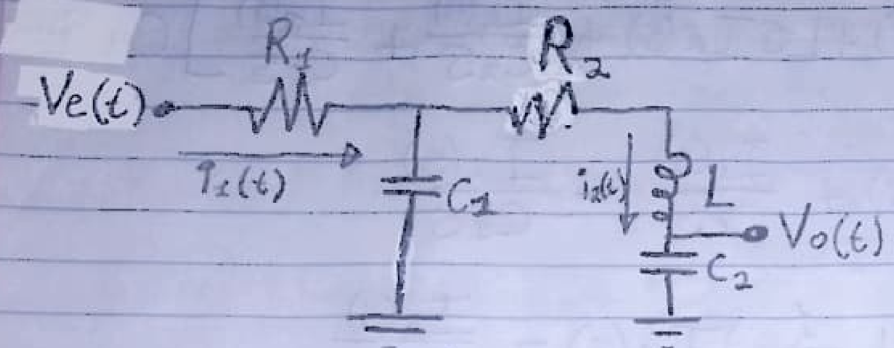
Sistema auditivo



① $V_e(t) = R_1 i_1(t) + \frac{1}{C_1}\int [i_1(t) - i_2(t)]\,dt$

② $\frac{1}{C_1}\int [i_1(t) - i_2(t)]\,dt = R_2 i_2(t) + \frac{L\,d[i_2(t)]}{dt} + \frac{1}{C_2}\int i_2(t)\,dt$

③ $V_o(t) = \frac{1}{C_2}\int i_2(t)\,dt$

Transformada de LaPlace

① $V_e(s) = R_1 I_1(s) + \frac{I_1(s) - I_2(s)}{C_1 S}$

② $\frac{I_1(s) - I_2(s)}{C_1 S} = R_2 I_2(s) + LS I_2(s) + \frac{I_2(s)}{C_2 S}$

③ $V_o(t) = \frac{I_2(s)}{C_2 S}$

Procedimiento algebraico

$$\frac{I_1(s)}{C_1 S} - \frac{I_2(s)}{C_1 S} = R_2 I_2(s) + LS I_2(s) + \frac{I_2(s)}{C_2 S}$$

$$\frac{I_1(s)}{C_1 S} = R_2 I_2(s) + LS I_2(s) + \frac{I_2(s)}{C_2 S} + \frac{I_2(s)}{C_1 S}$$

$$I_1(s) = \left[R_2 I_2(s) + LS\,I_2(s) + \frac{I_2(s)}{C_2 S} + \frac{I_2(s)}{C_1 S}\right] C_1 S$$

$$V_e(s) = R_1 I_1(s) + \frac{I_1(s)}{C_1 S} - \frac{I_2(s)}{C_1 S}$$

$$V_e(s) = \left(R_1 + \frac{1}{C_1 S}\right) I_1(s) - \frac{I_2(s)}{C_1 S}$$

$$V_e(s) = \left(\frac{C_1 R_1 S + 1}{C_1 S}\right) I_1(s) - \frac{I_2(s)}{C_1 S}$$

$$V_e(s) = \left(\frac{C_1 R_1 S + 1}{\cancel{C_1 S}}\right)\left[R_2 + LS + \frac{1}{C_2 S} + \frac{1}{C_1 S}\right] \cancel{C_1 S}\, I_2(s) - \frac{I_2(s)}{C_1 S}$$

$$V_e(s) = \left[(C_1 R_1 S + 1)\left(R_2 + LS + \frac{1}{C_2 S} + \frac{1}{C_1 S}\right) - \frac{1}{C_1 S}\right] I_2(s)$$

$$V_e(s) = \left[\left(C_1 R_1 R_2 S + C_1 R_1 L S^2 + \frac{C_1 R_1 \cancel{S}}{C_2 \cancel{S}} + \frac{\cancel{C_1 R_1 S}}{\cancel{C_1 S}} + R_2 + LS + \ldots\right.\right.$$

$$\left.\left.\frac{1}{C_2 S} + \frac{1}{C_1 S}\right) - \frac{1}{C_1 S}\right] I_2(s)$$

$$\frac{V_e(s)}{V_o(s)} = \frac{\left[(C_1 R_1 S + 1)\left(R_2 + LS + \frac{1}{C_2 S} + \frac{1}{C_1 S}\right) - \frac{1}{C_1 S}\right] \cancel{I_2(s)}}{\frac{\cancel{I_2(s)}}{C_2 S}}$$

$$\frac{V_e(s)}{V_o(s)} = \left[(C_1 R_1 S + 1)\left(R_2 + LS + \frac{1}{C_2 S} + \frac{1}{C_1 S}\right) - \frac{1}{C_1 S}\right] C_2 S$$

$$\frac{V_e(s)}{V_o(s)} = (C_1 R_1 S + 1)\left(R_2 + LS + \frac{1}{C_2 S} + \frac{1}{C_1 S}\right) C_2 S - \frac{C_2 \cancel{S}}{C_1 \cancel{S}}$$

$$\frac{V_e(S)}{V_o(S)} = (C_1 C_2 R_1 S^2 + C_2 S)\left(R_2 + LS + \frac{1}{C_2 S} + \frac{1}{C_1 S}\right) - \frac{C_2}{C_1}$$

$$= C_1C_2R_1R_2S^2 + C_1C_2R_1LS^3 + \frac{C_1\cancel{C_2}R_1S^{\cancel{2}}}{\cancel{C_2}\cancel{S}} + \frac{\cancel{C_1}C_2R_1S^{\cancel{2}}}{\cancel{C_1}\cancel{S}} + \dots$$

$$C_2R_2S + C_2LS^2 + \frac{\cancel{C_2S}}{\cancel{C_2S}} + \cancel{\frac{C_2\cancel{S}}{C_1\cancel{S}}} - \cancel{\frac{C_2}{C_1}}$$

$$= C_1C_2R_1R_2S^2 + C_1C_2R_1LS^3 + C_1R_1S + C_2R_1S + \dots$$

$$C_2R_2S + C_2LS^2 + 1$$

$$\frac{V_e(S)}{V_o(S)} = (C_1C_2R_1L)S^3 + [C_2(C_1R_1R_2 + L)]S^2 + (C_1R_1 + C_2R_1 + \dots$$

$$C_2R_2)S + 1$$

$$\frac{V_o(S)}{V_e(S)} = \frac{1}{(C_1C_2R_1L)S^3 + [C_2(C_1R_1R_2+L)]S^2 + (C_1R_1+C_2R_1+C_2R_2)S + 1}$$

Error en estado estacionario

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

$$e(s) = \lim_{S\to 0} \cancel{S}\,\frac{1}{\cancel{S}}\left[1 - \frac{1}{\cancel{(C_1C_2R_1L)S^3} + \cancel{[C_2(C_1R_1R_2+L)]S^2} + \cancel{(C_1R_1+C_2R_1+C_2R_2)S} + 1}\right]$$

$$e(s) = \lim_{S\to 0} = 1 - \frac{1}{1} = 1 - 1 = 0$$

Ecuaciones integro diferenciales

$$V_e(t) = R_1 i_1(t) + \frac{1}{C_1}\int [i_1(t) - i_2(t)]\,dt$$

$$R_1 \cdot i_1(t) = V_e(t) - \frac{1}{C_1}\int [i_1(t) - i_2(t)]\,dt$$

(1) $$i_1(t) = \left[V_e(t) - \frac{1}{C_1}\int [i_1(t) - i_2(t)]\,dt\right]\frac{1}{R_1}$$

$$\frac{1}{C_1}\int [i_1(t) - i_2(t)]\,dt = R_2 i_2(t) + \frac{L\,d[i_2(t)]}{dt} + \frac{1}{C_2}\int i_2(t)\,dt$$

$$R_2\, i_2(t) = \frac{1}{C_1}\int [i_1(t) - i_2(t)]\,dt - \frac{L\,d[i_2(t)]}{dt} - \frac{1}{C_2}\int i_2(t)\,dt$$

(2) $$i_2(t) = \left[\frac{1}{C_1}\int [i_1(t) - i_2(t)]\,dt - \frac{L\,d[i_2(t)]}{dt} - \frac{1}{C_2}\int i_2(t)\,dt\right]\frac{1}{R_2}$$

(3) $$V_o(t) = \frac{1}{C_2}\int i_2(t)\,dt$$

Estabilidad del circuito

$$\underbrace{(C_1C_2R_1L)}_{a_3}S^3 + \underbrace{[C_2(C_1R_1R_2+L)]}_{a_2}S^2 + \underbrace{(C_1R_1 + C_2R_1 + C_2R_1)}_{a_1}S + \underbrace{1}_{a_0}$$

$$a_3 > 0,\quad a_2 > 0,\quad a_1 > 0,\quad a_0 > 0$$

$$a_2 a_1 > a_3 a_0 \rightarrow [C_2(C_1R_1R_2+L)](C_1R_1 + C_2R_1 + C_2R_1) > (C_1C_2R_1L)(1)$$

Por lo tanto $a_2a_1 - a_3a_0 > 0$ ∴ El circuito es estable.

Polos Control:

$$[-5024.87560964 + 70887.24748774j,$$
$$-5024.87560964 - 70887.24748774j,$$
$$-4950.24878073 + 0j]$$

Las raíces son complejos conjugados con parte real negativa. Sistema estable con respuesta Subamortiguada

Polos caso:

$$[-9.99949495e+7,$$
$$-1.00255676e+4,$$
$$-2.49375035e+1]$$

Las raíces son reales negativos con diferente valor. Sistema estable con respuesto Sobreamortiguada.