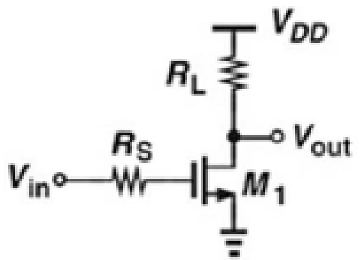
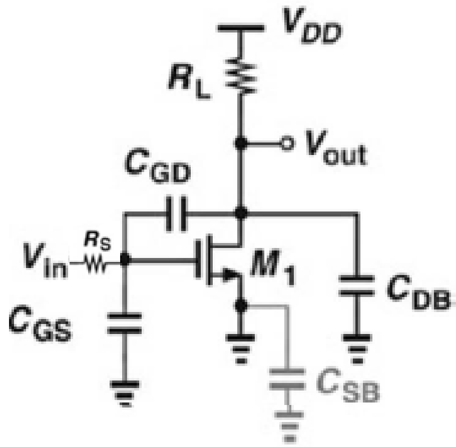
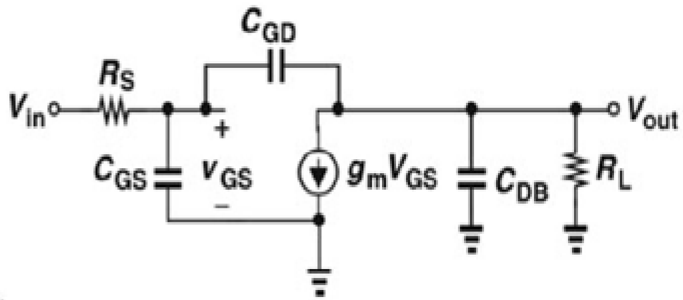
# Lect. 12: High-Frequency Response of MOS Amplifiers

(Razavi 11.1, 11.4)

- CS Amplifier



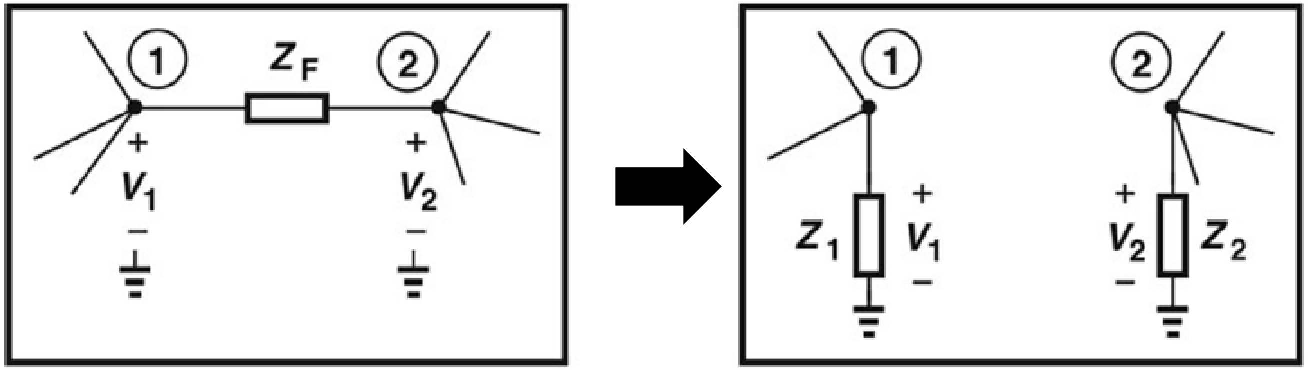




$V_{out}(s) / V_{in}(s)$ =?

Analysis complicated due to $C_{GD}$ linking input to output

Miller's Theorem

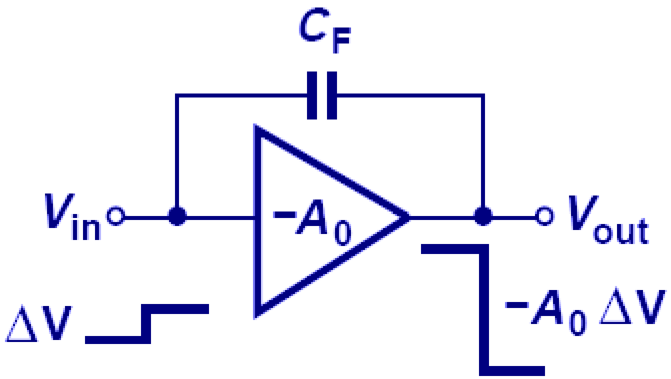


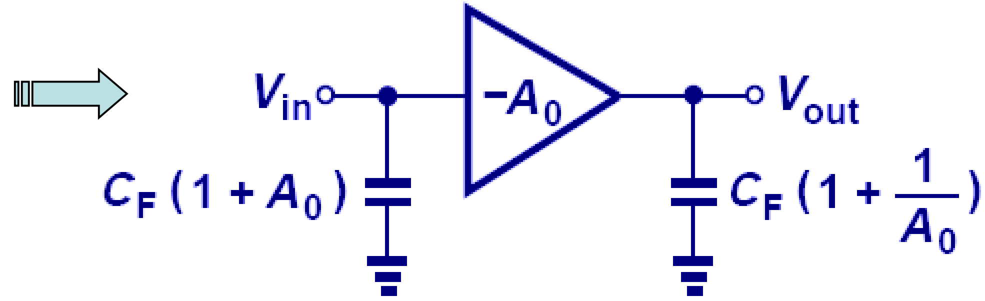

$$\frac{V_1 - V_2}{Z_F} = \frac{V_1}{Z_1} \qquad \frac{V_1 - V_2}{Z_F} = -\frac{V_2}{Z_2}.$$

$$Z_1 = Z_F \frac{V_1}{V_1 - V_2} \qquad Z_2 = Z_F \frac{-V_2}{V_1 - V_2}$$

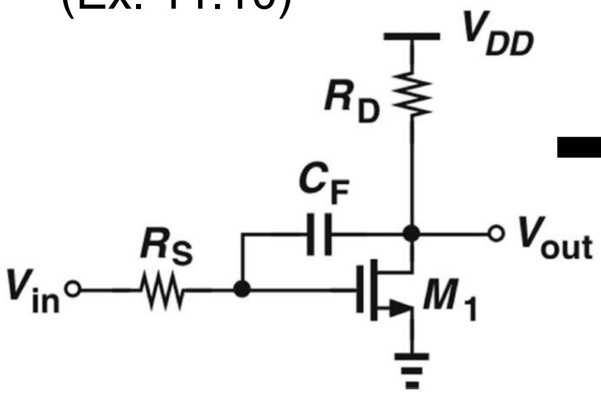
$$= \frac{Z_F}{1 - A_v} \qquad = \frac{Z_F}{1 - \frac{1}{A_v}}.$$

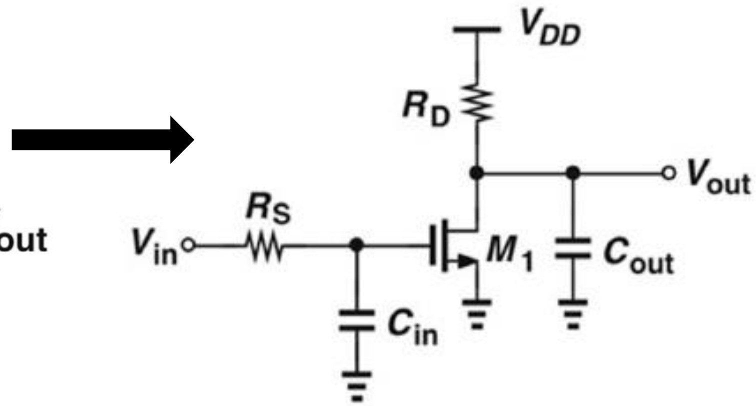
Miller Multiplication




(Ex. 11.10)




$C_{in}$, $C_{out}$?

$\omega_{p,in}$, $\omega_{p,out}$?

Approximation



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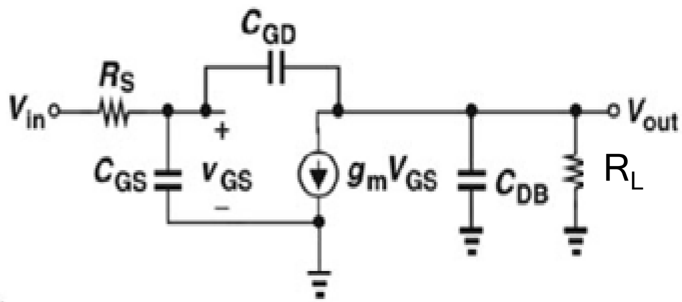
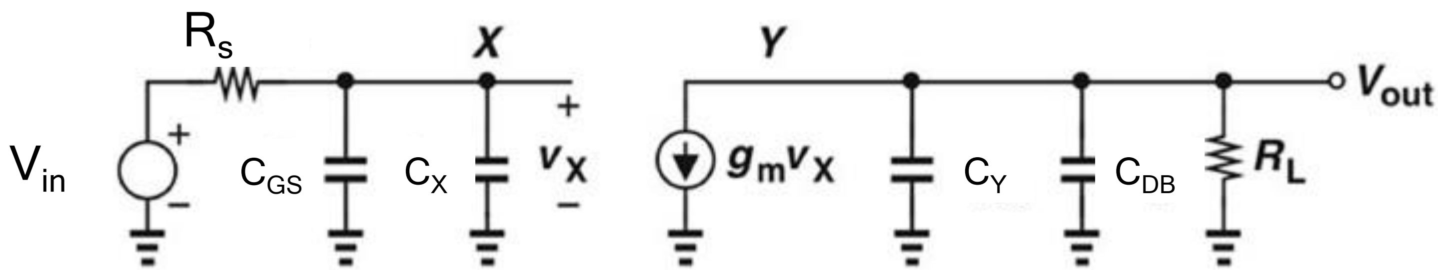
# Lect. 12: High-Frequency Response of MOS Amplifiers

- CS Amplifier




$C_X$, $C_Y$ ?

$$C_X = C_{GD}\,(1 + g_m R_L)$$

$$C_Y = C_{GD}\left(1 + \frac{1}{g_m R_L}\right)$$

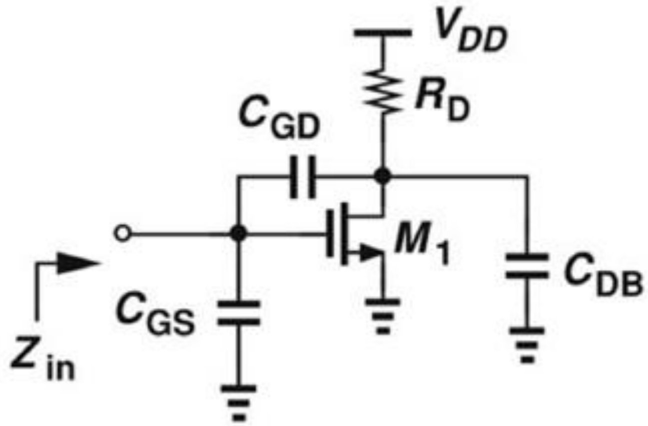
$$|\omega_{p,in}| = \frac{1}{R_S[C_{GS} + C_{GD}(1 + g_m R_L)]}$$

$$|\omega_{p,out}| = \frac{1}{R_L\left[C_{DB} + C_{GD}\left(1 + \frac{1}{g_m R_L}\right)\right]}$$

Dominant capacitor?

Speed limitation by the Miller effect

- Input impedance for CS Amplifier

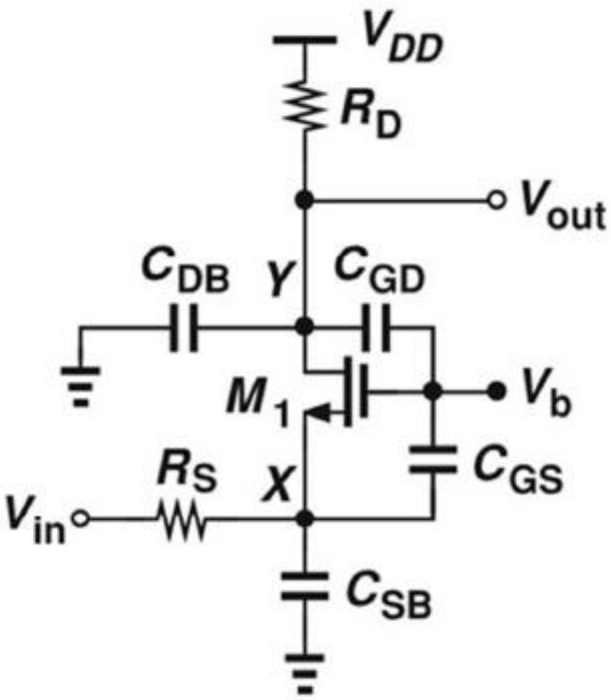



$$Z_{in} \approx \frac{1}{[C_{GS} + (1 + g_m R_D)C_{GD}]s}$$

Input impedance reduced at high freq. due to Miller effect

# Lect. 12: High-Frequency Response of MOS Amplifiers

- CG Amplifier



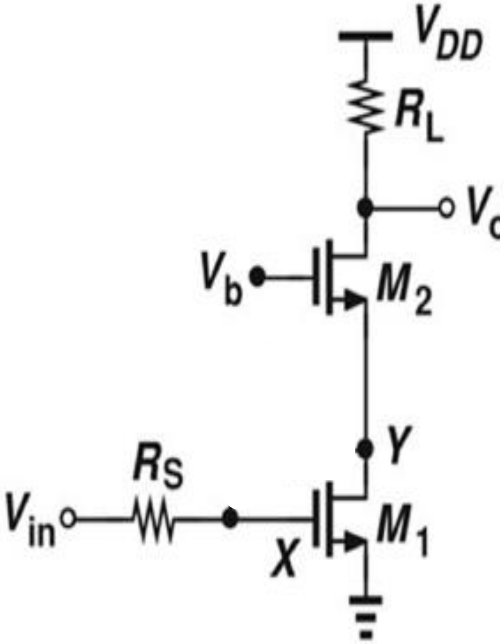

$$|\omega_{p,X}| = \frac{1}{\left(R_S \,\|\, \frac{1}{g_m}\right)(C_{GS} + C_{SB})}$$

$$|\omega_{p,Y}| = \frac{1}{R_D\,(C_{DB} + C_{GD})}$$

No speed limitation by the Miller effect

# Lect. 12: High-Frequency Response of MOS Amplifiers

- Cascode Amplifier

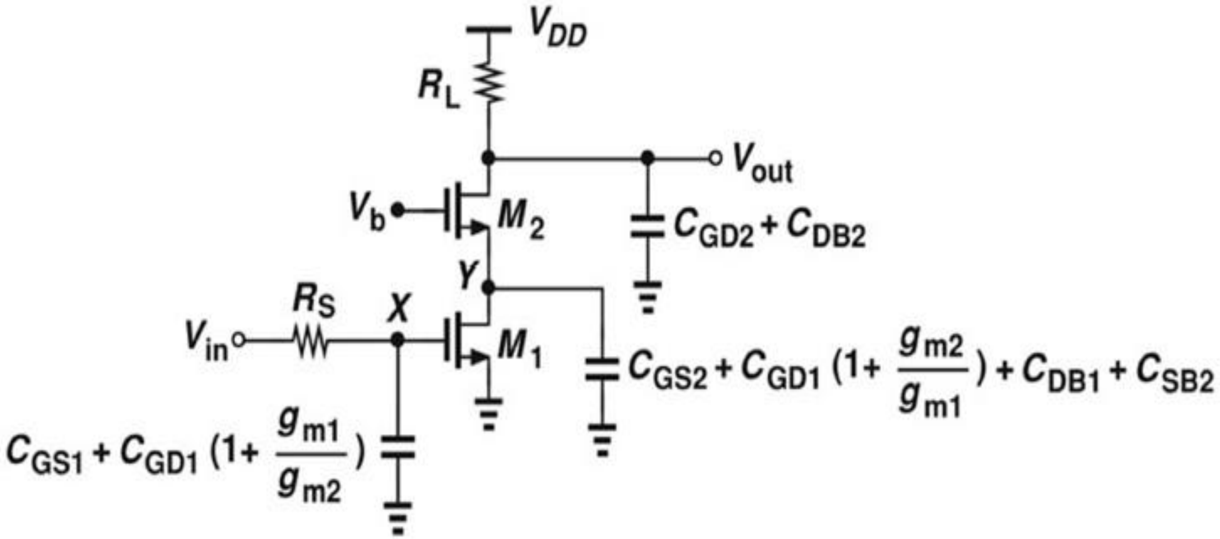



- CS and then CG

- Add capacitors for each transistor

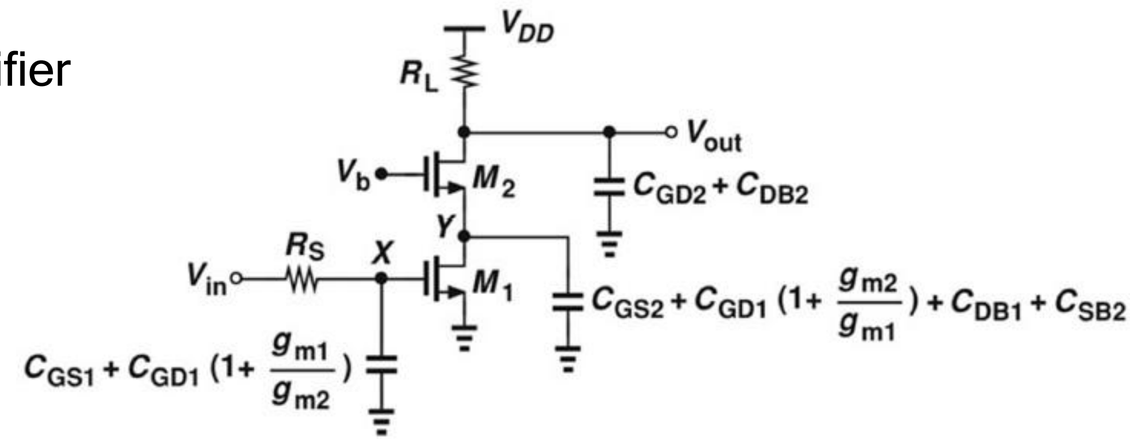
- Simplifiy

- Replace $C_{GD1}$ with $C_{in,1}$ and $C_{out,1}$



# Lect. 12: High-Frequency Response of MOS Amplifiers

- Cascode Amplifier




$$|\omega_{p,X}| = \frac{1}{R_S[C_{GS1} + \left(1+\frac{g_{m1}}{g_{m2}}\right)C_{GD1}]} \qquad |\omega_{p,Y}| = \frac{1}{\frac{1}{g_{m2}}[C_{DB1} + C_{GS2} + \left(1+\frac{g_{m2}}{g_{m1}}\right)C_{GD1} + C_{SB2}]} \qquad |\omega_{p,out}| = \frac{1}{R_L(C_{DB2}+C_{GD2})}$$

- Does this suffer from Miller effect?

- Cascode amp provides larger gain-bandwidth product than CS



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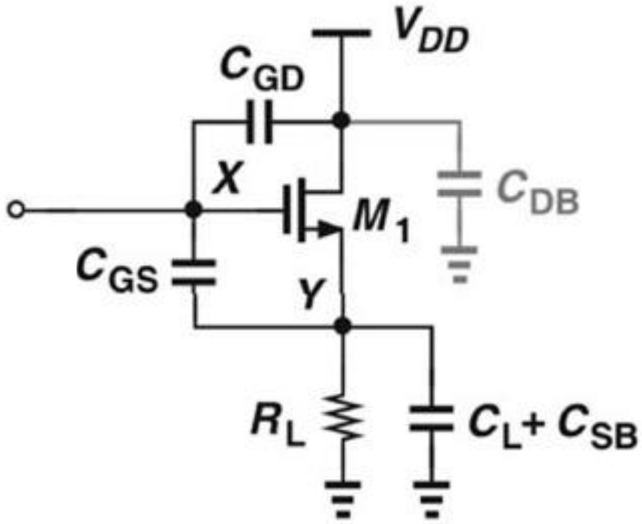
# Lect. 12: High-Frequency Response of MOS Amplifiers

- Source Follower



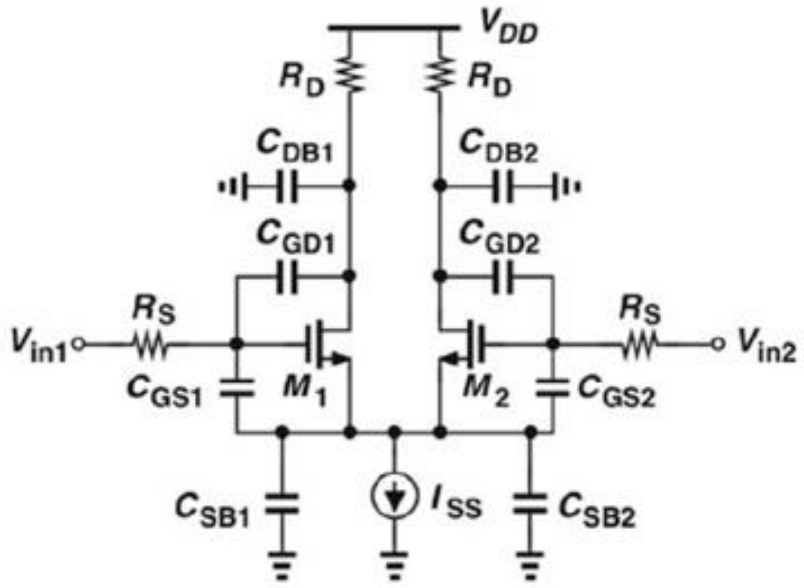

$$C_{in} = C_{GD} + C_{GS}(1 - AV)$$

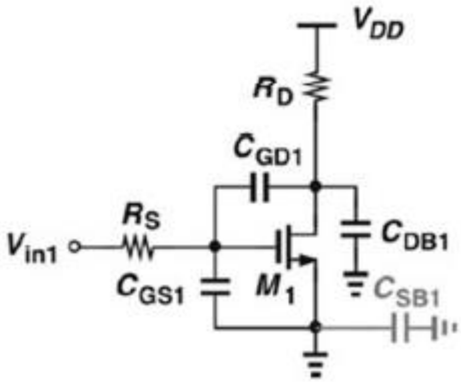
$$A_v = \frac{R_L}{R_L + \frac{1}{g_m}}$$

$$Z_{in} = \frac{1}{\left(C_{GD} + C_{GS}\frac{1}{1 + g_m R_L}\right)s}$$

Does this suffer from Miller effect?

- Differential Amplifier

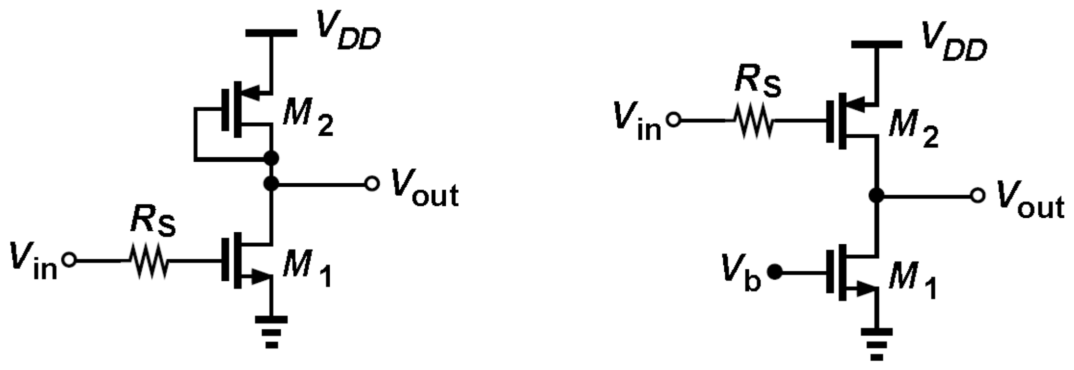



➔ CS amplifier

Homework

Assuming $\lambda > 0$ and using Miller's theorem, determine the input and output poles of the stages




(a) (b)