EECS 150 - Components and Design Techniques for Digital Systems

Lec 02 – CMOS Technology
9-2-04

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Outline

- Summary of last time
- Overview of Physical Implementations
- CMOS devices
- Announcements/Break
- CMOS transistor circuits
  - basic logic gates
  - tri-state buffers
  - flip-flops
    - » flip-flop timing basics
    - » example use
    - » circuits

We will learn in CS 150 ...

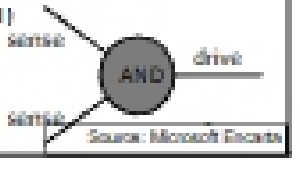
- Language of logic design
  - Logic optimization, state, timing, CAD tools
- Concept of state in digital systems
  - Analogous to variables and program counters in software systems
- Hardware system building
  - Datapath + control = digital systems
- Hardware system design *methodology*
  - Hardware description languages: Verilog
  - Tools to simulate design behavior: output = function (inputs)
  - Logic compilers synthesize hardware blocks of our designs
  - Mapping onto programmable hardware (code generation)
- Contract with software design
  - Both map specifications to physical devices
  - Both must be flawless...the price we pay for using discrete math

What is logic design?

- What is design?
  - Given problem spec, solve it with available components
  - While meeting criteria for size, cost, power, beauty, elegance, etc.
- What is logic design?
  - Choose digital logic components to perform specified control, data manipulation, or communication function and their interconnection
  - Which logic components to choose?
    Many implementation technologies (fixed-function components, programmable devices, individual transistors on a chip, etc.)
  - Design optimized/transformed to meet design constraints

What is digital hardware?

- Devices that sense/control wires carrying digital values (physical quantity interpreted as "0" or "1")
  - Digital logic: voltage < 0.8v is "0", > 2.0v is "1"
  - Pair of wires where "0"/"1" distinguished by which has higher voltage (differential)
  - Magnetic orientation signifies "0" or "1"
- Primitive digital hardware devices
  - Logic computation devices (sense and drive)
    - » two wires both "1" - make another be "1" (AND)
    - » at least one of two wires "1" - make another be "1" (OR)
    - » a wire "1" - then make another be "0" (NOT)
  - Memory devices (store)
    - » store a value
    - » recall a value previously stored



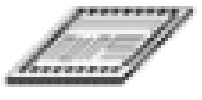
Source: Microsoft Encarta

Overview of Physical Implementations

The stuff out of which we make systems.

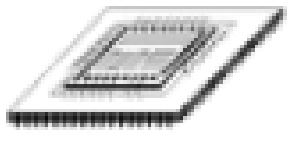
- Integrated Circuits (ICs)
  - Combinational logic circuits, memory elements, analog interfaces.
- Printed Circuits (PC) boards
  - substrate for ICs and interconnection, distribution of CLK, Vdd, and GND signals, heat dissipation.
- Power Supplies
  - Converts line AC voltage to regulated DC low voltage levels.
- Chassis (rack, card case, ...)
  - holds boards, power supply, provides physical interface to user or other systems.
- Connectors and Cables.

Integrated Circuits



- Primarily Crystalline Silicon
- 1mm - 25mm on a side
- 100 - 200M transistors
- (25 - 50M "logic gates")
- 3 - 10 conductive layers
- 2002 - feature size ~ 0.13um = 0.13 x 10^{-6} m
- "CMOS" most common - complementary metal oxide semiconductor

Chip in Package



- Package provides:
  - spreading of chip-level signal paths to board-level
  - heat dissipation.
- Ceramic or plastic with gold wires.

Printed Circuit Boards

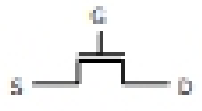
- fiberglass or ceramic
- 1-20 conductive layers
- 1-20in on a side
- IC packages are soldered down.

Multichip Modules (MCMs)

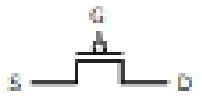
- Multiple chips directly connected to a substrate. (silicon, ceramic, plastic, fiberglass) without chip packages.

What Complementary about CMOS?

- Complementary devices work in pairs



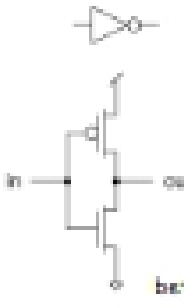
n-channel
open when voltage at G is low
closes when:
voltage(G) > voltage (S) + ε



p-channel
closed when voltage at G is low
opens when:
voltage(G) < voltage (S) – ε

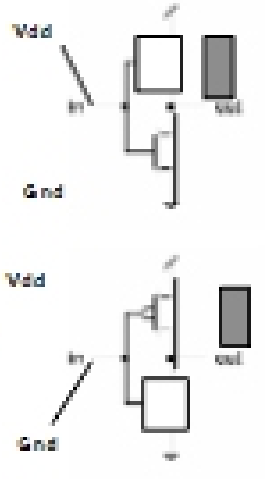
Transistor-level Logic Circuits (inv)

- Inverter (NOT gate):

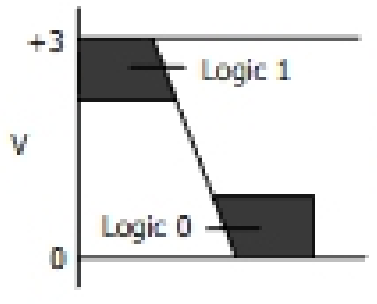


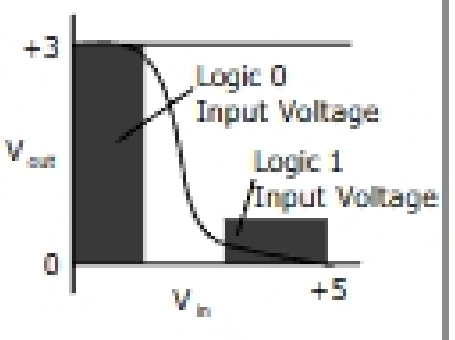
what is the relationship between in and out?

in	out
0 volts	
3 volts	



Logical Values





- Threshold
  - Logical 1 (true) : V > Vdd –Vth
  - Logical 0 (false) : V < Vth
- Noise margin?

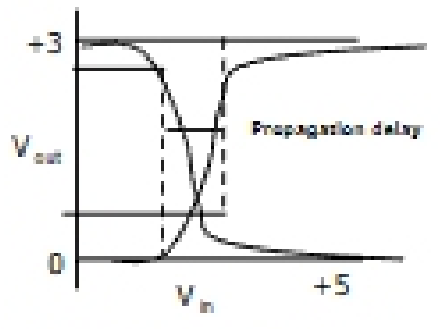
in	out
F	T
T	F

not(out, in)

Big idea: Self-restoring logic

- CMOS logic gates are self-restoring
  - Even if the inputs are imperfect, switching time is fast and outputs go rail to rail
  - Doesn't matter how many you cascade
    - Although propagation delay increases
- Manage fan-out to ensure sharp and complete transition

Element of Time



- Logical change is not instantaneous
- Broader digital design methodology has to make it appears as such
  - Clocking, delay estimation, glitch avoidance

Announcements

If you are on the wait list and would like to get into the class you must:

- Turn in an appeal for on third floor Soda
- Attend lectures and do the homework, the first two weeks.
- In the second week of classes, go to the lab section in which you wish to enroll. Give the TA your name and student ID.
- Later, we will process the waitlist based on these requests, and lab section openings.