Introduction to CMOS VLSI Design

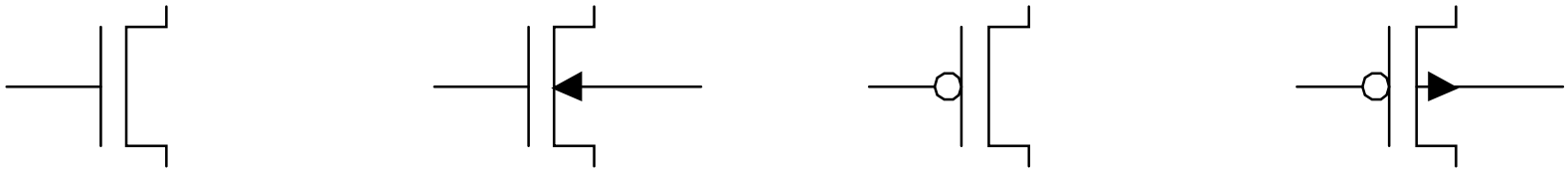
CMOS Transistor Theory

Outline

- Introduction
- MOS Capacitor
- nMOS I-V Characteristics
- pMOS I-V Characteristics
- Gate and Diffusion Capacitance
- Pass Transistors
- RC Delay Models

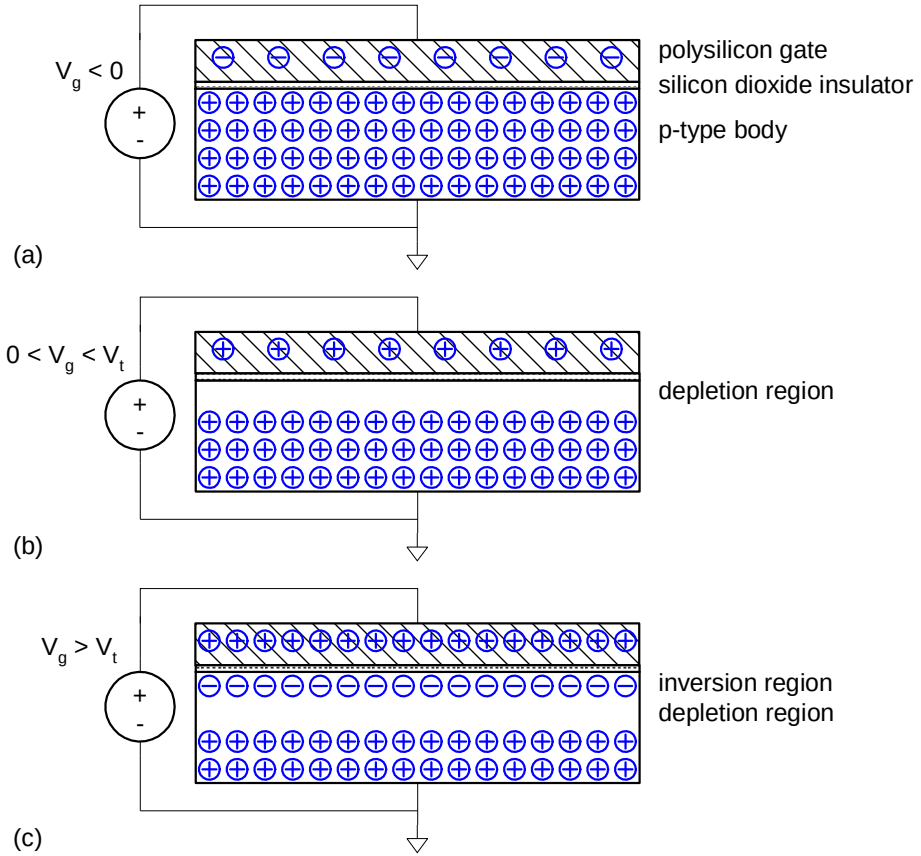
Introduction

- So far, we have treated transistors as ideal switches
- An ON transistor passes a finite amount of current
  - Depends on terminal voltages
  - Derive current-voltage (I-V) relationships
- Transistor gate, source, drain all have capacitance
  - $I = C (\Delta V/\Delta t) \rightarrow \Delta t = (C/I) \Delta V$
  - Capacitance and current determine speed
- Also explore what a “degraded level” really means



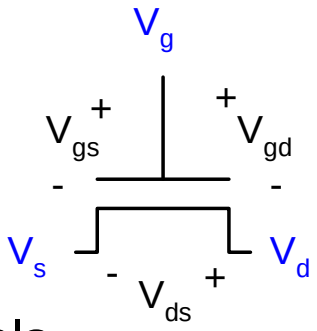
MOS Capacitor

- Gate and body form MOS capacitor
- Operating modes
  - Accumulation
  - Depletion
  - Inversion



Terminal Voltages

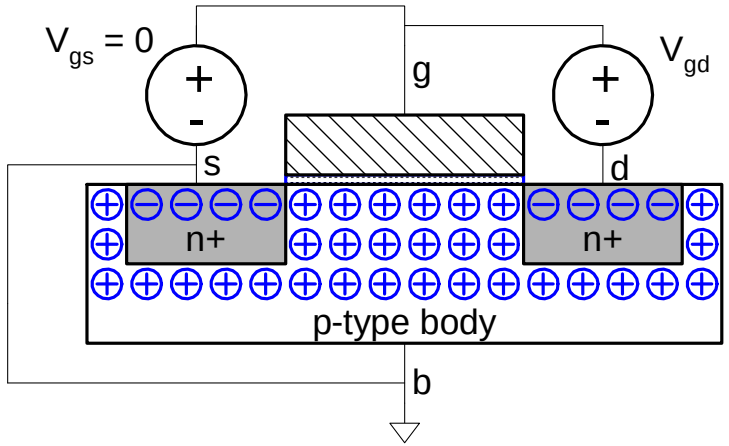
- Mode of operation depends on V_g, V_d, V_s
  - $V_{gs} = V_g - V_s$
  - $V_{gd} = V_g - V_d$
  - $V_{ds} = V_d - V_s = V_{gs} - V_{gd}$



- Source and drain are symmetric diffusion terminals
  - By convention, source is terminal at lower voltage
  - Hence $V_{ds} \geq 0$
- nMOS body is grounded. First assume source is 0 too.
- Three regions of operation
  - *Cutoff*
  - *Linear*
  - *Saturation*

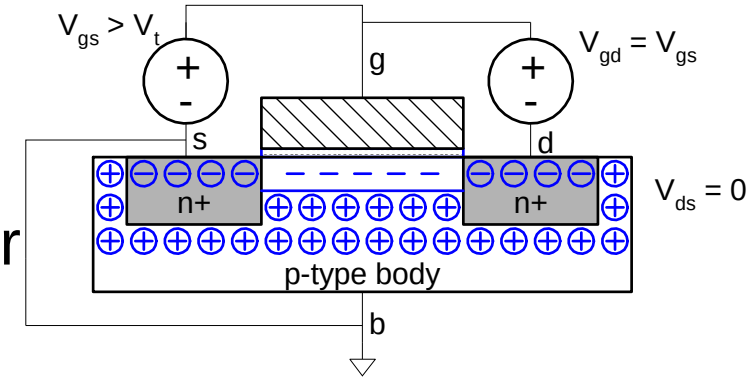
nMOS Cutoff

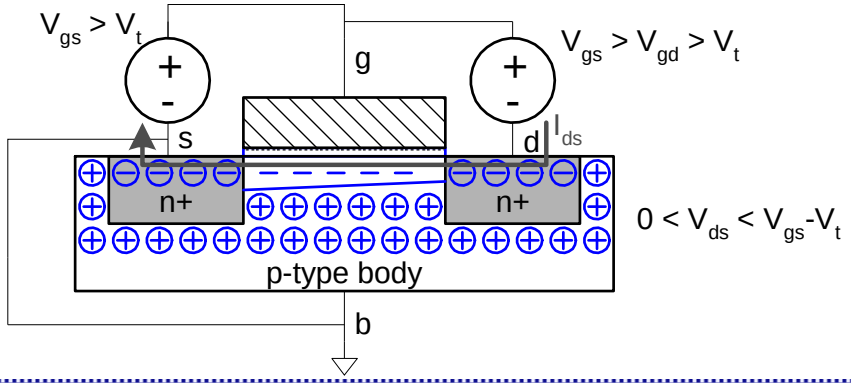
- No channel
- $I_{ds} = 0$



nMOS Linear

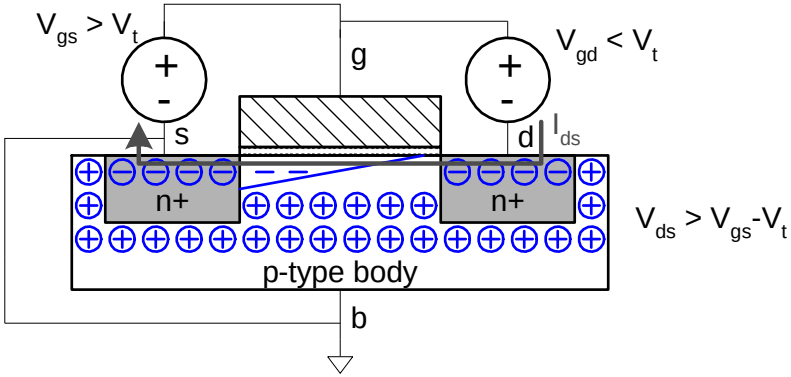
- Channel forms
- Current flows from d to s
  - e^- from s to d
- I_{ds} increases with V_{ds}
- Similar to linear resistor





nMOS Saturation

- Channel pinches off
- I_{ds} independent of V_{ds}
- We say current saturates
- Similar to current source



I-V Characteristics

- In Linear region, I_{ds} depends on
  - How much charge is in the channel?
  - How fast is the charge moving?