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CHE323/CHE384
Chemical Processes for Micro- and Nanofabrication

Lecture 8
Transistors

Chris A. Mack
Adjunct Associate Professor

Reading:
Chapter 16, *Fabrication Engineering at the Micro- and Nanoscale*, 4th edition, Campbell

 (some images obtained from Wikimedia Commons)

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Bipolar Transistors

- Bipolar transistor is a three-terminal device that can act as an (analog) amplifier or as a (digital) current-controlled switch
- Supplying current to the base (B) allows a larger amount of current to flow from the collector (C) to the emitter (E).
  - Switch the emitter current on using base current
  - The emitter current is an amplified version of the base current
- Used in early version of logic (ECL – emitter coupled logic)
- Commonly used today in high-frequency circuits (radio, wireless) as amplifiers
- Combined with CMOS (BiCMOS) in cell phones

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MOSFET

- FET = field effect transistor, can act as an (analog) amplifier or as a (digital) voltage-controlled switch
- Voltage on the gate (G) controls the current flowing from source (S) to drain (D)
- MOS = metal-oxide-semiconductor, the most common type of FET (also called MISFET, metal-insulator-semiconductor)

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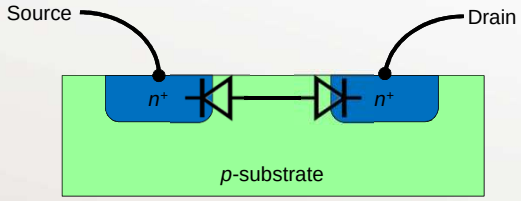
MOSFET



- Apply any voltage from source to drain and one of the p-n junctions will be reverse biased

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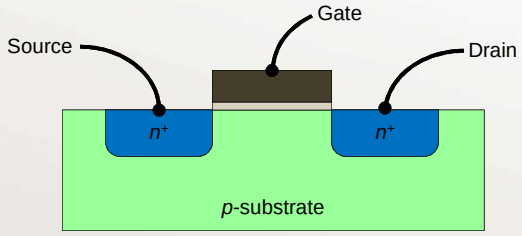
MOSFET



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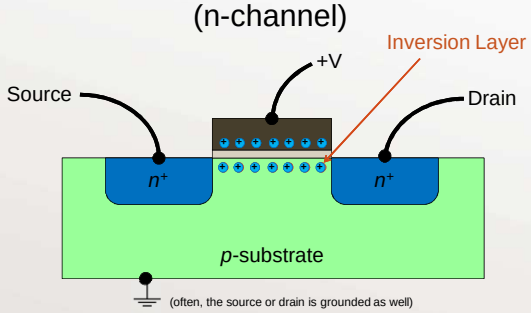
MOSFET Operation
(n-channel)



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N-channel  MOSFET  P-channel

- Threshold Voltage (V_{th}) – the minimum voltage required to create an inversion layer and thus turn on the device
- N-channel MOSFET (nMOS) – positive V_{th}
- P-channel MOSFET (pMOS) – negative V_{th}
- The threshold voltage is a function of the oxide thickness and the doping in the channel region

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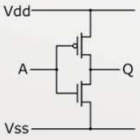
N-channel  CMOS  P-channel

- CMOS = complimentary MOS, one pMOS transistor and one nMOS transistor connected together



This circuit acts as an inverter

- Current flows only when A is switched between high and low voltage: low power operation

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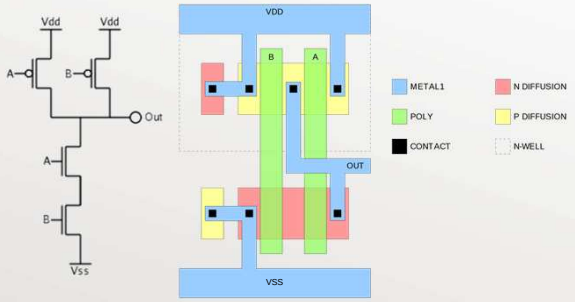
CMOS NAND Gate



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Lecture 8: What have we learned?

- When and why are bipolar transistors used in circuits?
- Describe the basic operation of an nMOS and a pMOS transistor
- What is an inversion layer?
- Define threshold voltage for MOS transistors
- What is the advantage of CMOS circuits for logic?

