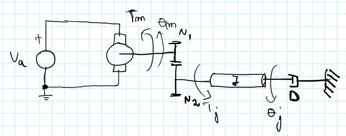
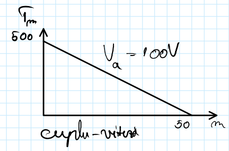
MP examen

Monday, February 7, 2022 12:53 PM

Motor electric de c.c. $N_2/N_1 = 7$





a) MM al motorului

K_e – const. tens. contra-electromotoare

$e(t) = K_e w_m(t) = K_e \dfrac{d\theta_m(t)}{dt}$

$T_m(t) = K_t \, i_a(t)$

$i_a = \dfrac{T_m(t)}{K_t}$

$u_a(t) = K_e w_m(t) + \dfrac{R_a T_m(t) + L_a \frac{dT_m}{dt}}{K_t}$

$T_m(t) = J_m \ddot{\theta}_m + D_m \dot{\theta}_m$

$i_a = \dfrac{T_m(t)}{K_t}$ i_a

$\theta_m =$ w_m

θ_m

$\begin{cases} x_1 = i_a \\ x_2 = w \end{cases}$ $\begin{cases} \dot{x}_1 = \\ \dot{x}_2 = \end{cases}$

$w_m = \dfrac{d\theta}{dt}$

$\dot{x}_2 = \dfrac{T_m}{J_m} - \dfrac{D_m}{J_m}$

$\theta = \int w_m$

$\theta = \int x_2$

$\dot{x}_2 = \dfrac{1}{J_m}(T_m - D_m x_2)$

$\dot{x}_2 = \dfrac{1}{J_m}(K_t x_1 - D_m x_2)$ $y = ax + bu$

$U_R + U_L + e = u_a$

$U_R = R \cdot i_a$

$U_L = L \cdot \dot{i}_a$

$e = K_e \cdot x_2$

$R x_1 + L \dot{x}_1 + K_e x_2 = U_a$

$\dot{x}_1 = -\dfrac{R}{L} x_1 - \dfrac{K_e}{L} x_2 + \dfrac{U_a}{L}$

$\dot{x}_2 = \dfrac{1}{J_m} K_t x_1 - \dfrac{D_m}{J_m} x_2$

$\dot{x}_1 = -\dfrac{R}{L} x_1 - \dfrac{K_e}{L} x_2 + \dfrac{U_a}{L}$

$$\dot{x} = \begin{pmatrix} -\frac{R}{L} & -\frac{K_e}{L} & 0 \\ 0 & w & 0 \\ -\frac{K_t}{J_m} & -\frac{K_e}{L} & 0 \end{pmatrix} \begin{pmatrix} i_a \\ \theta \\ w \end{pmatrix} + \begin{pmatrix} \frac{1}{L} \\ 0 \\ 0 \end{pmatrix} u_a$$

MM motor-sarcină

$\begin{cases} T_m = J \dfrac{dw}{dt} + Dw \iff K_t \cdot i_a = J \dfrac{dw}{dt} + Dw \\ \dfrac{d\theta}{dt} = w \end{cases}$

$U_a = R i_a + K_e w \Rightarrow i_a = \dfrac{-K_e}{R} w + \dfrac{U_a}{R}$

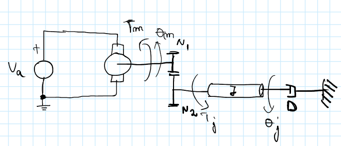
parametrii: $T_{m\,max} = 500$

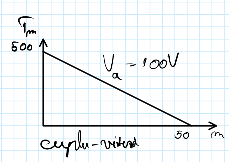
$T_{m\,min} = 0$

$\begin{cases} T_{m\,max} = K_t \cdot i_a \\ i_a = \dfrac{U_a}{R} \end{cases} \Rightarrow \boxed{T_{m\,max} = K_t \cdot \dfrac{U_a}{R}} \Rightarrow \dfrac{K_t}{R} = 2$

$u_a = K_e \cdot w_m \Rightarrow K_e = 5$

$= R = 2.5$





$\dfrac{N_2}{N_1} = 7$

a) MM cuplu-viteză pt m c.c.

$$J_m = K_t \cdot i_a = J \frac{dw}{dt} + Dw$$

b) parametrii

$J_{DCM} = 5\,kg$ $D_{DCM} = 2\,Nt/rad$

$T_{m\,max} = 500$

$u_a(t) = \dfrac{R_a T_m(t) + L_a \frac{dT_m}{dt}}{K_t} + K_e w_m(t)$

$m = J \dfrac{dw}{dt} + Dw$

$L_a = 0 \Rightarrow u_a(t) = \dfrac{R_a T_m}{K_t} + K_e w_m(t)$

$m = J_{DCM} \dfrac{dw}{dt} + D_{DCM} w$

$$u_a(t) = \frac{R_a i_m(t) + L_a \frac{di_m}{dt}}{k_t} + k_e\, \omega_m(t)$$

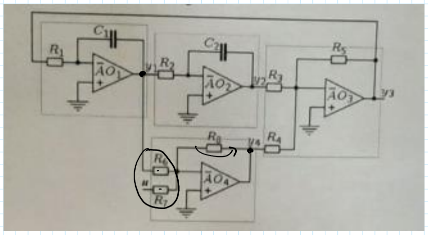
$$m = J\frac{d\omega}{dt} + D\omega$$

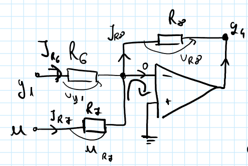
$$L_a \approx 0 \Rightarrow u_a(t) = \frac{R_a T_m}{k_t} + k_e\, \omega_m(t)$$

$$m = J_{m}\frac{d\omega}{dt} + D_{m}\,\omega$$

$$J_m = J_{DCM}\left(\frac{N_2}{N_1}\right) + J_J$$

$$D_m = D_{DCM}\left(\frac{N_2}{N_1}\right) + D_J$$





artificii

1) AO_4 $\quad u, y_1$ - intrări
y_4 = ieșire

$u^+ = u^-$

$$\boxed{y_4 = -U_{R8}}$$

LKI : $J_{R8} = J_{R6} + J_{R7}$

$$\frac{U_{R8}}{R_8} = \frac{U_{y_1}}{R_6} + \frac{U}{R_7}$$

$$\frac{U_{R8}}{R_8} = \frac{u_{y_1}}{R_6} + \frac{u}{R_7} \Rightarrow U_{R8} = R_8\left(\frac{u_{y_1}}{R_6} + \frac{u}{R_7}\right)$$

$$y_4 = -R_8\left(\frac{u_{y_1}}{R_6} + \frac{u}{R_7}\right) = -R_8\left(\frac{u_{y_1}}{R_6} + \frac{U}{R_7}\right)$$

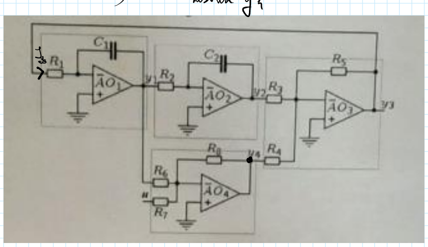
2) $R_6 = R_7 = 3.3\,k\Omega$
$R_8 = 6.8$

$$y_4 = \overset{2,1k\Omega}{\cancel{6.8}}\,k\Omega\left(\frac{u_{y_1} + u}{\cancel{3.3\,k\Omega}}\right)$$

$$y_4 = 2,1\,k\Omega\,(u_{y_1} + u)$$

3) intrări u
ieșire y_4

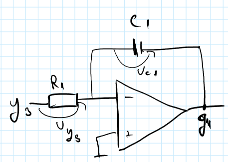
$$y_4 = -R_8\left(\frac{u_{y_1}}{R_6} + \frac{u}{R_7}\right)$$



$\bar{A}O_3$: intrare y_2, y_4
ieșire y_3

$$y_3 = -R_5\left(\frac{y_2}{R_3} + \frac{y_4}{R_4}\right)$$

$\bar{A}O_1$: intrare: y_3
ieșire: y_1



$x_1 = U_{C1}$.

$x_2 = U_{C2}$

$$\boxed{y_2 = -x_2}$$

$$\boxed{y_1 = -x_1}$$

$y_1 = -x_1$
u -

$$\boxed{y_4 = -R_8\left(\frac{-x_1}{R_6} + \frac{u}{R_7}\right)}$$

$$I_1 = J_{R1}$$

$$C_1\dot{x}_1 = \frac{U_{R1}}{R_1} = \frac{-R_5\left(\frac{y_2}{R_3} + \frac{y_4}{R_4}\right)}{R_1} = \frac{-R_5\left(\frac{-x_2}{R_3} - \frac{R_8\left(\frac{-x_1}{R_6} + \frac{u}{R_7}\right)}{R_4}\right)}{R_1}$$

$$C\dot{x}_1 = \frac{+R_5}{R_1R_3}x_2 - \frac{R_5 \cdot R_8}{R_1R_4 \cdot R_6}x_1 + \frac{R_5R_8}{R_1R_4R_7}u$$

$$\dot{x}_1 = \frac{R_5}{CR_1R_3}x_2 - \frac{R_5 \cdot R_8}{CR_1R_4R_6}x_1 + \frac{R_5R_8}{CR_1R_4R_7}u$$

$$J_{C2} = J_{R2}$$

$$C_2\dot{x}_2 = \frac{y_1}{R_2} = \frac{-x_1}{R_2}$$

$$\dot{x}_2 = \frac{-C_2}{R_2}x_1$$

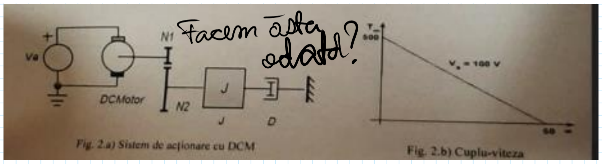
$$\dot{X} = \begin{pmatrix} -\frac{R_5 \cdot R_8}{C_1R_1R_4R_6} & +\frac{R_5}{C_1R_1R_3} \\ -\frac{1}{C_2R_2} & +\ 0 \end{pmatrix}\begin{pmatrix} x_1 \\ x_2 \end{pmatrix} + \begin{pmatrix} \frac{R_5R_8}{C_1R_1R_4R_7} \\ 0 \end{pmatrix}u$$

$$y_4 = \begin{pmatrix} \frac{+1}{R_8R_6} & 0 \end{pmatrix}x + \left(\frac{1}{R_7}\right)u$$

d) $R_i = R$
$C_1 = C_2$

$$\dot{x} = \begin{pmatrix} \frac{-1}{CR} & +\frac{1}{CR} \\ \frac{-1}{CR} & +\ 0 \end{pmatrix}\begin{pmatrix} x_1 \\ x_2 \end{pmatrix} + \begin{pmatrix} \frac{1}{CR} \\ 0 \end{pmatrix}u$$

$$y_4 = \begin{pmatrix} \frac{1}{R^2} & 0 \end{pmatrix}x + \left(\frac{1}{R}\right)u$$



Facem asta odată?

2. M.M – „cuplu - viteză unghiulară" al mcc

$T_{m\,max} = 500$

$\omega_{max} = 50 \rightarrow$ mers în gol $i = 0$

$\boxed{U_a = K_e\,\omega(t)}$

$100V = K_e \cdot 50 \Rightarrow K_e = 2.$

$K_e = K_T \Rightarrow K_T = 2$

$T_{m\,max} = K_T \cdot i_a$

$i_a = \frac{V_a}{R} \quad i_a = \frac{100V}{R}$

$\Rightarrow T_{m\,max} = K_T \cdot \frac{100V}{R}$

$T_m = J\,\dot{\omega}(t) + D \cdot \omega$

K

$e = K_e \cdot \omega$

$V_a = R \cdot i + e \;|\; T_m = K_T \cdot I_a \Rightarrow V_a = R\frac{T_m}{K_T} + K_e \cdot \omega$

$T_m = \frac{-K_e \cdot K_T}{R} \cdot \omega + \frac{K_T}{R} \cdot V_a$

$500 = 2 \cdot \frac{100}{R}$

$\cancel{\frac{200}{500R} = 1 = 2{,}5 = 0{,}4}$

$\boxed{R = \frac{200}{500} = 0{,}4}$

I | $T_m = 500 \Rightarrow \omega = 0$

II | $\omega = 50 \Rightarrow T_m = 0$

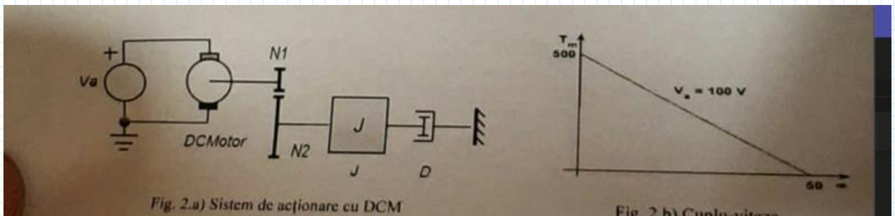


Fig. 2.a) Sistem de acționare cu DCM

Fig. 2.b) Cuplu-viteza

2.a) Să se prezinte *MM* al caracteristicii "*cuplu - viteză unghiulară*" pentru motorul de curent continuu.

2.b) Să se calculeze parametrii motorului pe baza caracteristicii *cuplu - viteză unghiulară* din Fig. 2.b. Să se calculeze viteza unghiulară de mers în gol pentru $J_{DCM} = 5\ kg \times m^2$, $D_{DCM} = 2\ Nms/rad$.

2.c) Să se determine *MM (u/x/y)* al sistemului din Fig. 2.a

2.d) Să se prezinte schema de simulare în Simulink pentru sistemul din Fig. 2.a ($J = 588\ kg \times m^2$, $D = 490\ Nms/rad$). S[ă] se precizeze pe caracteristica *cuplu - viteză unghiulară* "*punctul de funcționare*".

Motor

$V_a = R_a \cdot I_a(t) + L_a\,\dot{i}_a + e$

$L_a \approx 0$

$T_m = K_T \cdot i_a$

$e = K_e \cdot \omega$

$\cancel{\frac{R_a}{K_T} \cdot T_m + K_e \cdot \omega = V_a}$

$\boxed{\frac{R_a}{K_T} \cdot T_m + K_e \cdot \omega = V_a}$

$\boxed{J\ddot{\theta} + D\dot{\theta} = T_m}$

$\frac{R_a}{K_T}(J\ddot{\theta} + D\dot{\theta}) + K_e \cdot \omega = V_a$

$\dot{\theta} = \omega$

$\ddot{\theta} = \dot{\omega}$

$\frac{R_a}{K_T}(J_m\dot{\omega} + D_m\omega) + K_e \cdot \omega = V_a$

$\dot{\omega} = \ldots\ldots$

$\frac{R_a}{K_T}J\dot{\omega} + \frac{R_a}{K_T}D\omega + K_e \cdot \omega = V_a$

$\dot{\omega} = \frac{\cancel{K_T}}{\cancel{R_a}J} \cdot \frac{\cancel{R_a}}{\cancel{K_T}} D(-\omega) - \frac{K_T}{R_a J} K_e \omega + \frac{K_T}{R_a J} V_a$

$J_m = J\left(\frac{N_1}{N_2}\right)^2 + J_{DCM}$

$D_m = D\left(\frac{N_1}{N_2}\right)^2 + D_{DCM}$

$\cancel{\dot{\omega} = \frac{D}{J}\omega - K_T}$

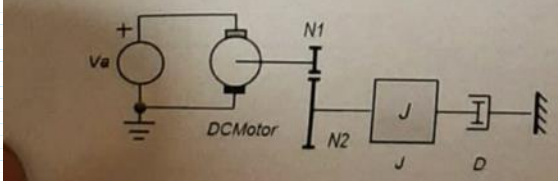


Fig. 2.a) Sistem de acționare cu DCM

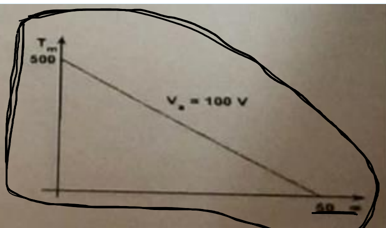


Fig. 2.b) Cuplu-viteza

2.a) Să se prezinte *MM* al caracteristicii "*cuplu - viteză unghiulară*" pentru motorul de curent continuu.
2.b) Să se calculeze parametrii motorului pe baza caracteristicii *cuplu - viteză unghiulară* din Fig. 2.b. Să se calculeze viteza unghiulară de mers în gol pentru $J_{DCM} = 5\ kg \times m^2$, $D_{DCM} = 2\ Nms/rad$.
2.c) Să se determine *MM (u/x/y)* al sistemului din Fig. 2.a.
2.d) Să se prezinte schema de simulare în Simulink pentru sistemul din Fig. 2.a ($J = 588\ kg \times m^2$, $D = 490\ Nms/rad$). Să se precizeze pe caracteristica *cuplu - viteză unghiulară* "*punctul de funcționare*".

$$\begin{cases} T_m = K_t \cdot I_a \\ I_a = \frac{U_a}{R} \end{cases}$$

$$\begin{cases} T_m = K_t \cdot \frac{U_a}{R} \\ U_a = 100 \end{cases} \qquad \frac{K_t}{R} = \frac{500}{100} \qquad R = \frac{200}{500} \qquad \boxed{R = 0,4}$$

$U_a = K_e \cdot \omega(t)$ ↳ 50

$100 = K_e \cdot 50 \Rightarrow K_e = 2$ $\quad \boxed{K_t = K_e}$

$x_1 = \omega$

$$J = J_{sarcina}\left(\frac{N_1}{N_2}\right)^2 + J_{DCM}$$
$$D = D\left(\frac{N_1}{N_2}\right)^2 + D_{DCM}$$
$\longrightarrow \boxed{T_m = J\dot{\omega} + D\omega}$

$U = \frac{R_a}{K_t} T_m + K_e \omega$

$$\begin{cases} \dot{\theta} = \omega \\ \dot{\omega} = \end{cases}$$

$x_1 = \cancel{\theta}$
$\cancel{x_2 = \dot\omega}$
$\dot{\omega} = x_2$
$i_a = x_3$

$U = I_a \cdot R_a + K_e \cdot \omega$

$I_a = \frac{-K_e \omega}{R_a} + \frac{U}{R_a}$

$T_m = K_t \cdot I_a$

$K_t I_a = J\dot{\omega} + D\omega$

$$\boxed{\dot{\omega} = \frac{-D}{J}\omega - \frac{K_t I_a}{J}}$$

$a = 0$ $\quad \frac{d\omega}{dt} = 0$

↳ din ec. îl aflu pe ω

$$0 = \frac{-D}{J}\omega - \frac{K_t\left(\frac{-K_e \omega}{R_a} + \frac{U}{R_a}\right)}{J}$$

ω = un nr rad/s

$T_m = D\omega$

20 rad/s .

20 rad ... s
x rad ... 60 s $\quad x = 1200$

2π rad ... 1 rot
1200 rad ... x rot

$\frac{1200}{2\pi} = 600\pi$ rot/min
300π rot/min

$v_+ = v_-$

$x_1 = u_{C_1}$
$x_2 = u_{C_2}$

u/x/y

LK I: A $\rightarrow I_{R_1} = I_{C_2} + I_{R_2}$
B $\rightarrow I_{R_2} = I_{C_1}$

$\frac{U_{R_1}}{R_1} = C_1 \dot{x}_1 + \frac{U_{R_2}}{R_2}$

$\boxed{\frac{U_{R_1}}{R_1} = C_2 \dot{x}_2 + C_1 \dot{x}_1}$

$y = u_{C_1}$
$\boxed{y = x_1}$

$u = U_{R_2} + U_{R_1} + U_{C_1}$

$\boxed{u = U_{R_1} + U_{R_2} + x_1}$

$\frac{U_{R_1}}{R_1} = C_2 \dot{x}_2 + C_1 \dot{x}_1$

$u = I_{C_1} \cdot R_2 + I_{R_1} R_1 + x_1$

* $U_{R_1} = u - u_{C_2} - y$

$u = C_1 \dot{x}_1 \cdot R_2 + (I_{C_2} + I_{C_1}) R_1 + x_1$

$u = C_1 \dot{x}_1 \cdot R_2 + U_{R_1} + x_1$ $\qquad C_1 \dot{x}_1 R_2 = -x_1 - U_{R_1} + u \Rightarrow \dot{x}_1 = \frac{-1}{C_1 R_2} x_1 - \frac{U_{R_1}}{C_1 R_2} + \frac{1}{C_1 R_2} u$

$u = C_1\dot{x}_1 \cdot R_2 + (J_{c2}+J_{c1})R_1 + x_1$

$u = C_1\dot{x}_1 \cdot R_2 + U_{R_1} + x_1 \qquad C_1\dot{x}_1 R_2 = -x_1 - U_{R_1} + u \Rightarrow \dot{x}_1 = \frac{-1}{C_1R_2}x_1 - \frac{U_{R_1}}{C_1R_2} + \frac{1}{C_1R_2}u$

$U_{R_1} = u - 2U_{c_1}$

$U_{R_1} = u - 2C_1\dot{x}_1$

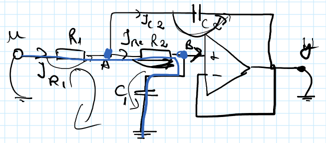
$\dot{x}_1 = \frac{-1}{C_1R_2}x_1 + \frac{2}{R_2}\dot{x}_1$

$\frac{R_2\dot{x}_1 - 2\dot{x}_1}{R_2} = \frac{-1}{C_1R_2}x_1$

$\frac{R_2-2}{R_2}\dot{x}_1 = \frac{-1}{C_1R_2}x_1$

$\dot{x} = (\ )x + (\ )u$

$\dot{x}_1 = \frac{-1}{C_1(R_2-2)}x_1$



$\boxed{J_{R_1} = J_{c_2} + J_{R_2}}$

$J_{R_1} = C_2\dot{x}_2 + \frac{U_{R_2}}{R_2}$

$\frac{U_{R_1}}{R_1} = C_2\dot{x}_2 + \frac{U_{R_2}}{R_2}$

$J_{R_2} = J_{c_1}$

$u = U_{R_1} + U_{R_2} + U_{c_1}$

$u = U_{R_1} + U_{c2} + y$

$u - U_{c2} - y = U_{R_1}$

$\frac{R_1C_2\dot{x}_2 + U_{R_2}R_1}{R_2} = u - U_{c2} - y$

$\dot{x}_2 R_1C_2 + \frac{x_2R_1}{R_2} = u - x_2 - x_1$

$\dot{x}_2 = \beta$

$J_{R_2} = \frac{U_{c_2}}{R_2} = C_1\frac{dy}{dt}$

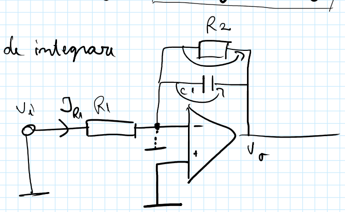
$U_{c_2} = R_2C_1\dot{y}$

$x_2 = R_2C_1\dot{y}$

$x_1 = y$

$U_{R_1} = u - U_{c2} - y \quad \boxed{= -R_2C_1\dot{y} + u - y}$

Circuit de integrare



$V^+ = V^-$

$x_1 = U_{c_1}$

$U_{R_2} = U_{c_1} \quad U_{R_2} = x_1$

$J_{R_1} = J_{R_2} + J_{c_1}$

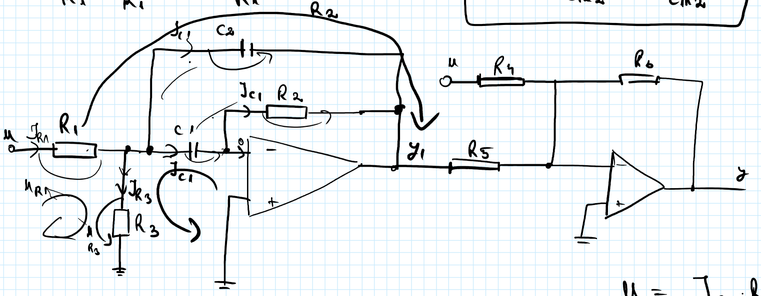
$V_o = (U_{R_2} + U_{c_1})$

$V_o = -2x_1$

$u = U_{R_1}*$

$J_{R_1} = \frac{U}{R_1} \qquad \frac{U}{R_1} = \frac{U_{c_1}}{R_2} + C_1\dot{x}_1$

$\boxed{\dot{x}_1 = \frac{-1}{C_1R_2}x_1 + \frac{1}{C_1R_2}u}$



$y_1 = -(\cancel{U_{c_2}} \, U_{c_1} + U_{R_2})$

$y_2 = \cancel{x_2} \quad x_1 - x_2$

$u = J_{R_1} \cdot R_1 + J_{R_3} \cdot R_3 \qquad u = U_{R_1} + x_1$

$\boxed{u = U_{R_1} + U_{R_3}}$

$x_1 = U_{c_1}$

$x_2 = U_{c_2}$

$U_{c_2} = U_{c_1} + U_{R_2}$

$x_2 = x_1 + J_{c_1}R_2$

$x_2 = x_1 + C_1\dot{x}_1R_2$

$\underbrace{\boxed{\dot{x}_1 = \frac{-1}{C_1R_2}x_1 + \frac{1}{C_1R_2}x_2}}_{\alpha}$

$U_{c_1} = U_{R_3} = x_1$

$u = U_{R_1} + U_{c_2} + y$

$y = u - U_{R_1} - U_{c_2}$

$y = U_{R_1} + U_{R_3} - \cancel{U_{R_1}} - U_{c_2}$

$\boxed{y = x_1 - x_2}$

$J_{R_1} = J_{c_2} + J_{R_3} + J_{c_1}$

$J_{R_1} = C_2\dot{x}_2 + U_{R_3}R_3 + C_1\dot{x}_1$

$C_2\dot{x}_2 = J_{R_1} - U_{R_3}R_3 - C_1\dot{x}_1$

$J_{R_3} \cdot R_3 = x_1$

$J_{R_3} = \frac{x_1}{R_3}$

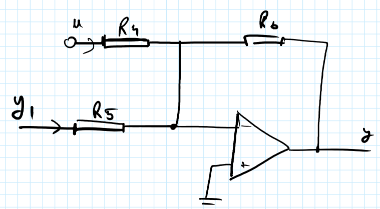
$J_{R_1} = C_2 \dot{x}_2 + U_{R_3} R_3 + C_1 \dot{x}_1$ $\quad U_{R_3} = x_1$ $\quad \boxed{y = x_1 - x_2}$

$C_2 \dot{x}_2 = J_{R_1} - U_{R_3} R_3 - C_1 \dot{x}_1$ $\quad J_{R_3} = \frac{x_1}{R_3}$

$C_2 \dot{x}_2 = \frac{1}{R_3} x_1 - x_1 R_3 - C_1 \dot{x}_1$

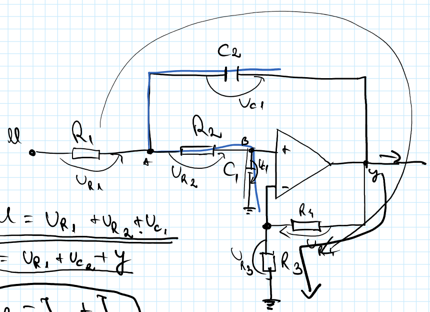
$$C_2 \dot{x}_2 = \frac{1}{R_3} x_1 - x_1 R_3 + \frac{1}{R_2} x_1 - \frac{1}{R_2} x_2 = \frac{2 - R_3^2}{R_3} x_1 - \frac{1}{R_2} x_2$$

$$\boxed{\dot{x}_2 = \frac{2 - R_3^2}{C_2 R_3} x_1 - \frac{1}{R_2 C_2} x_2}$$



$$y = -R_6 \left(\frac{y_1}{R_5} + \frac{u}{R_4} \right)$$

II



$y = U_{C_1} \left(1 + \frac{U_{R_3} + U_{R_4}}{R_3} \right) = U_{C_1} \left(\frac{R_3 + R_4}{R_3} \right)$

LkII: AB: $\underline{u = U_{R_1} + U_{R_2} + U_{C_1}}$

$y = x_1 \left(1 + \frac{R_4}{R_3} \right)$ $\quad y = U_{C_1} \left(\frac{R_3 + R_4}{R_3} \right)$

$\underline{u = U_{R_1} + U_{C_2} + y}$

LkI: A - $\boxed{J_{R_1} = J_{C_2} + J_{R_2}}$

$J_{R_2} = J_{C_1} = C_1 \dot{x}_1$ $\quad \underline{J_{R_1} = C_2 \dot{x}_2 + C_1 \dot{x}_1}$ $\quad \boxed{U_{C_2} = U_{R_2} + U_{C_1}} \rightarrow \cancel{x_2 = x_2}$

$\boxed{J_{R_1} = C_2 \dot{x}_2 + C_1 \dot{x}_1}$ $\quad \cancel{u = U_{R_1} + U_{C_2} + y}$

$U = U_{R_1} + U_{C_2} + x_1 \left(1 + \frac{R_4}{R_3} \right)$

$\boxed{U_{R_1} = U - x_2 - x_1 \left(1 + \frac{R_4}{R_3} \right)}$ $\quad \underline{u = U_{R_1} + U_{R_2} + x_1}$ $\quad \boxed{U_{R_2} = x_2 + x_1 \left(\frac{R_4}{R_3} \right)}$

$U_{R_2} = \cancel{u} - \cancel{u} + x_2 + x_1 \left(1 + \frac{R_4}{R_3} \right) - x_1$

$J_{R_1} = C_2 \dot{x}_2 + C_1 \dot{x}_1$ $\quad \boxed{\frac{U_{R_2}}{R_2} = C_1 \dot{x}_1}$ $\quad \dot{x}_1 = \frac{1}{C_1 R_2} \left(\frac{R_4}{R_3} \right) x_1 + \frac{1}{C_1 R_2} x_2$

$\frac{U_{R_1}}{R_1} = C_2 \dot{x}_2 + C_1 \dot{x}_1$

$$\frac{1}{R_1} \left(1 + \frac{R_4}{R_3} \right) (-x_1) - \frac{1}{R_1} x_2 + \frac{1}{R_1} u = C_2 \dot{x}_2 + \frac{1}{R_2} \left(\frac{R_4}{R_3} \right) x_1 + \frac{1}{R_2} x_2$$

$$C_2 \dot{x}_2 = x_1 \left(-\frac{1}{R_2} \left(\frac{R_4}{R_3} \right) - \frac{1}{R_1} \left(1 + \frac{R_4}{R_3} \right) \right) - x_2 \left(\frac{1}{R_1 R_2} \right) + \frac{1}{R_1} u$$

$u / x / y$

$$\boxed{\dot{x}_2 = \left(-\frac{1}{C_2} \right) \left(\frac{1}{R_2} \right) \left(\frac{R_4}{R_3} \right) x_1 - \frac{1}{R_1 C_2} \left(1 + \frac{R_4}{R_3} \right) x_2 + \frac{1}{C_2 R_1} u}$$

$y = x_1 \left(1 + \frac{R_4}{R_3} \right)$ $\quad x_1 = \frac{y}{1 + \frac{R_4}{R_3}} = \frac{R_3 \cdot y}{R_3 + R_4} = \left(\frac{R_3}{R_3 + R_4} \right) y$ $\quad x_1 = \left(\frac{R_3}{R_3 + R_4} \right) y$

$x_2 = \left(\frac{1}{C_2 R_1} \right) u$

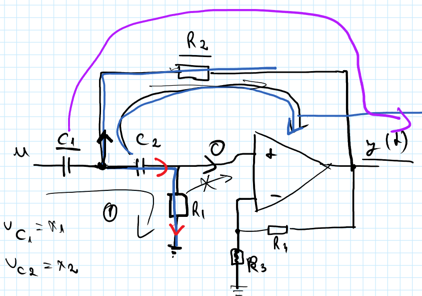
$\boxed{x_2 = \frac{1}{C_2 R_1} u}$ $\quad \cancel{u = \frac{1}{R_1}}$

$u = u - x_2 - x_1 \left(1 + \frac{R_3}{R_4} \right)$

$\frac{1}{C_2 R_1} u = \frac{R_3}{R_3 + R_4} \left(1 + \frac{R_3}{R_4} \right) y$ | De aici scadem din matr

$$\frac{1}{C_2R_1}u = \frac{R_3}{R_3+R_4}\left(1+\frac{R_3}{R_4}\right)y$$

De aici scadem din matr



$u_{C_1} = x_1$

$u_{C_2} = x_2$

$$\begin{cases} y = u - x_1 - x_2 \\ u_{C_2} = u_{R_2} \end{cases}$$

$$u = u_{C_1} + u_{C_2} + u_{R_1}$$

$$u = u_{C_1} + u_{R_2} + y$$

$$y = u - x_1 - u_{R_2} \qquad \boxed{u_{R_2} = u_{C_2}}$$

$$\left.\begin{matrix} y = u - x_1 - u_{R_2} \\ u_{R_2} = x_2 \end{matrix}\right\} \Rightarrow$$

$$y = u - x_1 - x_2$$

$$u = x_1 + x_2 + u_{R_1}$$

$$u = x_1 + x_2 + y$$

$$u_{R_1} = y$$

$$J_{C_1} = J_{R_2} + J_{C_2} \qquad J_{C_2} = J_{R_1}$$

$$C_1\dot{x}_1 = u_{R_2}/R_2 + C_2\dot{x}_2 \qquad \left.\begin{matrix} J_{C_2} = u_{R_1}/R_1 \\ u_{R_1} = u - x_1 - x_2 \end{matrix}\right\} \Rightarrow C_2\dot{x}_2 = \frac{u - x_1 - x_2}{R_1}$$

$$C_1\dot{x}_1 = x_2/R_2 + C_2\dot{x}_2$$

$$C_1\dot{x}_1 = \frac{x_2}{R_2} + C_2\dot{x}_2 \qquad \boxed{\dot{x}_2 = -\frac{1}{C_2R_1}x_1 - \frac{1}{C_2R_1}x_2 + \boxed{\frac{1}{C_2R_1}u}}$$

$$C_1\dot{x}_1 = \frac{1}{R_2}x_2 - \frac{1}{R_1}x_1 - \frac{1}{R_1}x_2 + \frac{1}{R_1}u$$

$$C_1\dot{x}_1 = -\frac{1}{R_1}x_1 + \left(\frac{1}{R_2} - \frac{1}{R_1}\right)x_2 + \frac{1}{R_1}u$$

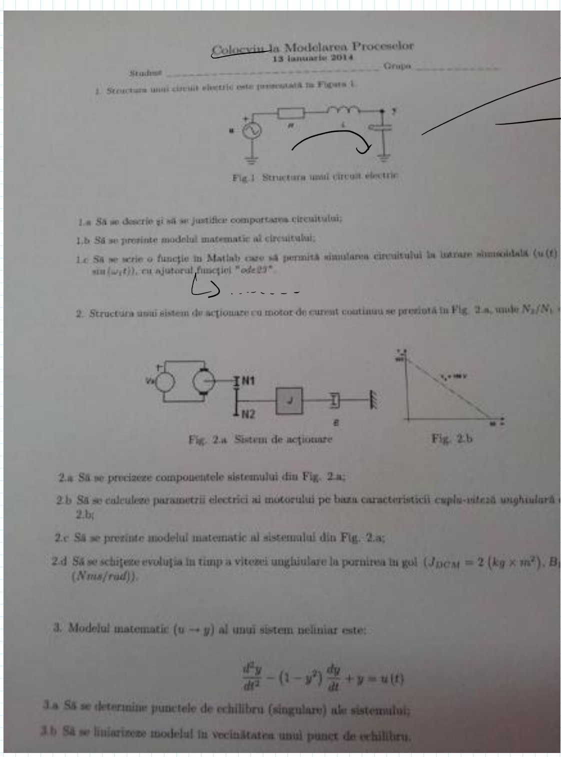
$$\dot{x}_1 = -\frac{1}{C_1R_1}x_1 + \frac{1}{C_1}\left(\frac{R_1-R_2}{R_1R_2}\right)x_2 + \frac{1}{C_1R_1}u$$

$$\dot{x} = \begin{pmatrix} -\frac{1}{C_1R_1} & \frac{R_1-R_2}{C_1R_1R_2} \\ -\frac{1}{C_2R_1} & -\frac{1}{C_2R_1} \end{pmatrix} x + \begin{pmatrix} \frac{1}{C_1R_1} \\ \frac{1}{C_2R_1} \end{pmatrix} u$$

$$y = (-1 \quad -1)\,x \quad + (1)u \qquad\qquad u = ax + iy$$

$$\dot{x}_1 = -\frac{1}{C_1R_1}x_1 + \frac{1}{C_1}\left(\frac{1}{R_2} - \frac{1}{R_1}\right)x_2 + \frac{1}{C_1R_1}u$$

$$\dot{x}_2 = -\frac{1}{C_2R_1}x_2 - \frac{1}{C_2R_1}x_1 + \frac{1}{C_2R_1}u$$



Colocviu la Modelarea Proceselor

13 ianuarie 2014

Student ______________________ Grupa ____________

1. Structura unui circuit electric este prezentată în Figura 1.

Fig.1 Structura unui circuit electric

1.a Să se descrie şi să se justifice comportarea circuitului;

1.b Să se prezinte modelul matematic al circuitului;

1.c Să se scrie o funcţie în Matlab care să permită simularea circuitului la intrare sinusoidală ($u(t)$ … $\sin(\omega_1 t)$), cu ajutorul funcţiei "ode23".

2. Structura unui sistem de acţionare cu motor de curent continuu se prezintă în Fig. 2.a, unde N_2/N_1 …

Fig. 2.a Sistem de acţionare

Fig. 2.b

2.a Să se precizeze componentele sistemului din Fig. 2.a;

2.b Să se calculeze parametrii electrici ai motorului pe baza caracteristicii cuplu-viteză unghiulară … 2.b;

2.c Să se prezinte modelul matematic al sistemului din Fig. 2.a;

2.d Să se schiţeze evoluţia în timp a vitezei unghiulare la pornirea în gol ($J_{DCM} = 2\,(kg \times m^2)$, B… (Nms/rad)).

3. Modelul matematic ($u \to y$) al unui sistem neliniar este:

$$\frac{d^2y}{dt^2} - (1-y^2)\frac{dy}{dt} + y = u(t)$$

3.a Să se determine punctele de echilibru (singulare) ale sistemului;

3.b Să se liniarizeze modelul în vecinătatea unui punct de echilibru.

Filtru trece jos

$$u = u_R + u_L + u_C$$

$$y = u_C \qquad x_1 = u_C \quad x_2 = J_L \qquad J_R = J_L$$

$$J_L = J_C$$

$$u = J_L \cdot R + L\dot{x}_2 + x_1 \qquad x_2 = C\dot{x}_1$$

$$u = x_2 \cdot R + L\dot{x}_2 + x_1 \qquad \dot{x}_1 = \frac{1}{C}x_2$$

$$L\dot{x}_2 = \cancel{-x_1(R+1)}\,u \qquad \dot{x} = \begin{pmatrix} 0 & \frac{1}{C} \\ -\frac{1}{L} & -\frac{R}{L} \end{pmatrix} x + \begin{pmatrix} 0 \\ \frac{1}{L} \end{pmatrix} u$$

$$\dot{x}_2 = -\frac{1}{L}x_1 - \frac{R}{L}x_2 + \frac{1}{L}u$$

$$y = (1 \quad 0)\,x$$

(u/y)

$$\boxed{\frac{d^2y}{dt^2} - (1-y^2)\frac{dy}{dt} + y = u(t)}$$

1.c) Să se prezinte trei răspunsuri la intrari sinusoidale din care să rezulte comportarea circuitului. Să se precizeze frecvențele celor trei semnale pentru care a fost calculat răspunsul circuitului.

---

2) Structura unui sistem de acționare cu motor de curent continuu se prezintă în Fig. 2.a, unde

$N_2/N_1 = 2\times m$; $J_{DCM} = m\ (kg \times m^2)$, $J = 25\times n\ (kg \times m^2)$, $B_{DCM} = 2\times m\ (Nms/rad)$, $B = 50\times n\ (Nms/rad)$

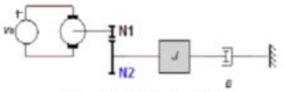


Fig.2.a) Sist. de acționare cu MPP

Fig.2.b) Cuplu-Viteză

2.a) Să se calculeze parametrii motorului pe baza caracteristicii *cuplu-viteză unghiulară* din Fig. 2.b, pentru $V_s = 50 \times \frac{n+m}{2n}\ (V)$.

2.b) Să se prezinte modelul matematic al sistemului din Fig. 2.a.

2.c) Să se prezinte evoluția în timp a vitezei unghiulare a motorului (ω_m) și a sistemului mecanic (ω). Să se calculeze vitezele unghiulare (ω_m, ω) în regim staționar a sistemului din Fig.2.a.

---

3) În Fig. 3 se prezintă un sistem de acumulare de lichid cu un rezervor de tip cub cu latura de 100 (cm), unde $R = \frac{m}{n+3}\ (sec/m^2)$.

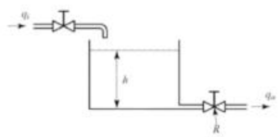


Fig.3 Sistem de acumulare de ichid

3.a) Să se determine modelul matematic intrare-stare-ieșire al sistemului de acumulare de lichid din Fig. 3.

3.b) Să se prezinte evoluția în timp a nivelului lichidului în rezervor și a debitului de ieșire pentru un debit de intrare $q_i = \frac{1}{m+1}\ (m^3/sec)$. Să se calculeze nivelului lichidului în rezervor și debitul de ieșire în regim staționar.

---

3. $R = \frac{m}{n+3}$ (sec $/m^2$)

$l = 100\ cm$

u/x/y.

R - debit laminar $= \frac{\Delta h}{\Delta Q} = \frac{H}{Q}$

$$\left.\begin{array}{l} Q = K \cdot H \Rightarrow R = \frac{1}{K} \\ R = \frac{m}{n+3} \end{array}\right\} \Rightarrow K = \frac{n+3}{m}$$

$C = \frac{\Delta V}{\Delta H}$

$h = 100\ cm = 1\ m$

$V = 1\ m^3$

$C = 1\ m^2$

$C\,dh = (q_i - q_o)\,dt$

$C\frac{dh}{dt} = q_i - q_o$

$\boxed{q_o = n+3}$

$q_o = \frac{H}{R} = \frac{(n+3)\ \cancel{\cdot}\ 1m}{m}$

$C\dot{h} = q_i - q_o$

$\dot{h} = \frac{q_i}{c} - \frac{q_o}{c}$

1.c) Să se prezinte trei răspunsuri la intrari sinusoidale din care să rezulte comportarea circuitului. Să se precizeze frecvențele celor trei semnale pentru care a fost calculat răspunsul circuitului.

---

2) Structura unui sistem de acționare cu motor de curent continuu se prezintă în Fig. 2.a, unde

$N_2/N_1 = 2\times m$; $J_{DCM} = m\ (kg\times m^2)$, $J = 25\times n\ (kg\times m^2)$, $B_{DCM} = 2\times m\ (Nms/rad)$, $B = 50\times n\ (Nms/rad)$

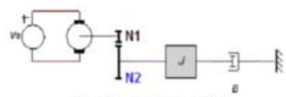


Fig.2.a) Sist. de acționare cu MPP

Fig.2.b) Cuplu-Viteză

2.a) Să se calculeze parametrii motorului pe baza caracteristicii cuplu-viteză unghiulară din Fig. 2.b, pentru $V_a = 50\times\frac{n+m}{2\pi}$ (V).

2.b) Să se prezinte modelul matematic al sistemului din Fig. 2.a.

2.c) Să se prezinte evoluția în timp a vitezei unghiulare a motorului (ω_m) și a sistemului mecanic (ω). Să se calculeze vitezele unghiulare (ω_m, ω) în regim staționar a sistemului din Fig.2.a.

January 15, 2021 page 2

3) În Fig. 3 se prezintă un sistem de acumulare de lichid cu un rezervor de tip cub cu latura de 100 (cm), unde $R = \frac{m}{n+1}$ (sec$/m^2$).

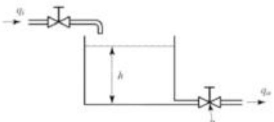


Fig.3 Sistem de acumulare de ichid

3.a) Să se determine modelul matematic intrare-stare-ieșire al sistemului de acumulare de lichid din Fig. 3.

3.b) Să se prezinte evoluția în timp a nivelului lichidului în rezervor și a debitului de ieșire pentru un debit de intrare $q_i = \frac{1}{m+1}$ (m^3/sec). Să se calculeze nivelului lichidului în rezervor și debitul de ieșire în regim staționar.

$V_a = 50$

$T_{m_{max}} = 500$

$$\left\{\begin{array}{l} T_m = K_t \cdot J_a \\ J_a = \frac{V_a}{R} \end{array}\right\} \Rightarrow 500 = 1\cdot\frac{50}{R} \Rightarrow R = \frac{5\cancel{0}}{50\cancel{0}} = 0{,}1\ \Omega$$

$$\left.\begin{array}{l} V_a = K_e\cdot\omega(t) \\ \qquad\quad \hookrightarrow 50 \\ V_a = 5 \end{array}\right\} \Rightarrow \left.\begin{array}{l} K_e = 1 \\ K_e = K_t \end{array}\right\} \Rightarrow K_t = K_e = 1$$

$$J_m = J\left(\frac{N_1}{N_2}\right)^2 + J_{DCM} = J_m$$

$$D_m = D\left(\frac{N_1}{N_2}\right)^2 + D_{DCM} = D_m$$

$$\left\{\begin{array}{l} \dot\theta = \omega = x_1 \\ \dot\omega = x_2 \\ J = x_3 \end{array}\right.$$

$$T_m = J_m\dot\omega + D\omega \longrightarrow K_t\cdot J_a = J\dot\omega + D\omega$$

$$\boxed{\dot\omega = \frac{-D}{J}\omega + \frac{K_t}{J}J_a}$$

$$U = \frac{R_a}{K_t}\cdot T_m + K_e\cdot\omega$$

$$U = J_a\cdot R_a + K_e\cdot\omega$$

$$J_a = \frac{-K_e}{R_a}\omega + \frac{1}{R_a}u$$

$$X = \begin{pmatrix} 1 & 0 & 0 \\ \frac{-D}{J} & 0 & \frac{K_t}{J} \\ \frac{-K_e}{R_a} & 0 & 0 \end{pmatrix} X + \begin{pmatrix} 0 \\ 0 \\ \frac{1}{R_a} \end{pmatrix} u$$

$$y = \begin{pmatrix} D & J & 0 \end{pmatrix} X$$

c) $\frac{d\omega}{dt} = 0$ $\qquad 0 = \frac{-D}{J}\omega - \frac{K_t}{J}\left(-\frac{K_e}{R_a}\omega + \frac{1}{R_a}u\right)$

$$0 = \frac{-D}{J}\omega + \frac{1}{JR}\omega - \frac{1}{JR}u$$

$$\omega\left(\frac{1}{JR} - \frac{D}{J}\right) = \frac{1}{JR}u$$

$$\omega = \alpha\ rad/s$$

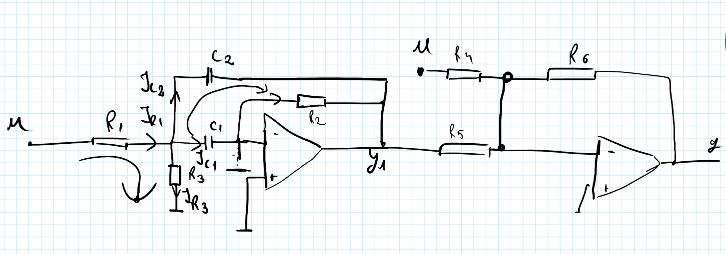
α rad 1s

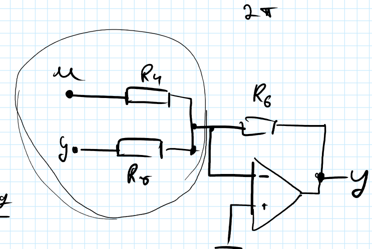
x rad 60s

$x = 60\alpha$ rad $\qquad$ 2π rad .... 1 rot

$\qquad\qquad\qquad\qquad$ 60α rad .... x rot

$$x = \frac{60\alpha}{2\pi}\ rot$$





$u = U_{R_1} + U_{R_3}$ $\qquad$ $x_1 = U_{C_1}$

$\qquad\qquad\qquad\qquad\quad$ $x_2 = U_{C_2}$

$J_{R_1} = J_{R_3} + J_{C_2} + I_1$ $\qquad$ $J_{C_1} = J_{R_2}$ $\qquad$ $U_{R_3} = U_{C_1}$

$J_{R_1} = \frac{U_{R_1}}{} = \frac{u - U_{R_3}}{}$ $\qquad$ $U_0 = x_1$

$0 = U_{R_2} + y_1$

$U_{R_2} = -y$ $\qquad$ $x_1 = x_2 + y$

$\boxed{y = x_1 - x_2}$

$U_{R_2} = x_2 - x_1$

$J_{R_1} = J_{R_3} + J_{C_2} + I_1$ $\qquad J_{C_1} = J_{R_2}$ $\qquad U_{R_3} = U_{C_1}$ $\qquad \boxed{y = x_1 - x_2}$

$J_{R_1} = \frac{U_{R_1}}{R_1} = \frac{u - U_{R_3}}{R_1}$ $\qquad U_{R_3} = x_1$ $\qquad J_{C_1} = J_{R_2}$ $\qquad U_{R_2} = x_2 - x_1$

$J_{R_1} = \frac{u - x_1}{R_1} \rightarrow \underbrace{\frac{u - x_1}{R_1} = \frac{x_1}{R_3} + C_2\dot{x}_2 + C_1\dot{x}_1}$ $\qquad C_1\dot{x}_1 = \frac{U_{R_2}}{R_2}$ $\qquad C_1\dot{x}_1 = \frac{x_2 - x_1}{R_2}$

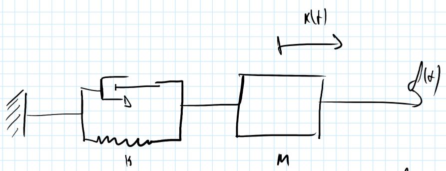
$\dot{x}_1 = \frac{-x_1}{C_1R_2} + \frac{x_2}{C_1R_2}$

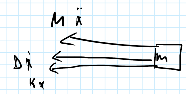
$\hookrightarrow C_2\dot{x}_2 = \frac{-x_1}{R_1} - \frac{x_1}{R_3} - C_1\dot{x}_1 + \frac{u}{R_1}$

$C_2\dot{x}_2 = \left(\frac{-x_1}{R_1} - \frac{x_1}{R_3} + \frac{x_1}{R_2}\right) - \frac{x_2}{R_2} + \frac{u}{R_1}$

$\dot{x}_2 = \frac{1}{C_2}\left(\frac{1}{R_2} - \frac{1}{R_1} - \frac{1}{R_3}\right)x_1 - \frac{1}{C_2R_2}x_2 + \frac{1}{C_2R_1}u$

$\left.\begin{array}{l} y_1 = x_1 - x_2 \\ u = u \end{array}\right\} \Rightarrow y = R_6\left(\frac{x_2 - x_1}{R_5} - \frac{u}{R_4}\right)$

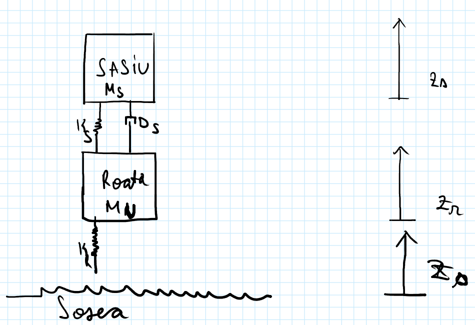


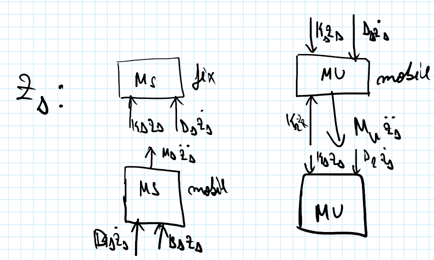


$f(t) = M\ddot{x} + D\dot{x} + K\cancel{x}$

$\begin{cases} x_1 = x \\ x_2 = \dot{x} \end{cases}$ $\qquad \begin{cases} \dot{x}_1 = x_2 \\ \dot{x}_2 = \frac{-K}{M}x_1 - \frac{D}{M}x_2 + \frac{f}{M} \end{cases}$

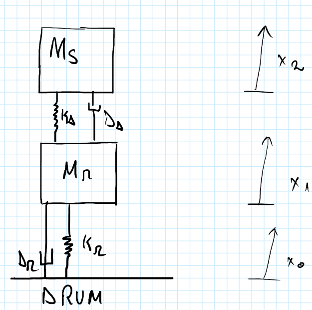
$\dot{\cancel{x}} = \begin{pmatrix} 0 & 1 \\ \frac{-K}{M} & \frac{-D}{M} \end{pmatrix} \cancel{x} + \begin{pmatrix} 0 \\ \frac{1}{M} \end{pmatrix} f$

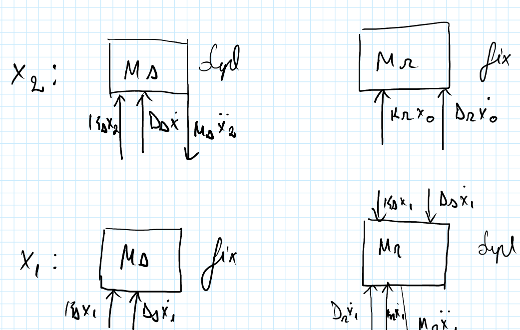




$M_s\ddot{z}_s + \cancel{D_s\dot{z}_s} + \cancel{K_sz_s} - \cancel{K_sz_s} - \cancel{D_s\dot{z}_s} = 0$

Suspensia :





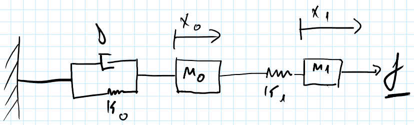
$M_s\ddot{x}_2 + D_s\dot{x}_2 + K_sx_2 - D_s\dot{x}_1 - K_sx_1 = 0$

$M_r\ddot{x}_1 + D_r\dot{x}_1 + K_rx_1 + K_sx_1 + D_s\dot{x}_1 - D_r\dot{x}_0 - K_rx_0 = 0$

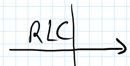
$$\begin{cases} y_1 = x_1 \\ y_2 = \dot{x}_1 \\ y_3 = x_2 \\ y_4 = \dot{x}_2 \end{cases} \qquad \begin{cases} \dot{y}_1 = y_2 \\ \dot{y}_2 = \left(\dfrac{-K_2 - K_0}{M_2}\right) y_1 + \left(\dfrac{-D_2 - D_0}{M_2}\right) y_2 + \dfrac{D_2}{M_2}\dot{x}_0 + \dfrac{K_2}{M_2} x_0 \\ \dot{y}_3 = y_4 \\ \dot{y}_4 = \left(\dfrac{D_0 + K_0}{M_0}\right) y_1 - \dfrac{K_0}{M_0} y_3 - \dfrac{D_0}{M_0} y_4 \end{cases}$$

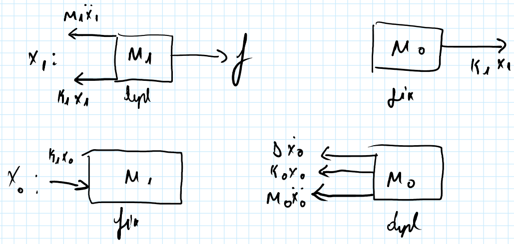
M – C (–||–) $\quad \frac{1}{K} = L$ (–mm–)

$\frac{1}{D}$ – R (–□–)

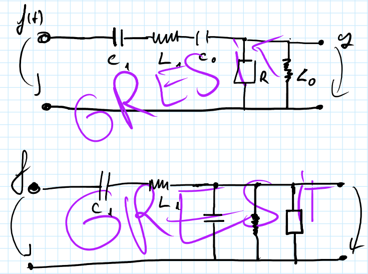


RLC



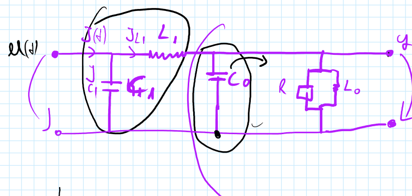


GRESIT



GRESIT

$$\begin{cases} f = J(t) \\ v = U(t) \end{cases}$$



$$M_1 \ddot{x}_1 + K_1 x_1 - K_1 x_0 - f = 0$$

$$M_0 \ddot{x}_0 + K_0 x_0 + D\dot{x}_0 - K_1 x_1 = 0$$

$$\begin{cases} a_1 = x_0 \\ a_2 = \dot{x}_0 \\ b_1 = x_1 \\ b_2 = \dot{x}_1 \end{cases} \qquad \begin{cases} \dot{a}_1 = a_2 \\ \dot{a}_2 = \dfrac{-K_0}{M_0} a_1 - \dfrac{D}{M_0} a_2 + \dfrac{K_1}{M_0} b_1 \\ \dot{b}_1 = b_2 \\ \dot{b}_2 = \dfrac{K_1}{M_1} a_1 - \dfrac{K_1}{M_1} b_1 + \dfrac{1}{M_1} f \end{cases}$$

$$\dot{X} = \begin{pmatrix} 0 & 1 & 0 & 0 \\ -\frac{K_0}{M_0} & -\frac{D}{M_0} & \frac{K_1}{M_0} & 0 \\ 0 & 0 & 0 & 1 \\ \frac{K_1}{M_1} & 0 & -\frac{K_1}{M_1} & 0 \end{pmatrix} X + \begin{pmatrix} 0 \\ 0 \\ 0 \\ \frac{1}{M_1} \end{pmatrix} f$$

$x_1 = U_{C_1}$

$x_2 = U_{C_0}$

$x_3 = J_{L_1}$

$x_4 = J_{L_0}$

$J_{C_1} = J_{L_1}$

$C_1 \dot{x}_1 = x_3$

$\dot{x}_1 = \frac{1}{C_1} x_3$

$y = U_0 = x_2$

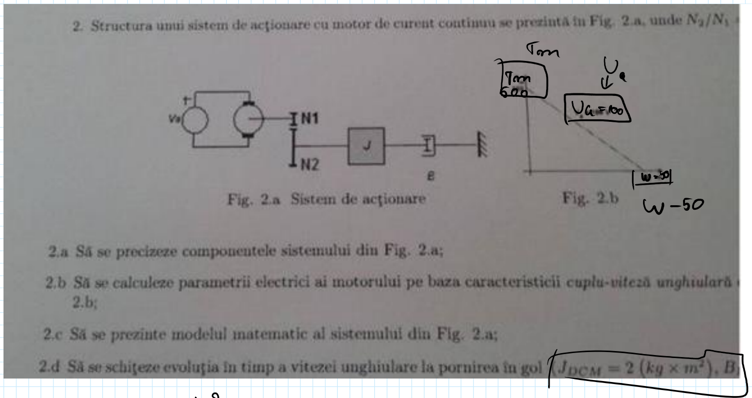
$U_R = U_{C_0}$

$J_{L_1} = J_{C_0} + J_R + J_{L_0}$

$J_{C_0} = J_{L_1} - J_{L_0} - J_R$

$C_0 \dot{x}_2 = x_3 - x_4 - x_2$

$\dot{x}_2 = -\frac{1}{C_0} x_2 + \frac{1}{C_0} x_3 - \frac{1}{C_0} x_4$



2. Structura unui sistem de acţionare cu motor de curent continuu se prezintă în Fig. 2.a, unde N_2/N_1

Fig. 2.a Sistem de acţionare

Fig. 2.b

2.a Să se precizeze componentele sistemului din Fig. 2.a;

2.b Să se calculeze parametrii electrici ai motorului pe baza caracteristicii *cuplu-viteză unghiulară* 2.b;

2.c Să se prezinte modelul matematic al sistemului din Fig. 2.a;

2.d Să se schiţeze evoluţia în timp a vitezei unghiulare la pornirea în gol ($J_{DCM} = 2\ (kg \times m^2)$, B

a, b)

$$\begin{cases} T_m = K_t \cdot J_a \\ J_a = \dfrac{U_a}{R} = \dfrac{100}{R} \end{cases}$$

$500 = 2 \cdot \frac{100}{R}$

$R = \frac{200}{600} = 0{,}4$

$\boxed{U_a = K_e \cdot \omega(t)}$

$100V = K_e \cdot 50$

$K_e = 2$

$K_e = K_t$

$$\begin{cases} J_a = x_3 \\ \dot{\theta} = \omega = x_1 \\ \dot{\omega} = x_2 \end{cases}$$

$T_m = J\dot{\omega} + D\omega$

$U = \frac{R_a}{K_t} \cdot T_m + K_e \cdot \omega$

$U = J_a \cdot R_a + K_e \cdot \omega$

$\boxed{J_a = \frac{-K_e \cdot \omega}{R_a} + \frac{U}{R_a}}$

$$J = J_m \left(\frac{N_1}{N_2}\right)^2 + J_{DCM}$$

$$D = D_m \left(\frac{N_1}{N_2}\right)^2 + D_{DCM}$$

$K_t \cdot J_a = J\dot{\omega} + D\omega$

$\dot{\omega} = \frac{-D}{J}\omega + \frac{K_t \cdot J_a}{J}$

$\dot{\omega} = \frac{-D}{J}\omega + \frac{K_t\left(\frac{-K_e \cdot \omega}{R_a} + \frac{U}{R_a}\right)}{J}$

$K_e = K_t$

$T_m = K_t \cdot J_a$

$K_e = K_t$

$T_m = K_t \cdot J_a$

$J_a = \frac{U_a}{R}$

$U_a = K_e \cdot \omega(t)$

$J = J_m\left(\frac{N_1}{N_2}\right)^2 + J_{DCM}$

$D = D_m\left(\frac{N_1}{N_2}\right)^2 + D_{DCM}$

$T_m = J \cdot \dot{\omega} + D\omega$

$U = J_a \cdot R_a + K_e \cdot \omega$

$\dot{\theta} = \omega$

$\dot{\omega} = ?$

$J_a = ?$

$$\dot{\omega} = \frac{-D}{J}\omega + \frac{K_t\left(\frac{-K_e \cdot \omega}{R_a} + \frac{U}{R_a}\right)}{J}$$

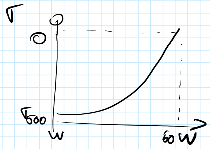
$$\dot{\omega} = \frac{-D}{J}\omega + \frac{K_t(-K_e)\cdot\omega + K_t U}{R_a J} \quad \ldots \quad \dot{\omega} = 30$$

$J_a = 0 \Rightarrow T_m = 0 \Rightarrow \dot{\omega} = 50$

$\dot{\omega} = 0$ → scot' ω

ω rad/s 1

x rad/s 50

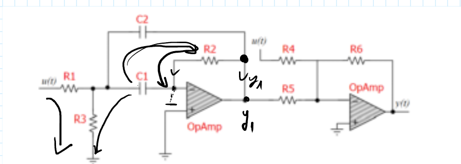


$x = 6\omega$ rad

2π rad .... 1 rot

6ω rad .... x rot

$x = \frac{6\omega \text{ rad}}{2\pi \text{ rad}} = \frac{3}{\pi}\omega$ rot/min



$U_{C_1} = x_1$

$U_{C_2} = x_2$

$\boxed{U_{C_1} = U_{C_2} + y}$

$L_{2K}: \; u = U_{R_1} + U_{R_3}$

$L_{1K}: \; J_{R_1} = J_{R_3} + J_{C_1} + J_{C_2} \rightarrow J_{R_2} = J_{C_1}$

$y_1 = U_{C_1} - U_{C_2}$ $\quad U_{R_2} = -y_1$

$y_1 = x_1 - x_2$ $\quad U_{R_2} = x_2 - x_1$

$U_{R_3} = U_{C_1} \rightarrow U_{R_3} = x_1$

$J_{R_2} = C_1\dot{x}_1 \quad \dot{x}_1 = \frac{U_{R_2}}{C_1 R_2}$

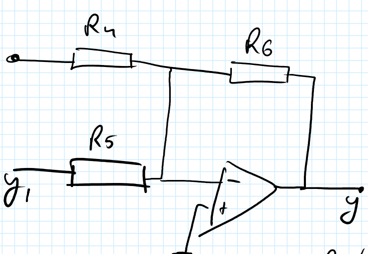
$J_{R_1} = \frac{U_{R_1}}{R_1} = \frac{u - U_{R_3}}{R_1}$

$J_{R_1} = J_{R_3} + C_1\dot{x}_1 + C_2\dot{x}_2$

$J_{R_1} = \frac{x_1}{R_3} + C_1\dot{x}_1 + C_2\dot{x}_2$

$\frac{u - x_1}{R_1} = \frac{x_1}{R_3} + C_1\dot{x}_1 + C_2\dot{x}_2$

$\dot{x}_1 = \frac{U_{R_2}}{C_1 R_2} \Rightarrow \dot{x}_1 = \frac{-x_1}{C_1 R_2} + \frac{x_2}{C_1 R_2}$

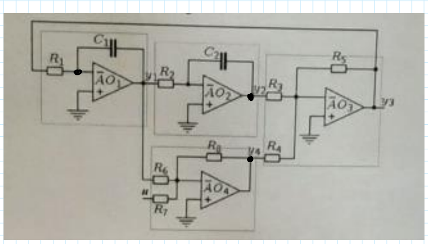


$C_2\dot{x}_2 = -\left(\frac{1}{R_1} + \frac{1}{R_3}\right)x_1 - C_1\dot{x}_1 + \frac{1}{R_1}u$

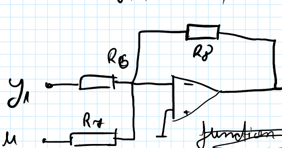
$C_2\dot{x}_2 = -\left(\frac{1}{R_1} + \frac{1}{R_3}\right)x_1 + \frac{x_1}{R_2} - \frac{x_2}{R_2} + \frac{1}{R_1}u$

$\dot{x}_2 = \frac{-1}{C}\left(\frac{1}{R_1} + \frac{1}{R_3} - \frac{1}{R_2}\right) - \frac{x_2}{C_2 R_2} + \frac{1}{C_2 R_1}u$

$$y = -R_6\left(\frac{U}{R_4} + \frac{y_1}{R_5}\right) = -R_6\left(\frac{U}{R_4} + \frac{x_1}{R_5} - \frac{x_2}{R_5}\right) = \boxed{-\frac{R_6}{R_5}x_1 + \frac{R_6}{R_5}x_2 - \frac{R_6}{R_4}u}$$



a) intrari y_1, u, iesiri y_4



$y = -R_8\left(\frac{y_1}{R_6} + \frac{u}{R_7}\right)$

~~function dee ramon (+)~~ y_4

$y \ldots, (y_1, u)$

figure;

plot (t, y); hold on;

plot (t, u)

$U_{C_2} = x_2$

$U_{C_1} = x_1$

c) $y_4 = -R_8\left(\frac{y_1}{R_6} + \frac{u}{R_7}\right)$

$y_3 = -R_5\left(\frac{y_2}{R_3} + \frac{y_4}{R_4}\right)$

$y_1 = -x_1$

$y_2 = -x_2$

$LKI: J_{C_1} = J_{R_1} = \frac{U_{R_1}}{R_1} \quad C_1\dot{x}_1 = \frac{U_{R_1}}{R_1} \,|\, \dot{x}_1 = \frac{U_{R_1}}{C_1 R_1}$

$\boxed{\dot{x}_1 = \frac{-R_5\left(\frac{y_2}{R_3} + \frac{y_4}{R_4}\right)}{R_1}}$

$U_{R_1} = y_3$

$LKI \; J_{C_2} = J_{R_2} \Rightarrow \dot{x}_2 = \frac{U_{R_2}}{R_2} = \frac{y_1}{R_2} \quad \dot{x}_2 = \frac{-x_1}{R_2}$

$C = \ldots;$

$\boxed{T = J\dot{\omega} + D\omega}$

$y_2 = -x_2$

LkI $\quad J_{C2} = J_{R2} \Rightarrow \dot{x}_2 = \frac{U_{R2}}{R_2} = \frac{y_1}{R_2} \qquad \dot{x}_2 = \frac{\ldots}{R_2}$

$C = \ldots;$
$R = \ldots;$
$dx = [$

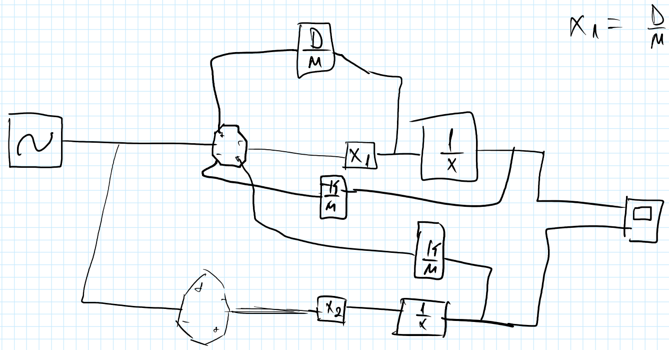
$$\boxed{I = J\dot{\omega} + D\omega}$$

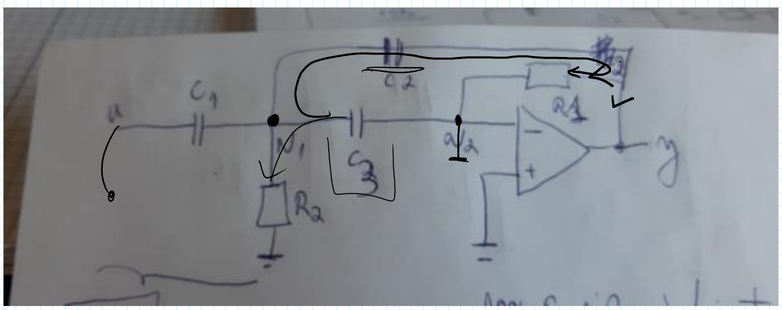
$$y_1 = -R_8\left(\frac{-x_1}{R_6} + \frac{u}{R_7}\right)$$

$$\begin{array}{ccc} \omega & \dot{\omega} & J_a \\ \end{array}$$
$$y = \begin{pmatrix} D & J & 0 \end{pmatrix}$$

$x_1 \quad \dot{x}_1 \quad x_2 \quad \dot{x}_2$

$$\dot{x}_1 = \frac{D}{M}x_1 + \frac{-K}{M}x_2 + \frac{K}{M}x_3 \quad \ldots 0$$





$x_1 = U_{C1}$
$x_2 = U_{C2}$
$x_3 = U_{C3}$

$J_{C1} = J_{C2} + J_{C3} + J_{R2}$

$C_1\dot{x}_1 = C_2\dot{x}_2 + C_3\dot{x}_3 + x_3/R_2$

$u = U_{C1} + U_{R2}$ $\qquad u = x_1 + x_2 + y$

$U_{C1} = u - x_3$ $\qquad U_{R1} = -y$

$x_1 = u - x_3$

$$\boxed{C_3\dot{x}_3 = U_{R1}/R_1}$$

$\cancel{x_3 = \frac{1}{C}\int J_{C}}$

$\cancel{\dot{x}_1 = x_1 = \frac{1}{C}\int \frac{J_{C1}}{dt}}$