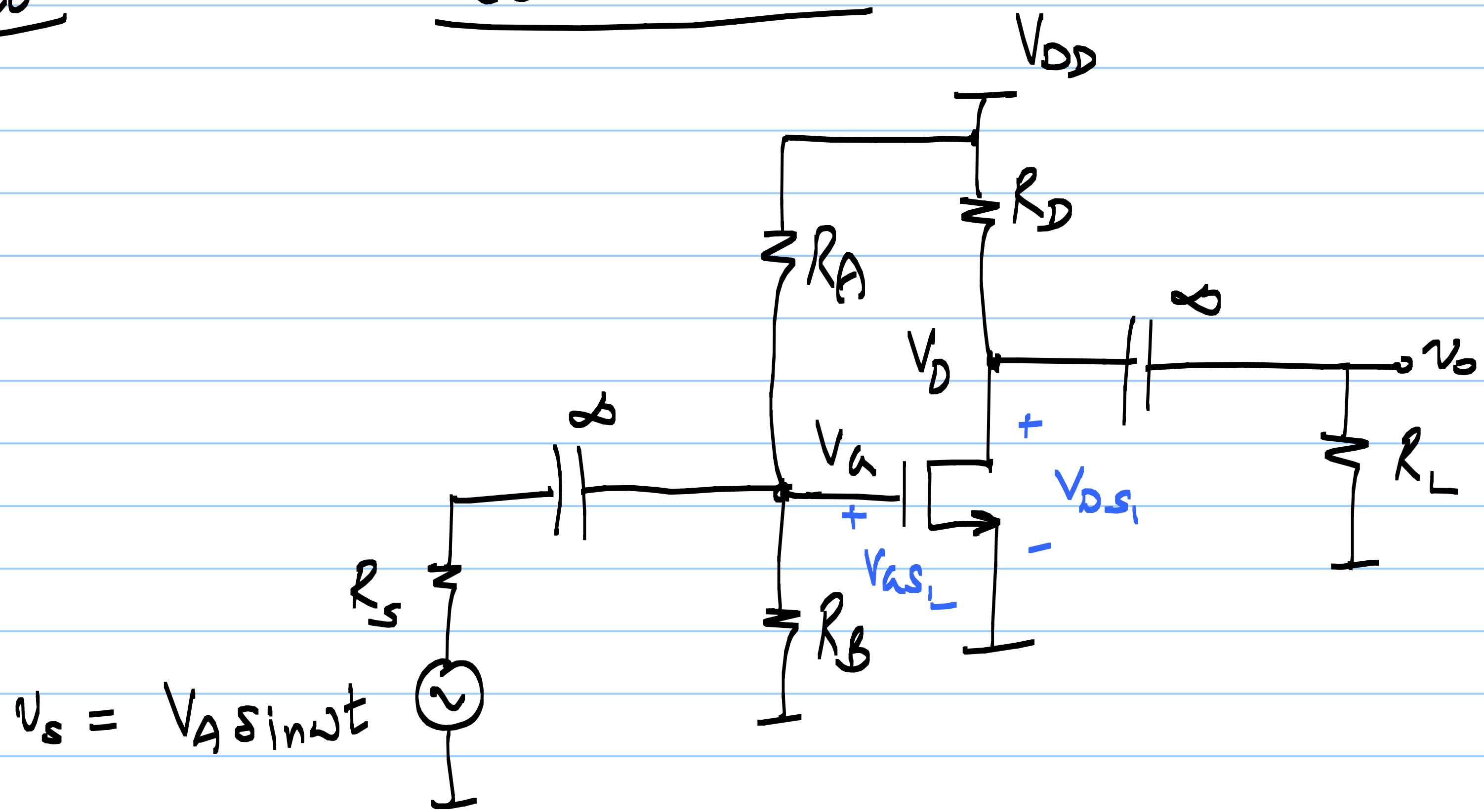
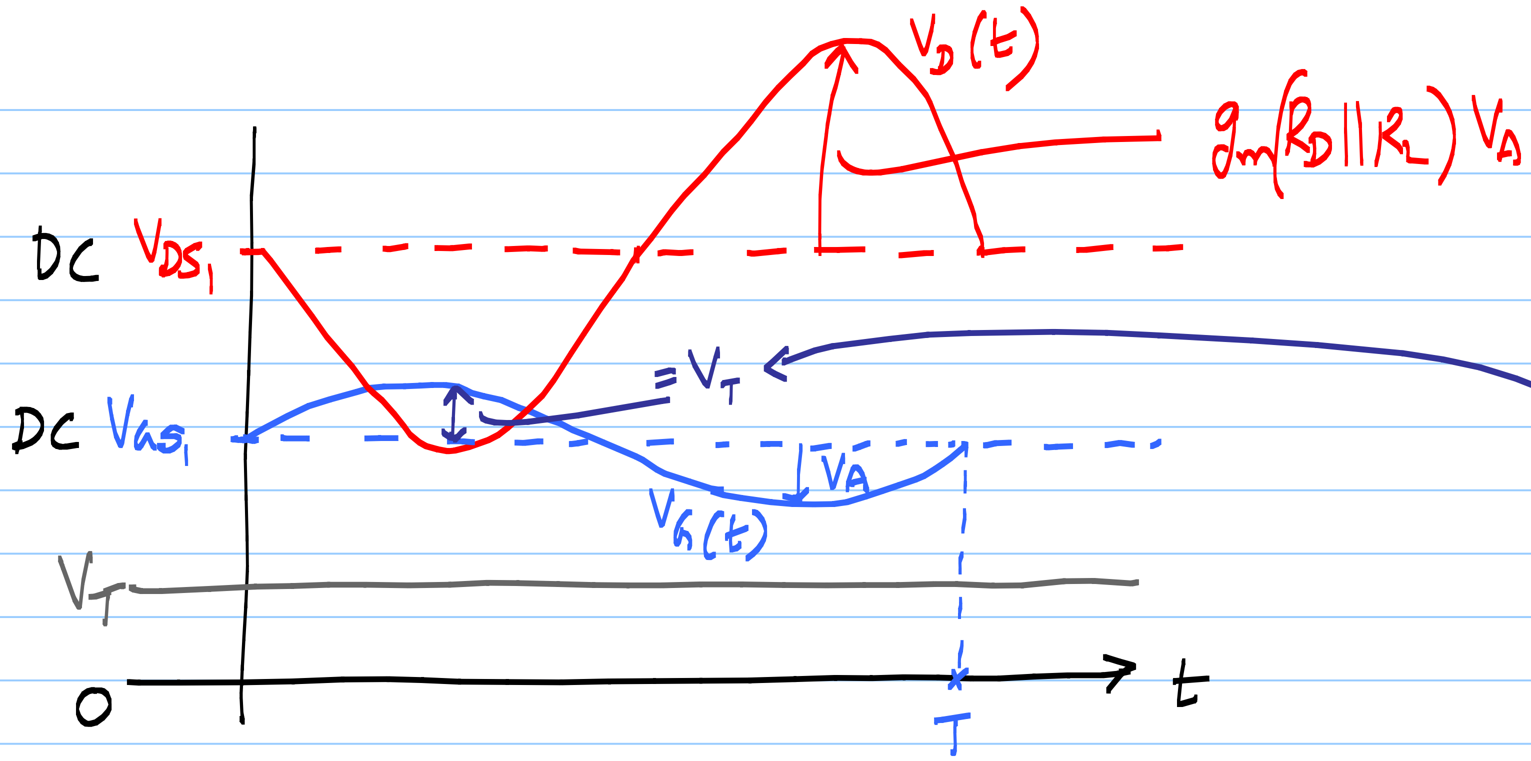
20/8/2020

Lecture 10



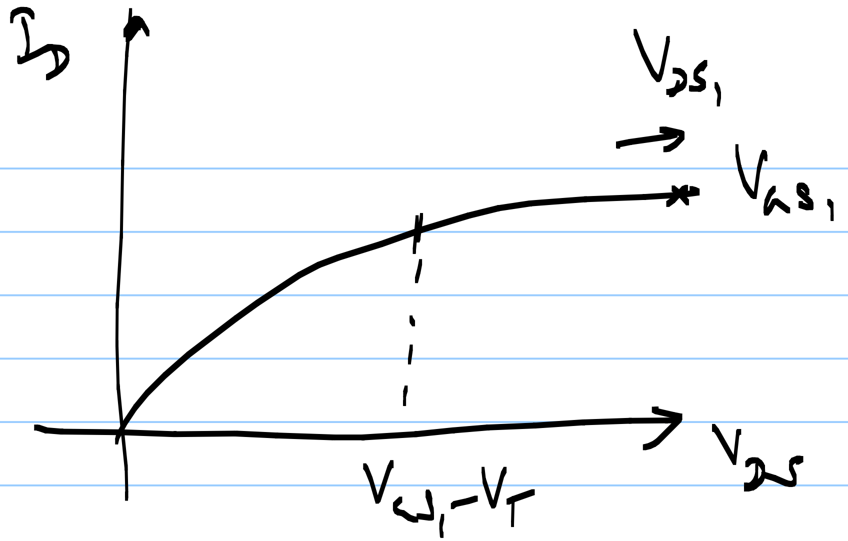
* $V_{DS}(t) > V_{GS}(t) - V_T$ at all times in the period so that device is in saturation.



1) Limit of V_A : instantaneous $V_{DS}(t) = V_{GS}(t) - V_T$

(or) $V_D(t) = V_G(t) - V_T$

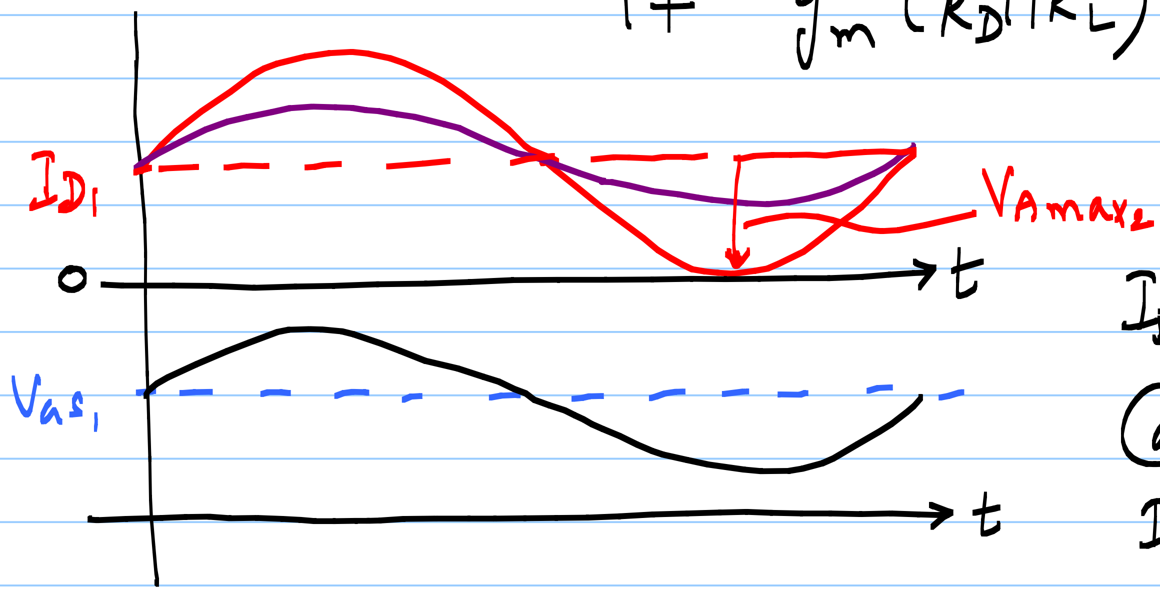
$V_{A_{max,1}}$ = maximum value of V_A that keeps M_1 from going into triode (+ve half cycle of input sinusoid)



larger V_{DS_1} = larger $V_{A\,max_1}$

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

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



$I_D = I_{D_1} + i_d$

$I_D(t) = I_{D_1} + g_m V_A \sin \omega t$

@ $V_A = V_{A\,max_2}$

$I_D(t) = 0$ @ neg. peak.

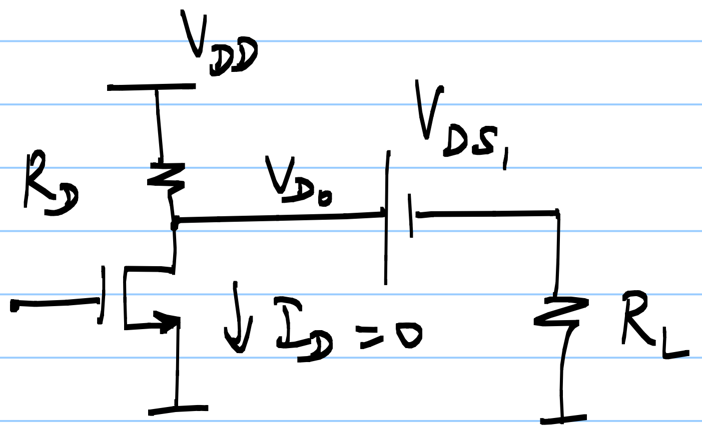
Device M_1 just cuts off. @ $V_{A_{max_2}}$

Any further increase in V_A → clipped sinusoid (current)

Set $I_D(t) = 0$ @ −ve peak

$$I_{D_1} - g_m V_{A_{max_2}} = 0 \Rightarrow V_{A_{max_2}} = \frac{I_{D_1}}{g_m}$$

What is $V_D(t)$ when $I_D(t) = 0$?



* $I_D = 0$

* KCL @ drain

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

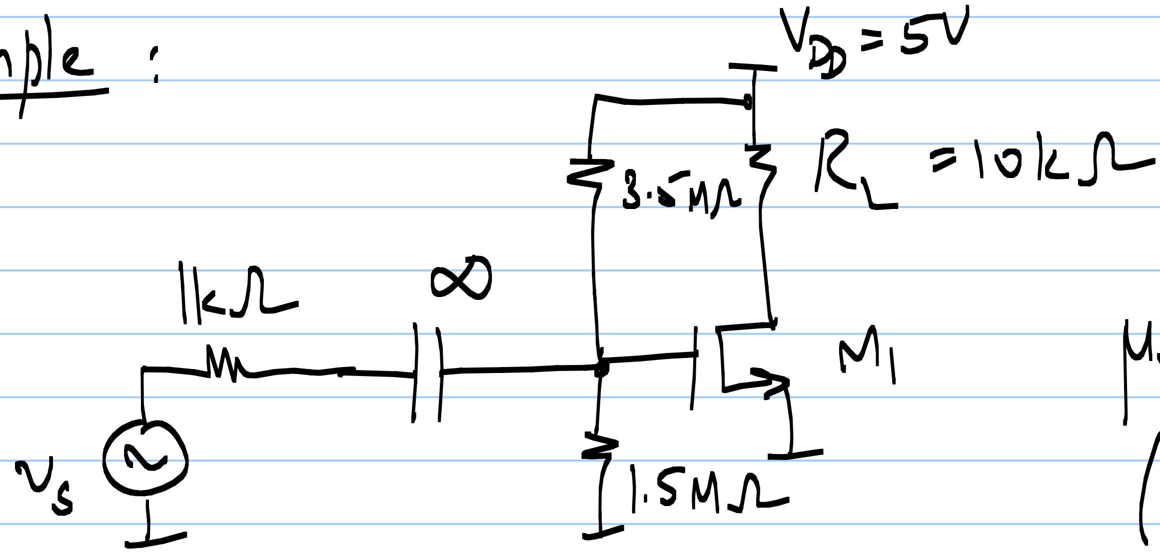
$$V_{D_0} = \frac{R_L V_{DD} + R_D V_{DS_1}}{R_L + R_D}$$

Swing limits of CSA

* In general, $V_{A_{max_1}} \neq V_{A_{max_2}}$
* swing limit $= \min\{V_{A_{max_1}}, V_{A_{max_2}}\}$
* Good design : choose $V_{A_{max_1}} = V_{A_{max_2}}$

choose (I_{D_1}, V_{DS_1}):
- @ +ve H.C. peak, M_1 just enters triode
- @ −ve H.C. peak, M_1 just cuts off

Example :



$V_T = 1V$

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

$\left(\frac{W}{L}\right) = 10$

$V_{GS_1} = 1.5V$

$I_{D_1} = \frac{1}{2} 100 \times 10^{-6} \times 10 \times (0.5)^2 = 125 \mu A$

$V_{DS_1} = V_{DD} - I_{D_1} \cdot R_L = 5 - (125 \times 10^{-6})(10 \times 10^3)$

$= 3.75V$

$g_{m_1} = \frac{2 I_{D_1}}{V_{GS_1} - V_T} = \frac{0.25 mA}{0.5} = 0.5 mS$

inc. gain $\quad G = -g_{m_1} R_L = -5$

<u>Triode limit</u> (+ve HC)

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

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

$V_D = V_G - V_T$

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

$$V_{A_1} = \frac{3.25}{6} = 541.67\ mV = V_{A_{max,1}}$$

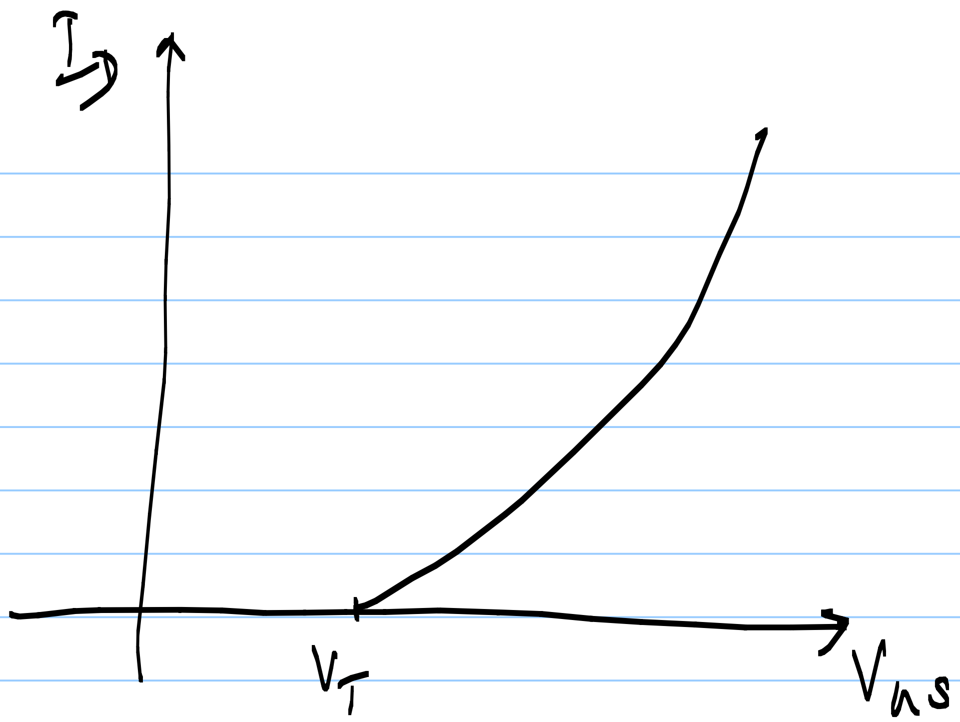
<u>Cut off limit</u> (−ve H.C.)

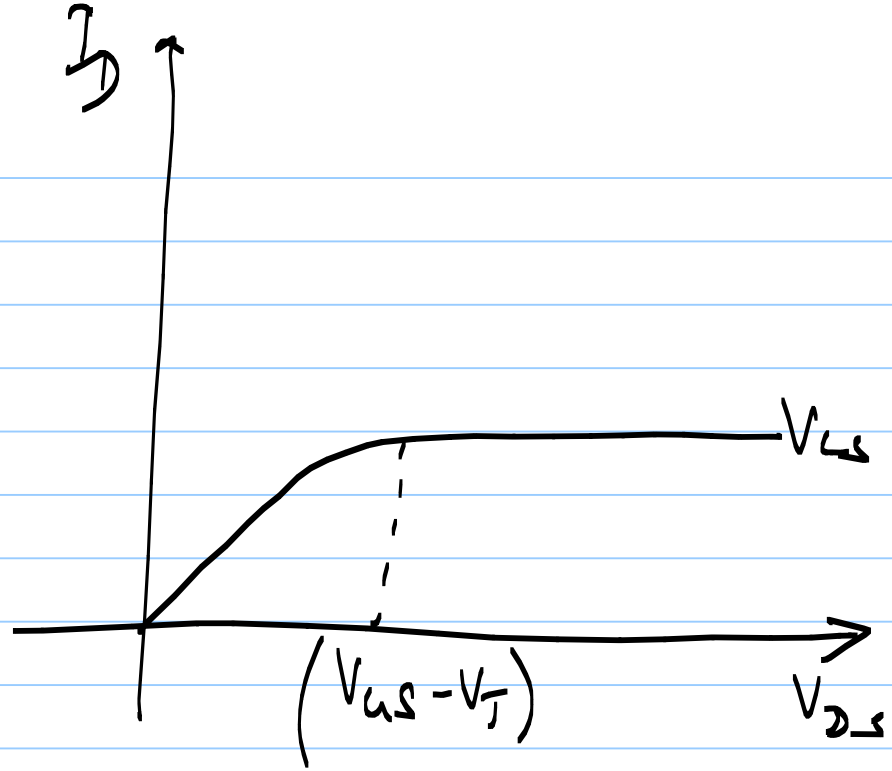
$$I_D = I_{D_1} + g_m V_A \sin\omega t$$

$$= 125\mu A + (0.5mS)\, V_A \sin\omega t$$

$$V_{A_2} = \frac{I_{D_1}}{g_m} = \frac{125\mu A}{0.5mS} = 250mV = V_{A_{max_2}}$$

$$V_{A\,max} = \min.\ \text{of}\ (V_{A_1}, V_{A_2}) = 250mV$$


I_D
V_T
V_GS


I_D
V_GS
(V_GS - V_T)
V_DS