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Course: ECE 3210

Subject: Lab 9, Filter Design

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1 Introduction

In this lab we are tasked with designing a low-pass filter that satisfies a set of requirements. Our target satisfies the following specifications:

- Pass band is 0 Hz to 7.5 kHz
- Stop band is 10 kHz to ∞
- Max ripple in the pass band is 1.5 dB
- Minimum attenuation in the stop band is -24 dB

2 Theory

We decided to build a Chebyshev filter, and after using the scipy function cheb1ord, we found the transfer function of the filter, shown in Eq. 1.

$$H(s) = \frac{2.2613 \times 10^{22}}{s^5 + 3.7766 \times 10^4 s^4 + 3.4889 \times 10^9 s^3 + 8.4179 \times 10^{13} s^2 + 2.4863 \times 10^{18} s + 2.2613 \times 10^{22}} \tag{1}$$

The results of the transfer function are shown in Fig. 2.

The denominator of this function is a fifth order expression, so we used a fifth order Chebyshev filter, which is shown in Fig. 1

This is essentially just two Sallen-key filter circuits just like the one from lab 8 stacked with a first order filter.

When selecting the component values for the circuit we used the equations from the last lab, but for different values of ω_c depending on the stage of the Chebyshev filter. The variables in those equations can be expressed in terms of the resistors and capacitors with the following equations:

$$\omega_c^2 = \frac{1}{R_1 \cdot R_2 \cdot C_1 \cdot C_2}$$

$$\omega_c \zeta = \frac{2R_1}{R_1 \cdot R_2 \cdot C_1}$$

We chose to select common resistor values for R_1 and R_2, and make them equal to each other, because the problem wasn't fully defined and left some room for our choice. Then we had sympy solve for given resistances until we found a set of capacitances that would work for each stage of the filter.

Table 1 shows the values that we decided to use to build the filter.

3 Results

The results of the Multisim simulation are shown in Fig. 3. Note that the results match the specifications of the circuit. As do the results from the prototyped circuit shown in Fig. 4.

We did not include a graph of the poles or zeros because there were none from this filter.

4 Discussion and Conclusions

Our design of a filter was successful. We built a filter that had a pass band of 0 to 7.5 kHz and the stop band was from 10 kHz to ∞. It is difficult to see in the graph, but the ripple was under 2 dB, only just a built over 1.5 dB.

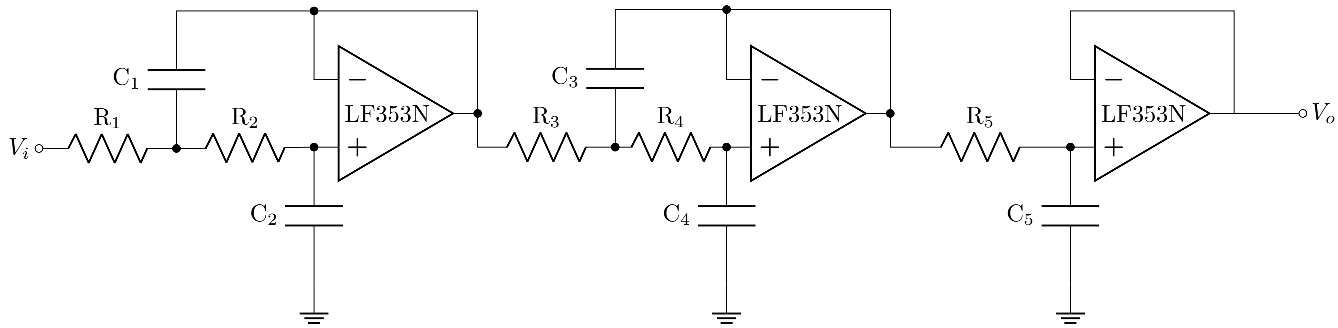

Figure 1: Fifth Order Chebyshev Filter

Component	**Value**
R_1	4.7 kΩ
R_2	4.7 kΩ
C_1	59 nF
C_2	357 pF
R_3	100 kΩ
R_4	100 kΩ
C_3	1 nF
C_4	104 pF
R_5	330 kΩ
C_6	259 pF

Table 1: Component Values

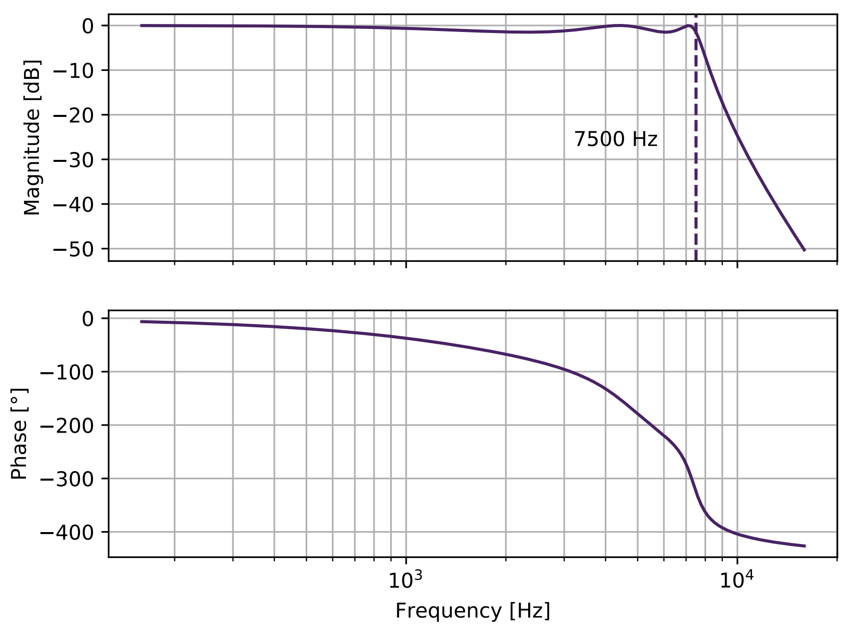

Figure 2: Python Calculation Results

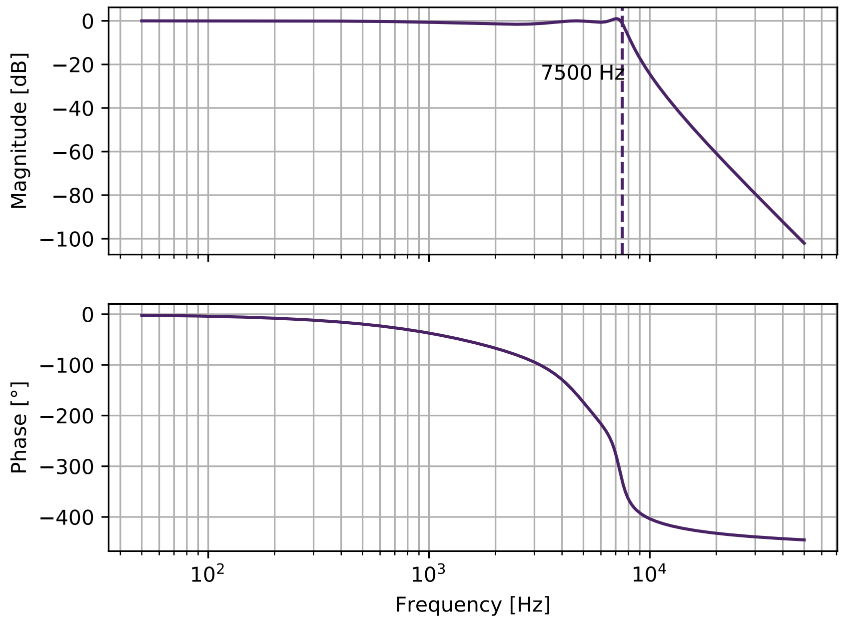

Figure 3: Multisim Simulation Results

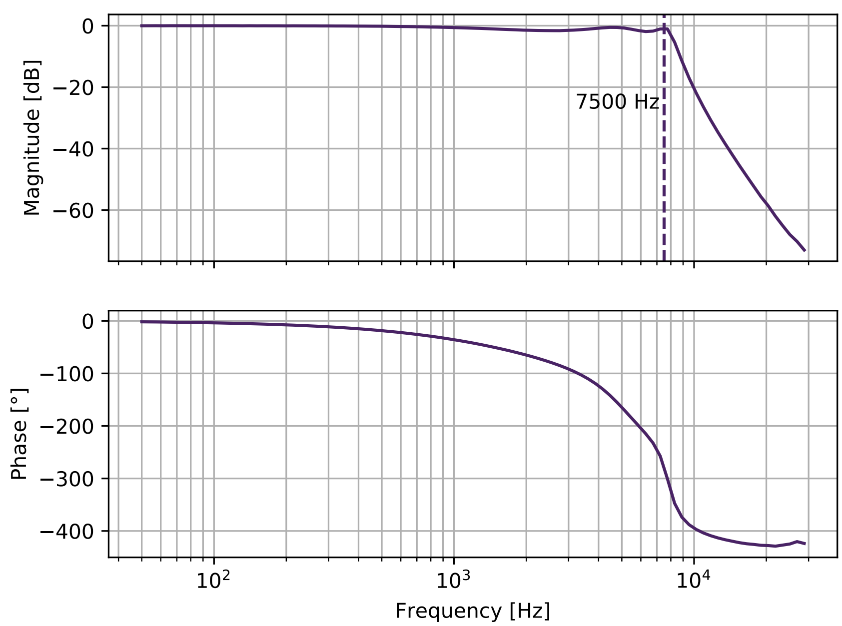

Figure 4: Prototyped Measurement Results