EECE 2510 – Circuits and Signals: Biomedical Applications

Lab 11, Sec 2

Op Amp Circuits, Design and Limitations

Introduction:

As discussed in class, Op Amps are useful building blocks in many sensing and measurement applications. To measure the ECG signal in the coming weeks, we will be using them to amplify small signals, to reject common-mode signals (which means that, if we measure signal waveforms as a voltage on two electrodes, we will want to attenuate components that measured by as very similar by both electrodes and amplify the components that are different between the two measurements), and to filter out unwanted high and low-frequency noise and interference.

Today, we will explore the same high pass filter that was analyzed using PSpice in Lab 10.

Building and Testing Active Filters.

1. Use the LM741 Operational Amplifier chip in an active high pass filter configuration. (see Figure 1).

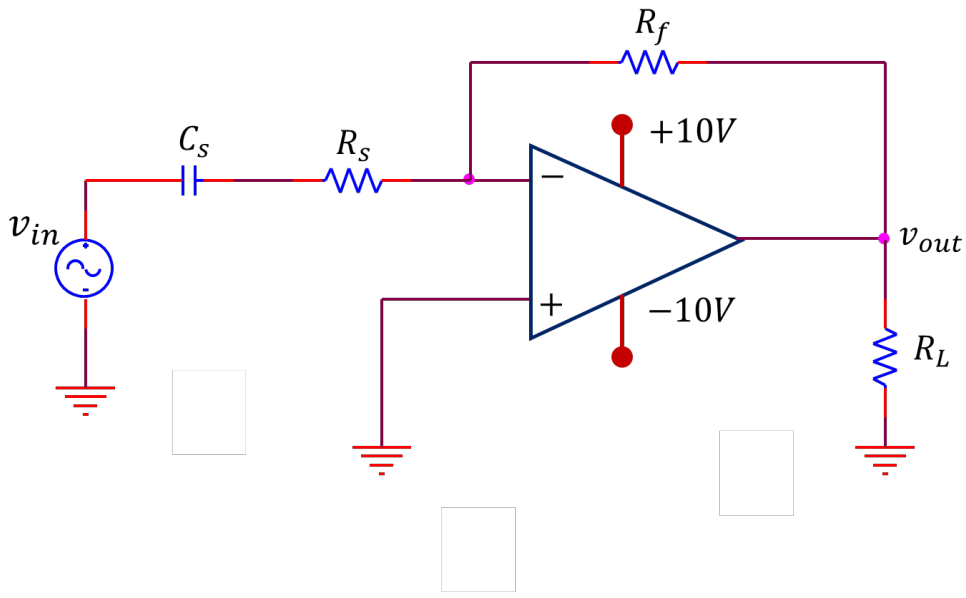

Figure 1: First order active high pass filter

$Use\, R_f = 200\, k\Omega\, , C_s = 10\, nF\, , R_s = 100\, k\Omega$

Q1: What is the theoretical in-band gain (or the magnitude of H(ω) in the passband), the time constant τ (in seconds), the cutoff angular frequency ω_c (rad/sec) at which the magnitude of $H(\omega)$ should be 1/ √2 down from the maximum, and the corresponding cutoff cycle frequency f_c (Hz) of the circuit?

2. Measure the actual values of your resistors and your capacitor (you can measure the capacitor using the LCR instrument next to the printer). **Q2: Recalculate the values from Q1 using the actual components you will use in your circuit. Note the change from what you got with the nominal values in Q1.**

3. Configure the function generator to produce a 0.1 V amplitude sine wave (0.2V peak to peak) with 5 kHz frequency. Measure the output of your filter at 5kHz. **Q3: What is the magnitude of the transfer function, |H(ω)|, of your circuit at 5kHz**?

4. Now perform a frequency sweep to measure the magnitude of the transfer function (also called the frequency response) of your circuit |H(ω)|. Measure from 10 Hz to 10 MHz, manually changing the frequency of the waveform and then measuring the results, including enough points to enable you to construct a reasonable plot of |H(ω)|. Don't try to use the "sweep" function on the signal generator –-- take these measurements one frequency at a time. Be sure to take enough measurements around the cutoff frequency $\mathbf{f_c}$ to capture how the circuit behaves. In thes process, you should try to experimentally determine the cutoff frequency (which, just for your reference, is also known as the 3dB frequency and the corner frequency) of your circuit. *Remember that you need to adjust the horizontal axis of your oscilloscope to properly view the sine wave at each frequency.* **Q4: Use your measurements to manually plot the magnitude of the transfer function, using a log scale on the horizontal axis and a linear scale on the vertical axis. Does the cutoff frequency agree with the theoretical value?** You should take enough high frequencies to observe that the gain gets smaller again at the highest frequencies. Discuss the reasons for this with the instructor or a TA and record your understanding of this phenomenon in your notebook.

5. Now set the function generator to produce a 50 Hz square wave with 0.5V amplitude and connect this to the filter input. Sketch this in your notebook and try to explain in words why the output wave looks as it does, thinking in both the time and frequency domains. Now change the frequency of the square wave to 2 kHz. **Q5: What happens? Why?**

Instructions For the Write-Up…

Hand in your answers to the 5 designated questions as well as your responses to the usual lab reflection questions listed on Blackboard.

DiMarzio Section: No Reflection.

IMPORTANT: BEFORE YOU LEAVE THE LAB:

(a) Place all of the components that your removed from the red tool box back in that box and return it to the cabinet that houses them

(b) Collect all used components and wires from your bench and place them in your group's reusable plastic container. If you are not going to use these components or wires again please discard them in the trash bin.

(c) Turn off all of the equipment you have used on your workbench.

(d) Make sure you return your protoboard, the equipment wires and your reusable container to the front window.

(e) **Make sure to have your notebook signed by an instructor before you leave the lab.**

Department of Electrical Engineering, Northeastern University.
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