ECEN 607 Exam 1 Problem 4 Solution

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Reverse Nested Miller Compensation (RNMC) with Voltage Buffers

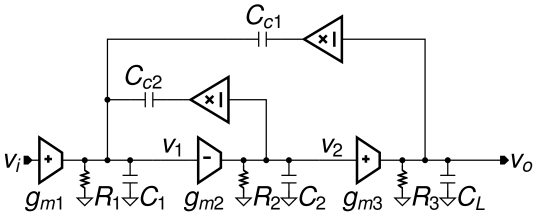

Figure : 3-Stage RNMC with Voltage Buffers Topology

- Write Nodal equations as usual:

$$\frac{v_1}{R_1} + v_1 sC_1 + (v_1 - v_2)sC_{c2} + (v_1 - v_o)sC_{c1} = g_{m1} v_i \qquad (1)$$

$$\frac{v_2}{R_2} + v_2 sC_2 = -g_{m2} v_1 \qquad (2)$$

$$\frac{v_3}{R_3} + v_3 sC_L = g_{m3} v_2 \qquad (3)$$

RNMC with Voltage Buffers: Signal Flow Graph (SFG)

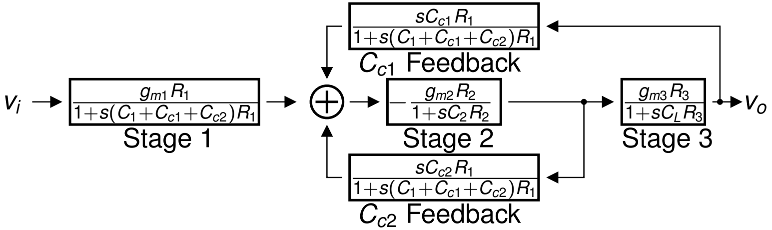

Figure : SFG of 3-Stage RNMC with Voltage Buffers

- Transform equations to SFG:

$$v_1 = \frac{g_{m1}R_1(v_i) + sC_{c2}R_1(v_2) + sC_{c1}R_1(v_o)}{1 + s(C_1 + C_{c1} + C_{c2})R_1} \tag{4}$$

$$v_2 = -\frac{g_{m2}R_2(v_1)}{1 + sC_2R_2} \tag{5}$$

$$v_3 = \frac{g_{m3}R_3(v_2)}{1 + sC_LR_3} \tag{6}$$

Solve SFG with Mason's Rule

- Use Mason's Rule,

$$\frac{v_o}{v_i} = \frac{-\overbrace{\frac{g_{m1}R_1}{1+s(C_1+C_{c1}+C_{c2})R_1}\frac{g_{m2}R_2}{1+sC_2R_2}\frac{g_{m3}R_3}{1+C_LR_3}}^{\text{Feedforward Path } v_i \text{ to } v_o}}{1+\underbrace{\frac{g_{m2}R_2}{1+sC_2R_2}\frac{sC_{c2}R_1}{1+s(C_1+C_{c1}+C_{c2})R_1}}_{C_{c2}\text{ Feedback}}+\underbrace{\frac{g_{m2}R_2}{1+sC_2R_2}\frac{g_{m3}R_3}{1+sC_LR_3}\frac{sC_{c1}R_1}{1+s(C_1+C_{c1}+C_{c2})R_1}}_{C_{c1}\text{ Feedback}}} \quad (7)$$

- Equalize Denominator,

$$\begin{aligned} D(s) = &(1+s(C_1+C_{c1}+C_{c2})R_1)(1+sC_2R_2)(1+sC_LR_3) \\ &+(1+sC_LR_3)g_{m2}R_2sC_{c2}R_1 \\ &+g_{m2}R_2g_{m3}R_3sC_{c1}R_1 \end{aligned} \quad (8)$$

- Expand denominator, separate coefficients, do approximation, ..., and done!

Comments

- "Works" because voltage buffers greatly simplify SFG (unidirectional).
- Without voltage buffers, C_{c1} and C_{c2} becomes bidirectional and you need to add extra feedforward paths in SFG.
- Mason's rule still holds but becomes more complicated.
- Good exercise to analyze Miller or Ahuja compensation or transistor-level circuits with this method.