

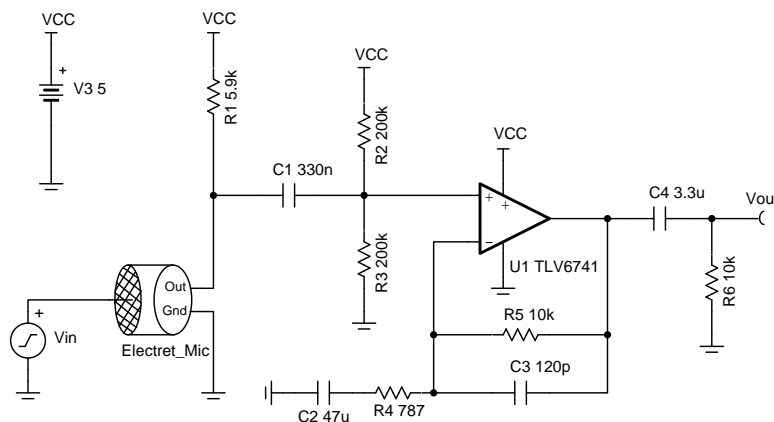
Non-inverting microphone pre-amplifier circuit

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

- Convert the sensitivity to volts per Pascal.

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

- Convert volts per Pascal to current per Pascal.

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

- Max output current occurs at max pressure 2Pa.

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

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

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

- Set the amplifier input common mode voltage to mid-supply voltage. The equivalent resistance of R₂ in parallel with R₃ should be 10 times larger than R₁ so that a majority of the microphone current flows through R₁.

$$R_{\text{eq}} = R_2 \parallel R_3 > 10 \times R_1 = 100\text{k}\Omega$$

Choose R₂ = R₃ = 200kΩ

- Calculate the maximum input voltage.

$$R_{\text{in}} = R_1 \parallel R_{\text{eq}} = 5.9\text{k}\Omega \parallel 100\text{k}\Omega = 5.571\text{k}\Omega$$

$$V_{\text{in}} = I_{\text{max}} \times R_{\text{in}} = 16.166\mu\text{A} \times 5.571\text{k}\Omega = 90.067\text{mV}$$

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

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

- Calculate R₄ to set the gain calculated in step 7. Select feedback resistor R₅ as 10kΩ.

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

The final gain of this circuit is:

$$\text{Gain} = 20 \log \frac{V_{\text{out}}}{V_{\text{in}}} = 20 \log \frac{16.166\mu\text{A} \times 5.571\text{k}\Omega \times \left(1 + \frac{10\text{k}\Omega}{787\Omega}\right)}{2\text{V}} = -4.191\text{dB}$$

- 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.

$$f_c = f \sqrt{\left(\frac{1}{G_{\text{pole1}}}\right)^2 - 1} = 20\text{Hz} \sqrt{\left(\frac{1}{10^{-\frac{0.5/3}{20}}}\right)^2 - 1} = 3.956\text{Hz}$$

- Calculate C₁ based on the cut off frequency calculated in step 9.

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

- Calculate C₂ based on the cut off frequency calculated in step 9.

$$C_2 = \frac{1}{2\pi \times R_4 \times f_c} = \frac{1}{2\pi \times 787\Omega \times 3.956\text{Hz}} = 51.121\mu\text{F} \approx 47\mu\text{F} \text{ (Standard Value)}$$

- 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".

$$f_p = \frac{f}{\sqrt{\left(\frac{1}{G_{\text{pole2}}}\right)^2 - 1}} = \frac{20\text{kHz}}{\sqrt{\left(\frac{1}{10^{-\frac{0.1}{20}}}\right)^2 - 1}} = 131.044\text{kHz}$$

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

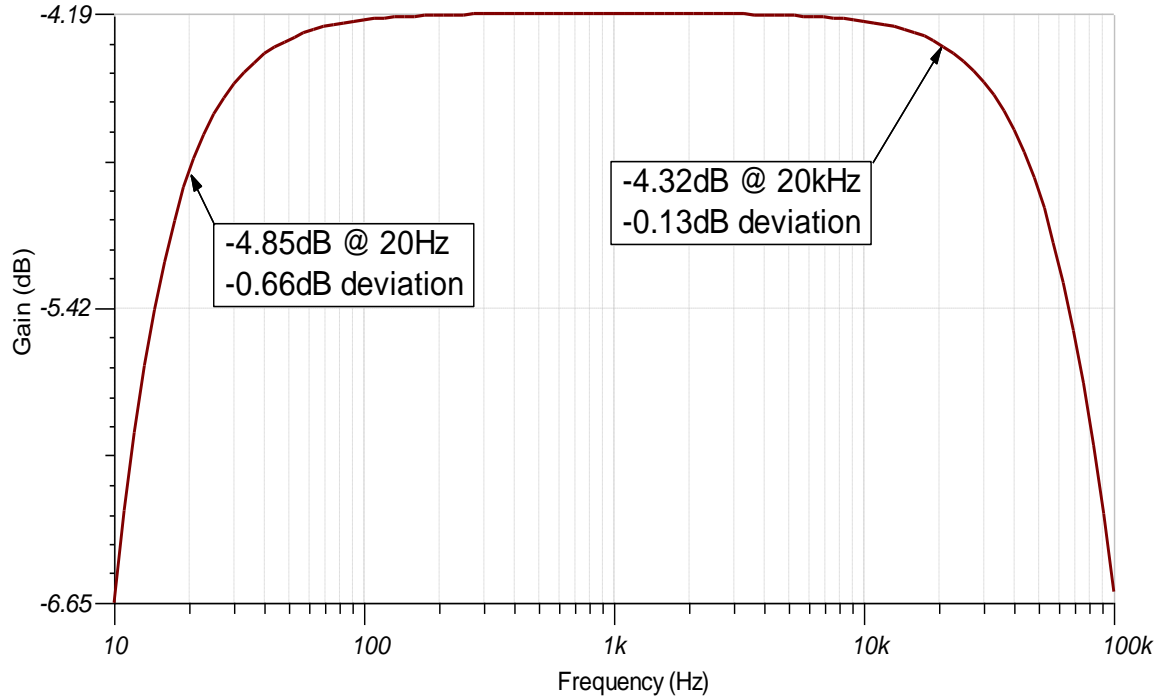
$$C_3 = \frac{1}{2\pi \times R_5 \times f_p} = \frac{1}{2\pi \times 10k\Omega \times 131.044kHz} = 121.451pF \approx 120pF \text{ (Standard Value)}$$

14. Calculate the output capacitor, C₄, based on the cut off frequency calculated in step 9. Assume the output load R₆ is 10kΩ.

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

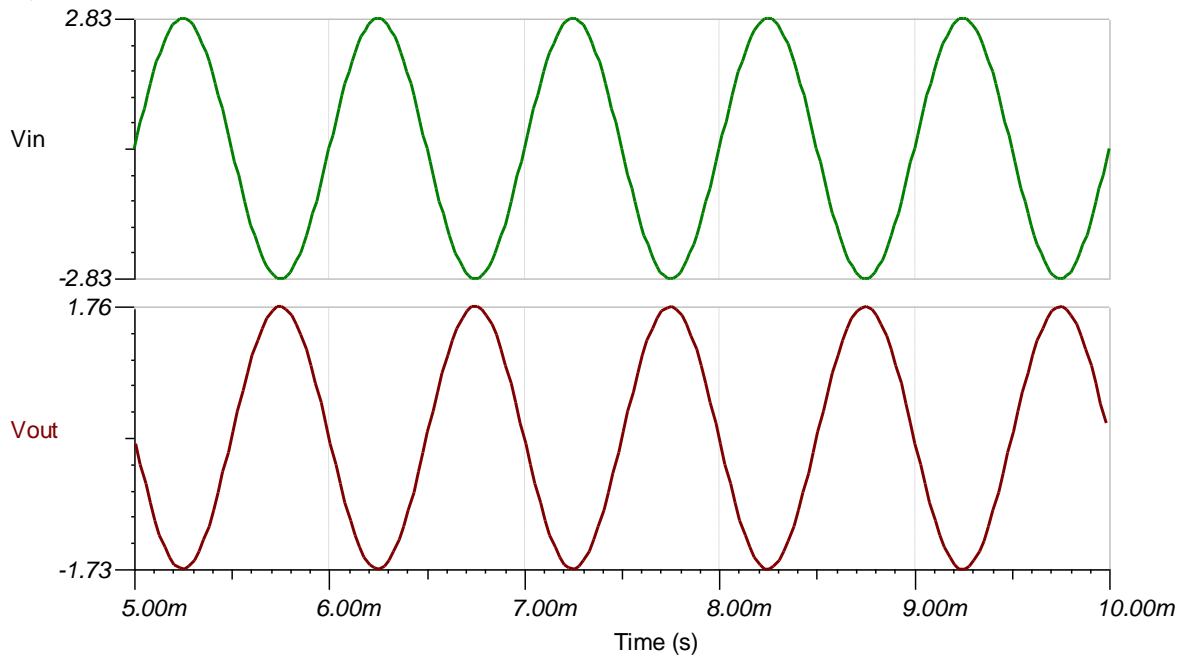
Design Simulations

AC Simulation Results



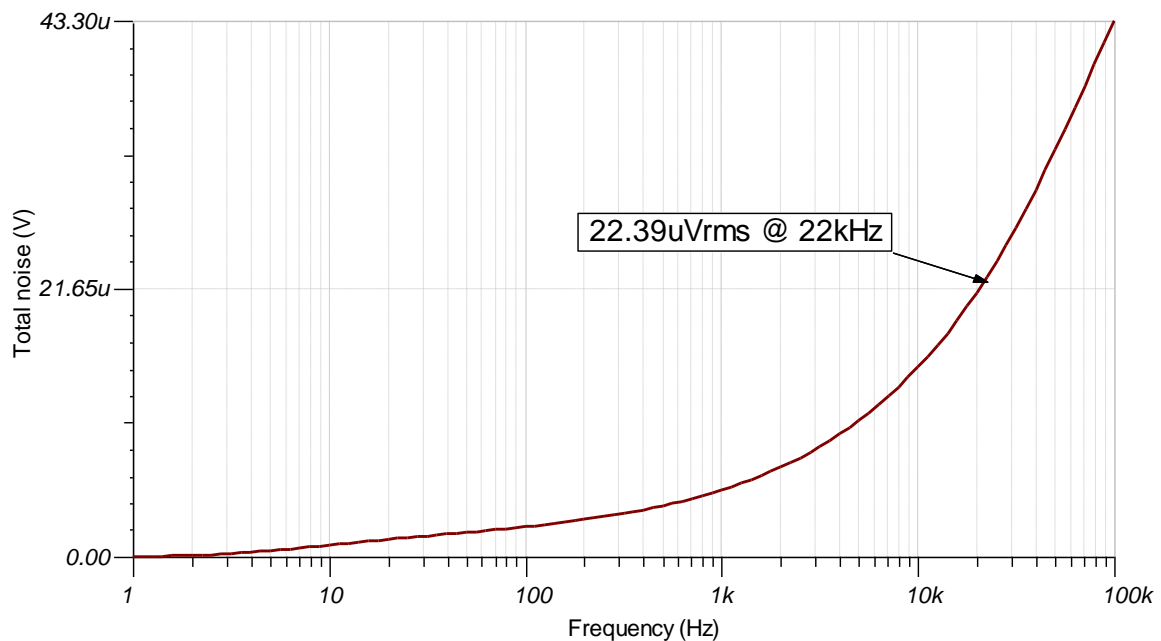
Transient Simulation Results

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 22.39 μV_{rms} 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}	150 μ V
I_q	890 μ A/Ch
I_b	10pA
UGBW	10MHz
SR	4.75V/ μ s
#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}	40 μ V
I_q	1.5mA/Ch
I_b	0.2pA
UGBW	20MHz
SR	10V/ μ s
#Channels	1, 2
www.ti.com/product/opa320	

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to [TI's Terms of Sale](#) or other applicable terms available either on [ti.com](#) or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2021, Texas Instruments Incorporated