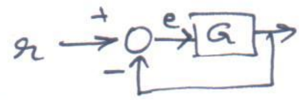
Tutorial 3 . EE302 Control Systems 20th Feb 2020.

Q-1 Consider  y. Assume (in this problem) closed loop is stable.

consider inputs: step, ramp, parabolic inputs.

· For type 0, type 1, type 2 systems, obtain steady state error (for each of the 3 inputs.)

	type 0	type 1	type 2
step			
ramp			
parabolic			

Q-2: Suppose G above is

$$\frac{K}{s^3+4s^2+2s+9}$$

Find range of K for closed loop stability using Routh Hurwitz table.

Q-3: Suppose G (in Prob 1) is $\dfrac{k}{(s^2+s+1)(s+5)}$.

(a) Find range of K for closed loop stability.

(b) Approximate G by a 2nd order system $\tilde{G}$ (but same position constant) and for $\tilde{G}$ obtain range of K for closed loop stability.

Q-3: Routh-Hurwitz table.

(a) Find number of OLHP/ORHP/ $j\mathbb{R}$ roots of $3s^7+9s^6+6s^5+4s^4+7s^3+8s^2+2s+6$.

(b) Deduce with reason just Hurwitz or not-Hurwitz (without Routh-Hurwitz table) & then with the table for $s^7-6s^6+3s^5+3s-10$ (at least 2 diff. reasons).

(c) For $s^5+2s^4+3s^3+6s^2+5s+3$, find OLHP, ORHP, $j\mathbb{R}$ breakup using ϵ-method & reciprocal polynomial (reverse coefficients).

(d) Find OLHP, ORHP, $j\mathbb{R}$ breakup for $(s^5+7s^4+6s^3+42s^2+8s+56) = p(s)$ and also for $s\,p(s)$ → with & without extracting s as a factor. (entire row is zero at some stage.)

Q-4: For $s^6+s^5-6s^4-s^2-s+6 =: p(s)$

split $p(s)$ into $P_{even}(s) + P_{odd}(s) = P_{higher} + P_{lower}$ (say).

Perform successive division of P_{higher} by P_{lower} to see that we get Routh-Hurwitz table exactly.

Swap: (P_{higher} → P_{even}, P_{lower} → P_{odd})

Q-5: For the polynomial

$$(2.04+6q_1+6q_2+2q_1q_2)+s(q_1+q_2+2)+s^2(q_1+q_2+2)+s^3$$

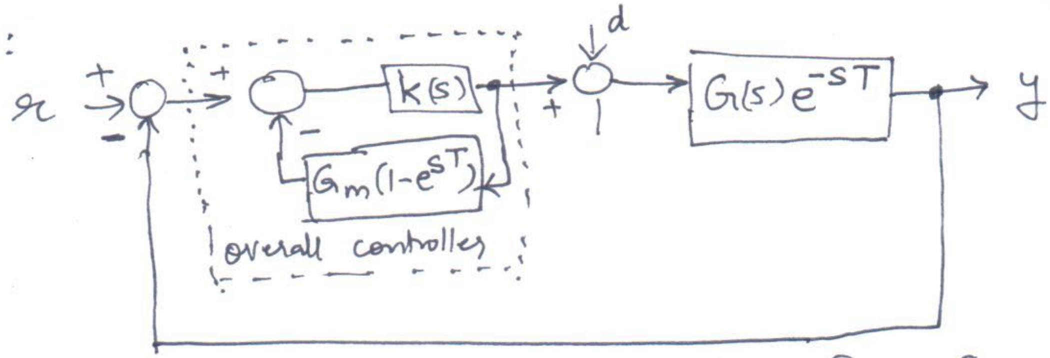
sketch the stable region in the q_1, q_2 parameter space.

Q-6: Can $(1+s+se^{-s})=0$ have a root in the RHP?

Justify using proper arguments. (This is called "transcendental equation" & arises due to pure-delays)

Q-7: Pure delays in the system are eliminated in the closed loop using "the Smith predictor" making controller design easier. Consider the following configuration (proposed by O.J. Smith in 1959.)

Q-7 contd:

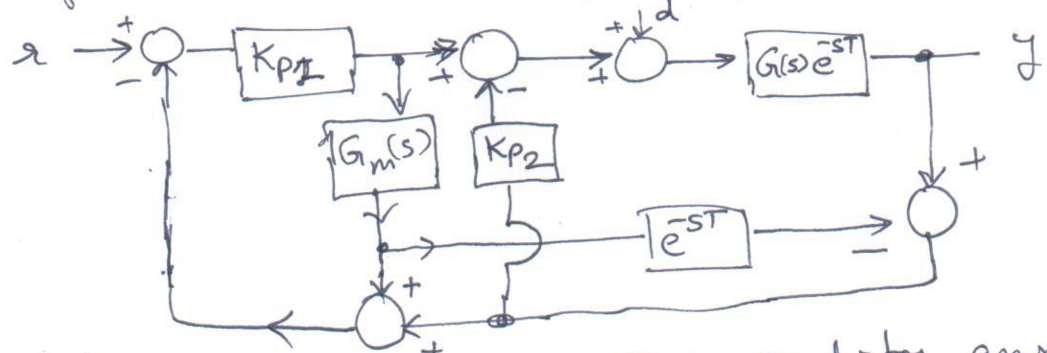


e^{-sT} ≡ pure delay of time T. Smith predictor: $G_m = G$

(a) Show that if $G(s)$ is of type 0, then $K(s) = K_p + \frac{K_I}{s}$ results in zero steady state error to step input and also rejects constant disturbance d. (Assume closed loop is stable.).

(b) Will the above setup work if the system is of type 1. ?

(c) Modified Smith predictor ($G_m = G$)



Show that the above modified Smith predictor ensures constant disturbance rejection & perfect tracking for $D(s) = \frac{1}{s} = R(s)$ when G is type 1 plant. (Assume closed loop is stable.).

Q-8: Root locus: For following examples, draw root locus and find (if relevant) (a) Breakaway/breakin point, corresponding k value,

(b) $j\mathbb{R}$ crossing ω value & relevant K value,

(c) Real axis segments,

(d) Range of K (within $[0,\infty)$) to have stability

(e) Asymptotes angles, intersection

$$\frac{(s+1)(s+3)}{(s+2)(s+4)}, \quad \frac{(s+1)(s+3)}{(s+4)(s+6)}, \quad \frac{\omega_n s}{s^2+\omega_n^2}, \quad \frac{(s-1)(s-2)}{(s+3)(s+4)}$$

Q-9: Find gain k to have 15% OS for following open loop systems:

$$\frac{1}{s(s+2)}, \quad \frac{1}{(s+0.01)(s+2)}, \quad \frac{s+1}{(s+4)(s+2)}.$$

For that k value, find steady state error for step input.

Q-10 For above transfer functions (Q-9), find value of K that gives 10 seconds settling time (for step input).

Q-11: Consider $d(s) + k\,n(s)$. Show that condition on k for repeated root in s is same as that for breakaway/breakin