Mechanical Control Systems (ME 4473)

Recitation - 4

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1. **Agenda:**
    - Revision
    - Problems(OLTF, CLTF, Sensitivity)

2. **Questions:**
    - **What is the meaning of sensitivity?**

Sensitivity is how certain parameters affects stability of a the closed loop transfer function of a system

- **What is the sensitivity of an open loop system?**

  1

- **What is the expression for sensitivity?**

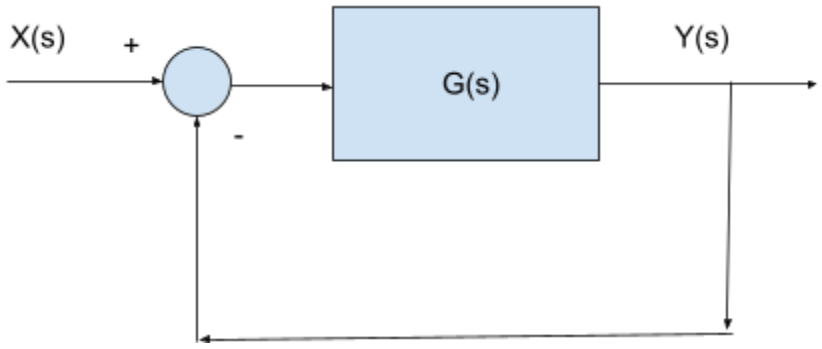
  $S_k^T = \frac{k}{T} * \frac{\delta T}{\delta k}$

<u>Instructions for the Questions below:</u>

- *In the breakout room, work in the pair of 4*
    - *1: A,B,C 2: F,G,H 3: J,K 4: Work on Matlab*
- *Check each other's answers by re-working the problems as*
    - *1: Matlab 2:A,B,C 3. F,G,H 4. J,K*
- *For the person working on Matlab: Also check to see how the sections in the matlab code corresponds to the problems in the worksheet*
- *For the rest of the problems and Matlab coding, work as a team*
- *Utilize Zoom' Screen Sharing feature*
- *In the Matlab, Replace '1' with the appropriate transfer functions from your worksheets*
- *After you are done with the worksheet, open the quiz and fill out your response*

3. Problems:

1. **For a given block diagram below:**



<u>Case-1:</u> Your G(s) = 0.38(s^2+ 0.1s + 0.55)/(s*(s+1)*(s^2 + 0.06s + 0.5)) .

A. **What is the loop transfer function(OLTF) for your system without substitution for G(s)?**

B. **What is the closed loop transfer function(CLTF) for your system without substitution for G(s)?**

C. **What is the sensitivity of the CLTF with respect to OLTF?**

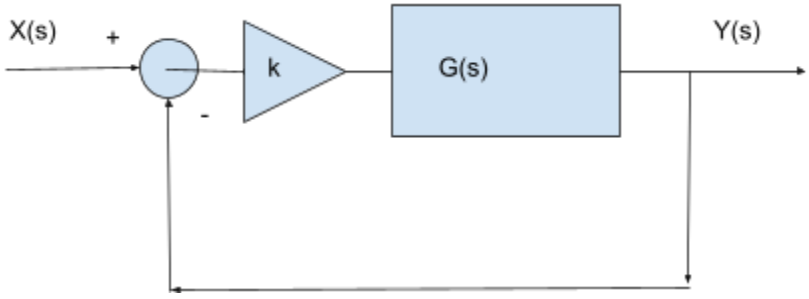
D. **Plot the Bode plot for the sensitivity using provided code. What is the peak magnitude?**

(Note: This is called nominal Sensitivity peak)

E. **Using the equation given in Bode plot appendix, find the magnitude of the sensitivity at the peak magnitude:**

(Before you input for Magnitude in the equation, round the Magnitude to floor value: eg floor(1.99) = 1)

<u>Case-2:</u> The sensitivity around 3.54 is too high. Typical desired sensitivity is between 1.3 & 2. Now, let's modify our system and add a gain element 'k' such that the block diagram of our system becomes ;



F. **What is the OLTF & CLTF for the system without substitution for k & G(s)?**

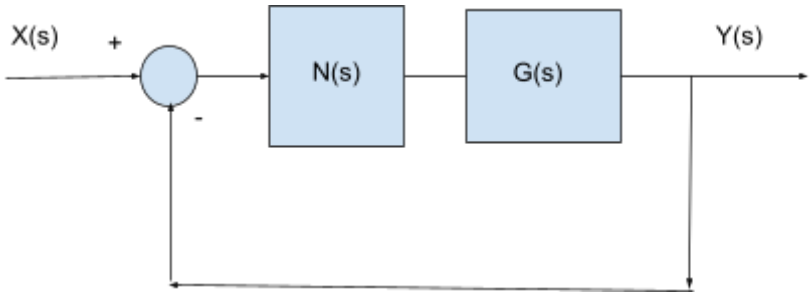
G. **What is the expression for sensitivity of the CLTF due to the variations in the new OLTF (without substitution for k & G(s))?**

H. **Evaluate F, G & H for k = 0.5.**

I. **Using the provided code plot the parameters for case-2.**
   a. **Did the magnitude of the Nominal sensitivity peak in the Closed Loop Sensitivity go down?**

   b. **In the step response, does the new system take more time or less time to get to the steady state region than the last one?**

Case-3: Lets try to approach this issue using this using a different approach (We don't want to slow the rise time). Instead of Gain Element, Let's add a notch filter such that the block diagram becomes:



(notch N(s) = (s^2 + 0.7^2)/(s^2 + 0.35*s + .49))
(This Notch filter has a notch at 0.7 rad/s with width of Q = 2)

J. **What is the OLTF & CLTF for the new system(without substitution for N(s) & G(s))?**

K. **What is the expression for the sensitivity for the new CLTF with respect to OLTF?**

L. **Using the provided code plot the parameters for case - 3.**
    a. **What happens to the Nominal sensitivity peak?**

    b. **In the step response, is the rise time of the system improved using the Notch filter than in Case II?**

Conclusion:

1. ….

2. ….

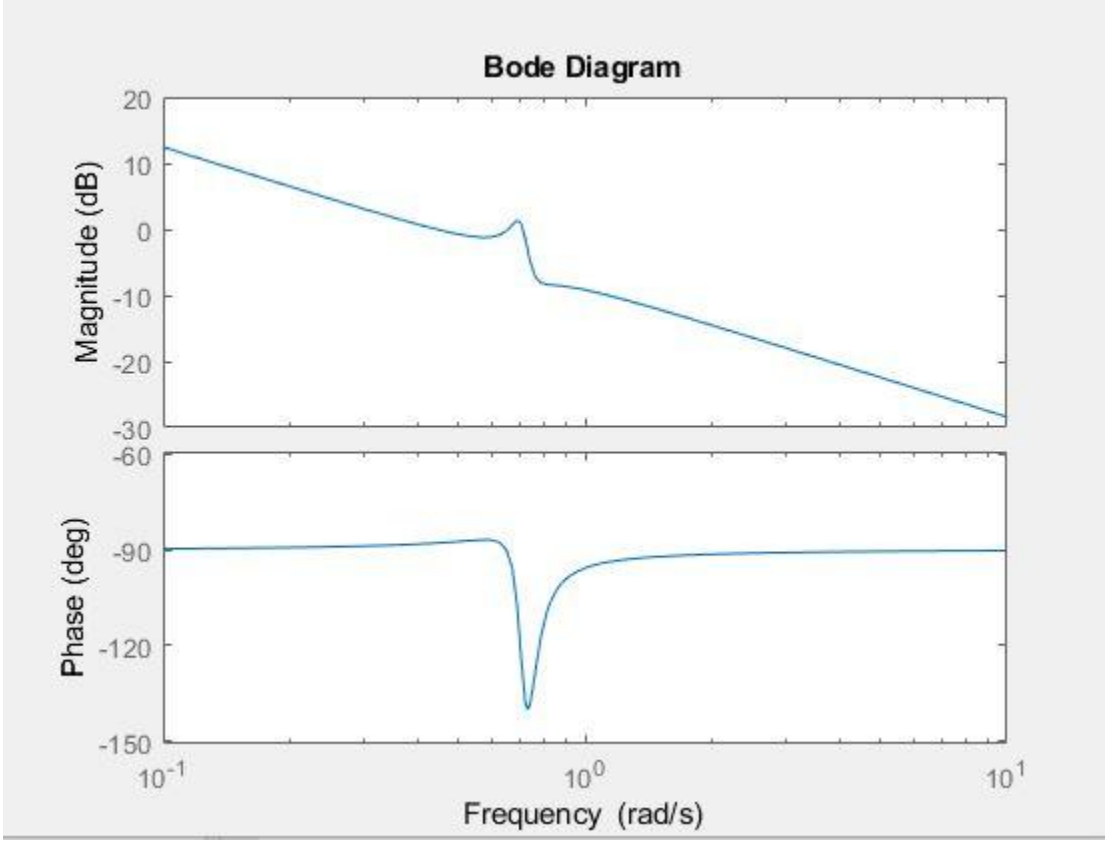
Bibliography:

- Understanding the Sensitivity function, https://www.youtube.com/watch?v=BAWdZvF1O40

Appendix:

1. **Bode Plot:**

Matlab Example:



- X-axis: Frequency(rad/s)
- Y -axis: Magnitude(dB) , Phase(degree)
- Resonant frequencies are shown by a spike in magnitude in the bode plot
- Matlab's keyword: bode(G)
- Matlab's plot has a zooming feature icon in the upper right corner of every plot.
- Also, by clicking on a certain point in the curve, it is possible to see the magnitude and frequency at that point

- For a transfer function G(jw),
  Magnitude(dB) = 20 log(base 10)(|G(jw)|)

- To find which plot corresponds to which section, click on the plot. Then go to: Insert -> Legend