Miller Effect Examples

Common source amplifier:
\[ A_{VC_{gd}} = \text{negative, large number (-100)} \]

Miller multiplied cap has detrimental impact on bandwidth

Common drain amplifier:
\[ A_{VC_{gd}} = \text{slightly less than 1} \]

"Bootstrapped"(cap has negligible impact on) bandwidth!
Method of Open Circuit Time Constants

- This is a technique to find the dominant pole of a circuit (only valid if there really is a dominant pole!)
- For each capacitor in the circuit you calculate an equivalent resistor “seen” by capacitor and form the time constant $\tau_i = R_i C_i$
- The dominant pole then is the sum of these time constants in the circuit

$$\omega_{p,\text{dom}} = \frac{1}{\tau_1 + \tau_2 + \cdots}$$
Equivalent Resistance “Seen” by Capacitor

- For each “small” capacitor in the circuit:
  - Open-circuit all other “small” capacitors
  - Short circuit all “big” capacitors
  - Turn off all independent sources
  - Replace cap under question with current or voltage source
  - Find equivalent input impedance seen by cap
  - Form RC time constant

- This procedure is best illustrated with an example...

Example Calculation

![Circuit Diagram]

\[
R_{\text{eq}} = R_{\text{gs}} \cdot C_{\text{gs}}
\]

\[
i_{\text{ce}} = \frac{\gamma_{\text{ce}}}{R_{\text{ce}}}
\]

\[
R_{\text{ce}} = \frac{V_{\text{ce}}}{i_{\text{ce}}} = R_{\text{S}}
\]
\[ \begin{align*}
\bar{C}_{g0} = 0 \\
R_s + \frac{\eta_s}{\bar{v}_s} = 0 \\
\eta_s = \bar{v}_s R_s \\
\eta_t = \bar{v}_t R_s + (1 + \eta_s R_s) \bar{v}_s \\
\frac{\eta_s}{\bar{v}_s} = R_s + (1 + \eta_s R_s) R_s' \\
R_{g0} = R_s + (1 + \eta_s R_s) R_s' \\
\omega_P = (\bar{C}_{g0} + \bar{\eta}_{g0})^{-1} = (C_{g0} R_s + C_{g0} (R_s + (1 + \eta_s R_s) R_s'))^{-1}
\end{align*} \]
Higher-Order Time Constants

General two-pole transfer function:

\[ A(j\omega) = A_0 \frac{(1 + j \frac{\omega}{\omega_{z1}})(1 + j \frac{\omega}{\omega_{z2}})}{(1 + j \frac{\omega}{\omega_{p1}})(1 + j \frac{\omega}{\omega_{p2}})} \]

\[ A(j\omega) = A_0 \frac{N(j\omega)}{1 + a_1 j\omega + a_2 (j\omega)^2} \]

\[ a_1 = \frac{1}{\omega_{p1}} + \frac{1}{\omega_{p2}} \]

\[ a_2 = \frac{1}{\omega_{p1}\omega_{p2}} \]
Higher-Order Time Constants

- Coefficient $a_1$
  
  $$a_1 = R_{11}^{0}C_1 + R_{22}^{0}C_2$$

- Coefficient $a_2$:
  
  $$a_2 = R_{11}^{2}C_1R_{22}^{0}C_2 = R_{11}^{0}C_1R_{22}^{1}C_2$$

- This is exact!

- If $\omega_p \ll \omega_{p2}$:
  
  $$\frac{\omega_{p1}}{\omega_{p2}} \approx \frac{a_1}{a_2}$$

Example Calculation

$$R_{gs}^o = R_s$$

$$R_{gd}^o = R_s + (1 + g_mR_s)R_o'$$

$R_{gs}^{slant}$ and $R_{gd}^{slant}$ need only one of those
\[
R_{gs}^{o} = R_{s}^o \quad R_{gs}^{o} = R_{o}^o
\]

\[
R_{gs}^{o} = R_{s}^o \parallel \frac{1}{\frac{1}{R_{o}^o} + \frac{1}{R_{gs}^{o}}}
\]

\[
\alpha_2 = C_{gs} R_{gs}^{o} C_{gd} R_{gd}^{o} = C_{gs} R_{s} C_{gd} R_{o}^o
\]

\[
= C_{gs} R_{gs}^{o} \cdot C_{gd} R_{gd}^{o} = C_{gs} \frac{R_{s}^o \parallel \frac{1}{\frac{1}{R_{o}^o} + \frac{1}{C_{gd}}} C_{gd} \left( R_{s}^o + \frac{1}{C_{gd} R_{o}^o} \right)}{R_{s}^o + \frac{1}{C_{gd} R_{o}^o}}
\]

\[
= C_{gs} \frac{R_{s}^o C_{gd} R_{o}^o}{R_{s}^o + \frac{1}{C_{gd} R_{o}^o}}
\]