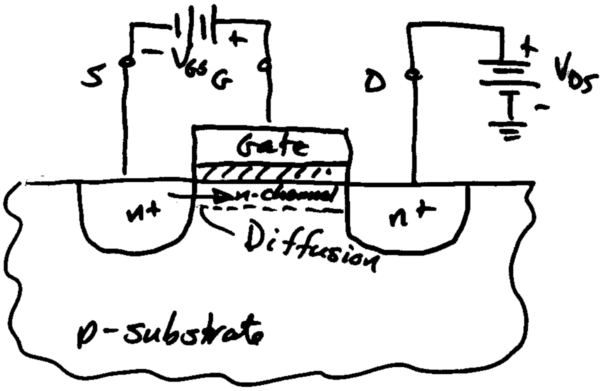
Summary of MOSFET Large Signal Model

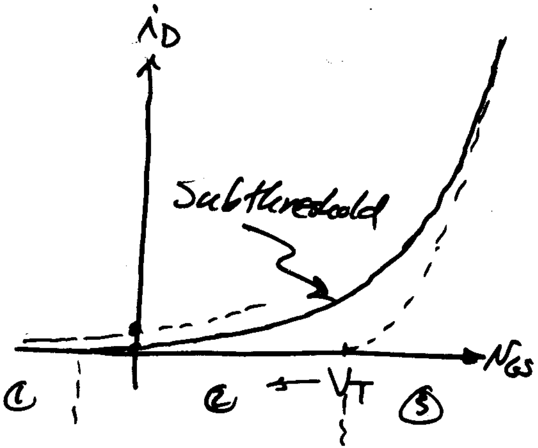
	Long Channel	Short Channel (v_{sat})
Linear $v_{DS} < V_{DS}(sat)$	$i_{DS} = k'\frac{W}{L}\left[v_{GS} - V_T - \frac{v_{DS}}{2}\right] v_{DS}$	$i_{DS} = \frac{W}{L}\left(\frac{\mu C_{ox}}{1+\frac{v_{DS}}{E_c L}}\right)\left(v_{GS}-V_T-\frac{v_{DS}}{2}\right)v_{DS}$
$V_{DS}(sat)$	$V_{DS}(sat) = v_{GS} - V_T$	$V_{DS}(sat) = \frac{(v_{GS}-V_T)E_cL}{(v_{GS}-V_T)+E_cL}$
Saturation $v_{DS} > V_{DS}(sat)$	$i_{DS} = \frac{k'}{2}\frac{W}{L}(v_{GS}-V_T)^2$	$i_{DS} = \frac{W\mu C_{ox}E_c}{2}\left[\frac{(v_{GS}-V_T)^2}{(v_{GS}-V_T)+E_cL}\right]$

Download lecture 7 & 8 for next Wednesday

Subthreshold Conduction and Models

Weak inversion (subthreshold) operation occurs when $v_{GS} < V_T$.





① Substrate is not inverted if $\phi_S < \phi_F$

② Channel is weakly inverted (diffusion current) – $\phi_F < \phi_S < 2\phi_F$

③ Strong inversion (drift current) – $2\phi_F < \phi_S$

Large Signal Model –

$$i_{subthreshold} = i_{sub} = I_S \exp\left(\frac{q(v_{GS}-V_T-V_{offset})}{nkT}\right)\left[1-\exp\left(\frac{-q v_{DS}}{kT}\right)\right]$$

$v_{GS} \leq V_T$

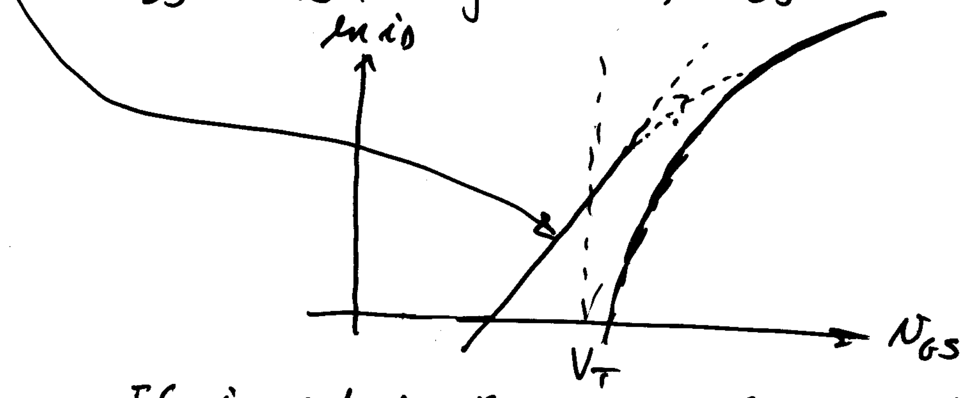
$$i_{sub} = I_S \exp\left(\frac{-qV_{offset}}{nkT}\right)\left[\exp\left(q\frac{(v_{GS}-V_T)}{nkT}\right)\right]\left[1-\exp\left(\frac{-q v_{DS}}{kT}\right)\right]$$

Finally,

$$i_{sub} = \frac{W}{L} I_x \exp\left[q\frac{(v_{GS}-V_T)}{nkT}\right]\underbrace{\left[1-\exp\left(\frac{-q\, v_{DS}}{kT}\right)\right]}_{(1+\lambda v_{DS})} \quad v_{DS}>0$$

$1.5 < n < 3$

$$i_{DS} = i_{DS}\,(\text{strong inversion}) + i_{DS}\,(\text{weak inversion})$$



If $i_{DS} \simeq 1\mu A$, the MOSFET for modest $\frac{W}{L}$'s is in subthreshold.

Models – $i_D = f(v_G, v_S, v_D, v_B)$

Ex. 2.11 (see next page)

Find the components of C_g in cutoff, linear & sat regions for a PMOS with t_{ox} = 22 Å, W = 400nm, L = 100nm and $V_{GS}=0$ in the cutoff region.

$$C_G = C_g W = \frac{\epsilon_{ox}}{t_{ox}} L W = \frac{(4)(8.85\times10^{-14})}{22\times10^{-8}} \times 400\times10^{-7} \times 100\times10^{-7}$$
$$= 0.64 fF$$

Cutoff: $C_{GS}=C_{GD}=0$, $C_{GB} \simeq \frac{1}{2} C_G = 0.32fF$, Linear: $C_{GS}=C_{GD}=0.32fF$, $C_{GB}=0$

Saturation: $C_{GS}=0.43fF$, $C_{GD}=0$ & $C_{GB}=0$

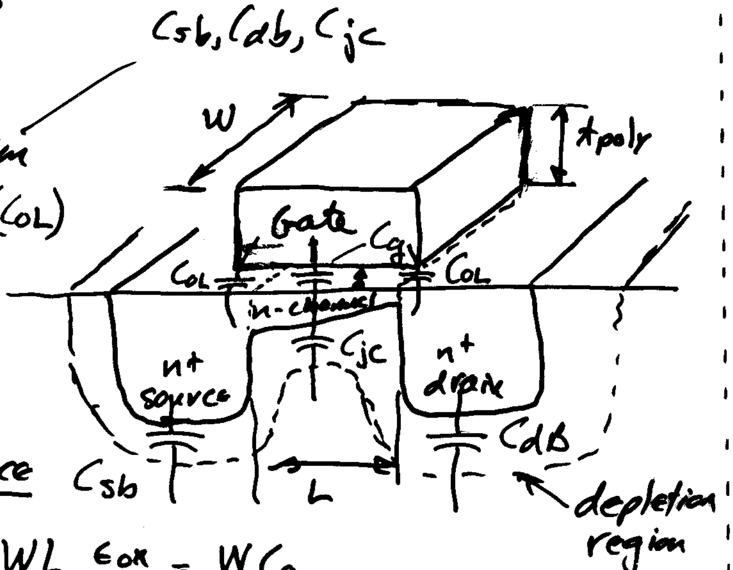
Capacitances of a MOSFET

Types of capacitances

1.) Thin oxide (C_g)

2.) pn junction depletion

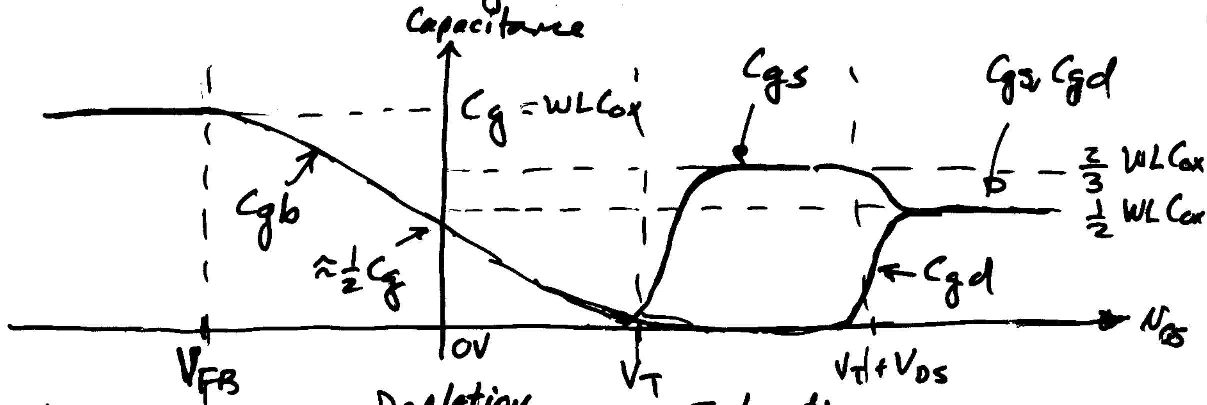
3.) Overlap (extrinsic) (C_{OL})

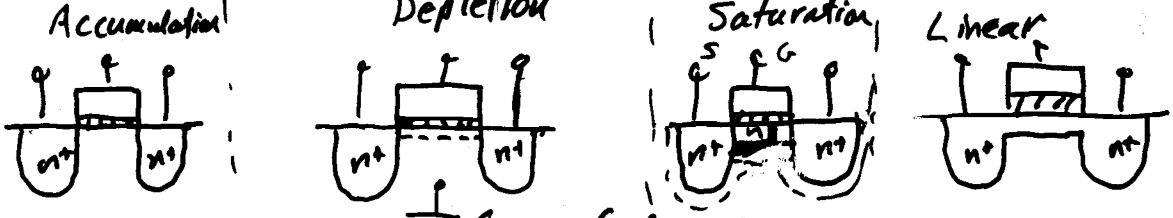


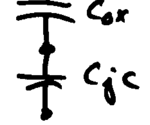
Thin-oxide capacitance

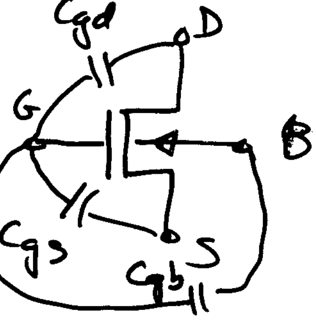
$$C_g = C_G = WLC_{ox} = WL\frac{\epsilon_{ox}}{t_{ox}} = WC_g$$

Decomposition of C_g into its parts- $V_{DS} \ge V_{GS} - V_T$

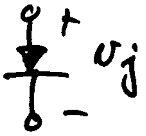


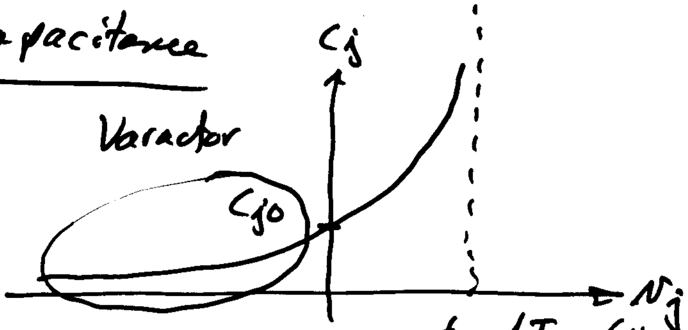






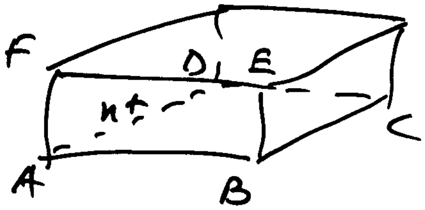
PN- Junction Capacitance





$$\phi_B = \frac{kT}{q}\ln\left(\frac{N_A N_D}{n_i^2}\right)$$

$$C_j = \frac{C_{jo}}{\left(1-\frac{v_j}{\phi_B}\right)^m} \qquad \frac{1}{3} < m < \frac{1}{2}$$



Bottom + Sidwall

Overlap Caps next