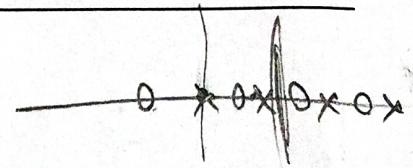


EE302-S2, Control Systems, Midsem Exam (26th Feb 2024)

Notes & instructions:

- Attempt all 7 questions: each question carries 10 marks. Unnecessarily long, convolved, redundant or irrelevant text could attract marks-reduction.
 - Root locus sketch means: (a) show real-axis segments, (b) direction of k changing from 0 to $+\infty$, for $k > 0$, (or, if explicitly sought for $k < 0$, from 0 to $-\infty$), (c) mark poles by \times and zeros by O , (d) calculate break-away and break-in point values and (e) classify the break-away/break-in points accordingly, (f) obtain angle of arrival/departure for every nonreal zero/pole, (g) asymptotes (if any): their angles and point of intersection: all these showing brief intermediate calculations. Make use of symmetry if sketching/calculating simplifies.
 - Unless otherwise explicitly specified, k is real and positive.
 - Some questions might not have the sought answer. In such a case, give reasons why the sought answer is not possible.
 - If you feel a question has ambiguity and/or needs clarification, then assume yourself appropriately, state and justify your assumption and then proceed to solve the problem with that assumption.
- Do not call any TA or instructor for your query.

Ques 1: Sketch the root-locus of $G(s) = \frac{1}{s(s+2)(s+4)(s+6)}$ for $k > 0$.



Ques 2: Sketch the root-locus of $G(s) = \frac{(s+1)}{(s^2+1)(s-1)}$ for $k > 0$.

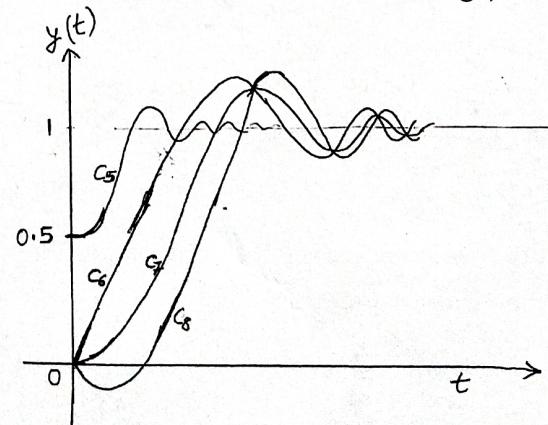
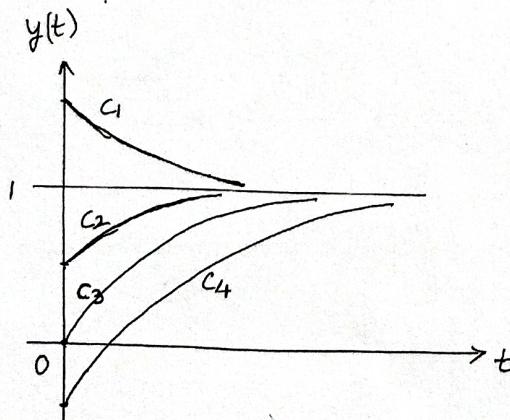
Ques 3: Sketch the root-locus of $G(s) = \frac{(s+1)(s-1)(s-3)(s-5)}{s(s-2)(s-4)(s-6)}$ for both $k > 0$ and $k < 0$.

Ques 4: Consider the 8 transfer functions below:

~~$$\frac{-s+5}{s^2+2s+5}, \quad \frac{1}{s+2}, \quad \frac{s-1}{s^2+2s+5}, \quad \frac{3s+2}{2s+2}, \quad \frac{5}{s^2+2s+5}, \quad \frac{-s+3}{3s+3}, \quad \frac{s+1}{s^2+2s+5}, \quad \frac{s+2}{2s+2}.$$~~

(a) Obtain initial rise rate $\dot{y}(0^+)$ for each of the transfer functions' step-response: all eight of them.

Below are 8 plots of step responses $y(t)$. (Note: curve C_5 satisfies: initial rate of change, i.e. $\dot{y}(0^+)$, is 0.)



(b) Match transfer functions to their step-responses, if its step response is shown.

(c) If a response is unmatched to any of the given transfer functions, then suggest a transfer function having same characteristics (like initial value, initial rise rate, underdamped/overdamped, final value).

Ques 5: Consider the step response of the 2nd order system $G(s) = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$.

(a) Plot curves C_1, C_2, C_3, C_4 and C_5 , within the same figure, with:

- C_1 : curve along which % Over-Shoot (OS) is constant, C_2 : curve along which 2% settling time T_s is constant,
 C_3 : curve along which peak time T_p is constant, C_4 : curve along which natural frequency ω_n is constant,
 C_5 : curve along which damped frequency ω_d is constant.

(Please cross-check that C_i are labelled exactly as above.)

(b) Describe how T_s changes along any three of the curves C_1, \dots, C_5 ,

(c) Describe how T_p changes along any three of the curves C_1, \dots, C_5 ,

(d) Describe how % OS changes along any three of the curves C_1, \dots, C_5 ,

(e) Describe how rise-time T_r changes along any three of the curves C_1, \dots, C_5 .

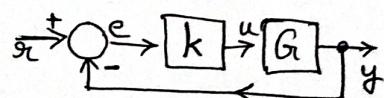
(Describing how a variable 'changes' means specifying whether the variable 'increases/decreases/remains-constant' along the curve.)

Ques 6: Use root-locus method to calculate value of k , if it exists, such that $d(s) + kn(s)$ has roots such that the roots correspond to poles resulting in the step response having:

- (a) 2% overshoot, and $T_s \leq 2$ s, with $d(s) = s^2 + 3s + 2$, $n(s) = 1$.
- (b) 2% overshoot, and $T_s \leq 1$ s, with $d(s) = s^2 + 3s + 2$, $n(s) = 1$.
- (c) 2% overshoot, $T_s \leq 1$ s, and $T_p = 2s$, with $d(s) = 3s + 2$, $n(s) = 1$.

(T_s and T_p as defined in Question-5. Non-use of root-locus method would fetch less marks.)

Ques 7: Consider the standard negative unity feedback configuration as shown beside, with r the unit step input.



Sketch the steady state error $e(\infty)$ (when it exists) as a function of k (with k varying from $-\infty$ to $+\infty$) for $G(s)$ being the following transfer functions.

- (a) $G(s) = \frac{5}{s+5}$, (b) $G(s) = \frac{s-5}{s+5}$, (c) $G(s) = \frac{s+5}{s-5}$.