Designing with the 508 Family

LC508/LP508 APPLICATION NOTE

INTRODUCTION

The 508 family of Class A amplifiers is presently offered in either an 8 pin or 10 pin version, which utilize Gennum's proprietary low voltage BiFET technology. This technology allows these amplifiers to operate with lower currents and increased supply rejection.

CIRCUIT DESCRIPTION

The LP508 is the 8 pin version consisting of a preamplifier, a 4 kΩ microphone decoupling resistor, and an output stage with a 27 mV reference voltage at the emitter of the output stage (R_E pin).

The LC508 is a 10 pin device which contains 2 preamps, a 4kΩ microphone decoupling resistor and an output stage with a 54 mV reference voltage at the emitter of the output stage (R_E pin). Access to pin R_E allows the manufacturer to set the amount of bias current flowing through the receiver for maximum efficiency.

The preamps found on both the LP508 and the LC508 can be compared to an operational amplifier. Most rules that apply to op-amps also apply to the preamp of a 508.

The negative input of an ideal op-amp would appear as a virtual ground when used as an inverting amplifier. This is also the case with the input of a 508 preamp. Any impedance or resistance connected to the input pin becomes the equivalent input impedance of the preamplifier, as with the industry standard op-amp of Fig.1a. Fig.1b shows how a 508 preamp performs the same function, while only requiring a single polarity power supply.

Op-Amp Equivalent Circuit vs 508 Preamp Equivalent Circuit

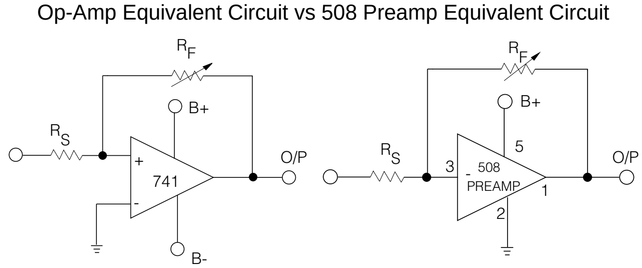

Fig.1a General Purpose Op - Amp   Fig.1b LP508 Preamp

The gain of an inverting amplifier can be determined by the ratio of the feedback resistor (R_F) to the source impedance (R_S). The gain (A_V) in dB can be calculated by the following formula :

$$A_V = 20 \log \left(\frac{R_F}{R_S}\right) \text{ for } A_V << A_{VOL}$$

where A_{VOL} = open loop gain

Typically the open loop gain (A_{vol}) of a 508 preamp is 45 dB. Knowing this value is important when calculating the gain of an amplifier, because closed loop gain must always be lower than open loop-gain. It is recommended that the maximum closed loop gain be 20 dB lower than the open loop gain. If the closed loop gain is less than 20 dB from the open loop gain, the gain should be calculated by:

$$A_{vcl} = \frac{A_{vol}}{1 + A_{vol} \times \frac{R_S}{R_F}}$$

where A_{vcl} = closed loop gain

The preamplifier has an open loop output impedance of typically 7 kΩ. When the preamplifier feedback loop is closed, the output impedance will be reduced by the difference between open loop gain and closed loop gain ($A_{vol} - A_{vcl}$). eg., if ($A_{vol} - A_{vcl}$) = 20 dB, or 10 times lower, the closed loop output impedance would be 700 Ω.

The 508 preamp and output stages are internally bias compensated preventing any DC current flow, via the volume control (feedback resistor), into or out of the input terminals of the device. Amplifiers requiring external biasing may experience audible scratchiness when volume control settings are changed. Internal biasing also allows the DC coupling of the stages because the inputs and outputs of all stages have identical DC voltage levels.

Since no op-amp is ideal, a residual amount (± 50 nA maximum) of bias current could flow. Thus, coupling between any two stages is possible without any appreciable DC voltage or current offset being created at the output.

OUTPUT STAGE

The current drive output stage of the 508 family is also an inverting amplifier. It is a unity gain voltage follower from the input to the R_E pin. The DC voltage at pin R_E is determined by an internally fixed reference voltage. This reference voltage, in conjunction with R_E, sets the bias current flowing through the receiver.

For the LP508, $I_{BIAS} = 27\text{ mV}/R_t$

LC508, $I_{BIAS} = 54\text{ mV}/R_t$

where $R_t = R_E \,//\, R_{EXT}$

The maximum input level that the output stage of the LP508 can handle is 27 mV peak. Since the LC508 output stage emitter (R_E pin) is referenced at 54 mV, it can handle input levels as large as 54 mV peak before limiting occurs.

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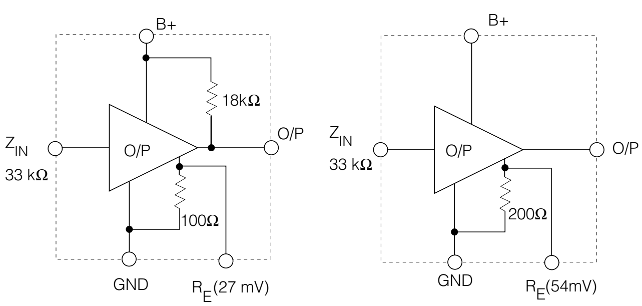
It is also important to know the maximum output drive capabilites of the 508 preamps. The maximum source current on the output of the preamps is typically 30 µA ± 45%. This means that once R_F is reduced to 1k Ω, the maximum peak voltage that the preamp can swing at its output before limiting is:

$$V = I \times R$$
$$= 30\ \mu A \times 1k\Omega$$
$$= 30\ mV\ peak$$

On the LP508, the output limiting voltage of the output stage is 27 mV peak and a 1 kΩ feedback resistor would be the limit before the preamp saturates prior to the output stage. As for the LC508, the limit resistor would be 2 kΩ because the peak output limiting voltage of the output stage is higher, at 54 mV.

It was necessary on the LP508, that an internal 18 kΩ resistor be placed on the collector of the output stage because of instability resulting from positive feedback (from output to input) and receiver impedance characteristics. This resistor limits the maximum gain of the amplifier.

The LC508 is an inverting amplifier, using negative feedback from input to output, therefore no output stage collector resistor is necessary. Input impedance of the output stage on both LC and LP508 is typically 33 kΩ . Knowing this impedance value makes calculating the output stage low-end frequency response straightforward.



LP508 Output Stage. LC508 Output Stage

Fig.2

EFFECTS OF VARYING MICROPHONE IMPEDANCE

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Since the tolerance of the output impedance of a Knowles microphone could vary by up to ≈ ± 4.7dB, and the closed loop gain of the preamp is dependent upon microphone output impedance, gain can also vary.

One way to reduce the effect of gain variance, (due to microphone impedance tolerances) is to use a resistor in series with the microphone.

e.g. If an 18 kΩ series resistor is used, the gain variation range will change from ± 4.7 dB down to ± 1 dB. The only disadvantage to this method is that at room temperature the 18 kΩ resistor has about 2.44 µV of noise associated with it.

To calculate total noise use :

$$N = \sqrt{n1 + n}$$

where n1 is 2.44 µV for an 18 kΩ resistor and n2 is 4 µV of microphone noise (26 dB).

Therefore, overall system noise can increase from 4 µV to 4.68 µV with the addition of an 18 kΩ series resistor.

FREQUENCY SHAPING

Because all input and output pins are accessible to the designer, frequency shaping can be easily achieved in many different areas of the amplifier.

Starting at the input of the preamp, a tone control can be achieved by using a capacitor value, selected for the desired corner frequency.

For low - end frequency filtering, (high pass filter), the -3dB break point is calculated by:

$$f_C\ (-3dB) = \frac{1}{2 \times \pi \times R_S \times C_{IN}}$$

Where R_S is the source impedance, (usually the output impedance of a microphone), and C_{IN} is the input coupling capacitor.

e.g. if $R_S = 3.5\ k\Omega$ and $C_{IN} = 0.1\mu F$

$$fc\ (-3dB) = \frac{1}{2 \times \pi \times R_S \times C_{IN}} = \frac{1}{2 \times \pi \times 3.5k\Omega \times 0.1\mu F}$$

$$= 455\ Hz$$

Another accessible point for filtering is between the preamp and output stage. The input impedance (Z_{IN}) of the output stage is known to be 33 kΩ therefore

$$f_C = \frac{1}{2 \times \pi \times Z_{IN} \times C2}$$

where Z_{IN} is the input impedance of the output stage and C2 is the coupling capacitor to that stage.

Because of the nature of the current drive output stage, low pass filtering can be achieved at the output stage collector by placing a capacitor in parallel with the receiver. This is sometimes called peak shifting and is shown in Fig. 3.

Peak Shifting using a Parallel Capacitor

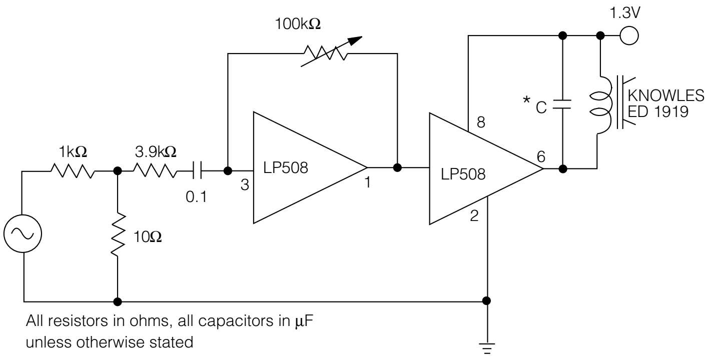


Fig. 3a Peak Shifting Circuit

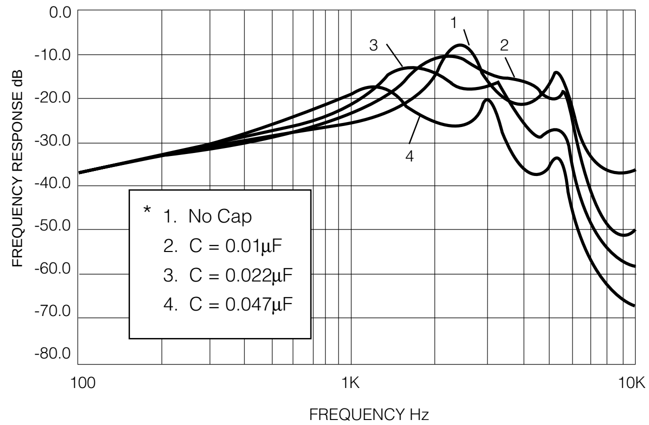


Fig. 3b Peak Shifting using Various Capacitor Values

ACTIVE FILTERING TECHNIQUES

MULTIPLE FEEDBACK FILTERS

The most common type of higher-order active filter designs involves the use of operational amplifiers. The 508 family of ICs can be used to design multiple feedback active filters. Detailed calculations and a more indepth understanding of active filtering is available in Gennum 600-9 article on Active Filtering for Hearing Aids.

ACTIVE BUFFER FILTERS

The output stage of a 508 may also be used as an active buffer filter, similar to an op-amp non-inverting buffer circuit. The following buffer circuits are designs using general purpose operational amplifiers (741). The same filters can be designed using the 508 output stage.

$R_1 = R_2$; $C_2 = 2C_1$

$$f_C = \frac{1}{2 \times \pi \times R_1 \times C_1 \times \sqrt{2}}$$

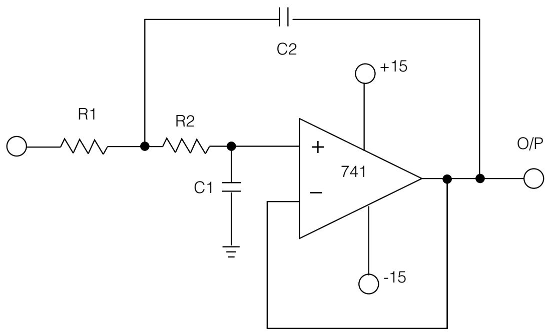


Fig. 4 Low Pass Filter using a General Purpose Op-Amp

$C_1 = C_2$; $R_2 = 2R_1$

$$f_C = \frac{1}{2 \times \pi \times R_1 \times C_1 \times \sqrt{2}}$$

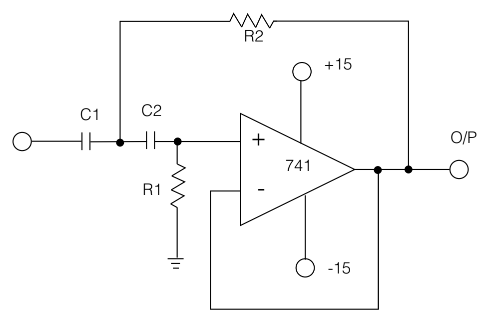


Fig. 5 High Pass Filter using a General Purpose Op-Amp

Output of the 508 is not an ideal op-amp therefore modifications are necessary when using the output stage as a buffer filter. The following diagrams show how this can be achieved.

$R_1 = R_2$; $C_2 = 2C_1$

$$f_C = \frac{1}{2 \times \pi \times R_1 \times C_1 \times \sqrt{2}}$$

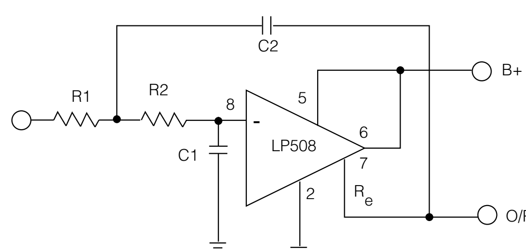


Fig. 6 Active Buffer Low Pass Filter using a 508 Output Stage.

$C_1 = C_2$; $R_2 = Z_{IN} = 2R_1$

$$f_C = \frac{1}{2 \times \pi \times R_1 \times C_1 \times \sqrt{2}}$$

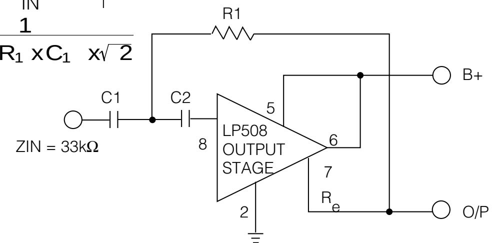


Fig. 7 Active Buffer High Pass Filter using a 508 Output Stage.

Note: 1) R1 and R2 must be 10 times less than Z_{IN} for low pass.

2) Collector output pin is tied to supply.

OTHER FEATURES

Both the LP and LC508 each have an internal 4 kΩ microphone decoupling resistor. With the addition of an external capacitor an effective decoupling network is achieved.

APPLICATION CIRCUITS

The circuit of Fig. 8 is an LC508 Class A Amplifier with the LV560 used as a digitally controlled volume control. The LV560 was designed to work around the feedback loop of a 508 preamp. Typically, the impedance of the LV560 is adjustable between 4 kΩ - 500 kΩ (42 dB). The gain of the LC508 preamp is calculated in the same manner as if a fixed resistor was used externally. For more information on the GT/LV560 Transconductance block, refer to data sheet No.510-64.

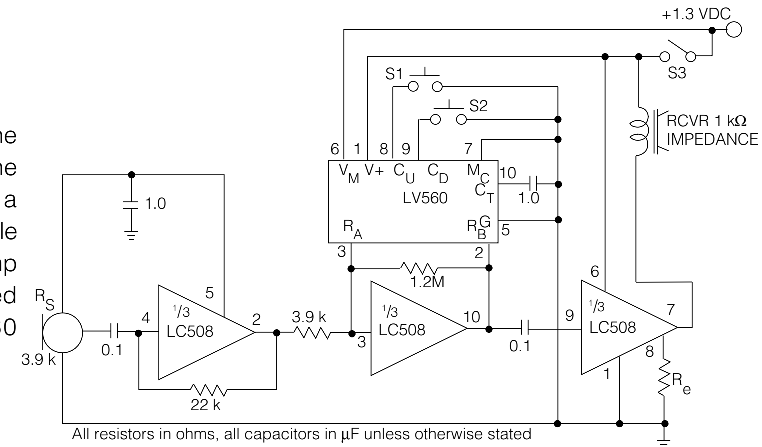
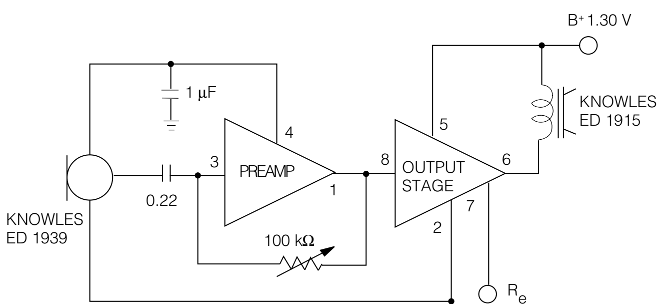
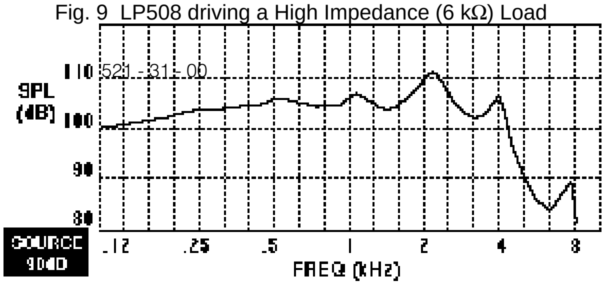


Fig. 8 LC508 with LV560 used as an Electronic Volume Control.

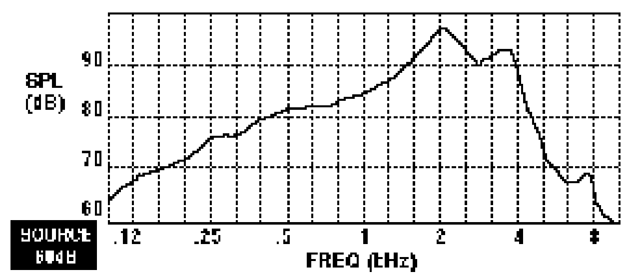


All resistors in ohms, all capacitors in µF unless otherwise stated

Fig. 9 LP508 driving a High Impedance (6 kΩ) Load

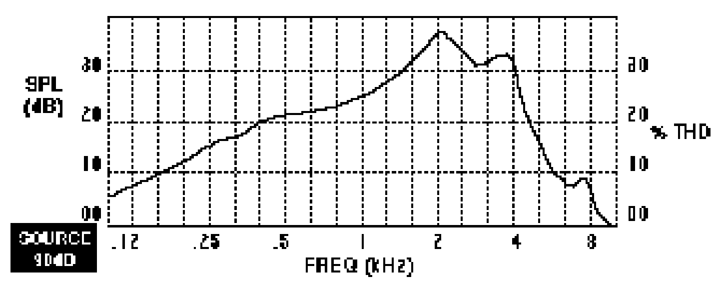


MAX OUTPUT 111.5 dBSPL at 2.12 kHz
HF AVG FULL ON GAIN 37.0 dB at 60.0 dBSPL INPUT
90 dB HF AVG 106.5 dBSPL
RESP. CURVE GAIN 29.5 dB
90 dB HF AVG-77 = 29.5 dB



RESPONSE LIMIT 69.5 dBSPL
F1: 0.151 kHz
F2: 5.60 kHz
EQUIVALENT INPUT NOISE 28.0 dBSPL
TOTAL HARMONIC DIST: 0% at 0.5 kHz
1% at 0.8 kHz
0% at 1.6 kHz

BATT. CURRENT 0.44 mA at
ZINC - AIR (1.30V) SETTING
WITH 65 dBSPL and 1.00 kHz INPUT



EQUIVALENT INPUT NOISE 31.0 dBSPL
HF AVG 89.5 dBSPL

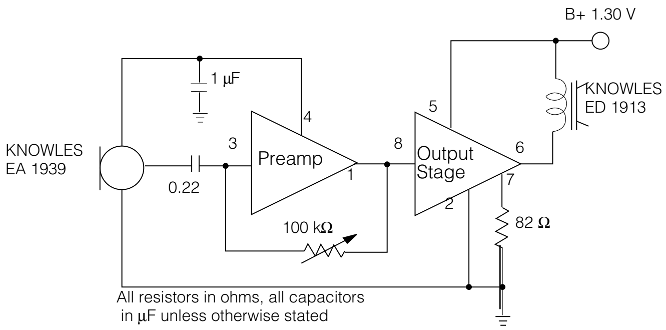
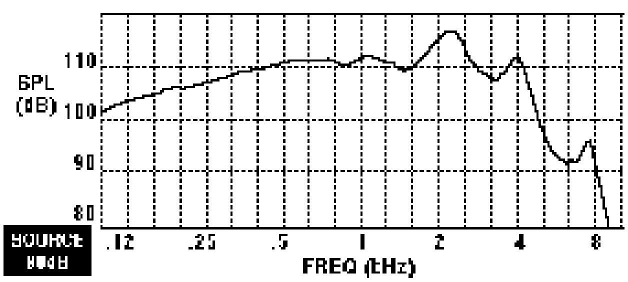
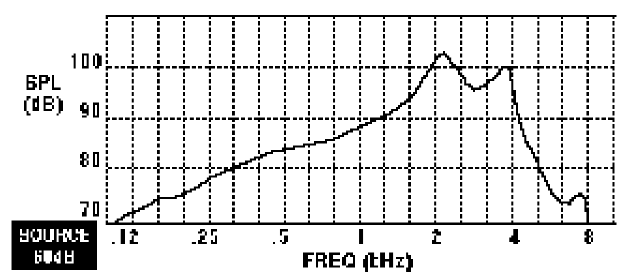


Fig. 10 LP508 driving a Low Impedance (1.5 kΩ) Load

Note: Acoustic responses for only the LP508 are shown because, with the exception of higher gain,similar responses can be achieved using the LC508.

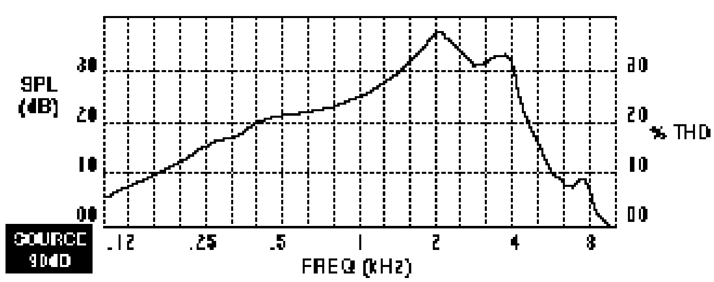


MAX OUTPUT 117.0 dBSPL at 2.240 kHz
HF AVG FULL ON GAIN 39.5 dB at 60.0 dBSPL INPUT
90 dB HF AVG 115.5 dBSPL
RESP. CURVE GAIN 34.0 dB
90 dB HF AVG-77 =34.5 dB



RESPONSE LIMIT 74.0 dBSPL
F1: 0.160 kHz
F2: 6.00 kHz
EQUIVALENT INPUT NOISE 28.0 dBSPL
TOTAL HARMONIC DIST: 1% at 0.5 kHz
1% at 0.8 kHz
0% at 1.6 kHz

BATT. CURRENT 0.84 mA at ZINC - AIR (1.30V)
SETTING WITH 65 dBSPL and 1.00 kHz INPUT



EQUIVALENT INPUT NOISE 31.0 dBSPL
% TOTAL HARMONIC DISTORTION
HF AVG FULL 94.0 dBSPL

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