Application Note

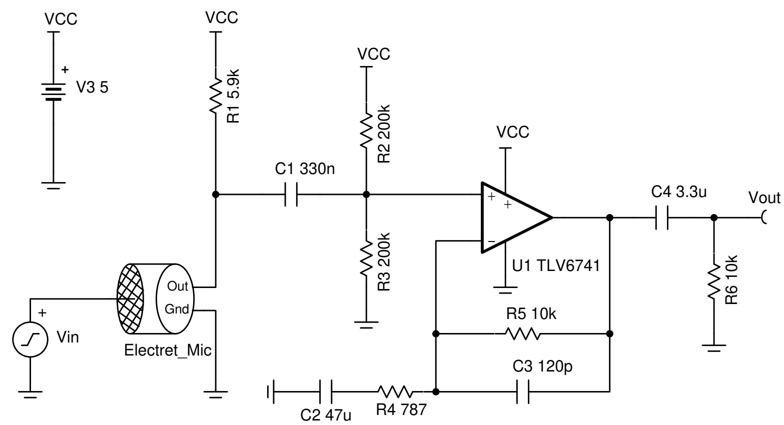
Non-inverting microphone pre-amplifier circuit

Design Goals

Input Pressure (Max)	Output Voltage (Max)	Supply		Frequency Response Deviation	
		V_{cc}	V_{ee}	@20Hz	@20kHz
100dB SPL (2 Pa)	$1.228V_{rms}$	5V	0V	–0.5dB	–0.1dB

Design Description

This circuit uses a non–inverting amplifier circuit configuration to amplify the microphone output signal. This circuit has very good magnitude flatness and exhibits minor frequency response deviations over the audio frequency range. The circuit is designed to be operated from a single 5V supply.



Design Notes

1. Operate within the op amp linear output operating range, which is usually specified under the A_{OL} test conditions.
2. Use low–K capacitors (tantalum, C0G, and so forth) and thin film resistors help to decrease distortion.
3. Use a battery to power this circuit to eliminate distortion caused by switching power supplies.
4. Use low value resistors and low noise op amps for low noise designs.
5. The common mode voltage is equal to the DC bias voltage set using the resistor divider plus any variation caused by the microphone output voltage. For op amps with a complementary pair input stage it is recommended to keep the common mode voltage away from the cross over region to eliminate the possibility of cross over distortion.
6. Resistor R_1 is used to bias the microphone internal JFET transistor to achieve the bias current specified by the microphone.
7. The equivalent input resistance is determined by R_1, R_2, R_3. Use large value resistors for R_2 and R_3 to increase the input resistance.
8. The voltage connected to R_1 to bias the microphone does not have to be the same as the op amp supply voltage. Using a higher voltage supply for the microphone bias allows for a lower bias resistor value.

Design Steps

This design procedure uses the microphone specifications provided in the following table.

Microphone Parameter	Value
Sensitivity @ 94dB SPL (1 Pa)	–35 ± 4 dBV
Current Consumption (Max)	0.5mA
Impedance	2.2kΩ
Standard Operating Voltage	2Vdc

1. Convert the sensitivity to volts per Pascal.

$$10^{\frac{-35dB}{20}} = 17.78\frac{mV}{Pa}$$

2. Convert volts per Pascal to current per Pascal.

$$\frac{17.78\frac{mV}{Pa}}{2.2k\Omega} = 8.083\frac{\mu A}{Pa}$$

3. Max output current occurs at max pressure 2Pa.

$$I_{Max} = 2Pa \times 8.083\frac{\mu A}{Pa} = 16.166\mu A$$

4. Calculate bias resistor. In the following equation, Vmic is microphone standard operating voltage.

$$R_1 = \frac{V_{cc} - V_{mic}}{I_S} = \frac{5V\text{-}2V}{0.5mA} = 6k\Omega \approx 5.9k\Omega \text{ (Standard Value)}$$

5. Set the amplifier input common mode voltage to mid–supply voltage. The equivalent resistance of R_2 in parallel with R_3 should be 10 times larger than R1 so that a majority of the microphone current flows through R_1.

$$R_{eq} = R2||R3 > 10 \times R1 = 100k\Omega$$
$$\text{Choose } R_2 = R_3 = 200k\Omega$$

6. Calculate the maximum input voltage.

$$R_{in} = R1||R_{eq} = 5.9k\Omega||100k\Omega = 5.571k\Omega$$
$$V_{in} = I_{max} \times R_{in} = 16.166uA \times 5.571k\Omega = 90.067mV$$

7. Calculate gain required to produce the largest output voltage swing.

$$Gain = \frac{V_{outmax}}{V_{in}} = \frac{1.228V}{90.067mV} = 13.634\frac{V}{V}$$

8. Calculate R_4 to set the gain calculated in step 7. Select feedback resistor R_5 as 10kΩ.

$$R_4 = \frac{R_5}{Gain\text{-}1} = \frac{10k\Omega}{13.634\text{-}1} = 791\Omega \approx 787\Omega \text{ (Standard Values)}$$

The final gain of this circuit is:

$$Gain = 20\log\left(\frac{Vout}{Vin}\right) = 20\log\left(\frac{16.166uA \times 5.571k\Omega \times \left(1+\frac{10k\Omega}{787\Omega}\right)}{2V}\right) = -4.191dB$$

9. Calculate the corner frequency at low frequency according to the allowed deviation at 20 Hz. In the following equation, G_pole1 is the gain contributed by each pole at frequency "f". Note that you divide by three because there are three poles.

$$f_c = f\sqrt{\left(\frac{1}{G\_pole1}\right)^2 - 1} = 20Hz\sqrt{\left(\frac{1}{10^{\frac{-0.5/3}{20}}}\right)^2 - 1} = 3.956Hz$$

10. Calculate C_1 based on the cut off frequency calculated in step 9.

$$C_1=\frac{1}{2\pi\times Req\times f_c}=\frac{1}{2\pi\times 100k\Omega\times 3.956Hz}=0.402\mu F\approx 0.33\mu F \text{ (Standard Value)}$$

11. Calculate C_2 based on the cut off frequency calculated in step 9.

$$C_2=\frac{1}{2\pi\times R4\times f_c}=\frac{1}{2\pi\times 787\Omega\times 3.956Hz}=51.121\mu F\approx 47\mu F \text{ (Standard Value)}$$

12. Calculate the high frequency pole according to the allowed deviation at 20 kHz. In the following equation, G_pole2 is the gain contributed by each pole at frequency “f”.

$$f_p=\frac{f}{\sqrt{\left(\frac{1}{G\_pole2}\right)^2-1}}=\frac{20kHz}{\sqrt{\left(\frac{1}{10^{\frac{-0.1}{20}}}\right)^2-1}}=131.044kHz$$

13. Calculate C3 to set the cut off frequency calculated in step 12.

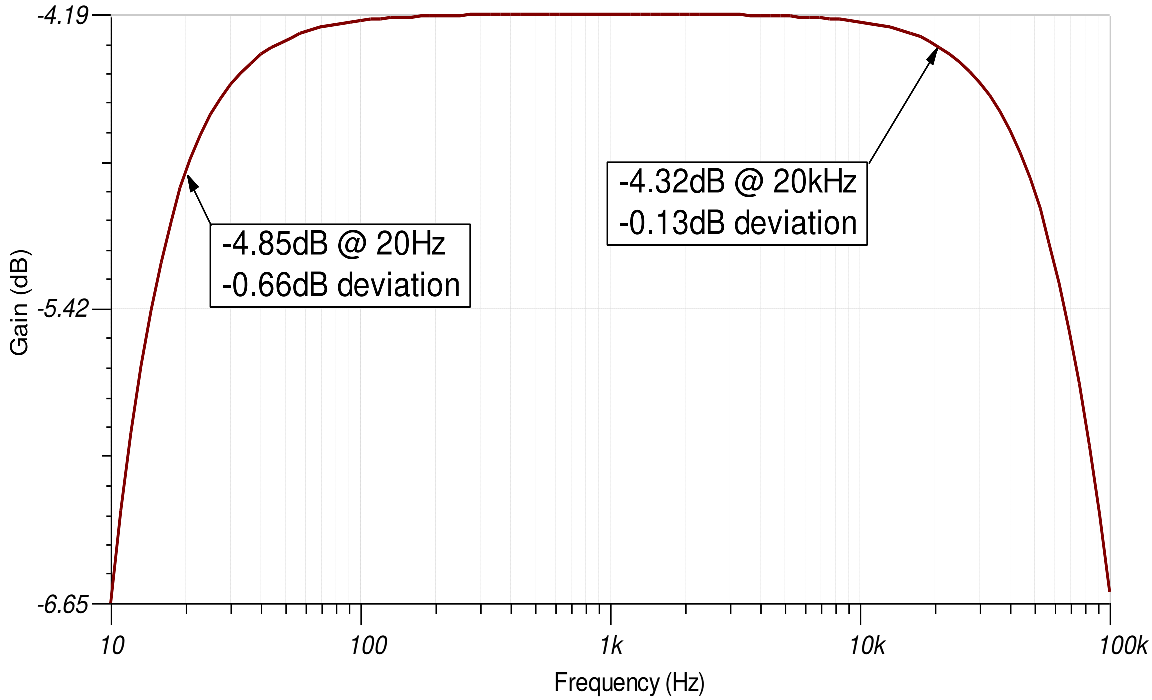
$$C_3=\frac{1}{2\pi\times R_5\times f_p}=\frac{1}{2\pi\times 10k\Omega\times 131.044kHz}=121.451pF\approx 120pF \text{ (Standard Value)}$$

14. Calculate the output capacitor, C_4, based on the cut off frequency calculated in step 9. Assume the output load R_6 is 10kΩ.

$$C_4=\frac{1}{2\pi\times R_6\times f_c}=\frac{1}{2\pi 10k\Omega\times 3.956Hz}=4.023\mu F\approx 3.3\mu F \text{ (Standard Value)}$$

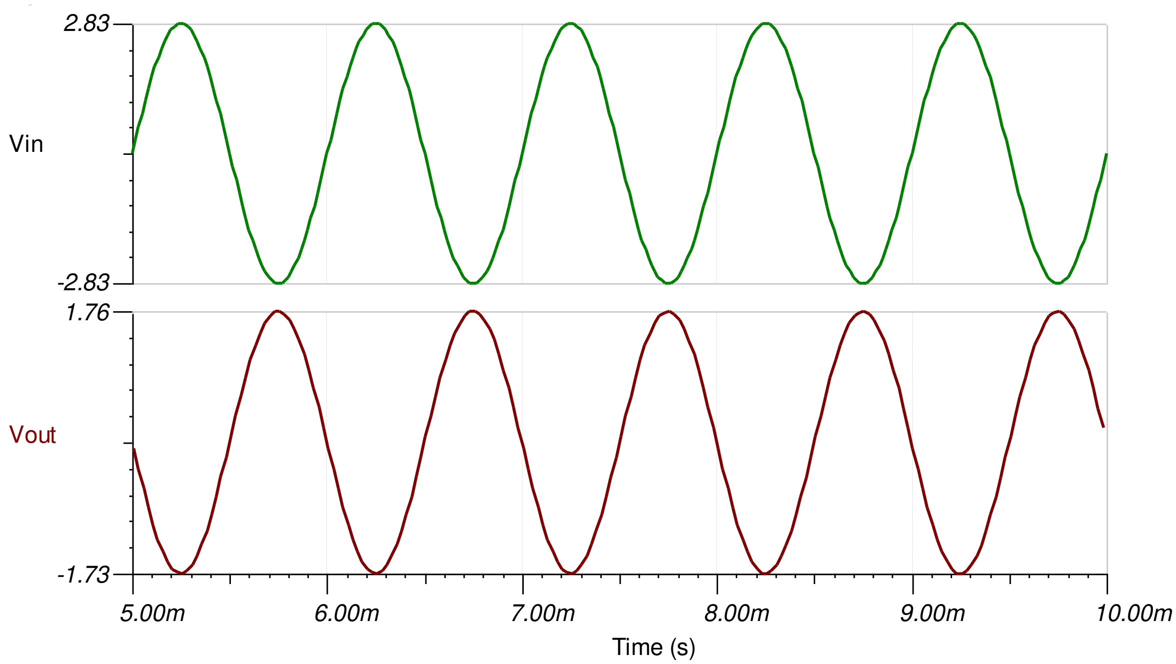
Design Simulations

AC Simulation Results



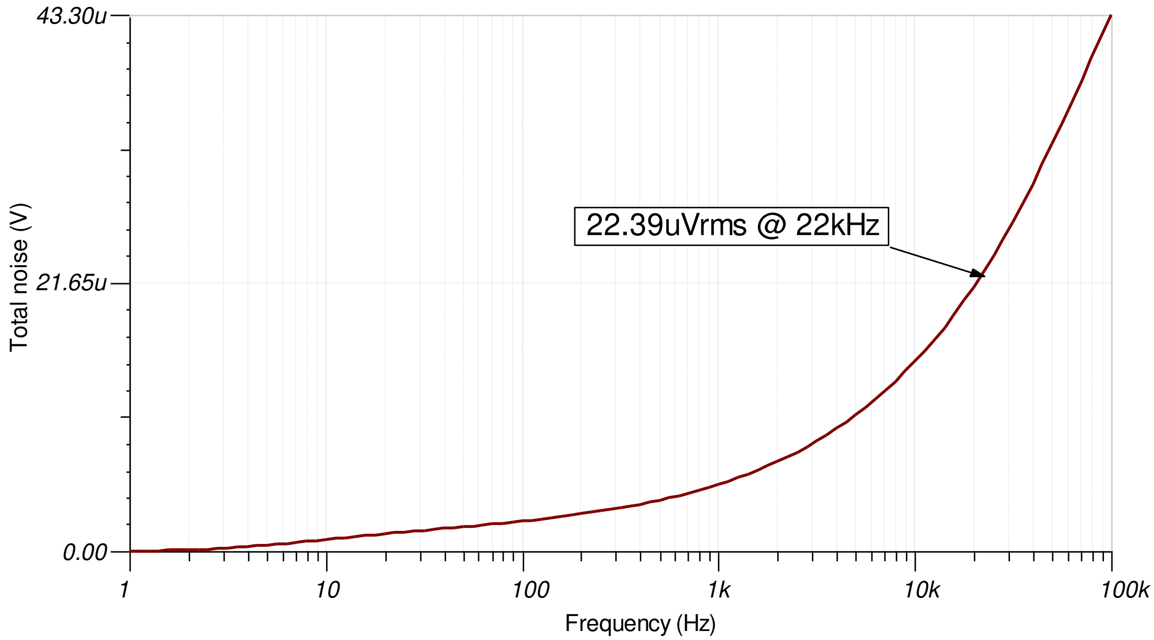
Transient Simulation Results

The input voltage represents the SPL of an input signal to the microphone. A 1 V_{rms} input signal represents 1 Pascal.



Noise Simulation Results

The following simulation results show 22.39uVrms of noise at 22kHz. The noise is measured at a bandwidth of 22kHz to represent the measured noise using an audio analyzer with the bandwidth set to 22kHz.



References:

1. Analog Engineer's Circuit Cookbooks
2. SPICE Simulation File SBOC525
3. TI Precision Designs TIPD181
4. TI Precision Labs

Design Featured Op Amp

TLV6741	
V_{ss}	1.8V to 5.5V
V_{inCM}	(Vee) to (Vcc –1.2V)
V_{out}	Rail–to–rail
V_{os}	150µV
I_q	890uA/Ch
I_b	10pA
UGBW	10MHz
SR	4.75V/µs
#Channels	1
www.ti.com/product/tlv6741	

Design Alternate Op Amp

OPA320	
V_{ss}	1.8V to 5.5V
V_{inCM}	Rail–to–rail
V_{out}	Rail–to–rail
V_{os}	40µV
I_q	1.5mA/Ch
I_b	0.2pA
UGBW	20MHz
SR	10V/µs
#Channels	1, 2
www.ti.com/product/opa320	