2.5. The CMOS inverter
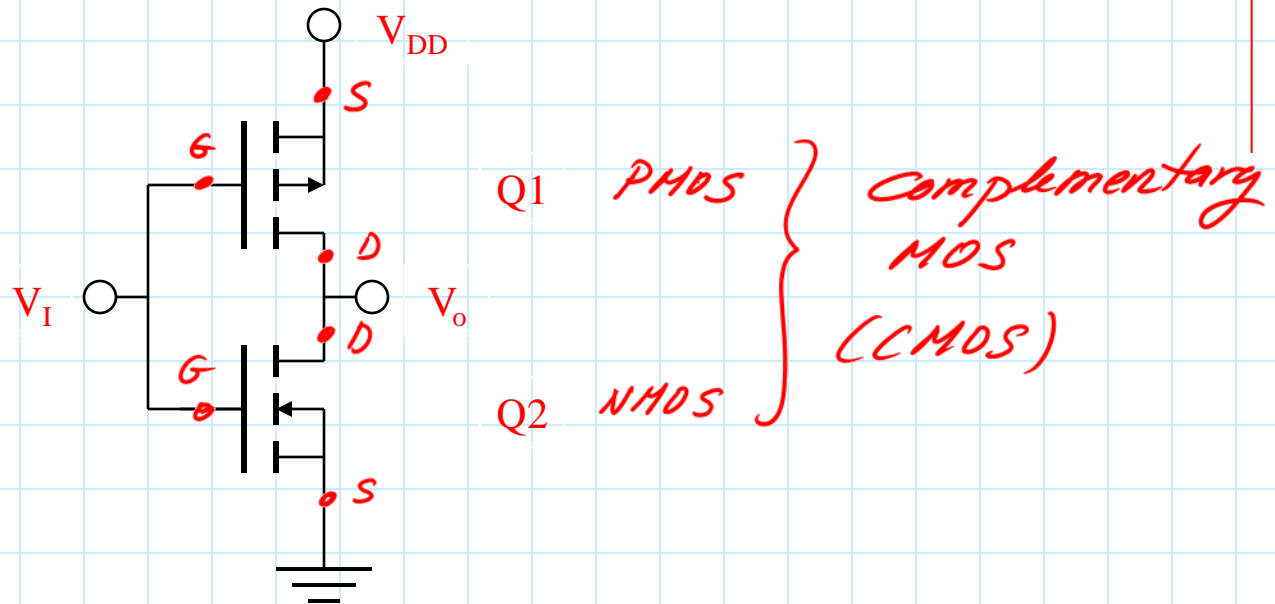

Digital input: $V_I = 0V = $ "0"; $V_I = V_{DD} = $ "1"

2.5. The CMOS inverter (2)

VDD

S
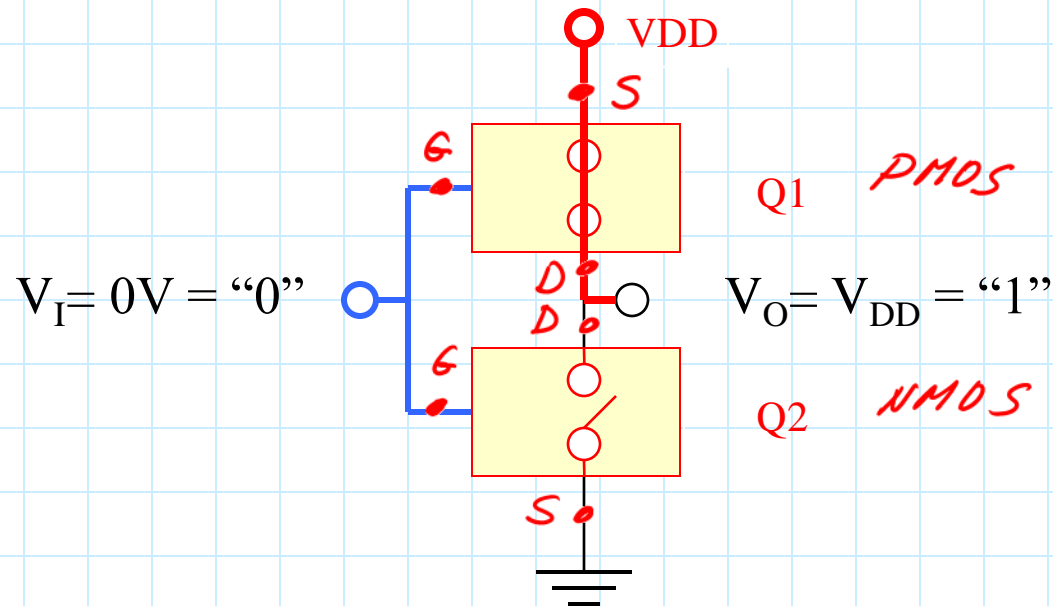
PMOS

Q1

D

$V_I = V_{DD} = "1"$ $V_O = 0V = "0"$

G

Q2   NMOS

S
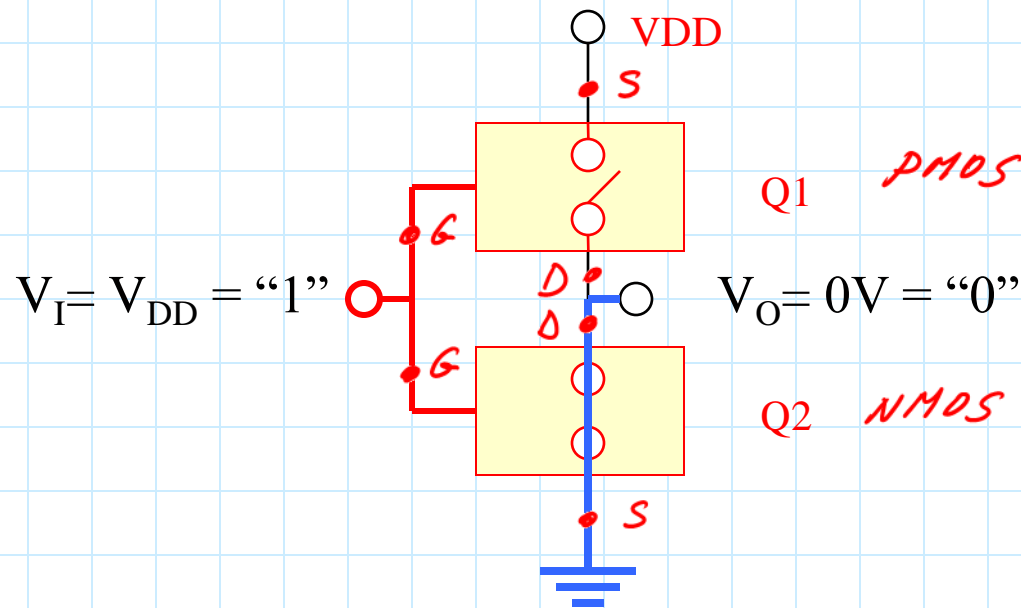
$V_{GS1} = V_{DD} - V_{DD} = 0V > -V_T \Rightarrow$ PMOS cut-off

$V_{GS2} = V_{DD} - 0V = V_{DD} > V_T \Rightarrow$ NMOS conducts

The static consumption is = 0

2.5. The CMOS inverter (3)

VDD

S

G
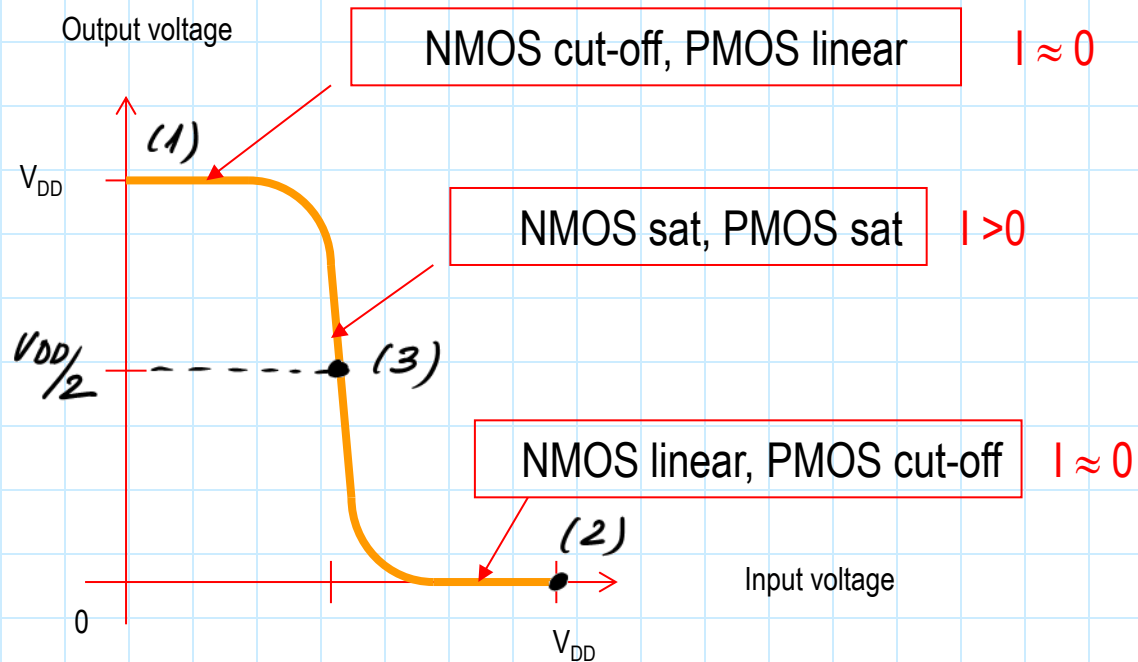
Q1   PMOS

$V_I = 0V = \text{"0"}$ D $V_O = V_{DD} = \text{"1"}$

D

G

Q2   NMOS

S

$V_{GS1} = 0V - V_{DD} = -V_{DD} < -V_T \Rightarrow$ PMOS conducs
$V_{GS2} = 0V - 0V = 0V < V_T \Rightarrow$ NMOS cut-off

The static consumption is = 0

2.5. The CMOS inverter (4)
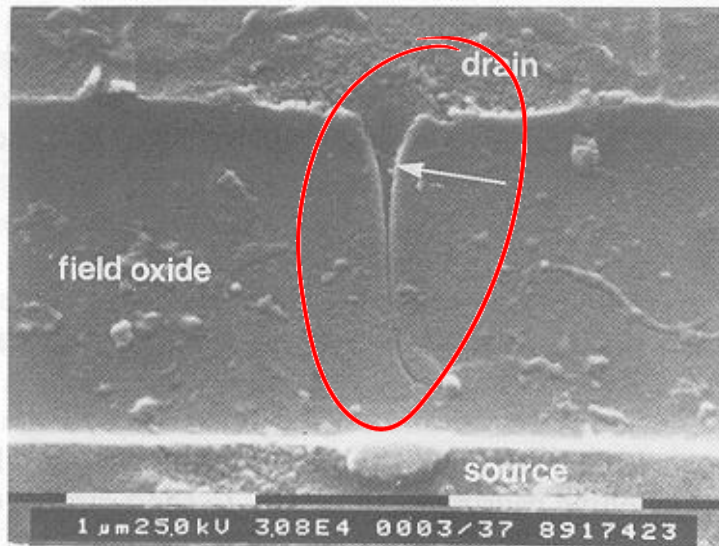
Transference curve:

NMOS cut-off, PMOS linear $I \approx 0$

NMOS sat, PMOS sat $I > 0$

NMOS linear, PMOS cut-off $I \approx 0$

Output voltage

V_{DD}

$V_{DD}/2$

(1)

(3)

(2)

0

V_{DD}

Input voltage

2.6. Protection of MOSFET transistors (1)

- MOSFET are sensitive to:

    - Overvoltages

    - Overcurrents

    - High electrostatic potentials

    - Radiations

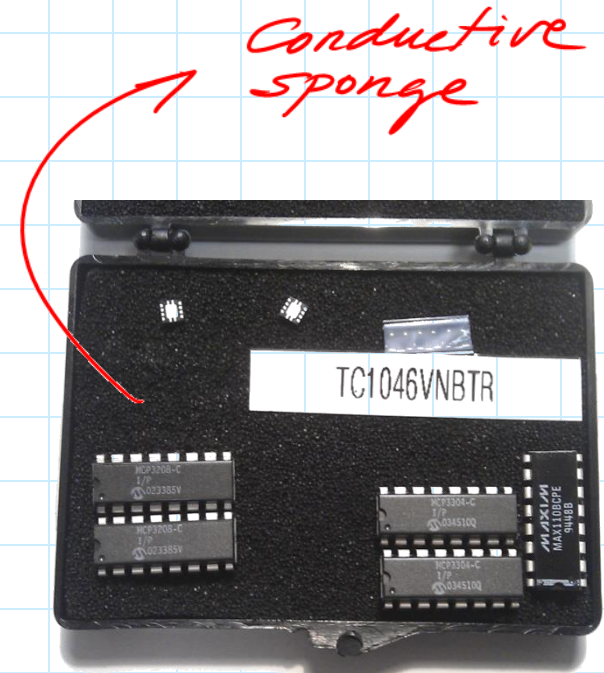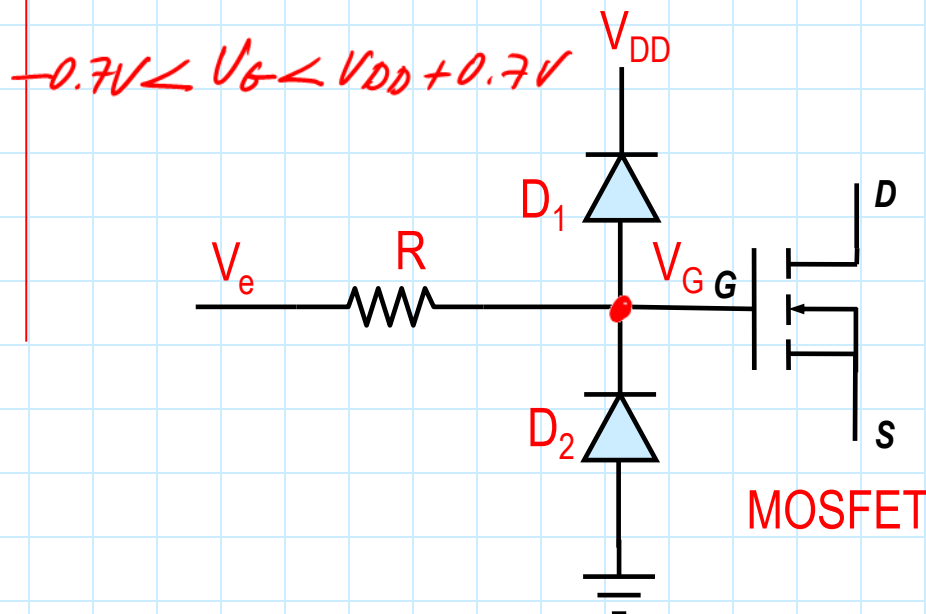- *thinox* layer: very thin, < 40Å in VLSI (1Å = 0.1 nm)

Thinox layer breakdown caused by electrostatic potentials at the gate

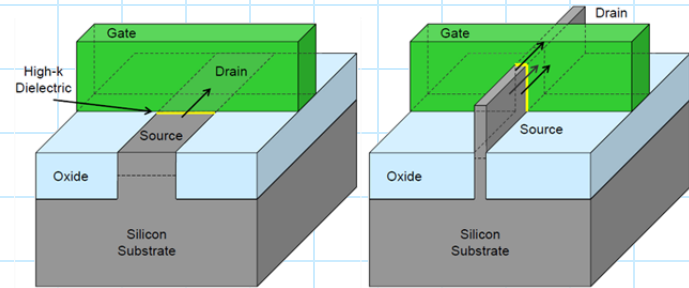# 2.6. Protection of MOSFET transistors (2)
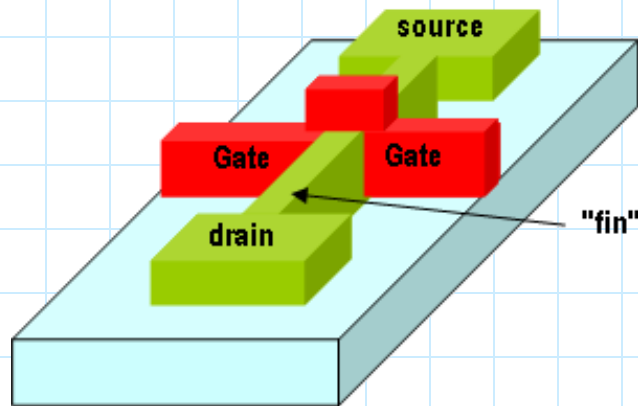
- Precautions when handling MOSFETs :

  * Storage in conducting material

  * Careful human manipulation $\rightarrow$ *Person manipulating connected to ground*

  * In operation, connect unused inputs to ground or   to V_{DD}.

- Clamping circuits

Conductive sponge

$-0.7V < V_G < V_{DD} + 0.7V$

V_{DD}

D_1

V_e R

V_G G

D

D_2

S

MOSFET

TC1046VNBTR

Latest developments : FinFET, tri-gate

Traditional   3D FinFET

- Higher speed
- Less consuption
- New material for isolators and semiconductors
  - Isolators: HfO_2, ZrO_2, Si_3N_4 *(Hafnium, Zirconium)...*
  - More mobility in channel, using different materials than Si: InGaAS, ... *(Indium, Gallium, Arsenic)*

2.7 Summary

- We have introduced the features that have made the MOSFET transistor the most important device of the digital age. We have assessed the importance and applications of this transistor.

- We have studied the internal functionement of enhancement MOSFETs, their structure, equations, curves and operating regions .

- We have learn how to solve DC circuits based on one or more MOSFET transistors.

- We know the switching mode of the MOSFETs, the states and the conditions of the transistor in this mode.

- We have introduced the main logic gates based on MOSFETs

- We have studied the basic techniques to protect these devices.