ECE130B Jan. 7, 2017

Home Work 1

Due date: Jan. 16, 2017 by 5 p.m. at the ECE130B homework boxes.

Reading assignment.

- Please read chapter 1 of the textbook, especially the parts concerned with digital signals and systems.
- Revise chapter three on the Fourier series representation of continuous periodic signals. I will assume that you are competent with this material from ECE130A.

The aim of this home work is to get you familiar with digital audio signals. You should learn how to record, playback and visualize digital sound recordings on your favorite computer platform. One possibility, especially on Linux, is `Audacity` for recording, playback and visualization. You can use your favourite language for processing these recordings. Possibilities include `Matlab`, `Octave`, `C` (using `libsndfile` for example), `Python` and `Julia` (see `http://www.seaandsailor.com/audiosp_julia.html` for some tips). My current favourite is `Julia`.

When doing the audio experiments in this class *please* make sure that the output volume is set as low as possible so that you do not damage your (and your neighbors') hearing.

Pure tones. A *pure tone* is an analog signal of the form $\cos(\omega_0 t + \varphi_0)$, where t is the time in seconds, ω_0 is the *frequency* of the tone in radians per second, and φ_0 is the *phase-shift* of the signal in radians. If you want to generate a tone that has 1000 periods (one period has one up and one down oscillation) in one second, you must choose $\omega_0 = 2\,\pi\,1000$ radians per second (the phase shift is immaterial). This is also called a 1000 Hertz signal (or 1KHz signal).

Sample rate. An analog signal is converted into a discrete signal by sampling at equally spaced time intervals. For example, if we pick a sample rate of 44,100Hz, it would mean that 44,100 samples will be taken per second of the original analog signal. This is equivalent to saying that the time between two samples is $1\,/\,44100$ seconds (why?). If f_s denotes the sample rate in Hertz, then the n-th sample of a pure tone with frequency ω_0 and phase-shift φ_0 is given by $\cos(\omega_0\, n\,/\,f_s + \varphi_0)$.

Exercise 1. Make a digital recording of yourself saying, "Hello World." What was the sample rate that you used? Make a plot of the first 30 samples in the "Hello" part of the signal. If you made a 2-channel recording, just plot from one of the channels. There is no need to submit the recording itself. (If you have difficulty speaking you can use another audio source of your choice, like clapping your hands twice.)

Exercise 2. *Middle C* is usually chosen to be a pure tone at 262Hz. Using your favorite programming language (`Julia`, `Octave`, `C`, etc.) create a synthetic digital audio recording of middle C that lasts for about 2 seconds. Make a plot of the first 100 samples (from any one channel) and mention the sample rate that you used. You need to submit the code fragment and the plot only. Make sure that the horizontal time axis of your plot has the *true* time marked along it. Did you hear (remember to turn down the volume) a click in the beginning as the recording is played back? If so, what do you think caused it?

Exercise 3. Using the code you developed in the previous Exercise carry out the following experiment. Humans can usually hear pure tones in the range 10Hz to 20KHz. Generate pure tones at different frequencies, listen (remember to turn down the volume) to them while they are played back and determine the lowest and highest frequencies at which *you* can hear pure tones. Plot the first 100 samples of the lowest tone that you could hear *and* the highest tone that you could hear. What was the sample rate you used in your recordings? Did it have an effect on the range of what you could hear? Submit any additional code fragments that you used and a description of how you carried out the experiment.

Exercise 4. Using a sample rate of 8000Hz generate pure tones at the three frequencies, 300Hz, 800Hz and 9000Hz. Next using a sample rate of 44100Hz generate pure tones at the same 3 frequencies. Listen (remember to turn down the volume) to all 6 recordings and write down your observations.