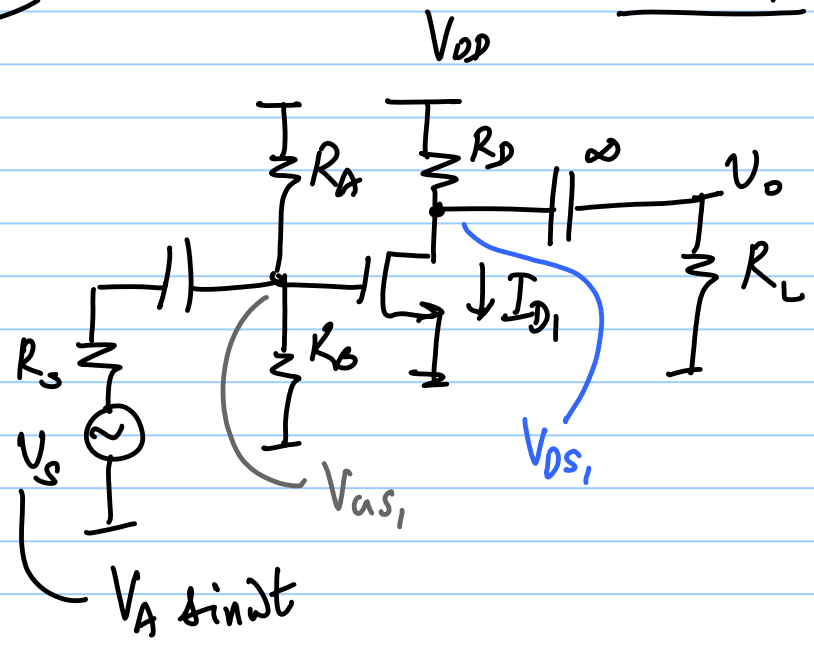
7/8/19

Lec 7

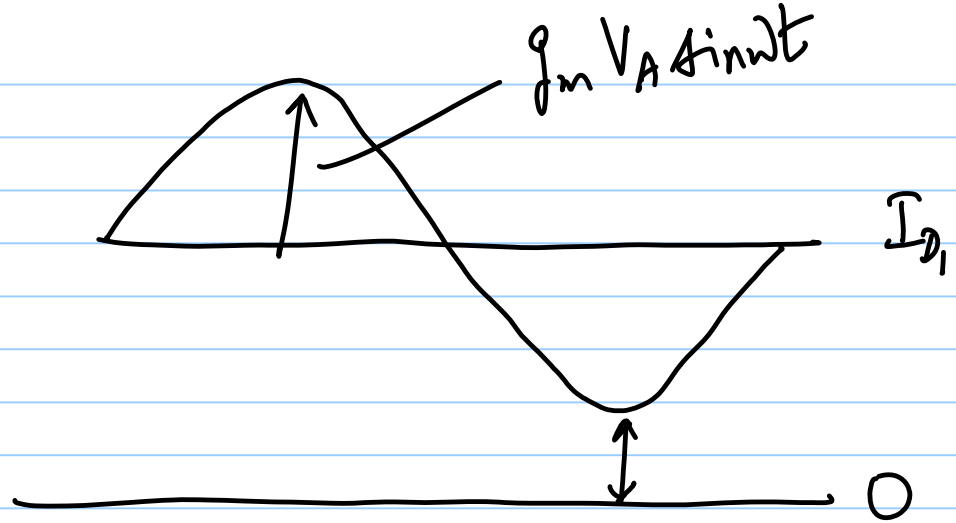


$$V_{DS} = V_{DS_1} - g_m (R_D \| R_L) \cdot V_A \sin\omega t$$

$$V_{GS} = V_{GS_1} + V_A \sin\omega t$$

Triode limit

$$V_{A_1} = \frac{V_{DS_1} - (V_{GS_1} - V_T)}{1 + g_m (R_D \| R_L)}$$

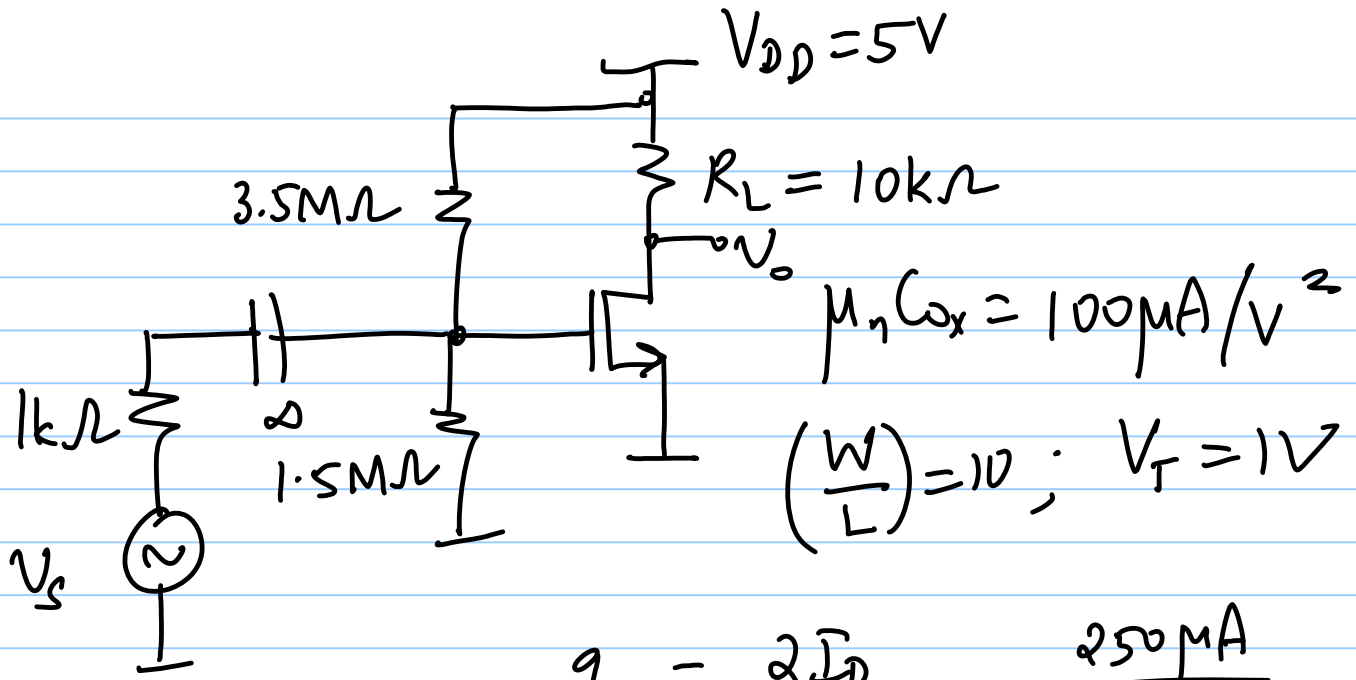


$$I_{D_1} + g_m V_A \sin\omega t = 0$$

@ negative peak

Cut-off limit $V_{A_2} = \dfrac{I_{D_1}}{g_m}$

Example



$\mu_n C_{ox} = 100\mu A/V^2$

$\left(\frac{W}{L}\right) = 10$; $V_T = 1V$

$V_{GS_1} = 1.5V$

$I_{D_1} = \frac{1}{2} \times (100\mu A/V^2) \times 10 \times (0.5V)^2$

$= 125\mu A$

$V_{DS_1} = 5V - 125\mu A \times 10k\Omega$

$= 3.75V$

$g_m = \frac{2I_D}{V_{GS} - V_T} = \frac{250\mu A}{0.5V}$

$= 0.5mS$

small-signal gain $\frac{v_o}{v_s} = -g_m R_L = -5 \text{ V/V}$

Swing limits

Triode limit

$V_G = 1.5V + V_A$ limit

$V_D = 3.75 - 5V_A$ limit

$V_D = V_G - V_T$

$3.75 - 5V_{A_1} = 1.5 + V_A - 1$

$V_{A_1} = \frac{3.25}{6} \simeq 542 \text{ mV}$

Cut off limit

$$I_D = 0$$

$$125\mu A + 0.5mS \cdot V_{A_2} \sin\omega t = 0$$

$$V_{A_2} = \frac{125\mu A}{0.5mS} = 250mV$$

max V_A for linear operation : $\min\{V_{A_1}, V_{A_2}\} = 250mV$

$\underline{V_A = V_T}$: $V_{GS_1} - V_{A_3} = V_T$

$V_{A_3} = V_{GS_1} - V_T = 0.5V$

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

$\times 2$ $\times 2$

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

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

$$I_{D_1} + \frac{\partial I_D}{\partial V_{GS}} \cdot v_{gs} + \frac{\partial I_D}{\partial V_{DS}} \cdot v_{ds}$$

($\frac{\partial I_D}{\partial V_{GS}}$: g_m, (I); $\frac{\partial I_D}{\partial V_{DS}} \to 0$)

$$+ \frac{1}{2}\frac{\partial^2 I_D}{\partial V_{GS}^2} \cdot v_{gs}^2 + \frac{1}{2}\frac{\partial^2 I_D}{\partial V_{DS}^2} \cdot v_{ds}^2$$

($\frac{\partial^2 I_D}{\partial V_{GS}^2}$: (II); $\frac{\partial^2 I_D}{\partial V_{DS}^2} \to 0$)

$$+ \ldots \to 0$$

$$II \ll I$$

$$\frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right) \cdot v_{gs}^2 \ll \mu_n C_{ox}\left(\frac{W}{L}\right)(V_{GS}-V_T) \cdot v_{gs}$$

$$\boxed{v_{gs} \ll 2(V_{GS}-V_T)}$$