Homework #3

Due Date: Jan. 31, 2005

1. O&W 2.28 (a-d)

2. O&W 2.29 (a-d)

3. O&W 2.50

4. Consider an LTI system with $h(t) = rect(t) = \begin{cases} 1 & |t| < 0.5 \\ 0 & otherwise \end{cases}$.

   a. Determine the $y(t)$ when $x(t) = \sin(\omega_0 t)$. For what values of ω_0 is $y(t)=0$?

   b. Determine the $y(t)$ when $x(t) = e^{j\omega_0 t}$. For what values of ω_0 is $y(t)=0$?

5. Using the provided Matlab function f4.m:
   a. Determine the output, when the input function is x = sin(2*pi*f0*n); where f0 = 1/50; and n = [0:100];. Determine the approximate amplitude and frequency of the output.
   b. Repeat for f0 = 1/10; and f0 = 1/5;
   c. Could this system be considered a low pass filter (a system that preferentially passes low frequency signals)?

6. Bruce 3.19

   3.19 To control blood pressure in a patient, a physician gives him a bolus injection of a vasoactive drug every hour. Consider each injection as a discrete event, $x[n]$. A patient who has received no drug suddenly starts to receive the same dose, $x[n] = K$, every hour and the change in his blood pressure (from its value before starting the injections), $p[n]$, is measured immediately after each injection. Assume the first injection is given at $n = 0$. $p[n]$ is found to be: $p[n] = 5K\{1 - 0.7(0.5)^n - 0.3(0.2)^n\}, n \geq 0$.

   a. Determine an equation for the impulse response, $h[n]$, of blood pressure to this drug and sketch $h[n]$.

   b. If instead of giving the patient a bolus of size K every hour, the patient is given a bolus of size $6K$ every 6 hours, how will his blood pressure vary over a 24-hour time period ? To solve this part, use MATLAB (assume $K = 1$) and convolve the impulse response with an appropriate input signal. Do you think it is better to give the drug every hour or every 6 hours? Why?

7. Bruce 3.23 (DT means discrete time and CT means continuous time).

3.23 (MATLAB exercise) Functional neuromuscular stimulation is the procedure by which natural activation of muscles is replaced by activation through electrical stimulation using trains of electrical pulses. For best control of the resulting force it is necessary to develop a model of the response of the muscle to electrical stimulation, then to use this model to calculate the "correct" stimulus to deliver. Recently Bernotas et al. determined models for two muscles of the cat hindlimb, the plantaris and the soleus. In their experimental preparation (and in the resulting models) the muscle was stimulated with a constant-frequency pulse train and the width of the pulse was varied. Therefore, the models represent the change in force caused by a change in pulse width from the baseline value of pulse width. Typical models were:

$$\text{soleus: } y[k] = 0.585y[k-1] + 0.147y[k-2] + 0.011x[k-1];$$

$$\text{plantaris: } y[k] = 0.653y[k-1] - 0.060y[k-2] + 0.018x[k-1],$$

where in both cases $x[k]$ is the input pulse width and $y[k]$ is the output force. In both cases the DT model was created by sampling the input and output signals every time that an input stimulus pulse occurred. For soleus, a stimulus pulse occurred every 30 msec and for plantaris, every 108 msec.

a. Determine and plot the impulse responses of these two muscles.

b. Plot the impulse responses again but convert the time axis to continuous-time by explictly accounting for the frequency at which the data were sampled. From the impulse responses, can you tell which muscle is a fast-twitch muscle and which is a slow-twitch one?

c. To compare the muscle responses to the same sinusoidal input, it is necessary to specify the input in CT and sample it at the corresponding frequency for each muscle. Generate a unit-amplitude, 1-Hz sine wave that starts at $t = 0$ and persist for 5 cycles, and sample it at 33.3 Hz (for the plantaris) and at 9.26 Hz (for the soleus). Excite each model with the corresponding DT input signal and determine the force output. Which muscle more closely follows this input signal?