MOSFET as capacitor

- Basic structure of gate is parallel-plate capacitor:

\[ C_{ox} = \frac{\varepsilon_{ox}}{x_{ox}} \]

Body effect

- Reorganize threshold voltage equation:
  \[ V_t = V_{t0} + \Delta V_t \]
- Threshold voltage is a function of source/substrate voltage \( V_{sb} \).
- Body effect \( \gamma \) is the coefficient for the \( V_{sb} \) dependence factor.

Channel length modulation

- \( \lambda \) describes small dependence of drain current on \( V_{ds} \) in saturation.
- Factor is measured empirically.
- New drain current equation:
  \[ I_d = 0.5k'(W/L)(V_{gs} - V_t)^2(1 - \lambda V_{ds}) \]
- Equation has a discontinuity between linear and saturation regions---small enough to be ignored.

Leakage and subthreshold current

- A variety of leakage currents draw current away from the main logic path.
- The subthreshold current is one particularly important type of leakage current.
Types of leakage current

- Weak inversion current (a.k.a. subthreshold current).
- Reverse-biased pn junctions.
- Drain-induced barrier lowering.
- Gate-induced drain leakage.
- Punchthrough currents.
- Gate oxide tunneling.
- Hot carriers.

Threshold voltage

Components of threshold voltage $V_t$:

$$V_{th} = V_{fb} + \phi_s + \frac{Q_s}{C_{ox}} + V_f$$

- $V_{fb}$ = flatband voltage; depends on difference in work function between gate and substrate and on fixed surface charge.
- $\phi_s$ = surface potential (about 2$\phi_f$).
- Voltage on parallel plate capacitor.
- Additional ion implantation.

Topics

- Wire and via structures.
- Wire parasitics.
- Transistor parasitics.
- Fabrication theory and practice.

Wires and vias
Many layers of metal interconnect are possible.
  - 12 layers of metal are common.
- Lower layers have smaller features, higher layers have larger features.
- Can’t directly go from a layer to any other layer.

Much better electrical characteristics.
- Copper is poisonous to semiconductors---must be isolated from silicon.
  - Bottom layer of interconnect is aluminum.