Lab 4 - Filtering

Objectives

The purpose of this lab is to demonstrate that if you know the frequency response of a filter and know how to find the Fourier Series coefficients of a periodic signal, you can predict the output of the filter given any periodic input.

Pre-Lab

We will be once again use the "Orange" filter in this lab. Complete the following calculations and record them in your lab notebook. Turn in a photocopy of your notebook during the lecture before lab.

1. Find H(f) for the filter you used in Lab 2. Compute H(f) for f = 1,3,5,7 kHz and record it in a table like:

	computed		measured	
f	|H(f)|	∠H(f)	|Y(f)|	∠Y(f)
1 kHz				
3				
...				
7				

   You will fill in the measured columns later.

2. Find the Fourier Series coefficients for a squarewave the goes from -1/2 to 1/2 volts with a period of T0 = 1 ms. Record them in a table like:

	computed	computed	
f	a_k	|Y(f)|	∠Y(f)
1 kHz			
3			
...			
7			

3. Verify your coefficients are correct by reconstructing the squarewave using your coefficients and your MATLAB function sumcos from last lab (include the plot in your prelab).

4. Compute the output of the filter Y(f) for each of the coefficients and record in the table above. Remember

$$Y(k\ f_0) = a_k\ H(k\ f_0)$$

Procedure

There are four main things you are to do in this lab.

1. Use MATLAB to simulate a 5th-order Butterworth filter and plot the outputs of the sinusoids computed in Part 1 of the pre-lab.

2. Measure the outputs of the "Orange" filter given the same sinusoids.

3. Use MATLAB to plot the predicted output given the coefficients computed in Part 3 of the pre-lab.

4. Measure the output of the "Orange" filter given a squarewave input.

Filtering Cosine Waves via MATLAB

The MATLAB code below (see next page) uses the `butter()` command to create a 5th-order Butterworth filter with a cutoff frequency of 3500 Hz. It then passes a 1 kHz cosine through the filter and plots both the input and output of the filter.
Modify the filter to have the cutoff frequency of the filter you measured in Lab 2. Modify the code to produce plots for f = 1,3,5,7 kHz. Are the magnitude and phase of the output what you predicted them to be in the pre-lab?

Instructor Verification (separate page)

Filtering Cosine Waves for Real

Use the "Orange" filter to filter sinusoids at f = 1,3,5,7 kHz. Be sure to record both the magnitude and phase. Are the magnitude and phase of the output what you predicted them to be in the pre-lab?

Filtering Square Waves via MATLAB

1. Use MATLAB to construct the waveform from the predicted coefficients from Part 3 of the pre-lab and plot the results.

2. Simulate a squarewave through the "Orange" filter by modifying the MATLAB code used before. Plot the input and output waveforms.

3. (Optional) Plot the constructed waveform and simulated waveforms on the same MATLAB plot.

Filtering Square Waves for Real

Use the "Orange" filter to filter the squarewave from step 2 of the pre-lab. (Hint: type `help square`) Carefully sketch the output into your MATLAB plot. Do they look the same?

Instructor Verification (separate page)

```
function lab4
fs = 44100;                   % Sample a CD rate of 44.1kHz
dt = 1/fs;                    % Time between samples
f0 = 1000;                    % Frequency of the input signal
T0 = 1/f0;                    % Period of input signal

f3db = 3500;                  % cutoff frequency of "orange" filter

[b a] = butter(5, f3db/(fs/2));   % make a 5th-order butterworth filter

tt = 0 : dt : 4*T0;           % Time vector, Compute 4 periods

k=1;                          % k tells which harmonic is being plotted
xx = cos(2*pi*f0*tt);
figure(k);                    % Put each harmonic in it's own window
subplot(2,1,1)
plot(tt, xx)
title(['Butterworth Filter, k = ', num2str(k)])
xlabel('t (sec)');  ylabel('x(t)')

yy = filter(b, a, xx); % filter the signal xx
subplot(2,1,2)                % plot it below the input signal
plot(tt,yy)
xlabel('t (sec)');  ylabel('y(t)')
```

Instructor Verification

Staple this page to the end of your Lab Memo.

Name: ________________________ Date: ____________________________

Cosines	
Squarewaves	