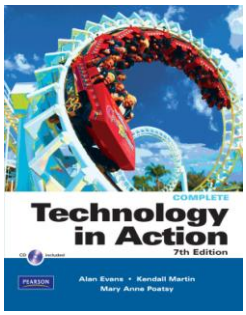


Technology in Action

Technology in Focus:
Under the Hood

Electrical Switches

- The system unit contains the CPU
- The CPU uses a large number of switches
  - Two states: 1 or 0 (on or off)
  - Binary language consists of two numbers: 1 or 0
- These switches are used to process data

Early Computer Switches

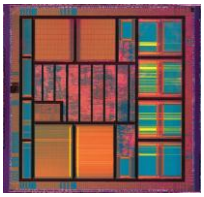
- Vacuum tubes
  - Allow or block the flow of electrical current
  - Take up a large amount of space
  - Generate heat and burn out frequently
  - Impractical due to size and reliability issues

Transistors

- Transistors
  - Electrical switches built of layers of silicon
  - Early transistors were built in separate units as small metal rods
    - Each rod was a small on/off switch
  - Smaller and faster than vacuum tubes
  - Produced less heat

Integrated Circuits

- Made of semiconductor material, silicon
- Contain huge number of transistors, resistors, capacitors, and diodes
- Small size, only ¼ inch in diameter



Microprocessors

- Chip that contains CPU
- Intel 4004
  - First complete microprocessor on a single integrated circuit
  - Built in 1971
  - Contained 2,300 transistors
- Current CPUs contain more than 500 million transistors

Base 10 Number System

- Organized plan for representing a number
  - Base 10 or decimal notation
  - Uses 10 digits (0–9)
  - System used to represent all of the numeric values we use each day

10^3 1,000s place	10^2 100s place	10^1 10s place	10^0 1s place
6 * 1,000 +	9 * 100 +	5 * 10 +	4 * 1

(6,000 + 900 + 50 + 4) = 6,954

Base 2 Number System

- Base 2 or binary
- Uses two digits (1,0)
- Computers use binary because each switch can be in one of two positions: on or off.

2^3 8s place	2^2 4s place	2^1 2s place	2^0 1s place
1	0	1	1

(8 + 0 + 2 + 1) = 11

Hexadecimal Notation: Base 16

- Base 16 (0–9, A–F)

Character representation

Base 10	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Base 16	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F

Hex 1A43 = 6,723 in Base 10

16^3 4,096s place	16^2 256s place	16^1 16s place	16^0 1s place
1	A	4	3
1 * 4,096 +	10 * 256 +	4 * 16 +	3 * 1
4,096 +	2,560 +	64 +	3
	6,723		

ASCII

- American Standard Code for Information Interchange
- Pronounced “As-key”
- Represents each letter or character as an 8-bit (or 1-byte) binary code.

ASCII Code	Represents This Symbol	ASCII Code	Represents This Symbol
01000001	A	01100001	a
01000010	B	01100010	b
01000011	C	01100011	c
01011010	Z	00100011	#
00100001	!	00100100	$
00100010	“	00100101	%

EBCDIC and Unicode

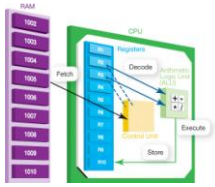
- EBCDIC
  - Used by older mainframe computers
- Unicode
  - Uses 16 bits (2 bytes)
  - Multilanguage support
  - Currently assigns more than 96,000 unique character symbols

Decimal Numbers

- Floating-point standard established by IEEE
- 32-bit (4-byte) system
  - First bit (sign bit) indicates positive or negative
  - Next 8 bits indicate magnitude (hundreds, millions, etc.)
  - Remaining 23 bits store number

CPU Machine Cycle

- All CPUs must perform a series of similar steps:
  - Fetch
  - Decode
  - Execute
  - Store



System Clock

- Moves CPU from one stage of the machine cycle to the next
- Acts as a metronome, keeping a steady beat or tick
  - Ticks, known as the clock cycle, set the pace
  - Pace, known as clock speed, is measured in hertz (Hz)

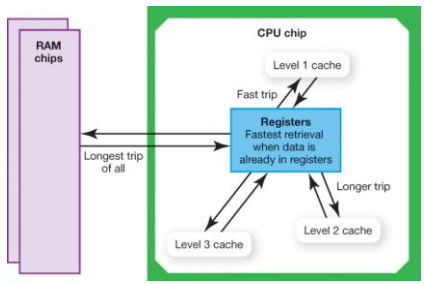
Control Unit

- Manages switches inside the CPU
- Remembers
  - Sequence of processing stages
  - How switches are set for each stage
- Uses beat of system clock to move switch to correct on or off setting for each stage

Stage 1: The Fetch Stage

- Data and program instructions stored in various areas of the computer
- Data moved from storage to RAM
- CPU accesses RAM and moves data into registers
- Cache memory
  - Stores recent or frequently used instructions
  - Faster to access than RAM

Cache Memory



Stage 2: The Decode Stage

- The CPU's control unit decodes a program's instructions into commands
- Instruction set
  - The collection of commands a CPU can interpret
  - Written in assembly language for programmers.
  - Assembly language is translated into machine language for the CPU

Stage 3: The Execute Stage

- Arithmetic logic unit (ALU) performs
  - Mathematical operations
    - Addition
    - Subtraction
    - Multiplication
    - Division
  - Test comparisons (<, >, =)
  - Logical OR, AND, and NOT operations

Stage 4: The Store Stage

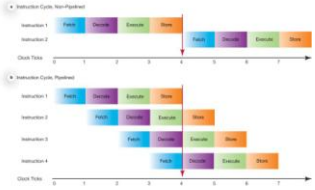
- Results produced by the ALU in Stage 3 are stored in the registers

Moore's Law

- The number of transistors on a processor doubles every 18 months
  - The first 8086 chip had 29,000 transistors and ran at 5 MHz
  - Today's Penryn chip for notebook computers has 820 million transistors and runs at 2.6 GHz

Pipelining

- Boosts CPU performance
- CPU works on more than one stage or instruction at a time



Multiple Processing

- Multiple processors or computers work on a problem simultaneously
  - Dual- or multicore: Multiple processors in one computer
  - Parallel processing: Multiple computers working on one problem
    - Problem must be able to be divided into a set of independent tasks

DNA Computers

- Use DNA molecules and special enzymes instead of silicon chips
- 330 trillion operations per second
- 100,000 times faster than current silicon-based computers
- No practical applications yet