SPRING 2007
TEST 1
50 MINUTES

NDU
ECCE DEPARTMENT
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75/100

NAME: [redacted]

NOTE1: OPEN BOOK, OPEN NOTES, CLOSED OLD TESTS AND SOLUTONS.
NOTE2: SHOW ALL WORK IN ORDER TO RECEIVE FULL CREDIT.

1. 30 Pts. Find the transfer function for Y(s)/R(s) for the idle speed control system for a fuel injected engine as shown in Fig.P1.

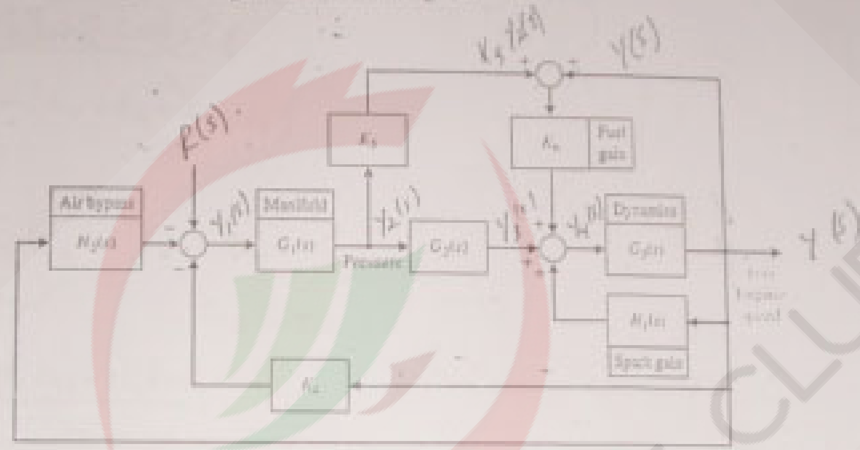
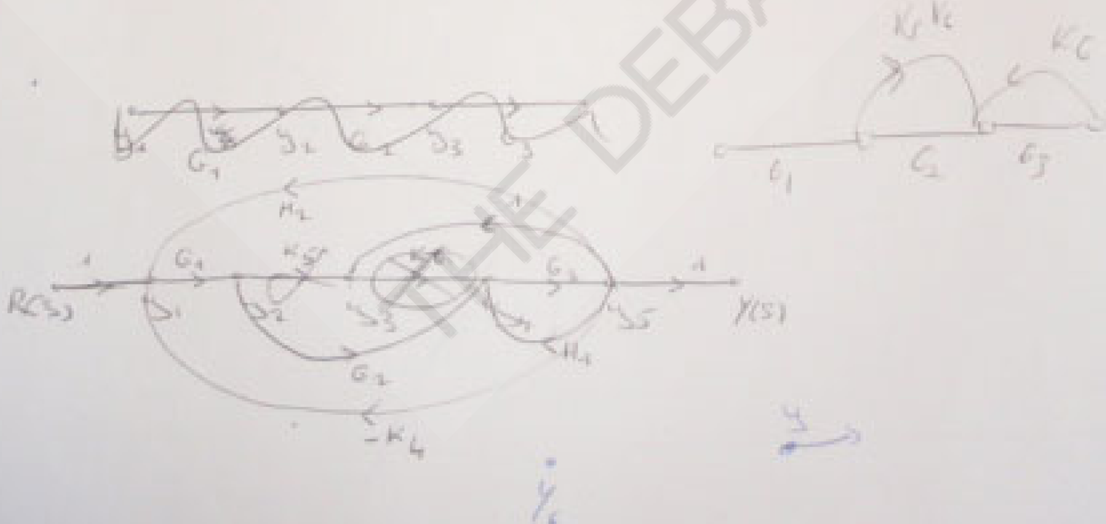


Fig.P1.



$\frac{Y(s)}{R(s)}$

Δ with

Loops: $-K_4 G_1 K_5 K_6 G_3$ (L_1)

$K_6 G_3$ (L_2)

$G_3 H_1$ (L_3)

$-G_1 K_5 K_6 G_3 H_2$ (L_4)

$-G_1 G_2 G_3 H_2$

$-G_1 G_2 G_3 K_4$

~~2 Non touching loops~~

$\Delta = 1 - (L_1 + L_2 + L_3 + L_4)$

$M_1 = G_1 K_5 K_6 G_3$ $\Delta_1 = 1$

$M_2 = G_1 G_2 G_3$ $\Delta_2 = 1$

$$\frac{Y(s)}{R(s)} = \frac{M_1 \Delta_1 + M_2 \Delta_2}{\Delta}$$

10

2. 35 Pts. A bridged-T network is often used in AC control systems as a filter network. The circuit of one bridged-T network is shown in Fig.P4. Show that the transfer function of the network is of the form:

$$\frac{V_o(s)}{V_i(s)} = \frac{1 + K_1 s + K_2 s^2}{1 + (2\alpha + \beta)Cs + K_2 s^2}$$

a) Find, K_1, K_2, α, and β.

b) Draw the pole-zero diagram when $R_1 = 0.5$, $R_2 = 1$, and $C = 0.5$.

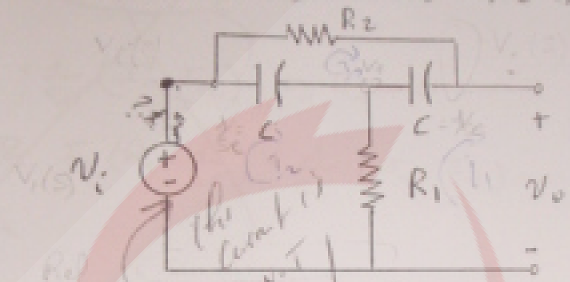


Fig.P4.

Needed

Nodal analysis

At node $V_o(S)$: $\frac{V_o(S) - V_i(S)}{R_2} + \frac{V_o(S) - V_1(S)}{1/SC} = 0 \Rightarrow V_o\left(\frac{1}{R_2} + SC\right) - \frac{V_i}{R_2} - S\ldots$ ①

At node $V_1(S)$: $\frac{V_1 - V_i}{1/SC} + \frac{V_1}{R_1} + \frac{V_1 - V_o}{1/SC} = 0$ ②

At node $V_i(S)$: $\frac{V_i - V_o}{R_2} + \frac{V_i - V_1}{1/SC} = 0$

$V_i\left(\frac{1}{R_2} + SC\right) - \frac{V_o}{R_2} - SCV_1 = 0$ ③

All you need

① and ③

① − ③ $\Rightarrow V_o\left(\frac{1}{R_2} + SC\right) - \frac{V_i}{R_2} - V_i\left(\frac{1}{R_2} + SC\right) + \frac{V_o}{R_2} = 0$

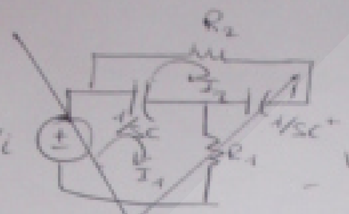
$V_o\left(\frac{1}{R_2} + SC + \frac{1}{R_2}\right) = V_i\left(\frac{1}{R_2} + \frac{1}{R_2} + SC\right)$

② $\Rightarrow V_1\left(SC + \frac{1}{R_1} + SC\right) - SCV_i - SCV_o = 0$

$V_1\left(2SC + \frac{1}{\ldots}\right) \ldots SCV\ldots$

$\times(2)$ $V_o\left(\frac{1}{R_2}+SC\right)-\frac{V_i}{R_2}-SCV_1=0$ ① ok!

$-SCV_o-SCV_i+V_1\left(2SC+\frac{1}{R_1}\right)=0$ ② ok!



$-V_i+\frac{1}{SC}(I_1-I_2)+I_1R_1=0$

$I_2\left(R_2+\frac{1}{SC}\right)+\frac{1}{SC}(I_2-I_1)=0$

① $\times\left(2SC+\frac{1}{R_1}\right) \Rightarrow V_o\left(2SC^2+\frac{SC}{R_1}+\frac{2SC}{R_2}+\frac{1}{R_1R_2}\right)-V_i\left(\frac{2SC}{R_2}+\frac{1}{R_1R_2}\right)-\ldots=0$

② $\times(SC) \Rightarrow -(SC)^2V_o-(SC)^2V_i$

① + ② $\Rightarrow V_o\left(2SC^2+SC\left(\frac{1}{R_1}+\frac{2}{R_2}\right)+\frac{1}{R_1R_2}\right)-V_i\left(SC^2+\frac{2SC}{R_2}+\frac{1}{R_1R_2}\right)$

$$\frac{V_o}{V_i}=\frac{SC^2+\frac{2SC}{R_2}+1/R_1R_2}{2SC^2+CS\left(\frac{1}{R_1}+\frac{2}{R_2}\right)+1/R_1R_2}=\frac{1+R_1R_2S^2C^2+2SCR_1}{1+2S^2C^2R_1R_2+SC(R_2+2R_1)}$$ ✓

$K_1=2R_1C$

$K_2=R_1R_2C^2$

$\alpha=2R_1$

$\beta=R_2$

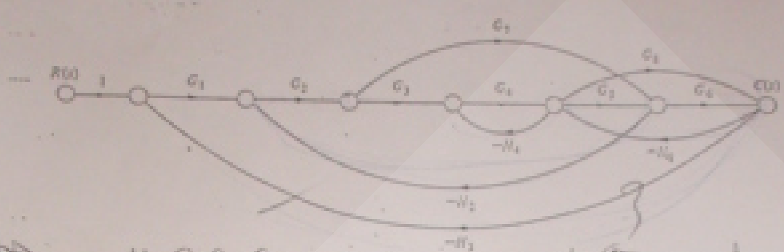
ok

$\Rightarrow \frac{V_o}{V_i}=1+0.5SC^2+$

25

$$\frac{V_o}{V_i}=\frac{1+2CR_1S+C^2R_1R_2S^2}{1+CS(2R_1+R_2)+S^2(C^2R_1R_2)}$$

3. 35 Pts. For the following signal-flow graph, find C(s)/R(s). (Hint: there are 8 loops).



Loops:

$-H_5G_1G_2G_3G_4G_5G_6$ (L_1)

$-H_2G_2G_3G_4G_5$ (L_2)

$-H_4G_4$ (L_3)

$-H_1G_5G_6$ (L_4)

$-H_3G_1G_2G_7G_6$ (L_5)

$-H_2G_2G_7$ (L_6)

$-H_1G_8$ (L_7)

$-H_3G_1G_2G_3G_4G_8$ (L_8)

2 non touching loops

$(-H_4G_4, -H_2G_2G_7)$ (L_3, L_6)

$(-H_4G_4, -G_1G_2G_7G_6H_3)$ (L_3, L_5)

$-G_8H_1 - G_2G_7H_2$

$$\Delta = 1 - (L_1+L_2+L_3+L_4+L_5+L_6+L_7+L_8) + (L_3L_6 + L_3L_5)$$

$$\frac{C(s)}{R(s)} = \frac{M_1\Delta_1 + M_2\Delta_2 + M_3\Delta_3}{\Delta}$$

$M_1 = G_1G_2G_3G_4G_5G_6$ $\quad \Delta_1 = 1$

$M_2 = G_1G_2G_7G_6$ $\quad \Delta_2 = 1 + H_4G_4 = 1 - L_3$

$M_3 = G_1G_2G_3G_4G_8$ $\quad \Delta_3 = 1$