Lecture8: MOSFET, IV

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Derivation of IV (1/2)

- Drain current
  - First of all, the current is given by

$$I(x) = Q_{elec}(x)\, v(x) \qquad (6.4)$$

  - Here, Q_{elec} is the electron charge density *per unit length*.
  - It follows

$$Q_{elec} = WC_{ox}[V_G - V(x) - V_{TH}] \qquad (6.3)$$

  - Also v is the electron velocity.

$$v = -\mu_n E = +\mu_n \frac{dV}{dx} \qquad (6.5 \text{ and } 6.6)$$

  - It is easy to understand that $I_D = I(x)$. The drain current is

$$I_D = WC_{ox}[V_G - V(x) - V_{TH}]\mu_n \frac{dV}{dx} \qquad (6.7)$$

Derivation of IV (2/2)

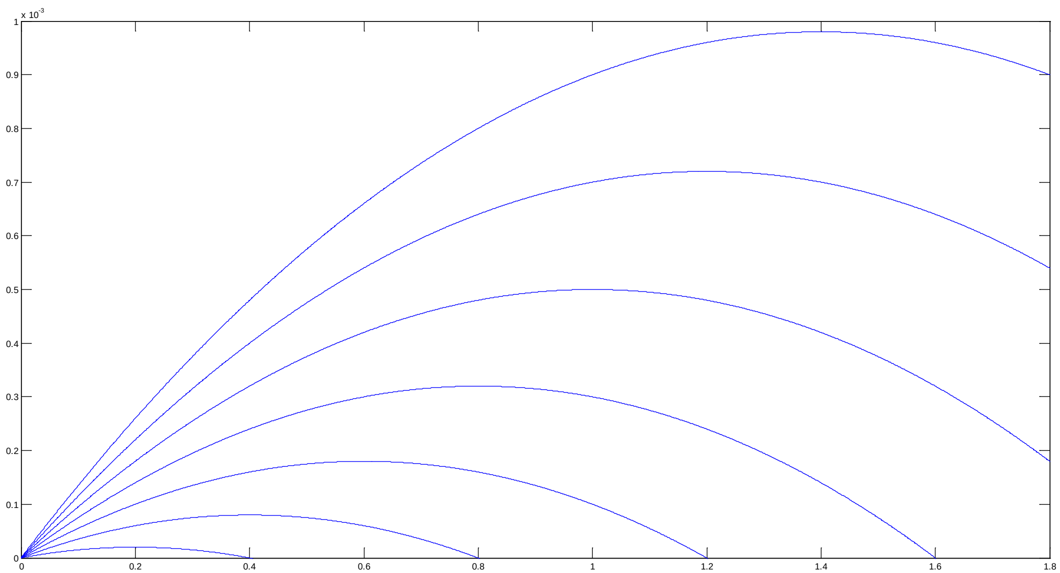
- Integration over the channel
  - Simply re-arranging,

$$I_D dx = \mu_n C_{ox} W [V_G - V(x) - V_{TH}] dV$$

  - When integrated,

$$I_D = \mu_n C_{ox} \frac{W}{L} \left[(V_G - V_{TH}) V_{DS} - \frac{1}{2} V_{DS}^2 \right]$$

Current



Voltage

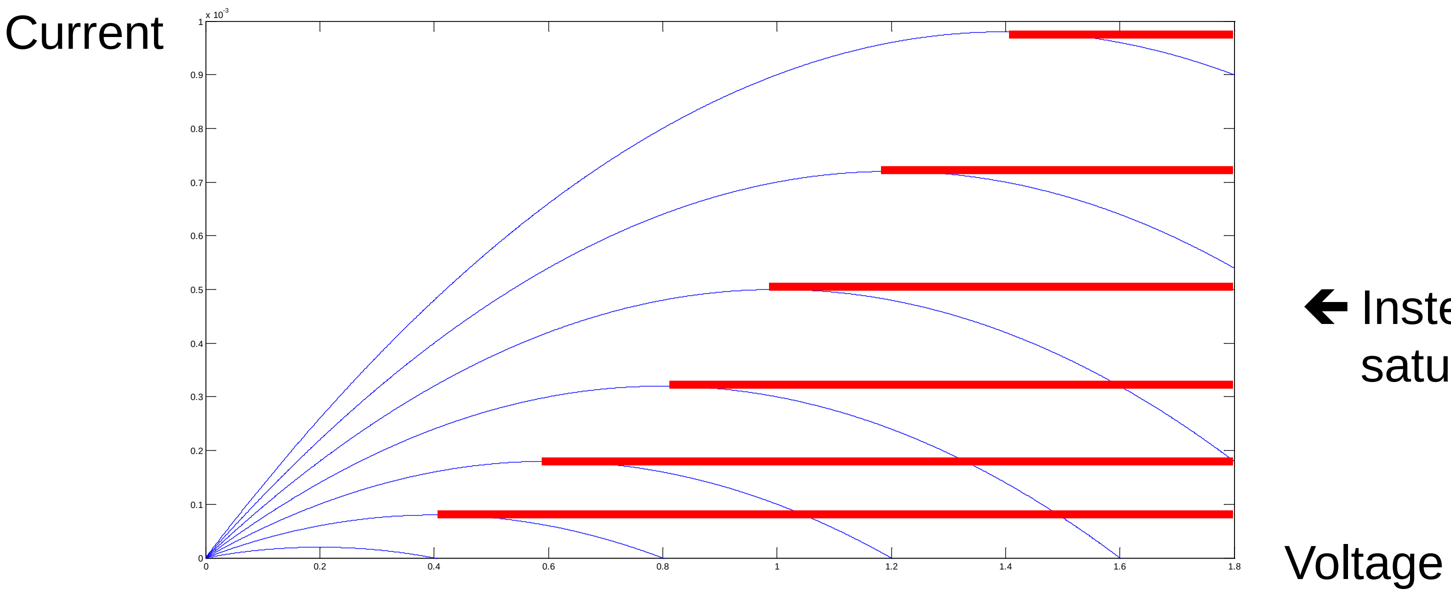
🡐 Is it acceptable?

Of course, not!

- Current usually increases as the voltage increases…
- Recall (6.3).

$$Q_{elec} = WC_{ox}[V_G - V(x) - V_{TH}] \quad (6.3)$$

  - What happens when $V(x) = V_G - V_{TH}$?
  - “Saturation region”

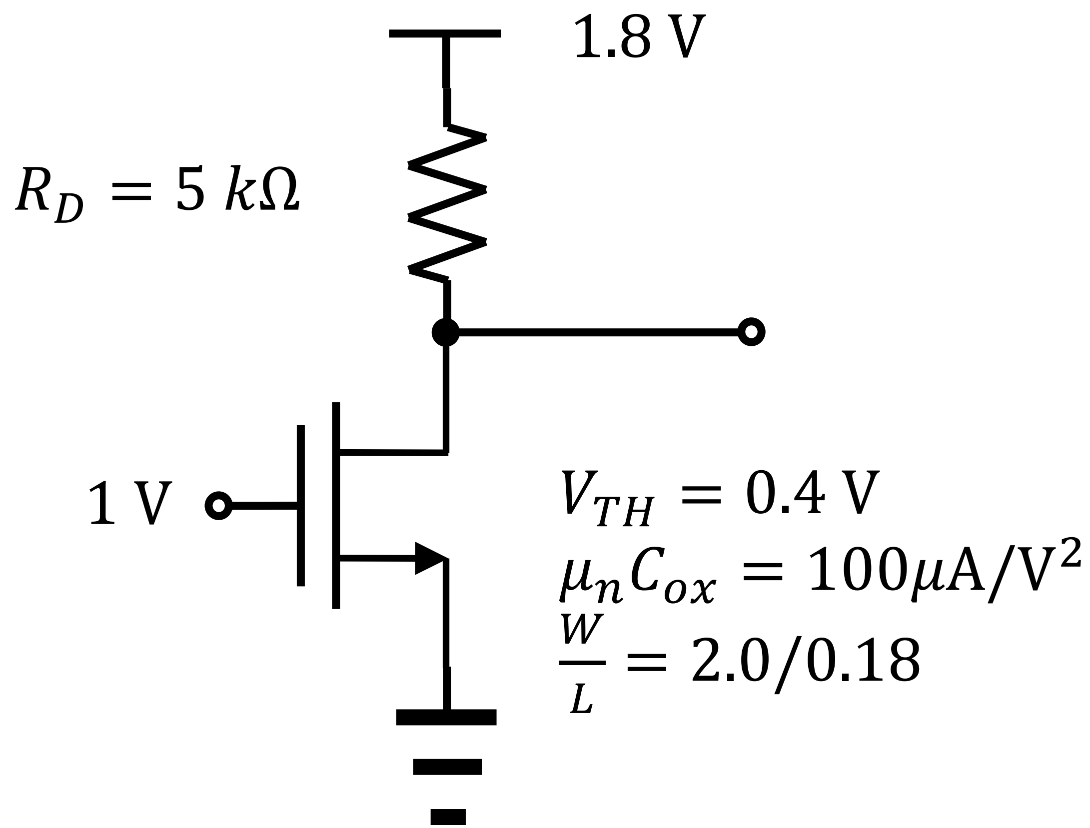


🡐 Instead, the current is saturated. (Red lines)

GIST Lecture on March 28, 2018 (Internal use only)

Example 6.6 (Razavi)

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



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,

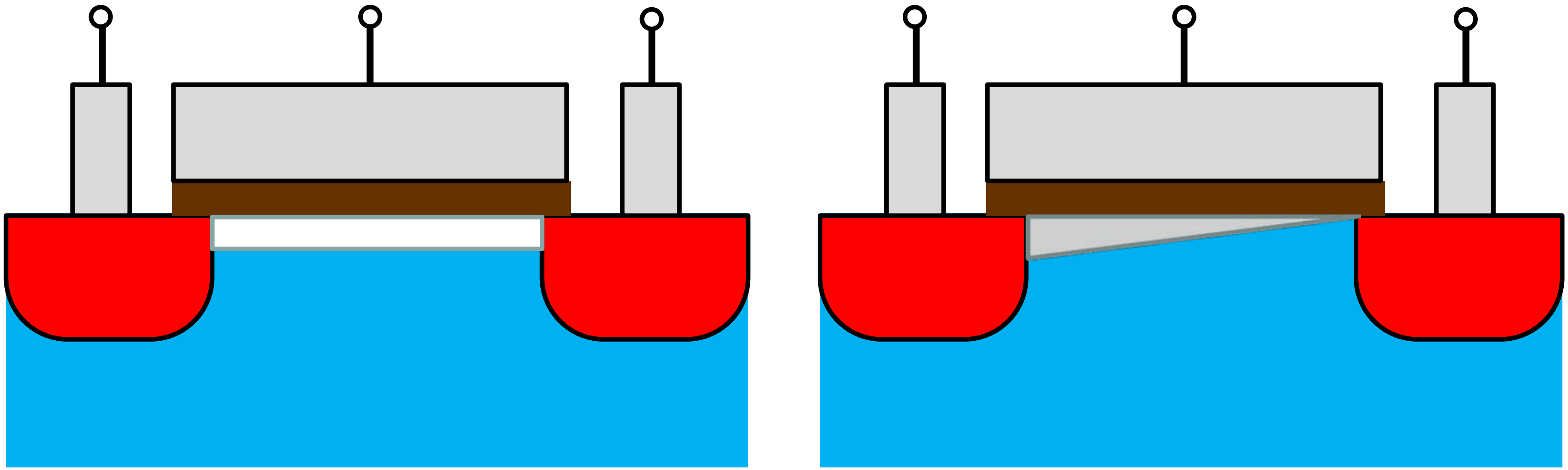
$$g_m = \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_{TH})$$

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

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

Channel length modulation

- Channel length modulation



- Output resistance?

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