

Experiment 12

Pre-Lab Activity

Read the above sections, the laboratory activity and the post-lab before coming to the Laboratory. Solve the following problems and submit your solution to your instructor.

Problems

1. Use Multisim and its Bode Plotter utility to generate the magnitude and phase plots for the transfer function of the low-pass circuit in Figure 3. Assume $R = 1.5\text{k}\Omega$ and $C = 0.1\mu\text{F}$. Measure the cut-off frequency ω_c from the magnitude plot (employ the available cursor of the Bode Plotter utility). Compare your answer to the theoretical value: $\omega_c = 1/RC$.
2. Use Multisim to find the response of the low-pass filter in Problem 1 to a positive square wave with a 4V amplitude and a frequency $f = 1\text{kHz}$.
3. Consider the signal $v_{in}(t) = 1 + 2\cos(5000t) + 4\cos(10^5t)$ as the input to the low-pass filter in Problem 1. Employ Equations (8), (11) and (12) to find the time-domain voltage $v_{out}(t)$. Plot $v_{in}(t)$ and $v_{out}(t)$ on the same set of axis.
4. Calculate the attenuation (in dB) for the low-pass filter in Problem 1 for the following frequencies: $\omega = 0, 5,000$ and $100,000$.
5. Use Multisim and its Bode Plotter utility to generate the magnitude and phase plots for the transfer function of the high-pass circuit in Figure 8. Assume $R = 1.5\text{k}\Omega$ and $C = 0.1\mu\text{F}$. Determine the cut-off frequency ω_c from the magnitude plot (employ the available cursor). Compare your answer to the theoretical value: $\omega_c = 1/RC$.
6. Use Multisim to find the response of the high-pass filter in Problem 5 to a positive square wave with a 4V amplitude and a frequency $f = 1\text{kHz}$.
7. Consider the signal $v_{in}(t) = 1 + 2\cos(4000t) + 4\cos(10^5t)$ as the input to the high-pass filter in Problem 1. Employ Equations (8), (17) and (18) to find the time-domain voltage $v_{out}(t)$. Plot $v_{in}(t)$ and $v_{out}(t)$ on the same set of axis.
8. Calculate the attenuation (in dB) for the high-pass filter in Problem 5 for the following frequencies: $\omega = 0, 4,000$ and 10^5 .

9. Use Multisim to generate the magnitude and angle plots for the band-pass filter in Figure 11. Assume $R = 470\Omega$, $C = 0.1\mu\text{F}$ and $L = 1\text{mH}$.
10. Use the formula in Equation (24) to solve for the cut-off frequencies for the band-pass filter of Problem 9.
11. Employ Equation (27) to solve for the values of the phase of $\mathbf{H}(\omega)$ at the cut-off frequencies.
12. Use Multisim to find the response of the band-pass filter in Problem 9 to a positive square wave with a 4V amplitude and a frequency $f = 1/(2\pi\sqrt{LC}) = 15.92\text{kHz}$.
13. Consider the notch filter in Figure 14 with $R = 1.5\text{k}\Omega$, $L = 1\text{mH}$ and $C = 0.1\mu\text{F}$. Determine the magnitude of $\mathbf{H}(\omega)$ (in dB) at $\omega = 1/\sqrt{LC}$, $\omega = 0$ and $\omega = \text{infinity}$. Also, determine the phase of $\mathbf{H}(\omega)$ for $\omega = 0$, $\omega = 1/\sqrt{LC} - \varepsilon$, $\omega = 1/\sqrt{LC} + \varepsilon$ and $\omega = \text{infinity}$ (ε is a positive number approaching zero).
14. Use Multisim to find the response of the notch filter in Problem 13 to a positive square wave with a 4V amplitude and a frequency $f = 1/(2\pi\sqrt{LC}) = 15.92\text{kHz}$.

Laboratory Activity

Required components:

One 470Ω resistor ($\pm 5\%$, $\frac{1}{2}$ W)

One $1.5\text{k}\Omega$ resistor ($\pm 5\%$, $\frac{1}{2}$ W)

One 1mH ferrite-cored inductor ($\pm 10\%$, 70mA)

One $0.1\mu\text{F}$ multilayer ceramic capacitor ($\pm 10\%$)

1. Measure and record the capacitor and resistors values.
2. Build the low-pass circuit shown in Figure 3. Use $R = 1.5\text{k}\Omega$ and $C = 0.1\mu\text{F}$. Apply a sinusoidal signal with 4V peak-to-peak (verify the amplitude using the scope). Set the frequency f of the input signal so that the output peak-to-peak value is about 2.83 volts. Record the value of f (this is the cut-off frequency in Hz).
3. Apply a *positive* square wave with amplitude of 4V and $f = 1\text{kHz}$. Use the scope to display the input and output signals. Save the display.
4. Repeat Steps 1 and 2 for the high-pass filter shown in Figure 8.
5. Build the band-pass filter shown in Figure 11 with $R = 470\Omega$, $L = 1\text{mH}$ and $C = 0.1\mu\text{F}$. Apply a sinusoidal signal with 4V peak-to-

- peak (verify the amplitude using the scope). Set the frequency f of the input signal so that the output peak-to-peak value is about 2.83 volts (hint: there are two distinct values of f that satisfy this requirement). Measure and record the values of the cut-off frequencies. Measure the phase of the output signal (with respect to the input) at the cut-off frequencies (employ the Lissajous method).
6. Generate and save the output waveform of the filter in Step 5 for a *positive* square wave input with amplitude of 4V and frequency $f = 1/(2\pi\sqrt{LC})$.
 7. Build the notch filter shown in Figure 14 with $R = 1.5\text{k}\Omega$, $L = 1\text{mH}$ and $C = 0.1\mu\text{F}$. Apply a sinusoidal signal with 4V peak-to-peak (verify the amplitude using the scope). Set the frequency f of the input signal so that the output peak-to-peak value is minimized. Record the value of f (this is the resonance frequency or the *rejection frequency*, in Hz).
 8. Generate and save the output waveform of the filter in Step 7 for a *positive* square wave input with 4V peak-to-peak value and frequency $f = 1/(2\pi\sqrt{LC})$.
 9. Sort all components and give them back to your instructor.

Post-Lab Activity

- Write a [technical report](#) that discusses your observations and includes analysis and justifications of all steps in this activity. Tabulate and/or plot experimental data whenever possible. Validate all experimental results using Multisim simulations and compare to the theoretical values.