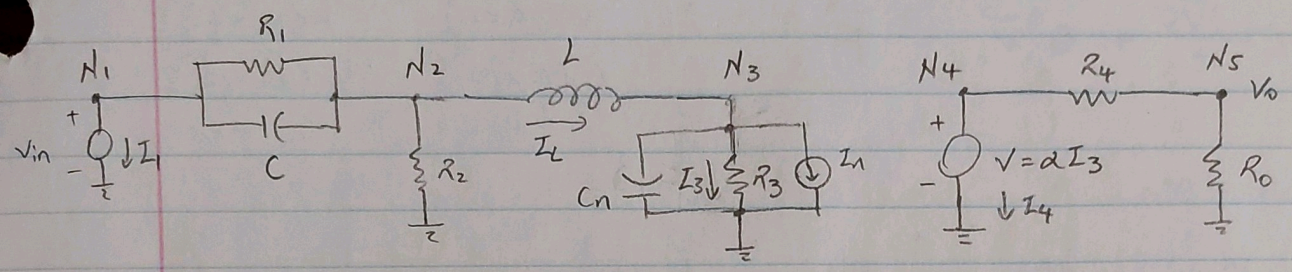
Appendix B Circuit with noise source



node N1: $N_1 = V_{in}$

$$I_1 + \frac{N_1 - N_2}{R_1} + C\frac{\partial (N_1 - N_2)}{\partial t} = 0$$

node N2: $$\frac{N_2 - N_1}{R_1} + C\frac{\partial (N_2 - N_1)}{\partial t} + \frac{N_2}{R_2} + I_L = 0$$

$$N_2 - N_3 = L\frac{\partial I_L}{\partial t}$$

node N3: $$-I_L + I_3 + I_n + C_n\frac{\partial N_3}{\partial t} = 0$$

$$I_3 = \frac{N_3}{R_3} \qquad I_n = I_n$$

node N4: $$I_4 + \frac{N_4 - N_5}{R_4} = 0 \qquad N_4 = \alpha I_3$$

node N5: $$\frac{N_5 - N_4}{R_4} + \frac{N_5}{R_o} = 0$$

$$V_o = N_5$$

$$C\frac{\partial \vec{v}}{\partial t} + G\vec{v} = \vec{F}$$

V (10x1) F (10x1)

C (10x10) G (10x10)

① $N_1 = V_{in}$

② $C\frac{\partial N_1}{\partial t} - C\frac{\partial N_2}{\partial t} + \frac{1}{R_1}N_1 - \frac{1}{R_1}N_2 + I_1 = 0$

③ $-C\frac{\partial N_1}{\partial t} + C\frac{\partial N_2}{\partial t} + -\frac{1}{R_1}N_1 + \left(\frac{1}{R_1} + \frac{1}{R_2}\right)N_2 + I_L = 0$

④ $-L\frac{\partial I_L}{\partial t} + N_2 - N_3 = 0$

⑤ $C_n\frac{\partial N_3}{\partial t} - I_L + I_3 + I_n = 0$

⑥ $-\frac{1}{R_3}N_3 + I_3 = 0$

⑦ $\frac{1}{R_4}N_4 - \frac{1}{R_4}N_5 + I_4 = 0$

⑧ $N_4 - \alpha I_3 = 0$

⑨ $-\frac{1}{R_4}N_4 + \left(\frac{1}{R_4} + \frac{1}{R_0}\right)N_5 = 0$

⑩ $I_n = I_n$

$$\vec{v} = \begin{bmatrix} N_1 \\ N_2 \\ N_3 \\ N_4 \\ N_5 \\ I_1 \\ I_L \\ I_3 \\ I_4 \\ I_n \end{bmatrix} \quad \vec{F} = \begin{bmatrix} V_{in} \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ I_n \end{bmatrix}$$

$$C = \begin{array}{c} \begin{matrix} N_1 & N_2 & N_3 & N_4 & N_5 & I_1 & I_L & I_3 & I_4 & I_n \end{matrix} \\ \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ C & -C & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ -C & C & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & -L & 0 & 0 & 0 \\ 0 & 0 & C_n & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \end{array}$$

$$G = \begin{array}{c} \begin{matrix} N_1 & N_2 & N_3 & N_4 & N_5 & I_1 & I_L & I_3 & I_4 & I_n \end{matrix} \\ \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \frac{1}{R_1} & -\frac{1}{R_1} & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ -\frac{1}{R_1} & \frac{1}{R_1}+\frac{1}{R_2} & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & -1 & 1 & 0 & 1 \\ 0 & 0 & -\frac{1}{R_3} & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & \frac{1}{R_4} & -\frac{1}{R_4} & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & -\alpha & 0 & 0 \\ 0 & 0 & 0 & -\frac{1}{R_4} & \frac{1}{R_4}+\frac{1}{R_0} & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \end{array}$$

$$C\frac{\partial \vec{V}}{\partial t} + G\vec{V} = \vec{F}$$

$$(G + jwC)\vec{V} = \vec{F}(w)$$

Time Domain:

$$\vec{V}^j = A^{-1}\left[\left(\frac{\vec{V}^{j-1}}{\partial t} + \vec{F}(t^j)\right)\right] \quad \text{where} \quad A = \frac{C}{\partial t} + G$$