Lecture23:
Dynamic characteristics

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

Semiconductor Device Simulation Lab.
School of Electrical Engineering and Computer Science
Gwangju Institute of Science and Technology

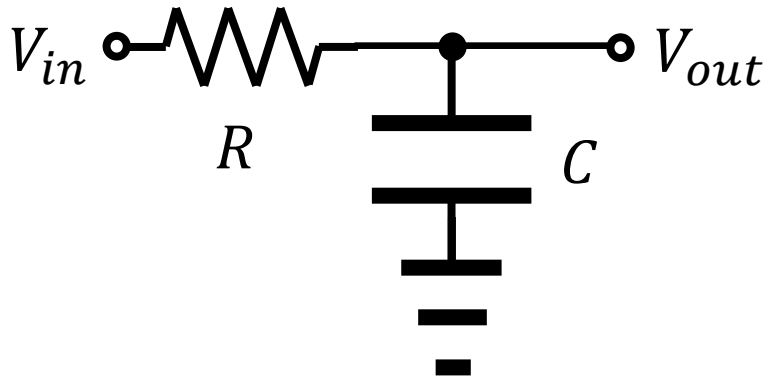
RC circuit

- Consider a serial RC circuit.
  - The KCL states

$$\frac{V_{out} - V_{in}}{R} + C\frac{dV_{out}}{dt} = 0$$

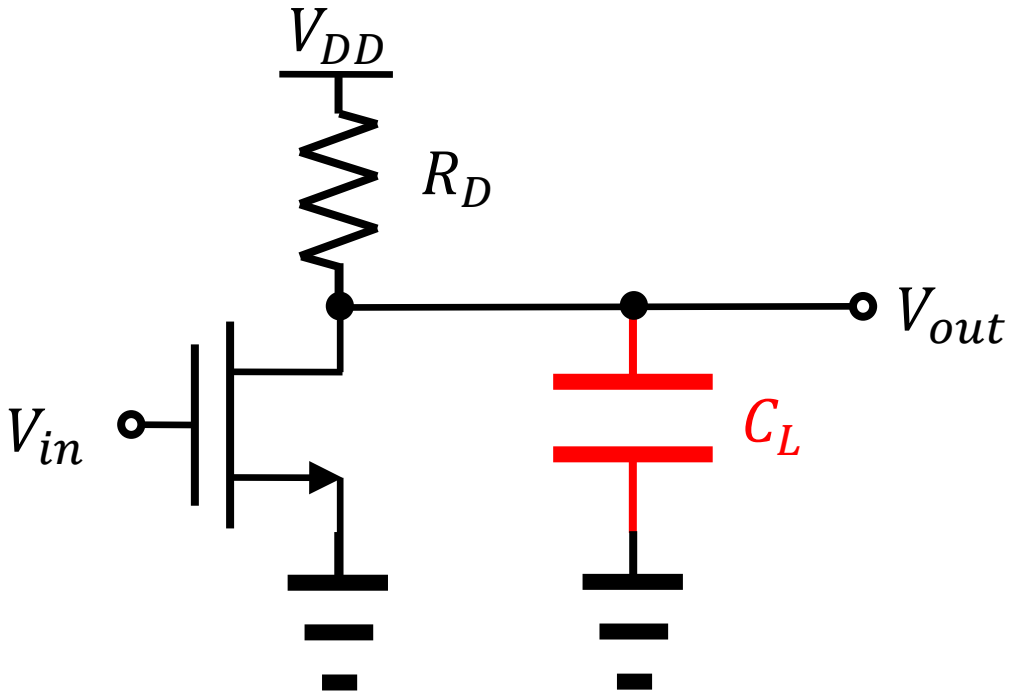
  - Assume a step-wise change of V_{in} at $t = 0$. It becomes V_{DD}.
  - Initial output voltage is V_0.
  - Its solution is given by

$$V_{out}(t) = V_{DD} + (V_0 - V_{DD})\exp\left(-\frac{t}{RC}\right)$$



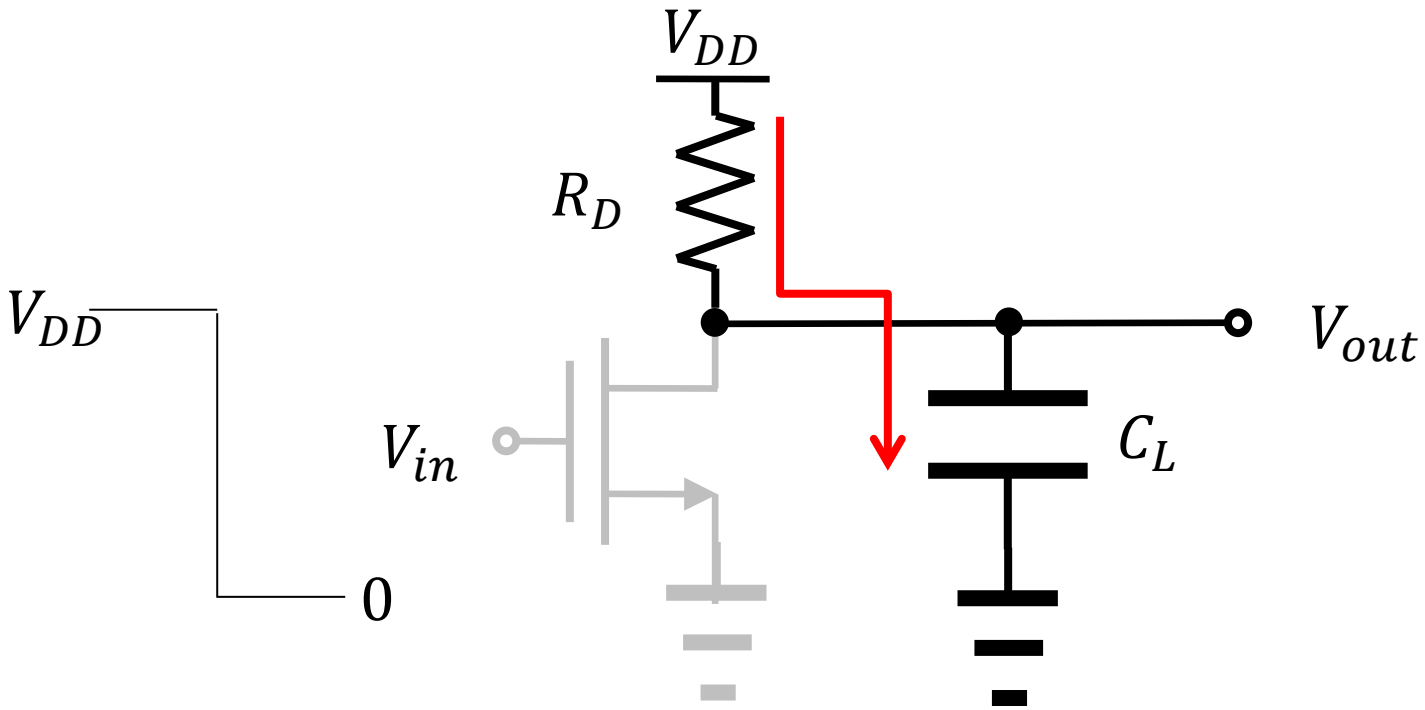
Speed of inverter (1/4)

- VTC merely describes the DC behavior.
  - Input voltages with different frequencies (1 kHz, 1 MHz, 1 GHz, …)
  - Time-dependent behavior



Speed of inverter (2/4)

- A rapid transition of V_{in} from V_{DD} to 0
  - The capacitor should be charged.



Speed of inverter (3/4)

- Simply, it is a RC circuit.
  - Then, the solution is simply

$$V_{out}(t) = V_{out}(0^-) + [V_{DD} - V_{out}(0^-)]\left(1 - \exp\frac{-t}{R_D C_L}\right)$$

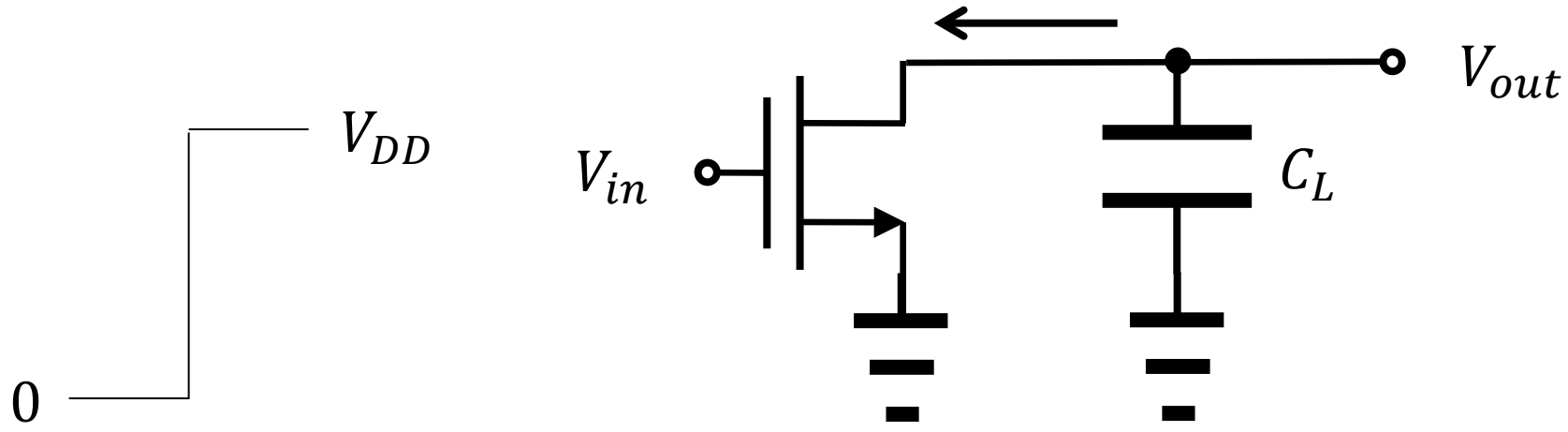
  - Since $\exp(-3) \approx 0.05$, after $3R_D C_L$, V_{out} reaches $0.95\ V_{DD}$.

  - Yes, it takes time to get the stable output voltage…
  - The delay restricts the maximum signal frequency.

Speed of inverter (4/4)

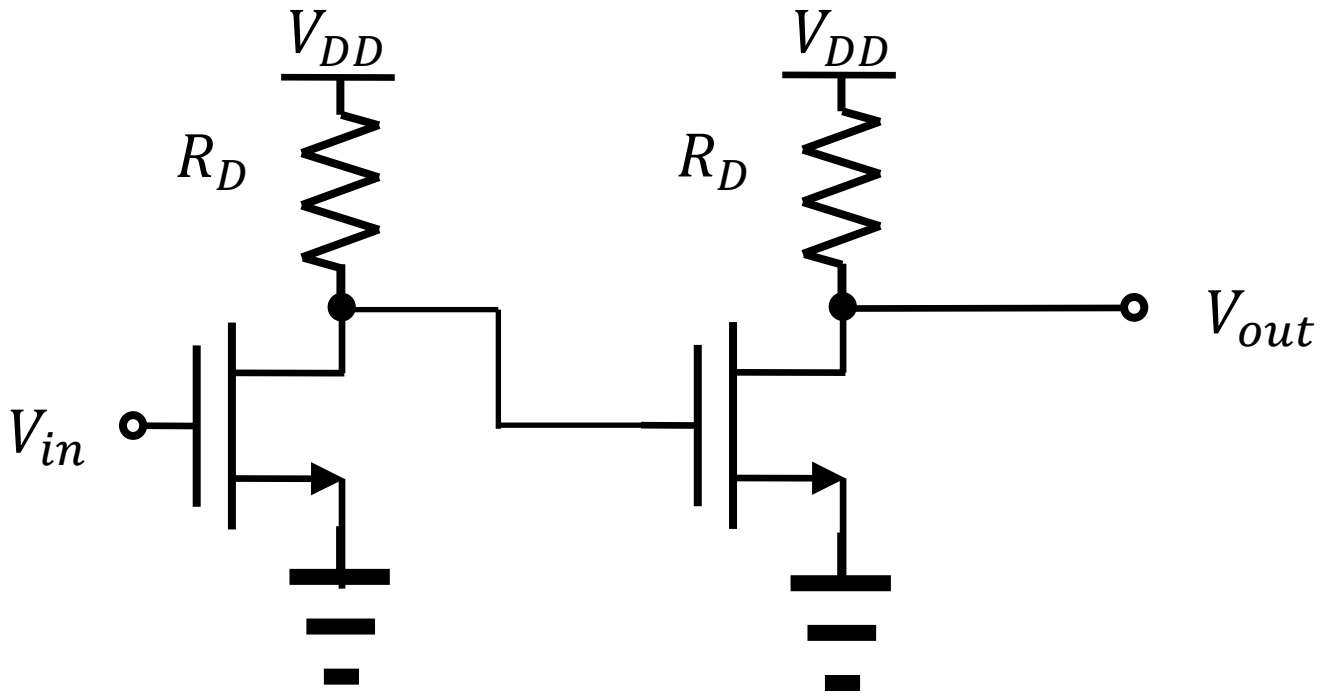
- A rapid transition of V_{in} from 0 to V_{DD} to 0
  - At the initial phase, the resistor does not conduct.
  - Also the MOSFET is operated in its saturation mode. Then,

$$I_{D,sat} + C_L \frac{dV_{out}}{dt} = 0$$



Origin of C_L?

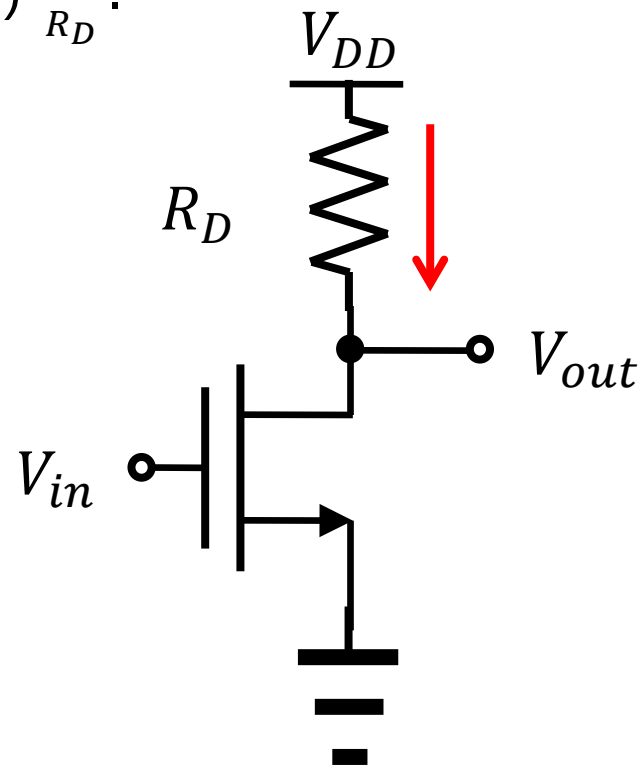
- Consider an inverter chain.
  - Then, what is the load capacitance for the first stage?



- Interconnect

Standby(!) power

- The biggest problem in the NMOS inverter
  - When $V_{in} = 0$, no standby power
  - When $V_{in} = V_{DD}$?
  - The power consumption is (approximately) $\frac{V_{DD}^2}{R_D}$.
  - If $V_{DD} = 1.8\ \mathrm{V}$ and $R_D = 10\ k\Omega$,
    324 μW!



$$I_D = \frac{V_{DD} - V_{out}}{R_D} \approx \frac{V_{DD}}{R_D}$$

Homework#10, the final

- Due: 09:00, **June 3 (Mon)**
- Solve the following problems of the final exam in 2018.
  - P26
  - P27
  - P28
  - P29
  - P30