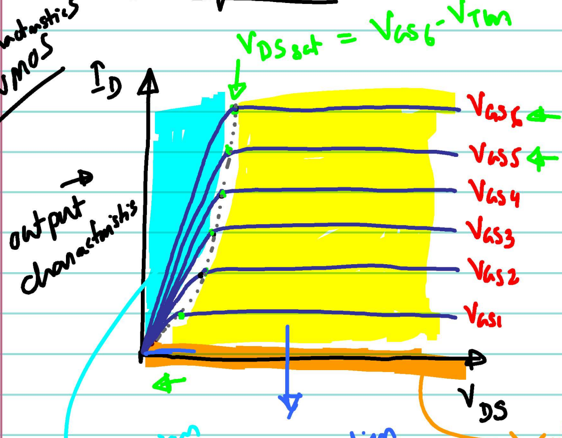
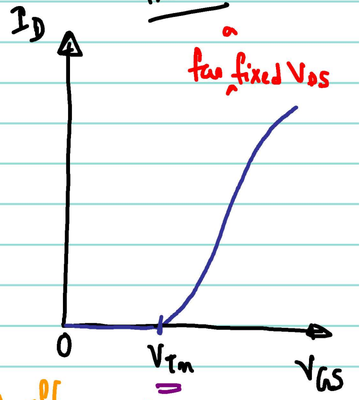
Lec-22

MOSFET Equations:

Characteristics NMOS



transfer characteristic
a few fixed V_{DS}



triode region or non-saturation region. (Switch)

Saturation Region (Amplifier)

cut-off (Switch)

triode region

Equations: $I_D = k_n[2(V_{GS}-V_{Tn})V_{DS} - V_{DS}^2]$; $V_{GS} > V_{Tn}$

$V_{DS} < V_{DS\text{-}sat}$.

Saturation region → $I_D = k_n(V_{GS}-V_{Tn})^2$; $V_{GS} > V_{Th}$

$V_{DS} > V_{DS\text{-}sat}$

NMOS

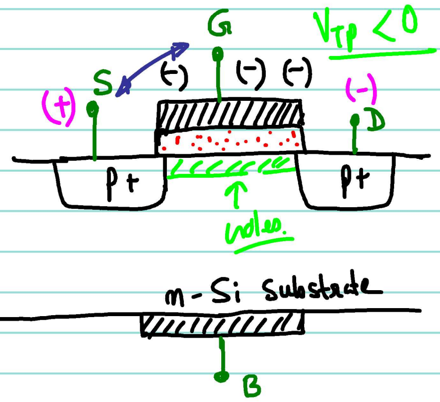
Conduction parameter → $k_n = \frac{1}{2}\frac{W}{L}\cdot \mu_n C_{ox}$; $k_n = \frac{1}{2}k'\cdot\frac{W}{L}$; $k' = \mu_n C_{ox}$

↳ mobility of electron

Gate capacitance per unit area. ↲ $C_{ox} = \frac{\epsilon_{ox}}{t_{ox}}$ ϵ_{ox} → Dielectric const of oxide (SiO_2)

t_{ox} → oxide thickness

P-Channel MOSFET or PMOS:



Changes required.

from

NMOS		PMOS
V_{GS}	→	V_{SG}
V_{DS}	→	V_{SD}
V_{Tn} (+)	→	V_{TP} (-)
k_n	→	k_p

p-ch.-MOSFET.

$k_p = 0.2\ mA/V^2$; $V_{TP} = -0.5V$, $V_{SG} = 2.08V$
Sat.

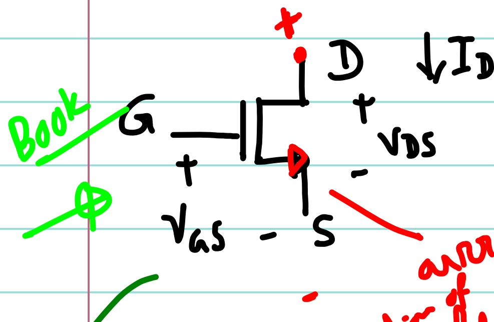
$I_D = k_p(V_{SG}+V_{TP})^2$

$= 0.2 \times (2.08 - 0.5)^2 \approx 0.5\ mA.$

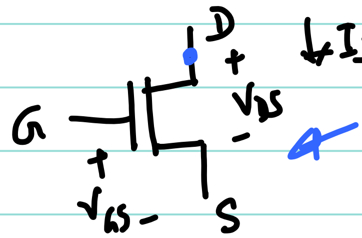
Circuit Symbol:

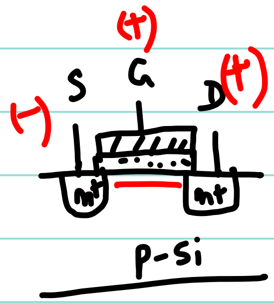
Symmetric device

n-channel MOSFET / NMOS.

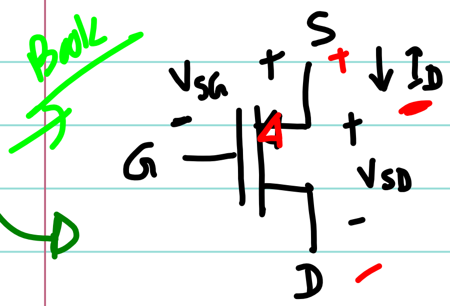


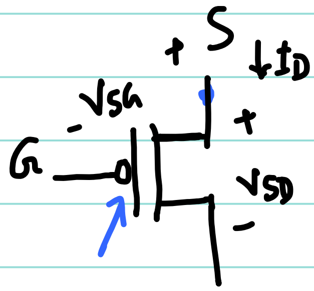
arrow indicates direction of flow of current.

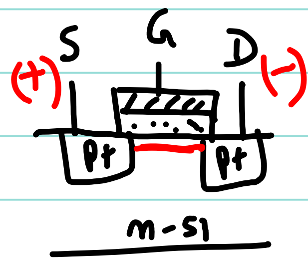




p-channel MOSFET / PMOS:

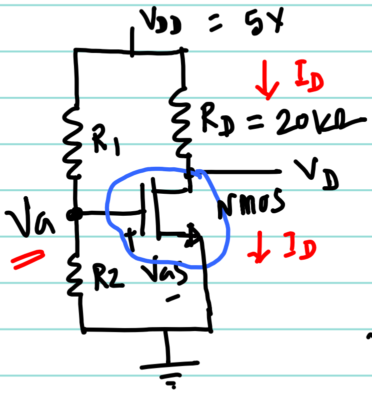






MOSFET DC Biasing:

(a) Fixed V_{GS} biasing:



Example:

→ $R_1 = 30k\Omega$, $R_2 = 20k\Omega$

$V_{Thn} = V_{Tn} = 1V$

$k_n = 0.1\ mA/V^2$

Find I_D?

$$V_G = V_{GS} = \frac{R_2}{R_1+R_2} \times V_{DD} = 2V > V_{Tn}$$

Transistor is ON.

Assume, MOSFET is in Saturation region.

$$I_D = k_n (V_{GS} - V_{Tn})^2 = 0.1\,(2-1)^2 = 0.1\ mA$$

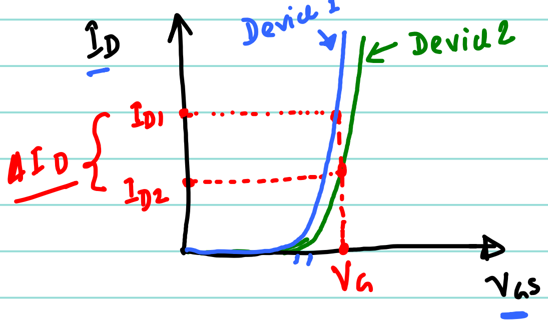
$$V_D = V_{DS} = V_{DD} - I_D R_D = 5 - 0.1 \times 20 = 3V > V_{DS\text{-}sat}$$

$$V_{DS\text{-}sat} = V_{GS} - V_{Tn} = 2-1 = 1\ V.$$

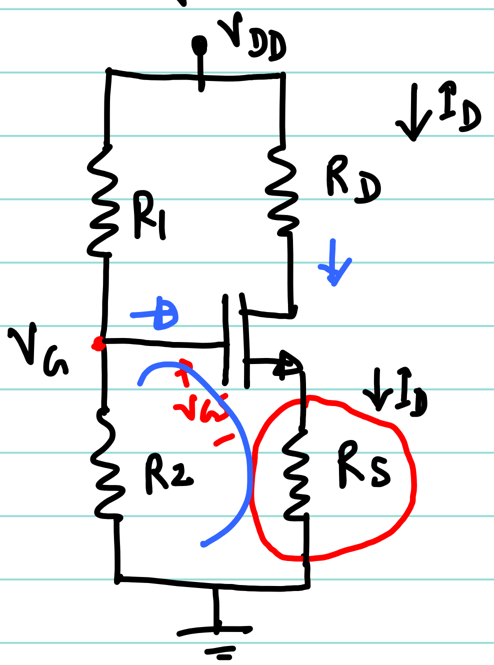
Saturation.

our assumption is correct.

Comment on the stability:



(b) Biasing with a Series resistance at source:



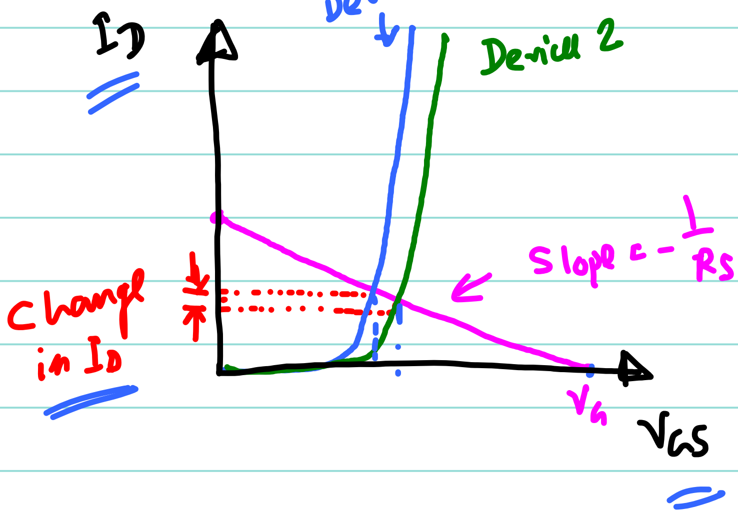
$\rightarrow V_G = V_{GS} + I_D R_S$

Fixed by R_1, R_2, V_{DD}

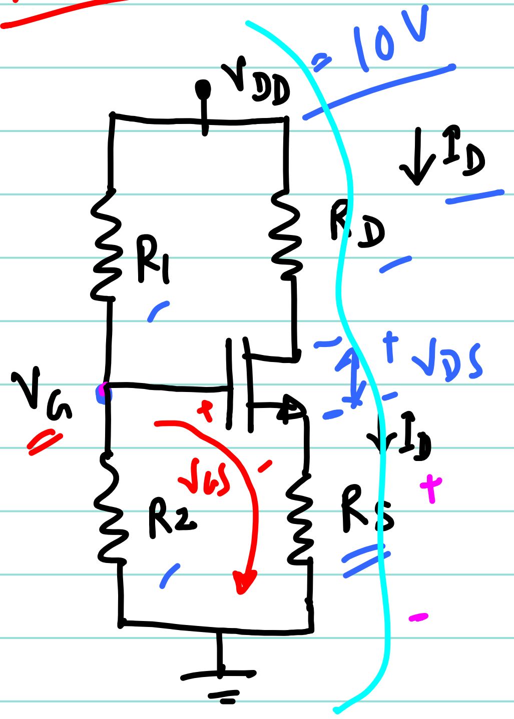
Negative Feedback by R_S

[for MOSFET, $I_G = 0$
$I_D = I_S$]

Stability:



Example:



$R_1 = R_2 = 10M\Omega$

$R_D = R_S = 6\,k\Omega$

$V_{Th} = 1V$, $k_n = 0.5\ mA/V^2$

Find I_D and V_{DS}.

$$V_G = V_{DD} \times \frac{R_2}{R_1+R_2} = 5V$$

$$V_G = V_{GS} + I_D R_S$$

$$V_{GS} = 5 - 6 I_D \quad ; \quad I_D \text{ is in } mA$$

Assuming saturation condition,

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

$$I_D = 0.5(5 - 6I_D - 1)^2$$

$$18 I_D^2 - 25 I_D + 9 = 0$$

$$I_D = \cancel{0.88}\ mA,\ 0.5\ mA.$$

$V_{GS} = 5 - 6I_D$

$= 5 - 6\times 0.5$

$V_{GS} = 2V.$

KVL Loop.

$$V_{DS} = V_{DD} - I_D(R_D + R_S)$$

$$V_{DS} = 4V > V_{DS\text{-}sat}.$$

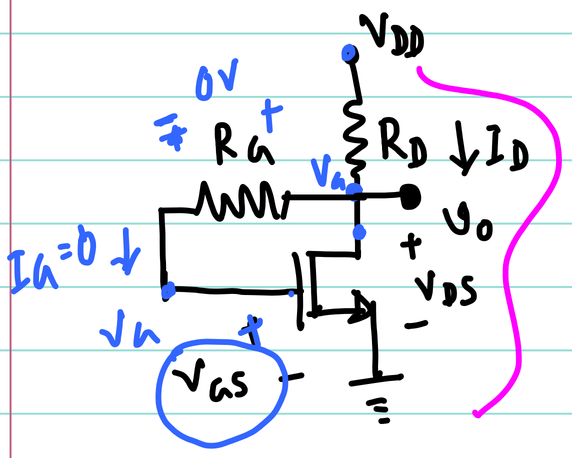
$V_{DS\text{-}sat} = V_{GS} - V_{Tn}$

$= 2 - 1$

$= 1V.$

↳ MOSFET is in saturation as assumed.

(C) Biasing using Drain to Gate Feedback Resistor:



$V_{GS} = V_{DS}$; $V_{DS\text{-}sat} = V_{GS} - V_{Th}$

$V_{DS} > V_{DS\text{-}sat}$

$\downarrow$

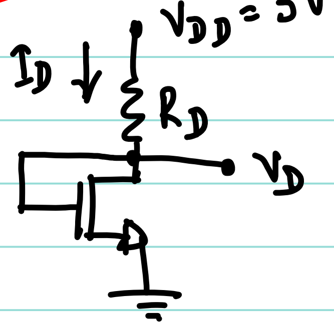
Saturation

$V_{DD} = I_D R_D + V_{DS}$

$V_{DD} = I_D R_D + V_{GS}$

Negative feedback, stability

Example:



$V_{Th} = 0.6V$, $\mu_n C_{ox} = 200\ \mu A/V^2$

$L = 0.8\ \mu m$, $W = 4\ \mu m$

$I_D = 80\ \mu A$

Find V_D.