

# Analog Engineer's Circuit

## TIA Microphone Amplifier Circuit

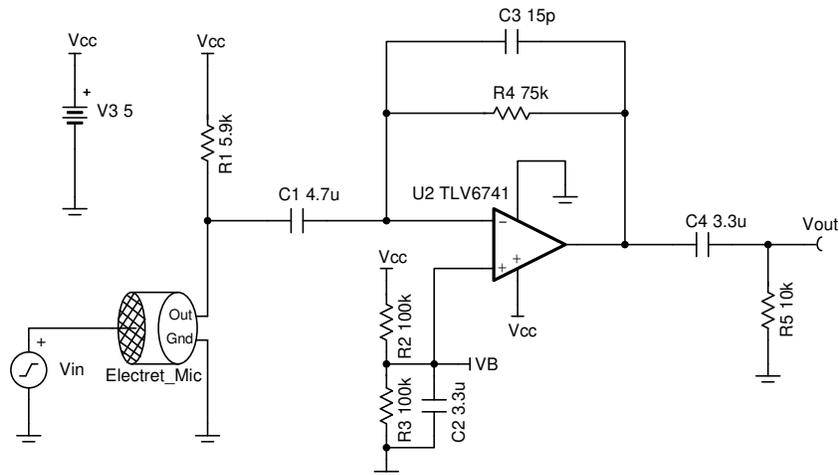


### Design Goals

Input pressure (Max)	Output Voltage (Max)	Supply		Frequency Response Deviation	
		$V_{cc}$	$V_{ee}$	At 20 Hz	At 20 kHz
100 dB SPL(2Pa)	1.228 V <sub>rms</sub>	5 V	0 V	-0.5 dB	-0.1 dB

### Design Description

This circuit uses an op amp in a transimpedance amplifier configuration to convert the output current from an electret capsule microphone into an output voltage. The common mode voltage of this circuit is constant and set to mid-supply eliminating any input-stage cross over distortion.



### Design Notes

1. Use the op amp in the 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 amp to achieve high performance low noise designs.
5. The voltage connected to  $R_1$  to bias the microphone does not have to match the supply voltage of the op amp. Using a larger microphone bias voltage allows for a larger value or  $R_1$  which decreases the noise gain of the op amp circuit while still maintaining normal operation of the microphone.
6. Capacitor  $C_1$  should be large enough that its impedance is much less than resistor  $R_1$  at audio frequency. Pay attention to the signal polarity when using tantalum capacitors.

## Design Steps

The following microphone is chosen as an example to design this circuit.

1.	Microphone parameter	Value
	Sensitivity at 94 dB SPL (1 Pa)	-35 ± 4 dBV
	Current Consumption (Max)	0.5 mA
	Impedance	2.2 kΩ
	Standard Operating Voltage	2 V <sub>dc</sub>

2. Convert the sensitivity to volts per Pascal.

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

3. Convert volts per Pascal to current per Pascal.

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

4. Max output current occurs at max sound pressure level of 2Pa.

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

5. Calculate the value of resistor R<sub>4</sub> to set the gain

$$R_4 = \frac{V_{\text{max}}}{I_{\text{max}}} = \frac{1.228\text{V}}{16.166\mu\text{A}} = 75.961 \text{ k}\Omega \approx 75\text{k}\Omega \text{ (Standard value)}$$

The final signal gain is:

$$\text{Gain} = 20 \times \log\left(\frac{V_{\text{out}}}{V_{\text{in}}}\right) = 20 \times \log\left(\frac{16.166\mu\text{A} \times 75\text{k}\Omega}{2\text{V}}\right) = -4.347 \text{ dB}$$

6. Calculate the value for the bias resistor R<sub>1</sub>. In the following equation, V<sub>mic</sub> is the standard operating voltage of the microphone

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

7. Calculate the high frequency pole according to the allowed deviation at 20 kHz. In the following equation, G<sub>pole1</sub> is the gain at frequency *f*.

$$f_p = \frac{f}{\sqrt{\left(\frac{1}{G_{\text{pole1}}}\right)^2 - 1}} = \frac{20\text{kHz}}{\sqrt{\left(\frac{1}{-0.1}\right)^2 - 1}} = 131.044 \text{ kHz}$$

8. Calculate C<sub>3</sub> based on the pole frequency calculated in step 6.

$$C_3 = \frac{1}{2\pi \times f_p \times R_4} = \frac{1}{2\pi \times 131.044\text{kHz} \times 75\text{k}\Omega} = 16.194 \text{ pF} \approx 15\text{pF} \text{ (Standard value)}$$

9. Calculate the corner frequency at low frequency according to the allowed deviation at 20 Hz. In the following equation, G<sub>pole2</sub> is the gain contributed by each pole at frequency *f* respectively. There are two poles, so divided by two.

$$f_c = f \times \sqrt{\left(\frac{1}{G_{\text{pole2}}}\right)^2 - 1} = 20\text{Hz} \times \sqrt{\left(\frac{1}{-0.5/2}\right)^2 - 1} = 4.868 \text{ Hz}$$

10. Calculate the input capacitor C<sub>1</sub> based on the cut off frequency calculated in step 8.

$$C_1 = \frac{1}{2\pi \times R_1 \times f_c} = \frac{1}{2\pi \times 5.9\text{k}\Omega \times 4.868\text{Hz}} = 5.541 \text{ }\mu\text{F} \approx 4.7 \text{ }\mu\text{F} \text{ (Standard value)}$$

11. Assuming the output load  $R_5$  is 10 k $\Omega$ , calculate the output capacitor  $C_4$  based on the cut off frequency calculated in step 8.

$$C_4 = \frac{1}{2\pi \times R_5 \times f_c} = \frac{1}{2\pi \times 10\text{k}\Omega \times 4.868\text{Hz}} = 3.269 \mu\text{F} \approx 3.3 \mu\text{F} \text{ (Standard value)}$$

12. Set the amplifier input common mode voltage to mid-supply voltage. Select  $R_2$  and  $R_3$  as 100 k $\Omega$ . The equivalent resistance equals to the parallel combination of the two resistors:

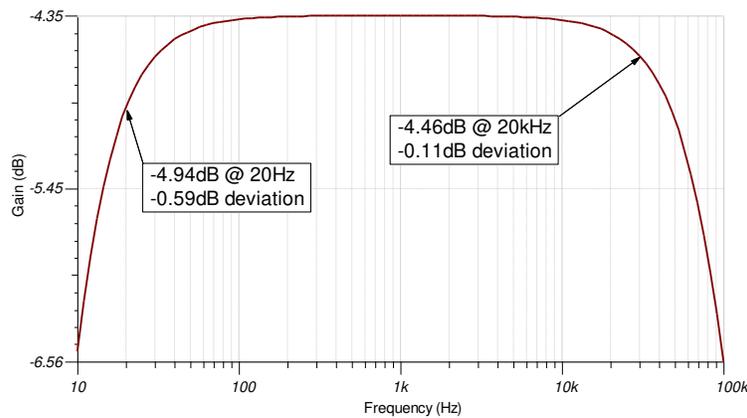
$$R_{eq} = R_2 || R_3 = 100\text{k}\Omega || 100\text{k}\Omega = 50\text{k}\Omega$$

13. Calculate the capacitor  $C_2$  to filter the power supply and resistor noise. Set the cutoff frequency to 1 Hz.

$$C_2 = \frac{1}{2\pi \times (R_2 || R_3) \times 1\text{Hz}} = \frac{1}{2\pi \times (100\text{k}\Omega || 100\text{k}\Omega) \times 1\text{Hz}} = 3.183 \mu\text{F} \approx 3.3 \mu\text{F} \text{ (Standard value)}$$

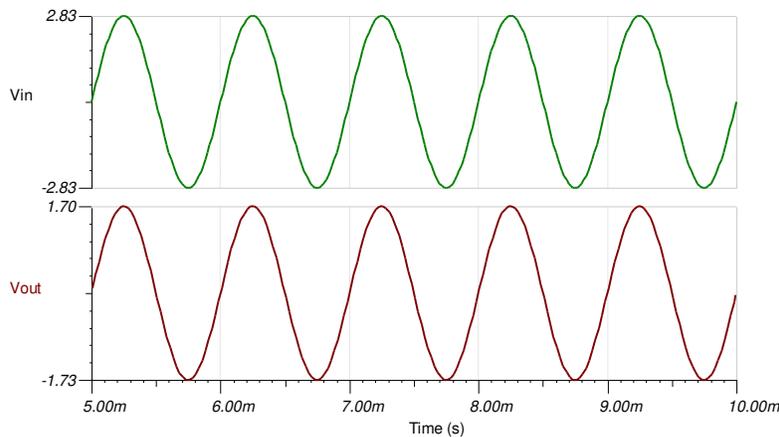
## Design Simulations

### AC Simulation Results

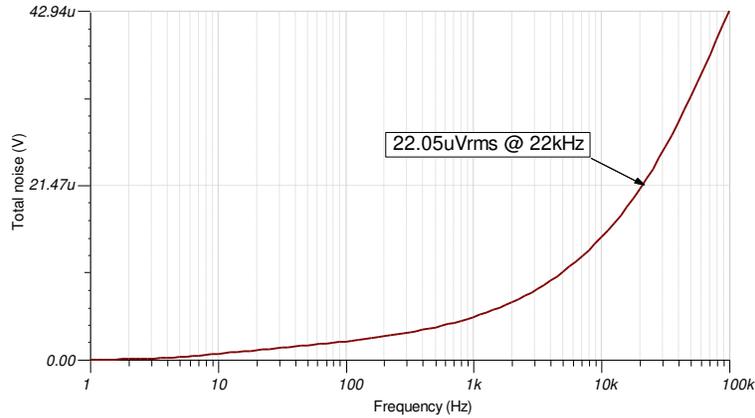


### Transient Simulation Results

The input voltage represents the SPL of an input signal to the microphone. A 2 V<sub>rms</sub> input signal represents 2 Pascal.



The following simulation results show 22.39  $\mu\text{V}_{\text{rms}}$  of noise at 22 kHz. The noise is measured at a bandwidth of 22 kHz to represent the measured noise using an audio analyzer with the bandwidth set to 22 kHz.



#### References:

1. [Analog Engineer's Circuit Cookbooks](#)
2. SPICE Simulation File [SBOC526](#)
3. TI Precision Designs [TIPD181](#)
4. [TI Precision Labs](#)

#### Design Featured Op Amp

TLV6741	
$V_{\text{SS}}$	1.8 V to 5.5 V
$V_{\text{inCM}}$	$V_{\text{ee}}$ to $V_{\text{cc}}-1.2$ V
$V_{\text{out}}$	Rail-to-rail
$V_{\text{os}}$	150 $\mu\text{V}$
$I_{\text{q}}$	890 $\mu\text{A}/\text{Ch}$
$I_{\text{b}}$	10 pA
UGBW	10 MHz
SR	4.75 V/ $\mu\text{s}$
#Channels	1
<a href="#">TLV6741</a>	

#### Design Alternate Op Amp

	OPA172	OPA192
$V_{\text{SS}}$	4.5 V to 36 V	4.5 V to 36 V
$V_{\text{inCM}}$	$V_{\text{ee}}-0.1$ V to $V_{\text{cc}}-2$ V	$V_{\text{ee}}-0.1$ V to $V_{\text{cc}}+0.1$ V
$V_{\text{out}}$	Rail-to-rail	Rail-to-rail
$V_{\text{os}}$	$\pm 200$ $\mu\text{V}$	$\pm 5$ $\mu\text{V}$
$I_{\text{q}}$	1.6 mA/Ch	1 mA/Ch
$I_{\text{b}}$	8 pA	5 pA
UGBW	10 MHz	10 MHz
SR	10 V/ $\mu\text{s}$	20 V/ $\mu\text{s}$
#Channels	1, 2, and 4	1, 2, and 4
	<a href="#">OPA172</a>	<a href="#">OPA192</a>

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