

11.3.4: Signal Conditioning – Audio Application

Overview:

When making time-varying measurements, the sensor being used often has at least a few undesirable characteristics. Common shortcomings of sensors are lower than desired sensitivity, excessive noise levels, and DC offsets. *Frequency selective circuits* are often used to *condition* the sensor's output signal to reduce the effects of these shortcomings. *Low-pass filters*, for example, can be used to increase the sensor's low-frequency sensitivity while reducing the high-frequency noise components in the sensor output signal.

In this lab assignment, we will condition the output from a microphone. The microphone is a sensor which converts acoustic waves to electrical signals. The microphone we will be using has fairly low output levels (on the order of 20mV) and a relatively large DC offset. Our goal is to design a filter to amplify the frequencies of interest – those frequencies associated with audio signals – and suppress the DC offset.

Before beginning this lab, you should be able to:

- Calculate the frequency response of a active electrical circuit
- Determine the DC gain, high frequency gain, and cutoff frequency of a first order filter
- Categorize frequency-selective circuits as high pass or low pass filters
- Measure the magnitude and phase responses of first order filter circuits (Labs 11.3.1, 11.3.2)

After completing this lab, you should be able to:

- Design an active filter high pass filter to provide a desired high frequency gain, cutoff frequency, and input impedance
- Use a frequency selective filter to process a microphone's output signal

This lab exercise requires:

- Analog Discovery module
- Diligent Analog Parts Kit
- Digital multimeter (optional)

Symbol Key:

	Demonstrate circuit operation to teaching assistant; teaching assistant should initial lab notebook and grade sheet, indicating that circuit operation is acceptable.
	Analysis; include principle results of analysis in laboratory report.
	Numerical simulation (using PSPICE or MATLAB as indicated); include results of MATLAB numerical analysis and/or simulation in laboratory report.
	Record data in your lab notebook.

1. Microphone:

A microphone converts sound to an electrical signal. We will be using an ADMP504 microphone in this lab project. The ADMP504 microphone is in a surface-mount package; this package does not allow direct implementation in our solderless breadboard. The ADMP504 part in your analog parts kit has been mounted onto a circuit board with pins which can be inserted directly in your breadboard. Figure 1 provides top and bottom views of this circuit board. The ADMP504 microphone is visible on the bottom view of the board, as shown in Figure 1(a). The pin indicator showing the location of pin 1 can also be seen in the bottom view. Pins are consecutively numbered clockwise from pin 1, also as shown in Figure 1(a). In the top view of the chip, a small hole is visible – this hole allows sound to contact the ADMP504 sensor. The hole, and the pin locations seen in the top view are shown in Figure 1(b).

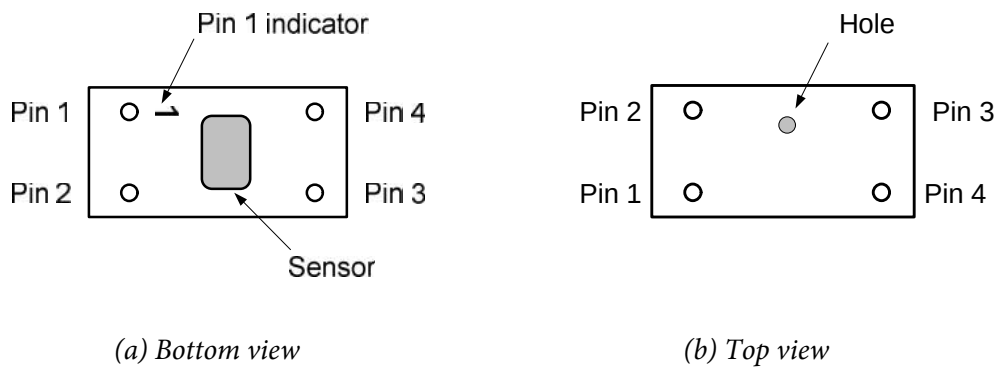


Figure 1. Top and bottom views of the analog parts kit chip on which the microphone is mounted.

The descriptions of the pins shown in Figure 1 are as follows:

- Pin 1: Output voltage. This pin provides a voltage which indicates the audio signal applied to the microphone.
- Pin 2: Ground.
- Pin 3: Voltage source, V_{DD} . This power source is necessary for the microphone to work. We will use $V_{DD} = 3.3V$.
- Pin 4: Not connected.

Additional information about the ADMP504 microphone can be found on the Analog Devices web site, <http://www.analog.com>.

Pre-lab:

None

Lab Procedures:

DATA

- a. In this portion of the lab project, we will measure the response of the sensor and use this data to determine the amplification necessary to provide us with an output signal of the desired sensitivity.

Use the arbitrary waveform generator to apply 3.3V to pin 3 of the microphone board¹. Connect pin 2 of the chip to ground. Use one channel of your oscilloscope to measure the voltage difference between pin 1 and ground. Make a sound² and verify that you are receiving a signal on the oscilloscope from the sensor. At this stage, you will probably want to use a fairly large time base on your oscilloscope (greater than 100msec/division).

DATA

- i. With a relatively large vertical scale (500 mV/division or so) measure and record the DC offset of the sensor.

- ii. With a relatively large vertical offset (approximately the negative of the DC voltage measured in part i above), set the vertical scale on your oscilloscope channel to be on the order of 10 – 20 msec/division. Measure and record the amplitude of the time-varying signal resulting from your sound source. It may be useful to decrease the time base on your oscilloscope significantly in order to accurately measure this value. Setting a trigger to acquire the waveform may assist you once you have reduced the time base.

DATA

- b. In Part II of this project, we want design a filter which uses the sensor output voltage to produce a minimum 1V peak-to-peak signal with no DC offset. Use the time varying data acquired in part ii above to estimate the amplification necessary to produce the desired 1V amplitude.

ANALYSIS

2. Signal Conditioning Circuit:

The circuit of Figure 2 is an inverting high pass filter. The frequency response of the circuit is

$$\frac{V_{OUT}}{V_{IN}} = -\frac{R_2}{R_1} \frac{j\omega}{j\omega + 1/R_1C} \quad (1)$$

so that the magnitude response is:

$$\left| \frac{V_{OUT}}{V_{IN}} \right| = \frac{R_2}{R_1} \frac{\omega}{\sqrt{\omega^2 + \left(1/R_1C\right)^2}} \quad (2)$$

¹ The waveform generator can be used to apply a constant voltage if the amplitude is set to 0V and the offset is set to 3.3V.

² Whistling or snapping your fingers tend to be good sound sources; they are fairly repeatable.

In this assignment, we will choose values of R_1 , R_2 , and C in the circuit of Figure 2 to meet design requirements set on:

- Input resistance: the input resistance is the ratio of input voltage to input current for a circuit. In the circuit of Figure 1, the input resistance is dependent upon both the capacitance and the frequency. However, at high frequencies, the capacitor behaves like a short circuit, and the input resistance is essentially the resistance R_1 .
- High frequency gain: the high frequency gain (the gain as $\omega \rightarrow \infty$) is, from equation (2), the ratio of R_2 to R_1 . Once R_1 is determined from the input resistance requirement, the high frequency gain specifies the required value for R_2 .
- Cutoff frequency: once R_2 is known, the cutoff frequency requirement specifies the value of the capacitor C .

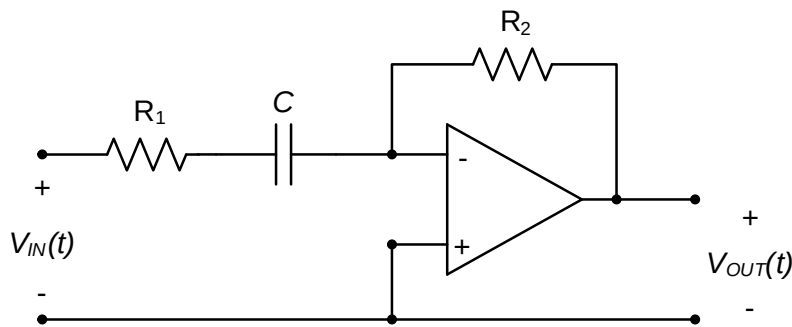


Figure 1. Inverting high-pass filter circuit.

Pre-lab:

ANALYSIS

Design the circuit of Figure 1 (e.g. choose values for R_1 , R_2 , and C) to meet the following design requirements:

- $R_1 \geq 2\text{k}\Omega$. (This essentially sets the input resistance for the filter.)
- High frequency gain (gain as $\omega \rightarrow \infty$) = Amplification value necessary to produce 1V peak-to-peak output voltage, as determined in the Lab Procedures for Part I.
- Cutoff frequency $\leq 500\text{Hz}$

ANALYSIS

Determine the response of the circuit of Figure 1 to a DC input voltage. What will the circuit's response be to the DC voltage provided by the sensor?

Lab Procedures:

- DATA** Construct the circuit you designed in the pre-lab. Be sure to measure the actual values.
- DATA** i. Measure the magnitude response of the circuit over a range of frequencies $\frac{\omega_c}{10} < \omega < 10\omega_c$, where ω_c is the cutoff frequency of the circuit³. Make sure you measure the response for at least six different frequencies.
- DEMO** ii. Demonstrate operation of your circuit to the TA and have them initial the appropriate page(s) of your lab notebook and the lab worksheet.
- ANALYSIS** iii. From your measured data, determine the actual cutoff frequency and high frequency gain of your circuit. Compare your measured values to the design requirements. Comment on the differences between the design requirements and your measured values.

3. Overall System Integration:

We will now integrate the signal conditioning circuit designed and built in Part II with the sensor of Part I. The goal is to amplify the “important” part of the response of the sensor – the time-varying signal corresponding to the sound – and remove the undesirable DC level in the sensor output. One possibly important drawback to this approach, of course, is that desirable lower-frequency information will also be removed from the data.

Pre-lab:

None

Lab Procedures:

- DATA** i. Apply the sensor output voltage to the input terminals of the signal conditioning circuit, $V_{IN}(t)$. Using the oscilloscope, measure both $V_{in}(t)$ from the sensor and the signal conditioning unit’s output voltage, $V_{OUT}(t)$ in Figure 2. Make a sound (clap your hands, whistle,...) and display the resulting waveform on the oscilloscope main window. Record an image of the oscilloscope window, showing the voltages $V_{IN}(t)$ and $V_{OUT}(t)$. Comment on your results relative to your expectations.
- DEMO** ii. Demonstrate operation of your circuit to the TA and have them initial the appropriate page(s) of your lab notebook and the lab worksheet.

³ Keep in mind that the units of ω are radians/second, while the design requirement on the cutoff frequency is given in Hz.