub> Maximum positive peak output voltage swing                            | R <sub>L</sub> = 10 kΩ  |                | 25°C                    | 3                | 4.3         | 13                       | 14            | V     |      |
|  |   |                | 0°C                     | 3                | 4.2         | 13                       | 14            |       |      |
|  |   |                | 70°C                    | 3                | 4.3         | 13                       | 14            |       |      |
| V <sub>OM-</sub> Maximum negative peak output voltage swing                            | R <sub>L</sub> = 10 kΩ  |                | 25°C                    | -3               | -4.2        | -12.5                    | -13.9         | V     |      |
|  |   |                | 0°C                     | -3               | -4.1        | -12.5                    | -13.9         |       |      |
|  |   |                | 70°C                    | -3               | -4.2        | -12.5                    | -14           |       |      |
| A <sub>VD</sub> Large-signal differential voltage amplification§                       | R <sub>L</sub> = 10 kΩ  |                | 25°C                    | 4                | 12          | 5                        | 14.3          | V/mV  |      |
|  |   |                | 0°C                     | 3                | 11.1        | 4                        | 13.5          |       |      |
|  |   |                | 70°C                    | 4                | 13.3        | 5                        | 15.2          |       |      |
| r <sub>i</sub> Input resistance  |   |                | 25°C                    | 10 <sup>12</sup> |             | 10 <sup>12</sup>         |               | Ω     |      |
| c <sub>i</sub> Input capacitance   |   |                | 25°C                    | 5                |             | 4                        |               | pF    |      |
| CMRR    Common-mode rejection ratio  | V <sub>IC</sub> = V <sub>ICRmin</sub> , V <sub>O</sub> = 0, R <sub>S</sub> = 50 Ω |                | 25°C                    | 70               | 87          | 75                       | 94            | dB    |      |
|  |   |                | 0°C                     | 70               | 87          | 75                       | 94            |       |      |
|  |   |                | 70°C                    | 70               | 87          | 75                       | 94            |       |      |
| k <sub>SVR</sub> Supply-voltage rejection ratio (ΔV <sub>CC±</sub> /ΔV <sub>IO</sub> ) | V <sub>O</sub> = 0, R <sub>S</sub> = 50 Ω   |                | 25°C                    | 75               | 96          | 75                       | 96            | dB    |      |
|  |   |                | 0°C                     | 75               | 96          | 75                       | 96            |       |      |
|  |   |                | 70°C                    | 75               | 96          | 75                       | 96            |       |      |

† Full range is 0°C to 70°C.

‡ Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T<sub>A</sub> = 150°C extrapolated to T<sub>A</sub> = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

§ At V<sub>CC±</sub> = ±5 V, V<sub>O</sub> = ±2.3 V; at V<sub>CC±</sub> = ±15 V, V<sub>O</sub> = ±10 V.



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## TL031C and TL031AC electrical characteristics at specified free-air temperature (continued)

| PARAMETER                              | TEST CONDITIONS             | T <sub>A</sub> | TL031C, TL031AC         |     |     |                          |     |     | UNIT |
|--|-----------------------------|----------------|-------------------------|-----|-----|--------------------------|-----|-----|------|
|  |                             |                | V <sub>CC±</sub> = ±5 V |     |     | V <sub>CC±</sub> = ±15 V |     |     |      |
|  |                             |                | MIN                     | TYP | MAX | MIN                      | TYP | MAX |      |
| P <sub>D</sub> Total power dissipation | V <sub>O</sub> = 0, No load | 25°C           |                         | 1.9 | 2.5 |                          | 6.5 | 8.4 | mW   |
|  |                             | 0°C            |                         | 1.8 | 2.5 |                          | 6.3 | 8.4 |      |
|  |                             | 70°C           |                         | 1.9 | 2.5 |                          | 6.3 | 8.4 |      |
| I <sub>CC</sub> Supply current         | V <sub>O</sub> = 0, No load | 25°C           |                         | 192 | 250 |                          | 217 | 280 | μA   |
|  |                             | 0°C            |                         | 184 | 250 |                          | 211 | 280 |      |
|  |                             | 70°C           |                         | 189 | 250 |                          | 210 | 280 |      |

## TL031C and TL031AC operating characteristics at specified free-air temperature

| PARAMETER   | TEST CONDITIONS  | T <sub>A</sub>   | TL031C, TL031AC                        |           |           |                          |       |        | UNIT |        |
|---|--|--|--|-----------|-----------|--------------------------|-------|--------|------|--------|
|   |  |  | V <sub>CC±</sub> = ±5 V                |           |           | V <sub>CC±</sub> = ±15 V |       |        |      |        |
|   |  |  | MIN                                    | TYP       | MAX       | MIN                      | TYP   | MAX    |      |        |
| SR <sup>+</sup> Positive slew rate at unity gain† | R <sub>L</sub> = 10 kΩ, C <sub>L</sub> = 100 pF,<br>See Figure 1   | 25°C   |  | 2         |           |                          | 1.5   | 2.9    | V/μs |        |
|   |  | 0°C  |  | 1.8       |           |                          | 1     | 2.6    |      |        |
|   |  | 70°C   |  | 2.2       |           |                          | 1.5   | 3.2    |      |        |
| SR <sup>-</sup> Negative slew rate at unity gain† |  | R <sub>L</sub> = 10 kΩ, C <sub>L</sub> = 100 pF,<br>See Figure 1                                 | 25°C                                   |           | 3.9       |                          |       | 1.5    | 5.1  | V/μs   |
|   |  |  | 0°C                                    |           | 3.7       |                          |       | 1.5    | 5    |        |
|   |  |  | 70°C                                   |           | 4         |                          |       | 1.5    | 5    |        |
| t <sub>r</sub> Rise time                          | V <sub>I(PP)</sub> = ±10 mV,<br>R <sub>L</sub> = 10 kΩ, C <sub>L</sub> = 100 pF,<br>See Figures 1 and 2  |  | 25°C                                   |           | 138       |                          |       | 132    | ns   |        |
|   |  |  | 0°C                                    |           | 134       |                          |       | 127    |      |        |
|   |  |  | 70°C                                   |           | 150       |                          |       | 142    |      |        |
| t <sub>f</sub> Fall time                          |  | V <sub>I(PP)</sub> = ±10 mV,<br>R <sub>L</sub> = 10 kΩ, C <sub>L</sub> = 100 pF,<br>See Figure 1 | 25°C                                   |           | 138       |                          |       | 132    | ns   |        |
|   |  |  | 0°C                                    |           | 134       |                          |       | 127    |      |        |
|   |  |  | 70°C                                   |           | 150       |                          |       | 142    |      |        |
| Overshoot factor                                  | V <sub>I(PP)</sub> = ±10 mV,<br>C <sub>L</sub> = 100 pF, C <sub>L</sub> = 100 pF,<br>See Figures 1 and 2 |  | 25°C                                   |           | 11%       |                          |       | 5%     |      |        |
|   |  |  | 0°C                                    |           | 10%       |                          |       | 4%     |      |        |
|   |  |  | 70°C                                   |           | 12%       |                          |       | 6%     |      |        |
| V <sub>n</sub> Equivalent input noise voltage     |  | TL031C   | R <sub>S</sub> = 20 Ω,<br>See Figure 3 | f = 10 Hz | 25°C      |                          | 61    |        | 61   | nV/√Hz |
|   |  |  |  |           | f = 1 kHz |                          | 41    |        | 41   |        |
|   |  |  | TL031AC                                | f = 10 Hz | 25°C      |                          | 61    |        | 61   |        |
|   | f = 1 kHz  |  |  |           |           | 41                       |       | 41     | 60   |        |
| I <sub>n</sub> Equivalent input noise current     | f = 1 kHz  | 25°C   |  | 0.003     |           |                          | 0.003 | pA/√Hz |      |        |
| B <sub>1</sub> Unity-gain bandwidth               | V <sub>I</sub> = 10 mV,<br>C <sub>L</sub> = 25 pF, R <sub>L</sub> = 10 kΩ,<br>See Figure 4               | 25°C   |  | 1         |           |                          | 1.1   | MHz    |      |        |
|   |  | 0°C  |  | 1         |           |                          | 1.1   |        |      |        |
|   |  | 70°C   |  | 1         |           |                          | 1     |        |      |        |
| φ <sub>m</sub> Phase margin at unity gain         | V <sub>I</sub> = 10 mV,<br>C <sub>L</sub> = 25 pF, R <sub>L</sub> = 10 kΩ,<br>See Figure 4               | 25°C   |  | 61°       |           |                          | 65°   |        |      |        |
|   |  | 0°C  |  | 61°       |           |                          | 65°   |        |      |        |
|   |  | 70°C   |  | 60°       |           |                          | 64°   |        |      |        |

† For V<sub>CC±</sub> = ±5 V, V<sub>I(PP)</sub> = ±1 V; for V<sub>CC±</sub> = ±15 V, V<sub>I(PP)</sub> = ±5 V.



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**TL031I and TL031AI electrical characteristics at specified free-air temperature**

| PARAMETER  | TEST CONDITIONS   | T <sub>A</sub> | TL031I, TL031AI         |                  |             |                          |               |       | UNIT |
|--|---|----------------|-------------------------|------------------|-------------|--------------------------|---------------|-------|------|
|  |   |                | V <sub>CC±</sub> = ±5 V |                  |             | V <sub>CC±</sub> = ±15 V |               |       |      |
|  |   |                | MIN                     | TYP              | MAX         | MIN                      | TYP           | MAX   |      |
| V <sub>IO</sub> Input offset voltage   |   | TL031I         | 25°C                    | 0.54             | 3.5         | 0.5                      | 1.5           | mV    |      |
|  |   |                | Full range†             | 5.3              |             |                          | 3.3           |       |      |
|  |   | TL031AI        | 25°C                    | 0.41             | 2.8         | 0.34                     | 0.8           |       |      |
|  |   |                | Full range†             | 4.6              |             |                          | 2.6           |       |      |
| α <sub>VIO</sub> Temperature coefficient of input offset voltage                       | V <sub>O</sub> = 0,<br>V <sub>IC</sub> = 0,<br>R <sub>S</sub> = 50 Ω                    | TL031I         | 25°C to 85°C            | 6.5              |             | 6.2                      |               | μV/°C |      |
|  |   | TL031AI        | 25°C to 85°C            | 6.5              |             | 6.2                      | 25            |       |      |
| Input offset voltage long-term drift‡  |   |                | 25°C                    | 0.04             |             | 0.04                     |               | μV/mo |      |
| I <sub>IO</sub> Input offset current   | V <sub>O</sub> = 0,    V <sub>IC</sub> = 0,<br>See Figure 5                             |                | 25°C                    | 1                | 100         | 1                        | 100           | pA    |      |
|  |   |                | 85°C                    | 0.02             | 0.45        | 0.02                     | 0.45          | nA    |      |
| I <sub>IB</sub> Input bias current   | V <sub>O</sub> = 0,    V <sub>IC</sub> = 0,<br>See Figure 5                             |                | 25°C                    | 2                | 200         | 2                        | 200           | pA    |      |
|  |   |                | 85°C                    | 0.2              | 0.9         | 0.2                      | 0.9           | nA    |      |
| V <sub>ICR</sub> Common-mode input voltage range                                       |   |                | 25°C                    | -1.5 to 4        | -3.4 to 5.4 | -11.5 to 14              | -13.4 to 15.4 | V     |      |
|  |   |                | Full range†             | -1.5 to 4        |             | -11.5 to 14              |               |       |      |
| V <sub>OM+</sub> Maximum positive peak output voltage swing                            | R <sub>L</sub> = 10 kΩ  |                | 25°C                    | 3                | 4.3         | 13                       | 14            | V     |      |
|  |   |                | -40°C                   | 3                | 4.1         | 13                       | 14            |       |      |
|  |   |                | 85°C                    | 3                | 4.4         | 13                       | 14            |       |      |
| V <sub>OM-</sub> Maximum negative peak output voltage swing                            | R <sub>L</sub> = 10 kΩ  |                | 25°C                    | -3               | -4.2        | -12.5                    | -13.9         | V     |      |
|  |   |                | -40°C                   | -3               | -4.1        | -12.5                    | -13.8         |       |      |
|  |   |                | 85°C                    | -3               | -4.2        | -12.5                    | -14           |       |      |
| A <sub>VD</sub> Large-signal differential voltage amplification§                       | R <sub>L</sub> = 10 kΩ  |                | 25°C                    | 4                | 12          | 5                        | 14.3          | V/mV  |      |
|  |   |                | -40°C                   | 3                | 8.4         | 4                        | 11.6          |       |      |
|  |   |                | 85°C                    | 4                | 13.5        | 5                        | 15.3          |       |      |
| r <sub>i</sub> Input resistance  |   |                | 25°C                    | 10 <sup>12</sup> |             | 10 <sup>12</sup>         |               | Ω     |      |
| c <sub>i</sub> Input capacitance   |   |                | 25°C                    | 5                |             | 4                        |               | pF    |      |
| CMRR    Common-mode rejection ratio  | V <sub>IC</sub> = V <sub>ICRmin</sub> ,<br>V <sub>O</sub> = 0,    R <sub>S</sub> = 50 Ω |                | 25°C                    | 70               | 87          | 75                       | 94            | dB    |      |
|  |   |                | -40°C                   | 70               | 87          | 75                       | 94            |       |      |
|  |   |                | 85°C                    | 70               | 87          | 75                       | 94            |       |      |
| k <sub>SVR</sub> Supply-voltage rejection ratio (ΔV <sub>CC±</sub> /ΔV <sub>IO</sub> ) | V <sub>O</sub> = 0,    R <sub>S</sub> = 50 Ω  |                | 25°C                    | 75               | 96          | 75                       | 96            | dB    |      |
|  |   |                | -40°C                   | 75               | 96          | 75                       | 96            |       |      |
|  |   |                | 85°C                    | 75               | 96          | 75                       | 96            |       |      |

† Full range is -40°C to 85°C.

‡ Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T<sub>A</sub> = 150°C extrapolated to T<sub>A</sub> = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

§ At V<sub>CC±</sub> = ±5 V, V<sub>O</sub> = ±2.3 V; at V<sub>CC±</sub> = ±15 V, V<sub>O</sub> = ±10 V.



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## TL031I and TL031AI electrical characteristics at specified free-air temperature (continued)

| PARAMETER                              | TEST CONDITIONS             | T <sub>A</sub> | TL031I, TL031AI         |     |     |                          |     |     | UNIT |
|--|-----------------------------|----------------|-------------------------|-----|-----|--------------------------|-----|-----|------|
|  |                             |                | V <sub>CC±</sub> = ±5 V |     |     | V <sub>CC±</sub> = ±15 V |     |     |      |
|  |                             |                | MIN                     | TYP | MAX | MIN                      | TYP | MAX |      |
| P <sub>D</sub> Total power dissipation | V <sub>O</sub> = 0, No load | 25°C           | 1.9                     | 2.5 |     | 6.5                      | 8.4 | mW  |      |
|  |                             | -40°C          | 1.4                     | 2.5 |     | 5.4                      | 8.4 |     |      |
|  |                             | 85°C           | 1.9                     | 2.5 |     | 6.2                      | 8.4 |     |      |
| I <sub>CC</sub> Supply current         | V <sub>O</sub> = 0, No load | 25°C           | 192                     | 250 |     | 217                      | 280 | μA  |      |
|  |                             | -40°C          | 144                     | 250 |     | 181                      | 280 |     |      |
|  |                             | 85°C           | 189                     | 250 |     | 207                      | 280 |     |      |

## TL031I and TL031AI operating characteristics at specified free-air temperature

| PARAMETER   | TEST CONDITIONS   | T <sub>A</sub>   | TL031I, TL031AI         |           |     |                          |        |        | UNIT |
|---|---|--|-------------------------|-----------|-----|--------------------------|--------|--------|------|
|   |   |  | V <sub>CC±</sub> = ±5 V |           |     | V <sub>CC±</sub> = ±15 V |        |        |      |
|   |   |  | MIN                     | TYP       | MAX | MIN                      | TYP    | MAX    |      |
| SR <sub>+</sub> Positive slew rate at unity gain† | R <sub>L</sub> = 10 kΩ, C <sub>L</sub> = 100 pF,<br>See Figure 1  | 25°C   |                         | 2         |     | 1.5                      | 2.9    | V/μs   |      |
|   |   | -40°C  |                         | 1.6       |     | 1                        | 2.1    |        |      |
|   |   | 85°C   |                         | 2.3       |     | 1.5                      | 3.3    |        |      |
| SR <sub>-</sub> Negative slew rate at unity gain† |   | R <sub>L</sub> = 10 kΩ, C <sub>L</sub> = 100 pF,<br>See Figure 1                                 | 25°C                    |           | 3.9 |                          | 1.5    | 5.1    | V/μs |
|   |   |  | -40°C                   |           | 3.3 |                          | 1.5    | 4.8    |      |
|   |   |  | 85°C                    |           | 4.1 |                          | 1.5    | 4.9    |      |
| t <sub>r</sub> Rise time                          | V <sub>I(PP)</sub> = ±10 mV,<br>R <sub>L</sub> = 10 kΩ, C <sub>L</sub> = 100 pF,<br>See Figures 1 and 2 |  | 25°C                    |           | 138 |                          | 132    | ns     |      |
|   |   |  | -40°C                   |           | 132 |                          | 123    |        |      |
|   |   |  | 85°C                    |           | 154 |                          | 146    |        |      |
| t <sub>f</sub> Fall time                          |   | V <sub>I(PP)</sub> = ±10 mV,<br>R <sub>L</sub> = 10 kΩ, C <sub>L</sub> = 100 pF,<br>See Figure 1 | 25°C                    |           | 138 |                          | 132    | ns     |      |
|   |   |  | -40°C                   |           | 132 |                          | 123    |        |      |
|   |   |  | 85°C                    |           | 154 |                          | 146    |        |      |
| Overshoot factor                                  | V <sub>I(PP)</sub> = ±10 mV,<br>R <sub>L</sub> = 10 kΩ, C <sub>L</sub> = 100 pF,<br>See Figures 1 and 2 |  | 25°C                    |           | 11% |                          | 5%     |        |      |
|   |   |  | -40°C                   |           | 12% |                          | 5%     |        |      |
|   |   |  | 85°C                    |           | 13% |                          | 7%     |        |      |
| V <sub>n</sub> Equivalent input noise voltage     |   | TL031I<br>R <sub>S</sub> = 20 Ω,<br>See Figure 3   | 25°C                    | f = 10 Hz |     | 61                       |        | nV/√Hz |      |
|   |   |  |                         | f = 1 kHz |     | 41                       |        |        | 41   |
|   |   |  | 25°C                    | f = 10 Hz |     | 61                       |        |        | 61   |
|   | f = 1 kHz   |  |                         |           | 41  |                          | 41     |        | 60   |
| I <sub>n</sub> Equivalent input noise current     | f = 1 kHz   | 25°C   |                         | 0.003     |     | 0.003                    | pA/√Hz |        |      |
| B <sub>1</sub> Unity-gain bandwidth               | V <sub>I</sub> = 10 mV, C <sub>L</sub> = 25 pF,<br>R <sub>L</sub> = 10 kΩ,<br>See Figure 4              | 25°C   |                         | 1         |     | 1.1                      | MHz    |        |      |
|   |   | -40°C  |                         | 1         |     | 1.1                      |        |        |      |
|   |   | 85°C   |                         | 0.9       |     | 1                        |        |        |      |
| φ <sub>m</sub> Phase margin at unity gain         | V <sub>I</sub> = 10 mV, C <sub>L</sub> = 25 pF,<br>R <sub>L</sub> = 10 kΩ,<br>See Figure 4              | 25°C   |                         | 61°       |     | 65°                      |        |        |      |
|   |   | -40°C  |                         | 60°       |     | 65°                      |        |        |      |
|   |   | 85°C   |                         | 60°       |     | 64°                      |        |        |      |

† For V<sub>CC±</sub> = ±5 V, V<sub>I(PP)</sub> = ±1 V; for V<sub>CC±</sub> = ±15 V, V<sub>I(PP)</sub> = ±5 V.



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**TL031M and TL031AM electrical characteristics at specified free-air temperature**

| PARAMETER  | TEST CONDITIONS  | T <sub>A</sub> | TL031M, TL031AM         |             |                  |                          |       |       | UNIT |
|--|--|----------------|-------------------------|-------------|------------------|--------------------------|-------|-------|------|
|  |  |                | V <sub>CC±</sub> = ±5 V |             |                  | V <sub>CC±</sub> = ±15 V |       |       |      |
|  |  |                | MIN                     | TYP         | MAX              | MIN                      | TYP   | MAX   |      |
| V <sub>IO</sub> Input offset voltage   | V <sub>O</sub> = 0,<br>V <sub>IC</sub> = 0,<br>R <sub>S</sub> = 50 Ω                 | TL031M         | 25°C                    | 0.54        | 3.5              | 0.5                      | 1.5   | mV    |      |
|  |  |                | Full range†             | 6.5         |                  |                          | 4.5   |       |      |
|  |  | TL031AM        | 25°C                    | 0.41        | 2.8              | 0.34                     | 0.8   |       |      |
|  |  |                | Full range†             | 5.8         |                  |                          | 3.8   |       |      |
| α <sub>VIO</sub> Temperature coefficient of input offset voltage                       | V <sub>O</sub> = 0,<br>V <sub>IC</sub> = 0,<br>R <sub>S</sub> = 50 Ω                 | TL031M         | 25°C to 125°C           | 5.1         |                  | 4.3                      |       | μV/°C |      |
|  |  | TL031AM        | 25°C to 125°C           | 5.1         |                  | 4.3                      |       |       |      |
| Input offset voltage long-term drift‡  |  | 25°C           | 0.04                    |             | 0.04             |                          | μV/mo |       |      |
| I <sub>IO</sub> Input offset current   | V <sub>O</sub> = 0, V <sub>IC</sub> = 0,<br>See Figure 5                             | 25°C           | 1                       | 100         | 1                | 100                      | pA    |       |      |
|  |  | 125°C          | 0.2                     | 10          | 0.2              | 10                       | nA    |       |      |
| I <sub>IB</sub> Input bias current   | V <sub>O</sub> = 0, V <sub>IC</sub> = 0,<br>See Figure 5                             | 25°C           | 2                       | 200         | 2                | 200                      | pA    |       |      |
|  |  | 125°C          | 7                       | 20          | 8                | 20                       | nA    |       |      |
| V <sub>ICR</sub> Common-mode input voltage range                                       |  | 25°C           | -1.5 to 4               | -3.4 to 5.4 | -11.5 to 14      | -13.4 to 15.4            | V     |       |      |
|  |  | Full range†    | -1.5 to 4               |             | -11.5 to 14      |                          |       |       |      |
| V <sub>OM+</sub> Maximum positive peak output voltage swing                            | R <sub>L</sub> = 10 kΩ   | 25°C           | 3                       | 4.3         | 13               | 14                       | V     |       |      |
|  |  | -55°C          | 3                       | 4.1         | 13               | 14                       |       |       |      |
|  |  | 125°C          | 3                       | 4.4         | 13               | 14                       |       |       |      |
| V <sub>OM-</sub> Maximum negative peak output voltage swing                            | R <sub>L</sub> = 10 kΩ   | 25°C           | -3                      | -4.2        | -12.5            | -13.9                    | V     |       |      |
|  |  | -55°C          | -3                      | -4          | -12.5            | -13.8                    |       |       |      |
|  |  | 125°C          | -3                      | -4.3        | -12.5            | -14                      |       |       |      |
| A <sub>VD</sub> Large-signal differential voltage amplification§                       | R <sub>L</sub> = 10 kΩ   | 25°C           | 4                       | 12          | 5                | 14.3                     | V/mV  |       |      |
|  |  | -55°C          | 3                       | 7.1         | 4                | 10.4                     |       |       |      |
|  |  | 125°C          | 3                       | 12.9        | 4                | 15                       |       |       |      |
| r <sub>i</sub> Input resistance  |  | 25°C           | 10 <sup>12</sup>        |             | 10 <sup>12</sup> |                          | Ω     |       |      |
| c <sub>i</sub> Input capacitance   |  | 25°C           | 5                       |             | 4                |                          | pF    |       |      |
| CMR <sub>R</sub> Common-mode rejection ratio   | V <sub>IC</sub> = V <sub>ICRmin</sub> ,<br>V <sub>O</sub> = 0, R <sub>S</sub> = 50 Ω | 25°C           | 70                      | 87          | 75               | 94                       | dB    |       |      |
|  |  | -55°C          | 70                      | 87          | 70               | 94                       |       |       |      |
|  |  | 125°C          | 70                      | 87          | 70               | 94                       |       |       |      |
| k <sub>SVR</sub> Supply-voltage rejection ratio (ΔV <sub>CC±</sub> /ΔV <sub>IO</sub> ) | V <sub>O</sub> = 0, R <sub>S</sub> = 50 Ω  | 25°C           | 75                      | 96          | 75               | 96                       | dB    |       |      |
|  |  | -55°C          | 75                      | 96          | 75               | 95                       |       |       |      |
|  |  | 125°C          | 75                      | 96          | 75               | 96                       |       |       |      |
| P <sub>D</sub> Total power dissipation   | V <sub>O</sub> = 0, No load  | 25°C           | 1.9                     | 2.5         | 6.5              | 8.4                      | mW    |       |      |
|  |  | -55°C          | 1.1                     | 2.5         | 4.7              | 8.4                      |       |       |      |
|  |  | 125°C          | 1.8                     | 2.5         | 5.8              | 8.4                      |       |       |      |

† Full range is -55°C to 125°C.

‡ Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T<sub>A</sub> = 150°C extrapolated to T<sub>A</sub> = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

§ At V<sub>CC±</sub> = ±5 V, V<sub>O</sub> = ±2.3 V; at V<sub>CC±</sub> = ±15 V, V<sub>O</sub> = ±10 V.



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## TL031M and TL031AM electrical characteristics at specified free-air temperature (continued)

| PARAMETER                      | TEST CONDITIONS             | T <sub>A</sub> | TL031M, TL031AM         |     |     |                          |     |     | UNIT |
|--------------------------------|-----------------------------|----------------|-------------------------|-----|-----|--------------------------|-----|-----|------|
|                                |                             |                | V <sub>CC±</sub> = ±5 V |     |     | V <sub>CC±</sub> = ±15 V |     |     |      |
|                                |                             |                | MIN                     | TYP | MAX | MIN                      | TYP | MAX |      |
| I <sub>CC</sub> Supply current | V <sub>O</sub> = 0, No load | 25°C           |                         | 192 | 250 |                          | 217 | 280 | μA   |
|                                |                             | -55°C          |                         | 114 | 250 |                          | 156 | 280 |      |
|                                |                             | 125°C          |                         | 178 | 250 |                          | 197 | 280 |      |

## TL031M and TL031AM operating characteristics at specified free-air temperature

| PARAMETER                                     | TEST CONDITIONS   | T <sub>A</sub>   | TL031M, TL031AM         |           |     |                          |        |      | UNIT   |
|---|---|--|-------------------------|-----------|-----|--------------------------|--------|------|--------|
|   |   |  | V <sub>CC±</sub> = ±5 V |           |     | V <sub>CC±</sub> = ±15 V |        |      |        |
|   |   |  | MIN                     | TYP       | MAX | MIN                      | TYP    | MAX  |        |
| SR+ Positive slew rate at unity gain†         | R <sub>L</sub> = 10 kΩ, C <sub>L</sub> = 100 pF,<br>See Figure 1  | 25°C   |                         | 2         |     | 1.5                      | 2.9    | V/μs |        |
|   |   | -55°C  |                         | 1.4       |     | 1                        | 1.9    |      |        |
|   |   | 125°C  |                         | 2.4       |     | 1                        | 3.5    |      |        |
| SR- Negative slew rate at unity gain†         |   | R <sub>L</sub> = 10 kΩ, C <sub>L</sub> = 100 pF,<br>See Figure 1                                 | 25°C                    |           | 3.9 |                          | 1.5    | 5.1  | V/μs   |
|   |   |  | -55°C                   |           | 3.2 |                          | 1      | 4.6  |        |
|   |   |  | 125°C                   |           | 4.1 |                          | 1      | 4.7  |        |
| t <sub>r</sub> Rise time                      | V <sub>I(PP)</sub> = ±10 mV,<br>R <sub>L</sub> = 10 kΩ, C <sub>L</sub> = 100 pF,<br>See Figures 1 and 2 |  | 25°C                    |           | 138 |                          | 132    | ns   |        |
|   |   |  | -55°C                   |           | 142 |                          | 123    |      |        |
|   |   |  | 125°C                   |           | 166 |                          | 158    |      |        |
| t <sub>f</sub> Fall time                      |   | V <sub>I(PP)</sub> = ±10 mV,<br>R <sub>L</sub> = 10 kΩ, C <sub>L</sub> = 100 pF,<br>See Figure 1 | 25°C                    |           | 138 |                          | 132    | ns   |        |
|   |   |  | -55°C                   |           | 142 |                          | 123    |      |        |
|   |   |  | 125°C                   |           | 166 |                          | 158    |      |        |
| Overshoot factor                              | V <sub>I(PP)</sub> = ±10 mV,<br>R <sub>L</sub> = 10 kΩ, C <sub>L</sub> = 100 pF,<br>See Figures 1 and 2 |  | 25°C                    |           | 11% |                          | 5%     |      |        |
|   |   |  | -55°C                   |           | 16% |                          | 6%     |      |        |
|   |   |  | 125°C                   |           | 14% |                          | 8%     |      |        |
| V <sub>n</sub> Equivalent input noise voltage |   | TL031M<br>R <sub>S</sub> = 20 Ω,<br>See Figure 3   | 25°C                    | f = 10 Hz |     | 61                       |        | 61   | nV/√Hz |
|   |   |  |                         | f = 1 kHz |     | 41                       |        | 41   |        |
|   |   |  | 25°C                    | f = 10 Hz |     | 61                       |        | 61   |        |
|   | f = 1 kHz   |  |                         |           | 41  |                          | 41     |      |        |
| I <sub>n</sub> Equivalent input noise current | f = 1 kHz   | 25°C   |                         | 0.003     |     | 0.003                    | pA/√Hz |      |        |
| B <sub>1</sub> Unity-gain bandwidth           | V <sub>I</sub> = 10 mV, R <sub>L</sub> = 10 kΩ,<br>C <sub>L</sub> = 25 pF, See Figure 4                 | 25°C   |                         | 1         |     | 1.1                      | MHz    |      |        |
|   |   | -55°C  |                         | 1         |     | 1.1                      |        |      |        |
|   |   | 125°C  |                         | 0.9       |     | 0.9                      |        |      |        |
| φ <sub>m</sub> Phase margin at unity gain     |   | V <sub>I</sub> = 10 mV, R <sub>L</sub> = 10 kΩ,<br>C <sub>L</sub> = 25 pF, See Figure 4          | 25°C                    |           | 61° |                          | 65°    |      |        |
|   |   |  | -55°C                   |           | 57° |                          | 64°    |      |        |
|   |   |  | 125°C                   |           | 59° |                          | 62°    |      |        |

† For V<sub>CC±</sub> = ±5 V, V<sub>I(PP)</sub> = ±1 V; for V<sub>CC±</sub> = ±15 V, V<sub>I(PP)</sub> = ±5 V.



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**TL031Y electrical characteristics,  $T_A = 25^\circ\text{C}$**

| PARAMETER   | TEST CONDITIONS                              | TL031Y                       |                   |     |                               |                     |     | UNIT |                              |
|---|--|------------------------------|-------------------|-----|-------------------------------|---------------------|-----|------|------------------------------|
|   |  | $V_{CC\pm} = \pm 5\text{ V}$ |                   |     | $V_{CC\pm} = \pm 15\text{ V}$ |                     |     |      |                              |
|   |  | MIN                          | TYP               | MAX | MIN                           | TYP                 | MAX |      |                              |
| $V_{IO}$ Input offset voltage   | $V_O = 0,$<br>$R_S = 50\ \Omega$             | $V_{IC} = 0,$                | 0.54              |     |                               | 0.5                 |     |      | mV                           |
| $\alpha_{VIO}$ Temperature coefficient of input offset voltage                |  |                              | 7.1               |     |                               | 5.9                 |     |      | $\mu\text{V}/^\circ\text{C}$ |
| $I_{IO}$ Input offset current   | $V_O = 0,$<br>See Figure 5                   | $V_{IC} = 0,$                | 1                 |     |                               | 1                   |     |      | pA                           |
| $I_{IB}$ Input bias current   |  |                              | 2                 |     |                               | 2                   |     |      | pA                           |
| $V_{ICR}$ Common-mode input voltage range                                     |  |                              | -3.4<br>to<br>5.4 |     |                               | -13.4<br>to<br>15.4 |     |      | V                            |
| $V_{OM+}$ Maximum positive peak output voltage swing                          | $R_L = 10\ \text{k}\Omega$                   |                              | 4.3               |     |                               | 14                  |     |      | V                            |
| $V_{OM-}$ Maximum negative peak output voltage swing                          | $R_L = 10\ \text{k}\Omega$                   |                              | -4.2              |     |                               | -13.9               |     |      | V                            |
| $A_{VD}$ Large-signal differential voltage amplification†                     | $R_L = 10\ \text{k}\Omega$                   |                              | 12                |     |                               | 14.3                |     |      | V/mV                         |
| $r_i$ Input resistance  |  |                              | $10^{12}$         |     |                               | $10^{12}$           |     |      | $\Omega$                     |
| $c_i$ Input capacitance   |  |                              | 5                 |     |                               | 4                   |     |      | pF                           |
| CMRR Common-mode rejection ratio  | $V_{IC} = V_{ICRmin},$<br>$R_S = 50\ \Omega$ | $V_O = 0,$                   | 87                |     |                               | 94                  |     |      | dB                           |
| $k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{CC\pm}/\Delta V_{IO}$ ) | $V_O = 0,$                                   | $R_S = 50\ \Omega$           | 96                |     |                               | 96                  |     |      | dB                           |
| $P_D$ Total power dissipation   | $V_O = 0,$                                   | No load                      | 1.9               |     |                               | 6.5                 |     |      | mW                           |
| $I_{CC}$ Supply current   |  |                              | 192               |     |                               | 217                 |     |      | $\mu\text{A}$                |

† At  $V_{CC\pm} = \pm 5\text{ V}$ ,  $V_O = \pm 2.3\text{ V}$ ; at  $V_{CC\pm} = \pm 15\text{ V}$ ,  $V_O = \pm 10\text{ V}$ .

**TL031Y operating characteristics,  $T_A = 25^\circ\text{C}$**

| PARAMETER                               | TEST CONDITIONS  | TL031Y   |       |     |                               |       |     | UNIT |                              |
|---|--|--|-------|-----|-------------------------------|-------|-----|------|------------------------------|
|   |  | $V_{CC\pm} = \pm 5\text{ V}$   |       |     | $V_{CC\pm} = \pm 15\text{ V}$ |       |     |      |                              |
|   |  | MIN  | TYP   | MAX | MIN                           | TYP   | MAX |      |                              |
| $SR+$ Positive slew rate at unity gain‡ | $R_L = 10\ \text{k}\Omega,$<br>$C_L = 100\ \text{pF},$<br>See Figure 1 | $R_L = 10\ \text{k}\Omega,$<br>$C_L = 100\ \text{pF},$<br>See Figure 1 | 2     |     |                               | 2.9   |     |      | V/ $\mu\text{s}$             |
| $SR-$ Negative slew rate at unity gain‡ |  |  | 3.9   |     |                               | 5.1   |     |      | V/ $\mu\text{s}$             |
| $t_r$ Rise time                         | $V_{I(PP)} = \pm 10\ \text{mV},$                                       |  | 138   |     |                               | 132   |     |      | ns                           |
| $t_f$ Fall time                         | $R_L = 10\ \text{k}\Omega,$  | $C_L = 100\ \text{pF},$  | 138   |     |                               | 132   |     |      | ns                           |
| Overshoot factor                        | See Figures 1 and 2  |  | 11%   |     |                               | 5%    |     |      |                              |
| $V_n$ Equivalent input noise voltage    | $R_S = 20\ \Omega,$<br>See Figure 3                                    | $f = 10\ \text{Hz}$  | 61    |     |                               | 61    |     |      | $\text{nV}/\sqrt{\text{Hz}}$ |
|   |  | $f = 1\ \text{kHz}$  | 41    |     |                               | 41    |     |      |                              |
| $I_n$ Equivalent input noise current    | $f = 1\ \text{kHz}$  |  | 0.003 |     |                               | 0.003 |     |      | $\text{pA}/\sqrt{\text{Hz}}$ |
| $B_1$ Unity-gain bandwidth              | $V_I = 10\ \text{mV},$<br>$C_L = 25\ \text{pF},$                       | $R_L = 10\ \text{k}\Omega,$<br>See Figure 4                            | 1     |     |                               | 1.1   |     |      | MHz                          |
| $\phi_m$ Phase margin at unity gain     | $V_I = 10\ \text{mV},$<br>$C_L = 25\ \text{pF},$                       | $R_L = 10\ \text{k}\Omega,$<br>See Figure 4                            | 61°   |     |                               | 65°   |     |      |                              |

‡ For  $V_{CC\pm} = \pm 5\text{ V}$ ,  $V_{I(PP)} = \pm 1\text{ V}$ ; for  $V_{CC\pm} = \pm 15\text{ V}$ ,  $V_{I(PP)} = \pm 5\text{ V}$ .



# TL03x, TL03xA, TL03xY ENHANCED-JFET LOW-POWER LOW-OFFSET OPERATIONAL AMPLIFIERS

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## TL032C and TL032AC electrical characteristics at specified free-air temperature

| PARAMETER  | TEST CONDITIONS  |                      | T <sub>A</sub> | TL032C, TL032AC         |             |                  |                          |               |      | UNIT |
|--|--|----------------------|----------------|-------------------------|-------------|------------------|--------------------------|---------------|------|------|
|  |  |                      |                | V <sub>CC±</sub> = ±5 V |             |                  | V <sub>CC±</sub> = ±15 V |               |      |      |
|  |  |                      |                | MIN                     | TYP         | MAX              | MIN                      | TYP           | MAX  |      |
| V <sub>IO</sub> Input offset voltage   |  | TL032C               | 25°C           | 0.69                    | 3.5         |                  | 0.57                     | 1.5           | mV   |      |
|  |  |                      | Full range†    |                         | 4.5         |                  | 2.5                      |               |      |      |
|  |  |                      | TL032AC        | 25°C                    | 0.53        | 2.8              |                          | 0.39          |      | 0.8  |
|  |  |                      |                | Full range†             |             | 3.8              |                          | 1.8           |      |      |
| αV <sub>IO</sub> Temperature coefficient of input offset voltage                       | V <sub>O</sub> = 0,<br>V <sub>IC</sub> = 0,<br>R <sub>S</sub> = 50 Ω                 | TL032C               | 25°C to 70°C   | 11.5                    |             | 10.8             |                          | μV/°C         |      |      |
|  |  | TL032AC              | 25°C to 70°C   | 11.5                    |             | 10.8 25          |                          |               |      |      |
| Input offset voltage long-term drift‡  |  |                      | 25°C           | 0.04                    |             | 0.04             |                          | μV/mo         |      |      |
| I <sub>IO</sub> Input offset current   | V <sub>O</sub> = 0,<br>See Figure 5  | V <sub>IC</sub> = 0, | 25°C           | 1                       | 100         |                  | 1                        | 100           | pA   |      |
|  |  |                      | 70°C           | 9                       | 200         |                  | 12                       | 200           |      |      |
| I <sub>IB</sub> Input bias current   | V <sub>O</sub> = 0,<br>See Figure 5  | V <sub>IC</sub> = 0, | 25°C           | 2                       | 200         |                  | 2                        | 200           | pA   |      |
|  |  |                      | 70°C           | 50                      | 400         |                  | 80                       | 400           |      |      |
| V <sub>ICR</sub> Common-mode input voltage range                                       |  |                      | 25°C           | -1.5 to 4               | -3.4 to 5.4 |                  | -11.5 to 14              | -13.4 to 15.4 | V    |      |
|  |  |                      | Full range†    | -1.5 to 4               |             |                  | -11.5 to 14              |               |      |      |
| V <sub>OM+</sub> Maximum positive peak output voltage swing                            | R <sub>L</sub> = 10 kΩ   |                      | 25°C           | 3                       | 4.3         |                  | 13                       | 14            | V    |      |
|  |  |                      | 0°C            | 3                       | 4.2         |                  | 13                       | 14            |      |      |
|  |  |                      | 70°C           | 3                       | 4.3         |                  | 13                       | 14            |      |      |
| V <sub>OM-</sub> Maximum negative peak output voltage swing                            | R <sub>L</sub> = 10 kΩ   |                      | 25°C           | -3                      | -4.2        |                  | -12.5                    | -13.9         | V    |      |
|  |  |                      | 0°C            | -3                      | -4.1        |                  | -12.5                    | -13.9         |      |      |
|  |  |                      | 70°C           | -3                      | -4.2        |                  | -12.5                    | -14           |      |      |
| A <sub>VD</sub> Large-signal differential voltage amplification§                       | R <sub>L</sub> = 10 kΩ   |                      | 25°C           | 4                       | 12          |                  | 5                        | 14.3          | V/mV |      |
|  |  |                      | 0°C            | 3                       | 11.1        |                  | 4                        | 13.5          |      |      |
|  |  |                      | 70°C           | 4                       | 13.3        |                  | 5                        | 15.2          |      |      |
| r <sub>i</sub> Input resistance  |  |                      | 25°C           | 10 <sup>12</sup>        |             | 10 <sup>12</sup> |                          | Ω             |      |      |
| c <sub>i</sub> Input capacitance   |  |                      | 25°C           | 5                       |             | 14               |                          | pF            |      |      |
| CMRR Common-mode rejection ratio   | V <sub>IC</sub> = V <sub>ICRmin</sub> ,<br>V <sub>O</sub> = 0, R <sub>S</sub> = 50 Ω |                      | 25°C           | 70                      | 87          |                  | 75                       | 94            | dB   |      |
|  |  |                      | 0°C            | 70                      | 87          |                  | 75                       | 94            |      |      |
|  |  |                      | 70°C           | 70                      | 87          |                  | 75                       | 94            |      |      |
| k <sub>SVR</sub> Supply-voltage rejection ratio (ΔV <sub>CC±</sub> /ΔV <sub>IO</sub> ) | V <sub>CC±</sub> = ±5 V to ±15 V,<br>V <sub>O</sub> = 0, R <sub>S</sub> = 50 Ω       |                      | 25°C           | 75                      | 96          |                  | 75                       | 96            | dB   |      |
|  |  |                      | 0°C            | 75                      | 96          |                  | 75                       | 96            |      |      |
|  |  |                      | 70°C           | 75                      | 96          |                  | 75                       | 96            |      |      |

† Full range is 0°C to 70°C.

‡ Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T<sub>A</sub> = 150°C extrapolated to T<sub>A</sub> = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

§ At V<sub>CC±</sub> = ±5 V, V<sub>O</sub> = 2.3 V; at V<sub>CC±</sub> = ±15 V, V<sub>O</sub> = ±10 V.





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**TL032C and TL032AC electrical characteristics at specified free-air temperature (continued)**

| PARAMETER                        | TEST CONDITIONS                             | T <sub>A</sub>              | TL032C, TL032AC         |     |     |                          |     |     | UNIT |
|----------------------------------|---|-----------------------------|-------------------------|-----|-----|--------------------------|-----|-----|------|
|                                  |   |                             | V <sub>CC±</sub> = ±5 V |     |     | V <sub>CC±</sub> = ±15 V |     |     |      |
|                                  |   |                             | MIN                     | TYP | MAX | MIN                      | TYP | MAX |      |
| P <sub>D</sub>                   | Total power dissipation<br>(two amplifiers) | V <sub>O</sub> = 0, No load | 25°C                    | 3.8 | 5   | 13                       | 17  | mW  |      |
|                                  |   |                             | 0°C                     | 3.7 | 5   | 12.7                     | 17  |     |      |
|                                  |   |                             | 70°C                    | 3.8 | 5   | 12.6                     | 17  |     |      |
| I <sub>CC</sub>                  | Supply current<br>(two amplifiers)          | V <sub>O</sub> = 0, No load | 0°C                     | 368 | 500 | 422                      | 560 | μA  |      |
|                                  |   |                             | 70°C                    | 378 | 500 | 420                      | 560 |     |      |
| V <sub>O1</sub> /V <sub>O2</sub> | Crosstalk attenuation                       | A <sub>VD</sub> = 100 dB    | 25°C                    | 120 |     | 120                      |     | dB  |      |

**TL032C and TL032AC operating characteristics at specified free-air temperature**

| PARAMETER        | TEST CONDITIONS                   | T <sub>A</sub>   | TL032C, TL032AC         |           |      |                          |        |        | UNIT |
|------------------|-----------------------------------|--|-------------------------|-----------|------|--------------------------|--------|--------|------|
|                  |                                   |  | V <sub>CC±</sub> = ±5 V |           |      | V <sub>CC±</sub> = ±15 V |        |        |      |
|                  |                                   |  | MIN                     | TYP       | MAX  | MIN                      | TYP    | MAX    |      |
| SR <sub>+</sub>  | Positive slew rate at unity gain† | R <sub>L</sub> = 10 kΩ, C <sub>L</sub> = 100 pF,<br>See Figure 1                                       | 25°C                    | 12        |      | 1.5                      | 2.9    | V/μs   |      |
|                  |                                   |  | 0°C                     | 1.8       |      | 1                        | 2.6    |        |      |
|                  |                                   |  | 70°C                    | 2.2       |      | 1.5                      | 3.2    |        |      |
| SR <sub>-</sub>  | Negative slew rate at unity gain† | R <sub>L</sub> = 10 kΩ, C <sub>L</sub> = 100 pF,<br>See Figure 1                                       | 25°C                    | 3.9       |      | 1.5                      | 5.1    | V/μs   |      |
|                  |                                   |  | 0°C                     | 3.7       |      | 1.5                      | 5      |        |      |
|                  |                                   |  | 70°C                    | 4         |      | 1.5                      | 5      |        |      |
| t <sub>r</sub>   | Rise time                         | V <sub>I(PP)</sub> = ±10 V,<br>R <sub>L</sub> = 10 kΩ, C <sub>L</sub> = 100 pF,<br>See Figures 1 and 2 | 25°C                    | 138       |      | 132                      | ns     |        |      |
|                  |                                   |  | 0°C                     | 134       |      | 127                      |        |        |      |
|                  |                                   |  | 70°C                    | 150       |      | 142                      |        |        |      |
| t <sub>f</sub>   | Fall time                         | V <sub>I(PP)</sub> = ±10 V,<br>R <sub>L</sub> = 10 kΩ, C <sub>L</sub> = 100 pF,<br>See Figures 1 and 2 | 25°C                    | 138       |      | 132                      | ns     |        |      |
|                  |                                   |  | 0°C                     | 134       |      | 127                      |        |        |      |
|                  |                                   |  | 70°C                    | 150       |      | 142                      |        |        |      |
| Overshoot factor |                                   | V <sub>I(PP)</sub> = ±10 V,<br>R <sub>L</sub> = 10 kΩ, C <sub>L</sub> = 100 pF,<br>See Figures 1 and 2 | 25°C                    | 11%       |      | 5%                       |        |        |      |
|                  |                                   |  | 0°C                     | 10%       |      | 4%                       |        |        |      |
|                  |                                   |  | 70°C                    | 12%       |      | 6%                       |        |        |      |
| V <sub>n</sub>   | Equivalent input noise voltage    | R <sub>S</sub> = 20 Ω,<br>See Figure 3   | TL032C                  | f = 10 Hz | 25°C | 49                       | 49     | nV/√Hz |      |
|                  |                                   |  |                         | f = 1 kHz | 25°C | 41                       | 41     |        |      |
|                  |                                   |  | TL032AC                 | f = 10 Hz | 25°C | 49                       | 49     |        |      |
|                  |                                   |  |                         | f = 1 kHz | 25°C | 41                       | 41 60  |        |      |
| I <sub>n</sub>   | Equivalent input noise current    | f = 1 kHz  | 25°C                    | 0.003     |      | 0.003                    | pA/√Hz |        |      |
| B <sub>1</sub>   | Unity-gain bandwidth              | V <sub>I</sub> = 10 mV, R <sub>L</sub> = 10 kΩ,<br>C <sub>L</sub> = 25 pF, See Figure 4                | 25°C                    | 1         |      | 1.1                      | MHz    |        |      |
|                  |                                   |  | 0°C                     | 1         |      | 1.1                      |        |        |      |
|                  |                                   |  | 70°C                    | 1         |      | 1                        |        |        |      |
| φ <sub>m</sub>   | Phase margin at unity gain        | V <sub>I</sub> = 10 mV, R <sub>L</sub> = 10 kΩ,<br>C <sub>L</sub> = 25 pF, See Figure 4                | 25°C                    | 61°       |      | 65°                      |        |        |      |
|                  |                                   |  | 0°C                     | 61°       |      | 65°                      |        |        |      |
|                  |                                   |  | 70°C                    | 60°       |      | 64°                      |        |        |      |

† For V<sub>CC±</sub> = ±5 V, V<sub>I(PP)</sub> = ±1 V; for V<sub>CC±</sub> = ±15 V, V<sub>I(PP)</sub> = ±5 V.



# TL03x, TL03xA, TL03xY ENHANCED-JFET LOW-POWER LOW-OFFSET OPERATIONAL AMPLIFIERS

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## TL032I and TL032AI electrical characteristics at specified free-air temperature

| PARAMETER  | TEST CONDITIONS  | T <sub>A</sub>       | TL032I, TL032AI         |           |                  |                          |               |       | UNIT |
|--|--|----------------------|-------------------------|-----------|------------------|--------------------------|---------------|-------|------|
|  |  |                      | V <sub>CC±</sub> = ±5 V |           |                  | V <sub>CC±</sub> = ±15 V |               |       |      |
|  |  |                      | MIN                     | TYP       | MAX              | MIN                      | TYP           | MAX   |      |
| V <sub>IO</sub> Input offset voltage   | V <sub>O</sub> = 0,<br>V <sub>IC</sub> = 0,<br>R <sub>S</sub> = 50 Ω                 | TL032I               | 25°C                    | 0.69      | 3.5              | 0.57                     | 1.5           | mV    |      |
|  |  |                      | Full range†             | 5.3       |                  |                          | 3.3           |       |      |
|  |  | TL032AI              | 25°C                    | 0.53      | 2.8              | 0.39                     | 0.8           |       |      |
|  |  |                      | Full range†             | 4.6       |                  |                          | 2.6           |       |      |
| α <sub>VIO</sub> Temperature coefficient of input offset voltage                       | V <sub>O</sub> = 0,<br>V <sub>IC</sub> = 0,<br>R <sub>S</sub> = 50 Ω                 | TL032I               | 25°C to 85°C            | 11.4      |                  | 10.8                     |               | μV/°C |      |
|  |  | TL032AI              | 25°C to 85°C            | 11.4      |                  | 10.8                     | 25            |       |      |
| Input offset voltage long-term drift‡  |  | 25°C                 | 0.04                    |           | 0.04             |                          | μV/mo         |       |      |
| I <sub>IO</sub> Input offset current   | V <sub>O</sub> = 0,<br>See Figure 5  | V <sub>IC</sub> = 0, | 25°C                    | 1         | 100              | 1                        | 100           | pA    |      |
|  |  |                      | 85°C                    | 0.02      | 0.45             | 0.02                     | 0.45          | nA    |      |
| I <sub>IB</sub> Input bias current   | V <sub>O</sub> = 0,<br>See Figure 5  | V <sub>IC</sub> = 0, | 25°C                    | 2         | 200              | 2                        | 200           | pA    |      |
|  |  |                      | 85°C                    | 0.2       | 0.9              | 0.3                      | 0.9           | nA    |      |
| V <sub>ICR</sub> Common-mode input voltage range                                       |  |                      | 25°C                    | -1.5 to 4 | -3.4 to 5.4      | -11.5 to 14              | -13.4 to 15.4 | V     |      |
|  |  |                      | Full range†             | -1.5 to 4 |                  | -11.5 to 14              |               |       |      |
| V <sub>OM+</sub> Maximum positive peak output voltage swing                            | R <sub>L</sub> = 10 kΩ   |                      | 25°C                    | 3         | 4.3              | 13                       | 14            | V     |      |
|  |  |                      | -40°C                   | 3         | 4.2              | 13                       | 14            |       |      |
|  |  |                      | 85°C                    | 3         | 4.4              | 13                       | 14            |       |      |
| V <sub>OM-</sub> Maximum negative peak output voltage swing                            | R <sub>L</sub> = 10 kΩ   |                      | 25°C                    | -3        | -4.2             | -12.5                    | -13.9         | V     |      |
|  |  |                      | -40°C                   | -3        | -4.1             | -12.5                    | -13.8         |       |      |
|  |  |                      | 85°C                    | -3        | -4.2             | -12.5                    | -14           |       |      |
| A <sub>VD</sub> Large-signal differential voltage amplification§                       | R <sub>L</sub> = 10 kΩ   |                      | -40°C                   | 3         | 8.4              | 4                        | 11.6          | V/mV  |      |
|  |  |                      | 85°C                    | 4         | 13.5             | 5                        | 15.3          |       |      |
| r <sub>i</sub> Input resistance  |  | 25°C                 | 10 <sup>12</sup>        |           | 10 <sup>12</sup> |                          | Ω             |       |      |
| c <sub>i</sub> Input capacitance   |  | 25°C                 | 5                       |           | 4                |                          | pF            |       |      |
| CMRR Common-mode rejection ratio   | V <sub>IC</sub> = V <sub>ICRmin</sub> ,<br>V <sub>O</sub> = 0, R <sub>S</sub> = 50 Ω |                      | 25°C                    | 70        | 87               | 75                       | 94            | dB    |      |
|  |  |                      | -40°C                   | 70        | 87               | 75                       | 94            |       |      |
|  |  |                      | 85°C                    | 70        | 87               | 75                       | 94            |       |      |
| k <sub>SVR</sub> Supply-voltage rejection ratio (ΔV <sub>CC±</sub> /ΔV <sub>IO</sub> ) | V <sub>CC±</sub> = ±5 V to ±15 V,<br>V <sub>O</sub> = 0, R <sub>S</sub> = 50 Ω       |                      | 25°C                    | 75        | 96               | 75                       | 96            | dB    |      |
|  |  |                      | -40°C                   | 75        | 96               | 75                       | 96            |       |      |
|  |  |                      | 85°C                    | 75        | 96               | 75                       | 96            |       |      |

† Full range is -40°C to 85°C.

‡ Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T<sub>A</sub> = 150°C extrapolated to T<sub>A</sub> = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

§ At V<sub>CC±</sub> = ±5 V, V<sub>O</sub> = 2.3 V; at V<sub>CC±</sub> = ±15 V, V<sub>O</sub> = ±10 V.



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**TL032I and TL032AI electrical characteristics at specified free-air temperature (continued)**

| PARAMETER                        | TEST CONDITIONS                             |                          | T <sub>A</sub> | TL032I, TL032AI         |     |     |                          |     |     | UNIT |
|----------------------------------|---|--------------------------|----------------|-------------------------|-----|-----|--------------------------|-----|-----|------|
|                                  |   |                          |                | V <sub>CC±</sub> = ±5 V |     |     | V <sub>CC±</sub> = ±15 V |     |     |      |
|                                  |   |                          |                | MIN                     | TYP | MAX | MIN                      | TYP | MAX |      |
| P <sub>D</sub>                   | Total power dissipation<br>(two amplifiers) | V <sub>O</sub> = 0,      | No load        | 25°C                    | 3.8 | 5   | 13                       | 17  | mW  |      |
|                                  |   |                          |                | -40°C                   | 2.9 | 5   | 10.9                     | 17  |     |      |
|                                  |   |                          |                | 85°C                    | 3.7 | 5   | 12.4                     | 17  |     |      |
| I <sub>CC</sub>                  | Supply current<br>(two amplifiers)          | V <sub>O</sub> = 0,      | No load        | 25°C                    | 384 | 500 | 434                      | 560 | μA  |      |
|                                  |   |                          |                | -40°C                   | 288 | 500 | 362                      | 560 |     |      |
|                                  |   |                          |                | 85°C                    | 372 | 500 | 414                      | 560 |     |      |
| V <sub>O1</sub> /V <sub>O2</sub> | Crosstalk attenuation                       | A <sub>VD</sub> = 100 dB |                | 25°C                    | 120 |     | 120                      | dB  |     |      |

**TL032I and TL032AI operating characteristics at specified free-air temperature**

| PARAMETER        | TEST CONDITIONS                   |  | T <sub>A</sub> | TL032I, TL032AI         |     |       |                          |        |      | UNIT |
|------------------|-----------------------------------|--|----------------|-------------------------|-----|-------|--------------------------|--------|------|------|
|                  |                                   |  |                | V <sub>CC±</sub> = ±5 V |     |       | V <sub>CC±</sub> = ±15 V |        |      |      |
|                  |                                   |  |                | MIN                     | TYP | MAX   | MIN                      | TYP    | MAX  |      |
| SR <sub>+</sub>  | Positive slew rate at unity gain† | R <sub>L</sub> = 10 kΩ, C <sub>L</sub> = 100 pF  | 25°C           |                         | 2   |       | 1.5                      | 2.9    | V/μs |      |
|                  |                                   |  | -40°C          |                         | 1.6 |       | 1                        | 2.1    |      |      |
|                  |                                   |  | 85°C           |                         | 2.3 |       | 1.5                      | 3.3    |      |      |
| SR <sub>-</sub>  | Negative slew rate at unity gain† | R <sub>L</sub> = 10 kΩ, C <sub>L</sub> = 100 pF  | 25°C           |                         | 3.9 |       | 1.5                      | 5.1    | V/μs |      |
|                  |                                   |  | -40°C          |                         | 3.3 |       | 1.5                      | 4.8    |      |      |
|                  |                                   |  | 85°C           |                         | 4.1 |       | 1.5                      | 4.9    |      |      |
| t <sub>r</sub>   | Rise time                         | V <sub>I(PP)</sub> = ±10 V,<br>R <sub>L</sub> = 10 kΩ, C <sub>L</sub> = 100 pF,<br>See Figures 1 and 2 | 25°C           |                         | 138 |       | 132                      | ns     |      |      |
|                  |                                   |  | -40°C          |                         | 132 |       | 123                      |        |      |      |
|                  |                                   |  | 85°C           |                         | 154 |       | 146                      |        |      |      |
| t <sub>f</sub>   | Fall time                         | V <sub>I(PP)</sub> = ±10 V,<br>R <sub>L</sub> = 10 kΩ, C <sub>L</sub> = 100 pF,<br>See Figure 1        | 25°C           |                         | 138 |       | 132                      | ns     |      |      |
|                  |                                   |  | -40°C          |                         | 132 |       | 123                      |        |      |      |
|                  |                                   |  | 85°C           |                         | 154 |       | 146                      |        |      |      |
| Overshoot factor |                                   | V <sub>I(PP)</sub> = ±10 V,<br>R <sub>L</sub> = 10 kΩ, C <sub>L</sub> = 100 pF,<br>See Figures 1 and 2 | 25°C           |                         | 11% |       | 5%                       |        |      |      |
|                  |                                   |  | -40°C          |                         | 12% |       | 5%                       |        |      |      |
|                  |                                   |  | 85°C           |                         | 13% |       | 7%                       |        |      |      |
| V <sub>n</sub>   | Equivalent input noise voltage    | TL032I   | f = 10 Hz      | 25°C                    | 49  |       | 49                       | nV/√Hz |      |      |
|                  |                                   |  | f = 1 kHz      | 25°C                    | 41  |       | 41                       |        |      |      |
|                  |                                   | TL032AI  | f = 10 Hz      | 25°C                    | 49  |       | 49                       |        |      |      |
|                  |                                   |  | f = 1 kHz      | 25°C                    | 41  |       | 41                       |        | 60   |      |
| I <sub>n</sub>   | Equivalent input noise current    | f = 1 kHz  | 25°C           | 0.003                   |     | 0.003 | pA/√Hz                   |        |      |      |
| B <sub>1</sub>   | Unity-gain bandwidth              | V <sub>I</sub> = 10 mV,<br>C <sub>L</sub> = 25 pF,<br>R <sub>L</sub> = 10 kΩ,<br>See Figure 4          | 25°C           |                         | 1   |       | 1.1                      | MHz    |      |      |
|                  |                                   |  | -40°C          |                         | 1   |       | 1.1                      |        |      |      |
|                  |                                   |  | 85°C           |                         | 0.9 |       | 1                        |        |      |      |
| φ <sub>m</sub>   | Phase margin at unity gain        | V <sub>I</sub> = 10 mV,<br>C <sub>L</sub> = 25 pF,<br>R <sub>L</sub> = 10 kΩ,<br>See Figure 4          | 25°C           |                         | 61° |       | 65°                      |        |      |      |
|                  |                                   |  | -40°C          |                         | 61° |       | 65°                      |        |      |      |
|                  |                                   |  | 85°C           |                         | 60° |       | 64°                      |        |      |      |

† For V<sub>CC±</sub> = ±5 V, V<sub>I(PP)</sub> = ±1 V; for V<sub>CC±</sub> = ±15 V, V<sub>I(PP)</sub> = ±5 V.



# TL03x, TL03xA, TL03xY ENHANCED-JFET LOW-POWER LOW-OFFSET OPERATIONAL AMPLIFIERS

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## TL032M and TL032AM electrical characteristics at specified free-air temperature

| PARAMETER  | TEST CONDITIONS  |                      | T <sub>A</sub> | TL032M, TL032AM         |             |     |                          |               |       | UNIT |
|--|--|----------------------|----------------|-------------------------|-------------|-----|--------------------------|---------------|-------|------|
|  |  |                      |                | V <sub>CC±</sub> = ±5 V |             |     | V <sub>CC±</sub> = ±15 V |               |       |      |
|  |  |                      |                | MIN                     | TYP         | MAX | MIN                      | TYP           | MAX   |      |
| V <sub>IO</sub> Input offset voltage   |  | TL032M               | 25°C           | 0.69                    | 3.5         |     | 0.57                     | 1.5           | mV    |      |
|  |  |                      | Full range†    |                         | 6.5         |     | 4.5                      |               |       |      |
|  |  | TL032AM              | 25°C           | 0.53                    | 2.8         |     | 0.39                     | 0.8           |       |      |
|  |  |                      | Full range†    |                         | 5.8         |     | 3.8                      |               |       |      |
| α <sub>VIO</sub> Temperature coefficient of input offset voltage                       | V <sub>O</sub> = 0,<br>V <sub>IC</sub> = 0,<br>R <sub>S</sub> = 50 Ω                 | TL032M               | 25°C to 125°C  | 9.7                     |             |     | 9.7                      |               | μV/°C |      |
|  |  | TL032AM              | 25°C to 125°C  | 9.7                     |             |     | 9.7                      |               |       |      |
| Input offset voltage long-term drift‡  |  |                      | 25°C           | 0.04                    |             |     | 0.04                     |               | μV/mo |      |
| I <sub>IO</sub> Input offset current   | V <sub>O</sub> = 0,<br>See Figure 5  | V <sub>IC</sub> = 0, | 25°C           | 1                       | 100         |     | 1                        | 100           | pA    |      |
|  |  |                      | 125°C          | 0.2                     | 10          |     | 0.2                      | 10            | nA    |      |
| I <sub>IB</sub> Input bias current   | V <sub>O</sub> = 0,<br>See Figure 5  | V <sub>IC</sub> = 0, | 25°C           | 2                       | 200         |     | 2                        | 200           | pA    |      |
|  |  |                      | 125°C          | 7                       | 20          |     | 8                        | 20            | nA    |      |
| V <sub>ICR</sub> Common-mode input voltage range                                       |  |                      | 25°C           | -1.5 to 4               | -3.4 to 5.4 |     | -11.5 to 14              | -13.4 to 15.4 | V     |      |
|  |  |                      | Full range†    | -1.5 to 4               |             |     | -11.5 to 14              |               |       |      |
| V <sub>OM+</sub> Maximum positive peak output voltage swing                            | R <sub>L</sub> = 10 kΩ   |                      | 25°C           | 3                       | 4.3         |     | 13                       | 14            | V     |      |
|  |  |                      | -55°C          | 3                       | 4.1         |     | 13                       | 14            |       |      |
|  |  |                      | 125°C          | 3                       | 4.4         |     | 13                       | 14            |       |      |
| V <sub>OM-</sub> Maximum negative peak output voltage swing                            | R <sub>L</sub> = 10 kΩ   |                      | 25°C           | -3                      | -4.2        |     | -12.5                    | -13.9         | V     |      |
|  |  |                      | -55°C          | -3                      | -4          |     | -12.5                    | -13.8         |       |      |
|  |  |                      | 125°C          | -3                      | -4.3        |     | -12.5                    | -14           |       |      |
| A <sub>VD</sub> Large-signal differential voltage amplification§                       | R <sub>L</sub> = 10 kΩ   |                      | 25°C           | 4                       | 12          |     | 5                        | 14.3          | V/mV  |      |
|  |  |                      | -55°C          | 3                       | 7.1         |     | 4                        | 10.4          |       |      |
|  |  |                      | 125°C          | 3                       | 12.9        |     | 4                        | 15            |       |      |
| r <sub>i</sub> Input resistance  |  |                      | 25°C           | 10 <sup>12</sup>        |             |     | 10 <sup>12</sup>         |               | Ω     |      |
| c <sub>i</sub> Input capacitance   |  |                      | 25°C           | 5                       |             |     | 4                        |               | pF    |      |
| CMRR Common-mode rejection ratio   | V <sub>IC</sub> = V <sub>ICRmin</sub> ,<br>V <sub>O</sub> = 0, R <sub>S</sub> = 50 Ω |                      | 25°C           | 70                      | 87          |     | 75                       | 94            | dB    |      |
|  |  |                      | -55°C          | 70                      | 87          |     | 70                       | 94            |       |      |
|  |  |                      | 125°C          | 70                      | 87          |     | 70                       | 94            |       |      |
| k <sub>SVR</sub> Supply-voltage rejection ratio (ΔV <sub>CC±</sub> /ΔV <sub>IO</sub> ) | V <sub>CC±</sub> = ±5 V to ±15 V,<br>V <sub>O</sub> = 0, R <sub>S</sub> = 50 Ω       |                      | 25°C           | 75                      | 96          |     | 75                       | 96            | dB    |      |
|  |  |                      | -55°C          | 75                      | 95          |     | 75                       | 95            |       |      |
|  |  |                      | 125°C          | 75                      | 96          |     | 75                       | 96            |       |      |

† Full range is -55°C to 125°C.

‡ Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T<sub>A</sub> = 150°C extrapolated to T<sub>A</sub> = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

§ At V<sub>CC±</sub> = ±5 V, V<sub>O</sub> = 2.3 V; at V<sub>CC±</sub> = ±15 V, V<sub>O</sub> = ±10 V.



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**TL032M and TL032AM electrical characteristics at specified free-air temperature (continued)**

| PARAMETER                        | TEST CONDITIONS                          | T <sub>A</sub>              | TL032M, TL032AM         |     |     |                          |     |     | UNIT |
|----------------------------------|--|-----------------------------|-------------------------|-----|-----|--------------------------|-----|-----|------|
|                                  |  |                             | V <sub>CC±</sub> = ±5 V |     |     | V <sub>CC±</sub> = ±15 V |     |     |      |
|                                  |  |                             | MIN                     | TYP | MAX | MIN                      | TYP | MAX |      |
| P <sub>D</sub>                   | Total power dissipation (two amplifiers) | V <sub>O</sub> = 0, No load | 25°C                    | 3.8 | 5   | 13                       | 17  | mW  |      |
|                                  |  |                             | -55°C                   | 2.3 | 5   | 9.4                      | 17  |     |      |
|                                  |  |                             | 125°C                   | 3.6 | 5   | 11.8                     | 17  |     |      |
| I <sub>CC</sub>                  | Supply current (two amplifiers)          | V <sub>O</sub> = 0, No load | 25°C                    | 384 | 500 | 434                      | 560 | μA  |      |
|                                  |  |                             | -55°C                   | 228 | 500 | 312                      | 560 |     |      |
|                                  |  |                             | 125°C                   | 356 | 500 | 394                      | 560 |     |      |
| V <sub>O1</sub> /V <sub>O2</sub> | Crosstalk attenuation                    | A <sub>VD</sub> = 100 dB    | 25°C                    | 120 |     | 120                      |     | dB  |      |

**TL032M and TL032AM operating characteristics at specified free-air temperature**

| PARAMETER        | TEST CONDITIONS                   | T <sub>A</sub>  | TL032M, TL032AM         |       |     |                          |        |        | UNIT |
|------------------|-----------------------------------|---|-------------------------|-------|-----|--------------------------|--------|--------|------|
|                  |                                   |   | V <sub>CC±</sub> = ±5 V |       |     | V <sub>CC±</sub> = ±15 V |        |        |      |
|                  |                                   |   | MIN                     | TYP   | MAX | MIN                      | TYP    | MAX    |      |
| SR <sub>+</sub>  | Positive slew rate at unity gain† | R <sub>L</sub> = 10 kΩ,<br>C <sub>L</sub> = 100 pF,<br>See and Figure 1                                   | 25°C                    | 2     |     | 1.5                      | 2.9    | V/μs   |      |
|                  |                                   |   | -55°C                   | 1.4   |     | 1                        | 1.9    |        |      |
|                  |                                   |   | 125°C                   | 2.4   |     | 1                        | 3.5    |        |      |
| SR <sub>-</sub>  | Negative slew rate at unity gain† | R <sub>L</sub> = 10 kΩ,<br>C <sub>L</sub> = 100 pF,<br>See and Figure 1                                   | 25°C                    | 3.9   |     | 1.5                      | 5.1    | V/μs   |      |
|                  |                                   |   | -55°C                   | 3.2   |     | 1                        | 4.6    |        |      |
|                  |                                   |   | 125°C                   | 4.1   |     | 1                        | 4.7    |        |      |
| t <sub>r</sub>   | Rise time                         | V <sub>I(PP)</sub> = ±10 V,<br>R <sub>L</sub> = 10 kΩ,<br>C <sub>L</sub> = 100 pF,<br>See Figures 1 and 2 | 25°C                    | 138   |     | 132                      | ns     |        |      |
|                  |                                   |   | -55°C                   | 142   |     | 123                      |        |        |      |
|                  |                                   |   | 125°C                   | 166   |     | 58                       |        |        |      |
| t <sub>f</sub>   | Fall time                         | V <sub>I(PP)</sub> = ±10 V,<br>R <sub>L</sub> = 10 kΩ,<br>C <sub>L</sub> = 100 pF,<br>See Figure 1        | 25°C                    | 138   |     | 132                      | ns     |        |      |
|                  |                                   |   | -55°C                   | 142   |     | 123                      |        |        |      |
|                  |                                   |   | 125°C                   | 166   |     | 158                      |        |        |      |
| Overshoot factor | Overshoot factor                  | V <sub>I(PP)</sub> = ±10 V,<br>R <sub>L</sub> = 10 kΩ,<br>C <sub>L</sub> = 100 pF,<br>See Figures 1 and 2 | 25°C                    | 11%   |     | 5%                       |        |        |      |
|                  |                                   |   | -55°C                   | 16%   |     | 6%                       |        |        |      |
|                  |                                   |   | 125°C                   | 14%   |     | 8%                       |        |        |      |
| V <sub>n</sub>   | Equivalent input noise voltage    | TL032M  | f = 10 Hz               | 25°C  | 49  |                          | 49     | nV/√Hz |      |
|                  |                                   |   | f = 1 kHz               | 25°C  | 41  |                          | 41     |        |      |
|                  |                                   | TL032AM   | f = 10 Hz               | 25°C  | 49  |                          | 49     |        |      |
|                  |                                   |   | f = 1 kHz               | 25°C  | 41  |                          | 41     |        |      |
| I <sub>n</sub>   | Equivalent input noise current    | f = 1 kHz   | 25°C                    | 0.003 |     | 0.003                    | pA/√Hz |        |      |
| B <sub>1</sub>   | Unity-gain bandwidth              | V <sub>I</sub> = 10 mV,<br>C <sub>L</sub> = 25 pF,<br>R <sub>L</sub> = 10 kΩ,<br>See Figure 4             | 25°C                    | 1     |     | 1.1                      | MHz    |        |      |
|                  |                                   |   | -55°C                   | 1     |     | 1.1                      |        |        |      |
|                  |                                   |   | 125°C                   | 0.9   |     | 0.9                      |        |        |      |
| φ <sub>m</sub>   | Phase margin at unity gain        | V <sub>I</sub> = 10 mV,<br>C <sub>L</sub> = 25 pF,<br>R <sub>L</sub> = 10 kΩ,<br>See Figure 4             | 25°C                    | 61°   |     | 65°                      |        |        |      |
|                  |                                   |   | -55°C                   | 57°   |     | 64°                      |        |        |      |
|                  |                                   |   | 125°C                   | 59°   |     | 62°                      |        |        |      |

† For V<sub>CC±</sub> = ±5 V, V<sub>I(PP)</sub> = ±1 V; for V<sub>CC±</sub> = ±15 V, V<sub>I(PP)</sub> = ±5 V.



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## TL032Y electrical characteristics, $T_A = 25^\circ\text{C}$

| PARAMETER   | TEST CONDITIONS  | TL032Y                       |                   |     |                               |                     |     | UNIT |                              |
|---|--|------------------------------|-------------------|-----|-------------------------------|---------------------|-----|------|------------------------------|
|   |  | $V_{CC\pm} = \pm 5\text{ V}$ |                   |     | $V_{CC\pm} = \pm 15\text{ V}$ |                     |     |      |                              |
|   |  | MIN                          | TYP               | MAX | MIN                           | TYP                 | MAX |      |                              |
| $V_{IO}$ Input offset voltage   | $V_O = 0,$<br>$R_S = 50\ \Omega$   | $V_{IC} = 0,$                | 0.69              |     |                               | 0.57                |     |      | mV                           |
| $\alpha V_{IO}$ Temperature coefficient of input offset voltage               |  |                              | 11.5              |     |                               | 10.8                |     |      | $\mu\text{V}/^\circ\text{C}$ |
| $I_{IO}$ Input offset current   | $V_O = 0,$<br>See Figure 5   | $V_{IC} = 0,$                | 1                 |     |                               | 1                   |     |      | pA                           |
| $I_{IB}$ Input bias current   | $V_O = 0,$<br>See Figure 5   | $V_{IC} = 0,$                | 2                 |     |                               | 2                   |     |      | pA                           |
| $V_{ICR}$ Common-mode input voltage range                                     |  |                              | -3.4<br>to<br>5.4 |     |                               | -13.4<br>to<br>15.4 |     |      | V                            |
| $V_{OM+}$ Maximum positive peak output voltage swing                          | $R_L = 10\ \text{k}\Omega$   |                              | 4.3               |     |                               | 14                  |     |      | V                            |
| $V_{OM-}$ Maximum negative peak output voltage swing                          | $R_L = 10\ \text{k}\Omega$   |                              | -4.2              |     |                               | -13.9               |     |      | V                            |
| $A_{VD}$ Large-signal differential voltage amplification†                     | $R_L = 10\ \text{k}\Omega$   |                              | 12                |     |                               | 14.3                |     |      | V/mV                         |
| $r_i$ Input resistance  |  |                              | $10^{12}$         |     |                               | $10^{12}$           |     |      | $\Omega$                     |
| $c_i$ Input capacitance   |  |                              | 5                 |     |                               | 14                  |     |      | pF                           |
| CMRR Common-mode rejection ratio  | $V_{IC} = V_{ICRmin},$<br>$V_O = 0, R_S = 50\ \Omega$                            |                              | 87                |     |                               | 94                  |     |      | dB                           |
| $k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{CC\pm}/\Delta V_{IO}$ ) | $V_{CC\pm} = \pm 5\text{ V to } \pm 15\text{ V},$<br>$V_O = 0, R_S = 50\ \Omega$ |                              | 96                |     |                               | 96                  |     |      | dB                           |
| $P_D$ Total power dissipation (two amplifiers)                                | $V_O = 0,$   | No load                      | 3.8               |     |                               | 13                  |     |      | mW                           |
| $V_{O1}/V_{O2}$ Crosstalk attenuation   | $A_{VD} = 100\ \text{dB}$  |                              | 120               |     |                               | 120                 |     |      | dB                           |

† At  $V_{CC\pm} = \pm 5\text{ V}, V_O = 2.3\text{ V};$  at  $V_{CC\pm} = \pm 15\text{ V}, V_O = \pm 10\text{ V}.$

## TL032Y operating characteristics, $T_A = 25^\circ\text{C}$

| PARAMETER                               | TEST CONDITIONS   | TL032Y                       |     |     |                               |     |     | UNIT                         |
|---|---|------------------------------|-----|-----|-------------------------------|-----|-----|------------------------------|
|   |   | $V_{CC\pm} = \pm 5\text{ V}$ |     |     | $V_{CC\pm} = \pm 15\text{ V}$ |     |     |                              |
|   |   | MIN                          | TYP | MAX | MIN                           | TYP | MAX |                              |
| $SR+$ Positive slew rate at unity gain† | $R_L = 10\ \text{k}\Omega,$ $C_L = 100\ \text{pF},$                                       | 12                           |     |     | 2.9                           |     |     | V/ $\mu\text{s}$             |
| $SR-$ Negative slew rate at unity gain† | See Figure 1 and Note 8   | 3.9                          |     |     | 5.1                           |     |     | V/ $\mu\text{s}$             |
| $t_r$ Rise time                         | $V_{I(pp)} = \pm 10\text{ V},$  | 138                          |     |     | 132                           |     |     | ns                           |
| $t_f$ Fall time                         | $R_L = 10\ \text{k}\Omega,$ $C_L = 100\ \text{pF},$                                       | 138                          |     |     | 132                           |     |     | ns                           |
| Overshoot factor                        | See Figures 1 and 2   | 11%                          |     |     | 5%                            |     |     |                              |
| $V_n$ Equivalent input noise voltage    | $R_S = 20\ \Omega,$ $f = 10\ \text{Hz}$<br>See Figure 3 $f = 1\ \text{kHz}$               | 49                           |     |     | 49                            |     |     | $\text{nV}/\sqrt{\text{Hz}}$ |
| $I_n$ Equivalent input noise current    | $f = 1\ \text{kHz}$   | 0.003                        |     |     | 0.003                         |     |     | $\text{pA}/\sqrt{\text{Hz}}$ |
| $B_1$ Unity-gain bandwidth              | $V_I = 10\ \text{mV},$ $R_L = 10\ \text{k}\Omega,$<br>$C_L = 25\ \text{pF},$ See Figure 4 | 1                            |     |     | 1.1                           |     |     | MHz                          |
| $\phi_m$ Phase margin at unity gain     | $V_I = 10\ \text{mV},$ $R_L = 10\ \text{k}\Omega,$<br>$C_L = 25\ \text{pF},$ See Figure 4 | 61°                          |     |     | 65°                           |     |     |                              |

† For  $V_{CC\pm} = \pm 5\text{ V}, V_{I(pp)} = \pm 1\text{ V};$  for  $V_{CC\pm} = \pm 15\text{ V}, V_{I(pp)} = \pm 5\text{ V}.$



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**TL034C and TL034AC electrical characteristics at specified free-air temperature**

| PARAMETER  | TEST CONDITIONS   | T <sub>A</sub> | TL034C, TL034AC         |                  |             |                          |             |               | UNIT |
|--|---|----------------|-------------------------|------------------|-------------|--------------------------|-------------|---------------|------|
|  |   |                | V <sub>CC±</sub> = ±5 V |                  |             | V <sub>CC±</sub> = ±15 V |             |               |      |
|  |   |                | MIN                     | TYP              | MAX         | MIN                      | TYP         | MAX           |      |
| V <sub>IO</sub> Input offset voltage   | V <sub>O</sub> = 0,<br>V <sub>IC</sub> = 0,<br>R <sub>S</sub> = 50 Ω                    | TL034C         | 25°C                    | 0.91             | 6           |                          | 0.79        | 4             | mV   |
|  |   |                | Full range†             |                  |             |                          | 8.2         | 6.2           |      |
|  |   | TL034AC        | 25°C                    | 0.7              | 3.5         |                          | 0.58        | 1.5           |      |
|  |   |                | Full range†             |                  |             |                          | 5.7         | 3.7           |      |
| α <sub>VIO</sub> Temperature coefficient of input offset voltage                       |   | TL034C         | 25°C to 70°C            | 11.6             |             | 12                       |             | μV/°C         |      |
|  |   | TL034AC        | 25°C to 70°C            | 11.6             |             | 12                       | 25          |               |      |
| Input offset voltage long-term drift‡  |   |                | 25°C                    | 0.04             |             | 0.04                     |             | μV/mo         |      |
| I <sub>IO</sub> Input offset current   | V <sub>O</sub> = 0, V <sub>IC</sub> = 0,<br>See Figure 5                                |                | 25°C                    | 1                | 100         |                          | 1           | 100           | pA   |
|  |   |                | 70°C                    | 9                | 200         |                          | 12          | 200           |      |
| I <sub>IB</sub> Input bias current   | V <sub>O</sub> = 0, V <sub>IC</sub> = 0,<br>See Figure 5                                |                | 25°C                    | 2                | 200         |                          | 2           | 200           | pA   |
|  |   |                | 70°C                    | 50               | 400         |                          | 80          | 400           |      |
| V <sub>ICR</sub> Common-mode input voltage range                                       |   |                | 25°C                    | -1.5 to 4        | -3.4 to 5.4 |                          | -11.5 to 14 | -13.4 to 15.4 | V    |
|  |   |                | Full range†             | -1.5 to 4        |             |                          | -11.5 to 14 |               |      |
| V <sub>OM+</sub> Maximum positive peak output voltage swing                            | R <sub>L</sub> = 10 kΩ  |                | 25°C                    | 3                | 4.3         |                          | 13          | 14            | V    |
|  |   |                | 0°C                     | 3                | 4.2         |                          | 13          | 14            |      |
|  |   |                | 70°C                    | 3                | 4.3         |                          | 13          | 14            |      |
| V <sub>OM-</sub> Maximum negative peak output voltage swing                            | R <sub>L</sub> = 10 kΩ  |                | 25°C                    | -3               | -4.2        |                          | -12.5       | -13.9         | V    |
|  |   |                | 0°C                     | -3               | -4.1        |                          | -12.5       | -13.9         |      |
|  |   |                | 70°C                    | -3               | -4.2        |                          | -12.5       | -14           |      |
| A <sub>VD</sub> Large-signal differential voltage amplification§                       | R <sub>L</sub> = 10 kΩ  |                | 25°C                    | 4                | 12          |                          | 5           | 14.3          | V/mV |
|  |   |                | 0°C                     | 3                | 11.1        |                          | 4           | 13.5          |      |
|  |   |                | 70°C                    | 4                | 13.3        |                          | 5           | 15.2          |      |
| r <sub>i</sub> Input resistance  |   |                | 25°C                    | 10 <sup>12</sup> |             | 10 <sup>12</sup>         |             | Ω             |      |
| c <sub>i</sub> Input capacitance   |   |                | 25°C                    | 5                |             | 14                       |             | pF            |      |
| CMRR    Common-mode rejection ratio  | V <sub>IC</sub> = V <sub>ICRmin</sub> ,<br>V <sub>O</sub> = 0,<br>R <sub>S</sub> = 50 Ω |                | 25°C                    | 70               | 87          |                          | 75          | 94            | dB   |
|  |   |                | 0°C                     | 70               | 87          |                          | 75          | 94            |      |
|  |   |                | 70°C                    | 70               | 87          |                          | 75          | 94            |      |
| k <sub>SVR</sub> Supply-voltage rejection ratio (ΔV <sub>CC±</sub> /ΔV <sub>IO</sub> ) | V <sub>O</sub> = 0, R <sub>S</sub> = 50 Ω   |                | 25°C                    | 75               | 96          |                          | 75          | 96            | dB   |
|  |   |                | 0°C                     | 75               | 96          |                          | 75          | 96            |      |
|  |   |                | 70°C                    | 75               | 96          |                          | 75          | 96            |      |

† Full range is 0°C to 70°C.

‡ Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T<sub>A</sub> = 150°C extrapolated to T<sub>A</sub> = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

§ At V<sub>CC±</sub> = ±5 V, V<sub>O</sub> = ±2.3 V; at V<sub>CC±</sub> = ±15 V, V<sub>O</sub> = ±10 V.



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## TL034C and TL034AC electrical characteristics at specified free-air temperature (continued)

| PARAMETER   | TEST CONDITIONS             | T <sub>A</sub> | TL034C, TL034AC         |     |     |                          |      |     | UNIT |
|---|-----------------------------|----------------|-------------------------|-----|-----|--------------------------|------|-----|------|
|   |                             |                | V <sub>CC±</sub> = ±5 V |     |     | V <sub>CC±</sub> = ±15 V |      |     |      |
|   |                             |                | MIN                     | TYP | MAX | MIN                      | TYP  | MAX |      |
| P <sub>D</sub> Total power dissipation (two amplifiers) | V <sub>O</sub> = 0, No load | 25°C           | 7.7                     | 10  |     | 26                       | 34   | mW  |      |
|   |                             | 0°C            | 7.4                     | 10  |     | 25.3                     | 34   |     |      |
|   |                             | 70°C           | 7.6                     | 10  |     | 25.2                     | 34   |     |      |
| I <sub>CC</sub> Supply current (four amplifiers)        | V <sub>O</sub> = 0, No load | 25°C           | 0.77                    | 1   |     | 0.87                     | 1.12 | mA  |      |
|   |                             | 0°C            | 0.74                    | 1   |     | 0.85                     | 1.12 |     |      |
|   |                             | 70°C           | 0.76                    | 1   |     | 0.84                     | 1.12 |     |      |
| V <sub>O1</sub> /V <sub>O2</sub> Crosstalk attenuation  | A <sub>VD</sub> = 100       | 25°C           | 120                     |     |     | 120                      |      |     | dB   |

## TL034C and TL034AC operating characteristics at specified free-air temperature

| PARAMETER   | TEST CONDITIONS  | T <sub>A</sub>                         | TL034C, TL034AC         |     |     |                          |     |     | UNIT   |        |
|---|--|--|-------------------------|-----|-----|--------------------------|-----|-----|--------|--------|
|   |  |  | V <sub>CC±</sub> = ±5 V |     |     | V <sub>CC±</sub> = ±15 V |     |     |        |        |
|   |  |  | MIN                     | TYP | MAX | MIN                      | TYP | MAX |        |        |
| SR <sub>+</sub> Positive slew rate at unity gain† | R <sub>L</sub> = 10 kΩ,<br>C <sub>L</sub> = 100 pF,<br>See Figure 1  | 25°C                                   | 2                       |     |     | 1.5 2.9                  |     |     | V/μs   |        |
|   |  | 0°C                                    | 1.8                     |     |     | 1 2.6                    |     |     |        |        |
|   |  | 70°C                                   | 2.2                     |     |     | 1.5 3.2                  |     |     |        |        |
| SR <sub>-</sub> Negative slew rate at unity gain† |  | 25°C                                   | 3.9                     |     |     | 1.5 5.1                  |     |     | V/μs   |        |
|   |  | 0°C                                    | 3.7                     |     |     | 1.5 5                    |     |     |        |        |
|   |  | 70°C                                   | 4                       |     |     | 1.5 5                    |     |     |        |        |
| t <sub>r</sub> Rise time                          | V <sub>I</sub> (PP) = ±10 V,<br>R <sub>L</sub> = 10 kΩ,<br>C <sub>L</sub> = 100 pF,<br>See Figures 1 and 2 | 25°C                                   | 138                     |     |     | 132                      |     |     | ns     |        |
|   |  | 0°C                                    | 134                     |     |     | 127                      |     |     |        |        |
|   |  | 70°C                                   | 150                     |     |     | 142                      |     |     |        |        |
| t <sub>f</sub> Fall time                          | V <sub>I</sub> (PP) = ±10 V,<br>R <sub>L</sub> = 10 kΩ,<br>C <sub>L</sub> = 100 pF,<br>See Figure 1        | 25°C                                   | 138                     |     |     | 132                      |     |     | ns     |        |
|   |  | 0°C                                    | 134                     |     |     | 127                      |     |     |        |        |
|   |  | 70°C                                   | 150                     |     |     | 142                      |     |     |        |        |
| Overshoot factor                                  | V <sub>I</sub> (PP) = ±10 V,<br>R <sub>L</sub> = 10 kΩ,<br>C <sub>L</sub> = 100 pF,<br>See Figures 1 and 2 | 25°C                                   | 11%                     |     |     | 5%                       |     |     |        |        |
|   |  | 0°C                                    | 10%                     |     |     | 4%                       |     |     |        |        |
|   |  | 70°C                                   | 12%                     |     |     | 6%                       |     |     |        |        |
| V <sub>n</sub> Equivalent input noise voltage     | TL034C   | R <sub>S</sub> = 20 Ω,<br>See Figure 3 | f = 10 Hz               | 83  |     |                          | 83  |     |        | nV/√Hz |
|   |  |  | f = 1 kHz               | 43  |     |                          | 43  |     |        |        |
|   | TL034AC  | f = 10 Hz                              | 83                      |     |     | 83                       |     |     |        |        |
|   |  | f = 1 kHz                              | 43                      |     |     | 43 60                    |     |     |        |        |
| I <sub>n</sub> Equivalent input noise current     | f = 1 kHz  | 25°C                                   | 0.003                   |     |     | 0.003                    |     |     | pA/√Hz |        |
| B <sub>1</sub> Unity-gain bandwidth               | V <sub>I</sub> = 10 mV, R <sub>L</sub> = 10 kΩ,<br>C <sub>L</sub> = 25 pF, See Figure 4                    | 25°C                                   | 1                       |     |     | 1.1                      |     |     | MHz    |        |
|   |  | 0°C                                    | 1                       |     |     | 1.1                      |     |     |        |        |
|   |  | 70°C                                   | 1                       |     |     | 1                        |     |     |        |        |
| φ <sub>m</sub> Phase margin at unity gain         | V <sub>I</sub> = 10 mV, R <sub>L</sub> = 10 kΩ,<br>C <sub>L</sub> = 25 pF, See Figure 4                    | 25°C                                   | 61°                     |     |     | 65°                      |     |     |        |        |
|   |  | 0°C                                    | 61°                     |     |     | 65°                      |     |     |        |        |
|   |  | 70°C                                   | 60°                     |     |     | 64°                      |     |     |        |        |

† For V<sub>CC±</sub> = ±5 V, V<sub>I</sub>(PP) = ±1 V; for V<sub>CC±</sub> = ±15 V, V<sub>I</sub>(PP) = ±5 V.





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**TL034I and TL034AI electrical characteristics at specified free-air temperature**

| PARAMETER  | TEST CONDITIONS   | T <sub>A</sub> | TL034I, TL034AI         |             |                  |                          |       |       | UNIT |
|--|---|----------------|-------------------------|-------------|------------------|--------------------------|-------|-------|------|
|  |   |                | V <sub>CC±</sub> = ±5 V |             |                  | V <sub>CC±</sub> = ±15 V |       |       |      |
|  |   |                | MIN                     | TYP         | MAX              | MIN                      | TYP   | MAX   |      |
| V <sub>IO</sub> Input offset voltage   | V <sub>O</sub> = 0,<br>V <sub>IC</sub> = 0,<br>R <sub>S</sub> = 50 Ω                    | TL034I         | 25°C                    | 0.91        | 3.6              | 0.79                     | 4     | mV    |      |
|  |   |                | Full range†             | 9.3         |                  | 7.3                      |       |       |      |
|  |   | TL034AI        | 25°C                    | 0.7         | 3.5              | 0.58                     | 1.5   |       |      |
|  |   |                | Full range†             | 6.8         |                  | 4.8                      |       |       |      |
| α <sub>VIO</sub> Temperature coefficient of input offset voltage                       |   | TL034I         | 25°C to 85°C            | 11.5        |                  | 11.6                     |       | μV/°C |      |
|  |   | TL034AI        | 25°C to 85°C            | 11.5        |                  | 11.6 25                  |       |       |      |
| Input offset voltage long-term drift‡  |   | 25°C           | 0.04                    |             | 0.04             |                          | μV/mo |       |      |
| I <sub>IO</sub> Input offset current   | V <sub>O</sub> = 0, V <sub>IC</sub> = 0,<br>See Figure 5                                | 25°C           | 1                       | 100         | 1                | 100                      | pA    |       |      |
|  |   | 85°C           | 0.02                    | 0.45        | 0.02             | 0.45                     | nA    |       |      |
| I <sub>IB</sub> Input bias current   | V <sub>O</sub> = 0, V <sub>IC</sub> = 0,<br>See Figure 5                                | 25°C           | 2                       | 200         | 2                | 200                      | pA    |       |      |
|  |   | 85°C           | 0.2                     | 0.9         | 0.3              | 0.9                      | nA    |       |      |
| V <sub>ICR</sub> Common-mode input voltage range                                       |   | 25°C           | -1.5 to 4               | -3.4 to 5.4 | -11.5 to 14      | -13.4 to 15.4            | V     |       |      |
|  |   | Full range†    | -1.5 to 4               |             | -11.5 to 14      |                          |       |       |      |
| V <sub>OM+</sub> Maximum positive peak output voltage swing                            | R <sub>L</sub> = 10 kΩ  | 25°C           | 3                       | 4.3         | 13               | 14                       | V     |       |      |
|  |   | -40°C          | 3                       | 4.1         | 13               | 14                       |       |       |      |
|  |   | 85°C           | 3                       | 4.4         | 13               | 14                       |       |       |      |
| V <sub>OM-</sub> Maximum negative peak output voltage swing                            | R <sub>L</sub> = 10 kΩ  | 25°C           | -3                      | -4.2        | -12.5            | -13.9                    | V     |       |      |
|  |   | -40°C          | -3                      | -4.1        | -12.5            | -13.8                    |       |       |      |
|  |   | 85°C           | -3                      | -4.2        | -12.5            | -14                      |       |       |      |
| A <sub>VD</sub> Large-signal differential voltage amplification§                       | R <sub>L</sub> = 10 kΩ  | -40°C          | 4                       | 12          | 5                | 14.3                     | V/mV  |       |      |
|  |   | 85°C           | 3                       | 8.4         | 4                | 11.6                     |       |       |      |
| r <sub>i</sub> Input resistance  |   | 25°C           | 10 <sup>12</sup>        |             | 10 <sup>12</sup> |                          | Ω     |       |      |
| c <sub>i</sub> Input capacitance   |   | 25°C           | 5                       |             | 4                |                          | pF    |       |      |
| CMRR Common-mode rejection ratio   | V <sub>IC</sub> = V <sub>ICRmin</sub> ,<br>V <sub>O</sub> = 0,<br>R <sub>S</sub> = 50 Ω | 25°C           | 70                      | 87          | 75               | 94                       | dB    |       |      |
|  |   | -40°C          | 70                      | 87          | 75               | 94                       |       |       |      |
|  |   | 85°C           | 70                      | 87          | 75               | 94                       |       |       |      |
| k <sub>SVR</sub> Supply-voltage rejection ratio (ΔV <sub>CC±</sub> /ΔV <sub>IO</sub> ) | V <sub>O</sub> = 0, R <sub>S</sub> = 50 Ω   | 25°C           | 75                      | 96          | 75               | 96                       | dB    |       |      |
|  |   | -40°C          | 75                      | 96          | 75               | 96                       |       |       |      |
|  |   | 85°C           | 75                      | 96          | 75               | 96                       |       |       |      |

† Full range is -40°C to 85°C.

‡ Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T<sub>A</sub> = 150°C extrapolated to T<sub>A</sub> = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

§ At V<sub>CC±</sub> = ±5 V, V<sub>O</sub> = ±2.3 V; at V<sub>CC±</sub> = ±15 V, V<sub>O</sub> = ±10 V.



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## TL034I and TL034AI electrical characteristics at specified free-air temperature (continued)

| PARAMETER                        | TEST CONDITIONS                              | T <sub>A</sub>              | TL034I, TL034AI         |      |     |                          |      |      | UNIT |
|----------------------------------|--|-----------------------------|-------------------------|------|-----|--------------------------|------|------|------|
|                                  |  |                             | V <sub>CC±</sub> = ±5 V |      |     | V <sub>CC±</sub> = ±15 V |      |      |      |
|                                  |  |                             | MIN                     | TYP  | MAX | MIN                      | TYP  | MAX  |      |
| P <sub>D</sub>                   | Total power dissipation<br>(four amplifiers) | V <sub>O</sub> = 0, No load | 25°C                    | 7.7  | 10  |                          | 26   | 34   | mW   |
|                                  |  |                             | -40°C                   | 5.8  | 10  |                          | 21.7 | 34   |      |
|                                  |  |                             | 85°C                    | 7.4  | 10  |                          | 24.8 | 34   |      |
| I <sub>CC</sub>                  | Supply current (four amplifiers)             | V <sub>O</sub> = 0, No load | 25°C                    | 0.77 | 1   |                          | 0.87 | 1.12 | mA   |
|                                  |  |                             | -40°C                   | 0.58 | 1   |                          | 0.72 | 1.12 |      |
|                                  |  |                             | 85°C                    | 0.74 | 1   |                          | 0.83 | 1.12 |      |
| V <sub>O1</sub> /V <sub>O2</sub> | Crosstalk attenuation                        | A <sub>V</sub> D = 100      | 25°C                    | 120  |     |                          | 120  | dB   |      |

## TL034I and TL034AI operating characteristics

| PARAMETER        | TEST CONDITIONS                   | T <sub>A</sub>   | TL034I, TL034AI         |           |      |                          |        |     | UNIT   |
|------------------|-----------------------------------|--|-------------------------|-----------|------|--------------------------|--------|-----|--------|
|                  |                                   |  | V <sub>CC±</sub> = ±5 V |           |      | V <sub>CC±</sub> = ±15 V |        |     |        |
|                  |                                   |  | MIN                     | TYP       | MAX  | MIN                      | TYP    | MAX |        |
| SR <sub>+</sub>  | Positive slew rate at unity gain† | R <sub>L</sub> = 10 kΩ, C <sub>L</sub> = 100 pF,<br>See Figure 1   | 25°C                    |           | 2    |                          | 1.5    | 2.9 | V/μs   |
|                  |                                   |  | -40°C                   |           | 1.6  |                          | 1      | 2.1 |        |
|                  |                                   |  | 85°C                    |           | 2.3  |                          | 1.5    | 3.3 |        |
| SR <sub>-</sub>  | Negative slew rate at unity gain† | R <sub>L</sub> = 10 kΩ, C <sub>L</sub> = 100 pF,<br>See Figure 1   | 25°C                    |           | 3.9  |                          | 1.5    | 5.1 | V/μs   |
|                  |                                   |  | -40°C                   |           | 3.3  |                          | 1.5    | 4.8 |        |
|                  |                                   |  | 85°C                    |           | 4.1  |                          | 1.5    | 4.9 |        |
| t <sub>r</sub>   | Rise time                         | V <sub>I</sub> (PP) = ±10 V,<br>R <sub>L</sub> = 10 kΩ,<br>C <sub>L</sub> = 100 pF,<br>See Figures 1 and 2 | 25°C                    |           | 138  |                          | 132    | ns  |        |
|                  |                                   |  | -40°C                   |           | 132  |                          | 123    |     |        |
|                  |                                   |  | 85°C                    |           | 154  |                          | 146    |     |        |
| t <sub>f</sub>   | Fall time                         | V <sub>I</sub> (PP) = ±10 V,<br>R <sub>L</sub> = 10 kΩ,<br>C <sub>L</sub> = 100 pF,<br>See Figures 1 and 2 | 25°C                    |           | 138  |                          | 132    | ns  |        |
|                  |                                   |  | -40°C                   |           | 132  |                          | 123    |     |        |
|                  |                                   |  | 85°C                    |           | 154  |                          | 146    |     |        |
| Overshoot factor |                                   | V <sub>I</sub> (PP) = ±10 V,<br>R <sub>L</sub> = 10 kΩ,<br>C <sub>L</sub> = 100 pF,<br>See Figures 1 and 2 | 25°C                    |           | 11%  |                          | 5%     |     |        |
|                  |                                   |  | -40°C                   |           | 12%  |                          | 5%     |     |        |
|                  |                                   |  | 85°C                    |           | 13%  |                          | 7%     |     |        |
| V <sub>n</sub>   | Equivalent input noise voltage    | R <sub>S</sub> = 20 Ω,<br>See Figure 3   | TL034I                  | f = 10 Hz | 25°C | 83                       |        | 83  | nV/√Hz |
|                  |                                   |  |                         | f = 1 kHz | 25°C | 43                       |        | 43  |        |
|                  |                                   |  | TL034AI                 | f = 10 Hz | 25°C | 83                       |        | 83  |        |
|                  |                                   |  |                         | f = 1 kHz | 25°C | 43                       |        | 43  |        |
| I <sub>n</sub>   | Equivalent input noise current    | f = 1 kHz  | 25°C                    | 0.003     |      | 0.003                    | pA/√Hz |     |        |
| B <sub>1</sub>   | Unity-gain bandwidth              | V <sub>I</sub> = 10 mV,<br>C <sub>L</sub> = 25 pF,<br>R <sub>L</sub> = 10 kΩ,<br>See Figure 4              | 25°C                    |           | 1    |                          | 1.1    | MHz |        |
|                  |                                   |  | -40°C                   |           | 1    |                          | 1.1    |     |        |
|                  |                                   |  | 85°C                    |           | 0.9  |                          | 1      |     |        |
| φ <sub>m</sub>   | Phase margin at unity gain        | V <sub>I</sub> = 10 mV,<br>C <sub>L</sub> = 25 pF,<br>R <sub>L</sub> = 10 kΩ,<br>See Figure 4              | 25°C                    |           | 61°  |                          | 65°    |     |        |
|                  |                                   |  | -40°C                   |           | 61°  |                          | 65°    |     |        |
|                  |                                   |  | 85°C                    |           | 60°  |                          | 64°    |     |        |

† For V<sub>CC±</sub> = ±5 V, V<sub>I</sub>(PP) = ±1 V; for V<sub>CC±</sub> = ±15 V, V<sub>I</sub>(PP) = ±5 V.



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**TL034M and TL034AM electrical characteristics at specified free-air temperature**

| PARAMETER  | TEST CONDITIONS  | T <sub>A</sub> | TL034M, TL034AM         |                  |             |                          |      |       | UNIT |
|--|--|----------------|-------------------------|------------------|-------------|--------------------------|------|-------|------|
|  |  |                | V <sub>CC±</sub> = ±5 V |                  |             | V <sub>CC±</sub> = ±15 V |      |       |      |
|  |  |                | MIN                     | TYP              | MAX         | MIN                      | TYP  | MAX   |      |
| V <sub>IO</sub> Input offset voltage   | V <sub>O</sub> = 0,<br>V <sub>IC</sub> = 0,<br>R <sub>S</sub> = 50 Ω                 | TL034M         | 25°C                    | 0.91             | 3.6         | 0.78                     | 4    | mV    |      |
|  |  |                | Full range†             |                  | 11          |                          | 9    |       |      |
|  |  | TL034AM        | 25°C                    | 0.7              | 3.5         | 0.58                     | 1.5  |       |      |
|  |  |                | Full range†             |                  | 8.5         |                          | 6.5  |       |      |
| α <sub>VIO</sub> Temperature coefficient of input offset voltage                       |  | TL034M         | 25°C to 125°C           | 10.6             |             | 10.9                     |      | μV/°C |      |
|  |  | TL034AM        | 25°C to 125°C           | 10.6             |             | 10.9                     |      |       |      |
| Input offset voltage long-term drift‡  |  | 25°C           |                         | 0.04             |             | 0.04                     |      | μV/mo |      |
| I <sub>IO</sub> Input offset current   | V <sub>O</sub> = 0, V <sub>IC</sub> = 0,<br>See Figure 5                             | 25°C           |                         | 1                | 100         | 1                        | 100  | pA    |      |
|  |  | 125°C          |                         | 0.2              | 10          | 0.2                      | 10   | nA    |      |
| I <sub>IB</sub> Input bias current   | V <sub>O</sub> = 0, V <sub>IC</sub> = 0,<br>See Figure 5                             | 25°C           |                         | 2                | 200         | 2                        | 200  | pA    |      |
|  |  | 125°C          |                         | 7                | 20          | 8                        | 20   | nA    |      |
| V <sub>ICR</sub> Common-mode input voltage range                                       |  | 25°C           | -1.5 to 4               | -3.4 to 5.4      | -11.5 to 14 | -13.4 to 15.4            |      | V     |      |
|  |  | Full range†    | -1.5 to 4               |                  | -11.5 to 14 |                          |      |       |      |
| V <sub>OM+</sub> Maximum positive peak output voltage swing                            | R <sub>L</sub> = 10 kΩ   | 25°C           | 3                       | 4.3              | 13          | 14                       | V    |       |      |
|  |  | -55°C          | 3                       | 4.1              | 13          | 14                       |      |       |      |
|  |  | 125°C          | 3                       | 4.4              | 13          | 14                       |      |       |      |
| V <sub>OM-</sub> Maximum negative peak output voltage swing                            | R <sub>L</sub> = 10 kΩ   | 25°C           | -3                      | -4.2             | -12.5       | -13.9                    | V    |       |      |
|  |  | -55°C          | -3                      | -4               | -12.5       | -13.8                    |      |       |      |
|  |  | 125°C          | -3                      | -4.3             | -12.5       | -14                      |      |       |      |
| A <sub>VD</sub> Large-signal differential voltage amplification§                       | R <sub>L</sub> = 10 kΩ   | 25°C           | 4                       | 12               | 5           | 14.3                     | V/mV |       |      |
|  |  | -55°C          | 3                       | 7.1              | 4           | 10.4                     |      |       |      |
|  |  | 125°C          | 3                       | 12.9             | 4           | 15                       |      |       |      |
| r <sub>i</sub> Input resistance  |  | 25°C           |                         | 10 <sup>12</sup> |             | 10 <sup>12</sup>         | Ω    |       |      |
| c <sub>i</sub> Input capacitance   |  | 25°C           |                         | 5                |             | 4                        | pF   |       |      |
| CMRR Common-mode rejection ratio   | V <sub>IC</sub> = V <sub>ICRmin</sub> ,<br>V <sub>O</sub> = 0, R <sub>S</sub> = 50 Ω | 25°C           | 70                      | 87               | 75          | 94                       | dB   |       |      |
|  |  | -55°C          | 70                      | 87               | 70          | 94                       |      |       |      |
|  |  | 125°C          | 70                      | 87               | 70          | 94                       |      |       |      |
| k <sub>SVR</sub> Supply-voltage rejection ratio (ΔV <sub>CC±</sub> /ΔV <sub>IO</sub> ) | V <sub>O</sub> = 0, R <sub>S</sub> = 50 Ω  | 25°C           | 75                      | 96               | 75          | 96                       | dB   |       |      |
|  |  | -55°C          | 75                      | 95               | 75          | 95                       |      |       |      |
|  |  | 125°C          | 75                      | 96               | 75          | 96                       |      |       |      |

† Full range is -55°C to 125°C.

‡ Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T<sub>A</sub> = 150°C extrapolated to T<sub>A</sub> = 25°C using the Arrhenius equation and assuming an activation energy of 0.96 eV.

§ At V<sub>CC±</sub> = ±5 V, V<sub>O</sub> = ±2.3 V; at V<sub>CC±</sub> = ±15 V, V<sub>O</sub> = ±10 V.



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## TL034M and TL034AM electrical characteristics at specified free-air temperature (continued)

| PARAMETER   | TEST CONDITIONS             | T <sub>A</sub> | TL034M, TL034AM         |     |     |                          |      |     | UNIT |
|---|-----------------------------|----------------|-------------------------|-----|-----|--------------------------|------|-----|------|
|   |                             |                | V <sub>CC±</sub> = ±5 V |     |     | V <sub>CC±</sub> = ±15 V |      |     |      |
|   |                             |                | MIN                     | TYP | MAX | MIN                      | TYP  | MAX |      |
| P <sub>D</sub> Total power dissipation (two amplifiers) | V <sub>O</sub> = 0, No load | 25°C           | 7.7                     | 10  |     | 26                       | 34   | mW  |      |
|   |                             | -55°C          | 4.6                     | 12  |     | 18.7                     | 45   |     |      |
|   |                             | 125°C          | 7.1                     | 12  |     | 23.6                     | 45   |     |      |
| I <sub>CC</sub> Supply current (two amplifiers)         | V <sub>O</sub> = 0, No load | 25°C           | 0.77                    | 1   |     | 0.87                     | 1.12 | mA  |      |
|   |                             | -55°C          | 0.46                    | 1.2 |     | 0.62                     | 1.5  |     |      |
|   |                             | 125°C          | 0.71                    | 1.2 |     | 0.79                     | 1.5  |     |      |
| V <sub>O1</sub> /V <sub>O2</sub> Crosstalk attenuation  | A <sub>VD</sub> = 100       | 25°C           | 120                     |     |     | 120                      |      |     | dB   |

## TL034M and TL034AM operating characteristics at specified free-air temperature

| PARAMETER   | TEST CONDITIONS   | T <sub>A</sub> | TL034M, TL034AM                        |           |     |                          |     |        | UNIT   |
|---|---|----------------|--|-----------|-----|--------------------------|-----|--------|--------|
|   |   |                | V <sub>CC±</sub> = ±5 V                |           |     | V <sub>CC±</sub> = ±15 V |     |        |        |
|   |   |                | MIN                                    | TYP       | MAX | MIN                      | TYP | MAX    |        |
| SR <sub>+</sub> Positive slew rate at unity gain† | R <sub>L</sub> = 10 kΩ,<br>C <sub>L</sub> = 100 pF,<br>See Figure 1                                       | 25°C           | 2                                      |           |     | 1.5 2.9                  |     |        | V/μs   |
|   |   | -55°C          | 1.4                                    |           |     | 1 1.9                    |     |        |        |
|   |   | 125°C          | 2.4                                    |           |     | 1 3.5                    |     |        |        |
| SR <sub>-</sub> Negative slew rate at unity gain† |   | 25°C           | 3.9                                    |           |     | 1.5 5.1                  |     |        | V/μs   |
|   |   | -55°C          | 3.2                                    |           |     | 1 4.6                    |     |        |        |
|   |   | 125°C          | 4.1                                    |           |     | 1 4.7                    |     |        |        |
| t <sub>r</sub> Rise time                          | V <sub>I(PP)</sub> = ±10 V,<br>R <sub>L</sub> = 10 kΩ,<br>C <sub>L</sub> = 100 pF,<br>See Figures 1 and 2 | 25°C           | 138                                    |           |     | 132                      |     |        | ns     |
|   |   | -55°C          | 142                                    |           |     | 123                      |     |        |        |
|   |   | 125°C          | 166                                    |           |     | 58                       |     |        |        |
| t <sub>f</sub> Fall time                          | V <sub>I(PP)</sub> = ±10 V,<br>R <sub>L</sub> = 10 kΩ,<br>C <sub>L</sub> = 100 pF,<br>See Figure 1        | 25°C           | 138                                    |           |     | 132                      |     |        | ns     |
|   |   | -55°C          | 142                                    |           |     | 123                      |     |        |        |
|   |   | 125°C          | 166                                    |           |     | 158                      |     |        |        |
| Overshoot factor                                  | V <sub>I(PP)</sub> = ±10 V,<br>R <sub>L</sub> = 10 kΩ,<br>C <sub>L</sub> = 100 pF,<br>See Figures 1 and 2 | 25°C           | 11%                                    |           |     | 5%                       |     |        |        |
|   |   | -55°C          | 16%                                    |           |     | 6%                       |     |        |        |
|   |   | 125°C          | 14%                                    |           |     | 8%                       |     |        |        |
| V <sub>n</sub> Equivalent input noise voltage     | TL034M<br>TL034AM   | 25°C           | R <sub>S</sub> = 20 Ω,<br>See Figure 3 | f = 10 Hz | 83  |                          |     | nV/√Hz |        |
|   |   |                |  | f = 1 kHz | 43  |                          |     |        |        |
|   |   | 25°C           | R <sub>S</sub> = 20 Ω,<br>See Figure 3 | f = 10 Hz | 83  |                          |     |        |        |
|   |   |                |  | f = 1 kHz | 43  |                          |     |        |        |
| I <sub>n</sub> Equivalent input noise current     | f = 1 kHz   | 25°C           | 0.003                                  |           |     | 0.003                    |     |        | pA/√Hz |
| B1 Unity-gain bandwidth                           | V <sub>I</sub> = 10 mV,<br>C <sub>L</sub> = 25 pF,<br>R <sub>L</sub> = 10 kΩ,<br>See Figure 4             | 25°C           | 1                                      |           |     | 1.1                      |     |        | MHz    |
|   |   | -55°C          | 1                                      |           |     | 1.1                      |     |        |        |
|   |   | 125°C          | 0.9                                    |           |     | 0.9                      |     |        |        |
| φ <sub>m</sub> Phase margin at unity gain         | V <sub>I</sub> = 10 mV,<br>C <sub>L</sub> = 25 pF,<br>R <sub>L</sub> = 10 kΩ,<br>See Figure 4             | 25°C           | 61°                                    |           |     | 65°                      |     |        |        |
|   |   | -55°C          | 57°                                    |           |     | 64°                      |     |        |        |
|   |   | 125°C          | 59°                                    |           |     | 62°                      |     |        |        |

† For V<sub>CC±</sub> = ±5 V, V<sub>I(PP)</sub> = ±1 V; for V<sub>CC±</sub> = ±15 V, V<sub>I(PP)</sub> = ±5 V.



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**TL034Y electrical characteristics,  $T_A = 25^\circ\text{C}$**

| PARAMETER   | TEST CONDITIONS                                       | TL034Y                       |     |     |                               |     |     | UNIT                         |
|---|---|------------------------------|-----|-----|-------------------------------|-----|-----|------------------------------|
|   |   | $V_{CC\pm} = \pm 5\text{ V}$ |     |     | $V_{CC\pm} = \pm 15\text{ V}$ |     |     |                              |
|   |   | MIN                          | TYP | MAX | MIN                           | TYP | MAX |                              |
| $V_{IO}$ Input offset voltage   | $V_O = 0, V_{IC} = 0,$<br>$R_S = 50\ \Omega$          | 0.91                         |     |     | 0.79                          |     |     | mV                           |
| $\alpha_{VIO}$ Temperature coefficient of input offset voltage                  |   | 11.6                         |     |     | 12                            |     |     | $\mu\text{V}/^\circ\text{C}$ |
| $I_{IO}$ Input offset current   | $V_O = 0, V_{IC} = 0,$<br>See Figure 5                | 1                            |     |     | 1                             |     |     | pA                           |
|   |   | 2                            |     |     | 2                             |     |     |                              |
| $I_{IB}$ Input bias current   | $V_O = 0, V_{IC} = 0,$<br>See Figure 5                | 2                            |     |     | 2                             |     |     | pA                           |
|   |   | 7                            |     |     | 8                             |     |     | nA                           |
| $V_{ICR}$ Common-mode input voltage range                                       |   | -3.4<br>to<br>5.4            |     |     | -13.4<br>to<br>15.4           |     |     | V                            |
| $V_{OM+}$ Maximum positive peak output voltage swing                            | $R_L = 10\ \text{k}\Omega$                            | 4.3                          |     |     | 14                            |     |     | V                            |
| $V_{OM-}$ Maximum negative peak output voltage swing                            | $R_L = 10\ \text{k}\Omega$                            | -4.2                         |     |     | -13.9                         |     |     | V                            |
| $A_{VD}$ Large-signal differential voltage amplification†                       | $R_L = 10\ \text{k}\Omega$                            | 12                           |     |     | 14.3                          |     |     | V/mV                         |
| $r_i$ Input resistance  |   | $10^{12}$                    |     |     | $10^{12}$                     |     |     | $\Omega$                     |
| $c_i$ Input capacitance   |   | 5                            |     |     | 4                             |     |     | pF                           |
| CMRR Common-mode rejection ratio  | $V_{IC} = V_{ICRmin},$<br>$V_O = 0, R_S = 50\ \Omega$ | 87                           |     |     | 94                            |     |     | dB                           |
| $k_{SVR}$ Supply-voltage rejection ratio ( $\Delta V_{CC\pm} / \Delta V_{IO}$ ) | $V_O = 0, R_S = 50\ \Omega$                           | 96                           |     |     | 96                            |     |     | dB                           |
| $P_D$ Total power dissipation (four amplifiers)                                 | $V_O = 0,$ No load                                    | 7.7                          |     |     | 26                            |     |     | mW                           |
| $I_{CC}$ Supply current (four amplifiers)                                       | $V_O = 0,$ No load                                    | 0.77                         |     |     | 0.87                          |     |     | mA                           |
| $V_{O1}/V_{O2}$ Crosstalk attenuation   | $A_{VD} = 100$  | 120                          |     |     | 120                           |     |     | dB                           |

† At  $V_{CC\pm} = \pm 5\text{ V}, V_O = \pm 2.3\text{ V}$ ; at  $V_{CC\pm} = \pm 15\text{ V}, V_O = \pm 10\text{ V}$ .

**TL034Y operating characteristics,  $T_A = 25^\circ\text{C}$**

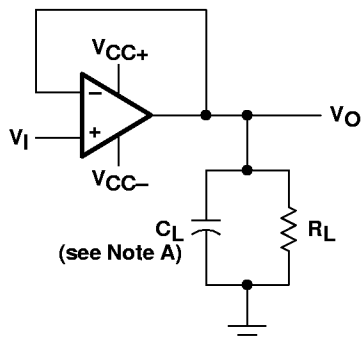
| PARAMETER                              | TEST CONDITIONS  | TL034Y                       |     |     |                               |     |     | UNIT                   |
|--|--|------------------------------|-----|-----|-------------------------------|-----|-----|------------------------|
|  |  | $V_{CC\pm} = \pm 5\text{ V}$ |     |     | $V_{CC\pm} = \pm 15\text{ V}$ |     |     |                        |
|  |  | MIN                          | TYP | MAX | MIN                           | TYP | MAX |                        |
| $SR+$ Positive slew rate at unity gain | $R_L = 10\ \text{k}\Omega, C_L = 100\ \text{pF},$<br>See Figure 1  | 2                            |     |     | 1.5 2.9                       |     |     | V/ $\mu\text{s}$       |
| $SR-$ Negative slew rate at unity gain |  | 3.9                          |     |     | 1.5 5.1                       |     |     | V/ $\mu\text{s}$       |
| $t_r$ Rise time                        | $V_I(PP) = \pm 10\text{ V},$<br>$R_L = 10\ \text{k}\Omega, C_L = 100\ \text{pF},$<br>See Figures 1 and 2 | 138                          |     |     | 132                           |     |     | ns                     |
| $t_f$ Fall time                        |  | 138                          |     |     | 132                           |     |     | ns                     |
| Overshoot factor                       |  | 11%                          |     |     | 5%                            |     |     |                        |
| $V_n$ Equivalent input noise voltage   | $R_S = 20\ \Omega,$<br>See Figure 3  | 83                           |     |     | 83                            |     |     | nV/ $\sqrt{\text{Hz}}$ |
|  |  | 43                           |     |     | 43                            |     |     |                        |
| $I_n$ Equivalent input noise current   | $f = 1\ \text{kHz}$  | 0.003                        |     |     | 0.003                         |     |     | pA/ $\sqrt{\text{Hz}}$ |
| B1 Unity-gain bandwidth                | $V_I = 10\ \text{mV}, R_L = 10\ \text{k}\Omega,$<br>$C_L = 25\ \text{pF},$ See Figure 4                  | 1                            |     |     | 1.1                           |     |     | MHz                    |
| $\phi_m$ Phase margin at unity gain    | $V_I = 10\ \text{mV}, R_L = 10\ \text{k}\Omega,$<br>$C_L = 25\ \text{pF},$ See Figure 4                  | 61°                          |     |     | 65°                           |     |     |                        |



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## PARAMETER MEASUREMENT INFORMATION



NOTE A:  $C_L$  includes fixture capacitance.

Figure 1. Slew-Rate and Overshoot Test Circuit

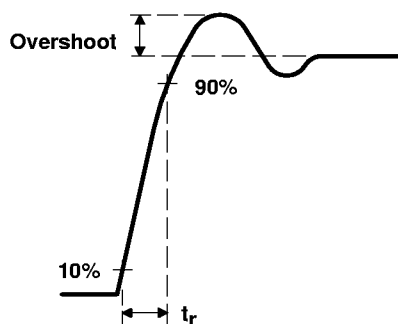


Figure 2. Rise Time and Overshoot Waveform

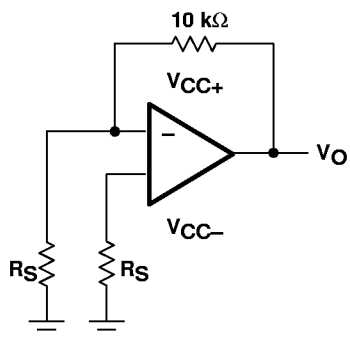
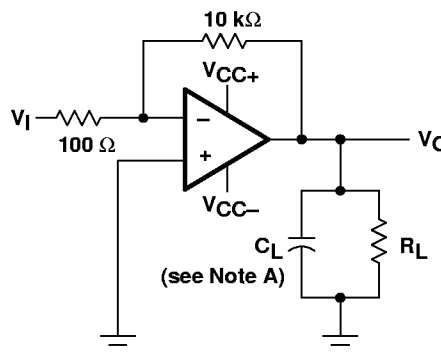


Figure 3. Noise-Voltage Test Circuit



NOTE A:  $C_L$  includes fixture capacitance.

Figure 4. Unity-Gain Bandwidth and Phase-Margin Test Circuit

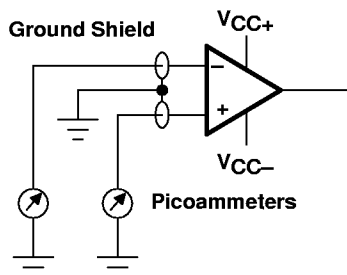


Figure 5. Input-Bias and Offset-Current Test Circuit

## PARAMETER MEASUREMENT INFORMATION

### typical values

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

### input bias and offset current

At the picoampere bias current level typical of the TL03x and TL03xA, accurate measurement of the bias current becomes difficult. Not only does this measurement require a picoammeter, but test-socket leakages easily can exceed the actual device bias currents. To accurately measure these small currents, Texas Instruments uses a two-step process. The socket leakage is measured using picoammeters with bias voltages applied but with no device in the socket. The device is then inserted into the socket and a second test that measures both the socket leakage and the device input bias current is performed. The two measurements are then subtracted algebraically to determine the bias current of the device.

### noise

With the increasing emphasis on low noise levels in many of today's applications, the input noise voltage density is performed at  $f = 1$  kHz, unless otherwise noted.

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TYPICAL CHARACTERISTICS

DISTRIBUTION OF TL031  
 INPUT OFFSET VOLTAGE

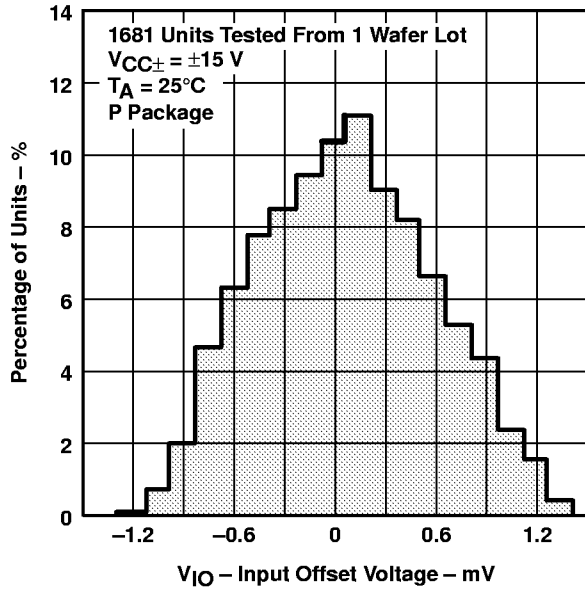


Figure 6

DISTRIBUTION OF TL031A  
 INPUT OFFSET VOLTAGE

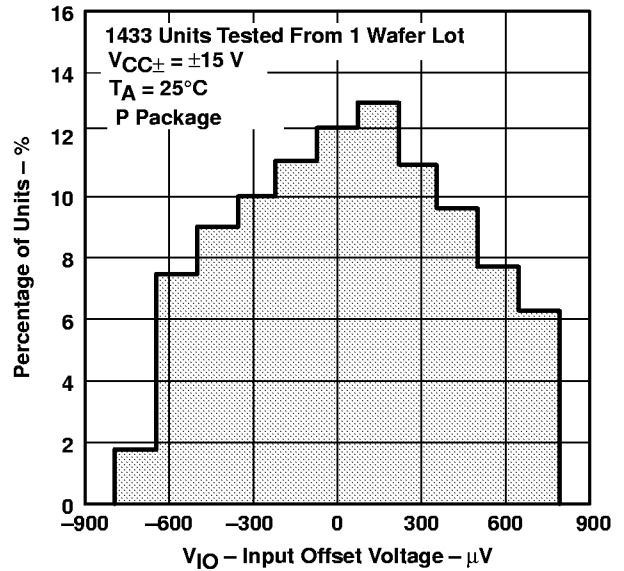


Figure 7

DISTRIBUTION OF TL032  
 INPUT OFFSET VOLTAGE

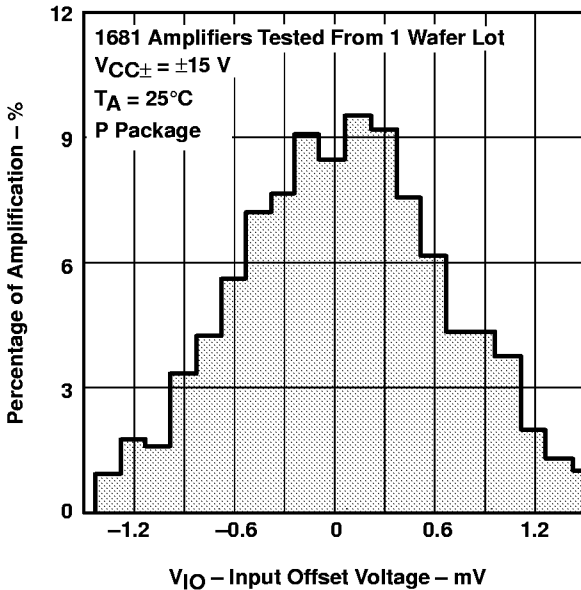


Figure 8

DISTRIBUTION OF TL032A  
 INPUT OFFSET VOLTAGE

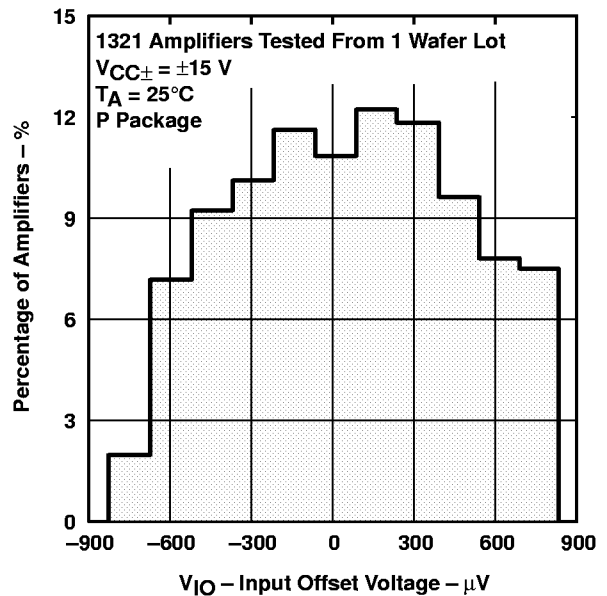


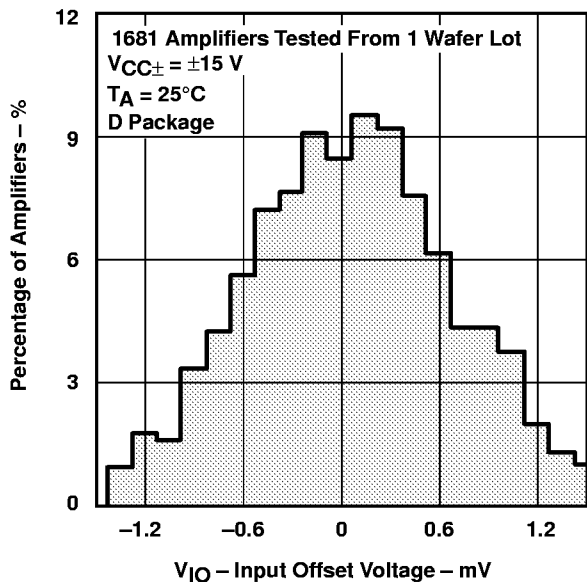
Figure 9

**TL03x, TL03xA, TL03xY**  
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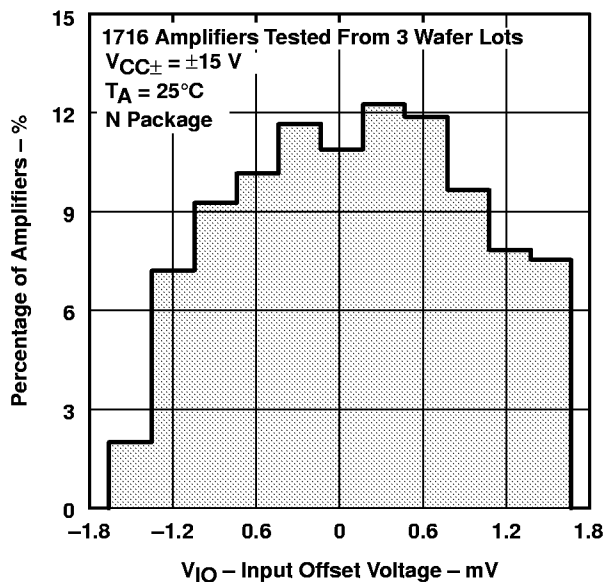
**TYPICAL CHARACTERISTICS**

**DISTRIBUTION OF TL034  
 INPUT OFFSET VOLTAGE**



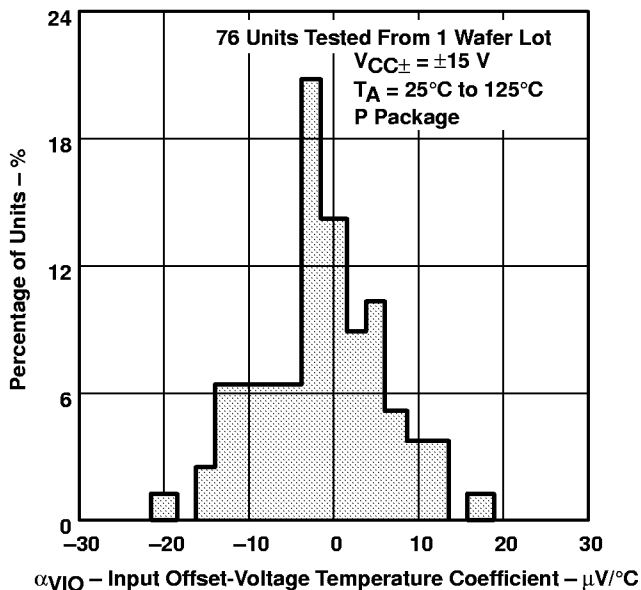
**Figure 10**

**DISTRIBUTION OF TL034A  
 INPUT OFFSET VOLTAGE**



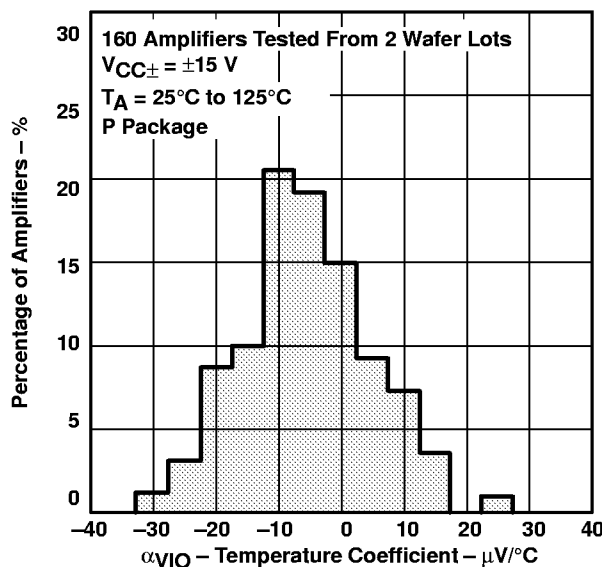
**Figure 11**

**DISTRIBUTION OF TL031  
 INPUT OFFSET-VOLTAGE  
 TEMPERATURE COEFFICIENT**



**Figure 12**

**DISTRIBUTION OF TL032  
 INPUT OFFSET-VOLTAGE  
 TEMPERATURE COEFFICIENT**



**Figure 13**

TYPICAL CHARACTERISTICS

DISTRIBUTION OF TL034  
 INPUT OFFSET-VOLTAGE  
 TEMPERATURE COEFFICIENT

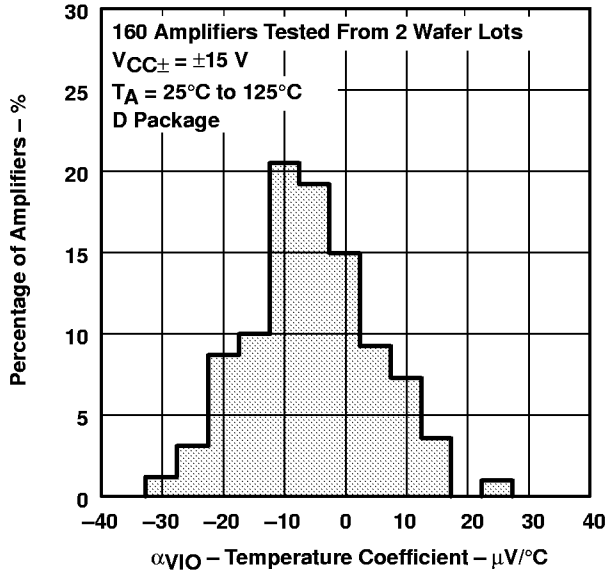


Figure 14

INPUT BIAS CURRENT  
 vs  
 COMMON-MODE INPUT VOLTAGE

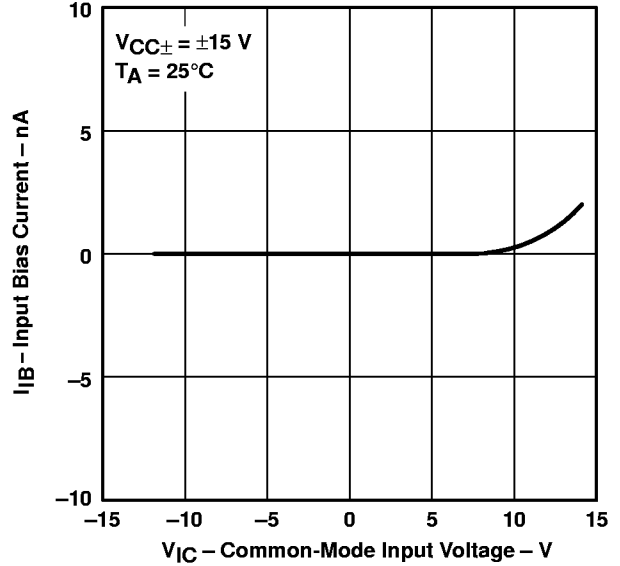


Figure 15

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

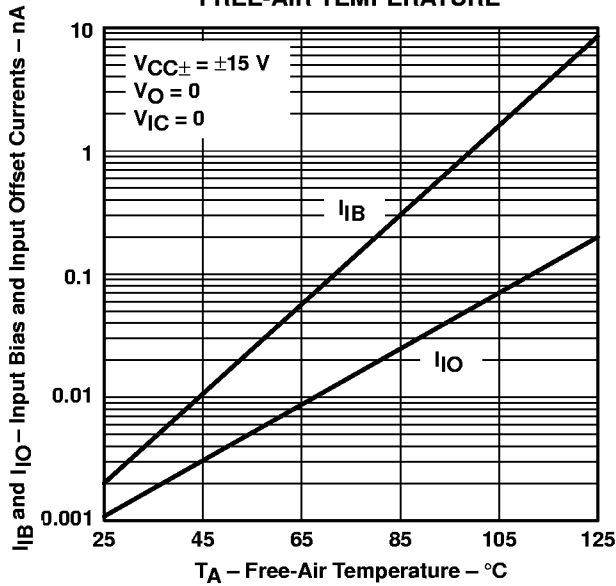


Figure 16

COMMON-MODE INPUT VOLTAGE  
 vs  
 SUPPLY VOLTAGE

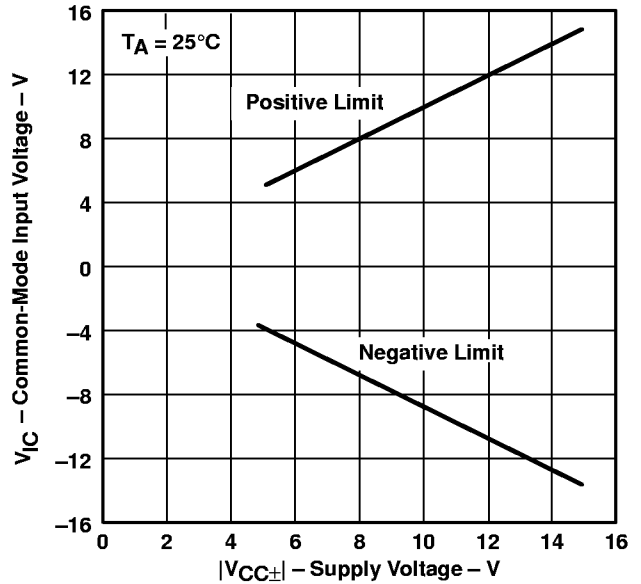


Figure 17

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

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## TYPICAL CHARACTERISTICS

**COMMON-MODE INPUT VOLTAGE RANGE†  
vs  
FREE-AIR TEMPERATURE**

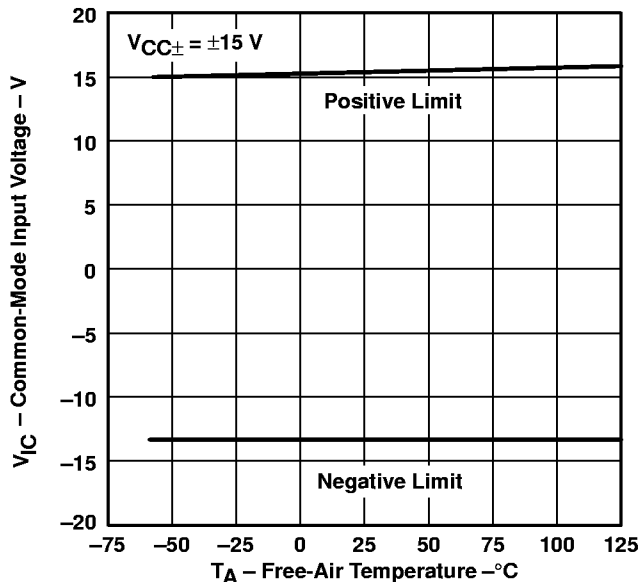


Figure 18

**OUTPUT VOLTAGE  
vs  
DIFFERENTIAL INPUT VOLTAGE**

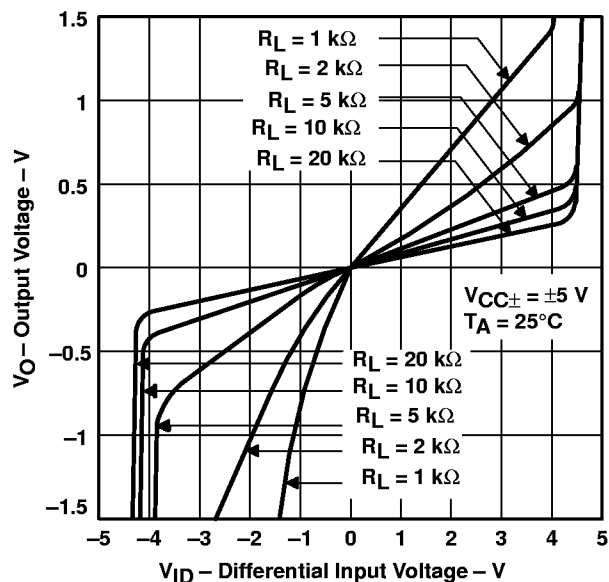


Figure 19

**OUTPUT VOLTAGE  
vs  
DIFFERENTIAL INPUT VOLTAGE**

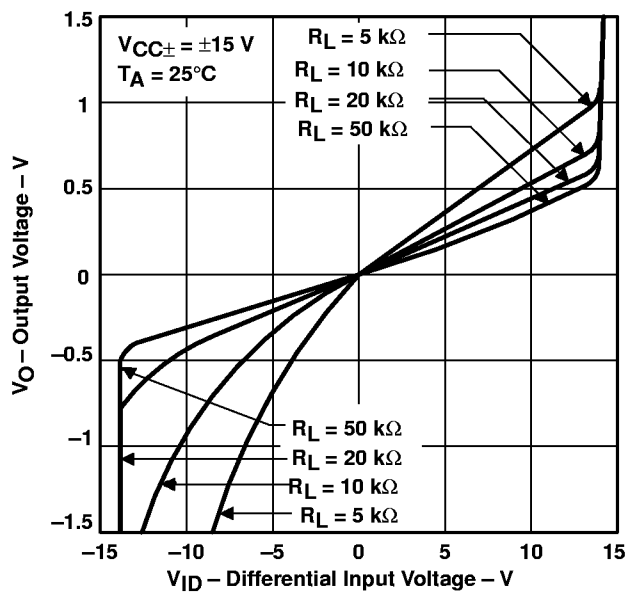


Figure 20

**MAXIMUM PEAK OUTPUT VOLTAGE  
vs  
SUPPLY VOLTAGE**

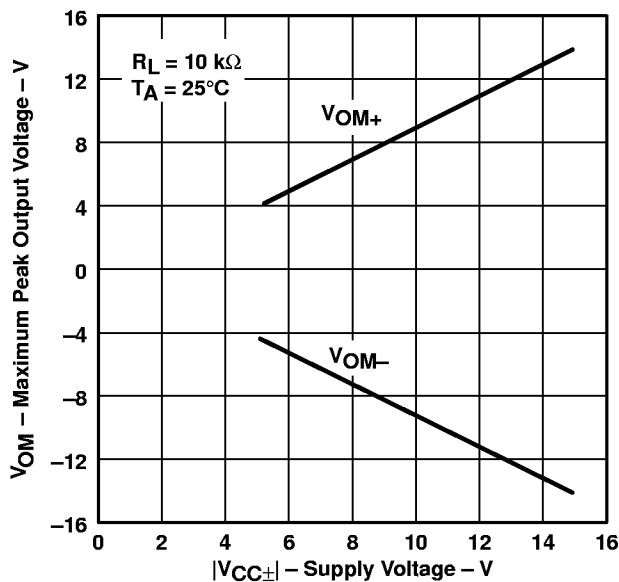


Figure 21

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



TYPICAL CHARACTERISTICS

MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE†  
 vs  
 FREQUENCY

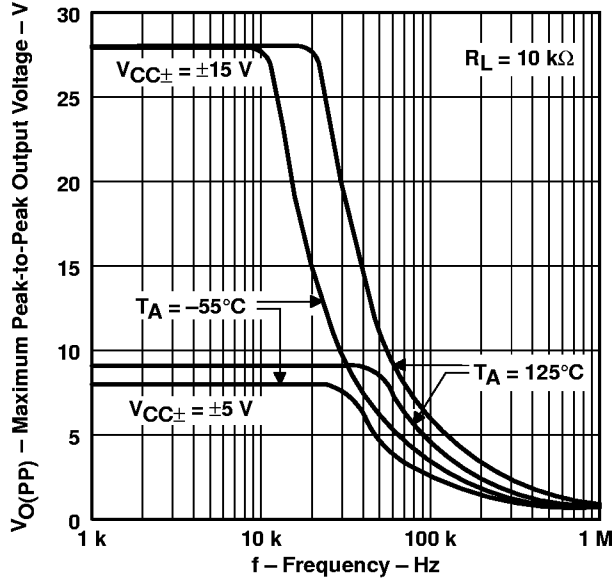


Figure 22

MAXIMUM PEAK OUTPUT VOLTAGE  
 vs  
 OUTPUT CURRENT

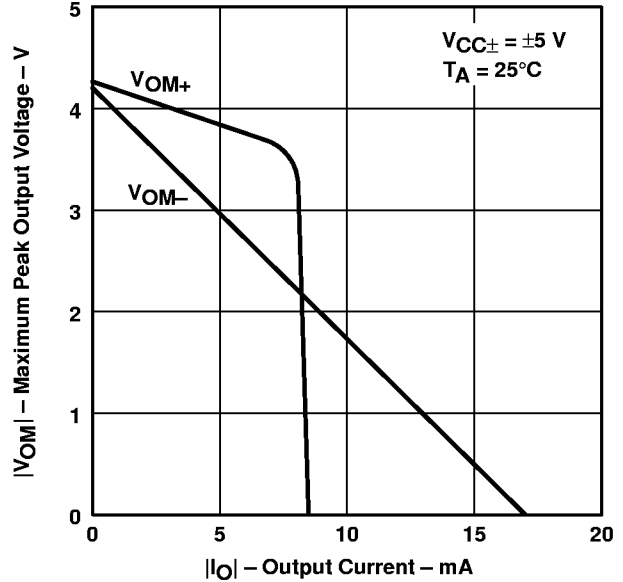


Figure 23

MAXIMUM PEAK OUTPUT VOLTAGE  
 vs  
 OUTPUT CURRENT

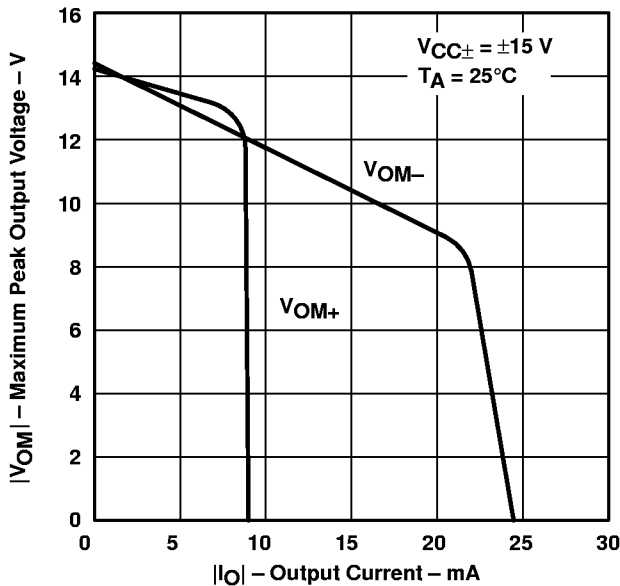


Figure 24

MAXIMUM PEAK OUTPUT VOLTAGE†  
 vs  
 FREE-AIR TEMPERATURE

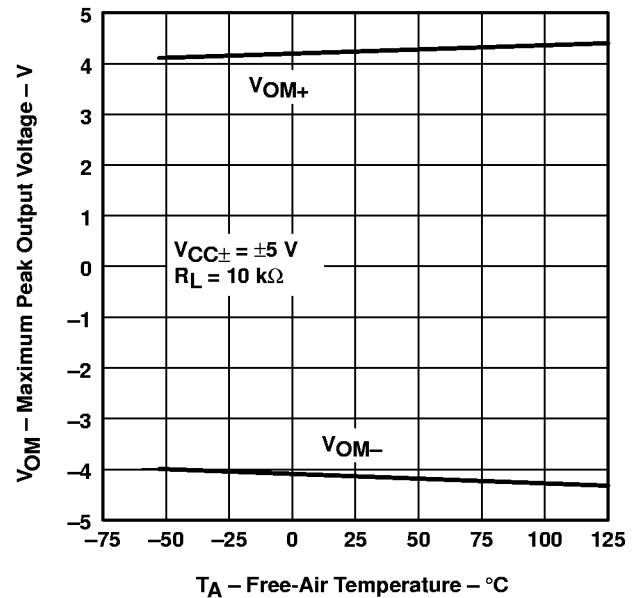


Figure 25

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

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## TYPICAL CHARACTERISTICS

**MAXIMUM PEAK OUTPUT VOLTAGE†  
vs  
FREE-AIR TEMPERATURE**

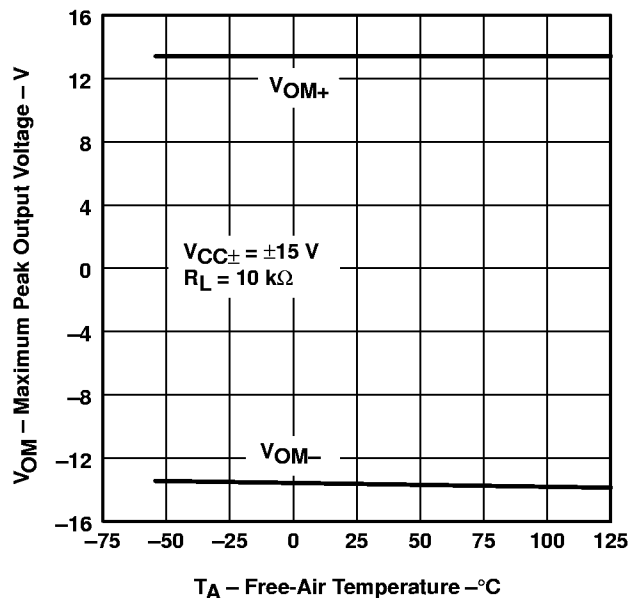


Figure 26

**LARGE-SIGNAL DIFFERENTIAL  
VOLTAGE AMPLIFICATION  
vs  
LOAD RESISTANCE**

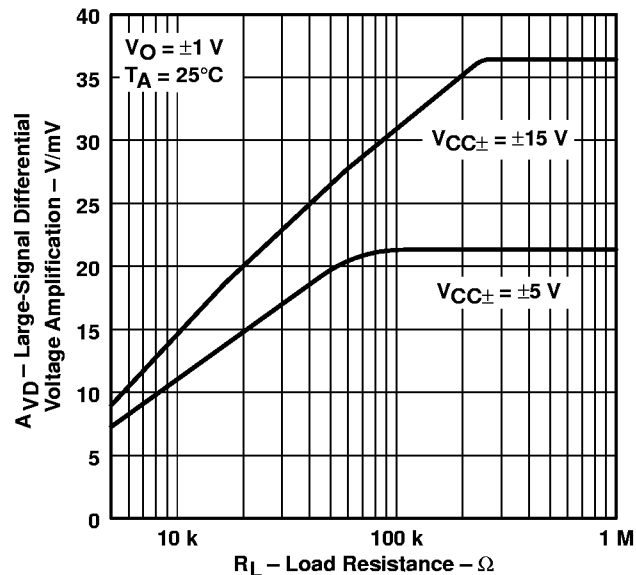


Figure 27

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

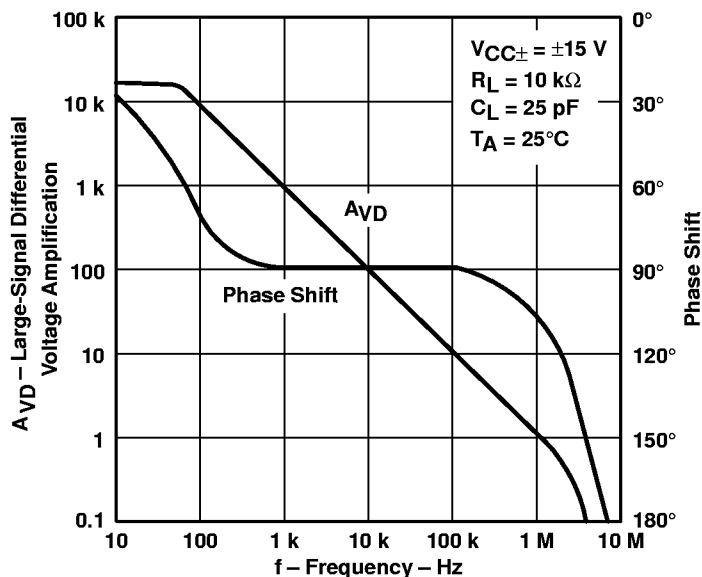


Figure 28

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

TYPICAL CHARACTERISTICS

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

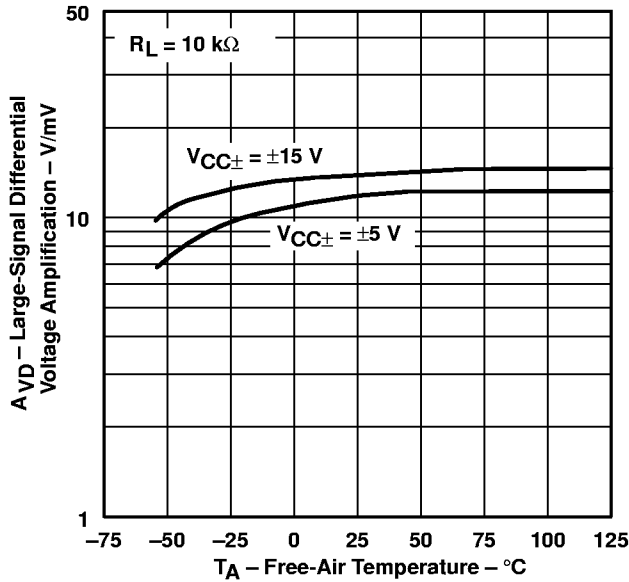


Figure 29

OUTPUT IMPEDANCE  
 vs  
 FREQUENCY

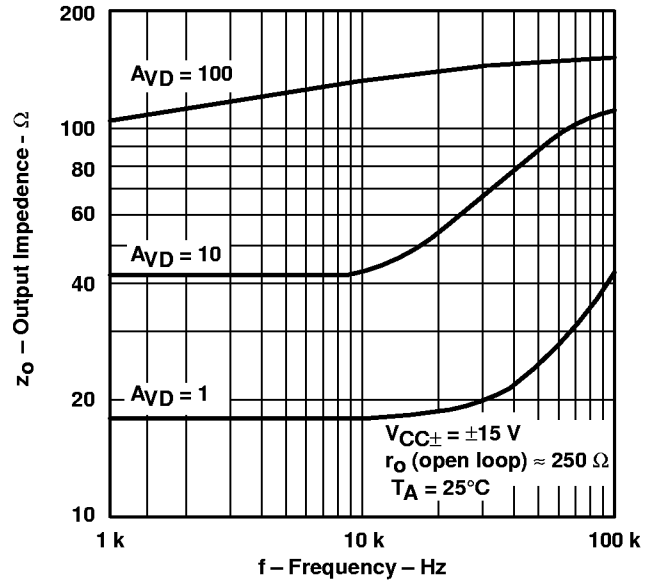


Figure 30

COMMON-MODE REJECTION RATIO  
 vs  
 FREQUENCY

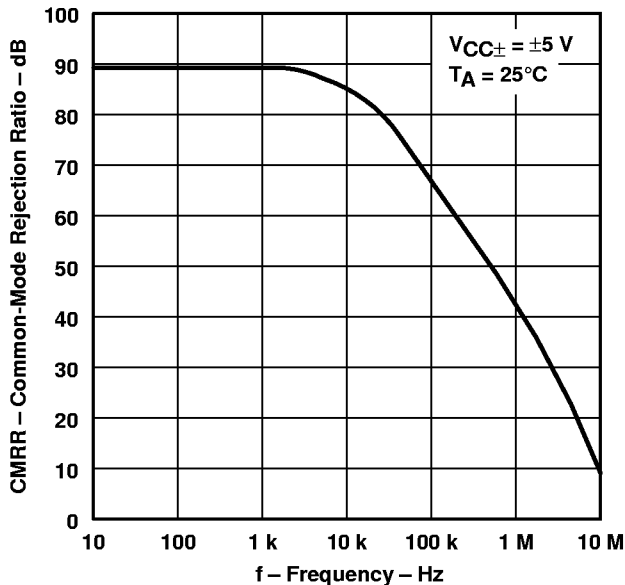


Figure 31

COMMON-MODE REJECTION RATIO  
 vs  
 FREQUENCY

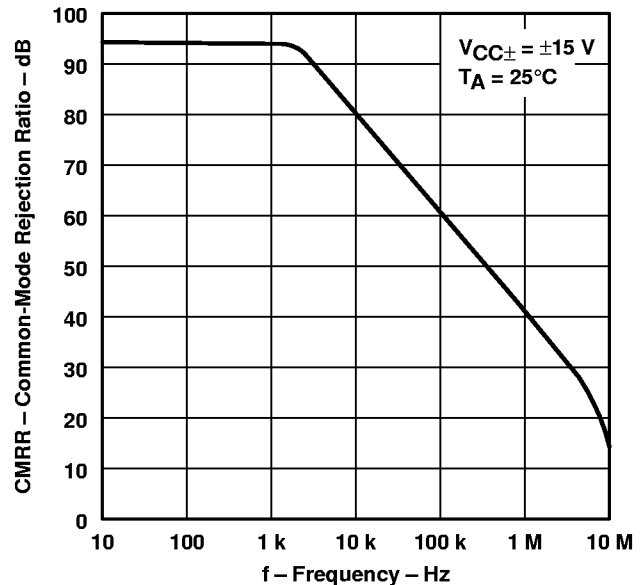


Figure 32

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

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## TYPICAL CHARACTERISTICS

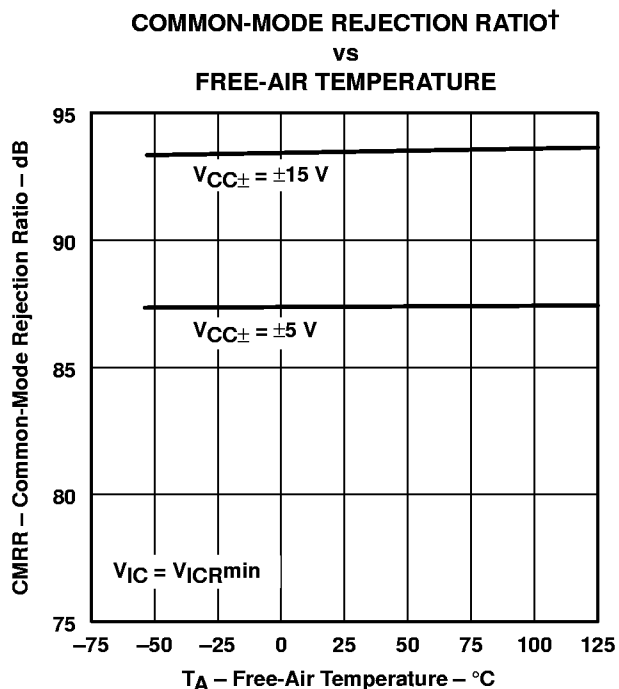


Figure 33

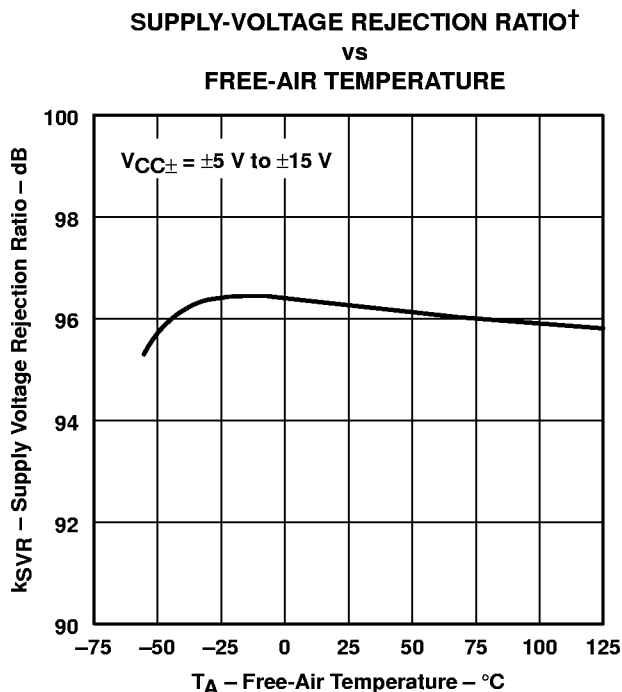


Figure 34

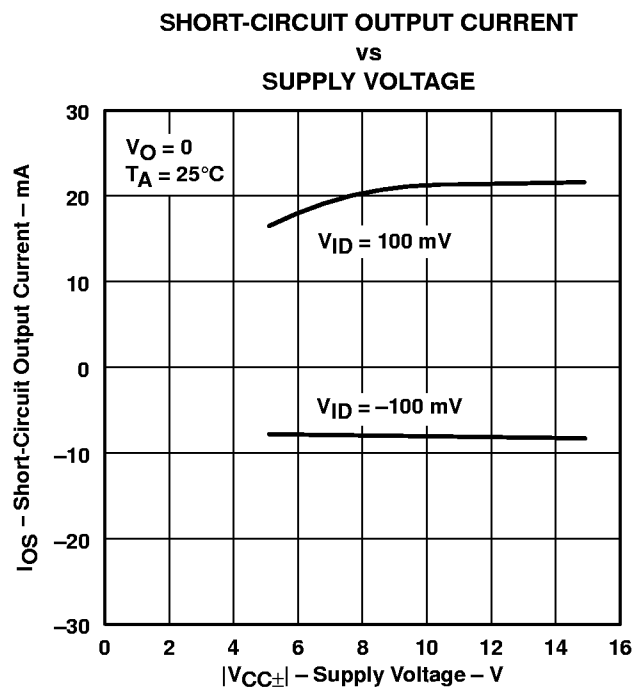


Figure 35

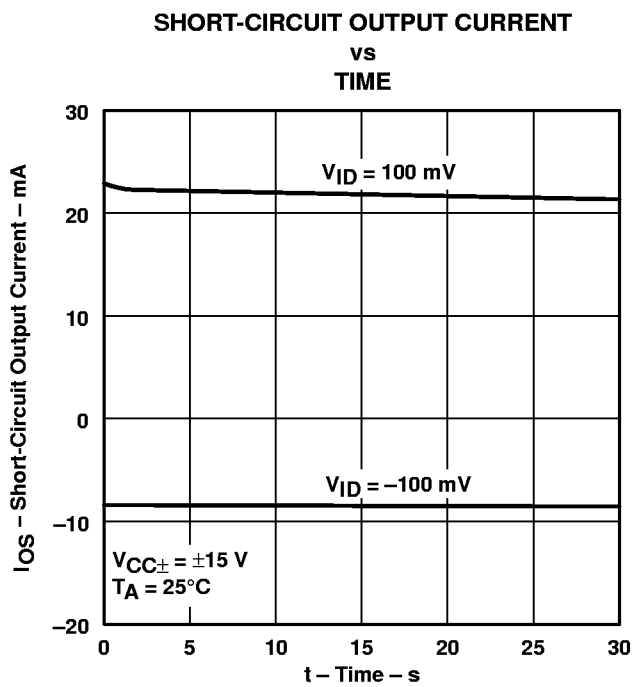


Figure 36

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



TYPICAL CHARACTERISTICS

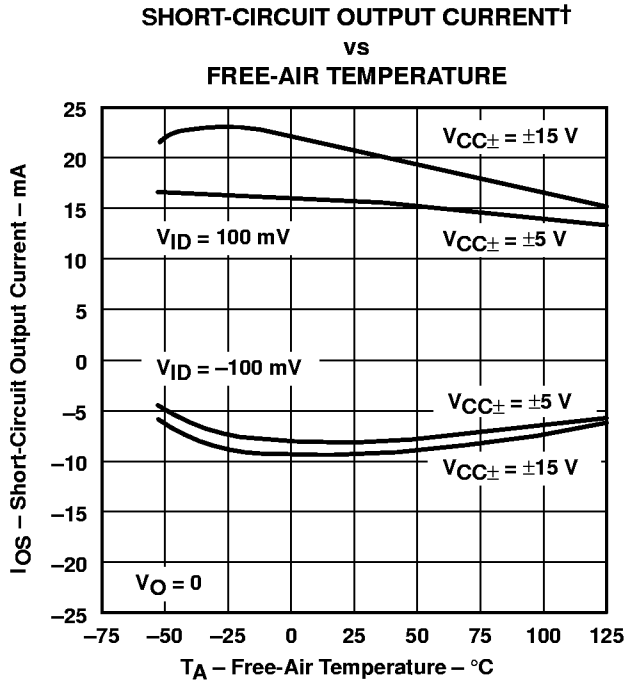


Figure 37

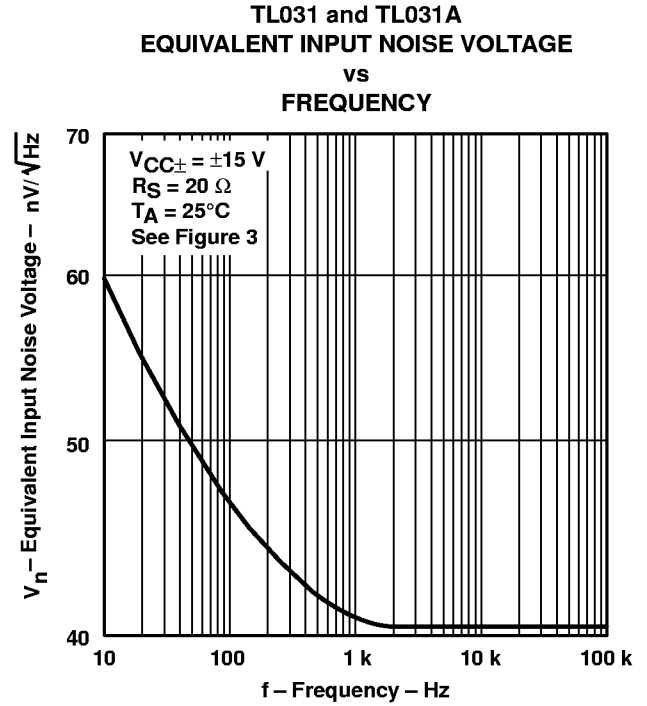


Figure 38

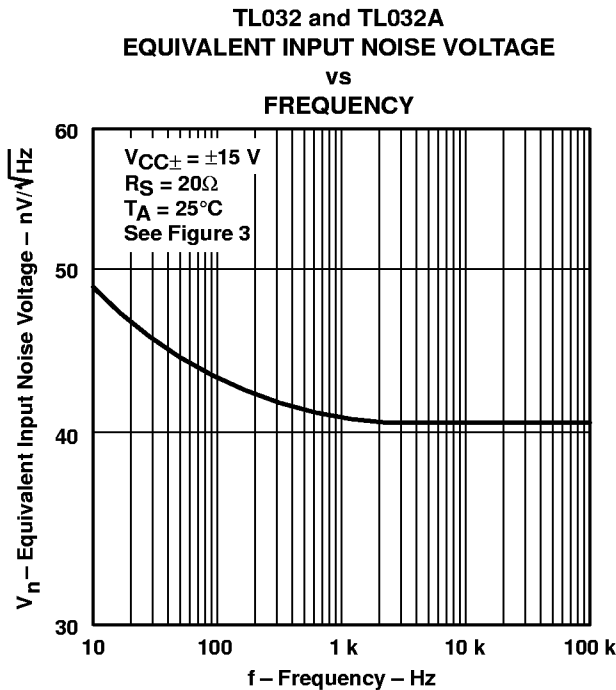


Figure 39

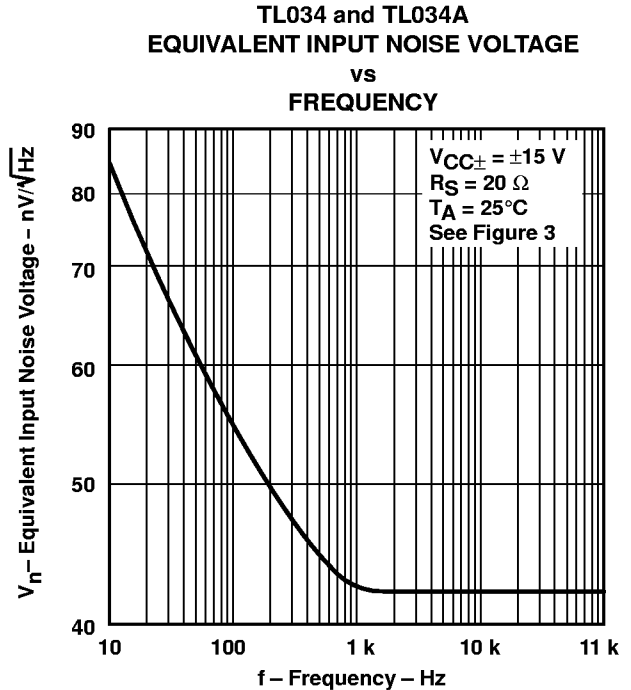


Figure 40

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

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## TYPICAL CHARACTERISTICS

TL031 and TL031A  
SUPPLY CURRENT†  
vs  
SUPPLY VOLTAGE

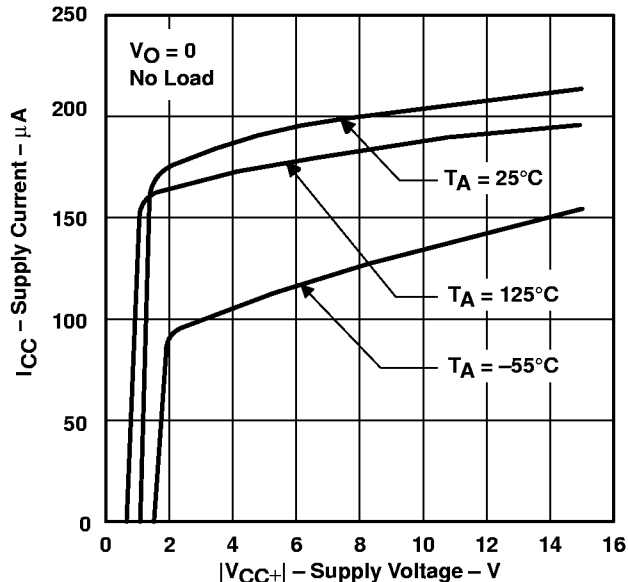


Figure 41

TL032 and TL032A  
SUPPLY CURRENT†  
vs  
SUPPLY VOLTAGE

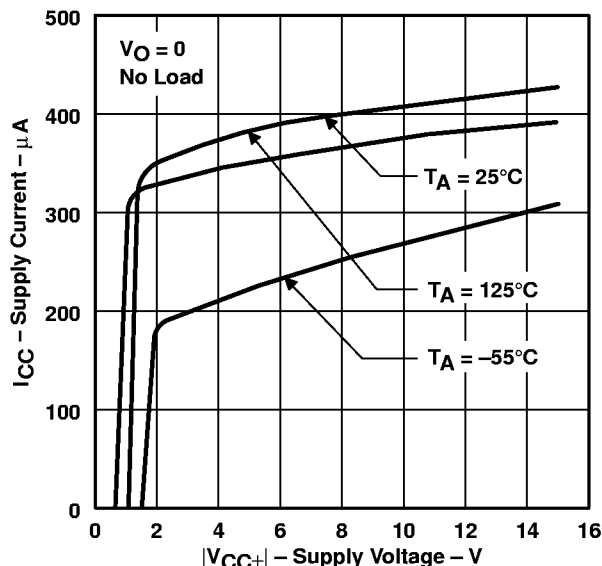


Figure 42

TL034 and TL034A  
SUPPLY CURRENT†  
vs  
SUPPLY VOLTAGE

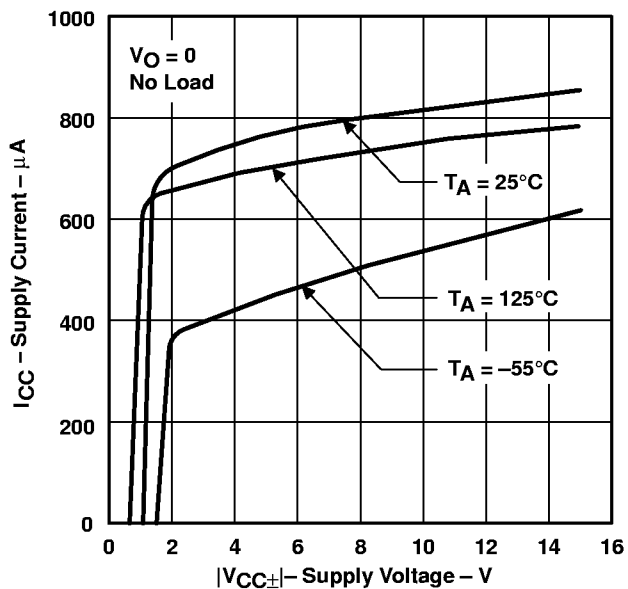


Figure 43

TL031 and TL031A  
SUPPLY CURRENT†  
vs  
FREE-AIR TEMPERATURE

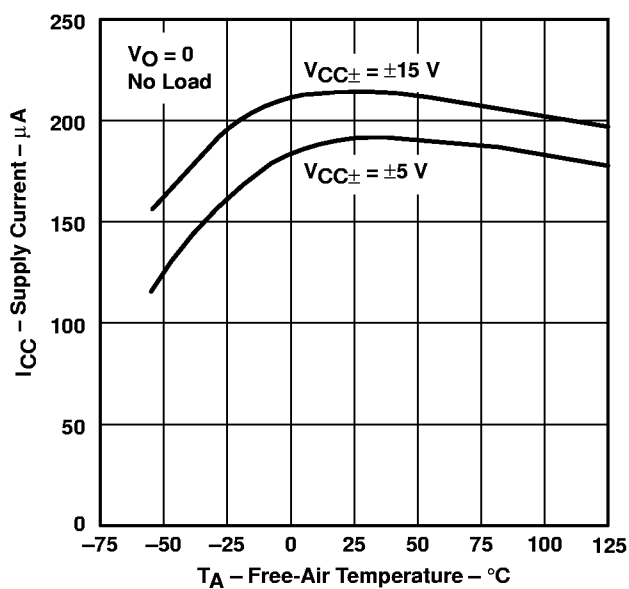
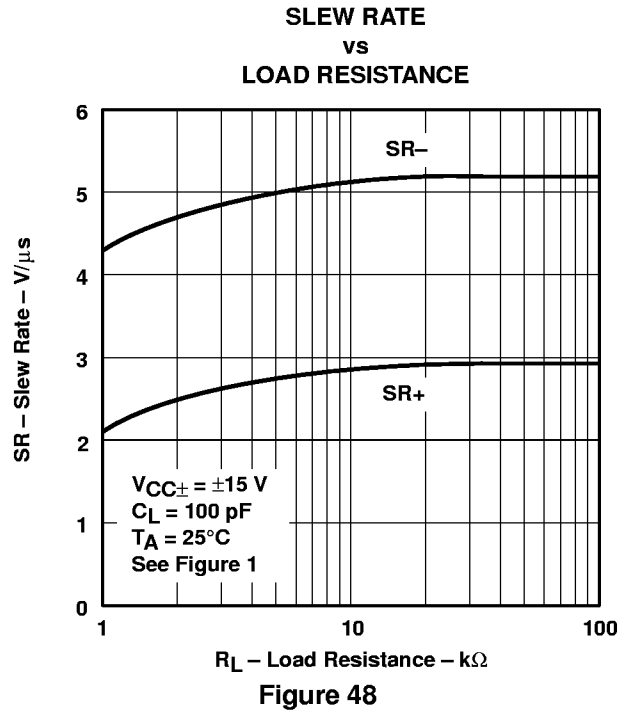
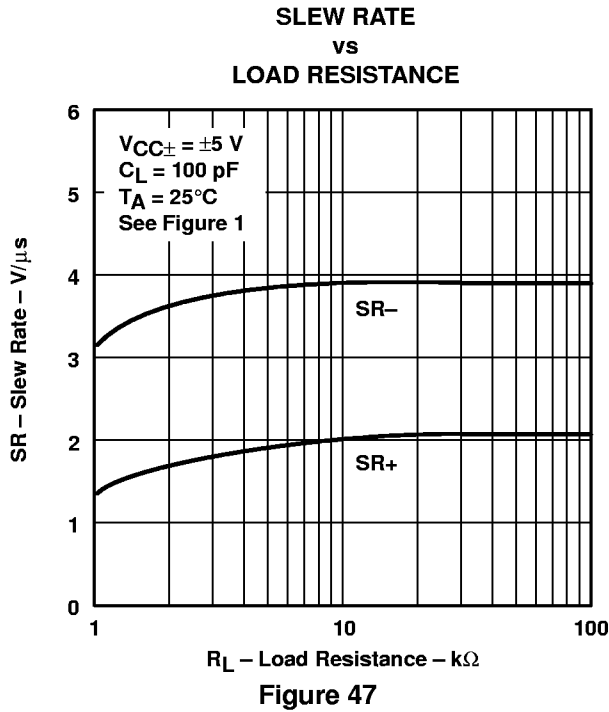
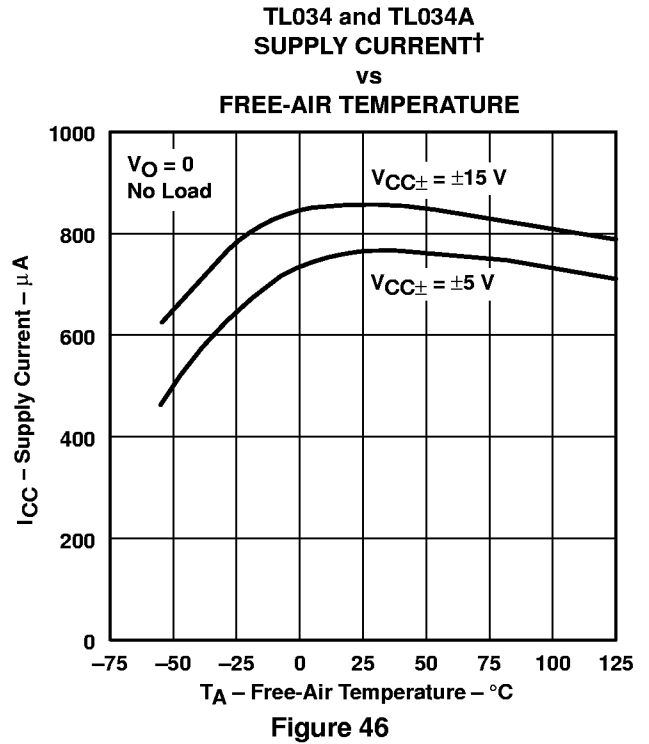
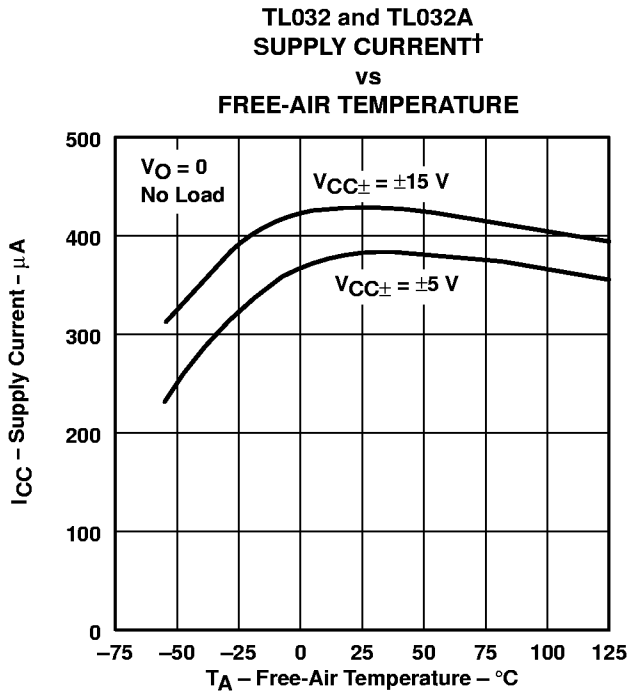


Figure 44

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

TYPICAL CHARACTERISTICS



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

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## TYPICAL CHARACTERISTICS

**SLEW RATE†  
vs  
FREE-AIR TEMPERATURE**

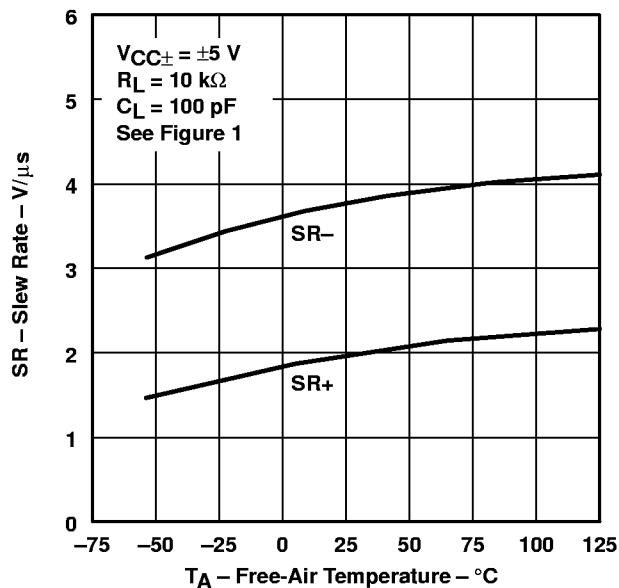


Figure 49

**SLEW RATE†  
vs  
FREE-AIR TEMPERATURE**

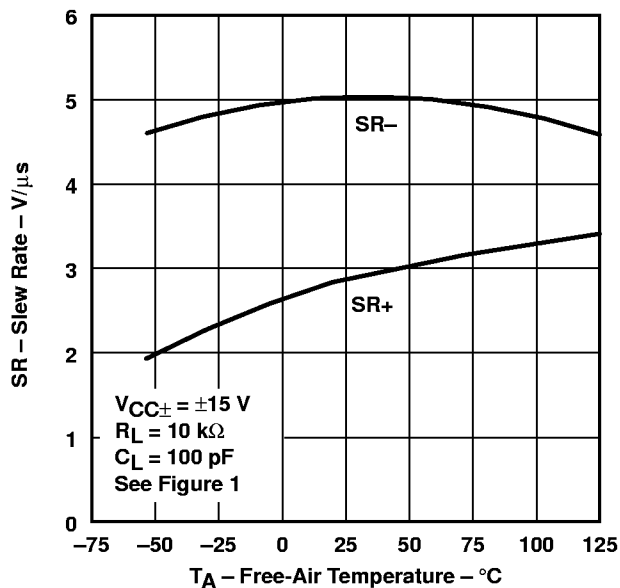


Figure 50

**OVERSHOOT FACTOR  
vs  
LOAD CAPACITANCE**

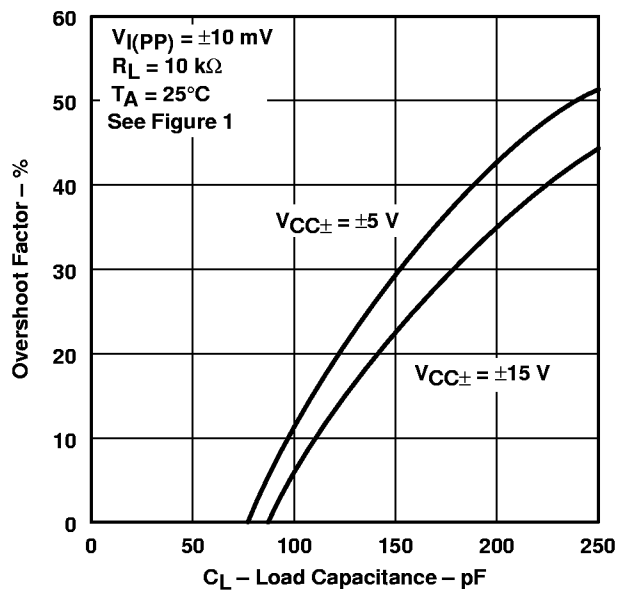


Figure 51

**TOTAL HARMONIC DISTORTION  
vs  
FREQUENCY**

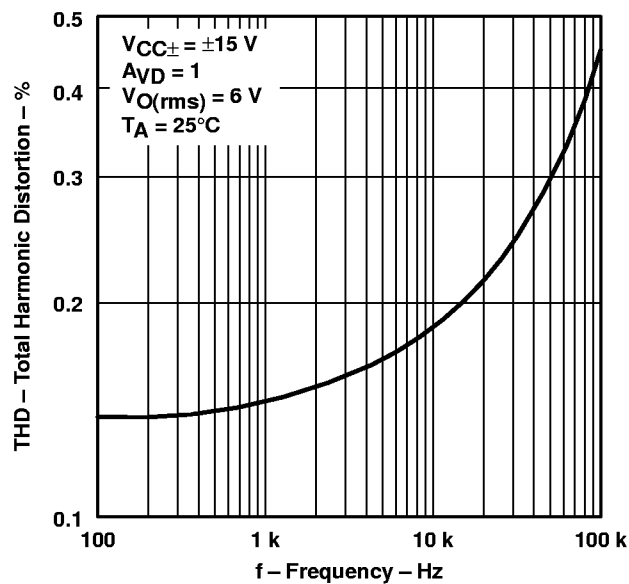
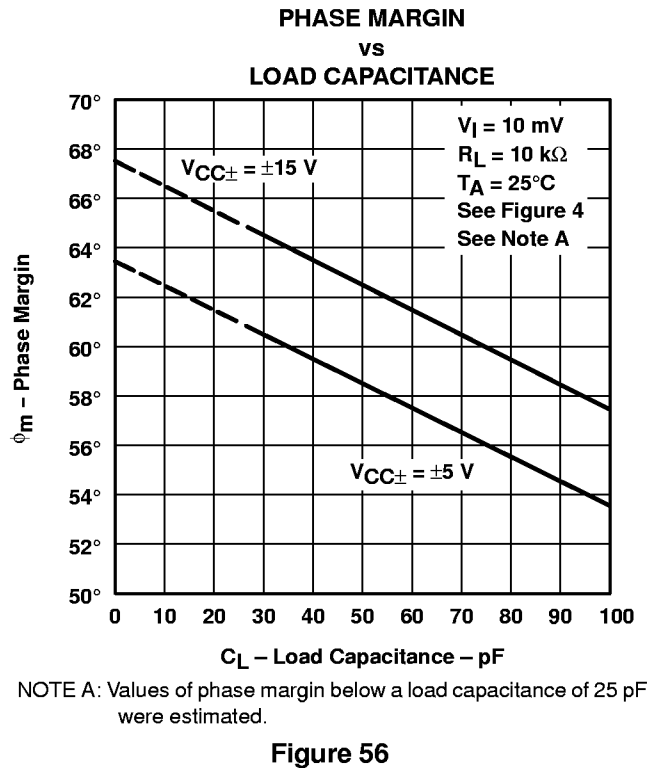
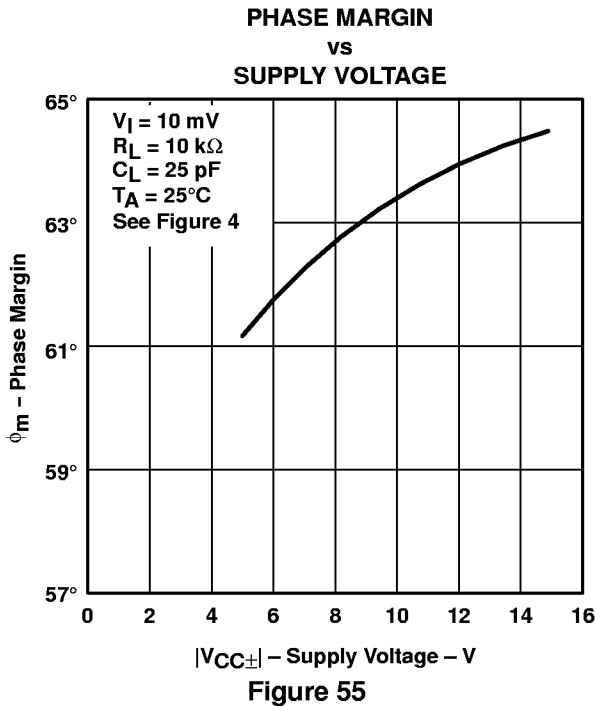
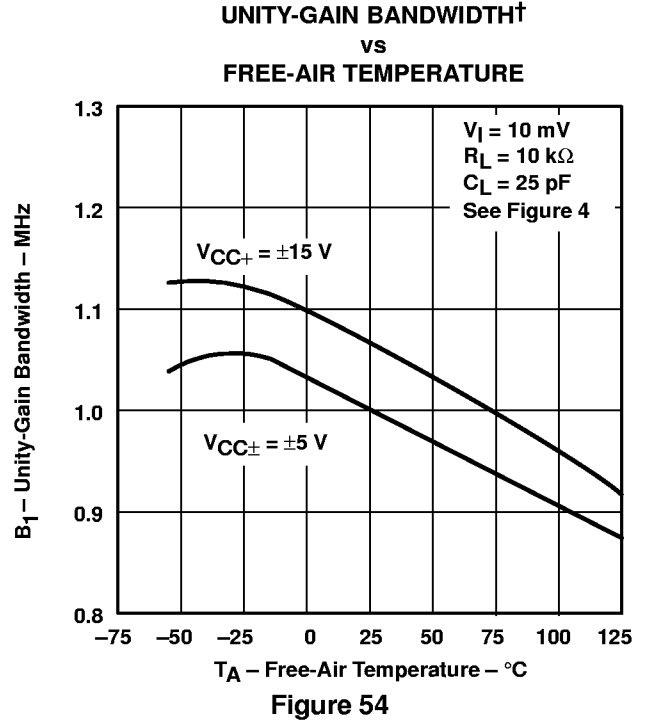
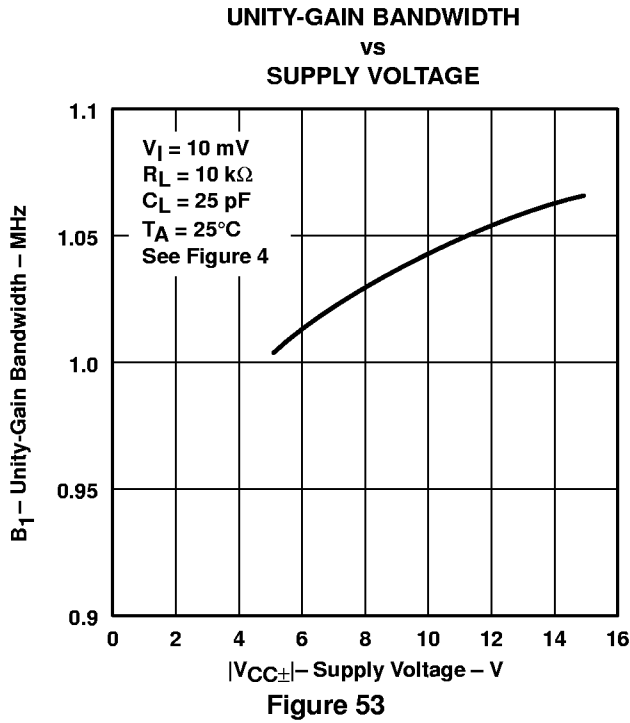


Figure 52

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

TYPICAL CHARACTERISTICS



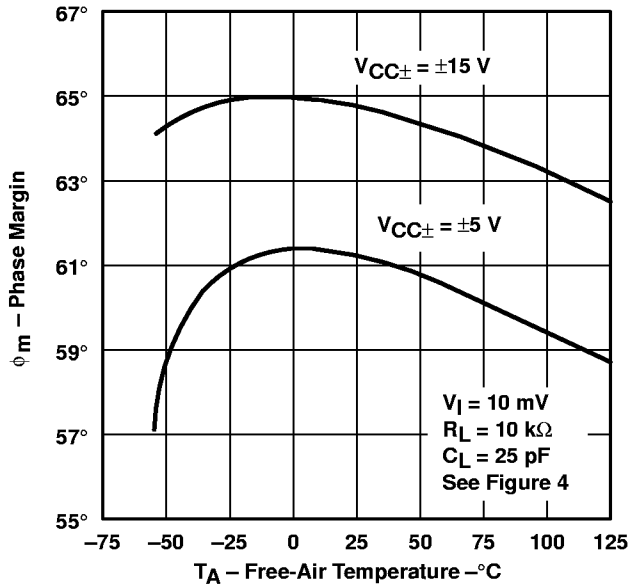
† Data at high and low temperatures are applicable only within the recommended operating free-air temperature ranges of the various devices.

**TL03x, TL03xA, TL03xY**  
**ENHANCED-JFET LOW-POWER LOW-OFFSET**  
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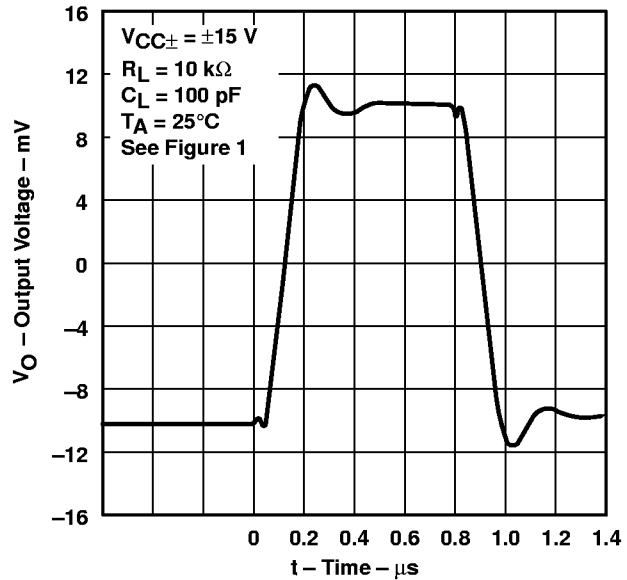
**TYPICAL CHARACTERISTICS**

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



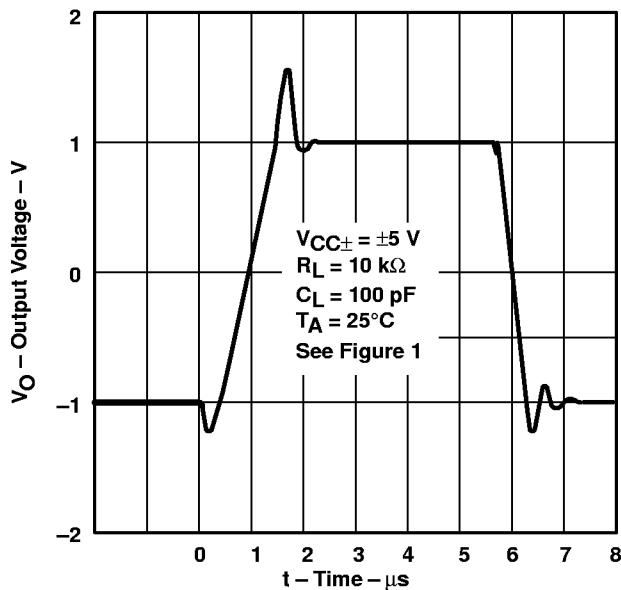
**Figure 57**

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



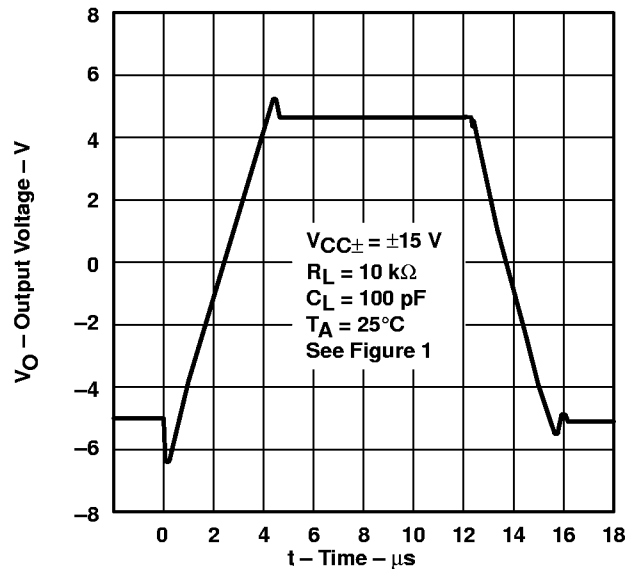
**Figure 58**

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



**Figure 59**

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



**Figure 60**

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

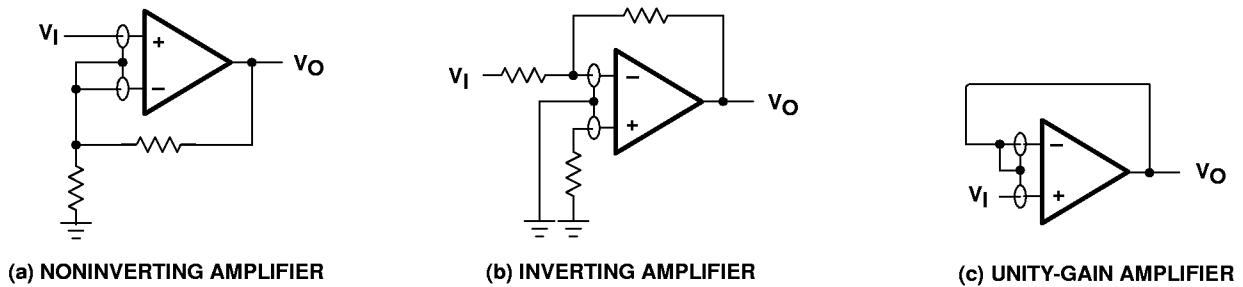
## APPLICATION INFORMATION

### input characteristics

The TL03x and TL03xA are specified with a minimum and a maximum input voltage that, if exceeded at either input, could cause the device to malfunction.

Due to the extremely high input impedance and resulting low bias-current requirements, the TL03x and TL03xA are well suited for low-level signal processing; however, leakage currents on printed circuit boards and sockets easily can exceed bias current requirements and cause degradation in system performance. It is a good practice to include guard rings around inputs (see Figure 61). These guard rings should be driven from a low-impedance source at the same voltage level as the common-mode input.

Unused amplifiers should be connected as grounded unity-gain followers to avoid oscillation.



**Figure 61. Use of Guard Rings**

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## APPLICATION INFORMATION

### output characteristics

All operating characteristics (except bandwidth and phase margin) are specified with 100-pF load capacitance. The TL03x and TL03xA drive higher capacitive loads; however, as the load capacitance increases, the resulting response pole occurs at lower frequencies, thereby causing ringing, peaking, or even oscillation. The value of the load capacitance at which oscillation occurs varies with production lots. If an application appears to be sensitive to oscillation due to load capacitance, adding a small resistance in series with the load should alleviate the problem (see Figure 63). Capacitive loads of 1000 pF and larger can be driven if enough resistance is added in series with the output (see Figure 62).

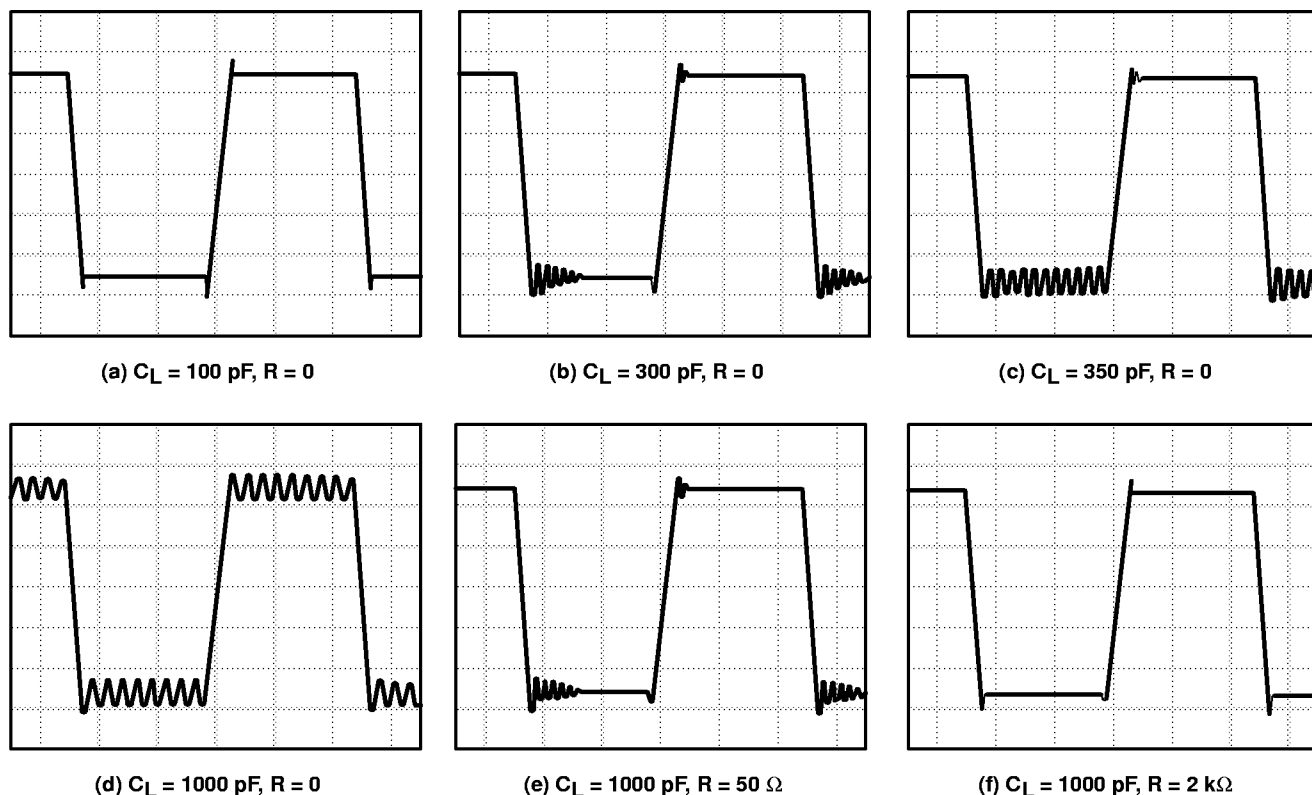


Figure 62. Effect of Capacitive Loads

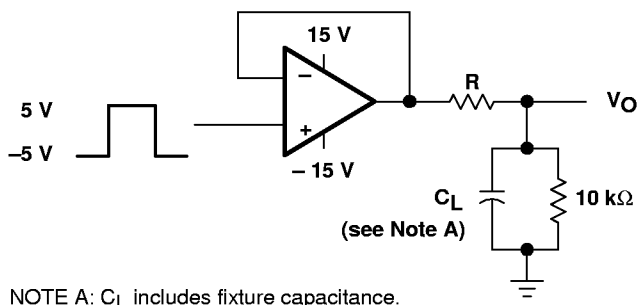


Figure 63. Test Circuit for Output Characteristics



APPLICATION INFORMATION

high-Q notch filter

In general, Texas Instruments enhanced-JFET operational amplifiers serve as excellent filters. The circuit in Figure 64 provides a narrow notch at a specific frequency. Notch filters are designed to eliminate frequencies that are interfering with the operation of an application. For this filter, the center frequency can be calculated as:

$$f_o = \frac{1}{2\pi \times R1 \times C1}$$

With the resistors and capacitors shown in Figure 64, the center frequency is 1 kHz.  $C1 = C3 = C2 + 2$  and  $R1 = R3 = 2 \times R2$ . The center frequency can be modified by varying these values. When adjusting the center frequency, ensure that the operational amplifier has sufficient gain at the frequency required.

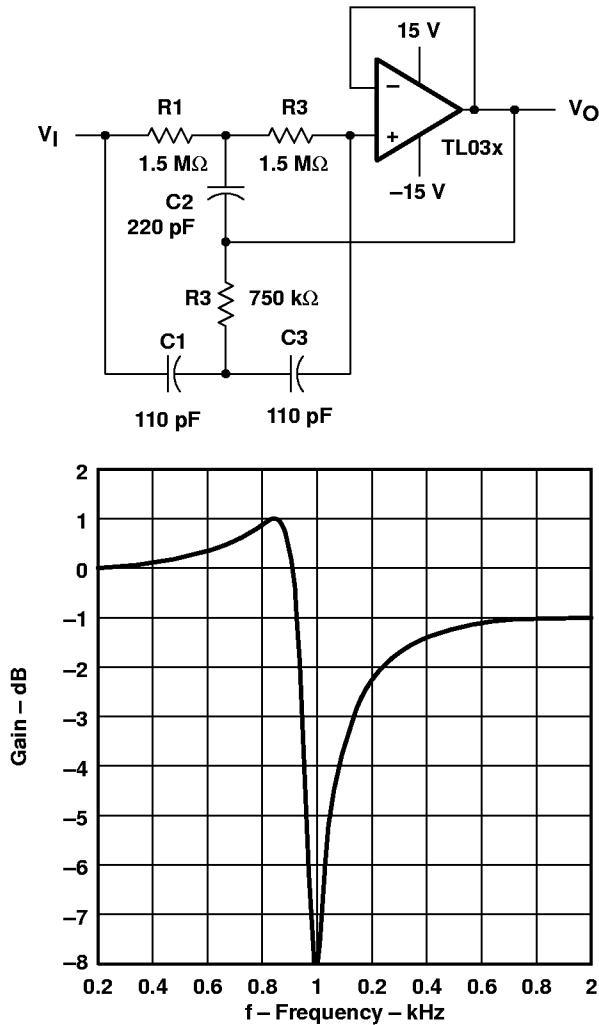


Figure 64. High-Q Notch Filter

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**APPLICATION INFORMATION**

**transimpedance amplifier**

The low-power precision TL03x allows accurate measurement of low currents. The high input impedance and low offset voltage of the TL03xA greatly simplify the design of a transimpedance amplifier. At room temperature, this design achieves 10-bit accuracy with an error of less than 1/2 LSB.

Assuming that R2 is much less than R1 and ignoring error terms, the output voltage can be expressed as:

$$V_O = -I_{IN} \times R_F \left( \frac{R1 + R2}{R2} \right)$$

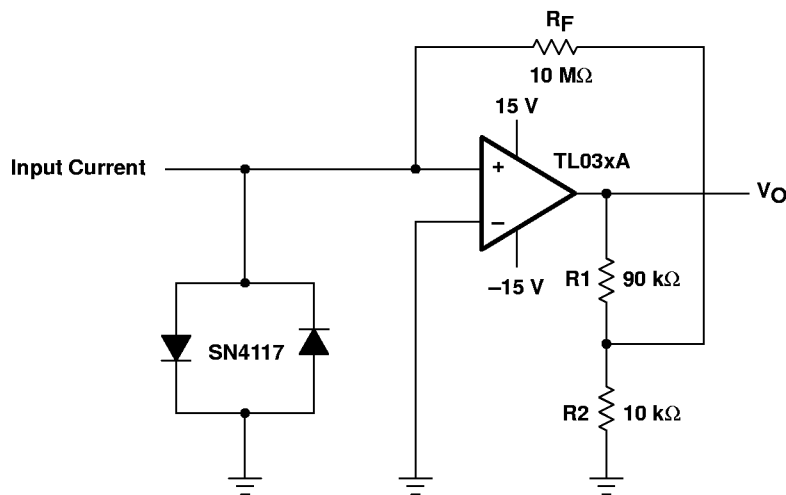
Using the resistor values shown in the schematic for a 1-nA input current, the output voltage equals -0.1 V. If the V<sub>O</sub> limit for the TL03xA is measured at ±12 V, the maximum input current for these resistor values is ±120 nA. Similarly, one LSB on a 10-bit scale corresponds to 12 mV of output voltage, or 120 pA of input current.

The following equation shows the effect of input offset voltage and input bias current on the output voltage:

$$V_O = - \left[ V_{IO} + R_F (I_{IO} + I_{IB}) \right] \left( \frac{R1 + R2}{R2} \right)$$

If the application requires input protection for the transimpedance amplifier, do not use standard PN diodes. Instead, use low-leakage Siliconix SN4117 JFETs (or equivalent) connected as diodes across the TL03xA inputs as shown in Figure 65.

As with all precision applications, special care must be taken to eliminate external sources of leakage and interference. Other precautions include using high-quality insulation, cleaning insulating surfaces to remove fluxes and other residue, and enclosing the application within a protective box.



**Figure 65. Transimpedance Amplifier**

## APPLICATION INFORMATION

### 4-mA to 20-mA current loops

Often, information from an analog sensor must be sent over a distance to the receiving circuitry. For many applications, the most feasible method involves converting voltage information to a current before transmission. The following circuits give two variations of low-power current loops. The circuit in Figure 66 requires three wires from the transmitting to receiving circuitry, while the second variation in Figure 67 requires only two wires, but includes an extra integrated circuit. Both circuits benefit from the high input impedance of the TL03xA because many inexpensive sensors do not have low output impedance.

Assuming that the voltage at the noninverting input of the TL03xA is zero, the following equation determines the output current:

$$I_O = V_I \left( \frac{R_3}{R_1 \times R_S} \right) + 5V \left( \frac{R_3}{R_2 \times R_S} \right) = 0.16 \times V_I + 4 \text{ mA}$$

The circuits presently provide 4-mA to 20-mA output current for an input voltage of 0 to 100 mV. By modifying R1, R2, and R3, the input voltage range or the output current range can be adjusted.

Including the offset voltage of the operational amplifier in the above equation clearly illustrates why the low offset TL03xA was chosen:

$$\begin{aligned} I_O &= V_I \left( \frac{R_3}{R_1 \times R_S} \right) + 5V \left( \frac{R_3}{R_2 \times R_S} \right) - V_I \left( \frac{R_3}{R_1 \times R_S} + \frac{R_3}{R_2 \times R_S} + \frac{R_1}{R_S} \right) \\ &= 0.16 \times V_I + 4 \text{ mA} - 0.17 \times V_I \end{aligned}$$

For example, an offset voltage of 1 mV decreases the output current by 0.17 mA.

Due to the low power consumption of the TL03xA, both circuits have at least 2 mA available to drive the actual sensor from the 5-V reference node.

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## 4-mA to 20-mA current loops (continued)

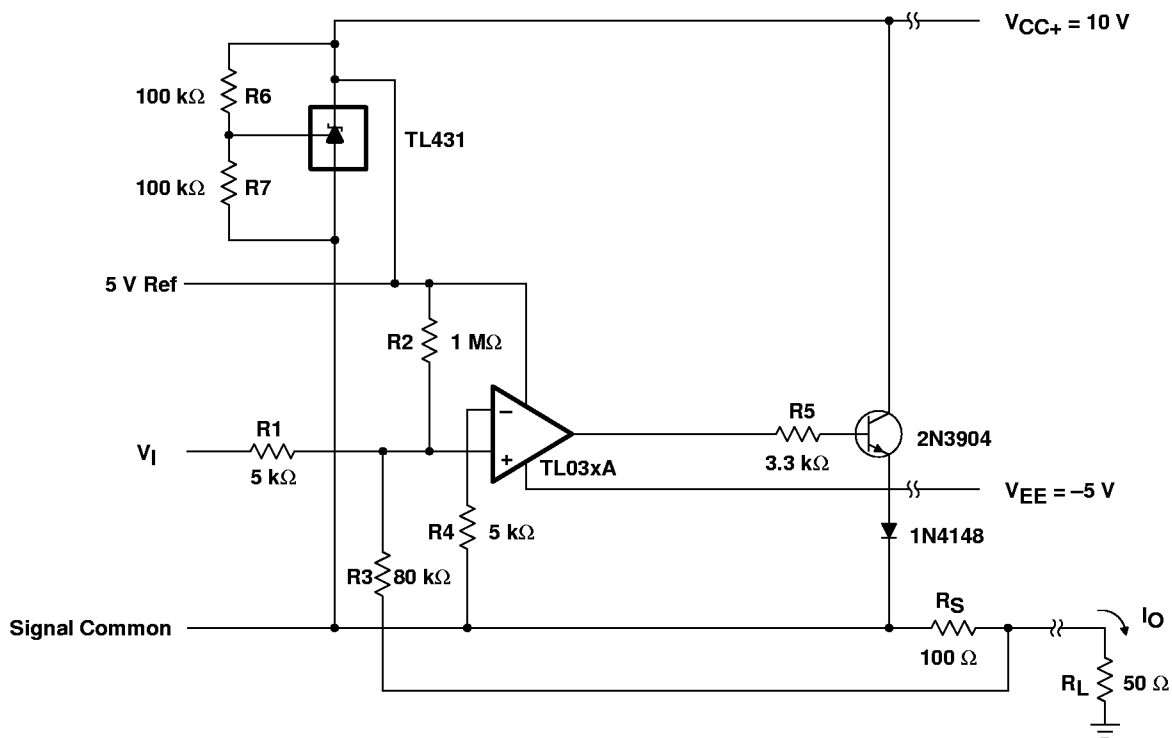


Figure 66. Three-Wire 4-mA to 20-mA Current Loop

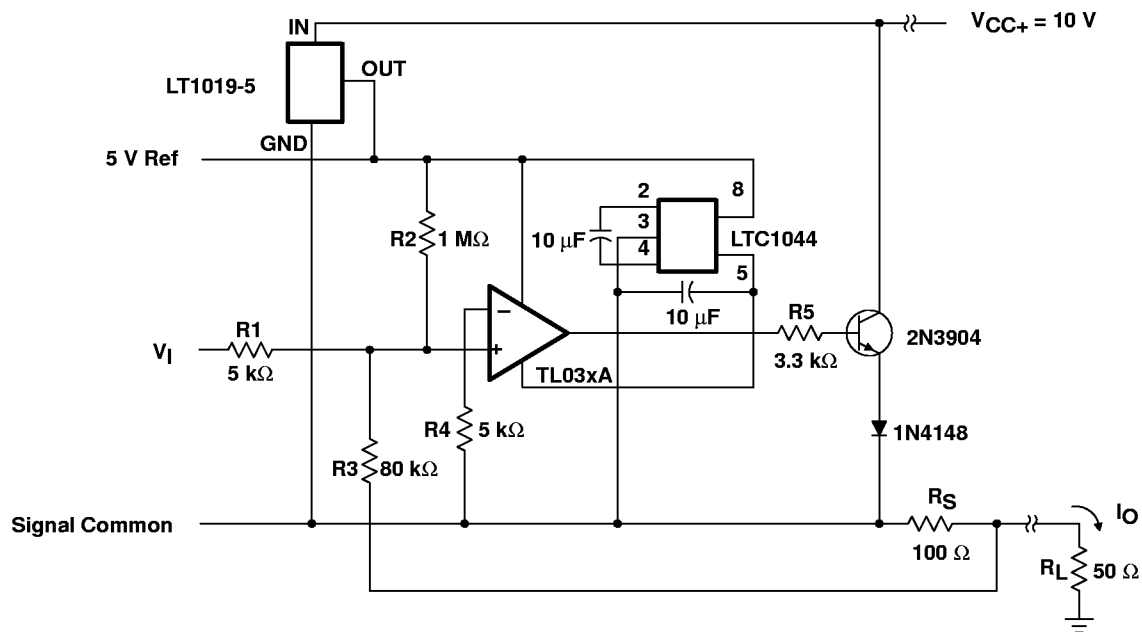


Figure 67. Two-Wire 4-mA to 20-mA Current Loop

APPLICATION INFORMATION

low-level light-detector preamplifier

Applications that need to detect small currents require high input-impedance operational amplifiers; otherwise, the bias currents of the operational amplifier camouflage the current being monitored. Phototransistors provide a current that is proportional to the light reaching the transistor. The TL03x allows even the small currents resulting from low-level light to be detected.

In Figure 68, if there is no light, the phototransistor is off and the output is high. As light is detected, the operational amplifier output begins pulling low. Adjusting R4 both compensates for offset voltage of the amplifier and adjusts the point of light detection by the amplifier.

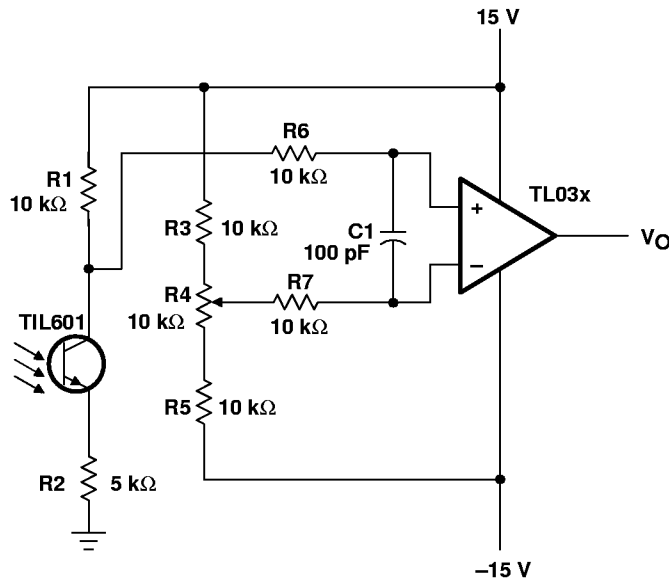


Figure 68. Low-Level Light-Detector Preamplifier

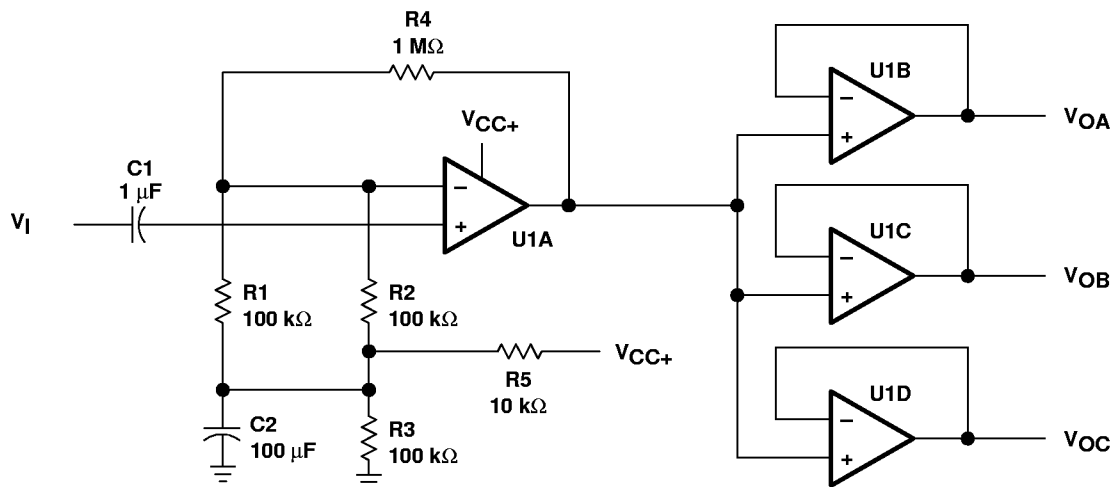
# TL03x, TL03xA, TL03xY ENHANCED-JFET LOW-POWER LOW-OFFSET OPERATIONAL AMPLIFIERS

SLOS180B – FEBRUARY 1997 – REVISED FEBRUARY 1999

## APPLICATION INFORMATION

### audio-distribution amplifier

This audio-distribution amplifier (see Figure 69) feeds the input signal to three separate output channels. U1A amplifies the input signal with a gain of 10, while U1B, U1C, and U1D serve as buffers to the output channels. The gain response of this circuit is very flat from 20 Hz to 20 kHz. The TL03x allows quick response to the input signal while maintaining low power consumption.



NOTE A: U1A through U1D = TL03x;  $V_{CC+} = 5\text{ V}$ .

Figure 69. Audio-Distribution Amplifier Circuit

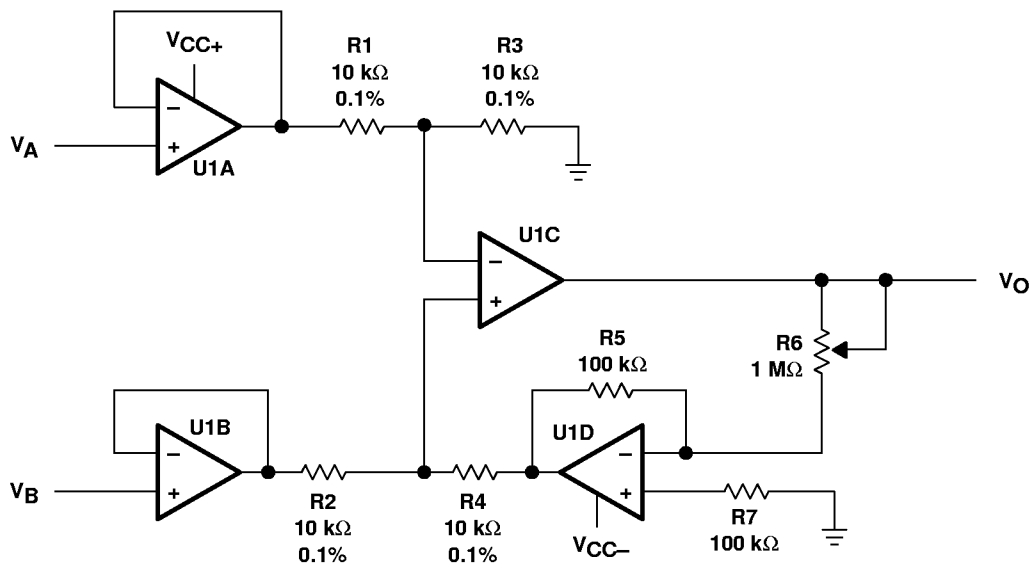
APPLICATION INFORMATION

Instrumentation amplifier with linear gain adjust

The low offset voltage and low power consumption of the TL03x provide an accurate but inexpensive instrumentation amplifier (see Figure 70). This particular configuration offers the advantage that the gain can be linearly set by one resistor:

$$V_O = \frac{R6}{R5} \times (V_B - V_A)$$

Adjusting R6 varies the gain. The value of R6 always should be greater than, or equal to, the value of R5 to ensure stability. The disadvantage of this instrumentation amplifier topology is the high degree of CMRR degradation resulting from mismatches between R1, R2, R3, and R4. For this reason, these four resistors should be 0.1%-tolerance resistors.



NOTE A: U1A through U1D = TL03x;  $V_{CC\pm} = \pm 15$  V.

Figure 70. Instrumentation Amplifier With Linear Gain-Adjust Circuit