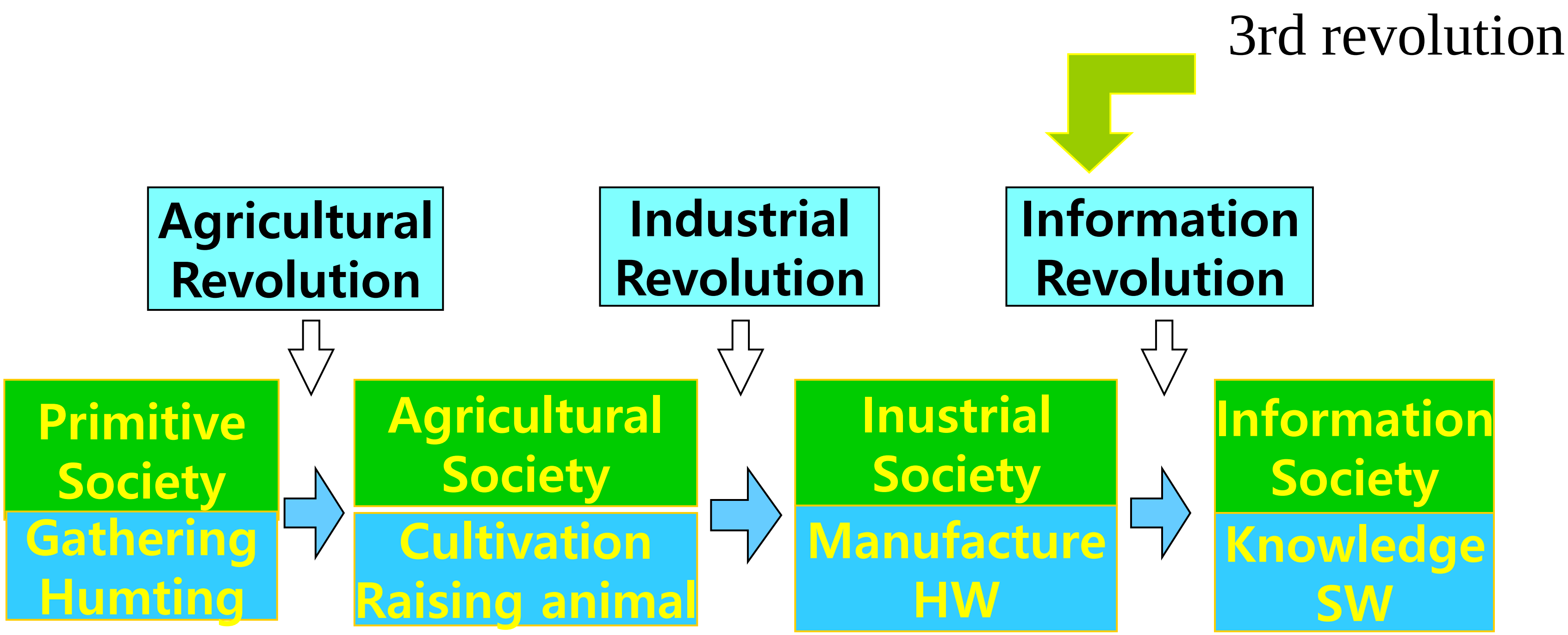
Chapter 1
Computer Abstraction and Technology

Computer Architecture and Organization

School of CSEE

Implication of Computer (Network) Technology

- **It has led the 3rd revolution for civilization**



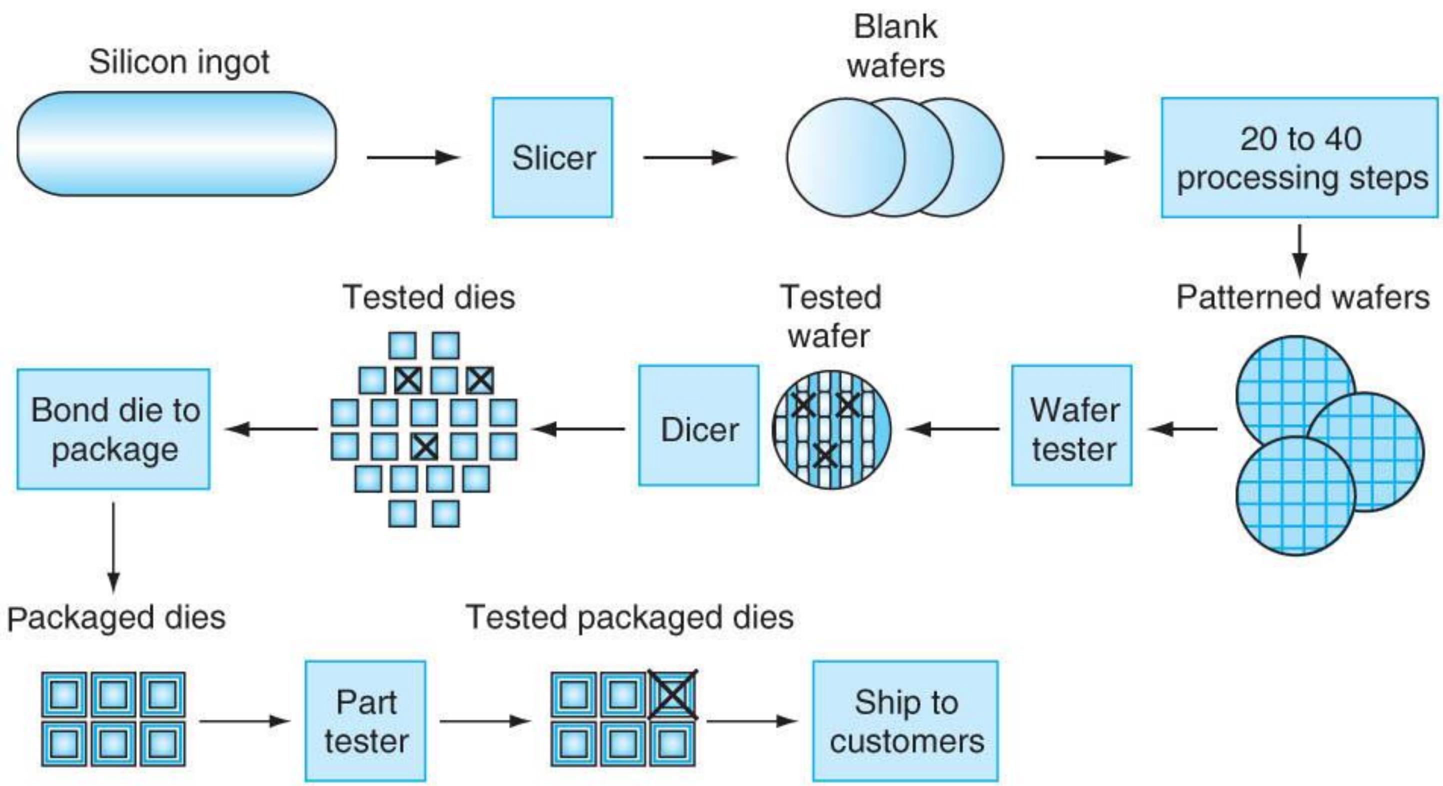
Implication of Computer (Network) Technology

- The Computer revolution continues
  - Applications that were economically infeasible suddenly become practical
  - e.g. World Wide Web, Computers in automobiles, Robot, Cell phone, Human genome project, peer-to-peer computing, Cloud computing, Smart home/factory/city, Telecommuting, IoT, Big data, AI, IT convergence etc.
- Advances in Computer Technology now affect almost every aspect of our society

Overview of Physical Implementations

The hardware 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.


Silicon ingot
Slicer
Blank wafers
20 to 40 processing steps
Patterned wafers
Wafer tester
Tested wafer
Dicer
Tested dies
Bond die to package
Packaged dies
Part tester
Tested packaged dies
Ship to customers

Classes of Computing Applications

- **Desktop computers**

  A computer designed for use by an individual, usually incorporating a graphics display, keyboard, and mouse.

- **Servers**

  A computer used for running larger programs for multiple users often simultaneously and typically accessed only via a network.

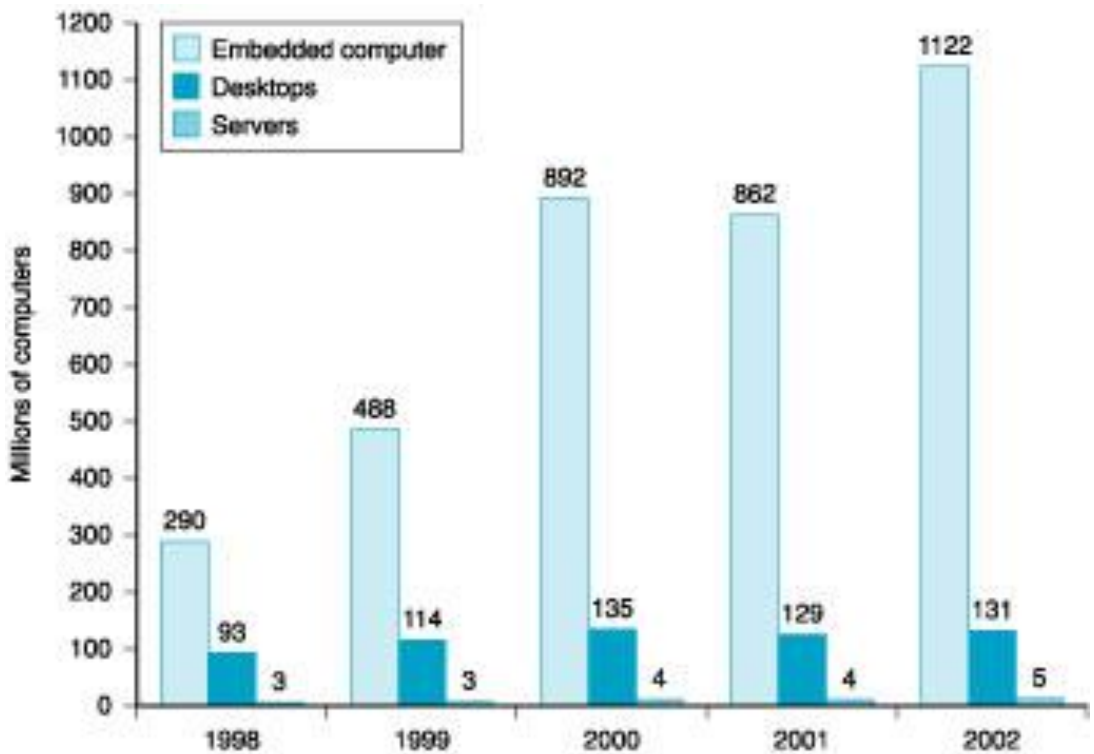
- **Embedded Computers**

  A computer inside another device used for running one predetermined applications or collection of software.

  - General purpose machine vs. Special purpose machine

Classes of Computing Applications

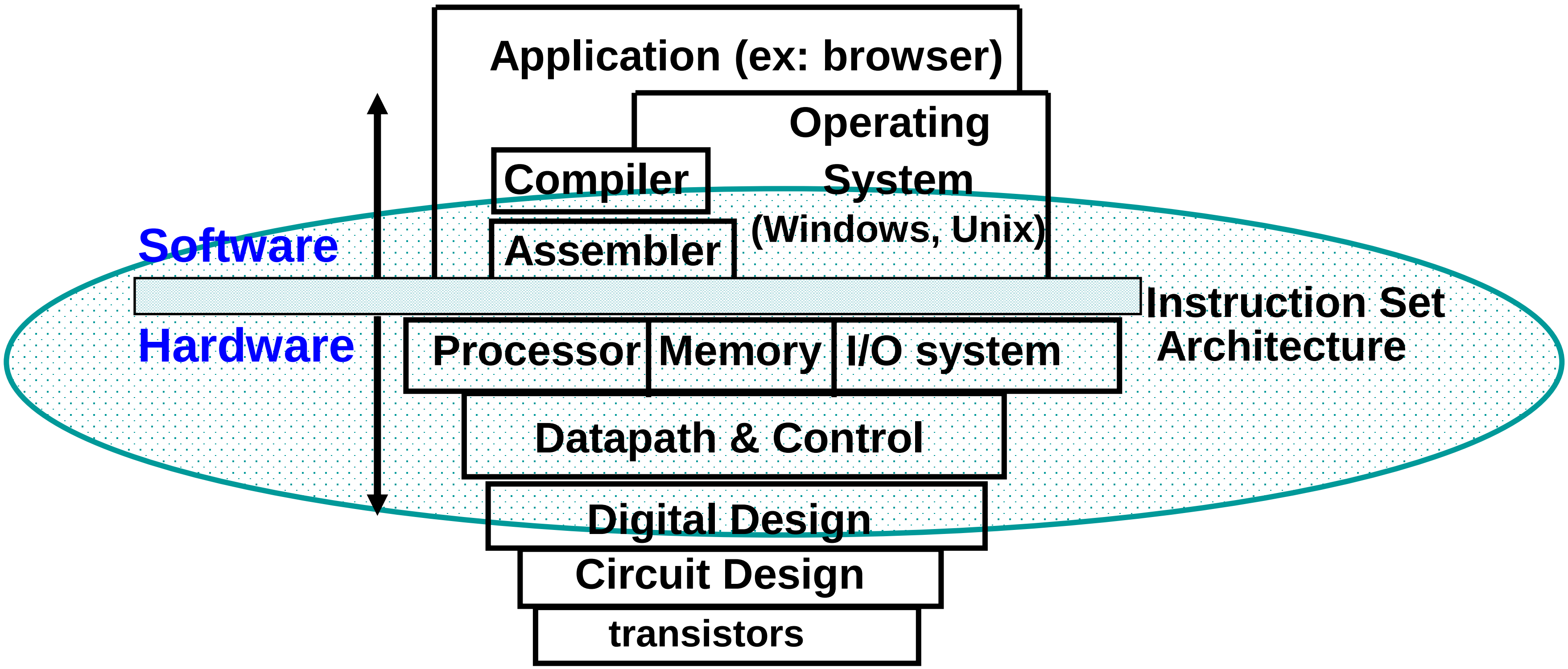
- Desktop Computers
  - Including laptops (notebook computers)
- Servers
  - Used to be called mainframes, minicomputers, and supercomputers
  - Supercomputer : consists of hundreds to thousands of computers
- Embedded Computers
  - Including microprocessors in washing machine, car, cell phone, video game, printers, …



What You Will Learn

- How programs are translated into the machine language.
  - And how the hardware executes them
- The hardware/software interface
- What determines program performance.
  - And how it can be improved
- How hardware designers improve performance.
- What is parallel processing.

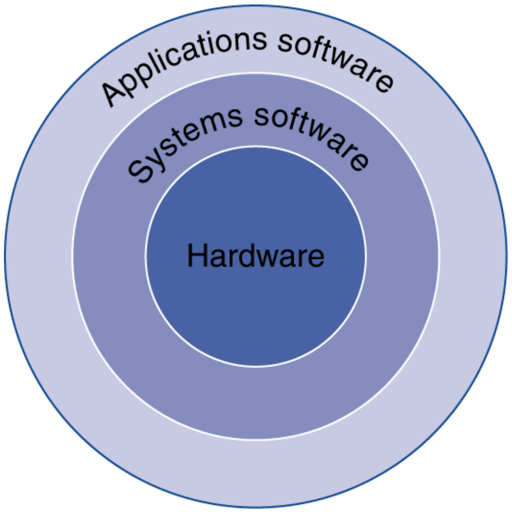
What are "Machine Structures"?



* Coordination of many

levels (layers) of abstraction

Below Your Program



- Application software
  - Written in high-level language
- System software
  - Compiler: translates HLL code to machine code
  - Operating System: service code
    - Handling input/output
    - Managing memory and storage
    - Scheduling tasks & sharing resources
- Hardware
  - Processor, memory, I/O controllers

Levels of Representation

High Level Language Program

```
temp = v[k];
v[k] = v[k+1];
v[k+1] = temp;
```

Compiler

Assembly Language Program

“instruction”

```
lw    $15,   0($2)
lw    $16,   4($2)
sw    $16,   0($2)
sw    $15,   4($2)
```

Assembler

Machine Language Program

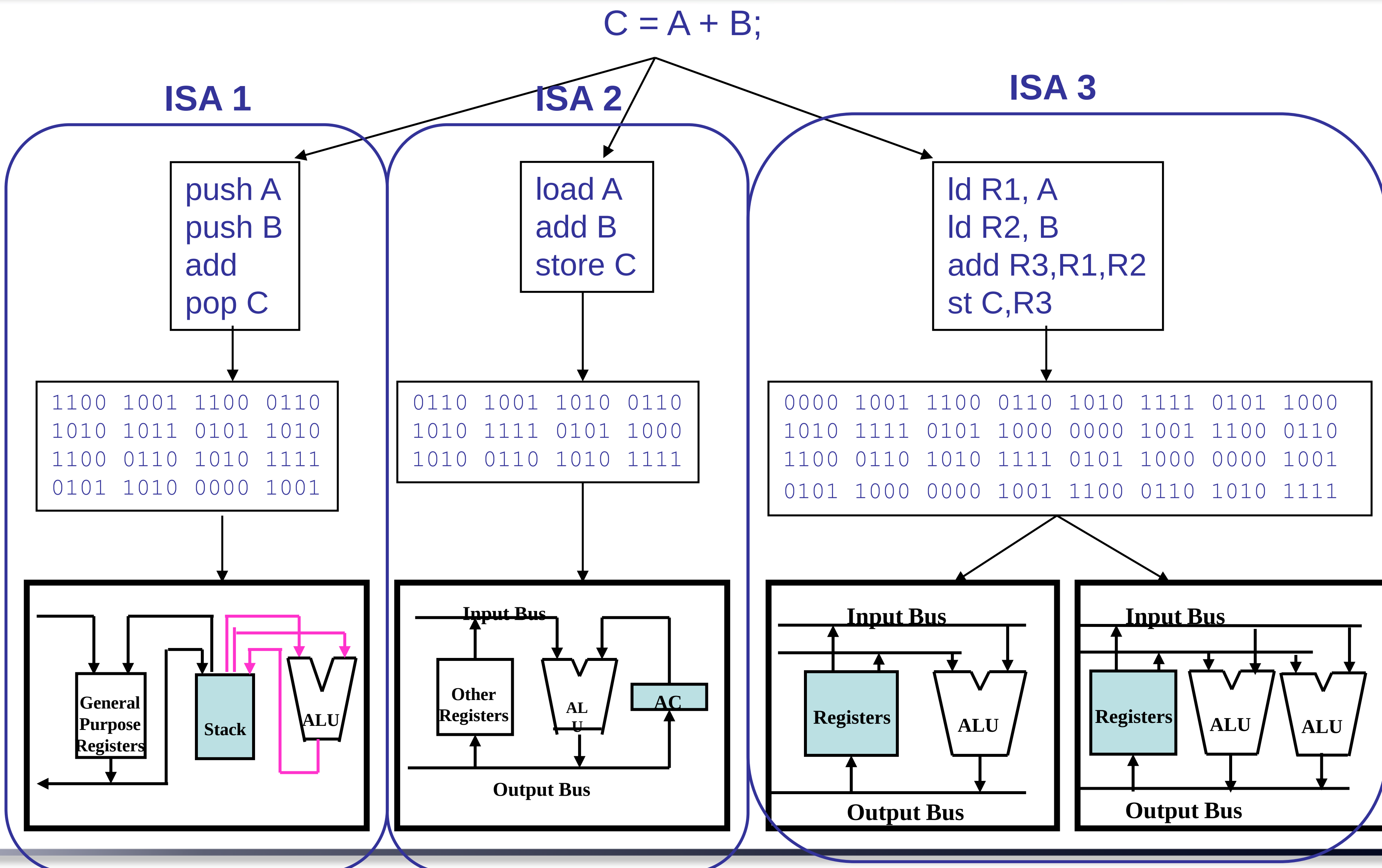
```
0000 1001 1100 0110 1010 1111 0101 1000
0000 1001 0101 1000 0000 1001 1100 0110
1100 0110 1010 1111 0101 1000 0000 1001
1100 0110 0000 1001 1100 0110 1010 1111
```

Machine Interpretation

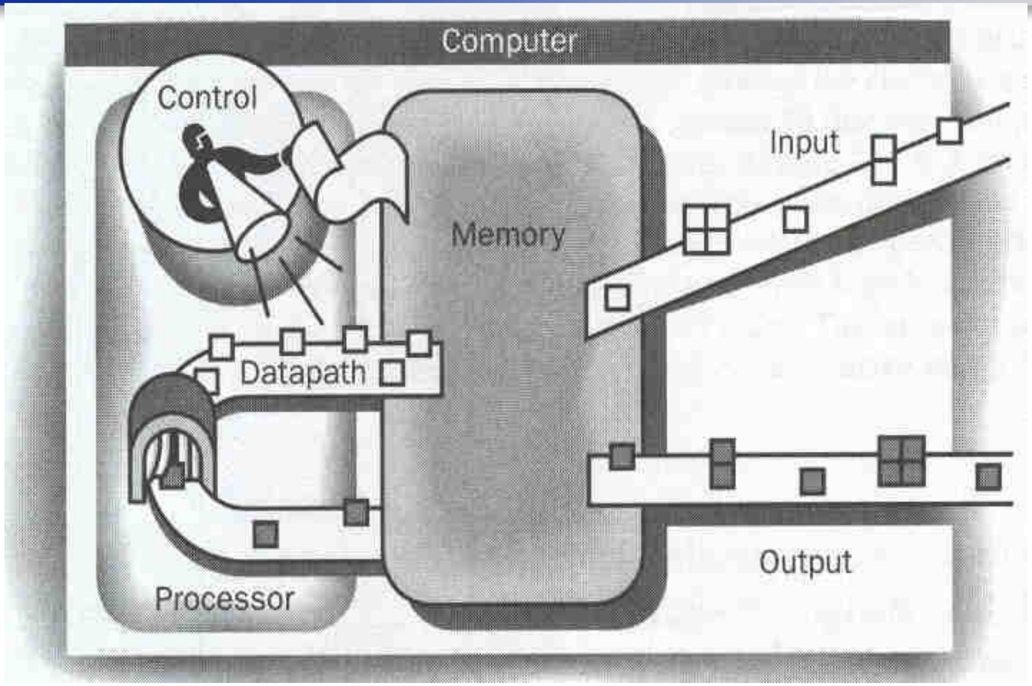
Control Signal Specification

High and low signals on control lines

Instruction Set Architecture (ISA)



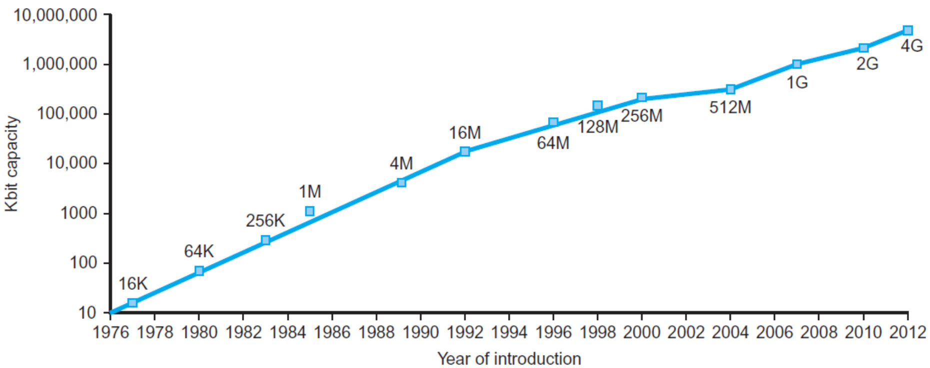
Computer System Organization



- 5 Classic components of computer:
  - Control
  - Datapath
  - Input (mouse, keyboard)
  - Output (display, printer)
  - Memory (disk drives, DRAM, SRAM, CD)
- Or CPU(Control & Datapath), Memory, I/O
- Our primary focus: the processor (datapath and control)
  - implemented using millions of transistors
- Note : SoC (System on Chip)

Technology Trends

- **Electronics technology continues to evolve**
  - **Increased capacity and performance**
  - **Reduced cost**



DRAM capacity

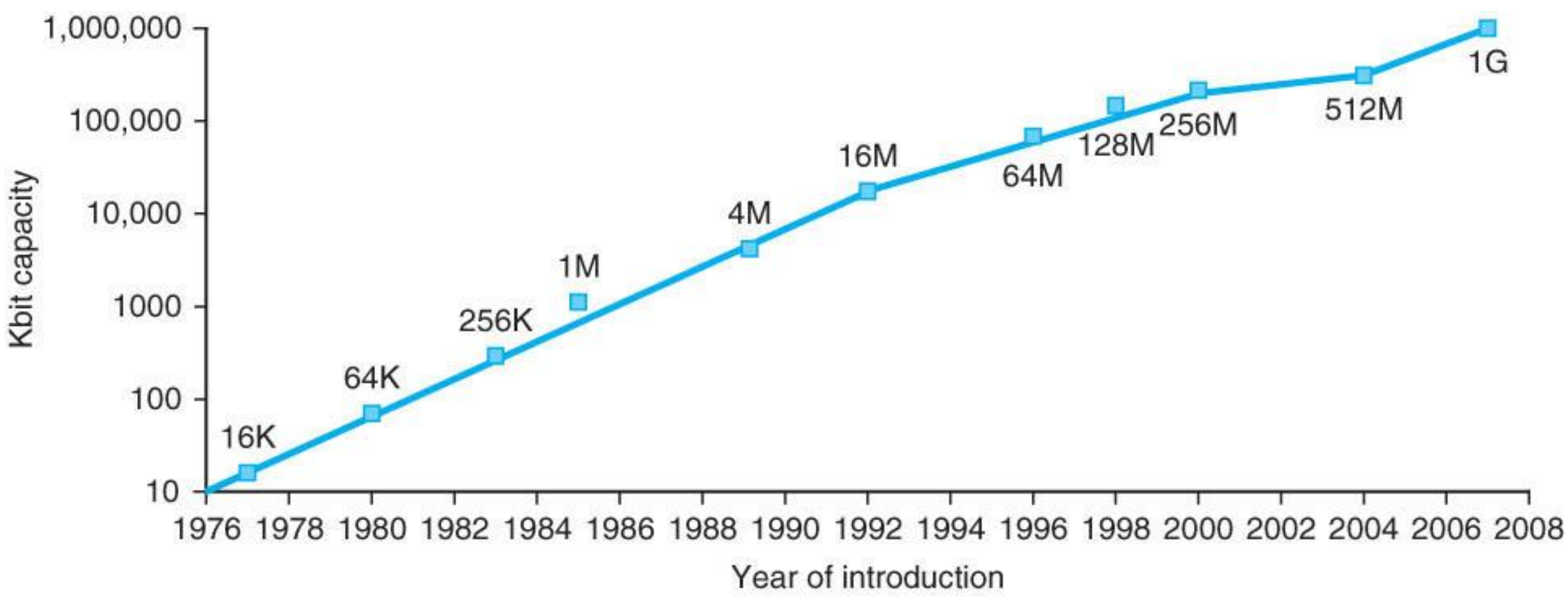
Year	Technology	Relative performance/cost
1951	Vacuum tube	1
1965	Transistor	35
1975	Integrated circuit (IC)	900
1995	Very large scale IC (VLSI)	2,400,000
2005	Ultra large scale IC	6,200,000,000

Technology Trends: Memory Capacity (Single-Chip DRAM)

- **Moore's law** : The number of transistors that can be inexpensively placed on an IC is doubling approximately every two years. (1965)

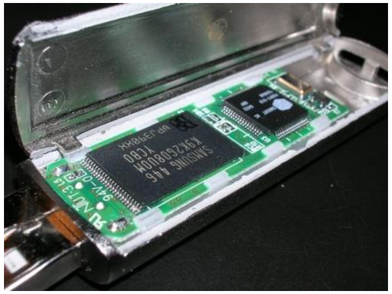
- **Hwang's law** : In 2002, Hwang put forward a new idea that supplanted the long-standing principle governing semiconductor capacity growth known as Moore's Law. Hwang's theory that capacity doubles every 12 months came to be known as Hwang's Law.

DRAM capacity

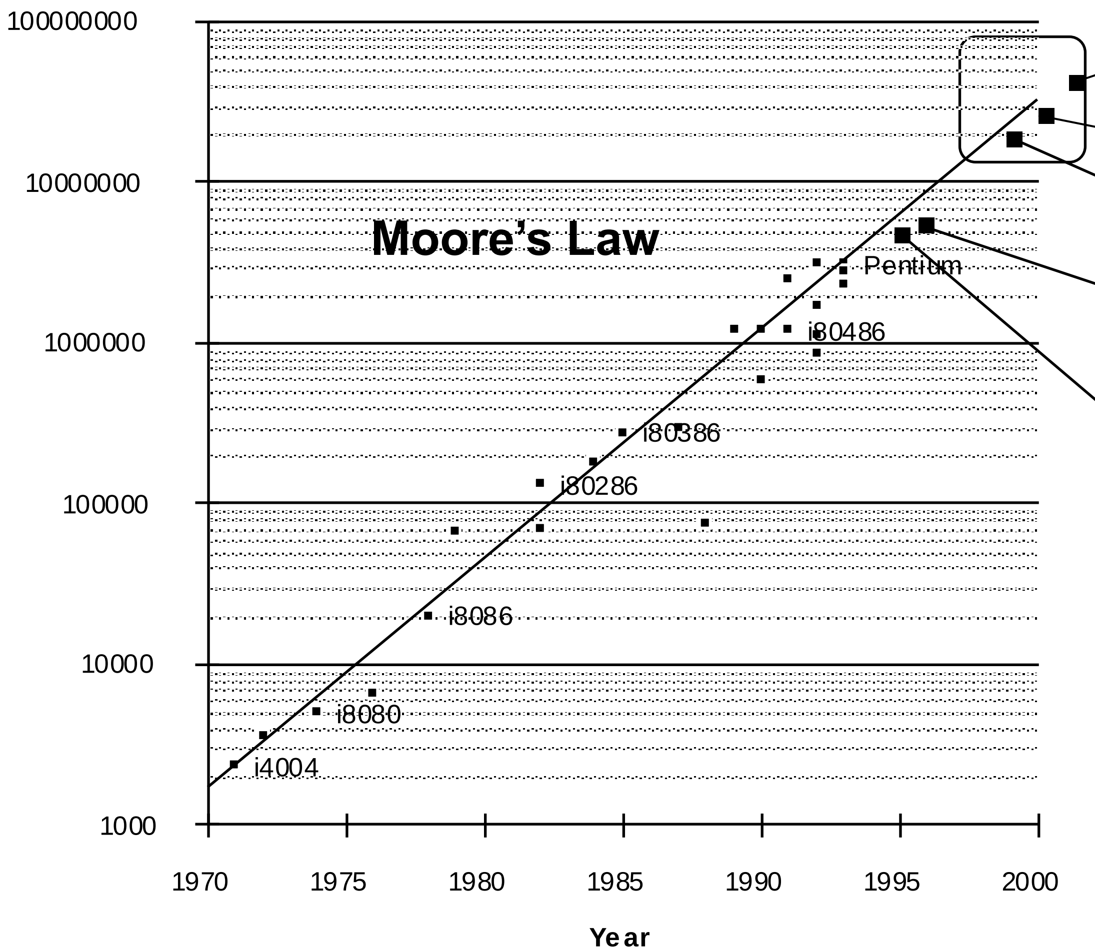


A Safe Place for Data

- **Volatile main memory**
  - **Loses instructions and data when power off**
- **Non-volatile secondary memory**
  - **Magnetic disk**
  - **Flash memory**
  - **Optical disk (CDROM, DVD)**



Technology Trends: Microprocessor Complexity



Itanium 2: 410 Million

Athlon (K7): 22 Million

Alpha 21264: 15 million

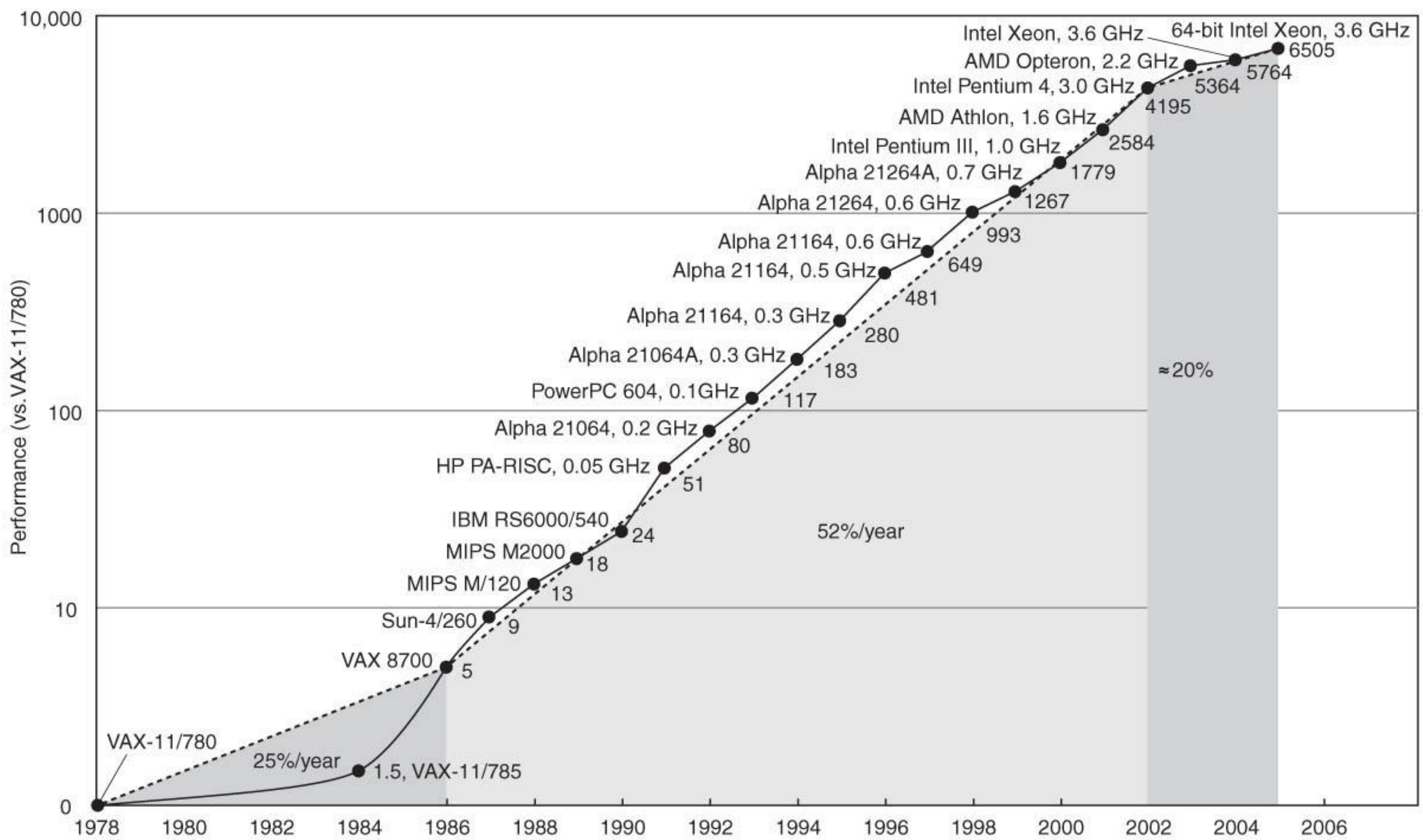
Pentium Pro: 5.5 million

PowerPC 620: 6.9 million

Alpha 21164: 9.3 million

Sparc Ultra: 5.2 million

Technology Trends: Processor Performance

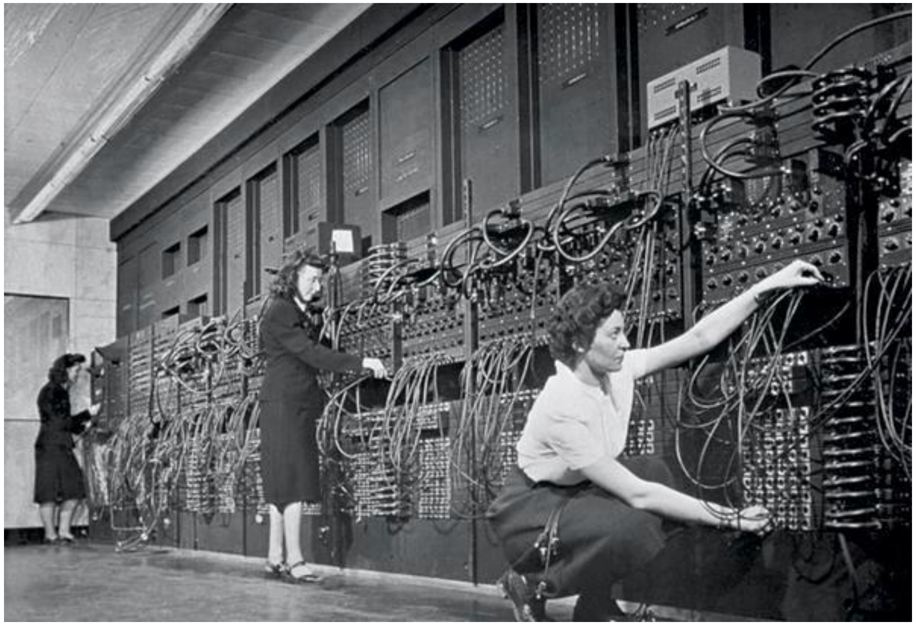


Computer Technology - Dramatic Change!

- **Memory**
  - **DRAM capacity: 2x / 12 months (since '96); 64x size improvement in last decade.**
- **Processor**
  - **Speed 2x / 1.5 years (since '85); 100X performance in last decade.**
- **Disk**
  - **Capacity: 2x / 1 year (since '97) 250X size in last decade.**

Historical Perspective

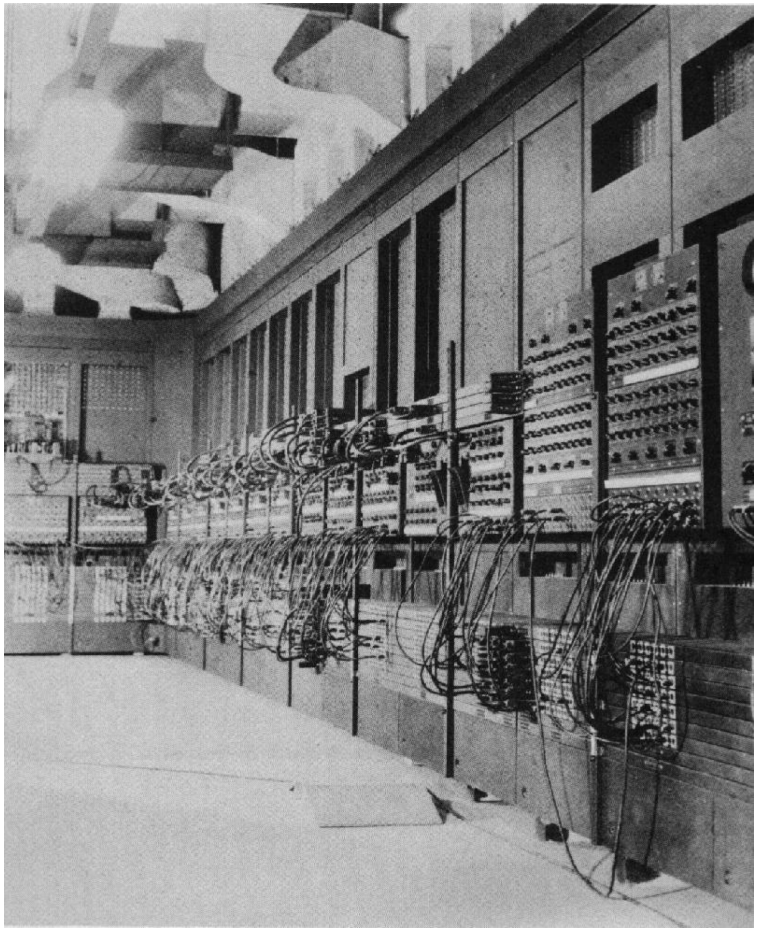
- ENIAC built in World War II was the first general purpose computer
  - Used for computing artillery firing tables
  - 80 feet long by 8.5 feet high and several feet wide
  - Each of the twenty 10 digit registers was 2 feet long
  - Used 18,000 vacuum tubes



– **Since then:**

Moore's Law
Hwang's law

ENIAC vs. Core Duo



DOWNSIZING AND UPGRADING

The inception of computing inspired a remarkable race for faster, smaller, lighter, cheaper hardware.

	ENIAC	Intel Core Duo chip
Debut	1946	2006
Performance	5,000 addition problems/sec	21.6 billion ops/sec
Power use	170,000 watts	31 watts max
Weight	28 tons	negligible
Size	80' w x 8' h	90.3 sq. mm.
What's inside	17,840 vacuum tubes	151.6 M transistors
Cost	$487,000	$637

In this course

- **Things you’ll be learning:**
  - **how computers work, a basic foundation**
  - **how to analyze their performance (or how not to!) - ?**
  - **issues affecting modern processors (caches, pipelines)**
- **Why learn this stuff?**
  - **you want to call yourself a “computer scientist (or engineer)”.**
  - **you want to build software people use (need performance)**
  - **you need to make a purchasing decision or offer “expert” advice**

Where we are headed

- **Instruction set architecture (Chapter 2)**
- **Arithmetic and how to build an ALU (Chapter 3)**
- **Performance issues (Chapter 1)** ***vocabulary and motivation***
- **Constructing a processor to execute our instructions (Chapter 4)**
- **Pipelining to improve performance (Chapter 4)**
- **Memory: caches and virtual memory (Chapter 5)**
- **I/O (Chapter 6)**
- **Multiprocssors (Chapter 7) ?**

Key to a good grade: reading the textbook!