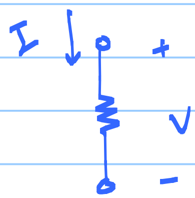
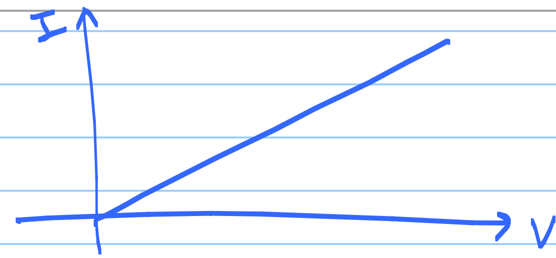
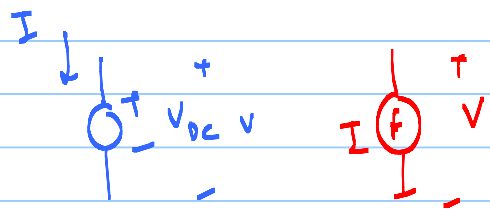
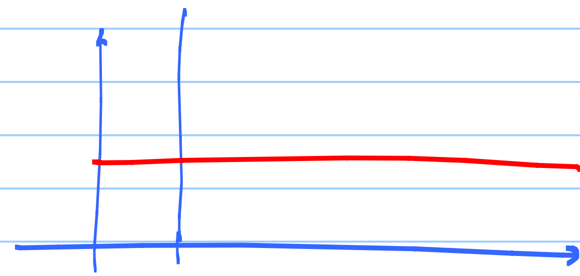
ECE 511 - Lecture 1

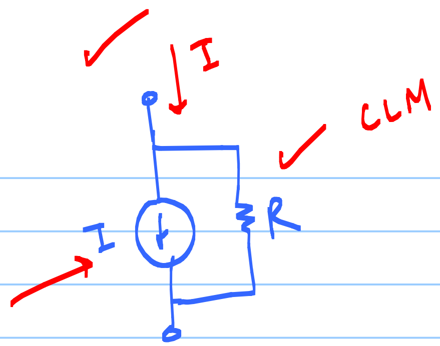
Note Title 1/22/2013







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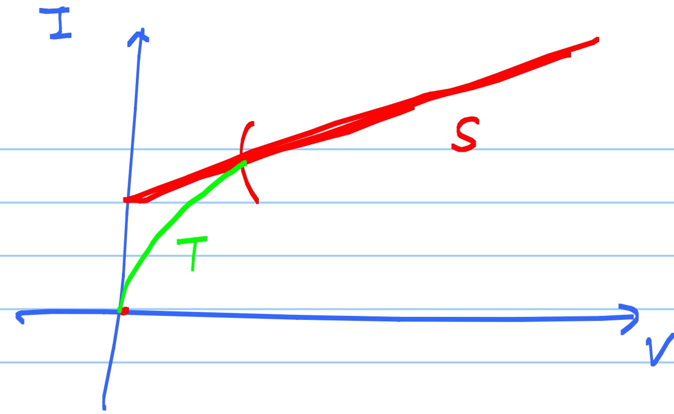
I
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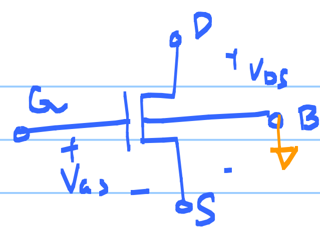
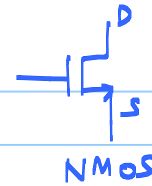
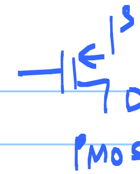
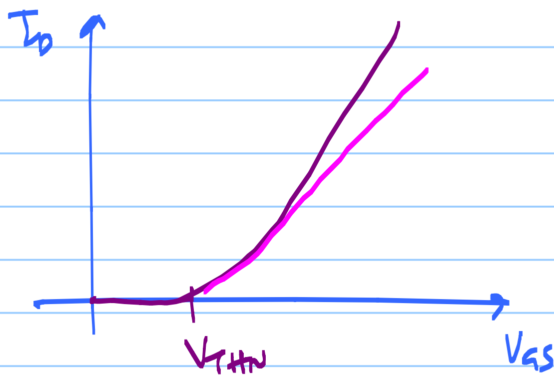
Square Law Equations

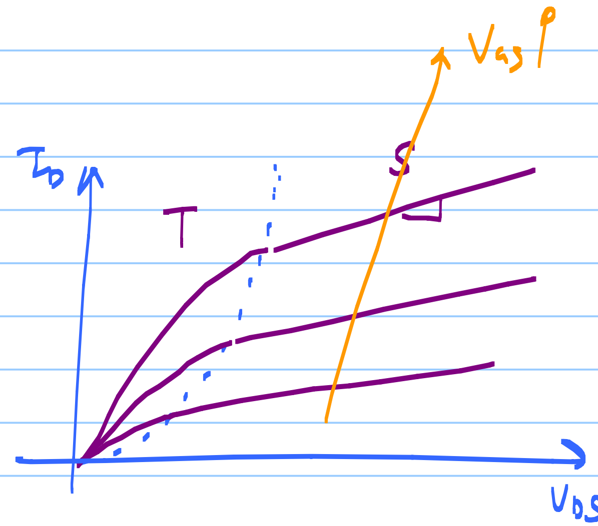






$$I_D = f(V_{GS},\ V_{DS},\ \cancel{V_{SB}})$$





for Saturation

$V_{DS} \geq V_{DS,sat}$

$V_{GS} - V_{THN}$

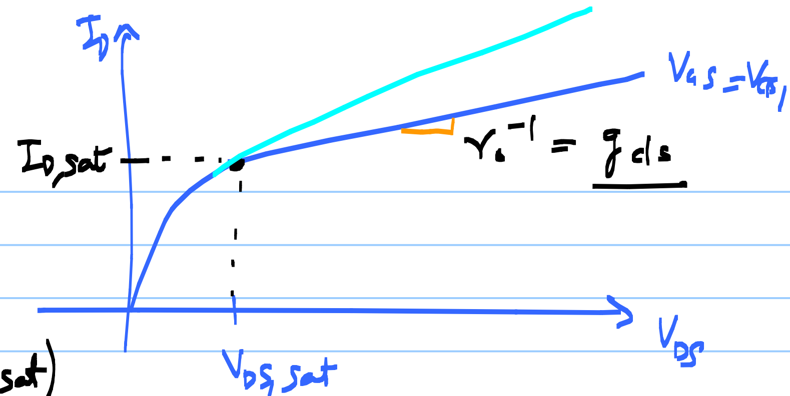
$$I_D = \begin{cases} 0, \text{ Cutoff} & V_{GS} < V_{THN} \\ \mu_n C_{ox} \frac{W}{L}\left[(V_{GS}-V_{THN})V_{DS} - \frac{V_{DS}^2}{2}\right] - \text{Triode} & (V_{DS} < V_{GS}-V_{THN}) \\ \underbrace{\frac{1}{2}\mu_n C_{ox} \frac{W}{L}\left[(V_{GS}-V_{THN})^2\right]}_{I_{D,sat}} \left(1+\lambda(V_{DS}-V_{DS,sat})\right) & \end{cases}$$

$(1+\lambda V_{DS})$ ✓

$V_{OV} = V_{GS} - V_{THN} \stackrel{\Delta}{=} V_{DS,sat}$

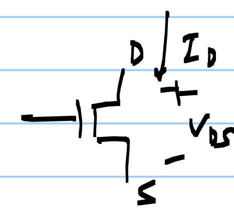
$\left(\frac{W}{L}\right) \leftarrow$ Aspect ratio

"sizing"



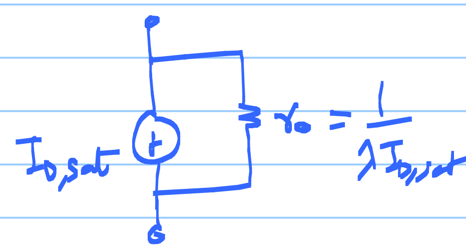
$$I_D = I_{D,sat} + I_{D,sat} \cdot \lambda \, (V_{DS} - V_{DS,sat})$$

$$r_o = \left(\frac{\partial I_D}{\partial V_{DS}}\right)^{-1} = \frac{1}{\lambda \, I_{D,sat}}$$



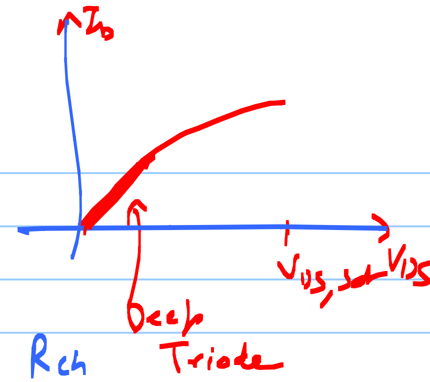
intrinsic gain

$g_m r_o$



g_n triode:

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

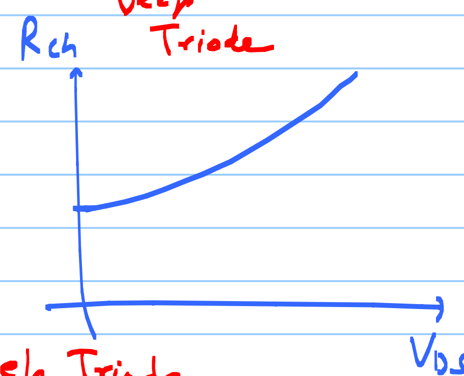


$$R_{ch} = \left[\frac{\partial I_D}{\partial V_{DS}}\right]^{-1} = \frac{1}{KP_n \cdot \frac{W}{L}\left[(V_{GS}-V_{THN}) - V_{DS}\right]}$$

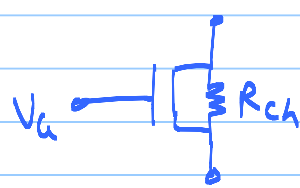
V_{GS} controlled variable resistance

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

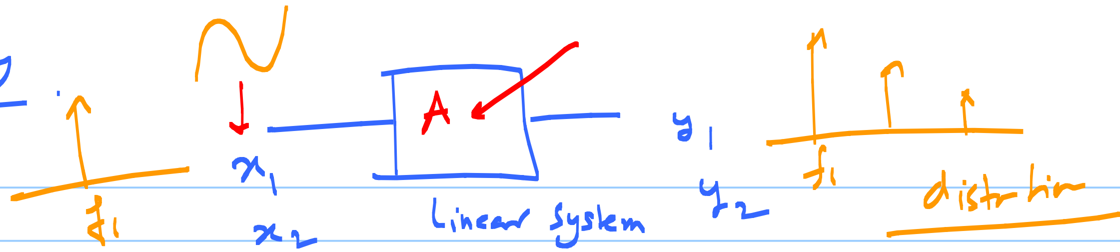
$$R_{ch} = \frac{1}{KP_n \frac{W}{L}(V_{GS}-V_{THN})}$$



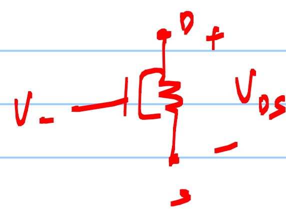
Deep Triode



Linearity

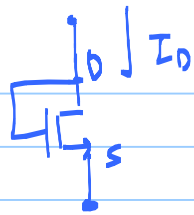


$y = \alpha_1 x_1 + \alpha_2 x_2 \Rightarrow \alpha_1 y_1 + \alpha_2 y_2$



$R_{ch} = f(V_{DS})$

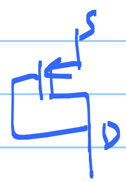
Diode Connected MOSFET



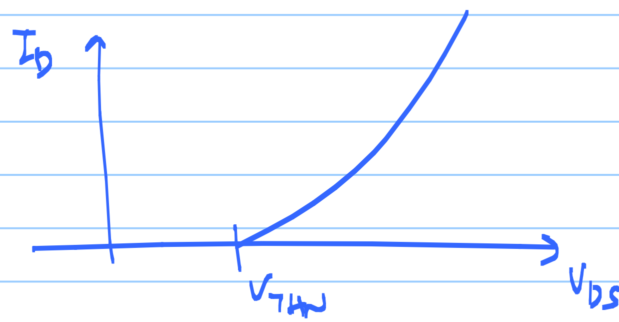
$$V_{DS} = V_{GS}$$

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

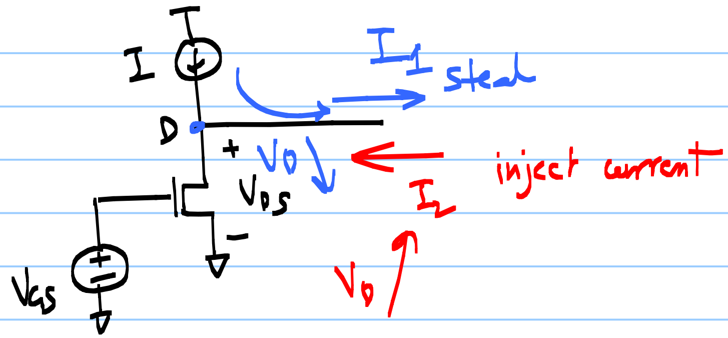
Always in saturation

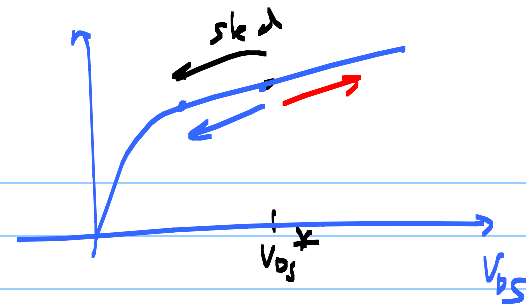


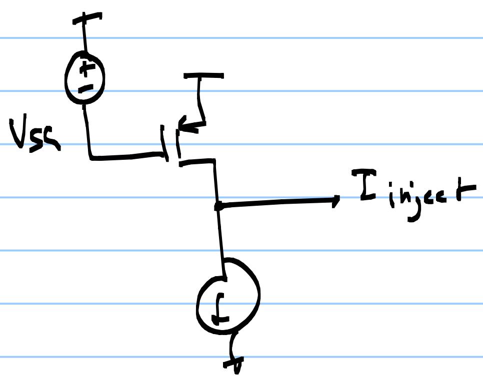
$$I_D = f(V_{GS})$$

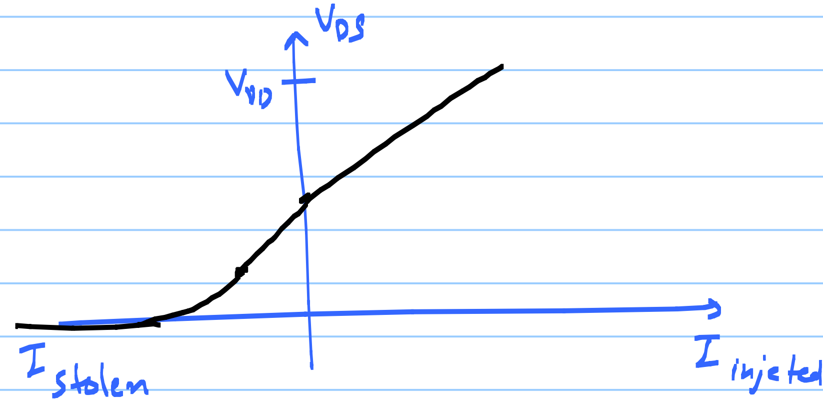


Intuition


I
D
+
V_D
V_{DS}
−
V_{GS}
I_1 steal
inject current
I_2
V_D

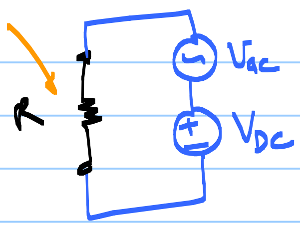

steal
V_{DS}^*
V_{DS}

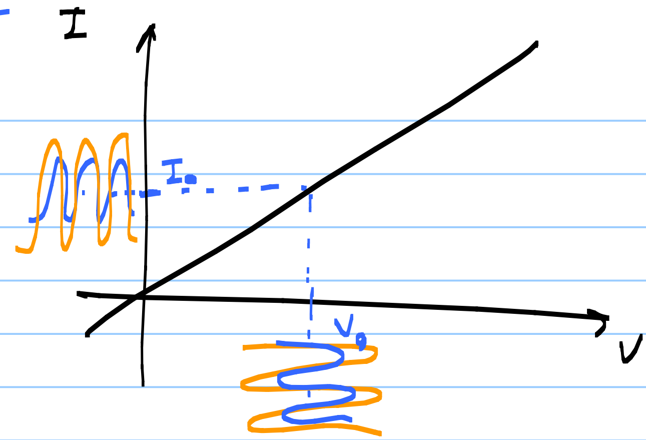

V_{SG}
I
I_{inject}


V_{DS}
V_{DD}
I_{stolen}
$I_{injected}$

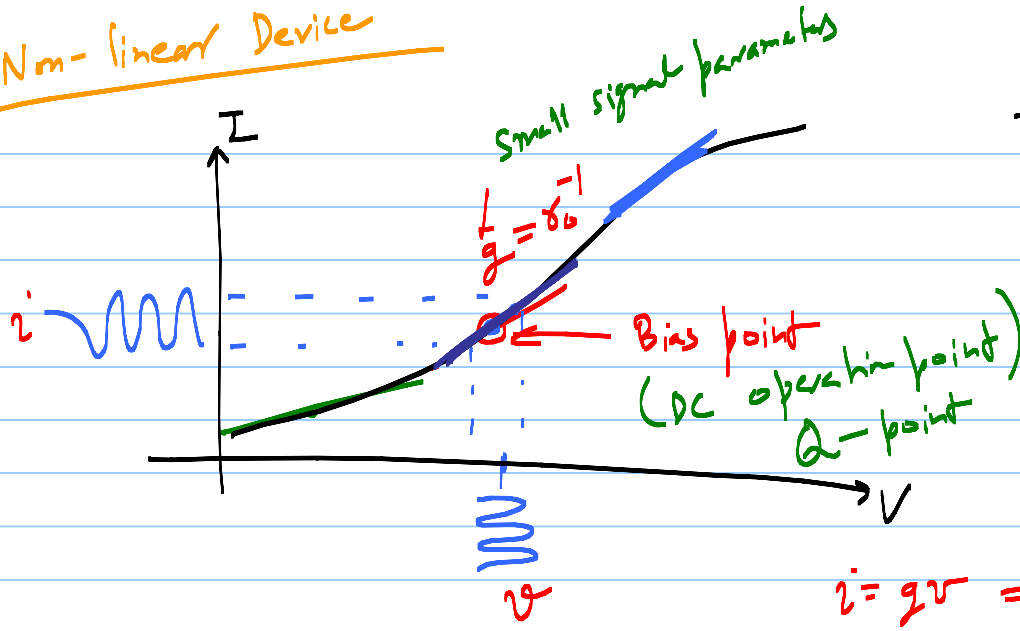
Small-signal behavior

Linear

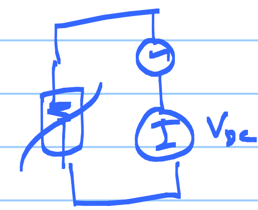




Non-linear Device



$$I = f(V)$$



$$i = gv = \frac{v}{r_o}$$

$\lfloor x = x!$

Taylor series Expansion around $V = V_0$

$I = f(V)$

$$= f(V_0) + \frac{f'(V_0)}{\lfloor 1} \cdot \underbrace{(V-V_0)}_{v} + \frac{f''(V_0)}{\lfloor 2} \underbrace{(V-V_0)^2}_{v^2} + \frac{f'''(V_0)}{\lfloor 3} \underbrace{(V-V_0)^3}_{v^3} + \cdots$$

$V = V_0 + v$

$$I = \underbrace{f(V_0)}_{I_0} + f'(V_0) \cdot v + \frac{f''(V_0)}{\lfloor 2} \cdot v^2 + \frac{f'''(V_0)}{\lfloor 3} \cdot v^3 + \cdots$$

$$i = I - I_0 = \alpha_1 v + \alpha_2 v^2 + \alpha_3 v^3 + \cdots$$

$f'(V_0) = g$

$v \uparrow$

for small v

$$i = g_1 v$$

v is larger

$$i = g_1 v + \underbrace{g_2 v^2 + g_3 v^3}_{\text{harmonic distortion}} + \cdots$$