

11.3.3: Active Low Pass Filter

Overview:

Active filter circuits provide a number of the same advantages as our previous active circuits:

- As we saw in Lab projects 7.5.1 and 7.5.3, applying a load to an active circuit can have less of effect on the circuit's behavior than if the circuit were passive
- For an active circuit, the output voltage can be larger than the input voltage – the active circuit can amplify a signal.
- The high input impedance of operational amplifiers can help reduce the effect that the passive filter has on the signal source. This can be particularly important in instrumentation applications; since many sensors provide extremely limited power, it is important to process the sensor's output with a circuit which draws little or no power from the sensor.

In this lab project, we will design an active low-pass filter to provide a desired DC gain, cutoff frequency, and input resistance. The circuit used in this project also *inverts* the input – the DC output voltage has the opposite sign as the input voltage.

Before beginning this lab, you should be able to:

- Calculate the frequency response of an active electrical circuit
- Determine the DC gain, high frequency gain, and cutoff frequency of a first order filter
- 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:

- Calculate the magnitude and phase responses of an active electrical circuit
- Design an active filter to provide a desired DC gain, cutoff frequency, and input impedance

This lab exercise requires:

- Analog Discovery module
- Digilent 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.

General Discussion:

The circuit of Figure 1 is an inverting low pass filter. The magnitude response of the circuit is

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

In this assignment, we will choose values of R_1 , R_2 , and C in the circuit of Figure 1 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 essentially specifies the resistance R_1 .
- DC gain: the DC gain is, from equation (1), the ratio of R_2 to R_1 . Once R_1 is determined from the input impedance requirement, the DC 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 .

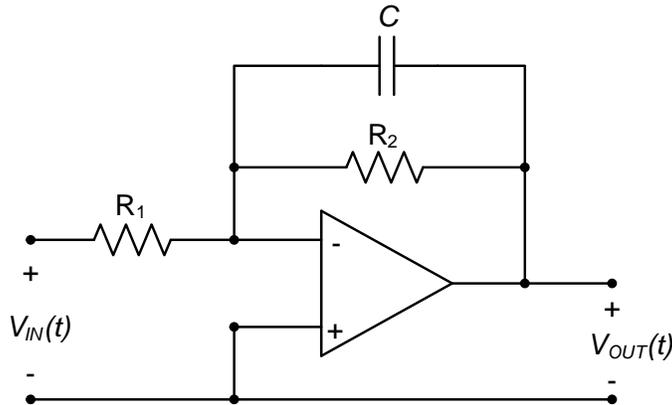


Figure 1. Inverting low-pass filter circuit.

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:

- Input impedance $\geq 10\text{k}\Omega$
- DC gain = 2
- Cutoff frequency = 10kHz

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

$\frac{\omega}{\omega_c} < 10 < 10 \omega_c$, where ω_c is the cutoff frequency of the circuit¹. 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 DC gain of your circuit. Compare your measured values to the design requirements. Comment on the differences between the design requirements and your measured values.

¹ Keep in mind that the units of ω are radians/second, while the design requirement on the cutoff frequency is given in Hz.