

CG3207

Computer Architecture

A/P Tay Teng Tiow

email: eletaytt@nus.edu.sg

<http://courses.nus.edu.sg/course/eletaytt/ee3207/ee3207.html>

What is a (Micro)-Computer ?

What is a (Micro)-Processor ?

- Micro-, Mini-, “*Right-size*”, Super- → have to be rapidly redefined as the years go by.
- No hard definitions.
 - Computer → loosely speaking, generally refers to a system containing a processor + memories (primary and/or secondary) + I/O devices.
 - Processor → loosely speaking, generally refers to the computing part of the computer.
 - But today, exceptions appear more than the rules – so it may be meaningless trying to differentiate.
- A PC is only one type of computer.
 - In fact many little processors/computers lie within the PC box.
 - The main processor (Intel Pentium, AMD Thunderbird for example)
 - The graphics processor,
 - The processor in the hard-disk, keyboard, mouse, ethernet card, and many others. – Easily 10-20 depending on your PC configuration.

What is a Processor ?

- It processes an algorithm.
 - Example: find the average series of numbers, 8 at a time.
 - Method 1
 - Read in all 8 numbers together
 - Add: $K_0 = N_0 + N_1$, $K_1 = N_2 + N_3$, $K_2 = N_4 + N_5$, $K_3 = N_6 + N_7$
 - Add $L_0 = K_0 + K_1$, $L_1 = K_2 + K_3$
 - Add $M = L_0 + L_1$
 - Divide M by 8.
 - Method 2
 - The “Computer” way. Write a program loop.
 - Different structure of implementation – different architecture
- Processing using
 - Hardwired mode – Application Specific Processor (ASP)
 - Normally referred as ASIC
 - Interpreted mode – General Purpose Processor
 - Normally referred as processor
 - Programmable hardwired components – Application Domain Specific Processor (ADSP)
 - Comes different names such as DSP, Image Processor, etc.

What is a Processor ?

- Types of processors
 - General Purpose Processors
 - Application Domain Specific Processors
 - Application Specific Processors
- General Purpose Processors
 - Targeted at general algorithms → implies the algorithm can be changed after the processor is built.
 - Uses an interpreted mode
 - Means has a bunch of instructions that comprehensive enough to perform all the computations required in all digital algorithms.
 - To execute a particular algorithm, the various instructions are called in some specific sequence.
 - Typically sequential → typically there is only one instance for each instruction. Therefore cannot do things in parallel. (*but it is changing*)
 - So it is “slow”.
 - Besides sequential, also needs to fetch instruction, decode and then execute.

What is a Processor ?

- Application Domain Specific Processors
 - Examples are DSPs
 - Targeted at a certain domain of applications.
 - Eg: implementation of filtering or some signal processing algorithms.
 - Typically require to perform a multiple and accumulate operation.
 - Such operations are “hardwired” so that the operation can be done quickly.
 - Programmability of the special functions are normally provided – so that the chip is good for a range of applications and not just one only.
 - Some form of instructions is present.
- Application Specific Processors
 - Very often refers to as ASIC
 - Target only for one application
 - Eg: Real-time MPEG2 encoder
- The bulk of discussions will be targeted towards programmable processors.

What is so interesting about a General Purpose Processor?

- Stored program concept.
 - Hardware is fixed:
 - Functional components
 - A set of fundamental instructions
 - Rearrangement of the instructions (a program) solve different problems!
 - Divided the solution into hardware and software
 - Gives rise to great flexibility
 - Can do changes anytime – almost essential as logic become more complex.
 - Can amortized the expensive setup cost for hardware over more units – as there is little customization needed.
- However
 - Inefficient as processing unit may not be well suited to solution space.
 - Has to provide complete set of processing components and yet some may not be used. Multiple instances may be needed on other cases.
 - Slow – sequential, not parallel.

Module Learning Outcome

- Able to explain the working principles behind the broad spectrum of processors, computing machines and their application to the solutions of modern day problems.
- Able to critically consider and analyse the issues involved in the architectural design of the digital processors and computing machines.
- Able to critically consider and analyse the trade-off in the application of the processor in a wide spectrum of engineering problems.
- Able to design a simple processor using hardware descriptive languages and to demonstrate a working design on an FPGA.

Module Structure

- Lectures, tutorials and 3-person group project.
- Project: 65% of final marks
 - The design of a microprocessor and its implementation on a Xilinx FPGA board
- Final written examination: 30% of final marks
 - Consisting of 40 multiple choice questions relating to critical analysis.
- Class formative online exercises after every chapter: 5%

Scope

- Introduction
- Logic design of a microprocessor
- Supporting tools
- High Performance Processor Design Techniques
- Memory organisation
- Multiprocessor
- More on Hardware Design Techniques
- References:
 - *Computer System Architecture, Mano, M.M., 3rd ed, Prentice Hall.*
 - *Computer Architecture, Baron, R.J. and Higbie, L., Addison Wesley.*
 - *Lecture notes.*

Introduction

- Computer Architecture
- Historical Perspectives
- A Classification of Computer Architectures
- Measuring the Quality of a Computer Architecture
- Factors Influencing the Success of a Computer Architecture
- System Performance

Computer Architecture

- Refers to the design of their instruction set hardware components and system organization
- 2 major parts
 - Instruction Set Architecture (ISA) specifies a computer's behavioral characteristics.
 - The specifications that determine how machine-language programmers will interact with the computer.
 - How it is controlled?
 - What is available to be controlled?
 - A computer is generally viewed in terms of its ISA
 - Hardware System Architecture (HSA) :
 - The specification of the computer's major hardware subsystems, e.g., CPU and I/O system.
 - HSA specifies a computer's structural characteristics and efficiency.
- An implementation of an ISA
 - Architecture vs implementation

Historical Perspectives

- First generation computers (1945 - 1955)
 - Technologies: Vacuum tubes
 - Major architectural innovations: Stored program computer
 - Examples:
 - ABC (Atanasoff-Berry Computer)
 - ENIAC (Electronic Numerical Integrator and Calculator)
 - EDVAC (Electronic Discrete Variable Computer)
 - EDSAC (Electronic Delay Storage Automatic Calculator) : The first stored program computer (von Neumann machine)
 - IAS (Princeton's Institute of Advanced Studies)
- Second generation computers (1955 - 1965)
 - Technologies: Transistors and magnetic-core memory,
 - Examples:
 - TX-0, TX-2 (Transistor eXperimental computer)
 - PDP-1, PDP-8 (Programmed Data Processor)
 - IBM 7090, 7094
 - CDC 6600 (Control Data Corporation)

Historical Perspectives

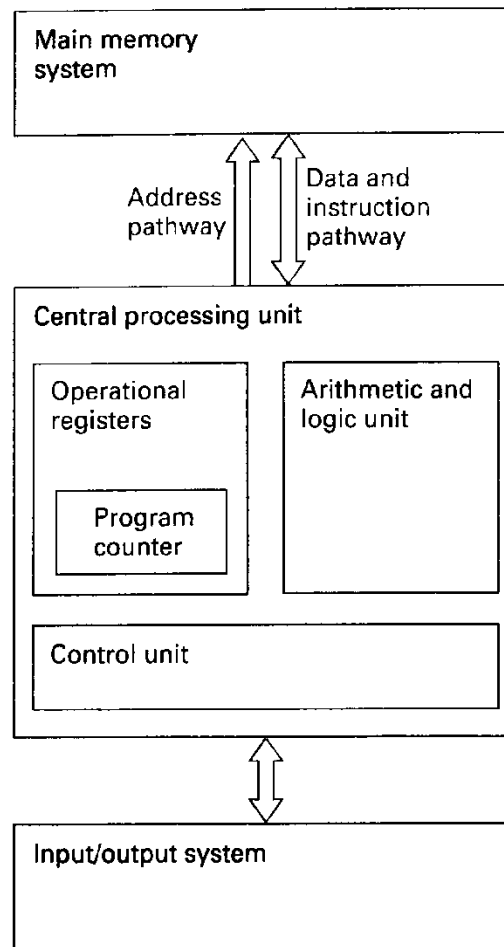
- Third generation computers (1965- 1980)
 - Technologies: Integrated circuits, solid-state or magnetic-core memory, batch-processing operating systems, multiprogramming operating systems
 - Major architectural innovations:
 - Computer-family architecture
 - Microprogramming control units
 - Execution-stack architecture
 - Hardware support for high-level programming language
 - Pipelining and multiple arithmetic units in CPU
 - Highly parallel computer
 - Cache memory
 - Examples:
 - IBM System/360-370, DEC PDP-11, ILLIAC IV, CRAY-1

Historical Perspectives

- Fourth generation computers (1980-)
 - Technologies:
 - VLSI, solid-state memory,
 - time-sharing operating systems,
 - virtual memory,
 - support for many high-level programming languages
 - Major architectural innovations:
 - Reduced-instruction-set computers
 - multiprocessor computers
 - Dataflow architecture
 - Examples:
 - Personal computers
 - Workstations
 - Mainframes
 - Supercomputers

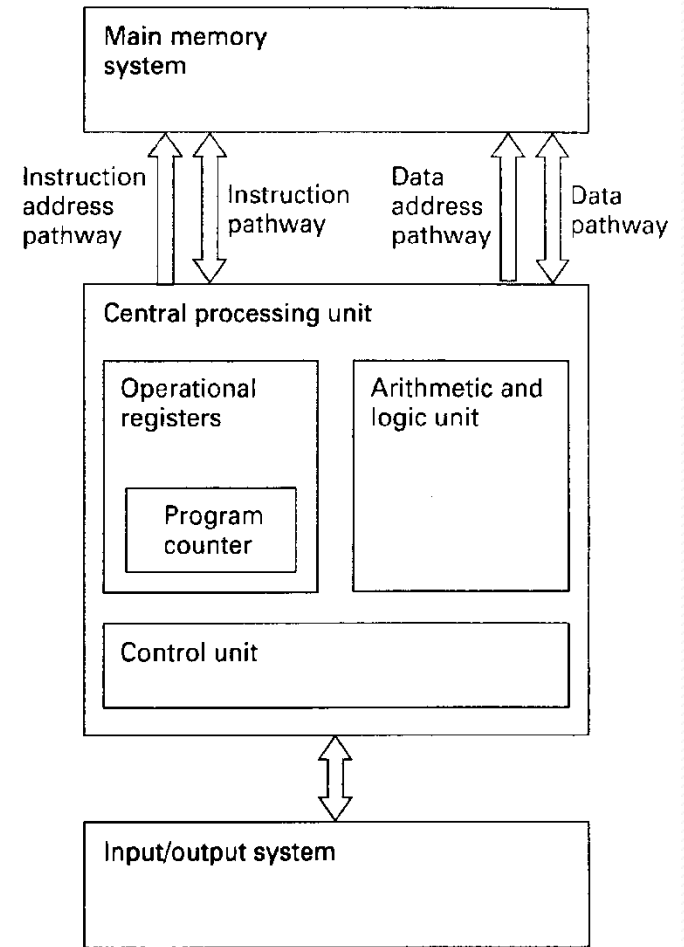
A Classification of Computer Architectures

- Von Neumann Machines
 - a CPU,
 - a main-memory system,
 - an I/O system.
- It is a stored-program computer.
- It carries out instructions sequentially.
- It has a single path between the main memory system and the control unit of the CPU.
- **Harvard: different path for data and instructions**



a.

Von Neumann

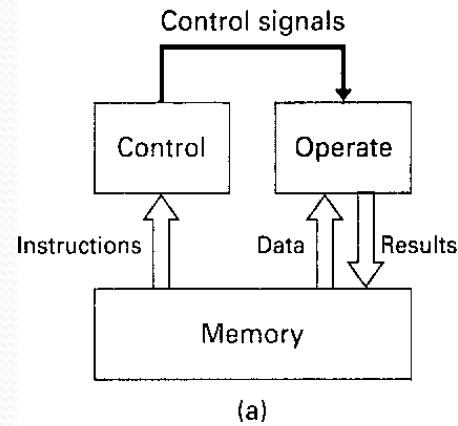


b.

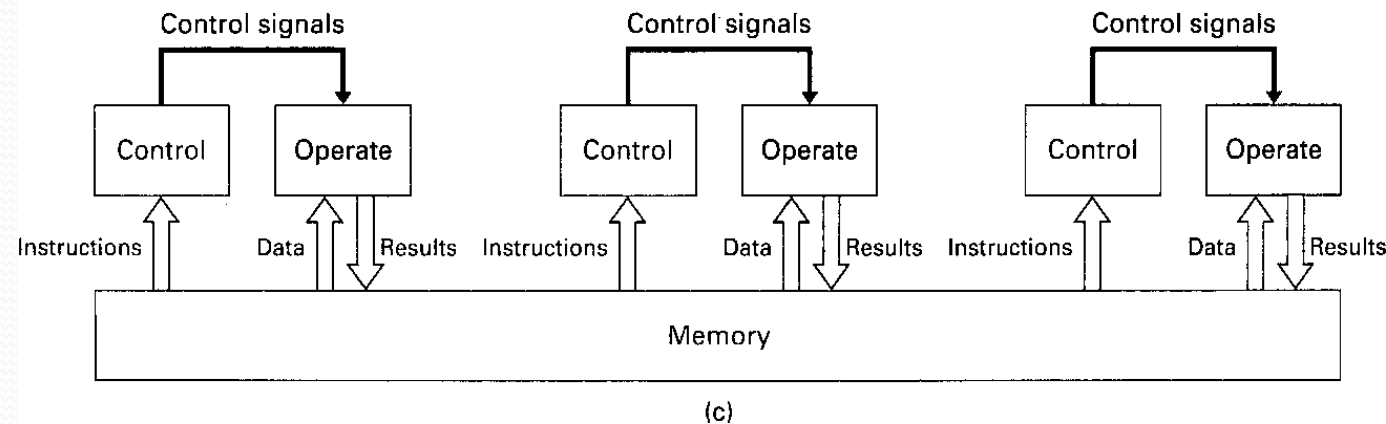
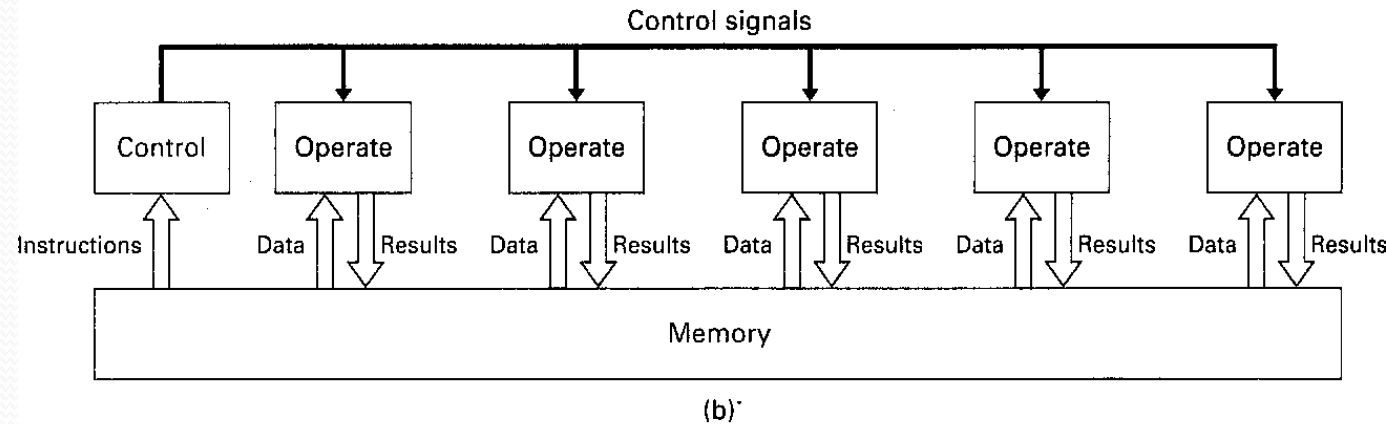
Harvard Architecture

Flynn's classification

- A) Single Instruction stream, single data stream (SISD)
- B) Single Instruction stream, multiple data stream (SIMD)
- C) Multiple Instruction stream, multiple data stream (MIMD)
- D) Multiple Instruction stream, single data stream (MISD)



Von Neumann



References Materials for Bed time Reading

- Intel IA32 Software Developer Volume 1 on Basic Architecture – available from Intel website. + others
 - <http://support.intel.com/design/mobile/documentation.htm#manuals>
- **Great Microprocessors of the Past and Present**
 - <http://www.cpushack.com/CPU/cpu.html#tableofcontents>