Computer Components

- To store binary information the most basic components of a computer must exist in two states
  - State # 1 = 1
  - State # 2 = 0
Transistors

- Computers use transistors to store binary information

Deep Inside: Transistors
Deep Inside: Transistors

- Key active component in all modern electronics, including computers
- One of the most influential inventions in modern history

Transistors

- “Solid-state,” usually slightly impure silicon
- Field effect transistor shown here
- Controls the flow of current
  - Current flowing = “on”
  - No current = “off”
Transistors

- Used in all parts of computer
- One example: computer memory

Random Access Memory (RAM)

- Volatile
  - Only works when computer is on
- The memory quoted in advertisements
  - Usually in 2 GB – 8 GB range
    - K = thousand (10^3)
    - M = million (10^6)
    - G = billion (10^9)
    - T = trillion (10^{12})
How RAM Works

- State of transistor determines charge of capacitor
  - Charged = 1
  - Uncharged = 0
- Capacitors lose charge quickly in dynamic RAM
  - Must be refreshed continuously
  - When computer is off, RAM loses data

Flash Memory

- Nonvolatile
- USB drives
- Permanent memory in computer
How Flash Memory Works

- Depends on thin layer of metal oxide
- Holds its charge permanently

Integrated Circuits
Integrated Circuits

- Transistors are part of small chips called “integrated circuits.”

- Integrated circuits are a “big idea” that made small computers possible.

Integrated Circuits

- Small transistors are not useful if they are separate parts that must be wired together by hand or machines.
**Integrated Circuits**

- **The “big idea”:** Manufacture the entire circuit in layers, laying down transistors, wires, etc. at the same time

![Image of integrated circuit layers]

**Integrated Circuits**

- Fabricate in layers
- Each layer contains millions of “wires” and transistor pieces
- Generally fabricate many ICs at once on a wafer
Integrated Circuits

- The size of integrated circuit components has deceased rapidly over the years
- Allows manufacturers to pack more and more transistors in the same area

Moore’s Law

- Attributed to Gordon Moore
  - Co-founder of Intel
Moore’s Law

- The complexity of ICs per dollar doubles about every 24 months

- Every two years you will be able to get about twice the computing power for the same amount of money

Integrated Circuits

- Can this go on forever?
Integrated Circuits

- May reach physical limits eventually
  - May get too small for fabrication
  - Quantum effects may cause “leakage” of electrons within transistors
- Cost of fabrication plants are climbing
- May need other technologies
  - Discussed in reading

Central Processing Unit (CPU)

- The CPU is an Integrated Circuit
- Also called “processor” or “microprocessor”
CPU

- Contains Arithmetic and Logic Unit (ALU) and Control Unit
- Shown here with other components of computer

![CPU Diagram]

CPU

- CPUs conform to the Von Neumann architecture
  - Instructions and data stored together in memory
- CPU uses Fetch/Execute cycle to get instructions and data from memory
Fetch/Execute Cycle

- General process is the following:
  - Get instructions from memory
  - Get data needed by instructions from memory
  - Operate on data according to instructions
  - Put resulting data back into memory

- Computer’s operations are simple
  - Basic arithmetic: Add, multiply, divide
  - Tests: Compares data
    - True or false?
    - Which is larger?
  - Moves data and instructions around

- Computer does these over and over and over – very, very quickly
Central Clock
- Computer’s clock controls rate of Fetch/Execute cycle
- Fast clock means more instructions can be accomplished in a given time
- 2 GHz clock speed => 2 billion instructions per second

Computer Power
- Several things determine a computer’s power
- Number of cores in processor
  - # separate processors within a processor chip
  - Dual core, quad core
Computer Power

- Clock speed
  - Pace of system clock
  - GHz (billions of cycles/sec)
- Bus speed
  - How fast can bus move data around

- Amount of RAM
  - If there is not enough RAM for a software, computer must use slower hard drive
- Memory access time
  - How fast can data be moved to and from the RAM
- Speed of cache
Cache

- RAM – generally cheap memory (slow)