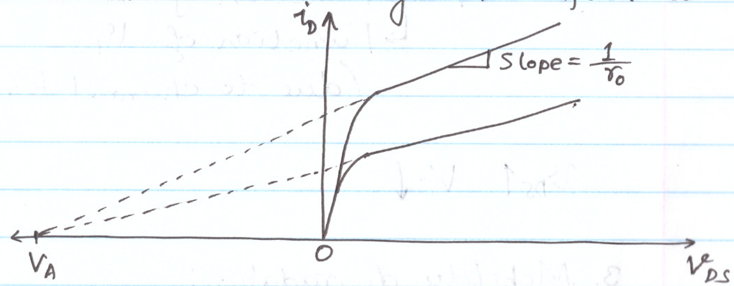
Advantages of CMOS: or MOSFETs

1. Compact
2. Low power
3. Robust
4. High density fabrication.

h. Non-ideal MOSFET characteristics:

i) V-I characteristics gets modified due to V_A.



In saturation region,

$$i_D = K_n\left[(v_{GS} - V_{Tn})^2 \cdot (1 + \lambda . v_{DS})\right]$$

where,

$\lambda \Rightarrow$ Channel length modulation parameter.

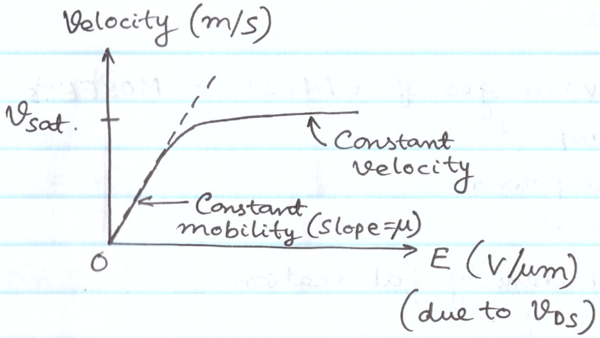
$$\therefore\ r_o = \frac{1}{\lambda . I_{Dq}} = \frac{V_A}{I_{Dq}} \quad \text{(O/P resistance)}$$

$$\therefore\ V_A = \frac{1}{\lambda}$$

ii) Short channel effects:

1. Velocity saturation (→ e^- or h^+)

$v_{DS}\uparrow$ $\quad E_{DS}\uparrow$ (horizontal) $\quad$ Velocity of carrier$\uparrow$ (upto a limit of v_{DS})



2. Threshold voltage variation:

V_T → Function of 'L' (directly proportional)
→ Function of v_{DS}
(due to channel length modulation)

$v_{DS} \uparrow$ $V_T \downarrow$

3. Mobility degradation:

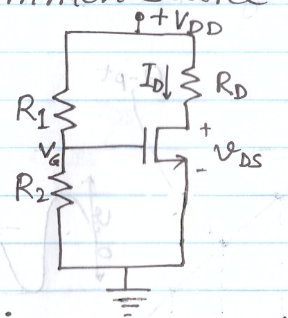
$v_{GS}\uparrow$ or v_{SG} $E_{vertical}\uparrow$ $\mu\downarrow$

(related to velocity saturation).

iii) Body effect & substrate biasing:

A single substrate is shared among multiple MOSFETs (eg. two n-ch). This causes threshold voltage variation in some MOSFETs as compared to others of same type.

i) Common source (DC) ckt:

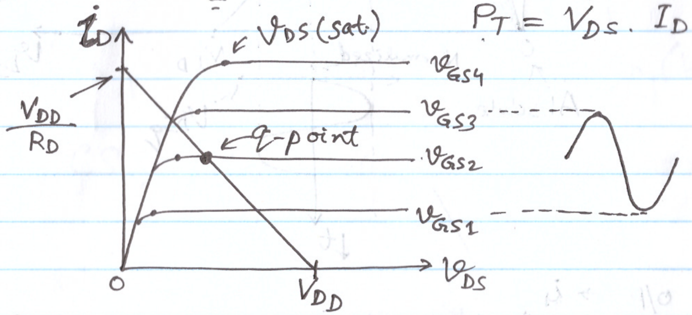


$$V_G = V_{GS} = \frac{R_2}{R_1+R_2} \cdot V_{DD}$$

$$I_D = K_n (V_{GS} - V_{Tn})^2$$
(Saturation)

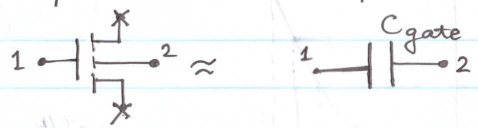
$$V_{DS} = V_{DD} - I_D \cdot R_D$$

$$P_T = V_{DS} \cdot I_D$$

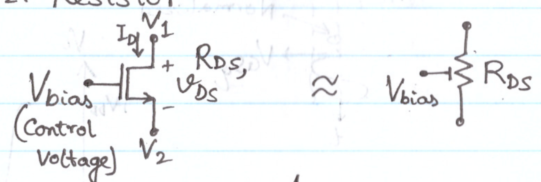


j) MOSFET as other electrical components:

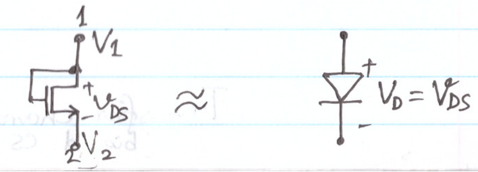
1. Capacitor : MOS capacitor

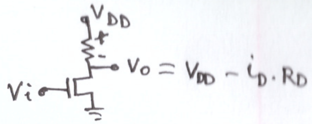


2. Resistor



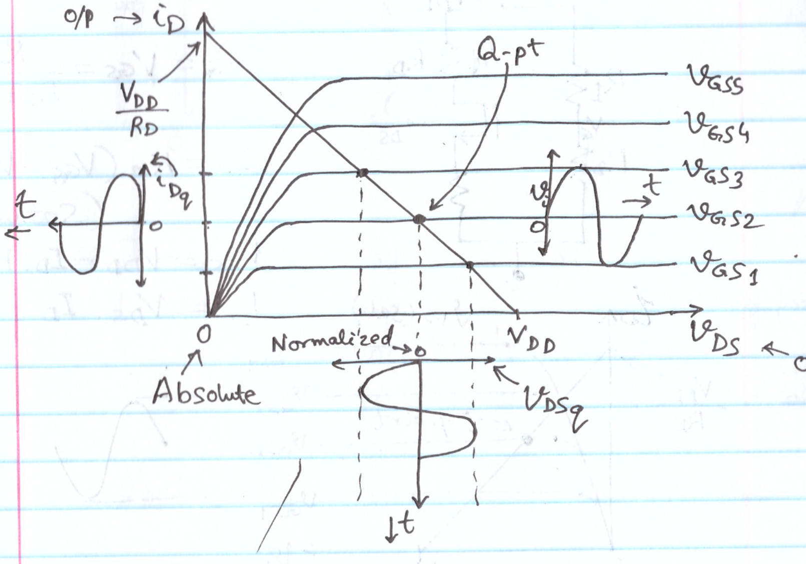
3. Diode
(V_t [= V_{GS} = V_T])

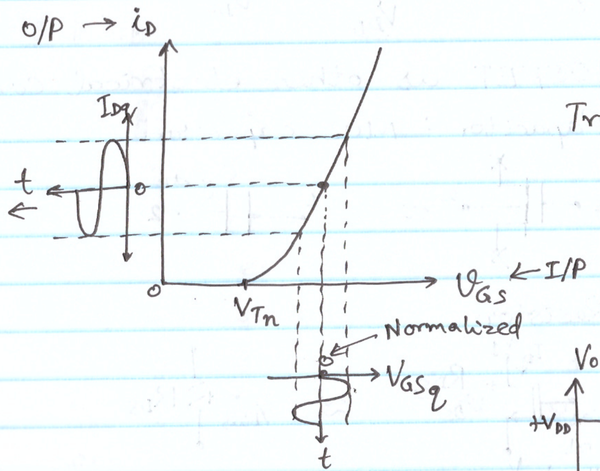




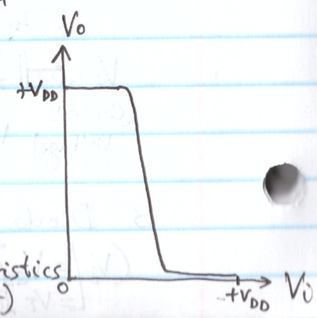
k. MOSFET amplifier: Common Source

→ n-ch



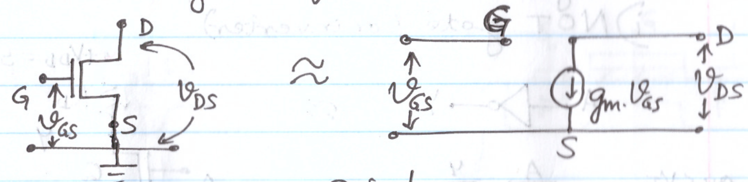


Transfer ch.
(n-ch e-mode MOSFET)



Transfer characteristics
(biased CS-ckt)

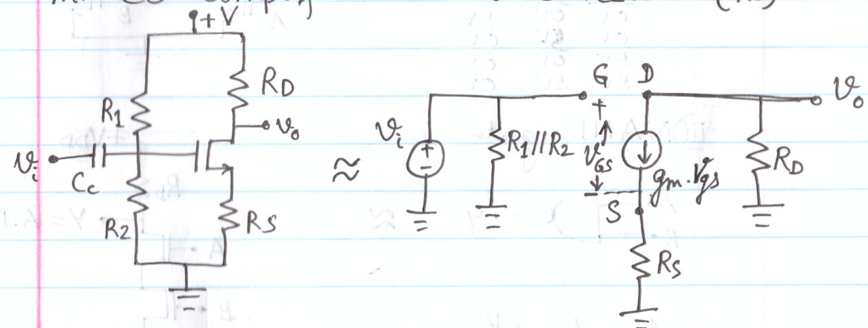
l. Small signal equivalent ckt: AC



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

$$g_m = 2\sqrt{K_n \cdot I_{Dq}} = 2 \cdot K_n (V_{GSq} - V_{Tn})$$

m. CS amplifier with S-resistor (R_S)



$$v_o = -g_m \cdot v_{GS} \cdot R_D$$

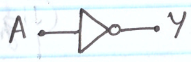
$$v_i = v_{gs} + (g_m \cdot v_{gs}) R_S = v_{gs}(1 + g_m \cdot R_S)$$

$$A_v = \frac{v_o}{v_i} = \frac{-g_m \cdot R_D}{1 + g_m \cdot R_S} \approx -\frac{R_D}{R_S}$$

($\because g_m$ is large)

m. Digital circuits using MOSFETs:

i) NOT gate (or inverter)



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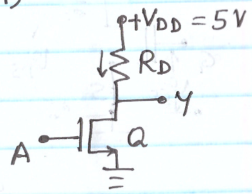
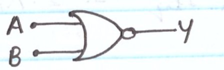


$0V < V_{Tn}$
$5V > V_{Tn}$

A	Y
0V	5V
5V	0V

$Y = \overline{A}$

ii) NOR gate:



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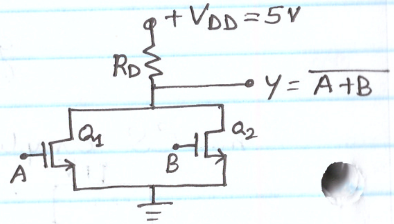
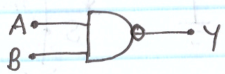


A	B	Y
0V	0V	5V
0V	5V	0V
5V	0V	0V
5V	5V	0V

iii) NAND gate:



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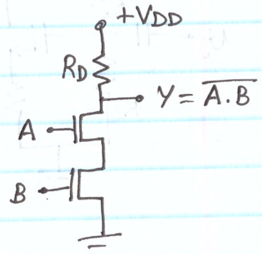


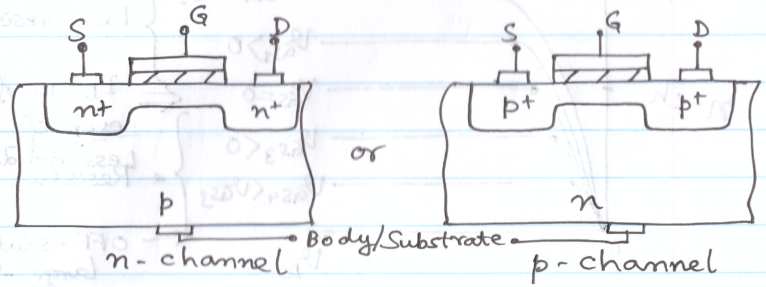
A	B	Y
0V	0V	5V
0V	5V	5V
5V	0V	5V
5V	5V	0V

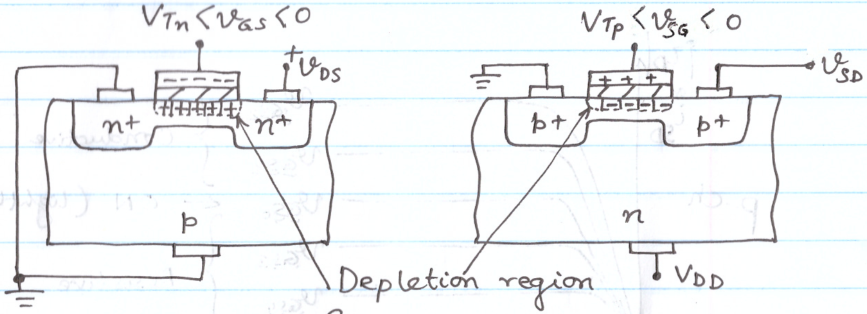
0V: Logic '0'

5V: Logic '1' (or $+V_{DD}$)

n. Depletion-mode MOSFETs (Normally-ON) : n & p channels.

Structure



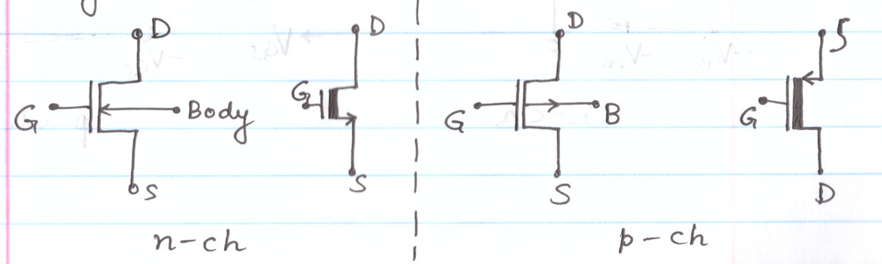


Depletion region forms due to inversion (blocks the channel)

At $v_{GS} \approx V_T$, the channel is completely blocked. → OFF

At $v_{GS} \approx 0$, " " " " ON.

Symbols of depletion-mode MOSFETs:



V-I characteristics (n-ch) & (p-ch)