Discussion 13

Series - shunt. The circuit aims at providing an ideal voltage reading at the input and at ensuring the impedance of the output node to provide as good ideal of an output voltage as possible.

A.C.L.

- R.R. - cut the loop at the gate of H3

\[ R_R = -g_{m3} \cdot \frac{r_{03}}{r_{02}/R_{D2} + R_F + R_{s1} + \frac{1}{g_{m4}}} \]

\[ R_{eq} = \frac{R_{s1}}{R_{s1} + \frac{g_{m4}}{g_{m4}}} \cdot \frac{r_{02}/[r_{01} (1+g_{m2} R_S) + \frac{1}{g_{m4}}]}{r_{02}/[r_{01} (1+g_{m2} R_S) + \frac{1}{g_{m4}}]} \]

\[ R_{eq} = R_{s1} || \left[ R_F + \left( \frac{R_{D2}}{r_{03}} \right) \right] \]
\[ A_p = 1 + \frac{R_f}{R_s} \]

The source of \( V_1 \) needs to follow the gate, to limit \( V_{GS1} \) to 0, not to create infinite current in \( H_4 \) \((G_{M1} \gg R)\). So \( V_y = V_1 \).

Also, no current flows in \( H_4 \) otherwise it will create a drop on \( R_3 \), \( V_{OH2} \), and a finite \( V_{GS1} \), which would cause infinite current at the output. Because \( G_{M2} \gg R \),

\[ V_o = V_y + V_{RF} = V_{in} + R_f \frac{V_{in}}{R_s} = \left(1 + \frac{R_f}{R_s}\right)V_{in} \]

\[ A_0 = 0 \]

Since the input is fed to a deactivated device, no signal can flow to the output.

\[ A_{CL} = \frac{A_{in}}{1 + \frac{A_{in}}{RR}} \]

**Input impedance**

The input impedance \( R_{in} \rightarrow \infty \) because the input is fed to the gate of a MOS
Output impedance

Using Blackman's formulas

\[ z_{\text{out}} = \frac{z_{\text{out}}(a=0)}{1 + R R_{\text{open}}} \]

\[ z_{\text{out}}(a=0) = \frac{1}{R_{03} \parallel R_{D2} \parallel [R_{F} + (R_{S4} \parallel \frac{1}{S_{in}})]} \]

\[ R R_{\text{short}} = 0 \]

\[ R R_{\text{open}} = R R \]

The short output causes a lowering the output impedance.

Now with two-port

\[ P \]

\[ \alpha = \frac{S_{in} \parallel R_{02} \parallel [R_{04} (a + S_{in} \frac{1}{R_{S4}}) + R_{S0} \parallel R_{F}]}{1 + S_{in} \frac{1}{R_{S0} \parallel R_{F}}} \]

\[ a = \frac{S_{in} \parallel R_{02} \parallel \frac{1}{R_{S4}}}{1 + S_{in} \frac{1}{R_{S0} \parallel R_{F}}} \]

\[ \alpha = -\frac{S_{in} \parallel R_{02} \parallel (R_{S4} + R_{F})}{1 + S_{in} \frac{1}{R_{S0} \parallel R_{F}}} \]
\[ a \frac{R_{2c}}{1 + a \tau_f} \]

\[ T_{in} = \text{as} \]

\[ T_{out} = T_{out}(a=0) \cdot \frac{1}{1 + a \tau_f} \]

Slew correction

Now we modify the circuit as follows

We have added a source-follower \( M_4 \) to the circuit. This helps to make the circuit indeed uni-directional.

\[ R_R = \frac{g_{m4}}{1 + g_{m4} \cdot \frac{V_{gsa}}{g_{m4}}} \cdot R_{o2} \parallel \left[ r_{o4}(1 + g_{m4} \cdot \frac{V_{gsa}}{g_{m4}}) \right] \]

\[ \frac{-g_{m3} \cdot R_{o2} \parallel r_{o3} \parallel R_{S1} + R_F}{R_{S1} + R_F} \]

\[ R_{1} = R_{S1} + R_F \]

\[ A_{in} = 1 + \frac{R_F}{R_{S1}} \]

\[ A_0 = 0 \]
New with two port analysis

\[ a = \frac{Gw_1}{1 + Gw_1^2 \frac{r_{02}}{2w_4}} \cdot \frac{r_{02}}{r_{03}(1 + Gw_4 - \frac{r_1}{2w_4})} \]

\[ P = \frac{R_{52}}{R_{52} + P} \]

\[ => Nsw \quad RR = aP \]

This shows that the approaches coincide when the load is truly ac-coupled! Otherwise, two-port method is just an approximation, while RR gives the exact answer.