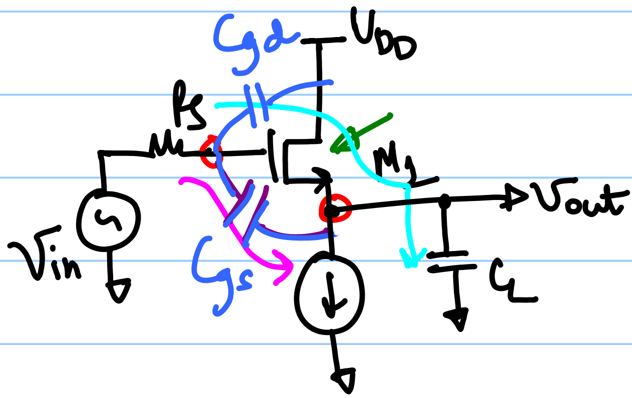
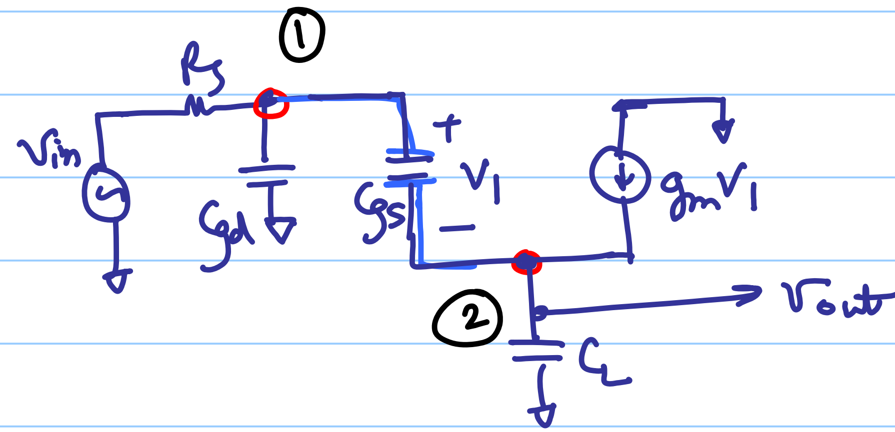
ECE 511- Lecture 18

Note Title 4/1/2014

Source Followers frequency response

$\gamma = 0$

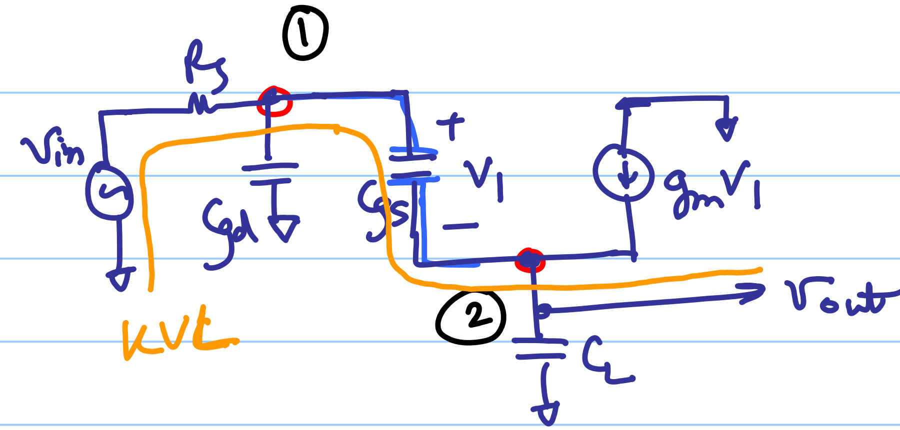




Feed forward current is adding to the output with same polarity
↳ adding to the phase
↳ LHP zero

2 nodes coupled to each other thru C_{gs}
⇒ 2 poles

@ node 2



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

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

KVL

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

$$\frac{V_{out}}{V_{in}}(s) = \frac{(g_m + C_{gs} s)}{\underbrace{R_s \left[C_{gs} C_L + C_{gs} C_{gd} + C_{gd} C_L \right] s^2 + \left[g_m R_s C_{gd} + C_L + C_{gs} \right] s}_{\frac{1}{\omega_{p1}} + \cancel{\frac{1}{\omega_{p2}}}} + g_m}$$

$$\omega_z = -\frac{g_m}{C_{gs}}$$ LHP zero

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

$\rightarrow$ Dominant pole

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

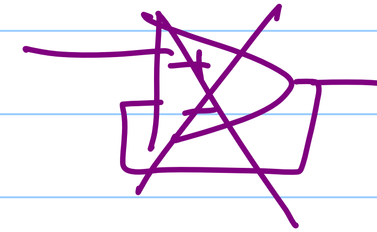
(using same method as CS freq. response)

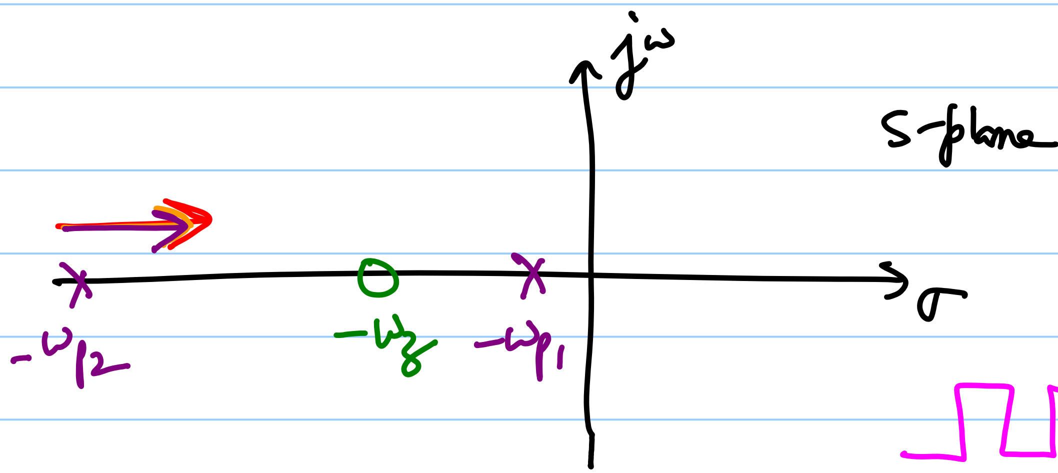
$$= \frac{1}{R_s C_{gd} + \left(\frac{C_L + C_{gs}}{g_m}\right)}$$

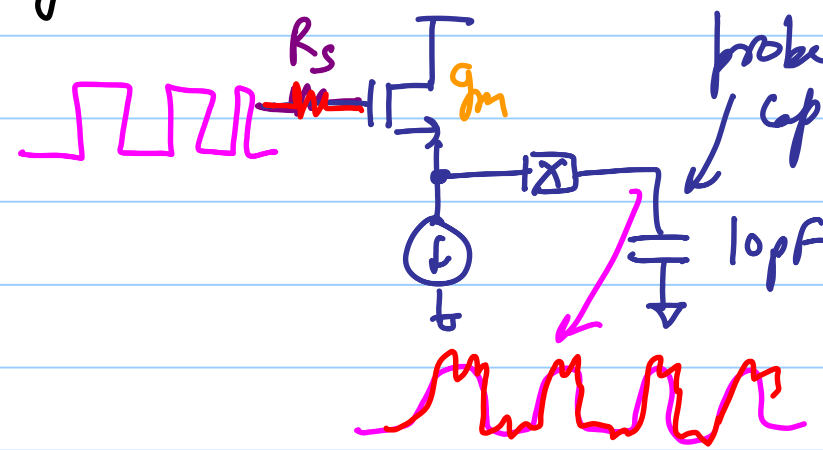
$R_s = 0$

$$\boxed{\omega_{p1} \simeq \frac{g_{m1}}{C_{gs} + C_L}}$$

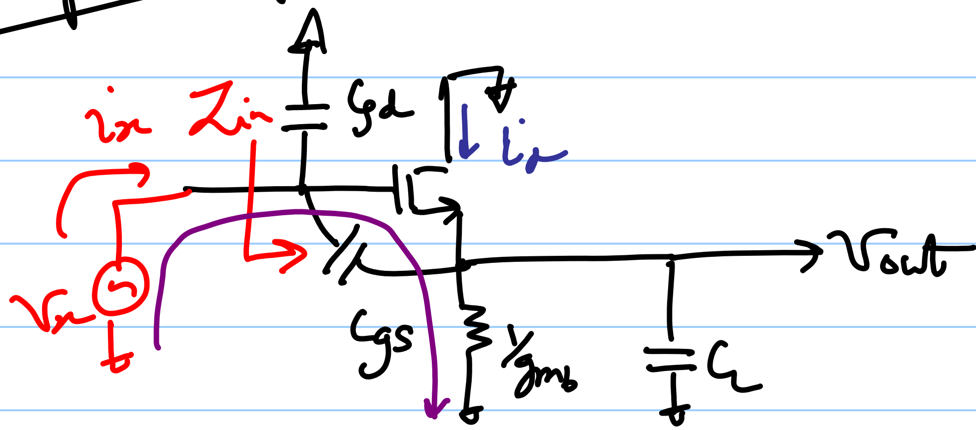
Large C_L $\Rightarrow$ $g_{m1} \uparrow$ $\Rightarrow$ $\frac{W}{L}$ or V_{ov}







Input Impedance



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

$\Rightarrow$

$$i_d = g_m v_{gs} = \frac{g_m i_x}{sC_{gs}} \longrightarrow ①$$

$$v_x = \frac{i_x}{sC_{gs}} + \left(i_x + \frac{g_m i_x}{sC_{gs}} \right) \left(\frac{1}{g_{mb}} \,\Big\|\, \frac{1}{sC_L} \right) \longrightarrow ②$$

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

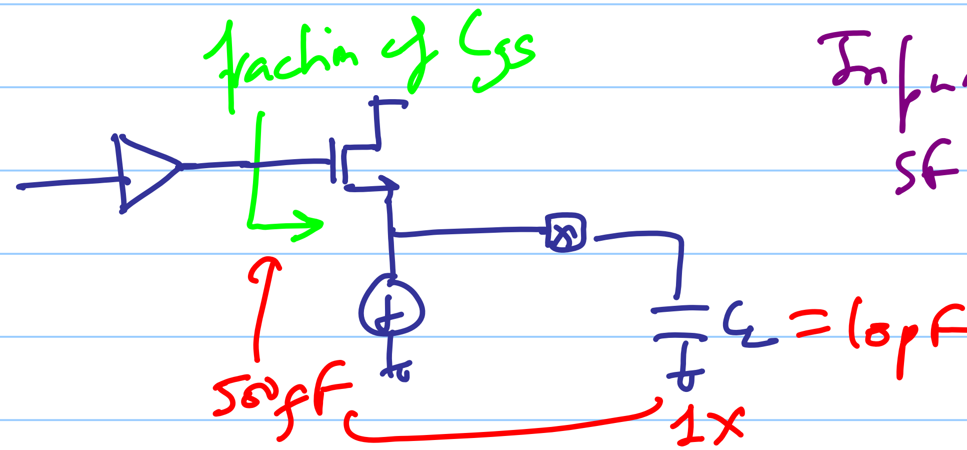
$$Z_{in_1} = \frac{1}{\dfrac{sC_{gs}}{(1 + g_m/g_{mb})}} + \frac{1}{g_{mb}}$$

Input Cap $\Rightarrow$ $\dfrac{C_{gs}}{\left(1+\dfrac{g_m}{g_{mb}}\right)}$

fraction of C_{gs}

$\boxed{\text{Refer to Razavi}}$

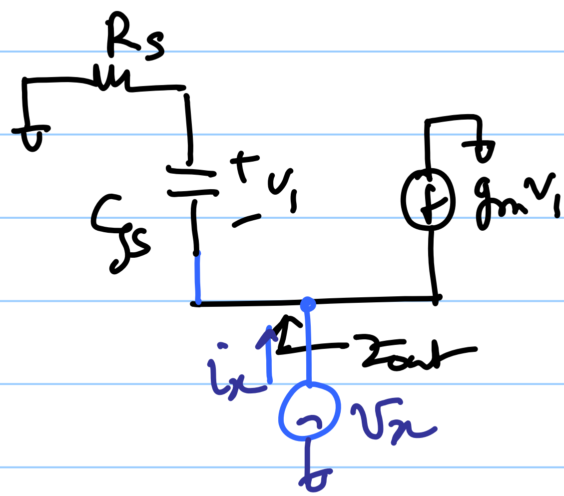
Post notes online



Input Cap of the SF is small

Voltage buffer

output impedance of a SF

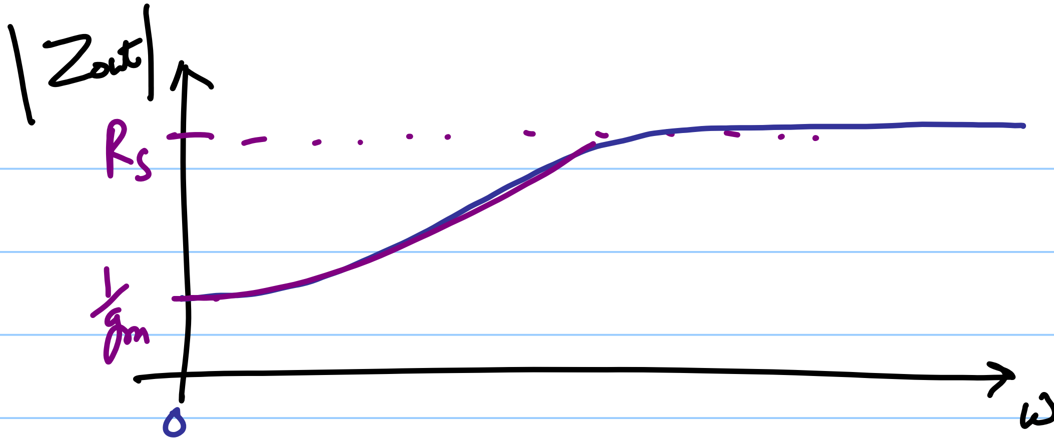


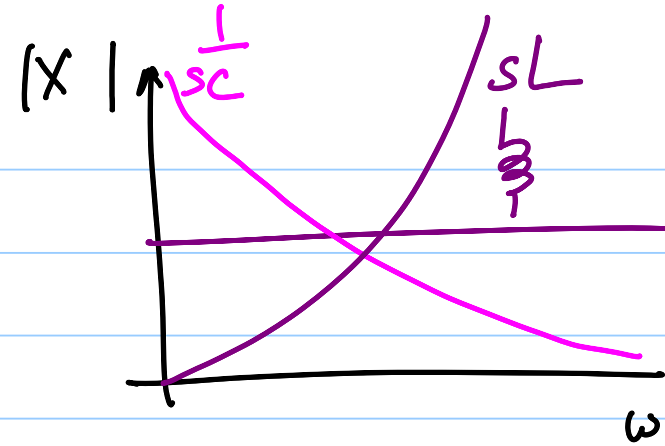
$$Z_{out} = \frac{R_S C_{gs} s + 1}{g_m + s C_{gs}}$$

* at low frequencies $j\omega \to 0 \Rightarrow s \to 0$

$$Z_{out} \simeq \frac{1}{g_m}$$

* at high frequencies $j\omega \to \infty \Rightarrow Z_{out} \simeq R_S$

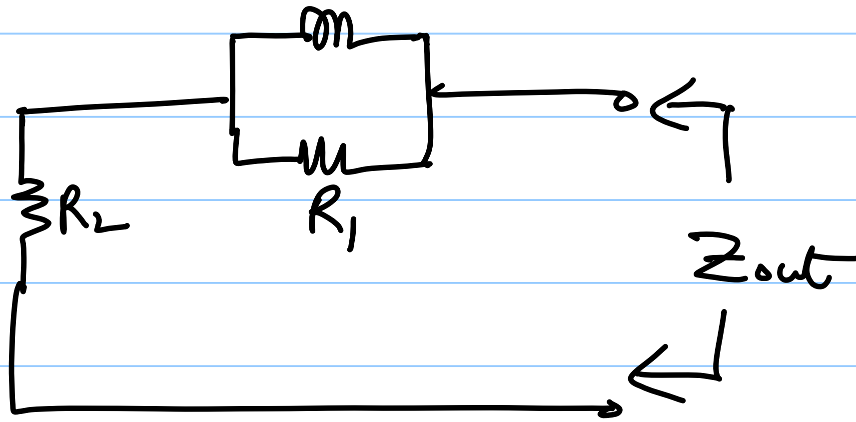




$L \leftarrow C_{gs}, g_m, R_s$

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

$Z_{out} \triangleq$



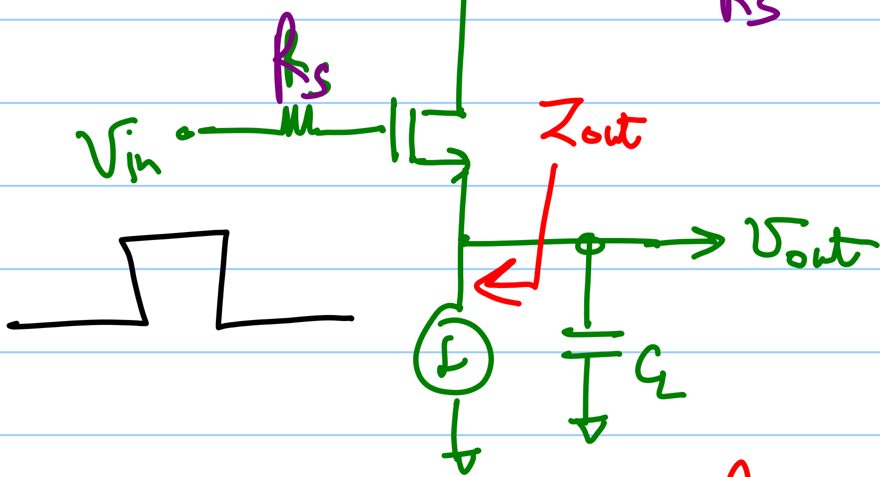
$$R_1 = R_s - \frac{1}{g_m}$$

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

$C_{gs} \rightarrow W/L$

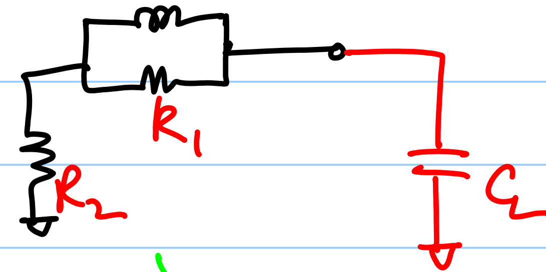
R_s

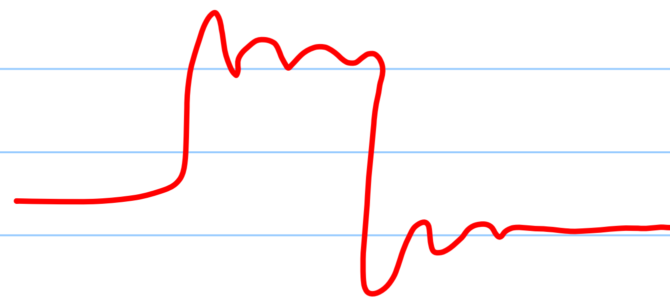
$R_s > \frac{1}{g_m}$

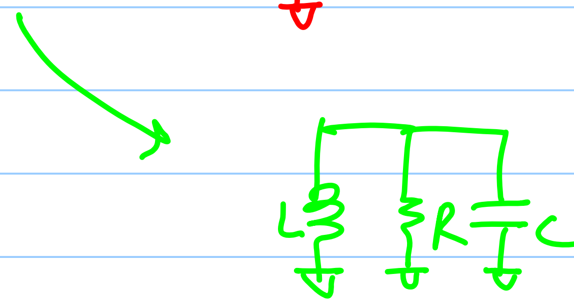


Z_{out}

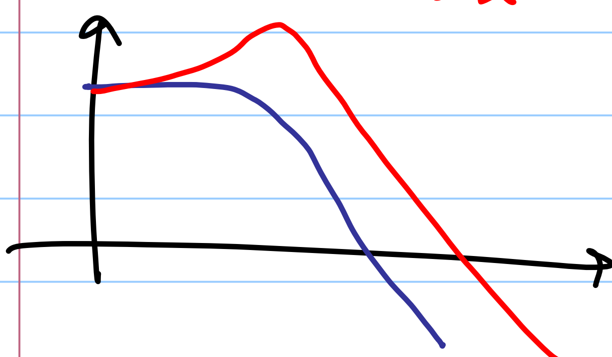
$$L = \frac{C_{gs}}{g_m}\left(R_s - \frac{1}{g_m}\right)$$







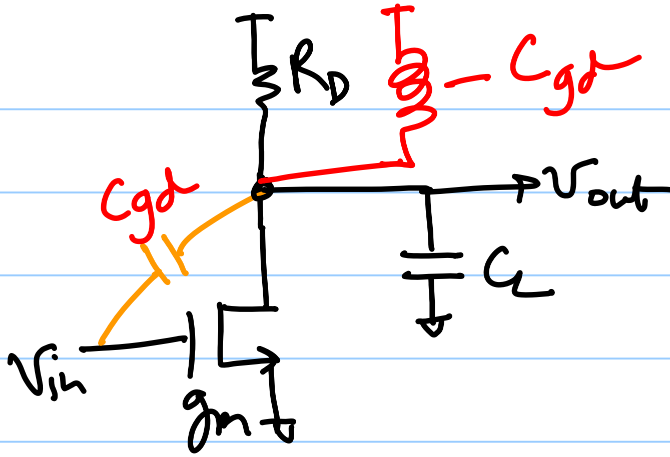
10GHz



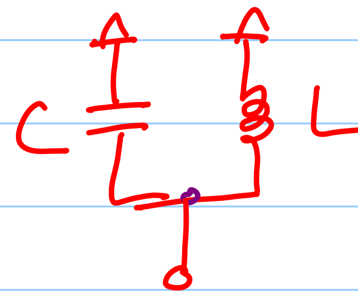
Idea is used to realize Active-L

↳ wide band amplifiers

BW peaking



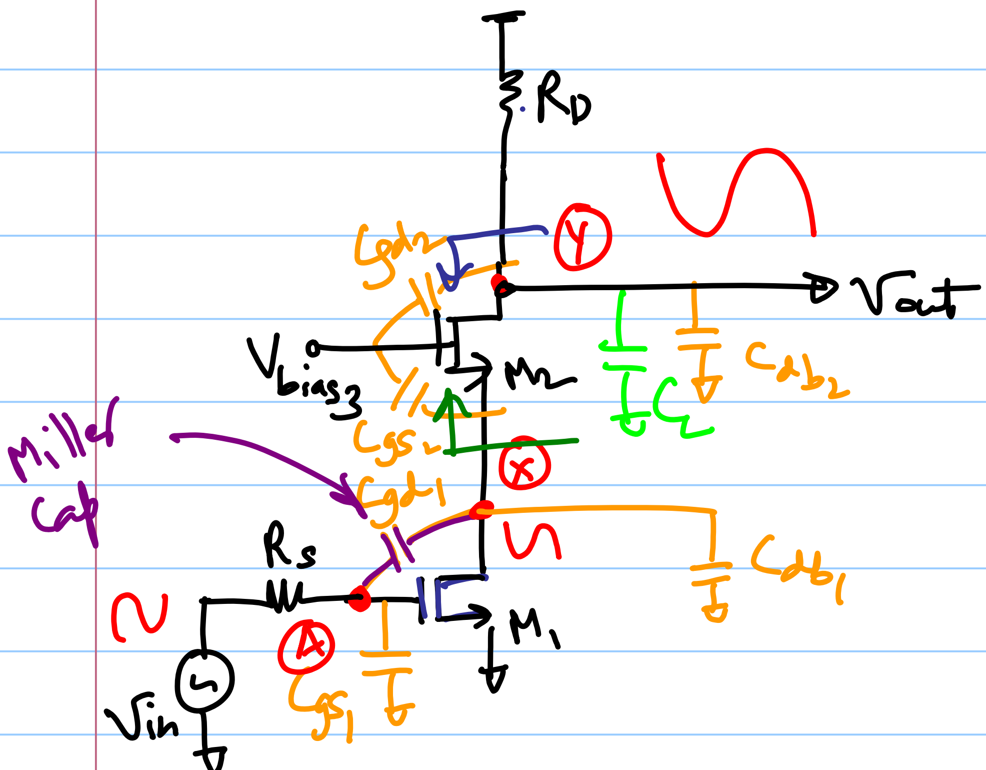
$$\omega_p \simeq \frac{1}{R_D(C_L + C_{gd})}$$



$$Y = \frac{1}{Z} = j\omega C + \frac{1}{j\omega L}$$

$$= j\omega \quad -\frac{j}{\omega L}$$

Cascode Amplifier frequency Response



$A_v = -g_{m1} \cdot R_{out}$

$\downarrow$

$R_D \| \underbrace{g_{m2} r_{o2} r_{o1}}_{g_m r_o^2}$

3 nodes

$\Rightarrow$ 3 poles

Gain from node A to X

assume R_D is small

$A_{A \to X} = -g_{m1} \cdot R_X$

$\downarrow$

$r_{o1} \| \dfrac{1}{(g_{m2}+g_{mb2})}$

$\simeq -\dfrac{g_{m1}}{g_{m2}} \simeq -1$

gain across Miller cap $C_{gd1} \Rightarrow -1$

$\Rightarrow$ Miller Effect at input is reduced

Pole at node (A)

$$\omega_{pA} \simeq \frac{1}{R_s\left[C_{gs_1} + \left(1+\frac{g_{m_1}}{g_{m_2}+g_{m_{2b}}}\right)C_{gd_1}\right]}$$

Pole at node (X)

$$C_X = 2C_{gd_1} + C_{db_1} + C_{gs_2} + C_{sb_1}$$

$$R_X \simeq \frac{1}{g_{m_2}+g_{m_{2b}}}$$ ← Assuming R_D is small

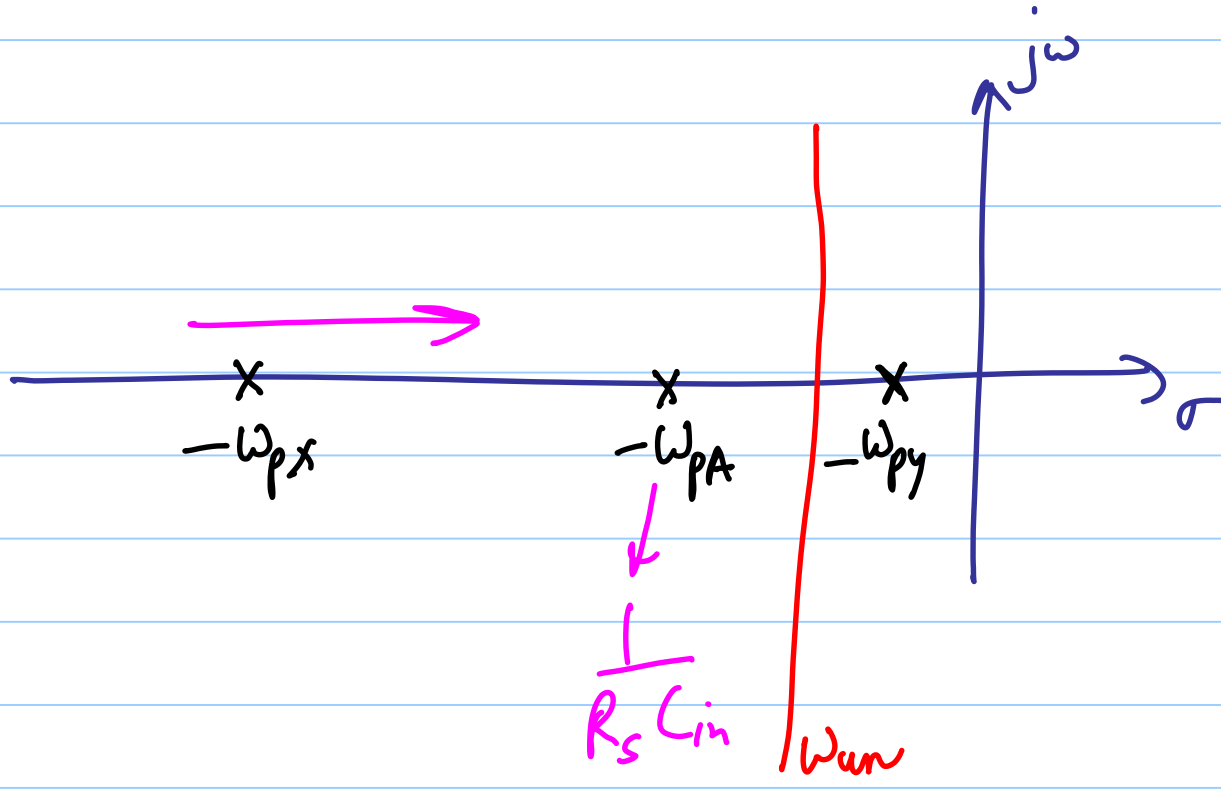
$g_{mp} r_{op}^2$

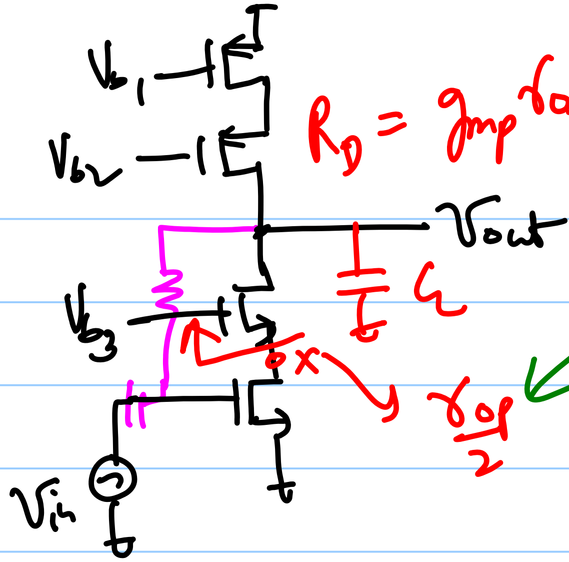
$$\omega_{pX} = \frac{1}{R_X C_X} = \frac{g_{m_2} + g_{m_{2b}}}{2C_{gd_1} + C_{db_1} + C_{sb_2} + C_{gs_2}}$$

$*$ Assuming R_D is small

$$\omega_{py} \simeq \frac{1}{R_D(C_{db_2} + C_L + C_{gd_2})}$$

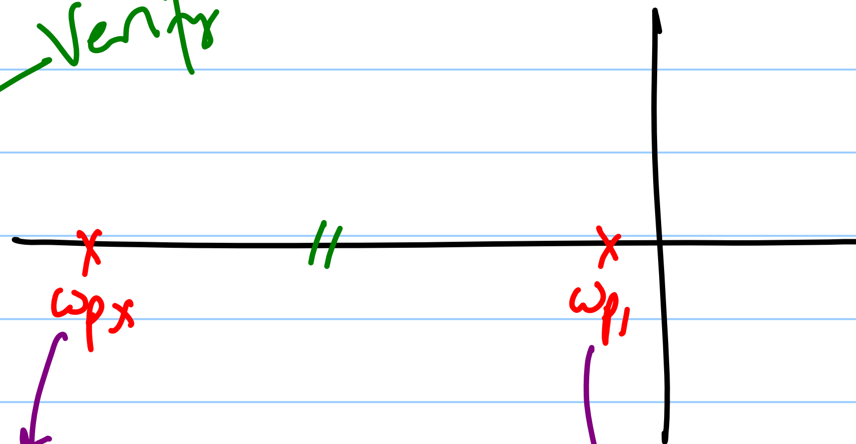
large C_L





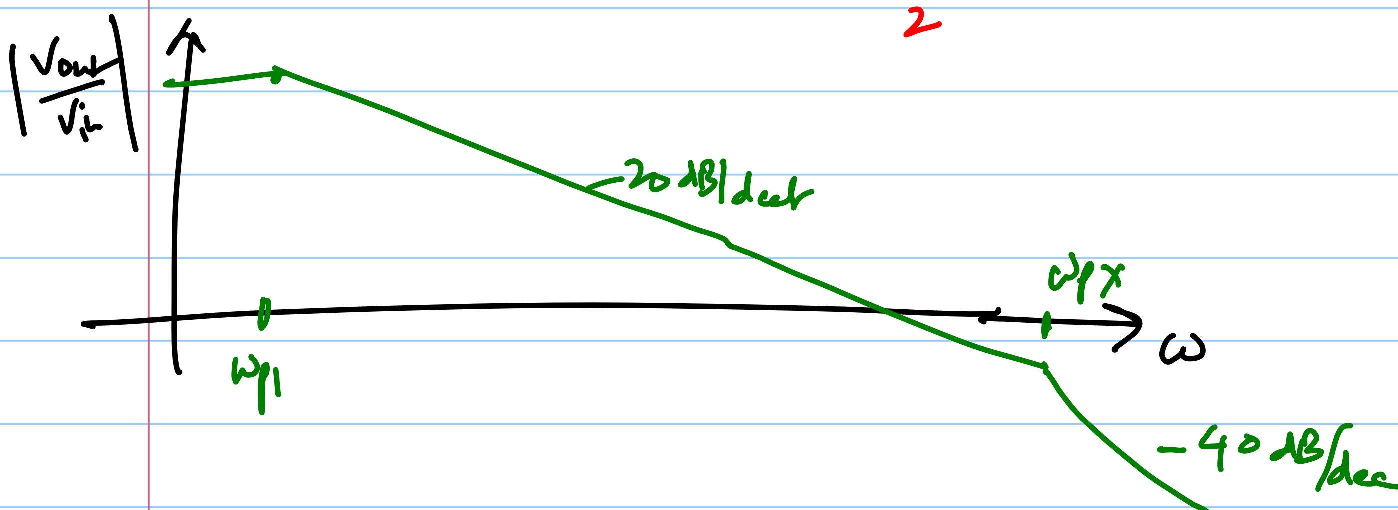
$R_D = g_{mp} r_{op}^2$

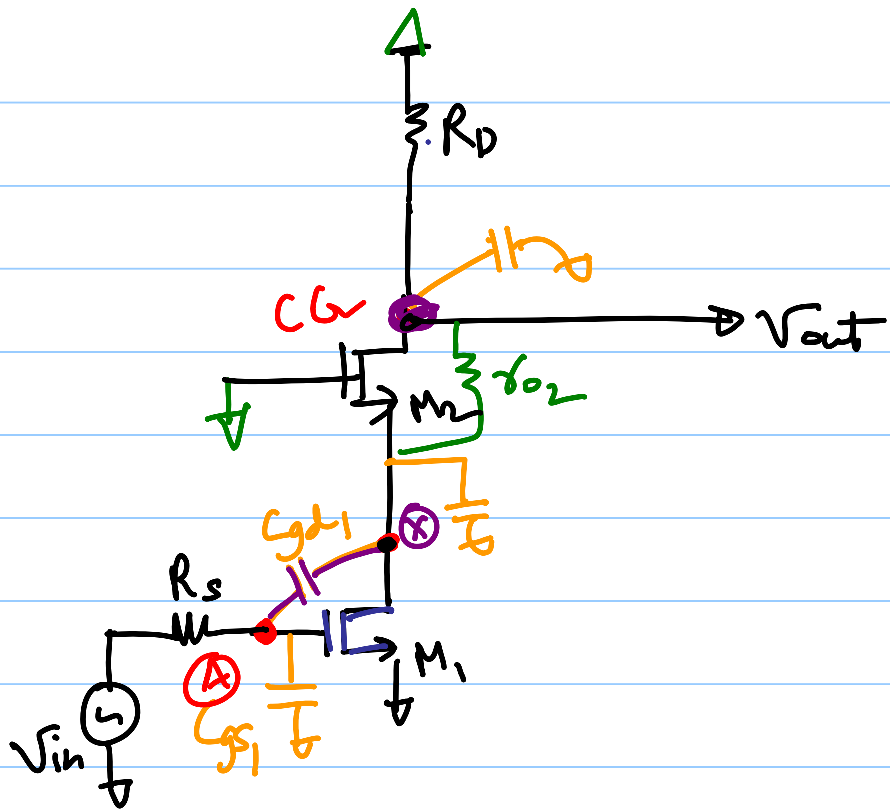
Verify this



$$\omega_{px} \rightarrow \frac{1}{\frac{r_{op}}{2} \cdot C_x}$$

$$\omega_{p1} \rightarrow \frac{1}{R_{out} C_L} \rightarrow (g_{mp} r_{op}^2) \parallel (g_{mn} r_{on}^2)$$

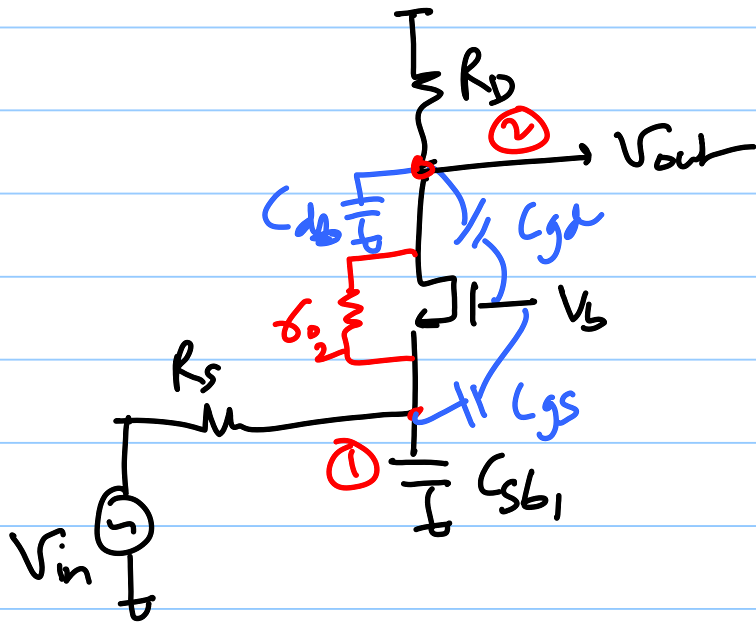




No zeros
↳ isolation due to M_2

⇒ Miller effect is reduced

Common Gate



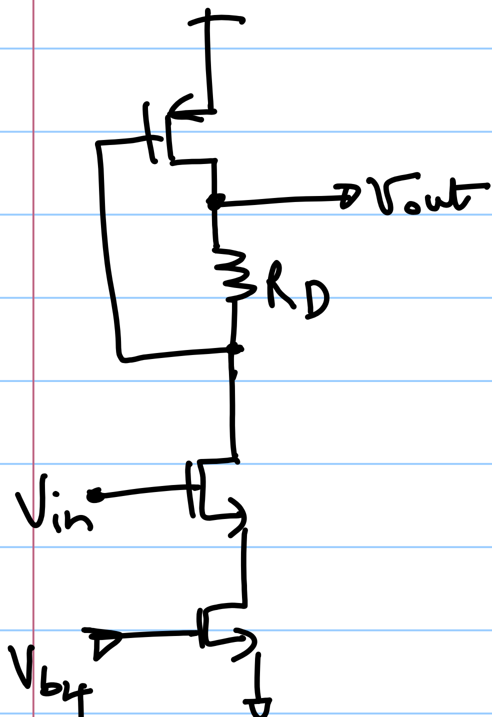
$$\omega_{in} \simeq \frac{1}{\left(R_S \,\|\, \frac{1}{g_m + g_{mb}}\right) C_{in}}$$

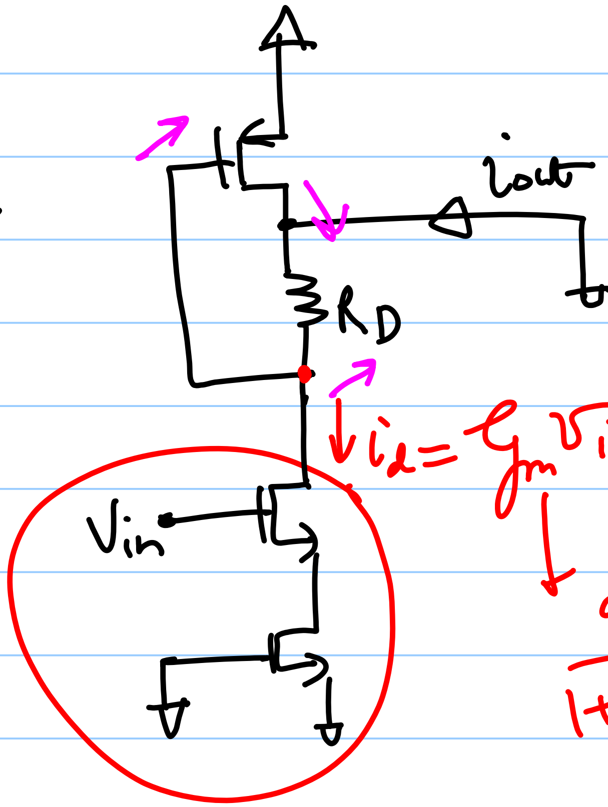
$$\omega_{out} \simeq \frac{1}{R_D C_2}$$

No zero.

(e)

g_m, R_{out}

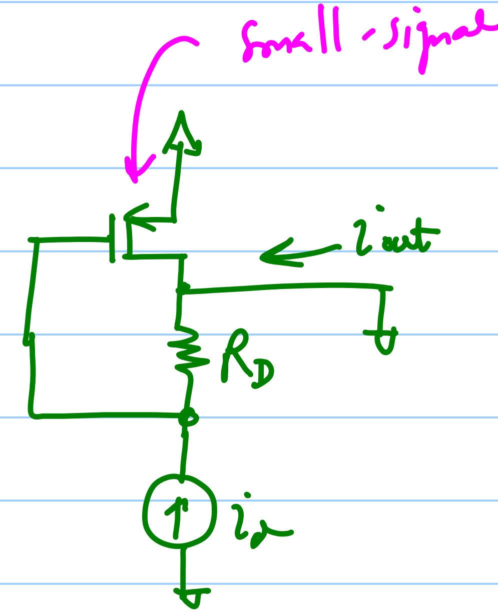




$i_d = g_m v_{in}$

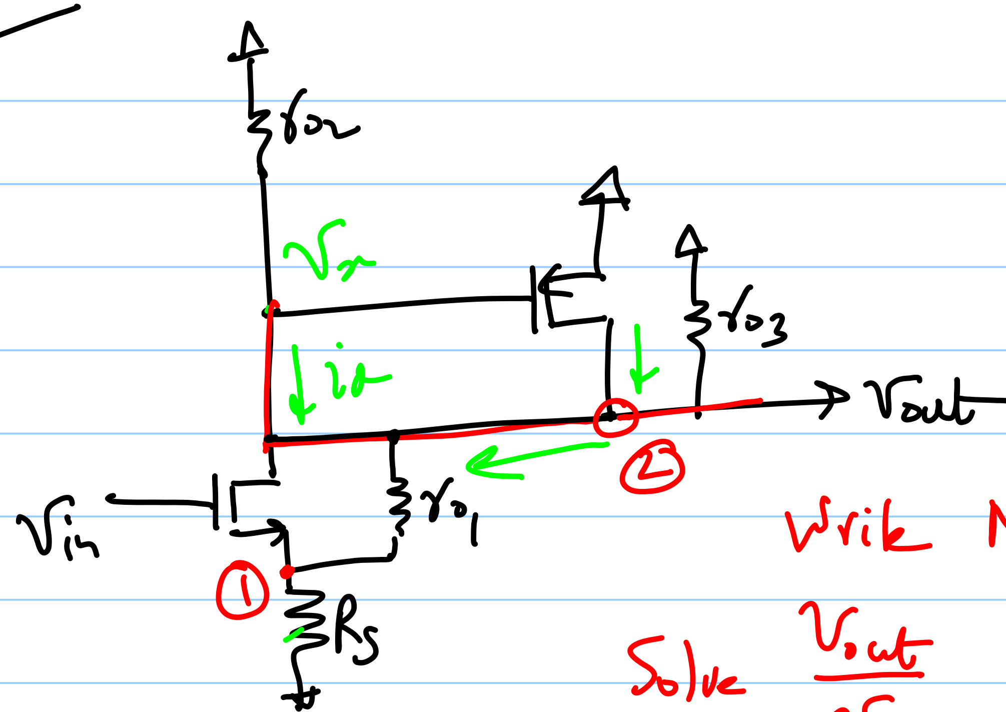
$\downarrow$

$\frac{g_m}{1+g_m r_o}$



Problem 3

$\gamma = 0$

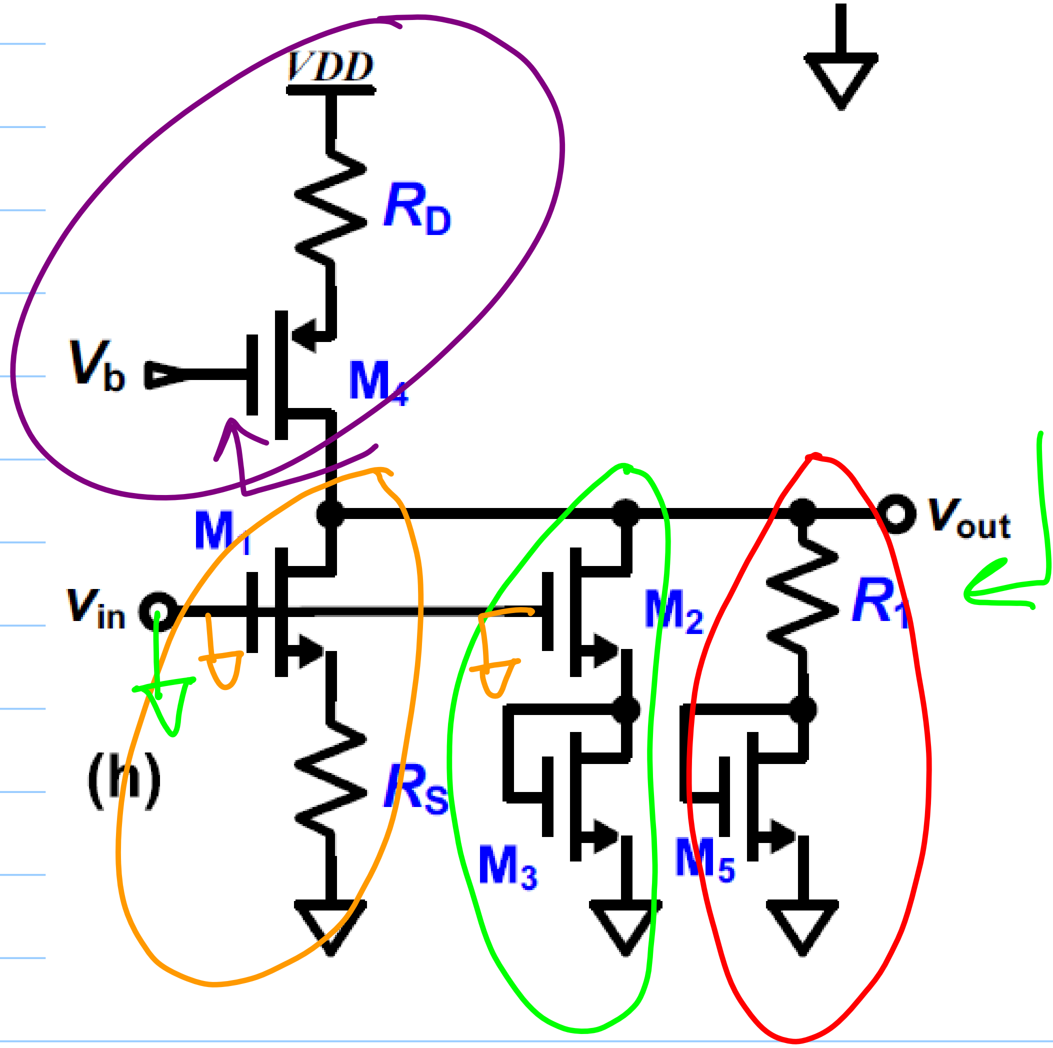


Write Nodal equations

Solve $\dfrac{v_{out}}{v_{in}}$

Algebra

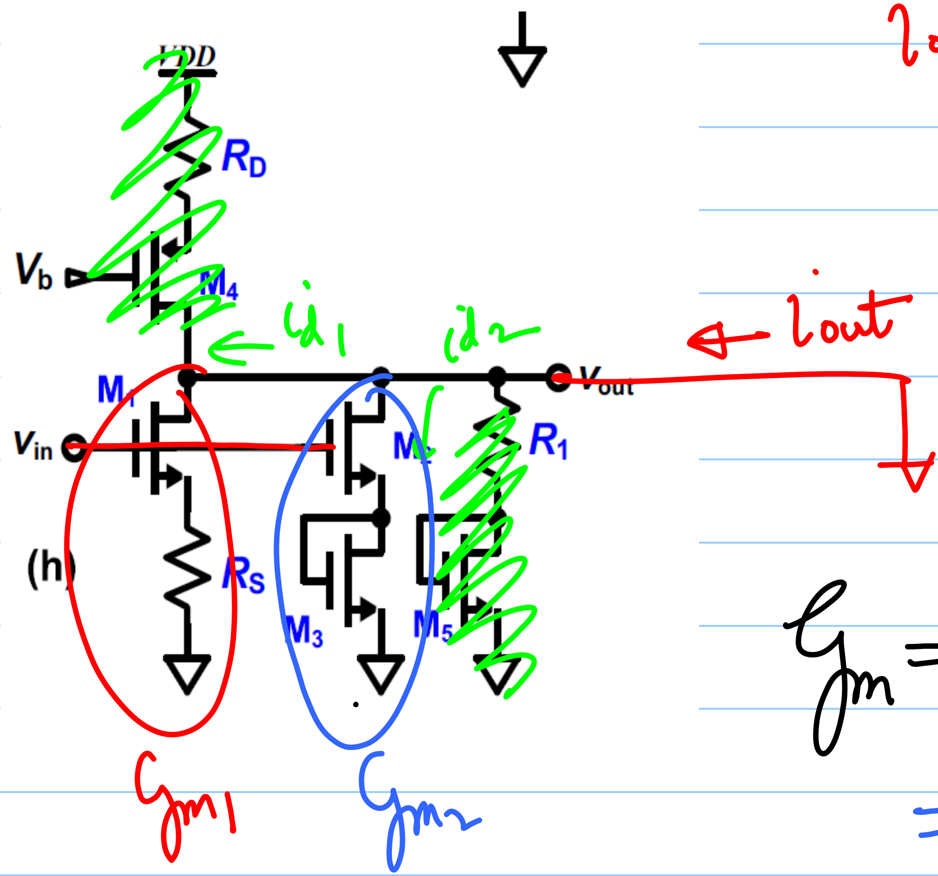
1(h)



R_{out}

$$= g_{m4} r_{o4} R_D \;||\; g_{m1} r_{o1} R_S \;||\; g_{m2} r_{o2} \cdot \frac{1}{g_{m3}} \;||\; R_1 + \frac{1}{g_{m5}}$$

$$\simeq R_1 + \frac{1}{g_{m5}}$$

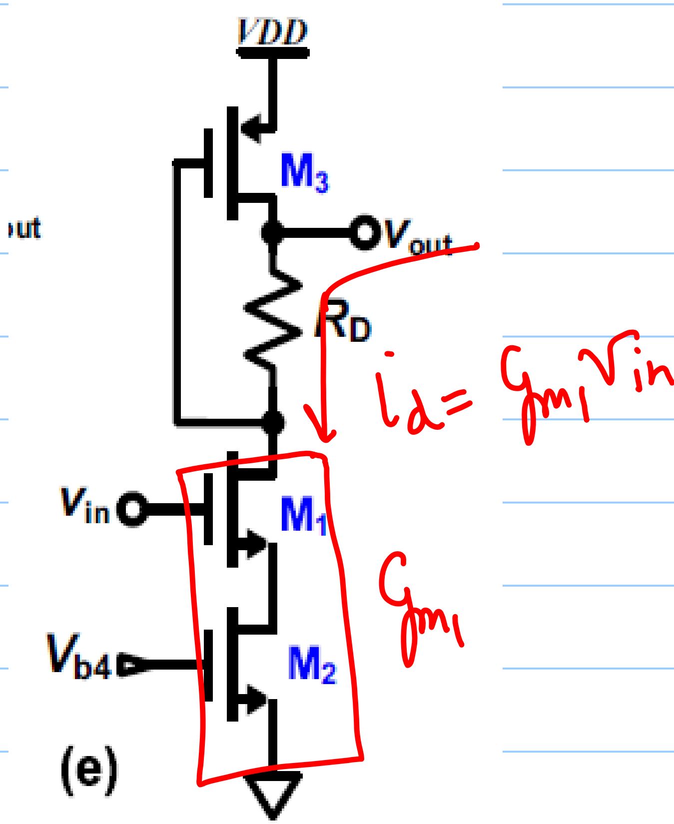


$$i_{out} = i_{d_1} + i_{d_2}$$

$$=$$

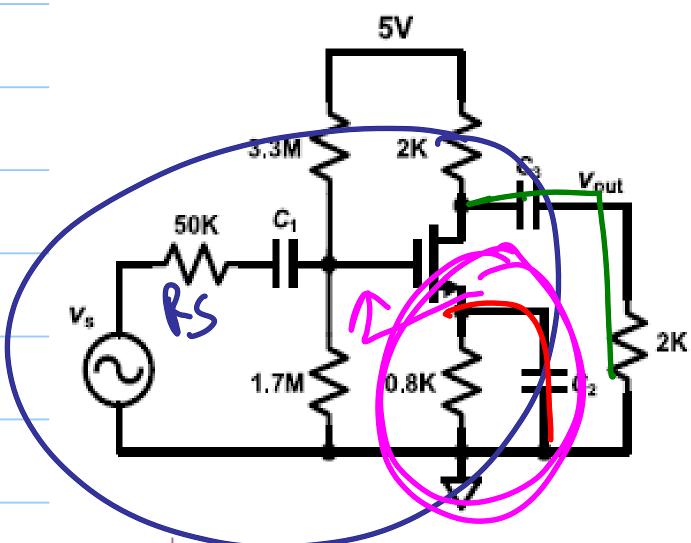
$$G_m = G_{m_1} + G_{m_2}$$

$$= \left(\frac{g_{m_1}}{1+g_{m_1}R_S}\right) + \left(\frac{g_{m2}}{1+\frac{g_{m2}}{g_{m3}}}\right)$$

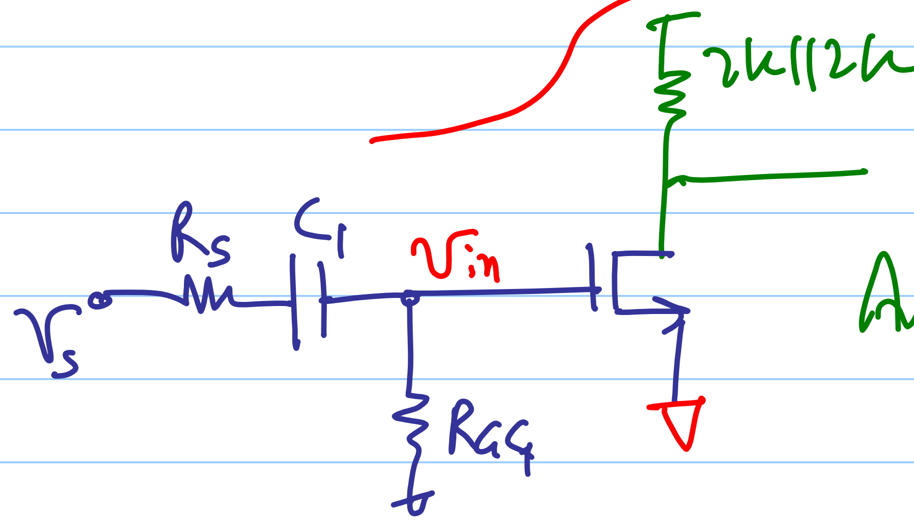


(e)

Problem 2



$$\frac{\omega_{in}}{10} = \frac{1}{\left(\frac{1}{g_m} \| 0.8k\right) C_2}$$



$$A_v = -g_m \cdot 1K$$

$\frac{V_{in}}{V_s} \Rightarrow$ time-constant $(R_s + R_{GG}) C_1$

$$\frac{1}{(R_s + R_{GG}) C_1} < \frac{\omega_{in}}{10}$$