EECS 451 FALL 2013 HOMEWORK 2 DUE SEPTEMBER 17

After a genuine attempt to solve the homework problems by yourself, you are free to collaborate with your fellow students to find solutions to the homework problems. Regardless of whether you collaborate with other 451 students, you are required to write your own solutions to hand in. Copying homework solutions from another student or from existing solutions will be considered a violation of the honor code. Finally, if you choose to collaborate, you must include the names of your collaborators on your submitted homework.

Please take advantage of the Piazza discussion forum on CTools and the professor's and GSI's office hours. We are all in this together.

1. (4 points) Show that the convolution operator is commutative, i.e. that
$$x_1[n] * x_2[n] = x_2[n] * x_1[n] \ .$$
2. (12 points total, 6 points each sub-part) Compute the convolution $y[n] = x[n] * h[n]$ of the following pairs of signals.
   (a) Let a, b be real numbers that are not zero. Compute the convolution for $x[n] = a^n u[n]$, $h[n] = b^n u[n]$, when $a \neq b$ and when $a = b$.
   (b) $x[n] = u[n] - u[n-5]$, $h[n] = u[n-2] + u[n-11]$. Hint: use what you know from the first part along with properties of convolution.
3. (18 points total, 6 points each sub-part) Consider an LTI system whose impulse response is $h[n] = (0.5)^n u[n]$.
   (a) Determine the frequency response of the system. Sketch the magnitude of the frequency response. Is the system highpass, bandpass, or lowpass?
   (b) Let $x[n] = \cos(\pi n) + 4\cos\left(\frac{\pi}{2} n\right)$ be the input to this system. Compute the output $y[n] = x[n] * h[n]$.
   (c) Let $x[n] = \delta[n-1] + 3\delta[n-3]$ be the input to the system. Compute the output $y[n] = x[n] * h[n]$.
4. (6 points) Textbook 2.88 b, c, d. Justify your answers.
5. (6 points) Graduate students only: Textbook 2.88 a, e. Justify your answers.
6. (10 points) Download the Matlab data file
`http://web.eecs.umich.edu/~girasole/teaching/451/mclips.mat`
and the Matlab program
`http://web.eecs.umich.edu/~girasole/teaching/451/musicHW2.m`.

   The mclips.mat file contains two music clips in the variables x and y. The program will play these clips for you. The clip x is the original, and the clip y has been digitally processed in Matlab to produce an "echo" effect. It also has the variable $f_s = 44100$, which is the number of samples per second.

   (a) Design and implement a linear system in Matlab that processes the original clip x to produce an echo with a 0.1 second delay. (Your result should sound similar to y.) Turn in the derivation for your echo filter and your Matlab implementation code.

(b) Design and implement a *nonlinear* system in Matlab that produces distortion as follows. You want your system to mimic the saturation effect, also called "clipping": if the magnitude of x gets greater than the threshold (e.g. $x[n] \geq 0.8$), set it to the threshold value. Turn in the Matlab code and a plot of the resulting signal.