

Lecture #19

ANNOUNCEMENTS

- Midterm 2 thurs. april 15, 9:40-11am.
- A-M initials in 10 Evans
- N-Z initials in Sibley auditorium
- Closed book, except for two 8.5 x 11 inch cheat sheets

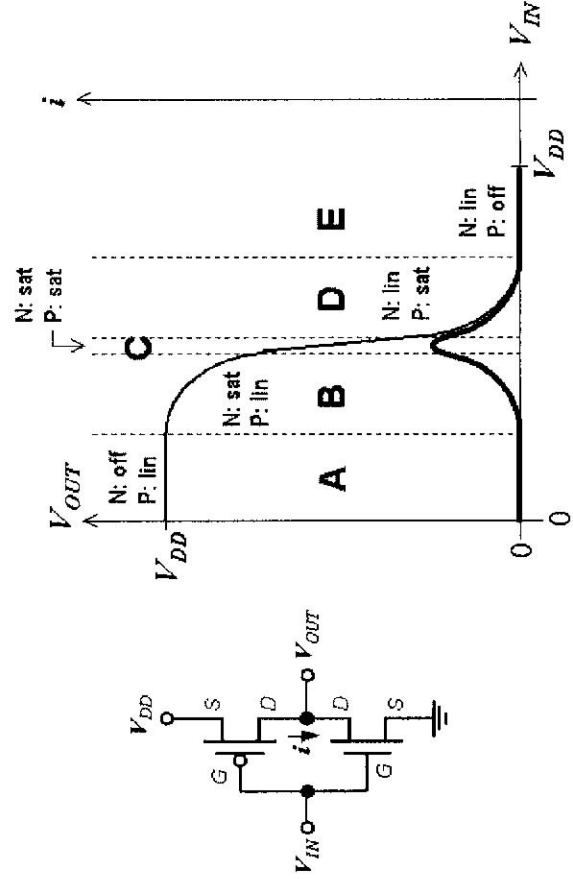
OUTLINE

- The CMOS inverter (cont'd)
- CMOS logic gates
- The body effect

Reading (Rabaey et al.)

Chapter 5.5.1 (p.220); 6.2.1

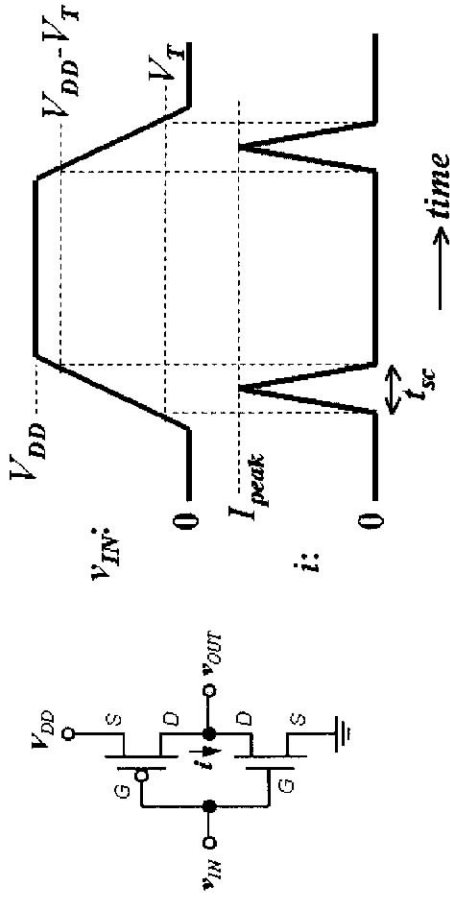
The CMOS Inverter: Current Flow during Switching



Features of CMOS Digital Circuits

- The output is always connected to V_{DD} or **GND** in steady state
 - Full logic swing; large noise margins
 - Logic levels are not dependent upon the relative sizes of the devices ("ratioless")
- There is no direct path between V_{DD} and **GND** in steady state
 - no static power dissipation

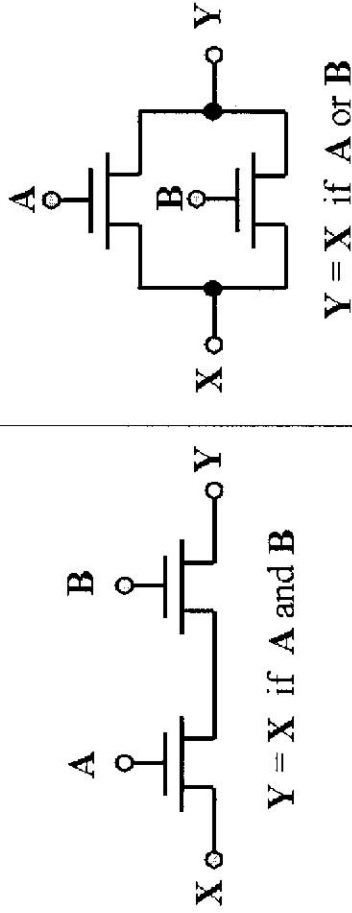
Power Dissipation due to Direct-Path Current



Energy consumed per switching period: $E_{dp} = t_{sc} V_{DD} I_{peak}$

N-Channel MOSFET Operation

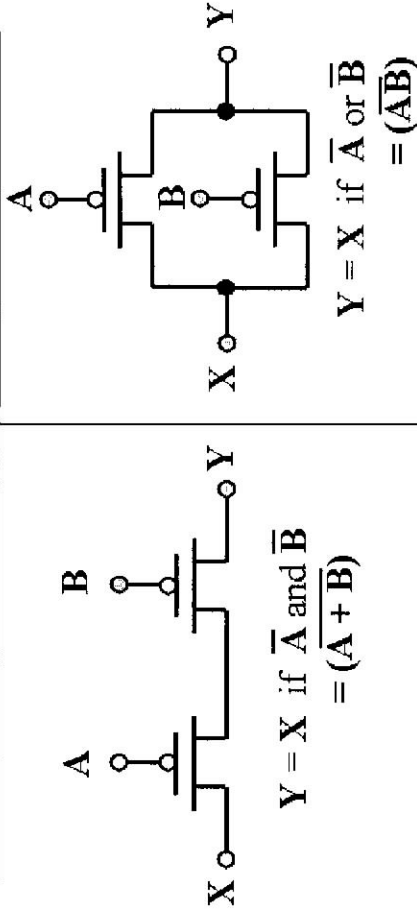
An NMOSFET is a closed switch when the input is high



NMOSFETs pass a "strong" 0 but a "weak" 1

P-Channel MOSFET Operation

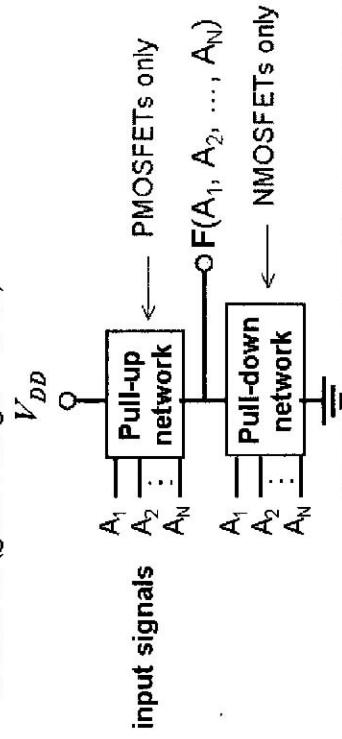
A PMOSFET is a closed switch when the input is low



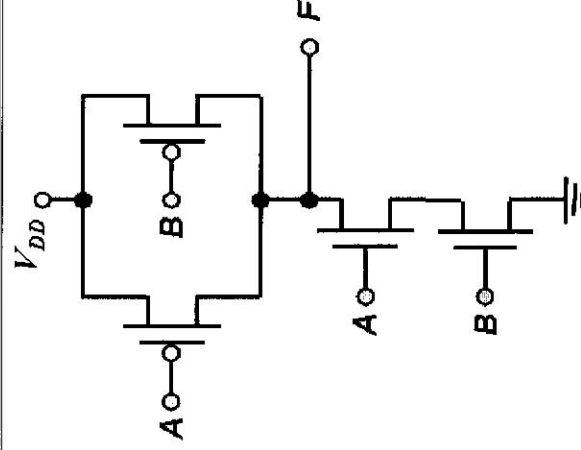
PMOSFETs pass a "strong" 1 but a "weak" 0

Pull-Down and Pull-Up Devices

- In CMOS logic gates, NMOSFETs are used to connect the output to GND, whereas PMOSFETs are used to connect the output to V_{DD} .
 - An NMOSFET functions as a **pull-down device** when it is turned on (gate voltage = V_{DD})
 - A PMOSFET functions as a **pull-up device** when it is turned on (gate voltage = GND)

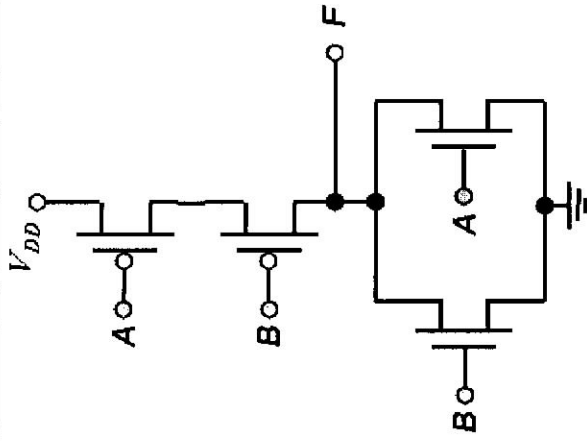


CMOS NAND Gate



A	B	F
0	0	1
0	1	1
1	0	1
1	1	0

CMOS NOR Gate



A	B	F
0	0	1
0	1	0
1	0	0
1	1	0

The "Body Effect"

V_T is a function of V_{SB} :

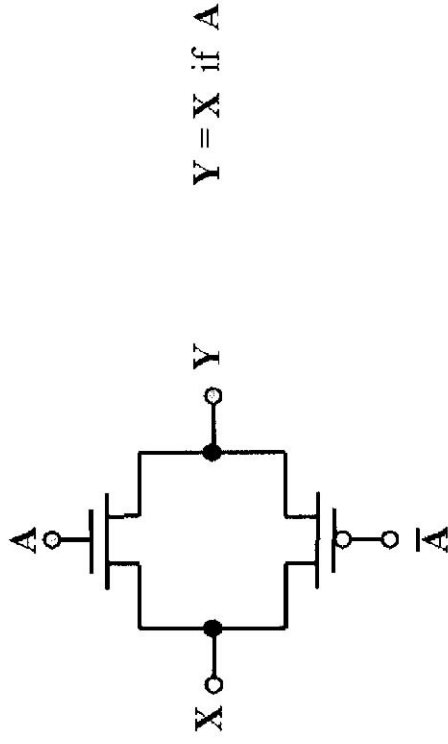
$$V_T = V_{T0} + \gamma \left(\sqrt{2\phi_F + V_{SB}} - \sqrt{2\phi_F} \right)$$

$$\text{where } \phi_F = \frac{kT}{q} \ln \left(\frac{N_B}{n_i} \right)$$

γ is the **body effect coefficient**

When the body-source pn junction is reverse-biased, $|V_T|$ increases. Usually, we want to minimize γ so that I_{Dsat} will be the same for all transistors in a circuit.

CMOS Pass Gate



$Y = X$ if A

Example (0.25 μ m CMOS technology)

