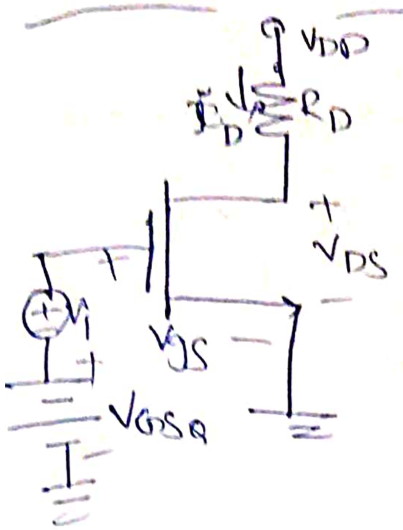
MOSFET Amplifier

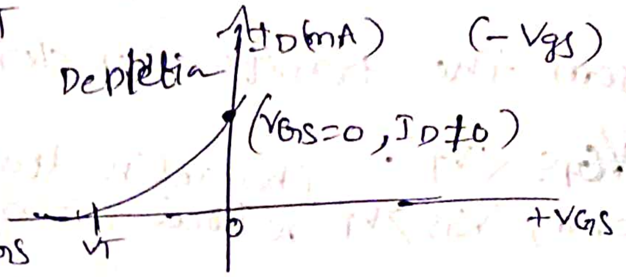


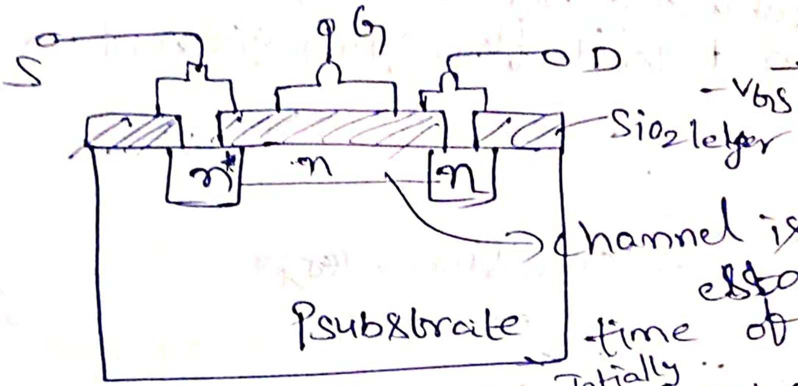
High input resistance due to oxide layer.

MOSFET

1. Depletion MOSFET
2. Enhancement MOSFET

Transfer characteristics



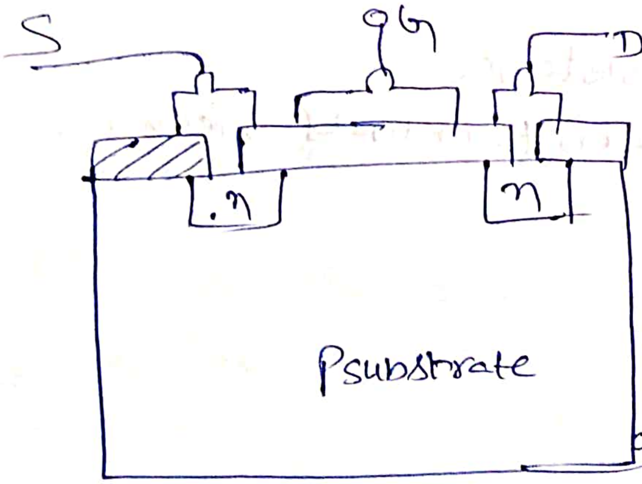


→ Channel is established due to doping at the time of construction

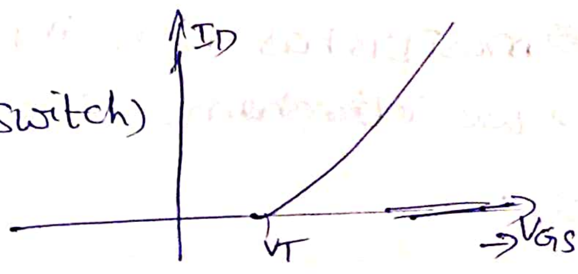
Initially (ON switch) (Both enhance & Depletion mosfet)

Depletion

(+ve Vgs)



(OFF Switch)



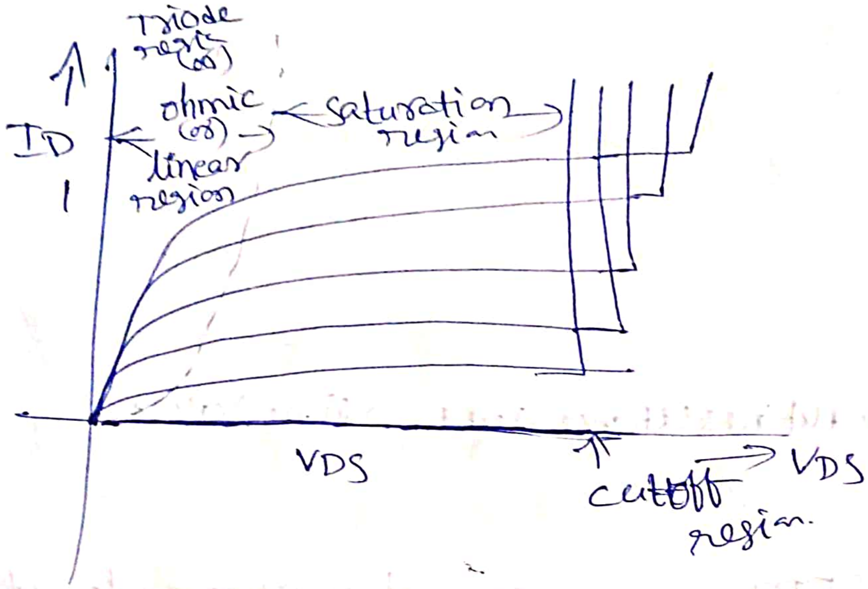
$I_D = K\,(V_{GS} - V_T)^2$

only enhancement mode

K → constant, it is depend on oxide & construction of MOSFET

Enhancement MOSFET. Initially "no channel" is present. channel is indued i.e channel is developed by applying greaterthan Threshold voltage $V_{gs} > V_T$

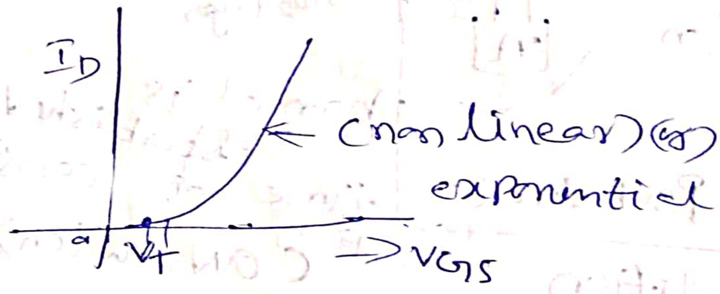
Drain characterstics (o/p characteristics)



From the transfer characterstics Drain current is zero $V_{GS} < V_T$. Channel is established between S & Drain. when $V_{GS} > V_T$ & Drain current will flow from source to drain. Then ID

$$I_D = K(V_{GS} - V_T)^2$$

$$K = \mu_n C_{ox}\left(\frac{W}{L}\right)$$



⇒ MOSFETs has high input resistance
→ we interchange source & Drain terminals viceversa
→

MOSFET Drain current

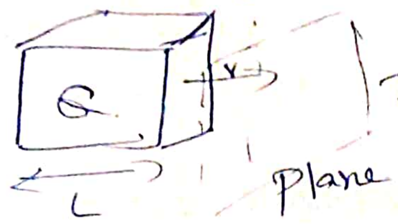
$I_{DS} = ?$

MOSFET acts like capacitor

Capacitor charge $Q = CV$

$= C(V - V_t)$ threshold voltage)

$I =$



$I = \frac{Q}{\Delta t}$ time taken to charge (or) flow through the plane

$$\Delta t = \frac{\text{length of cube}}{\text{velocity of charge}}$$

$$I = \frac{Q}{L} \vec{V_a}$$

$Q = CV = C(V - V_t)$

$$= I = \frac{C(V - V_t)}{L} \cdot \vec{V_a}$$

semiconductor

$V_a =$

mobility of charge particle

velocity of charge $V_a = \mu_Q E$ electric field

$$= I = \frac{C(V_{gc} - V_t)}{L}$$

capacitor

$$= \frac{C(V_{gc} - V_t)\mu E}{L}$$

capacitance

$$C = \frac{A \cdot \varepsilon}{t_{ox}}$$

$C = \frac{A \cdot \varepsilon}{t_{oxide}}$ = $\frac{\text{Area times the dielectric}}{\text{thickness of plates (or) distance between plates}}$

Area $= W \cdot L$ (width, length)

then $C = \frac{W \cdot L \cdot \varepsilon}{t_{ox}}$

$$= \frac{W l E}{t_{ox} \cdot L} \mu ($$

$$= \frac{W K E}{(t_{ox}/K)} \mu_E (V_{gc} - V_t)$$

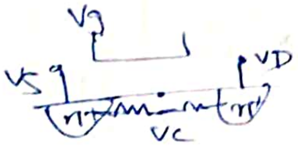
$$= {}^{\prime}C_{ox}$$

$$I = W C_{ox} \mu E (V_{gc} - V_t)$$

Electric field $= E = \frac{V_{DS}}{L}$

$$I = \mu C_{ox} \cdot \frac{W}{L} V_{DS} (V_{gc} - V_t)$$

V_{gc} = voltage between channel and gate.



$$V_C = \frac{V_S + V_D}{2}$$

$$V_C = \frac{V_S}{2} + \frac{V_D}{2} + \left(\frac{V_S}{2} - \frac{V_D}{2}\right)$$

$$I_{DS} = \mu_n C_{ox} \frac{W}{L} V_{DS} \left(V_g - \left(\frac{V_S}{\cdot} + \frac{V_D}{2} - \frac{V_D}{2}\right) - V_t\right)$$

$$= \mu_n C_{ox} \frac{W}{L} V_{DS} \left(V_g - V_S - \frac{1}{2} V_{DS} - V_t\right)$$

$$= \mu_n C_{ox} \frac{W}{L} V_{DS} \left(V_{gs} - \frac{1}{2} V_{DS} - V_t\right)$$

$$I_{DS} = \mu_n C_{ox} \frac{W}{L} \left[(V_{gs} - V_t) V_{DS} - \frac{1}{2} V_{DS}^2\right]$$

$$\boxed{I_{DS} = k_n \left[(V_{gs} - V_t) V_{DS} - \frac{1}{2} V_{DS}^2\right]}$$ (In saturation region)

let: $\boxed{k_n = \mu_n C_{ox} \frac{W}{L}}$

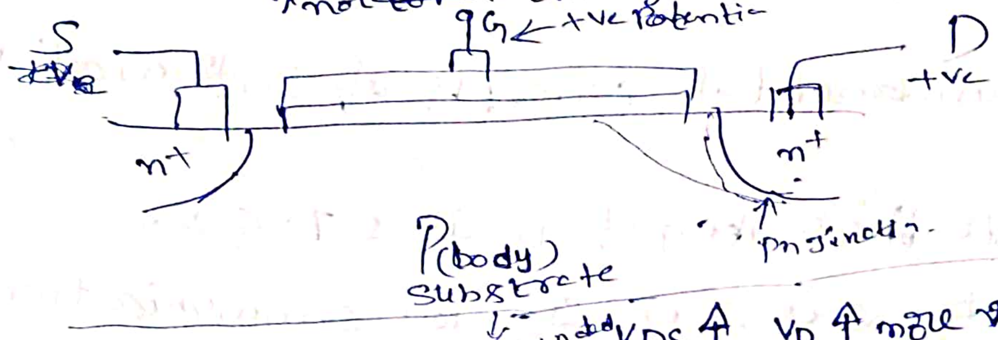
Drain current in channel length modulation

$$I_D = \frac{1}{2} \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_t)^2$$

I_D is not depending on VDS. I_D ≠

I_D is independent of VDS. So it is perfect current source

I_D = constant (Perfect current source)
not ~~correct~~ entirely correct why means observe construction of MOSFET

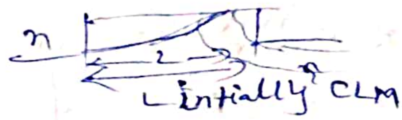


$V_{GS} > V_t$ channel will form

VDS ↑ V_D ↑ more reverse bias ↑ depletion region at Jn is thick so channel is going to reduce. channel length reduces Vt. channel length modulation

L↓ I_D ↑

L ↓ I_D ↑



$$I_D = \frac{1}{2} \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_t)^2$$

$$I_D = \frac{1}{2} \mu_n C_{ox} \frac{W}{L - \Delta L} (V_{GS} - V_t)^2$$

$$= \frac{1}{2} \mu_n C_{ox} \frac{W}{L(1 - \frac{\Delta L}{L})} (V_{GS} - V_t)^2$$

$$= \frac{1}{2} \mu_n C_{ox} \frac{W}{L} (1 - \frac{\Delta L}{L})^{-1} (V_{GS} - V_t)^2$$

$$= \frac{1}{2} \mu_n C_{ox} \frac{W}{L} (1 + \frac{\Delta L}{L}) (V_{GS} - V_t)^2$$

$$= \frac{1}{2} \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_t)^2 (1 + \lambda V_{DS})$$

$\Delta L \propto V_{DS}$

$\frac{\Delta L}{L} \propto \frac{V_{DS}}{L}$

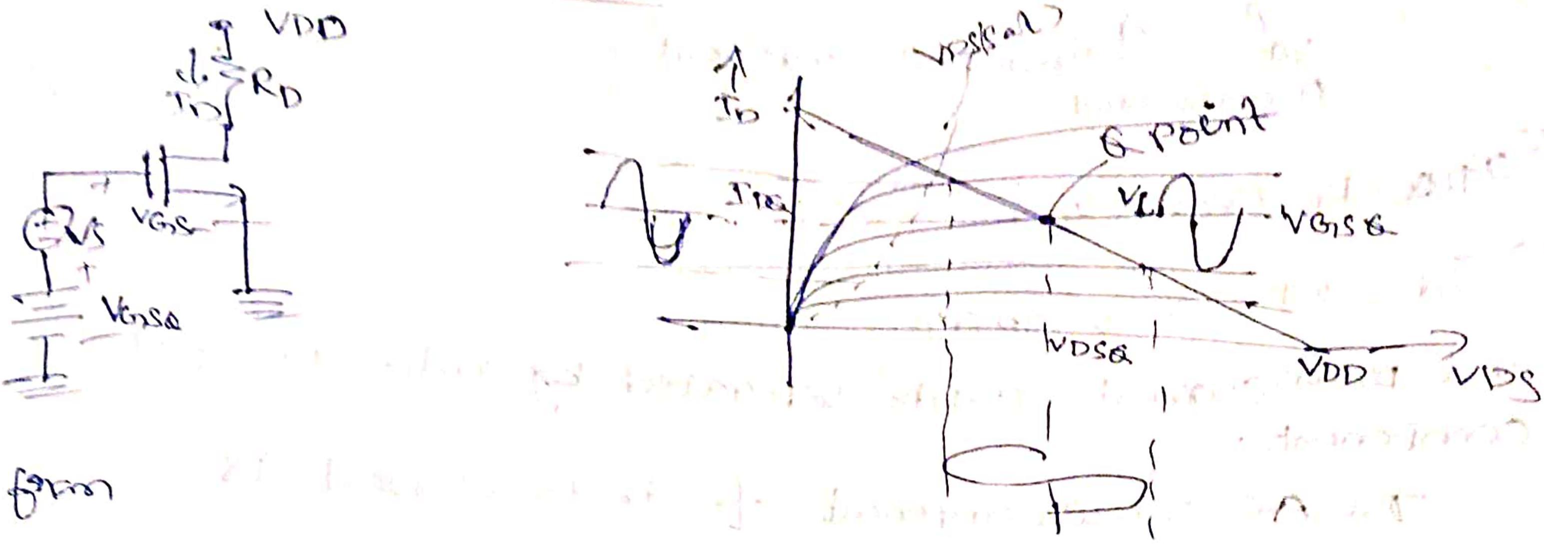
$\frac{\Delta L}{L} = C \frac{V_{DS}}{L}$ ← constant

$\frac{\Delta L}{L} = \lambda V_{DS}$ $\quad (\because \frac{C}{L} = \lambda)$ $\quad \boxed{\lambda = V^{-1}}$

$$I_d = \frac{1}{2} \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_t)^2 (1 + \lambda V_{DS})$$

Graphical Analysis, Load lines and small signal parameters

Common source transfer characteristics



from above figs

$$V_{GS} = V_{GSQ} + V_i = \underbrace{V_{GSQ}}_{\text{DC component}} + \underbrace{v_{gs}}_{\text{AC component}} \longrightarrow (1)$$

$$i_D = K_n (V_{GS} - V_{TN})^2 \longrightarrow (2)$$

substitute eq (1) into eq (2) then

$$i_D = K_n ((V_{GSQ} + v_{gs}) - V_{TN})^2$$

$$= K_n ((V_{GSQ} - V_{TN}) + v_{gs})^2 \qquad (a+b)^2$$

$$= \underbrace{K_n (V_{GSQ} - V_{TN})^2}_{(1)} + \underbrace{2K_n (V_{GSQ} - V_{TN}) \cdot v_{gs}}_{(2)} + \underbrace{K_n v_{gs}^2}_{(3)}$$

(1) term indicates DC (or) quiescent drain current I_{DQ}.

(2) term indicates time varying drain component that is linearly related to v_{gs} (AC component)

(3) square of signal voltage, but it produces harmonics (or) nonlinear distortion.

To minimize nonlinear distortion we require

$$v_{gs} \ll 2(V_{GSQ} - V_{TN}).$$

Then we neglecting v_{gs}^2 term hence it is small

Compared to $(V_{GSQ}-V_{TN})$
Then

$$i_D = I_{DQ} + i_d$$

1st DC component; 2nd term (AC component)

$\because I_{DQ} = K_n (V_{GSQ} - V_{TN})^2$

$\because i_d = 2K_n (V_{GSQ} - V_{TN}) v_{gs}$

Total Drain current can be separated ~~by~~ into a DC & AC component.

The AC (or) ac component of drain current is

$$i_d = 2K_n (V_{GSQ} - V_{TN}) v_{gs}$$

$$\frac{i_d}{v_{gs}} = 2K_n (V_{GSQ} - V_{TN})$$

$$g_m = \frac{\text{output current}}{\text{input Voltgs}} = \text{transconductance}$$

$$= \frac{i_d}{v_{gs}} = 2K_n (V_{GSQ} - V_{TN})$$

(or) we can derive transconductance can be obtained from the derivative

$$g_m = \left.\frac{\partial i_D}{\partial V_{GS}}\right|_{V_{DS} = \text{constant}} =$$

$$= \frac{\partial}{\partial v_{gs}} \left(2K_n (V_{GSQ} - V_{TN}) v_{gs} \right)$$

$$= 2K_n (V_{GSQ} - V_{TN})$$

$$g_m = 2\sqrt{K_n I_{DQ}}$$