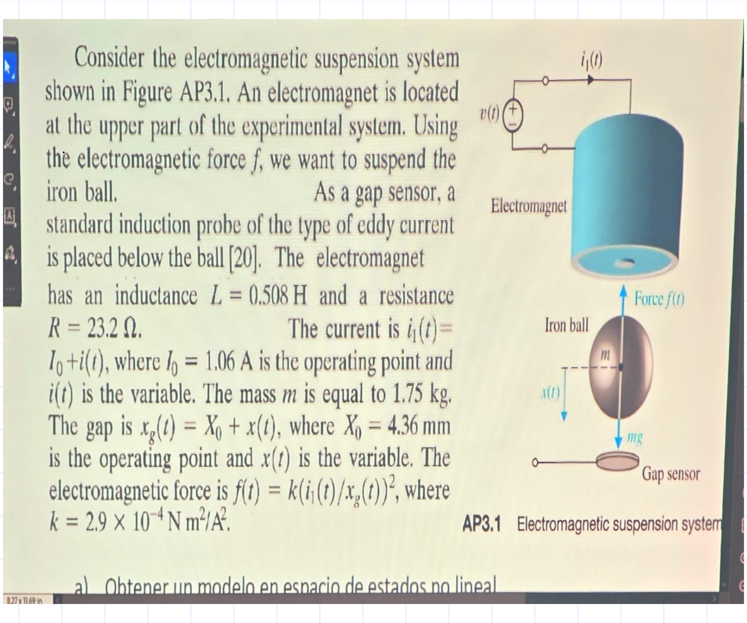
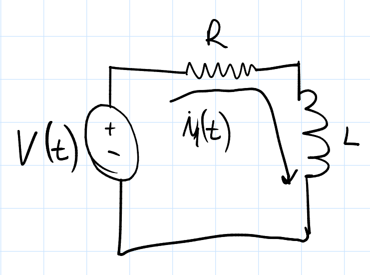
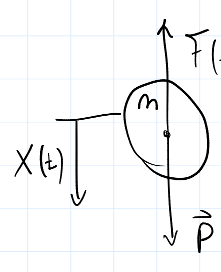

Consider the electromagnetic suspension system shown in Figure AP3.1. An electromagnet is located at the upper part of the experimental system. Using the electromagnetic force f, we want to suspend the iron ball. As a gap sensor, a standard induction probe of the type of eddy current is placed below the ball [20]. The electromagnet has an inductance $L = 0.508$ H and a resistance $R = 23.2\ \Omega$. The current is $i_1(t) = I_0 + i(t)$, where $I_0 = 1.06$ A is the operating point and $i(t)$ is the variable. The mass m is equal to 1.75 kg. The gap is $x_g(t) = X_0 + x(t)$, where $X_0 = 4.36$ mm is the operating point and $x(t)$ is the variable. The electromagnetic force is $f(t) = k(i_1(t)/x_g(t))^2$, where $k = 2.9 \times 10^{-4}\ N m^2/A^2$.

AP3.1 Electromagnetic suspension system

a) Obtener un modelo en espacio de estados no lineal





$$F(t) = K\left(\frac{i_1(t)}{x_g(t)}\right)^2$$

$$i_1(t) = I_0 + i(t)$$
$$X_g(t) = X_0 + X(t)$$
$$V(t) = V_0 + W(t)$$

$$V(t) = i_1(t)R + L\frac{\partial i_1(t)}{\partial t}$$

$$m\ddot{X}_g(t) = P - K\left(\frac{i_1(t)}{X_g(t)}\right)^2$$

$$\underbrace{V_0 + w(t)}_{u} = \underbrace{(I_0 + i(t))}_{z_1}R + L\frac{\partial}{\partial t}\underbrace{(I_0 + i(t))}_{z_1}$$

$$m\frac{d^2}{dt^2}\underbrace{(X_0 + X(t))}_{z_2} = mg - K\left(\frac{I_0 + i(t)}{\underbrace{X_0 + X(t)}_{z_2}}\right)^2$$

Variables de estado

$$X_g(t) \longrightarrow z_2$$
$$\dot{x}_g(t) \longrightarrow z_3$$
$$i_1(t) \longrightarrow z_1$$

$$V(t) = u$$

$$\dot{z}_2 = z_3$$
$$\dot{z}_3 = \ddot{X}_g(t)$$
$$\dot{z}_1 = \dot{i}_1(t)$$

$$u = z_1 R + L\dot{z}_1$$

$$m\dot{z}_3 = mg - k\left(\frac{z_1}{z_2}\right)^2$$

$$\dot{z}_1 = -\frac{R}{L}z_1 + \frac{1}{L}u = F_1$$
$$\dot{z}_2 = z_3 = F_2$$
$$\dot{z}_3 = g - \frac{K}{m}\left(\frac{z_1}{z_2}\right)^2 = F_3$$

$$z_{1eq} = I_0$$
$$z_{2eq} = X_0$$
$$z_{3eq} = 0$$
$$u_{eq} = V_0 = I_0 R$$

$$\begin{bmatrix} \left.\frac{\partial F_1}{\partial z_1}\right|_{eq} & \cdots & \left.\frac{\partial F_1}{\partial z_3}\right|_{eq} \\ \left.\frac{\partial F_2}{\partial z_1}\right|_{eq} & \cdots & \frac{\partial F_2}{\partial z_3} \\ \frac{\partial F_3}{\partial z_1} & \cdots & \frac{\partial F_3}{\partial z_3} \end{bmatrix} \Rightarrow A = \begin{bmatrix} -R/L & 0 & 0 \\ 0 & 0 & 1 \\ \frac{-2KI_0}{mX_0^2} & \frac{2KI_0^2}{mX_0^3} & 0 \end{bmatrix}$$

$$B = \begin{bmatrix} 1/L \\ 0 \\ 0 \end{bmatrix}$$

B ⇓ Jacobiano Respecto a U

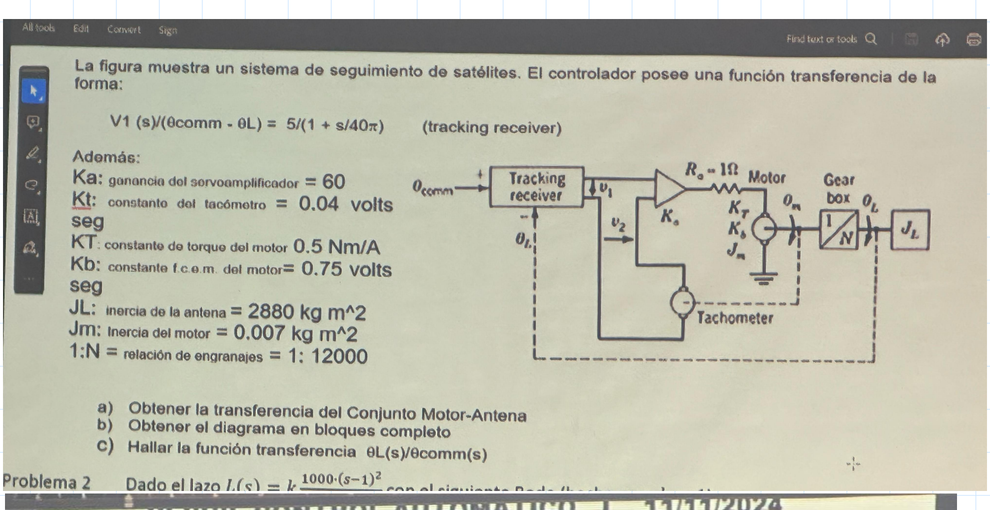
$C = [0\ 1\ 0] \Rightarrow$ el enunciado pide X como Salida.

$D = 0$

$$A = \begin{bmatrix} -45,67 & 0 & 0 \\ 0 & 0 & 1 \\ -18,48 & 4493 & 0 \end{bmatrix} \qquad B = \begin{bmatrix} 1,968 \\ 0 \\ 0 \end{bmatrix}$$

$$\dot{X}_1 = -45,67X_1 + 1,968w$$
$$\dot{X}_2 = X_3$$
$$\dot{X}_3 = -18,48X_1 + 4493X_2$$

$$\frac{X(s)}{W(s)} = \frac{-36,368}{(s^2 - 4493)(s + 45,67)}$$


La figura muestra un sistema de seguimiento de satélites. El controlador posee una función transferencia de la forma:

V1 (s)/(θcomm - θL) = 5/(1 + s/40π) (tracking receiver)

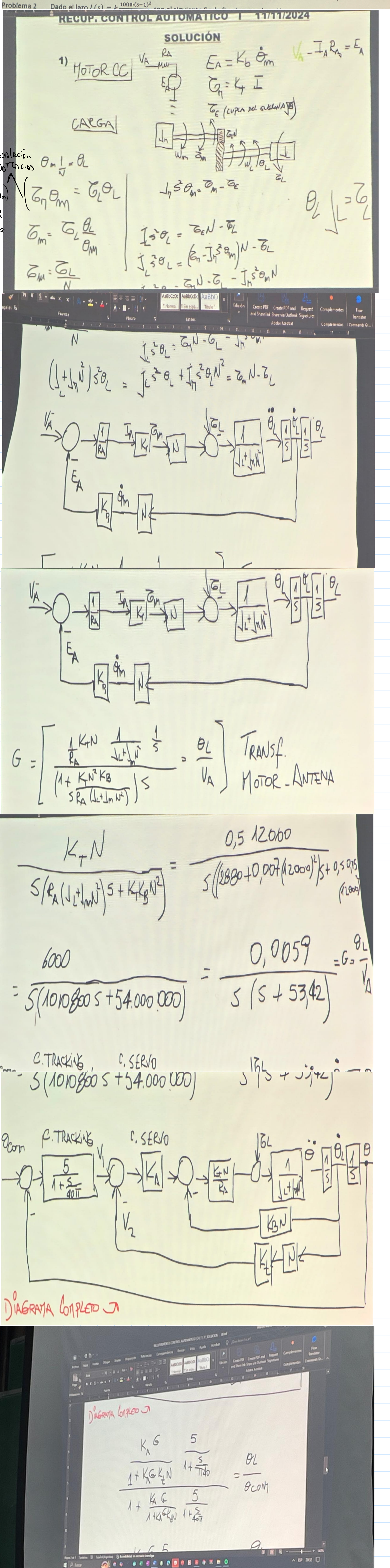
Además:
Ka: ganancia del servoamplificador = 60
Kt: constante del tacómetro = 0.04 volts seg
KT: constante de torque del motor 0.5 Nm/A
Kb: constante f.c.e.m. del motor= 0.75 volts seg
JL: inercia de la antena = 2880 kg m^2
Jm: inercia del motor = 0.007 kg m^2
1:N = relación de engranajes = 1: 12000

a) Obtener la transferencia del Conjunto Motor-Antena
b) Obtener el diagrama en bloques completo
c) Hallar la función transferencia θL(s)/θcomm(s)

Problema 2 Dado el lazo $L(s) = k\frac{1000\cdot(s-1)^2}{}$

$$\tau_m = J\cdot\ddot{\theta}_m + B\dot{\theta}_m$$
$$I\cdot\dot{w}_m \qquad w_m$$

Igualación de potencias
$(\tau\cdot\dot{\theta}_m)$
se puede trasladar a θ

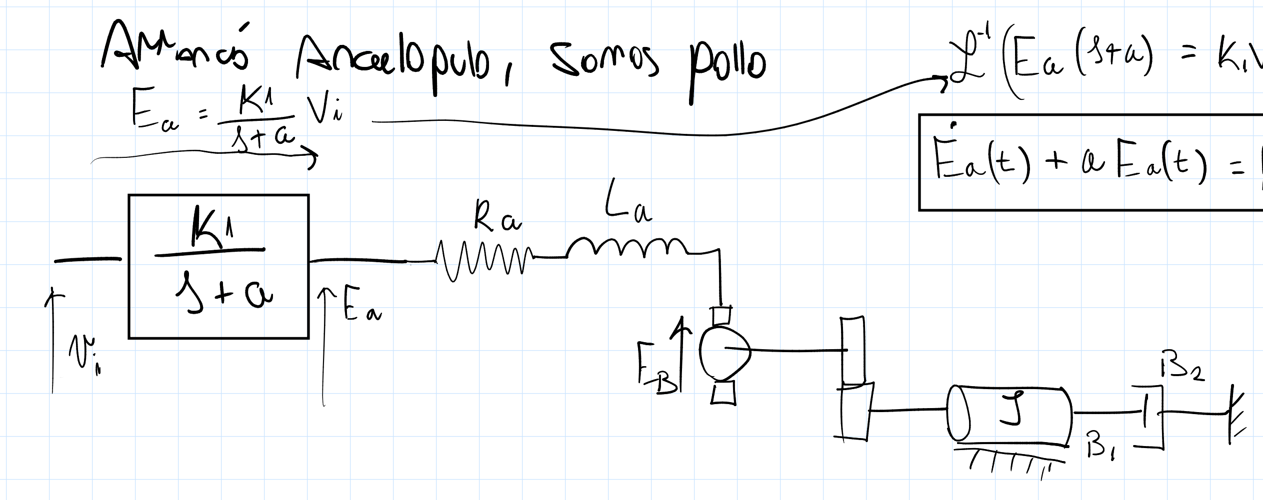


Amancó Ancelopulo, somos pollo

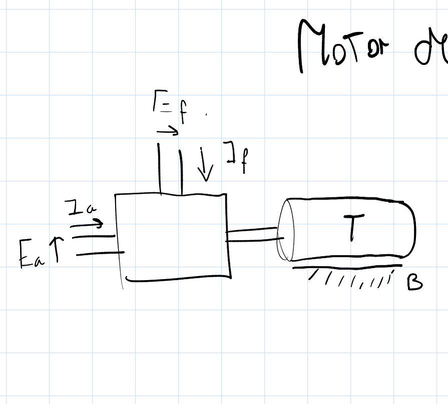
$$E_a = \frac{K_1}{s+a}V_i$$

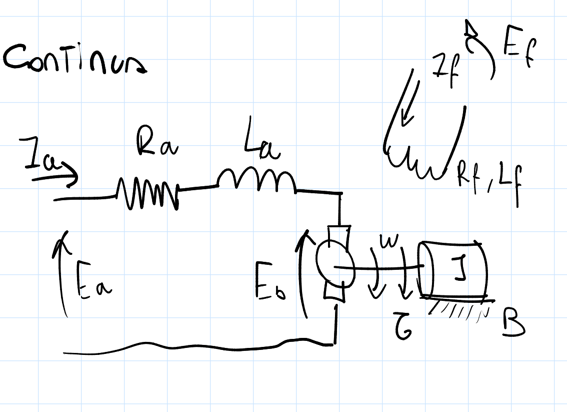
$$\mathcal{L}^{-1}\left(E_a(s+a) = K_1 V_i\right)$$

$$\boxed{\dot{E}_a(t) + aE_a(t) = K_1 V_i(t)}$$



Motor de corriente continua





$$\tau = K_1 I_a I_f \qquad E_b = K_2 w I_f$$

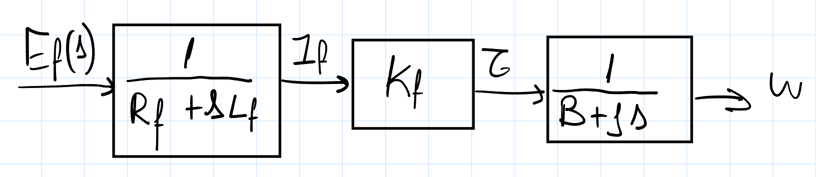
Controlado por Campo $\qquad I_a = cte$ $\qquad w = \dot{\theta}$, $\dot{w} = \ddot{\theta}$

$$\tau(t) = K_f I_f \quad (1) \Rightarrow \mathcal{L} \Rightarrow \tau(s) = K_f I_f(s) \quad (I)$$

$$\tau(t) = B\dot{\theta} + J\ddot{\theta} \quad (2) \Rightarrow \mathcal{L} \Rightarrow \tau(s) = (B + Js)\, w(s) \quad (II)$$

Fuerza de control E_f

$$E_f(t) = R_f I_f + L_f \frac{\partial I_f}{\partial t} \quad (3) \Rightarrow \mathcal{L} \Rightarrow E_f(s) = (R_f + L_f s)\, I_f(s) \quad (III)$$



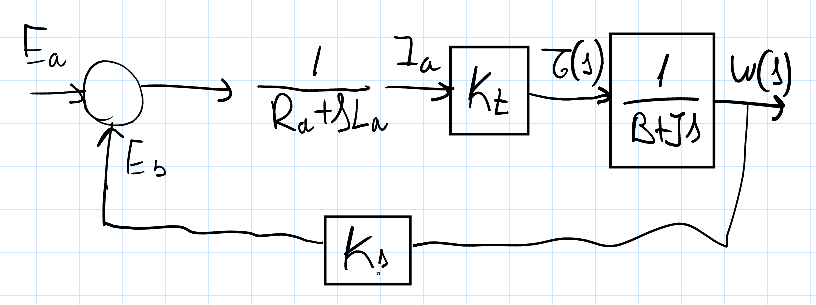
$$H(s) = \frac{K_f}{(R_f + sL_f)(B + Js)}$$

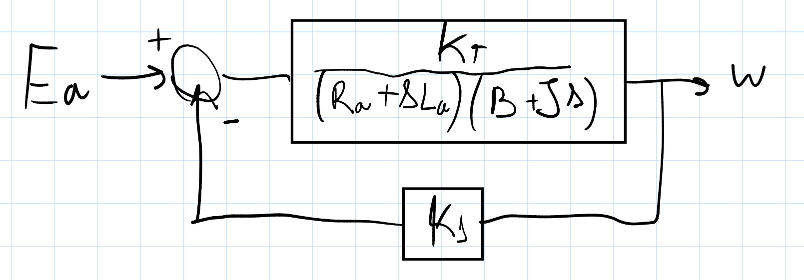
Controlado por Armadura $\qquad I_f = cte$

$$\text{Motor} \begin{cases} \tau(t) = \overset{\text{Torquimetrica}}{K_t} I_a \quad (1) \overset{\mathcal{L}}{\Rightarrow} \tau(s) = K_t I_a(s) \\ E_b(t) = \underset{\text{Torquimetrica.}}{K_b} w(t) \quad (2) \overset{\mathcal{L}}{\Rightarrow} E_b(s) = K_b w(s) \end{cases}$$

$$E_a(t) = R_a I_a(t) + L_a \frac{\partial I_a}{\partial t} + E_b \quad (3) \overset{\mathcal{L}}{\Rightarrow} E_a(s) = (R_a + sL_a) I_a(s) + E_b(s)$$

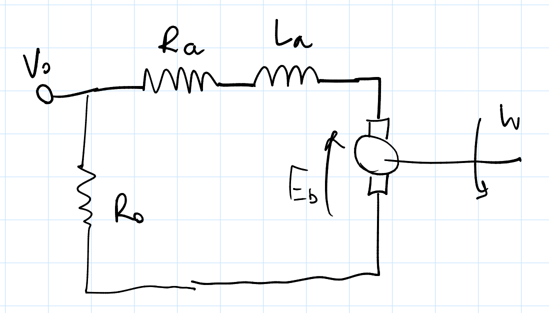
$$\tau(t) = Bw(t) + J\dot{w}(t) \overset{\mathcal{L}}{\Rightarrow} \tau(s) = (B + Js)\, w(s)$$





$$\frac{W}{E_a} = \frac{K_T/(R_a + sL_a)(B+Js)}{1 + \frac{K_T K_b}{(R_a + sL_a)(B + Js)}} = \frac{K_T}{(R_a + sL_a)(B + Js) + K_b K_T}$$

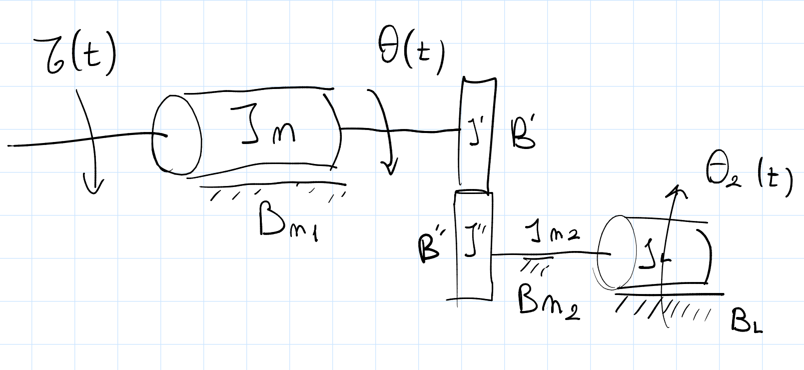
Tacómetro



Tacometro

$$\boxed{V_T = K_T\, w}$$

$E_b = K_b w \qquad V_o = \frac{R_o}{R_o + R_a} E_b$



$J_1 = J_{m_1} + J' \qquad B_1 = B_{m_1} + B' \qquad w_1 = \dot{\theta}_1 \qquad w_2 = \dot{\theta}_2$

$J_2 = J_{m_2} + J'' + J_L \qquad B_2 = B_{m_2} + B'' + B_L \qquad \dot{w}_1 = \ddot{\theta}_1 \qquad \dot{w}_2 = \ddot{\theta}_2$

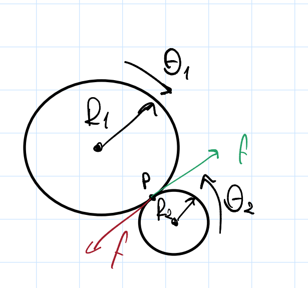
Influencia de J'' Sobre J'

$$\tau(t) - B_1 w_1 - \tau_1 = J_1 \dot{w}_1 \quad (1)$$

$$\tau_2(t) = B_2 w_2 + J_2 \dot{w}_2 \quad (2)$$

$$\frac{\tau_1}{\tau_2} = \frac{R_1}{R_2} = \frac{1}{n} \quad (3)$$

$$\frac{R_1}{R_2} = \frac{w_2}{w_1} = \frac{1}{n} \quad (4)$$



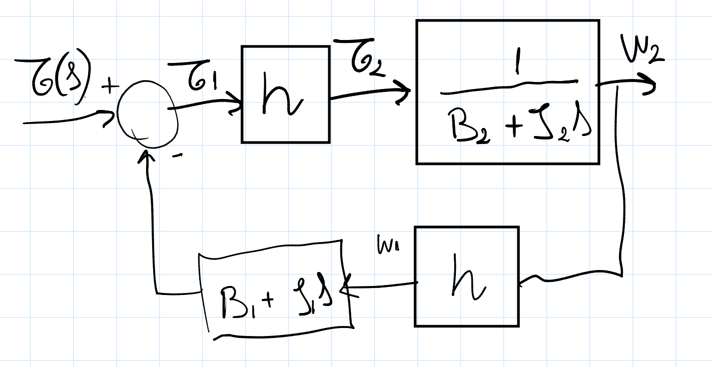
$\tau_1 = f R_1 \qquad V_p = R_1 w_1$

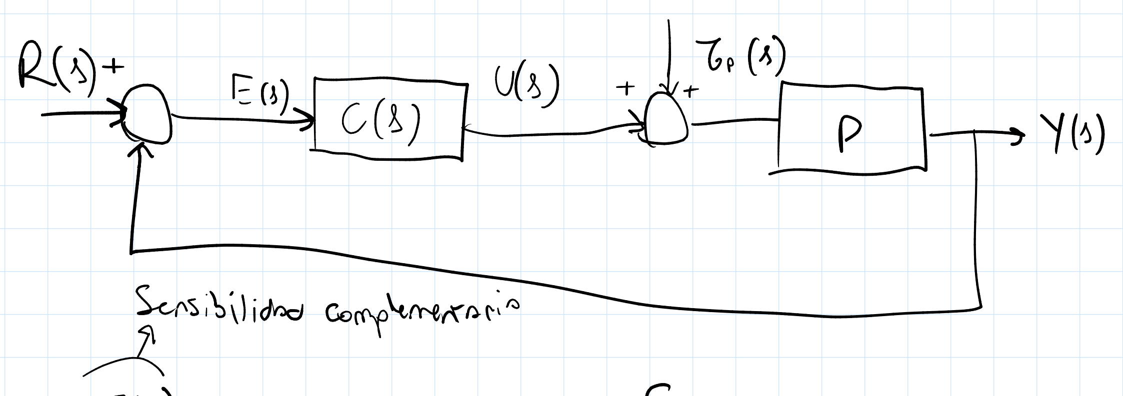
$\tau_2 = f R_2 \qquad V_p = R_2 w_2$

$R_1 w_1 = R_2 w_2$

$$\tau(s) - \tau_1 = (B_1 + J_1 s)\, w_1(s) \quad (I)$$

$$\tau_2 = (B_2 + J_2 s)\, W_2(s) \quad (II)$$





Sensibilidad complementaria

$$T(s) = \frac{Y(s)}{R(s)} \qquad C(s)S(s) = \frac{U(s)}{R(s)}$$

$$\underset{\text{Sensibilidad}}{S(s)} = \frac{E(s)}{R(s)} \qquad P(s)S(s) = \frac{Y(s)}{\tau_p(s)}$$

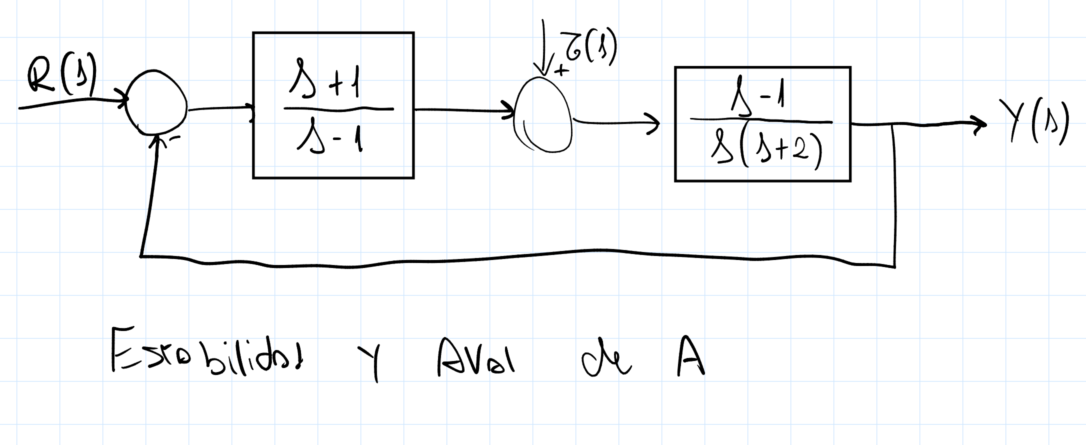
es Internamente estable Si las 4 Transferencias son estables

orden del $\overset{\text{Matu Hacete cortar}}{}$ sistema $\Rightarrow$ Cant de Autovalores de la Matriz A de Todo el Sistema

$L(s) = C(s)P(s) \qquad T(s) + S(s) = 1$

$$T = \frac{Y}{R} = \frac{C(s)P(s)}{1 + C(s)P(s)} = \frac{L(s)}{1 + L(s)} \qquad CS(s) = \frac{U(s)}{R} = \frac{C(s)}{1 + L(s)}$$

$$E(s) = \frac{1}{1 + C(s)P(s)} = \frac{1}{1 + L(s)} \qquad PS(s) = \frac{P}{1 + L(s)} \qquad \lambda(s) = \det(sI - A)$$



Estabilidad y Aval de A

una transf es estable cuando la parte real de los polos es estrictamente negativa