ELEC 341 – p2

Project Part 2 – Controller
100 Marks

Required Files

Available on Canvas

- **e341-p2.pdf** *Project description (this document)*
- **p2Submit.p** *Grading script (**LATEST** version)*
- **e341-APE.pdf** *Instructions for submitting graded work (for reference)*

Topics

Controller Identifications
- overhead & filtering delay

Optimal Control
- phase margin

Heuristic Tuning
- performance metrics & RCGs

DESCRIPTION

A system model is shown in **Fig 4**.

- Task-Space coordinates are defined by **Desired Pos** and **Actual Pos**.
- **Desired Pos** (y_d) & **Actual Pos** (y_a) are the circumferential distance the gripper would travel **IF** the tine was infinitely stiff (even though it really isn't).
- The results from Part 1 may be used to solve the system model, all except for the controller model (G_c & H_c).

The controller parameters are shown in **Table 4**.

- The ISR runs at a control frequency **CF**.
- The duty-cycle of the micro-controller is **DC**. This accounts for total processing time, including all filter calculations.

The RCGs are shown in **Table 5**.

- The resolution of the Newtonian search used to optimize controller poles is specified by **MagRes** and **AngRes**.
- The target phase margin used to determine master gain is **TargPM**.
- After heuristic tuning, the required reduction in overshoot is OS_u.
- After heuristic tuning, the required reduction in settle time is T_s.
- After heuristic tuning, the response must not be over-damped ($T_r < T_s$).
- After heuristic tuning, the steady-state error must satisfy the required E_{ss}.

Begin with a unity gain, 0-order controller. In other words, $G_c = 1$.

Find the forward path gain: $G = x_4/x_2$ (see **Fig 4**)

Find the task→jnt transform: $K_{tj} = x_1/y_d$ (see **Fig 4**)

Find the jnt→task transform: $K_{jt} = y_a/x_4$ (see **Fig 4**)

11. 5 mark(s) Forward Path

- Q11.G (rad/V) LTI Object
- Q11.Ktj (rad/m) scalar
- Q11.Kjt (m/rad) scalar

Whether or not any filtering is done, any controller has delay associated with computations that take place during the duty-cycle, and holding the output signal for 1 control cycle.

Find the delay multiple N_{oh} that accounts for this overhead.

12. 5 mark(s) Delay Overhead

- Q12.Noh (pure) Scalar

Find the frequency of the most dominant pole $\mathbf{w_d}$ of **G**x**Hs**.

Find the maximum filter delay $\mathbf{N_f}$ for non-dominant controller FB dynamics.

For the purpose of finding $\mathbf{N_f}$, round $\mathbf{w_d}$ up to the nearest integer.

Find the corresponding **IIR** filter time constant **tau** and weighting factor **beta**.

Find the total delay **N**, which includes both the filter and overhead delay.

13. 10 mark(s) IIR Filter

- Q13.wd (rad/s) Scalar
- Q13.Nf (pure) Scalar
- Q13.tau (s) Scalar
- Q13.beta (pure) Scalar
- Q13.N (pure) Scalar

For an FIR filter with a **4τ** window, find the number of coefficients **NC**.

Find the normalized **FIR** filter coefficients **W**.

14. 10 mark(s) FIR Filter

- Q14.NC (pure) Scalar
- Q14.W (pure) 1x**NC** Vector

COW: *A 1st order LP FIR filter is easy to verify.*

If you have a **4τ** window: ***W(last) / W(1) ≈ 2%***

If you have a **5τ** window: *W**(last) / W(1) ≈ 1%***

Find controller feedback gain: $\mathbf{H_c = x_6/x_5}$ (see **Fig 4**)

Find feedback gain: $\mathbf{H\ = x_6/x_4}$ (see **Fig 4**)

15. 5 mark(s) Feedback Path

- Q15.Hc (rad/V) LTI Object
- Q15.H (pure) LTI Object

COW:

*What is the DC gain of **H** ??? What should it be ???*

*Do you expect **H** to resemble a 1st or 2nd order system ??? Under or Over-damped ???*

To compensate for FDD noise, use an **IIR** filter in the derivative path with a time constant ½ as large as the one used to filter sensor data in the feedback path.

Find the Partial Dynamics $\mathbf{D_p}$.

Find the initial gain for marginal stability $\mathbf{K_0}$ using the partial dynamics $\mathbf{D_p}$.

Find the cross-over frequency $\mathbf{w_{xo}}$.

16. 10 mark(s) Initial Gain

- Q16.Dp (pure) LTI Object
- Q16.K0 (Vs/m) Scalar
- Q16.wxo (rad/s) Scalar

COW*: Are GM & PM both 0 ??? Should they be ???*

Find optimal ω_n & ζ values to maximize phase margin **PM** using search resolution **WnRes** & **ZetaRes** shown in **Table 5**. Only search values rounded to the search resolution.

Find the associated zero(s) **Z** from the optimal ω_n & ζ values.

Find the full dynamics **D**.

17. 15 mark(s) Controller Zeros

- Q17.Z (rad/s) 1x2 Vector
- Q17.PM (deg) Scalar
- Q17.D (V/rad) LTI Object

Find the master gain **K** that delivers the **TargetPM** shown in **Table 5**.

18. 5 mark(s) Master Gain

- Q18.K (V/rad) Scalar

Find the **Reference** gains K_p, K_i, K_d , corresponding to unity master gain **K=1**.

19. 5 mark(s) Reference Gains

- Q19.Kp (pure) Scalar
- Q19.Ki (sec^{-1}) Scalar
- Q19.Kd (sec) Scalar

Find the **Reference** performance metrics, rise time T_r, peak time T_p, settle time T_s, and input overshoot OS_u.

20. 10 mark(s) Reference Performance Metrics

- Q20.Tr (sec) Scalar
- Q20.Tp (sec) Scalar
- Q20.Ts (sec) Scalar
- Q20.OSu (%) Scalar

Use heuristic tuning to satisfy the RCGs shown in **Table 5**. All RCGs are relative to the **Reference** performance metrics.

Find the **Tuned** gains K_p, K_i, K_d , corresponding to unity master gain **K=1**.

21. 10 mark(s) Tuned Gains

- Q21.Kp (pure) Scalar
- Q21.Ki (sec^{-1}) Scalar
- Q21.Kd (sec) Scalar

Find the **Tuned** performance metrics, rise time T_r, peak time T_p, settle time T_s, and input overshoot OS_u.

22. 10 mark(s) Tuned Performance Metrics

- Q22.Tr (sec) Scalar
- Q22.Tp (sec) Scalar
- Q22.Ts (sec) Scalar
- Q22.OSu (%) Scalar