THE UNIVERSITY OF TEXAS AT AUSTIN
Dept. of Electrical and Computer Engineering

EE313 Linear Systems and Signals
Problem Set #7: Audio Processing and Fourier Series

Prof. Brian L. Evans

Date assigned:	October 15, 2010
Date due:	October 21, 2010

Homework is due at 11:00 am sharp in class. Late homework will not be accepted.

Reading: *Signals and Systems*, Sections 4.1–4.4

You may use any computer program to help you solve these problems, check answers, etc.

As stated on the course descriptor, "Discussion of homework questions is encouraged. Please be absolutely sure to submit your own independent homework solution."

The office hours in ENS 433B for Prof. Evans follow:

- Tuesday 12:15pm–1:00pm (right after lecture)
- Wednesday 7:30pm–9:00pm
- Thursday 12:15pm–1:00pm (right after lecture)
- Friday 9:30am–11:00am

Prof. Evans can be reached at `bevans@ece.utexas.edu`.

The teaching assistant is Mr. Jackson Massey. His office hours will be on Wednesdays 4:00pm–7:00pm in ENS 138. Mr. Massey can be reached at `jackson.massey@gmail.com`.

The ECE Department is offering tutoring sessions for all basic sequence ECE courses, including EE 313, on Sundays through Thursdays, 7:00–10:00 pm, in ENS 314. Mr. Massey will be a tutor during the Monday and Wednesday evening sessions.

Applets illustrating the Fourier series are available at `http://www.jhu.edu/~signals/`.

Please see the homework hints Web page for the Web links and Matlab code used in this homework assignment.

Problem 7.1 Western Musical Scale and Spectrum Plots

The spectrum of a signal refers to its frequency content. For example, in continuous time, the signal $Ae^{j2\pi f_0 t+\Phi}$ has a single frequency f_0 in Hz with magnitude A and phase Φ. Each frequency component in a signal has a magnitude and phase associated with it. We can plot magnitude as a function of frequency, or the phase as a function of frequency, or both. In many cases, but not always, spectrum refers to the magnitude of the frequency content.

In this problem, we will be experimenting with the Western Musical Scale to look more deeply into signal spectra. Please read the following Web page on the Western Musical Scale:

`http://ptolemy.eecs.berkeley.edu/eecs20/week8/scale.html`

Please complete the following parts:

(a) Here is the Matlab code to play the note A in the Western Musical Scale at 440 Hz for one second.

```
load gong
n = 1 : Fs;
f0 = 440;
w0 = 2*pi*f0/Fs;
noteSound = cos(w0*n);
sound(noteSound);
```

Submit the plot of the spectrum of the A note using the following Matlab code:

```
y = noteSound;
freqPoints = (-1 + 2*cumsum(ones(1,length(y)))/length(y))*Fs/2;
magValuesIndB = 20*log10(fftshift(abs(fft(y))));
plot( freqPoints, magValuesIndB );
```

How many significant frequency components are there? Why?

Note: The fft command in the above Matlab code is the fast Fourier transform (FFT). The FFT is a fast algorithm for computing the Fourier series for a discrete-time signal. See Sections 4.8–4.11 in Roberts' book if you are interested in knowing more.

(b) Here are the whole notes in the Western Musical Scale between A at 440 Hz and A at 880 Hz, inclusive, along with the Matlab code to play them one at a time:

```
%%% Set the sampling rate, Fs, of sound card
load gong

wholeNotesWesternScale = [ 440 494 523 587 659 698 784 880 ];
n = 1 : Fs;
```

```
%%% Play one note at a time
for f0 = wholeNotesWesternScale
  w0 = 2*pi*f0/Fs;
  noteSound = cos(w0*n);
  sound(noteSound);
end
```

Download the file "homework7sound.mat" from the homework hints page. Submit a plot of the spectrum using the following code:

```
load homework7sound.mat
sound(homework7sound);
y = homework7sound;
freqPoints = (-1 + 2*cumsum(ones(1,length(y)))/length(y))*Fs/2;
magValuesIndB = 20*log10(fftshift(abs(fft(y))));
plot( freqPoints, magValuesIndB );
```

What note(s) from the Western Musical Scale is(are) being played?

Hint: In Matlab, you can zoom in or out of a plot by selecting zoom tool (via the zoom in item in the tools menu) and then drawing a box around the part of the plot you'd like to expand.

Problem 7.2

Roberts, Chapter 4, Problem 22.

Problem 7.3

Compute the Fourier series for a square wave in Figure 4.37 on page 258 in Roberts' book. Show all intermediate work.

Problem 7.4

The following signal

$$\delta_{T_s}(t) = \sum_{k=-\infty}^{\infty} \delta(t - kT_s)$$

is known as the impulse train. The parameter T_s is a positive real constant.

(a) Plot $\delta_{T_s}(t)$ in the time domain.

(b) What is the fundamental period?

(b) Compute the continuous-time Fourier series.

(c) Plot the continuous-time Fourier series.