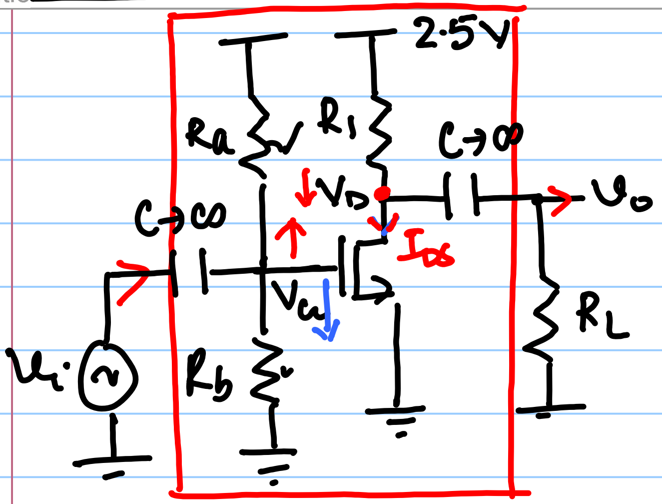
Note Title — 25-08-2021

lecture # 11



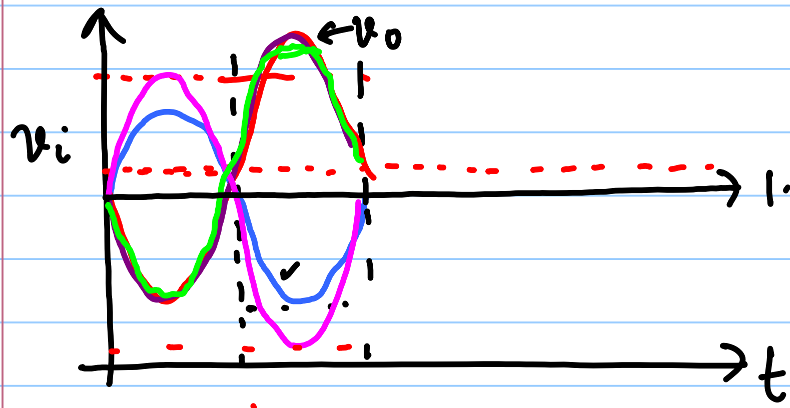
$$\frac{v_o}{v_D} = 1 \qquad \frac{v_o}{v_D} = \frac{R_L}{R_L + \frac{1}{sC}} = \frac{sCR_L}{1 + sCR_L}$$

$$\left|\frac{v_o}{v_D}\right| \approx 1 \Rightarrow \left|\frac{sCR_L}{1+sCR_L}\right|_{s=j\omega} \approx 1$$

$$|sCR_L| \gg 1 \Rightarrow C \gg \left|\frac{1}{\omega_{min} R_L}\right|$$

$$|j\omega_{min} C R_L| = 10$$

@ i/p $\quad C \gg \dfrac{1}{\omega_{min}(R_a \| R_b)}$



$v_o = A v_{in}$ $\quad$ A is the gain of amp.

@ operating point $\quad A = -2V/V$

– Lower limit on v_i:

$V_G = 1.2 - \underline{v_i \sin(\omega_o t)} \rightarrow I_{DS} = g_m v_i$ $\quad$ small signal.

– Upper limit on v_i: $\Rightarrow$ linear region.

Upper limit : +ve amp ✓

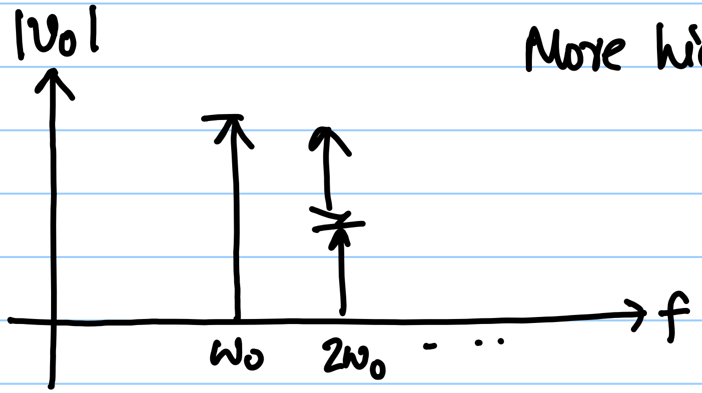
lower limit : -ve amp ✓

$V_{DS} = 1.5V - \underbrace{g_m R_L} \cdot v_i = 1.2 + v_i - V_{th}.$

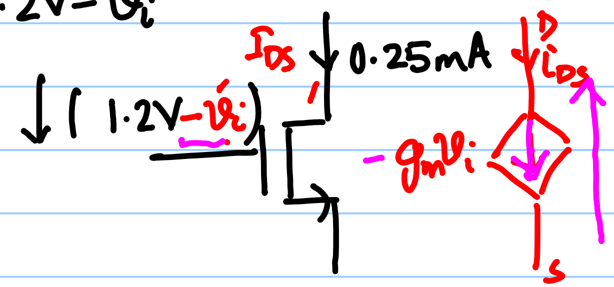
- lower & upper swing limits are evaluated from small-signal model.

$v_o(t) = -2 v_i \sin(\omega_o t) + \underbrace{\ldots (2\omega_o t)}_{\text{Negligible.}}$ ✗

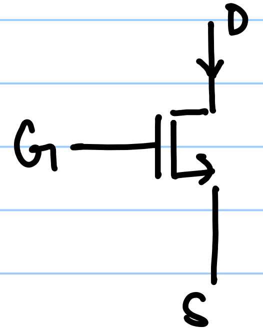
More higher order terms.



$V_{GS} = 1.2V - v_i$



$0.25mA - g_m v_i = 0$

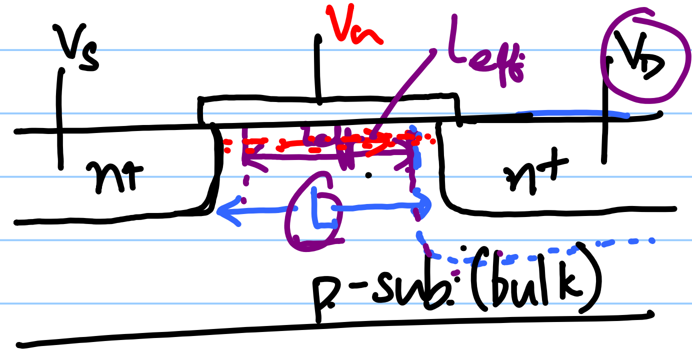


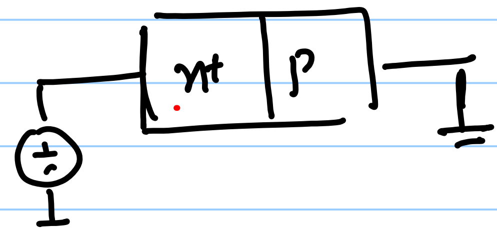
$$I_{DS} = \frac{\mu_n C_{ox}}{2} \frac{W}{L} (V_{GS} - V_T)^2$$

$$I_{DS} = \frac{\mu_n C_{ox}}{2} \frac{W}{(L - \Delta L)} (V_{GS} - V_T)^2$$

$$= \frac{\mu_n C_{ox}}{2} \frac{W}{L} (V_{GS} - V_T)^2 \left(1 - \frac{\Delta L}{L}\right)^{-1}$$

$$\approx \frac{\mu_n C_{ox}}{2} \frac{W}{L} (V_{GS} - V_T)^2 \left(1 + \frac{\Delta L}{L}\right)$$





$$\frac{\Delta L}{L} \propto V_{DS} \Rightarrow \frac{\Delta L}{L} = \lambda V_{DS}$$

where λ is a constant: channel length modulation

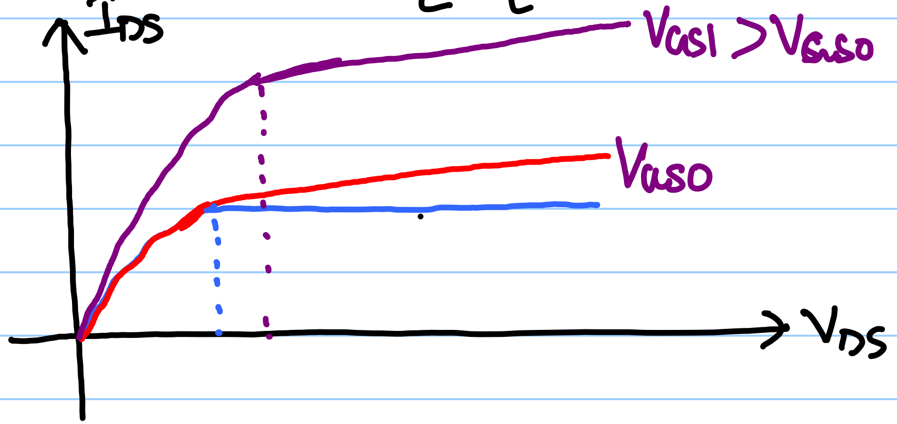
In saturation region.

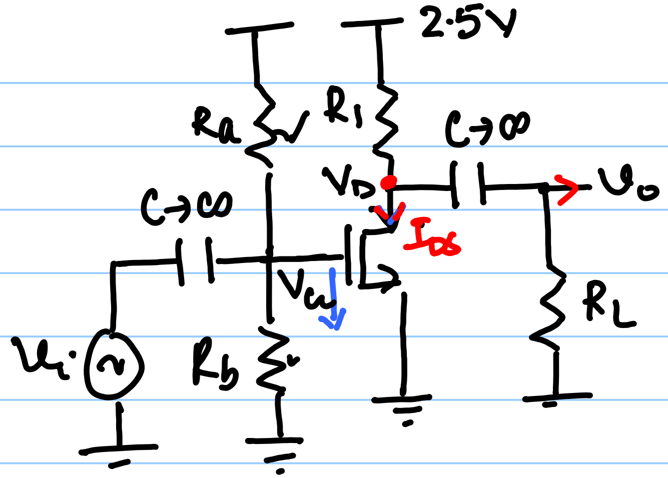
$$I_{DS} = \frac{\mu_n C_{ox}}{2} \frac{W}{L} (V_{GS}-V_{th})^2 (1+\lambda V_{DS})$$ ✓

- $\lambda \propto \frac{1}{L}$ constant

In linear region.

$$I_{DS} = \mu_n C_{ox} \frac{W}{L} \left[(V_{GS}-V_{th}) V_{DS} - \frac{V_{DS}^2}{2} \right]$$



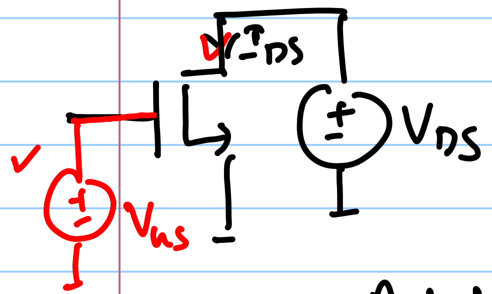


$V_G = 1.2V$, $V_{tn} = 0.7$, $V_{DS} = 1.5V$, $\lambda = 0.1$

$\mu_n C_{ox} = 100\mu A/V^2$, $\frac{W}{L} = 20$. $R_1 = 4K$

$I_{DS} = 0.25\,mA$ (Yesterday)

$$\boxed{I_{DS} = \frac{\mu_n C_{ox}}{2}\frac{W}{L}(V_{GS}-V_{tn})^2(1+\lambda V_{DS}) = \frac{2.5-V_{DS}}{4K}}$$



$= 0.25\,mA\,(1+0.1\times1.5)$ (Assumption)

$= 0.25 \times 1.15 = 0.2875\,mA$.

Actual $V_{DS} = 2.5 - 0.2875\,mA \times 4K$

$$0.25\,mA\,(1+0.1V_{DS}) = \frac{2.5-V_{DS}}{4K}$$

$$1+0.1V_{DS} = 2.5 - V_{DS}.$$

$$V_{DS} = \frac{1.5}{1.1} = 1.36V$$

$$I_{DS} = \frac{2.5-1.36}{4K} = \frac{1.14}{4K} = 0.235\,mA$$

$$I_{DS} = f(V_{GS}, V_{DS})$$

$$\begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} i_G \\ i_{DS} \end{bmatrix} = \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix} \begin{bmatrix} v_{GS} \\ v_{DS} \end{bmatrix}$$

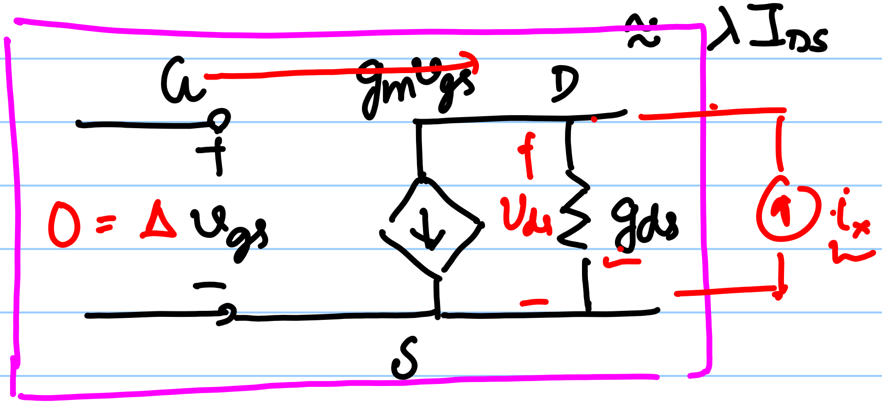
$$y_{11} = 0 \;, \quad y_{12} = 0$$

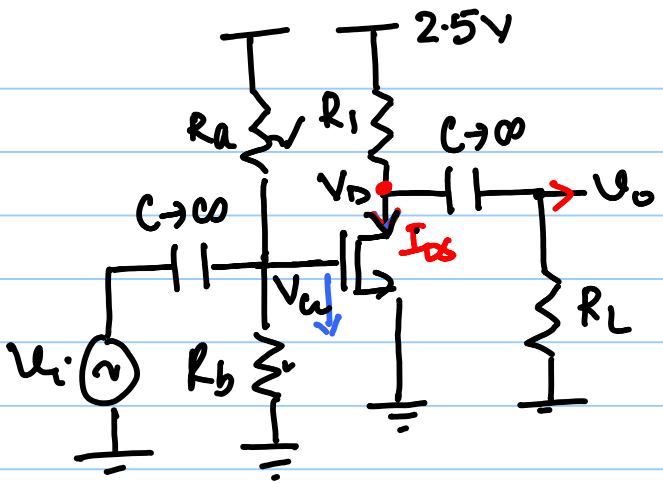
$$y_{21} = g_m = \frac{\partial I_{DS}}{\partial V_{GS}} = \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_{tn})(1 + \lambda V_{DS}) \quad \text{"Accurate"}$$

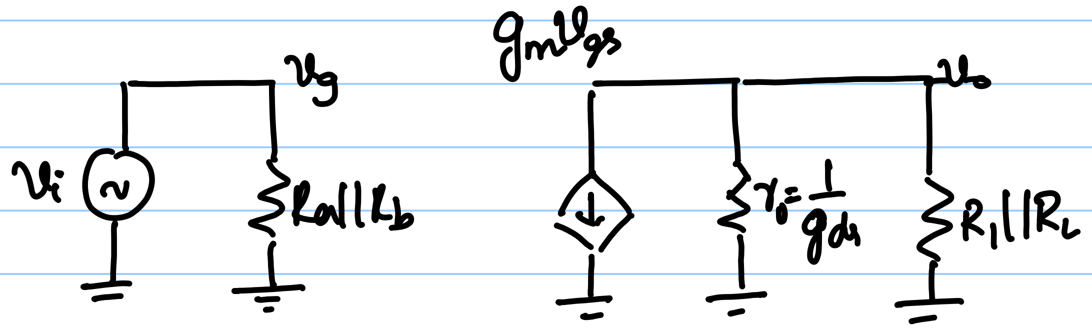
$$\approx \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_{tn})$$

$$y_{22} = g_{ds} = \frac{\partial I_{DS}}{\partial V_{DS}} = \frac{\mu_n C_{ox}}{2} \frac{W}{L} (V_{GS} - V_{tn})^2 \lambda \quad \text{"Accurate"}$$

$$\approx \lambda I_{DS}$$







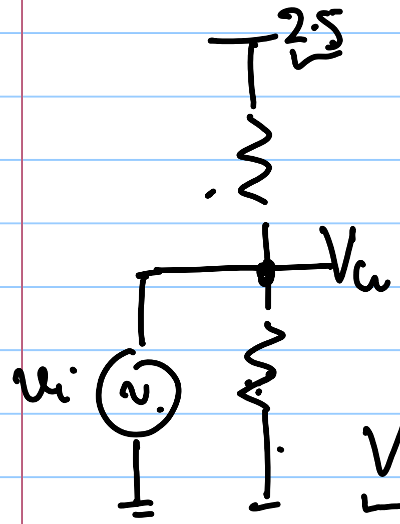
$$\frac{v_o}{v_i} = -g_m \left(\underbrace{r_o \| R_1 \| R_2}_{< (R_1 \| R_L)} \right)$$

To have high gain $r_o \to \infty$

$$r_o = \frac{1}{g_{ds}} = \frac{1}{\left(\mu_n C_{ox} \left(\frac{2W}{2L}\right) (V_{GS} - V_{tn})^2\right) \lambda}$$

$\lambda \propto \frac{1}{L}$

To increase $r_o \longrightarrow$ Increase L



$\underline{V_G = v_i = a \sin(\omega_0 t)}$