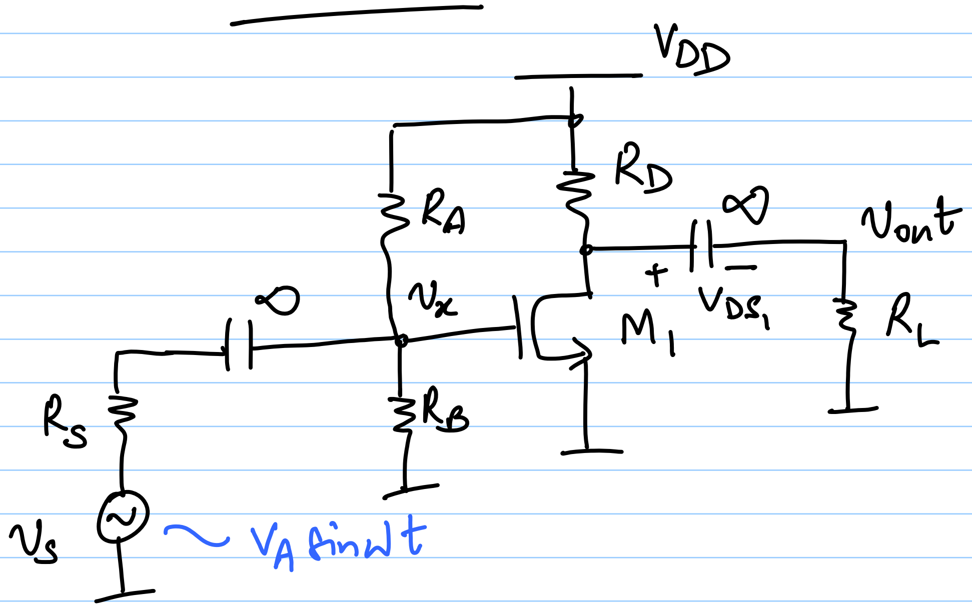
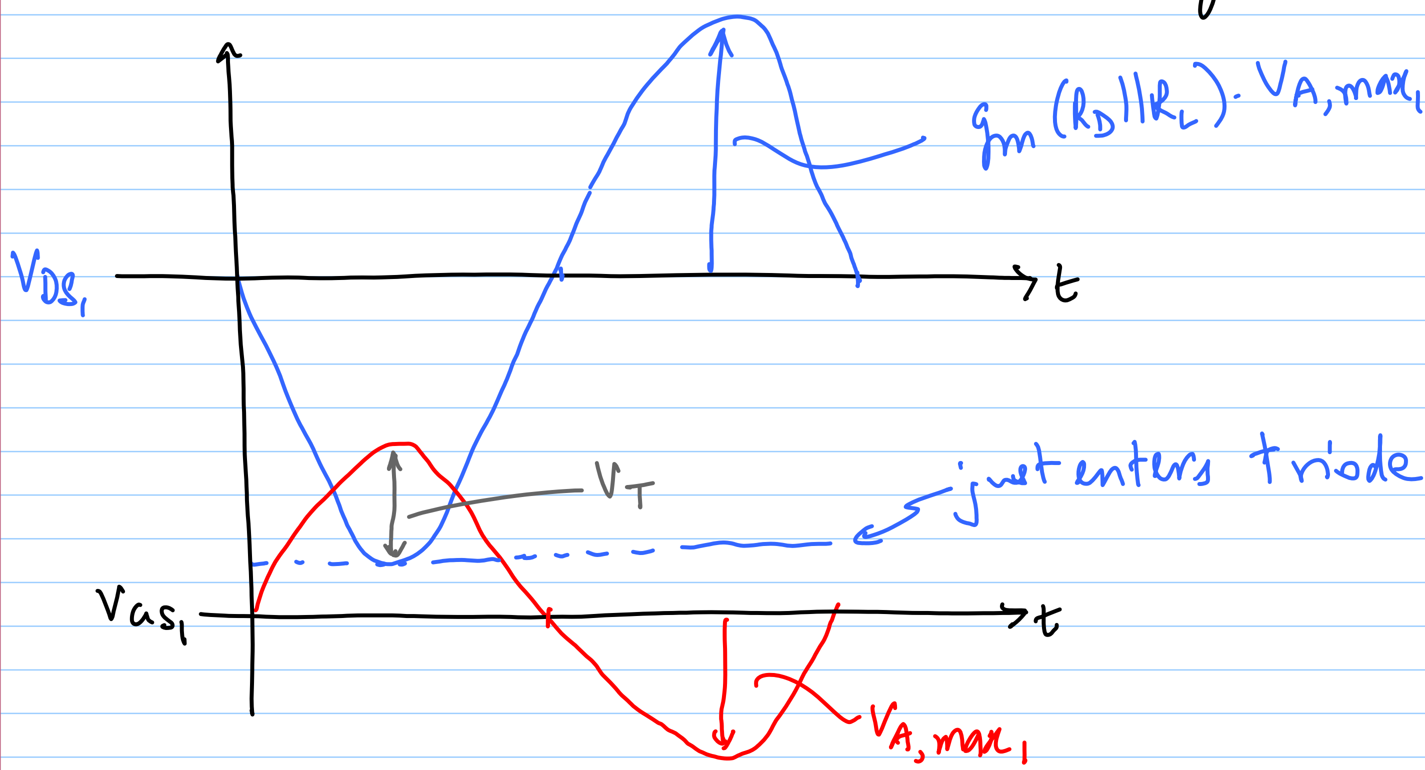
17-8-12

Lec 10



* M_1 – sat region
* $R_A \| R_B \gg R_s \Rightarrow v_x \approx v_s$
* Gain $|A| = g_m (R_D \| R_L) \gg 1$

* As $V_G \uparrow$, $V_D \downarrow \Rightarrow$ as V_A increases, M_1 moves towards triode region



V_{A,max_1} = maximum value of V_A that keeps M_1 from going into triode region at any time (positive half cycle)

* V_{A,max_1} depends on O.P. (e.g. V_{DS_1})

in general,

$$V_a = V_{GS} + v_s$$

$$V_D = V_{DS_1} - g_m (R_D \| R_L) \cdot v_s$$

@ V_{A,max_1}, $V_D = V_G - V_T$

$$\Rightarrow V_{DS_1} - g_m (R_D \| R_L) V_{A,max_1} = V_{GS_1} + V_{A,max_1} - V_T$$

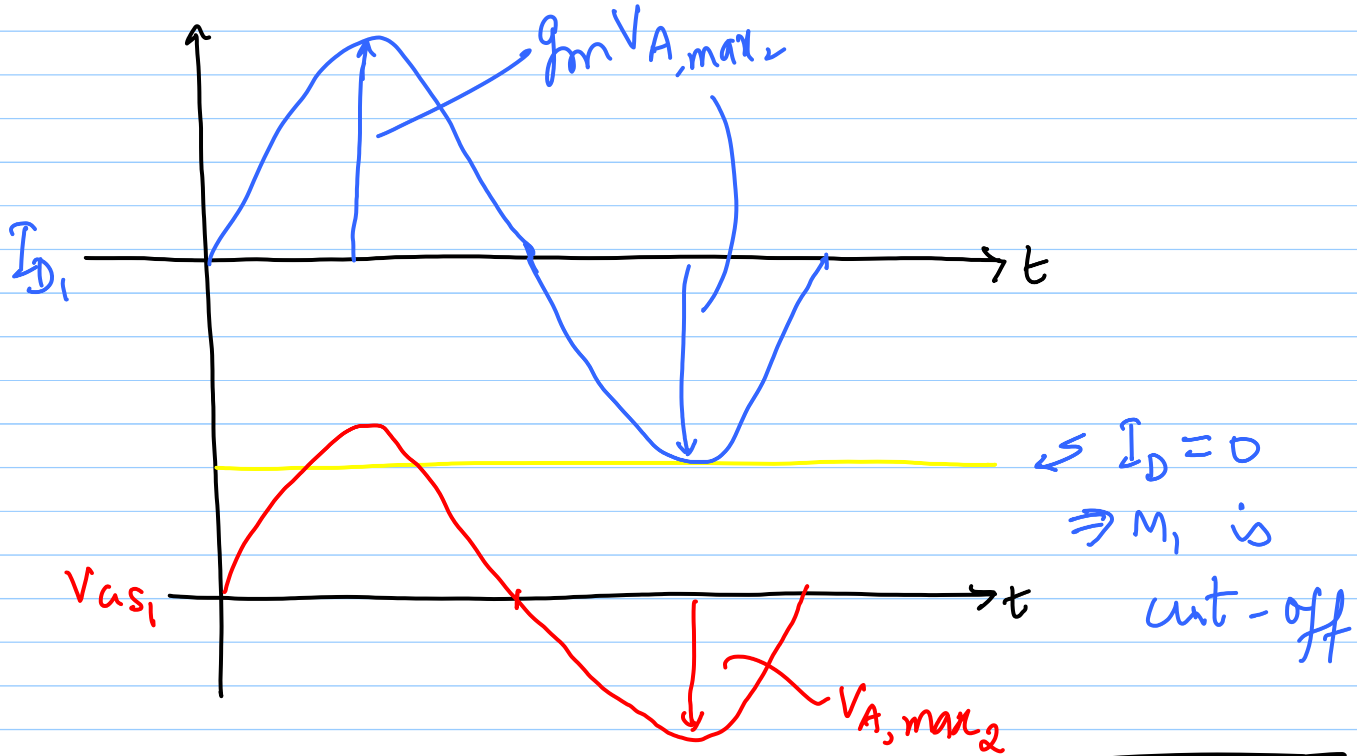
$$\boxed{V_{A,max_1} = \frac{V_{DS_1} - V_{GS_1} + V_T}{1 + g_m (R_D \| R_L)}}$$

<u>Negative half cycle</u>

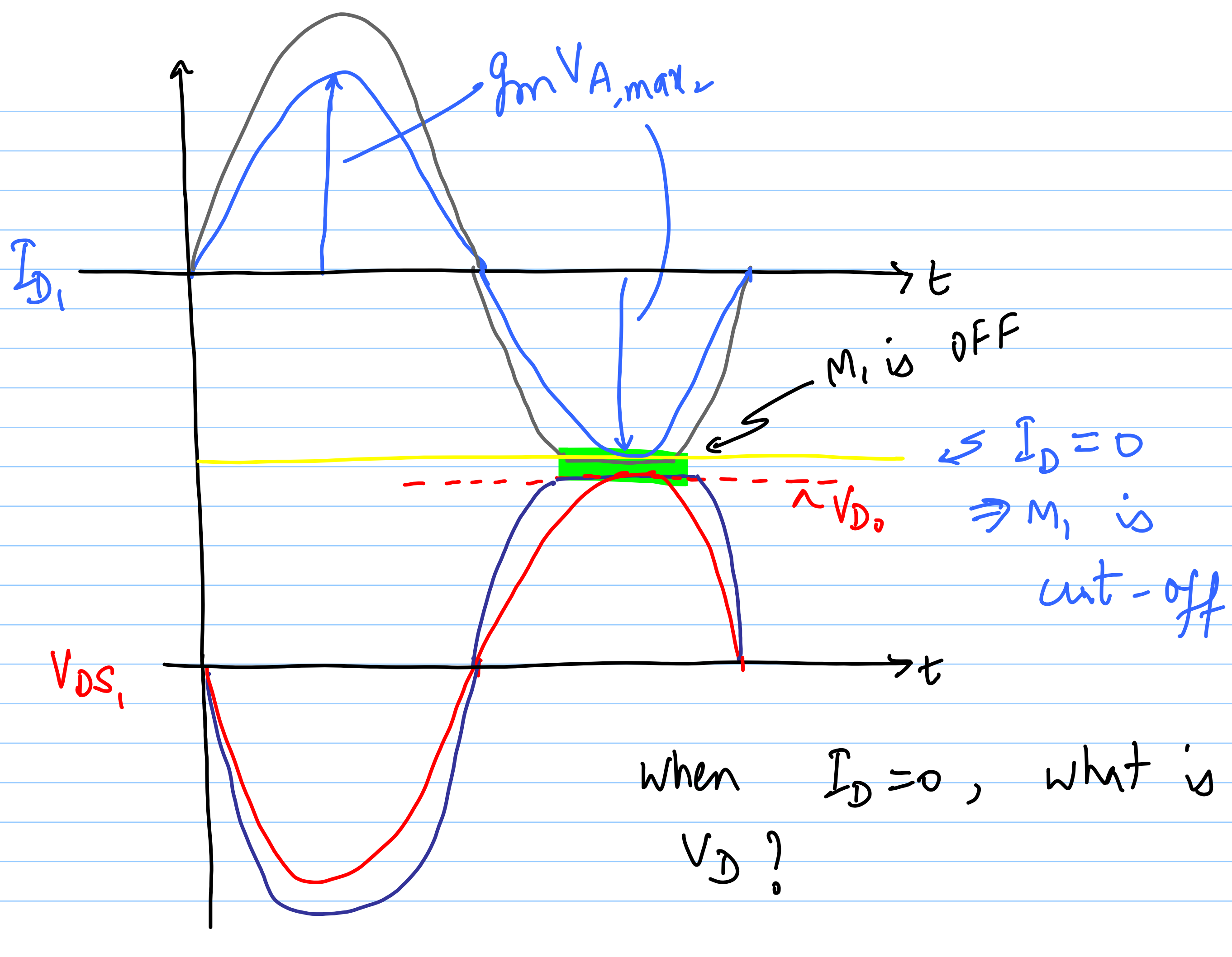
MOSFET drain current

$$I_D = \underbrace{I_{D_1}}_{\text{quiescent current}} + \underbrace{g_m v_s}_{\text{incremental current}}$$

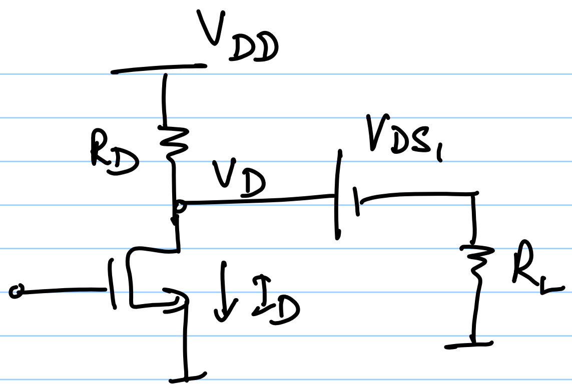
in-phase with v_s



$$\Rightarrow \quad I_{D_1} = g_m V_{A,max_2} \Rightarrow \boxed{V_{A max_2} = \frac{I_{D_1}}{g_m}}$$



When $I_D = 0$, what is V_D?



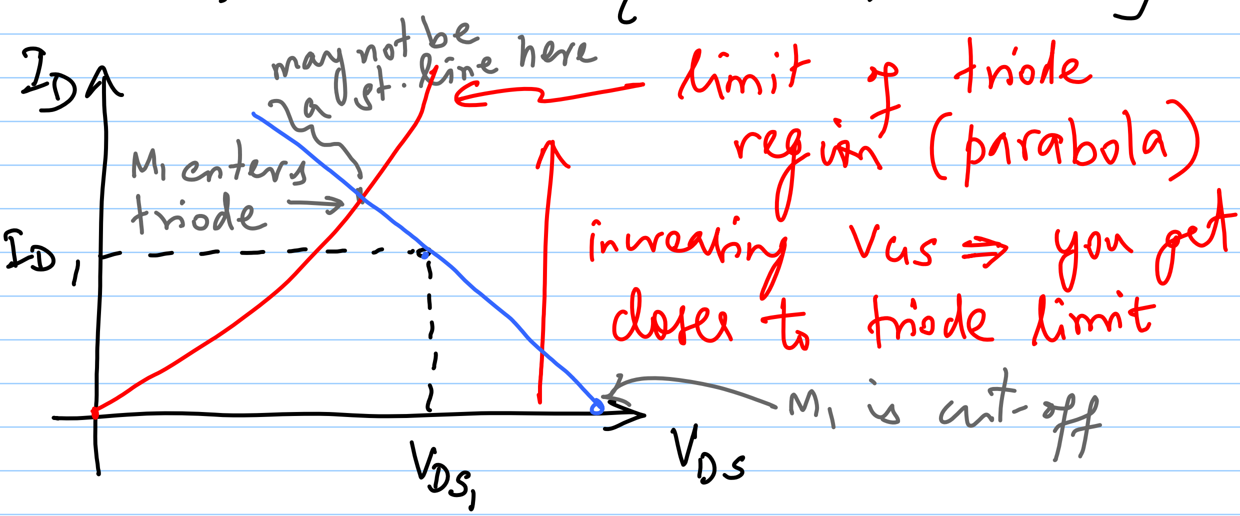
If $I_D = 0$, KCL @ drain gives:

$$\frac{V_{DD} - V_{D_0}}{R_D} = \frac{V_{D_0} - V_{DS_1}}{R_L}$$

$$\Rightarrow \boxed{V_{D_0} = \frac{R_L V_{DD} + R_D V_{DS_1}}{R_D + R_L}}$$

* Max limit on V_A (no clipping):

$$V_{A,max} = \min\{V_{A,max_1}, V_{A,max_2}\}$$



locus of $I_D - V_{DS}$ points as v_s is applied = straight line (linear approx. in small signal)

→ As $v_s \uparrow$, $I_D \uparrow$ & $V_{DS} \downarrow$ (+ve half cycle)

and vice versa

slope of line $= \dfrac{\partial I}{\partial V_{DS}} = \dfrac{-1}{\text{inc. res. @ drain}}$

$= \dfrac{-1}{R_D \| R_L}$

$$\left.\begin{aligned} v_d &= -g_m (R_D \| R_L) \cdot v_s \\ i_d &= g_m v_s \end{aligned}\right\}$$

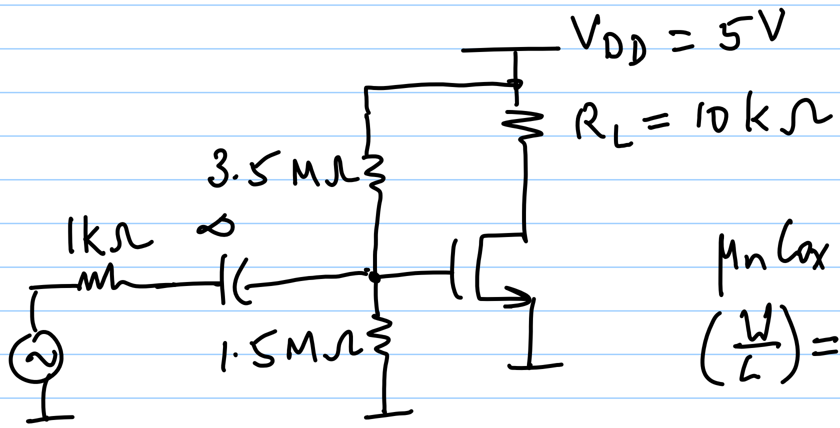
* To maximise swing, choose (I_{D_1}, V_{DS_1}) equidistant between triode & cut-off

i.e. +ve H.C. ⇒ M_1 just enters triode

-ve H.C. ⇒ M_1 just cuts off

⇒ choose $V_{A,max_1} = V_{A,max_2}$

E.g.



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

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

$V_{GS} = 1.5\,V$

$I_D = \frac{1}{2}\left(100\,\frac{\mu A}{V^2}\right) \cdot 10 \cdot (0.5\,V)^2$

$= 125\,\mu A$

$\Rightarrow V_{DS} = V_{DD} - I_D R_L = 5 - (0.125)(10k)$

$= 3.75\,V$

$g_m = \frac{2 I_D}{V_{GS} - V_T} = \frac{0.25\,mA}{0.5} = 0.5\,mS$

$\Rightarrow$ inc. gain $= -g_m R_L = -5$

Swing limits :

triode (+ve HC)

$V_G = 1.5\,V + V_A \sin\omega t$

$V_D = 3.75\,V - 5\,V_A \sin\omega t$

for triode limit, $V_D = V_G - V_T$

$3.75 - 5V_A = 1.5 + V_A - 1$

$\Rightarrow \quad V_A = \frac{3.25}{6} \approx 541.67\,mV \quad (= V_{A\,max_1})$

cut-off (−ve HC)

$I_D = 0$ at −ve peak

$I_D = 125\,\mu A + g_m V_A \sin\omega t$

$\Rightarrow \quad V_A = \dfrac{125\,\mu A}{0.5\,mS} = 250\,mV$

$(= V_{A,max_2})$

$\therefore$ max V_A for no clipping $= \underline{\underline{250\,mV}}$

normally, cut off is specified by

$I_D = 0 \Rightarrow V_{GS} \leq V_T$

$\therefore$ limit of cut-off region is

$V_{GS} = V_T$

$V_{GS_1} - V_{A max_2} = V_T$

$\Rightarrow V_{A max_2} = V_{GS_1} - V_T = 1.5V - 1V$

$= 0.5V$

whereas we calculated $V_{A,max_2} = 0.25V$

Where is the discrepancy?