

CENG 3420

Computer Organization & Design



Lecture 01: Introduction

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(Textbook: Chapters 1.3 & 1.4)

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Instructor:

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Tutors:

- Chen Bai (cbai@cse.cuhk.edu.hk)
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Grade Determinates

5% Attendance

15% Homework

15% Midterm (Mar. 18)

25% Three Labs (Individual project)

40% Final Exam

- Late submission **per day** is subject to 10% of penalty.
- A student must gain at least 50% of the full marks in order to pass the course.
- A student must attend at least 80% of lectures in order to gain all class attendance credits.



Textbook:

- *Computer Organization and Design, RISC-V Edition*
- Soft copy, [amazon.cn](https://www.amazon.cn), or [amazon.com](https://www.amazon.com)

Manuals:

- LC-3 Instruction Set Architecture (ISA)
- Lab tutorials (slides)

Slides:

- On the course web page before lecture
- Summary may be uploaded afterwards





- Introduction to the major components of a computer system, how they function together in executing a program.
- Introduction to CPU datapath and control unit design
- Introduction to techniques to improve performance and energy-efficiency of computer systems
- Introduction to multiprocessor architecture



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Philosophy

To learn what determines the capabilities and performance of computer systems and to understand the interactions between the computer's architecture and its software so that **future software** designers (compiler writers, operating system designers, database programmers, application programmers, ...) can achieve the best cost-performance trade-offs and so that **future architects** understand the effects of their design choices on software.



- You want to call yourself a “computer scientist/engineer”
- You want to build HW/SW people use (so need performance/power)
- You need to make a purchasing decision or offer “expert” advice

Both hardware and software affect performance/power

- Algorithm determines number of source-level statements
- Language/compiler/architecture determine the number of machine-level instructions
- Processor/memory determine how fast and how power-hungry machine-level instructions are executed



- Basic logic design & machine organization
 - logical minimization, FSMs, component design
 - processor, memory, I/O
- Create, run, debug programs in an assembly language
 - Will be introduced in tutorial
- Create, compile, and run C/C++ programs
- Create, organize, and edit files and run programs on Unix/Linux



- This course is all about how computers work
- But what do we mean by a computer?
 - Different **types**: embedded, laptop, desktop, server
 - Different **uses**: automobiles, graphics, finance, genomics ...
 - Different **manufacturers**: Intel, Apple, IBM, Sony, Oracle ...
 - Different underlying technologies and different costs
- Analogy: Consider a course on “automotive vehicles”
 - Many similarities from vehicle to vehicle (e.g., wheels)
 - Huge differences from vehicle to vehicle (e.g., gas vs. electric)
- **Best way to learn:**
 - Focus on a specific instance and learn how it works
 - While learning general principles and historical perspectives



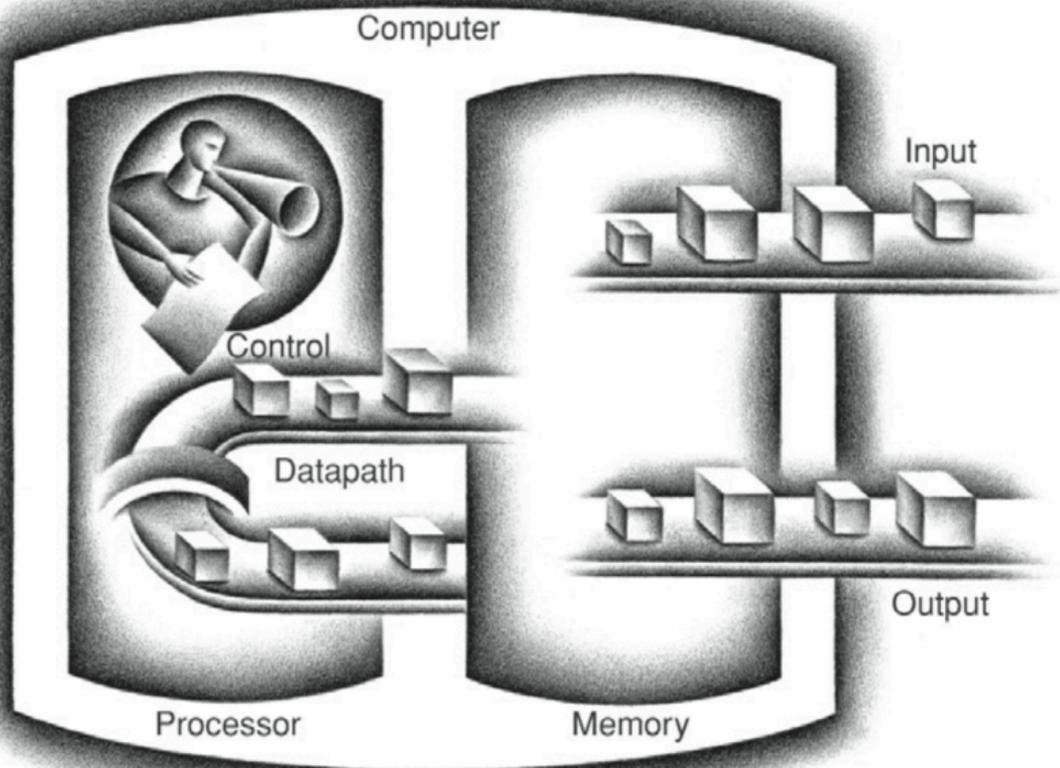
Components

- processor (datapath, control)
- input (mouse, keyboard)
- output (display, printer)
- memory (cache, main memory, disk drive, CD/DVD)
- network

Our primary focus: the processor (datapath and control) and its interaction with memory systems

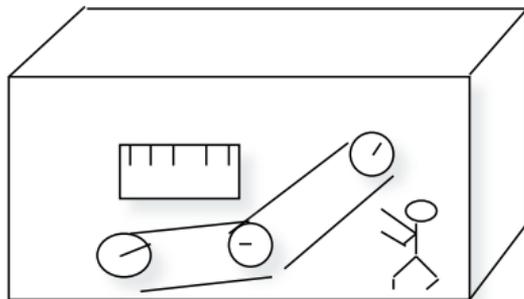
- Implemented using tens/hundreds of millions of transistors
- Impossible to understand by looking at each transistor
- We need abstraction!

Major Components of a Computer





- Capabilities and performance characteristics of the principal Functional Units (FUs). (e.g., register file, ALU, multiplexors, memories, ...)
- The ways those FUs are interconnected (e.g., buses)
- Logic and means by which information flow between FUs is controlled
- The machine's Instruction Set Architecture (ISA)
- Register Transfer Level (RTL) machine description



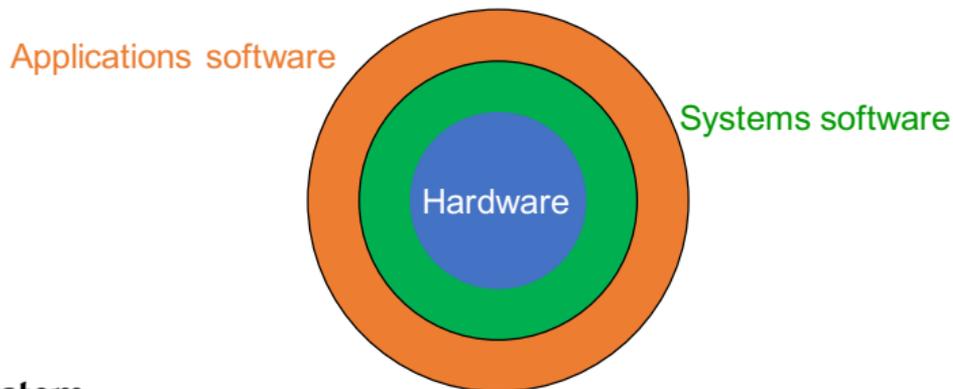


Control needs to have **circuitry** to

- Decide which is the next instruction and input it from memory
- Decode the instruction
- Issue signals that control the way information flows between datapath components
- Control what operations the datapath's functional units perform

Datapath needs to have **circuitry** to

- Execute instructions - functional units (e.g., adder) and storage locations (e.g., register file)
- Interconnect the functional units so that the instructions can be executed as required
- Load data from and store data to memory



Operating System

- Supervising program that interfaces the user's program with the hardware (e.g., Linux, iOS, Windows)
- Handles basic input and output operations
- Allocates storage and memory
- Provides for protected sharing among multiple applications

Compiler

- Translate programs written in a high-level language (e.g., C, Java) into instructions that the hardware can execute



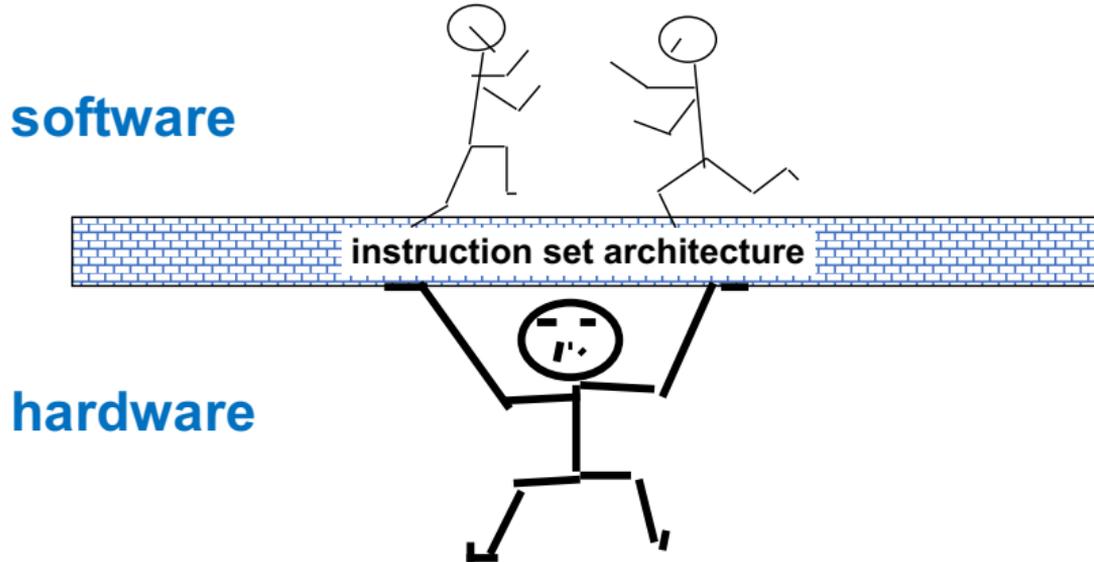
- Allow the programmer to think in a **more natural language** and for their intended use (Fortran for scientific computation, Cobol for business programming, Lisp for symbol manipulation, Java for web programming, ...)
- Improve programmer **productivity** – more understandable code that is easier to debug and validate
- Improve program **maintainability**
- Allow programs to be **independent** of the computer on which they are developed (compilers and assemblers can translate high-level language programs to the binary instructions of any machine)
- Emergence of optimizing compilers that produce very efficient assembly code optimized for the target machine

As a result, very little programming is done today at the assembler level



Instruction Set Architecture (ISA)

The interface description separating the software and hardware





- ISA, or simply architecture – the abstract interface between the hardware and the lowest level software that includes all the information necessary to write a machine language program, including instructions, registers, memory access, I/O, ...
- Enables **implementations** of varying cost and performance to run identical software
- The combination of the basic instruction set (the ISA) and the operating system interface is called the application binary interface (**ABI**)
- ABI: The user portion of the instruction set plus the operating system interfaces used by application programmers. Defines a standard for binary portability across computers.



Instruction Categories

- Load and Store instructions
- Bitwise instructions
- Arithmetic instructions
- Control transfer instructions
- Pseudo instructions

4 Base Instruction Formats: all 32 bits wide

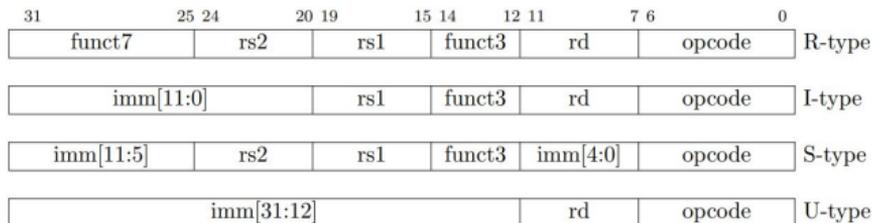
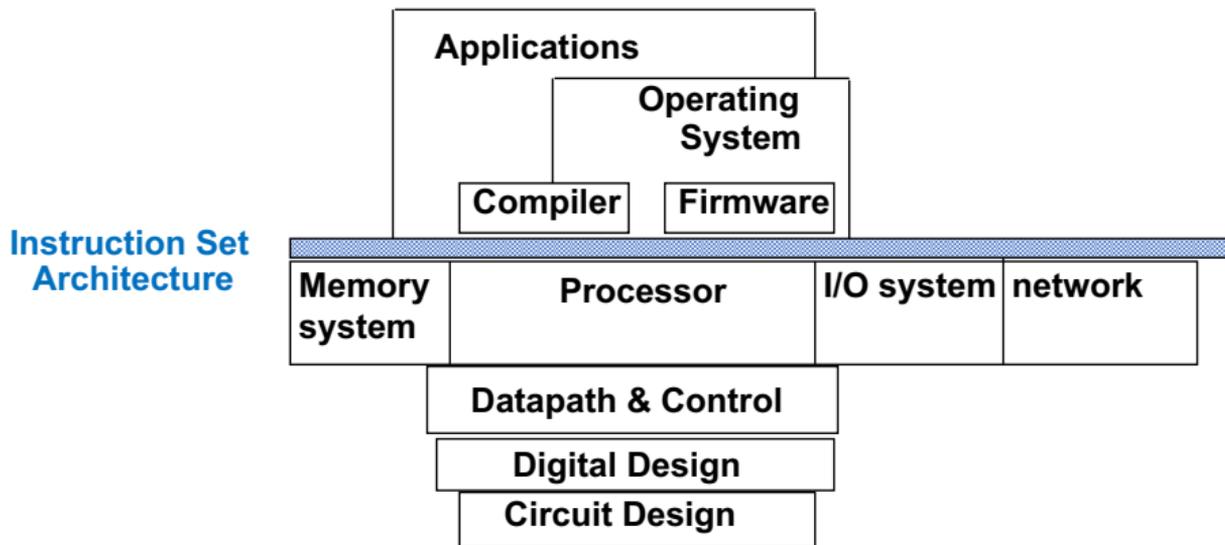




Table: Register names and descriptions

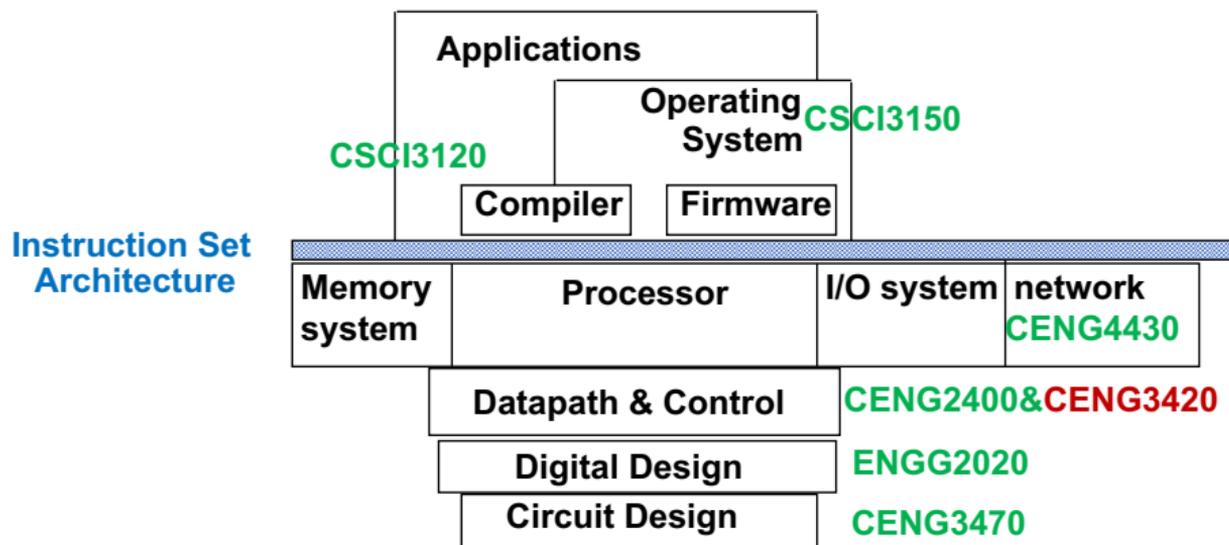
Register Names	ABI Names	Description
x0	zero	Hard-wired zero
x1	ra	Return address
x2	sp	Stack pointer
x3	gp	Global pointer
x4	tp	Thread pointer
x5	t0	Temporary / Alternate link register
x6-7	t1 - t2	Temporary register
x8	s0 / fp	Saved register / Frame pointer
x9	s1	Saved register
x10-11	a0-a1	Function argument / Return value registers
x12-17	a2-a7	Function argument registers
x18-27	s2-s11	Saved registers
x28-31	t3-t6	Temporary registers

How Do the Pieces Fit Together?



- Coordination of many **levels of abstraction**
- Under a **rapidly changing** set of forces
- Design, measurement, **and** evaluation

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