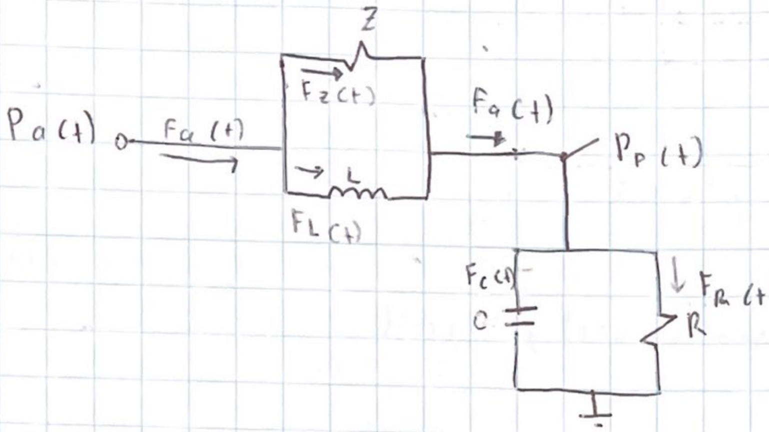
Modelado de sistemas fisiologicos 10/10/25

Práctica 5.4
Sistema Cardiovascular



Ecuaciones principales

$$F_a(t) = F_z(t) + F_L(t) = F_c(t) + F_R(t)$$

$$F_z(t) = \frac{P_a(t) - P_p(t)}{Z} \qquad F_c(t) = \frac{C\,d\,P_p(t)}{dt}$$

$$F_L(t) = \frac{1}{L}\int [P_a(t) - P_p(t)]\,dt \qquad F_R(t) = \frac{P_p(t)}{R}$$

Procedimiento algebraico

$$\frac{P_a(t)}{Z} - \frac{P_p(t)}{Z} + \frac{1}{L}\int [P_a(t) - P_p(t)]\,dt = \frac{C\,d\,P_p(t)}{dt} + \frac{P_p(t)}{R}$$

$$\frac{P_a(s)}{Z} - \frac{P_p(s)}{Z} + \frac{P_a(s) - P_p(s)}{Ls} = Cs\,P_p(s) + \frac{P_p(s)}{R}$$

$$\left(\frac{1}{Z} + \frac{1}{Ls}\right) P_a(s) = \left(Cs + \frac{1}{R} + \frac{1}{Z} + \frac{1}{Ls}\right) P_p(s)$$

Función de transferencia

$$\frac{Ls+Z}{LZs}\,Pa(s) = \frac{(LS)^2 + LZs + RLs + RZ}{RLZs}\,Pp(s)$$

$$\frac{Pp(s)}{Pa(s)} = \frac{\dfrac{Ls+Z}{LZs}}{\dfrac{(LS^2 + (LZs + RL)s + R_Z}{RLZs}}$$

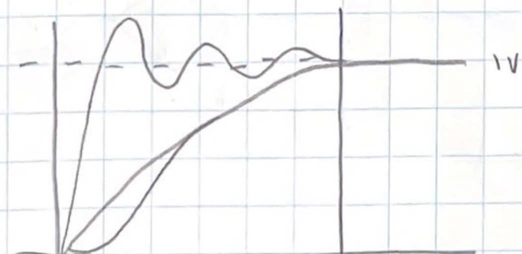
$$\frac{Pp(s)}{Pa(s)} = \frac{RLs + RZ}{(L\,s^2 + (L_Z + RL)s + RZ}$$

Error en estado estacionario

$$e(s) = \lim_{s \to 0} s \; Pa(s)\left[1 - \frac{Pp(s)}{Pa(s)}\right]$$

$$= \lim_{s \to 0} \cancel{s} * \frac{1}{\cancel{s}}\left[1 - \frac{RL\cancel{s}^{0} + R_Z}{(L\cancel{RZ}\,s^{2\,0} + (LZ + \cancel{RL})\,s^{0} + R_Z}\right]$$

$$= 1 - \frac{R_Z}{R_Z} = 0V$$



Transitorio | Estado estacionario

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Estabilidad en lazo abierto

$$\lambda_{1,2} = \frac{-b \pm \sqrt{b^2+4ac}}{2a}$$

$a = CLRZ$
$b = LZ + RL$
$c = RZ$

$$\lambda_{1,2} = \frac{-(LZ+RL) \pm \sqrt{(LZ+RL)^2 - 4CLR^2Z^2}}{2CLRZ} = \frac{(-)(\,)}{+}$$

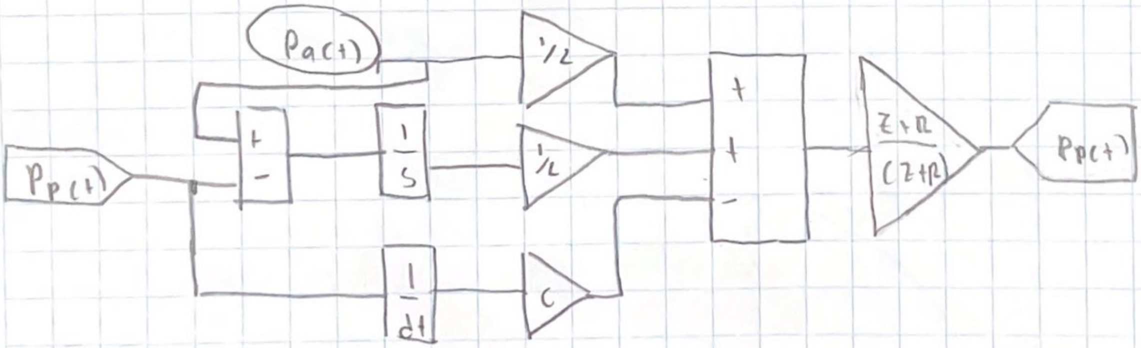
El sistema tiene una respuesta estable porque

$$Re\,\lambda_{1,2} < 0$$

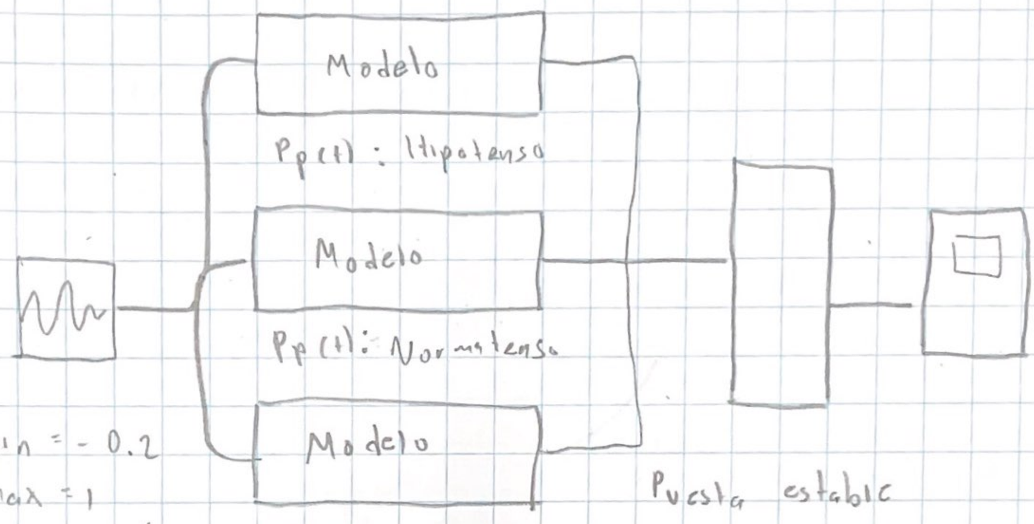
Modelo de ecuaciones integro-diferenciales

$$P_p(t)\left(\frac{1}{R} + \frac{1}{Z}\right) = \frac{P_a(t)}{Z} + \frac{1}{L}\int [P_a(t) - P_p(t)]\,dt - \frac{C\,dP_p(t)}{dt}$$

$$P_p(t) = \left(\frac{P_a(t)}{Z} + \frac{1}{L}\int [P_a(t) - P_p(t)\,dt - \frac{C\,dP_p(t)}{dt}\right)\frac{ZR}{Z+R}$$



Lazo abierto



min = -0.2
max = 1
seed = 106

$$\frac{P_p(s)}{P_a(s)} = \frac{R_1 s + R_2}{(C L R_2 s^2 + C L_2 + R_L) s + R_2}$$