

$$\begin{cases} e_b = k_b \omega_m \\ \tau_m = k_m i_a \end{cases}$$

① KVL: $V_a = R i_a + L \dot{i}_a + e_b$

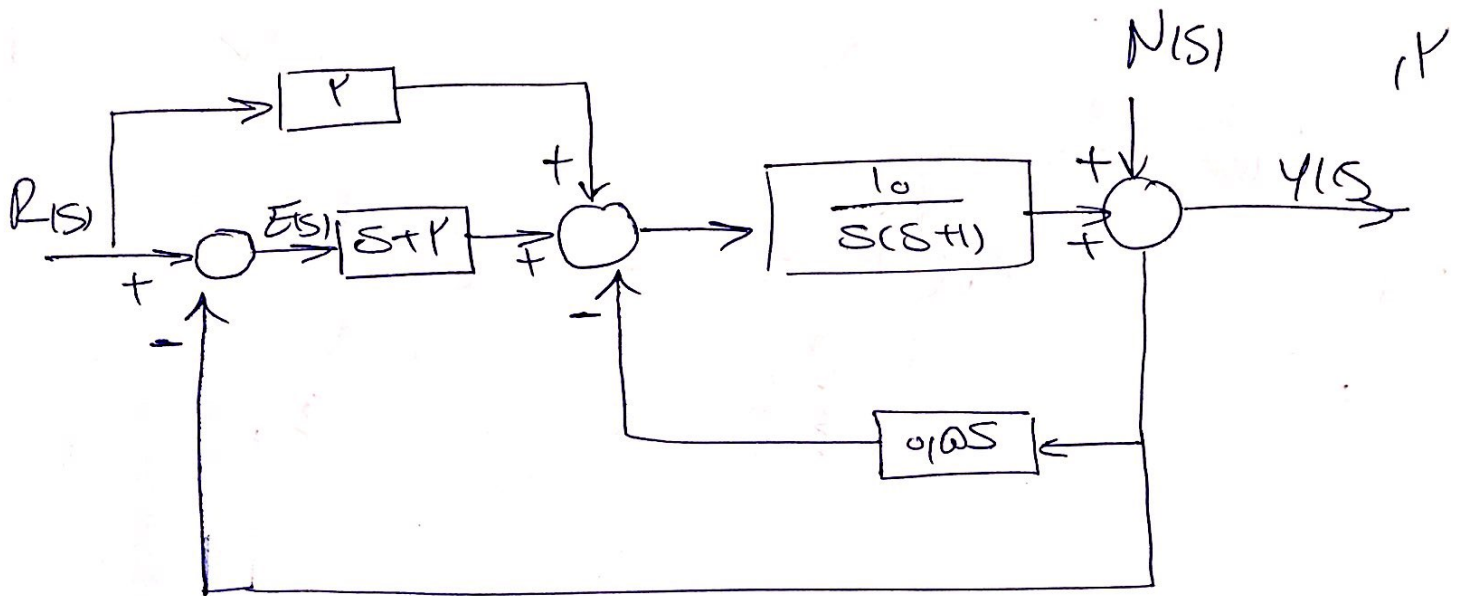
First principles:
$$\begin{cases} \tau_m - k(\theta_{mr} - \theta_{m1}) = J_0 \ddot{\theta}_{m1} \\ -\tau_L + k(\theta_{mr} - \theta_{m1}) = J_1 \ddot{\theta}_{mr} \end{cases}$$

LTI سیستم $\xrightarrow{L(s)}$

$$\begin{cases} V_a = (R + sL) I_a + k_b s \theta_{m1} & \text{I} \\ s^2 J_0 \theta_{m1} = k_m I_a - k \theta_{mr} + k \theta_{m1} & \text{II} \\ -\tau_L = -s^2 J_1 \theta_{mr} + k \theta_{mr} - k \theta_{m1} & \text{III} \end{cases}$$

II, $\Rightarrow \theta_{m1} = \frac{k_m I_a - k \theta_{mr}}{s^2 J_0 - k}$

III, $\Rightarrow \tau_L = (k - s^2 J_1) \theta_{mr} - k \frac{(k_m I_a - k \theta_{mr})}{s^2 J_0 - k}$

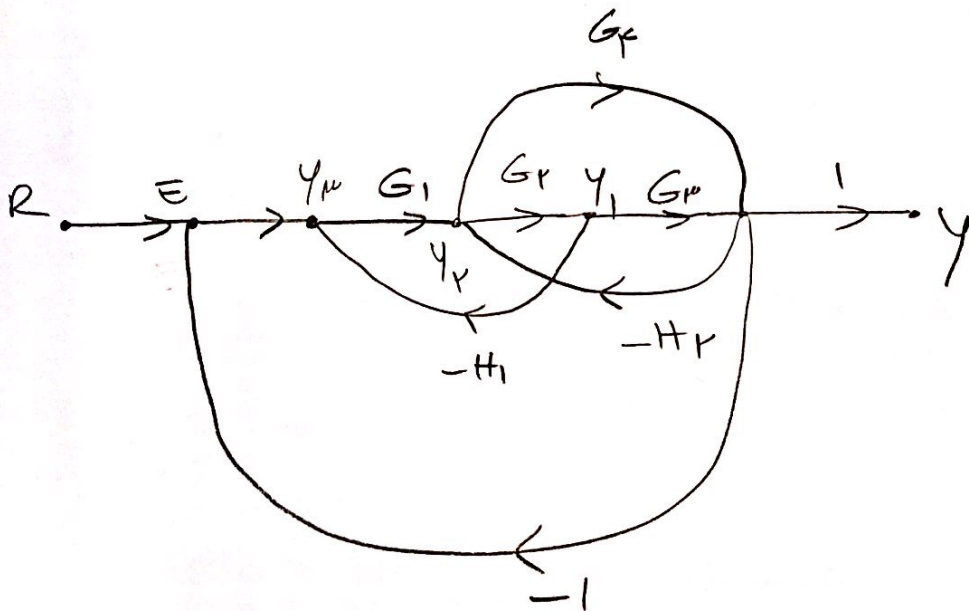
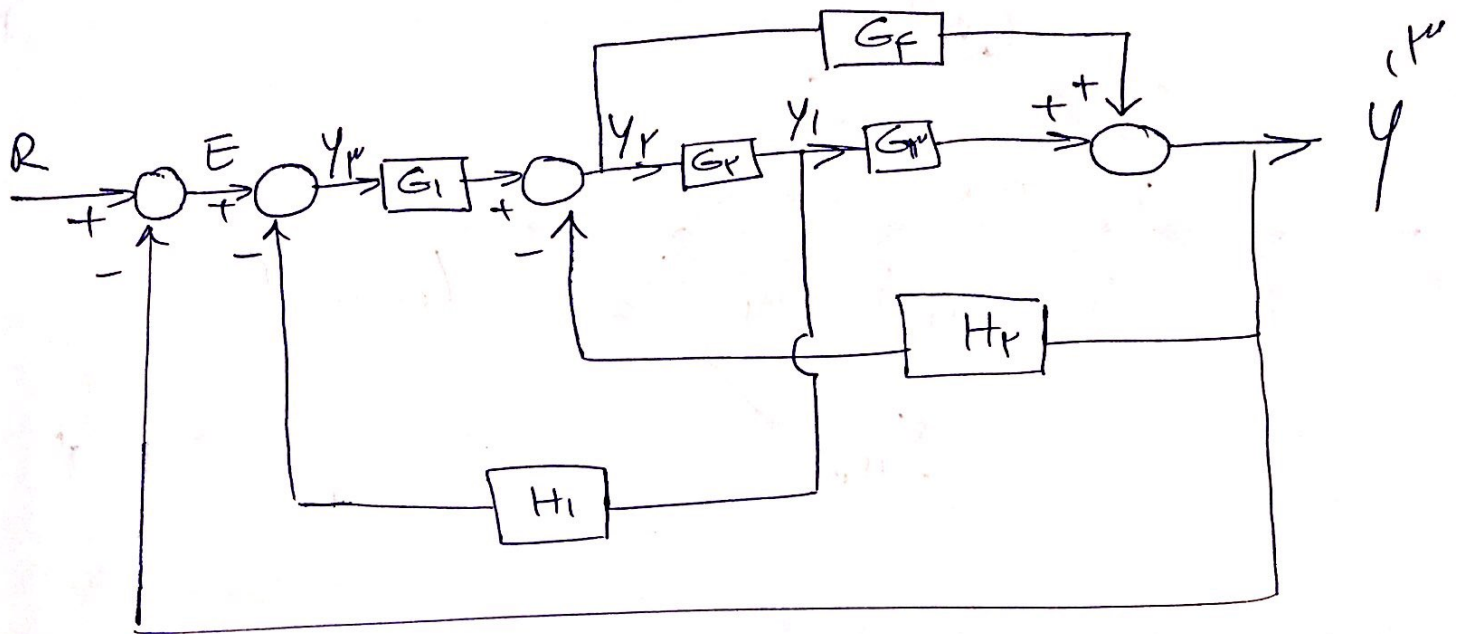


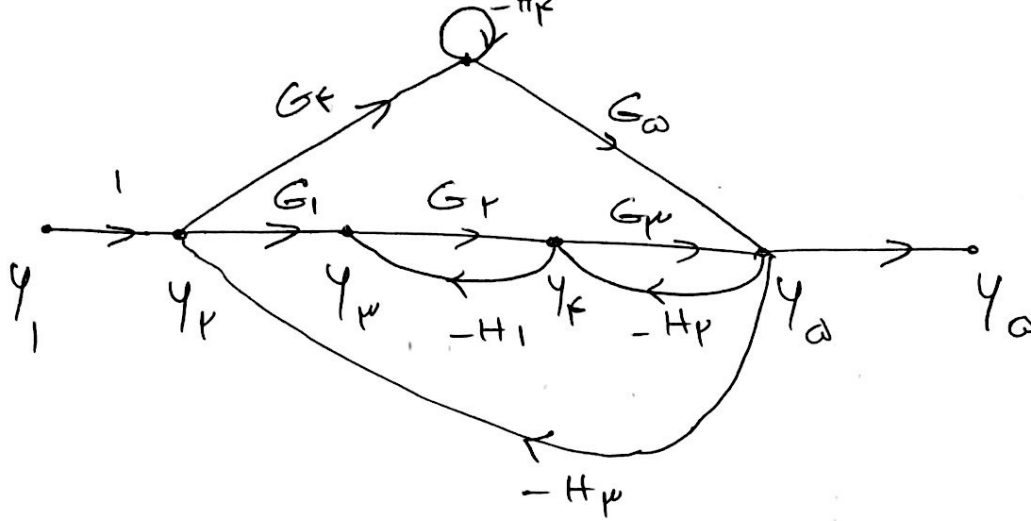
$$(a) \left. \frac{Y(s)}{R(s)} \right|_{N=0} = \frac{\frac{10(s+K)}{s(s+1)}}{1 + \frac{0.1s}{s(s+1)} + \frac{10(s+K)}{s(s+1)}} = \frac{10(s+K)}{s^2 + 1.1s + K_0}$$

$$(b) \left. \frac{Y(s)}{E(s)} \right|_{N=0} = \frac{Y(s)/R(s)}{E(s)/R(s)} \Big|_{N=0} = \frac{\frac{10(s+K)}{s(s+1)}}{1 + \frac{0.1s}{s(s+1)} - \frac{K_0}{s(s+1)}} = \frac{10(s+K)}{s^2 + 1.1s - K_0}$$

$$(c) \left. \frac{Y(s)}{N(s)} \right|_{R=0} = \frac{1}{1 + \frac{0.1s}{s(s+1)} + \frac{10(s+K)}{s(s+1)}} = \frac{s(s+1)}{s^2 + 1.1s + K_0}$$

$$(d) Y(s) = \left. \frac{Y(s)}{R(s)} \right|_{N=0} R(s) + \left. \frac{Y(s)}{N(s)} \right|_{R=0} N(s)$$





$$\Delta = 1 + G_r H_1 + G_p H_r + H_f + G_f G_d H_p + G_1 G_r G_p H_p + G_r H_1 H_f + G_p H_r H_f + G_1 G_r G_p H_p H_f + G_r G_f H_1 H_p$$

$$Y_d/Y_1 = \frac{G_1 G_r G_p (1 + H_f) + G_f G_d (1 + G_r H_1)}{\Delta}$$

$$Y_r/Y_1 = \frac{1 + G_r H_1 + G_p H_r + H_f + G_r H_1 H_f + G_p H_r H_f}{\Delta}$$

$$Y_d/Y_r = \frac{Y_d/Y_1}{Y_r/Y_1} = \frac{G_1 G_r G_p (1 + H_f) + G_f G_d (1 + G_r H_1)}{1 + G_r H_1 + G_p H_r + H_f + G_r H_1 H_f + G_p H_r H_f}$$

نکته: حلقه‌ای که در یک حلقه باشد، رانیز مانند دیگر حلقه‌ها خصوصیاتی