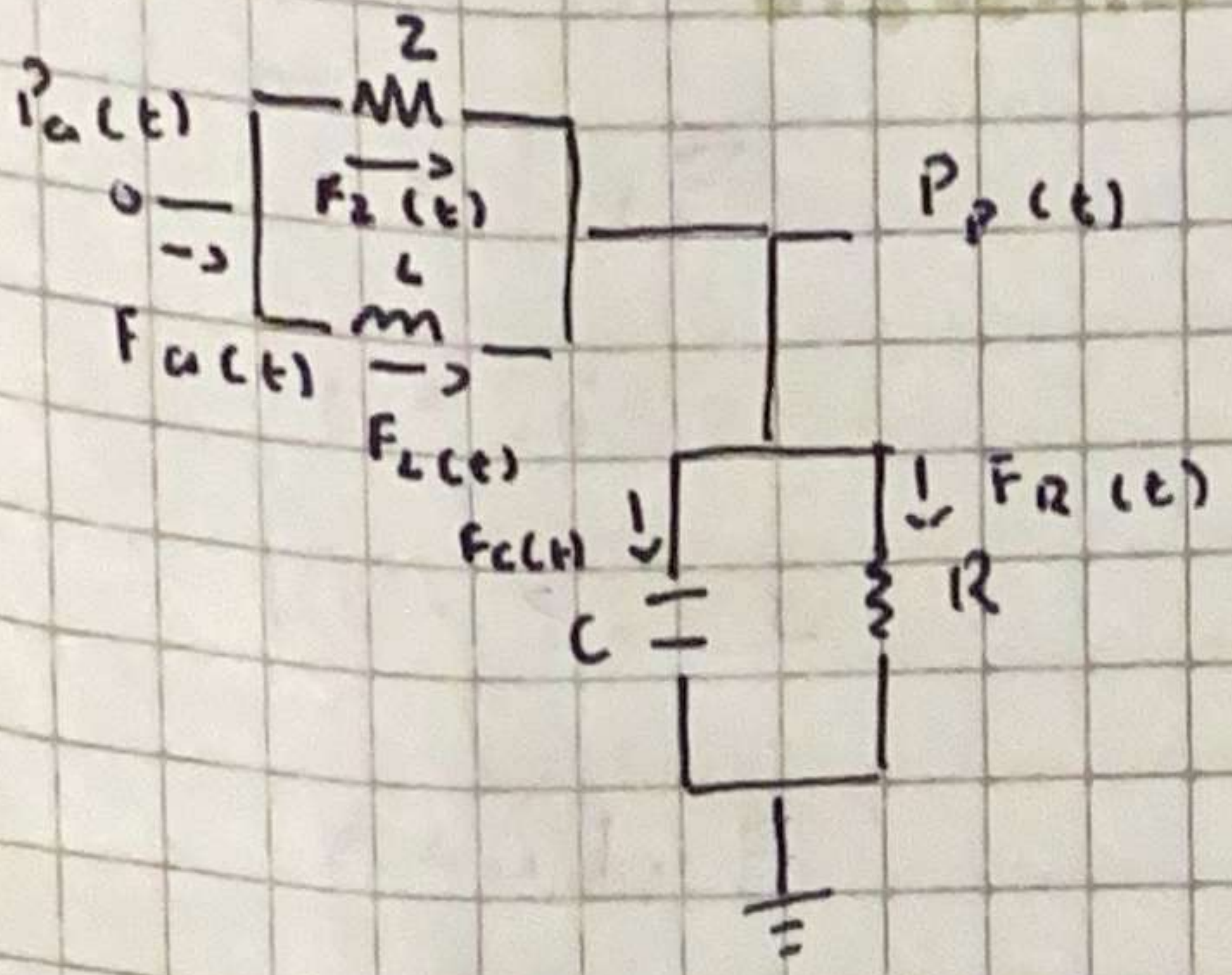
Sistema cardiovascular



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

$$F_Z(t) = \frac{P_a(t) - P_p(t)}{Z} \qquad F_C(t) = C\,\frac{dP_p(t)}{dt}$$

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

Procedimiento algebraico

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

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

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

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

$$\frac{Ls + z}{Lsz} P_a(s) = \frac{CLs^2 + Lzs + RLC + Rz}{RLzs} P_p(s)$$

$$\frac{P_p(s)}{P_a(s)} = \frac{\dfrac{CLs^2 + Lzs + LRC + Rz}{RLzs}}{\dfrac{Ls + z}{Lsz}}$$

$$\frac{P_p(s)}{P_a(s)} = \frac{CL^2s^2z + L^2s^2z^2 + L^2szRC + Lsz^2R}{RLzs^2 + RLz^2s}$$

$$\frac{P_p(s)}{P_a(s)} = \frac{CL^2S^2Z + L^2S^2Z^2 + L^2SZRC + LSZ^2R}{RLZS(S + Z)}$$

$$\frac{P_p(s)}{P_a(s)} = \frac{RLS + RZ}{CLRZ + (LZ + RL)S + RZ}$$

$$\text{Respuesta} = \frac{RLS + RZ}{CLRZ^2 + (LZ + RL)S + RZ}$$

Error estacionario

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

$$= \lim_{s \to 0} s * \frac{1}{s} \left[1 - \frac{RLs + Rz}{CLRZs^2 + (LZ + RL)s + RZ} \right]$$

$$= 1 - \frac{Rz}{Rz} = 0$$

Estabilidad en lazo abierto

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

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

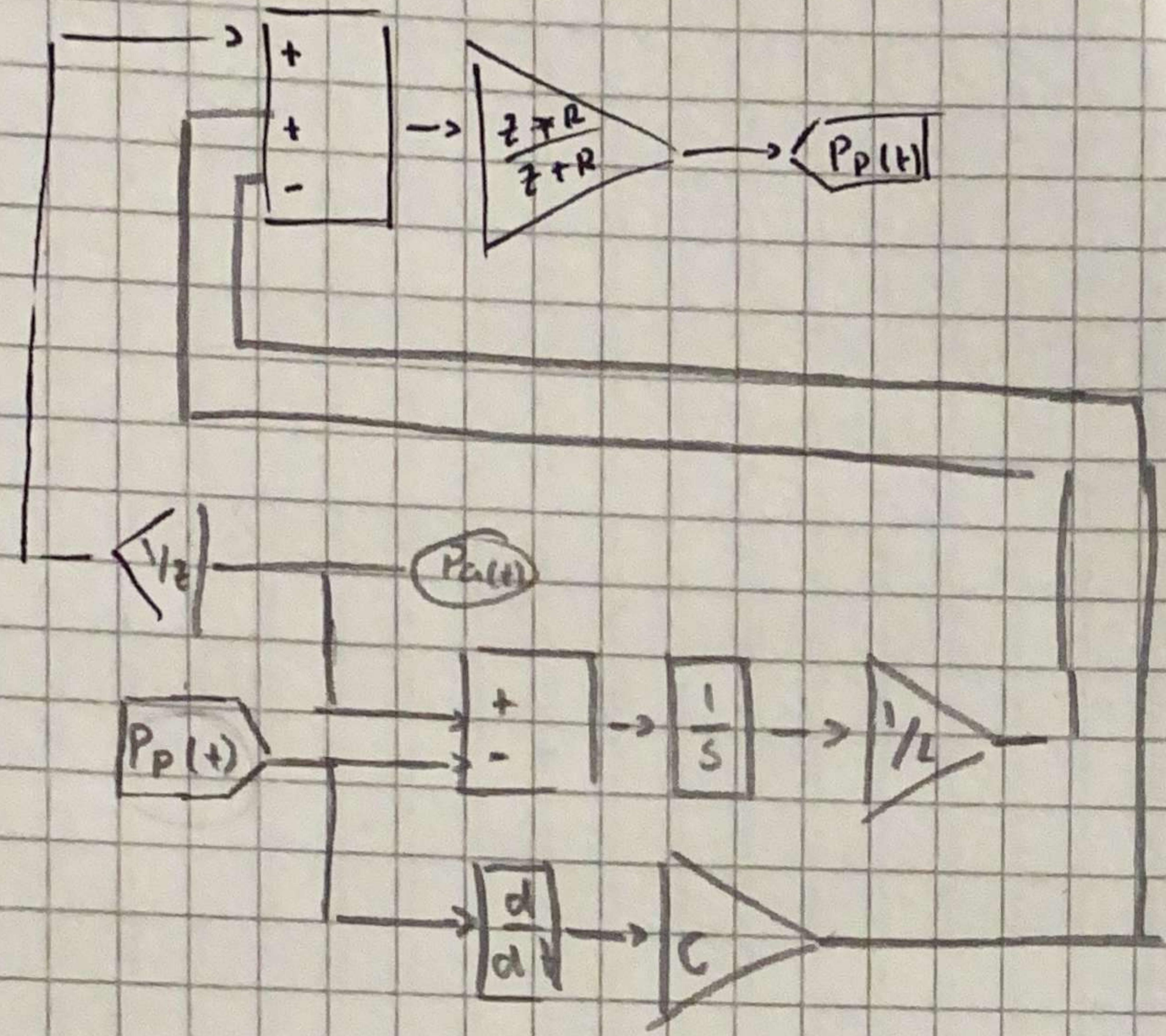
$$\lambda_{1,2} = \frac{-(LZ + RL) \pm \sqrt{(LZ^2 + RL)^2 - 4(CLRZ)(RZ)}}{2CLRZ}$$

El sistema es estable porque $\lambda_{1,2} < 0$

Modelo de ec. integro-diferenciales

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

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


+
+
-
Z + R
Z + R
Pp(t)
1/Z
Pa(t)
Pp(t)
+
-
1
s
1/L
d
d
C