ELEC 341 – Electro-Mechanical Control Project

Project Part 2
Controller Design

20 Marks

<u>WARNING</u>

Fix any errors in Part 1 before moving on to Part 2.

*The **CORRECT** system model will be used to grade your controller.*

If you use an incorrect system model to design your controller, it will not satisfy the RCGs for the correct system model.

It will be good practice, but you won't get any marks for this work.

*In Part 1, you found the **loop** transfer function GH.*

It may not seem like this includes a controller, but it does. It's a unity-gain (K=1) proportional (D=1) controller with the feedback dynamics (H) you designed.

KDGH=GH when K=1 & D=1

*That's how you were able to plot the **closed-loop** response. Since it didn't track the desired output very well, it's time to improve the controller design.*

Use the 10-Step Process to design a controller. You already developed frmal RCGs (Step 1), performed system identification (Step 2), and designed the feedback path (Step 3).

Q8 2 mark(s) Step 4

You decided to use a PID controller.

Use a weighted sum filter that places your **derivative pole** as close as possible to the controller pole in the feedback path. Find the associated N and Nhat.

Compute the resulting partial dynamics Dp, and Kref.

- Q8.N (pure) Scalar
- Q8.Nhat (pure) Scalar
- Q8.Dp (pure) LTI

Q9 2 mark(s) Step 5

Compute Kref and the associated cross-over frequency wxo.

- Q9.Kref (Vs/m) Scalar
- Q9.wxo (rad/s) Scalar

Q10 3 mark(s) Step 6

Find the zeros Z that maximize Phase Margin with Kref applied.

Compute the associated Phase Margin PM, and full PID dynamics D.

- Q10.Z (rad/s) Vector 1x2
- Q10.PM (deg) Scalar
- Q10.D (pure) LTI

Q11 3 mark(s) Step 7

Find the gain K that achieves a **Phase Margin** of **30°**.

Compute the associated PID controller gains for the controller dynamics you computed.

- Q11.K (Vs/m) Scalar
- Q11.Kp (pure) Scalar
- Q11.Ki (pure) Scalar
- Q11.Kd (pure) Scalar

***COW:** Generate Nyquist plots to verify KrefDpGH is marginally stable and KrefDGH has the expected phase margin.*

REQUIREMENTS:

1. *OS < 20%*
2. *Ts < 200 ms*

CONSTRAINTS:

1. *You may not change the control frequency.*
2. *You may not change the derivative filter.*

GOALS (in decreasing order of importance):

1. *No undershoot (never drops below FV after peak – most important)*
2. *OS as small as possible*
3. *Ts as small as possible*

Q12 3 mark(s) Step 8a

Tune the PID controller gains to satisfy the above RCGs. Normalize them so **Ki=1**.

- Q12.K (Vs/m) Scalar
- Q12.Kp (pure) Scalar
- Q12.Ki (pure) Scalar
- Q12.Kd (pure) Scalar

Q13 2 mark(s) Step 8b

Compute the zeros and phase margin of your tuned gains.

- Q13.Z (rad/s) Vector 1x2
- Q13.PM (deg) Scalar

You implemented your controller in a micro-controller and connected it to a gripper. You find the friction in the linkage (Joints b & c in Fig. 2) is not as negligible as expected. Damping Bf is 50% higher than originally estimated.

Adjust Bf in your model and re-calculate the forward path gain G:

- *the Amplifier transfer function Ga, originally calculated in Q2*
- *the electro-mechanical transfer function Gj, originally calculated in Q4*

Re-tune your gains to satisfy the RCGs.

Q14 2 mark(s) Step 9

Find G: Input = Control Signal (V) Output = Actual Rotor Ang (deg)

- Q14.G (deg/V) LTI

Q15 3 mark(s) Step 8a – Round 2

Tune the PID controller gains to satisfy the original RCGs and to **DUPLICATE THE RESPONSE** from Q12, as closely as possible. Normalize the gains so **Ki=1**.

- Q15.K (Vs/m) Scalar
- Q15.Kp (pure) Scalar
- Q15.Ki (pure) Scalar
- Q15.Kd (pure) Scalar

COW: *Plot the step responses from Q12 & Q15 on the same figure. Were you able to compensate for the added friction?*