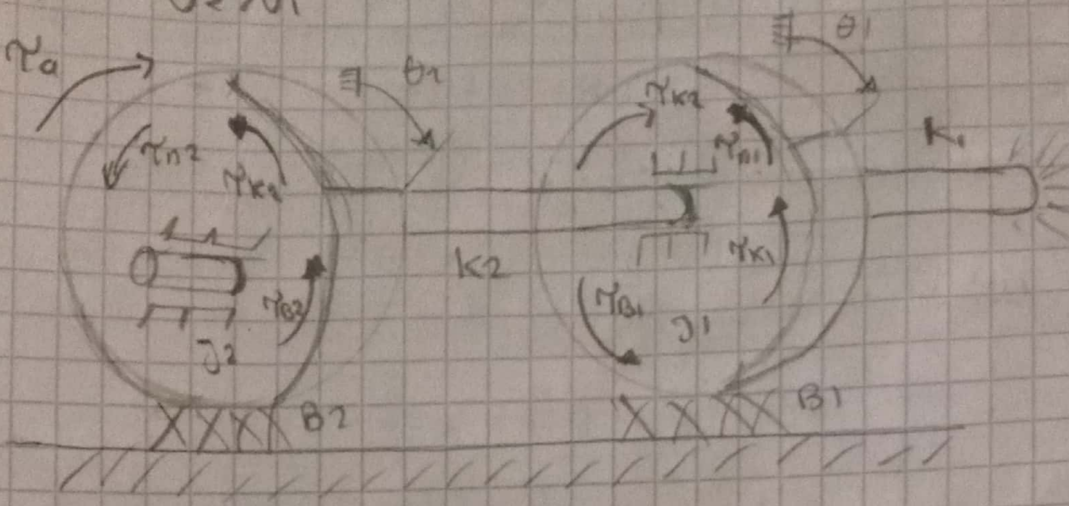
• $\theta_2 > \theta_1$



$T_{n1} = J_1 \ddot{\theta}_1$

$T_{B1} = B_1 \dot{\theta}_1$

$T_{k1} = k_1 \theta_1$

$T_{n2} = J_2 \ddot{\theta}_2$

$T_{B2} = B_2 \dot{\theta}_2$

$T_{k2} = k_2(\theta_2 - \theta_1)$

$T_a = T_{n2} + T_{B2} + T_{k2}$ $\qquad$ $T_{k2} = T_{n1} + T_{B1} + T_{k1}$

$T_a = J_2 \ddot{\theta}_2 + B_2 \dot{\theta}_2 + k_2(\theta_2 - \theta_1)$ $\qquad$ $k_2(\theta_2 - \theta_1) = J_1 \ddot{\theta}_1 + B_1 \dot{\theta}_1 + k_1 \theta_1$

Aplicando Laplace

$k_2(\theta_2 - \theta_1) = (J_1 s^2 + B_1 s + k_1)\theta_1$

$k_2 \theta_2 = (J_1 s^2 + B_1 s + k_1 + k_2)\theta_1$

$$\theta_1 = \frac{k_2}{J_1 s^2 + B_1 s + k_1 + k_2}\theta_2$$

$$T_a = \left(J_2 s^2 + B_2 s + \frac{k_2(J_1 s^2 + B_1 s + k_1)}{J_1 s^2 + B_1 s + k_1 + k_2}\right)\theta_2$$

$$\frac{\theta_2}{T_a} = \frac{J_1 s^2 + B_1 s + k_1 + k_2}{(J_2 s^2 + B_2 s)(J_1 s^2 + B_1 s + k_1 + k_2) + k_2(J_1 s^2 + B_1 s + k_1)}$$

Definiendo estados:

$x_1 = \theta_2$ $\qquad$ $x_2 = \dot{x}_1$ $\qquad$ $x_3 = \theta_1$ $\qquad$ $x_4 = \dot{x}_3$ $\qquad$ $U = T_a$ $\qquad$ $y = x_1$

$U = J_2 \dot{x}_2 + B_2 x_2 + k_2 x_1 - k_2 x_3$

$$\dot{x}_2 = -\frac{k_2}{J_2}x_1 - \frac{B_2}{J_2}x_2 + \frac{k_2}{J_2}x_3 + \frac{1}{J_2}U$$

$k_2 x_1 - k_2 x_3 = J_1 \dot{x}_4 + B_1 x_4 + k_1 x_3$

$$\dot{x}_4 = \frac{k_2}{J_1}x_1 - \frac{(k_1 + k_2)}{J_1}x_3 - \frac{B_1}{J_1}x_4$$

$$\dot{\vec{X}} = \begin{bmatrix} 0 & 1 & 0 & 0 \\ -\frac{k_2}{J_2} & -\frac{B_2}{J_2} & \frac{k_2}{J_2} & 0 \\ 0 & 0 & 0 & 1 \\ \frac{k_2}{J_1} & 0 & -\frac{(k_1+k_2)}{J_1} & -\frac{B_1}{J_1} \end{bmatrix} \vec{X} + \begin{bmatrix} 0 \\ \frac{1}{J_1} \\ 0 \\ 0 \end{bmatrix} U$$

$$y = [1 \quad 0 \quad 0 \quad 0]\vec{X} + \vec{0}\,U$$

Diagrama en bloques:

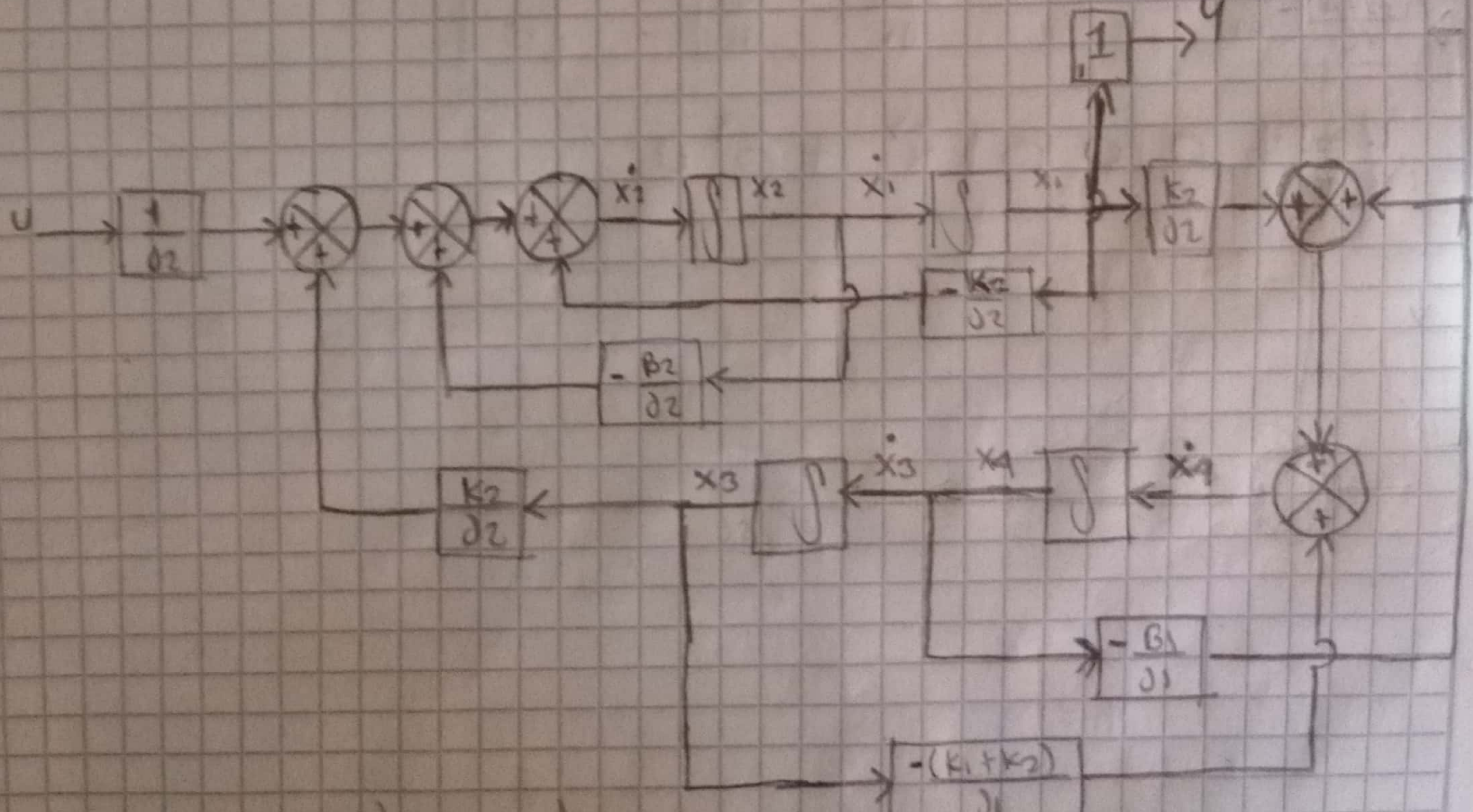


Diagrama flujo de señal: