ECEN 607 Exam 1 Problem 4 Solution

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Reverse Nested Miller Compensation (RNMC) with Voltage Buffers

![3-Stage RNMC with Voltage Buffers Topology](image)

Write Nodal equations as usual:

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

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

\[
\frac{v_3}{R_3} + v_3 sC_L = g_{m3} v_2 
\]  
(3)
RNMC with Voltage Buffers: Signal Flow Graph (SFG)

Stage 1

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

Stage 2

\[ g_{m2} R_2 \]

Stage 3

\[ g_{m3} R_3 \]

Figure: SFG of 3-Stage RNMC with Voltage Buffers

Transform equations to SFG:

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

(4)

\[ v_2 = -\frac{g_{m2} R_2 (v_1)}{1 + sC_2 R_2} \]  

(5)

\[ v_3 = \frac{g_{m3} R_3 (v_2)}{1 + sC_L R_3} \]  

(6)
Solve SFG with Mason’s Rule

- Use Mason’s Rule,

\[
\frac{v_o}{v_i} = \frac{g_{m1} R_1}{1 + s(C_1 + C_{c1} + C_{c2}) R_1} \frac{g_{m2} R_2}{1 + sC_2 R_2} \frac{g_{m3} R_3}{1 + sC_L R_3}
\]

\[= \left( \frac{g_{m2} R_2}{1 + sC_2 R_2} \frac{g_{m3} R_3}{1 + sC_L R_3} \right) + \left( \frac{g_{m1} R_1}{1 + s(C_1 + C_{c1} + C_{c2}) R_1} \right)
\]

- Equalize Denominator,

\[D(s) = (1 + s(C_1 + C_{c1} + C_{c2}) R_1)(1 + sC_2 R_2)(1 + sC_L R_3)
\]

\[+ (1 + sC_L R_3) g_{m2} R_2 sC_2 R_1
\]

\[+ g_{m2} R_2 g_{m3} R_3 sC_{c1} R_1
\]

- 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.