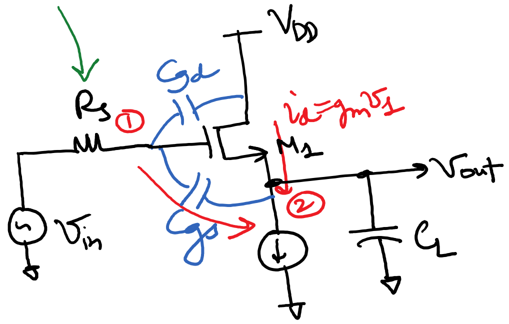
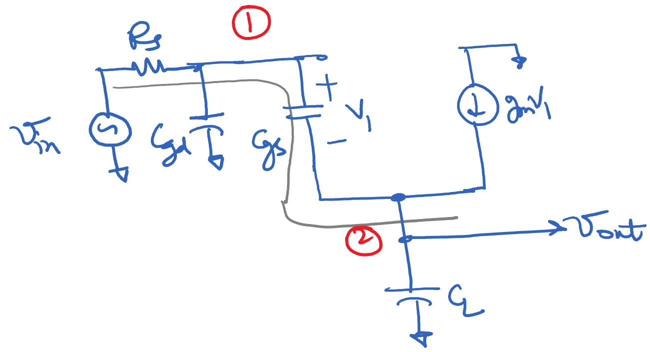
ECE 515 - Lecture 18

Tuesday, October 23, 2018 11:03 AM

SF frequency Response :

$\lambda = 0$
$\gamma = 0$





KCL
@ node-2

$$V_1 sC_{gs} + g_m V_1 = v_{out} sC_L$$

$$\Rightarrow \quad V_1 = \frac{sC_L}{g_m + sC_{gs}} \cdot v_{out}$$

* KVL beginning from V_{in}

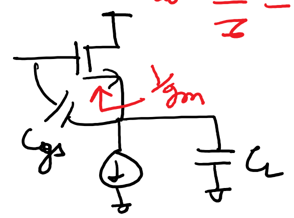
$$v_{in} = R_s\left[v_1 sC_{gs} + (V_1 + V_{out})sC_{gd}\right] + V_1 + V_{out}$$

Substitute V_1

$$\frac{v_{out}}{v_{in}}(s) = \frac{(g_m + sC_{gs})}{R_s\left[C_{gs}C_L + C_{gs}C_{gd} + C_{gd}C_L\right]s^2 + \left[g_m R_s C_{gd} + C_L + C_{gs}\right]s + g_m}$$

LHP zero $\quad \omega_z = -\frac{g_m}{C_{gs}}$ $\Rightarrow$ signal conducted by C_{gs} adds to the signal carried by the main transistor with the same polarity.

Assuming $|\omega_{p1}| << |\omega_{p2}|$



$$\omega_{out} = \frac{1}{\tau} = \frac{1}{\frac{1}{g_m}\cdot(C_{gs}+C_L)} = \frac{g_m}{C_{gs}+C_L}$$

* Dominant pole:

$$\omega_{p1} \simeq \frac{g_m}{g_m R_S C_{gd} + C_L + C_{gs}}$$

$$= \frac{1}{R_S C_{gd} + \frac{C_L + C_{gs}}{g_m}} = \frac{g_m}{C_L + C_{gs}} \text{ iff } R_S = 0$$

$$f_T = \frac{g_m}{C_{gs}}$$

* wideband buffers

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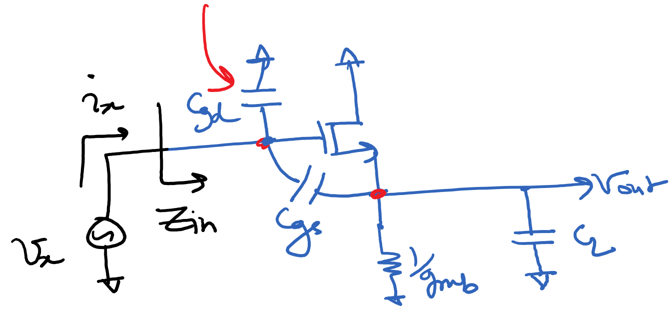
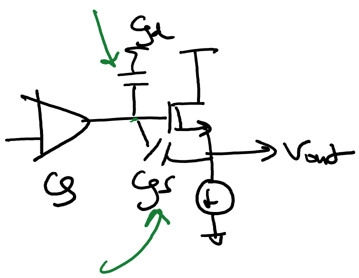
Input Impedance of SF:



$$Z_{in} = \underbrace{\frac{1}{sC_{gd}}}_{C_{gd}} + \underbrace{\left(1 + \frac{g_m}{sC_{gs}}\right)\frac{1}{g_{mb} + sC_L}}_{\text{modified } C_{gs}}$$

* @ low-frequencies

$$g_{mb} >> |sC_L|$$



$$\Rightarrow Z_{in,1} \cong \frac{1}{sC_{gs}}\left(1 + \frac{g_m}{g_{mb}}\right) + \frac{1}{g_{mb}} = \frac{1}{\dfrac{sC_{gs}}{\left(1 + \frac{g_m}{g_{mb}}\right)}} + \frac{1}{g_{mb}}$$

↳ input cap is only a fraction of C_{gs}.

↳ loading on the driving stage is reduced

* At higher frequencies

$$g_m << |sC_L|$$

$$\Rightarrow Z_{in,1} \simeq \frac{1}{sC_{gs}} + \frac{1}{sC_L} + \frac{g_m}{C_{gs} C_L s^2}$$

for some $s = j\omega$

$$Z_{in,1} = \underbrace{\frac{1}{j\omega}\left[\frac{1}{C_{gs}} + \frac{1}{C_L}\right]}_{\text{Capacitance}} - \underbrace{\frac{g_m}{C_{gs} C_L \omega^2}}_{\text{Negative resistance}}$$

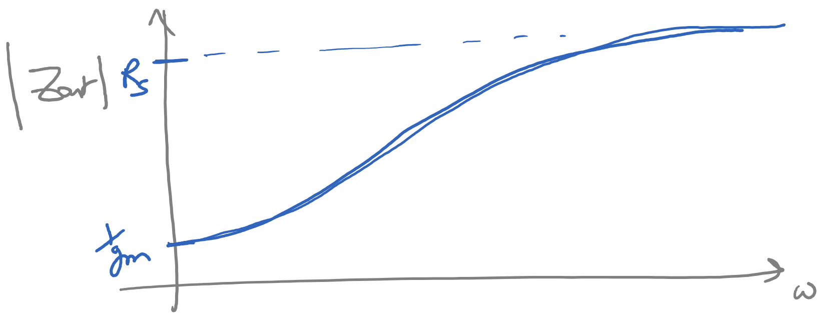
→ Can lead to oscillations

Output Impedance:

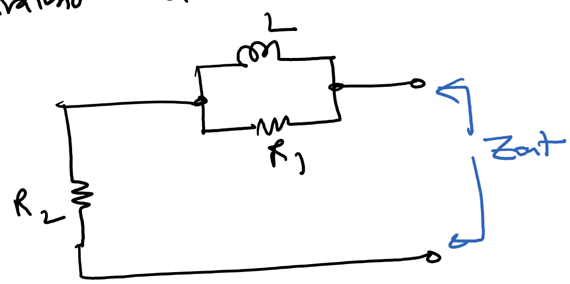
$$Z_{out} = \frac{s R_s C_{gs} + 1}{g_m + s C_{gs}}$$

@ low frequencies $\Rightarrow$ $Z_{out} = \frac{1}{g_m}$

@ very high f $\Rightarrow$ $Z_{out} = R_s$



Equivalent circuit



$R_2 = \frac{1}{g_m}$

$R_1 = R_s - \frac{1}{g_m}$

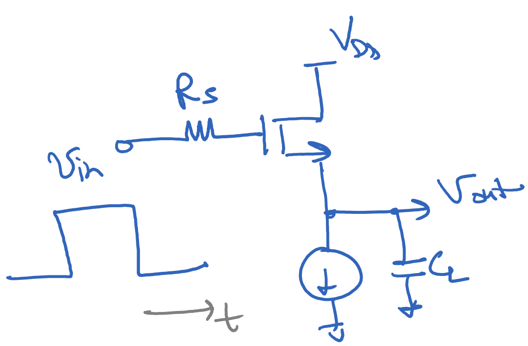
$L = \frac{C_{gs}}{g_m}\left(R_s - \frac{1}{g_m}\right)$

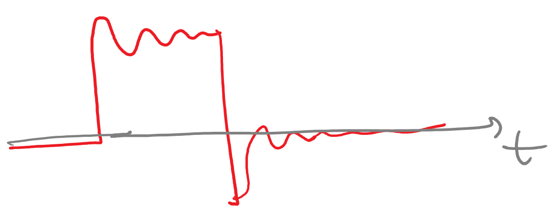
$$L = \frac{C_{gs}}{g_m}\left(R_s - \frac{1}{g_m}\right)$$

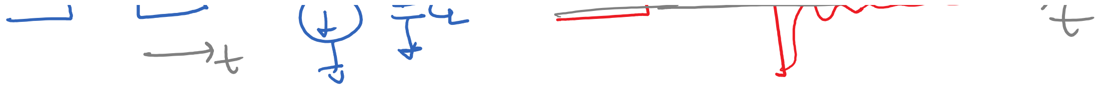
* If the SF is driven by a large R_s

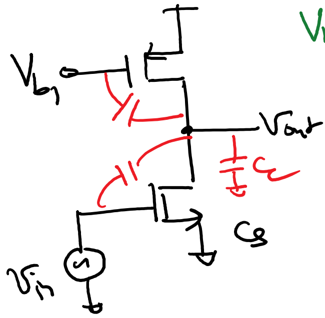
$R_s \gg \frac{1}{g_m}$

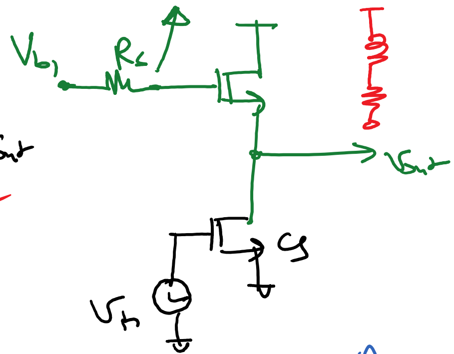
$\Rightarrow$ substantial inductive behavior

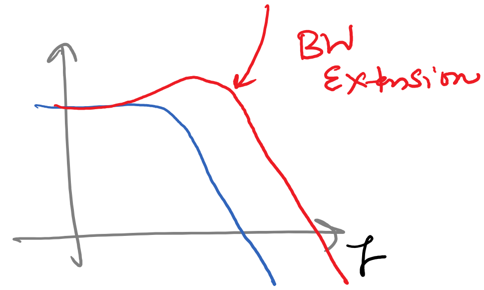






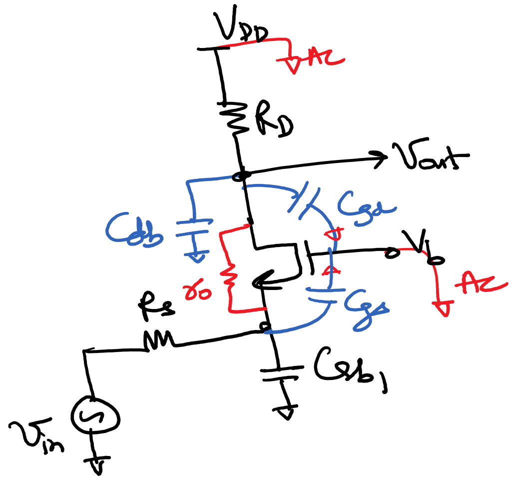






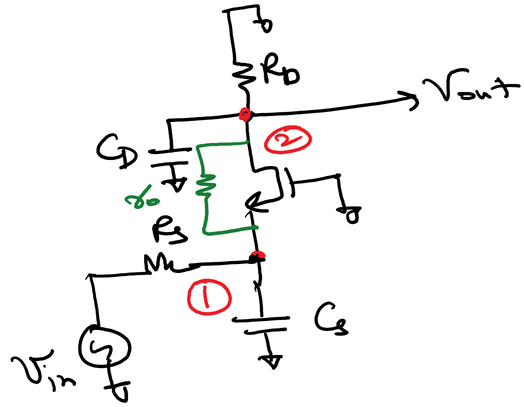
* An active inductor load for BW Extension

Common Gate Frequency Response:



⇒

Ac picture



No Miller Cap

↳ nodes 1 & 2 are isolated

$C_S = C_{gs_1} + C_{sb_1}$

$C_D = C_{gd_1} + C_{db}$

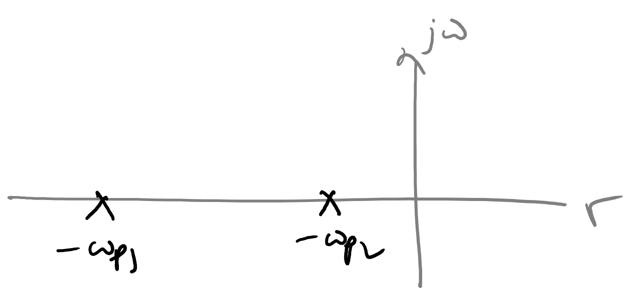
$$\omega_{p_1} = \omega_{in} = \frac{1}{\left(R_s \,\|\, \frac{1}{(g_m + g_{mb})}\right) C_S} \simeq \frac{g_m}{C_S} \rightarrow \infty \text{ if } R_s \rightarrow 0$$

$$\omega_{p_2} = \omega_{out} = \frac{1}{R_D C_D} \simeq \frac{1}{R_D C_L}$$

$$\Rightarrow \frac{V_{out}}{V_{in}}(s) = \frac{1}{\left(1 + s/\omega_{p_1}\right)\left(1 + s/\omega_{p_2}\right)}$$

only Two poles

→ No zeros



Cascode Amplifier Frequency Response:

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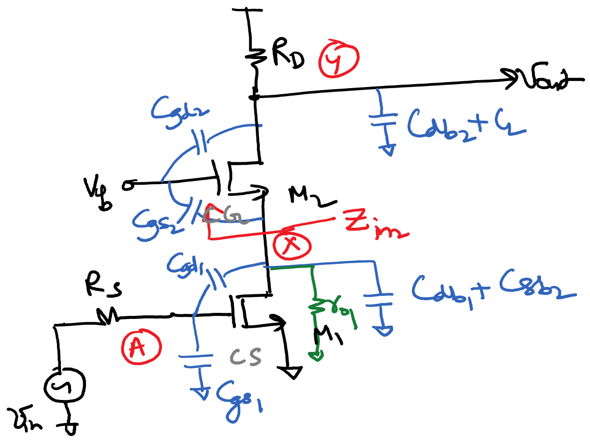

Miller Cap $\Rightarrow C_{gd1}$

* Miller effect of C_{gd1} is determined by the gain from A to X

* Assuming $R_D \le r_o$

$$Z_{in2} = \frac{1}{g_{m2}+g_{mb2}}$$

$$A_{A\to X} = -g_{m1}\cdot(Z_{in2} \| r_{o1})$$

$$\simeq -\frac{g_{m1}}{g_{m2}+g_{mb}} \simeq -\frac{g_{m1}}{g_{m2}}$$

$\simeq -1$ if M_1 & M_2 are identical

* Assume M_1 & M_2 to be identical

$\Rightarrow C_{gd1}$ is multiplied by $2X$, instead of $(1+|A_V|)$

↳ Miller effect is less significant in Cascode amplifiers than in CS stage

↳ Miller Killer!

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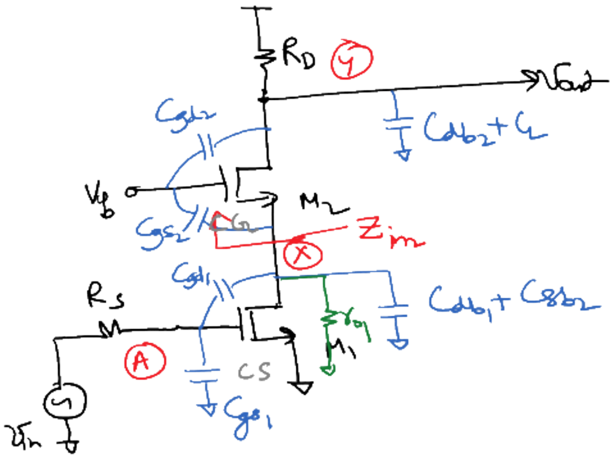


Using Miller Approximation

$$\omega_{pA} = \frac{1}{R_A C_A} = \frac{1}{R_S \cdot \left[C_{gs1} + \underbrace{\left(1+\frac{g_{m1}}{g_{m2}+g_{mb2}}\right)}_{\simeq 2} C_{gd1}\right]}$$

Low-Z node $\Rightarrow$ higher frequency pole

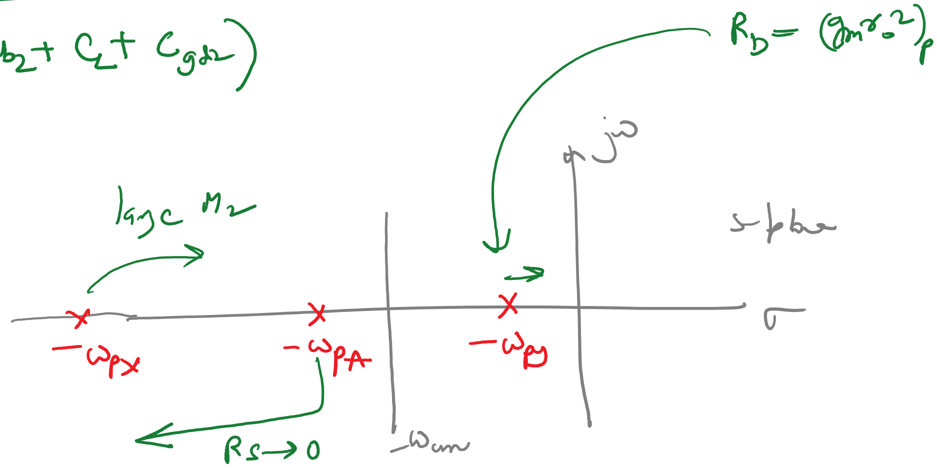
$$\omega_{px} = \frac{1}{R_x C_x} = \frac{1}{\frac{1}{(g_{m2}+g_{mb2})} \cdot \underbrace{\left[2C_{gd1} + C_{db1} + C_{sb2} + C_{gs2}\right]}_{C_x}}$$

$$\simeq \frac{g_{m2}}{C_x}$$

High Z node, low-frequency pole.

$$\omega_{py} = \frac{1}{R_D \| (g_{m2} r_{o2} r_{o1}) \cdot (C_{db2} + C_L + C_{gd2})}$$

$$\simeq \frac{1}{R_D C_L}$$



Slewing

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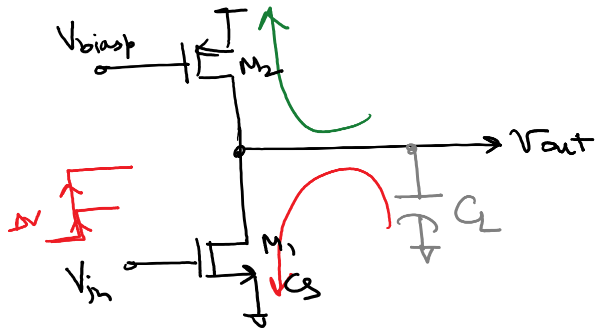
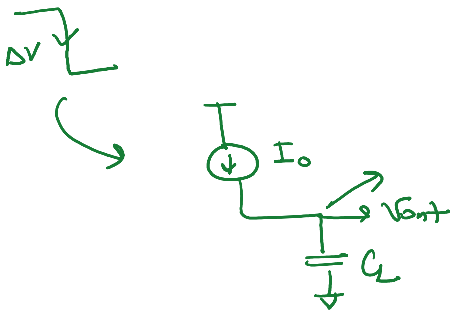


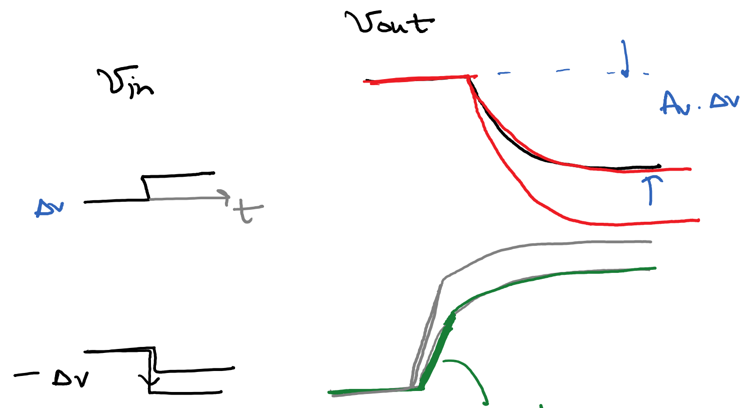
$$\frac{v_{out}}{v_{in}} = -\frac{g_{m1}(r_{o1}||r_{o2})}{\left(1+\frac{s}{\omega_p}\right)}, \quad \omega_p = \frac{1}{(r_{o1}||r_{o2})C_L}$$

$$\omega_{un} = \frac{g_{m1}}{C_L}$$

1st order response



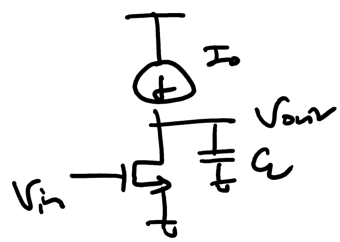
$$\frac{dV_{out}}{dt} = \frac{I_o}{C_L}$$



$\Rightarrow$ slewing is a non linear behavior

$$\left|\frac{dV_{out}}{dt}\right| < SR^+ = \frac{I_o}{C_L}$$

Class-A stage



SR^+

no SR limitation when discharging.