Today’s Topics

Technology for Computers
A Technology Driven Field

Upcoming
Computer Architecture (Chapter 8)

Reading
(not in text)

What is Needed to Compute?

- Primitive Arithmetic Aids
  - Stones
  - Abacus
  - Hash Marks, Writing
- Multiplication/Division
  - Slide Rule
    - Uses properties of logarithms
  - Mechanical and Electromechanical Calculators
    - Use wheels, gears, etc.
    - Multiplication is repeated adding
    - Division is repeated subtracting
- Want More:
  - Programmable!

The Basic Technology

- What do we need?
  - Logic
    - NOT function
    - AND function
    - OR function
  - Memory
- All computer functions can be constructed from these
- Simplest device to allow this implementation is the Relay

Older Technology: Relay

- Relay: An electrically controlled switch

Switch (double-throw)
Older Technology: Relays

- Relays: How they work
  - Electromagnet moves switch
  - Switch can be quite complicated
- Problems with Relay Computers
  - Speed
  - Power consumption
  - Reliability
  - Size
  - Weight
  - Noise

Older Technology: Vacuum Tube

- Vacuum Tube: an electronically controlled switch

Older Technology: Vacuum Tubes

- Vacuum Tubes: How they work
  - Filament (heater) causes electrons to boil off cathode
  - Allows current to flow to plate (anode)
  - Grid (screen) voltage can repel electrons: control flow
  - Essentially voltage amplifiers
- Present Day Use of Vacuum Tubes
  - Televisions (cheaper, heavier)
  - Computer Monitors (being replaced by LCD)
  - Very High Power Applications
    - Radio stations
- Advantage of Tubes
  - Much-much faster than relays
- Problems with Vacuum Tube Computers
  - Power consumption (filament always on)
  - Size
  - Weight
  - Reliability
  - Noise (cooling)
  - Speed (~1/size) -- slow by modern standards
Technology: Transistors

- Transistors
  - Two basic kinds (also N & P polarities)
    - Junction
    - Field Effect
  - Junction Transistors/Bipolar Transistors
    - Historically first
    - Current amplifiers
    - Close to relays
    - Current always flowing!
    - Still use much power

- Field Effect Transistor (FET):
  - Electronically controlled switch

Modern Technology: MOS FETs

- Metal Oxide Semiconductor Field Effect Transistors
- How do they work
  - Voltage on gate controls flow from source to drain
  - Similarity to vacuum tube: Voltage Driven
  - For computer use: on/off
  - Almost no current (CMOS)
- Complementary (N type & P type) is current tech
  - Called CMOS
  - Use of single transistors is not current
  - One big step remains: integration

Modern Technology: MOS FETs

- Advantages of using (singly) MOS FETs
  - Low power use
  - Fast
  - Small (but not tiny)
  - As fast as tubes
- Disadvantages
  - Need very many for modern computing
    - Space (distance)
    - Distance takes time: on slow side
  - The interconnection problem
Modern Technology: Integrated Circuits

- What is missing?
  - Need way to mass produce
  - Need to get many transistors on a single chip

- Integrated Circuits -- VLSI
  - Multiple Transistors on a Chip
  - Use photo-lithography to "print" wires and transistors
  - SSI, MSI, LSI, VLSI
  - Now get millions of transistors on 1/4 inch square chip

- Economics of Silicon (Micro-electronics)
  - Tremendous cost to produce one chip
  - If it works, extra copies almost free
  - Do simulations of everything to get it right the first time
  - Plant to produce memory chips costs $ billions

Comparing Technologies

- CPUs in Everything
  - Use programmed general purpose chips in place of special purpose chips
  - Programs in ROM (read-only memory)

- Technology Summary

<table>
<thead>
<tr>
<th>Measure:</th>
<th>speed</th>
<th>Power / heat</th>
<th>weight</th>
<th>Reliability (MTF)</th>
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<tr>
<td>technology</td>
<td>(ops/s)</td>
<td>(mW/bit)</td>
<td>(kg/cpu)</td>
<td>(hours)</td>
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Note: Assume computer equivalent to low cost PC in power
Note: All values are very rough estimates

Limitations of Technology

- Some Fundamental (Physical) Limitations
  - Speed of light (distance)
  - Heat dissipations (temperature)
  - Capacitance and inductance (time delays)
  - DC losses (Ohm's Law)
  - AC losses (radiation)

- Important Practical Concerns
  - Noise
  - Lifetime (mean time to failure)
  - Space, weight (volume)
  - Power needs
  - Comes down to Economics !!! (cost)

Other Computing Technologies

- Other Fascinating Technology Trails
  - Displays
    - CRT
    - LCD
    - Plasma
  - Printing
    - Impact
    - Laser
    - Ink-jet
  - Storage
    - Tapes
    - Disks
    - Laser read/write (CDRoms, DVDs)
  - CPU in EVERYTHING / VOLUME is EVERYTHING