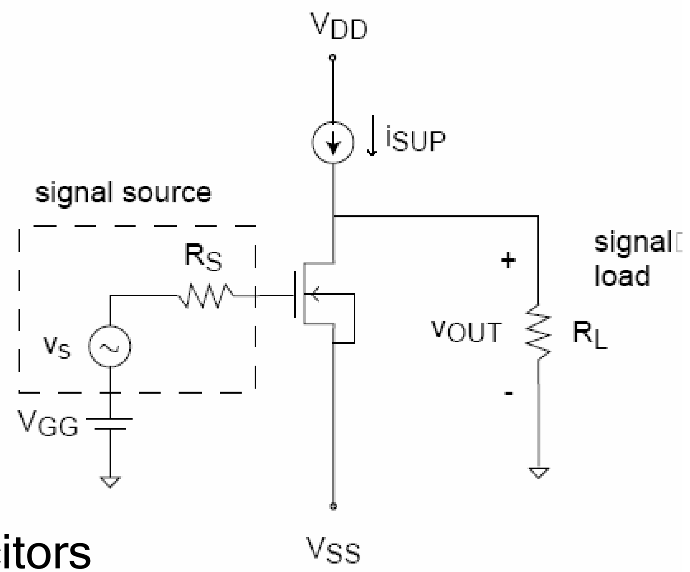
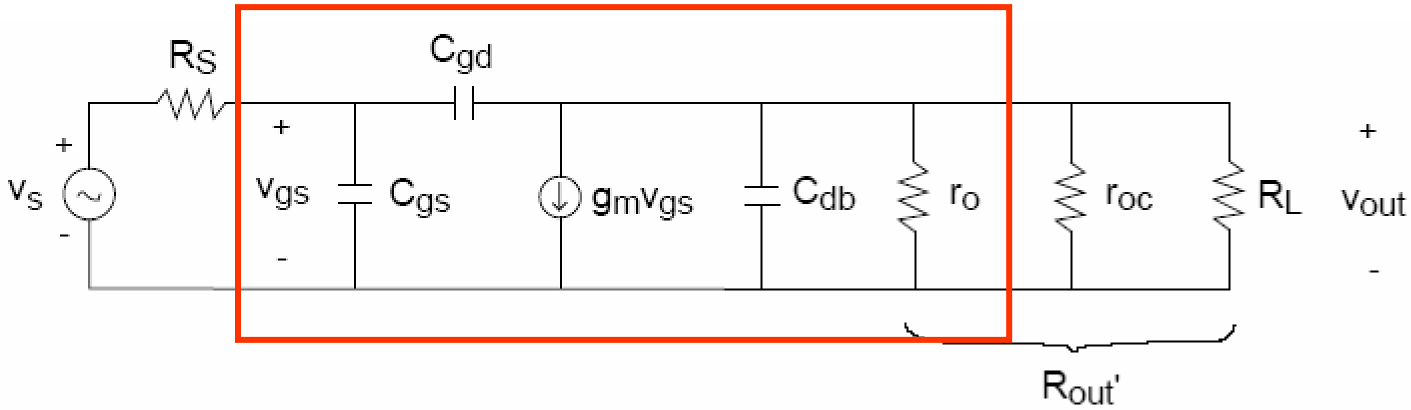
# Lect. 7: Amplifier Frequency Response

Common Source Amplifier




Small-signal model with capacitors



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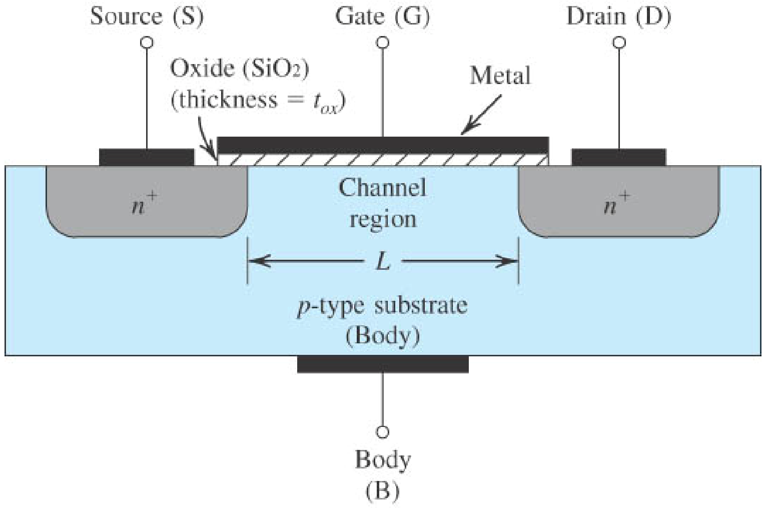

(b)

$C_{db}$:
Capacitance between drain and body
Due to depletion-layer between D and B

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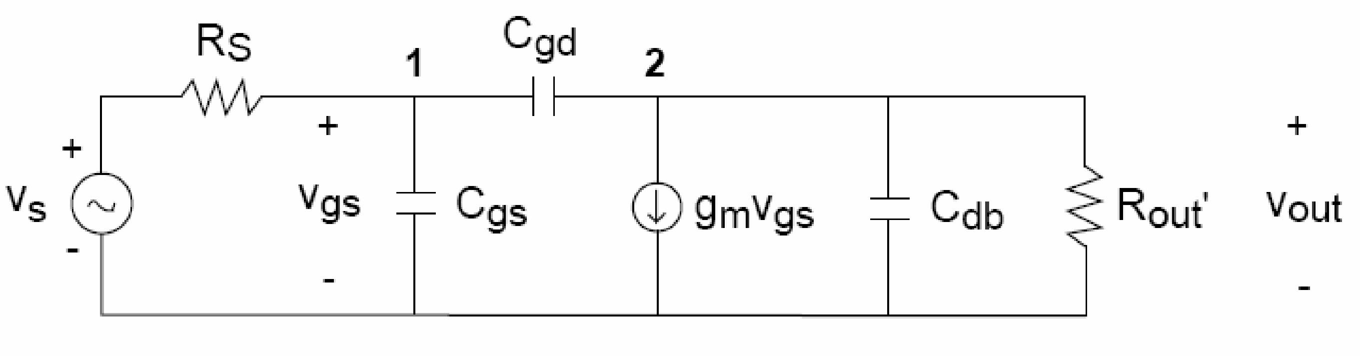


$$A_v = \frac{-(g_m - j\omega C_{gd})R'_{out}}{DEN}$$

$$DEN = 1 + j\omega\{R_S C_{gs} + R_S C_{gd}[1 + R'_{out}(\frac{1}{R_S} + g_m)] + R'_{out}C_{db}\} - \omega^2 R_S R'_{out} C_{gs}(C_{gd} + C_{db})$$

Assumptions for simplication:

(1) $\omega \ll \omega_T = \frac{g_m}{C_{gs}+C_{gd}} \Rightarrow g_m \gg \omega(C_{gs} + C_{gd}) > \omega C_{gs},\ \omega C_{gd}$

(2): Ignore $\omega^2$ term

(3): $\frac{1}{R_S} + g_m \simeq g_m$

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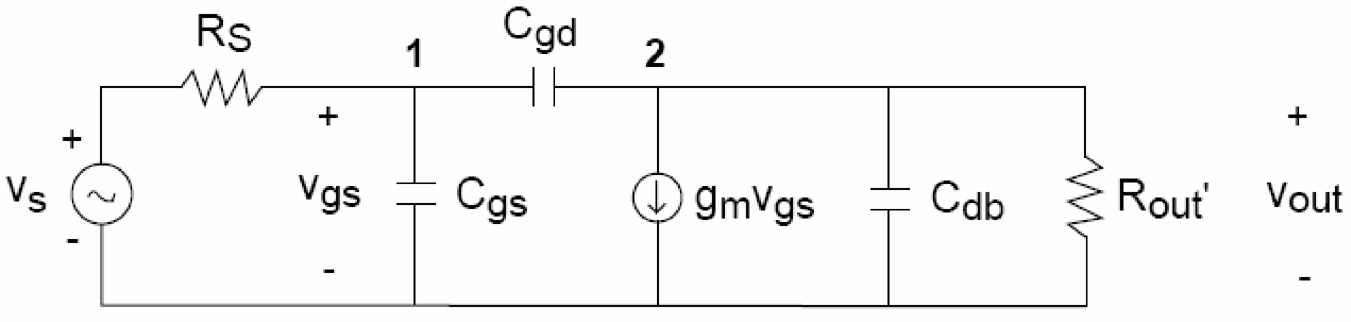


$$A_v \simeq \frac{-g_m R'_{out}}{1 + j\omega[R_S C_{gs} + R_S C_{gd}(1 + g_m R'_{out}) + R'_{out} C_{db}]}$$

Or $A_v(\omega) = \frac{A_{v,LF}}{1 + j\frac{\omega}{\omega_H}}$ with $\omega_H = \frac{1}{R_S C_{gs} + R_S C_{gd}(1 + g_m R'_{out}) + R'_{out} C_{db}}$

Frequency response of CS limited by $C_{gs}$, $C_{gd}$ for input and $C_{db}$ for output.

Compare $f_H$ with $f_T$

$$f_H = \frac{1}{2\pi\{R_S[C_{gs} + C_{gd}(1 + |A_{v,LF}|)] + R'_{out}C_{db}\}}$$

$$f_T = \frac{g_m}{2\pi(C_{gs} + C_{gd})}$$

$$f_H \ll f_T$$

Mainly because $f_H$ has $A_{v,LF}$ in denominator making $C_{gd}$ effectively very large

➔ Miller Effect

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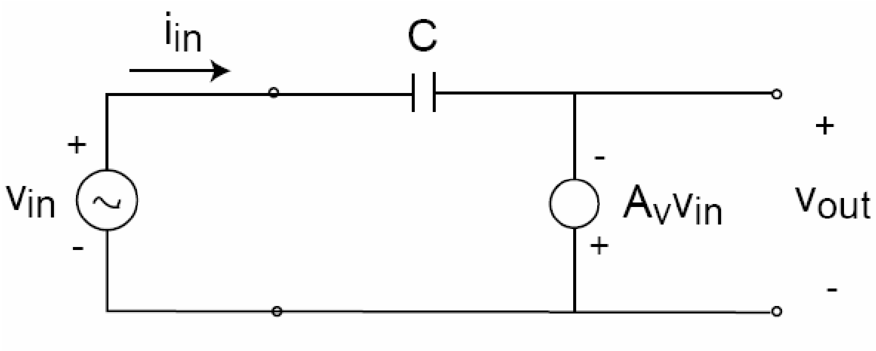
Miller Effect




$$C_{Miller} = C(1 + A_v)$$

$$v_{in} \uparrow \Rightarrow \ v_{out} = -A_v v_{in} \downarrow\downarrow \Rightarrow (v_{in} - v_{out}) \uparrow\uparrow \Rightarrow i_{in} \uparrow\uparrow$$

➔ Less impedance ➔ Larger capacitance

In CS, $C_{gd}$ causes Miller effect: Larger gain ➔ Slower

Is it always bad? Can be used for implementing large capacitor values in IC.

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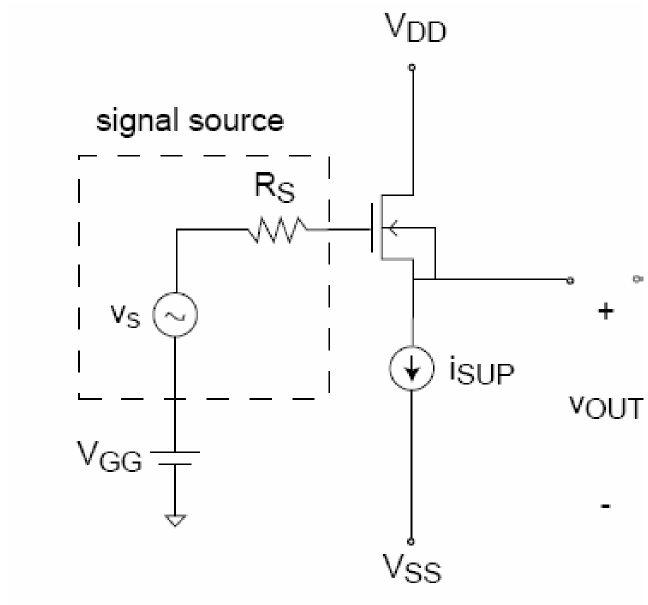
Does CD suffer from Miller effect?




$A_v$ is almost 1!

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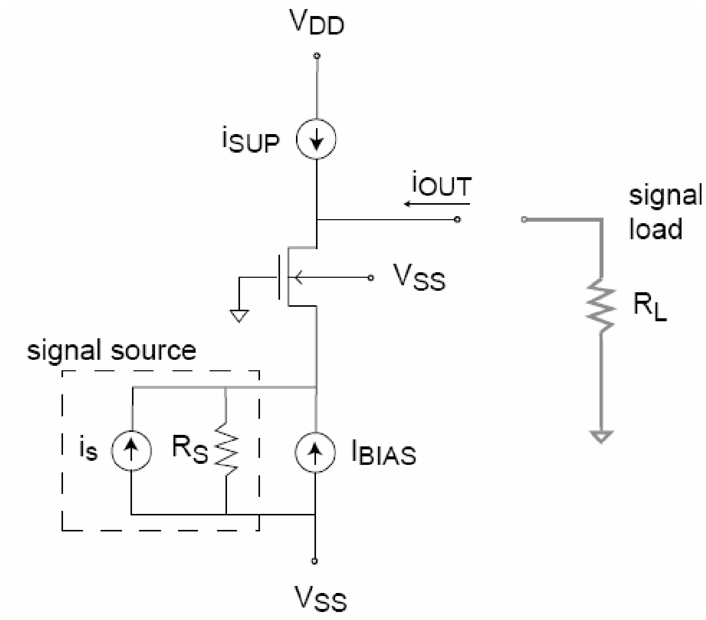
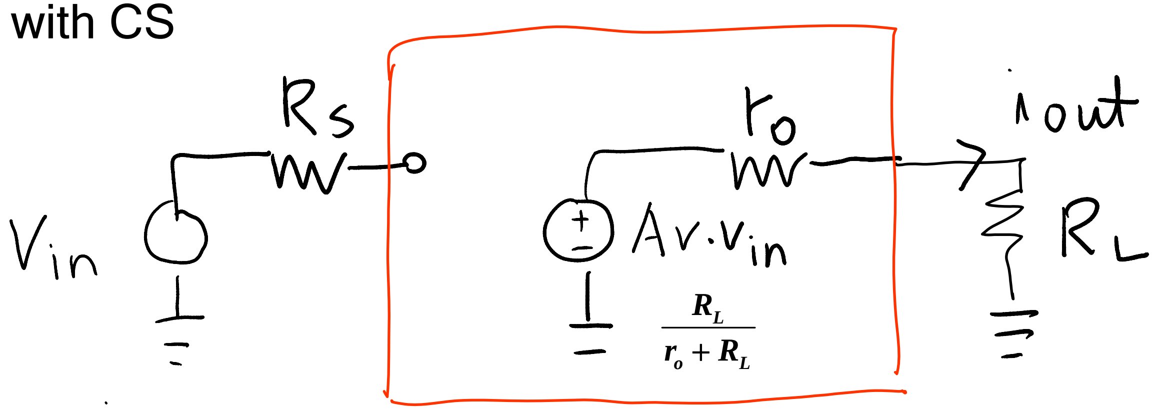
Does CG suffer from Miller effect?




No Miller capacitor!

Design large gain, high-speed transconductance amplifier

Start with CS




$$i_{out} = \frac{A_{vo}v_{in}}{r_o}\frac{r_o}{r_o + R_L} = \frac{-g_m r_o v_{in}}{r_o}\frac{r_o}{r_o + R_L} = -g_m v_{in}\frac{r_o}{r_o + R_L}$$

$$\frac{i_{out}}{v_{in}} = -g_m\frac{r_o}{r_o + R_L}$$

Problem if $R_L > r_o$

➔ Use current buffer

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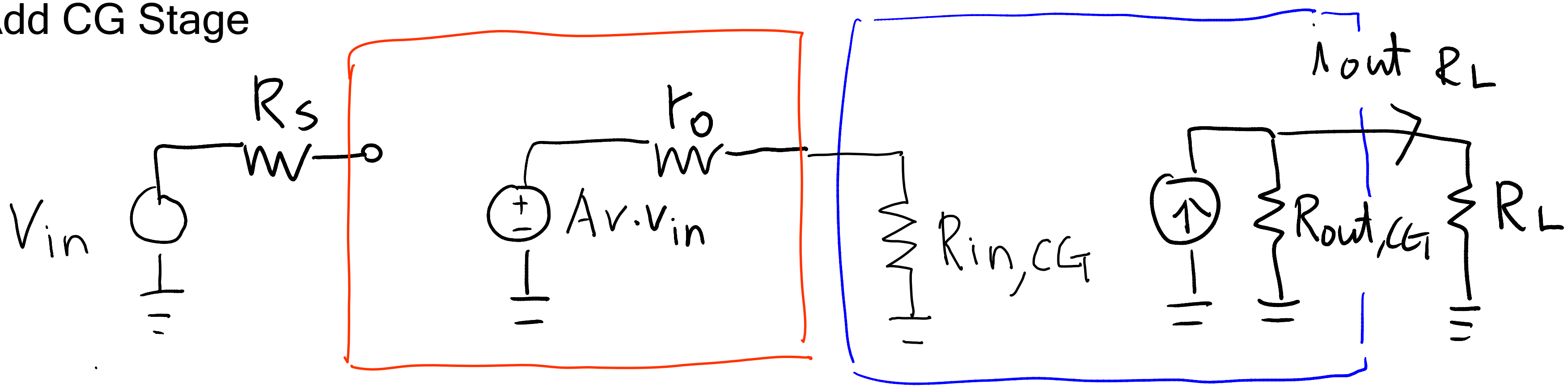
Design large gain, high-speed transconductance amplifier

Add CG Stage




Assuming ideal current buffer,

$$\frac{i_{out}}{v_{in}} = -g_m \quad \text{(CS + CG)}$$

$$\frac{i_{out}}{v_{in}} = -g_m \frac{r_o}{r_o + R_L} \quad \text{(CS only)}$$

In addition, CG is fast!

For a given target gain,
we can achieve higher speed transconductance speed amp by reducing $g_m$!

➔ Cascode amplifier



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