ECEN 214 Electric Circuit Theory, Fall 2024

Honor's Section Final Project

The object of this project is to design and simulate a Low-pass Filter for voiceband signals. The object is for the filter is to pass frequencies lower than 4kHz and stop frequencies higher than 4kHz. To achieve that functionality, you will design a 6th order low-pass circuit whose characteristic equation has roots at

$$s = 2\pi \cdot 4000 \cdot e^{j(75^\circ + k \cdot 30^\circ)} \text{ for } k = 1, 2, 3, \dots, 6.$$

In order to implement this system, you can group the roots into complex conjugate pairs. Each pair will define a second order (underdamped) circuit. You can then cascade three second order circuits together to form the sixth order circuit.

When designing your circuit, try to stick to the following guidelines:

- Use component values that are readily available to you or can reasonably be obtained.
- All op-amps should be powered by a supply voltage of 9V (e.g., a 9V battery).
- The circuit should be able to handle sinusoidal inputs with amplitudes of at least 6V without any op-amps saturating.

Your response to this project should provide the following:

1) Provide a schematic diagram of your sixth order circuit showing all component values. Be sure to specify how you arrived at your various component values.
2) Prove that the theoretical magnitude response of a sixth order circuit with roots as specified above is given by
$$|H(\omega)|^2 = \frac{1}{1+(\omega/\omega_o)^{12}}, \text{ where } \omega_o = 2\pi \cdot 4000.$$
3) Compute the actual magnitude response of your circuit (using the component values from part 1). Your actual magnitude response will be slightly different from the theoretical one due to the fact that component values readily available to you will likely not produce the exact roots you need. Compare the theoretical with the actual magnitude response (plot them together).
4) Run an AC simulation (SPICE or MULTISIM) of your actual circuit. Show the simulated magnitude response or your circuit to make sure that the circuit actually functions the way you think it should. Use an AC input with 6V amplitude together with 9V supplies for your op-amps.

Warning: In theory it shouldn't matter in what order you cascade your three second order circuits. In practice it does make a difference. Try playing around with the order to see what difference it makes in your simulations. Choose the order that results in the best match with theory and comment on why this order matters.