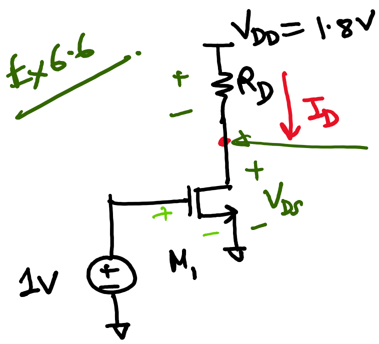
ECE 310 - Lecture 20

Friday, March 2, 2018 10:31 AM



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

$V_{THN} = 0.4V$

$\frac{W}{L} = \frac{2\mu m}{0.18\mu m}$

$\boxed{R_D = 5k\Omega}$

Assume M_1 is in SAT

$\boxed{\lambda = 0}$

$I_D = \frac{1}{2} KP_n \left(\frac{W}{L}\right)(V_{GS} - V_{THN})^2$

$= 200\mu A$

$V_{DS} = V_{DD} - I_D \cdot R_D = 0.8V$

$V_{DS,sat} = V_{GS} - V_{THN} = 1 - 0.4 = 0.6V$

Yes, M_1 is in SAT, $\left.\begin{array}{l} I_D = 200\mu A \\ V_{DS} = 0.8V \end{array}\right\}$ Ans.

$\boxed{R_D = 8k\Omega}$

$V_{DS} = V_{DD} - I_D \times 8k\Omega = 1.8 - \underbrace{200\mu \times 8k}_{1.6} = 0.2V$

$\underset{V_{DS}}{0.2} < \underset{V_{DS,sat}}{0.6V}$

M_1 is now in TRIODE.

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

let $x \equiv V_{DS}$

$1.8 - x = 100\mu \times 8k \times \left(\frac{2}{0.18}\right)\left[0.6x - \frac{x^2}{2}\right]$

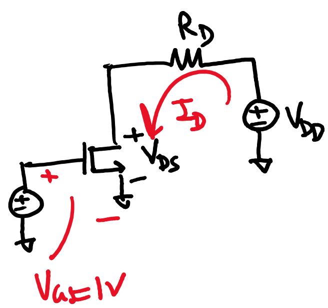
$$\Rightarrow \quad 1.8 - x = 5.333x - 4.444x^2$$

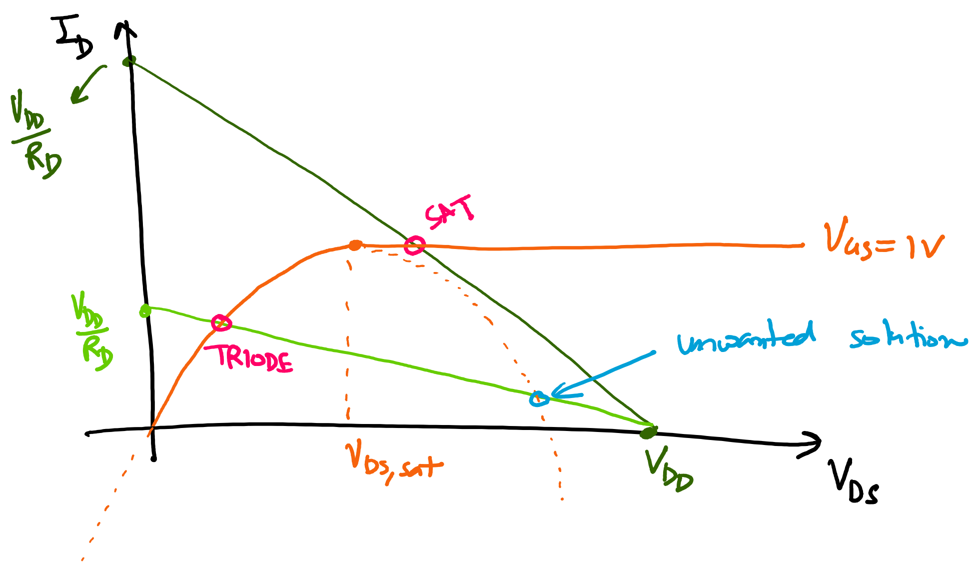
$$\Rightarrow \quad 4.444x^2 - 6.333x + 1.8 = 0$$

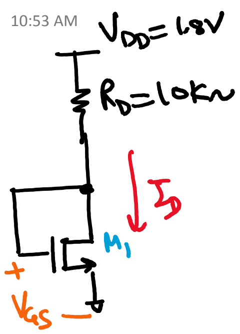
Solve for $\quad x = 0.392\,V, \quad \cancel{1.033\,V}$ → This would mean we are in SAT

$V_{DS} = 0.392\,V$

$$I_D = \frac{V_{DD} - V_{DS}}{R_D} = \frac{1.8 - 0.392}{8k} = \boxed{176\mu A}$$







Diode-connected MOSFET $\rightarrow$ can never be in Triode

$V_{DS} = V_{GS}$

for M_1 to be ON $\Rightarrow$ $V_{GS} > V_{THN}$

$\boxed{\lambda = 0}$

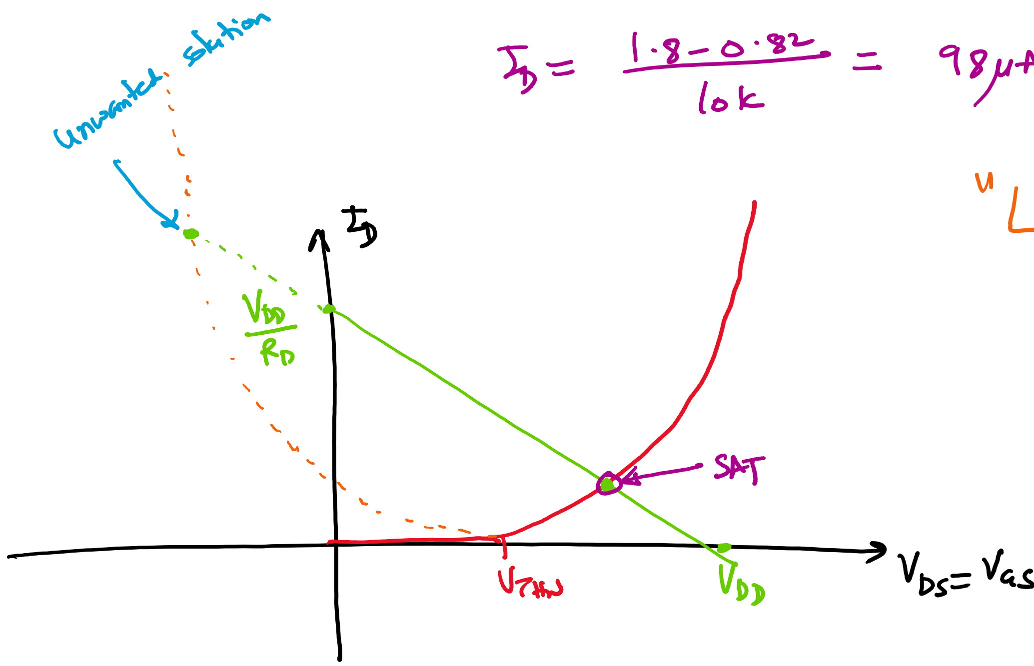
$$\frac{V_{DD} - V_{GS}}{R_D} = I_D = \frac{1}{2} KP_n \left[V_{GS} - V_{THN}\right]^2$$

$x = V_{GS} = 0.82, \ \cancel{-0.2}$

$V_{GS} = V_{DS} = 0.82\,V$

$$I_D = \frac{1.8 - 0.82}{10k} = 98\,\mu A$$

"Loihi Chip from Intel"



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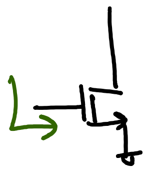
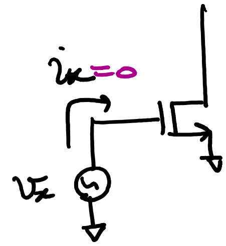
AC analysis ← small signal MOSFET model

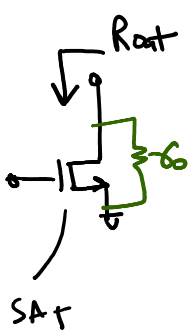
low-frequency

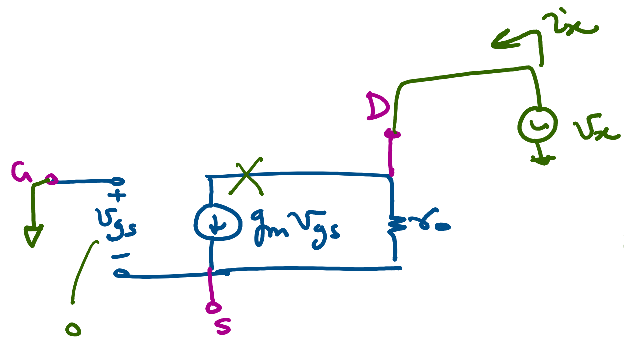




$Z_{in} \equiv R_{in} = \dfrac{v_x}{i_x}$

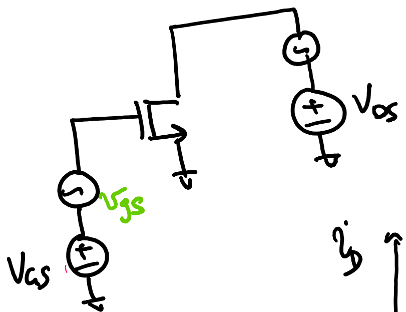
$R_{in} \to \infty$

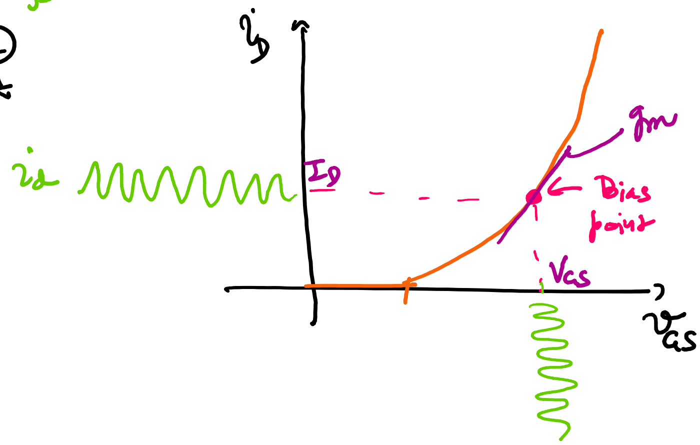


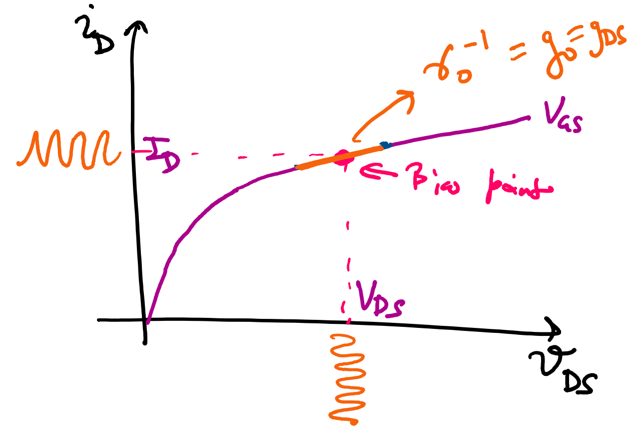


$R_{out} = \dfrac{v_x}{i_x} = r_o$

Biasing → All DC voltages & currents in the circuit are defined







$$g_m \equiv \text{Transconductance} = \left.\frac{\partial I_D}{\partial v_{GS}}\right|_{v_{GS}=V_{GS}}$$

total

$$v_{GS} = V_{GS} + v_{gs}$$

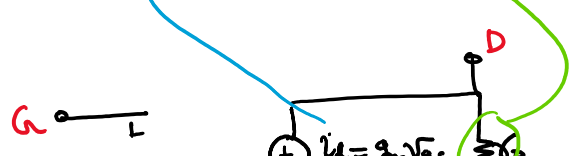
$$v_{DS} = V_{DS} + v_{ds}$$

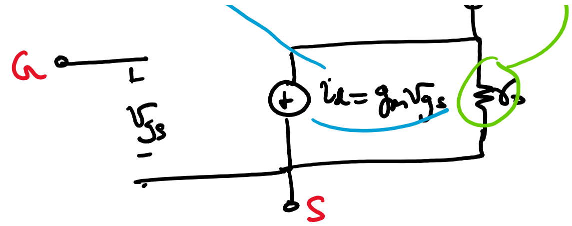
$$i_D = I_D + i_d$$

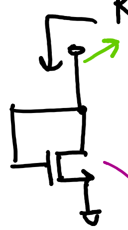
$$r_o = \left.\left(\frac{\partial I_D}{\partial v_{DS}}\right)^{-1}\right|_{v_{DS}=V_{DS}}$$

$$\left.\begin{aligned} i_d &= g_m v_{gs} \\ i_d &= \frac{v_{ds}}{r_o} \end{aligned}\right\}$$ Small-signal equation

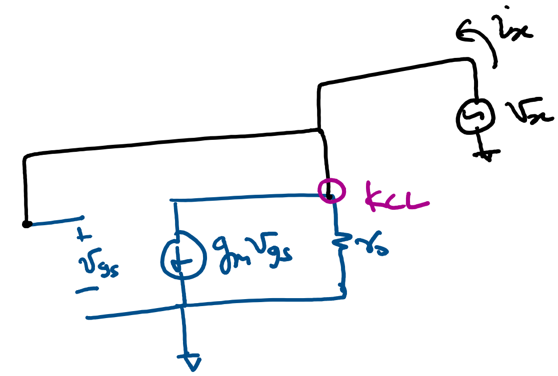
↳ linear




G
S
+
v_{gs}
−
$i_d = g_m v_{gs}$
r_o



$R_{out} \Rightarrow 1/g_m$



$v_{gs} = v_x$

$$i_x - \frac{v_x}{r_o} - g_m v_x = 0$$

$$i_x = v_x\left(g_m + 1/r_o\right)$$

$$R_{out} = \frac{v_x}{i_x} = \frac{1}{g_m + 1/r_o} = \frac{1}{g_m} \| r_o \simeq \frac{1}{g_m}$$

$$r_o \gg 1/g_m$$