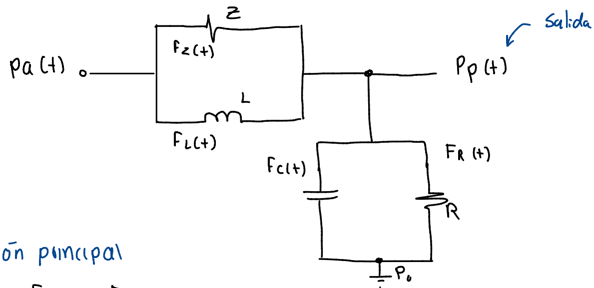
Sistema cardiovascular

08-10-2025



Ecuación principal

$$F_a(t) = F_Z(t) + F_L(t) = F_C(t) + F_R(t)$$

$$F_Z(t) = \frac{P_a(t) - P_p(t)}{Z}$$

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

$$F_C(t) = \frac{C\,d\,P_p(t)}{dt}$$

$$F_R(t) = \frac{P_p(t)}{R}$$

Componentes de la Ec Principal

Transformada de Laplace

$$F_Z(s) + F_L(s) = F_C(s) + F_R(s)$$

$$F_C(s) = CS\,P_p(s)$$

$$F_Z(s) = \frac{P_a(s) - P_p(s)}{Z}$$

$$F_R(s) = \frac{P_p(s)}{R}$$

$$F_L(s) = \frac{P_a(s) - P_p(s)}{LS}$$

Sustituir en la ecuación principal.

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

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Procedimiento algebraico.

$$\frac{P_a(s)}{Z} + \frac{P_a(s)}{Ls} = CsP_p(s) + \frac{P_p(s)}{R} + \frac{P_p(s)}{Z} + \frac{P_p(s)}{Ls}$$

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

$$+L(Z+R)S$$

$$P_a(s)\,\frac{LS+Z}{ZLS} = P_p(s)\,\frac{CLRZS^2 + LZS + LRS + RZ}{LRZS}$$

Función de transferencia

$$\frac{P_p(s)}{P_a(s)} = \frac{(LS+Z)LRZS}{CLRZS^2 + L(Z+R)(S+RZ)LZS}$$

$$= \frac{RLS + RZ}{CLRZS^2 + (LZ+LR)S + RZ}$$

Modelo de ecuaciones integro-diferenciales

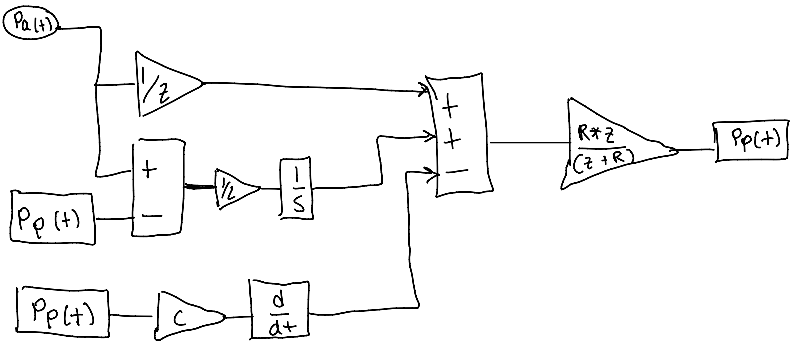
$$F_Z(t) + F_L(t) = F_C(t) + F_R(t)$$

Se despeja $P_p(t)$ de ambos lados

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

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

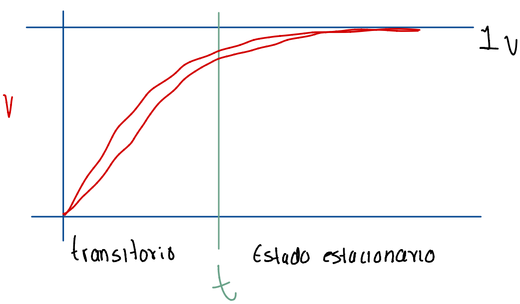
$$Pp(t) = \left[\frac{Pa(t)}{Z} + \frac{1}{L} \int \left[Pa(t) - Pp(t) \right] dt - c\frac{dPp(t)}{dt} \right] \frac{Rz}{z+}$$



Error en estado estacionario.

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

$$= \lim_{s \to 0} s \frac{1}{S} \left[1 - \frac{RLS + RZ}{CLRZS^2 + (CLZ + LR)S + RZ} \right]$$



Estabilidad en lazo abierto

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

$$a = CLRZ$$
$$b = (LZ + LR)$$
$$c = RZ$$

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

$$\lambda_1 = Re < \emptyset$$
$$\lambda_2 = Re < \emptyset$$

La respuesta del sistema es estable.