Rensselaer Polytechnic Institute
Department of Electrical, Computer, and Systems Engineering
ECSE 4530: Digital Signal Processing, Fall 2020

Homework #1: due Monday, Sep. 14^{th}, at the beginning of class.

The homeworks in this class will be a mixture of paper-and-pencil problems to turn in using Gradescope for electronic submission, and MATLAB problems to submit online. The MATLAB problems use a system called MATLAB Grader. You should already have gotten an invitation to the coding course at your RCS email, and you will also need to make a MathWorks account if you don't have one. The analytical problems will be graded by the TA, while the MATLAB problems will be automatically graded. There will be no partial credit given on the Grader questions since either your program will pass the automated tests or it won't. (There are both visible tests to help you make sure your code creates the right output, and hidden tests to make sure your code works when you don't know what the inputs will be.) Hopefully the Grader problems will give you a more hands-on feeling for real-world DSP problems. Note that it may not always be easy to figure out why your code isn't passing the tests from the online interface. it might be better to use your local copy of MATLAB to debug/solve the problems, then upload the solution to the website once you've got it working. Use Piazza to ask questions (but please remember not to post code that will give the problem away to other students).

MATLAB Grader Problems

A full description of all the Grader problems is provided at the Grader link. You don't need to physically hand anything in for the Grader problems (but make sure that you hit Submit and see a green check mark to make sure your solution has been recorded).

1. (15 points). Create a signal with harmonics.
2. (15 points). Create a signal envelope.
3. (20 points). Create a simple synthesizer, based on the results of the previous two problems.

Analytical Problems

4. (10 points) **Discrete-time signals.** Consider the discrete-time signal $x[n]$ given by

$$x[n] = \begin{cases} 1, & n = -2, -1, \\ 0, & n = 0, \\ 2, & n = 1, 2 \\ 0, & \text{elsewhere.} \end{cases}$$

   Sketch each of the following signals. Be sure to show intermediate steps that explain your reasoning and do not forget to provide the labelings.

   (a) $y_1[n] = x[n] * \delta[n-1]$ (* denotes the convolution operator)
   (b) $y_2[n] = -3x[-2n+1]$
   (c) $y_3[n] = x[-n]u[1-n]$
   (d) $y_4[n] = \text{Odd(x[n])}$

5. (25 points) **System properties.** Consider the system $y[n] = x[n^2]$.

   (a) Determine whether the given system is linear and time invariant.

   (b) Assume that the following signal is applied to the system:

$$x[n] = \begin{cases} 1, & 0 \le n \le 2 \\ 0, & \text{else.} \end{cases}$$

   i. Sketch $x[n]$.
   ii. Determine and sketch $y[n]$.
   iii. Sketch $z_1[n] = y[n-3]$.
   iv. Determine and sketch $x[n-3]$.
   v. Determine and sketch the system output $z_2[n]$ when $x[n-3]$ is applied to the system.
   vi. Compare the signals you determined in iii. and v. What is your conclusion?
   vii. Is $y[n]$ periodic? If so, determine its period.

   Note: You need to prove if each statement is true, and otherwise give a counter example.

6. (15 points) **Convolution.** Compute and sketch the convolution $y[n] = x[n] * h[n]$ for the following signal and impulse response pairs.

   (a) $x[n] = \begin{cases} 1, & n = -2, -1, 0, 1, 2 \\ 0, & \text{else,} \end{cases} \quad , \quad h[n] = x[n+2].$

   (b) $x[n] = u[n], \quad h[n] = (1/4)^n u[n-2].$

Readings from textbook: 2.1-2.3.
Suggested practice problems from textbook: 2.2, 2.7 2.8, 2.17, 2.40.