University of Jordan
Elect. Eng. Dept.
First Exam
Reg. No. 0140754
(19)

Control Systems 903441
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**Answers should be written in ink**

Wednesday 15/3/2017
Mark out of 20
**Exam Duration: 50 mi**

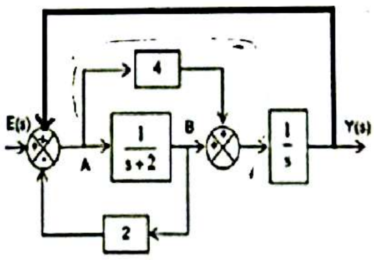
15

**Q1 a)** Consider the following systems with present day design. Classify them as **open loop** or **closed loop** stating the **type of feedback** if the system is closed loop and any **appreciable** parameter variations and external disturbances if applicable . Feel free to express your ideas in **Arabic** if you wish.

| System | Open or closed loop? | Type of feedback +ve or -ve | Parameter variations | External disturbances |
|---|---|---|---|---|
| Microwave ovens | open loop | No feedback | waves in the microwave, | Electric short, |
| Two angry persons arguing | closed loop | +ve ~~feed~~ | Shouting, ~~[illegible]~~ ~~around them~~ Temper, | People around, The mood of the place, ~~[illegible]~~ |
| Most read article المقال الاكثر قراءة | Closed loop | +ve | المزاج سرعة الغضب | |

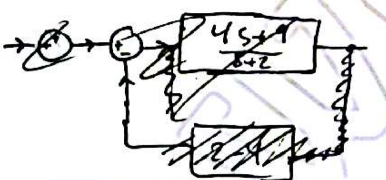
3

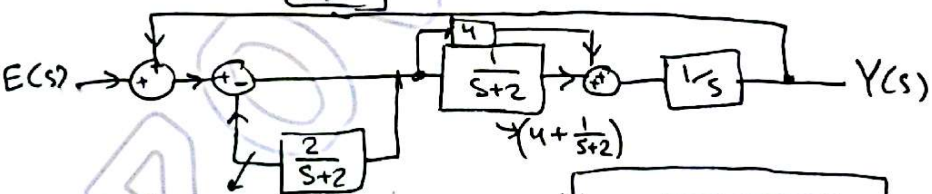
b) Given the diagram shown, use block diagram reduction techniques to determine $Y(s)/E(s)$. Hence, calculate the poles and zeros of the overall system.



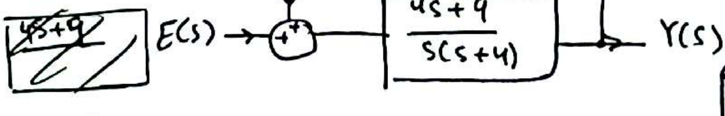

$4+\frac{1}{s+2}$

$\frac{4s+9}{s+2}$




$\frac{1}{1+\frac{2}{s+2}}$




$$\frac{Y(s)}{E(s)} = \frac{\frac{4s+9}{s(s+4)}}{1-\frac{4s+9}{s(s+4)}}$$

$$\boxed{\frac{Y(s)}{E(s)} = \frac{4s+9}{s^2-9}}$$

~~Poles of the system~~

$$\frac{4s+9}{(s-3)(s+3)} \rightarrow \boxed{\begin{matrix} P_1 = 3 \\ P_2 = -3 \end{matrix}}$$ Poles of the system

zero $= -\frac{9}{4}$

3.5

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$u(t) - 5e^{-5t} t u(t) - e^{-5t}$

**Q2** A system is given by the following transfer function $G(s) = \frac{25}{s^2+10\zeta s+25}$.

I) Calculate the unit step output response when the system is **critically damped**.

$\zeta = 1 \quad G(s) = \frac{25}{s^2+10s+25}$

$\omega_n = 5$

$C(s) = \frac{1}{s} \cdot G(s)$

$\boxed{C(s) = \frac{25}{s^3+10s+25s}}$

$c(t) = \int_0^t 25 e^{+5t} t - 100 e^{+5t} \, dt$

$\frac{25}{(s-5)^2}$

$B = \lim_{s\to 5} \frac{d}{ds} \frac{25}{s(s-5)^2} (s-5)$

$\frac{A}{(s+5)^2} + \frac{B}{(s+5)} \longrightarrow A = 25 \quad + \frac{C}{S}$

$B = -100$

II) Calculate the unit step output response when $\zeta = 0.6$ **by any method** you know of.

$\zeta = 0.6 \quad \omega_n = 5$

$c(t) = \left[1 - \frac{e^{-\zeta\omega_n t}}{\sqrt{1-\zeta^2}} \sin(\omega_d t + \cos^{-1}\zeta)\right] \cdot u(t)$

$\boxed{c(t) = \left[1 - \frac{5}{4} e^{-3t} \sin(4t + 53.13^\circ)\right] \cdot u(t)}$

$\zeta\omega_n = 3$

$\sqrt{1-\zeta^2} = \frac{4}{5}$

$\omega_d = 4$

$\omega_n \sqrt{1-\zeta^2}$

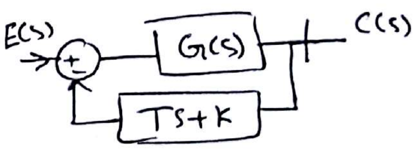
2.5

III) In order to slow down the output response when $\zeta = 0.6$, a controller is needed to get a new system with settling time of 2 units and a damping ratio of 0.7, and a steady state output of 3 units. Design such a controller.

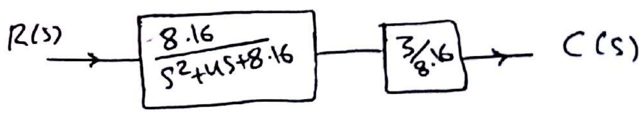
$T_s = 2, \quad \zeta = 0.7 \quad C_{ss} = 3, \quad \omega_n = 2.857$

$T_s = \frac{4}{\zeta\omega_n}$

$G(s) = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2} = \frac{8.16}{s^2 + 4s + 8.16}$




$= \frac{3}{s^2}$




K ?
T ?

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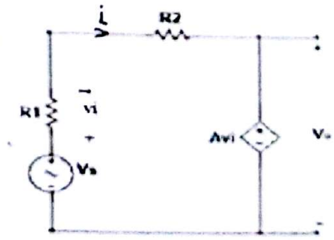
**Q3** Consider the circuit shown. Represent it with the forward transfer function **G** being **A** only. What is the feedback network **H** in this case? Hence, determine $v_o(s)/v_s(s)$.




$V_o = AV_i$

$V_i = IR_1$

$I = \frac{V_s - V_o}{R_1+R_2}$

$V_o = AR_1\left(\frac{V_s - V_o}{R_1+R_2}\right)$

$= \frac{AR_1V_s}{R_1+R_2} - \frac{AR_1V_o}{R_1+R_2}$

$V_o\left(1 + \frac{AR_1}{R_1+R_2}\right) = \frac{AR_1V_s}{R_1+R_2}$

$V_o(R_1+R_2+AR_1) = AR_1V_s$

$\frac{V_o}{V_s} = \frac{AR_1}{R_1+R_2+AR_1}$

$= \frac{A}{1 + \frac{R_2}{R_1} + A}$

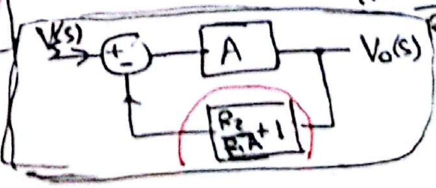
$\frac{G}{1+GH}$

$\frac{A}{1+AH}$

$\frac{R_2}{R_1} + A = AH$

$\boxed{H(s) = \frac{R_2}{R_1A} + 1}$

$H = \frac{R_2}{R_1A} + 1$

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