ESE 351 Spring 2024 Homework #3 – Matlab supplement
Assigned Tuesday, February 6
Due Friday, February 16 – Submit on gradescope

Complete the tasks below. Each student must write and submit their own work. You are welcome to discuss the assignment, course contents, and Matlab code with others, but you must write your own m-file and you must acknowledge any collaborators at the top of your m-file.

Submit your working m-file and a "published" pdf report. Include comments in your m-file so that a published pdf of your script output is a self-contained description of your work. See ESE351ExampleScript.m and ESE351ExampleScript.pdf on canvas for a Matlab example with general expectations. Pay close attention to the generation of figures that illustrate your results clearly. When helpful, use subplot and/or plot multiple items in a single graph. Include titles on all figures or subplots and label all axes. Use the **plot**() command for plotting CT functions and **stem**() for DT functions.

Introduction In this week's assignment, you'll explore the output of LTI systems to a complex exponential input and use that output to compute the system frequency response. Then you'll simulate a simple DC to AC converter that filters a square wave DC signal to create a 60-Hz AC signal.

In the RC circuit portions of parts 1 and 2 below, use these values for R, C, and the sampling frequency f_s: $R = 1k\Omega, C = 5\mu F$, and $f_s = 44.1kHz$. For modeling the RC circuits, you can use **lsim()** directly, or you can use a DT approximation as in HW1 and HW2.

1. **Complex exponential inputs.** For the lowpass and highpass RC circuits as in Homeworks 1 and 2, simulate the response to a complex exponential, $e^{j\omega t}$, at angular frequency $\omega = 2\pi f$. Simulate the response for multiple frequencies but include in your report results for each circuit at $f = 10\ Hz$ and $1000\ Hz$. Plot the input and output on a common plot; since both signals are complex-valued, plot the real and imaginary parts as well as the magnitude, e.g., in three subplots, one each for the real, imaginary and magnitude, with input and output in each. Plot for enough periods of the input signal to see both the transient and steady-state behavior. Do the signals behave as expected?
2. **Bode plot**. A Bode plot shows the system frequency response as magnitude vs. frequency and phase vs. frequency. Use your code from part 1 to find the complex gain $H(\omega)$ (the ratio of the steady-state output to the input). Compute $H(\omega)$ for frequencies between 10 Hz and 10 kHz (you can use **logspace**() for generating evenly spaced values in a log scale; about 3 values per decade should be sufficient). Plot the magnitude, $|H(\omega)|$, in dB ($20\log_{10}|H(\omega)|$), and plot the phase in units normalized by π ($\angle H(\omega)/\pi$). Commands **abs()** and **angle()** return the magnitude and phase for complex-valued data. Note: the command **freqs(b,a)** computes the frequency response analytically for a system with LCCDE coefficients **b** and **a**. Your result should be close to the **freqs()** result.

DC to AC converter. Electric power systems that generate natively DC (constant, direct current) power, e.g., photovoltaics, batteries, fuel cells, need to be converted to AC (alternating current) to connect to the 60Hz power grid. Electronics can generate switched voltage outputs to create a 60Hz square wave output from a DC source, but an approximately sinusoidal output is needed for connection to the grid.

For the task below, use sample frequency $f_s = 10kHz$. Choose values for R, C as needed to implement the converter. Choose a time range for computation that allows you to illustrate your results and characterize the system frequency response from the steady-state output. The command **square**() may be useful for generating a square wave.

3. Construct a square wave DC signal at 60Hz (amplitude switching from +1 to -1 with a period of 1/60 seconds). Use any combination of RC circuits (serial or parallel combination) to create a system that generates an approximately sinusoidal 60Hz AC output while maximizing the power efficiency as defined below.
    a. Plot the input and output to show the shape of each signal.
    b. Generate a Bode plot as above to show the frequency response of your system.
    c. Compute the power efficiency (P_{out}/P_{in}) of your converter. Recall that electric power is proportional to voltage squared. Compute the average power in each signal as $P_{avg} \propto \frac{1}{T_0}\int_0^{T_0} V^2 dt$ (ignoring effects of load resistance, active and reactive power, etc.). Compare your efficiency to the theoretical maximum based on the power in the 60Hz component in a Fourier series expansion of the square wave.