# ECE 205 Lab – Filters and Op-Amps

Challenge: Filters and Op-Amps

Filters are a critical part of many designs, to emphasize a signal, and/or to deemphasize unwanted noise. Simple passive filters, constructed from resistors, capacitors, and inductors are important, but have some limitations. We can compensate for these limitations by using op-amps to create active filters.

Let's construct a simple passive RC filter, and analyze the behavior in simulation. Then we will turn this passive RC filter to an active filter using an op-amp.

Prelab Deliverables:
- Note that the filter schematic (within the left box) is a simple RC filter.
  - What is its cutoff frequency?
  - Is this filter a low-pass or high-pass filter?


Circuit Diagram
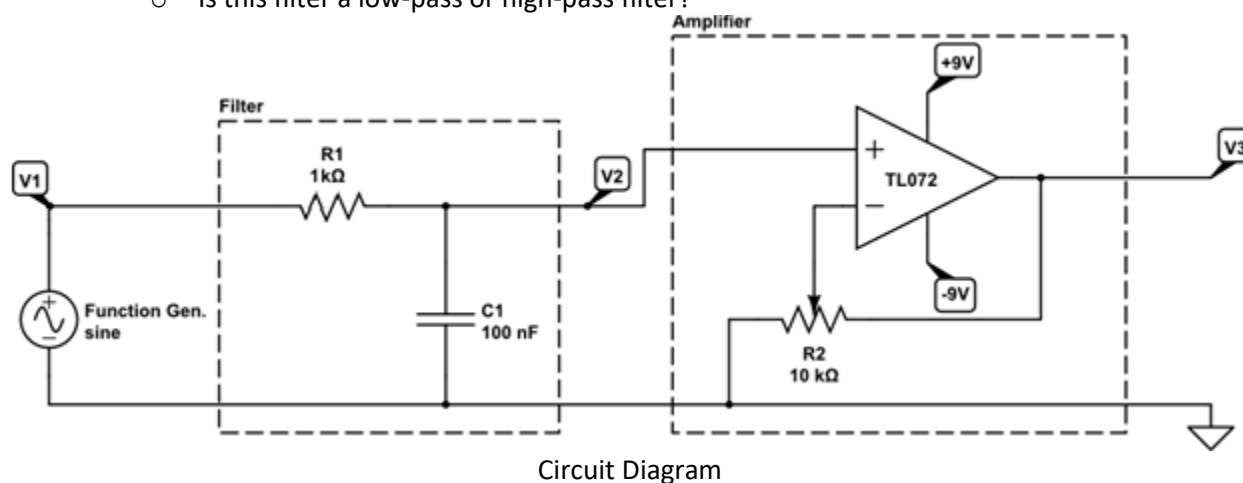
Challenge 1:
Build the filter in LTSpice. Note that this only requires that you build the portion denoted inside the Filter box, as well as create an input voltage source (V1).
- V1 (the input signal) may be replaced by a voltage source of Amplitude 1V and the Sine waveform at 1kHz (the sweep will override the frequency)
- Perform an .ac simulation (see section 4.4 in the LTSpice tutorial) of the input (denoted V1 in original diagram). Your sweep range should cover what we typically consider the human auditory range of 20-20kHz.
- Measure V2 (the output of the filter portion of the circuit) - confirm that your simulation plots what you derived in the prelab.

Challenge 2 (do this when you have completed Challenge 1):
Build the remainder of the circuit in LTSpice, the amplifier portion. Use an AD820 op-amp (found under the op-amps subdirectory) for the op-amp (rather than the TL072 in the schematic above).

- Note that the voltage sources for powering the op-amp (in class we refer to these as Vpower+ and Vpower-) must share a common ground (as seen in the figure to the right). Note that they are in series so the total voltage between +9 and -9 is 18V (as you would expect) but ground denotes the middle point (which between +9 and -9 is 0 V, as per the definition)
- As a start, replace the potentiometer (10kΩ - R2) with its equivalent as a voltage divider set 'half way', as seen below. This creates an amplifier circuit that you learned about in class – which circuit is it (inverting/non-inverting/other)?
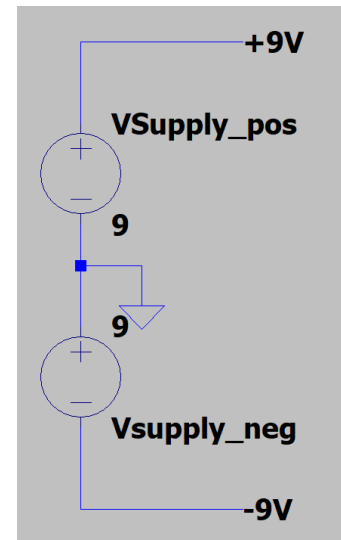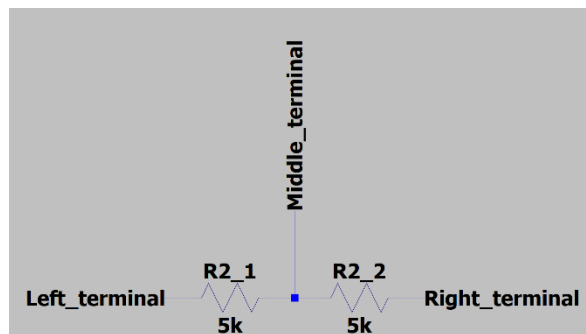
- The potentiometer R2 serves as a volume control for your circuit, changing the ratio of R2_1 and R2_2 determines the magnitude of the gain (e.g. how much amplification the op-amp provides). Note that R2_1 and R2_2 (the two halves of the potentiometer) will always add to 10kΩ. If you do not remember how the potentiometer works from previous labs, Wikipedia is a excellent resource for this.
- An ideal op-amp will be able to amplify up to Vpower+ and Vpower- (e.g. remember the op-amp rule about this), however the AD820 op-amp is not an ideal op-amp. What is the maximum amplitude of the output signal which may be generated by the AD820 op-amp when powered by +9 and -9 volts? To determine this, run a transient simulation (as you did previously) and plot the output of the entire circuit (V3). At what point does the output stop looking like a sine wave due to distortion? What does this distortion look like?

Challenge 3 (optional):
- A (experimental) feature of LTSpice allows you to pass audio through the simulation. This uses the .wave directive (see this link).
- Try replacing the input V1 signal with a short snippet of music and listen to the effect of this circuit on the output. Note that this simulation could be slow, so use a short audio clip. Note also that you will need to convert your music into .wav format if it is in another format (e.g. mp3).

Report Deliverables:
- Provide your prelab calculations.
- Provide the schematic you created in LTSpice.
- Provide the result (AC sweep) from Challenge 1 (this should be a plot), estimate the cutoff frequency from this plot and confirm it matches your prelab.
- Provide a plot from Challenge 2 which justifies your answer for the maximum amplitude of the op-amp output in this configuration. For example, this may be a transient simulation showing distortion.