Experiment 7: Active Filters

1. Purpose

Filters are one of the main signal processor building blocks that are used to block or amplify certain frequency components of their input signals. Along with signal sources like oscillators, they can be used to generate different waveform signals. Their transfer functions determine which frequency components they amplify or attenuate, and their phase difference.

Filters can be either passive or active. Passive filters, as the name indicates, are designed using passive components, while active filters employ active components like amplifiers. Main difference in terms of input/output between passive and active filters is that in passive filters, output signal energy is less than input signal energy; while in active filters, output signal energy can be less or more than input signal energy.

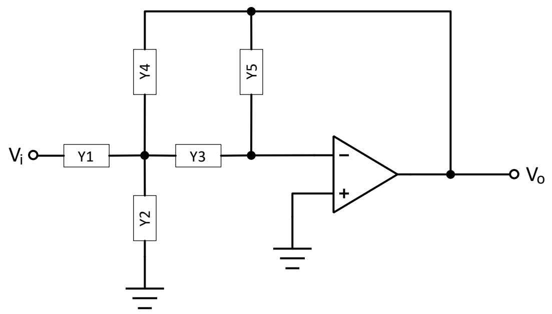
In this experiment, active filters and their active and passive components are shown. Using basic circuit analysis, their transfer functions are extracted. Then, using transient simulations, their time domain behavior is analyzed.

2. Preliminary Work

1. Find out the component values for $H_0 = 10$, $f_0 = 20\ kHz$, Q = 5 in Multiple Feedback Filter in Figure 1.b. Assume $C_3 = C_4$, do the calculations for 100 pF, 200 pF and 270 pF.
2. Find out the component values for $H_0 = 1$, $f_c = 20\ kHz$, Q = $1/\sqrt{2}$ in Sallen-Key filter in Figure 2.b. Assume $C_1 = C_2$, do the calculations for 100 pF, 200 pF and 270 pF.
3. How can we achieve the unity gain amplifier shown in Fig 2(a)? Show in a simple schematic. What type of circuit is it
4. Find and inspect the datasheet AD823. Is it possible to build a true high pass filter using this circuit? If not, what limits its possibility to be a true high pass filter?

3. Experiment 7.1 – Band Pass Multiple Feedback Filter

Figure 1.a shows a multiple feedback filter topology schematic and Figure 1.b shows the circuit that will be used in this experiment. Build the circuit in LTSpice using AD823 as opamp. Use the passive component values shared by the assistant.



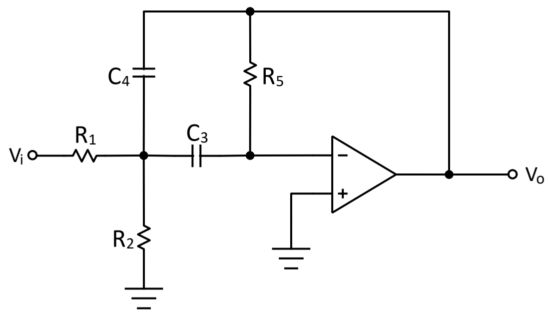


Figure 1. a. Multiple feedback filter topology b. Filter to be used in the experiment

Formulas below give the characteristics of the filter circuit, where H_0 is passband gain, f_0 is the center frequency and Q is the quality factor.

$$H(s) = \frac{V_o}{v_i} = \frac{-Y_1 Y_3}{Y_5(Y_1 + Y_2 + Y_3 + Y_4) + Y_3 Y_4}$$

$$H_0 = \frac{1}{\frac{R_1}{R_5}[1 + \frac{C_4}{C_3}]}$$

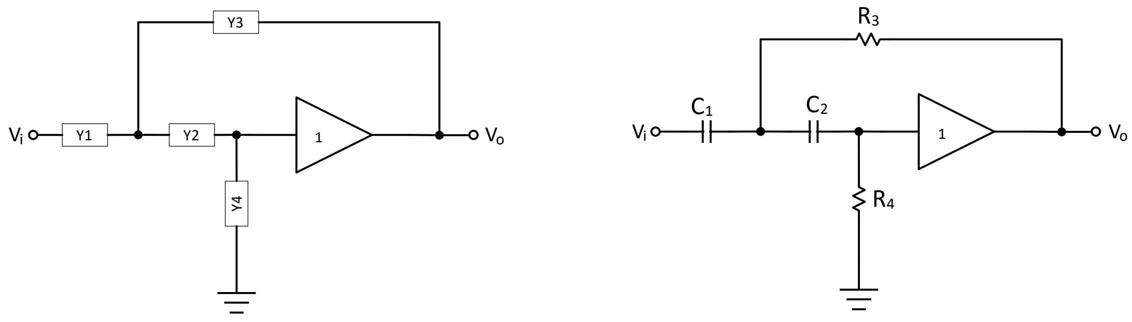
$$\omega_0 = \sqrt{\frac{1}{R_5 C_3 C_4}\left(\frac{1}{R_1} + \frac{1}{R_2}\right)}$$

$$Q = \frac{\sqrt{R_5\left(\frac{1}{R_1} + \frac{1}{R_2}\right)}}{\sqrt{\frac{C_3}{C_4}} + \sqrt{\frac{C_4}{C_3}}}$$

1. Build the circuit in LTSpice. Apply $V_{DD} = 18\,V$ and $-V_{SS} = -18\,V$. Use AD823 as opamp.
2. Apply a sinusoid signal with an amplitude 1 V peak to peak or less.
3. Apply the same amplitude sinusoid, changing the frequency from 10 Hz to 10 MHz logarithmically. Note input amplitude and output amplitude on a table.
4. Find cutoff frequencies and center frequency. Fine tune the frequency to find the exact frequency value around the interval that output amplitude peak occurs.
5. Calculate the quality factor Q.
6. Apply square and triangle wave input at center frequency of the filter and observe the output.

4. Experiment 7.2 – High Pass Sallen-Key Filter

Figure 2.a shows a Sallen-Key filter topology schematic and Figure 2.b shows the circuit that will be used in this experiment. Build the circuit in LTSpice using AD823 as opamp. Use the passive component values shared by the assistant.



a. b.

Figure 2. a. Sallen-Key filter topology b. Filter to be used in the experiment

Formulas below give the characteristics of the filter circuit, where H_0 is passband gain, f_0 is the center frequency and Q is the quality factor.

$$H(s) = \frac{V_o}{v_i} = \frac{Y_1 Y_2}{Y_4(Y_1 + Y_2 + Y_3) + Y_1 Y_2}$$

$$H_0 = 1$$

$$\omega_0 = \sqrt{\frac{1}{C_1 C_2 R_3 R_4}}$$

$$Q = \frac{1}{\sqrt{\frac{R_3 C_1}{R_4 C_2}} + \sqrt{\frac{R_3 C_2}{R_4 C_1}}}$$

1. Build the circuit in LTSpice. Apply $V_{DD} = 18\,V$ and $-V_{SS} = -18\,V$. Use AD823 as opamp.
2. Apply a sinusoid signal with an amplitude 1 V peak to peak or less.
3. Apply the same amplitude sinusoid, changing the frequency from 10 Hz to 10 MHz logarithmically. Note input amplitude and output amplitude on a table.
4. Find the lower cutoff frequency. Fine tune the input frequency to find the exact frequency value around the interval that output amplitude peak occurs.
5. Calculate the quality factor Q.
6. Apply square and triangle wave input at center frequency of the filter and observe the output.

5. Report

- Include your preliminary work.
- For both experiments, add your input-output table for logarithmically increased frequency.
- Include at least one of the sinusoidal input simulation outputs, also add triangle and square wave input simulations. Show the input and output in different plot panes. Run the simulations for 4 periods.
- Add an AC simulation for each circuit. Run the simulation between 1 Hz and 100 MHz. Configure the voltage source amplitude 0.5 V

Additional Work

a. Using circuit and systems analysis knowledge, extract the transfer functions $H_1(w)$ and $H_2(w)$ for both topologies.

b. Using the values you found in your preliminary work and transfer functions you extracted in a., plot $|H(w)|$, ∠H(w) in MATLAB. Determine midband gain H_0, cutoff frequencies and quality factor Q.

c. For both filter circuits, comment on the output waveforms for when square and triangle wave inputs were applied.

d. Run the simulations for Sallen-Key filter circuit with an ideal operational amplifier (UniversalOpamp2 in LTSpice). What is the difference? Comment on the reason of this difference.

e. Give examples on low pass, high pass, band pass and band stop filter applications from common engineering problems.

For questions, mail: aydinogluo@itu.edu.tr