EECE 2510 – Circuits and Signals: Biomedical Applications

Lab 11

Op-Amp Circuits, Design and Limitations

Introduction:

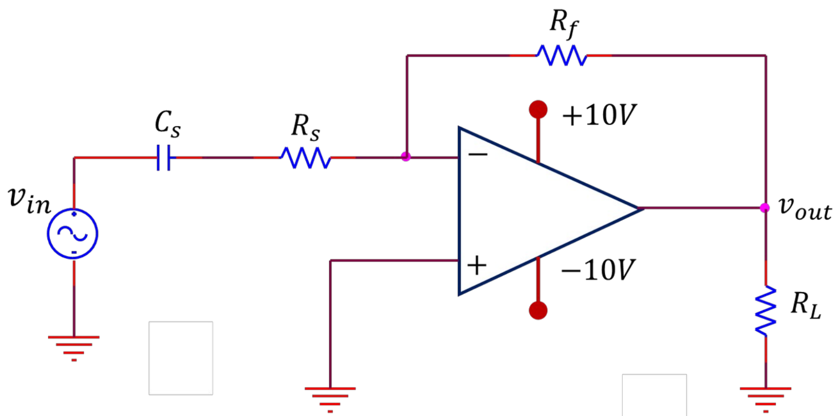
As discussed in class, Op-amps are useful building blocks in many sensing and measurement applications. To measure the ECG signal in the coming weeks, we will be using them to amplify small signals, to reject common-mode signals, and to filter out unwanted high and low-frequency noise and interference.

Today, we will explore the same high pass filter that was analyzed using LTSpice.

Building and Testing Active Filters.

1.1 Use the LT1490 Operational Amplifier chip in an active high pass filter configuration shown in figure 1. $Use\ R_f = 200\,k\Omega, C_s = 10\,nF, R_s = 100\,k\Omega$. Figure 2 shows the DC power supply and signal connections to the Op-Amp.

Q1: What is the theoretical in-band gain (or the magnitude of $H(\omega) = \frac{V_{out}(\omega)}{V_{¿}(\omega)}$ in the passband), the time constant τ, the cutoff angular frequency $\omega_c(Rad/sec)$ and the



$$H(\omega) = \frac{V_{out}(\omega)}{V_{¿}(\omega)} = \frac{-R_f}{R_s} \frac{j\omega C_s R_s}{1 + j\omega R_s C_s} = \frac{-R_f}{R_s} \frac{j\frac{\omega}{\omega_c}}{1 + j\frac{\omega}{\omega_c}}$$

cutoff frequency $f_c(Hz)$ of the circuit?

Figure 1: First order active high pass filter

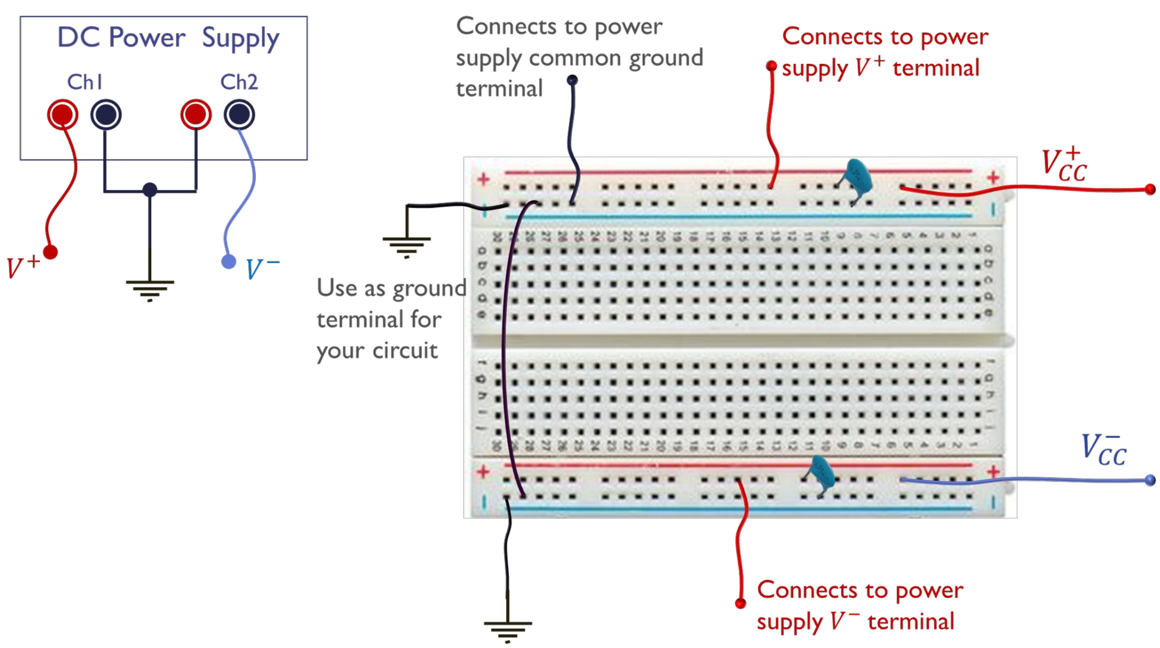


Figure 2. Block diagram showing DC power supply connections to the Op-amp. Notice the commode node of the power supply, taken as your reference ground for the entire circuit, this includes the ground connection of the signal generator and pin (3) of the Op-Amp.

1.2 Configure the function generator to produce a $0.1\,V$ amplitude sine wave ¿ peak to peak) with $5\,kHz$ frequency. Measure the output of your filter at $5\,kHz$. **Q2: What is the measured gain of your circuit**?

1.3 Now perform a frequency sweep to measure the cutoff frequency (aka $3\,dB$ frequency, or corner frequency) of your circuit. Measure the gain all the way from $10\,Hz$ to $10\,MHz$. *Remember that you need to adjust the horizontal axis of your oscilloscope to properly view the sine wave at each frequency*.

Q3: Plot the magnitude of the transfer function¿ $H(\omega)\vee$¿ $\left|\frac{V_{out}(\omega)}{V_{¿}(\omega)}\right|$ **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?** $f_c=\frac{1}{2\pi R_s C_s}$ **Q4: Why does the gain get smaller again at higher frequencies?**

1.4 Now configure your function generator to produce a $50\,Hz$ square wave with $0.5\,V$ amplitude and connect this to the filter input. **Q5: What do you measure at the output**? Sketch this in your lab-book and try to explain why the output wave looks as it does, thinking in both the time and frequency domains. Try changing the frequency of the square wave to $2\,kHz$. **Q6: What happens? Why?**

Instructions For the Write-Up…

Please see instructions for writing lab reports on Canvas

IMPORTANT: BEFORE YOU LEAVE THE LAB:

- **a.** Place all of the components that your removed from the red toolbox 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 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.

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Last updated: 8/21/2021, I. Salama, 3/2/16, N. McGruer