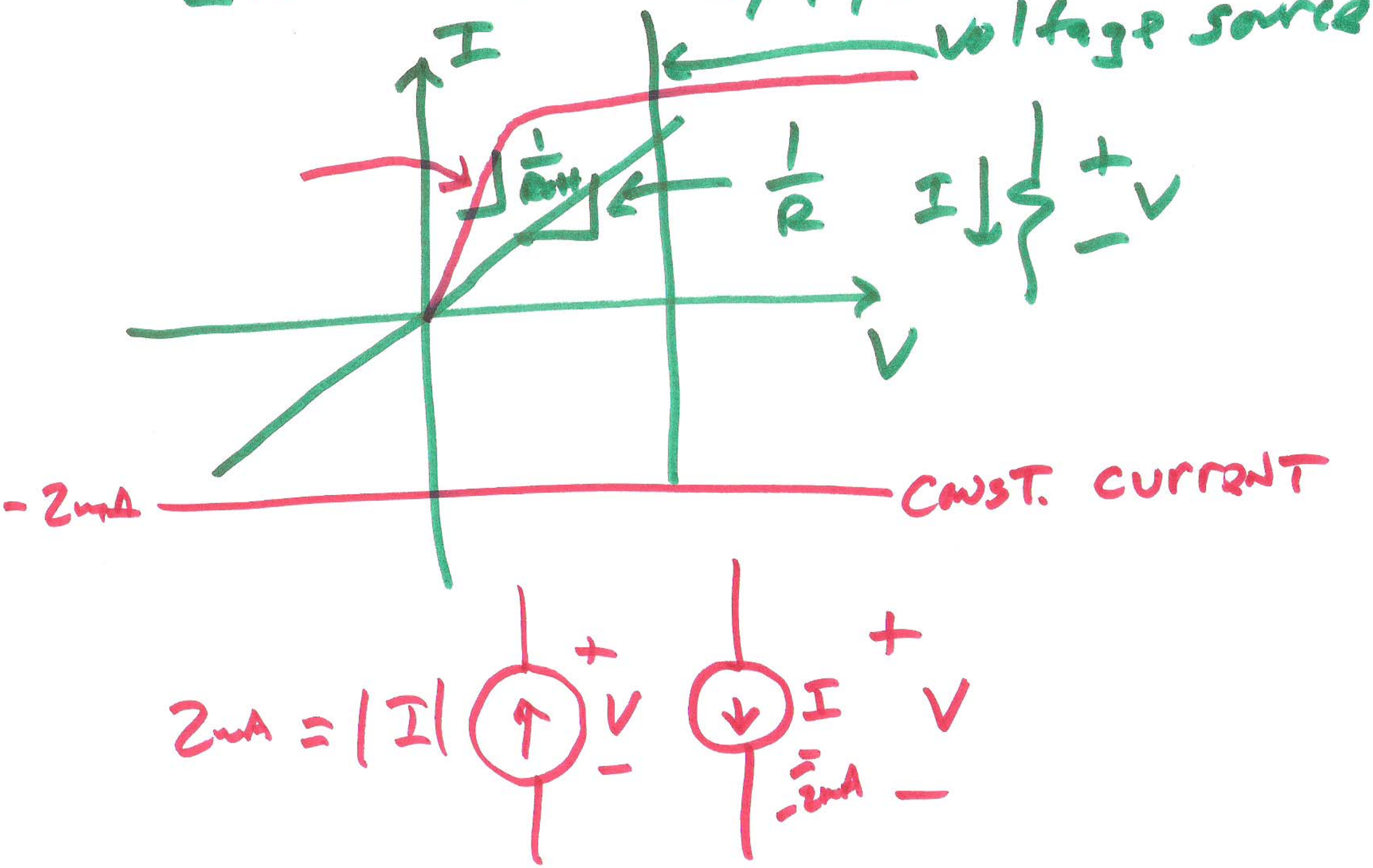
ECE 622 EE 422

Analog IC Design

Lecture 4 2/4/13



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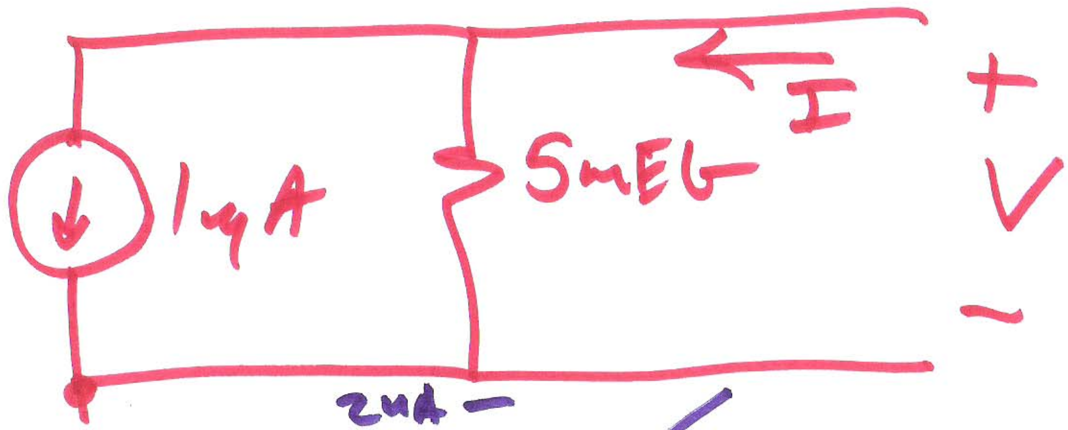
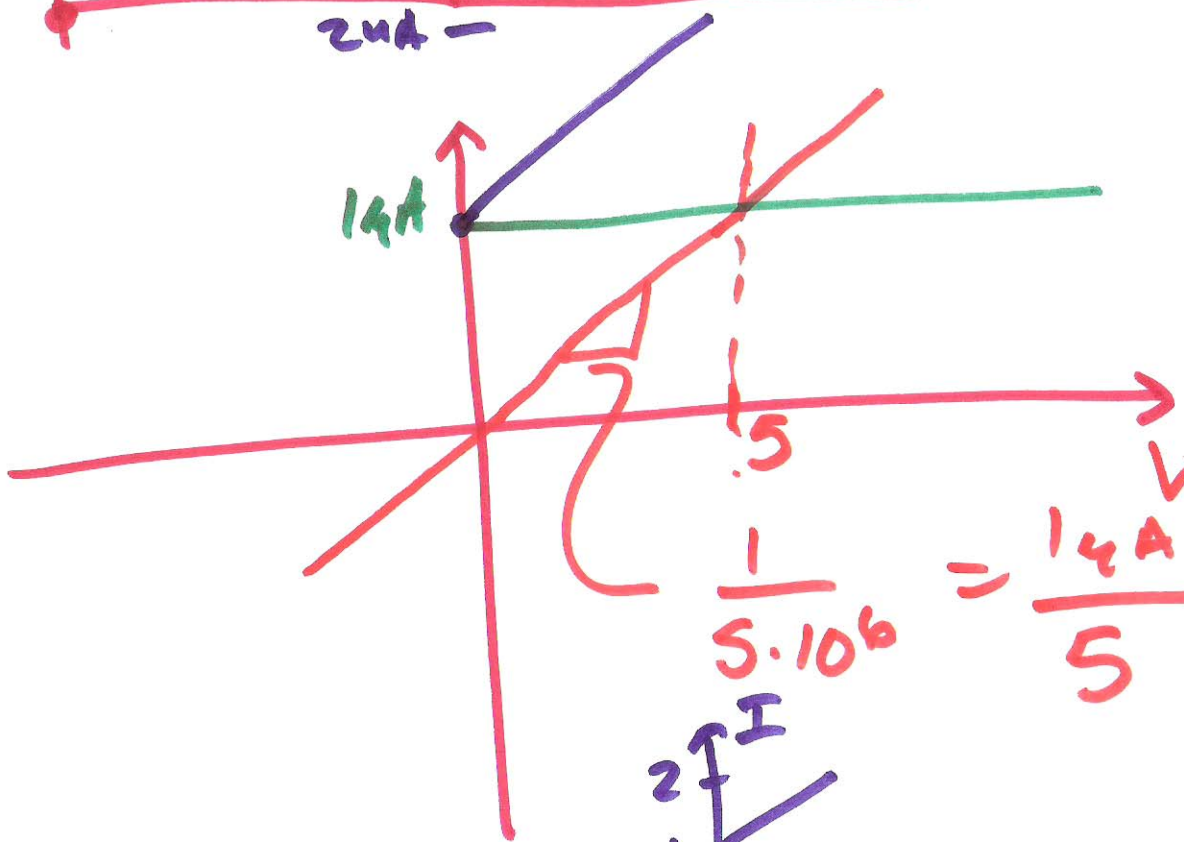
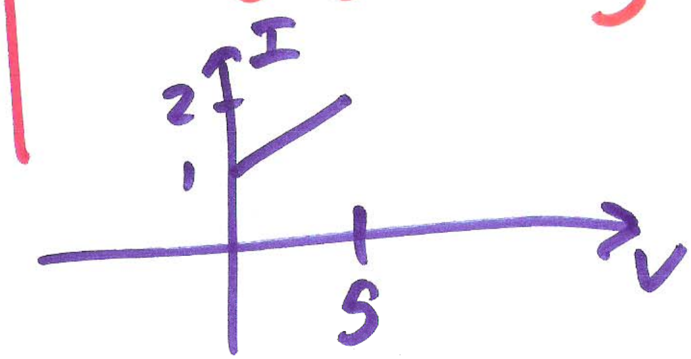




$$\frac{1}{5\cdot10^6} = \frac{1\mu A}{5} = \frac{10^{-6}A}{5}$$



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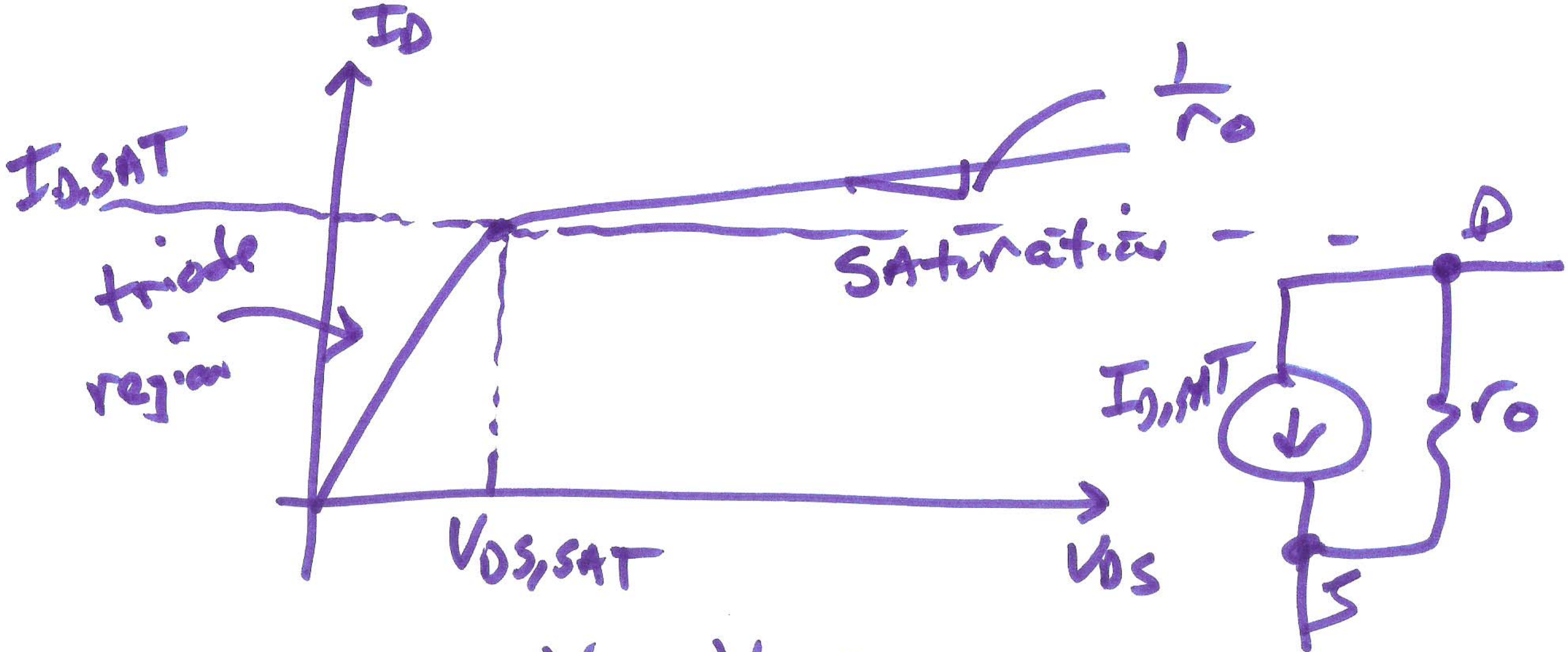
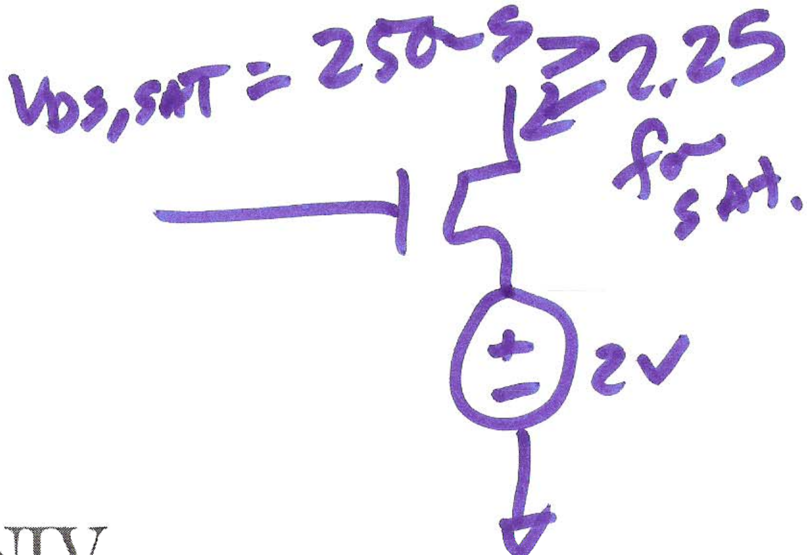
2)

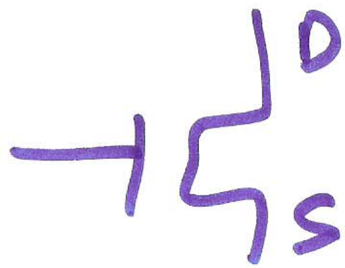


I_D
$I_{D,SAT}$
$\frac{1}{r_o}$
triode region
Saturation
D
$I_{D,SAT}$
r_o
S
$V_{DS,SAT}$
V_{DS}

$= V_{GS} - V_{THN}$



$V_{DS,SAT} = 250$ mV
≥ 2.25
for sat.
2V



D
S

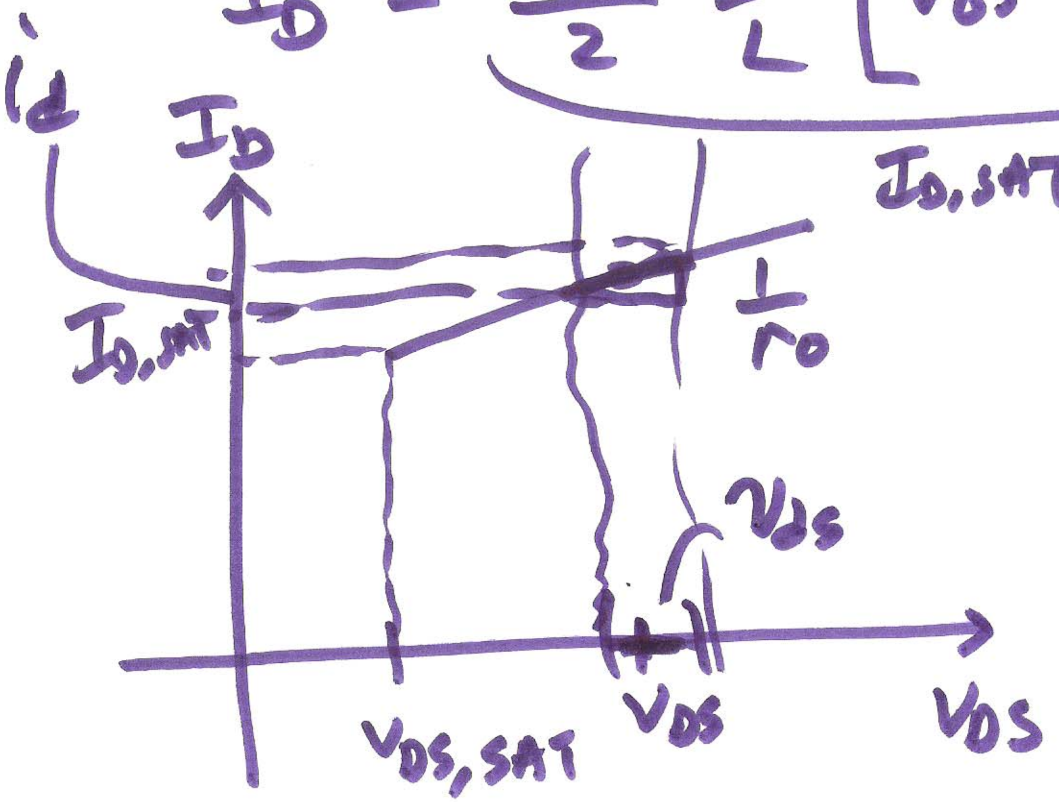
The square-law equations

$$I_D = \underbrace{\frac{KP_n}{2} \cdot \frac{W}{L} \cdot \left[V_{GS} - V_{THN}\right]^2}_{I_{D,SAT}} \left(1 + \lambda\left(V_{DS} - V_{DS,SAT}\right)\right)$$

$V_{GS} > V_{THN}$

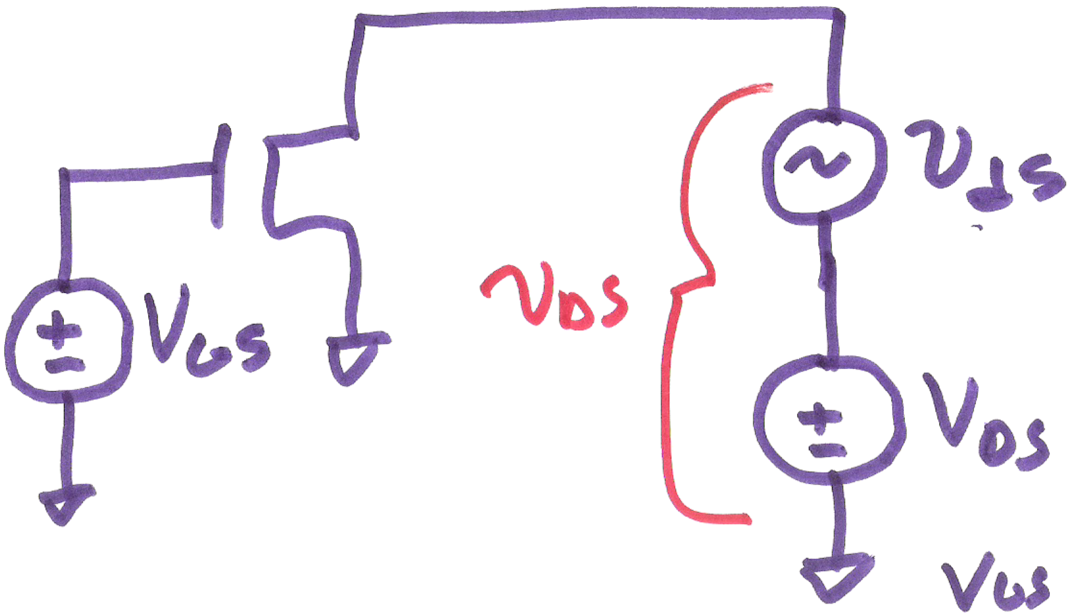
$V_{DS} \geq V_{GS} - V_{THN}$

for saturation



$V_{DS,SAT} = V_{GS} - V_{THN}$

$I_D + i_d = i_D$

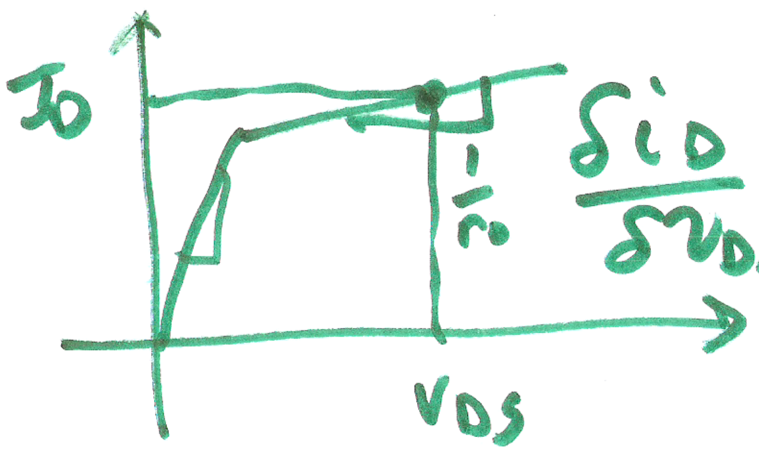


$v_{DS} = v_{ds} + V_{DS}$ (v_{ds}: AC, V_{DS}: DC, v_{DS}: AC+DC)

$v_{ds} \ll V_{DS}$

$I_D + i_d = i_D = \frac{KP_n}{2}\cdot\frac{W}{L}\left(v_{GS} - V_{THN}\right)^2\left(1 + \lambda\left(v_{DS} - V_{DS,sat}\right)\right)$

($v_{GS} \rightarrow V_{GS}$; $v_{DS} \rightarrow V_{DS} + v_{ds}$)



$$\left.\frac{\delta i_D}{\delta v_{DS}}\right|_{\substack{I_D = CONST \\ V_{DS} = CONST}} = \frac{1}{r_o}$$

$$\frac{1}{r_o} = \left.\frac{\delta i_D}{\delta v_{DS}}\right|_{\substack{I_D = CONST \\ V_{DS} = CONST}} = \frac{\delta\, \frac{KP_n}{2} \cdot \frac{W}{L}\left(V_{GS} - V_{THN}\right)^2\left(1 + \lambda\left(v_{DS} - V_{DS,SAT}\right)\right)}{\delta v_{DS}}$$

$$= \frac{\delta}{\delta v_{DS}}\left(\frac{KP_n}{2}\frac{W}{L}\left(V_{GS} - V_{THN}\right)^2 \lambda v_{DS}\right)$$

$$\frac{1}{r_o} = \underbrace{\frac{KP_n}{2} \cdot \frac{W}{L}\left(V_{GS} - V_{THN}\right)^2}_{I_{D,SAT}} \lambda \cdot \frac{\delta v_{DS}}{\delta v_{DS}}$$

$$\boxed{r_o = \frac{1}{\lambda \cdot I_{D,SAT}}}$$

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for triode

$V_{GS} > V_{THN}$

$V_{DS} \leq V_{GS} - V_{THN}$

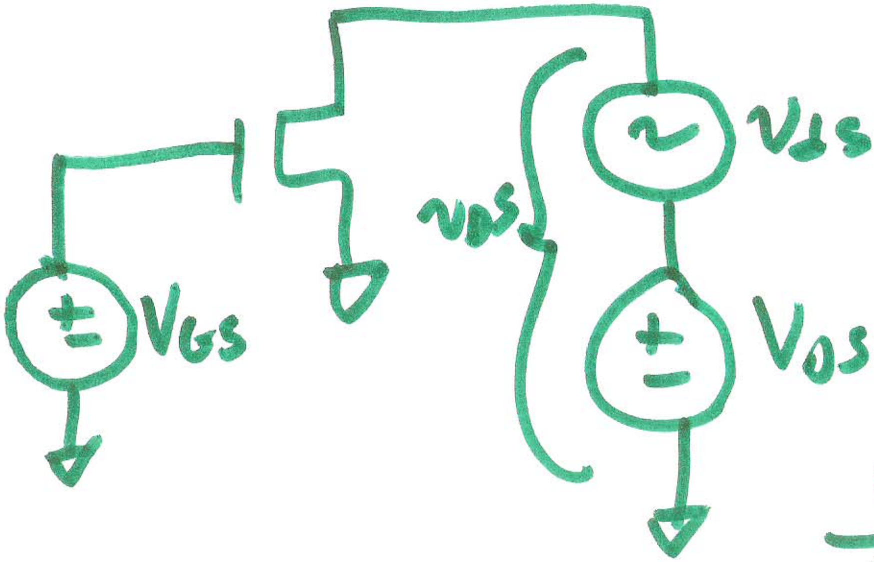
$$I_D = KP_N \cdot \frac{W}{L}\left((V_{GS} - V_{THN})V_{DS} - \frac{V_{DS}^2}{2}\right)$$

for SAT at border between SAT & triode

$$I_D = \frac{KP_N}{2} \cdot \frac{W}{L}(V_{GS} - V_{THN})^2$$

at Border

$V_{DS} = V_{GS} - V_{THN}$



$$\frac{\delta i_D}{\delta v_{DS}} = \frac{\delta \left\{ KP \cdot \frac{W}{L}\left[(V_{GS}-V_{THN}) v_{DS} - \frac{v_{DS}^2}{2} \right] \right\}}{\delta v_{DS}}$$

$$\left. \frac{\delta i_D}{\delta v_{DS}} \right| = \frac{1}{R_{CH}} = \frac{KP}{L} \cdot W (V_{GS}-V_{THN})$$

$$= \frac{KP}{L} W (V_{GS}-V_{THN})$$

V_{DS}

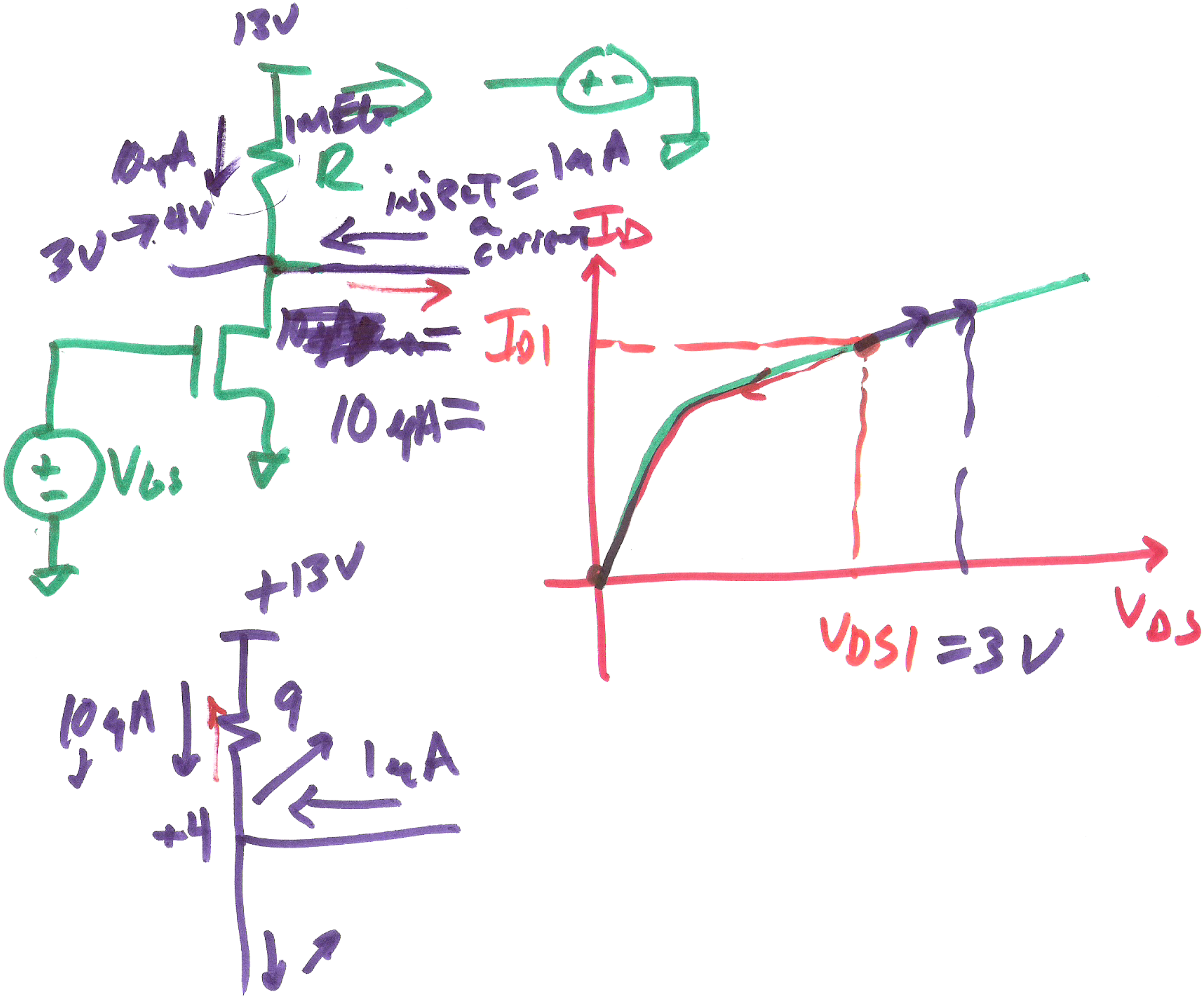
$I_D = \text{const}$

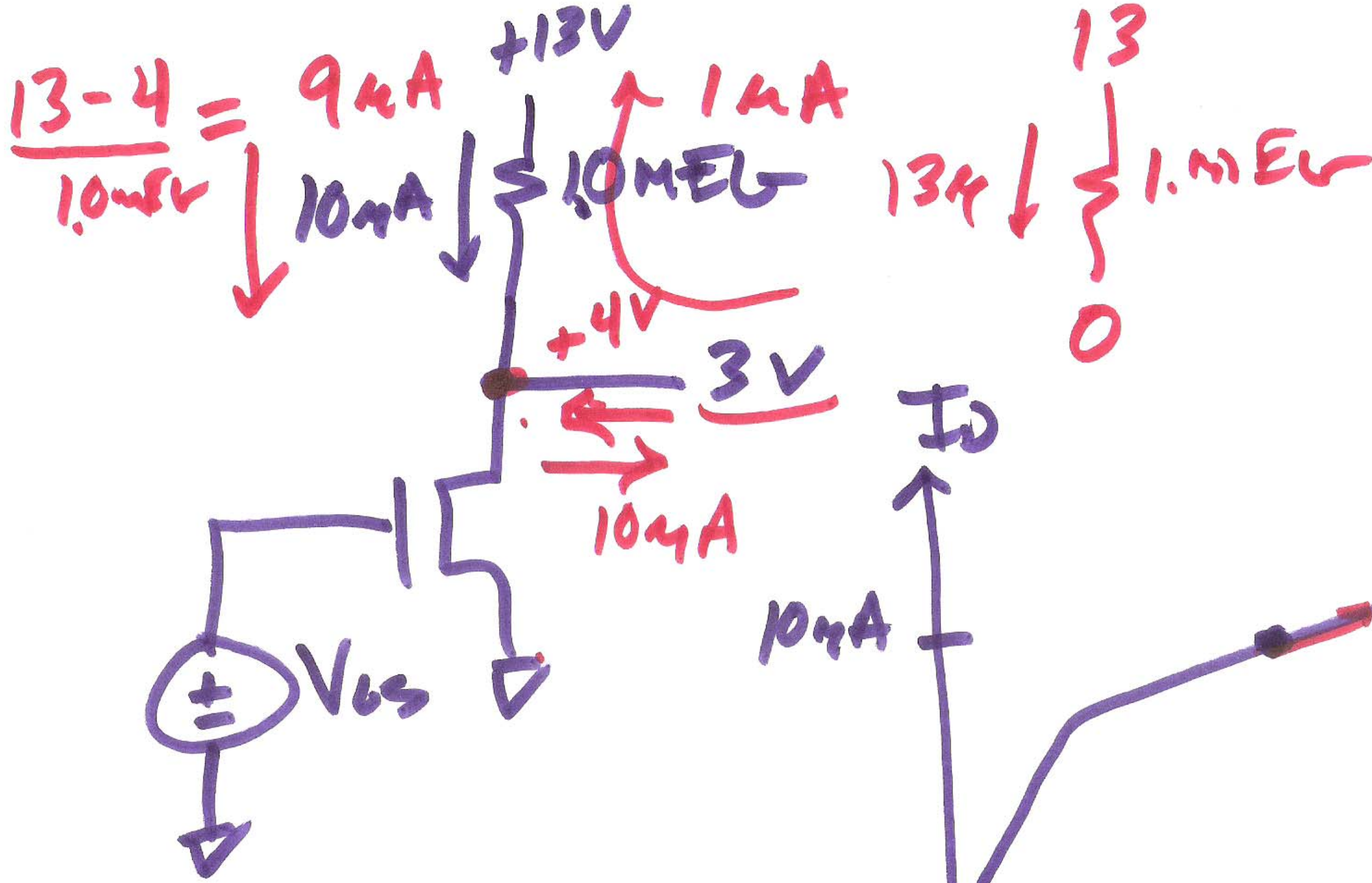
$V_{DS} = \text{cons}$

$$\frac{\delta \frac{1}{R_{CH}}}{\delta R_{CH}} \quad \frac{1}{R_{CH}} = KP \frac{W}{L} (V_{DS} - V_{THN}) -$$

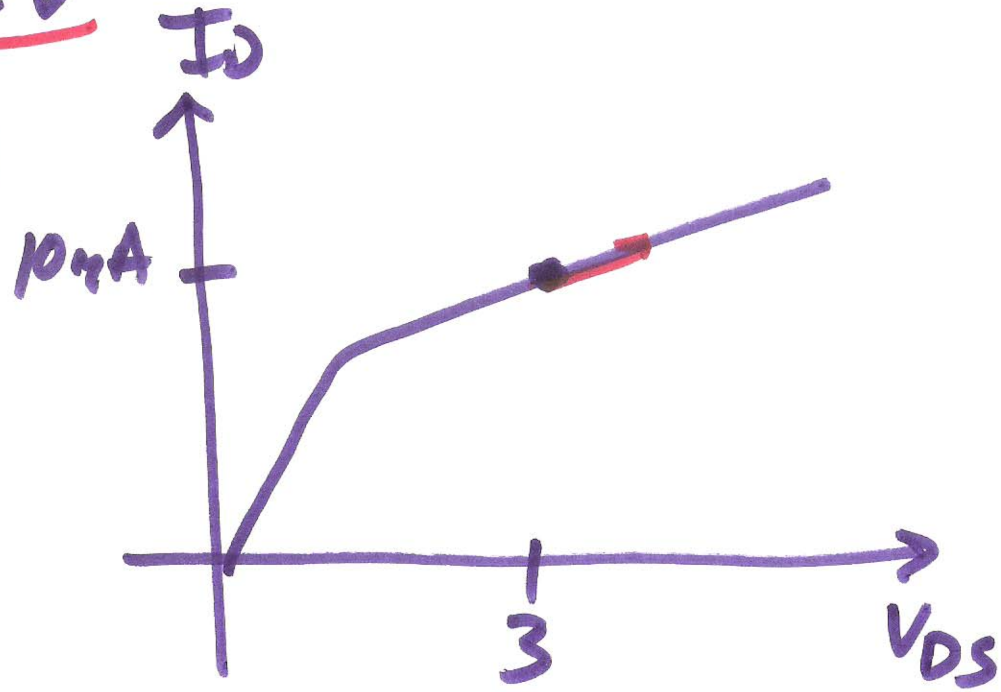
$$KP \frac{W}{L} (V_{GS} - V_{THN}) V_{DS}$$

if V_{DS} is small $R_{CH} \simeq \dfrac{1}{KP \cdot \frac{W}{L} \cdot (V_{GS} - V_{THN})}$


13V
1MEG
R
10μA
3V → 4V
inject = 1μA
a current
I_D
I_D1
10 μA =
V_GS
+13V
10μA
9
1μA
+4
V_DS1 = 3V
V_DS



13 − 4 / 1.0MEG = 9mA
+13V
1mA
10mA
10MEG
13
13mA
1MEG
0
+4V
3V
10mA
VGS



ID
10mA
3
VDS