LME49710
High Performance, High Fidelity Audio Operational Amplifier

General Description
The LME49710 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 LME49710 audio operational amplifiers deliver superior audio signal amplification for outstanding audio performance. The LME49710 combines extremely low voltage noise density (2.5nV/√Hz) with vanishingly low THD+N (0.00003%) to easily satisfy the most demanding audio applications. To ensure that the most challenging loads are driven without compromise, the LME49710 has a high slew rate of ±20V/μs and an output current capability of ±26mA. Further, dynamic range is maximized by an output stage that drives 2kΩ loads to within 1V of either power supply voltage and to within 1.4V when driving 600Ω loads.

The LME49710’s outstanding CMRR(120dB), PSRR(120dB), and $V_{OS}$ (0.05mV) give the amplifier excellent operational amplifier DC performance.

The LME49710 has a wide supply range of ±2.5V to ±17V. Over this supply range the LME49710’s input circuitry maintains excellent common-mode and power supply rejection, as well as maintaining its low input bias current. The LME49710 is unity gain stable. The Audio Operational Amplifier achieves outstanding AC performance while driving complex loads with values as high as 100pF.

The LME49710 is available in 8–lead narrow body SOIC, 8–lead plastic DIP, and 8–lead metal can TO-99. Demonstration boards are available for each package.

Key Specifications
- Power Supply Voltage Range: ±2.5V to ±17V
- THD+N ($A_v = 1$, $V_{OUT} = 3V_{RMS}$, $f_{IN} = 1kHz$)
  \[ R_L = 2k\Omega \]
  \[ R_L = 600\Omega \]
  0.00003% (typ)
  0.00003% (typ)
- Input Noise Density: 2.5nV/√Hz (typ)
- Slew Rate: ±20V/μs (typ)
- Gain Bandwidth Product: 55MHz (typ)
- Open Loop Gain ($R_L = 600\Omega$): 140dB (typ)
- Input Bias Current: 7nA (typ)
- Input Offset Voltage: 0.05mV (typ)
- DC Gain Linearity Error: 0.000009%

Features
- Easily drives 600Ω loads
- Optimized for superior audio signal fidelity
- Output short circuit protection
- PSRR and CMRR exceed 120dB (typ)
- SOIC, DIP, TO-99 metal can packages

Applications
- Ultra high quality 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
Typical Application

FIGURE 1. Passively Equalized RIAA Phono Preamplifier

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

Order Number LME49710MA
See NS Package Number — M08A
Order Number LME49710NA
See NS Package Number — N08E

Order Number LME49710HA
See NS Package Number — H08C
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): 2000V
- ESD Susceptibility (Note 5): 200V
- Junction Temperature: 150°C
- Thermal Resistance:
  - θ JA (SO) = 145°C/W
  - θ JA (NA) = 102°C/W
  - θ JA (HA) = 150°C/W
- Temperature Range: T_MIN ≤ T_A ≤ T_MAX
  - −40°C ≤ T_A ≤ 85°C
- Supply Voltage Range: ±2.5V ≤ V_S ≤ ±17V

Electrical Characteristics (Notes 1, 2)

The following specifications apply for V_S = ±15V, R_L = 2kΩ, f_IN = 1kHz, and T_A = 25°C, unless otherwise specified.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
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<th>LME49710</th>
<th>Units (Limits)</th>
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<tr>
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<td></td>
<td></td>
<td>Typical</td>
<td>Limit (Note 6)</td>
</tr>
<tr>
<td>THD+N</td>
<td>Total Harmonic Distortion + Noise</td>
<td>A_V = 1, V_OUT = 3V_RMS</td>
<td>0.00003</td>
<td>0.00003</td>
</tr>
<tr>
<td>IMD</td>
<td>Intermodulation Distortion</td>
<td>A_V = 1, V_OUT = 3V_RMS</td>
<td>0.00005</td>
<td>% (max)</td>
</tr>
<tr>
<td>GBWP</td>
<td>Gain Bandwidth Product</td>
<td></td>
<td>55</td>
<td>45</td>
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<td>SR</td>
<td>Slew Rate</td>
<td></td>
<td>±20</td>
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<td>FPBW</td>
<td>Full Power Bandwidth</td>
<td>V_OUT = 1V_P-P, −3dB referenced to output magnitude at f = 1kHz</td>
<td>10</td>
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<td>Settling time</td>
<td>A_V = 1, 10V step, C_L = 100pF 0.1% error range</td>
<td>1.2</td>
<td>μs</td>
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<td>η_n</td>
<td>Equivalent Input Noise Voltage</td>
<td></td>
<td>0.34</td>
<td>0.65</td>
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<td>Equivalent Input Noise Density</td>
<td></td>
<td>2.5</td>
<td>4.7</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>6.4</td>
<td>110</td>
</tr>
<tr>
<td>I_n</td>
<td>Current Noise Density</td>
<td></td>
<td>1.6</td>
<td>3.1</td>
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<td></td>
<td></td>
<td></td>
<td>1.6</td>
<td>3.1</td>
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<td>V_OS</td>
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<td>ΔV_OS/ΔTemp</td>
<td>Average Input Offset Voltage Drift vs Temperature</td>
<td>40°C ≤ T_A ≤ 85°C</td>
<td>0.2</td>
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<td>Average Input Offset Voltage Shift vs Power Supply Voltage</td>
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<td>I_B</td>
<td>Input Bias Current</td>
<td>V_CM = 0V</td>
<td>7</td>
<td>72</td>
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<td>Input Bias Current Drift vs Temperature</td>
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<td>Input Offset Current</td>
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<td>Common-Mode Input Voltage Range</td>
<td>+14.1</td>
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<td>CMRR</td>
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<td>Z_IN</td>
<td>Differential Input Impedance</td>
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<td></td>
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<td>1000</td>
<td>MΩ</td>
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<td>A_VOL</td>
<td>Open Loop Voltage Gain</td>
<td></td>
<td>−10V &lt; V_OUT &lt; 10V, R_L = 600Ω</td>
<td>140</td>
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<tr>
<td></td>
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<td>−10V &lt; V_OUT &lt; 10V, R_L = 2kΩ</td>
<td>140</td>
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<td>−10V &lt; V_OUT &lt; 10V, R_L = 10kΩ</td>
<td>140</td>
</tr>
<tr>
<td>Symbol</td>
<td>Parameter</td>
<td>Conditions</td>
<td>LME49710</td>
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<td>Typical</td>
<td>Limit</td>
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<td>V&lt;sub&gt;OUTMAX&lt;/sub&gt;</td>
<td>Maximum Output Voltage Swing</td>
<td>R&lt;sub&gt;L&lt;/sub&gt; = 600Ω</td>
<td>±13.6</td>
<td>±12.5</td>
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<tr>
<td></td>
<td></td>
<td>R&lt;sub&gt;L&lt;/sub&gt; = 2kΩ</td>
<td>±14.0</td>
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<td>±14.1</td>
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<tr>
<td>I&lt;sub&gt;OUT&lt;/sub&gt;</td>
<td>Output Current</td>
<td>R&lt;sub&gt;L&lt;/sub&gt; = 600Ω, V&lt;sub&gt;S&lt;/sub&gt; = ±17V</td>
<td>±26</td>
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<td>−42</td>
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<td>f&lt;sub&gt;IN&lt;/sub&gt; = 10kHz</td>
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<td>Closed-Loop</td>
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<td></td>
<td>Open-Loop</td>
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<td></td>
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<td>Quiescent Current</td>
<td>I&lt;sub&gt;OUT&lt;/sub&gt; = 0mA</td>
<td>4.8</td>
<td>5.5</td>
</tr>
</tbody>
</table>

**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 +25ºC and represent the most likely parametric norm.

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

**Note 8:** Datasheet min/max specification limits are guaranteed by design, test, or statistical analysis.

**Note 9:** 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

THD+N vs Output Voltage
$V_{CC} = 15V, V_{EE} = -15V, R_L = 2k\Omega$

THD+N vs Output Voltage
$V_{CC} = 12V, V_{EE} = -12V, R_L = 2k\Omega$

THD+N vs Output Voltage
$V_{CC} = 17V, V_{EE} = -17V, R_L = 2k\Omega$

THD+N vs Output Voltage
$V_{CC} = 2.5V, V_{EE} = -2.5V, R_L = 2k\Omega$

THD+N vs Output Voltage
$V_{CC} = 15V, V_{EE} = -15V, R_L = 600\Omega$

THD+N vs Output Voltage
$V_{CC} = 12V, V_{EE} = -12V, R_L = 600\Omega$
THD+N vs Frequency
V_{CC} = 15\,V, \, V_{EE} = -15\,V,
R_L = 2k\Omega, \, V_{OUT} = 3V_{RMS}

THD+N vs Frequency
V_{CC} = 17\,V, \, V_{EE} = -17\,V,
R_L = 2k\Omega, \, V_{OUT} = 3V_{RMS}

THD+N vs Frequency
V_{CC} = 15\,V, \, V_{EE} = -15\,V,
R_L = 600\Omega, \, V_{OUT} = 3V_{RMS}

THD+N vs Frequency
V_{CC} = 17\,V, \, V_{EE} = -17\,V,
R_L = 600\Omega, \, V_{OUT} = 3V_{RMS}

THD+N vs Frequency
V_{CC} = 15\,V, \, V_{EE} = -15\,V,
R_L = 10k\Omega, \, V_{OUT} = 3V_{RMS}

THD+N vs Frequency
V_{CC} = 17\,V, \, V_{EE} = -17\,V,
R_L = 10k\Omega, \, V_{OUT} = 3V_{RMS}
IMD vs Output Voltage

- $V_{CC} = 17V, V_{EE} = -17V, R_L = 600\Omega$
- $V_{CC} = 2.5V, V_{EE} = -2.5V, R_L = 600\Omega$
- $V_{CC} = 15V, V_{EE} = -15V, R_L = 10k\Omega$
- $V_{CC} = 12V, V_{EE} = -12V, R_L = 10k\Omega$
- $V_{CC} = 17V, V_{EE} = -17V, R_L = 10k\Omega$
- $V_{CC} = 2.5V, V_{EE} = -2.5V, R_L = 10k\Omega$
Voltage Noise Density vs Frequency

Current Noise Density vs Frequency

PSRR+ vs Frequency
$V_{CC} = 2.5V$, $V_{EE} = -2.5V$, $R_L = 2k\Omega$, $V_{RIPPLE} = 200mVpp$

PSRR- vs Frequency
$V_{CC} = 2.5V$, $V_{EE} = -2.5V$, $R_L = 2k\Omega$, $V_{RIPPLE} = 200mVpp$

PSRR+ vs Frequency
$V_{CC} = 12V$, $V_{EE} = -12V$, $R_L = 2k\Omega$, $V_{RIPPLE} = 200mVpp$

PSRR- vs Frequency
$V_{CC} = 12V$, $V_{EE} = -12V$, $R_L = 2k\Omega$, $V_{RIPPLE} = 200mVpp$
PSRR+ vs Frequency
$V_{CC} = 15V, V_{EE} = -15V,$
$R_L = 2k\Omega, V_{RIPPLE} = 200mVpp$

PSRR- vs Frequency
$V_{CC} = 15V, V_{EE} = -15V,$
$R_L = 2k\Omega, V_{RIPPLE} = 200mVpp$

PSRR+ vs Frequency
$V_{CC} = 17V, V_{EE} = -17V,$
$R_L = 2k\Omega, V_{RIPPLE} = 200mVpp$

PSRR- vs Frequency
$V_{CC} = 17V, V_{EE} = -17V,$
$R_L = 2k\Omega, V_{RIPPLE} = 200mVpp$

PSRR+ vs Frequency
$V_{CC} = 2.5V, V_{EE} = -2.5V,$
$R_L = 600\Omega, V_{RIPPLE} = 200mVpp$

PSRR- vs Frequency
$V_{CC} = 2.5V, V_{EE} = -2.5V,$
$R_L = 600\Omega, V_{RIPPLE} = 200mVpp$
PSRR+ vs Frequency
$V_{CC} = 12V$, $V_{EE} = -12V$, $R_L = 600\Omega$, $V_{RIPPLE} = 200mVpp$

PSRR- vs Frequency
$V_{CC} = 12V$, $V_{EE} = -12V$, $R_L = 600\Omega$, $V_{RIPPLE} = 200mVpp$

PSRR+ vs Frequency
$V_{CC} = 15V$, $V_{EE} = -15V$, $R_L = 600\Omega$, $V_{RIPPLE} = 200mVpp$

PSRR- vs Frequency
$V_{CC} = 15V$, $V_{EE} = -15V$, $R_L = 600\Omega$, $V_{RIPPLE} = 200mVpp$

PSRR+ vs Frequency
$V_{CC} = 17V$, $V_{EE} = -17V$, $R_L = 600\Omega$, $V_{RIPPLE} = 200mVpp$

PSRR- vs Frequency
$V_{CC} = 17V$, $V_{EE} = -17V$, $R_L = 600\Omega$, $V_{RIPPLE} = 200mVpp$
PSRR+ vs Frequency
$V_{CC} = 17V$, $V_{EE} = -17V$, $R_L = 10k\Omega$, $V_{RIPPLE} = 200mVpp$

PSRR- vs Frequency
$V_{CC} = 17V$, $V_{EE} = -17V$, $R_L = 10k\Omega$, $V_{RIPPLE} = 200mVpp$

CMRR vs Frequency
$V_{CC} = 15V$, $V_{EE} = -15V$, $R_L = 2k\Omega$

CMRR vs Frequency
$V_{CC} = 12V$, $V_{EE} = -12V$, $R_L = 2k\Omega$

CMRR vs Frequency
$V_{CC} = 17V$, $V_{EE} = -17V$, $R_L = 2k\Omega$

CMRR vs Frequency
$V_{CC} = 2.5V$, $V_{EE} = -2.5V$, $R_L = 2k\Omega$
CMRR vs Frequency
$V_{CC} = 15V, V_{EE} = -15V,$
$R_L = 600\Omega$

CMRR vs Frequency
$V_{CC} = 12V, V_{EE} = -12V,$
$R_L = 600\Omega$

CMRR vs Frequency
$V_{CC} = 17V, V_{EE} = -17V,$
$R_L = 600\Omega$

CMRR vs Frequency
$V_{CC} = 2.5V, V_{EE} = -2.5V,$
$R_L = 600\Omega$

CMRR vs Frequency
$V_{CC} = 15V, V_{EE} = -15V,$
$R_L = 10k\Omega$

CMRR vs Frequency
$V_{CC} = 12V, V_{EE} = -12V,$
$R_L = 10k\Omega$
CMRR vs Frequency
$V_{CC} = 17V, V_{EE} = -17V, R_L = 10k\Omega$

CMRR vs Frequency
$V_{CC} = 2.5V, V_{EE} = -2.5V, R_L = 10k\Omega$

Output Voltage vs Supply Voltage
$R_L = 2k\Omega, \text{THD+N} = 1\%$

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

Output Voltage vs Supply Voltage
$R_L = 10k\Omega, \text{THD+N} = 1\%$

Output Voltage vs Load Resistance
$V_{CC} = 15V, V_{EE} = -15V, \text{THD+N} = 1\%$

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Output Voltage vs Load Resistance
$V_{CC} = 17V, V_{EE} = -17V, THD+N = 1\%$

Output Voltage vs Load Resistance
$V_{CC} = 2.5V, V_{EE} = -2.5V, THD+N = 1\%$

Small-Signal Transient Response
$A_v = -1, C_L = 100pF$

Large-Signal Transient Response
$A_v = -1, C_L = 100pF$
Application Hints

The LME49710 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.

Noise Measurement Circuit

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

Total Gain: 115 dB at f = 1 kHz
Input Referred Noise Voltage: \( e_n = \frac{V_O}{560,000} \) (V)

RIAA Preamp Voltage Gain
RIAA Deviation vs Frequency
\( V_{IN} = 10mV, A_V = 35.0dB, f = 1kHz \)

Flat Amp Voltage Gain vs Frequency
\( V_O = 0dB, A_V = 80.0dB, f = 1kHz \)
Typical Applications

NAB Preamp

![NAB Preamp Diagram](image1)

- $A_v = 34.5$
- $F = 1 \text{ kHz}$
- $E_n = 0.38 \mu V$
- A Weighted

NAB Preamp Voltage Gain vs Frequency

![NAB Preamp Voltage Gain Graph](image2)

- $V_{IN} = 10\text{mV}, 34.5\text{dB}, f = 1\text{kHz}$

Balanced to Single Ended Converter

![Balanced to Single Ended Converter Diagram](image3)

- $V_o = V1 - V2$

Adder/Subtractor

![Adder/Subtractor Diagram](image4)

- $V_o = V1 + V2 - V3 - V4$

Sine Wave Oscillator

![Sine Wave Oscillator Diagram](image5)

- $f_o = \frac{1}{2\pi RC}$
Second Order High Pass Filter (Butterworth)

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

Illustration is \( f_0 = 1 \text{ kHz} \)

Second Order Low Pass Filter (Butterworth)

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

Illustration is \( f_0 = 1 \text{ kHz} \)

State Variable Filter

Illustration is \( f_0 = 1 \text{ kHz} \)
Line Driver

LME49710

R1 R2
V1

R3 10Ω

R4 R7 33

R5 10k

R6 10k

R8 33

Q1 Q2

Tone Control

V1

R1

C1 0.05 \mu F

R2

C1 0.05 \mu F

R3

C2 0.005 \mu F

R4

C2 0.005 \mu F

R5

R6

R7

R8

BOOST--BASS--CUT

R1

R2

C1 0.05 \mu F

R3

C2 0.005 \mu F

R4

C2 0.005 \mu F

R5

R6

R7

R8

LME49710

V2

\begin{align*}
  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}
\end{align*}

20 dB

17 dB

3 dB

-20 dB

\begin{align*}
  f_L, f_{LB}, f_H, f_{HB}
\end{align*}
RIAA Preamp

$A_v = 35 \text{ dB}$

$E_n = 0.33 \mu V$

S/N = 90 dB

$f = 1 \text{ kHz}$

A Weighted

A Weighted, $V_{IN} = 10 \text{ mV}$

@ $f = 1 \text{ kHz}$

Balanced Input Mic Amp

Illustration is:

$V_0 = 101(V_2 - V_1)$

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

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

DISTORTION MEASUREMENTS

The vanishingly low residual distortion produced by LME49710 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 LME49710’s low residual distortion is an input referred internal error. As shown in Figure 2, adding the 10Ω 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 2.

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.

FIGURE 2. THD+N and IMD Distortion Test Circuit
### Revision History

<table>
<thead>
<tr>
<th>Rev</th>
<th>Date</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>11/16/07</td>
<td>Initial release.</td>
</tr>
<tr>
<td>1.1</td>
<td>12/12/06</td>
<td>Added the Typical Performance curves.</td>
</tr>
<tr>
<td>1.2</td>
<td>01/15/07</td>
<td>Added more curves and input some text edits.</td>
</tr>
<tr>
<td>1.3</td>
<td>03/09/07</td>
<td>Fixed graphics 20210489 and 90.</td>
</tr>
</tbody>
</table>
Physical Dimensions

inches (millimeters) unless otherwise noted

Dual-In-Line Package
Order Number LME49710MA
NS Package Number M08A

Dual-In-Line Package
Order Number LME49710NA
NS Package Number N08E
TO-99 Metal Can
Order Number LME49710HA
NS Package Number H08C

REFERENCE PLANE

SEATING PLANE

MAX UNCONTROLLED LEAD DIA

DIA TYP

45° EQUALLY SPACED