# LME49721 High-Performance, High-Fidelity Rail-to-Rail Input/Output Audio Operational Amplifier

Check for Samples: LME49721

## FEATURES

- **Rail-to-Rail Input and Output**
- **Easily Drives 10kΩ Loads to Within 10mV of Each Power Supply Voltage**
- **Optimized for Superior Audio Signal Fidelity**
- **Output Short Circuit Protection**

## APPLICATIONS

- **Ultra High-Quality Portable Audio Amplification**
- **High-Fidelity Preamplifiers**
- **High-Fidelity Multimedia**
- **State-of-the-Art Phono Pre Amps**
- **High-Performance Professional Audio**
- **High-Fidelity Equalization and Crossover Networks**
- **High-Performance Line Drivers**
- **High-Performance Line Receivers**
- **High-Fidelity Active Filters**
- **DAC I–V Converter**
- **ADC Front-End Signal Conditioning**

## KEY SPECIFICATIONS

- **Power Supply Voltage Range: 2.2V to 5.5V**
- **Quiescent Current: 2.15mA (typ)**
- **THD+N ($A_V$ = 2, $V_{OUT}$ = 4$V_{p-p}$, $f_{IN}$ = 1kHz)**
  - **$R_L$ = 2kΩ: 0.00008% (typ)**
  - **$R_L$ = 600Ω: 0.0001% (typ)**
- **Input Noise Density: 4nV/$\sqrt{Hz}$ (typ), @ 1kHz**
- **Slew Rate: ±8.5V/μs (typ)**
- **Gain Bandwidth Product: 20MHz (typ)**
- **Open Loop Gain ($R_L$ = 600Ω): 118dB (typ)**
- **Input Bias Current: 40fA (typ)**
- **Input Offset Voltage: 0.3mV (typ)**
- **PSRR: 103dB (typ)**

## DESCRIPTION

The LME49721 is a low-distortion, low-noise Rail-to-Rail Input/Output operational amplifier optimized and fully specified for high-performance, high-fidelity applications. Combining advanced leading-edge process technology with state-of-the-art circuit design, the LME49721 Rail-to-Rail Input/Output operational amplifier delivers superior signal amplification for outstanding performance. The LME49721 combines a very high slew rate with low THD+N to easily satisfy demanding applications. To ensure that the most challenging loads are driven without compromise, the LME49721 has a high slew rate of ±8.5V/μs and an output current capability of ±9.7mA. Further, dynamic range is maximized by an output stage that drives 10kΩ loads to within 10mV of either power supply voltage.

The LME49721 has a wide supply range of 2.2V to 5.5V. Over this supply range the LME49721's input circuitry maintains excellent common-mode and power supply rejection, as well as maintaining its low input bias current. The LME49721 is unity gain stable.

## TYPICAL CONNECTION AND PINOUT

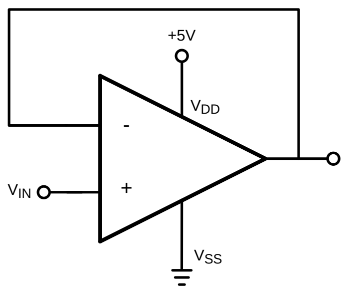



**Figure 1. Buffer Amplifier**

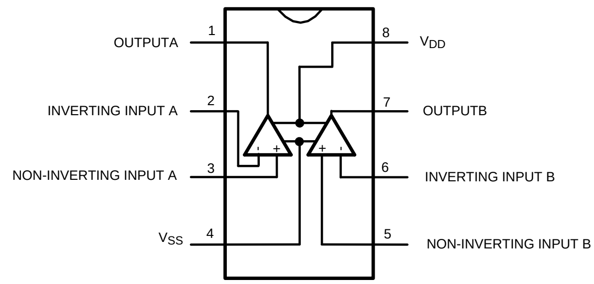



**Figure 2. 8-Pin SOIC (D Package)**

These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

## ABSOLUTE MAXIMUM RATINGS(1)(2)(3)

| | |
|---|---|
| Power Supply Voltage ($V_S = V^+ - V^-$) | 6V |
| Storage Temperature | −65°C to 150°C |
| Input Voltage | (V-) - 0.7V to (V+) + 0.7V |
| Output Short Circuit(4) | Continuous |
| Power Dissipation | Internally Limited |
| ESD Rating(5) | 2000V |
| ESD Rating(6) | 200V |
| Junction Temperature | 150°C |
| Thermal Resistance, $\theta_{JA}$ (SOIC) | 165°C/W |
| Temperature Range, $T_{MIN} \le T_A \le T_{MAX}$ | –40°C ≤ $T_A$ ≤ 85°C |
| Supply Voltage Range | 2.2V ≤ $V_S$ ≤ 5.5V |

(1) “Absolute Maximum Ratings” indicate limits beyond which damage to the device may occur, including inoperability and degradation of device reliability and/or performance. Functional operation of the device and/or non-degradation at the Absolute Maximum Ratings or other conditions beyond those indicated in the Recommended Operating Conditions is not implied. The Recommended Operating Conditions indicate conditions at which the device is functional and the device should not be operated beyond such conditions. All voltages are measured with respect to the ground pin, unless otherwise specified

(2) The Electrical Characteristics table lists ensured specifications under the listed Recommended Operating Conditions except as otherwise modified or specified by the Electrical Characteristics Conditions and/or Notes. Typical specifications are estimations only and are not ensured.

(3) If Military/Aerospace specified devices are required, please contact the Texas Instruments Sales Office/Distributors for availability and specifications.

(4) The maximum power dissipation must be derated at elevated temperatures and is dictated by $T_{JMAX}$, $\theta_{JA}$, and the ambient temperature, $T_A$. The maximum allowable power dissipation is $P_{DMAX} = (T_{JMAX} - T_A) / \theta_{JA}$ or the number given in Absolute Maximum Ratings, whichever is lower.

(5) Human body model, applicable std. JESD22-A114C.

(6) Machine model, applicable std. JESD22-A115-A.

## ELECTRICAL CHARACTERISTICS FOR THE LME49721

The following specifications apply for the circuit shown in Figure 1. $V_S$ = 5V, $R_L$ = 10kΩ, $R_{SOURCE}$ = 10Ω, $f_{IN}$ = 1kHz, and $T_A$ = 25°C, unless otherwise specified.

| Symbol | Parameter | Conditions | LME49721 | | Units (Limits) |
|---|---|---|---|---|---|
| | | | **Typical**[1] | **Limit**[2] | |
| THD+N | Total Harmonic Distortion + Noise | $A_V$ = +1, $V_{OUT}$ = $2V_{p-p}$,<br>$R_L$ = 2kΩ<br>$R_L$ = 600Ω | <br>0.0002<br>0.0002 | <br><br>0.001 | <br><br>% (max) |
| IMD | Intermodulation Distortion | $A_V$ = +1, $V_{OUT}$ = $2V_{p-p}$,<br>Two-tone, 60Hz & 7kHz 4:1 | 0.0004 | | % |
| GBWP | Gain Bandwidth Product | | 20 | 15 | MHz (min) |
| SR | Slew Rate | $A_V$ = +1 | 8.5 | | V/μs (min) |
| FPBW | Full Power Bandwidth | $V_{OUT}$ = $1V_{P-P}$, –3dB<br>referenced to output magnitude<br>at f = 1kHz | 2.2 | | MHz |
| $t_s$ | Settling time | $A_V$ = 1, 4V step<br>0.1% error range | 800 | | ns |
| $e_n$ | Equivalent Input Noise Voltage | $f_{BW}$ = 20Hz to 20kHz,<br>A-weighted | .707 | 1.13 | $\mu V_{P-P}$ (max) |
| | Equivalent Input Noise Density | f = 1kHz<br>A-weighted | 4 | 6 | nV/√Hz (max) |
| $I_n$ | Current Noise Density | f = 10kHz | 4.0 | | fA/√Hz |
| $V_{OS}$ | Offset Voltage | | 0.3 | 1.5 | mV (max) |
| $\Delta V_{OS}/\Delta Temp$ | Average Input Offset Voltage Drift vs Temperature | 40°C ≤ $T_A$ ≤ 85°C | 1.1 | | μV/°C |
| PSRR | Average Input Offset Voltage Shift vs Power Supply Voltage | | 103 | 85 | dB (min) |
| $ISO_{CH-CH}$ | Channel-to-Channel Isolation | $f_{IN}$ = 1kHz | 117 | | dB |
| $I_B$ | Input Bias Current | $V_{CM}$ = $V_S$/2 | 40 | | fA |
| $\Delta I_{OS}/\Delta Temp$ | Input Bias Current Drift vs Temperature | –40°C ≤ $T_A$ ≤ 85°C | 48 | | fA/°C |
| $I_{OS}$ | Input Offset Current | $V_{CM}$ = $V_S$/2 | 60 | | fA |
| $V_{IN-CM}$ | Common-Mode Input Voltage Range | | | (V+) – 0.1<br>(V-) + 0.1 | V (min) |
| CMRR | Common-Mode Rejection | $V_{SS}$ - 100mV < $V_{CM}$ < $V_{DD}$ + 100mV | 93 | 70 | dB (min) |
| | 1/f Corner Frequency | | 2000 | | Hz |
| $A_{VOL}$ | Open Loop Voltage Gain | $V_{SS}$ - 200mV < $V_{OUT}$ < $V_{DD}$ + 200mV | | | |
| | | $R_L$ = 600Ω | 118 | 100 | dB (min) |
| | | $R_L$ = 2kΩ | 122 | | dB (min) |
| | | $R_L$ = 10kΩ | 130 | 115 | dB (min) |
| $V_{OUTMIN}$ | Output Voltage Swing | $R_L$ = 600Ω | $V_{DD}$ – 30mV | $V_{DD}$ – 80mV | V (min) |
| | | | $V_{SS}$ + 30mV | $V_{SS}$ + 80mV | V (min) |
| | | $R_L$ = 10kΩ, $V_S$ = 5.0V | $V_{DD}$ – 10mV | $V_{DD}$ – 20mV | V (min) |
| | | | $V_{SS}$ + 10mV | $V_{SS}$ + 20mV | V (min) |
| $I_{OUT}$ | Output Current | $R_L$ = 250Ω, $V_S$ = 5.0V | 9.7 | 9.3 | mA (min) |
| $I_{OUT-SC}$ | Short Circuit Current | | 100 | | mA |
| $R_{OUT}$ | Output Impedance | $f_{IN}$ = 10kHz<br>Closed-Loop<br>Open-Loop | <br>0.01<br>46 | | Ω |
| $I_S$ | Quiescent Current per Amplifier | $I_{OUT}$ = 0mA | 2.15 | 3.25 | mA (max) |

(1) Typical values represent most likely parametric norms at $T_A$ = +25ºC, and at the Recommended Operation Conditions at the time of product characterization and are not ensured.
(2) Datasheet min/max specification limits are ensured by test or statistical analysis.

## TYPICAL PERFORMANCE CHARACTERISTICS

Graphs were taken in dual supply configuration.

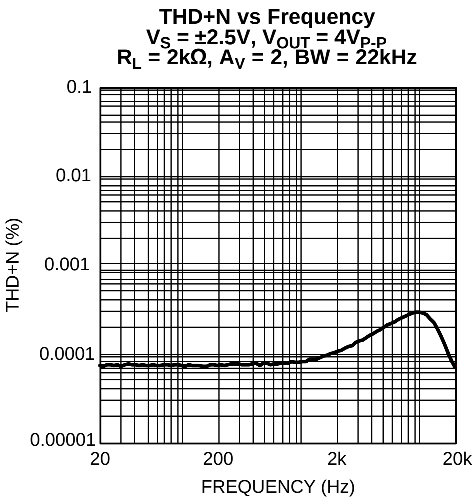



**Figure 3.**

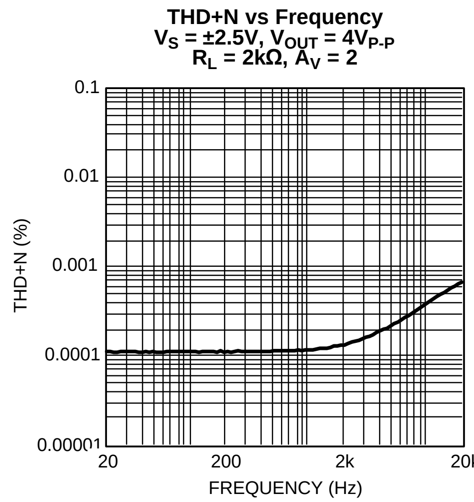



**Figure 4.**

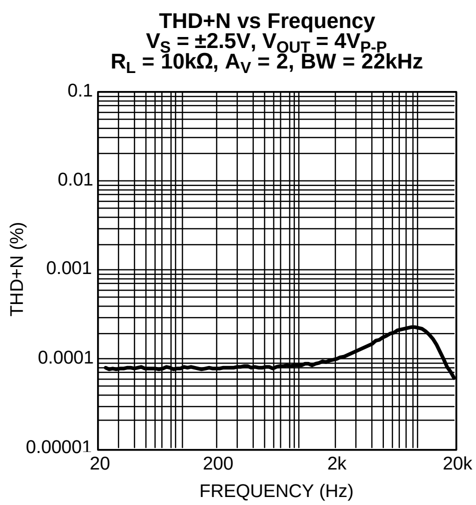



**Figure 5.**

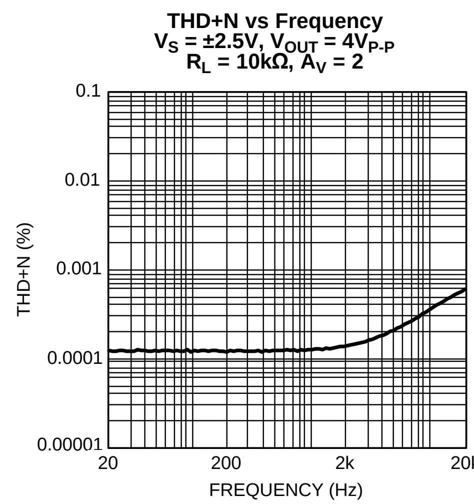



**Figure 6.**

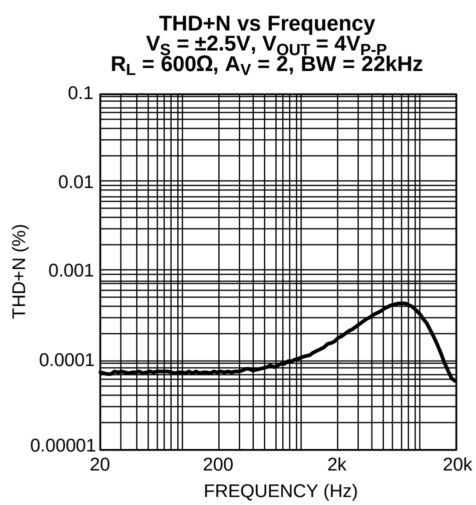



**Figure 7.**

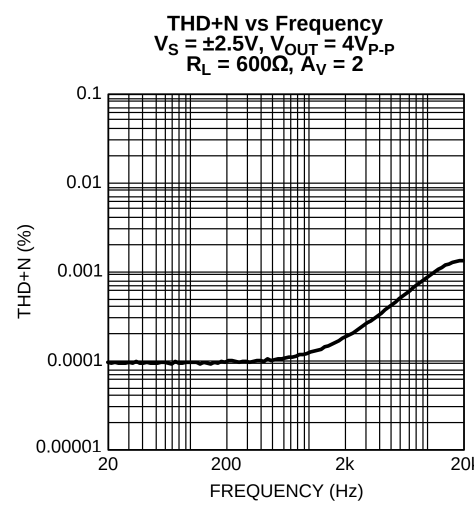



**Figure 8.**

## TYPICAL PERFORMANCE CHARACTERISTICS (continued)

Graphs were taken in dual supply configuration.

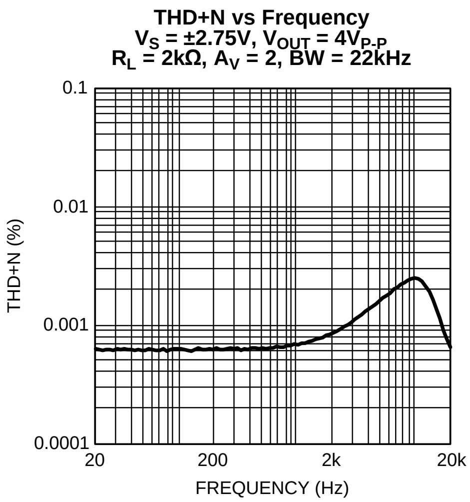



**Figure 9.**

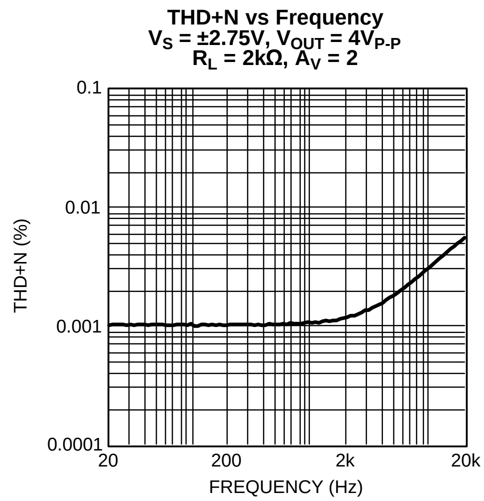



**Figure 10.**

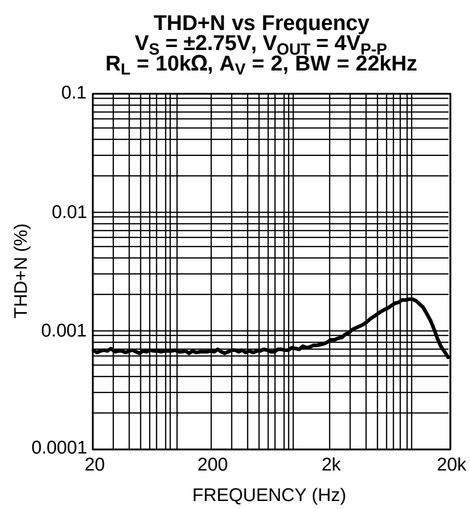



**Figure 11.**

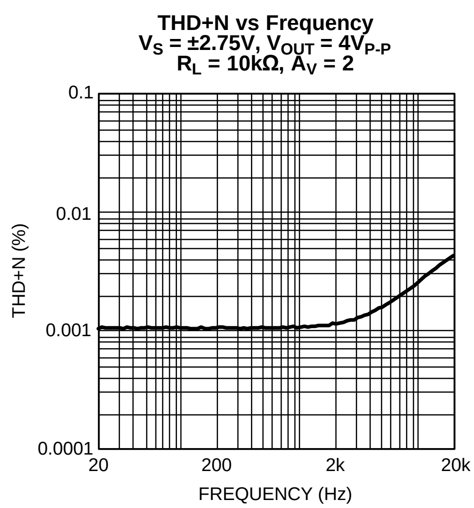



**Figure 12.**

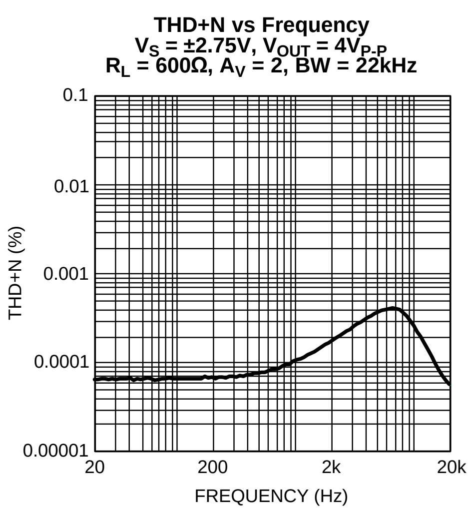



**Figure 13.**

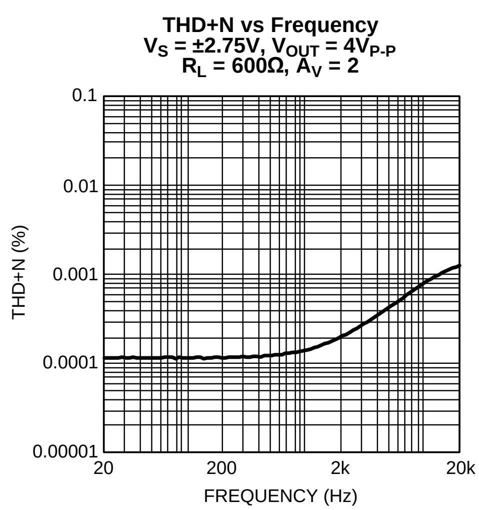



**Figure 14.**

## TYPICAL PERFORMANCE CHARACTERISTICS (continued)

Graphs were taken in dual supply configuration.

**THD+N vs Output Voltage**
**$V_S$ = ±1.1V**
**$R_L$ = 2kΩ, $A_V$ = 2**

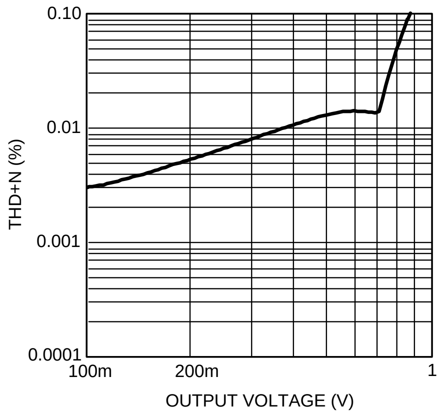



**Figure 15.**

**THD+N vs Output Voltage**
**$V_S$ = ±1.1V**
**$R_L$ = 10kΩ, $A_V$ = 2**

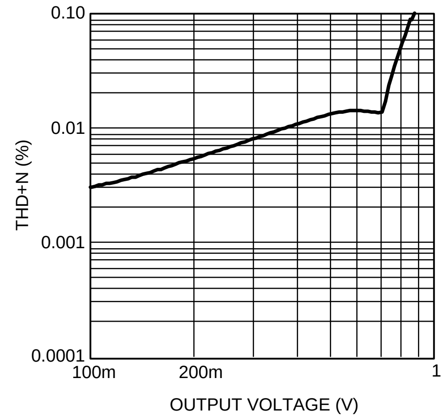



**Figure 16.**

**THD+N vs Output Voltage**
**$V_S$ = ±1.1V**
**$R_L$ = 600Ω, $A_V$ = 2**

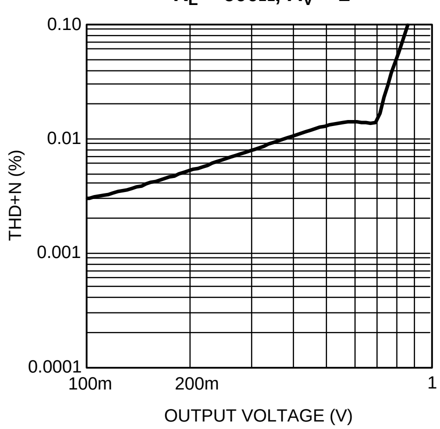



**Figure 17.**

**THD+N vs Output Voltage**
**$V_S$ = ±1.5V**
**$R_L$ = 2kΩ, $A_V$ = 2**

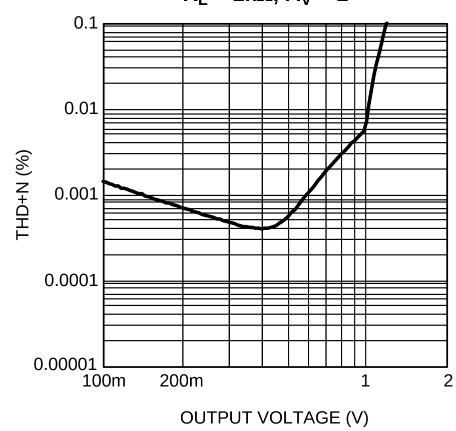



**Figure 18.**

**THD+N vs Output Voltage**
**$V_S$ = ±1.5V**
**$R_L$ = 10kΩ, $A_V$ = 2**

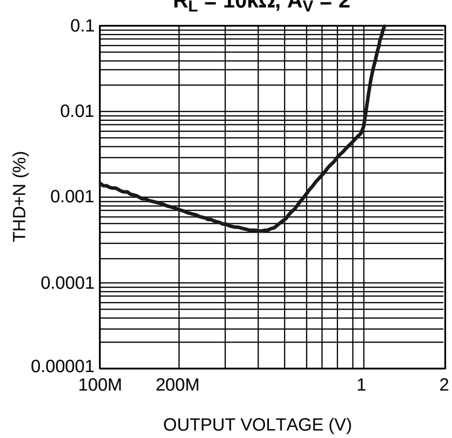



**Figure 19.**

**THD+N vs Output Voltage**
**$V_S$ = ±1.5V**
**$R_L$ = 600Ω, $A_V$ = 2**

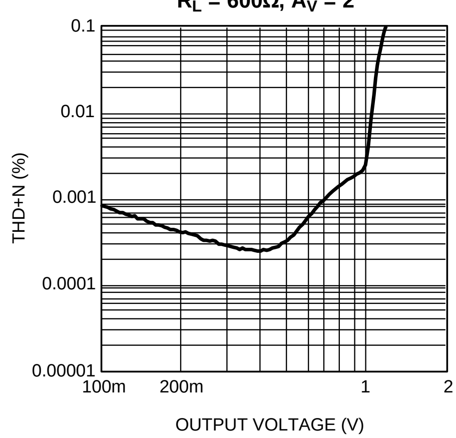



**Figure 20.**

## TYPICAL PERFORMANCE CHARACTERISTICS (continued)

Graphs were taken in dual supply configuration.

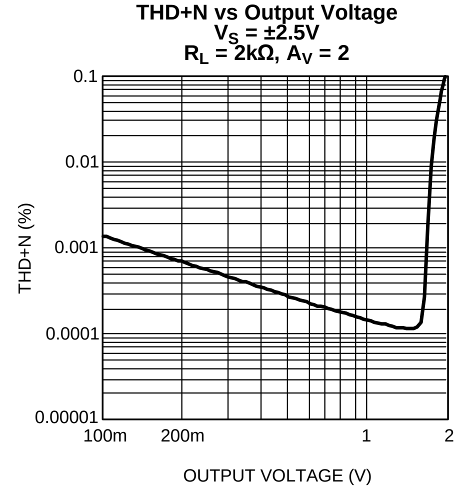



**Figure 21.**

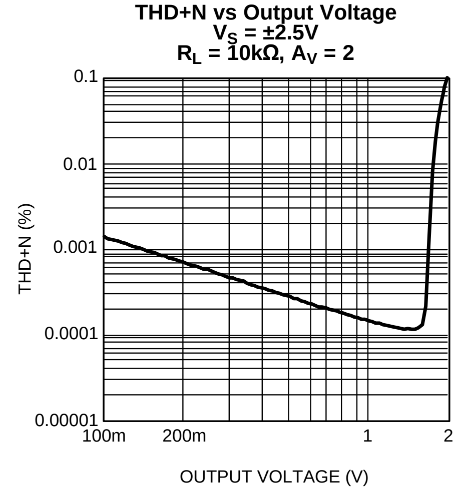



**Figure 22.**

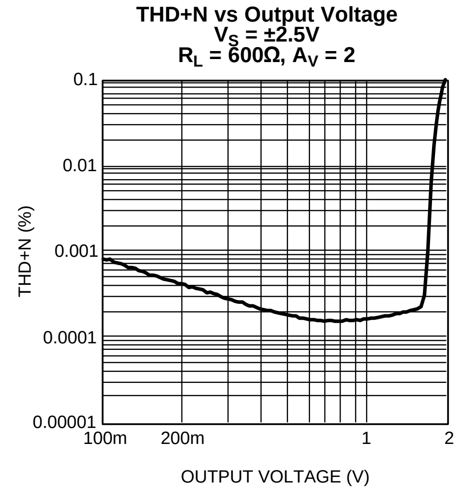



**Figure 23.**

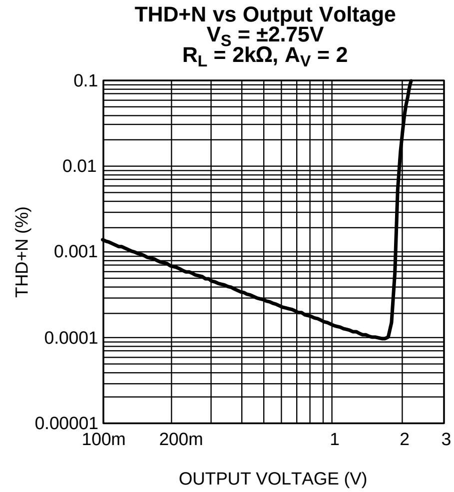



**Figure 24.**

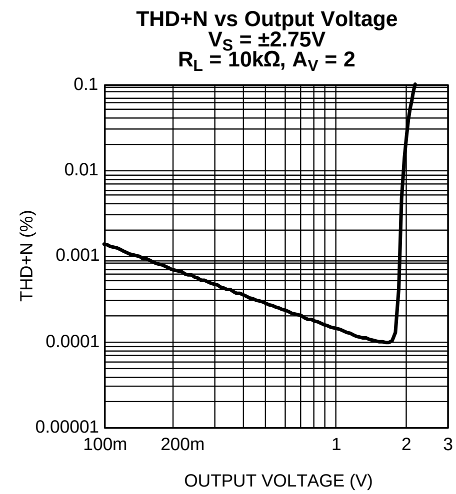



**Figure 25.**

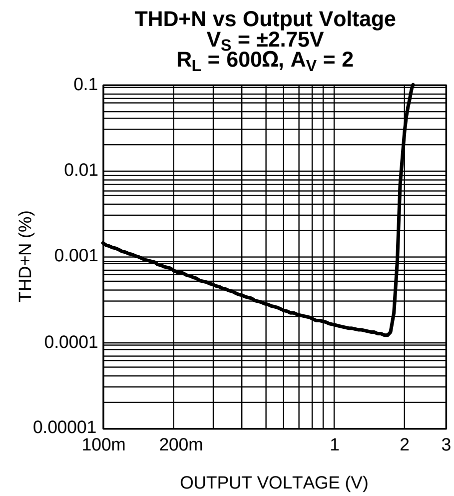



**Figure 26.**

## TYPICAL PERFORMANCE CHARACTERISTICS (continued)

Graphs were taken in dual supply configuration.

**Crosstalk vs Frequency**
**$V_S$ = ±1.1V**
**$V_{OUT}$ = 2$V_{p-p}$**
**$R_L$ = 2kΩ**

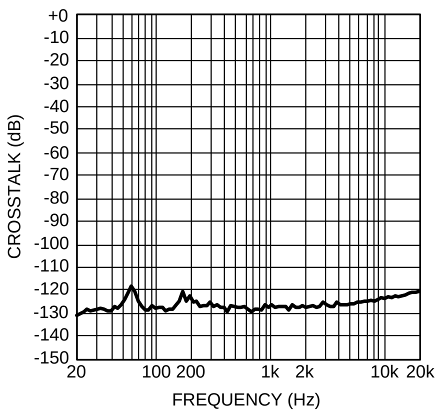



**Figure 27.**

**Crosstalk vs Frequency**
**$V_S$ = ±1.1V**
**$V_{OUT}$ = 2$V_{p-p}$**
**$R_L$ = 10kΩ**

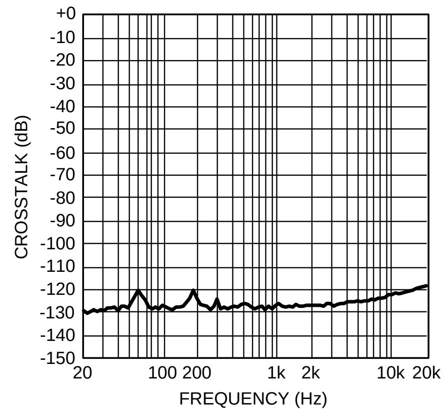



**Figure 28.**

**Crosstalk vs Frequency**
**$V_S$ = ±1.1V**
**$V_{OUT}$ = 2$V_{p-p}$**
**$R_L$ = 600Ω**

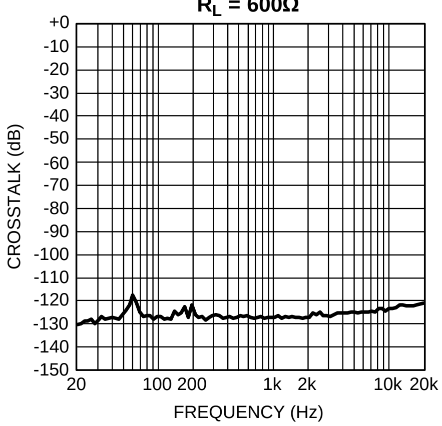



**Figure 29.**

**Crosstalk vs Frequency**
**$V_S$ = ±1.5V,**
**$V_{OUT}$ = 2$V_{p-p}$**
**$R_L$ = 2kΩ**

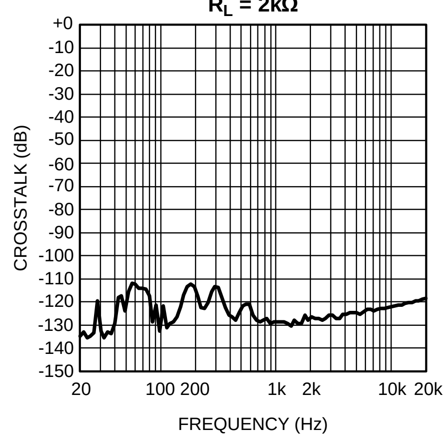



**Figure 30.**

**Crosstalk vs Frequency**
**$V_S$ = ±1.5V**
**$V_{OUT}$ = 2$V_{p-p}$**
**$R_L$ = 10kΩ**

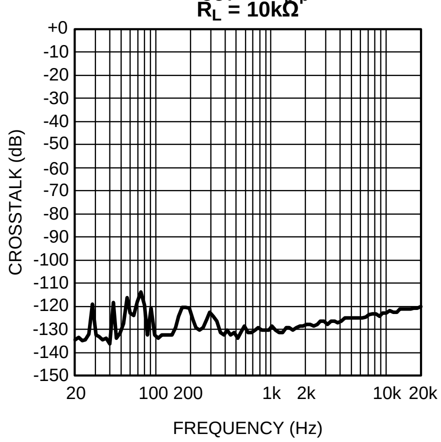



**Figure 31.**

**Crosstalk vs Frequency**
**$V_S$ = ±1.5V**
**$V_{OUT}$ = 2$V_{p-p}$**
**$R_L$ = 600Ω**

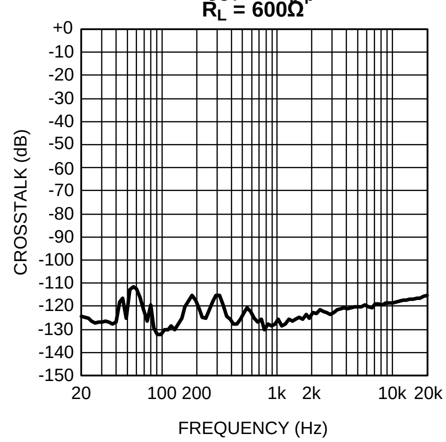



**Figure 32.**

## TYPICAL PERFORMANCE CHARACTERISTICS (continued)

Graphs were taken in dual supply configuration.

**Crosstalk vs Frequency**
**$V_S = \pm 2.5V$**
**$V_{OUT} = 4V_{p-p}$**
**$R_L = 2k\Omega$**

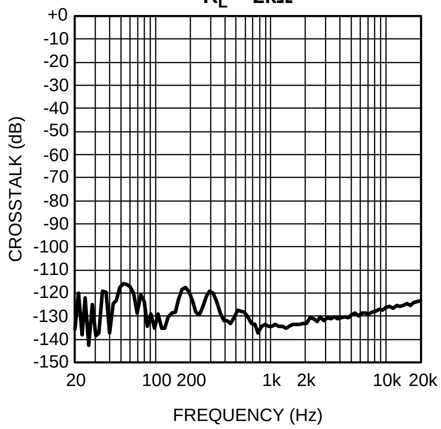



**Figure 33.**

**Crosstalk vs Frequency**
**$V_S = \pm 2.5V$**
**$V_{OUT} = 4V_{p-p}$**
**$R_L = 10k\Omega$**

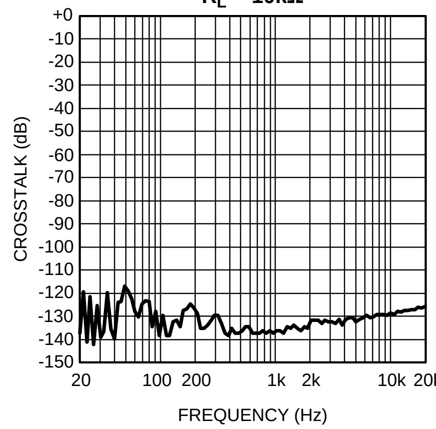



**Figure 34.**

**Crosstalk vs Frequency**
**$V_S = \pm 2.5V$**
**$V_{OUT} = 4V_{p-p}$**
**$R_L = 600\Omega$**

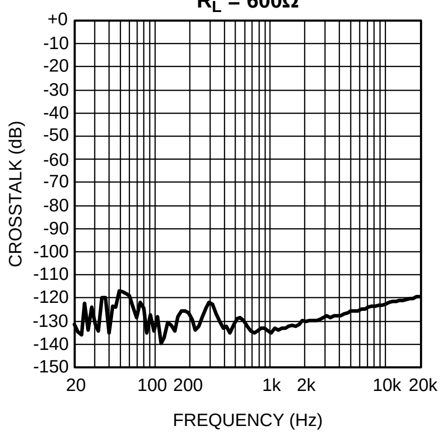



**Figure 35.**

**Crosstalk vs Frequency**
**$V_S = \pm 2.75V$**
**$V_{OUT} = 4V_{p-p}$**
**$R_L = 2k\Omega$**

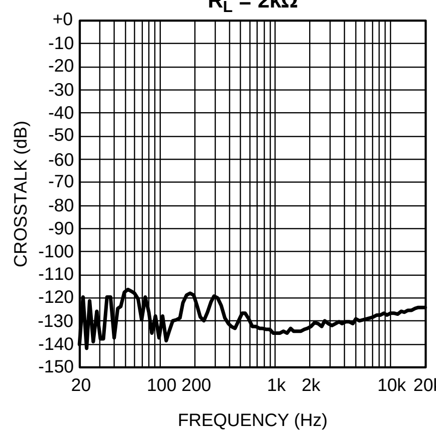



**Figure 36.**

**Crosstalk vs Frequency**
**$V_S = \pm 2.75V$**
**$V_{OUT} = 4V_{p-p}$**
**$R_L = 10k\Omega$**

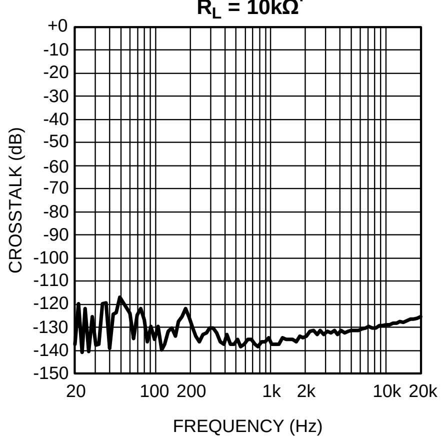



**Figure 37.**

**Crosstalk vs Frequency**
**$V_S = \pm 2.75V$**
**$V_{OUT} = 4V_{p-p}$**
**$R_L = 600\Omega$**

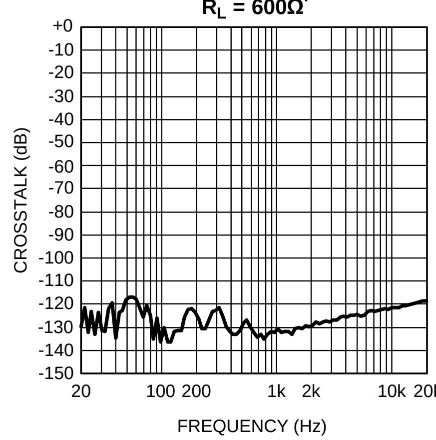



**Figure 38.**

## TYPICAL PERFORMANCE CHARACTERISTICS (continued)

Graphs were taken in dual supply configuration.

**PSRR vs Frequency**
**$V_S = \pm1.1V$**
**$V_{RIPPLE} = 200mV_{P\text{-}P}$**
**$R_L = 2k\Omega$**

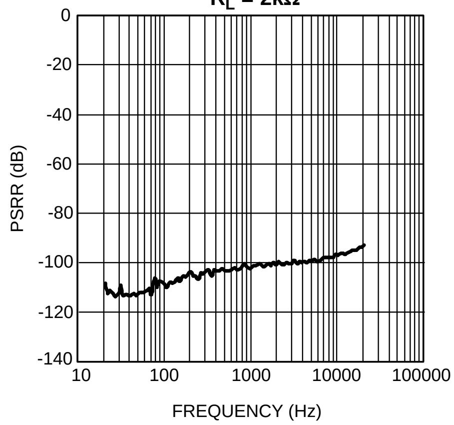



**Figure 39.**

**PSRR vs Frequency**
**$V_S = \pm1.1V$**
**$V_{RIPPLE} = 200mV_{P\text{-}P}$**
**$R_L = 10k\Omega$**

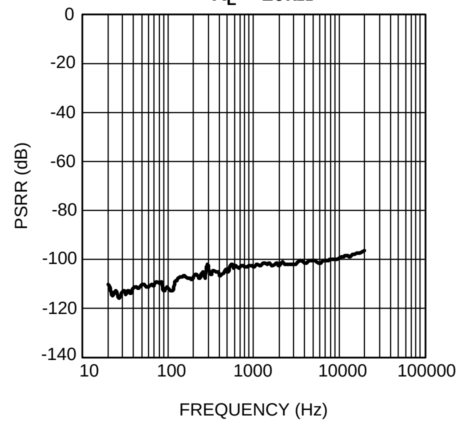



**Figure 40.**

**PSRR vs Frequency**
**$V_S = \pm1.1V$**
**$V_{RIPPLE} = 200mV_{P\text{-}P}$**
**$R_L = 600\Omega$**

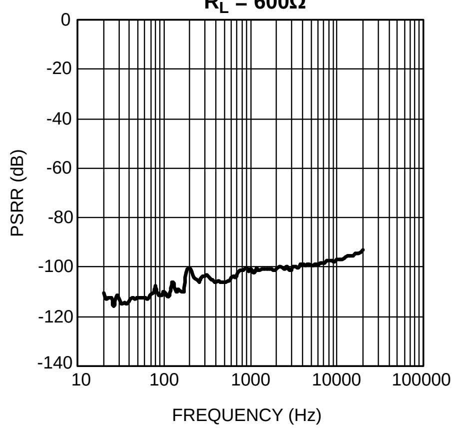



**Figure 41.**

**PSRR vs Frequency**
**$V_S = \pm1.5V$**
**$V_{RIPPLE} = 200mV_{P\text{-}P}$**
**$R_L = 2k\Omega$**

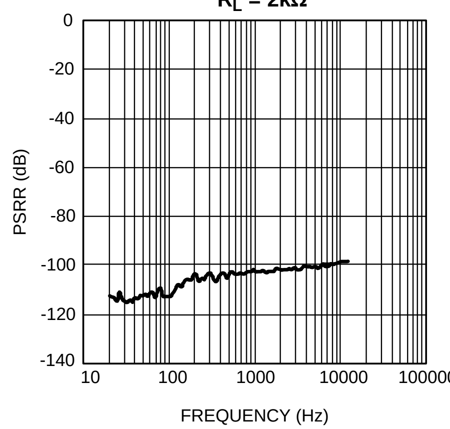



**Figure 42.**

**PSRR vs Frequency**
**$V_S = \pm1.5V$**
**$V_{RIPPLE} = 200mV_{P\text{-}P}$**
**$R_L = 10k\Omega$**

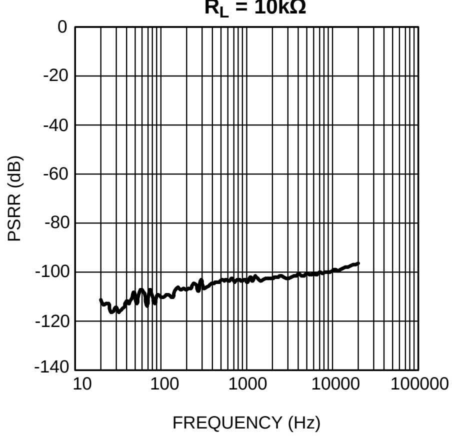



**Figure 43.**

**PSRR vs Frequency**
**$V_S = \pm1.5V$**
**$V_{RIPPLE} = 200mV_{P\text{-}P}$**
**$R_L = 600\Omega$**

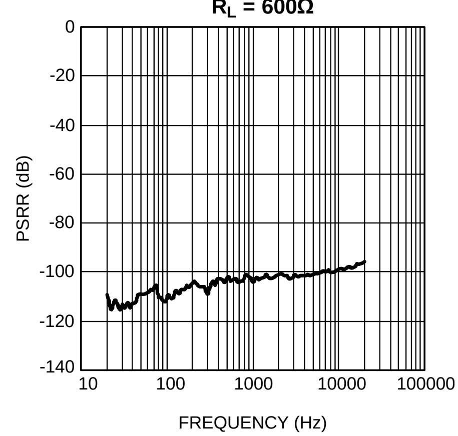



**Figure 44.**

## TYPICAL PERFORMANCE CHARACTERISTICS (continued)

Graphs were taken in dual supply configuration.

**PSRR vs Frequency**
**$V_S = \pm 2.5V$**
**$V_{RIPPLE} = 200mV_{P-P}$**
**$R_L = 2k\Omega$**

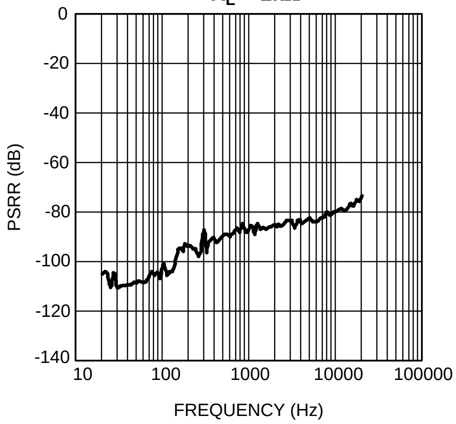



**Figure 45.**

**PSRR vs Frequency**
**$V_S = \pm 2.5V$**
**$V_{RIPPLE} = 200mV_{P-P}$**
**$R_L = 10k\Omega$**

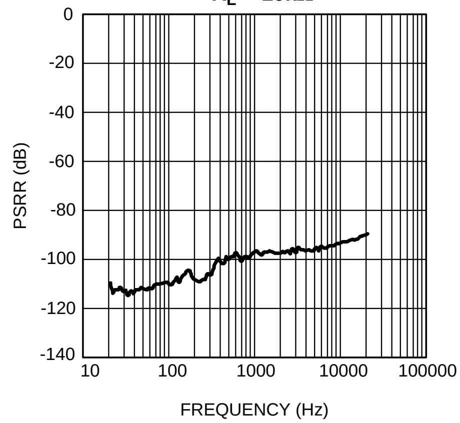



**Figure 46.**

**PSRR vs Frequency**
**$V_S = \pm 2.5V$**
**$V_{RIPPLE} = 200mV_{P-P}$**
**$R_L = 600\Omega$**

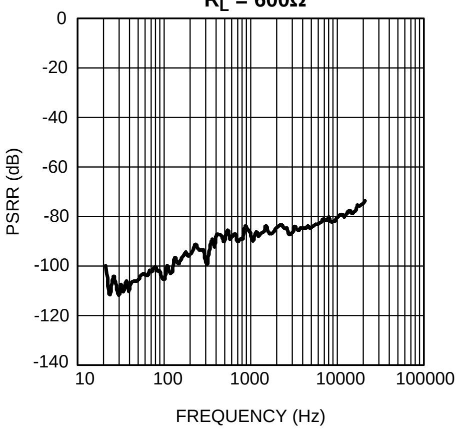



**Figure 47.**

**PSRR vs Frequency**
**$V_S = \pm 2.75V$**
**$V_{RIPPLE} = 200mV_{P-P}$**
**$R_L = 2k\Omega$**

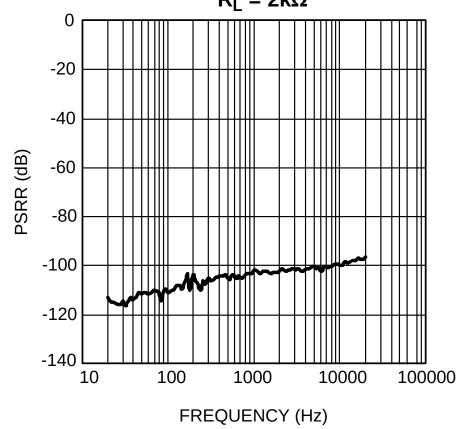



**Figure 48.**

**PSRR vs Frequency**
**$V_S = \pm 2.75V$**
**$V_{RIPPLE} = 200mV_{P-P}$**
**$R_L = 10k\Omega$**

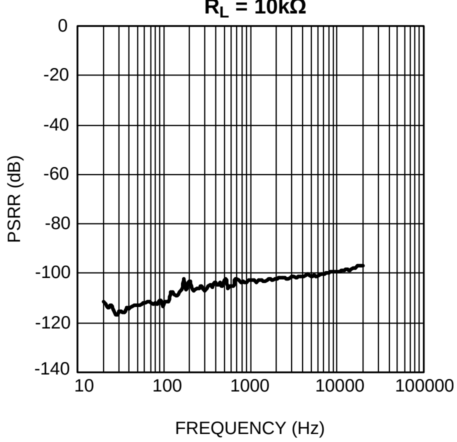



**Figure 49.**

**PSRR vs Frequency**
**$V_S = \pm 2.75V$**
**$V_{RIPPLE} = 200mV_{P-P}$**
**$R_L = 600\Omega$**

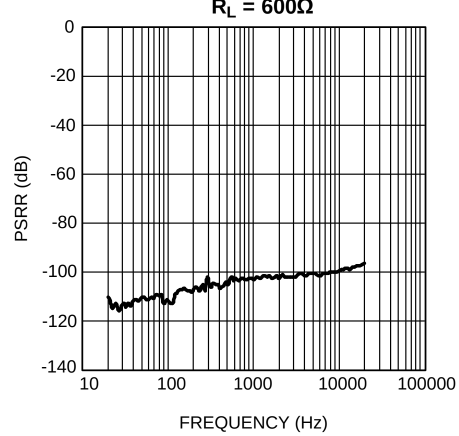



**Figure 50.**

## TYPICAL PERFORMANCE CHARACTERISTICS (continued)

Graphs were taken in dual supply configuration.

**CMRR vs Frequency**
**$V_S$ = ±1.5V**
**$R_L$ = 2kΩ**

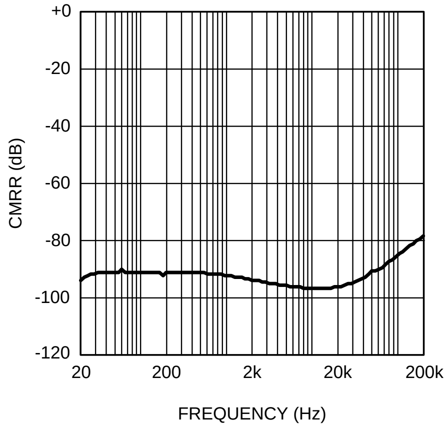



**Figure 51.**

**CMRR vs Frequency**
**$V_S$ = ±1.5V**
**$R_L$ = 10kΩ**

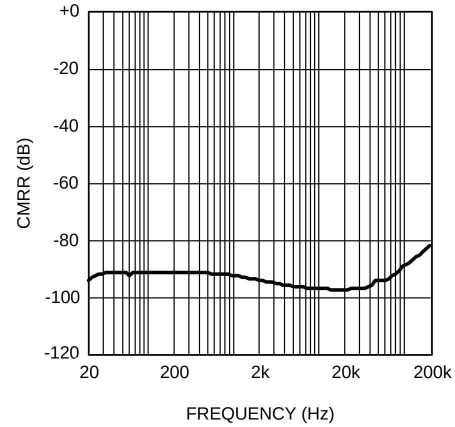



**Figure 52.**

**CMRR vs Frequency**
**$V_S$ = ±1.5V**
**$R_L$ = 600Ω**

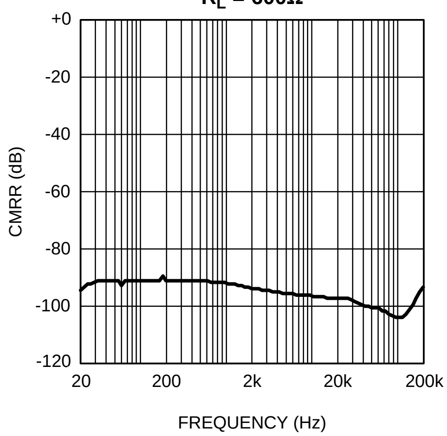



**Figure 53.**

**CMRR vs Frequency**
**$V_S$ = ±2.5V**
**$R_L$ = 2kΩ**

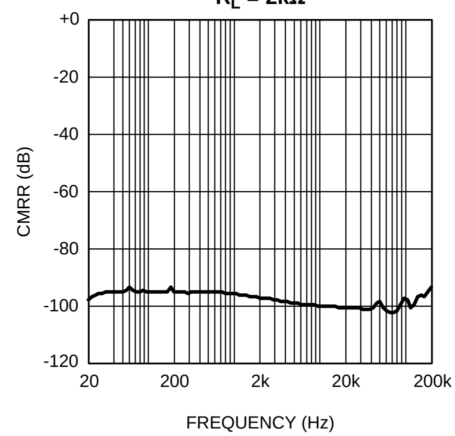



**Figure 54.**

**CMRR vs Frequency**
**$V_S$ = ±2.5V**
**$R_L$ = 10kΩ**

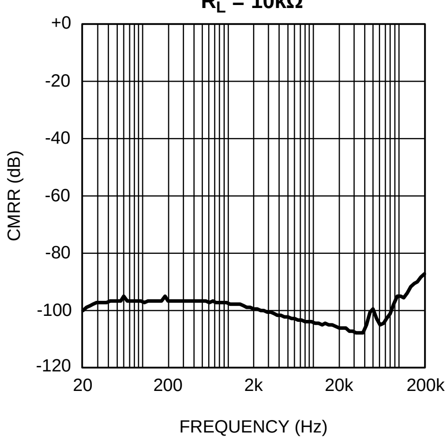



**Figure 55.**

**CMRR vs Frequency**
**$V_S$ = ±2.5V**
**$R_L$ = 600Ω**

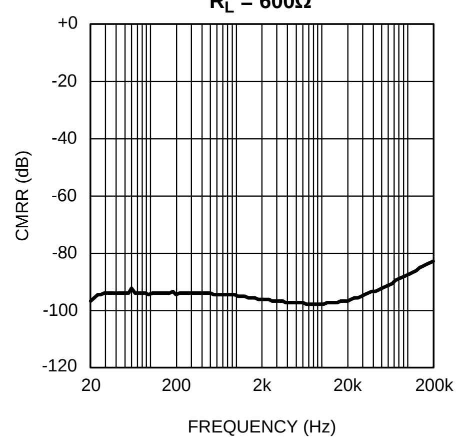



**Figure 56.**

## TYPICAL PERFORMANCE CHARACTERISTICS (continued)

Graphs were taken in dual supply configuration.

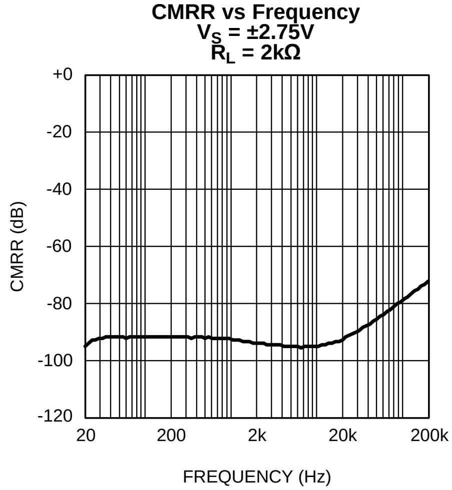



**Figure 57.**

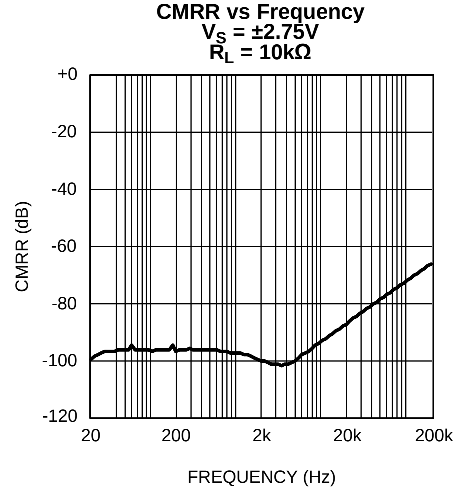



**Figure 58.**

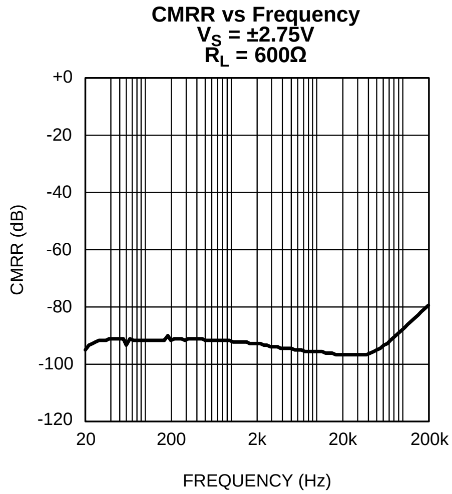



**Figure 59.**

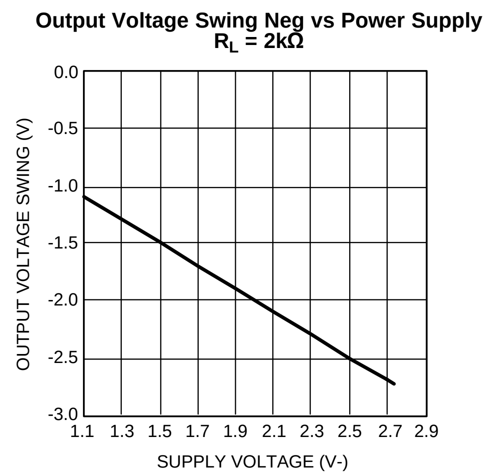



**Figure 60.**

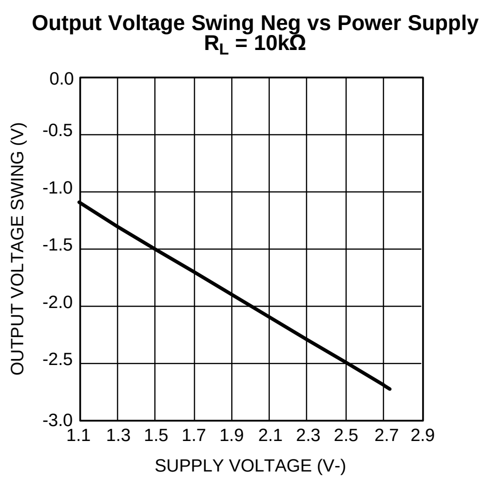



**Figure 61.**

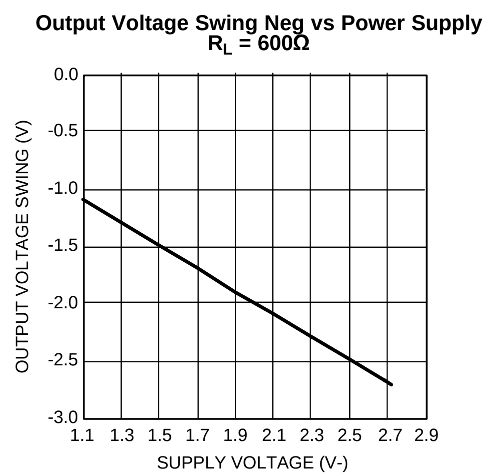



**Figure 62.**

## TYPICAL PERFORMANCE CHARACTERISTICS (continued)

Graphs were taken in dual supply configuration.

**Output Voltage Swing Pos vs Power Supply**
**$R_L$ = 2kΩ**

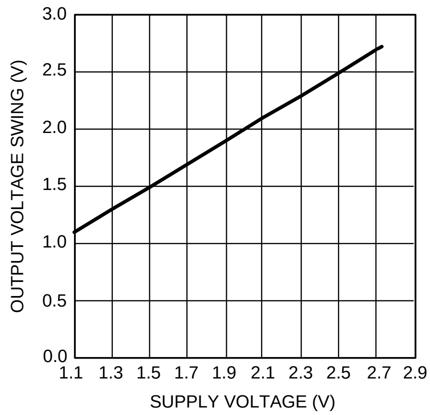



**Figure 63.**

**Output Voltage Swing Pos vs Power Supply**
**$R_L$ = 10kΩ**

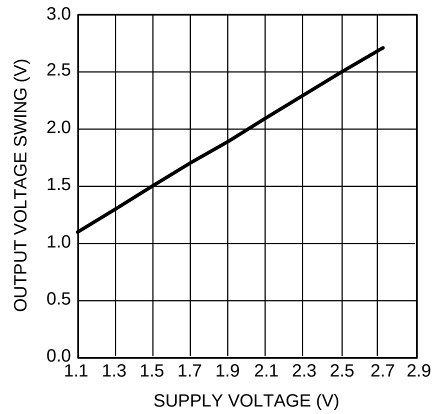



**Figure 64.**

**Output Voltage Swing Pos vs Power Supply**
**$R_L$ = 600Ω**

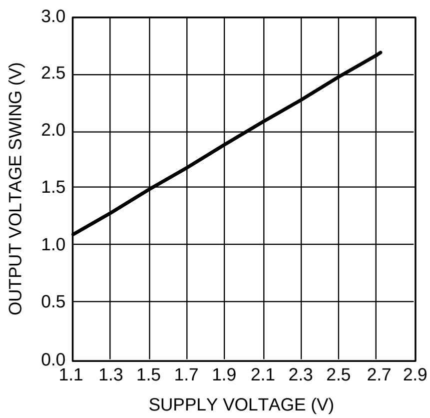



**Figure 65.**

**Supply Current per amplifier vs Power Supply**
**$R_L$ = 2kΩ, Dual Supply**

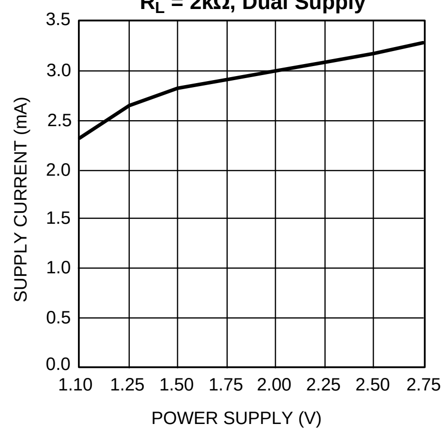



**Figure 66.**

**Supply Current per amplifier vs Power Supply**
**$R_L$ = 10kΩ, Dual Supply**

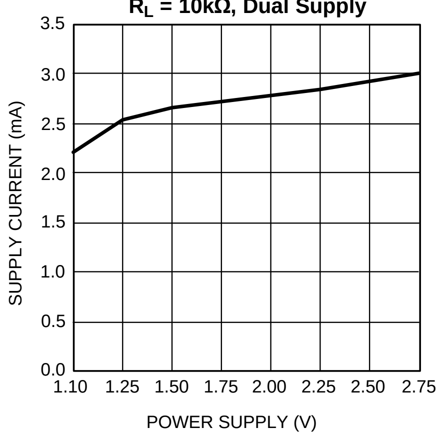



**Figure 67.**

**Supply Current per amplifier vs Power Supply**
**$R_L$ = 600Ω, Dual Supply**

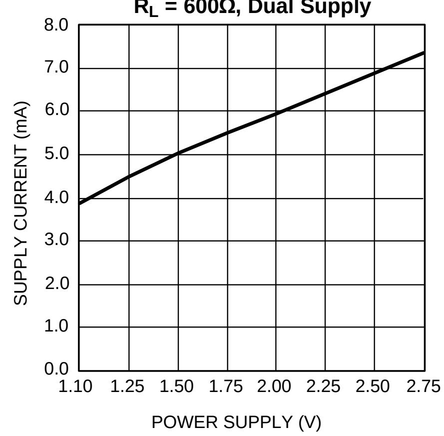



**Figure 68.**

# APPLICATION INFORMATION

## DISTORTION MEASUREMENTS

The vanishingly low residual distortion produced by LME49721 is below the capabilities of all commercially available equipment. This makes distortion measurements just slightly more difficult than simply connecting a distortion meter to the amplifier's inputs and outputs. The solution. however, is quite simple: an additional resistor. Adding this resistor extends the resolution of the distortion measurement equipment.

The LME49721's low residual is an input referred internal error. As shown in Figure 69, adding the 10Ω resistor connected between a the amplifier's inverting and non-inverting inputs changes the amplifier's noise gain. The result is that the error signal (distortion) is amplified by a factor of 101. Although the amplifier's closed-loop gain is unaltered, the feedback available to correct distortion errors is reduced by 101. To ensure minimum effects on distortion measurements, keep the value of R1 low as shown in Figure 69.

This technique is verified by duplicating the measurements with high closed-loop gain and/or making the measurements at high frequencies. Doing so, produces distortion components that are within equipments capabilities. This datasheet's THD+N and IMD values were generated using the above described circuit connected to an Audio Precision System Two Cascade.

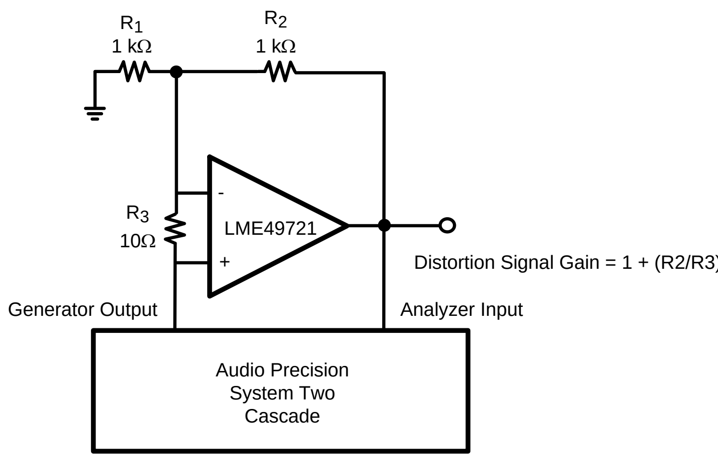



**Figure 69. THD+N and IMD Distortion Test Circuit with $A_V$ = 2**

## OPERATING RATINGS AND BASIC DESIGN GUIDELINES

The LME49721 has a supply voltage range from +2.2V to +5.5V single supply or ±1.1 to ±2.75V dual supply.

Bypassed capacitors for the supplies should be placed as close to the amplifier as possible. This will help minimize any inductance between the power supply and the supply pins. In addition to a 10μF capacitor, a 0.1μF capacitor is also recommended in CMOS amplifiers.

The amplifier's inputs lead lengths should also be as short as possible. If the op amp does not have a bypass capacitor, it may oscillate.

## BASIC AMPLIFIER CONFIGURATIONS

The LME49721 may be operated with either a single supply or dual supplies. Figure 70 shows the typical connection for a single supply inverting amplifier. The output voltage for a single supply amplifier will be centered around the common-mode voltage Vcm. Note: the voltage applied to the Vcm insures the output stays above ground. Typically, the Vcm should be equal to $V_{DD}$/2. This is done by putting a resistor divider ckt at this node, see Figure 70.

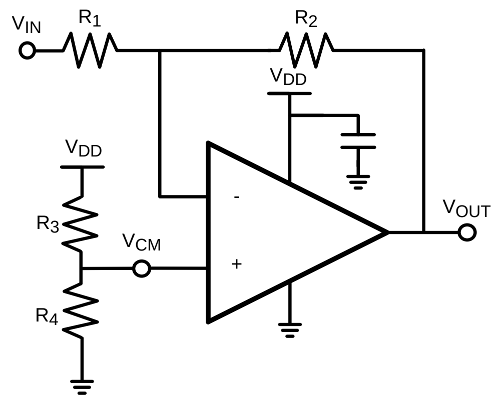



**Figure 70. Single-Supply Inverting Op Amp**

Figure 71 shows the typical connection for a dual supply inverting amplifier. The output voltage is centered on zero.

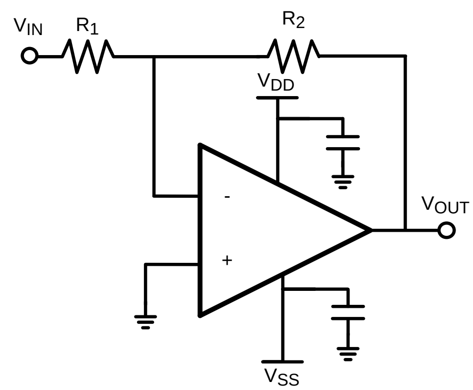



**Figure 71. Dual-Supply Inverting Op Amp**

Figure 72 shows the typical connection for the Buffer Amplifier or also called a Voltage Follower. A Buffer Amplifier can be used to solve impedance matching problems, to reduce power consumption in the source, or to drive heavy loads. The input impedance of the op amp is very high. Therefore, the input of the op amp does not load down the source. The output impedance on the other hand is very low. It allows the load to either supply or absorb energy to a circuit while a secondary voltage source dissipates energy from a circuit. The Buffer is a unity stable amplifier, 1V/V. Although the feedback loop is tied from the output of the amplifier to the inverting input, the gain is still positive. Note: if a positive feedback is used, the amplifier will most likely drive to either rail at the output.

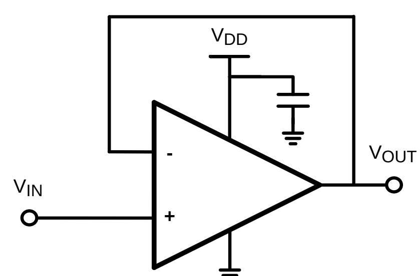
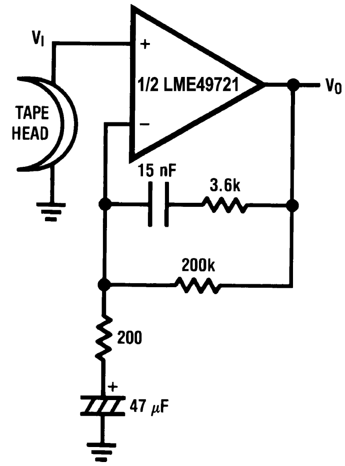



**Figure 72. Buffer**

## TYPICAL APPLICATIONS




$A_V = 34.5$
F = 1 kHz
$E_n = 0.38\ \mu V$
A Weighted

**Figure 73. ANAB Preamp**

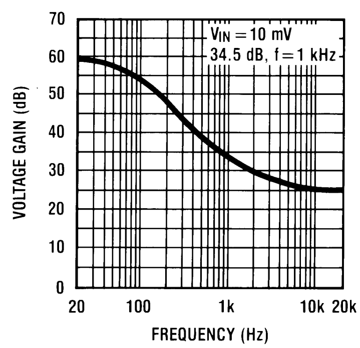
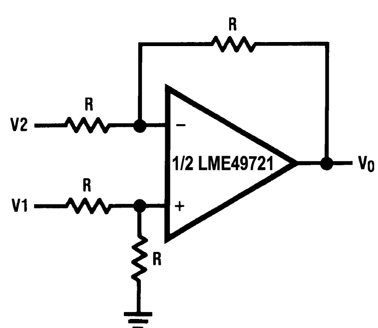
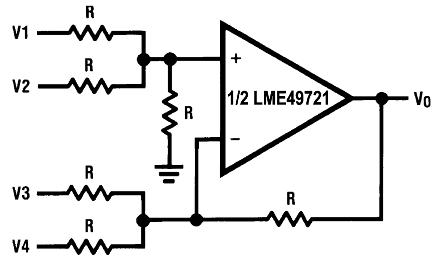



**Figure 74. NAB Preamp Voltage Gain vs Frequency**



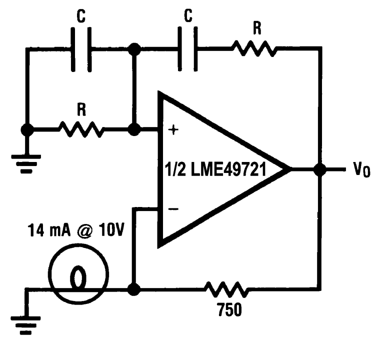

$V_O = V1 – V2$

**Figure 75. Balanced to Single-Ended Converter**



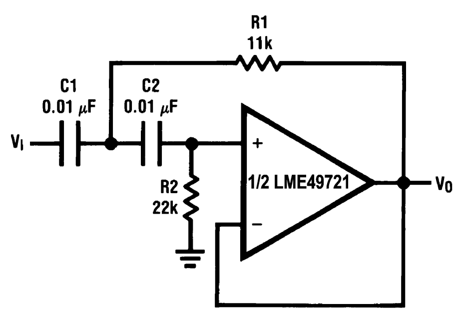

$V_O = V1 + V2 - V3 - V4$

**Figure 76. Adder/Subtracter**




$$f_o = \frac{1}{2\pi RC}$$

**Figure 77. Sine Wave Oscillator**



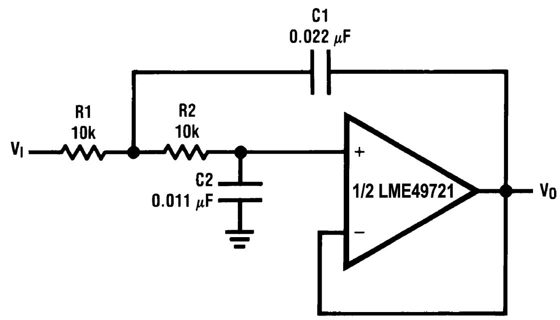

if $C1 = C2 = C$

$$R1 = \frac{\sqrt{2}}{2\omega_o C}$$

$R2 = 2 \bullet R1$

Illustration is $f_0 = 1$ kHz

**Figure 78. Second-Order High-Pass Filter (Butterworth)**



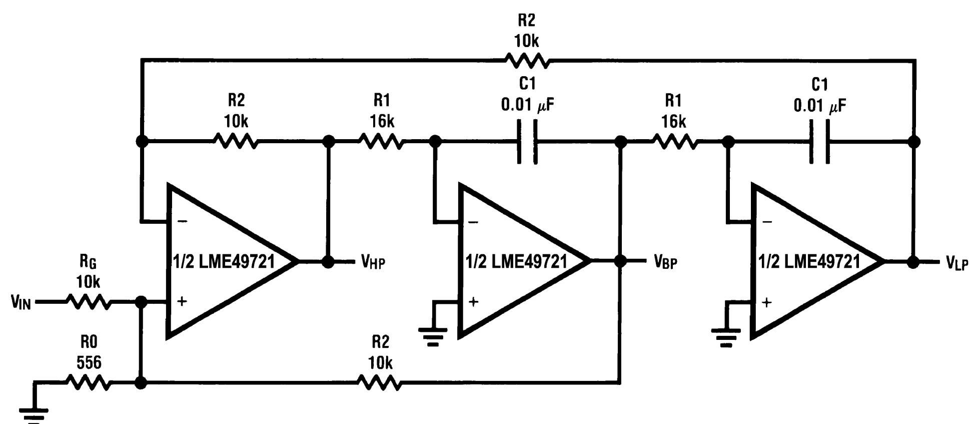

if R1 = R2 = R

$$C1 = \frac{\sqrt{2}}{\omega_0 R}$$

$$C2 = \frac{C1}{2}$$

Illustration is $f_0$ = 1 kHz

**Figure 79. Second-Order Low-Pass Filter (Butterworth)**




$$f_0 = \frac{1}{2\pi C1R1},\ Q = \frac{1}{2}\left(1 + \frac{R2}{R0} + \frac{R2}{RG}\right),\ A_{BP} = QA_{LP} = QA_{LH} = \frac{R2}{RG}$$

Illustration is $f_0$ = 1 kHz, Q = 10, $A_{BP}$ = 1

**Figure 80. State Variable Filter**

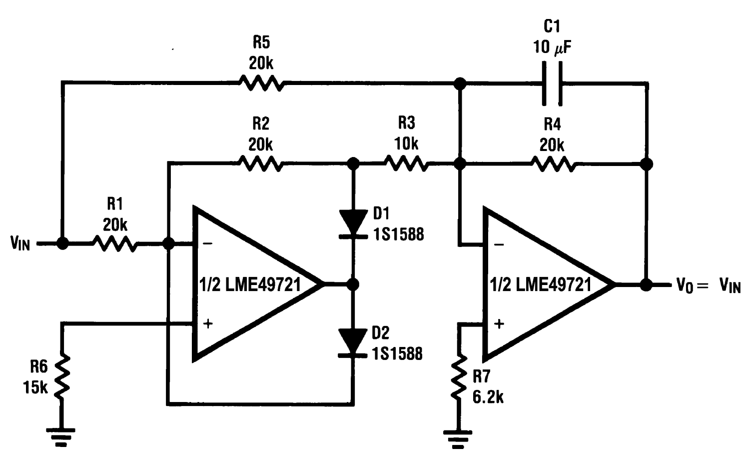



**Figure 81. AC/DC Converter**

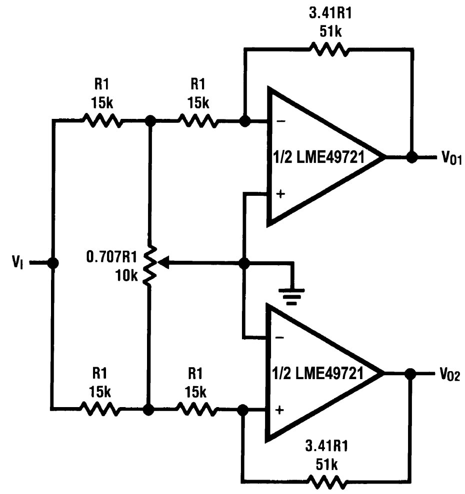



**Figure 82. 2-Channel Panning Circuit (Pan Pot)**

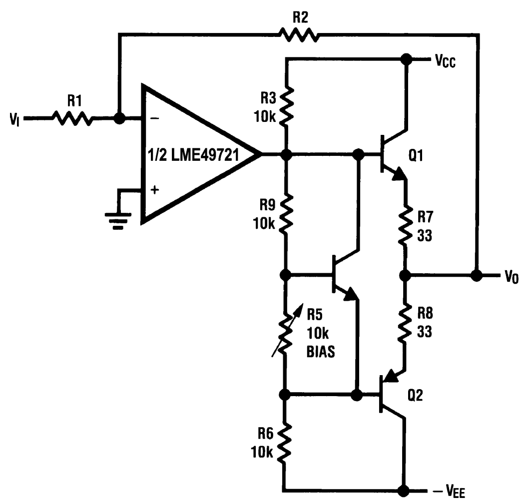
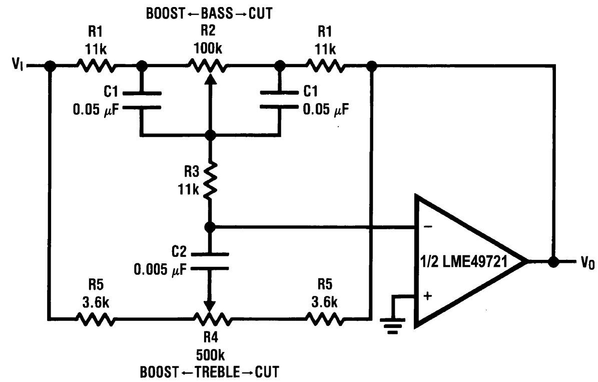



**Figure 83. Line Driver**




$f_L = \frac{1}{2\pi R2C1}$, $f_{LB} = \frac{1}{2\pi R1C1}$

$f_H = \frac{1}{2\pi R5C2}$, $f_{HB} = \frac{1}{2\pi (R1 + R5 + 2R3)C2}$

Illustration is:

$f_L$ = 32 Hz, $f_{LB}$ = 320 Hz

$f_H$ =11 kHz, $f_{HB}$ = 1.1 kHz

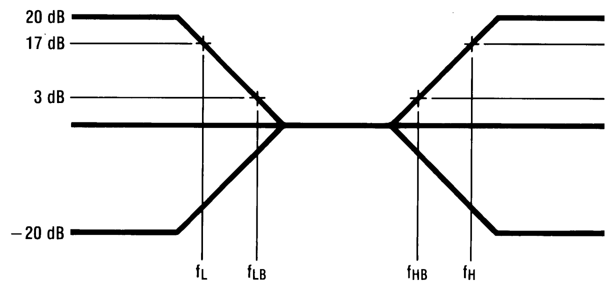
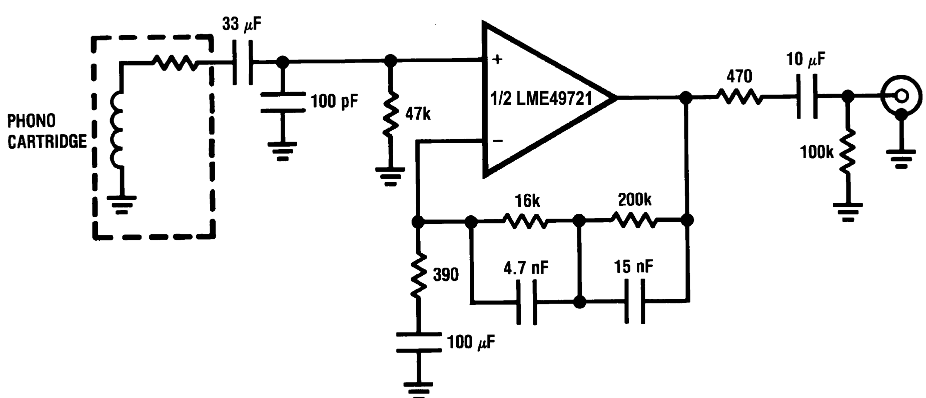
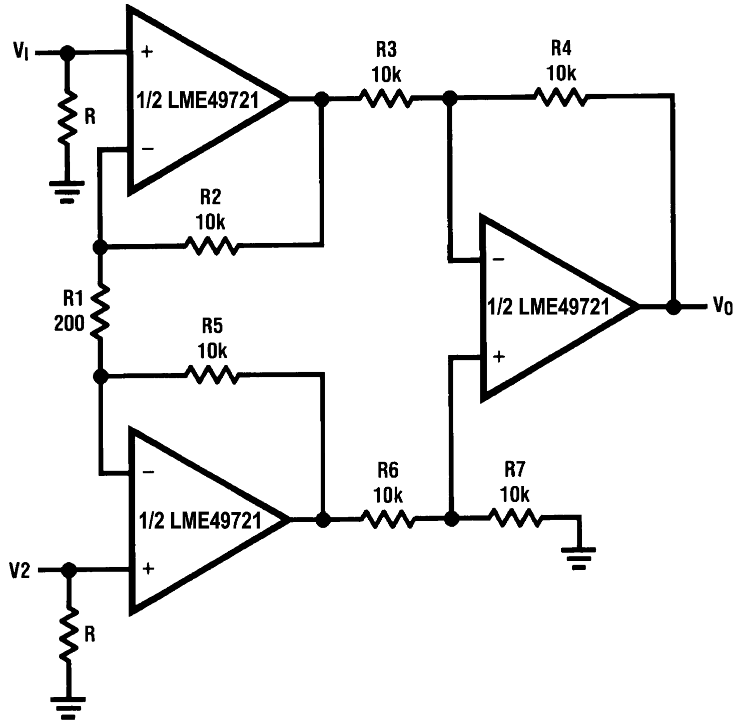



**Figure 84. Tone Control**




$A_V$ = 35 dB
$E_n$ = 0.33 µV
S/N = 90 dB
f = 1 kHz
A Weighted
A Weighted, $V_{IN}$ = 10 mV
@f = 1 kHz

**Figure 85. RIAA Preamp**

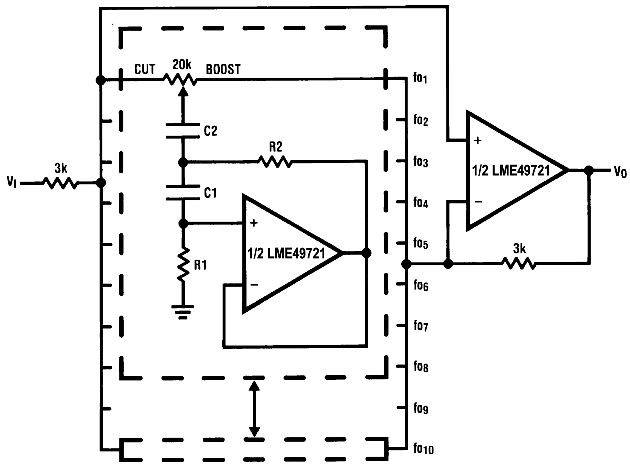



If R2 = R5, R3 = R6, R4 = R7

$$V0 = \left(1 + \frac{2R2}{R1}\right)\frac{R4}{R3}(V2 - V1)$$

Illustration is:
V0 = 101(V2 − V1)

**Figure 86. Balanced Input Mic Amp**




A. See Table 1.

**Figure 87. 10-Band Graphic Equalizer**

**Table 1. $C_1$, $C_2$, $R_1$, and $R_2$ Values for Figure 87(1)**

| fo (Hz) | $C_1$ | $C_2$ | $R_1$ | $R_2$ |
|---|---|---|---|---|
| 32 | 0.12µF | 4.7µF | 75kΩ | 500Ω |
| 64 | 0.056µF | 3.3µF | 68kΩ | 510Ω |
| 125 | 0.033µF | 1.5µF | 62kΩ | 510Ω |
| 250 | 0.015µF | 0.82µF | 68kΩ | 470Ω |
| 500 | 8200pF | 0.39µF | 62kΩ | 470Ω |
| 1k | 3900pF | 0.22µF | 68kΩ | 470Ω |
| 2k | 2000pF | 0.1µF | 68kΩ | 470Ω |
| 4k | 1100pF | 0.056µF | 62kΩ | 470Ω |
| 8k | 510pF | 0.022µF | 68kΩ | 510Ω |
| 16k | 330pF | 0.012µF | 51kΩ | 510Ω |

(1) At volume of change = ±12 dB Q = 1.7

## REVISION HISTORY

| Rev | Date | Description |
|---|---|---|
| 1.0 | 09/26/07 | Initial release. |
| 1.1 | 10/01/07 | Input more info under the Buffer Amplifier. |
| 1.2 | 04/21/10 | Added the Ordering Information table. |
| C | 04/04/13 | Changed layout of National Data Sheet to TI format. |

## PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish | MSL Peak Temp (3) | Op Temp (°C) | Top-Side Markings (4) | Samples |
|---|---|---|---|---|---|---|---|---|---|---|---|
| LME49721MA/NOPB | ACTIVE | SOIC | D | 8 | 95 | Green (RoHS & no Sb/Br) | CU SN | Level-1-260C-UNLIM | -40 to 85 | L49721 MA | Samples |
| LME49721MAX/NOPB | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU SN | Level-1-260C-UNLIM | -40 to 85 | L49721 MA | Samples |

(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.

(4) Multiple Top-Side Markings will be inside parentheses. Only one Top-Side Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Top-Side Marking for that device.

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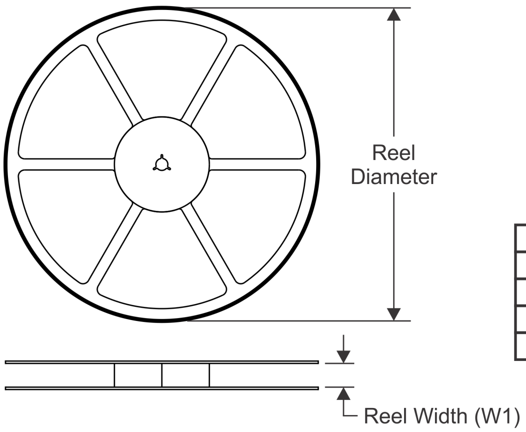
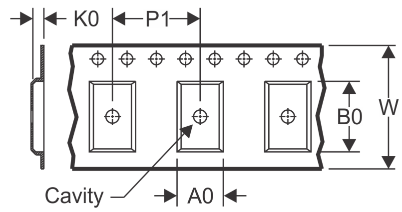
## TAPE AND REEL INFORMATION

### REEL DIMENSIONS

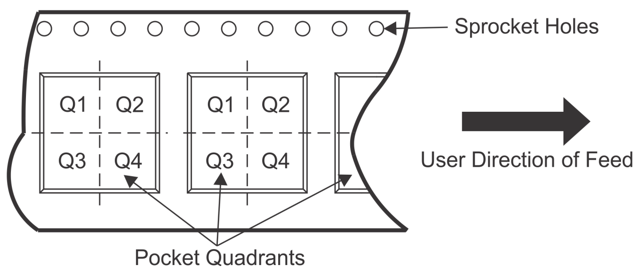



### TAPE DIMENSIONS




| | |
|---|---|
| A0 | Dimension designed to accommodate the component width |
| B0 | Dimension designed to accommodate the component length |
| K0 | Dimension designed to accommodate the component thickness |
| W | Overall width of the carrier tape |
| P1 | Pitch between successive cavity centers |

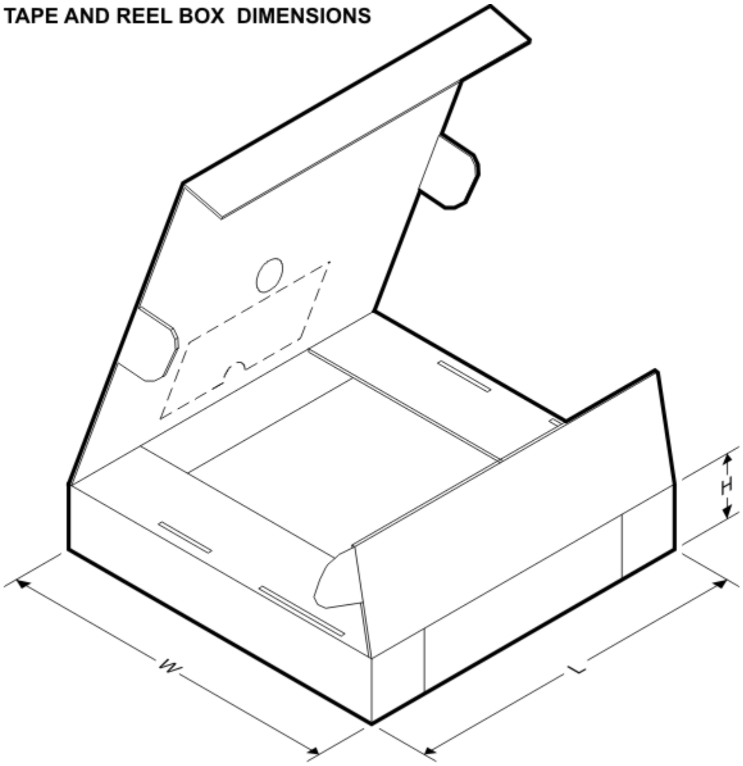
### QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE




*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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LME49721MAX/NOPB | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.5 | 5.4 | 2.0 | 8.0 | 12.0 | Q1 |

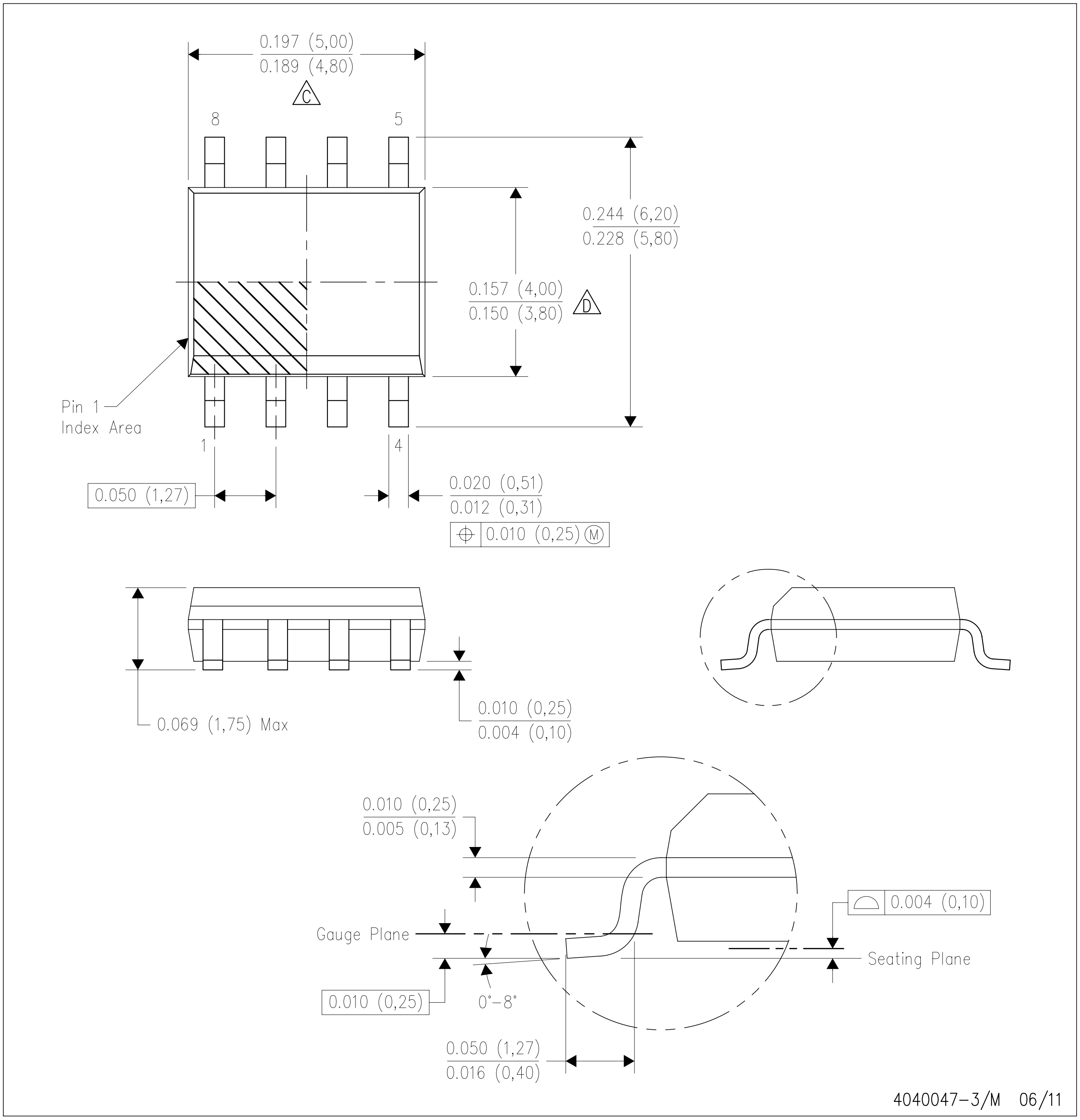
**TAPE AND REEL BOX DIMENSIONS**




*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---|---|---|---|---|---|---|---|
| LME49721MAX/NOPB | SOIC | D | 8 | 2500 | 349.0 | 337.0 | 45.0 |

D (R-PDSO-G8) PLASTIC SMALL OUTLINE




NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
D. Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
E. Reference JEDEC MS-012 variation AA.