# AFTER MID

13 MAR 2024

## # Carry Select Adder

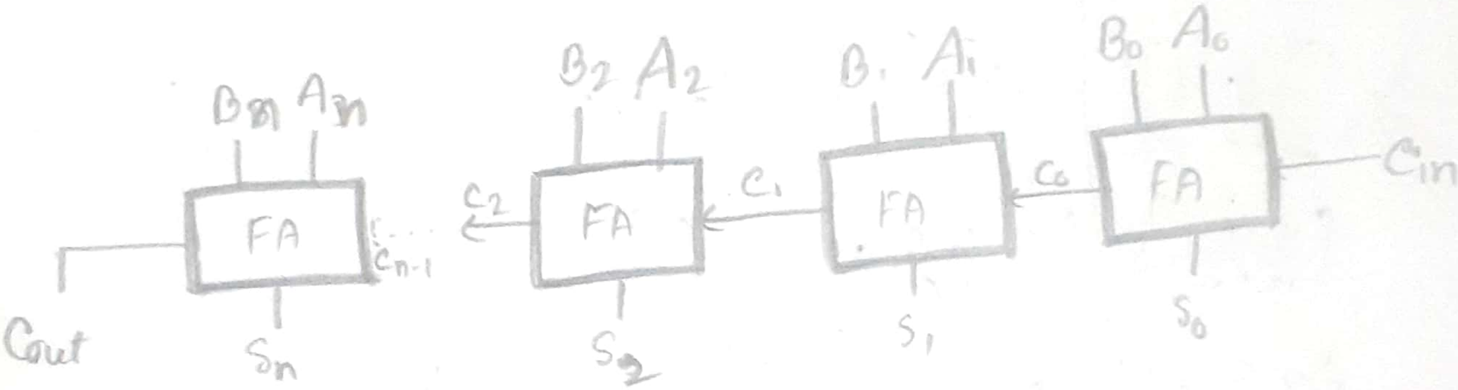
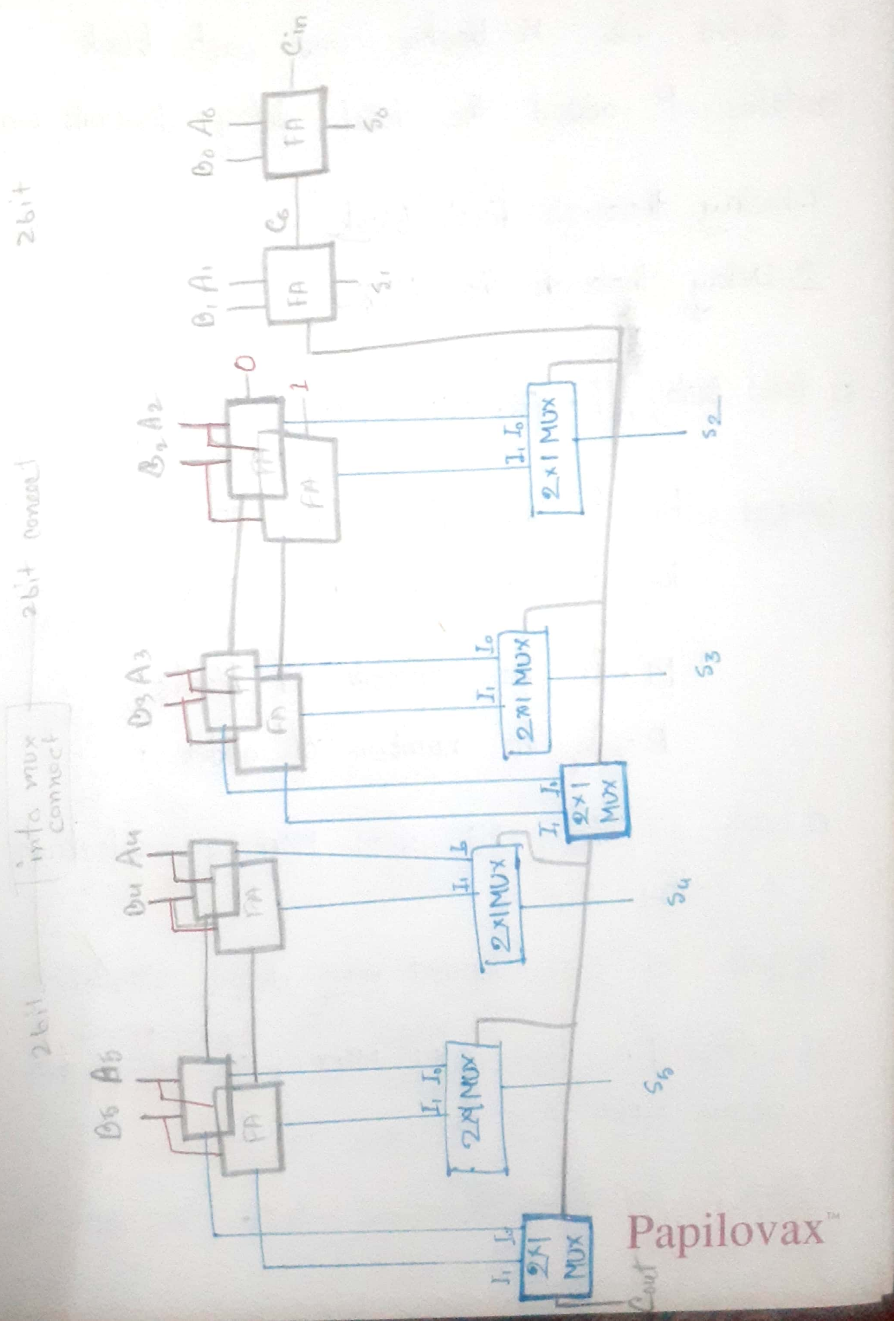



figure : n bit ripple carry adder.

if we conside a n-bit ripple carry adder and $k_1$ is the delay for a FA.

Total delay, $\boxed{T = nk_1}$ — ①

# 6-bit carry select adder.



If we consider a n-bit carry select adder is divided into M blocks and each block contains P added the total delay depends on –

1. Delay through first block
2. Delay through the MUX

so, total Delay, $\boxed{T = Pk_1 + (M-1)k_2}$ — ②

where, $k_1$ = is the delay for FA

$k_2$ = is the delay for MUX

M = is the number of blocks

P = is the number of adder.

- যেকটা FA delay হবে, একটা MUX এর selection এ Delay হবে।
- gate এর উপর depent করে delay হওয়াটা।
- একটা FA আর 2×1 MUX এর মধ্যে কোন delay বেশি হবে ?

Ans : 5 gate লাগে

□ যদি একটা একটা FA delay = 1 sec হয়।

$k_1 = 1$ sec , $n = 20$ bit .

(i) → total delay, $T = nk_1 = 20 \times 1 = 20$ delay

(ii) $T = 20 \geq 2 \times pk_1 + (M-1)\,k_2$

$= 2 \times 1 + (10-1) \cdot 1$ .

$= 2 + 9$ sec .

$= 11$ sec .

20 MAR, 2024

# Programm Logic Array (PLA)

AND-OR PLA

$F_1 = \bar{x}y + xyz + zx \quad = P_1 + P_2 + P_3$

$F_2 = xyz + \bar{x}\bar{y}z + \bar{x}zy \quad = P_2 + P_4 + P_5$

□ 1টা PLA তে 3টা input, 2টা output, 5টা Product আছে।

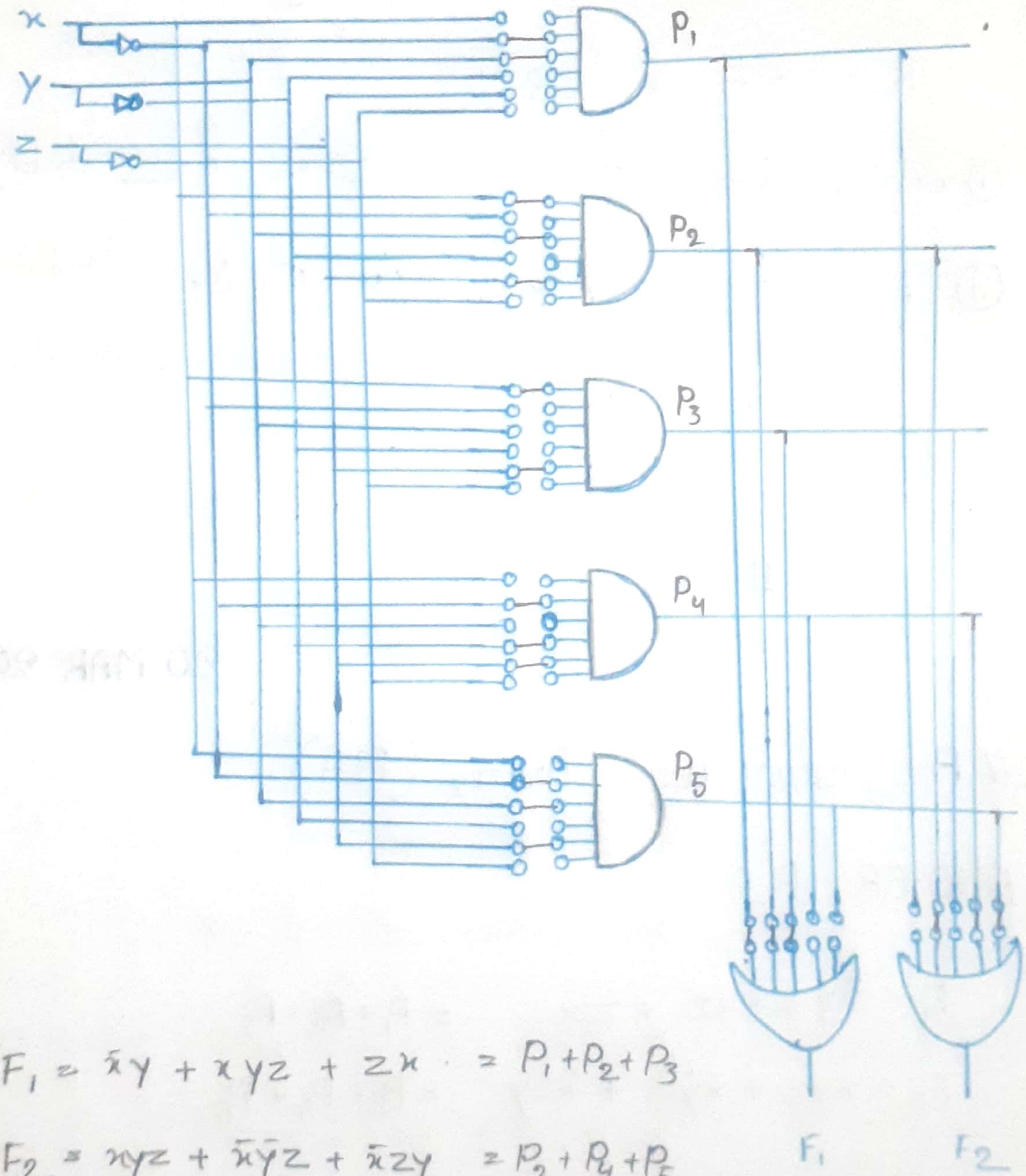
□ V = number of input

P = number of product

Z = number of output

□ size of PLA = V × P × Z

$= 3 \times 5 \times 2$




$$F_1 = \bar{x}y + xyz + zx = P_1 + P_2 + P_3$$

$$F_2 = xyz + \bar{x}\bar{y}z + \bar{x}zy = P_2 + P_4 + P_5.$$

□ NOR gate দিয়ে implement করতে চাইলে

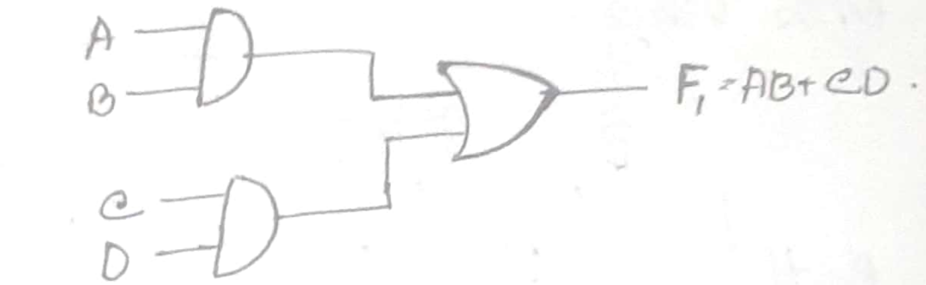
NMOS-এর input কে inverse করতে হবে.

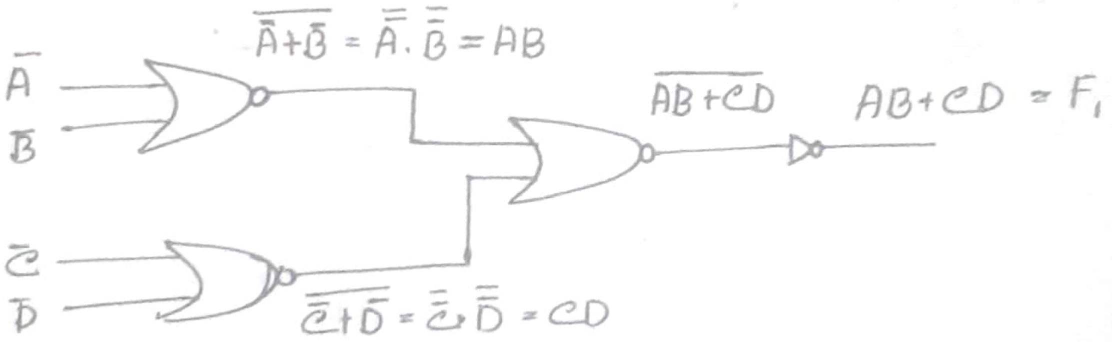
final output কে আবার inverse/বার/ [$\bar{A}$] হবে.

## # NOR - NOR

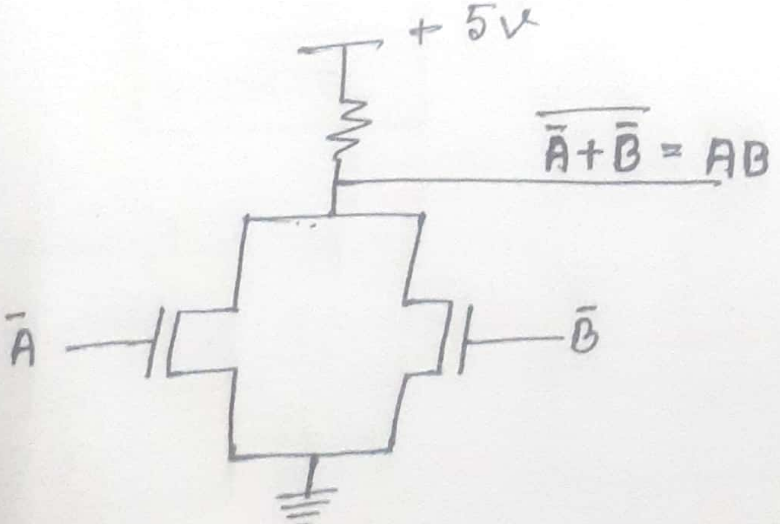
$F_1 = AB + CD$

circuit normal




using NOR gate with NMOS



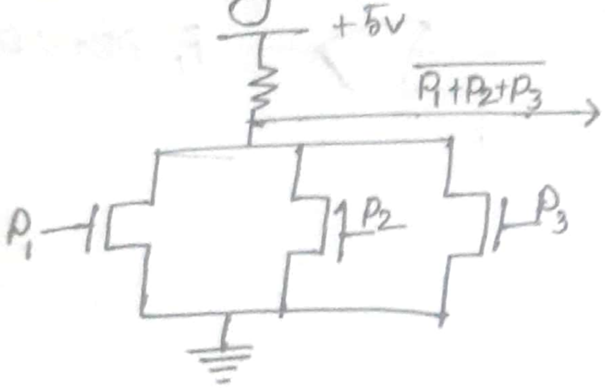
# NOR - NOR PLA

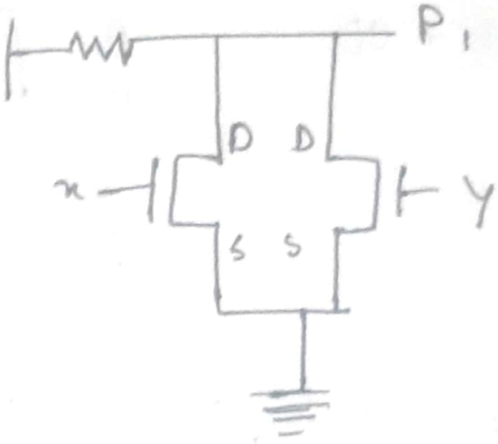
$F_1 = \bar{x}\bar{y} + x\bar{y}z + zx \quad = P_1 + P_2 + P_3$

$F_2 = x\bar{y}z + \bar{x}y + xy\bar{z} \quad = P_2 + P_4 + P_5$

size of PLA = $(3 \times 5 \times 2)$

NMOS using -

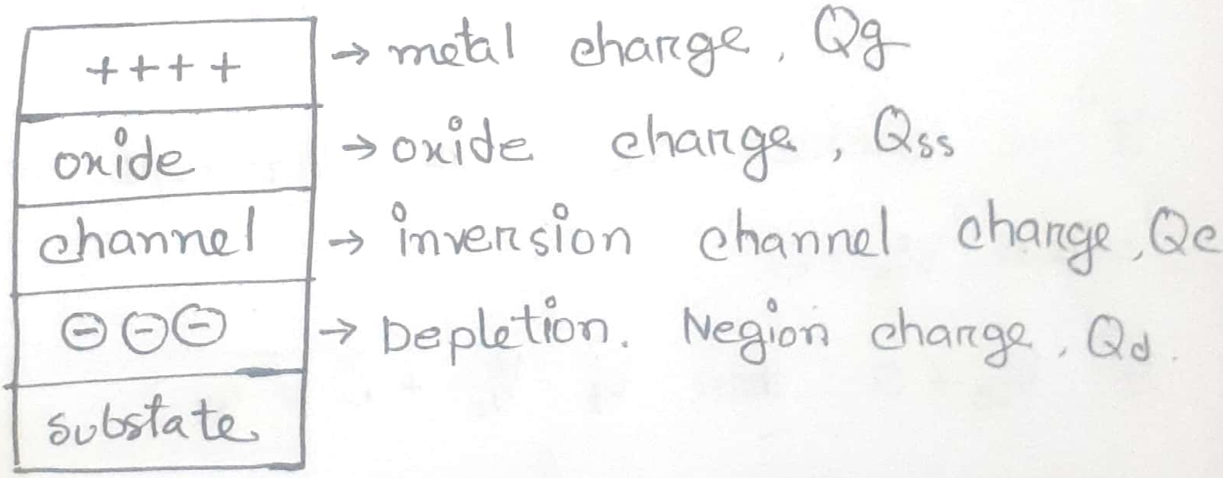


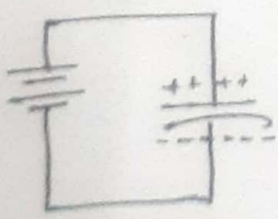
# Threshold voltage : threshold voltage is the minimum gate voltage that is needed to create a conducting path between Drain and Source.

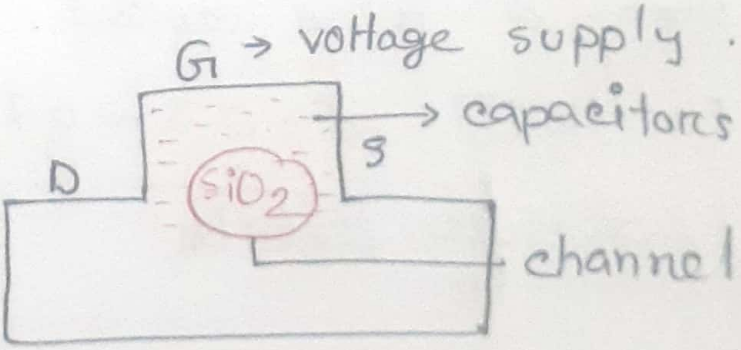
□ gate এর মধ্যে যে পরিমাণ voltage supply দিলে* Drain & Source
এর মধ্যে যে পরিমাণ conducting path তৈরি হয় তাকে
আমরা threshold voltage বলি।

- gate এ যে supply ওটা Drain & source এর
মধ্যে channel তৈরি করে।




capacitors, Cg



we can write, $Q_g + Q_{ss} = Q_c + Q_d$

$\therefore Q_g = Q_c + Q_d - Q_{ss}$

Threshold voltage, $V_t = \frac{Q_g}{C_g} = \frac{Q_c + Q_d - Q_{ss}}{C_g}$

where, $C_g$ is the gate capacitance

## # Body effect

- body terminal সবসময় source এর সাথে sort করা; sort / শর্ট করে থাকার কারণে এটার voltage সবসময় zero ই থাকবে। এটাকে Body effect বলে।

if we consider $V_{t_0}$ is the threshold voltage when, $V_{SB} = 0$

if $V_{SB} \neq 0$, then $V_t = V_{t_0} + \gamma \sqrt{V_{SB}}$

when $\gamma$ = is a constant.

For MOSFET, $\gamma = 0.3 \sim 0.7$

$$\gamma = \frac{t_{ox}}{\epsilon_{ox}} \sqrt{2q\epsilon_{si} N_A}$$

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where, $t_{ox}$ = thickness of $O_2$

$\epsilon_{ox}$ = Oxide Permitivite

$q$ = charge of an electron

$\epsilon_s$ = Permitivity of silicon

$N_A$ = Dopoing ~~Con~~centration.

$V_{SB} = 0$ হয় theshold থেকে থেকে ওটার equation বসবে

$V_{SB} \neq 0$ হয় তাহলে বুঝবে body effect আছে,
তখন ওটার equation বসাবে.

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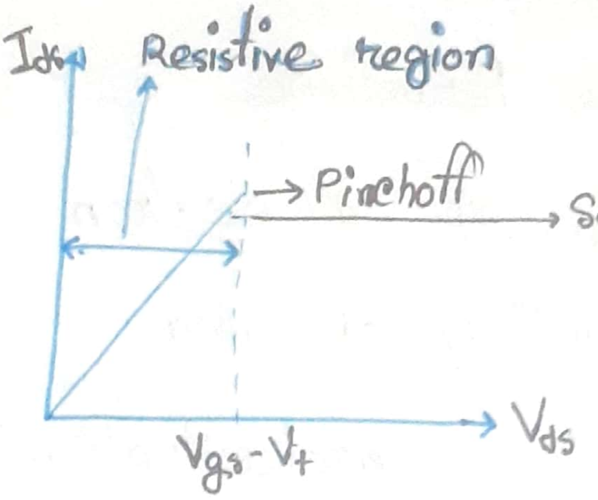
# I-V characteristics of MOSFET




- MOSFET টা কোন mode (Resistive / saturation region) এ তা বোঝার জন্য NMOS | PMOS calculated করা লাগবে।

## for NMOS

if $V_{ds} < V_{gs} - V_t$ $\boxed{\text{resistive Mode}}$

$$I_{ds} = \frac{\epsilon \mu_n}{D} \cdot \frac{W_n}{L_n} \left\{ (V_{gs} - V_t) V_{ds} - \frac{V_{ds}^2}{2} \right\}$$

if $V_{ds} \geq V_{gs} - V_t$ $\boxed{\text{saturation mode}}$

$$I_{ds} = \frac{\epsilon \mu_n}{2D} \cdot \frac{W_n}{L_n} \left\{ (V_{gs} - V_t)^2 \right\}$$

## For PMOS

### resistive Mode

if $V_{sd} < V_{sg} - V_t$

$$I_{sd} = \frac{\epsilon \mu_p}{D} \cdot \frac{W_p}{L_p} \left\{ (V_{sg} - V_t) V_{sd} - \frac{V_{sd}^2}{2} \right\}$$

### saturation Mode

if $V_{sd} \geq V_{sg} - V_t$

$$I_{sd} = \frac{\epsilon \mu_p}{2D} \cdot \frac{W_p}{L_p} \left\{ (V_{sg} - V_t)^2 \right\}$$

where, $D \rightarrow$ Depth of $O_2$

$\mu_n \rightarrow$ Mobility of Electron

$\mu_p \rightarrow$ Mobility of Hole

$\epsilon \rightarrow$ Permitivity

$W_p / W_n \rightarrow$ channel width

$L_p / L_n \rightarrow$ channel length

$V_{gs} = V_g - V_s$

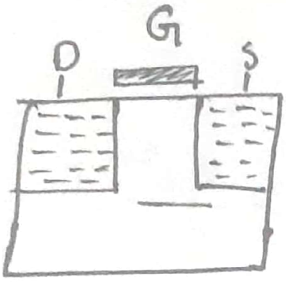
$V_g$ = gate voltage

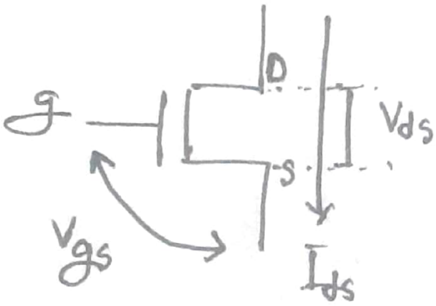
$V_s$ = source voltage



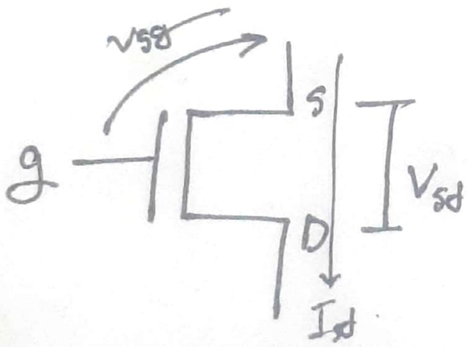
pinchoff = যেই point এর পরে voltage বাড়ালেও Ids বাড়ে না

MOSFET - একটি electronic switch.

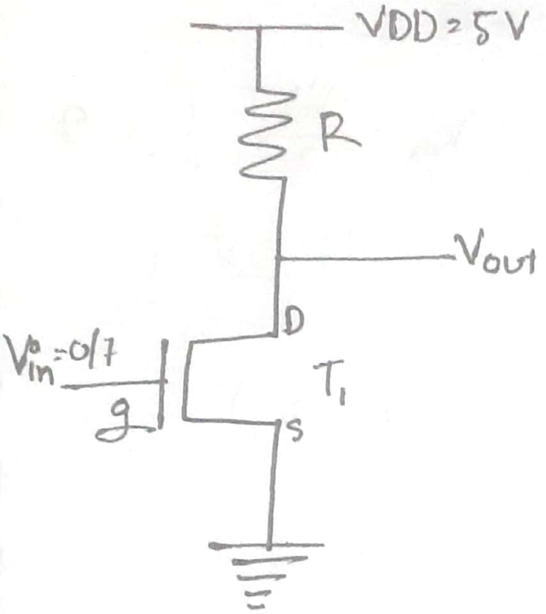



$V_{ds}$ → এখানে current flow হবে $I_{ds}$.



# NMOS inverter with Resistive load




let, $\epsilon \mu_n = 30\ \mu A/v^2$

$\frac{W}{L} = 1$

$V_t = 1V$

Solve - if $V_{in} = 0$, $T_1 \rightarrow$ OFF. $T_2 \rightarrow$ Always on.

$V_{out} = V_{DD} - V_R = VDD - V_{t2}$

[OFF থাকলে not need,
cz, $V_{in} = 0$ হলে current flow হবে না।]

if $\boxed{V_{in} = 5V}$, $T_1 \rightarrow$ ON.

$V_{out} = \frac{1}{3} \times V_t = 0.33\ V$.

$V_{ds} = V_d - V_s = \underbrace{0.33}_{\text{Vout এ}} - \underbrace{0}_{\text{gnd এ connect}} = 0.33\ V$.

$V_{gs} = \underbrace{V_g}_{\text{এ vin supply হচ্ছে } \boxed{5V}} - V_s = 5 - 0 = 5V$

now, $V_{gs} - V_t = 5 - 1 = 4V$.

see, $V_{ds} < V_{gs} - V_t$ ;  $0.33v < 4v$

$T_1$ operates at resistive mode.

$$T_1 = I_{ds} = \frac{\epsilon \mu_n}{D} \cdot \frac{W_n}{L_n} \left\{ (V_{gs} - V_t) V_{ds} - \frac{V_{ds}^2}{2} \right\} = ?$$

here,

$\frac{\epsilon \mu_n}{D} = 30 \mu A/v^2$

$\frac{W_n}{L_n} = 1.$

$V_{gs} = 4v$

$V_t = 1v$

$V_{ds} = 0.33$

$$= 30 \times 1 \left\{ (5-1) \times 0.33 - \frac{(0.33)^2}{2} \right\}$$

$$= 30 \; (4 \times 0.33 - 0.05445)$$

$$= 30 \times 1.26555$$

$$= 37.96 \; \mu A$$

$$\therefore R = \frac{VDD - V_{out}}{I_{ds}}$$

$$= \frac{5 - 0.33}{37.96 \times 10^{-6}}$$

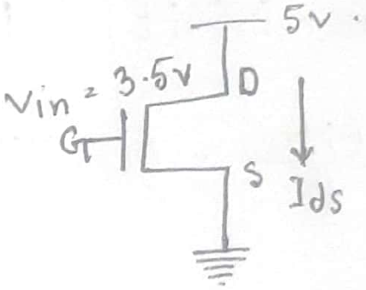
$$= 123056.65 \; \Omega$$

$$= 123 \; k\Omega.$$

Example : $VDD = 3v$, $\frac{\epsilon \mu_n}{D} = 50\ \mu A/v^2$, $\frac{W}{L} = 4$

$R = ?$ $V_t = 0.75v$, $V_{ds} = 0.2v$, $V_{in} = 3.5v$

Solve : ~~if $V_{in} = 0$~~, ~~$I_{ds}$ = OFF~~




~~if $V_{in} = 5v$~~, ~~$I_{ds}$ = ON~~

$V_{in} = 3.5V = V_g$

$V_{gs} = V_g - V_s = 3.5 - 0\ v = 3.5\ v$

$\therefore V_{gs} - V_t = (3.5 - 0.75)\ v = 2.75\ v$

see, $V_{ds} < V_{gs} - V_t$ ; $0.2v < 2.75v$

$I_{ds}$ operates at resistive Mode.

$$I_{ds} = \frac{\epsilon \mu_n}{D} \cdot \frac{W}{L} \left\{ (V_{gs} - V_t) V_{ds} - \frac{V_{ds}^2}{2} \right\}$$

$$= 50 \times 4 \left\{ (3.5 - 0.75)\, 0.2 - \frac{(0.2)^2}{2} \right\}$$

$$= 200\, (2.75 \times 0.2 - 0.02)$$

$$= 200 \times 0.53$$

$$= 106$$

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Problem: A NMOS inverter with Enhancement type load is biased at VDD = 3v,

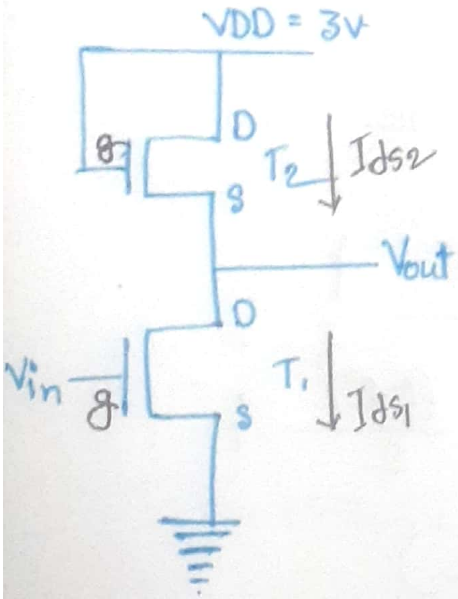
The MOSFET Parameters are $V_{t_1} = V_{t_2} = 0.4V$.

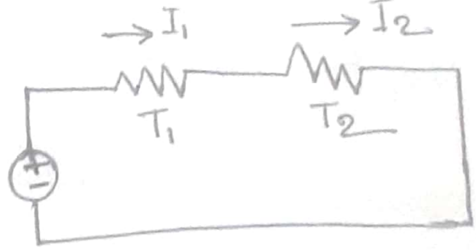
$\frac{\varepsilon \mu n}{D} = 60\ \mu A/v^2$, $\frac{w_1}{L_1} = 16$, $\frac{w_2}{L_2} = 2$.

Find the output voltage when (i) $V_{in} = 0v$,

(ii) $V_{in} = 2.6v$

Also calculate the Power dissipated in the inverter when $V_{in} = 2.6v$.




- input, output voltage বের করতে বললে connection কোনটা কোন mode আছে আগে জানা লাগবে। বের করা লাগবে

Solve = (i) $V_{in} = 0v$ হলে, $V_{out} = V_{DD} - V_{t_2}$

$T_1$ = off

$T_2$ = always on

$= 3 - 0.4 = 2.6\ V$

(ii) $V_{in} = 2.6\ v$ হলে, $V_{ds} = V_d - V_s = V_{out} - V_s$

$\Rightarrow V_{ds} = V_{out} - 0$.

$V_{out} = V_{ds}$

Power dissipated -

$T_1$

$V_{ds} = ?$

$V_{gs} = 2.6\ V$

$V_{t_1} = 0.4\ V$

$V_{gs} - V_{t_1} = 2.2\ V$

$T_2$

$V_{ds} = \cancel{V_{DD}} = \cancel{V_{DS}}\ ?$

$V_{gs} = V_{DD} - V_{out}$

$= 3 - V_{out}$

$V_{t_2} = 0.4\ V.$

$V_{gs} - V_{t_2} = 3 - 0.4 = 2.6$

$V_{ds} < V_{gs} - V_{t_1}$ ; $V_{ds} < V_{gs} - V_{t_2}$

$\Rightarrow\ < 2.2$ $\quad \Rightarrow 3 < 2.6$

$\Rightarrow 3 > 2.6$

saturation Mode.

resistive mode, $T_1$.

now, $I_{ds1} = I_{ds2}$ $\qquad$ $V_{out} = V_{ds}$.

$$\Rightarrow \frac{\epsilon \mu_n}{D} \cdot \frac{W_1}{L_1} \left\{ (\underbrace{V_{gs}}_{\text{input}} - V_{t_1}) \underbrace{V_{ds}}_{\text{output}} - \frac{V_{ds}^2}{2} \right\}$$

$$= \frac{\epsilon \mu_n}{2D} \cdot \frac{W_2}{L_2} \cdot (V_{gs} - V_{t_2})^2$$

$$\Rightarrow 16 \left\{ (2.6 - 0.4) V_{ds} - \frac{V_{ds}^2}{2} \right\} = \frac{1}{\cancel{2}} \cdot \cancel{2} (3 - \underbrace{V_{out}}_{V_{ds}} - 0.4)^2$$

$$\Rightarrow 16 \times \left\{ 2.2 V_{ds} - \frac{V_{ds}^2}{2} \right\} = (V_{ds} - 2.6)^2$$

$$\Rightarrow 16 \times \left( \frac{4.4 V_{ds} - V_{ds}^2}{2} \right) = V_{ds}^2 - 5.2 V_{ds} + 6.76$$

$$\Rightarrow 8 (4.4 V_{ds} - V_{ds}^2) = V_{ds}^2 - 5.2 V_{ds} + 6.76$$

$$\Rightarrow 35.2 V_{ds} - 8 V_{ds}^2 - V_{ds}^2 + 5.2 V_{ds} - 6.76 = 0$$

$$\Rightarrow -9 V_{ds}^2 + 40.4 V_{ds} - 6.76 = 0$$

$$\Rightarrow V_{ds}^2 - 4.489 V_{ds} + 0.75 = 0$$

$$\Rightarrow V_{ds}^2 - 2 \times 2.2445 \times V_{ds} + (2.2445)^2 - 4.288 = 0$$

$$\Rightarrow (V_{ds} - 2.2445)^2 - 4.288 = 0$$

$$\Rightarrow \sqrt{(V_{ds} - 2.2445)^2} = \sqrt{4.288}$$

$$\Rightarrow V_{ds} = 2.07 + 2.2445$$

$$\therefore V_{ds} = 4.315 \text{ v}$$

$$I_{ds2} = \frac{\epsilon \mu_n}{2D} \cdot \frac{W_2}{L_2} (V_{gs} - V_{t_2})^2$$

$$= \frac{60}{2} \times 2 (3 - 0.174 - 0.4)^2$$

$$= 353 \ \mu A$$

$\therefore$ $P = VI$

$$= 3 \times I_{ds}$$

$$= 3 \times 353 \times 10^{-6} \ . \ N$$

$$= 0.001059 \ N.$$

Problem: $VDD = 5v$, $V_{t1} = V_{t2} = 0.8\ v$.

$\frac{\epsilon M_n}{D} = 35\ MA / v^2$, $V_o = 0.1\ V$, $V_{in} = 4.2\ v$.

$\frac{W_1/L_1}{W_2/L_2} = ?$ $P = ?$

Solve: if $V_o = 0\ V$, $T_1 = off$, $T_2 \rightarrow$ always on

$V_{to} = 1V$.

$\gamma = 0.5$

$V_{out} = V_{DD} - V_{t2}$

$= V_{DD} - (V_{to} + \gamma\sqrt{V_{SB}})$

$\Rightarrow V_{out} = 5 - (1 + 0.5\sqrt{V_{out}})$

$\Rightarrow V_{out} = 4 \mp 0.5\sqrt{V_{out}}$

$\Rightarrow 2V_{out} = 8 \mp 0.5 \times 2\sqrt{V_{out}}$

$\Rightarrow 2V_{out} = 8 \mp 1\sqrt{V_{out}}$

$\Rightarrow \sqrt{V_{out}} = 8 - 2V_{out}$

$\Rightarrow V_{out} = 64 - 32V_{out} + 4V_{out}^2$

$\Rightarrow 4V_{out}^2 - 33V_{out} + 64 = 0$.

$\Rightarrow V_{out}^2 - 8.25V_{out} + 16 = 0$.

$\Rightarrow V_{out}^2 - 2 \times V_{out} \times 4.125 + (4.125)^2 - 1.015625 = 0$

$\Rightarrow (V_{out} - 4.125)^2 = 1.015625$

$\Rightarrow V_{out} = 1.015625 + 4125$

$\Rightarrow V_{out} = 5.140625$.

$\therefore V_{out} = 5.13\ v$ or $3.12\ v$.