EECS150 - Digital Design
Lecture 2 - CMOS

January 24, 2002
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Outline

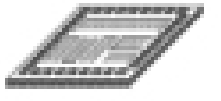
- Overview of Physical Implementations
- CMOS devices
- Announcements/Break
- CMOS transistor circuits
  - basic logic gates
  - tri-state buffers
  - flip-flops
    - flip-flop timing basics
    - circuits
    - example use

Overview of Physical Implementations

The stuff out of which we make systems.

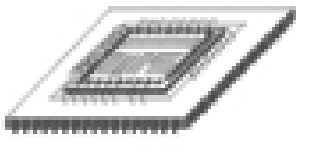
- Integrated Circuits (ICs)
  - CL, memory elements, analog interfaces.
- Printed Circuits (PC) boards
  - substrate for ICs and interconnection, distribution of CLK, Vdd, and GND signals, heat dissipation.
- Power Supplies
  - Converts line AC voltage to regulated DC low voltage levels.
- Chassis (rack,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

Integrated Circuits



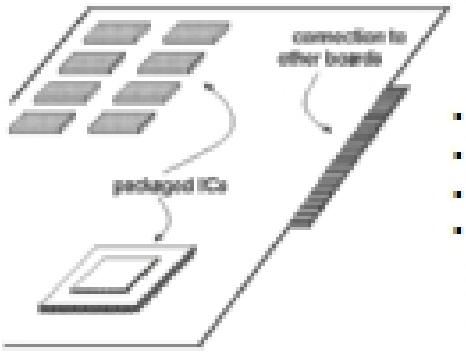
- Primarily Crystalline Silicon
- 1mm - 25mm on a side
- 100 - 100M transistors
- (25 - 25M "gates")
- 3 - 10 conductive layers
- 2002 - feature size ~ 0.13um = 0.13 x 10^{-6} m
- "CMOS" most common - complementary metal oxide semiconductor

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



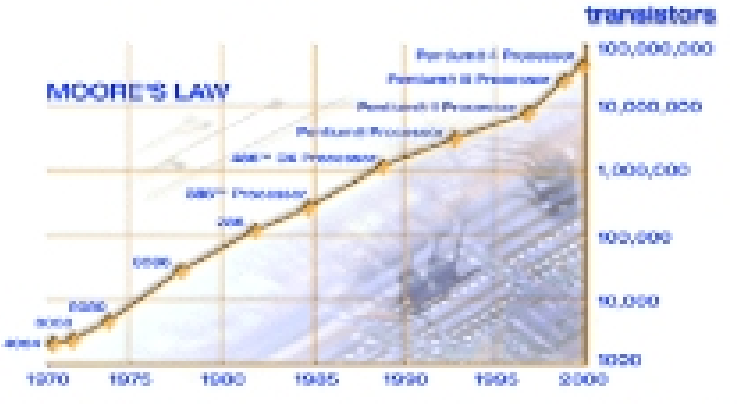
- fiberglass or ceramic
- 1-20 conductive layers
- 1-20in on a side
- IC packages are soldered down.

Multichip Modules (MCMs)

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

Integrated Circuits

- Moore's Law has fueled innovation for the last 3 decades.



- "Number of transistors on a die doubles every 18 months."
- What are the side effects of Moore's law?

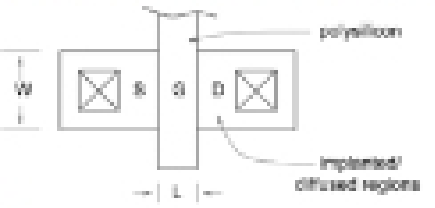
Integrated Circuits

- Uses for digital IC technology today:
  - standard microprocessors
    - used in desktop PCs, and embedded applications
    - simple system design (mostly software development)
  - memory chips (DRAM, SRAM)
  - application specific ICs (ASICs)
    - custom designed to match particular application
    - can be optimized for low-power, low-cost, high-performance
    - high-design cost
  - field programmable logic devices (FPGAs, CPLDs)
    - customized to particular application
    - short time to market
    - relatively high part cost
  - standardized low-density components
    - still manufactured for compatibility with older system designs

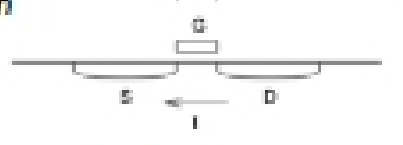
CMOS Devices

- MOSFET (Metal Oxide Semiconductor Field Effect Transistor).

Top View



Cross Section



The gate acts like a capacitor. A high voltage on the gate attracts charge into the channel. If a voltage exists between the source and drain a current will flow. In its simplest approximation the device acts like a switch.

Announcements

- If you are enrolled and plan to take the course you must attend your lab section next week, otherwise will be dropped from the class roster.
- Please note: Thursday morning lab section will not be held. If you are enrolled in that lab section, please change (using Telebears) to a different lab before next week.

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

1. Turn in an appeal for on third floor Soda.
2. Attend lectures and do the homework, the first two weeks.
3. 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.
4. Later, we will process the waitlist based on these requests, and lab section openings.

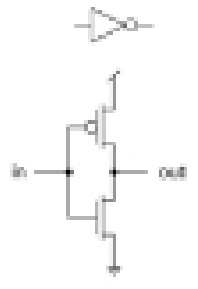
→ The final class roster will be posted at noon on Friday Feb 1.

Announcements

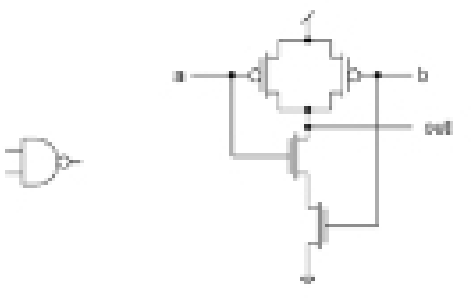
- Lectures are being taped and will be available for viewing through CalView in McLaughlin Hall.
- Reading assignment for this week.
  - All of chapter 1
  - Chapter 10 sections 1,2,7,8,9
- Homework exercises will be posted later today.

Transistor-level Logic Circuits

- Inverter (NOT gate):



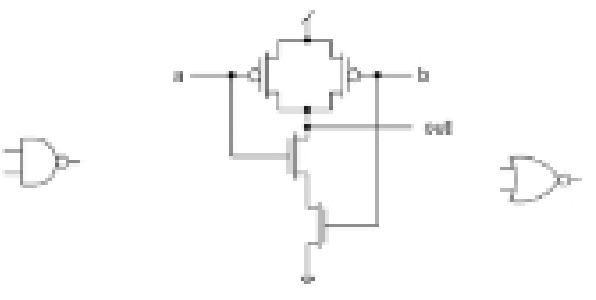
- NAND gate



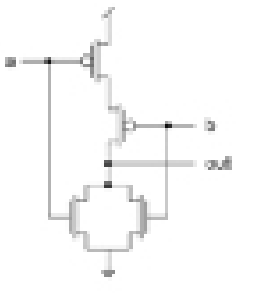
How about AND gate?

Transistor-level Logic Circuits

- NAND gate

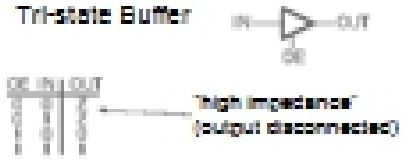


- NOR gate

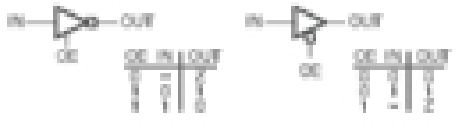


Transistor-level Logic Circuits

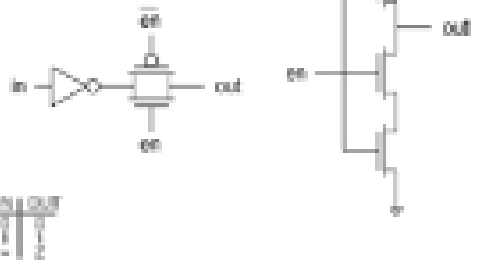
- Tri-state Buffer



- Variations

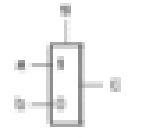


- Transistor circuit

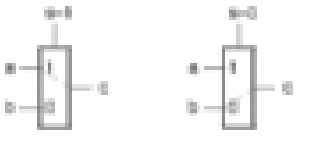


Transistor-level Logic Circuits

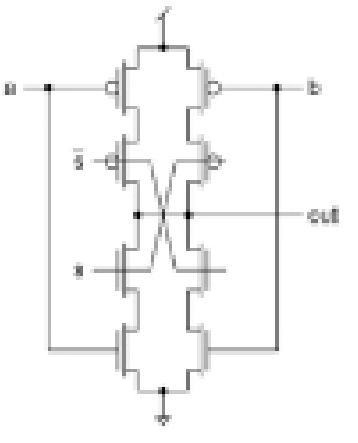
- Multiplexor



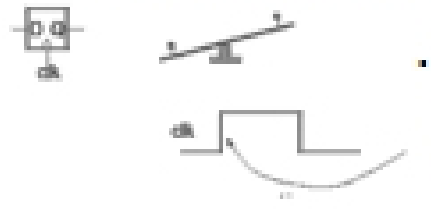
If s=1 then c=a else c=b

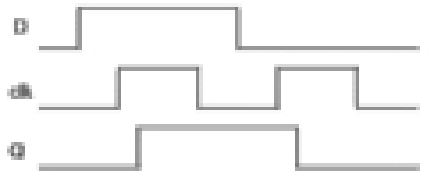


- Transistor Circuit



D-type edge-triggered flip-flop



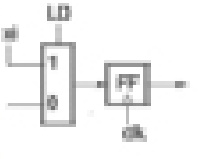


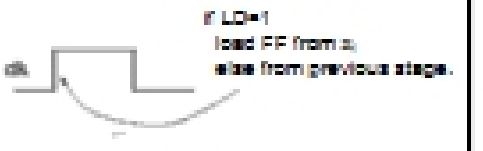
- The edge of the clock is used to sample the "D" input & send it to "Q" (positive edge triggering).
  - At all other times the output Q is independent of the input D (just stores previously sampled value).
  - The input must be stable for a short time before the clock edge.

Parallel to Serial Converter Example

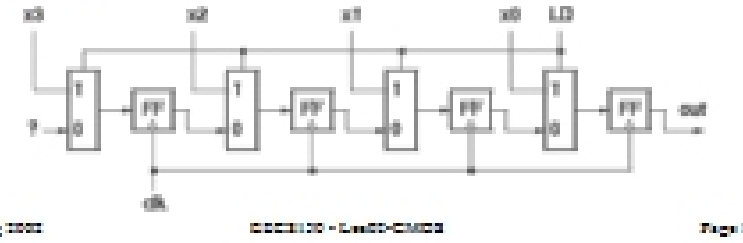
- Operation:
  - cycle 1: load x, output x_0
  - cycle i: output x_i

- Each stage:

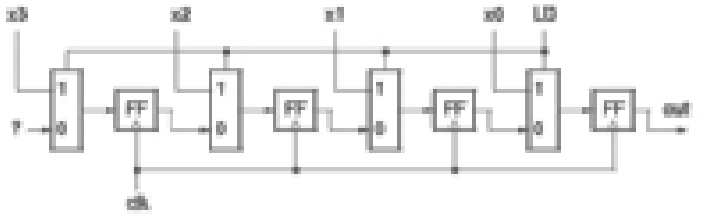




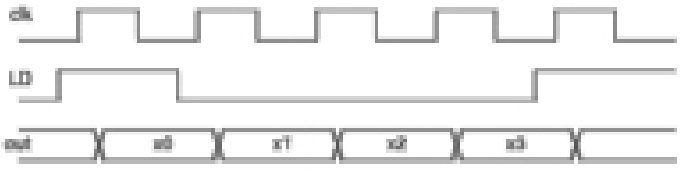
- 4-bit version:



Parallel to Serial Converter Example

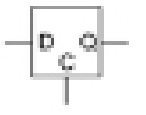


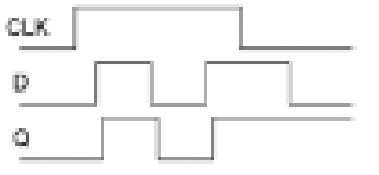
- timing:

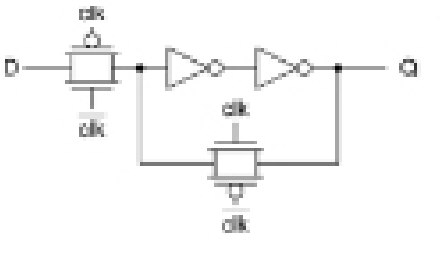


Transistor-level Logic Circuits

- Level-sensitive latch







- Edge-triggered flip-flop