

# LME49723

## Dual High Fidelity Audio Operational Amplifier

### General Description

The LME49723 is part of the ultra-low distortion, low noise, high slew rate operational amplifier series optimized and fully specified for high performance, high fidelity applications. Combining advanced leading-edge process technology with state-of-the-art circuit design, the LME49723 audio operational amplifiers deliver superior audio signal amplification for outstanding audio performance. The LME49723 combines extremely low voltage noise density ( $3.6\text{nV}/\sqrt{\text{Hz}}$ ) with vanishingly low THD+N (0.0002%) to easily satisfy the most demanding audio applications. To ensure that the most challenging loads are driven without compromise, the LME49723 has a high slew rate of  $\pm 20\text{V}/\mu\text{s}$  and an output current capability of  $\pm 26\text{mA}$ . Further, dynamic range is maximized by an output stage that drives  $2\text{k}\Omega$  loads to within 1V of either power supply voltage and to within 1.4V when driving  $600\Omega$  loads. The LME49723's outstanding CMRR (100dB), PSRR (100dB), and  $V_{\text{OS}}$  (0.3mV) give the amplifier excellent operational amplifier DC performance.

The LME49723 has a wide supply range of  $\pm 2.5\text{V}$  to  $\pm 17\text{V}$ . Over this supply range the LME49723's input circuitry maintains excellent common-mode and power supply rejection, as well as maintaining its low input bias current. The LME49723 is unity gain stable.

The LME49723 is available in an 8-lead narrow body SOIC. Demonstration boards are available for each package.

### Key Specifications

- Power Supply Voltage Range  $\pm 2.5\text{V}$  to  $\pm 17\text{V}$
- THD+N ( $A_V = 1$ ,  $V_{\text{OUT}} = 3V_{\text{RMS}}$ ,  $f_{\text{IN}} = 1\text{kHz}$ )  
 $R_L = 2\text{k}\Omega$  0.0002% (typ)

$R_L = 600\Omega$	0.0002% (typ)
■ Input Noise Density	$3.6\text{nV}/\sqrt{\text{Hz}}$ (typ)
■ Slew Rate	$\pm 8\text{V}/\mu\text{s}$ (typ)
■ Gain Bandwidth Product	17MHz (typ)
■ Open Loop Gain ( $R_L = 600\Omega$ )	105dB (typ)
■ Input Bias Current	200nA (typ)
■ Input Offset Voltage	0.3mV (typ)

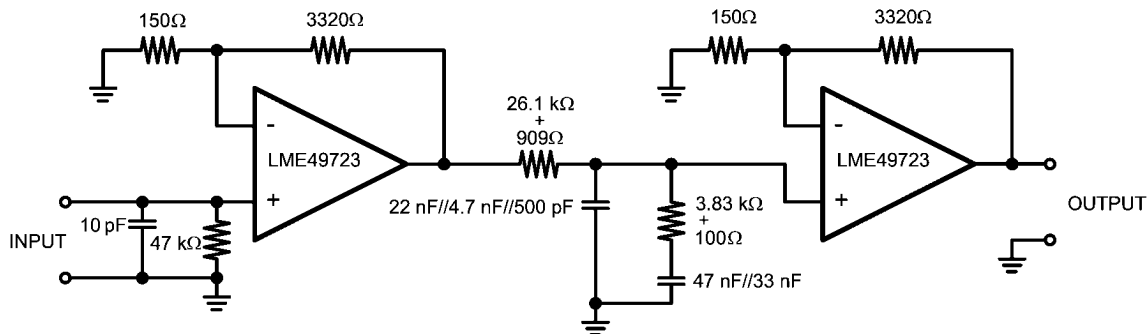
### Features

- Easily drives  $600\Omega$  loads
- Optimized for superior audio signal fidelity
- Output short circuit protection
- PSRR and CMRR exceed 100dB (typ)
- SOIC package

### Applications

- High quality audio amplification
- High fidelity preamplifiers
- High fidelity multimedia
- 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

### Typical Application

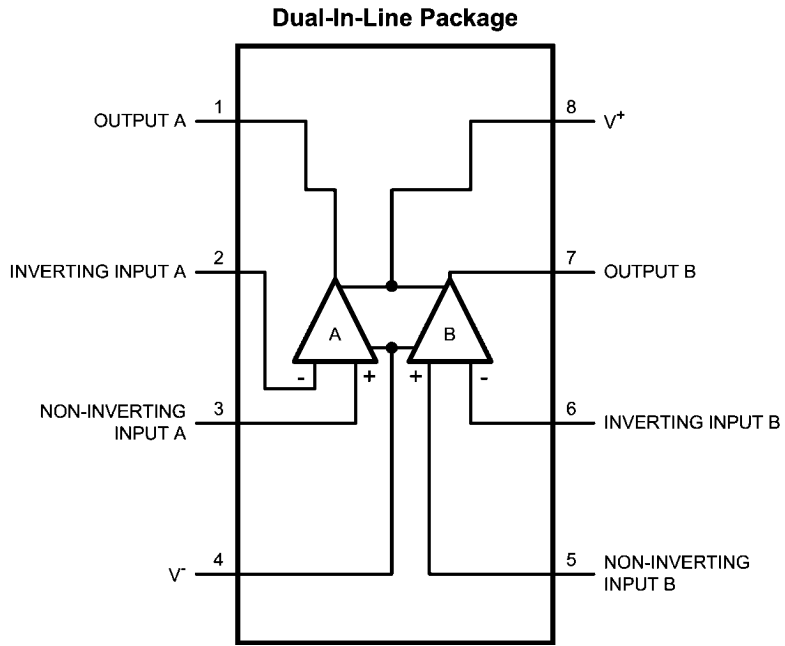


Note: 1% metal film resistors, 5% polypropylene capacitors

**Passively Equalized RIAA Phono Preamp**

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# Connection Diagram



**Order Number LME49723MA**  
**See NS Package Number — M08A**

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**Absolute Maximum Ratings** (Notes 1, 2)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Power Supply Voltage ( $V_S = V^+ - V^-$ )	36V
Storage Temperature	-65°C to 150°C
Input Voltage	(V-) - 0.7V to (V+) + 0.7V
Output Short Circuit (Note 3)	Continuous

Power Dissipation	Internally Limited
ESD Susceptibility (Note 4)	800V
ESD Susceptibility (Note 5)	180V
Junction Temperature	150°C
Thermal Resistance	
$\theta_{JA}$ (SO)	145°C/W
Temperature Range	
$T_{MIN} \leq T_A \leq T_{MAX}$	-40°C $\leq T_A \leq$ 85°C
Supply Voltage Range	$\pm 2.5V \leq V_S \leq \pm 17V$

**Electrical Characteristics for the LME49723** (Notes 1, 2) The specifications apply for  $V_S = \pm 15V$ ,  $R_L = 2k\Omega$ ,  $f_{IN} = 1kHz$ ,  $T_A = 25^\circ C$ , unless otherwise specified.

Symbol	Parameter	Conditions	LME49723		Units (Limits)
			Typical	Limit	
			(Note 6)	(Note 7)	
THD+N	Total Harmonic Distortion + Noise	$A_V = 1$ , $V_{OUT} = 3V_{rms}$ $R_L = 2k\Omega$ $R_L = 600\Omega$	0.0002 0.0002	0.0004	% (max)
IMD	Intermodulation Distortion	$A_V = 1$ , $V_{OUT} = 3V_{RMS}$ Two-tone, 60Hz & 7kHz 4:1	0.0005		%
GBWP	Gain Bandwidth Product		19	15	MHz (min)
SR	Slew Rate		$\pm 8$	$\pm 6$	V/ $\mu s$ (min)
FPBW	Full Power Bandwidth	$V_{OUT} = 1V_{P-P}$ , -3dB referenced to output magnitude at $f = 1kHz$	4		MHz
$e_n$	Equivalent Input Noise Voltage	$f_{BW} = 20Hz$ to 20kHz	0.45	0.65	$\mu V_{RMS}$ (max)
	Equivalent Input Noise Density	$f = 1kHz$ $f = 10Hz$	3.2 8.5	5	nV/ $\sqrt{Hz}$ (max)
$i_n$	Current Noise Density	$f = 1kHz$ $f = 10Hz$	0.7 1.3		pA/ $\sqrt{Hz}$
$V_{OS}$	Offset Voltage		$\pm 0.3$	1	mV (max)
$\Delta V_{OS}/\Delta Temp$	Average Input Offset Voltage Drift vs Temperature	-40°C $\leq T_A \leq$ 85°C	0.2		$\mu V/^\circ C$
PSRR	Average Input Offset Voltage Shift vs Power Supply Voltage	$\Delta V_S = 20V$ (Note 8)	100	95	dB (min)
ISO <sub>CH-CH</sub>	Channel-to-Channel Isolation	$f_{IN} = 1kHz$ $f_{IN} = 20kHz$	118 112		dB
$I_B$	Input Bias Current	$V_{CM} = 0V$	200	300	nA (max)
$\Delta I_{OS}/\Delta Temp$	Input Bias Current Drift vs Temperature	-40°C $\leq T_A \leq$ 85°C	0.1		nA/ $^\circ C$
$I_{OS}$	Input Offset Current	$V_{CM} = 0V$	7	100	nA (max)
$V_{IN-CM}$	Common-Mode Input Voltage Range		$\pm 14$	(V+) - 2.0 (V-) + 2.0	V (min)
CMRR	Common-Mode Rejection	-10V < $V_{cm}$ < 10V	100	90	dB (min)
$Z_{IN}$	Differential Input Impedance		30		k $\Omega$
	Common Mode Input Impedance	-10V < $V_{cm}$ < 10V	1000		M $\Omega$
$A_{VOL}$	Open Loop Voltage Gain	-10V < $V_{out}$ < 10V, $R_L = 600\Omega$	100	98	dB (min)
		-10V < $V_{out}$ < 10V, $R_L = 2k\Omega$	105		
		-10V < $V_{out}$ < 10V, $R_L = 10k\Omega$	105		

Symbol	Parameter	Conditions	LME49723		Units (Limits)
			Typical	Limit	
			(Note 6)	(Note 7)	
V <sub>OUTMAX</sub>	Maximum Output Voltage Swing	R <sub>L</sub> = 600Ω	±13.5	±12.5	V (min)
		R <sub>L</sub> = 2kΩ	±14.0		
		R <sub>L</sub> = 10kΩ	±14.1		
I <sub>OUT</sub>	Output Current	R <sub>L</sub> = 600Ω, V <sub>S</sub> = ±17V	±25	±21	mA (min)
I <sub>OUT-CC</sub>	Instantaneous Short Circuit Current		+53 -42		mA
R <sub>OUT</sub>	Output Impedance	f <sub>IN</sub> = 10kHz			Ω
		Closed-Loop Open-Loop	0.01 13		
C <sub>LOAD</sub>	Capacitive Load Drive Overshoot	100pF	16		%
I <sub>S</sub>	Total Quiescent Current	I <sub>OUT</sub> = 0mA	6.7	7.5	mA (max)

**Note 1:** *Absolute Maximum Ratings* indicate limits beyond which damage to the device may occur.

**Note 2:** *Operating Ratings* indicate conditions for which the device is functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics. The guaranteed specifications apply only for the test conditions listed. Some performance characteristics may degrade when the device is not operated under the listed test conditions.

**Note 3:** Amplifier output connected to GND, any number of amplifiers within a package.

**Note 4:** Human body model, 100pF discharged through a 1.5kΩ resistor.

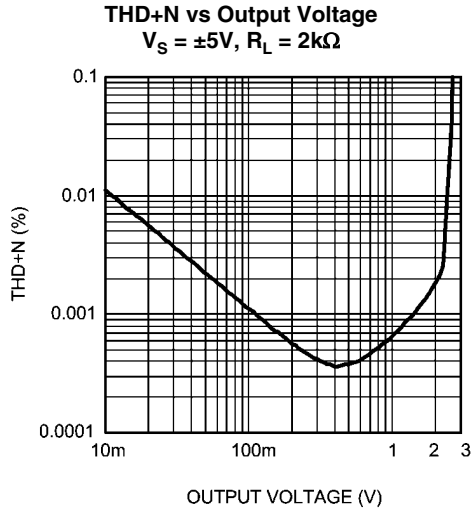
**Note 5:** Machine Model ESD test is covered by specification EIAJ IC-121-1981. A 200pF cap is charged to the specified voltage and then discharged directly into the IC with no external series resistor (resistance of discharge path must be under 50Ω).

**Note 6:** Typical specifications are specified at +25°C and represent the most likely parametric norm.

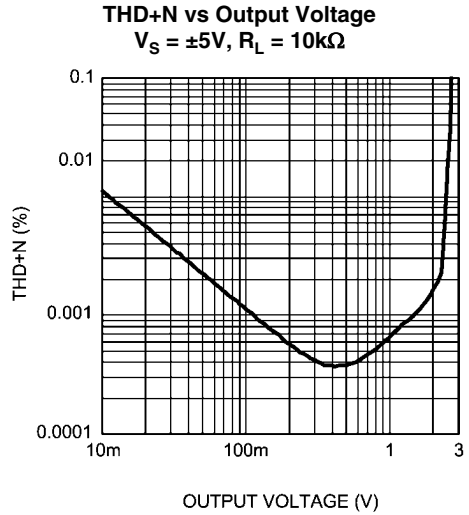
**Note 7:** Tested limits are guaranteed to National's AOQL (Average Outgoing Quality Level).

**Note 8:** PSRR is measured as follows: V<sub>OS</sub> is measured at two supply voltages, ±5V and ±15V. PSRR = | 20log(ΔV<sub>OS</sub>/ΔV<sub>S</sub>) |.

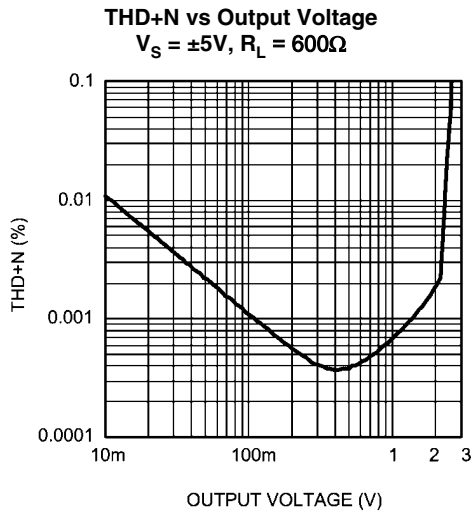
# Typical Performance Characteristics



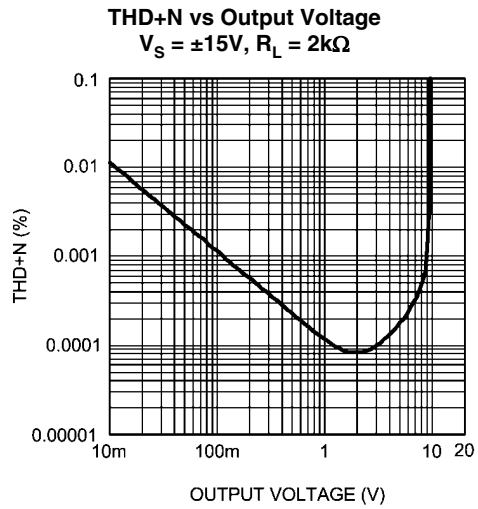
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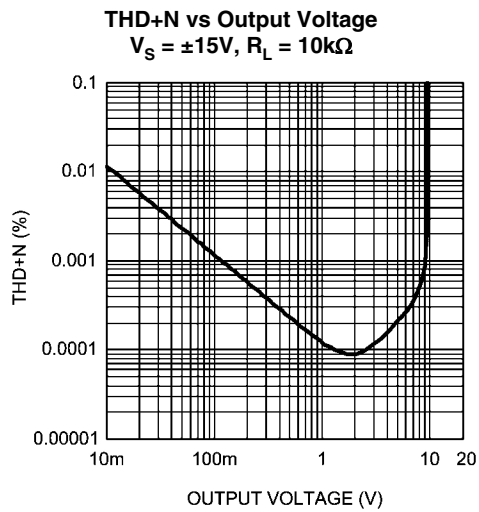
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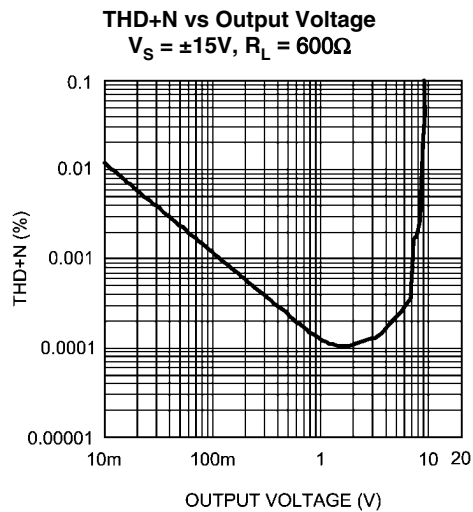
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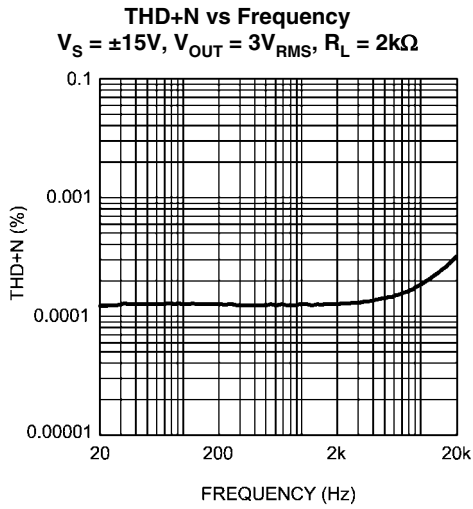
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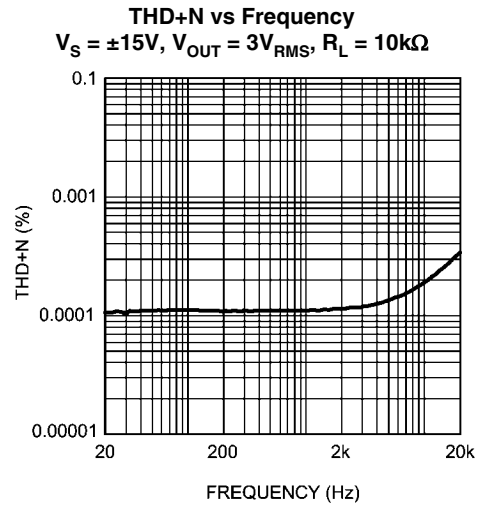
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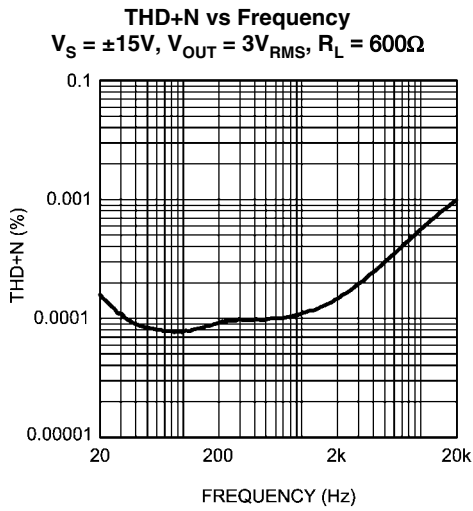
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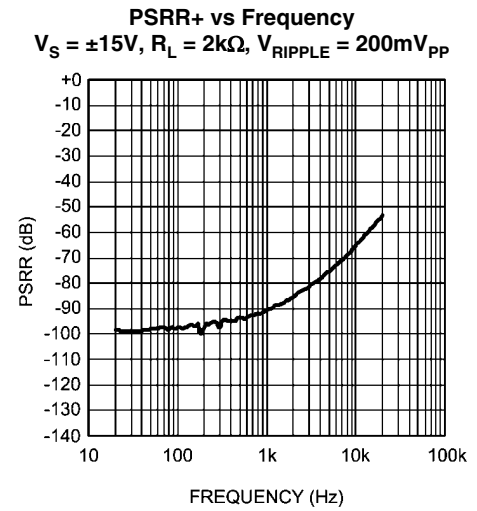
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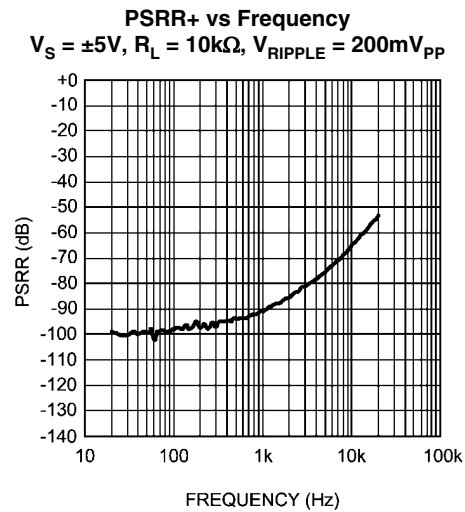
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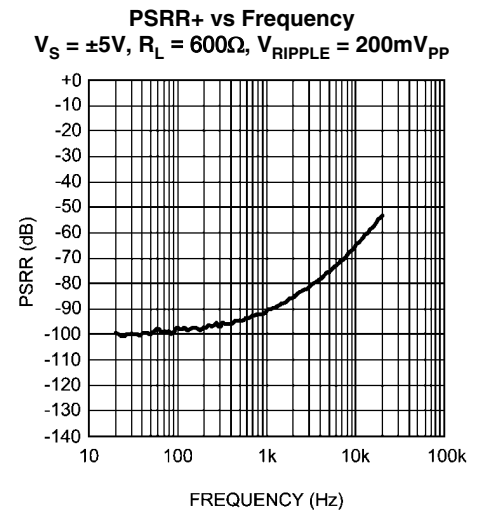
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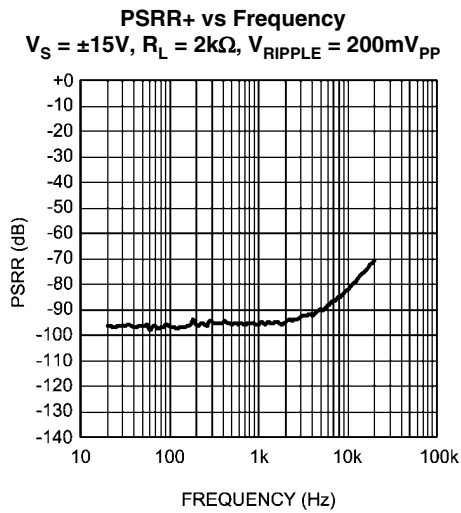
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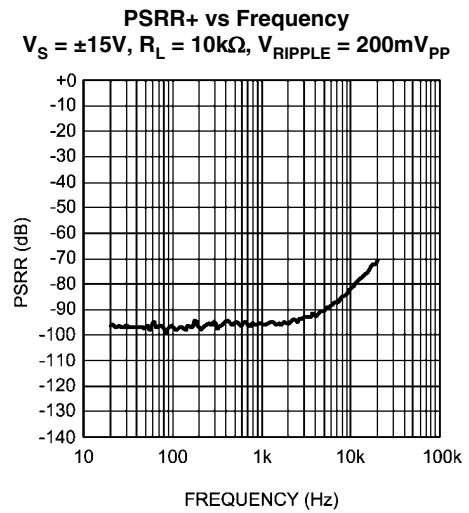
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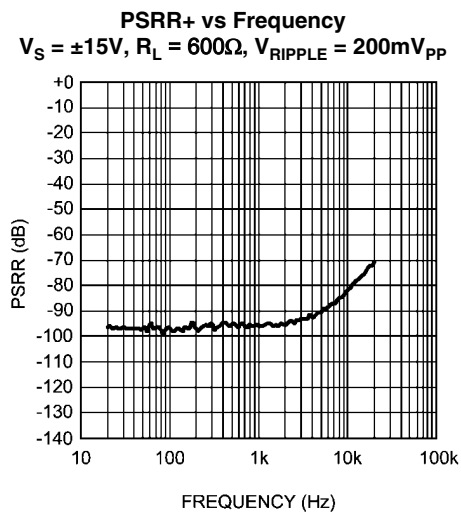
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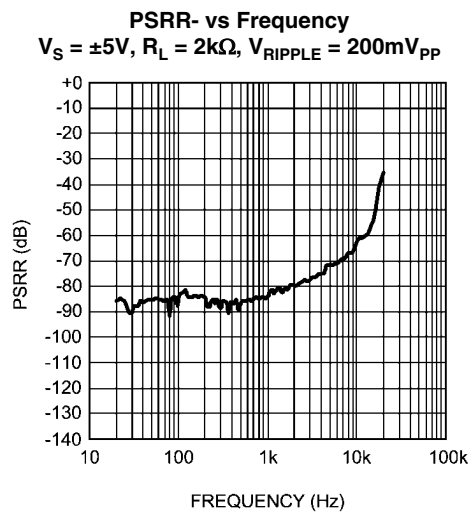
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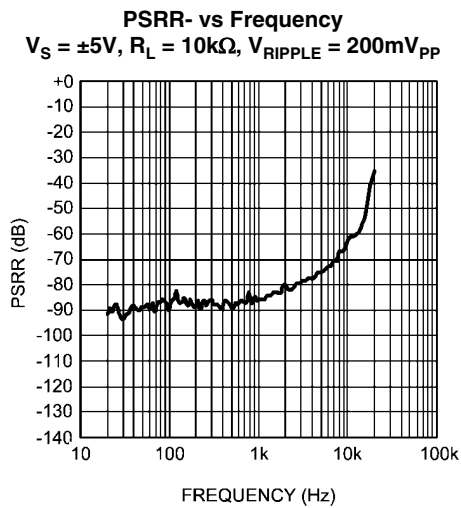
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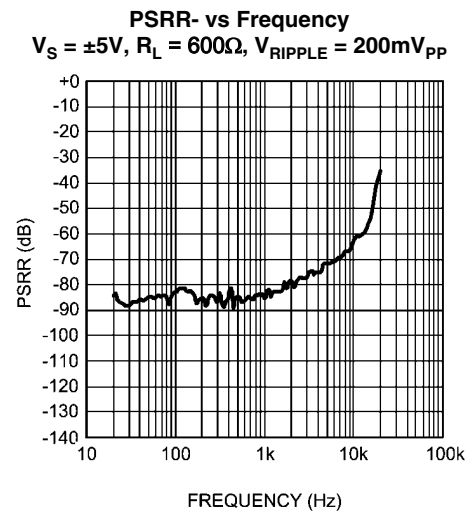
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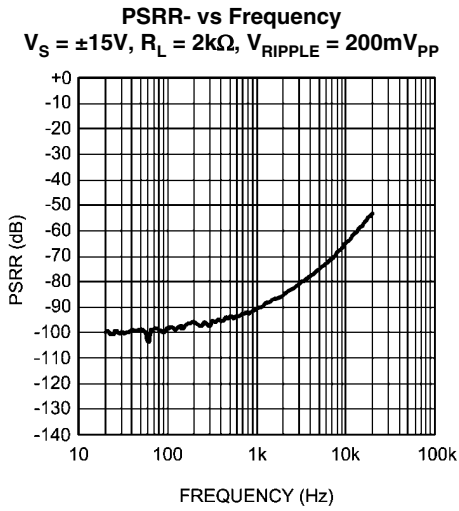
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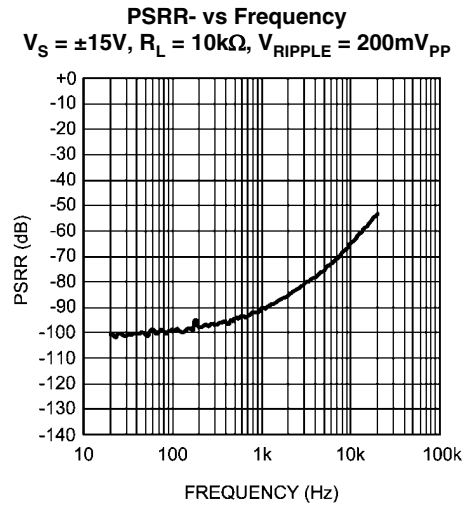
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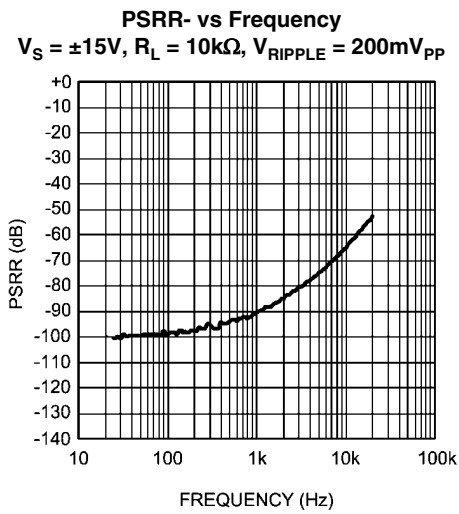
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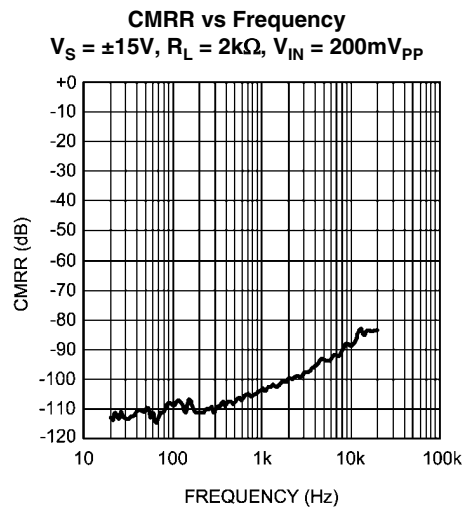
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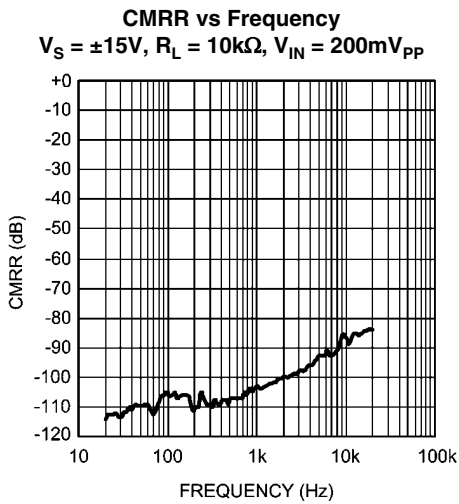
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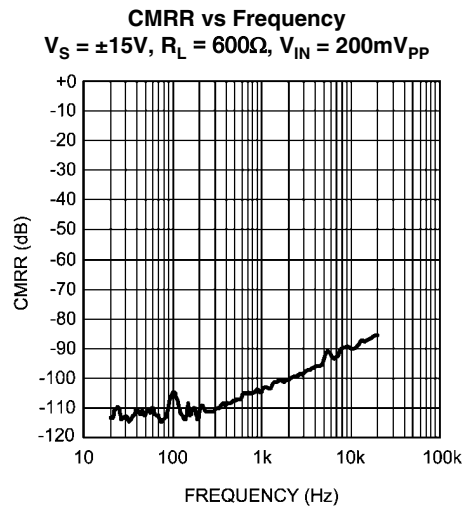
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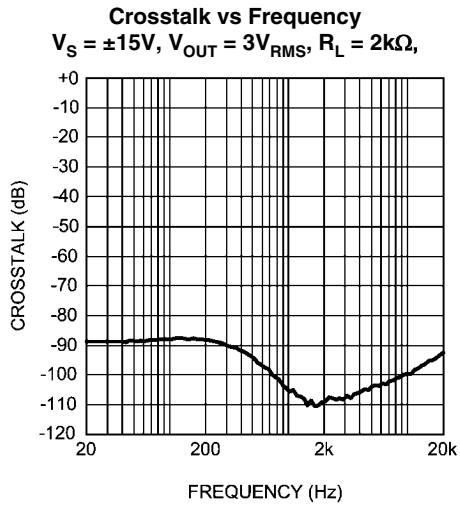


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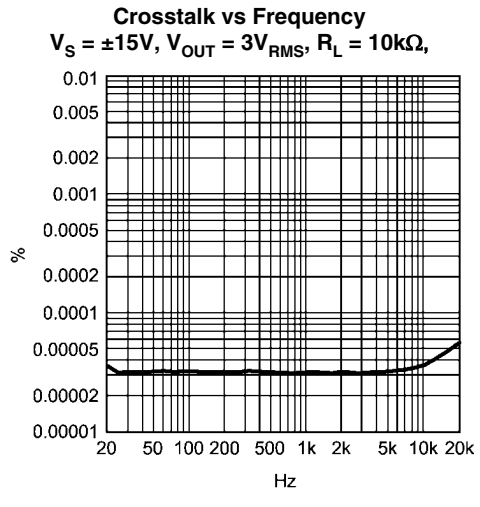


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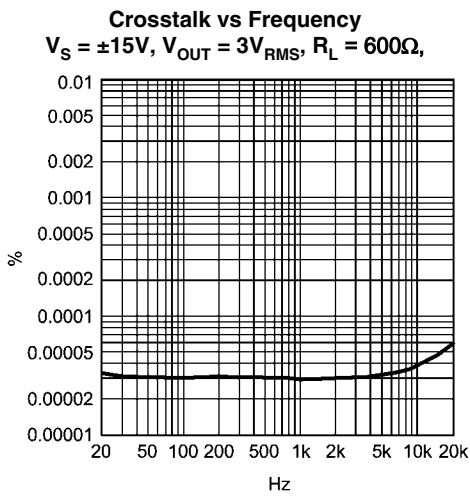




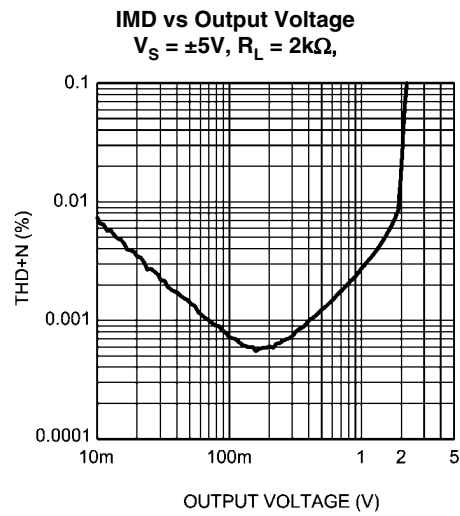
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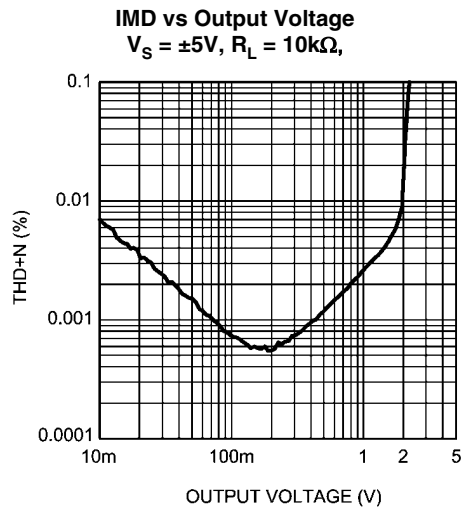
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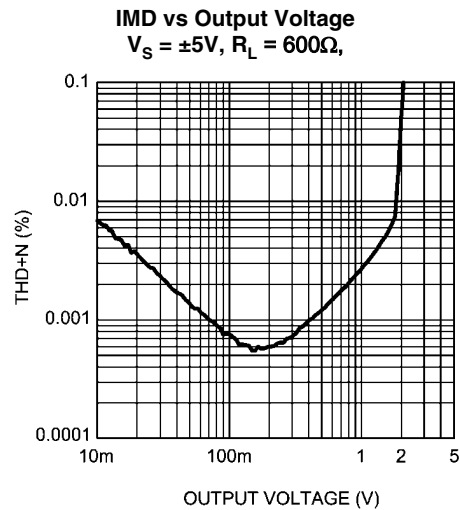
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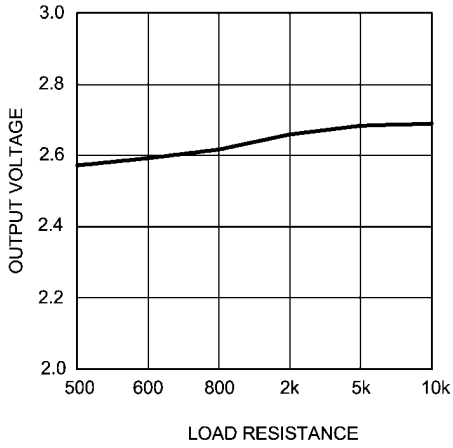


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**Output Voltage vs Load Resistance**  
 $V_S = \pm 5V$ , THD+N = 1%



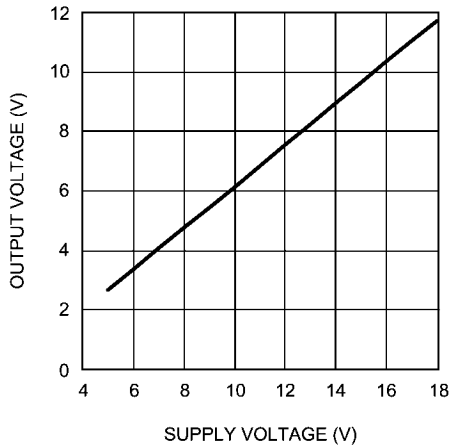
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**Output Voltage vs Load Resistance**  
 $V_{DD} = 15V$ ,  $V_{SS} = -15V$ , THD+N = 0.1%



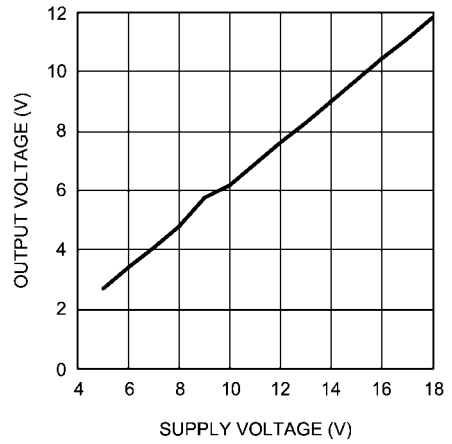
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**Output Voltage vs Supply Voltage**  
 $R_L = 2k\Omega$ , THD+N = 0.1%



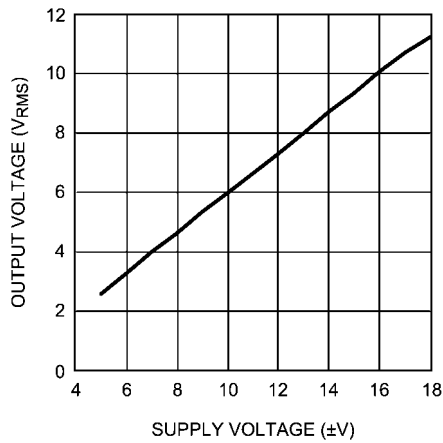
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**Output Voltage vs Supply Voltage**  
 $R_L = 10k\Omega$ , THD+N = 0.1%



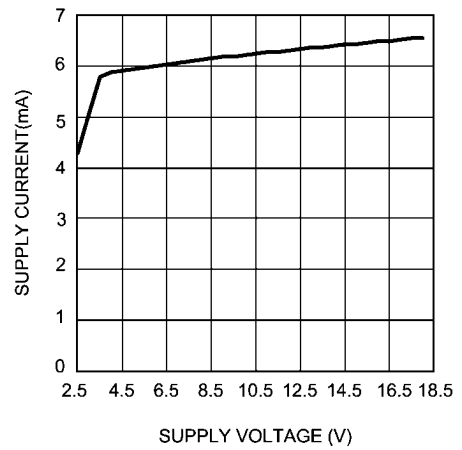
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**Output Voltage vs Supply Voltage**  
 $R_L = 600\Omega$ , THD+N = 1%



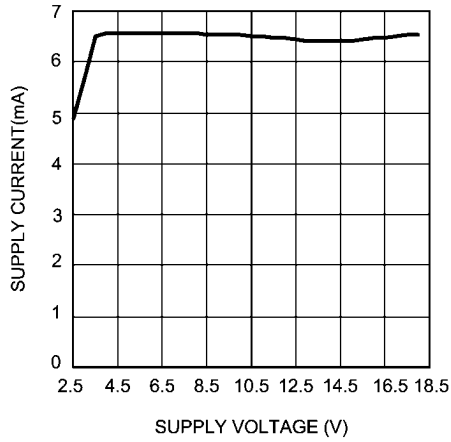
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**Supply Current vs Supply Voltage**  
 $R_L = 2k\Omega$



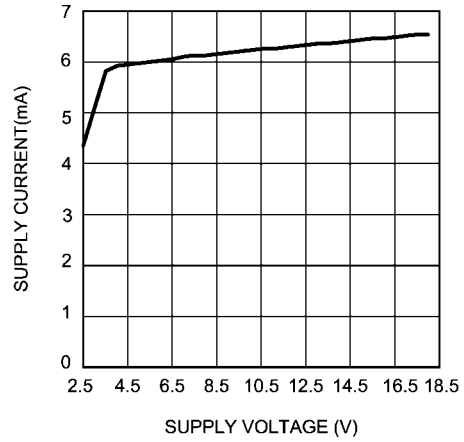
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Supply Current vs Supply Voltage  
 $R_L = 10k\Omega$



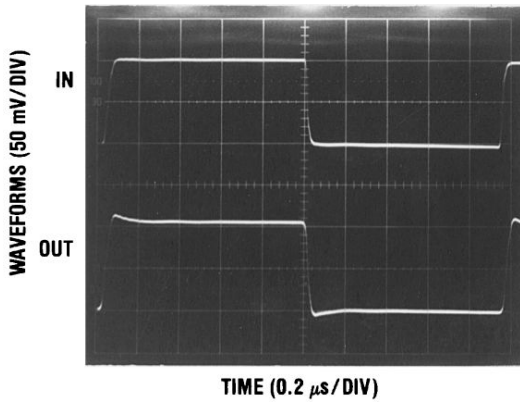
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Supply Current vs Supply Voltage  
 $R_L = 600\Omega$



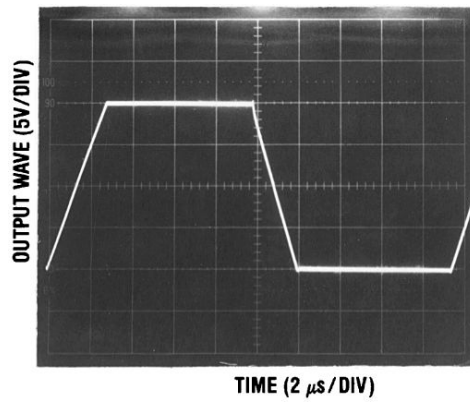
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Noninverting Amp



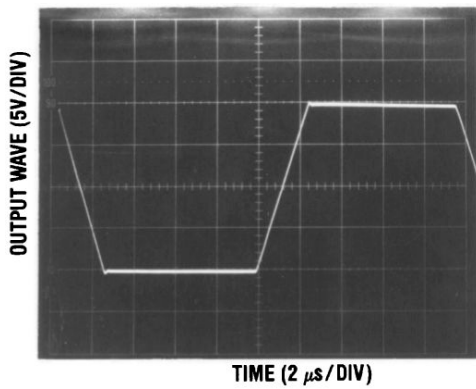
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Noninverting Amp



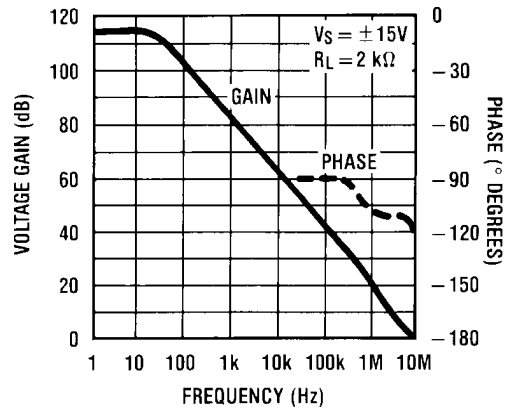
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Inverting Amp

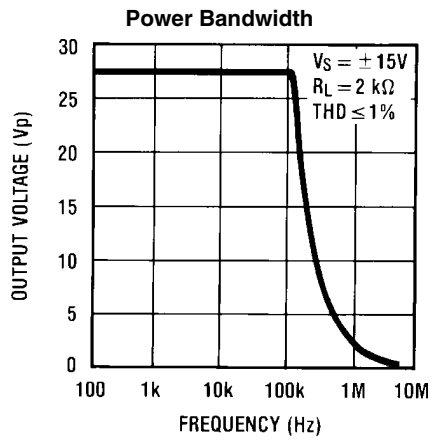


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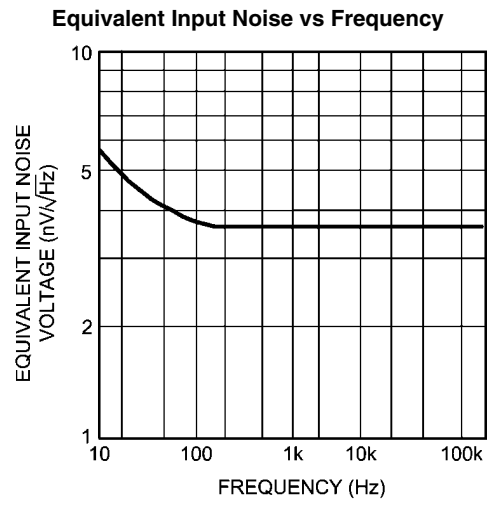
Voltage Gain & Phase vs Frequency



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## Application Information

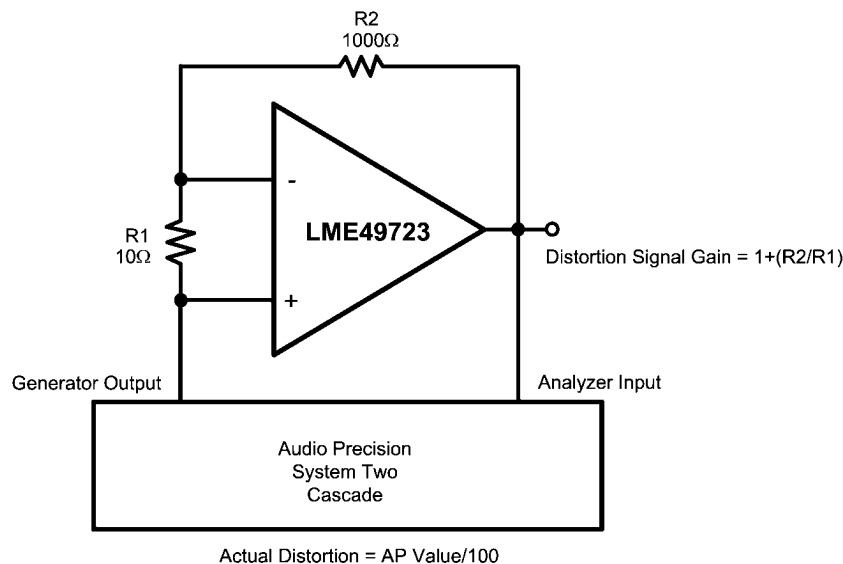
### DISTORTION MEASUREMENTS

The vanishingly low residual distortion produced by LME49723 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 LME49723's low residual distortion is an input referred internal error. As shown in Figure 1, adding the  $10\Omega$  resistor connected between 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, which means that measurement resolution increases by 101. To ensure minimum effects on distortion measurements, keep the value of R1 low as shown in Figure 1.

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 the measurement equipment's capabilities. This datasheet's THD+N and IMD values were generated using the above described circuit connected to an Audio Precision System Two Cascade.



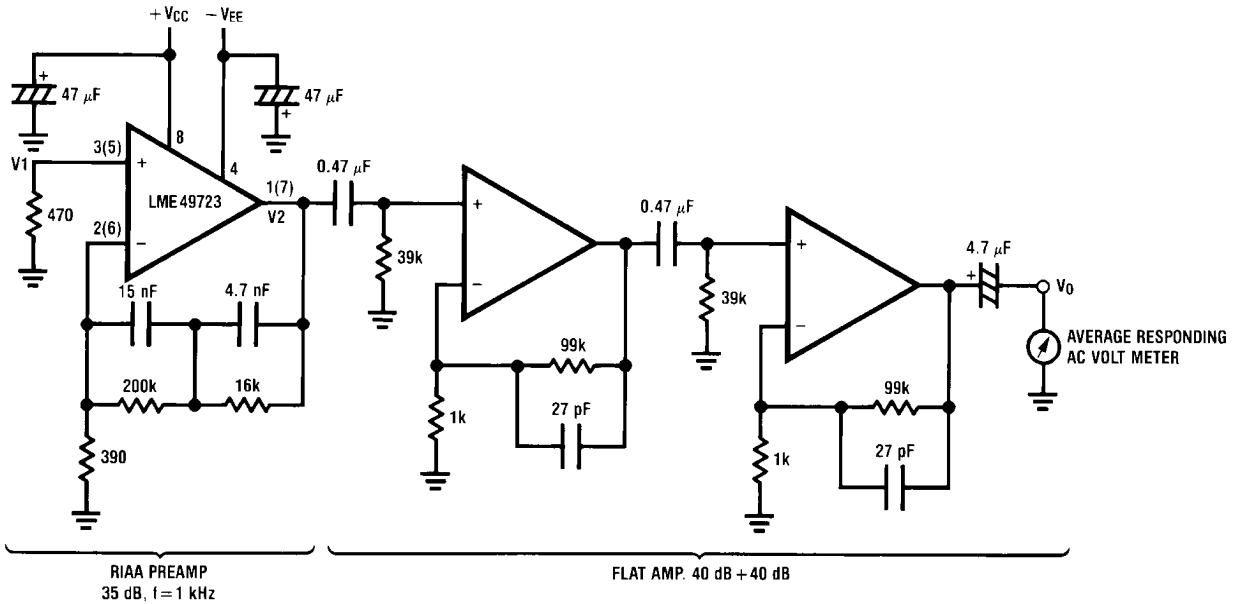
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**FIGURE 1. THD+N and IMD Distortion Test Circuit**

The LME49723 is a high speed op amp with excellent phase margin and stability. Capacitive loads up to 100pF will cause little change in the phase characteristics of the amplifiers and are therefore allowable.

Capacitive loads greater than 100pF must be isolated from the output. The most straightforward way to do this is to put

a resistor in series with the output. This resistor will also prevent excess power dissipation if the output is accidentally shorted.

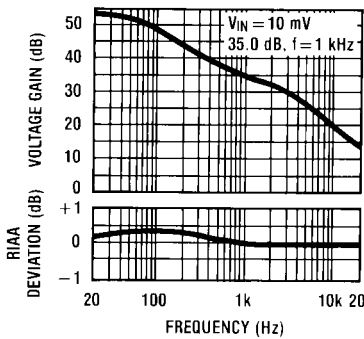


Complete shielding is required to prevent induced pick up from external sources. Always check with oscilloscope for power line noise.

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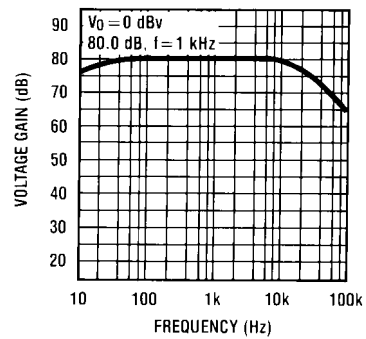
**Noise Measurement Circuit**  
**Total Gain: 115 dB @f = 1 kHz**  
**Input Referred Noise Voltage:  $e_n = V_0/560,000$  (V)**

**RIAA Preamp Voltage Gain, RIAA Deviation vs Frequency**



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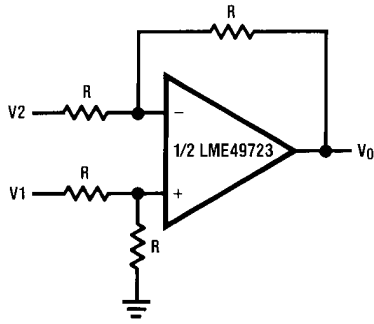
**Flat Amp Voltage Gain vs Frequency**



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TYPICAL APPLICATIONS

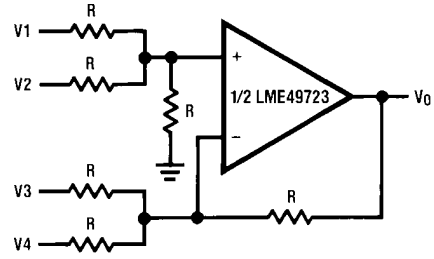
Balanced to Single Ended Converter



$V_O = V1 - V2$

30036232

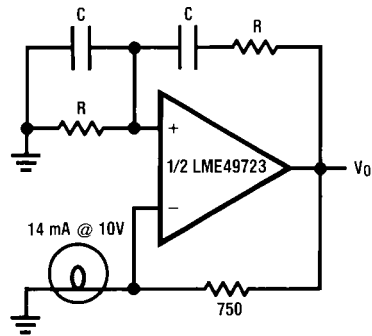
Adder/Subtractor



$V_O = V1 + V2 - V3 - V4$

30036233

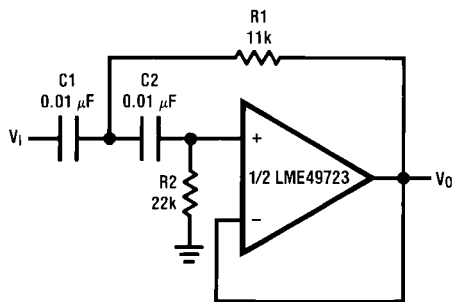
Sine Wave Oscillator



30036234

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

Second Order High Pass Filter (Butterworth)



30036235

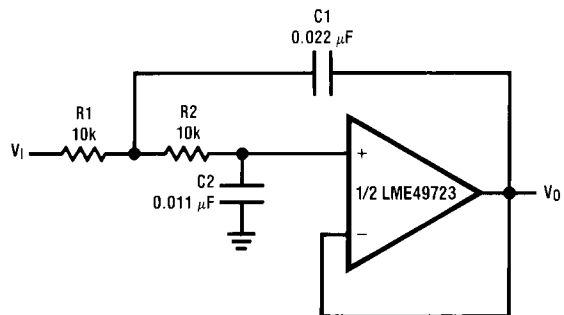
if  $C1 = C2 = C$

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

$R2 = 2 \cdot R1$

Illustration is  $f_o = 1$  kHz

Second Order Low Pass Filter (Butterworth)



30036236

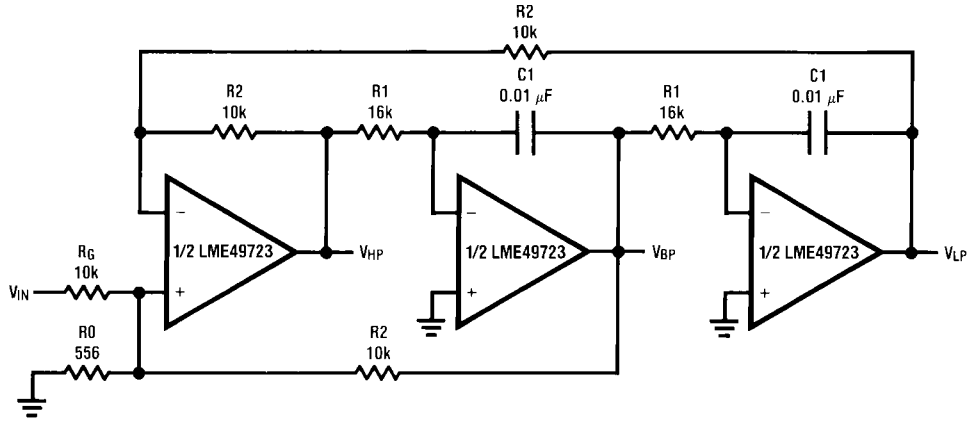
if  $R1 = R2 = R$

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

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

Illustration is  $f_o = 1$  kHz

State Variable Filter

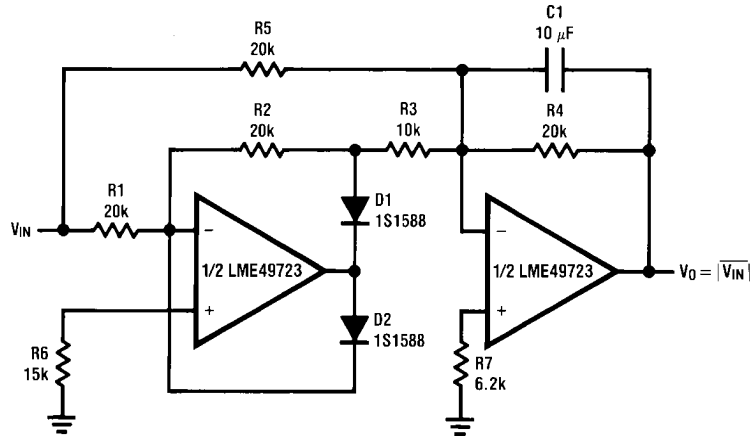


30036237

$$f_0 = \frac{1}{2\pi C_1 R_1}, Q = \frac{1}{2} \left( 1 + \frac{R_2}{R_0} + \frac{R_2}{R_G} \right), A_{BP} = Q A_{LP} = Q A_{LH} = \frac{R_2}{R_G}$$

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

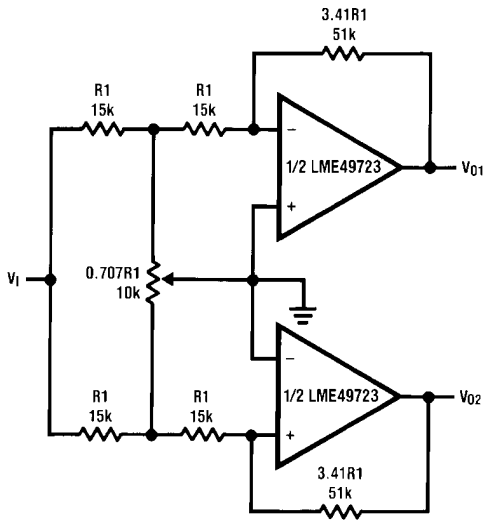
AC/DC Converter



30036238

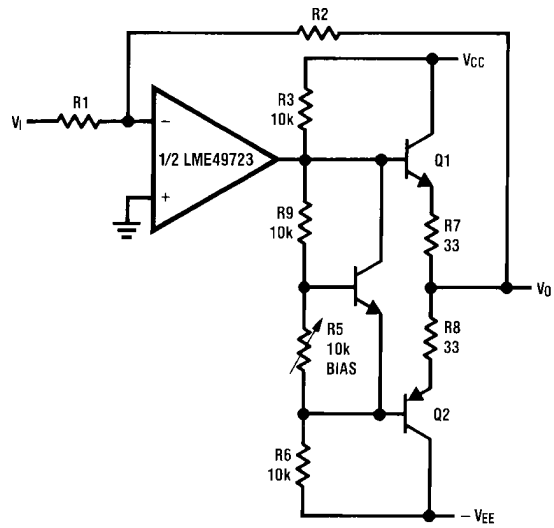


2 Channel Panning Circuit (Pan Pot)



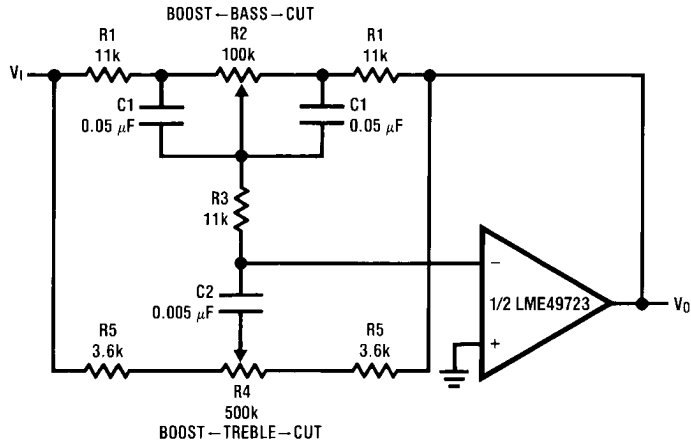
30036239

Line Driver



30036240

**Tone Control**



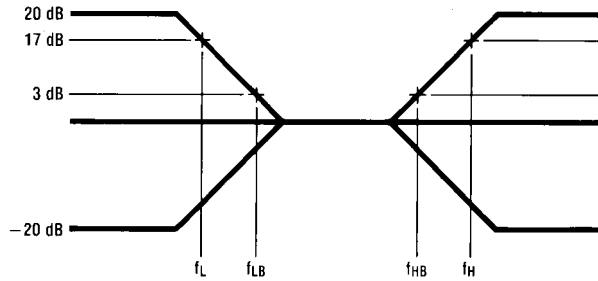
30036241

$$f_L = \frac{1}{2\pi R_2 C_1}, f_{LB} = \frac{1}{2\pi R_1 C_1}$$

$$f_H = \frac{1}{2\pi R_5 C_2}, f_{HB} = \frac{1}{2\pi (R_1 + R_5 + 2R_3) C_2}$$

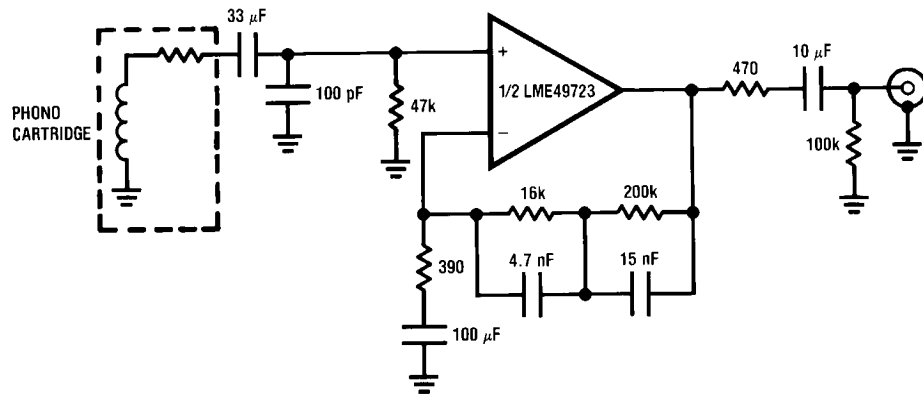
Illustration is:

$f_L = 32 \text{ Hz}, f_{LB} = 320 \text{ Hz}$   
 $f_H = 11 \text{ kHz}, f_{HB} = 1.1 \text{ kHz}$



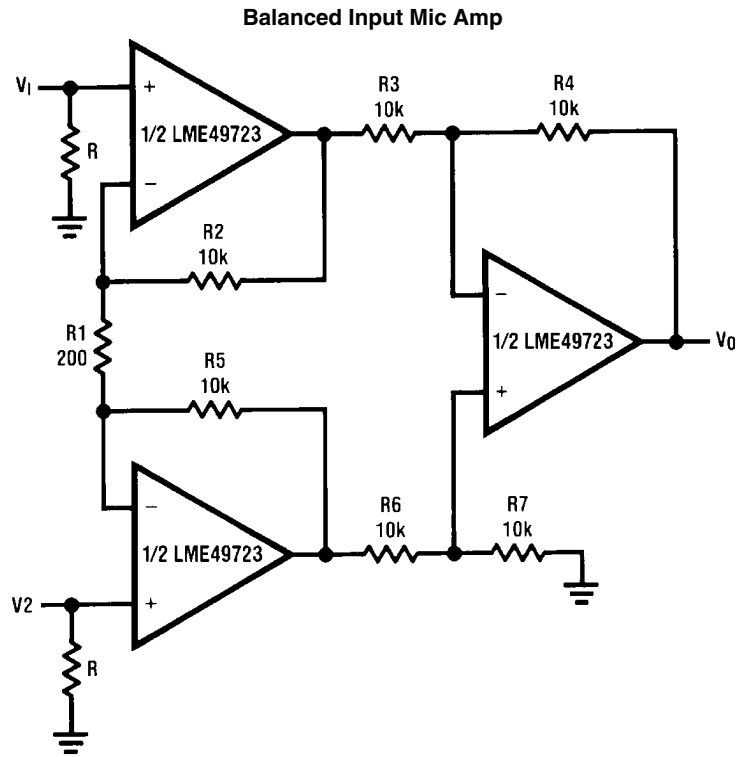
30036242

**RIAA Preamp**



30036203

$A_v = 35 \text{ dB}$   
 $E_n = 0.33 \mu\text{V}$   
 $S/N = 90 \text{ dB}$   
 $f = 1 \text{ kHz}$   
 A Weighted  
 A Weighted,  $V_{IN} = 10 \text{ mV}$   
 @  $f = 1 \text{ kHz}$



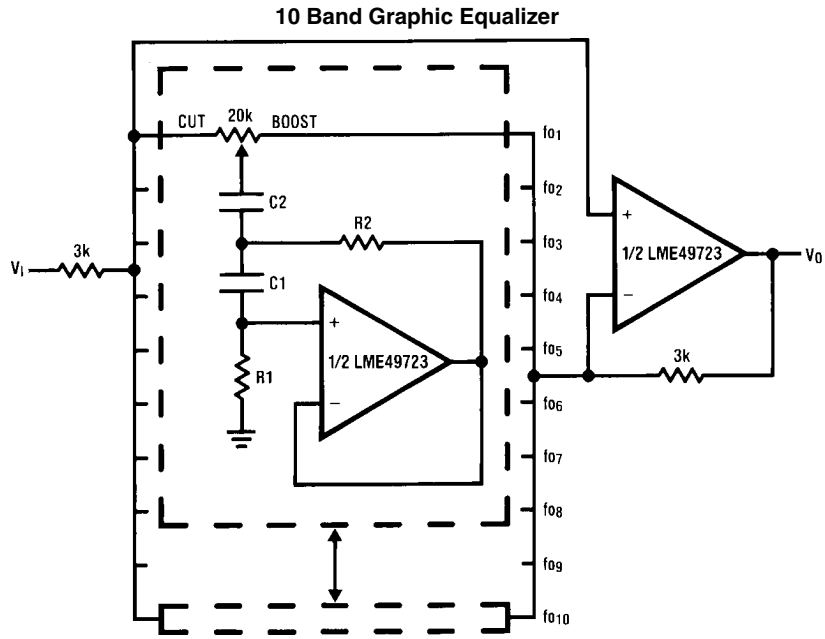
30036243

If  $R_2 = R_5$ ,  $R_3 = R_6$ ,  $R_4 = R_7$

$$V_0 = \left(1 + \frac{2R_2}{R_1}\right) \frac{R_4}{R_3} (V_2 - V_1)$$

Illustration is:

$$V_0 = 101(V_2 - V_1)$$



30036244

fo (Hz)	C <sub>1</sub>	C <sub>2</sub>	R <sub>1</sub>	R <sub>2</sub>
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

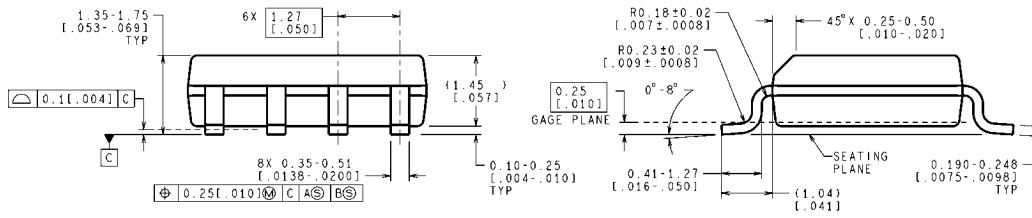
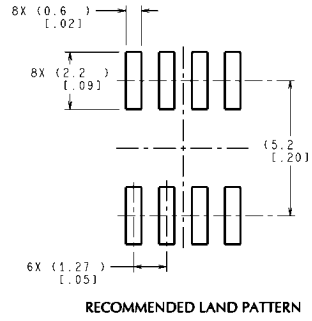
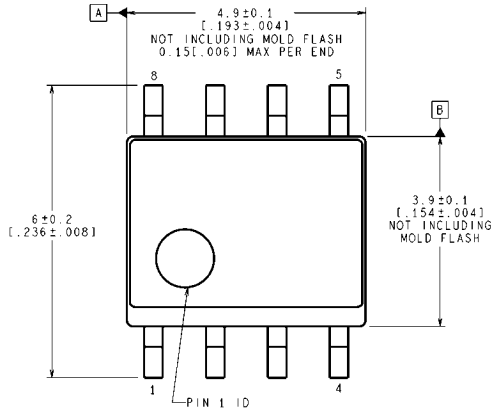
**Note 9:** At volume of change = ±12 dB  
Q = 1.7

Reference: "AUDIO/RADIO HANDBOOK", National Semiconductor, 1980, Page 2-61

## Revision History

Rev	Date	Description
1.0	01/07/08	Initial release.
1.01	02/11/08	Text edits.

**Physical Dimensions** inches (millimeters) unless otherwise noted



CONTROLLING DIMENSION IS MILLIMETER  
VALUES IN [ ] ARE INCHES  
DIMENSIONS IN ( ) FOR REFERENCE ONLY

M08A (Rev L)

**Narrow SOIC Package**  
**Order Number LME49723MA**  
**NS Package Number M08A**

# Notes

## Notes

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