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Course: ECE 3210

Subject: Lab 8, Designing a Low-pass Filter

Date: November 22, 2024

1 Introduction

In this lab we are building a 2nd order Sallen-Key low pass filter. We will have to select the component avlues ourselves, after which we will build the circuit and compare the results.

2 Theory

Fig. 1 shows the circuit that we are using. To select the values of the components, we need to derive a transfer function for the circuit.

We can analyze this circuit with two nodal-analyses, which are shown as follows:

$$\frac{V_s - V_i}{R_1} + \frac{V_s - V_0}{R_2} + \frac{V_s - V_0}{1/(sC_1)} = 0$$

$$\frac{V_0}{1/(sC_2)} + \frac{V_0 - V_s}{R_2} = 0$$

Rearranging these two expressions and combining them we get the tranfer function, shown in Eq. 1.

$$H(s) = \frac{1/(R_1 R_2 C_1 C_2)}{s^2 + s\frac{R_1+R_2}{R_1 R_2 C_1} + \frac{1}{R_1 R_2 C_1 C_2}} \tag{1}$$

This can be mapped to the Sallen-Key transfer function if we used the following equations:

$$\omega_c = \frac{1}{\sqrt{R_1 R_2 C_1 C_2}}$$

$$\zeta = \frac{1}{R_1 C_1} + \frac{1}{R_2 C_1}$$

To build the circuit with a cutoff frequency of 10 kHz and a damping ratio of 0.5 (underdamped), we were able to select values for the resistors and capacitors. We chose $R_1 = 220\ \Omega$, and $R_2 = 220\ \Omega$, and accordingly calculated $C_1 = 144.7$ nF, and $C_2 = 36.17$ nF.

3 Results

Building the circuit we used $C_1 = 150$ nF and $C_2 = 33$ nF. These values were close enough to the calculated values and proved effective for the circuit.

The three Figs. 2, 3, and 4 show the frequency response of the circuit when calculated, simulated, and measured. The plots show similar patterns, note the bump at the knee of the gain curve, as well as the slope of the gain curve after the cutoff frequency.

4 Discussion and Conclusions

The simulation and measurements both show that the components that we selected created an effective filter. Right at 10 kHz the gain starts to drop significantly, it shows as a rate of about 20 dB per decade. The bump before the cutoff frequency occurs because the circuit is underdamped, just as we designed the circuit for with those components.

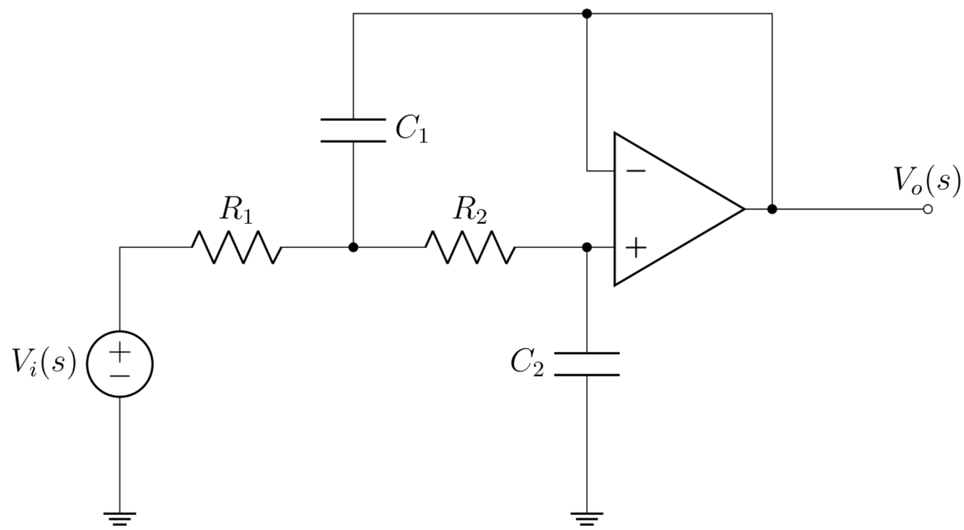

Figure 1: Sallen-Key Circuit

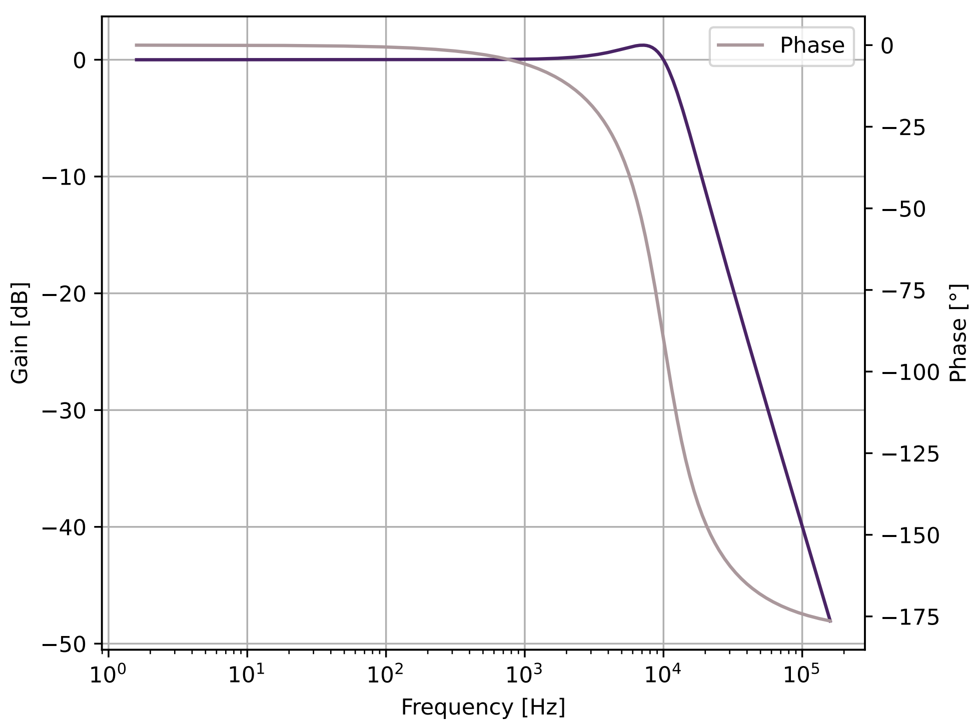

Figure 2: Calculation Results

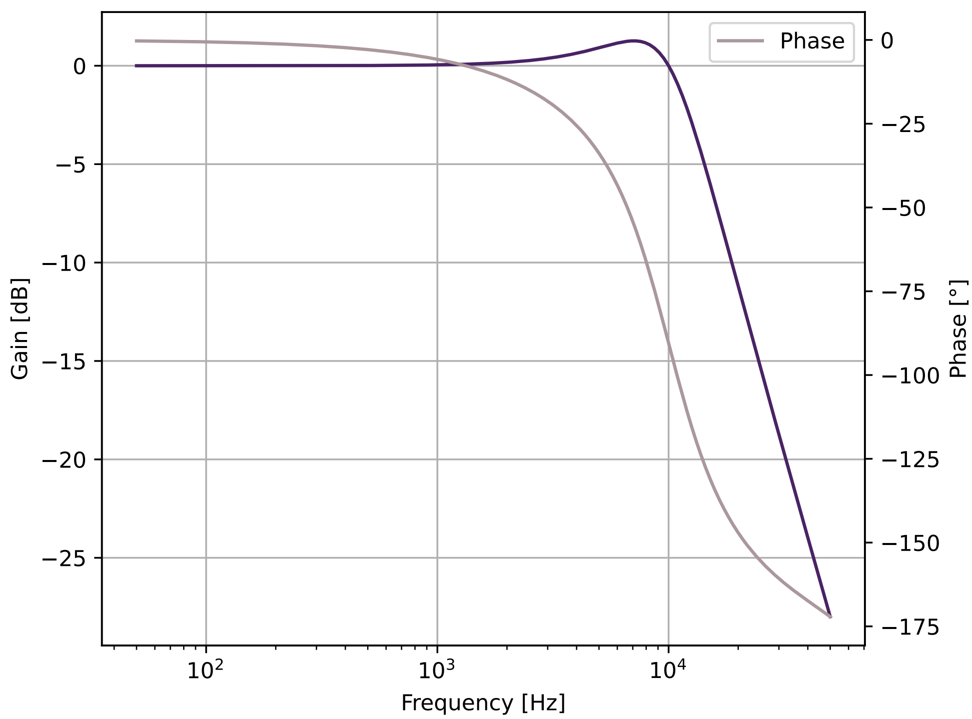

Figure 3: Simulation Results

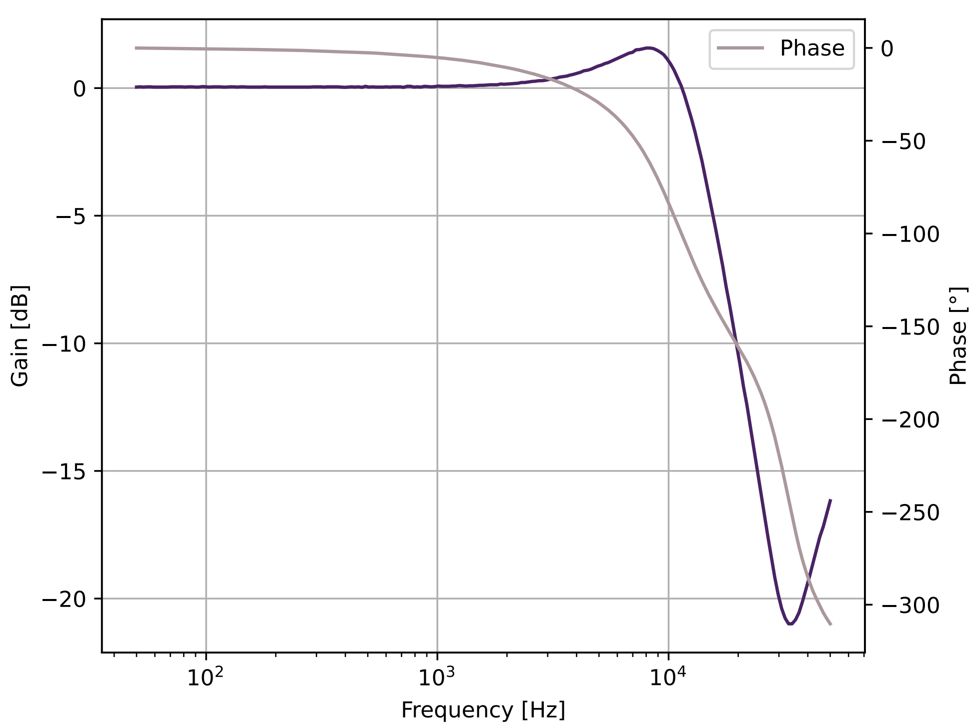

Figure 4: Measurement Results