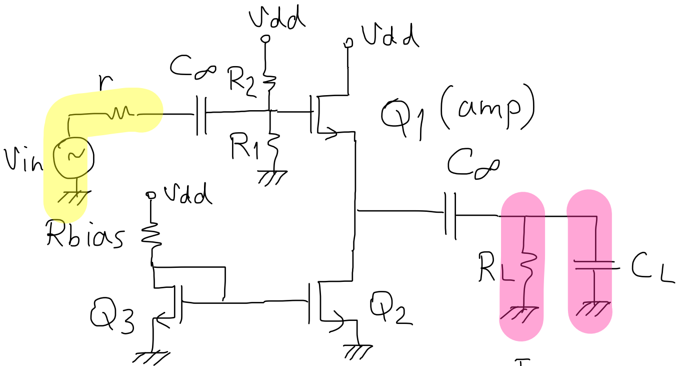
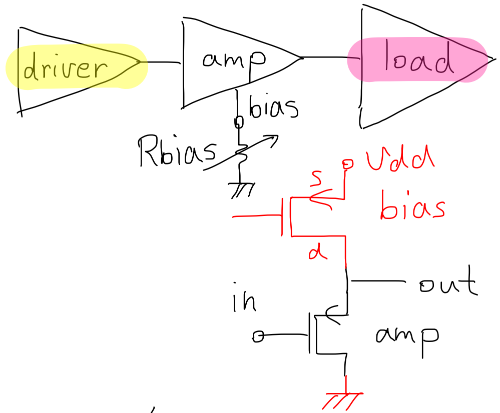
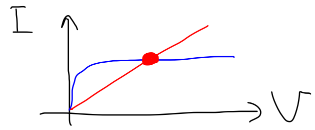
* Common Drain Amplifier:

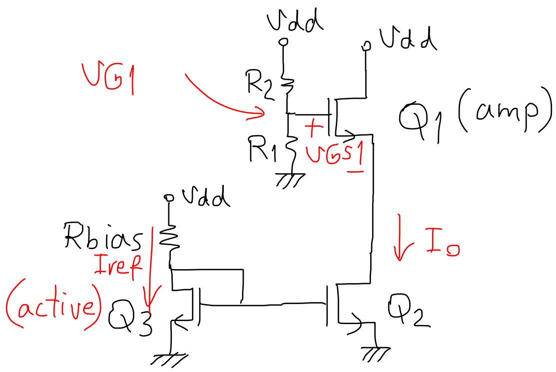




(pmos Common Drain)



* DC Analysis:



→ assume Q_1 is in the active

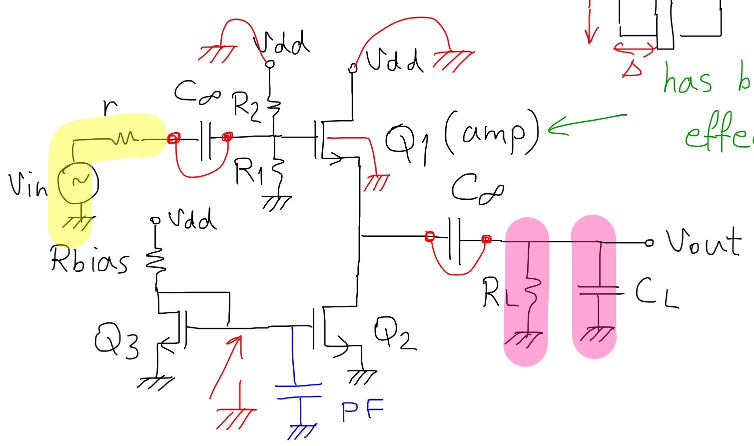
$$\begin{cases} I_{DS1} = \frac{1}{2}\mu_n C_{ox} \frac{W_1}{L_1}(V_{GS1}-V_{th})^2\left[1+\lambda\left(V_{DS1}-(V_{GS1}-V_{th})\right)\right] \\ I_{DS2} = \frac{1}{2}\mu_n C_{ox} \frac{W_2}{L_2}(V_{GS2}-V_{th})^2\left[1+\lambda\left(V_{DS2}-(V_{GS2}-V_{th})\right)\right] \\ V_{dd} = V_{DS1} + V_{DS2} \end{cases}$$

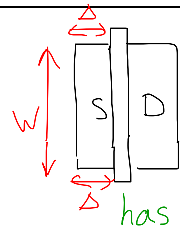
$\Longrightarrow$ solve to find $\begin{cases} V_{GS1} \\ V_{DS1} \\ V_{DS2} \end{cases}$ $\Longrightarrow$ verify if Q_1 is operating in the active

$$\begin{cases} V_{GS1} \geq V_{th} \; ✓ \\ V_{DS1} \geq V_{GS1} - V_{th} \; ✓ \end{cases}$$

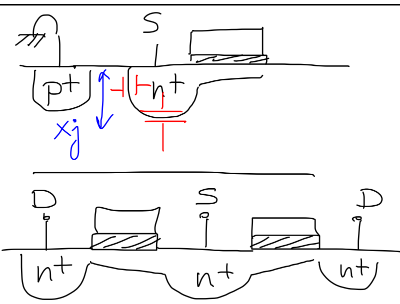
$\Longrightarrow$ find g_{m1}, r_{ds1}, $r_{ds2} = \frac{1}{\lambda I_o}$ and proceed with AC analysis

* AC Analysis:

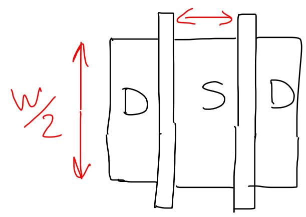




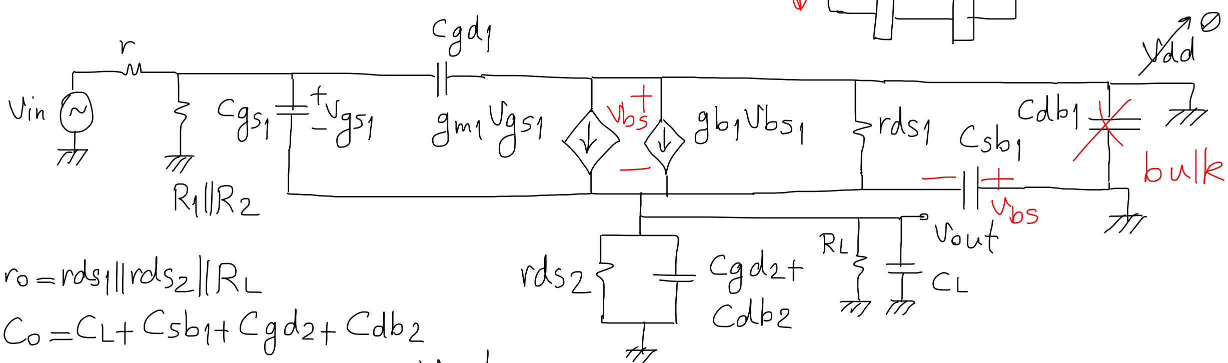
has body effect



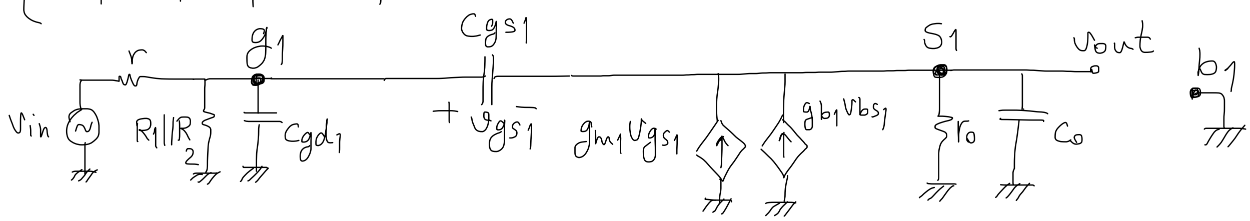
$C_{sb} = \Delta \frac{W}{2} C_j + x_j P C_j$

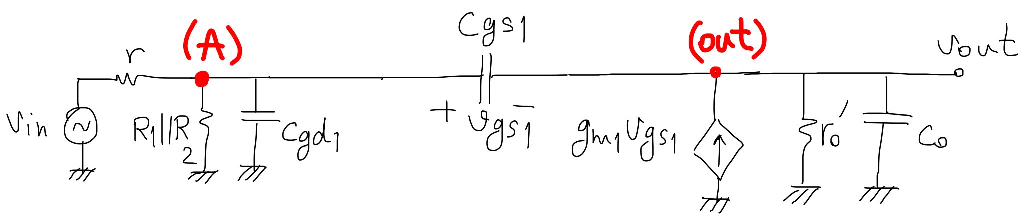


$P = 2\Delta$

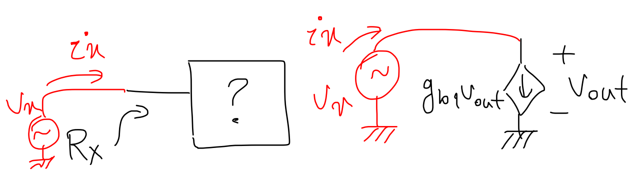


$$\begin{cases} r_o = r_{ds1} \| r_{ds2} \| R_L \\ C_o = C_L + C_{sb1} + C_{gd2} + C_{db2} \\ V_{bs1} = V_{b1} - V_{s1} = -V_{s1} = -V_{out} \end{cases}$$





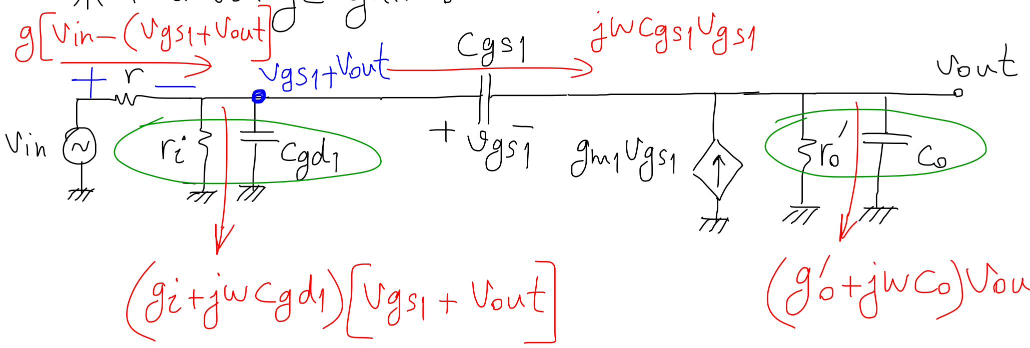
$r_o' = r_o \| \frac{1}{g_{b1}}$



$\frac{V_x}{i_x} = \frac{\cancel{V_{out}}}{g_{b1} \cancel{V_{out}}} = \frac{1}{g_{b1}}$

* find voltage gain :

$r_i = R_1 \| R_2$



$$\text{KCL(in)}: \; g[V_{in} - V_{gs1} - V_{out}] = (g_i + j\omega C_{gd1})(V_{gs1} + V_{out}) + j\omega C_{gs1} V_{gs1} \quad \textbf{EQ.1}$$

$$\text{KCL(out)}: \; j\omega C_{gs1} V_{gs1} + g_{m1} V_{gs1} = (g_o' + j\omega C_o) V_{out} \quad \textbf{EQ.2}$$

$$\xRightarrow{\text{EQ.2}} \; V_{gs1} = V_{out} \frac{g_o' + j\omega C_o}{g_{m1} + j\omega C_{gs1}} \quad \textbf{EQ.3}$$

$$\xRightarrow{\text{EQs.1 and 3}} \; g \cdot V_{in} = V_{out}\left[g + g_i + j\omega C_{gd1} + \frac{(g_o' + j\omega C_o)(g + g_i + j\omega(C_{gd1} + C_{gs1}))}{g_{m1} + j\omega C_{gs1}} \right]$$

$$\frac{V_{out}}{V_{in}} = \frac{\overbrace{g \cdot g_{m1}}^{K_1}\left(1 + j\omega \frac{C_{gs1}}{g_{m1}}\right)}{\underbrace{(g+g_i) g_{m1} + g_o'(g+g_i)}_{K_2} + j\omega\Big[\underbrace{(g+g_i) C_{gs1} + g_{m1} C_{gd1} + g_o'(C_{gd1} + C_{gs1}) + (g+g_i) C_o}_{K_3}\Big] + \cdots + (j\omega)^2 \Big[\underbrace{C_{gd1} C_{gs1} + C_o (C_{gd1} + C_{gs1})}_{K_4}\Big]}$$

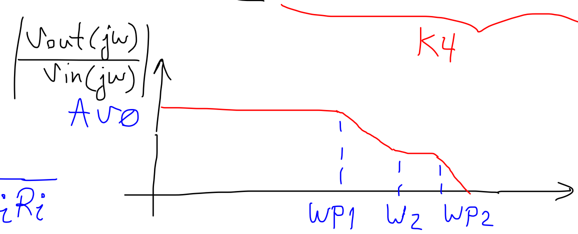
$$\left(1 + j\omega \frac{C_{gs1}}{g_{m1}}\right) \equiv \left(1 + j \frac{\omega}{\omega_z}\right)$$

$$\omega_z = \frac{-g_{m1}}{C_{gs1}}$$

$$A_{v0} = \frac{K_1}{K_2}$$

$$\omega_{p1} = \frac{K_2}{K_3} = \frac{1}{\sum C_i R_i}$$

$$\omega_{p2} = \frac{K_3}{K_4}$$

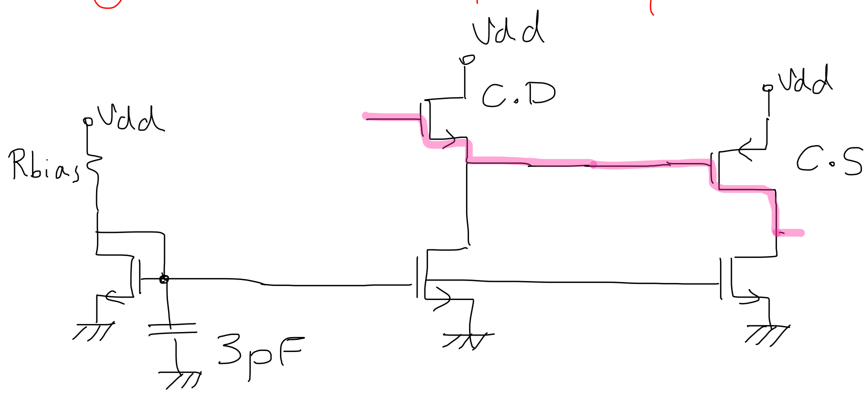


$$\omega_{p1} \ll \begin{cases} \omega_z \\ \omega_{p2} \end{cases}$$

Exam: $Q_1 \rightarrow$ DC Analysis $\begin{cases} \text{operating point} \\ V_{GS}, V_{DS}, I_{DS} \\ \text{verify} \\ g_m, r_{ds} \end{cases}$

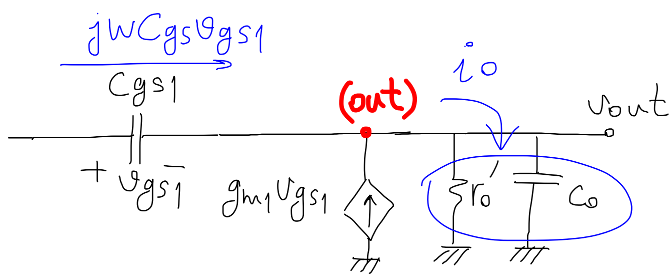
$Q_2 \rightarrow$ AC analysis $\begin{cases} A_{v0} \text{ or } \omega_{p1} \text{ or } \omega_{p2} \\ \text{or } \omega_z \\ \text{or } R_{in} \\ \text{or } R_{out} \end{cases}$

Analog (DC+AC) $\xrightarrow[\text{superposition}]{\text{use}}$ $\begin{cases} \text{DC} \\ \text{AC} \end{cases}$



$$\sum C_{gs} = 375_{fF} \ @ \ 1\text{GHz} \Rightarrow X_{gs} = \frac{1}{375\times10^{-15}\times 2\pi\times10^{9}}$$

$$X_{gs} = \frac{1}{2000\times10^{-6}} = 500\Omega$$



$$\cancel{i_o}^{\,0} = \underbrace{(g_o + j\omega C_o)}_{\neq 0}\, \cancel{v_o}^{\,0} \quad ; \quad \text{if } i_o = 0 \Rightarrow V_{out} = 0$$

$$\text{KCL(out)}: \ i_o = \underbrace{j\omega C_{gs1} v_{gs1} + g_{m1} v_{gs1}}_{\underbrace{(g_{m1} + j\omega C_{gs1})}_{=0} v_{gs1}} = 0$$

$$g_{m1} + j\omega_z C_{gs1} = 0 \Rightarrow j\omega_z = \frac{-g_{m1}}{C_{gs1}}$$