

TLE2161, TLE2161A, TLE2161B

EXCALIBUR JFET-INPUT HIGH-OUTPUT-DRIVE μPOWER OPERATIONAL AMPLIFIERS

SLOS049D – NOVEMBER 1989 – REVISED MAY 1996

- **Excellent Output Drive Capability**
 $V_O = \pm 2.5 \text{ V Min at } R_L = 100 \ \Omega,$
 $V_{CC\pm} = \pm 5 \text{ V}$
 $V_O = \pm 12.5 \text{ V Min at } R_L = 600 \ \Omega,$
 $V_{CC\pm} = \pm 15 \text{ V}$
- **Low Supply Current . . . 280 μA Typ**
- **Decompensated for High Slew Rate and Gain-Bandwidth Product**
 $A_{VD} = 0.5 \text{ Min}$
Slew Rate = 10 V/μs Typ
Gain-Bandwidth Product = 6.5 MHz Typ

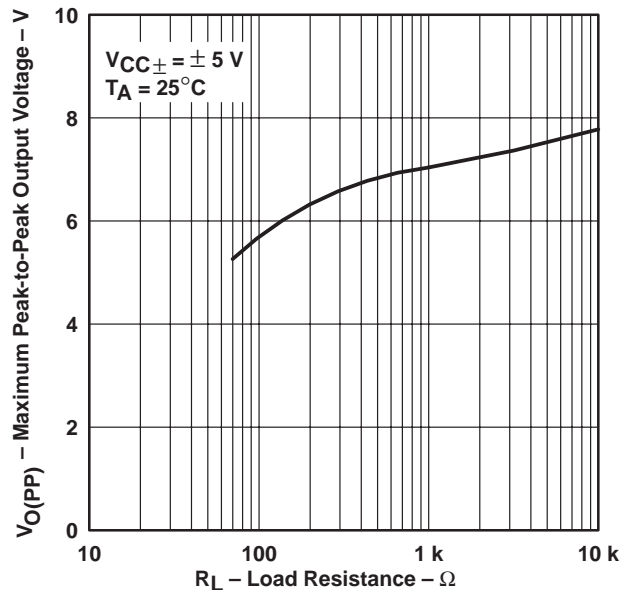
- **Wide Operating Supply Voltage Range**
 $V_{CC\pm} = \pm 3.5 \text{ V to } \pm 18 \text{ V}$
- **High Open-Loop Gain . . . 280 V/mV Typ**
- **Low Offset Voltage . . . 500 μV Max**
- **Low Offset Voltage Drift With Time**
0.04 μV/Month Typ
- **Low Input Bias Current . . . 5 pA Typ**

description

The TLE2161, TLE2161A, and TLE2161B are JFET-input, low-power, precision operational amplifiers manufactured using the Texas Instruments Excalibur process. Decompensated for stability with a minimum closed-loop gain of 5, these devices combine outstanding output drive capability with low power consumption, excellent dc precision, and high gain-bandwidth product.

In addition to maintaining the traditional JFET advantages of fast slew rates and low input bias and offset currents, the Excalibur process offers outstanding parametric stability over time and temperature. This results in a device that remains precise even with changes in temperature and over years of use.

**MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE
vs
LOAD RESISTANCE**



AVAILABLE OPTIONS

| T_A | V_{IOmax} AT 25°C | PACKAGE | | | |
|----------------------|--------------------------|------------------------------|--------------------------------|--|---------------------------------------|
| | | SMALL OUTLINE (D) | CHIP CARRIER (FK) | CERAMIC DIP (JG) | PLASTIC DIP (P) |
| 0°C to 70°C | 500 μV 1.5 mV 3 mV | — TLE2161ACD TLE2161CD | — — | — — | TLE2161BCP TLE2161ACP TLE2161CP |
| -40°C to 85°C | 500 μV 1.5 mV 3 mV | — TLE2161AID TLE2161ID | — — | — — | TLE2161BIP TLE2161AIP TLE2161IP |
| -55°C to 125°C | 500 μV 1.5 mV 3 mV | — TLE2161AMD TLE2161MD | — TLE2161AMFK TLE2161MFK | TLE2161BMJG TLE2161AMJG TLE2161MJG | TLE2161BMP TLE2161AMP TLE2161MP |

The D packages are available taped and reeled. Add R suffix to device type (e.g., TLE2161ACDR).



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

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**

POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

Copyright © 1996, Texas Instruments Incorporated

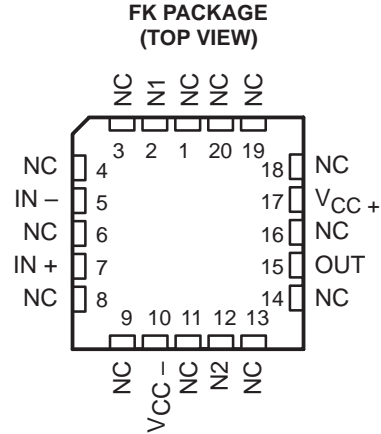
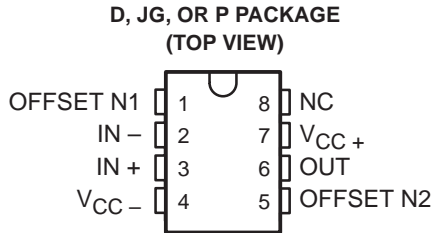
TLE2161, TLE2161A, TLE2161B EXCALIBUR JFET-INPUT HIGH-OUTPUT-DRIVE μPOWER OPERATIONAL AMPLIFIERS

SLOS049D – NOVEMBER 1989 – REVISED MAY 1996

description (continued)

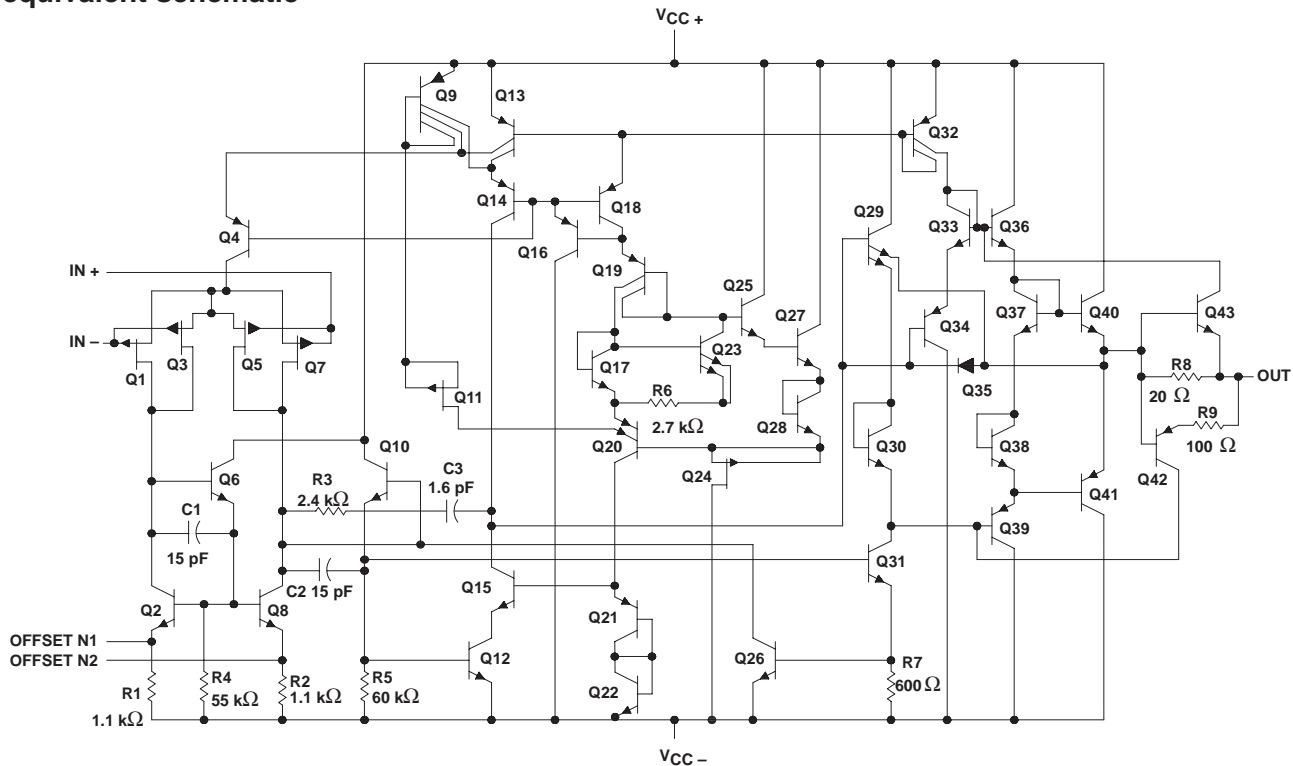
A variety of available options includes small-outline packages and chip-carrier versions for high-density system applications.

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



NC – No internal connection

equivalent schematic



All component values are nominal.

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

| | |
|--|------------------------------|
| Supply voltage, V_{CC+} (see Note 1) | 19 V |
| Supply voltage, V_{CC-} | – 19 V |
| Differential input voltage, V_{ID} (see Note 2) | ± 38 V |
| Input voltage range, V_I (any input) | $V_{CC\pm}$ |
| Input current, I_I (each input) | ± 1 mA |
| Output current, I_O | ± 80 mA |
| Total current into V_{CC+} | 80 mA |
| Total current out of V_{CC-} | 80 mA |
| Duration of short-circuit current at (or below) 25°C (see Note 3) | unlimited |
| Continuous total power dissipation | See Dissipation Rating Table |
| Operating free-air temperature range, T_A : C suffix | 0°C to 70°C |
| I suffix | – 40°C to 85°C |
| M suffix | – 55°C to 125°C |
| Storage temperature range, T_{stg} | – 65°C to 150°C |
| Case temperature for 60 seconds: FK package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60seconds: 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 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 | $T_A \leq 25^\circ\text{C}$ | DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$ | $T_A = 70^\circ\text{C}$ | $T_A = 85^\circ\text{C}$ | $T_A = 125^\circ\text{C}$ |
|---------|-----------------------------|---|--------------------------|--------------------------|---------------------------|
| | POWER RATING | | POWER RATING | POWER RATING | POWER RATING |
| D | 725 mW | 5.8 mW/°C | 464 mW | 377 mW | 145 mW |
| FK | 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 |
| P | 1000 mW | 8.0 mW/°C | 640 mW | 520 mW | 200 mW |

recommended operating conditions

| | C SUFFIX | | I SUFFIX | | M SUFFIX | | UNIT |
|---------------------------------------|----------------------|----------|-----------|----------|----------|----------|------|
| | MIN | MAX | MIN | MAX | MIN | MAX | |
| Supply voltage, $V_{CC\pm}$ | ± 3.5 | ± 18 | ± 3.5 | ± 18 | $+3.5$ | ± 18 | V |
| Common-mode input voltage, V_{IC} | $V_{CC\pm} \pm 5$ V | | –1.6 | 4 | –1.6 | 4 | V |
| | $V_{CC\pm} \pm 15$ V | | –11 | 13 | –11 | 13 | |
| Operating free-air temperature, T_A | 0 | 70 | –40 | 85 | –55 | 125 | °C |

TLE2161, TLE2161A, TLE2161B

EXCALIBUR JFET-INPUT HIGH-OUTPUT-DRIVE

μPOWER OPERATIONAL AMPLIFIERS

SLOS049D – NOVEMBER 1989 – REVISED MAY 1996

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

| PARAMETER | | TEST CONDITIONS | T_A † | TLE2161C, TLE2161AC TLE2161BC | | | UNIT | |
|-----------------|---|--|---|----------------------------------|------|---------------|------------------------------|--|
| | | | | MIN | TYP | MAX | | |
| V_{IO} | Input offset voltage | $V_{IC} = 0, \quad R_S = 50\ \Omega$ | 25°C | 0.8 | 3.1 | mV | | |
| | | | Full range | 4 | | | | |
| | | | 25°C | 0.6 | 2.6 | | | |
| | Full range | | 3.5 | | | | | |
| | 25°C | | 0.5 | 1.9 | | | | |
| | Full range | | 2.4 | | | | | |
| | αV_{IO} | | Temperature coefficient of input offset voltage | Full range | 6 | | $\mu\text{V}/^\circ\text{C}$ | |
| | Input offset voltage long-term drift (see Note 4) | | 25°C | 0.04 | | | $\mu\text{V}/\text{mo}$ | |
| | I_{IO} | | Input offset current | 25°C | 1 | | pA | |
| I_{IB} | Input bias current | Full range | 0.8 | | nA | | | |
| | | 25°C | 3 | | pA | | | |
| V_{ICR} | Common-mode input voltage range | 25°C | -1.6 to 4 | -2 to 6 | V | | | |
| | | Full range | -1.6 to 4 | | V | | | |
| V_{OM+} | Maximum positive peak output voltage swing | $R_L = 10\ \text{k}\Omega$ | 25°C | 3.5 | 3.7 | V | | |
| | | | Full range | 3.3 | | | | |
| | | $R_L = 100\ \Omega$ | 25°C | 2.5 | 3.1 | | | |
| | | | Full range | 2 | | | | |
| V_{OM-} | Maximum negative peak output voltage swing | $R_L = 10\ \text{k}\Omega$ | 25°C | -3.7 | -3.9 | V | | |
| | | | Full range | -3.3 | | | | |
| | | $R_L = 100\ \Omega$ | 25°C | -2.5 | -2.7 | | | |
| | | | Full range | -2 | | | | |
| A_{VD} | Large-signal differential voltage amplification | $V_O = \pm 2.8\ \text{V}, \quad R_L = 10\ \text{k}\Omega$ | 25°C | 15 | 80 | V/mV | | |
| | | | Full range | 2 | | | | |
| | | $V_O = 0\ \text{to}\ 2\ \text{V}, \quad R_L = 100\ \Omega$ | 25°C | 0.75 | 45 | | | |
| | | | Full range | 0.5 | | | | |
| | | $V_O = 0\ \text{to}\ -2\ \text{V}, \quad R_L = 100\ \Omega$ | 25°C | 0.5 | 3 | | | |
| | | | Full range | 0.25 | | | | |
| r_i | Input resistance | | 25°C | 10^{12} | | Ω | | |
| c_i | Input capacitance | | 25°C | 4 | | pF | | |
| z_o | Open-loop output impedance | $I_O = 0$ | 25°C | 280 | | Ω | | |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICRmin}, \quad R_S = 50\ \Omega$ | 25°C | 65 | 82 | dB | | |
| | | | Full range | 65 | | | | |
| kSVR | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC\pm} = \pm 5\ \text{V}\ \text{to}\ \pm 15\ \text{V}, \quad R_S = 50\ \Omega$ | 25°C | 75 | 93 | dB | | |
| | | | Full range | 75 | | | | |
| I_{CC} | Supply current | $V_O = 0, \quad \text{No load}$ | 25°C | 280 | 325 | μA | | |
| | | | Full range | 350 | | | | |
| ΔI_{CC} | Supply-current change over operating temperature range | | Full range | 29 | | μA | | |

† Full range is 0°C to 70°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150^\circ\text{C}$ extrapolated to $T_A = 25^\circ\text{C}$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.



TLE2161, TLE2161A, TLE2161B
EXCALIBUR JFET-INPUT HIGH-OUTPUT-DRIVE
 μ POWER OPERATIONAL AMPLIFIERS
SLOS049D – NOVEMBER 1989 – REVISED MAY 1996

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

| PARAMETER | TEST CONDITIONS | T_A † | TLE2161C, TLE2161AC TLE2161BC | | | UNIT |
|---|---|------------|----------------------------------|--------|-----|------------------------|
| | | | MIN | TYP | MAX | |
| SR Slew rate (see Figure 1) | $A_{VD} = 5, R_L = 10 \text{ k}\Omega, C_L = 100 \text{ pF}$ | 25°C | 7 | 10 | | V/ μ s |
| | | Full range | 5 | | | |
| V_n Equivalent input noise voltage (see Figure 2) | $R_S = 20 \Omega, f = 10 \text{ Hz}$ | 25°C | | 59 | 100 | nV/ $\sqrt{\text{Hz}}$ |
| | $R_S = 20 \Omega, f = 1 \text{ kHz}$ | | | 43 | 60 | |
| $V_{n(PP)}$ Peak-to-peak equivalent input noise voltage | $f = 0.1 \text{ Hz to } 10 \text{ Hz}$ | 25°C | | 1.1 | | μ V |
| I_n Equivalent input noise current | $f = 1 \text{ kHz}$ | 25°C | | 1 | | fA/ $\sqrt{\text{Hz}}$ |
| THD Total harmonic distortion | $V_{O(PP)} = 2 \text{ V}, A_{VD} = 5, f = 10 \text{ kHz}, R_L = 10 \text{ k}\Omega$ | 25°C | | 0.025% | | |
| Gain-bandwidth product (see Figure 3) | $f = 100 \text{ kHz}, R_L = 10 \text{ k}\Omega, C_L = 100 \text{ pF}$ | 25°C | | 5.8 | | MHz |
| | $f = 100 \text{ kHz}, R_L = 100 \text{ k}\Omega, C_L = 100 \text{ pF}$ | | | 4.3 | | |
| t_s Settling time | $\epsilon = 0.1\%$ | 25°C | | 5 | | μ s |
| | $\epsilon = 0.01\%$ | | | 10 | | |
| B_{OM} Maximum output-swing bandwidth | $A_{VD} = 5, R_L = 10 \text{ k}\Omega$ | 25°C | | 420 | | kHz |
| ϕ_m Phase margin (see Figure 3) | $A_{VD} = 5, R_L = 10 \text{ k}\Omega, C_L = 100 \text{ pF}$ | 25°C | | 70° | | |
| | $A_{VD} = 5, R_L = 100 \Omega, C_L = 100 \text{ pF}$ | | | 84° | | |

† Full range is 0°C to 70°C.

TLE2161, TLE2161A, TLE2161B

EXCALIBUR JFET-INPUT HIGH-OUTPUT-DRIVE

μPOWER OPERATIONAL AMPLIFIERS

SLOS049D – NOVEMBER 1989 – REVISED MAY 1996

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

| PARAMETER | | TEST CONDITIONS | T_A † | TLE2161C, TLE2161AC TLE2161BC | | | UNIT |
|-----------------|---|---|------------|----------------------------------|-----------|------------------------------|------|
| | | | | MIN | TYP | MAX | |
| V_{IO} | Input offset voltage | $V_{IC} = 0,$ $R_S = 50\ \Omega$ | 25°C | 0.6 | 3 | mV | |
| | | | Full range | 3.9 | | | |
| | | | 25°C | 0.5 | 1.5 | | |
| | | | Full range | 2.5 | | | |
| | | | 25°C | 0.3 | 0.5 | | |
| | | | Full range | 1 | | | |
| α_{VIO} | Temperature coefficient of input offset voltage | $V_{IC} = 0,$ $R_S = 50\ \Omega$ | Full range | 6 | | $\mu\text{V}/^\circ\text{C}$ | |
| | Input offset voltage long-term drift (see Note 4) | | 25°C | 0.04 | | $\mu\text{V}/\text{mo}$ | |
| I_{IO} | Input offset current | | 25°C | 2 | | pA | |
| | | | Full range | 1 | | nA | |
| I_{IB} | Input bias current | | 25°C | 4 | | pA | |
| | | | Full range | 3 | | nA | |
| V_{ICR} | Common-mode input voltage range | | 25°C | -11 to 13 | -12 to 16 | V | |
| | | | Full range | -11 to 13 | | V | |
| V_{OM+} | Maximum positive peak output voltage swing | $R_L = 10\ \text{k}\Omega$ | 25°C | 13.2 | 13.7 | V | |
| | | | Full range | 13 | | | |
| | | $R_L = 600\ \Omega$ | 25°C | 12.5 | 13.2 | | |
| | | | Full range | 12 | | | |
| V_{OM-} | Maximum negative peak output voltage swing | $R_L = 10\ \text{k}\Omega$ | 25°C | -13.2 | -13.7 | V | |
| | | | Full range | -13 | | | |
| | | $R_L = 600\ \Omega$ | 25°C | -12.5 | -13 | | |
| | | | Full range | -12 | | | |
| A_{VD} | Large-signal differential voltage amplification | $V_O = \pm 10\ \text{V},$ $R_L = 10\ \text{k}\Omega$ | 25°C | 30 | 230 | V/mV | |
| | | | Full range | 20 | | | |
| | | $V_O = 0\ \text{to}\ 8\ \text{V},$ $R_L = 600\ \Omega$ | 25°C | 25 | 100 | | |
| | | | Full range | 10 | | | |
| | | $V_O = 0\ \text{to}\ -8\ \text{V},$ $R_L = 600\ \Omega$ | 25°C | 3 | 25 | | |
| | | | Full range | 1 | | | |
| r_i | Input resistance | | 25°C | 10^{12} | | Ω | |
| c_i | Input capacitance | | 25°C | 4 | | pF | |
| z_o | Open-loop output impedance | $I_O = 0$ | 25°C | 280 | | Ω | |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICRmin},$ $R_S = 50\ \Omega$ | 25°C | 72 | 90 | dB | |
| | | | Full range | 70 | | | |
| k_{SVR} | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC\pm} = \pm 5\ \text{V}\ \text{to}\ \pm 15\ \text{V},$ $R_S = 50\ \Omega$ | 25°C | 75 | 93 | dB | |
| | | | Full range | 75 | | | |
| I_{CC} | Supply current | $V_O = 0,$ No load | 25°C | 290 | 350 | μA | |
| | | | Full range | 375 | | | |
| ΔI_{CC} | Supply-current change over operating temperature range | | Full range | 34 | | μA | |

† Full range is 0°C to 70°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150^\circ\text{C}$ extrapolated to $T_A = 25^\circ\text{C}$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.



TLE2161, TLE2161A, TLE2161B
EXCALIBUR JFET-INPUT HIGH-OUTPUT-DRIVE
μPOWER OPERATIONAL AMPLIFIERS
SLOS049D – NOVEMBER 1989 – REVISED MAY 1996

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

| PARAMETER | TEST CONDITIONS | T_A † | TLE2161C, TLE2161AC TLE2161BC | | | UNIT |
|---|---|------------|----------------------------------|--------|-----|------------------------|
| | | | MIN | TYP | MAX | |
| SR Slew rate (see Figure 1) | $A_{VD} = 5$, $R_L = 10$ k Ω , $C_L = 100$ pF | 25°C | 7 | 10 | | V/ μ s |
| | | Full range | 5 | | | |
| V_n Equivalent input noise voltage (see Figure 2) | $R_S = 20$ Ω , $f = 10$ Hz | 25°C | | 70 | 100 | nV/ $\sqrt{\text{Hz}}$ |
| | $R_S = 20$ Ω , $f = 1$ kHz | | | 40 | 60 | |
| $V_{n(PP)}$ Peak-to-peak equivalent input noise voltage | $f = 0.1$ Hz to 10 Hz | 25°C | | 1.1 | | μ V |
| I_n Equivalent input noise current | $f = 1$ kHz | 25°C | | 1.1 | | fA/ $\sqrt{\text{Hz}}$ |
| THD Total harmonic distortion | $V_{O(PP)} = 2$ V, $A_{VD} = 5$, $f = 10$ kHz, $R_L = 10$ k Ω | 25°C | | 0.025% | | |
| Gain-bandwidth product (see Figure 3) | $f = 100$ kHz, $R_L = 10$ k Ω , $C_L = 100$ pF | 25°C | | 6.4 | | MHz |
| | $f = 100$ kHz, $R_L = 600$ Ω , $C_L = 100$ pF | | | 5.6 | | |
| t_s Settling time | $\epsilon = 0.1\%$ | 25°C | | 5 | | μ s |
| | $\epsilon = 0.01\%$ | | | 10 | | |
| BOM Maximum output-swing bandwidth | $A_{VD} = 5$, $R_L = 10$ k Ω | 25°C | | 116 | | kHz |
| ϕ_m Phase margin (see Figure 3) | $A_{VD} = 5$, $R_L = 10$ k Ω , $C_L = 100$ pF | 25°C | | 72° | | |
| | $A_{VD} = 5$, $R_L = 600$ Ω , $C_L = 100$ pF | | | 78° | | |

† Full range is 0°C to 70°C.

TLE2161, TLE2161A, TLE2161B
EXCALIBUR JFET-INPUT HIGH-OUTPUT-DRIVE
μPOWER OPERATIONAL AMPLIFIERS

SLOS049D – NOVEMBER 1989 – REVISED MAY 1996

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

| PARAMETER | | TEST CONDITIONS | T_A † | TLE2161I, TLE2161AI TLE2161BI | | | UNIT |
|-----------------|---|--|------------|----------------------------------|---------|------------------------------|---------------|
| | | | | MIN | TYP | MAX | |
| V_{IO} | Input offset voltage | $V_{IC} = 0, R_S = 50\ \Omega$ | 25°C | 0.8 | 3.1 | mV | |
| | | | Full range | 4.4 | | | |
| | | | 25°C | 0.6 | 2.6 | | |
| | | | Full range | 3.9 | | | |
| | | | 25°C | 0.5 | 1.9 | | |
| | | | Full range | 2.7 | | | |
| α_{VIO} | Temperature coefficient of input offset voltage | $V_{IC} = 0, R_S = 50\ \Omega$ | Full range | 6 | | $\mu\text{V}/^\circ\text{C}$ | |
| | Input offset voltage long-term drift (see Note 4) | | 25°C | 0.04 | | $\mu\text{V}/\text{mo}$ | |
| I_{IO} | Input offset current | | 25°C | 1 | | pA | |
| | | | Full range | 2 | | nA | |
| I_{IB} | Input bias current | | 25°C | 3 | | pA | |
| | | | Full range | 4 | | nA | |
| V_{ICR} | Common-mode input voltage range | | 25°C | -1.6 to 4 | -2 to 6 | V | |
| | | | Full range | -1.6 to 4 | | | |
| V_{OM+} | Maximum positive peak output voltage | $R_L = 10\ \text{k}\Omega$ | 25°C | 3.5 | 3.7 | V | |
| | | | Full range | 3.1 | | | |
| | | $R_L = 100\ \Omega$ | 25°C | 2.5 | 3.1 | | |
| | | | Full range | 2 | | | |
| V_{OM-} | Maximum negative peak output voltage swing | $R_L = 10\ \text{k}\Omega$ | 25°C | -3.7 | -3.9 | V | |
| | | | Full range | -3.1 | | | |
| | | $R_L = 100\ \Omega$ | 25°C | -2.5 | -2.7 | | |
| | | | Full range | -2 | | | |
| A_{VD} | Large-signal differential voltage amplification | $V_O = \pm 2.8\ \text{V}, R_L = 10\ \text{k}\Omega$ | 25°C | 15 | 80 | V/mV | |
| | | | Full range | 2 | | | |
| | | $V_O = 0\ \text{to}\ 2\ \text{V}, R_L = 100\ \Omega$ | 25°C | 0.75 | 45 | | |
| | | | Full range | 0.5 | | | |
| | | $V_O = 0\ \text{to}\ -2\ \text{V}, R_L = 100\ \Omega$ | 25°C | 0.5 | 3 | | |
| | | | Full range | 0.25 | | | |
| r_i | Input resistance | | 25°C | 10 ¹² | | Ω | |
| c_i | Input capacitance | | 25°C | 4 | | pF | |
| z_o | Open-loop output impedance | $I_O = 0$ | 25°C | 280 | | Ω | |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICRmin}, R_S = 50\ \Omega$ | 25°C | 65 | 82 | dB | |
| | | | Full range | 65 | | | |
| kSVR | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC\pm} = \pm 5\ \text{V to } \pm 15\ \text{V}, R_S = 50\ \Omega$ | 25°C | 75 | 93 | dB | |
| | | | Full range | 65 | | | |
| I_{CC} | Supply current | $V_O = 0, \text{ No load}$ | 25°C | 280 | 325 | μA | |
| | | | Full range | 350 | | | |
| ΔI_{CC} | Supply-current change over operating temperature range | | | Full range | 29 | | μA |

† Full range is -40°C to 85°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150^\circ\text{C}$ extrapolated to $T_A = 25^\circ\text{C}$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.



TLE2161, TLE2161A, TLE2161B
EXCALIBUR JFET-INPUT HIGH-OUTPUT-DRIVE
μPOWER OPERATIONAL AMPLIFIERS
SLOS049D – NOVEMBER 1989 – REVISED MAY 1996

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

| PARAMETER | | TEST CONDITIONS | T_A † | TLE2161, TLE2161A TLE2161BI | | | UNIT |
|-------------|---|--|------------|--------------------------------|--------|-----|--------|
| | | | | MIN | TYP | MAX | |
| SR | Slew rate (see Figure 1) | $A_{VD} = 5$, $R_L = 10\text{ k}\Omega$, $C_L = 100\text{ pF}$ | 25°C | 7 | 10 | | V/μs |
| | | | Full range | 5 | | | |
| V_n | Equivalent input noise voltage (see Figure 2) | $R_S = 20\ \Omega$, $f = 10\text{ Hz}$ | 25°C | | 59 | 100 | nV/√Hz |
| | | $R_S = 20\ \Omega$, $f = 1\text{ kHz}$ | | | 43 | 60 | |
| $V_{n(PP)}$ | Peak-to-peak equivalent input noise voltage | $f = 0.1\text{ Hz to }10\text{ Hz}$ | 25°C | | 1.1 | | μV |
| I_n | Equivalent input noise current | $f = 1\text{ kHz}$ | 25°C | | 1 | | fA/√Hz |
| THD | Total harmonic distortion | $V_{O(PP)} = 2\text{ V}$, $R_L = 10\text{ k}\Omega$, $A_{VD} = 5$, $f = 10\text{ kHz}$ | 25°C | | 0.025% | | |
| | Gain-bandwidth product (see Figure 3) | $f = 100\text{ kHz}$, $R_L = 10\text{ k}\Omega$, $C_L = 100\text{ pF}$ | 25°C | | 5.8 | | MHz |
| | | $f = 100\text{ kHz}$, $R_L = 100\ \Omega$, $C_L = 100\text{ pF}$ | | | 4.3 | | |
| t_s | Settling time | $\epsilon = 0.1\%$ | 25°C | | 5 | | μs |
| | | $\epsilon = 0.01\%$ | | | 10 | | |
| B_{OM} | Maximum output-swing bandwidth | $A_{VD} = 5$, $R_L = 10\text{ k}\Omega$ | 25°C | | 420 | | kHz |
| ϕ_m | Phase margin (see Figure 3) | $A_{VD} = 5$, $R_L = 10\text{ k}\Omega$, $C_L = 100\text{ pF}$ | 25°C | | 70° | | |
| | | $A_{VD} = 5$, $R_L = 100\ \Omega$, $C_L = 100\text{ pF}$ | | | 84° | | |

† Full range is – 40°C to 85°C.

TLE2161, TLE2161A, TLE2161B
EXCALIBUR JFET-INPUT HIGH-OUTPUT-DRIVE
μPOWER OPERATIONAL AMPLIFIERS

SLOS049D – NOVEMBER 1989 – REVISED MAY 1996

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

| PARAMETER | | TEST CONDITIONS | T_A^\dagger | TLE2161, TLE2161A TLE2161B | | | UNIT |
|-----------------|---|--|---------------|-------------------------------|-----------|------------------------------|------|
| | | | | MIN | TYP | MAX | |
| V_{IO} | Input offset voltage | $V_{IC} = 0, R_S = 50\ \Omega$ | 25°C | 0.6 | 3 | mV | |
| | | | Full range | 4.3 | | | |
| | | | 25°C | 0.5 | 1.5 | | |
| | | | Full range | 2.9 | | | |
| | | | 25°C | 0.3 | 0.5 | | |
| | | | Full range | 1.3 | | | |
| α_{VIO} | Temperature coefficient of input offset voltage | $V_{IC} = 0, R_S = 50\ \Omega$ | Full range | 6 | | $\mu\text{V}/^\circ\text{C}$ | |
| | Input offset voltage long-term drift (see Note 4) | | 25°C | 0.04 | | $\mu\text{V}/\text{mo}$ | |
| I_{IO} | Input offset current | | 25°C | 2 | | pA | |
| | | | Full range | 3 | | nA | |
| I_{IB} | Input bias current | | 25°C | 4 | | pA | |
| | | | Full range | 5 | | nA | |
| V_{ICR} | Common-mode input voltage range | | 25°C | -11 to 13 | -12 to 16 | V | |
| | | | Full range | -11 to 13 | | V | |
| V_{OM+} | Maximum positive peak output voltage swing | $R_L = 10\ \text{k}\Omega$ | 25°C | 13.2 | 13.7 | V | |
| | | | Full range | 13 | | | |
| | | | 25°C | 12.5 | 13.2 | | |
| | | | Full range | 12 | | | |
| V_{OM-} | Maximum negative peak output voltage swing | $R_L = 10\ \text{k}\Omega$ | 25°C | -13.2 | -13.7 | V | |
| | | | Full range | -13 | | | |
| | | | 25°C | -12.5 | -13 | | |
| | | | Full range | -12 | | | |
| A_{VD} | Large-signal differential voltage amplification | $V_0 = \pm 10\ \text{V}, R_L = 10\ \text{k}\Omega$ | 25°C | 30 | 230 | V/mV | |
| | | | Full range | 20 | | | |
| | | $V_0 = 0\ \text{to}\ 8\ \text{V}, R_L = 600\ \Omega$ | 25°C | 25 | 100 | | |
| | | | Full range | 10 | | | |
| | | $V_0 = 0\ \text{to}\ -8\ \text{V}, R_L = 600\ \Omega$ | 25°C | 3 | 25 | | |
| | | | Full range | 1 | | | |
| r_i | Input resistance | | 25°C | 10^{12} | | Ω | |
| c_i | Input capacitance | | 25°C | 4 | | pF | |
| z_o | Open-loop output impedance | $I_O = 0$ | 25°C | 280 | | Ω | |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICRmin}, R_S = 50\ \Omega$ | 25°C | 72 | 90 | dB | |
| | | | Full range | 65 | | | |
| k_{SVR} | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC\pm} = \pm 5\ \text{V to } \pm 15\ \text{V}, R_S = 50\ \Omega$ | 25°C | 75 | 93 | dB | |
| | | | Full range | 65 | | | |
| I_{CC} | Supply current | $V_0 = 0, \text{ No load}$ | 25°C | 290 | 350 | μA | |
| | | | Full range | 375 | | | |
| ΔI_{CC} | Supply-current change over operating temperature range | | Full range | 34 | | μA | |

† Full range is -40°C to 85°C .

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150^\circ\text{C}$ extrapolated to $T_A = 25^\circ\text{C}$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.



TLE2161, TLE2161A, TLE2161B
EXCALIBUR JFET-INPUT HIGH-OUTPUT-DRIVE
μPOWER OPERATIONAL AMPLIFIERS
SLOS049D – NOVEMBER 1989 – REVISED MAY 1996

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

| PARAMETER | TEST CONDITIONS | T_A † | TLE2161, TLE2161A TLE2161B | | | UNIT |
|---|---|------------|-------------------------------|--------|-----|------------------------|
| | | | MIN | TYP | MAX | |
| SR Slew rate (see Figure 1) | $A_{VD} = 5$, $R_L = 10$ k Ω , $C_L = 100$ pF | 25°C | 7 | 10 | | V/ μ s |
| | | Full range | 5 | | | |
| V_n Equivalent input noise voltage (see Figure 2) | $R_S = 20$ Ω , $f = 10$ Hz | 25°C | | 70 | 100 | nV/ $\sqrt{\text{Hz}}$ |
| | $R_S = 20$ Ω , $f = 1$ kHz | | | 40 | 60 | |
| $V_{n(PP)}$ Peak-to-peak equivalent input noise voltage | $f = 0.1$ Hz to 10 Hz | 25°C | | 1.1 | | μ V |
| I_n Equivalent input noise current | $f = 1$ kHz | 25°C | | 1.1 | | fA/ $\sqrt{\text{Hz}}$ |
| THD Total harmonic distortion | $V_{O(PP)} = 2$ V, $A_{VD} = 5$, $f = 10$ kHz, $R_L = 10$ k Ω | 25°C | | 0.025% | | |
| Gain-bandwidth product (see Figure 3) | $f = 100$ kHz, $R_L = 10$ k Ω , $C_L = 100$ pF | 25°C | | 6.4 | | MHz |
| | $f = 100$ kHz, $R_L = 600$ Ω , $C_L = 100$ pF | | | 5.6 | | |
| t_s Settling time | $\epsilon = 0.1\%$ | 25°C | | 5 | | μ s |
| | $\epsilon = 0.01\%$ | | | 10 | | |
| B_{OM} Maximum output-swing bandwidth | $A_{VD} = 5$, $R_L = 10$ k Ω | 25°C | | 116 | | kHz |
| ϕ_m Phase margin (see Figure 3) | $A_{VD} = 5$, $R_L = 10$ k Ω , $C_L = 100$ pF | 25°C | | 72° | | |
| | $A_{VD} = 5$, $R_L = 600$ Ω , $C_L = 100$ pF | | | 78° | | |

† Full range is – 40°C to 85°C.

TLE2161, TLE2161A, TLE2161B

EXCALIBUR JFET-INPUT HIGH-OUTPUT-DRIVE

μPOWER OPERATIONAL AMPLIFIERS

SLOS049D – NOVEMBER 1989 – REVISED MAY 1996

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

| PARAMETER | | TEST CONDITIONS | T_A^\dagger | TLE2161M TLE2161AM TLE2161BM | | | UNIT | | | | | |
|----------------|---|-------------------------------------|--|------------------------------------|-----|-----|------------|-----------|------------------------------|------|------|------|
| | | | | MIN | TYP | MAX | | | | | | |
| V_{IO} | Input offset voltage | | | | | | 25°C | 0.8 | 3.1 | mV | | |
| | | | | | | | Full range | | 6 | | | |
| | | | | | | | 25°C | 0.6 | 2.6 | | | |
| | | | | | | | Full range | | 4.6 | | | |
| | | | | | | | 25°C | 0.5 | 1.9 | | | |
| | | | | | | | Full range | | 3.1 | | | |
| α_{VIO} | Temperature coefficient of input offset voltage | $V_{IC} = 0,$ $R_S = 50\ \Omega$ | | | | | Full range | 6 | $\mu\text{V}/^\circ\text{C}$ | | | |
| | Input offset voltage long-term drift (see Note 4) | | | | | | 25°C | 0.04 | $\mu\text{V}/\text{mo}$ | | | |
| I_{IO} | Input offset current | | | | | | 25°C | 1 | pA | | | |
| I_{IB} | Input bias current | | | | | | Full range | 15 | nA | | | |
| | | | | | | | 25°C | 3 | pA | | | |
| V_{ICR} | Common-mode input voltage range | | | | | | 25°C | -1.6 to 4 | -2 to 6 | V | | |
| | | | | | | | Full range | -1.6 to 4 | | V | | |
| V_{OM+} | Maximum positive peak output voltage swing | All packages | $R_L = 10\ \text{k}\Omega$ | | | | 25°C | 3.5 | 3.7 | V | | |
| | | | | | | | Full range | | 3 | | | |
| | | FK and JG packages | $R_L = 600\ \Omega$ | | | | | | 25°C | 2.5 | 3.6 | V |
| | | | | | | | | | Full range | | 2 | |
| | | D and P packages | $R_L = 100\ \Omega$ | | | | | | 25°C | 2.5 | 3.1 | V |
| | | | | | | | | | Full range | | 2 | |
| V_{OM-} | Maximum negative peak output voltage swing | All packages | $R_L = 10\ \text{k}\Omega$ | | | | 25°C | -3.7 | -3.9 | V | | |
| | | | | | | | Full range | | -3 | | | |
| | | FK and JG packages | $R_L = 600\ \Omega$ | | | | | | 25°C | -2.5 | -3.5 | V |
| | | | | | | | | | Full range | | -2 | |
| | | D and P packages | $R_L = 100\ \Omega$ | | | | | | 25°C | -2.5 | -2.7 | V |
| | | | | | | | | | Full range | | -2 | |
| AVD | Large-signal differential voltage amplification | All packages | $V_0 = \pm 2.8\ \text{V},$ $R_L = 10\ \text{k}\Omega$ | | | | 25°C | 15 | 80 | V/mV | | |
| | | | | | | | Full range | | 2 | | | |
| | | FK and JG packages | $V_0 = 0\ \text{to}\ 2.5\ \text{V},$ $R_L = 600\ \Omega$ | | | | | | 25°C | | 1 | 65 |
| | | | | | | | | | Full range | | | 0.5 |
| | | FK and JG packages | $V_0 = 0\ \text{to}\ -2.5\ \text{V},$ $R_L = 600\ \Omega$ | | | | | | 25°C | | 1 | 16 |
| | | | | | | | | | Full range | | | 0.5 |
| | | D and P packages | $V_0 = 0\ \text{to}\ 2\ \text{V},$ $R_L = 100\ \Omega$ | | | | | | 25°C | | 0.75 | 45 |
| | | | | | | | | | Full range | | | 0.5 |
| | | D and P packages | $V_0 = 0\ \text{to}\ -2\ \text{V},$ $R_L = 100\ \Omega$ | | | | | | 25°C | | 0.5 | 3 |
| | | | | | | | | | Full range | | | 0.25 |

† Full range is -55°C to 125°C .

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150^\circ\text{C}$ extrapolated to $T_A = 25^\circ\text{C}$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.



POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

TLE2161, TLE2161A, TLE2161B
EXCALIBUR JFET-INPUT HIGH-OUTPUT-DRIVE
μPOWER OPERATIONAL AMPLIFIERS
 SLOS049D – NOVEMBER 1989 – REVISED MAY 1996

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

| PARAMETER | TEST CONDITIONS | T_A † | TLE2161M TLE2161AM TLE2161BM | | | UNIT |
|---|--|------------|------------------------------------|-----|-----|------|
| | | | MIN | TYP | MAX | |
| r_i Input resistance | | 25°C | 10 ¹² | | | Ω |
| c_i Input capacitance | | 25°C | 4 | | | pF |
| z_o Open-loop output impedance | $I_O = 0$ | 25°C | 280 | | | Ω |
| CMRR Common-mode rejection ratio | $V_{IC} = V_{ICRmin}, R_S = 50\ \Omega$ | 25°C | 65 | 82 | | dB |
| | | Full range | 60 | | | |
| k_{SVR} Supply-voltage rejection ratio ($\Delta V_{CC\pm}/\Delta V_{IO}$) | $V_{CC\pm} = \pm 5\text{ V to } \pm 15\text{ V}, R_S = 50\ \Omega$ | 25°C | 75 | 93 | | dB |
| | | Full range | 65 | | | |
| I_{CC} Supply current | $V_O = 0,$ No load | 25°C | 280 | 325 | | μA |
| | | Full range | 350 | | | |
| ΔI_{CC} Supply-current change over operating temperature range | | Full range | 39 | | | μA |

† Full range is –55°C to 125°C.

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

| PARAMETER | TEST CONDITIONS | TLE2161M TLE2161AM TLE2161BM | | | UNIT |
|---|--|------------------------------------|-----|-----|--------|
| | | MIN | TYP | MAX | |
| SR Slew rate (see Figure 1) | $A_{VD} = 5, R_L = 10\text{ k}\Omega, C_L = 100\text{ pF}$ | 10 | | | V/μs |
| V_n Equivalent input noise voltage (see Figure 2) | $R_S = 20\ \Omega, f = 10\text{ Hz}$ | 59 | | | nV/√Hz |
| | $R_S = 20\ \Omega, f = 1\text{ kHz}$ | 43 | | | |
| $V_n(PP)$ Peak-to-peak equivalent input noise voltage | $f = 0.1\text{ Hz to } 10\text{ Hz}$ | 1.1 | | | μV |
| I_n Equivalent input noise current | $f = 1\text{ kHz}$ | 1 | | | fA/√Hz |
| THD Total harmonic distortion | $A_{VD} = 5, R_L = 10\text{ k}\Omega, V_O(PP) = 2\text{ V}, f = 10\text{ kHz}$ | 0.025% | | | |
| Gain-bandwidth product (see Figure 3) | $f = 100\text{ kHz}, R_L = 10\text{ k}\Omega, C_L = 100\text{ pF}$ | 5.8 | | | MHz |
| | $f = 100\text{ kHz}, R_L = 600\text{ k}\Omega, C_L = 100\text{ pF}$ | 4.3 | | | |
| t_s Settling time | $\epsilon = 0.1\%$ | 5 | | | μs |
| | $\epsilon = 0.01\%$ | 10 | | | |
| B_{OM} Maximum output-swing bandwidth | $A_{VD} = 5, R_L = 10\text{ k}\Omega$ | 420 | | | kHz |
| ϕ_m Phase margin (see Figure 3) | $A_{VD} = 5, R_L = 10\text{ k}\Omega, C_L = 100\text{ pF}$ | 70° | | | |
| | $A_{VD} = 5, R_L = 600\ \Omega, C_L = 100\text{ pF}$ | 84° | | | |

TLE2161, TLE2161A, TLE2161B
EXCALIBUR JFET-INPUT HIGH-OUTPUT-DRIVE
μPOWER OPERATIONAL AMPLIFIERS

SLOS049D – NOVEMBER 1989 – REVISED MAY 1996

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

| PARAMETER | | TEST CONDITIONS | T_A † | TLE2161M TLE2161AM TLE2161BM | | | UNIT |
|---|---|--|------------|------------------------------------|-------|------------------------------|------|
| | | | | MIN | TYP | MAX | |
| V_{IO} | Input offset voltage | $V_{IC} = 0, R_S = 50\ \Omega$ | 25°C | 0.6 | 3 | mV | |
| | | | Full range | 6 | | | |
| | | | 25°C | 0.5 | 1.5 | | |
| | | | Full range | 3.6 | | | |
| | | | 25°C | 0.3 | 0.5 | | |
| | | | Full range | 1.7 | | | |
| αV_{IO} | Temperature coefficient of input offset voltage | $V_{IC} = 0, R_S = 50\ \Omega$ | Full range | 6 | | $\mu\text{V}/^\circ\text{C}$ | |
| Input offset voltage long-term drift (see Note 4) | | | 25°C | 0.04 | | $\mu\text{V}/\text{mo}$ | |
| I_{IO} | Input offset current | | 25°C | 2 | | pA | |
| | | | Full range | 20 | | nA | |
| I_{IB} | Input bias current | 25°C | 4 | | pA | | |
| | | Full range | 40 | | nA | | |
| V_{ICR} | Common-mode input voltage range | 25°C | -11 to 13 | -12 to 16 | V | | |
| | | Full range | -11 to 13 | | V | | |
| V_{OM+} | Maximum positive peak output voltage swing | $R_L = 10\ \text{k}\Omega$ | 25°C | 13.2 | 13.7 | V | |
| | | | Full range | 12.5 | | | |
| | | $R_L = 600\ \Omega$ | 25°C | 12.5 | 13.2 | | |
| | | | Full range | 12 | | | |
| V_{OM-} | Maximum negative peak output voltage swing | $R_L = 10\ \text{k}\Omega$ | 25°C | -13.2 | -13.7 | V | |
| | | | Full range | -12.5 | | | |
| | | $R_L = 600\ \Omega$ | 25°C | -12.5 | -13 | | |
| | | | Full range | -12 | | | |
| A_{VD} | Large-signal differential voltage amplification | $V_O = \pm 10\ \text{V}, R_L = 10\ \text{k}\Omega$ | 25°C | 30 | 230 | V/mV | |
| | | | Full range | 20 | | | |
| | | $V_O = 0\ \text{to}\ 8\ \text{V}, R_L = 600\ \Omega$ | 25°C | 25 | 100 | | |
| | | | Full range | 7 | | | |
| | | $V_O = 0\ \text{to}\ -8\ \text{V}, R_L = 600\ \Omega$ | 25°C | 3 | 25 | | |
| | | | Full range | 1 | | | |
| r_i | Input resistance | | 25°C | 10 ¹² | | Ω | |
| c_i | Input capacitance | | 25°C | 4 | | pF | |
| z_o | Open-loop output impedance | $I_O = 0$ | 25°C | 280 | | Ω | |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICR\text{min}}, R_S = 50\ \Omega$ | 25°C | 72 | 90 | dB | |
| | | | Full range | 65 | | | |
| k_{SVR} | Supply-voltage rejection ratio ($\Delta V_{CC\pm} / \Delta V_{IO}$) | $V_{CC\pm} = \pm 5\ \text{V to } \pm 15\ \text{V}, R_S = 50\ \Omega$ | 25°C | 75 | 93 | dB | |
| | | | Full range | 65 | | | |
| I_{CC} | Supply current | $V_O = 0, \text{ No load}$ | 25°C | 290 | 350 | μA | |
| | | | Full range | 375 | | | |
| ΔI_{CC} | Supply-current change over operating temperature range | | Full range | 46 | | μA | |

† Full range is -55°C to 125°C.

NOTE 4: Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150^\circ\text{C}$ extrapolated to $T_A = 25^\circ\text{C}$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.



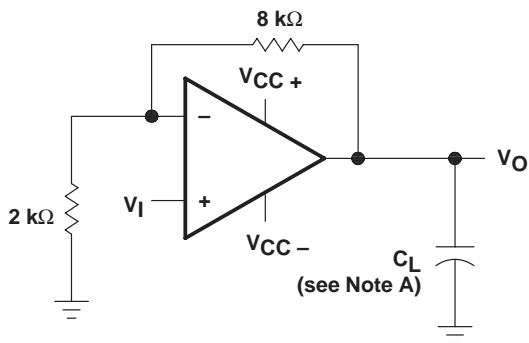
TLE2161, TLE2161A, TLE2161B
EXCALIBUR JFET-INPUT HIGH-OUTPUT-DRIVE
 μ POWER OPERATIONAL AMPLIFIERS
SLOS049D – NOVEMBER 1989 – REVISED MAY 1996

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

| PARAMETER | TEST CONDITIONS | T_A † | TLE2161M TLE2161AM TLE2161BM | | | UNIT |
|---|---|------------|------------------------------------|-----|-----|------------------------|
| | | | MIN | TYP | MAX | |
| SR Slew rate (see Figure 1) | $A_{VD} = 5, R_L = 10 \text{ k}\Omega, C_L = 100 \text{ pF}$ | 25°C | 7 | 10 | | V/ μ s |
| | | Full range | 5 | | | |
| V_n Equivalent input noise voltage (see Figure 2) | $R_S = 20 \Omega, f = 10 \text{ Hz}$ | 25°C | 70 | | | nV/ $\sqrt{\text{Hz}}$ |
| | $R_S = 20 \Omega, f = 1 \text{ kHz}$ | | 40 | | | |
| $V_{N(PP)}$ Peak-to-peak equivalent input noise voltage | $f = 0.1 \text{ Hz to } 10 \text{ Hz}$ | 25°C | 1.1 | | | μ V |
| I_n Equivalent input noise current | $f = 1 \text{ Hz}$ | 25°C | 1.1 | | | fA/ $\sqrt{\text{Hz}}$ |
| THD Total harmonic distortion | $V_{O(PP)} = 2 \text{ V}, A_{VD} = 5, f = 10 \text{ kHz}, R_L = 10 \text{ k}\Omega$ | 25°C | 0.025% | | | |
| Gain-bandwidth product (see Figure 3) | $f = 100 \text{ kHz}, R_L = 10 \text{ k}\Omega, C_L = 100 \text{ pF}$ | 25°C | 6.4 | | | MHz |
| | $f = 100 \text{ kHz}, R_L = 600 \Omega, C_L = 100 \text{ pF}$ | | 5.6 | | | |
| t_s Settling time | $\epsilon = 0.1\%$ | 25°C | 5 | | | μ s |
| | $\epsilon = 0.01\%$ | | 10 | | | |
| B_{OM} Maximum output-swing bandwidth | $A_{VD} = 5, R_L = 10 \text{ k}\Omega$ | 25°C | 116 | | | kHz |
| ϕ_m Phase margin (see Figure 3) | $A_{VD} = 5, R_L = 10 \text{ k}\Omega, C_L = 100 \text{ pF}$ | 25°C | 72° | | | |
| | $A_{VD} = 5, R_L = 600 \Omega, C_L = 100 \text{ pF}$ | | 78° | | | |

† Full range is – 55°C to 125°C.

PARAMETER MEASUREMENT INFORMATION



NOTE A: C_L includes fixture capacitance.

Figure 1. Slew-Rate Test Circuit

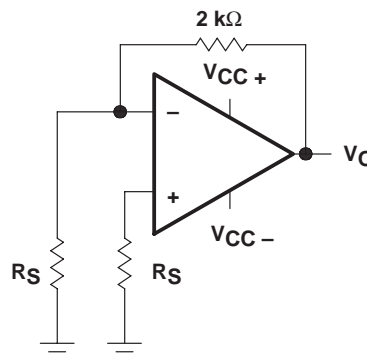
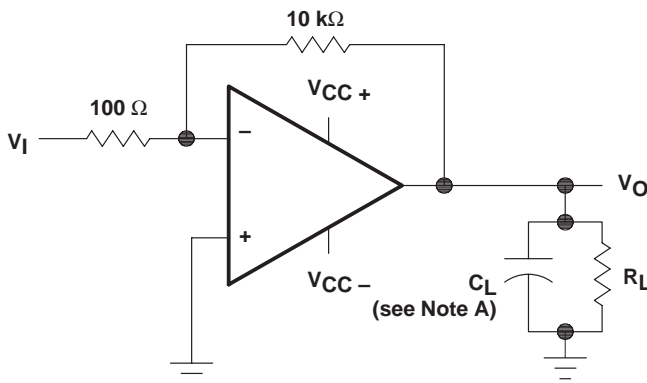


Figure 2. Noise-Voltage Test Circuit



NOTE A: C_L includes fixture capacitance.

Figure 3. Gain-Bandwidth Product and Phase-Margin Test Circuit

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 TLE2161, TLE2161A, and TLE2161B, accurate measurement of the bias current becomes difficult. Not only does this measurement require a picoammeter, but test socket leakages can easily 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.

TYPICAL CHARACTERISTICS

Table of Graphs

| | | | FIGURE |
|-------------|---|------------------------------------|------------|
| V_{IO} | Input offset voltage | Distribution | 4 |
| I_{IB} | Input bias current | vs Common-mode input voltage | 5 |
| | | vs Free-air temperature | 6 |
| I_{IO} | Input offset current | vs Free-air temperature | 6 |
| V_{ICR} | Common-mode input voltage range limits | vs Free-air temperature | 7 |
| V_{OM} | Maximum positive peak output voltage | vs Output current | 8 |
| V_{OM} | Maximum negative peak output voltage | vs Output current | 9 |
| V_{OM} | Maximum peak output voltage | vs Supply voltage | 10, 11, 12 |
| $V_{O(PP)}$ | Maximum peak-to-peak output voltage | vs Frequency | 13, 14, 15 |
| A_{VD} | Large-signal differential voltage amplification | vs Frequency | 16 |
| | | vs Free-air temperature | 17 |
| I_{OS} | Short-circuit output current | vs Elapsed time | 18 |
| | | Large-signal voltage amplification | 19 |
| z_o | Output impedance | vs Frequency | 20 |
| CMRR | Common-mode rejection ratio | vs Frequency | 21 |
| I_{CC} | Supply current | vs Supply voltage | 22 |
| | | vs Free-air temperature | 23 |
| | Pulse response | Small signal | 24, 25 |
| | | Large signal | 26, 27 |
| | Noise voltage (referred to input) | 0.1 to 10 Hz | 28 |
| V_n | Equivalent input noise voltage | vs Frequency | 29 |
| THD | Total harmonic distortion | vs Frequency | 30, 31 |
| | | Gain-bandwidth product | 32 |
| | | vs Supply voltage | 33 |
| | | vs Free-air temperature | 33 |
| ϕ_m | Phase margin | vs Supply voltage | 34 |
| | | vs Free-air temperature | 35 |
| | Phase shift | vs Frequency | 16 |

TYPICAL CHARACTERISTICS†

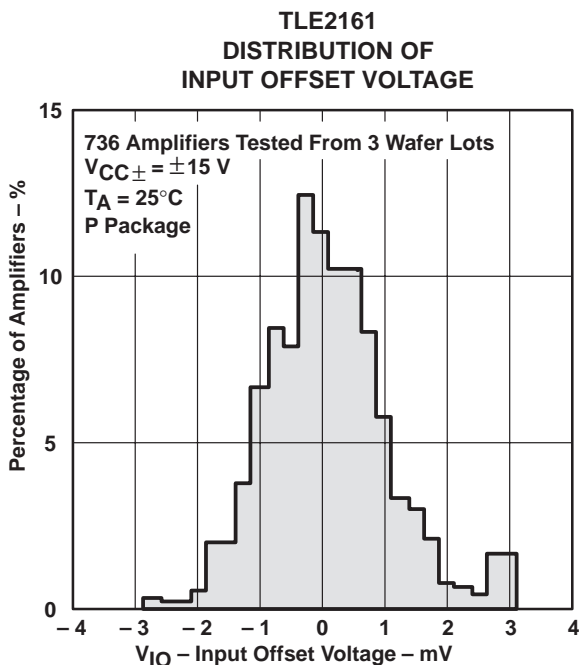


Figure 4

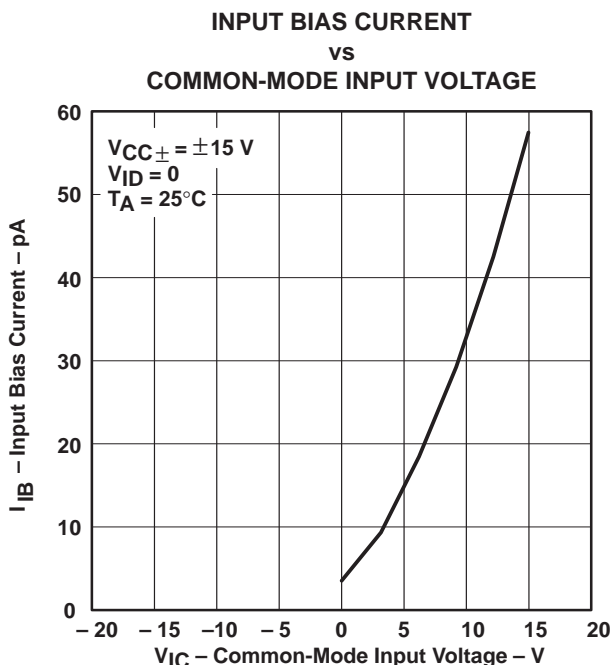


Figure 5

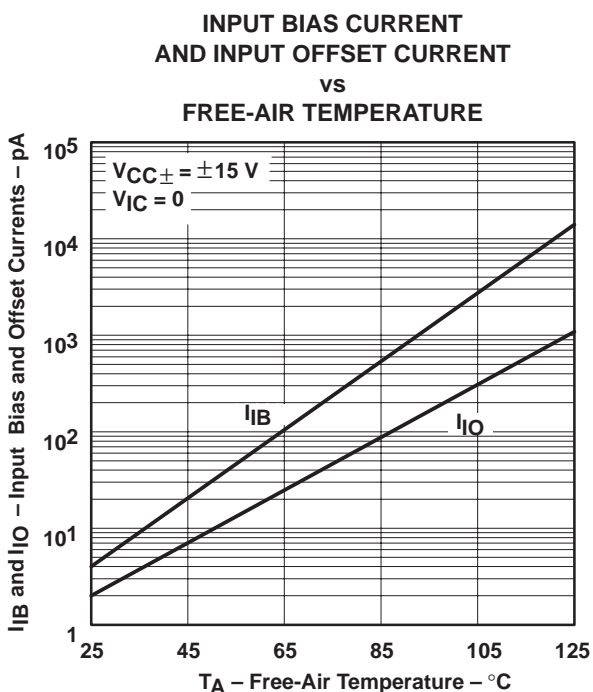


Figure 6

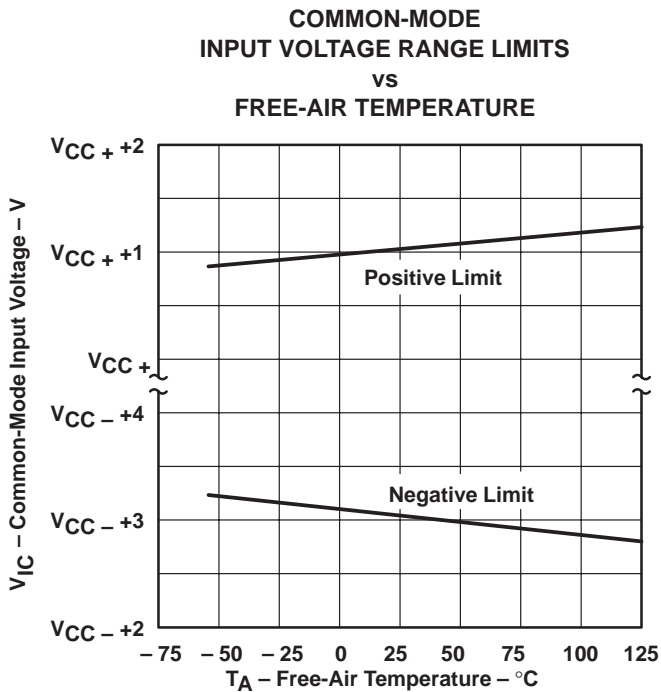


Figure 7

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

TYPICAL CHARACTERISTICS

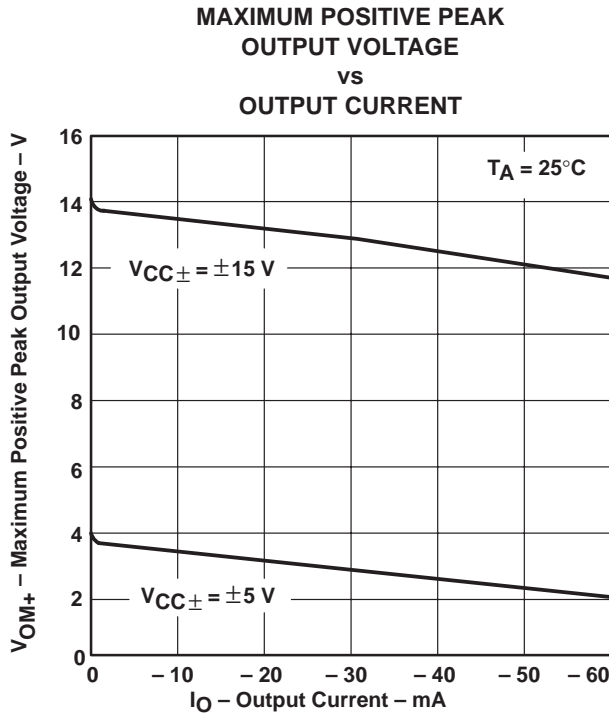


Figure 8

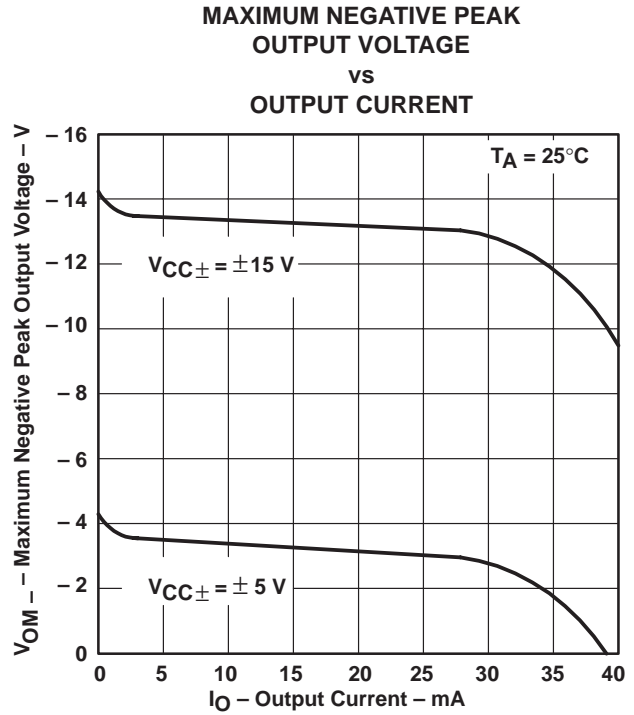


Figure 9

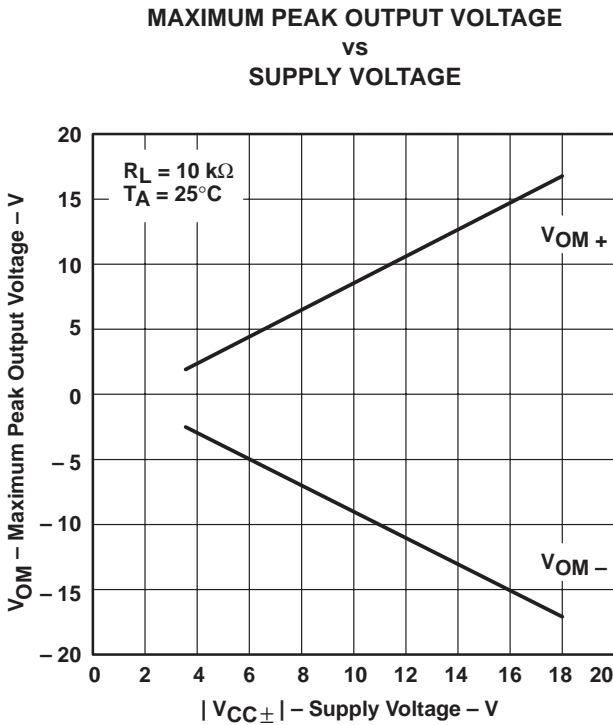


Figure 10

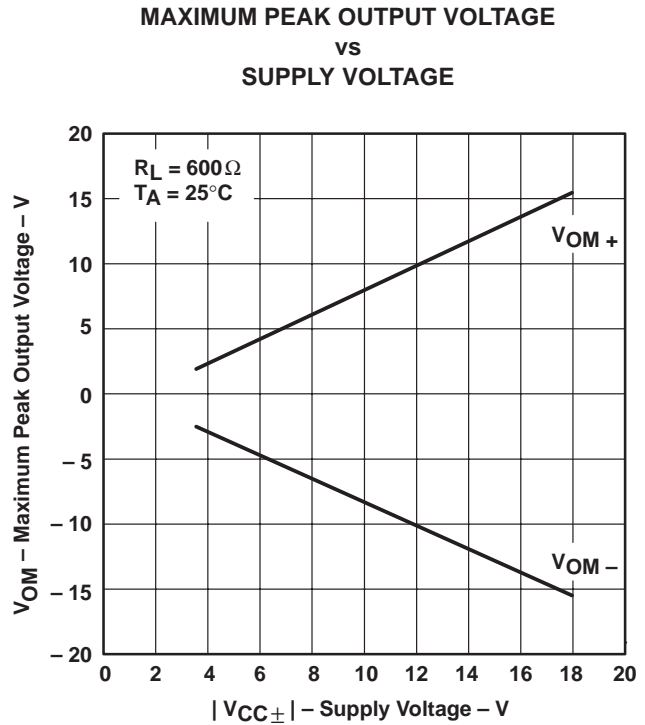


Figure 11

TYPICAL CHARACTERISTICS

MAXIMUM PEAK OUTPUT VOLTAGE
 vs
 SUPPLY VOLTAGE

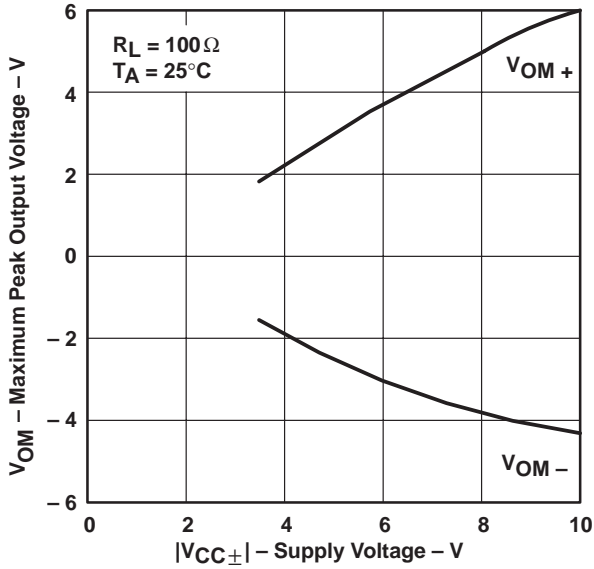


Figure 12

MAXIMUM PEAK-TO-PEAK
 OUTPUT VOLTAGE
 vs
 FREQUENCY

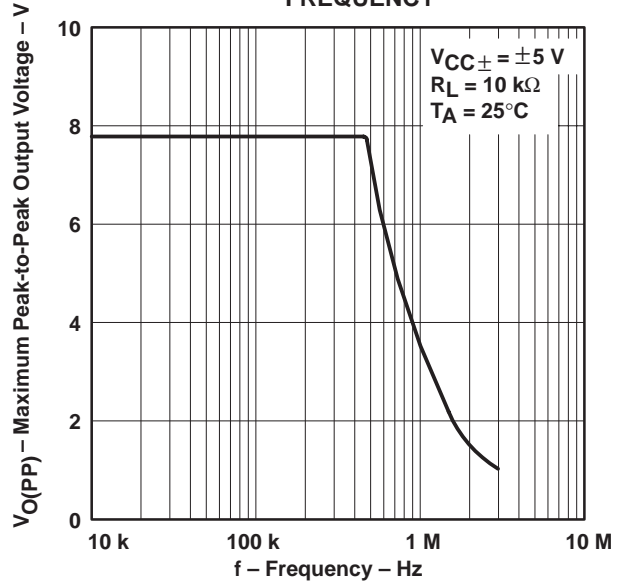


Figure 13

MAXIMUM PEAK-TO-PEAK
 OUTPUT VOLTAGE
 vs
 FREQUENCY

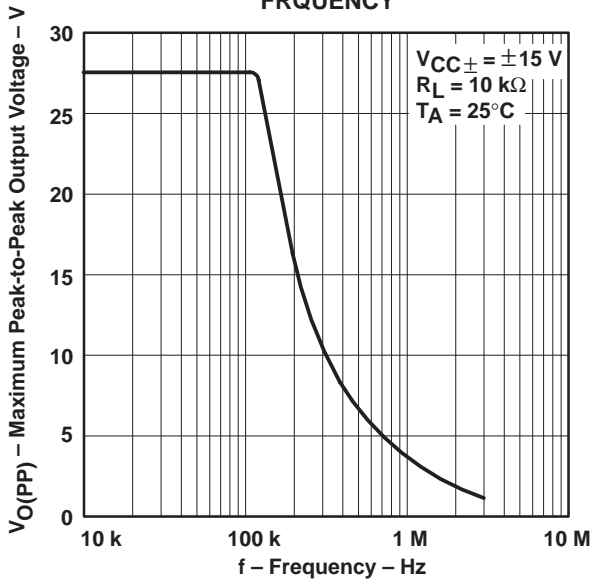


Figure 14

MAXIMUM PEAK-TO-PEAK
 OUTPUT VOLTAGE
 vs
 FREQUENCY

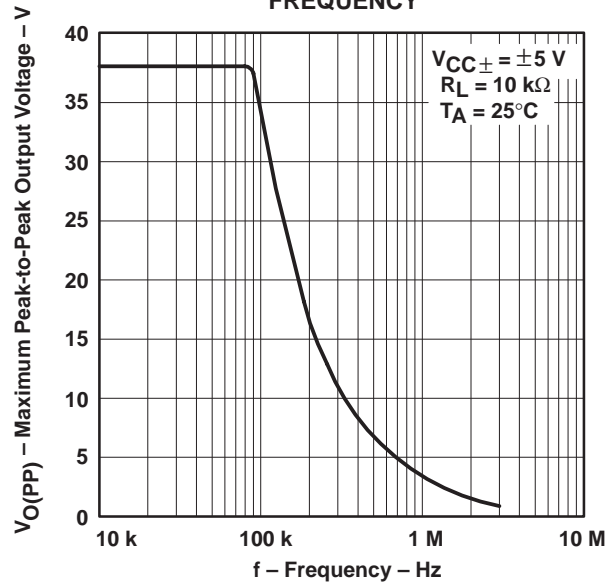


Figure 15

TYPICAL CHARACTERISTICS†

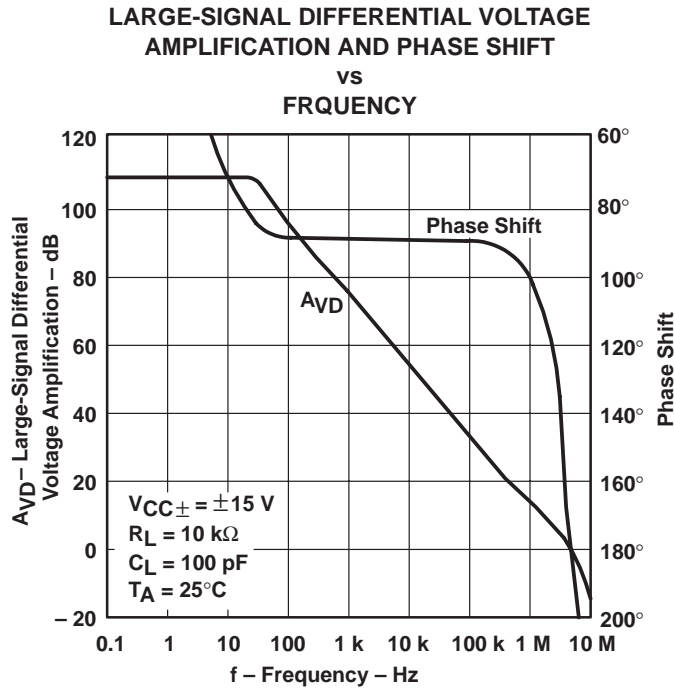


Figure 16

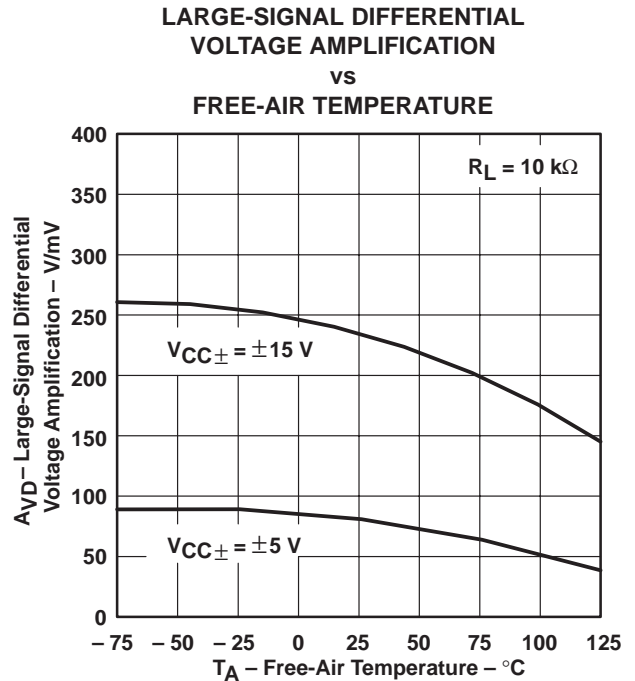


Figure 17

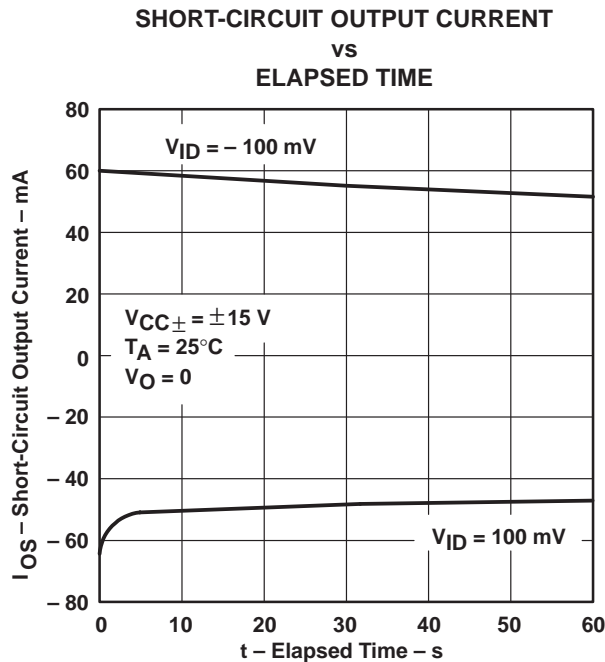


Figure 18

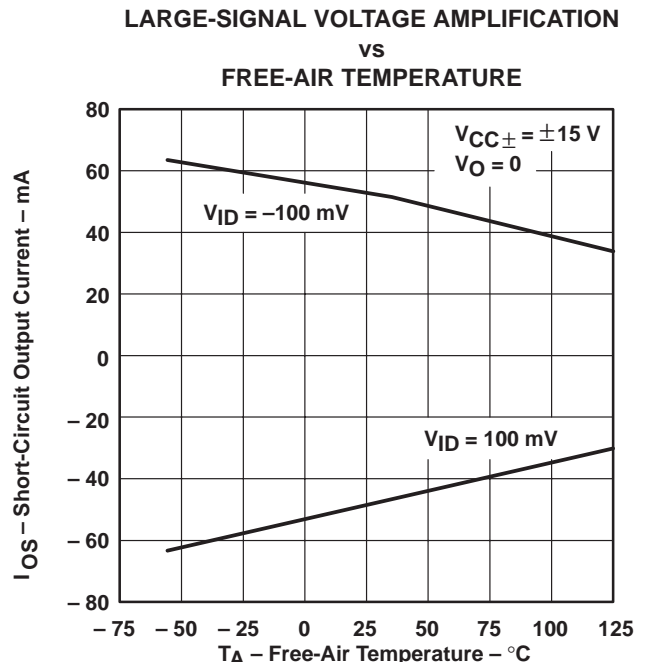


Figure 19

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

TYPICAL CHARACTERISTICS†

OUTPUT IMPEDANCE
 VS
 FREQUENCY

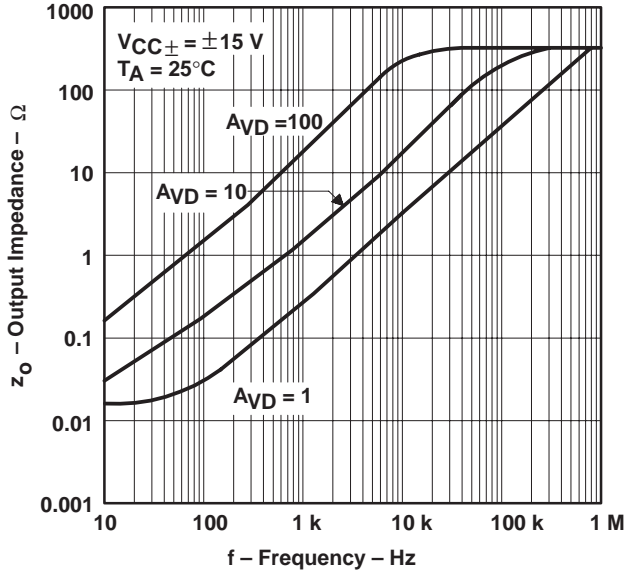


Figure 20

COMMON-MODE REJECTION RATIO
 VS
 FREQUENCY

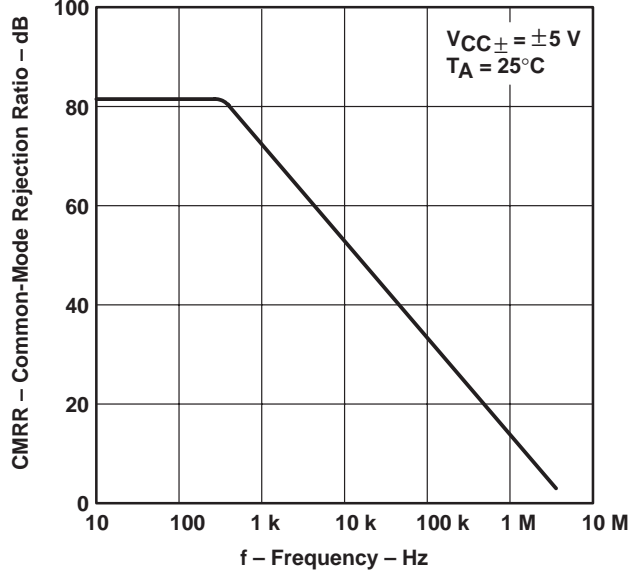


Figure 21

SUPPLY CURRENT
 VS
 SUPPLY VOLTAGE

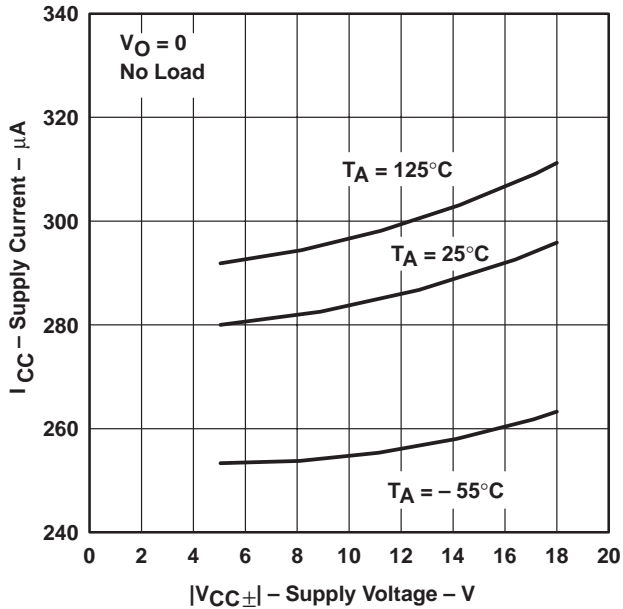


Figure 22

SUPPLY CURRENT
 VS
 FREE-AIR TEMPERATURE

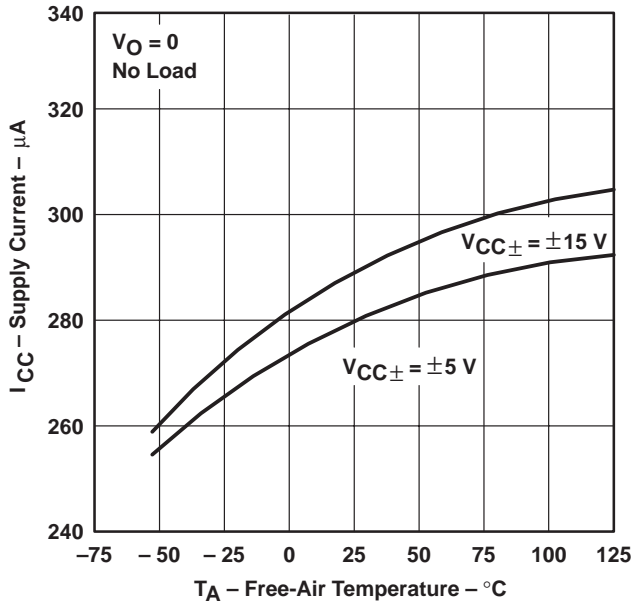


Figure 23

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

TYPICAL CHARACTERISTICS

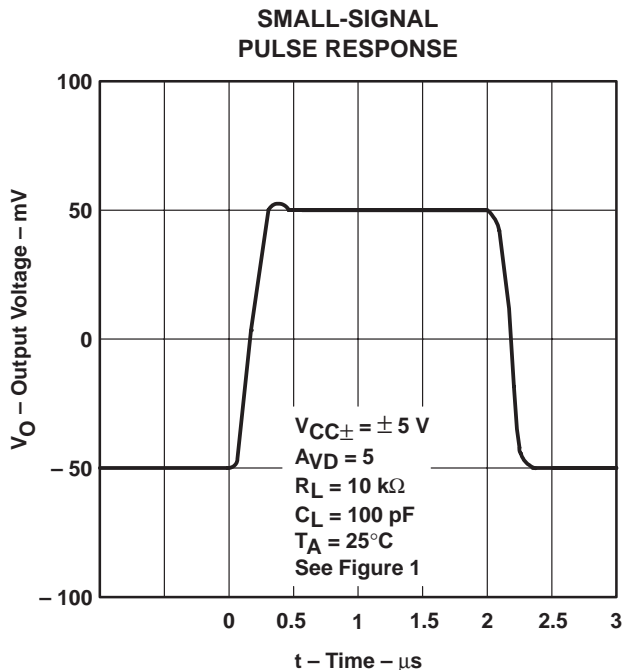


Figure 24

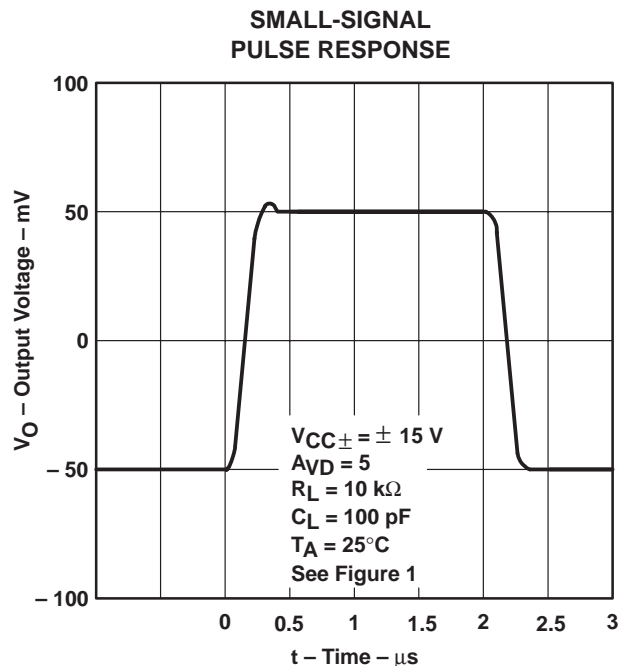


Figure 25

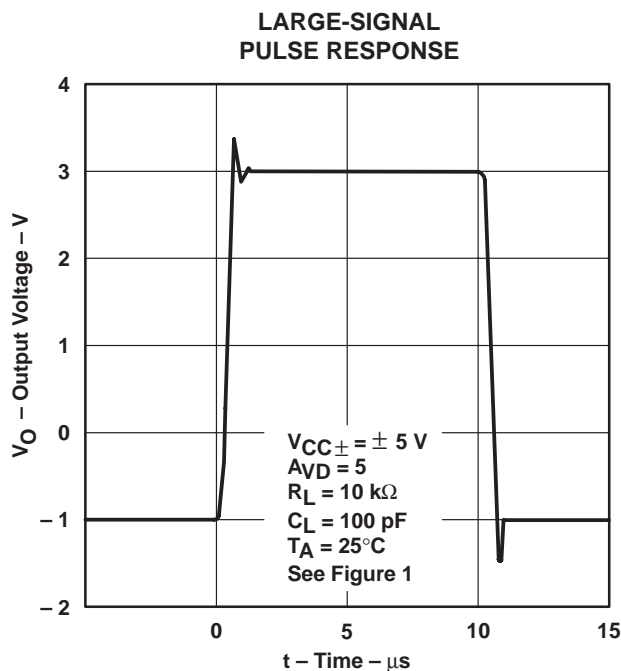


Figure 26

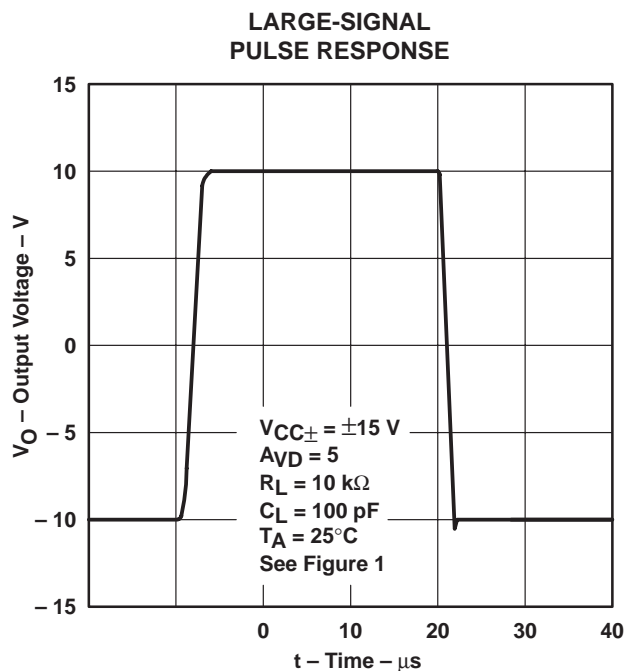


Figure 27

TYPICAL CHARACTERISTICS

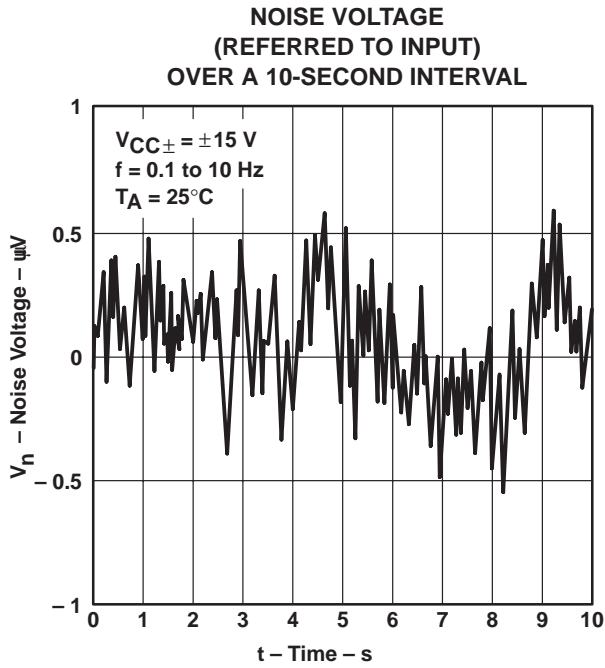


Figure 28

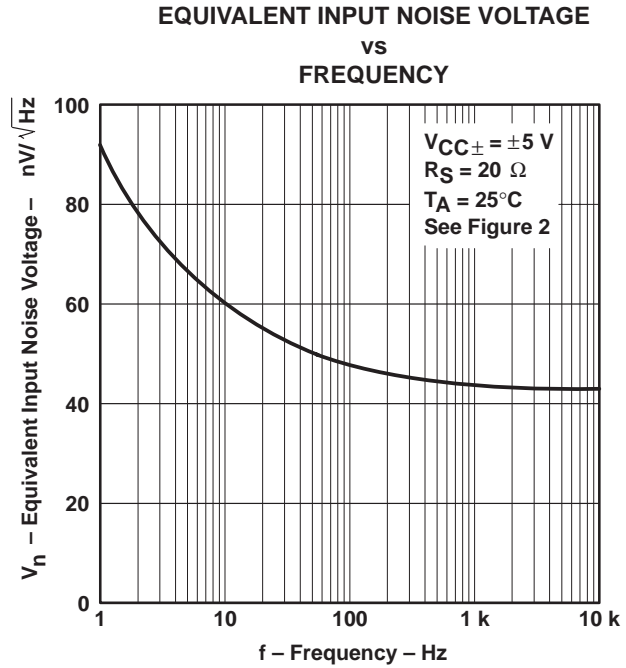


Figure 29

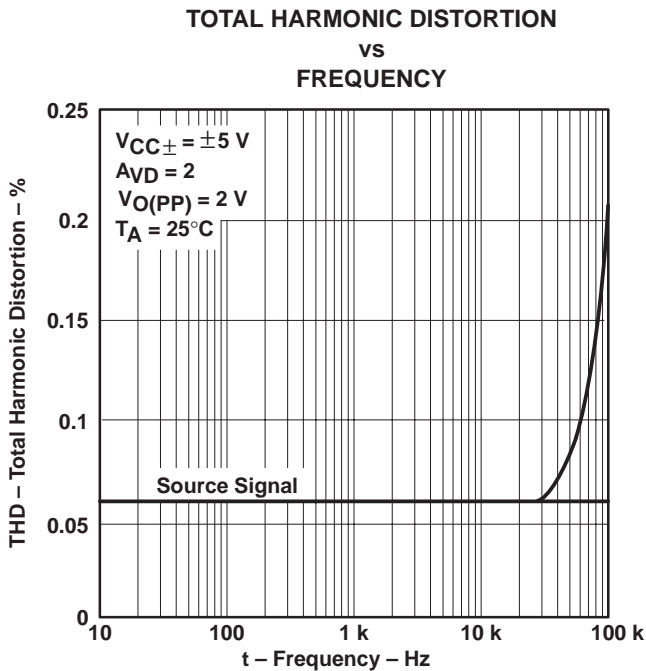


Figure 30

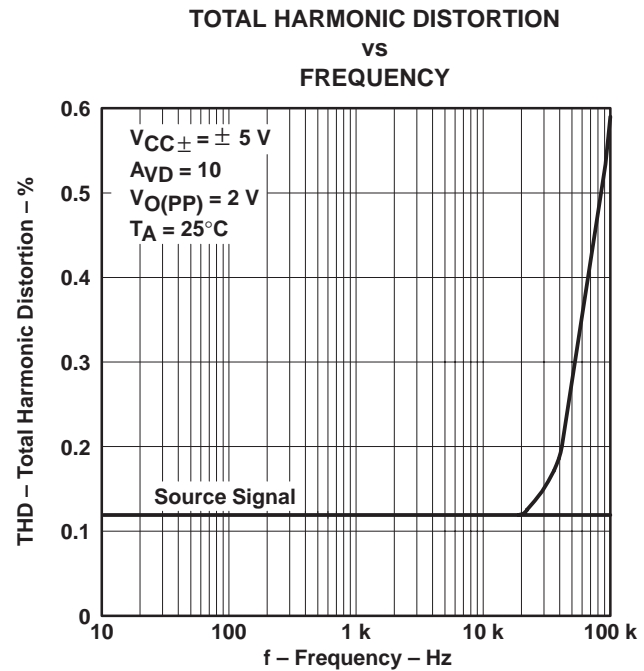


Figure 31

TYPICAL CHARACTERISTICS

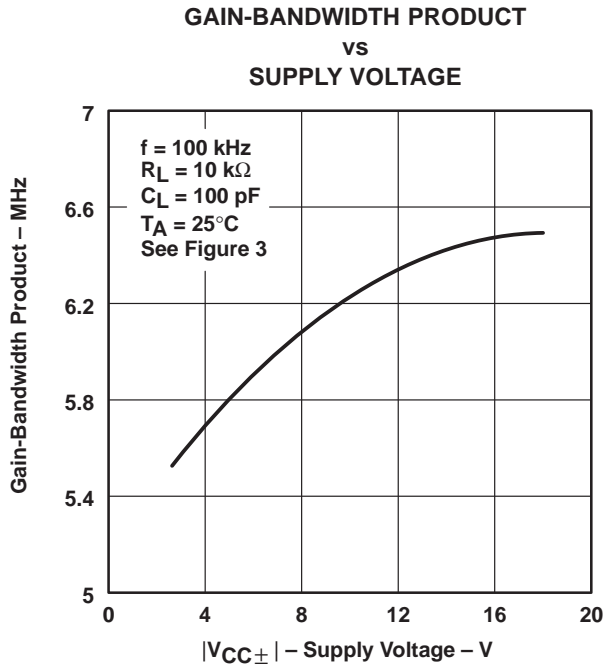


Figure 32

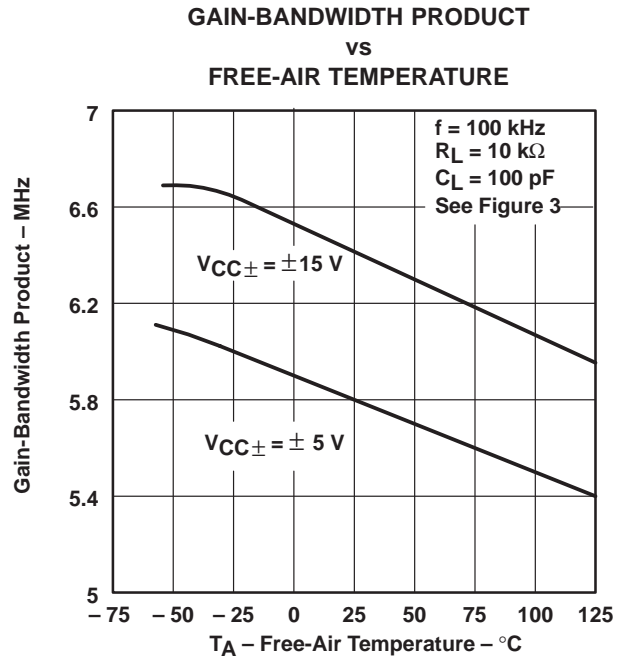


Figure 33

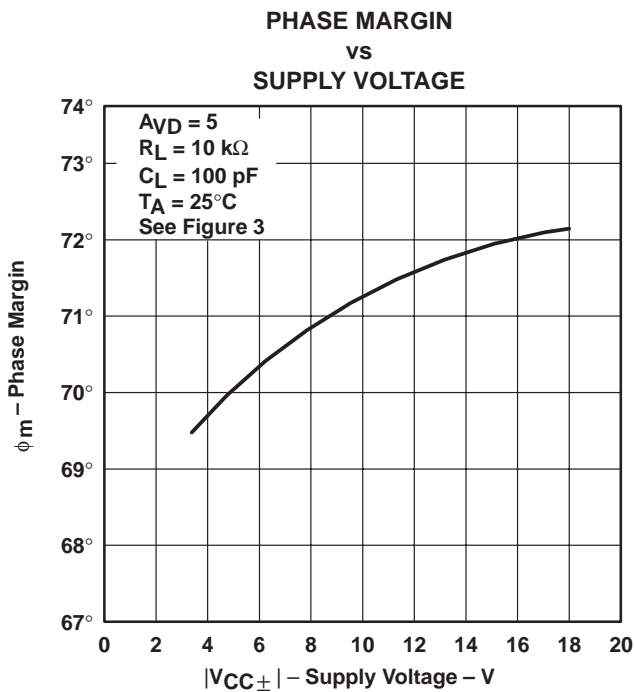


Figure 34

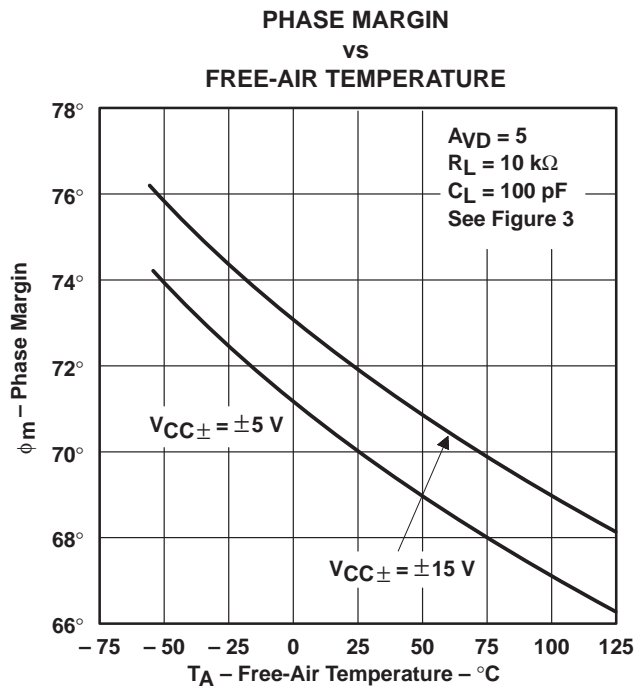


Figure 35

APPLICATION INFORMATION

macromodel information

Macromodel information provided was derived using Microsim *Parts*™, the model generation software used with Microsim *PSpice*™. The Boyle macromodel (see Note 5) and subcircuit in Figure 36 and Figure 37 were generated using the TLE2161 typical electrical and operating characteristics at 25°C. Using this information, output simulations of the following key parameters can be generated to a tolerance of 20% (in most cases):

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

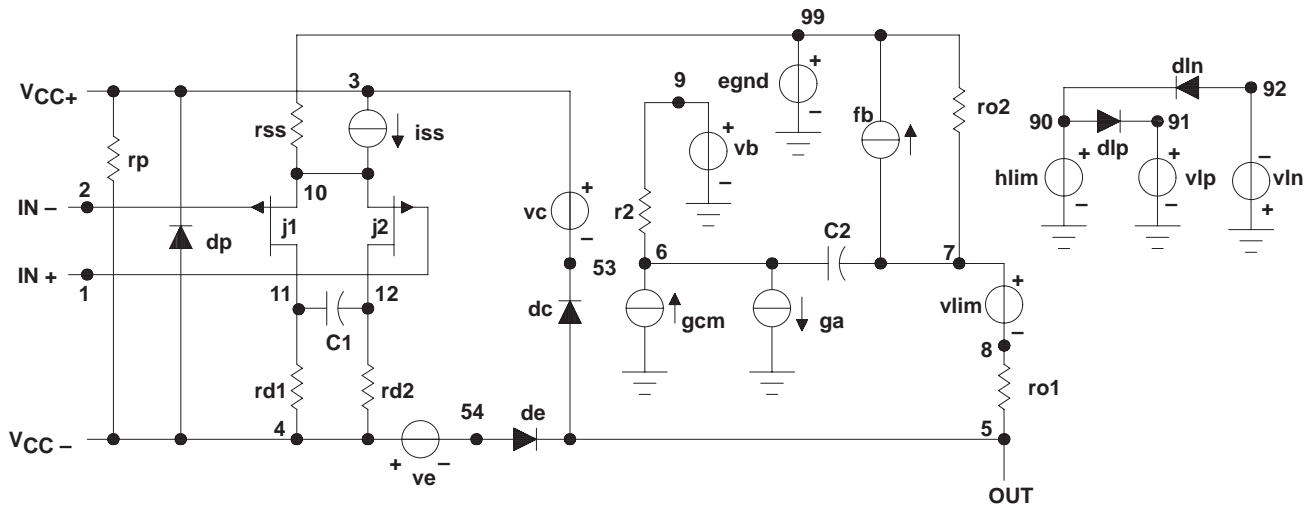


Figure 36. Boyle Macromodel

NOTE 5: G. R. Boyle, B. M. Cohn, D. O. Pederson, and J. E. Solomon, "Macromodeling of Integrated Circuit Operational Amplifiers", *IEEE Journal of Solid-State Circuits*, SC-9, 353 (1974).

PSpice and *Parts* are trademark of MicroSim Corporation.



APPLICATION INFORMATION

macromodel information (continued)

```
.subckt TLE2161 1 2 3 4 5
c1 11 12 125.4E-14
c2 6 7 5.000E-12
dc 5 53 dx
de 54 5d x
dlp 90 91 dx
dln 92 90 dx
dp 4 3 dx
egnd 99 0 poly(2) (3,0) (4,0) 0 .5 .5
fb 7 99 poly(5) vb vc ve vlp vln 0 4.085E6 -4E6 4E6 4E6 -4E6
ga 6 0 11 12 201.1E-6
gcm 0 6 10 99 3.576E-9
iss 3 10 dc 45.00E-6
hlim 90 0 vlim 1K
j1 11 2 10 jx
j2 12 1 10 jx
r2 6 9 100.0E3
rd1 4 11 4.973E3
rd2 4 12 4.973E3
ro1 8 5 280
ro2 7 99 280
rp 3 4 113.2E3
rss 10 99 4.444E6
vb 9 0 dc 0
vc 3 53 dc 2
ve 54 4 dc 2
vlim 7 8 dc 0
vlp 91 0 dc 50
vln 0 92 dc 50
.model dx D (Is=800.0E-18)
.model jx Pjf (Is=1.000E-12 Beta=480E-6 Vto=-1)
.ends
```

Figure 37. Macromodel Subcircuit

APPLICATION INFORMATION

input characteristics

The TLE2161, TLE2161A and TLE2161B are specified with a minimum and a maximum input voltage that if exceeded at either input could cause the device to malfunction.

Because of the extremely high input impedance and resulting low bias-current requirements, the TLE2161, TLE2161A, and TLE2161B are well suited for low-level signal processing; however, leakage currents on printed circuit boards and sockets can easily exceed bias-current requirements and cause degradation in system performance. It is a good practice to include guard rings around inputs (see Figure 38). These guards should be driven from a low-impedance source at the same voltage level as the common-mode input.

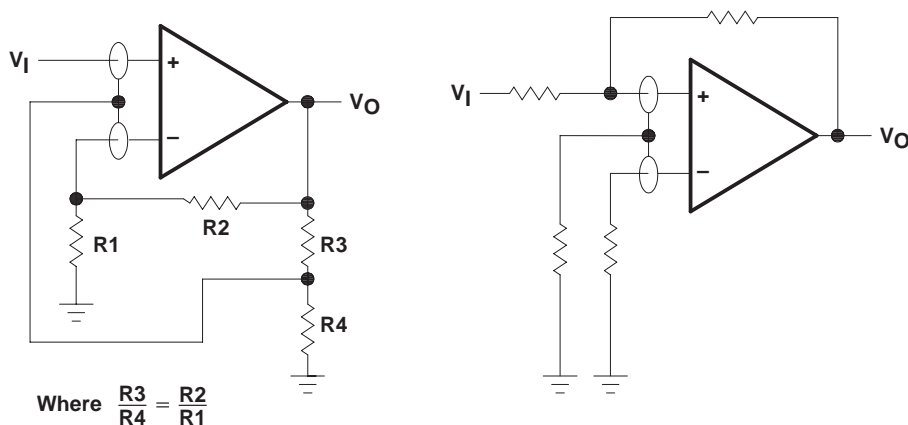


Figure 38. Use of Guard Rings

input offset voltage nulling

The TLE2161 series offers external null pins that can further reduce the input offset voltage. The circuit in Figure 39 can be connected as shown if the feature is desired. When external nulling is not needed, the null pins may be left disconnected.

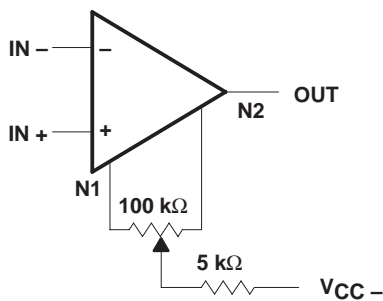


Figure 39. Input Offset Voltage Nulling

PACKAGING INFORMATION

| Orderable Device | Status ⁽¹⁾ | Package Type | Package Drawing | Pins | Package Qty | Eco Plan ⁽²⁾ | Lead/Ball Finish | MSL Peak Temp ⁽³⁾ |
|------------------|-----------------------|--------------|-----------------|------|-------------|-------------------------|------------------|------------------------------|
| 5962-9095801Q2A | ACTIVE | LCCC | FK | 20 | 1 | TBD | POST-PLATE | N / A for Pkg Type |
| 5962-9095801QPA | ACTIVE | CDIP | JG | 8 | 1 | TBD | A42 SNPB | N / A for Pkg Type |
| 5962-9095802Q2A | ACTIVE | LCCC | FK | 20 | 1 | TBD | POST-PLATE | N / A for Pkg Type |
| 5962-9095802QPA | ACTIVE | CDIP | JG | 8 | 1 | TBD | A42 SNPB | N / A for Pkg Type |
| 5962-9095803Q2A | ACTIVE | LCCC | FK | 20 | 1 | TBD | POST-PLATE | N / A for Pkg Type |
| 5962-9095803QPA | ACTIVE | CDIP | JG | 8 | 1 | TBD | A42 SNPB | N / A for Pkg Type |
| TLE2161ACD | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLE2161ACDG4 | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLE2161ACP | OBSOLETE | PDIP | P | 8 | | TBD | Call TI | Call TI |
| TLE2161AID | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLE2161AIDG4 | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLE2161AIDR | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLE2161AIDRG4 | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLE2161AIP | OBSOLETE | PDIP | P | 8 | | TBD | Call TI | Call TI |
| TLE2161AMFKB | ACTIVE | LCCC | FK | 20 | 1 | TBD | POST-PLATE | N / A for Pkg Type |
| TLE2161AMJGB | ACTIVE | CDIP | JG | 8 | 1 | TBD | A42 SNPB | N / A for Pkg Type |
| TLE2161BCP | OBSOLETE | PDIP | P | 8 | | TBD | Call TI | Call TI |
| TLE2161BIP | OBSOLETE | PDIP | P | 8 | | TBD | Call TI | Call TI |
| TLE2161BMFKB | ACTIVE | LCCC | FK | 20 | 1 | TBD | POST-PLATE | N / A for Pkg Type |
| TLE2161BMJG | ACTIVE | CDIP | JG | 8 | 1 | TBD | A42 SNPB | N / A for Pkg Type |
| TLE2161BMJGB | ACTIVE | CDIP | JG | 8 | 1 | TBD | A42 SNPB | N / A for Pkg Type |
| TLE2161BMP | OBSOLETE | PDIP | P | 8 | | TBD | Call TI | Call TI |
| TLE2161CD | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLE2161CDG4 | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLE2161CP | OBSOLETE | PDIP | P | 8 | | TBD | Call TI | Call TI |
| TLE2161ID | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLE2161IDG4 | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLE2161IDR | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLE2161IDRG4 | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TLE2161IP | OBSOLETE | PDIP | P | 8 | | TBD | Call TI | Call TI |
| TLE2161MFKB | ACTIVE | LCCC | FK | 20 | 1 | TBD | POST-PLATE | N / A for Pkg Type |
| TLE2161MJGB | ACTIVE | CDIP | JG | 8 | 1 | TBD | A42 SNPB | N / A for Pkg Type |
| TLE2161MP | OBSOLETE | PDIP | P | 8 | | TBD | Call TI | Call TI |

(1) The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

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

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

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

OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

TBD: The Pb-Free/Green conversion plan has not been defined.

Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

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

Important Information and Disclaimer:The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

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

TAPE AND REEL INFORMATION



QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|-------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TLE2161AIDR | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| TLE2161AIDR | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| TLE2161IDR | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|-------------|--------------|-----------------|------|------|-------------|------------|-------------|
| TLE2161AIDR | SOIC | D | 8 | 2500 | 340.5 | 338.1 | 20.6 |
| TLE2161AIDR | SOIC | D | 8 | 2500 | 346.0 | 346.0 | 29.0 |
| TLE2161IDR | SOIC | D | 8 | 2500 | 346.0 | 346.0 | 29.0 |

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products

| | |
|-----------------------------|--|
| Amplifiers | amplifier.ti.com |
| Data Converters | dataconverter.ti.com |
| DSP | dsp.ti.com |
| Clocks and Timers | www.ti.com/clocks |
| Interface | interface.ti.com |
| Logic | logic.ti.com |
| Power Mgmt | power.ti.com |
| Microcontrollers | microcontroller.ti.com |
| RFID | www.ti-rfid.com |
| RF/IF and ZigBee® Solutions | www.ti.com/lprf |

Applications

| | |
|--------------------|--|
| Audio | www.ti.com/audio |
| Automotive | www.ti.com/automotive |
| Broadband | www.ti.com/broadband |
| Digital Control | www.ti.com/digitalcontrol |
| Medical | www.ti.com/medical |
| Military | www.ti.com/military |
| Optical Networking | www.ti.com/opticalnetwork |
| Security | www.ti.com/security |
| Telephony | www.ti.com/telephony |
| Video & Imaging | www.ti.com/video |
| Wireless | www.ti.com/wireless |

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2008, Texas Instruments Incorporated