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CSC2510 - Computer Organization

Lecture 1: Introduction

Philip Leong

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Course Details

- Lecturer: Prof. Philip Leong
- Tutor: Miss Tu Zhou (Wed 1:30pm LHCG06, Thur 4:30pm LHC101)
- Lectures:
 - M9-10 changed from HCA 332 to ERB 401 (starting Mon 11th).
 - T5 ERB712
- Credit: 50% Final, 25% Mid-Term, 25% Homework


Thanks to Drs Y.S. Moon (CUHK), O. Mencer (Imperial), N. Dulay (Imperial) for some of the slides used in this course

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- Textbook: Hamacher, Vranesic, Zaky , Computer Organization (5th ed.), McGraw Hill, 2002
- Academic honesty: <http://www.cuhk.edu.hk/policy/academichonesty/>
- Website: <http://www.cse.cuhk.edu.hk/~phwl/teaching/csc2510>
- Email: phwl@cse.cuhk.edu.hk, tzhou@cse.cuhk.edu.hk

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What is a Computer?

- Apple Macintosh “Personal Computer” (circa 1990)

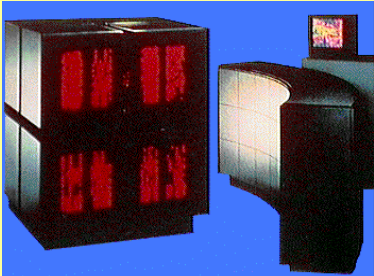


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What is a Computer?



- Thinking Machines “Connection Machine”



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What is a Computer?

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What are they used for?

- Word processing
- Image processing
- Art: Music/Pictures/Movies creation, distribution
- Entertainment / Games
- AI - Robotics
- Simulation
- Communications e.g. Chat, Email, Video conferencing, etc.

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What are they used for?

- Email
- Internet Browsing
- Games
- Databases
- Word Processing
- Spreadsheets
- Desktop / Web Publishing
- Accounts/Stock Control/Banking
- Payroll
- Education
- Machines/Appliances/Electronic Devices
- Computer-Aided Design
- Air-Traffic Control
- Weather Prediction
- Weapons
- Designer Drugs
- Oil Exploration
- Human Genome Project
- Financial Markets
- Nuclear Reactor Control
- Exploring Space
- Art: Music, Pictures, Movies, creation and distribution

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Computers & CPUs



COMPUTER

Apple
Power Macintosh
7100/66

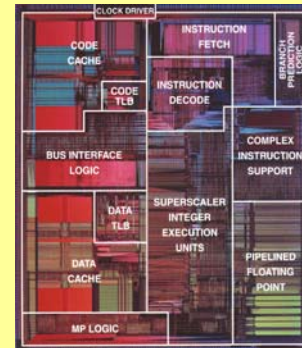
CPU

Motorola
PowerPC 601/66

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CPU on a Chip -> Microprocessor



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CPUs

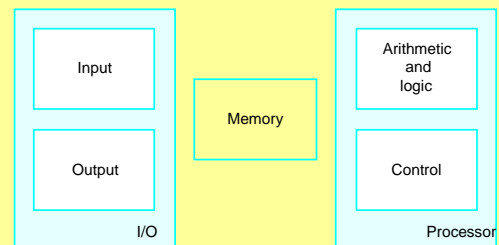
- Intel Pentium
 - Motorola/IBM PowerPC
 - AMD K7
 - ARM StrongArm
 - Compaq (DIGITAL) Alpha
 - Zilog Z80
 - Motorola 68000
 - 6502
 - MIPS
- Interesting details about CPUs
http://bwrc.eecs.berkeley.edu/CIC/archive/cpu_history.html

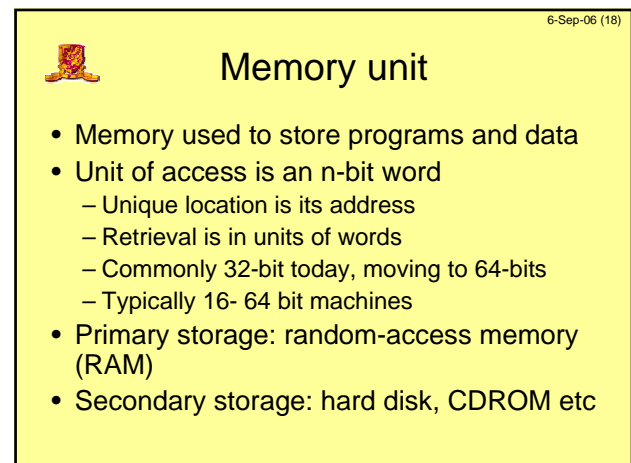
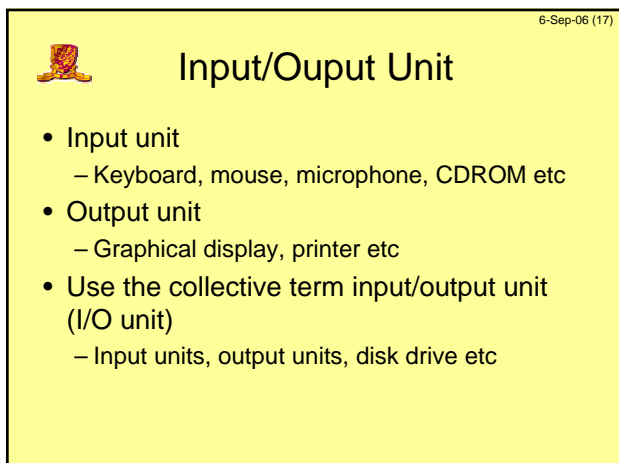
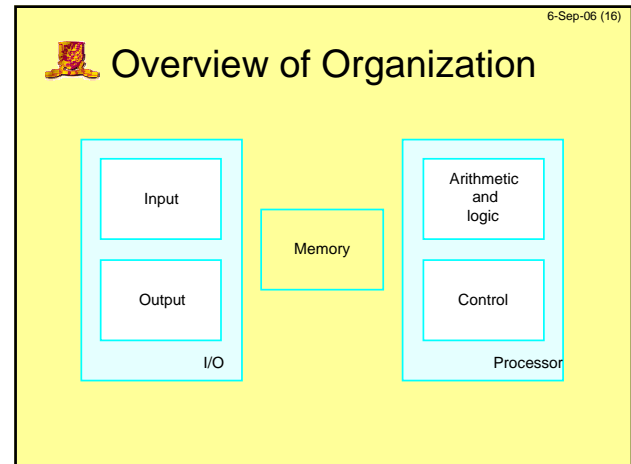
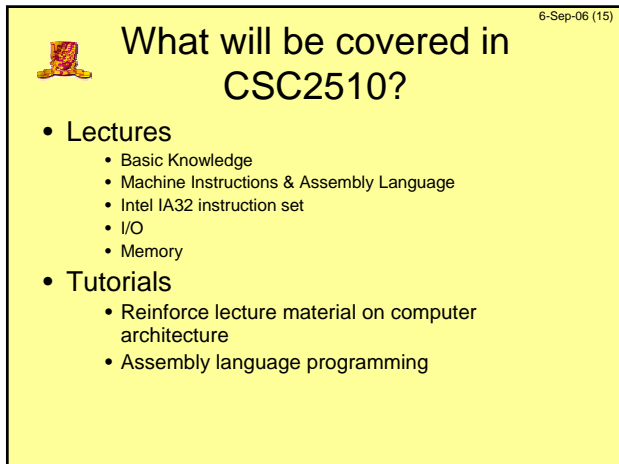
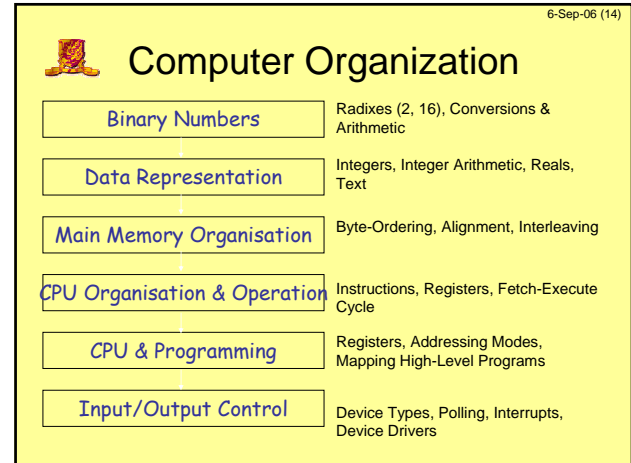
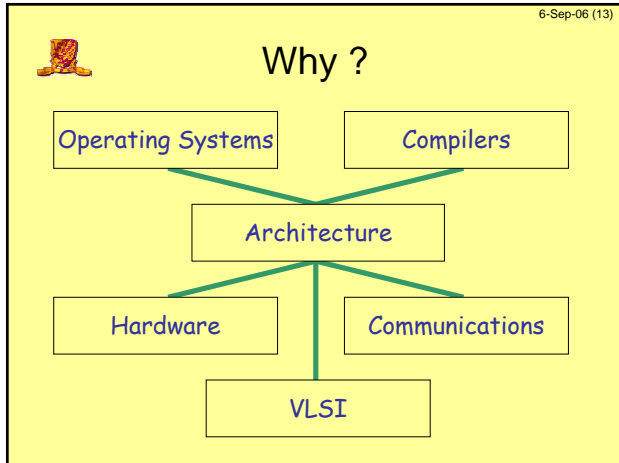
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Course Aims

In this course we shall focus on the Organisation & Operation of the **CPU**. This involves computer architecture and assembly language programming





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Processor

- Registers
 - Small but fast storage of intermediate values in a computation
- Arithmetic logic unit: performs computations
 - e.g. add, divide, logical operations etc
 - c.f. calculator
 - Operands taken from registers
- Control
 - Orchestrates the transfer of data and sequencing of operations between memory, registers, ALU, I/O devices

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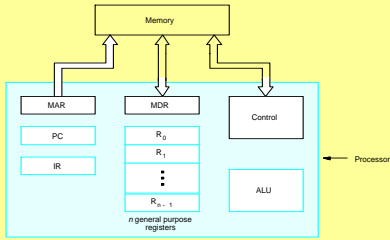
How a program is executed

- Program and data reside on CDROM or hard disk
- Data stored in memory is fetched under program control into ALU and processed
- Processed information sent back to I/O unit
- All activities directed by control unit

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Processor detail

- Machine has n registers
- PC used to keep track of execution of a program
- Points to the next instruction to be fetched from memory
- Memory address register (MAR) used to specify address for memory transfer
- Memory data register (MDR) contains data to be written or data read from memory
- Some instructions specify I/O operations



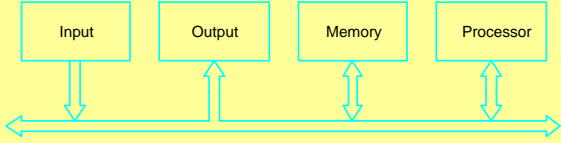
The diagram shows a central 'Processor' box containing several components: MAR (Memory Address Register), MDR (Memory Data Register), PC (Program Counter), IR (Instruction Register), Control, ALU, and a set of n general purpose registers labeled R_0 through R_{n-1} . Above the processor is a 'Memory' box. Bidirectional arrows connect the Memory to the MAR, MDR, and Control. A single arrow points from the Memory to the PC. A single arrow points from the IR to the Memory. A single arrow points from the ALU to the Memory. A single arrow points from the Control to the Memory.

Figure 1.2. Connections between the processor and the memory.

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Bus

- A bus is used for communications between the processor, memory and I/O
- advantages?
 - multiple buses are often used for higher performance



The diagram shows four boxes labeled 'Input', 'Output', 'Memory', and 'Processor' arranged horizontally. Below them is a long horizontal line representing a bus. Bidirectional arrows connect each box to the bus.

Figure 1.3. Single-bus structure.

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Bus

- Allows computer to be customised for different applications e.g. different peripherals
- Design criteria – speed, cost, etc
- Word length can be different depending on application
 - E.g. USB is serial (1-bit), PCI bus is 32-bit

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System Software

- Receive and interpret user commands
- Storage and retrieval from secondary storage
- Running standard application programs e.g. games, word processors, spreadsheets, editors, compilers, assemblers, linkers
- Interface to I/O units e.g. printer
- A key piece of system software is the operating system

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Operating system (OS)

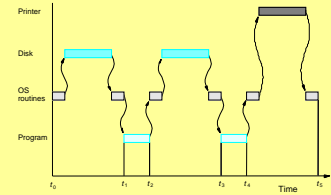
- Assigns computer resources to application programs
 - e.g. sharing of the I/O units, processor, memory, running applications programs

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Multitasking

- Assume computer with 1 processor, 1 disk and 1 printer and application program is in machine code on disk
- t0: the OS loads the program from the disk to memory
- t1: program executes
- t2: program accesses disk
- t3-t4: program executes some more
- t4: program accesses printer
- t5: program terminates



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Applications programs

- Normally written in high level language such as C, C++, Java, Fortran
 - Compiler translates to assembly language and then machine code which the computer can directly execute

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Performance

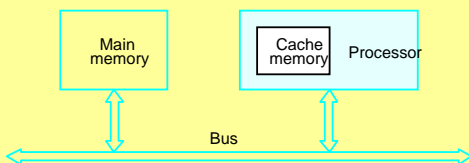
- Most important measure is how quickly it executes your program (t5-t0 of earlier example)
 - Compiler, instruction set and hardware architecture, program all have impact on performance

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Caching

- Optimising memory for speed (cache)
 - Commonly used data are copied to on-processor memory (cache) to reduce access time
 - Small memories can be made higher speed than large ones. In a computer, we need both.



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Performance

- Performance (T=execution time, N=number of instructions, S=average cycles per instruction, R=clock rate in cycles per second)

$$T = \frac{N \times S}{R}$$

- Processor circuits are controlled by a clock (R) e.g. 3.2GHz Pentium operates at 3.2 GHz
 - Control circuit (but not memory) operates at this frequency

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Pipelining and Superscalar

- Pipelining
 - Like a production line, instruction execution overlapped so greater parallelism is achieved
 - What parameters in $T = \frac{N \times S}{R}$ are improved?
- Superscalar operation
 - Execute several instructions simultaneously
 - Multiple ALUs

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CISC vs RISC

- Reduced instruction set computer
 - Large N, small S
- Complex instruction set computer
 - Small N, large S

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Compiler

- Translates high level language such as C, C++, Java to machine instructions
- Aims to reduce $N \times S$

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Performance Measurement

- Computer architects use performance estimates to evaluate the effectiveness of new features
 - Practice is to use benchmarks available to all manufacturers e.g. SPEC benchmark
- Benchmark figures are for real computers
- There are n individual programs and the geometric mean compared with a 300MHz UltraSPARC-IIi machine is the benchmark value
 - Value indicates how much faster e.g. SPEC rating of 10 means it is 10× faster than the UltraSPARC-IIi