LM4562
Dual High Performance, High Fidelity Audio Operational Amplifier

General Description
The LM4562 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 LM4562 audio operational amplifiers deliver superior audio signal amplification for outstanding audio performance. The LM4562 combines extremely low voltage noise density (2.7nV/√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 LM4562 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 LM4562’s outstanding CMRR (120dB), PSRR (120dB), and VOS (0.1mV) give the amplifier excellent operational amplifier DC performance.

The LM4562 has a wide supply range of ±2.5V to ±17V. Over this supply range the LM4562’s input circuitry maintains excellent common-mode and power supply rejection, as well as maintaining its low input bias current. The LM4562 is unity gain stable. This Audio Operational Amplifier achieves outstanding AC performance while driving complex loads with values as high as 100pF.

The LM4562 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 = 3VRMS, f_IN = 1kHz)

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 preamps
- High performance professional audio
- High fidelity equalization and crossover networks
- High performance line drivers
- High performance line receivers
- High fidelity active filters

Typical Application

Passively Equalized RIAA Phono Preamplifier

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

Dual-In-Line Package

Order Number LM4562MA
See NS Package Number — M08A
Order Number LM4562NA
See NS Package Number — N08E

Metal Can

Order Number LM4562HA
See NS Package Number — H08C

www.national.com
### 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.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
<th>Pins 1, 4, 7 and 8</th>
<th>Pins 2, 3, 5 and 6</th>
<th>Junction Temperature</th>
<th>Thermal Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Supply Voltage</td>
<td>( V_{S} = V^{+} \cdot V^{-} )</td>
<td>36V</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storage Temperature</td>
<td>(-65^\circ C ) to (150^\circ C)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input Voltage</td>
<td>((V^{-}) \cdot 0.7V ) to ((V^{+}) + 0.7V)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output Short Circuit</td>
<td>Continuous</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ESD Susceptibility</td>
<td>Internally Limited</td>
<td>2000V</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Electrical Characteristics for the LM4562 (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.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>LM4562</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Typical</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(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></td>
</tr>
<tr>
<td></td>
<td></td>
<td>( R_L = 2k\Omega )</td>
<td>0.00003</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( R_C = 600\Omega )</td>
<td>0.00003</td>
</tr>
<tr>
<td>IMD</td>
<td>Intermodulation Distortion</td>
<td>( A_V = 1, V_{OUT} = 3V_{rms} )</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Two-tone, 60Hz &amp; 7kHz 4:1</td>
<td>0.00005</td>
</tr>
<tr>
<td>GBWP</td>
<td>Gain Bandwidth Product</td>
<td></td>
<td>55</td>
</tr>
<tr>
<td>SR</td>
<td>Slew Rate</td>
<td></td>
<td>±20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Referenced to output magnitude</td>
<td>MHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>At ( f = 1kHz )</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>( A_V = -1, 10V ) step, ( C_L = 100pF )</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.1% error range</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td>Equivalent Input Noise Voltage</td>
<td>( f_{BW} = 20Hz ) to 20kHz</td>
<td>0.34</td>
</tr>
<tr>
<td></td>
<td>Equivalent Input Noise Density</td>
<td>( f = 1kHz )</td>
<td>2.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( f = 10Hz )</td>
<td>6.4</td>
</tr>
<tr>
<td></td>
<td>Current Noise Density</td>
<td>( f = 1kHz )</td>
<td>1.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( f = 10Hz )</td>
<td>3.1</td>
</tr>
<tr>
<td></td>
<td>Offset Voltage</td>
<td></td>
<td>±0.1</td>
</tr>
<tr>
<td></td>
<td>Average Input Offset Voltage Drift vs Temperature</td>
<td>(-40^\circ C \leq T_{A} \leq 85^\circ C)</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>Average Input Offset Voltage Shift vs Power Supply Voltage</td>
<td>( \Delta V_{S} = 20V ) (Note 8)</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td>Channel-to-Channel Isolation</td>
<td>( f_{IN} = 1kHz )</td>
<td>118</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( f_{IN} = 20kHz )</td>
<td>112</td>
</tr>
<tr>
<td></td>
<td>Input Bias Current</td>
<td>( V_{CM} = 0V )</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Input Bias Current Drift vs Temperature</td>
<td>(-40^\circ C \leq T_{A} \leq 85^\circ C)</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>Input Offset Current</td>
<td>( V_{CM} = 0V )</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Common-Mode Input Voltage Range</td>
<td>( V_{IN-CM} )</td>
<td>+14.1</td>
</tr>
<tr>
<td></td>
<td>Common-Mode Rejection</td>
<td>(-10V &lt; V_{CM} &lt; 10V )</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td>Differential Input Impedance</td>
<td></td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Common Mode Input Impedance</td>
<td>(-10V &lt; V_{CM} &lt; 10V )</td>
<td>1000</td>
</tr>
<tr>
<td>Symbol</td>
<td>Parameter</td>
<td>Conditions</td>
<td>LM4562</td>
</tr>
<tr>
<td>--------</td>
<td>-----------</td>
<td>------------</td>
<td>--------</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Typical</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(Note 6)</td>
</tr>
<tr>
<td>$A_{\text{VOL}}$</td>
<td>Open Loop Voltage Gain</td>
<td>$-10V &lt; V_{\text{out}} &lt; 10V, R_L = 600\Omega$</td>
<td>140</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$-10V &lt; V_{\text{out}} &lt; 10V, R_L = 2k\Omega$</td>
<td>140</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$-10V &lt; V_{\text{out}} &lt; 10V, R_L = 10k\Omega$</td>
<td>140</td>
</tr>
<tr>
<td>$V_{\text{OUTMAX}}$</td>
<td>Maximum Output Voltage Swing</td>
<td>$R_L = 600\Omega$</td>
<td>±13.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$R_L = 2k\Omega$</td>
<td>±14.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$R_L = 10k\Omega$</td>
<td>±14.1</td>
</tr>
<tr>
<td>$I_{\text{OUT}}$</td>
<td>Output Current</td>
<td>$R_L = 600\Omega, V_S = \pm 17V$</td>
<td>±26</td>
</tr>
<tr>
<td>$I_{\text{OUT-CC}}$</td>
<td>Instantaneous Short Circuit Current</td>
<td>$R_L = 600\Omega, V_S = \pm 17V$</td>
<td>+53</td>
</tr>
<tr>
<td>$R_{\text{OUT}}$</td>
<td>Output Impedance</td>
<td>$f_{\text{IN}} = 10kHz$</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Closed-Loop</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Open-Loop</td>
<td></td>
</tr>
<tr>
<td>$C_{\text{LOAD}}$</td>
<td>Capacitive Load Drive Overshoot</td>
<td>100pF</td>
<td>16</td>
</tr>
<tr>
<td>$I_S$</td>
<td>Total Quiescent Current</td>
<td>$I_{\text{OUT}} = 0mA$</td>
<td>10</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 +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: $V_{\text{OS}}$ is measured at two supply voltages, ±5V and ±15V. $\text{PSRR} = 10 \log_{10}(\Delta V_{\text{OS}}/\Delta V_S)$.
THD+N vs Output Voltage
$V_{CC} = 17V, V_{EE} = -17V$
$R_L = 600\Omega$

THD+N vs Output Voltage
$V_{CC} = 2.5V, V_{EE} = -2.5V$
$R_L = 600\Omega$

THD+N vs Output Voltage
$V_{CC} = 15V, V_{EE} = -15V$
$R_L = 10k\Omega$

THD+N vs Output Voltage
$V_{CC} = 12V, V_{EE} = -12V$
$R_L = 10k\Omega$

THD+N vs Output Voltage
$V_{CC} = 17V, V_{EE} = -17V$
$R_L = 10k\Omega$

THD+N vs Output Voltage
$V_{CC} = 2.5V, V_{EE} = -2.5V$
$R_L = 10k\Omega$
THD+N vs Frequency

$V_{CC} = 15V, V_{EE} = -15V, V_{OUT} = 3V_{RMS}$
$R_L = 2k\Omega$

$V_{CC} = 12V, V_{EE} = -12V, V_{OUT} = 3V_{RMS}$
$R_L = 2k\Omega$

$V_{CC} = 17V, V_{EE} = -17V, V_{OUT} = 3V_{RMS}$
$R_L = 600\Omega$

$V_{CC} = 12V, V_{EE} = -12V, V_{OUT} = 3V_{RMS}$
$R_L = 600\Omega$

$V_{CC} = 17V, V_{EE} = -17V, V_{OUT} = 3V_{RMS}$
$R_L = 600\Omega$
IMD vs Output Voltage

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

$V_{CC} = 15V, V_{EE} = -15V$
$R_L = 600\Omega$

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

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

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

$V_{CC} = 15V, V_{EE} = -15V$
$R_L = 10k\Omega$
IMD vs Output Voltage
$V_{CC} = 12V, V_{EE} = -12V$
$R_L = 10k\Omega$

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

IMD vs Output Voltage
$V_{CC} = 2.5V, V_{EE} = -2.5V$
$R_L = 10k\Omega$

Voltage Noise Density vs Frequency

Current Noise Density vs Frequency

Crosstalk vs Frequency
$V_{CC} = 15V, V_{EE} = -15V, V_{OUT} = 3V_{RMS}$
$A_V = 0dB, R_L = 2k\Omega$
Crosstalk vs Frequency

- **Case 1:**
  - $V_{CC} = 2.5V$, $V_{EE} = -2.5V$, $V_{OUT} = 1V_{RMS}$
  - $A_v = 0dB$, $R_L = 600\Omega$

- **Case 2:**
  - $V_{CC} = 15V$, $V_{EE} = -15V$, $V_{OUT} = 3V_{RMS}$
  - $A_v = 0dB$, $R_L = 10k\Omega$

- **Case 3:**
  - $V_{CC} = 12V$, $V_{EE} = -12V$, $V_{OUT} = 10V_{RMS}$
  - $A_v = 0dB$, $R_L = 10k\Omega$

- **Case 4:**
  - $V_{CC} = 17V$, $V_{EE} = -17V$, $V_{OUT} = 3V_{RMS}$
  - $A_v = 0dB$, $R_L = 10k\Omega$
PSRR+ vs Frequency
$V_{CC} = 15V, V_{EE} = -15V$
$R_L = 600\Omega, f = 200kHz, V_{RIPPLE} = 200mVpp$

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

PSRR+ vs Frequency
$V_{CC} = 12V, V_{EE} = -12V$
$R_L = 10k\Omega, f = 200kHz, V_{RIPPLE} = 200mVpp$

PSRR- vs Frequency
$V_{CC} = 12V, V_{EE} = -12V$
$R_L = 10k\Omega, f = 200kHz, V_{RIPPLE} = 200mVpp$

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

PSRR- vs Frequency
$V_{CC} = 12V, V_{EE} = -12V$
$R_L = 2k\Omega, f = 200kHz, V_{RIPPLE} = 200mVpp$
PSRR+ vs Frequency
$V_{CC} = 12V, V_{EE} = -12V$
$R_L = 600\Omega, f = 200kHz, V_{RIPPLE} = 200mVpp$

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

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

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

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

PSRR– vs Frequency
$V_{CC} = 17V, V_{EE} = -17V$
$R_L = 2k\Omega, f = 200kHz, V_{RIPPLE} = 200mVpp$
PSRR+ vs Frequency  
$V_{CC} = 17V$, $V_{EE} = -17V$  
$R_L = 600\Omega$, $f = 200kHz$, $V_{RIPPLE} = 200mVpp$  

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

PSRR+ vs Frequency  
$V_{CC} = 2.5V$, $V_{EE} = -2.5V$  
$R_L = 10k\Omega$, $f = 200kHz$, $V_{RIPPLE} = 200mVpp$  

PSRR– vs Frequency  
$V_{CC} = 2.5V$, $V_{EE} = -2.5V$  
$R_L = 10k\Omega$, $f = 200kHz$, $V_{RIPPLE} = 200mVpp$  

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

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

$V_{CC} = 15V, V_{EE} = -15V$
$R_L = 600\Omega$

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

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

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

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

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

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

Output Voltage vs Load Resistance
$V_{DD} = 12V, V_{EE} = -12V$
THD+N = 1%

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

Output Voltage vs Load Resistance
$V_{DD} = 2.5V, V_{EE} = -2.5V$
THD+N = 1%
Output Voltage vs Supply Voltage
\( R_L = 2k\Omega, \ THD+N = 1\% \)

Output Voltage vs Supply Voltage
\( R_L = 600\Omega, \ THD+N = 1\% \)

Output Voltage vs Supply Voltage
\( R_L = 10k\Omega, \ THD+N = 1\% \)

Supply Current vs Supply Voltage
\( R_L = 2k\Omega \)

Supply Current vs Supply Voltage
\( R_L = 600\Omega \)

Supply Current vs Supply Voltage
\( R_L = 10k\Omega \)
Full Power Bandwidth vs Frequency

Gain Phase vs Frequency

Small-Signal Transient Response
\[ A_V = 1, \quad C_L = 10\text{pF} \]

Small-Signal Transient Response
\[ A_V = 1, \quad C_L = 100\text{pF} \]
Application Information

DISTORTION MEASUREMENTS
The vanishingly low residual distortion produced by LM4562 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 LM4562’s low residual distortion is an input referred internal error. As shown in Figure 1, 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 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.

![FIGURE 1. THD+N and IMD Distortion Test Circuit](image)
The LM4562 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.

**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**

**Flat Amp Voltage Gain vs Frequency**

www.national.com
**TYPICAL APPLICATIONS**

**NAB Preamp**

![NAB Preamp Diagram]

\[ A_V = 34.5 \]
\[ F = 1 \text{ kHz} \]
\[ E_n = 0.38 \mu \text{V} \]

A Weighted

**Balanced to Single Ended Converter**

\[ V_O = V_1 - V_2 \]

**Adder/Subtractor**

\[ V_O = V_1 + V_2 - V_3 - V_4 \]

**Sine Wave Oscillator**

\[ f_0 = \frac{1}{2\pi RC} \]
**Second Order High Pass Filter (Butterworth)**

- \( C_1 = 0.01 \, \mu F \)
- \( C_2 = 0.01 \, \mu F \)
- \( R_1 = 11k \)
- \( R_2 = 22k \)

\[ R_1 = \frac{3}{2 \alpha_0 C} \]

\[ R_2 = 2 \times R_1 \]

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

**Second Order Low Pass Filter (Butterworth)**

- \( C_1 = 0.022 \, \mu F \)
- \( C_2 = 0.011 \, \mu F \)
- \( R_1 = 10k \)
- \( R_2 = 10k \)

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

**State Variable Filter**

- \( C_1 = 0.01 \, \mu F \)
- \( R_1 = 10k \)
- \( R_2 = 10k \)
- \( R_6 = 10k \)
- \( R_8 = 556 \)
- \( R_0 = 10k \)

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

Illustration is \( f_0 = 1 \, \text{kHz}, \, Q = 10, \, A_{BP} = 1 \)
**Tone Control**

- **Illustration is:**
  - $f_L = 32$ Hz, $f_{LB} = 320$ Hz
  - $f_H = 11$ kHz, $f_{HB} = 1.1$ kHz

**RIAA Preamp**

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

---

[Image of Tone Control Circuit]

[Image of RIAA Preamp Circuit]

---

**www.national.com**
Illustration is:
\[ V_0 = 101(V_2 - V_1) \]
10 Band Graphic Equalizer

<table>
<thead>
<tr>
<th>$f_0$ (Hz)</th>
<th>$C_1$</th>
<th>$C_2$</th>
<th>$R_1$</th>
<th>$R_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>32</td>
<td>0.12μF</td>
<td>4.7μF</td>
<td>75kΩ</td>
<td>500Ω</td>
</tr>
<tr>
<td>64</td>
<td>0.056μF</td>
<td>3.3μF</td>
<td>68kΩ</td>
<td>510Ω</td>
</tr>
<tr>
<td>125</td>
<td>0.033μF</td>
<td>1.5μF</td>
<td>62kΩ</td>
<td>510Ω</td>
</tr>
<tr>
<td>250</td>
<td>0.015μF</td>
<td>0.82μF</td>
<td>68kΩ</td>
<td>470Ω</td>
</tr>
<tr>
<td>500</td>
<td>8200pF</td>
<td>0.39μF</td>
<td>62kΩ</td>
<td>470Ω</td>
</tr>
<tr>
<td>1k</td>
<td>3900pF</td>
<td>0.22μF</td>
<td>68kΩ</td>
<td>470Ω</td>
</tr>
<tr>
<td>2k</td>
<td>2000pF</td>
<td>0.1μF</td>
<td>68kΩ</td>
<td>470Ω</td>
</tr>
<tr>
<td>4k</td>
<td>1100pF</td>
<td>0.056μF</td>
<td>62kΩ</td>
<td>470Ω</td>
</tr>
<tr>
<td>8k</td>
<td>510pF</td>
<td>0.022μF</td>
<td>68kΩ</td>
<td>510Ω</td>
</tr>
<tr>
<td>16k</td>
<td>330pF</td>
<td>0.012μF</td>
<td>51kΩ</td>
<td>510Ω</td>
</tr>
</tbody>
</table>

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

$Q = 1.7$

## Revision History

<table>
<thead>
<tr>
<th>Rev</th>
<th>Date</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>08/16/06</td>
<td>Initial release.</td>
</tr>
<tr>
<td>1.1</td>
<td>08/22/06</td>
<td>Updated the Instantaneous Short Circuit Current specification.</td>
</tr>
<tr>
<td>1.2</td>
<td>09/12/06</td>
<td>Updated the three ±15V CMRR Typical Performance Curves.</td>
</tr>
<tr>
<td>1.3</td>
<td>09/26/06</td>
<td>Updated interstage filter capacitor values on page 1 Typical Application</td>
</tr>
<tr>
<td></td>
<td></td>
<td>schematic.</td>
</tr>
<tr>
<td>1.4</td>
<td>05/03/07</td>
<td>Added the “general note” under the EC table.</td>
</tr>
<tr>
<td>1.5</td>
<td>10/17/07</td>
<td>Replaced all the PSRR curves.</td>
</tr>
</tbody>
</table>
Physical Dimensions  inches (millimeters) unless otherwise noted

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

M08A (Rev L)