EECE 2150 - Circuits and Signals: Biomedical Applications

LAB 6: Creating and Combining Sinusoids in MATLAB

Preliminaries: In this and future labs you will write some MATLAB code. As always be sure to follow the guidelines for good coding practice as posted on Canvas.

(a) Sine and cosine signals will play a huge role in this course (and play a huge role in general in Electrical Engineering education and practice). In this Lab we will experiment with generating, observing, and listening to discrete time (DT) sinusoids in MATLAB (DT signals are the only kind we can generate, store, or manipulate on a computer, remember !). We will be paying particular attention to how the parameters that define a particular sinusoid affect both the appearance and the sound of the sinusoid.

Notation: To distinguish continuous time (CT) from DT sinusoids in this course, we will write CT sinusoid as $x(t)=A\sin(\omega t+\theta) \vee A\sin(2\pi ft+\theta)$ where ω has units of radians/second, f has units of cycles/second, and θ has units of radians. We will write DT sinusoids as $x[n]=A\sin(\Omega n+\theta) \vee A\sin(2\pi Fn+\theta)$, where Ω has units of radians/sample and F units of cycles/sample (note the distinction between f and F!). **Q1:** Verify (write it down in your notebook) that these units give angles - arguments of sinusoids should be angles, and thus either be in radians or degrees (radians here).

In summary, there are three parameters that define a CT or DT sinusoid: 1. The amplitude, A; 2. The frequency (angular frequency), ω or Ω; and 3. The phase, θ. Given any three numbers A, ω or Ω, and θ, we know exactly what signal we have.

Part I

As an example of using MATLAB in this course, use the function sampled_sine_example_2150.m (on Canvas) for the following. Note that you can modify it if you would like to.

- **a.** First, create a sinusoid with an amplitude $A=1$, $f=1000\,Hz$, $f_s=sampling\,frequency=16000\,Hz$, duration¿$0.01$, and phase¿$0$. (In MATLAB, this is $[x\,t]=sampled_{¿}(1,1000,16000,0.01,0)$; The variables x and t are the output vectors of the signal and the corresponding times. What is F (F, not f!)? How many samples are there per cycle?
- **b.** Repeat a, but change the phase to 0.5. What is different?
- **c.** Repeat a, but with a duration of 1 second. You should hear the sound, but the plots will show too many cycles to be useful.
- **d.** Repeat c, but with the phase changed to 0.5. Do you hear any difference?

- **e.** Repeat d, with an amplitude of 0.1 – is the sound different? What has changed in the function? What has changed in the sound?
- **f.** Repeat a (at an amplitude of 1 and a phase of 0) with sampling frequencies of 7000, 3000, and 1300. What looks different in the different plots?
- **g.** Repeat c with a sampling frequency of 7000, 3000, 1700, 1300, and 1100. Is the sound the same for all sampling rates? What do you think might be happening?

PART II

For this part you can either use the function from Part I and then do the plotting and combining in the command window, or (probably better) you can edit the function to obtain the desired results.

- **a.** Create three sinusoids with frequency $f=1000\,Hz$ and three values of $A=0.1,0.3,\wedge 1$, all with the same frequency F of $\frac{1}{16}$, i.e. $16\frac{samples}{cylce}$, phase of 0, and with a total of 80 samples $[0,1,\ldots 79]$, or in other terms, 5 cycles of the wave,. Note that $F=\frac{f}{f_s}$. *(hint: the parameters given can be used to find the duration of the sinusoid).* Plot the three sinusoids on the same plot using the `plot` command (hold may also be useful – type help hold in MATLAB), using your time sample vector to define the horizontal axis, and describe what aspect of the sinusoid is controlled by A. Be sure to vary the color and/or line/symbol style for each signal so that you can distinguish them on the plot. Label your horizontal access in an appropriate unit. Give your plot an appropriate title. Print your plot or take a photo to put in your notebook to document your work.
- **b.** Using your function, create three sinusoids with $f=1000\,Hz, A=1, F=1/16, 80$ samples, but with three values of the phase, $\theta=0,\pi/4$, and $\pi/2$. Plot the three sinusoids on the same plot using the `plot` command (hold may be useful – type help hold in MATLAB), and describe what aspect of the appearance of the sinusoid is controlled by the phase. Again be sure to pay attention to labeling the plot appropriately. Repeat using the values of $\theta=0,\pi,4\pi$. What do you notice this time? Again document all plots in your notebook with printouts or sketches.
- **c.** Using your function, create three sinusoids with $f=1000\,Hz, A=1, F=1/16$. This time use 8000 samples, use three values of the phase, $\theta=0,\pi/4$, and $\pi/2$. Does the sound of the sinusoid depend on the phase? The parameters are the same as those used in the *first* part

of (b) except with 8000 samples (longer duration) to allow you to listen to the sound. No need to plot in this case.

PART III

a. Use your function to create a sinusoid with an amplitude of $\frac{2}{\pi}$, $f=1000\,Hz$, sampling frequency=$50000\,Hz$, duration=$0.005\,s$, and phase=0. Plot the waveform generated.

b. Add a sinusoid with an amplitude of $2/3\pi$, $f=3000\,Hz$, sampling frequency=$50000\,Hz$, duration=$0.005\,s$, and phase=0 to the sinusoid from part a. Plot the sum – not both waves, but the sum of the two waves.

c. Continue adding sinusoids with amplitude $\frac{2}{n\pi}$ and frequency $n f_0$, where $f_0=1000\,Hz$, one at a time, $n=5,7,9,\ldots$ through at least $n=9$. Describe what is happening to the waveform as more sinusoids are added.

d. Now go back and create 1 second long waves with otherwise the same parameters as in a-c and listen to them. How do the sounds compare with the sound of a pure sinusoid?

PART IV

If you have time:

a. What happens if you add the waves together with different weighting? (That is, something other than the $\frac{2}{n\pi}$. Save an example of another wave you have constructed.

b. What happens if you use the same weighting as in Part III c., but change the phase by some fraction of 2π each time?