COMPUTER ORGANISATION
(TỔ CHỨC MÁY TÍNH)

Computer Organisation

Acknowledgement

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Overview

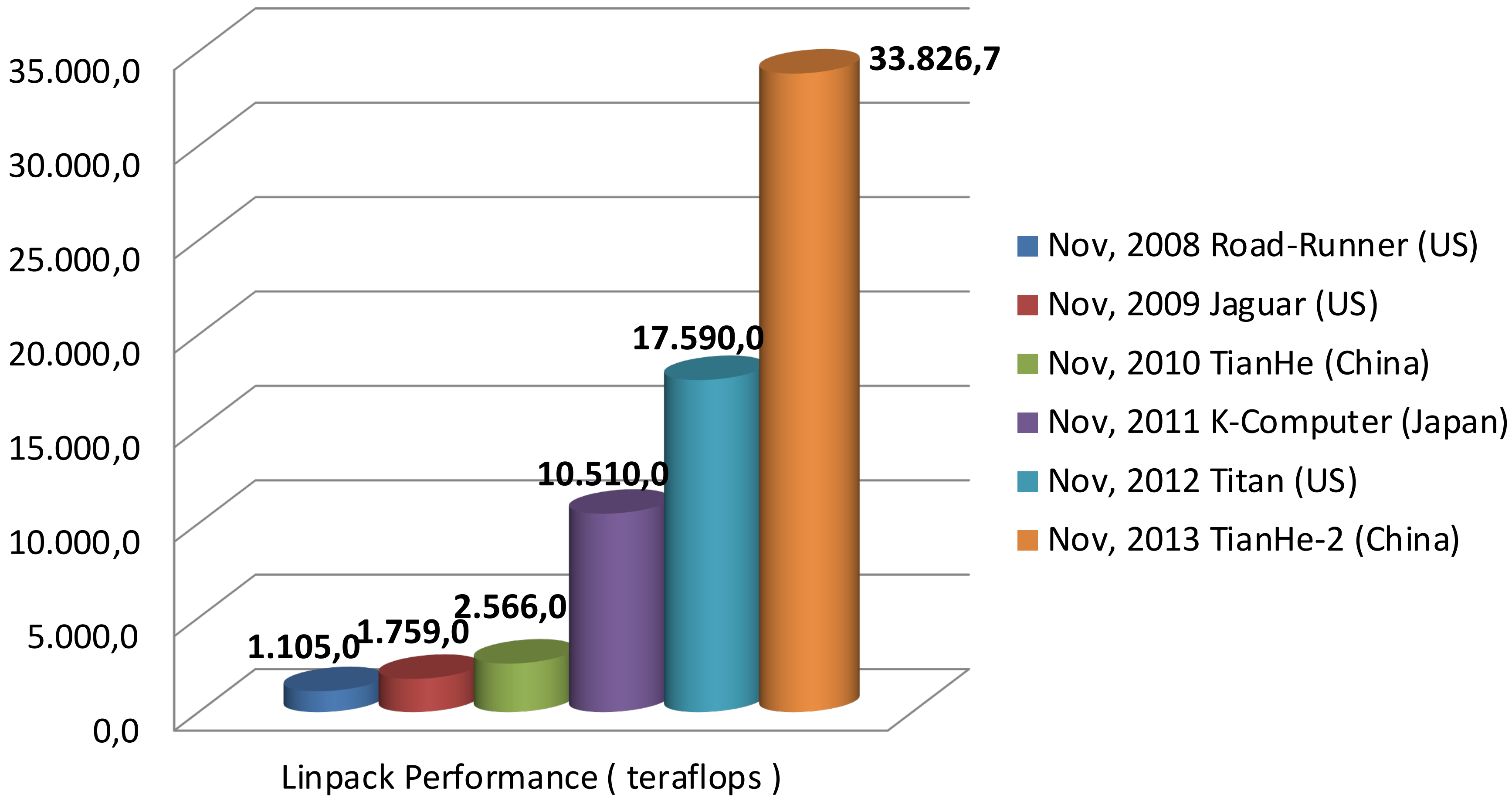
- The Big Picture
  - Brief History of Computer
  - Current Trend

- The Course (2^{nd} Part)
  - Von Neumann Architecture
  - Instruction Set Architecture
  - Compilation Flow
  - Instruction Execution Flow

The Brief History of Computers

Year	Name	Speed	Remarks
1946	ENIAC	~1900 addition/sec	First electronic computer
1951	UNIVAC	~2000 addition/sec	First commercial computer
1964	IBM 360	500k ops/sec	Best known mainframe
1965	PDP-8	330k ops/sec	First minicomputer
1971	Intel 4004	100k ops/sec	First microprocessor
1977	Apple II	200k ops/sec	"First" PC
1981	IBM PC (Intel 8088 + MS-DOS)	240k ops/sec	Dominated market since then
2003	Intel Pentium 4	6G flops	"Last" Unicore
2011	Intel Core i7	~120G flops	Representative multicores

The Brief History: **Supercomputer**

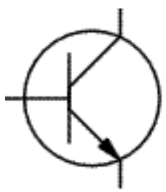


The Brief History: **Embedded**

- **Everywhere**
  - Smart-phone
  - Game consoles
  - DVD / Blue-Ray player
  - Car, Fridge, Washing Machine……… etc etc

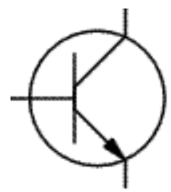
Summary: From a few to many^n

Transistor is the building block of CPU since 1960s



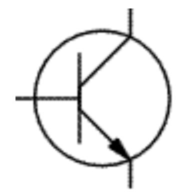
1970 - 1980

2K – **100**K



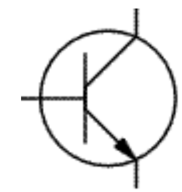
1980 - 1990

100K – **1**M



1990 - 2000

1M – **100**M



2000 - 2011

100M – **2.2**B

Current World Population = 7 billion

about the number of transistors in 3 CPU chips!

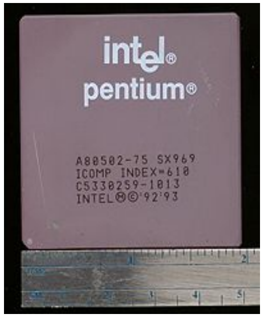
Summary: From **BIG** to small

Process size = Minimum *length* of a transistor

80286

1982

1.5 µm



Pentium

1993

0.80 µm - 0.25 µm

Pentium 4

2000

0.180 µm - 0.065 µm

Core i7

2010

0.045 µm - 0.032 µm

Wave length of visible light = 350nm (violet) to 780nm (red)

Process size now smaller than wavelength of violet light!

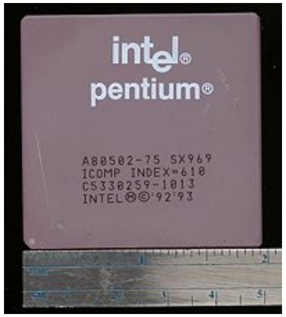
Summary: From S-L-O-W to *fast*

FLOPS = **FL**oating-point **O**peration **P**er **S**econd

80286

1982

1.8 MIPS*



Pentium

1993

200 MFLOPS#

Pentium 4

2000

4 GFLOPS#

Core i7

2011

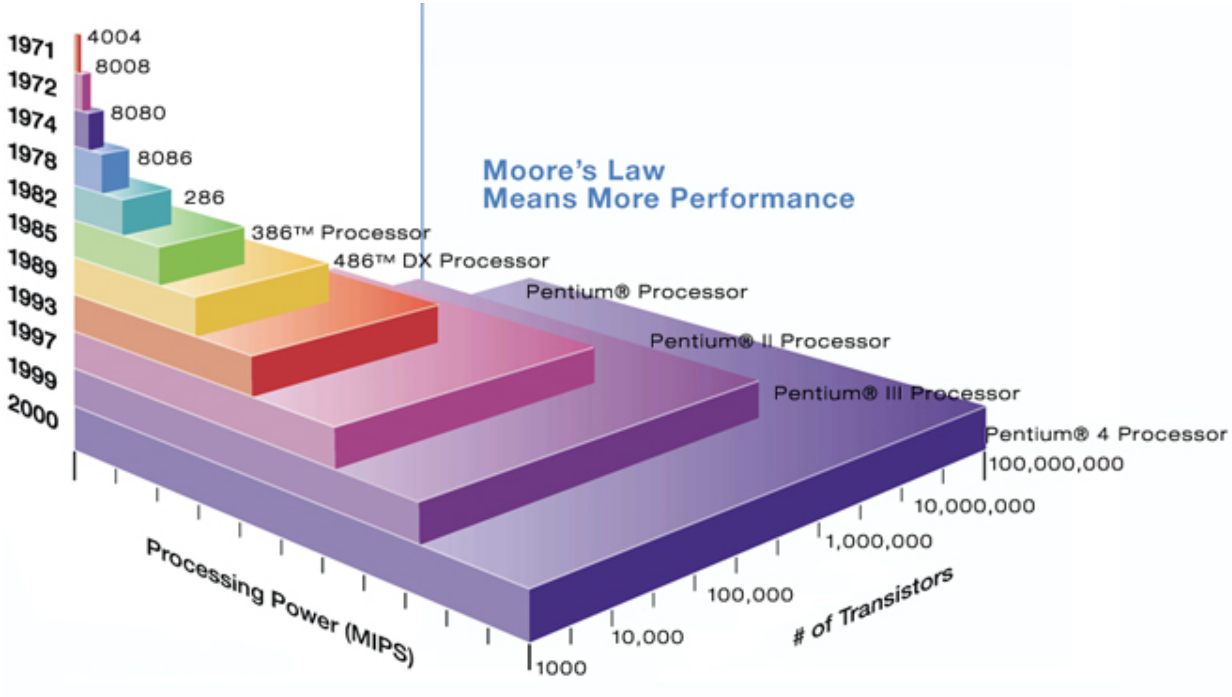
120 GFLOPS #

Summary: The Age of Computer

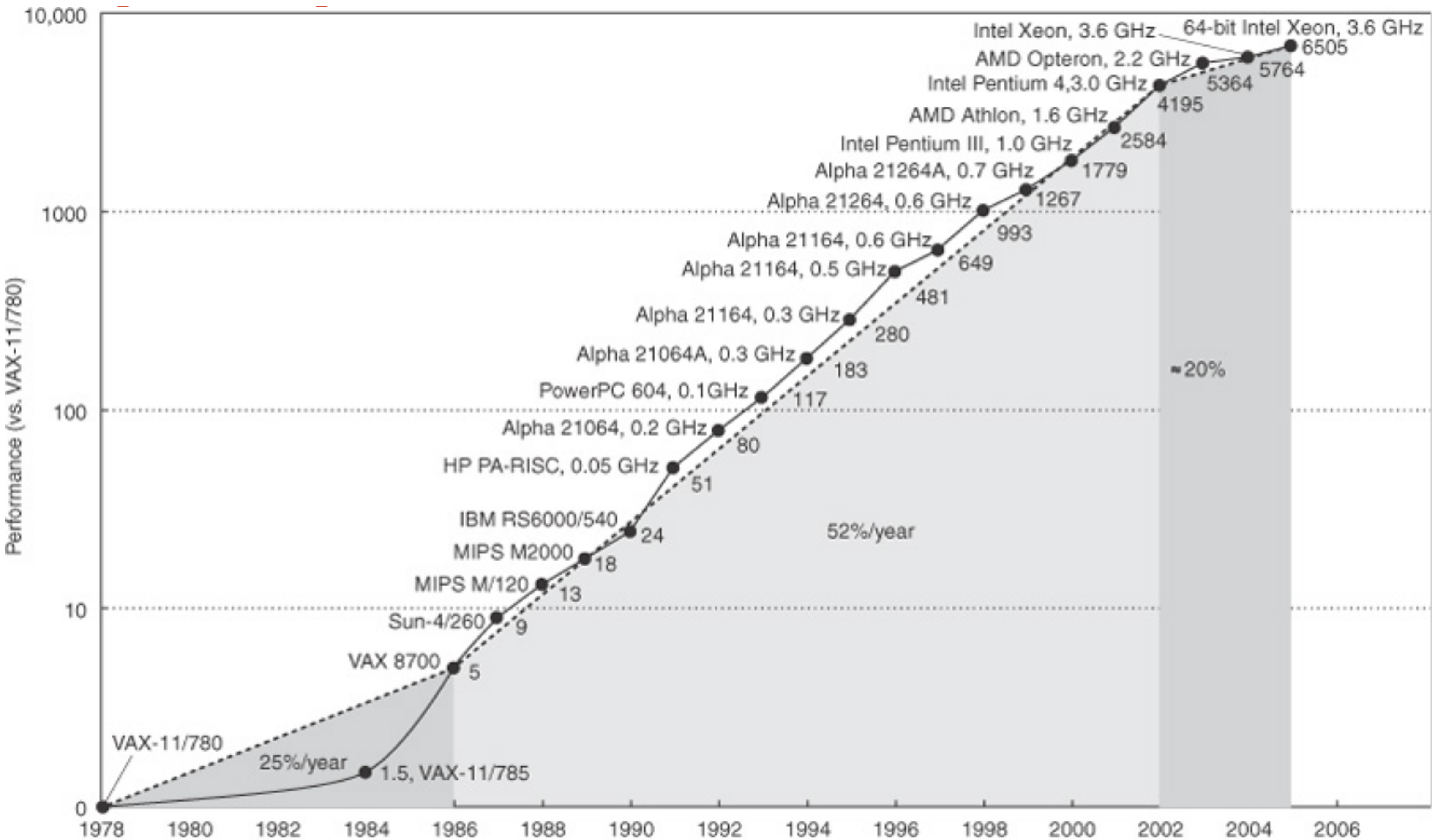
- **Unprecedented** progress since late 1940s
- Performance doubling ~2 years (1971-2005):
  - Total of 36,000X improvement!
  - If transportation industry matched this improvement, we could have travelled from Singapore to Shanghai, China in about a second for roughly a few cents!
- Incredible amount of innovations to revolutionize the computing industry again and again

Moore's Law

- Intel co-founder Gordon Moore "predicted" in 1965 that Transistor density will double every 18 months



PROCESSOR PERFORMANCE



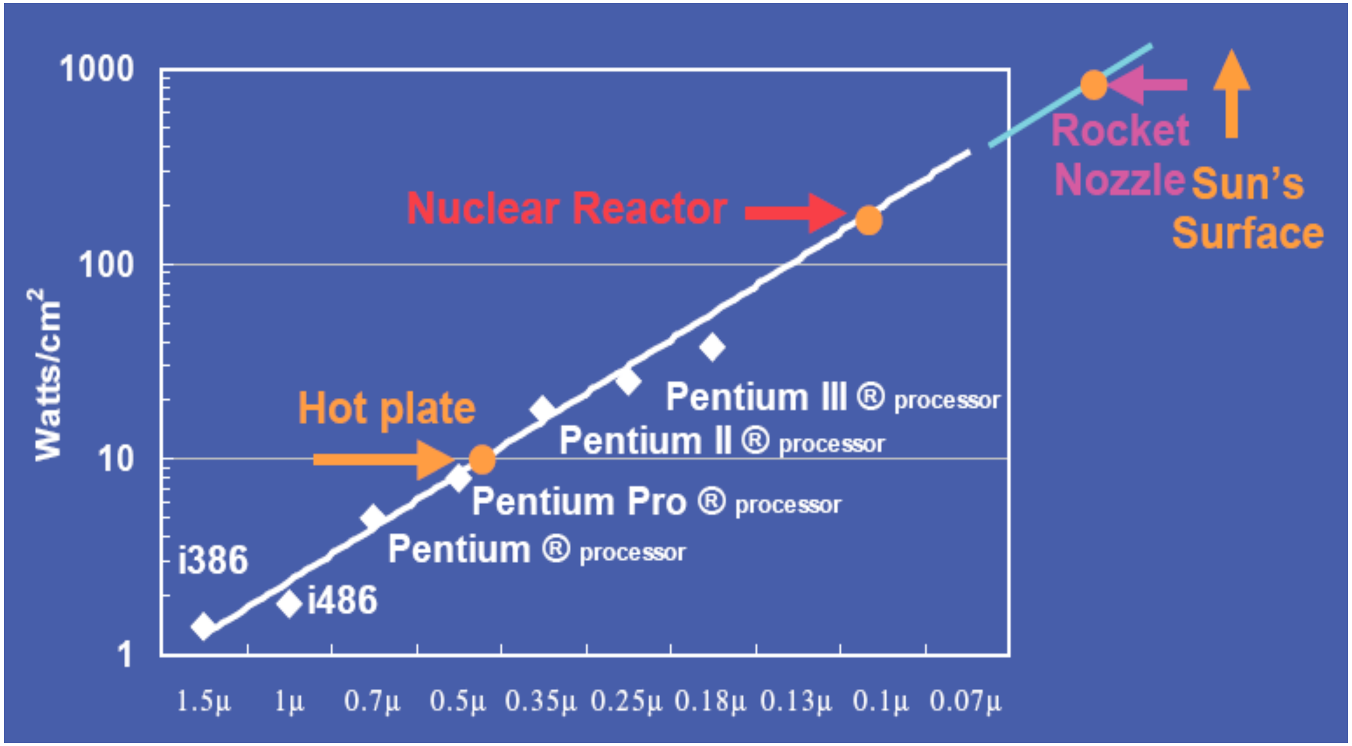
The Three Walls

- Three major reasons for the unsustainable growth in uniprocessor performance

1. **The Memory Wall:**
    - Increasing gap between CPU and Main memory speed
2. **The ILP Wall:**
    - Decreasing amount of "work" (instruction level parallelism) for processor
3. **The Power Wall:**
    - Increasing power consumption of processor

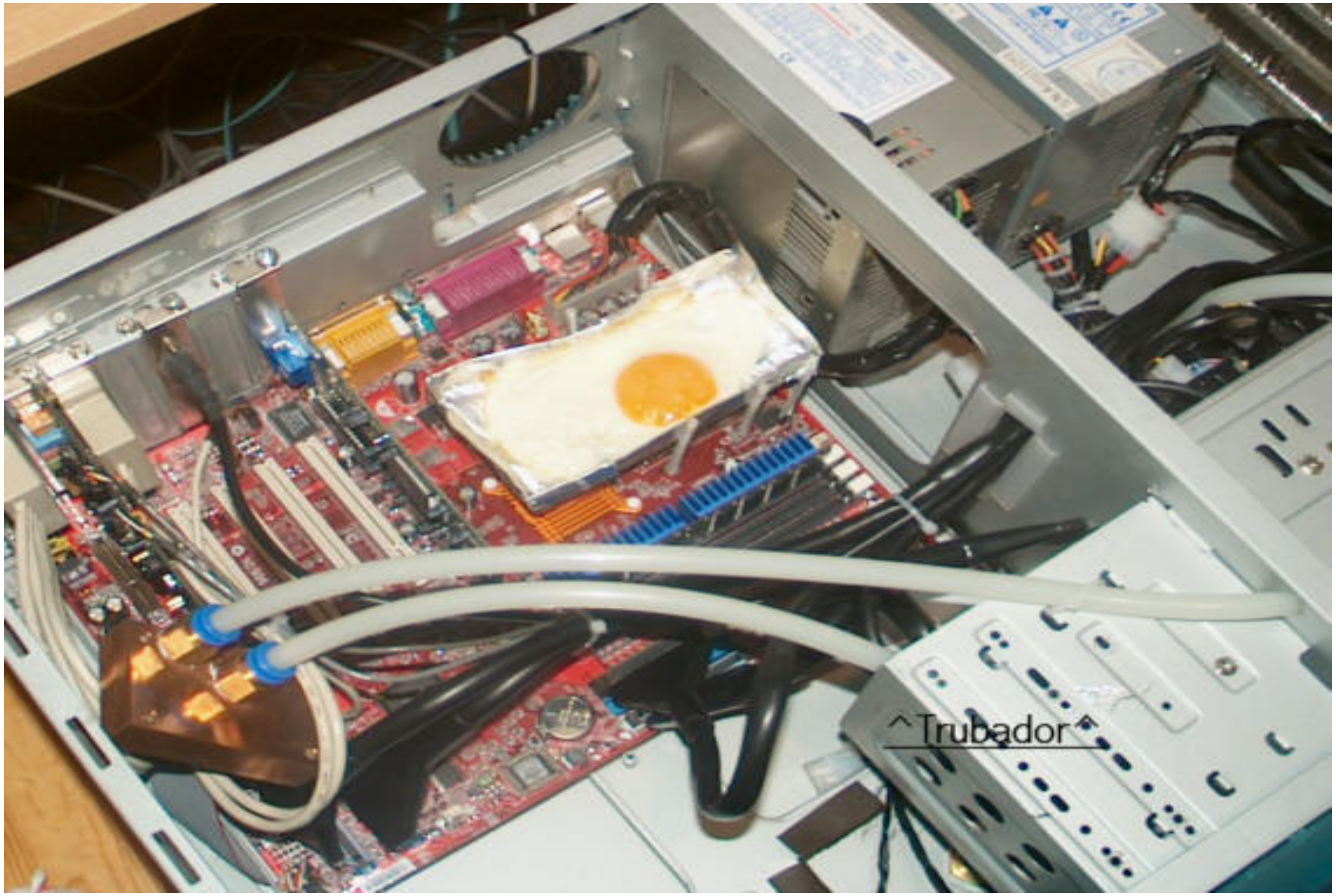
The Power Wall

- We can now cramp more transistor into a chip than the ability (power) to turn them on!



Breakfast Anyone?

- Hot enough to cook an egg!



Current State of Computer

- Multicore is the future
  - All PC chip manufacturers have abandoned unicore development
  - Expect to have more cores in a single chip

  ➔Parallel programming is more important than ever (CS3210, CS3211)
- Great opportunity for computing professional
  - New programming model is required
  - Parallelising existing software
  - Innovative ways to tap into the computing power

2ND PART OF C.O

So, what do we get to learn?

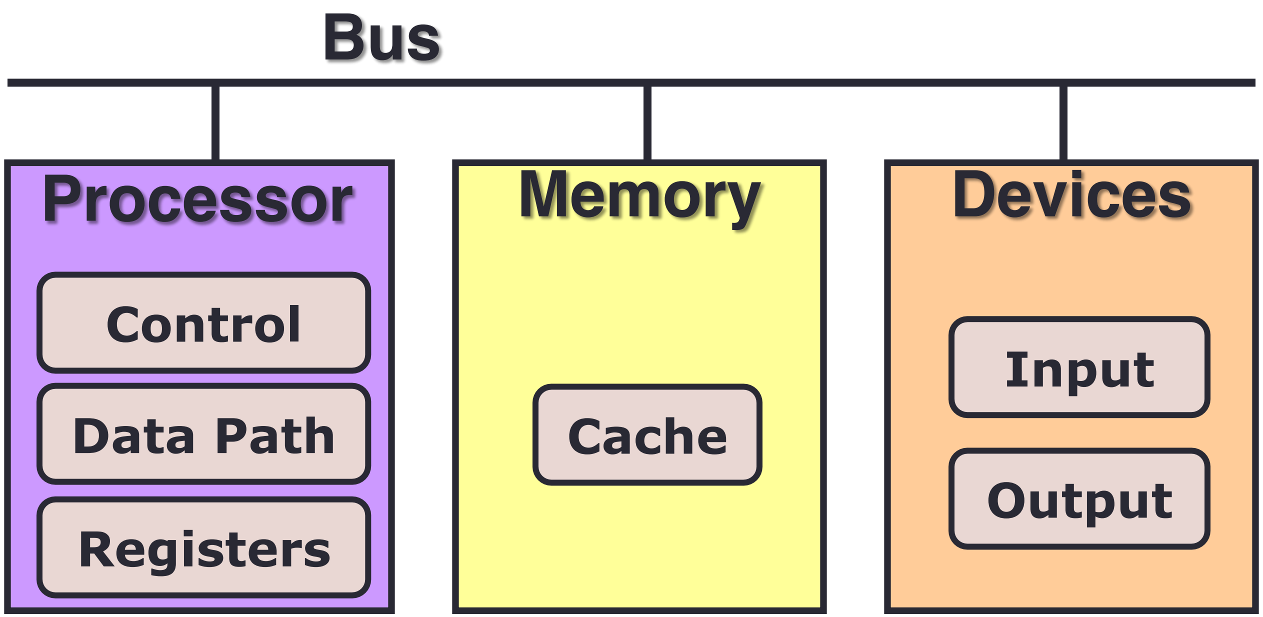
Computer Organization vs Architecture

- **Computer Organization**:
  - Electronic Engineer's view of a computer system
- **Computer Architecture**:
  - Assembly Programmers' view of a computer system
    - High level abstract view

- This course aims to:
  - Give an in-depth understanding of the inner working of a computer system
  - Concentrate on conceptual understanding rather than hardware implementation

Von Neumann Architecture

- Proposed by ***John Von Neumann*** et al, 1945
- Major components of a computer system:

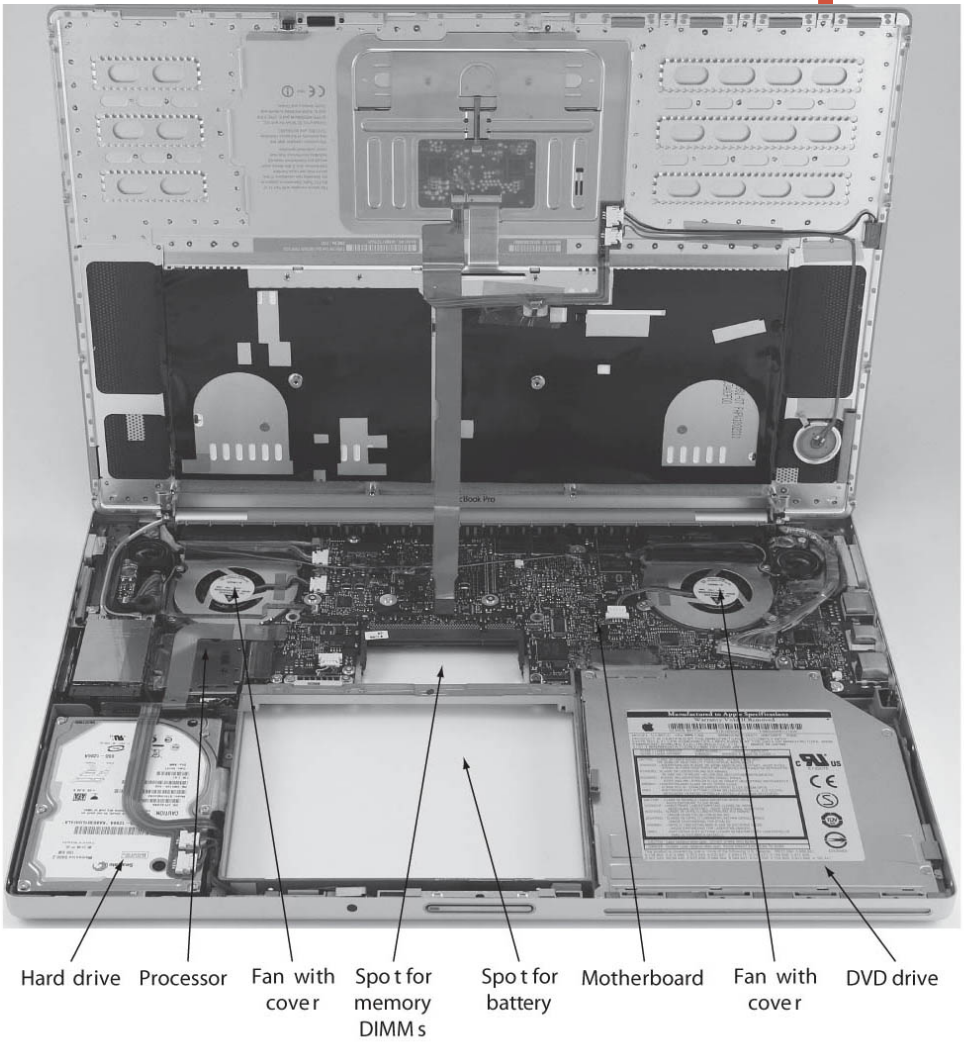


- Stored-Memory Concept:
  - Data and program are stored in memory

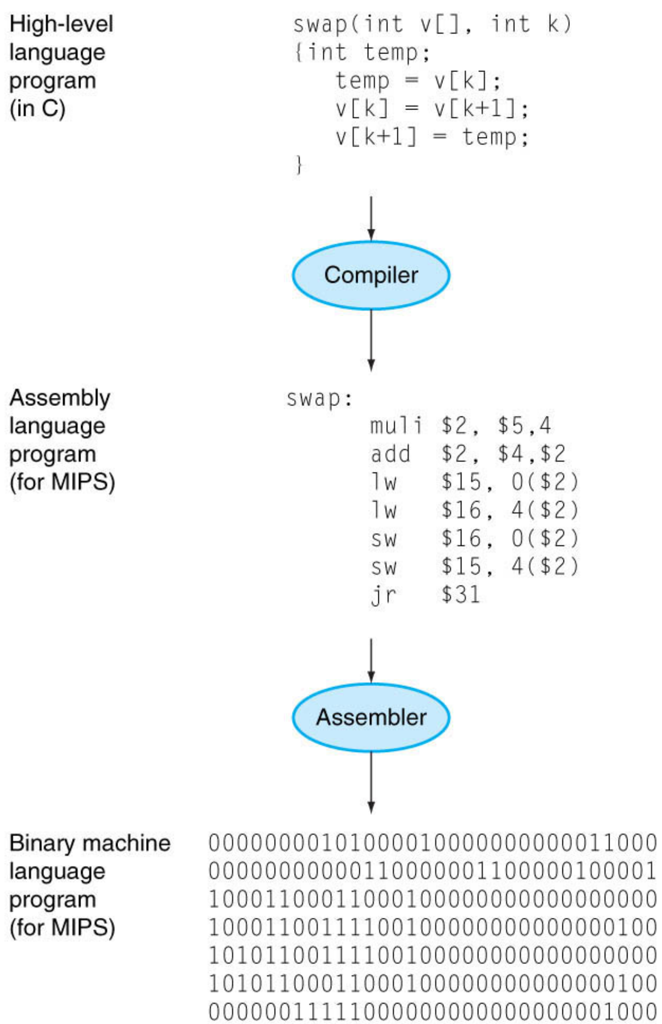
Components of Computer

Datapath:	• Reads data from memory, processes it, writes it back to memory
Control:	• Sends signals that determines the operation of datapath, memory, I/O
Register:	• Fast intermediate storage for values and control information
Memory:	• stores program and data
Input:	• feeds data (keyboard, mouse)
Output:	• processing result to user (display)

Example: **Inside Your Laptop**



How do we "control" the hardware?



- You write programs in high level programming languages, e.g., C/C++, Java:

```
A + B
```

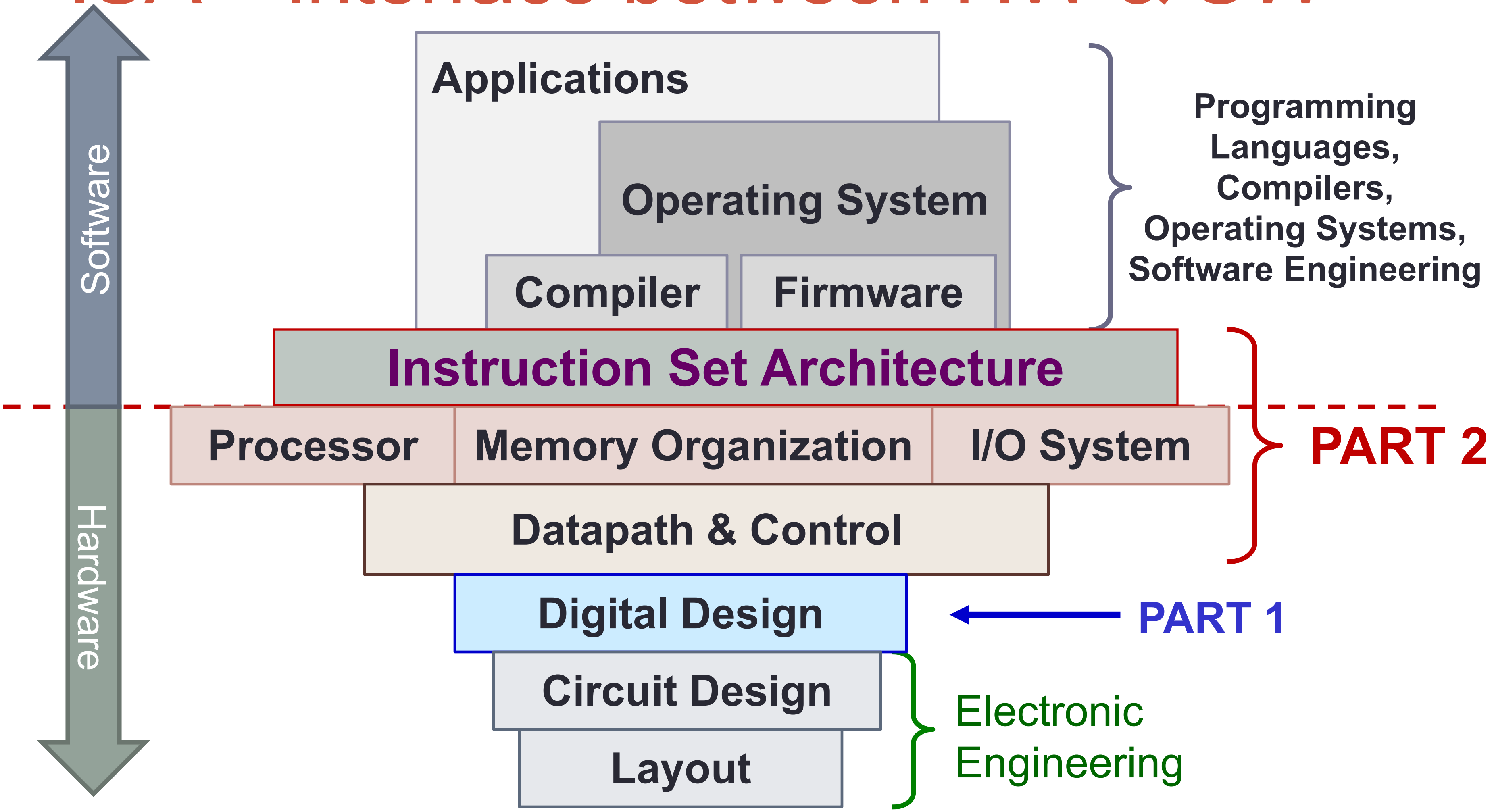
- Compiler translates this into assembly language statement:

```
add A, B
```

- Assembler translates this statement into machine language instructions that the processor can execute:

```
1000 1100 1010 0000
```

ISA – Interface between HW & SW



Instruction Set Architecture (ISA)

- Instruction Set Architecture (ISA)
  - A subpart of computer architecture that is related to programming, as seen by the programmer and compiler

- ISA exposes the capabilities of the underlying processor as a set of well defined instructions
  - Serves as the interface between hardware and software
  - Serves as an abstraction which allow freedom in hardware implementations

Instruction Set Architecture - Examples

x86-32 (IA32)

- Intel 80486, Pentium (2,3, 4), Core i3, i5, i7
- AMD K5, K6, Athlon, Duron, Sempron
- **Dominates the PC market**

MIPS

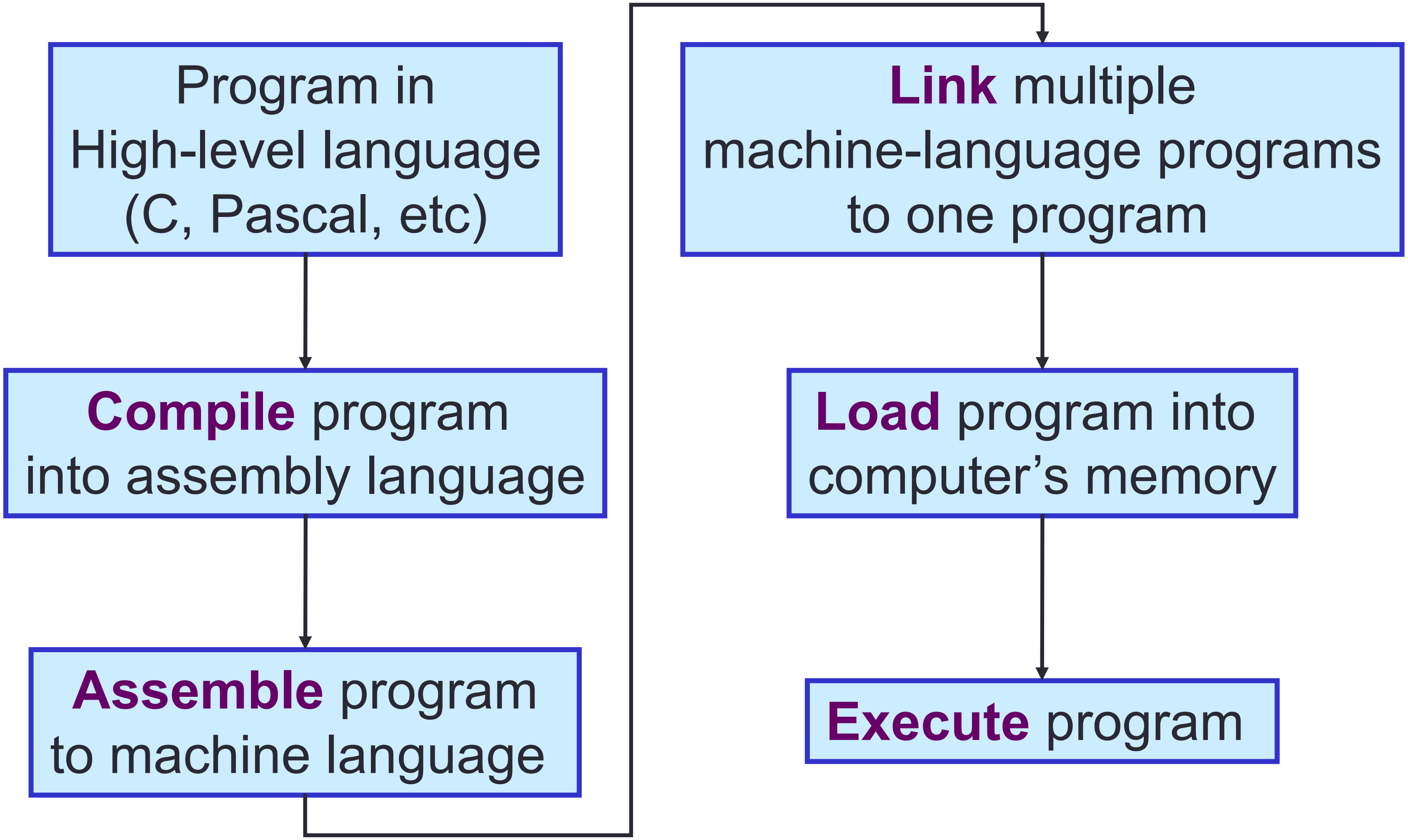
- R2000, R3000, …., R10000
- **Widely used in Comp. Org/Arch courses as RISC example**

ARM

- Generations of chips: ARMv1, v2, …., v7
- StrongARM, ARM Cortex
- **Most popular embedded system chip**

- Observe that each ISA has a family of chips i.e. multiple hardware implementations

The *Life* of a program



Code Execution

- ***Instruction Execution Cycle*** in the Processor:

Fetch:
- Fetch next instruction from memory into processor

Decode:
- Decode the instruction

Execute:
- Get operands
- Execute instruction
- Store the execution result

Road Map for 2nd Part

Topic	Lecture Set(s)
Processor Performance	10
MIPS Assembly Language	11, 12, 13
The processor: - Datapath - Control	 14 15
Pipelining	16
Memory : Cache	17, 18
Input / Output	19*

Reading Assignment

- Computer Abstractions and Technology
  - Read up COD sections 1.1 – 1.3.

Q&A