

Assignment 1

Due Date: To be announced during the lectures and posted on the course web site.

Note: Problems identified only by number (e.g., A.1, 2.1, etc.) can be found in the textbook.

More specifically, Problem $x.y$ can be found in the textbook at the end of chapter/appendix x .

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Regular Problems

- ◇ A.1 a [convert to Cartesian form]
- ◇ A.2 a c [convert to polar form, principal argument]
- ◇ A.3 a b c d e [complex arithmetic]
- ◇ A.4 a d [properties of complex numbers]
- ◇ A.5 a [Euler's relation]
- ◇ A.6 d f [poles/zeros]
- ◇ A.7 a b [continuity, differentiability, analyticity]
- ◇ A.9 a b [magnitude/argument]

Assignment 2

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Regular Problems

- ◇ 2.1 e [time/amplitude transformations]
- ◇ 2.3 a b c d e [time/amplitude transformations]
- ◇ 2.4 a e f [even/odd symmetry]
- ◇ 2.5 a c f [symmetry and sums/products]
- ◇ 2.8 [causal, even/odd symmetry, even/odd parts]
- ◇ 2.9 a b c [periodicity]
- ◇ 2.10 a b c d e [properties of delta function]
- ◇ 2.11 [representations using unit-step function]
- ◇ 2.12 a c d [linearity]
- ◇ 2.13 a c e [time invariance]
- ◇ 2.14 a c e [causality, memory]
- ◇ 2.15 a c d [invertibility]
- ◇ 2.16 a b c [BIBO stability]
- ◇ 2.19 [time transformations]

MATLAB Problems

For each of the MATLAB problems below, you **must** submit a hardcopy of the MATLAB code in addition to the output/results produced from the execution of the code, unless explicitly instructed otherwise. **Note:** It is **highly recommended** that you read the MATLAB appendix (i.e., Appendix E) of the textbook before attempting any of the MATLAB problems in this course. In the long run, you will likely save yourself considerable time by doing so.

- ◇ E.101 a b c d e [MATLAB identifiers]
- ◇ E.106 a b c d [MATLAB expressions]
- ◇ E.102 [temperature conversion, looping]

◇ E.107 a b c [**write unit-step function**]

Assignment 3

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Regular Problems

- ◇ 3.1 c d [compute convolution]
- ◇ 3.2 a c d e [compute convolution]
- ◇ 3.3 [manipulation of expressions involving convolution]
- ◇ 3.4 a [convolution property proof]
- ◇ 3.7 a b c [find impulse response]
- ◇ 3.8 a b [impulse response and series/parallel interconnection]
- ◇ 3.9 [meaning of LTI]
- ◇ 3.10 b c [convolution, impulse response, system interconnection]
- ◇ 3.12 a e f g [causality, memory]
- ◇ 3.13 a b c f [BIBO stability]
- ◇ 3.14 [inverse system]

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- ◇ E.103 [plot, abs, angle, complex numbers]
- ◇ E.108 a b [graphic patterns]

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Regular Problems

- ◇ 4.1 a c [find Fourier series]
- ◇ 4.2 a c [find Fourier series]
- ◇ 4.6 b [odd harmonic proof]
- ◇ 4.8 [find/plot frequency spectrum]
- ◇ 4.9 [filtering]

MATLAB Problems

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- ◇ 4.101 a b c [Fourier series convergence] [Note: It is not a requirement that you use the Symbolic Math Toolbox for this problem. If, however, you do use this approach, Appendix E of the textbook has some helpful material on the MATLAB Symbolic Math Toolbox (e.g., functions such as symsum, sym, subs, etc.). Refer to the section titled “Symbolic Math Toolbox”.]

Assignment 5

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Regular Problems

- ◇ 5.1 d e [find Fourier transform by first principles]
- ◇ 5.2 c d e f g [find Fourier transform]
- ◇ 5.5 a b c d e f [find Fourier transform]
- ◇ 5.6 a [find Fourier transform of periodic signal]
- ◇ 5.9 a [find frequency/magnitude/phase spectrum]
- ◇ 5.10 b [differential equation to frequency response]
- ◇ 5.11 b [frequency response to differential equation]
- ◇ 5.12 [filtering]
- ◇ 5.13 a b c [circuit analysis, frequency response, impulse response]
- ◇ 5.18 a b [amplitude modulation]
- ◇ 5.19 a b c [sampling]
- ◇ Problem P.1: A communication channel heavily distorts high frequencies but does not significantly affect very low frequencies. Determine which of the following signals would be least distorted by the communication channel: (a) $x_1(t) = \delta(t)$; (b) $x_2(t) = 5$; (c) $x_3(t) = 10e^{j1000t}$; (d) $x_4(t) = 1/t$. [communication systems]
- ◇ Problem P.2: A signal $x(t)$ is bandlimited to 22 kHz (i.e., only has spectral content for frequencies f in the range $[-22000, 22000]$). Due to excessive noise, the portion of the spectrum that corresponds to frequencies f satisfying $|f| > 20000$ has been badly corrupted and rendered useless. (a) Determine the minimum sampling rate for $x(t)$ that would allow the uncorrupted part of the spectrum to be recovered. (b) Suppose now that the corrupted part of the spectrum were eliminated by filtering prior to sampling. In this case, determine the minimum sampling rate for $x(t)$. [sampling]

MATLAB Problems

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- ◇ 5.101 a b c [**calculate frequency response**]
- ◇ 5.103 a b c d [**filters**] [**Hint:** The MATLAB appendix (i.e., Appendix E) in the textbook has some examples of how to use the `butter` and `besself` functions. Refer to the section titled “Signal Processing” and its associated subsections for more information. In particular, the specific pages of relevance can be found by looking up the terms “Butterworth filter” and “Bessel filter” in the textbook index. To compute the frequency response from the coefficient vectors obtained from the `butter` and `besself` functions, you can use the `freqw` function developed in Problem 5.101. Alternatively, the `freqs` function can be used to calculate the frequency responses of the filters from the coefficient vectors returned by the `butter` and `besself` functions.]

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Regular Problems

- ◇ 6.1 c [find Laplace transform by first principles]
- ◇ 6.2 b c d e [find Laplace transform]
- ◇ 6.3 e [find Laplace transform]
- ◇ 6.8 a b [initial/final value theorem]
- ◇ 6.18 [find Laplace transform]
- ◇ 6.9 a [find inverse Laplace transform]
- ◇ 6.11 [find inverse Laplace transform]
- ◇ 6.12 [system function to differential equation]
- ◇ 6.13 [differential equation to system function]
- ◇ 6.14 a b [stability analysis]
- ◇ 6.15 a b c [circuit analysis, stability analysis, step response]
- ◇ 6.16 [solve differential equation]
- ◇ 6.19 [inverse systems and system function]
- ◇ Problem P.1: Consider a system consisting of a communication channel with input $x(t)$ and output $y(t)$. Since the channel is not ideal, $y(t)$ is typically a distorted version of $x(t)$. Suppose that the channel can be modelled as a causal LTI system with impulse response $h(t) = e^{-t}u(t) + \delta(t)$. Determine whether we can devise a physically-realizable stable system that recovers $x(t)$ from $y(t)$. If such a system exists, find its impulse response $g(t)$. [communication systems, equalization]
- ◇ Problem P.2: In wireless communication channels, the transmitted signal is propagated simultaneously along multiple paths of varying lengths. Consequently, the signal received from the channel is the sum of numerous delayed and amplified/attenuated versions of the original transmitted signal. In this way, the channel distorts the transmitted signal. This is commonly referred to as the multipath problem. In what follows, we examine a simple instance of this problem.
Consider a LTI communication channel with input $x(t)$ and output $y(t)$. Suppose that the transmitted signal $x(t)$ propagates along two paths. Along the intended direct path, the channel has a delay of T and gain of one. Along a

second (unintended indirect) path, the signal experiences a delay of $T + \tau$ and gain of a . Thus, the received signal $y(t)$ is given by $y(t) = x(t - T) + ax(t - T - \tau)$. Find the transfer function $H(s)$ of a system that can be connected in series with the output of the communication channel in order to recover the (delayed) signal $x(t - T)$ without any distortion. The system must be physically realizable. [communication systems, equalization]

MATLAB Problems

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Note: In the case of Problem M.1, since the MATLAB source code is provided, it is not necessary to include a copy of this source code in your assignment submission.

- ◇ 6.101 a b [stability analysis] [Hint: The roots function might be helpful.]
- ◇ 6.102 a b [impulse/step response] [Note: Appendix E of the textbook has some information on the MATLAB Signal Processing Toolbox (e.g., functions such as tf, impulse, step, etc.). Refer to the section titled “Signal Processing” and its associated subsections.]
- ◇ Problem M.1:

Background: The sampling theorem states that a (bandlimited) continuous-time signal can be uniquely/unambiguously represented by its samples. Therefore, all of the operations that we can apply to a continuous-time signal can be converted into equivalent operations on their samples. When processing signals inside of a computer, this is always how things are done. That is, we operate on the samples of a continuous-time signal instead of the original continuous-time signal directly. In this problem, you will experiment with some code that processes continuous-time signals by performing equivalent operations on their samples.

Comment on Negative Frequencies: In this problem (and the associated MATLAB code), when dealing with frequency spectra, we only concern ourselves with nonnegative frequencies since real-valued signals always have even/odd symmetry in their magnitude/phase spectra, making the half of the spectra for negative frequencies redundant.

Problem: Download the audioDemo.zip Zip archive from the “Assignments” section of the course web-site home page. This archive contains several MATLAB source files. Extract the contents of the Zip file using the unzip command (i.e., “unzip audioDemo.zip”) and place the extracted files in a directory in which MATLAB searches for M-files. The main program file is called audioDemo.m. Examine this file in some detail as it provides a basic template for doing this problem. That is, to do this problem, you will only need to comment/uncomment or make very trivial changes to various lines in this file. You should not need to change any of the code except the code in audioDemo.m.

(a) For the train audio signal, use the template program provided (in audioDemo.m) to plot the signal and its frequency spectrum as well as to play the signal on the audio device (i.e., speaker). Make a hardcopy of the plot of the signal and its frequency spectrum. By examining the frequency spectrum, identify at which three (nonnegative) frequencies the train whistle has the most information/energy.

(b) For the handel audio signal, use the template program provided (in audioDemo.m) to plot the signal and its frequency spectrum as well as to play the signal on the audio device. Make a hardcopy of the plot of the signal and its frequency spectrum. Then, do the same thing for the noisyHandel audio signal, which is essentially the handel signal with a significant amount of noise added for (nonnegative) frequencies in the range [3000, 3500] Hz. Identify the noise on the plot of the frequency spectrum. Apply a bandstop filter with a stopband corresponding to (nonnegative) frequencies in the range [2950, 3550] Hz to the noisy signal. (Note that a bandstop filter is like a bandpass filter, except that instead of passing frequencies in a certain range, frequencies in a certain range are eliminated.) Again, plot the signal spectrum and play the signal on the audio device. Describe what effect the filter had on the signal being processed.

Note: Since you will be using the computer’s audio device, it is highly recommended that you **bring headphones** with you to the lab. By using headphones, you can avoid disturbing/upsetting other people in the lab when you are using the computer’s audio device. If you use headphones on the machines in the Linux Software Lab (ELW B215), you will need to ensure that the headphone jack sense is enabled; otherwise, the computer will still play audio on the loudspeaker (in addition to the headphones), when headphones are plugged in. To ensure this setting is enabled,

right click on the volume-control speaker icon in the top right corner of your screen and choose “Open Volume Control”. From the “Edit” menu, select “Preferences”. In the “Volume Control Preferences” window, ensure that the checkbox for “Headphone Jack Sense” is checked, and then close this window. Then, in the main volume control window, click on the “Switches” tab. Ensure that the “Headphone Jack Sense” box is checked. With the above setting in place, the computer should not play audio on the loudspeaker when headphones are plugged in (i.e., the audio should only be sent to the headphones). [**filtering**]