EE 387 – Signal Processing

Lab 3: System Functions and Frequency Response

1. Objectives

1. Learn MATLAB basics to use system functions.
2. Use MATLAB to determine the frequency response of a given LTI system.

2. Procedure

PART 1: Pole-Zero Diagrams in MATLAB.

A pole-zero diagram displays the “poles” and “zeros” of the system function by placing an ‘x’ at each pole location and an ‘o’ at each zero location in the complex *s*-plane. Poles and zeros can be found out by using *roots* function in matlab.

Example: Find out the zeros and poles of the following system function and plot them

$$\mathrm{H(s)} = \frac{s-1}{s^2+2s+2}$$

```
clear all;
close all;

b = [1 -1]; % Numerator coefficients
a = [1 3 2]; % Demoninator coefficients
zs = roots(b); % Generetes Zeros
ps = roots(a); % Generetes poles
pzmap(ps,zs); % generates pole-zero diagram
```

Exercise

Using the method given above, find out the zeros and poles of the following system functions and plot them:

1. $\mathrm{H(s)} = \frac{s+5}{s^2+2s+3}$
2. $\mathrm{H(s)} = \frac{2s^2+5s+12}{s^2+2s+10}$
3. $\mathrm{H(s)} = \frac{2s^2+5s+12}{(s^2+2s+10)(s+2)}$

PART 2: Frequency Response and Bode Plots in MATLAB

Consider a system function:

$$H(s) = \frac{2s^2 + 2s + 17}{s^2 + 4s + 104}$$

1. Define the numerator and denominator polynomial coefficients as vector *b* and *a* respectively.

2. Use the *freqs* function to evaluate the frequency response of a Laplace transform.

```
H = freqs(b,a,omega);
```

   where $-20 \leq \omega \leq 20$ (ω) is the frequency vector in rad/s. (Hint: use *linspace* to generate a vector with 200 samples.)

3. Plot the magnitude and phase of the frequency response.

4. Plot the bode plot of the given $H(S)$ by utilizing the results in 2. (Hint: use the definitions of the bode plot)

Exercise

1. Plot the bode plot of each four system functions given in the part 1.

2. Select three sinusoidal signals with unit magnitude, zero phase and three different frequencies (f_1, f_2, f_3 *in kHz*, here $f_i = Registration\ number * i$). Assume that they are three inputs for abovementioned four systems. Then find the corresponding three outputs for each system.

PART 3: Surface Plots of a System Function in MATLAB

Complex number *s* in the Laplace transform is represented as:

$$s = \sigma + j\omega$$

A 3-D surface plot of the system transform function H(s) at the range of interests, i.e. $-20 \leq \omega \leq 20$ and, $-5 \leq \sigma \leq 5$ is extremely useful to illustrate the relationship between the frequency response H(s) and the pole-zero locations.

The system response matrix *s* can be generated from ω and σ (sigma) using *meshgrid* function:

```
[sigmagrid,omegagrid] = meshgrid(sigma,omega);
```

hence, $s = \sigma + j\omega$ is:

```
sgrid = sigmagrid+j*omegagrid;
```

use function *polyval* to evaluate the numerator and denominator polynomials at the specific range:

```
H1 = polyval(b,sgrid)./polyval(a,sgrid);
```

Finally, use *mesh()* function to generate the surface graph of the magnitude of *H(s)* in dB:

```
mesh(sigma,omega,20*log10(abs(H1)));
```

Exercise

Where are the poles and zeros on the surface plot? What's the relationship between the surface plot and the plot in 2.(2) ?.