ME 417 - Homework #2

Control of Mechanical Systems - Spring 2021

Homework Due: Thu, 06 May 2021 23:59

Complete the following problems and submit a hard copy of your solutions. You are encouraged to work together to discuss the problems but submitted work **MUST** be your own. This is an **individually** submitted assignment. Perform long calculations with the aid of a computer

Problem 1

Stability Analysis (15pts)

For each of the following systems, find the poles of the system and determine the system's stability classification. Justify your answer.

a. $G(s) = \dfrac{s-19}{s^2+4s+23}$

b. $G(s) = \dfrac{s^2-25}{(s^2-3s+100)\,(s^2+2s+20)}$

c. $G(s) = \dfrac{25}{(s+10)\,(s^2+100)^2}$

d. $G(s) = \dfrac{s-10}{s\,(s^2+5s+25)}$

Problem 2

Second Order Approximation (20pts)

For each of the following systems, determine if a 2nd-order approximation is valid. Justify your answer.

a. $G(s) = \dfrac{300s+3000}{(s+2)^2\,(s^2+4s+100)}$

b. $G(s) = \dfrac{20s+100}{(s+1)\,(s^2+4)}$

c. $G(s) = \dfrac{s+30}{(s+4)\,(s^2+2s+40)}$

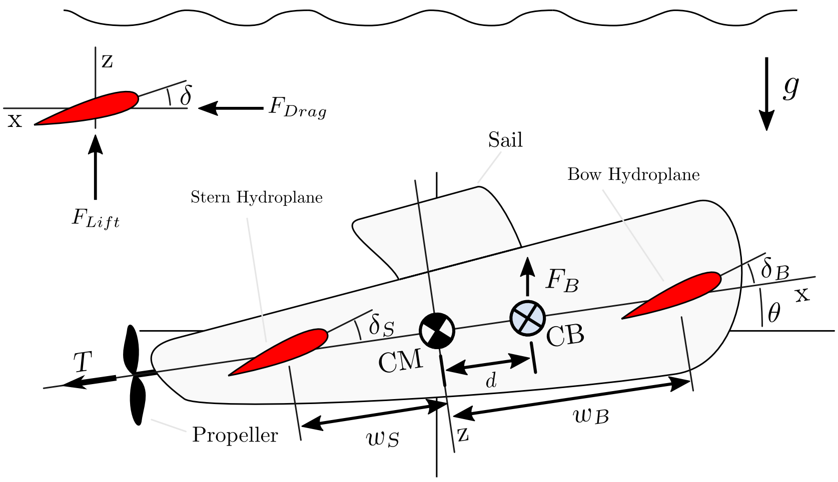
d. $G(s) = \dfrac{s+4}{(s+3.8)\,(s^2+2s+20)}$

Hint: 5 times rule of thumb for higher order poles, or if zeros are present, compare the magnitude of the higher order term. You can use MATLAB to perform PFE.

Problem 3

Stability and Feedback Form (40pts)

A simple submarine model is shown. The submarine is designed to be neutrally buoyant, meaning the weight of the submarine is equal to the weight of the water displaced by the submarine. However, the center of mass and the center of buoyancy are not coincident. So, while the net force in the gravity direction is zero, there is still a net moment around the center of mass (mass center of gravity).



The propeller provides thrust forward in the body x direction. The hydroplanes are control surfaces, based on their angles the drag and lift forces on them will vary.

- θ is the submarine pitch angle
- δ_s is the stern hydroplane angle
- δ_b is the bow hydroplane angle
- CM is the center of mass
- CB is the center of buoyancy

Assuming the hydrodynamic affects on the stern and bow hydroplanes are similar.
Assuming the heave (z-direction) speed is small compared to surge (x-direction).

Hydroplanes:

- $F_{Drag} = 25sin(\delta)\dot{x}$
- $F_{Lift} = 25cos(\delta)\dot{x}$

Submarine:

- $F_{SurgeDrag} = 200\dot{x}$
- $F_{HeaveDrag} = 20\dot{y}$
- $M_{PitchDrag} = 5\dot{\theta}$

a. Derive the equations of motion for the system (3 directions)

b. List the transfers functions (just the input output signal expression) required to express all the dynamics of the system.

c. With the hydroplane angles values constant with $\delta s = \delta b = 20^o$. Derive the transfer function relating T to $\dot{\theta}$, the angular velocity of the submarine in the pitch direction.

d. Assess the stability of this system $\frac{\dot{\Theta}}{T}$

Given $m = 2000kg, I_{Gy} = 8000.0kg \cdot m^2, d = 0.25m$

Problem 4

Block Diagram Manipulation (15pts)

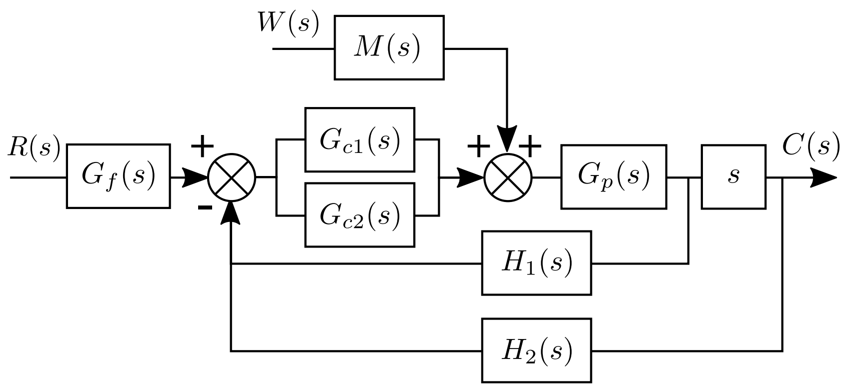
Given the following block diagram, with

$G_f = 12,\ G_{c1} = 0.5s + 5.0,\ G_{c2} = 20,\ G_p = \frac{6.0}{1.0s^3 + 10.0s},\ H_1 = \frac{1.0}{s},\ H_2 = 5,\ M = 5.0s$

a. Derive the transfer function that relates the reference $R(s)$ to the output $C(s)$

b. Derive the transfer function that relates the reference $R(s)$ to the input to the plant $U(s)$

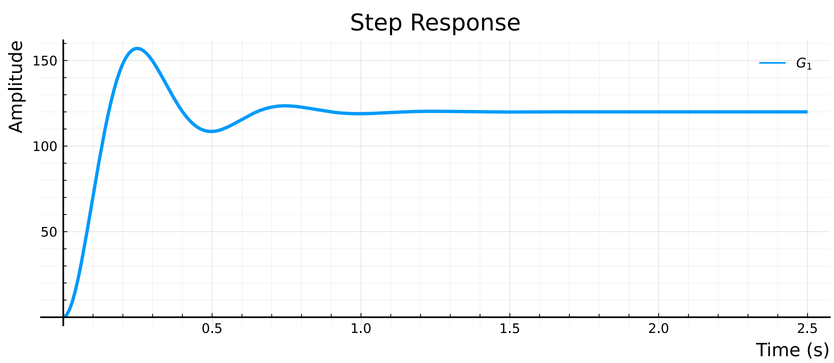
c. Derive the transfer function that relates the disturbance (noise) $W(s)$ to the output $C(s)$



Problem 5

Derive System from Response (10pts)

The following is the response of a second-order system to a step input $u = 8$



Derive, approximately, the transfer function of the system