DIC L7: MOSFET (1)

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GIST Lecture on October 8, 2019

2.1. Introduction (1)

- MOS capacitor
  - Gate / oxide / body
- Operating modes
  - (a) Accumulation
  - (b) Depletion
  - (c) Inversion

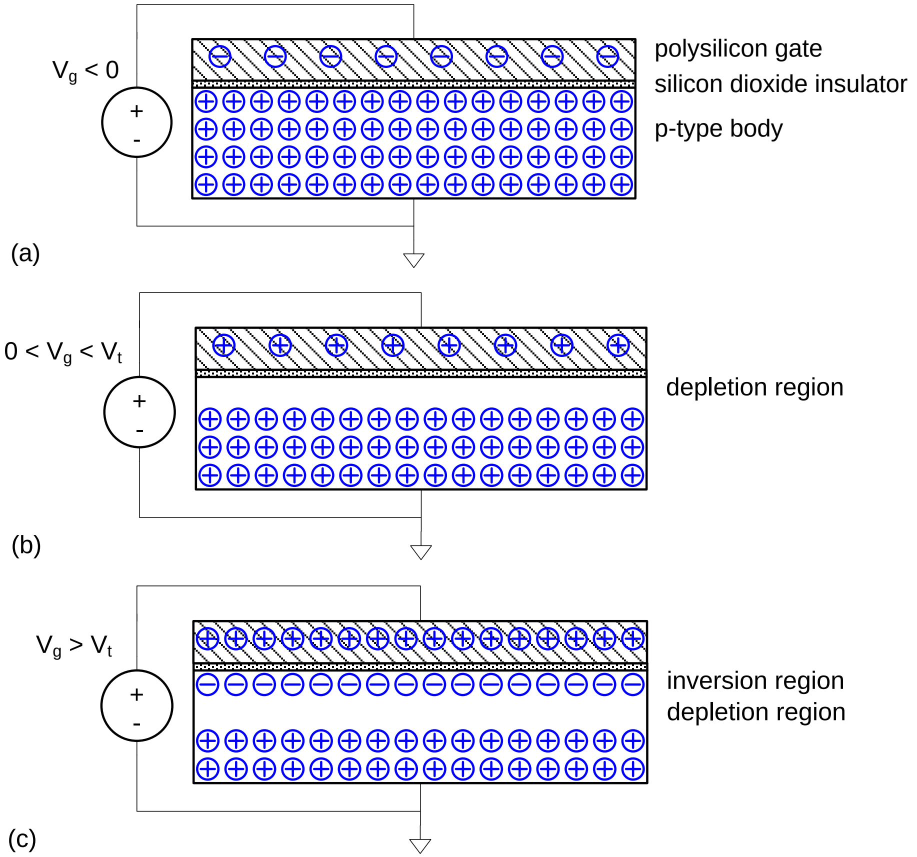
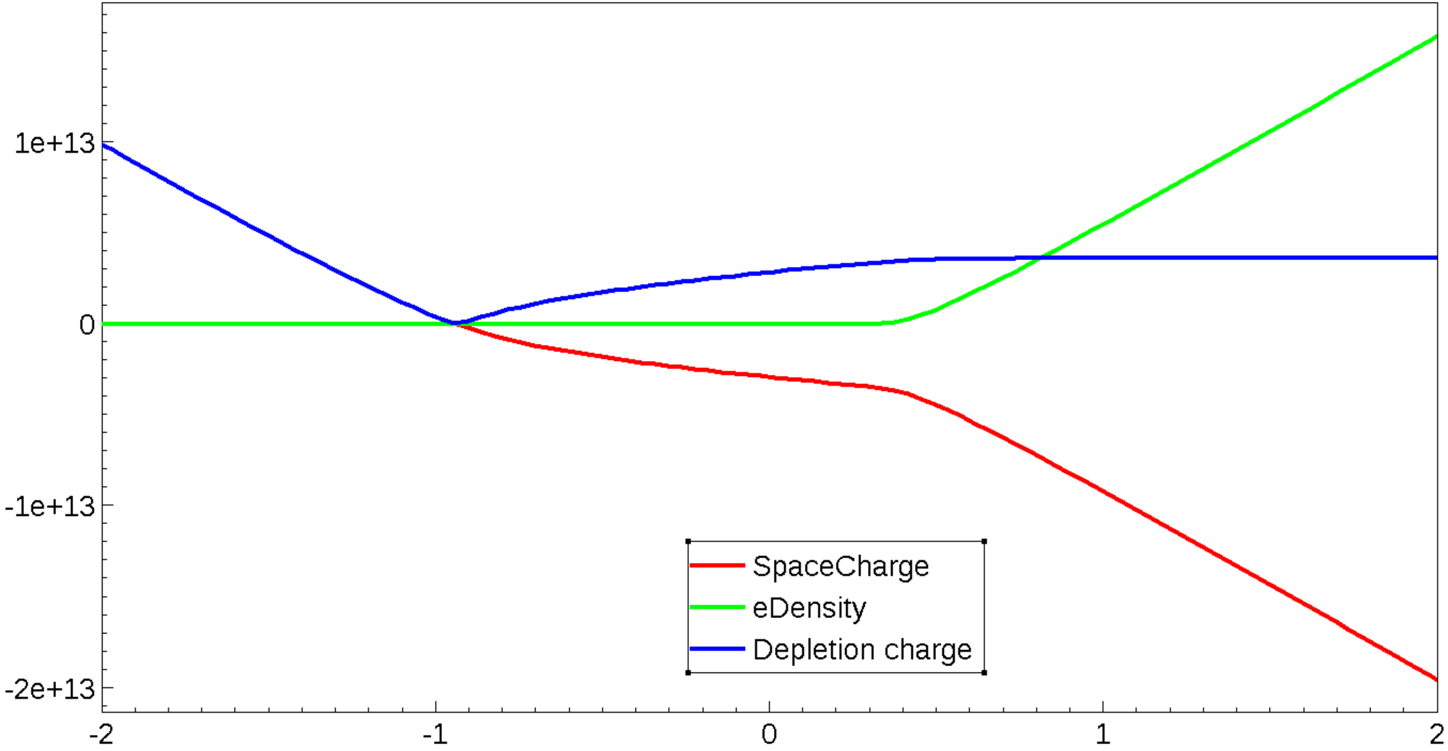


Fig. 2.2

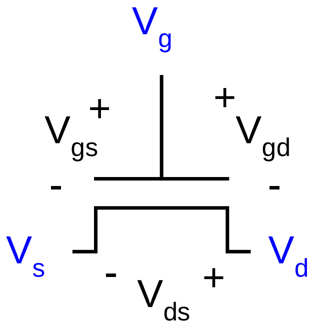
2.1. Introduction (2)

- An example



2.1. Introduction (3)

- Four termianl device



  – Source and drain are symmetric.
    - By convention, the source is biased with at a lower voltage.
    - Therefore, $V_{ds} \geq 0$
  – NMOS body is grounded.
  – Operation regions: Subthreshold (“cutoff” in the textbook), linear, and saturation

2.1. Introduction (4)

- When the gate-to-source voltage is less than the threshold voltage (V_t),
  - No mobile carrier

$$I_d \approx 0$$

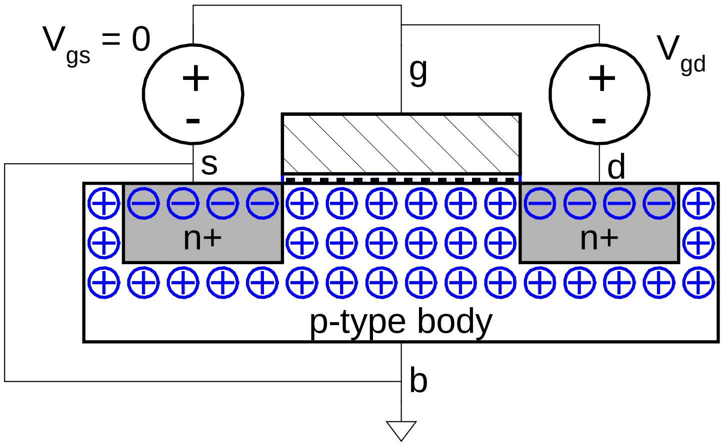


Fig. 2.3(a)

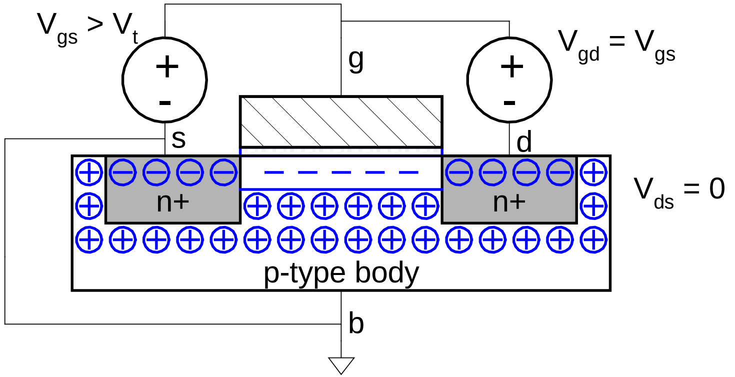
2.1. Introduction (5)

- Linear mode
  - When $V_{gs} > V_t$,

  we have an inversion channel.

  - By applying a positive V_{ds},

  we have $I_d > 0$.



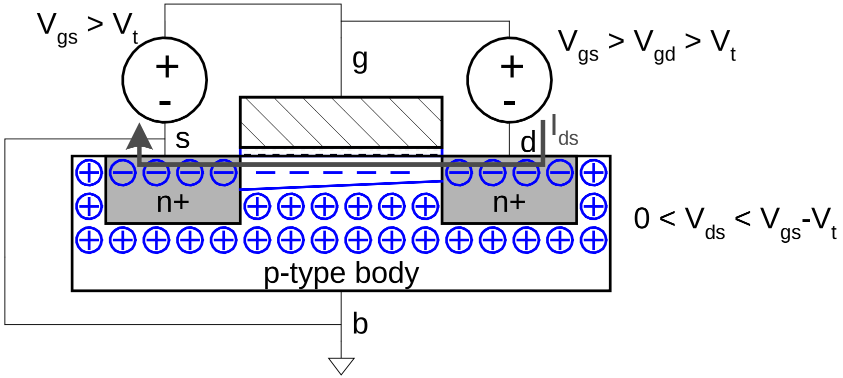


Fig. 2.3(b) & 2.3(c)

2.1. Introduction (6)

- Saturation mode
  - When $V_{ds} > V_{gs} - V_t$
  - The drain current is controlled only by the gate voltage and ceases to be influenced by the drain.

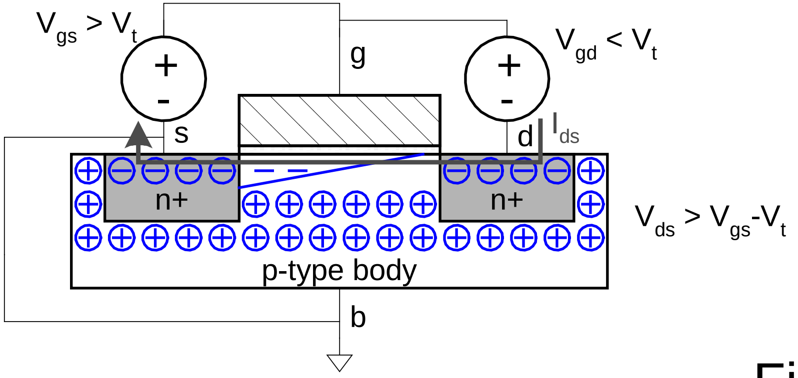


Fig. 2.3(d)

2.1. Long-channel (1)

- Current through the channel depends on
  - How much “electron” charge is in the channel?
    - Number of mobilie carriers
  - How fast is the charge moving?
- Charge

$$Q_{channel} = C_g\left(V_{gc} - V_t\right) \qquad \text{Eq. (2.1)}$$

  - Note) $Q_{channel}$ for electrons. (It should be negative, but in Eq. (2.1), it is understood.)
  - Note) V_{gc} appears instead of V_{gb}.

2.1. Long-channel (2)

- Capacitance

$$C_g = C_{OX} W L \qquad \text{Eq. (2.2)}$$

  - The "oxide capacitance," C_{OX}, is given as

$$C_{OX} = \frac{\epsilon_{OX}}{t_{OX}}$$

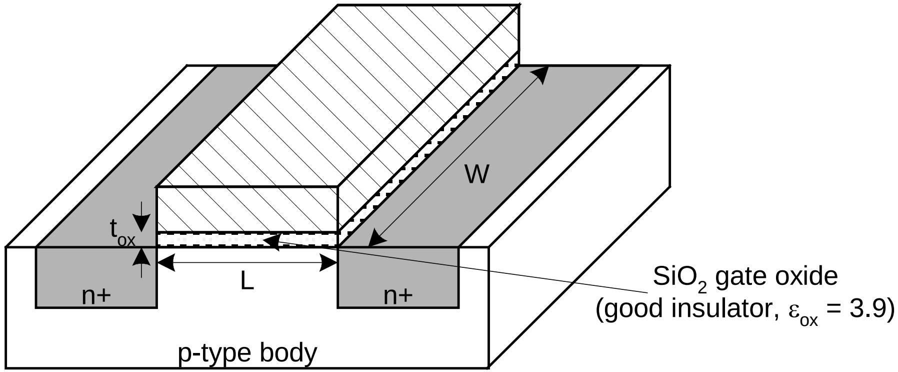


Fig. 2.6

2.1. Long-channel (3)

- IV characteristics
  - After some manipulation, we have

$$I_d = 0$$

$$I_d = \beta\left(V_{gs} - V_t - \frac{V_{ds}}{2}\right)V_{ds} \qquad \text{Eq. (2.10)}$$

$$I_d = \frac{\beta}{2}\left(V_{gs} - V_t\right)^2$$

  - Here,

$$\beta = \mu_n C_{OX} \frac{W}{L}$$