(1) * Capacitors in Cutoff operating region: $Q = C \cdot V$
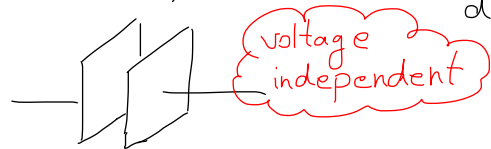
$C_j \left[\frac{F}{m^2}\right]$ $C_j \cdot x_j \left[\frac{F}{m}\right]$

① parallel-plate: $C = \dfrac{\varepsilon_0 \varepsilon_r A}{d}$ ε_0: permittivity of air $8.854 \times 10^{-12} \left[\frac{F}{m}\right]$

voltage independent

ε_r: relative permittivity of SiO_2

$3.9 < \varepsilon_r < 4.2$

d: oxide tickness (t_{ox})

oxide capacitance per unit area: $C_{ox} = \dfrac{\varepsilon_0 \varepsilon_r}{t_{ox}} \left[\frac{F}{m^2}\right]$ $C_{gse} = C_{gde} = C_{ox} \cdot W \cdot L_{ov}$

$C_{gb} = C_{ox} \cdot W \cdot L_{eff}$

② buttom-plate juncition capacitance $C_j = \dfrac{C_{j0}}{\left(1 + \frac{V_r}{\phi_0}\right)^n} \left[\frac{F}{m^2}\right]$
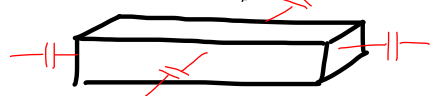
junction capacitance at 0 biasing voltage

juntion built-in voltage

$C_{js} = C_j \cdot L_j \cdot W = C_j A_s$
$C_{jd} = C_j \cdot L_j \cdot W = C_j A_d$

③ sidewall junction capacitor
$C_{jsw} = \dfrac{C_{jsw0}}{\left(1 + \frac{V_r}{\phi_D}\right)^n} \left[\frac{F}{m}\right]$

overlap length

$L_{ov} \ll L$

$L_{eff} = L - 2 L_{ov}$

$C_{jsw-s} = 2(L_j + W) C_{jsw}$
$C_{jsw-d} = 2(L_j + W) C_{jsw}$
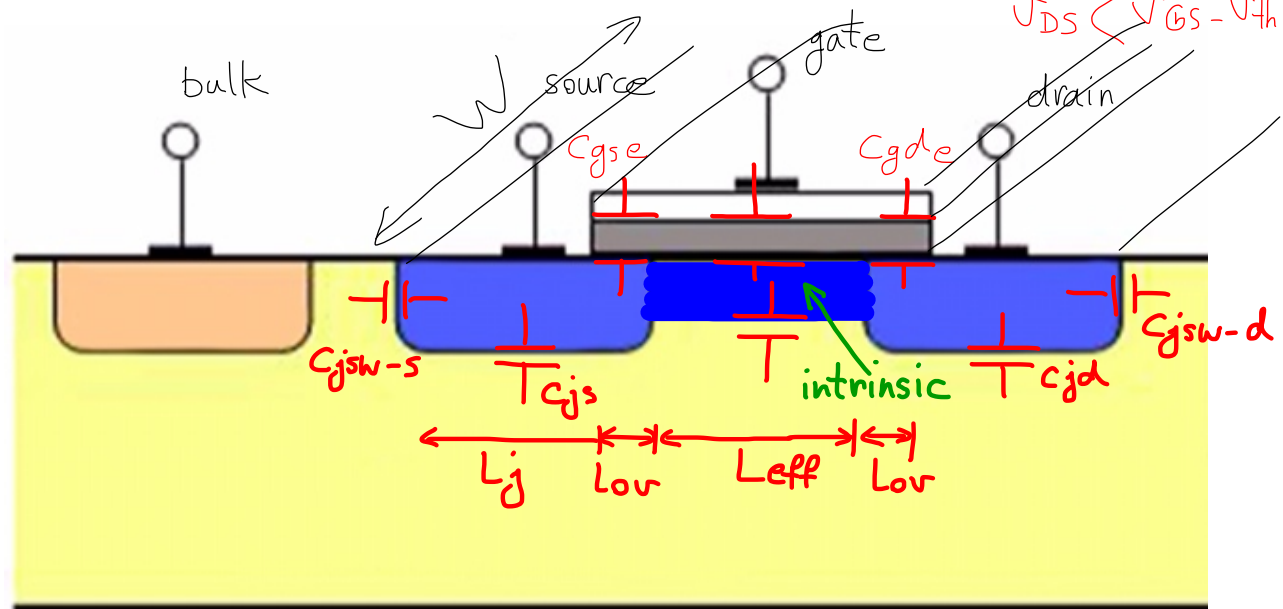
P_s: source Periphery , P_d: drain periphery
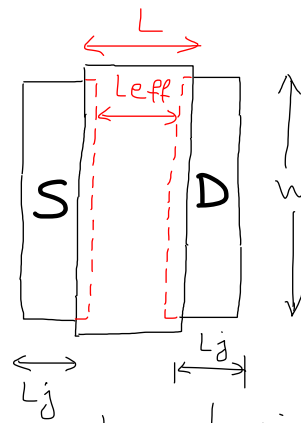
layout view

(2) * Capacitors in triode operating region :

$V_{GS} \geq V_{th}$
$V_{DS} < V_{GS} - V_{th}$

bulk   W source   gate   drain

C_{gse} C_{gde}

C_{jsw-s} T_{Cjs} intrinsic T_{Cjd} C_{jsw-d}

L_j L_{ov} L_{eff} L_{ov}

in triode channel is symmetrical
because $V_d \approx V_s$

g   d
s   b

Extrinsic
Intrinsic

$$C_{gse} = C_{gde} = C_{ox} \cdot L_{ov} \cdot W$$
$$C_{gsi} = C_{gdi} = C_{ox} \cdot \frac{L_{eff}}{2} \cdot W \quad , \quad (L_{eff} \approx L)$$
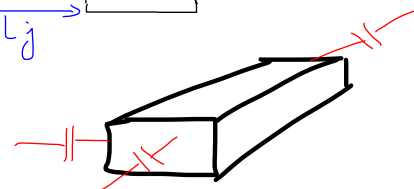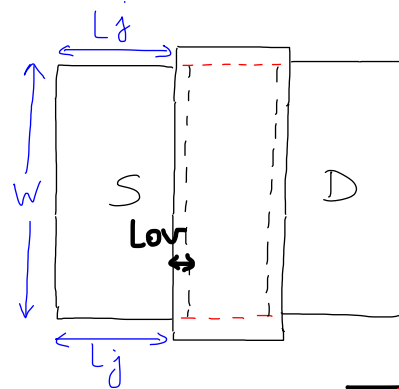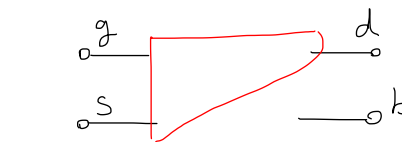
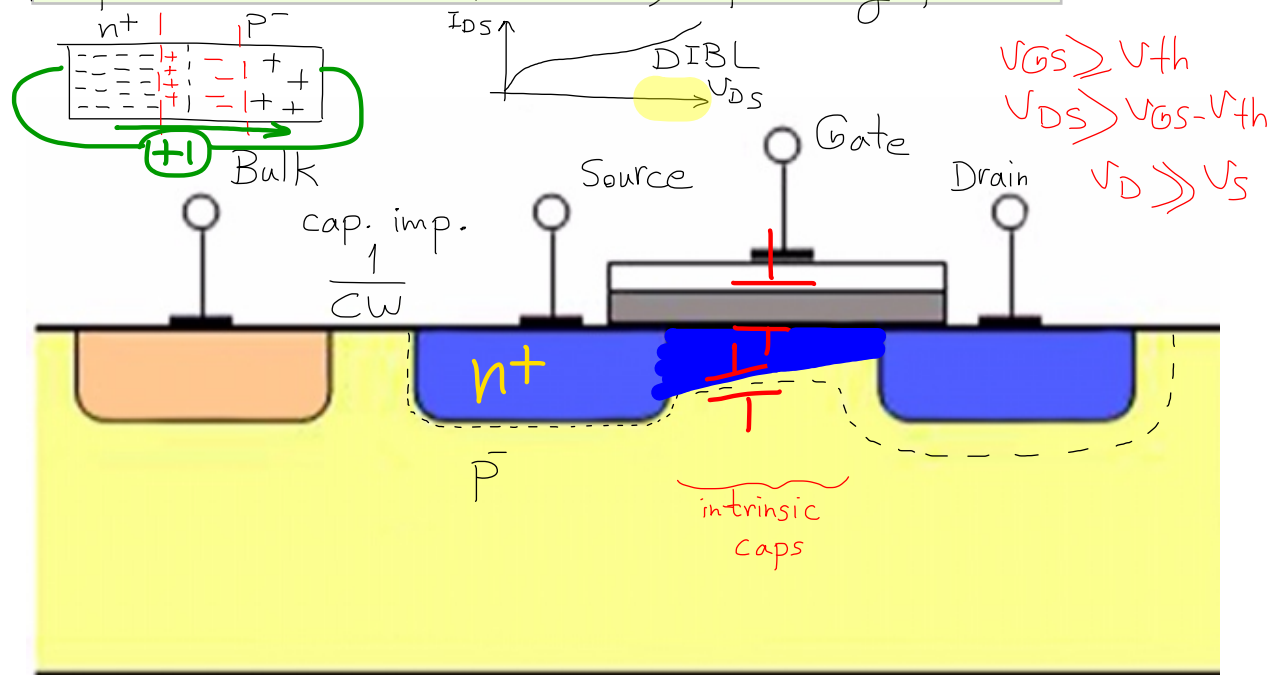gate-channel capacitor $= C_{gsi} + C_{gdi}$

* total source buttom-plate junction cap:

$$C_{js} = C_{j0} \cdot L_j \cdot W + \underbrace{C_{j0} \cdot \left(\frac{L_{eff}}{2} \cdot W\right)}_{intrinsic} = C_{jd}$$

L_j
W   S L_{ov} D
L_j

* total source side-wall junction capacitor:

$$C_{jsw-s} = C_{jsw} \cdot (2L_j + W) = C_{jswd}$$

▷

(3) ∗ Capacitors in active (saturation) operating points :

$V_{GS} \geq V_{th}$

$V_{DS} > V_{GS} - V_{th}$

$V_D \gg V_S$

DIBL

I_{DS} / U_{DS}

Bulk   +1

n+   P−

cap. imp. $\frac{1}{CW}$

Source   Gate   Drain

n+   P−

intrinsic Caps
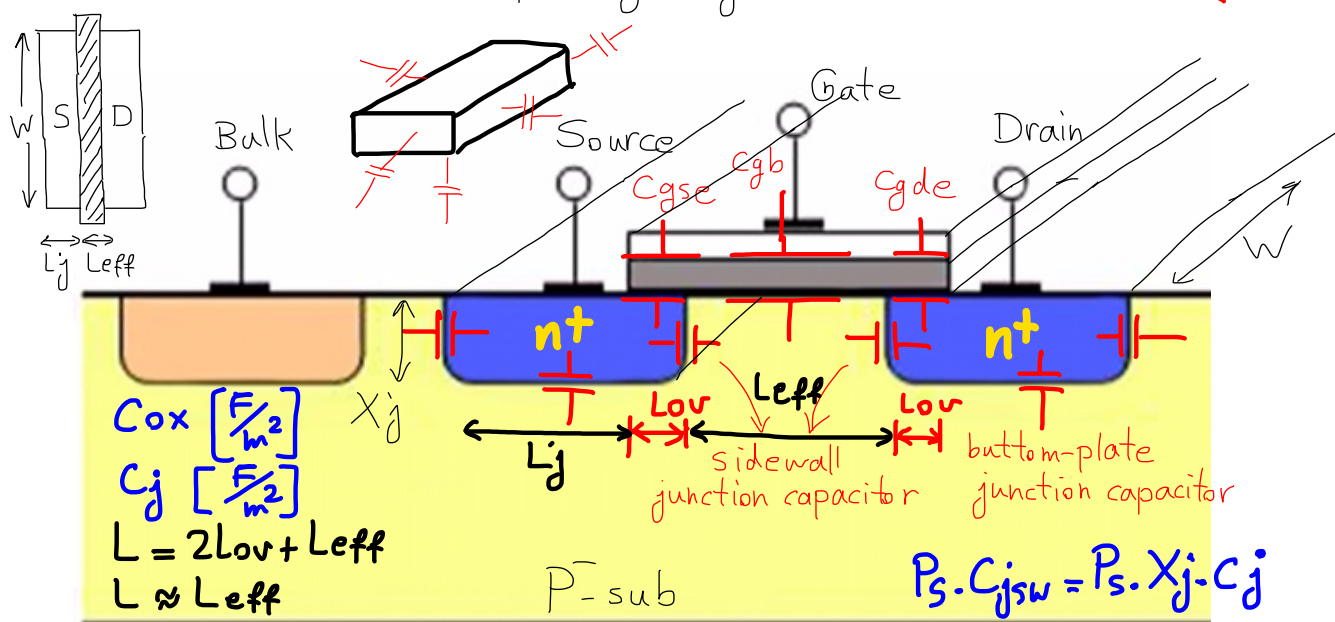
$\begin{cases} C_{gsi} = \frac{2}{3} C_{ox} L_{eff} \cdot W \\ C_{gdi} = \frac{1}{3} C_{ox} L_{eff} \cdot W \end{cases}$

$\begin{cases} C_{jsi} = \frac{2}{3} C_j \cdot L_{eff} \cdot W \\ C_{jdi} = \frac{1}{3} C_j \cdot L_{eff} \cdot W \end{cases}$

$L_{eff} \approx L$
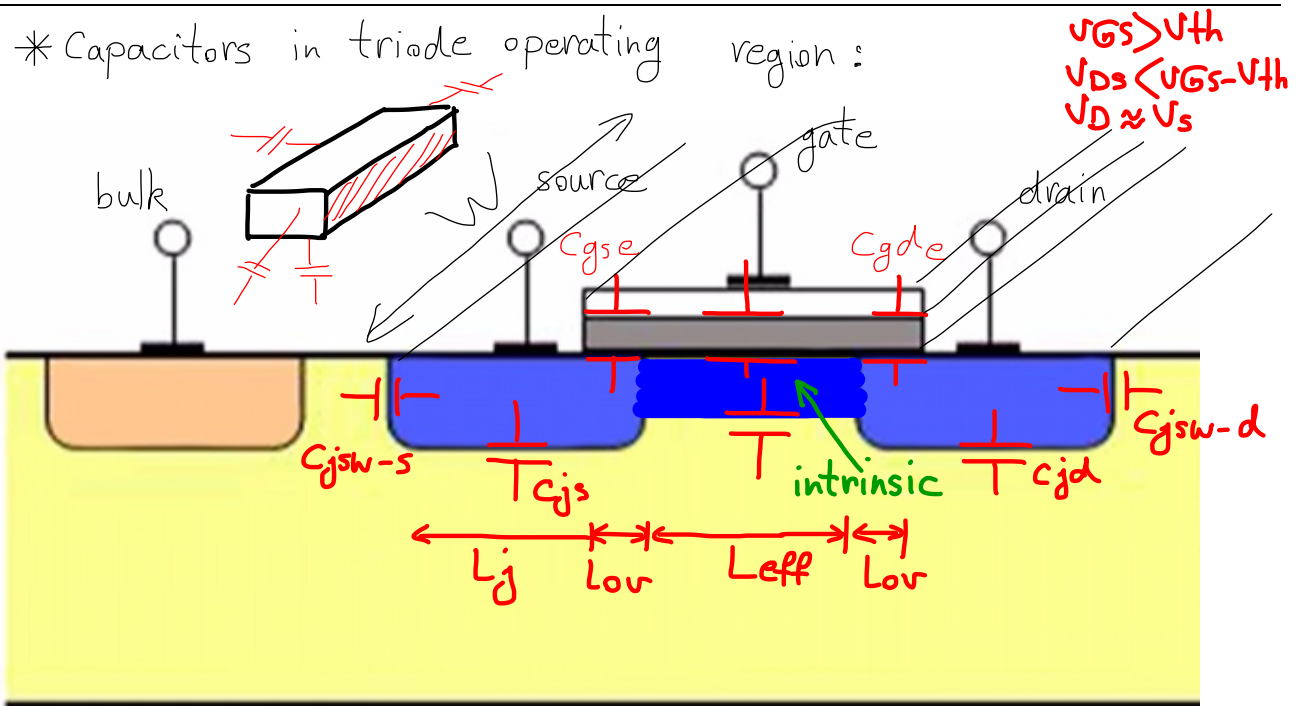
Gate

Source   Drain

$\frac{2}{3} C$ $\frac{1}{3} C$

$\frac{2}{3} C$ $\frac{1}{3} C$

Bulk

* Capacitors in Cutoff operating region: $V_{GS} < V_{th}$

$C_{ox} \left[\frac{F}{m^2}\right]$

$C_j \left[\frac{F}{m^2}\right]$

$L = 2 Lov + Leff$

$L \approx Leff$

$P_s \cdot C_{jsw} = P_s \cdot X_j \cdot C_j$

	$C_{gse}=C_{gde}$	C_{gb}	C_{gsi}	C_{gdi}	C_{sbi}	C_{dbi}	C_{sbe}	C_{dbe}
cutoff	$C_{ox}.W.Lov$	$C_{ox}.W.Leff$	$\emptyset$	$\emptyset$	$\emptyset$	$\emptyset$	$A_s C_j + P_s C_{jsw}$	$A_d.C_j + P_d.C_{jsw}$
triode	$C_{ox}.W.Lov$	$\emptyset$	$\frac{1}{2}CoxW\,Leff$	$\frac{1}{2}CoxW\,Leff$	$\frac{1}{2}C_j Leff.W$	$\frac{1}{2}C_j\,Leff.W$	$A_s.C_j + P_s' C_{jsw}$	$A_d C_j + P_s'.C_{jsw}$
saturation (active)	$C_{ox}.W.Lov$	$\emptyset$	$\frac{2}{3}CoxW\,Leff$	$\frac{1}{3}CoxW\,Leff$	$\frac{2}{3}C_j Leff W$	$\frac{1}{3}C_j Leff\,W$	$A_s.C_j + P_s' C_{jsw}$	$A_d.C_j + P_d'.C_{jsw}$

✳ Capacitors in triode operating region:

$v_{GS} > V_{th}$
$V_{DS} < v_{GS} - V_{th}$
$V_D \approx V_S$

bulk   W   source   gate   drain

C_{gse} C_{gde}

C_{jsw-s} C_{js} intrinsic C_{jd} C_{jsw-d}

L_j L_{ov} L_{eff} L_{ov}

	$C_{gse} = C_{gde}$	C_{gb}	C_{gsi}	C_{gdi}	C_{sbi}	C_{dbi}	C_{sbe}	C_{dbe}
cutoff	$C_{ox} \cdot W \cdot L_{ov}$	$C_{ox} \cdot W \cdot L_{eff}$	$\emptyset$	$\emptyset$	$\emptyset$	$\emptyset$	$A_s C_j + P_s C_{jsw}$	$A_d \cdot C_j + P_d \cdot C_{jsw}$
triode	$C_{ox} \cdot W \cdot L_{ov}$	$\emptyset$	$\frac{1}{2} C_{ox} W L_{eff}$	$\frac{1}{2} C_{ox} W L_{eff}$	$\frac{1}{2} C_j L_{eff} \cdot W$	$\frac{1}{2} C_j L_{eff} \cdot W$	$A_s \cdot C_j + P'_s C_{jsw}$	$A_d C_j + P'_s \cdot C_{jsw}$
saturation (active)	$C_{ox} \cdot W \cdot L_{ov}$	$\emptyset$	$\frac{2}{3} C_{ox} W L_{eff}$	$\frac{1}{3} C_{ox} W L_{eff}$	$\frac{2}{3} C_j L_{eff} W$	$\frac{1}{3} C_j L_{eff} W$	$A_s \cdot C_j + P'_s C_{jsw}$	$A_d \cdot C_j + P'_d \cdot C_{jsw}$

* Capacitors in active (saturation) operating points :

$V_{GS} > V_{th}$
$V_{DS} > V_{GS} - V_{th}$
$V_D \gg V_S$

Bulk   Source   Gate   Drain

n^+

P^-

intrinsic caps

	$C_{gse} = C_{gde}$	C_{gb}	C_{gsi}	C_{gdi}	C_{sbi}	C_{dbi}	C_{sbe}	C_{dbe}
cutoff	$C_{ox}.W.L_{ov}$	$C_{ox}.W.L_{eff}$	$\emptyset$	$\emptyset$	$\emptyset$	$\emptyset$	$A_s C_j + P_s C_{jsw}$	$A_d.C_j + P_d.C_{jsw}$
triode	$C_{ox}.W.L_{ov}$	$\emptyset$	$\frac{1}{2}C_{ox}WL_{eff}$	$\frac{1}{2}C_{ox}WL_{eff}$	$\frac{1}{2}C_jL_{eff}.W$	$\frac{1}{2}C_jL_{eff}.W$	$A_s.C_j + P_s'C_{jsw}$	$A_dC_j + P_s'.C_{jsw}$
saturation (active)	$C_{ox}.W.L_{ov}$	$\emptyset$	$\frac{2}{3}C_{ox}WL_{eff}$	$\frac{1}{3}C_{ox}WL_{eff}$	$\frac{2}{3}C_jL_{eff}W$	$\frac{1}{3}C_jL_{eff}W$	$A_s.C_j + P_s'C_{jsw}$	$A_d.C_j + P_d'.C_{jsw}$