Lecture12: Physics of MOS transistors (4)

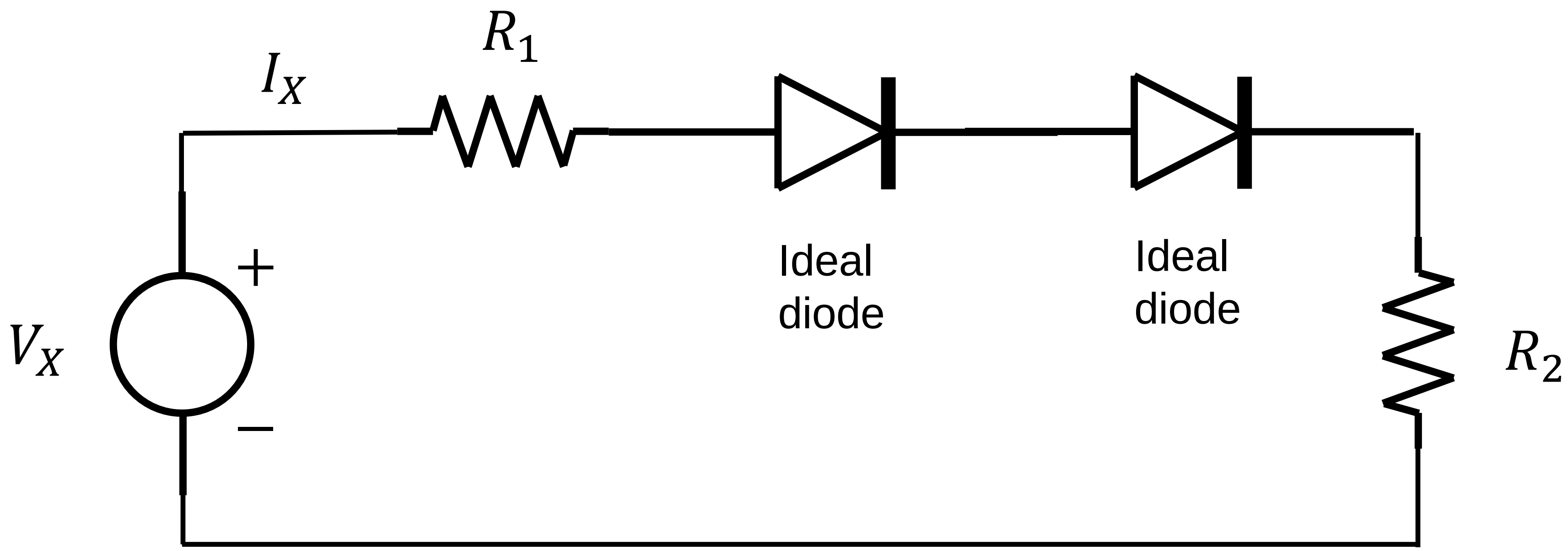
Sung-Min Hong (smhong@gist.ac.kr)

Semiconductor Device Simulation Lab.
School of Information and Communications
Gwangju Institute of Science and Technology

GIST Lecture on April 8, 2015 (Internal use only)

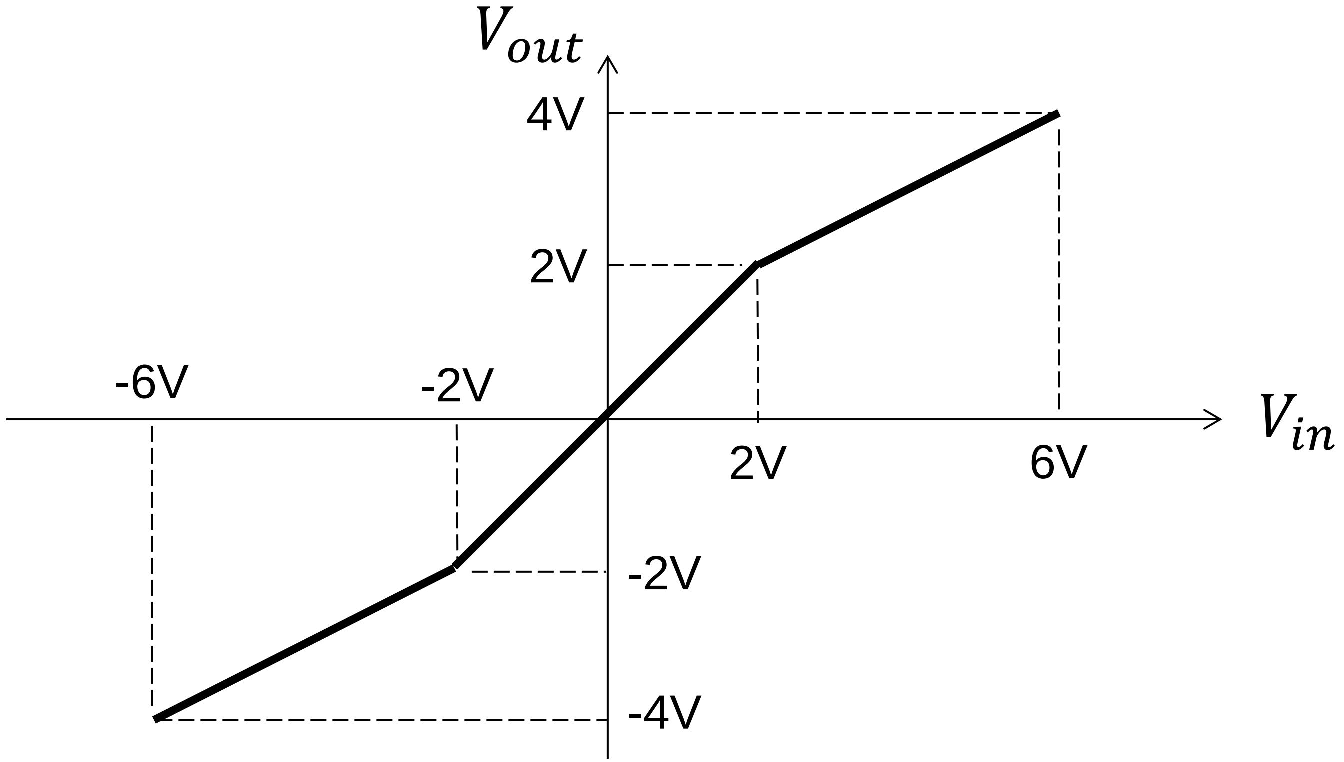
Homework#2-1

- Problem1:
  - Plot the IV characteristics.



Homework#2-2

- Problem1:
  – We wish to design a circuit that exhibits the input/output characteristic shown below. Using 1-kΩ resistors, ideal diodes, and other components, construct the circuit.



Homework#2-3

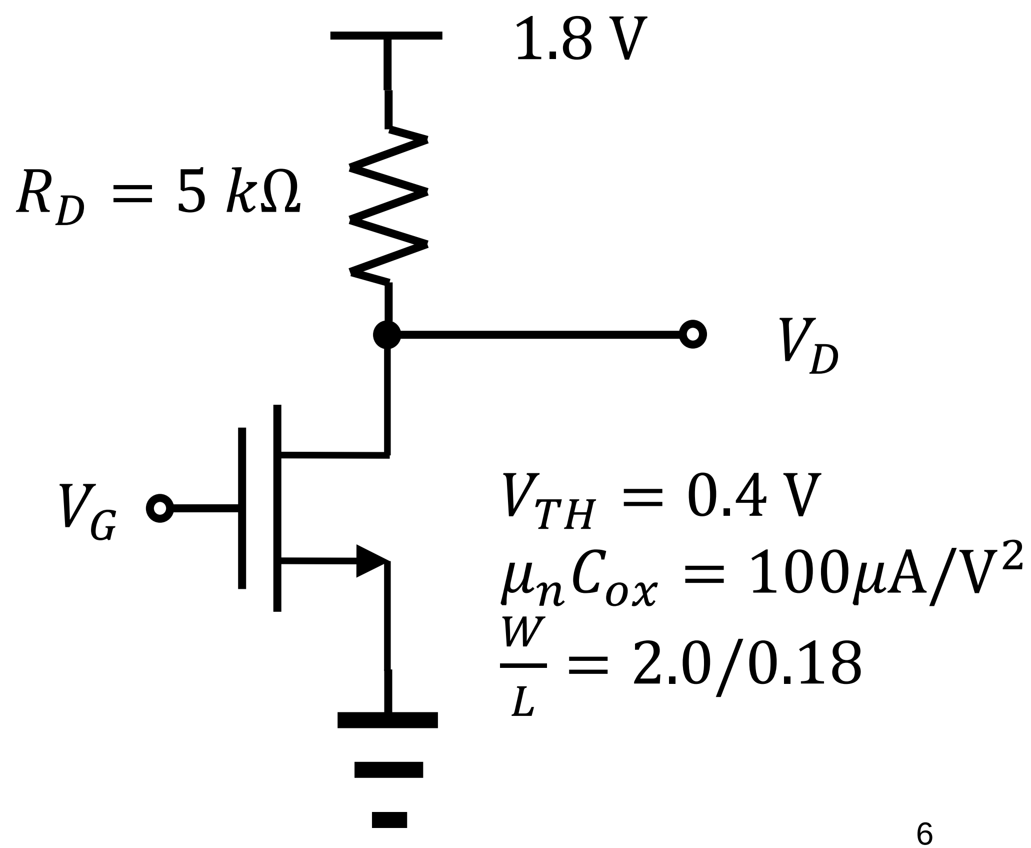
- Problem3:
  - We studied the depletion approximation for the pn junction.
  - In the MOS structure, we can also consider the depletion region in the p-type substrate, whose acceptor density is N_A.
  - When the electric field ***<u>in the oxide</u>*** is E_{ox}, calculate the length of the depletion region, W_{depl}.
  - Then, what is the potential difference between the interface and the substrate?
  - (Neglect the electrons in this problem.)

Homework#2-4

- Problem4:
  - Select one CMOS technology node. (It's up to you.)
  - Specify the following parameters:
    - Gate length
    - Threshold voltage
    - Oxide thickness
    - Operation voltage
    - (And more parameters are welcome.)
  - Explicitly show the reference. (URL, paper, book, etc)

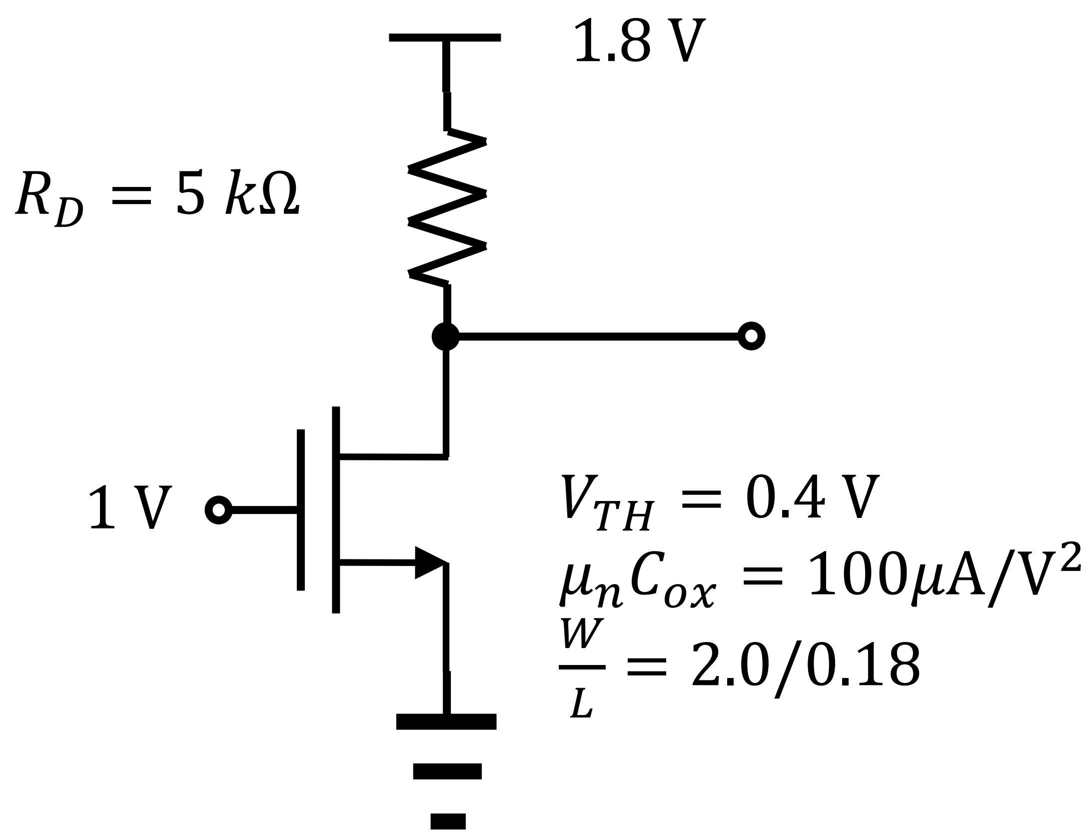
Homework#2-5

- Problem5:
  - Draw the V_D as a function of V_G. (0 V ~ 1.8 V)
  - No hand drawing.
  - Use a computer.
  - Any program is acceptable.



Example 6.6

- Assume the saturation region.
  - Then, the saturation current becomes $200\ \mu\text{A}$.



Long vs. short

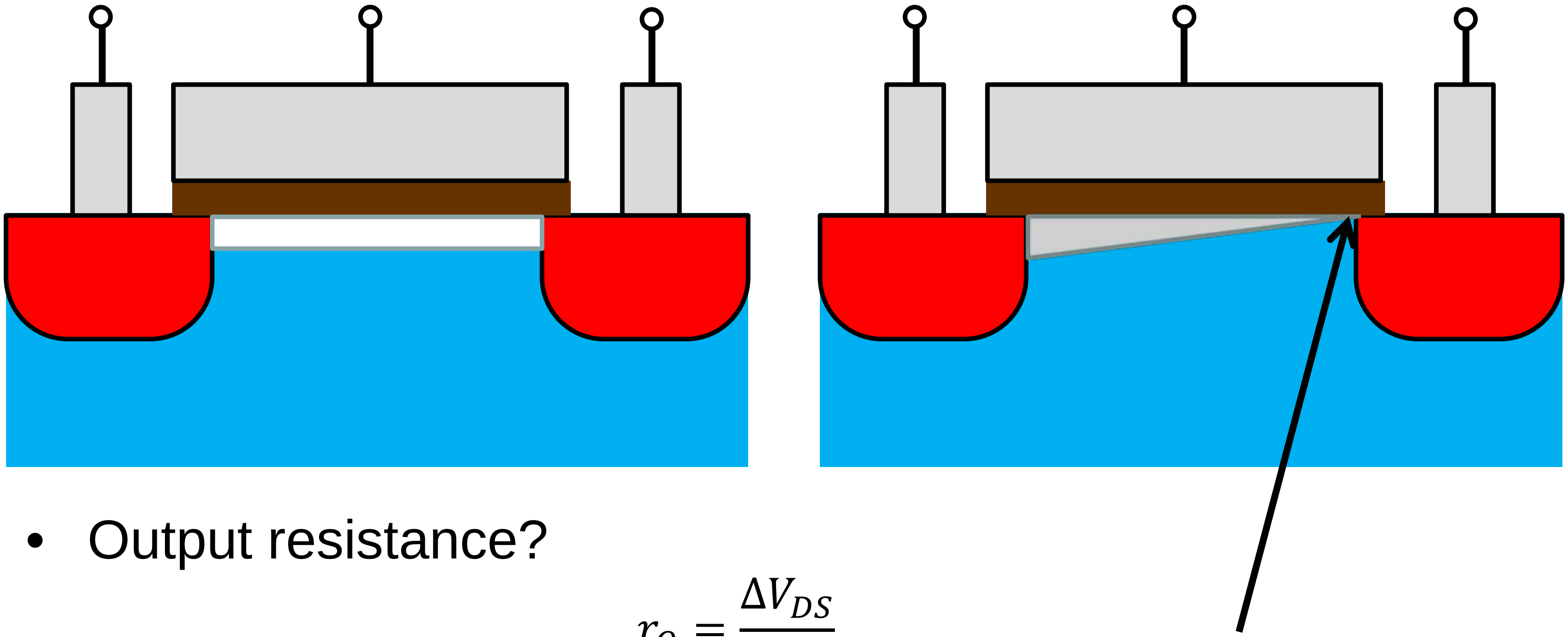
- Long channel device
  - "Long"?
  - It depends on the situation.

- Short channel device
  - "Short"?
  - Again, it depends on the situation.

- Channel-length modulation
- Velocity saturation
- Body effect

Channel length modulation

- Channel length modulation



- Output resistance?

$$r_O = \frac{\Delta V_{DS}}{\Delta I_D}$$

Recall that

$$Q = WC_{ox}[V_G - V(x) - V_{TH}]$$

MOS transconductance

- "conductance" of a simple resistor
  - It means $\frac{I}{V}$.
- "trans" + "conductance"
  - Between different terminals

$$g_m = \frac{\partial I_D}{\partial V_{GS}} \tag{6.44}$$

  - For the saturation region,

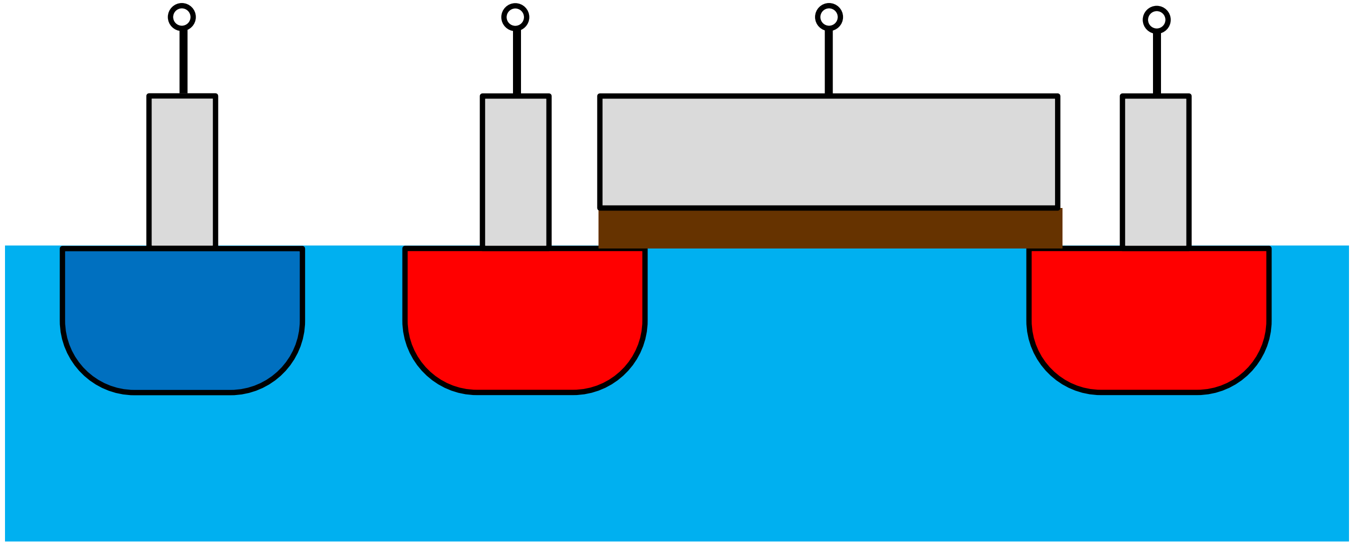
$$g_m = \mu_n C_{ox} \frac{W}{L}(V_{GS} - V_{TH})$$ ← Why?

$$g_m = \sqrt{2\mu_n C_{ox} \frac{W}{L} I_D}$$

$$g_m = \frac{2I_D}{V_{GS} - V_{TH}}$$

Body effect

- Actually, a MOSFET is a four-terminal device.
  - Substrate (or bulk)
  - Threshold voltage, V_{TH}, varies. (In which direction?)



Two more issues

- Velocity saturation
  - Once again, the current is given by

$$I = Q\ v \tag{6.4}$$

  - How did we have the saturation?

- Subthreshold conduction
  - Although not covered, it's the critical issue!

Summary

- MOS structure
  - Two different mechanisms to provide negative charges
  - Threshold voltage
  - Once the MOS is inverted, it is a capacitor.
- MOS IV
  - Current as a product of density and velocity
  - Triode region and saturation region
  - Concept of transconductance
  - Channel length modulation
  - Body effect
  - Velocity saturation
  - Subthreshold swing

Intermission

- Device vs. circuit
  - We are moving toward the circuit part!

(Google Images)