ECE 511 — Lecture 18

Note Title 3/19/2015

Recap

CS stage

↳ 2^{nd} order response

↳ ω_{p1}, ω_{p2} & ω_z

↳ Miller compensation $C_c \uparrow$

pole splitting

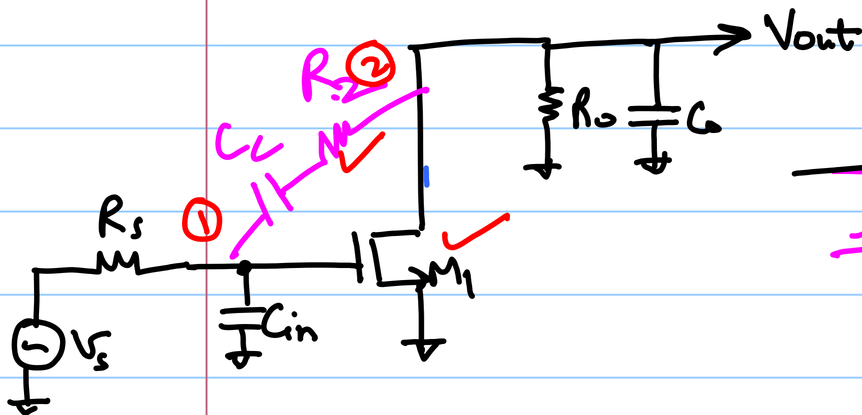
↳ RHP zero degrades phase

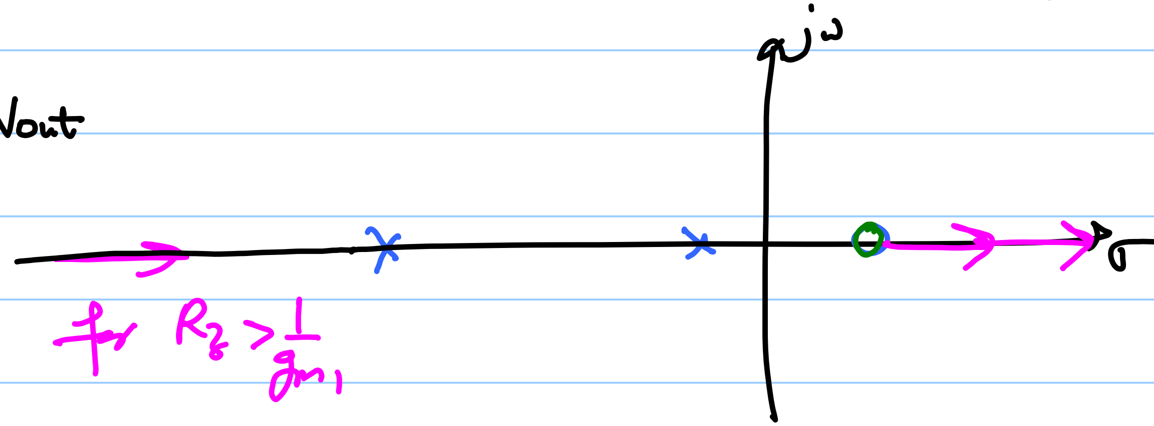
↳ ω_{un} ← unity gain frequency

↳ for dominant pole

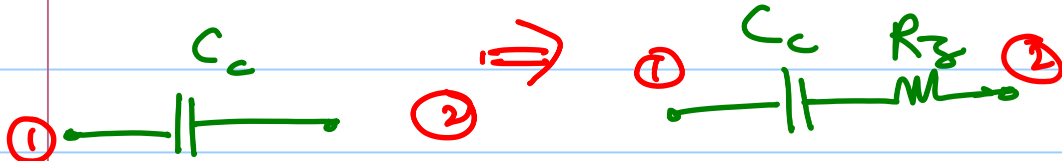
$\omega_{un} = A_v \times \omega_{3dB}$

RHP zero at $\omega_z = \frac{g_{m1}}{C_c}$





for $R_z > \frac{1}{g_{m1}}$



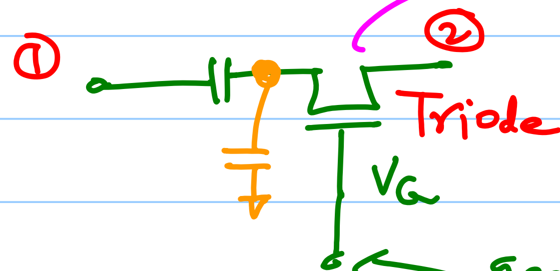
$$\omega_z = \frac{1}{C_c\left(\frac{1}{g_{m1}} - R_z\right)}$$ instead of $\frac{g_{m1}}{C_c}$

Now if set $\boxed{R_z = \frac{1}{g_{m1}}}$ $\Rightarrow$ $\omega_z \to \infty$

$\Rightarrow$ pushes RHP zero to ∞

Use a trio

should track $R_{on} = \frac{1}{g_{m1}}$



generate this using constant g_m biasing

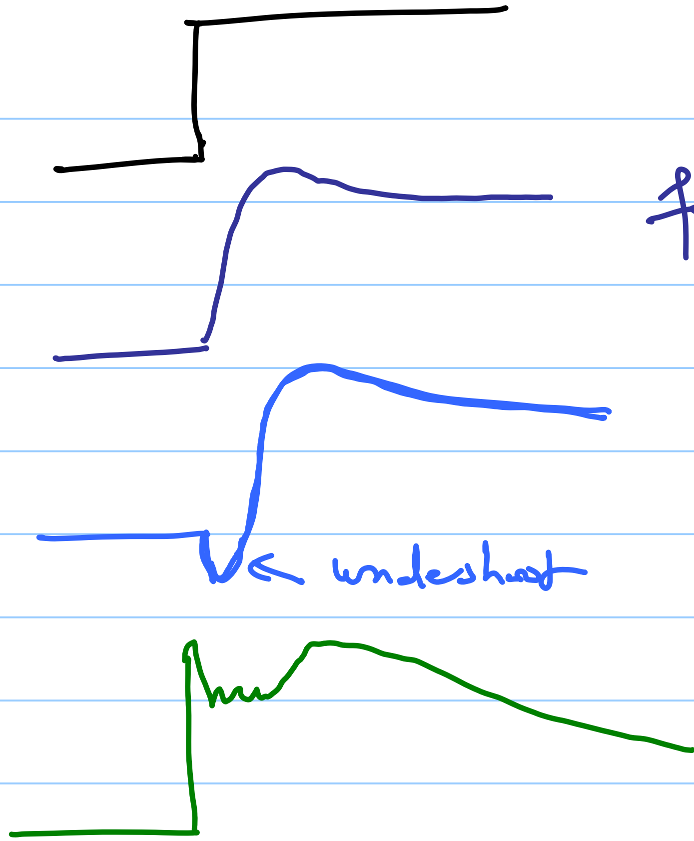
Servo loop

* RHP zero canceling

* What if $R_z = \frac{2}{g_{m1}} \Rightarrow \omega_z = -\frac{g_{m1}}{C_c}$

LHP zero

$$\Delta\phi = +\tan^{-1}\left(\frac{\omega}{\omega_z}\right) \text{ for LHP zero}$$



for PM = 60°

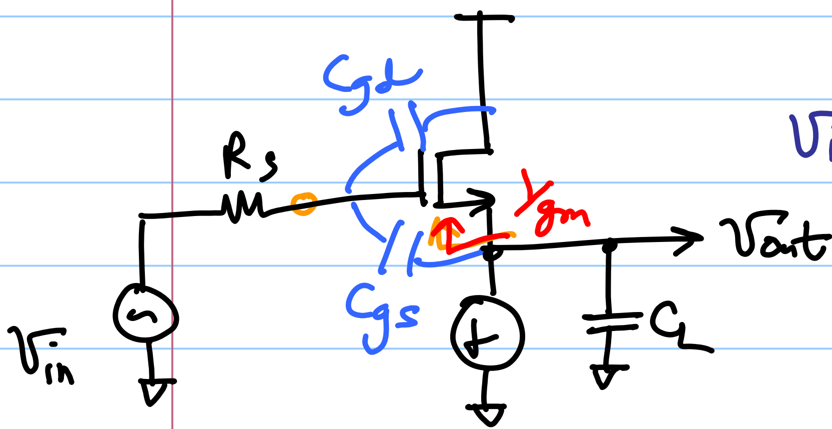
2 poles no zero

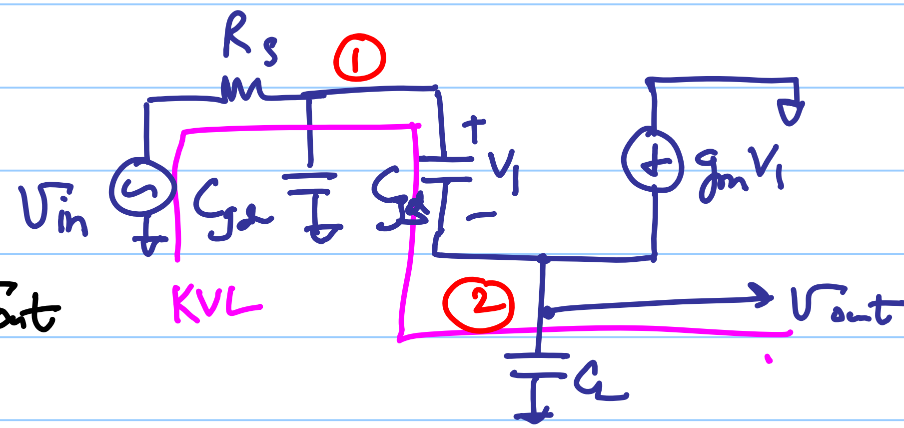
2 poles & RHP zero

2 poles & LHP zero around ω_{un}

Source follower Frequency Response

$\lambda = 0$





@ node ②

$$V_1 C_{gs} s + g_m V_1 = V_{out} s C_L$$

$$\Rightarrow \quad V_1 = \frac{s C_L}{g_m + C_{gs} s} V_{out} \longrightarrow ①$$

* KVL beginning from V_1

$$V_{in} = R_S\left[V_1 C_{gs} s + (V_1 + V_{out}) s C_{gd} \right] + V_1 + V_{out} \longrightarrow ②$$

① → ②

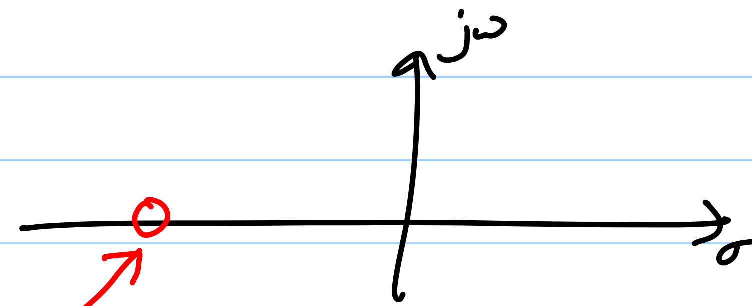
$$\frac{V_{out}}{V_{in}}(s) = \frac{\boxed{g_m + sC_{gs}}}{R_s\left[C_{gs}C_L + C_{gs}C_{gd} + C_{gd}C_L\right]s^2 + \left[g_m R_s C_{gd} + C_L + C_{gs}\right]s + g_m}$$

zero:

$N(s) = 0$

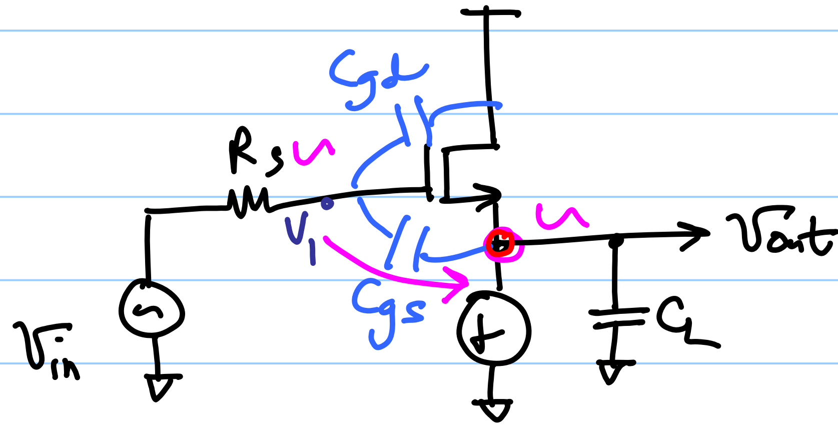
$g_m + sC_{gs} = 0$

$\Rightarrow \quad s = j\omega_z = -\dfrac{g_m}{C_{gs}}$



$\boxed{\text{LHP zero}}$

* Why LHP zero?



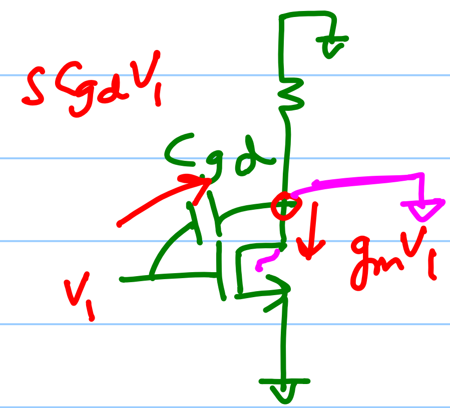
$$g_m V_1 + sC_{gs}V_1 = 0$$

$$\Rightarrow \quad s_z = -\frac{g_m}{C_{gs}}$$

main path & FF currents add up the same phase.

ASIDE

$\boxed{CS}$



RHP zero

$$s_z = +\frac{g_m}{C_{gd}}$$

$$-g_m V_1 + sC_{gd}V_1 = 0$$

Dominant pole is at

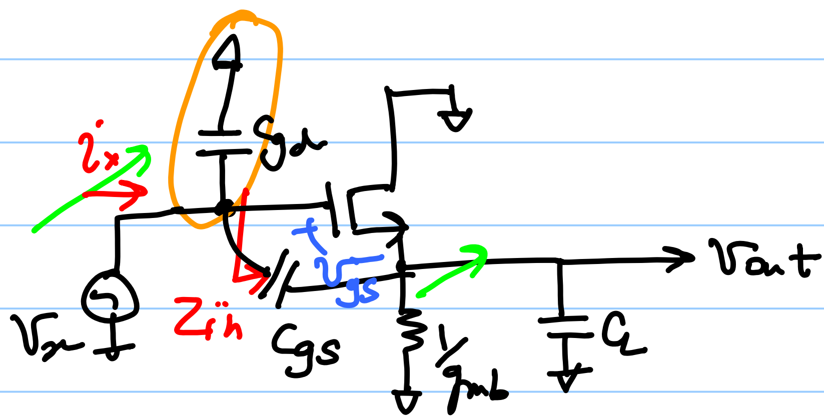
$$\omega_{p_1} \simeq \frac{g_m}{g_m R_S C_{gd} + C_L + C_{gs}}$$

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

$$\simeq \boxed{\frac{g_m}{C_L + C_{gs}}}$$

single pole when $R_S = 0$

Input Impedance :



$$v_{gs} = \frac{i_x}{sC_{gs}}$$

& $$i_d = g_m v_{gs} = \frac{g_m i_x}{s C_{gs}}$$

$\Rightarrow$

$$v_x = \frac{i_x}{C_{gs}} + \left(i_x + \frac{g_m i_x}{sC_{gs}}\right)\left(\frac{1}{g_{mb}} \parallel \frac{1}{sC_L}\right)$$

$$Z_{in_1} = \frac{1}{sC_{gs}} + \left(1 + \frac{g_m}{sC_{gs}}\right) \frac{1}{g_{mb} + sC_L}$$

@ low-frequencies $\quad g_{mb} \gg |sC_L|$

$$\Rightarrow \quad Z_{in_1} \simeq \frac{1}{sC_{gs}}\left(1 + \frac{g_m}{g_{mb}}\right) + \frac{1}{g_{mb}}$$

$$= \frac{1}{g_{mb}} + \frac{1}{\dfrac{sC_{gs}}{\left(1 + \dfrac{g_m}{g_{mb}}\right)}}$$

Total input impedance $= \dfrac{1}{sC_{gd}} + \dfrac{1}{g_{mb}} + \dfrac{1}{\dfrac{sC_{gs}}{\left(1 + \dfrac{g_m}{g_{mb}}\right)}}$

Equivalent input Cap $\Rightarrow C_{gd} + \dfrac{C_{gs}}{\left(1 + \frac{g_m}{g_{mb}}\right)}$

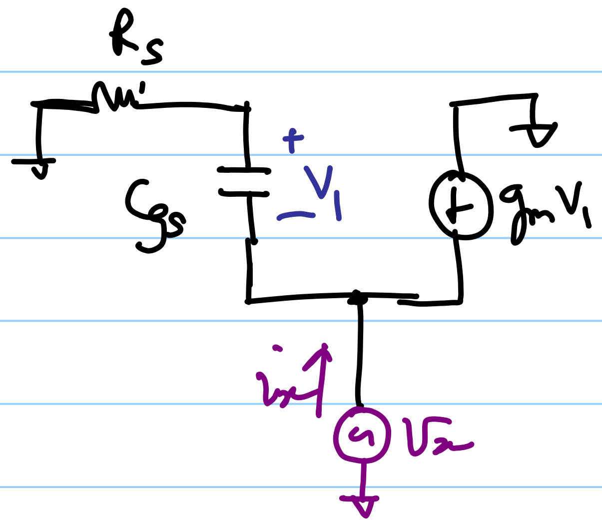
↳ fraction of $C_{gd} + C_{gs}$

→ Low input Cap
→ Low output Resistance
↳ large BW $\propto \dfrac{g_m}{C_L}$

} good Voltage Buffer

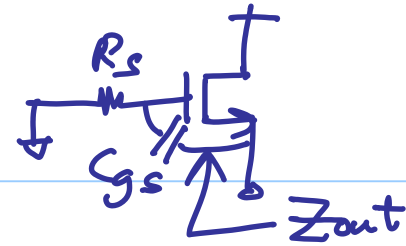
output impedance:

neglecting C_{gd} & g_{mb}



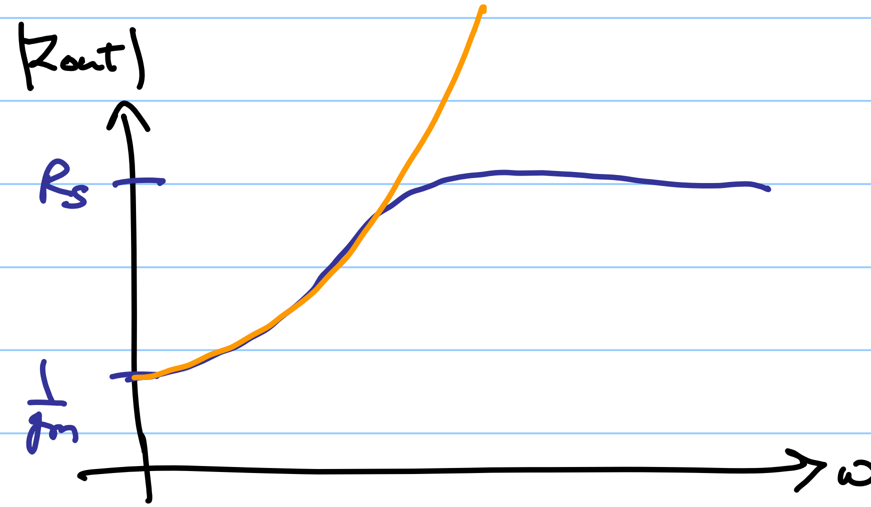
$$Z_{out} = \frac{V_x}{i_x} = \frac{R_s C_{gs} s + 1}{g_m + s C_{gs}}$$

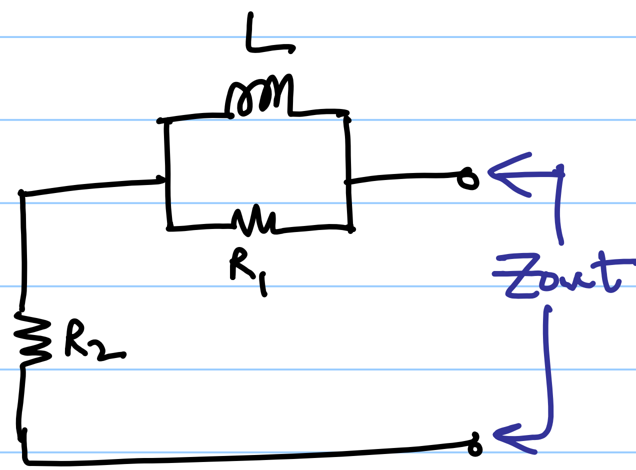
$$Z_{out} = \frac{s \cdot R_s C_{gs} + 1}{g_m + s C_{gs}}$$



@ low-f: $Z_{out} = \frac{1}{g_m}$

@ high-f: $Z_{out} = R_s$



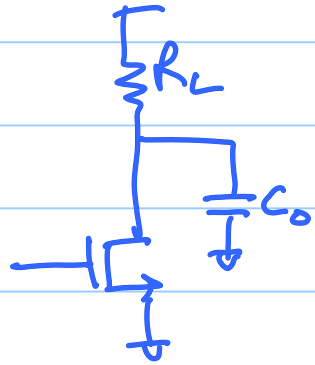


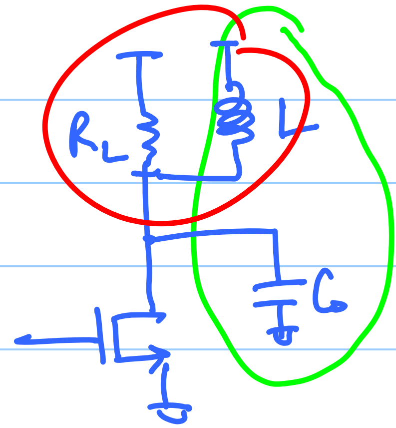
$R_2 = \frac{1}{g_m}$

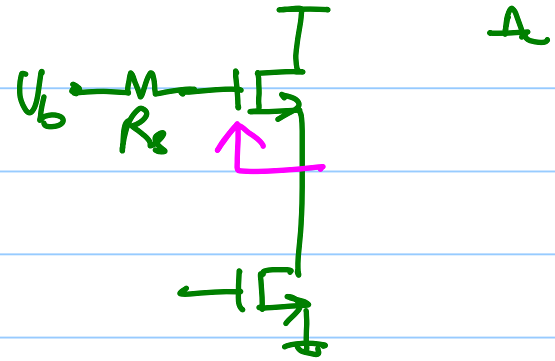
$R_1 = R_s - \frac{1}{g_m}$

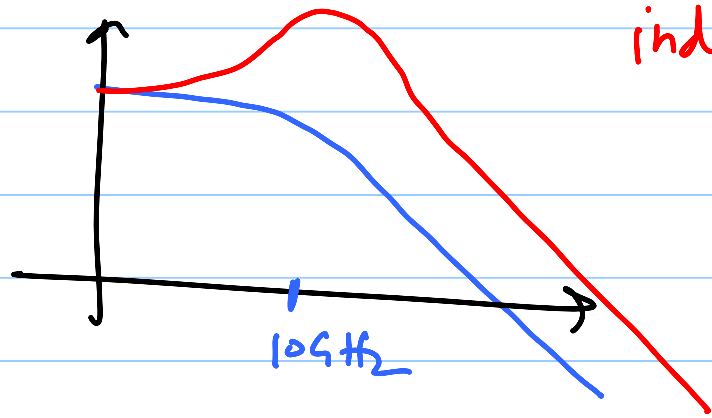
$L = \frac{C_{gs}}{g_m}\left(R_s - \frac{1}{g_m}\right)$

Active-L

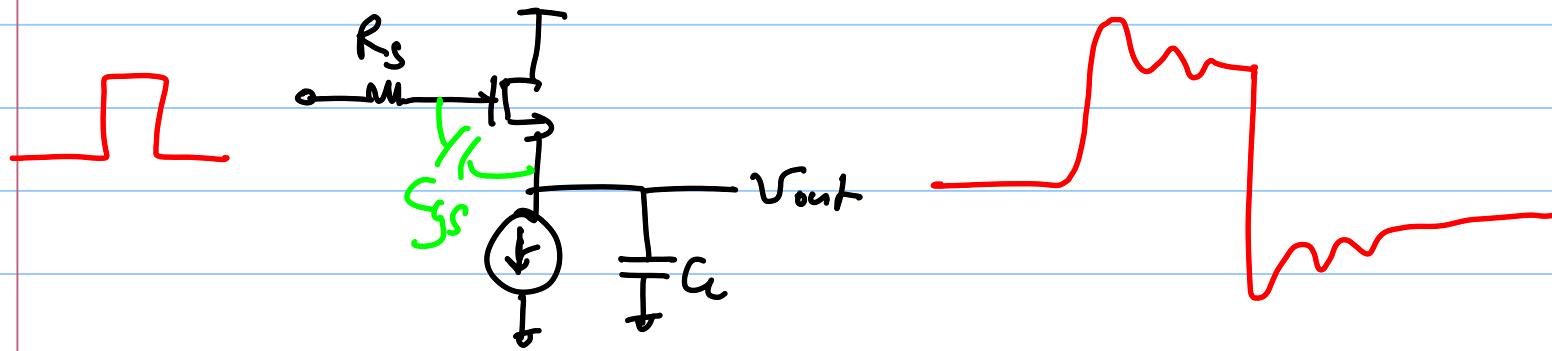








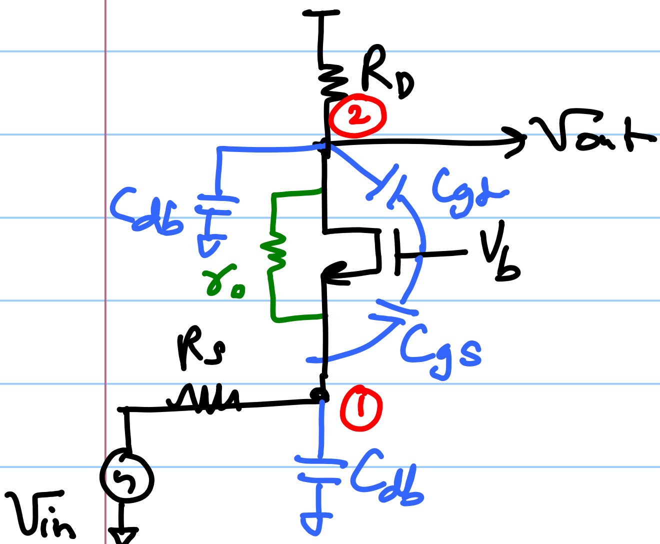
inductive peaking

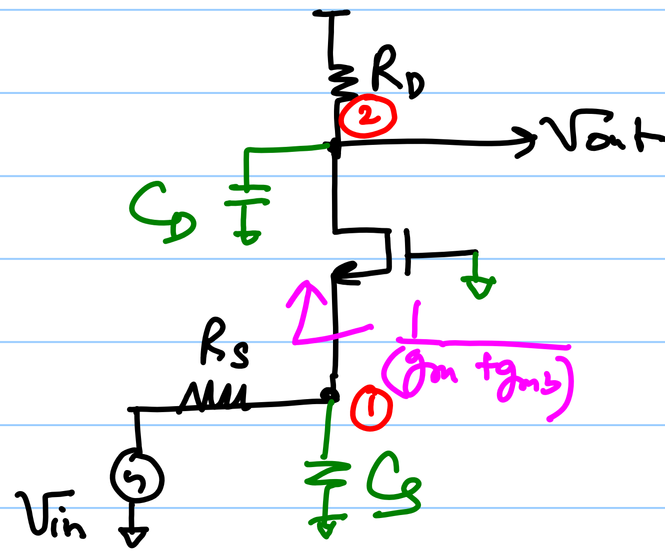


* inductive behavior can manifest as ringing

Common Gate Frequency Response

① & ② are isolated if $\lambda = 0$, $r_o \to \infty$





@ node-1

$$\omega_{p_1} = \omega_{in} = \frac{1}{\left(R_S \,\|\, \frac{1}{g_m + g_{mb}}\right) C_S}$$

assuming $R_D \lesssim r_o$

@ node 2

$$\omega_{p2} = \omega_{out} = \frac{1}{R_D C_D}$$

DC gain with R_S

$$\frac{V_{out}}{V_{in}}(s) = \boxed{\frac{(g_m + g_{mb})R_D}{1 + (g_m + g_{mb})R_S}} \times \frac{1}{\left(1 + \frac{s}{\omega_{p1}}\right)\left(1 + \frac{s}{\omega_{p2}}\right)}$$

(+) No Miller Effect of Capacitor

↳ potentially wideband

↳ low input impedance

↳ trans-impedance amplifier