FALL 25 EC516 Homework 01

Due: Sunday September 14 (Before 11:59pm)

You must submit your homework attempt on Blackboard. For this purpose, you must convert your homework attempt to a single pdf file and upload it at the corresponding homework assignment on Blackboard.

Problem 1.1 (Complex Exponential Basics)

A) Given that $e^{j\omega t} = \cos(\omega t) + j sin(\omega t)$, show that $\cos(\omega t) = 0.5e^{j\omega t} + 0.5e^{-j\omega t}$

B) Let $x(t) = \frac{1}{2\pi}\int_{-\infty}^{\infty} X(j\omega)\, e^{j\omega t} d\omega$ where $X(j\omega) = \pi\delta(\omega - 400\pi) + \pi\delta(\omega + 400\pi)$
Show that $x(t)$ is a sinusoid and determine how much and in which direction that sinusoid would have to be shifted in time to make it into an odd signal.

A) Consider the complex exponential signal $g(t) = 2e^{j20\pi t}$ to answer each of the following questions

  a) Is the signal $g(t)$ periodic? Justify your answer.
  b) Plot by hand or via any software the real part of $g(t)$ as a function of t.
  c) Plot by hand or via any software the imaginary part of $g(t)$ as a function of t.
  d) Plot by hand or via software the absolute value of $g(t)$ as a function of t.

Problem 1.2 (CTFT Basics)

Part (A):
Calculate the CTFT of each of the following signals using $X(j\omega) = \int_{-\infty}^{\infty} x(t)e^{-j\omega t}\, dt$ and plot $|X(j\omega)|$ as a function of ω.

a) $x(t) = \delta(t - t_0)$, where $\delta(t)$ is the continuous-time unit impulse.
b) $x(t) = u(t + T) - u(t - T)$, where $u(t)$ is the continuous-time unit step.

Part(B):
For each CTFT given below, compute the corresponding signal using $x(t) = \frac{1}{2\pi}\int_{-\infty}^{\infty} X(j\omega)e^{j\omega t}\, d\omega$ and plot $|x(t)|$ as a function of *t*.

(a) $X(j\omega) = 2\pi\delta(\omega - 100\pi)$
(b) $X(j\omega) = u(\omega + 2\pi) - u(\omega - 2\pi)$

Part (C):
If $x(t)$ is a real-valued signal with $X(j1000\pi) = 1 + j$, use $X(j\omega) = \int_{-\infty}^{\infty} x(t)e^{-j\omega t}\, dt$ to determine the value of $X(-j1000\pi)$. This result shows that any algorithm for determining the CTFT of a real-valued signal need not directly calculate the CTFT for negative frequencies.

Problem 1.3 (Analog Sampling Basics)

Throughout this problem, we consider an impulse train $m(t) = \sum_{k=-\infty}^{\infty} \delta(t - kT)$ of period T.

(a) Sketch $m(t)$ for the case where $T = 1$.
(b) Sketch $m(t)$ for the case where $T = 2$.
(c) Determine and sketch as a function of integer variable k, the Fourier series coefficients a_k of $m(t)$ using the formula $a_k = \frac{1}{T}\int_{-T/2}^{T/2} m(t)e^{-jk2\pi/T}$.
(d) Using the Fourier series expansion $m(t) = \sum_{k=-\infty}^{\infty} a_k\, e^{j2\pi k/T}$, and the fact that the CTFT of $e^{j\omega_0 t}$ is $2\pi\delta(\omega - \omega_0)$, argue that the CTFT of an impulse train is also an impulse train.
(e) Using the fact that the CTFT $Y(j\omega)$ of $y(t) = x(t) \times m(t)$ is the convolution, $\frac{1}{2\pi}X(j\omega) * M(j\omega)$, and the result of part (d) of this problem, argue that $Y(j\omega)$ consists of replicas of $X(j\omega)$, each replica amplitude-scaled by $\frac{1}{T}$.

Problem 1.4 (Basic DSP Formulae)

The *Finite Sum Formula* and the *Infinite Sum Formula* are very useful in DSP.

a) Show that the *Finite Sum Formula*, given as $\sum_{n=0}^{N-1} \alpha^n = \frac{1-\alpha^N}{1-\alpha}$, is valid for all non-zero complex numbers $\alpha \neq 1$
b) Determine the range of complex values α for which the Infinite Sum Formula, given below, is valid. *Justify your answer*.

$$\sum_{n=0}^{\infty} \alpha^n = \frac{1}{1-\alpha}$$

Experiential DSP Exercise 01

Part A: Basic visualization of the provided audio file.

1) Load and play the file.
   a. Place `ece516.wav` in your current MATLAB folder (check with `pwd` or use the Current Folder pane).
   b. Read the audio and sampling rate using the `audioread` command. (Note that this command gives you two outputs, `x` and `F`. We need both outputs for this assignment.)
   c. Play the audio (use `soundsc` to avoid clipping).
   d. Listen and write down in your report what you hear (the spoken content).
2) Waveform
   a. Use `x` and `F` from earlier to compute the duration of the file.

b. Create a time axis in seconds.
c. Plot the waveform of the signal using the `plot` command.

3) Arbitrary speech section
   a. Choose a section of the speech waveform starting at some index `k`.
   b. Extract 320 samples from the file starting from chosen `k`. (Be careful that `k + 319 ≤ length(x)`).
   c. Create a stem plot of the chosen chunk using the `stem` command.

Part B: Now you record!

1) Record and save:
   a. Open the MATLAB software.
   b. Set these variables: `Fs = 16000; nBits = 16; nChannels = 1;`
   c. Create an audio recorder object using the `recObj = audiorecorder(Fs, nBits, nChannels)` command and pass the defined variables in step 1 to it.
   d. Use the `record(recObj)` command to start recording. In the recording, you should say: "My name is YYY," where YYY is your first and last names.
   e. Write the command `pause`. With this command, you can stop recording by pressing any key on your keyboard.
   f. Use the `stop(recObj)` command to stop recording.
   g. Get the recorded data using by `getaudiodata(recObj)` command.
   h. Save the recorded audio using the `audiowrite(filename, audioData, Fs);` choose `filename` as: `Firstname_Lastname.wav.`
2) Apply all the steps in part A to your recording.

Part C: Plotting Spectrograms

1) Load both `ece516.wav` and `Firstname_Lastname.wav` audio files.
2) Create the spectrogram plots of `ece516.wav` and your audio file using the `spectrogram` command.
3) In each spectrogram, identify the regions where the speaker is silent. Explain how you find those regions. How are they different from the rest of the plot?