EECE 2150 - Circuits and Signals: Biomedical Applications

Lab 13, Frequency Components, FFT, and Filtering

Introduction

In this lab you will learn how to use Matlab to simulate the effect of a filter with a specified transfer function on a segment of a periodic input signal (such as a square wave or a ramp wave).

Part I: Understand operation of the FFT-based Matlab Low Pass Filter script.

1.1 Run the script provided. Describe what is being shown on each plot, and make sure each plot is clearly distinguished from other similar plots. The purpose of this exercise is to help you understand the overall operation of the function. **Q1: What is the cutoff frequency of the filter in the script (in Hz, not Rad/s)?**

Part II: Modify the script to filter and then use it to filter sine waves of various frequencies.

2.1 Change the cutoff frequency of the prototype CT low-pass filter to 10 Hz (f, not ω!), and make the in-band gain of the filter -2 and sample that in Matlab.

2.2 Input sine waves with DT frequencies equivalent to 1, 5, 10, 20, and 100 Hz to the FFT-based filter and plot the input and output waveforms on the same graph so that you can see the relative magnitudes and relative phases at the different frequencies. **Q2: Approximately what is the magnitude of H(ω) from your plots for each frequency (1, 5, 10, 20, and 100)? Q3: Approximately what is the phase shift for each frequency, in degrees (for example, 90, 100, 110, … ? (Don't need to be precise!)**

2.3 Now compute (with Matlab or a calculator – Matlab is easier!) H(ω) for 1, 5, 10, 20, and 100 Hz, in polar form. **Q4: Do these results agree with your answers for 2.2?**

Part III: Filter a 10 Hz square wave.

3.1 Next, supply a square wave input at 10 Hz, as in the original function, but to your modified filter. Note that each frequency in the Fourier transform is multiplied by a different H(ω), depending on its frequency. **Q5: Carefully compare the magnitudes of the unfiltered and filtered Fourier components at the fundamental frequency, and at 3x, 5x, 7x, and 9x the fundamental frequency.**

Do the relative magnitudes change? Q6: How is the frequency content of the filtered signal different than the frequency content of the original signal? Q7: How does the filtered time-domain waveform look? Is this what you expect from the frequency domain information (explain)?

Part IV: Create a high-pass filter.

4.1 Now, change the script to compute frequency samples (at the same frequencies as before) of the transfer function (or frequency response) of a first-order op-amp high-pass filter with an in-band gain of -2 and a cutoff frequency of 50 Hz.

Part V: Filter a 10 Hz square wave.

5.1 Next, supply a square wave input at 10 Hz, as in the original function to your new filter. Note that each frequency in the Fourier transform is multiplied by a different $H(\omega)$, depending on its frequency. **Q11: Carefully compare the magnitudes of the unfiltered and filtered Fourier components at the fundamental frequency, and at 3x, 5x, 7x, and 9x the fundamental frequency. Do the relative magnitudes change? Q12: How is the frequency content of the filtered signal different than the frequency content of the original signal? Q13: How does the filtered time-domain waveform look? Is this what you expect from the frequency-domain results (explain)? Q14: Does this result agree with what you saw in the op-amp filter lab?**

What to hand in: As usual, hand in your responses to the Lab Reflection as outlined on Blackboard

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 located in your lab room.

(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.**

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