EE302-S1, Control Systems, Midsem Exam (24th Feb 2025)

Notes & instructions: read these very carefully and then read all questions before starting to attempt:

- Attempt all questions: each question carries 10 marks. Unnecessarily long, convolved, redundant or irrelevant text could attract marks-reduction. Show intermediate steps briefly for all calculations.
- Root locus sketch means: (a) show real-axis segments, (b) direction of k changing from 0 to $+\infty$, for $k > 0$, (c) mark poles by $\times$ and zeros by O, (d) calculate break-away and break-in point values and classify the break-away/break-in points accordingly, (e) obtain angle of arrival/departure for every nonreal zero/pole, (f) asymptotes (if any): their angles and point of intersection, (g) $j\mathbb{R}$ axis intersection point(s) and corresponding k value(s); all these showing brief intermediate calculations. Make use of symmetry if sketching/calculating simplifies.
- Unless otherwise explicitly specified, k is real and positive, and feedback configuration is always the standard negative unity feedback configuration, with constant gain k in the forward path and also the open loop transfer function $G(s)$ in the forward path.
- 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 solve the problem with that assumption. Do not call any TA or instructor for your query.

Ques 1: Sketch the root-locus of $G(s) = \dfrac{1}{s(s+3)(s+4)(s+1)}$ for $k > 0$.

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

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

Ques 4: Sketch four plots (of four step-responses) within the same figure. While exact values in the plot need not be to scale, plots are supposed to be qualitative as follows.

(a) relative values of % over-shoot, and steady state error

(b) initial value and initial rise-rate: whether zero, positive or negative,

(c) whether there are oscillations or not,

The transfer functions: (i) $\dfrac{s+5}{s^2+2s+6}$, (ii) $\dfrac{5}{s^2+2s+6}$, (iii) $\dfrac{2s+5}{s^2+2s+6}$, (iv) $\dfrac{s+5}{2s+6}$.

(Show clearly in your plots which is (i), ..., (iv). Numerical values of rise-rate: not needed to be calculated.)

Ques 5: Suppose the open loop transfer function is $G(s) = \dfrac{(s-z)}{s^2+5s+4}$ and the step response of the closed loop is required to have %OS and 2% settling time as 4.3213918% and 1 second respectively.

(For this problem, ignore that a zero can cause a change in the %OS.)

(a) Where should the closed loop poles lie for the desired specifications?

(b) Using root-locus techniques, and in particular, the angle-condition for a point s_0 to be on the root-locus, calculate the value of z such that the closed loop requirements are met.

(c) Obtain (approximately) the value of k that results in the desired closed loop poles.

Ques 6: Use Routh Hurwitz criteria to get a count of number of OLHP, $j\mathbb{R}$ and ORHP roots of the polynomial $s^5 + 2s^4 + 3s^3 + 6s^2 + 5s + 3$.

Ques 7: Suppose the open loop transfer function is $G(s) = \frac{1}{(s+1)(s+2)(s+3)}$. For the standard negative unity feedback configuration, and the reference signal $r(t)$ being the unit step input, plot the error $e(\infty)$ as a function of k for positive k.

Ques 8: For a certain polynomial $p(s)$, the Routh table is shown.

Note:

The following two operations have been done on some rows.

(i) multiplying an entire row by a positive constant,

(ii) entire row zero, if any: appropriate derivative's coefficients have been used for proceeding further.

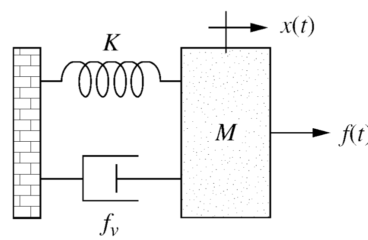
s^8	1	12	39	48	20
s^7	1	22	59	38	
s^6	-10	-20	10	20	
s^5	20	60	40		
s^4	1	3	2		
s^3	2	3			
s^2	3	4			
s	1				
1	4				

(a) Write the monic polynomial $p(s)$, for which this is the Routh table. Is any non-uniqueness in $p(s)$ possible, give reasons.

(b) If $p(s)$ has an odd or an even polynomial as a factor, write that polynomial giving reasons. If not, give reasons.

(c) Obtain number of ORHP roots, $j\mathbb{R}$ roots, and OLHP roots for $p(s)$. Give justification for your answer.

Ques 9: Consider the the spring mass damper system shown in which the applied force $f(t)$ is the input and the position $x(t)$ is the output. Assume that the displacement $x(t)$ is zero when the force is zero and all the system components are 'at rest' at $x = 0$.



(The spring constant is K, the damper/dashpot's parameter is f_v, and M is the mass: all in SI units.)

(a) Write the differential equation governing the system.

(b) Find the transfer function from f to x (assuming all initial conditions are zero.)

(b) Write an equivalent RLC circuit in which the force f is the input current source, and set up the analogy, and show calculations to conclude that the equations of the RLC circuit are same as the spring/mass/damper equations of (a) above.

(c) Write an equivalent RLC circuit in which the force f is the input voltage source, and do the rest same as in (b) above.