Kafrelsheikh University
Faculty of Engineering
Electrical Engineering Department
Model Answer-Final Exam, 2017/2018
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3rd Year (Electrical Engineering)
Automatic Control (2)
Time: 180 minutes
Marks= 90
Date: 31-12-2017

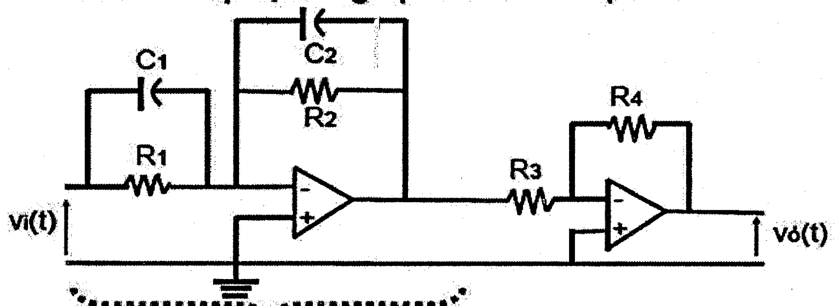
Answer all the following questions:

Intended learning outcomes (ILOs): [a1, a4, a12 , b2, b6, b11, b12, b14, c3,c14]

Problem 1: (35 Marks) - - **(ILOs):** [a1, a12, b2, b6, c3]

a) Construct the configuration of the electronic lag compensator using operational amplifiers and drive the transfer function of the compensator. (10 Marks)

- **One example, using operational amplifiers**

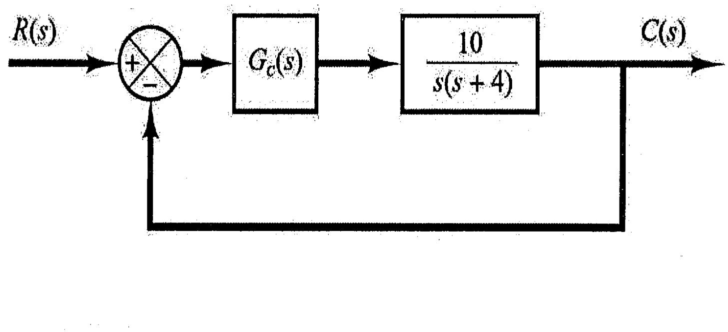


$$\frac{R_2}{R_1}\cdot\frac{R_1C_1s+1}{R_2C_2s+1}$$

- **Transfer function**

$$C(s)=\frac{V_o(s)}{V_i(s)}=\frac{\dfrac{\frac{R_2}{C_2s}}{R_2+\frac{1}{C_2s}}}{\dfrac{\frac{R_1}{C_1s}}{R_1+\frac{1}{C_1s}}}\cdot\frac{R_4}{R_3}=\underbrace{\frac{R_4C_1}{R_3C_2}}_{K}\;\frac{s+\overbrace{\frac{1}{R_1C_1}}^{z}}{s+\underbrace{\frac{1}{R_2C_2}}_{p}}$$

b) Design a lag compensator for following unity feedback system such that the static velocity error constant is 50 sec^{-1} without appreciably changing the closed loop poles, which are at $s=-2\pm j\sqrt{6}$. **(15 Marks)**



Solution. Assume that the transfer function of the lag compensator is

$$G_c(s) = \hat{K}_c \frac{s + \frac{1}{T}}{s + \frac{1}{\beta T}} \qquad (\beta > 1)$$

Since K_v is specified as 50 sec^{-1}, we have

$$K_v = \lim_{s \to 0} sG_c(s)\frac{10}{s(s+4)} = \hat{K}_c\beta 2.5 = 50$$

Thus

$$\hat{K}_c\beta = 20$$

Now choose $\hat{K}_c = 1$. Then

$$\beta = 20$$

Choose $T = 10$. Then the lag compensator can be given by

$$G_c(s) = \frac{s + 0.1}{s + 0.005}$$

The angle contribution of the lag compensator at the closed-loop pole $s = -2 + j\sqrt{6}$ is

$$\left. \angle G_c(s) \right|_{s=-2+j\sqrt{6}} = \tan^{-1}\frac{\sqrt{6}}{-1.9} - \tan^{-1}\frac{\sqrt{6}}{-1.995}$$
$$= -1.3616°$$

which is small. Thus the change in the location of the dominant closed-loop poles is very small.

The open-loop transfer function of the system becomes

$$G_c(s)G(s) = \frac{s + 0.1}{s + 0.005}\frac{10}{s(s+4)}$$

The closed-loop transfer function is

$$\frac{C(s)}{R(s)} = \frac{10s + 1}{s^3 + 4.005s^2 + 10.02s + 1}$$

c) Draw the bode diagram of the following transfer function:

$$G(j\omega) = \frac{5(1 + j0.1\omega)}{j\omega(1 + j0.5\omega)(1 + j0.6\frac{\omega}{50} + \left(\frac{j\omega}{50}\right)^2)}$$

After plotting Bode diagram evaluate the gain margin and the phase margin of the system and Comment on the stability of the system whose Bode diagram. **(10 Marks)**