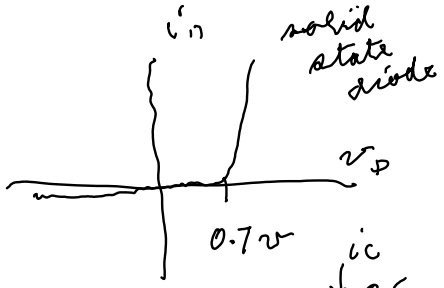
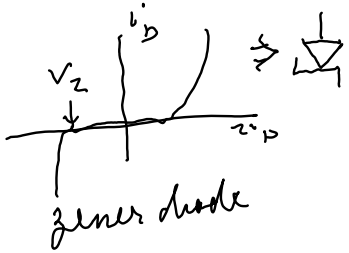
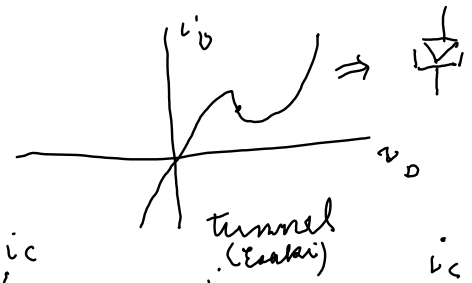
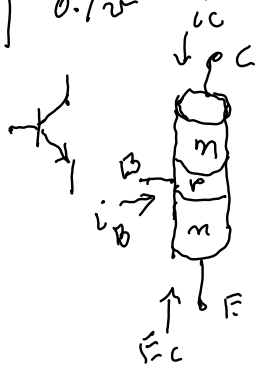
ENee303
02/07/19

Note Title 2/7/2019



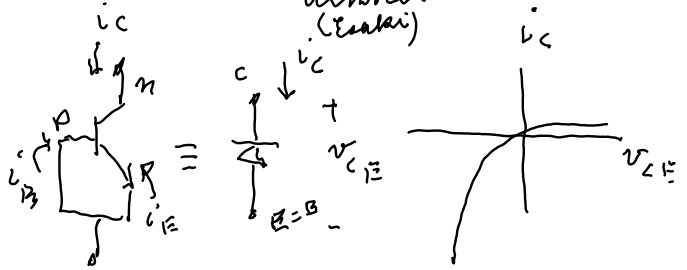






KCL $0 = i_C + i_B + i_E$

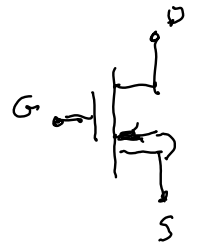
$i_C = \alpha(-i_E)$



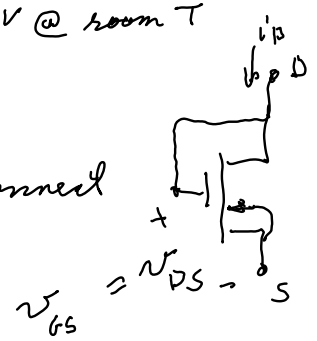
if not $i_D = I_S\left(e^{v_D/V_T} - 1\right)$ $\quad V_T$ = thermal voltage $= kT/|q|$, $T = {}^\circ$Kelvin

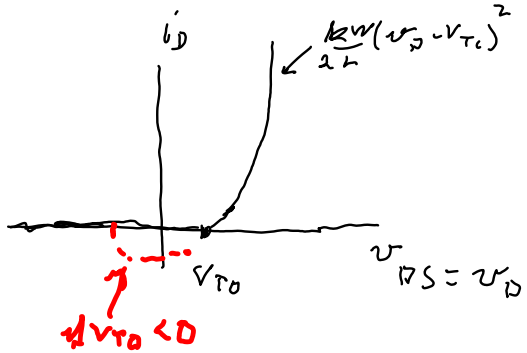
$\simeq 26\,mV$ @ room T

Back to CMOS



$\Rightarrow$ diode connect

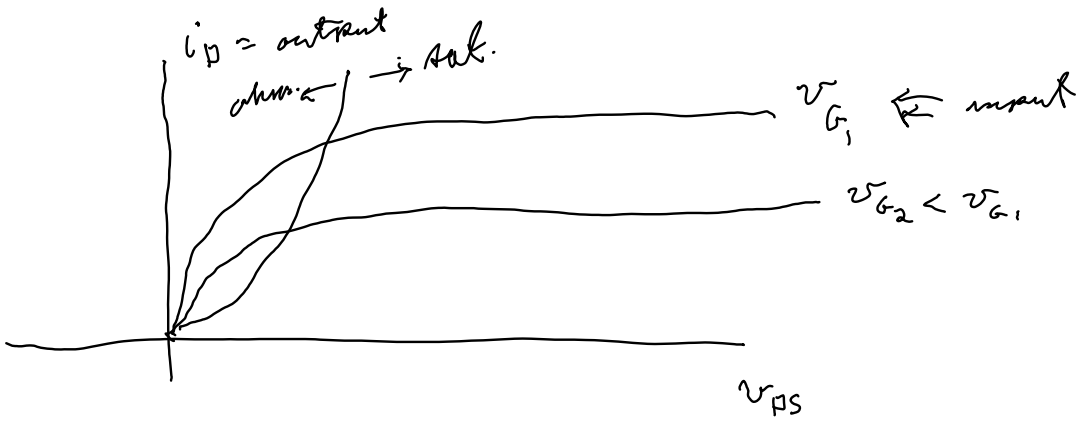


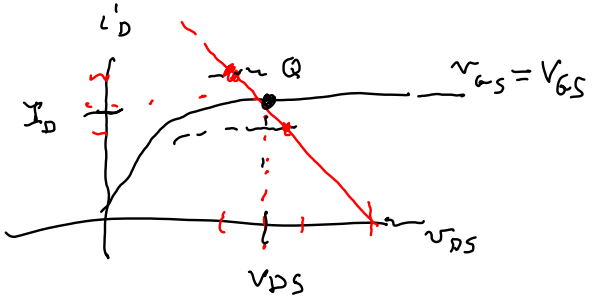


$v_{DS} \overset{?}{\geq} v_{GS} - V_{TO}$ here $v_{DS} > v_{DS} - V_{TO}$ if $V_{TO} > 0$ then $\Rightarrow$ in saturation

$$i_D = \frac{k}{2}\frac{W}{L}\underbrace{\left(v_{GS} - V_{TO}\right)}_{v_D}{}^2 \cdot \left(1 + \lambda \underbrace{v_{DS}}_{v_D}\right) \simeq \frac{k}{2}\frac{W}{L}\left(v_D - V_{TO}\right)^2$$

if $V_{TO} < 0$ we have a depletion mode NMOS





$$i_D = I_D + \left.\frac{\partial i_D}{\partial v_{DS}}\right|_Q (v_{DS} - V_{DS}) + \left.\frac{\partial i_D}{\partial v_{GS}}\right|_Q (v_{GS} - V_{GS}) + \text{higher orders in } v_{ds} \text{ \& } v_{gs} \Rightarrow \text{ignore for small signal}$$

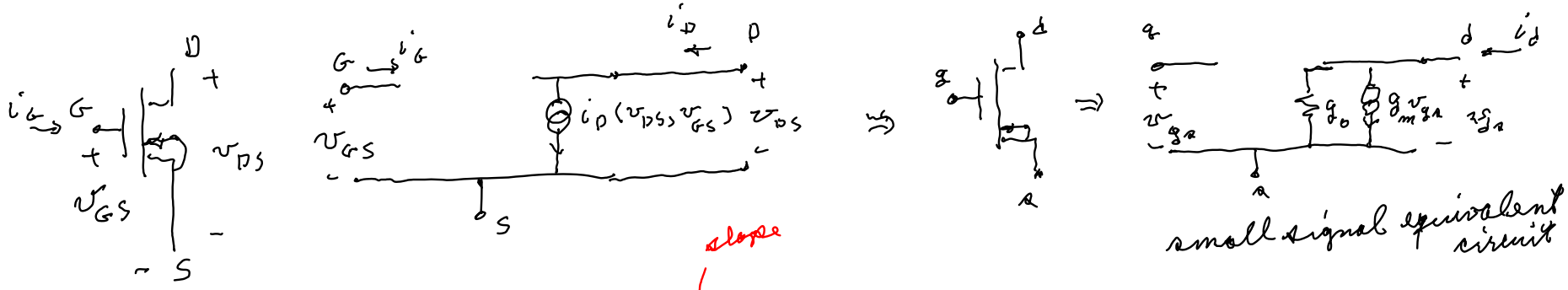
$v_{GS} = V_{GS}$
$v_{DS} = V_{DS}$

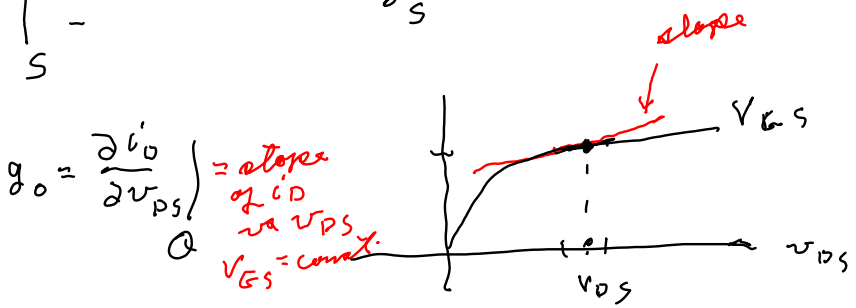
$$i_d = i_D - I_D$$
$$v_{ds} = v_{DS} - V_{DS}$$
$$v_{gs} = v_{GS} - V_{GS}$$

$$i_D - I_D = i_d = \left.\frac{\partial i_D}{\partial v_{DS}}\right|_Q v_{ds} + \left.\frac{\partial i_D}{\partial v_{GS}}\right|_Q v_{gs}$$

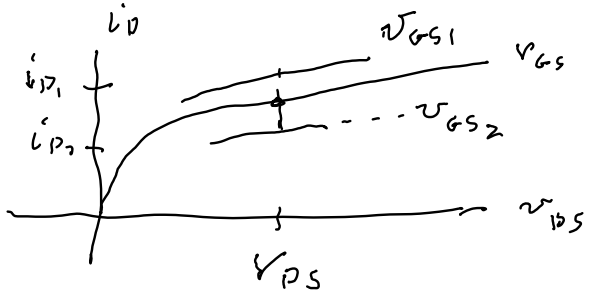
$\left.\frac{\partial i_D}{\partial v_{DS}}\right|_Q = g_o$ = output

$\left.\frac{\partial i_D}{\partial v_{GS}}\right|_Q = g_m$ = mutual





$$g_o = \left.\frac{\partial i_D}{\partial v_{DS}}\right|_Q$$ = slope of i_D vs v_{DS} at V_{GS} = const.



$$g_m = \left.\frac{\partial i_D}{\partial v_{GS}}\right|_Q$$ = slope of i_D vs v_{GS} at V_{DS} = const

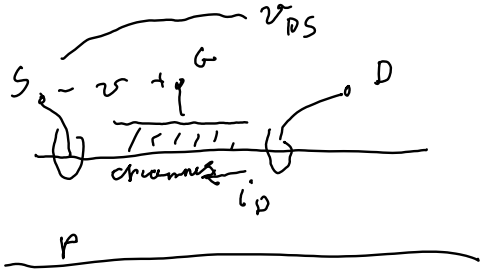
$$g_m \approx \left.\frac{i_{D_1} - i_{D_2}}{v_{GS_1} - v_{GS_2}}\right| \quad (\text{mho}\ \Omega)$$

when $v_{DS} = V_{DS}$

in Spice G component = VCCS
R " " = resistor

$$\begin{bmatrix} i_g \\ i_d \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ g_m & g_o \end{bmatrix} \begin{bmatrix} v_{gs} \\ v_{ds} \end{bmatrix} \Rightarrow i = Yv, \quad Y = \text{2-port} = \begin{bmatrix} 0 & 0 \\ g_m & g_o \end{bmatrix} \approx \begin{bmatrix} 0 & 0 \\ g_m & 0 \end{bmatrix}$$

low frequency 2-port Y of NMOS (2×2 matrix)



$$g_m \text{ in saturation} = \frac{\partial\left(\frac{k_p W}{2L}(v_{GS}-V_{TO})^2\right)}{\partial v_{GS}} = 2\cdot\frac{k_p W}{2L}(v_{GS}-V_{TO})\Big|_{v_{GS}=V_{GS}}$$

$$\downarrow = \frac{2\cdot I_D}{(V_{GS}-V_{TO})} = \frac{2\cdot I_D}{V_{OD}}$$

" overdrive