Welcome!

Introduction to Computer Architecture

(Computer Organization and Design: ARM Edition)

Instructor:

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Abu.Asaduzzaman@wichita.edu

ARM - Advanced RISC Machines
RISC - Reduced Instruction Set Computing (a computer architecture)

Intro to Computer Architecture

Lecture 3

Reading: See Reading Assignments on Blackboard

Tests: HW-1 (Week 2), HW-2 (Week 3), Quiz-1 (Week 4), …

- **Syllabus; K-Probe return; Computer Architecture; HW-1;**
- **Introduction to Computers (from zyBooks)**
  - **1.1 Introduction**
  - **1.2 Eight great ideas about computer architecture**
  - **1.3 Below your program**
  - **1.4 Under the covers**
  - **1.5 Technologies for processors and memory**
  - **1.6 Performance**

Intro to Computer Architecture

From Syllabus

*** Important ***
Please read the syllabus!

ECE 394, Introduction to Computer Architecture, Fall, 2024
(Computer Organization and Design: The Hardware Software Interface)

- Instructor: Abu Asaduzzaman (DRZ)
- Department: Electrical and Computer Engineering (ECE)
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- Preferred Method of Contact: In person during office hours or e-mail
- Classroom, Day/Time: 202-EB, Tuesday & Thursday 9:30-10:45 AM
- Student/Office Hours: Tuesday 11:00-12:30 & Wednesday 10:00-11:30 AM
- Prerequisites: ECE 194 and CS 211
- Teaching Assistant (TA): Grading – Md "Raihan" Uddin
- TA Contacts: Grading – mxuddin11@shockers.wichita.edu

Textbook: zyBooks: ECE 394: Introduction to Computer Architecture ["Computer Organization and Design: The Hardware / Software Interface, ARM Edition," by David A. Patterson and John L. Hennessy, Morgan Kaufmann, 2017 edition.]

Students will access zyBooks directly. Instructions for students:

1) Sign in or create an account at learn.zybooks.com
2) Enter zyBook code: WICHITAECE394AsaduzzamanFall2024
3) Subscribe

Grading Assignments/Components	Values (%)
Readings (as assigned on zyBooks.com)	10%
Homework (five of six, take home via Blackboard)	15%
Quiz (two of three, 30-minute during class-time)	10%
Exam-1 (~ Week 5, 65-minute during class-time)	20%
Exam-2 (~ Week 10, 65-minute during class-time)	20%
Exam-3 (cumulative, 65-minute during class-time)	25%

Intro to Computer Architecture

From Syllabus

Brief List of Topics to Cover

Chapter 1: Introduction

- Eight great ideas in computer architecture
- Technologies for building processors and memory
- Performance
- From uniprocessors to multiprocessors

Handout: Multilevel Computers

- Evolution of multilevel machines
- Milestones in computer architecture
- The Computer Zoo

Chapter 3: The Processor

- Building a datapath
- Parallelism: Pipelining
- Data hazards, Control hazards

Chapter 4: Memory Hierarchy

- Memory, Caches
- Virtual memory

Chapter 5: Parallel Processors

- Parallel processing
- SISD, MIMD, SIMD, SPMD, and vector
- Hardware multithreading
- Multicore and other shared memory multiprocessors

Tentative Schedule

Week Tue	Note	Important topics/readings, assignments, due dates, and reminders are listed here so that you can organize your time and academic work.
1 08/20		ECE 394: Intro to Computer Architecture, Syllabus; K-probe; zyBook 1.1 (Intro to Computers); Homework, Quiz, and Exam;
2 08/27	HW-1	HW-1 Discussion; zyBook 1.2-1.5 (eight ideas, processors); HW-1 (due on Blackboard); zyBook 1.6 (performance);
3 09/03	HW-2	9/02 (Labor Day) No Class/Lab; HW-2 (Bb); zyBook 1.7-1.9 (… uni- and multiprocessors, Core i7);
4 09/10	Quiz-1	Quiz-1 Discussion; Handout: Multilevel Computers; Quiz-1 (class test, 30-min / 30-pts, closed book);
5 09/17	Exam-1	Exam-1 Discussion; Handout: Computer Generations; Exam-1 (class test, 65-min / 65-pts, closed book);
6 09/24	Update	zyBook: 3.1 (The Processor: Introduction); zyBook: 3.2-3.3 (The Processor: Datapath, Pipelining);
7 10/01	HW-3	zyBook 3.4-3.5 (Data hazards: Forwarding versus stalling); HW-3 (Bb); zyBook 3.6 (Data hazards and Control hazards);
8 10/08	Mid-Pt HW-4	zyBook 3.7 (Parallelism via instructions); HW-4 (Bb); zyBook 3.8 (Going faster: ILP and matrix multiply);
9 10/15	Fal-Brk Quiz-2	10/12 (Sat) to 10/15 (Tue) (Fall Break) No Class; Quiz-2 (class test, 30-min / 30-pts, closed book);
10 10/22	Exam-2	Exam-2 Discussion; zyBook 4.1 (Memory Hierarchy: Introduction); Exam-2 (class test, 65-min / 65-pts, closed book);
11 10/29	Update	zyBook 4.2-4.3 (Memory Hierarchy: Caches); zyBook 4.4-4.5 (Memory Hierarchy: Virtual memory);
12 11/05	HW-5	zyBook 5.1 (Parallel Processors: Introduction); HW-5 (Bb); zyBook 5.2 (Difficulty of Parallel Processing);
13 11/12	HW-6	zyBook 5.3 (SISD, MIMD, SIMD, SPMD, and vector); HW-6 (Bb); zyBook 5.4 (Hardware multithreading);
14 11/19	Quiz-3	zyBook 5.5-5.6 (Multicore processors, graphics processing units); Quiz-3 (class test, 30-min / 30-pts, closed book);
15 11/26	Thx-Brk	Future of Computers (selected materials); 11/27 (Wed) to 12/01 (Sun) (Thanksgiving Break) No Class;
16 12/03	Exam-3	Exam-3 Discussion; Exam-3 (class test, 65-min / 65-pts, closed book);
Finals		None!

Note: A date in Column 1 indicates the Tuesday of that week. Here, 12/03 is Tueday of Week 16.

Intro to Computer Architecture

K-Probe Feedback (37 of 43)

4 BSCE, 29 BSCS, and 4 BSEE

- **Pre-Requisites**
  - Mostly A's and B's
  - Some didn't answer
- **Q1 Familiarity**
  - 'No' to CPU, machine code/language
  - Need to know all
- **Q2 Decimal to binary**
  - Many correct answers
  - Some incorrect answers
- **Q3 Binary to hexadecimal**
  - Many correct answers
  - Some incorrect answers
- **Q4 Real (decimal) to binary**
  - Some good tries; no diagram!
  - Many didn't try
- **Q5 Programming in C/C++**
  - Some good answers
  - Some incomplete tries
  - Some didn't try
- **Other Concerns**
  - Better understanding of computer or system architecture
  - Coding? (CS 211 and ECE 194 knowledge is needed)
  - "I am here to help!" ~ DRZ

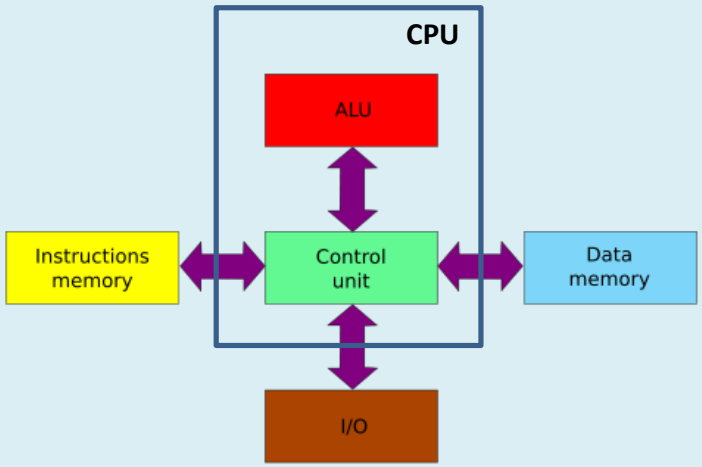
Background materials are selected based on K-Probe feedback.

Intro to Computer Architecture

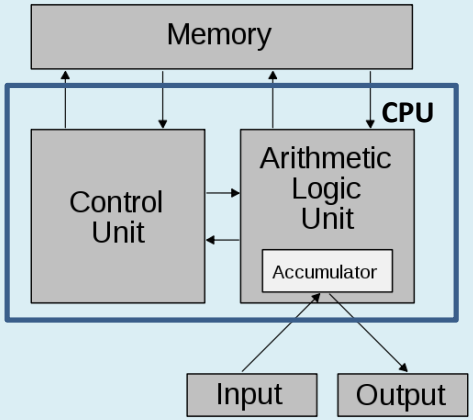
Key components of a simple computer system

- CPU (CU, ALU, Registers)
- Memory (Main/Primary Memory, split or unified)
- Bus (collection of wires)

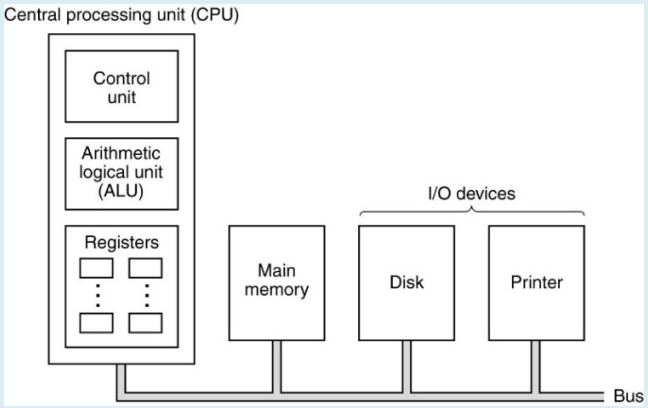
What/how does 'it' do/work?



Pure Harvard Arch



Von Neumann Arch



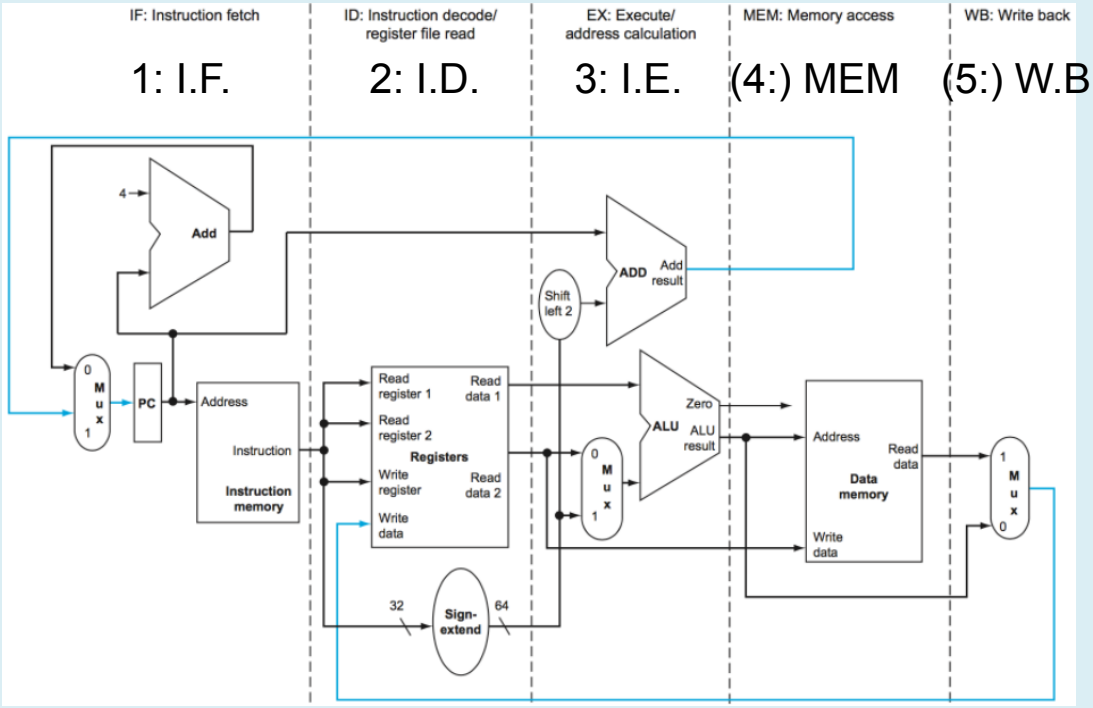
PDP-8

Intro to Computer Architecture

Computer System:

- ➢ Programs
- ➢ Execution

A logical organization of computer components



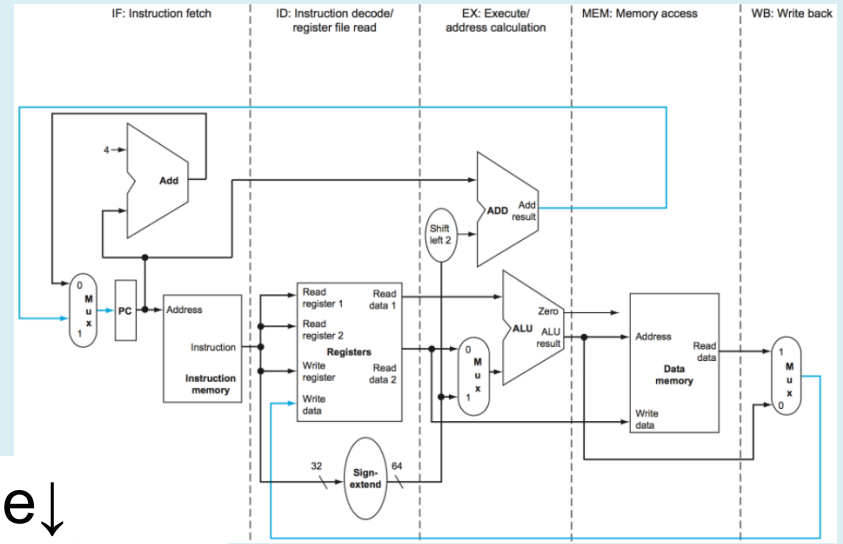
Major Steps to Execute an Instruction

1. Instruction Fetch
2. Instruction Decode
3. Instruction Execution
(4) MEMory access (optional, not for every operation)
(5) Result Write Back to Main Memory (optional)

Intro to Computer Architecture

Example → Practice

- **Which of the five steps are needed?**
  1) **[Mem-x] = [Mem-y] + [Mem-z]**
     x = y + z;
     (all steps are needed)
  2) **[Reg-1] = [Reg-2] – [Reg-3]**
     (1, 2, and 3 are needed)
  3) **[Reg-4] = [Mem-a] + 1**
     (5 not needed)
  4) **[Mem-b] = 7**
  5) **Go to [Mem-c]**



Time↓

t1 1: I.F.

t2 2: I.D.

t3 3: I.E.

t4 (4:) MEM

t5 (5:) W.B.

…

Homework Preparation / Submission

Homework Preparation and Submission

- **How to prepare/submit homework?**
  - **Must have: Course #; Semester; and HW #**
  - **Must have: Name & WSU ID**
  - **Must submit: Everything in one single PDF file via Blackboard**
  - **…**
  - **Collaborate, do not cheat!!!**
  - **No e-mail submission!**
  - **Late submission: Penalty 10% per day for five days!!**

- **Homework**
  - **(Blackboard) Discussion on Tuesday, Submission on Thursday**

Intro to Computer Architecture

Do you have any questions?

10:57 AM

Intro to Computer Architecture

Lecture 3

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Introduction to Computers

1.1 Introduction

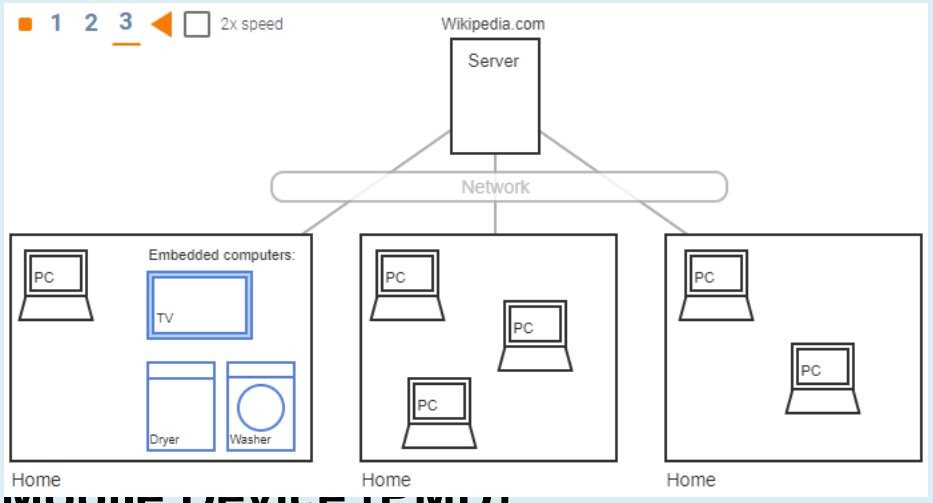
- **Introduction**
  - ➢ **Transportation, airplane, computer (information revolution)**
  - ➢ **Electronic computing in the late 1940s**
  - ➢ **Computers in automobiles, cellphones, research, … (what not?)**
- **The information revolution**
  - ➢ **1) False**
  - ➢ **2) True**
  - ➢ **3) False**

1) The computing industry has not improved quite as rapidly as the transportation industry.
   - ○ True
   - ○ False
2) The agricultural and industrial revolutions each transformed society. Computers have led to a relatively recent information revolution.
   - ○ True
   - ○ False
3) Computer improvements have led to previously undreamt applications like cell phones, but most signs suggest the improvements are now coming to an end.
   - ○ True
   - ○ False

Introduction to Computers

1.1 Introduction

- **Traditional classes of computing applications**
  - **(see zyBooks) Personal Computer (PC), Server, and Embedded Computer**



  - **Supercomputer, …**
  - **Post-PC ear → Personal Mobile Device (PMD)**
  - **Server → Cloud Computing … Warehouse Scale Computer (WSC)**
  - **Software as a Service (SaaS) – Software and Data over the Internet**

Introduction to Computers

1.1 Introduction

- **Important questions**
  - **How are high-level language programs translated into the hardware language, and how does the hardware execute the program?**
  - **What is performance, and how can a programmer improve it?**
  - **What techniques can be used by hardware designers to improve performance and energy efficiency?**
  - **Since 1950, what great ideas did computer architects come up with that lay the foundation of modern computing? (Multicore Systems)**

Acronym: A word constructed by taking the initial letters of a string of words. For example: *RAM* is an acronym for Random Access Memory, and *CPU* is an acronym for Central Processing Unit.

Introduction to Computers

1.1 Introduction

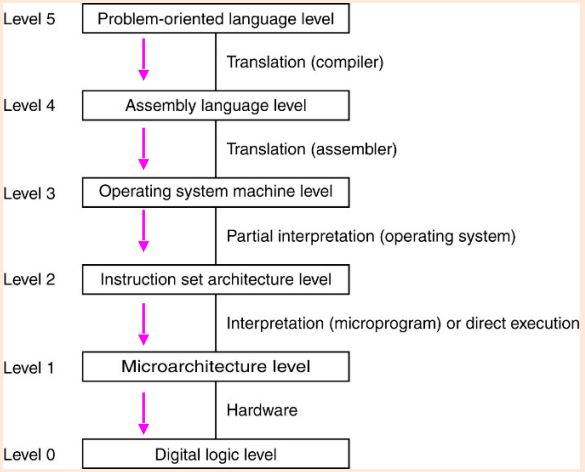
- **Terabyte (TB) vs. Tebibyte (TiB)**
  - **1 TB = 2^12 bytes | 1 TiB = 2^40 bytes**

Decimal	Abbreviation	Value	Binary term	Abbreviation	Value	% Larger
kilobyte	KB	10^3	kibibyte	KiB	2^{10}	2%
megabyte	MB	10^6	mebibyte	MiB	2^{20}	5%
gigabyte	GB	10^9	gibibyte	GiB	2^{30}	7%
terabyte	TB	10^{12}	tebibyte	TiB	2^{40}	10%
petabyte	PB	10^{15}	pebibyte	PiB	2^{50}	13%
exabyte	EB	10^{18}	exbibyte	EiB	2^{60}	15%
zettabyte	ZB	10^{21}	zebibyte	ZiB	2^{70}	18%
yottabyte	YB	10^{24}	yobibyte	YiB	2^{80}	21%

Computing Systems: Two Approaches

Computer Architecture: A Multilevel Approach [1]

- ✓ The Tanenbaum and Austin book (Structured Computer Organization)
- ✓ Higher (human friendly) to lower (machine friendly)
- ✓ Multilevel Computers: https://users.cs.fiu.edu/~downeyt/cop3402/levels.html



COMPUTER ARCHITECTURE: A Quantitative Approach [2]

- ✓ The Hennessy and Patterson book
- ✓ Quantitative principles of computer design: to make the common case fast.
- ✓ To quantify the principles → Amdahl's Law, CPU performance, Principle of Locality, Advantage of Parallelism, etc.
- ✓ Quantitative Principles of Computer Design: http://www.brainkart.com/article/Quantitative-Principles-of-Computer-Design_8830/

[1] "Structured Computer Organization" by Tanenbaum and Austin
[2] "COMPUTER ARCHITECTURE: A Quantitative Approach" by Hennessy and Patterson

Introduction to Computers

1.2 Eight great ideas about computer architecture

- Design for Moore's Law
- Use abstraction to simplify design
- Make the common case fast
- Performance via parallelism
- Performance via pipelining
- Performance via prediction
- Hierarchy of memories
- Dependability via redundancy

Practice Questions:
1) Assembly lines in automobile manufacturing
2) Express elevators in buildings

Answers:
1) Performance via Pipelining
2) Make the Common Case Fast

About the symbols:
up and to the right
abstract painting icon
fast small/sports car
multiple jet engines of a plane
sequence of pipes
fortune-teller's crystal ball
layered triangle icon
tractor-trailer (dual tires)

Introduction to Computers

1.2 Eight great ideas about computer architecture

1 Dependability via Redundancy

2 Performance via Pipelining

3 Performance via Prediction

4 Performance via Parallelism

Match the situation with the closest analog of a great idea in computer architecture.

4	A sister is hanging clothes to dry. Her brother helps by hanging clothes simultaneously.
2	A brother is washing and drying dishes. His sister helps by drying each dish immediately after the brother washes each.
3	A mom expects her son will be hungry after a long airplane flight, so she cooks dinner just in case. If he's not hungry, she'll whip up a dessert instead.
1	A drummer's stick breaks, but he quickly grabs another one and continues playing the song.

Introduction to Computers

1.2 Eight great ideas about computer architecture

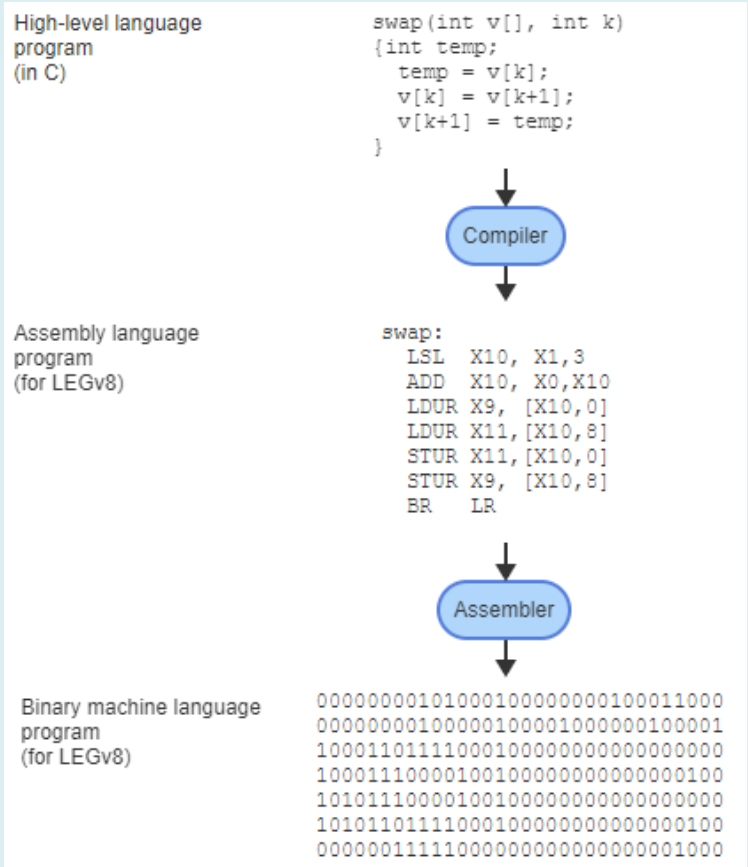
Performance via Parallelism	A sister is hanging clothes to dry. Her brother helps by hanging clothes simultaneously. In this case, two people working in parallel can halve the task's time.	Correct
Performance via Pipelining	A brother is washing and drying dishes. His sister helps by drying each dish immediately after the brother washes each. Dividing a task into pieces in a way of improving performance. If pieces are equal sizes, task time may be halved.	Correct
Performance via Prediction	A mom expects her son will be hungry after a long airplane flight, so she cooks dinner just in case. If he's not hungry, she'll whip up a dessert instead. By predicting he'll be hungry, she's able to finish the job (end his hunger) faster than if she waited for him to get home.	Correct
Dependability via Redundancy	A drummer's stick breaks, but he quickly grabs another one and continues playing the song. Having extras/backups is a good idea in many scenarios.	Correct

Introduction to Computers

1.3 Below your program

- **Abstraction**
  - ➢ **Abstraction is a fundamental concept in computing that helps manage complexity by hiding the intricate details of a system and exposing only the essential features.**
  - ➢ **It allows one to work with higher-level concepts without needing to understand the underlying specifics.**

Underlying Software



Limp Elastic General-purpose v8 (LEGv8) is a simplified, educational version of the ARMv8 architecture, which is a widely-used instruction set architecture (ISA) for ARM processors.
ARM - Advanced RISC Machines | RISC - Reduced Instruction Set Computing (a computer architecture)

Introduction to Computers

1.3 Below your program — Underlying Software

- **High-Level Languages**
  - ➢ **Programming languages that provide a high degree of abstraction from the hardware, making it easier for programmers to write code.**
  - ➢ **A portable language such as C that is composed of words and algebraic notation that can be translated by a compiler into assembly language.**
- **Systems software**
  - ➢ **Software that provides services that are commonly useful, including operating systems, compilers, loaders, and assemblers.**
- **Operating System**
  - ➢ **Supervising program that manages the resources of a computer for the benefit of the programs that run on that computer.**

Introduction to Computers

1.3 Below your program — Underlying Software

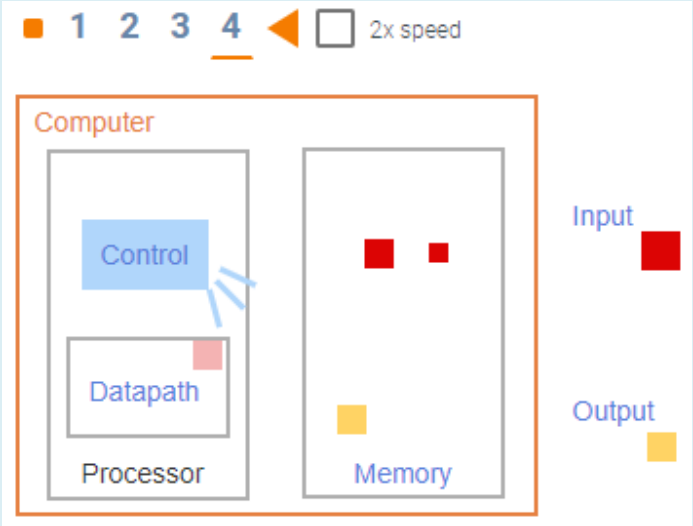
- **Compiler**
  - ➢ **A program that translates high-level language statements into assembly language statements.**
- **Assembler**
  - ➢ **A program that translates a symbolic version of instructions into the binary version.**
- **Assembly language**
  - ➢ **A symbolic representation of machine instructions.**
- **Machine language**
  - ➢ **A binary representation of machine instructions.**
- **Instruction**
  - ➢ **A command that computer hardware understands and obeys.**

Introduction to Computers

1.4 Under the covers

- **The underlying hardware in any computer performs the same basic functions: inputting data, outputting data, processing data, and storing data.**
- **Important components**
  - ➢ **Input device: Keyboard**
  - ➢ **Output device: Display**

Underlying Hardware



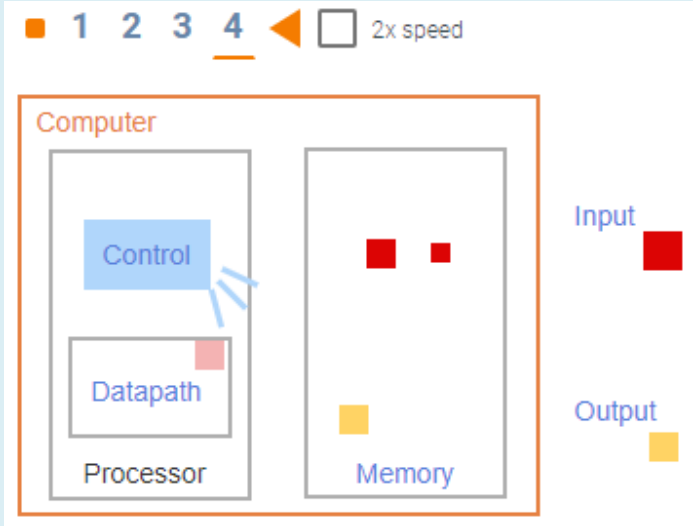
- ➢ **Memory: Stores programs and data | Cache: a small fast memory**
- ➢ **Dynamic random access memory (DRAM): Integrated Circuit (IC)**
- ➢ **Static random access memory (SRAM): IC, faster than DRAM**
- ➢ **Datapath: Performs operations on data**
- ➢ **Control: Signals that determine the operation of the datapath**

Introduction to Computers

1.4 Under the covers

- **Integrated Circuit (IC)**
  - ➢ **Also called a chip. A device combining dozens to millions of transistors.**
- **Central Processor Unit (CPU)**
  - ➢ **Also called processor. The active part of the computer, which contains the datapath and control and which adds numbers, and so on.**

Underlying Hardware



- **Instruction set architecture**
  - ➢ **Also called architecture. An abstract interface between the hardware and the lowest-level software that encompasses all the information necessary to write a machine language program.**

Introduction to Computers

1.4 Under the covers

Underlying Hardware

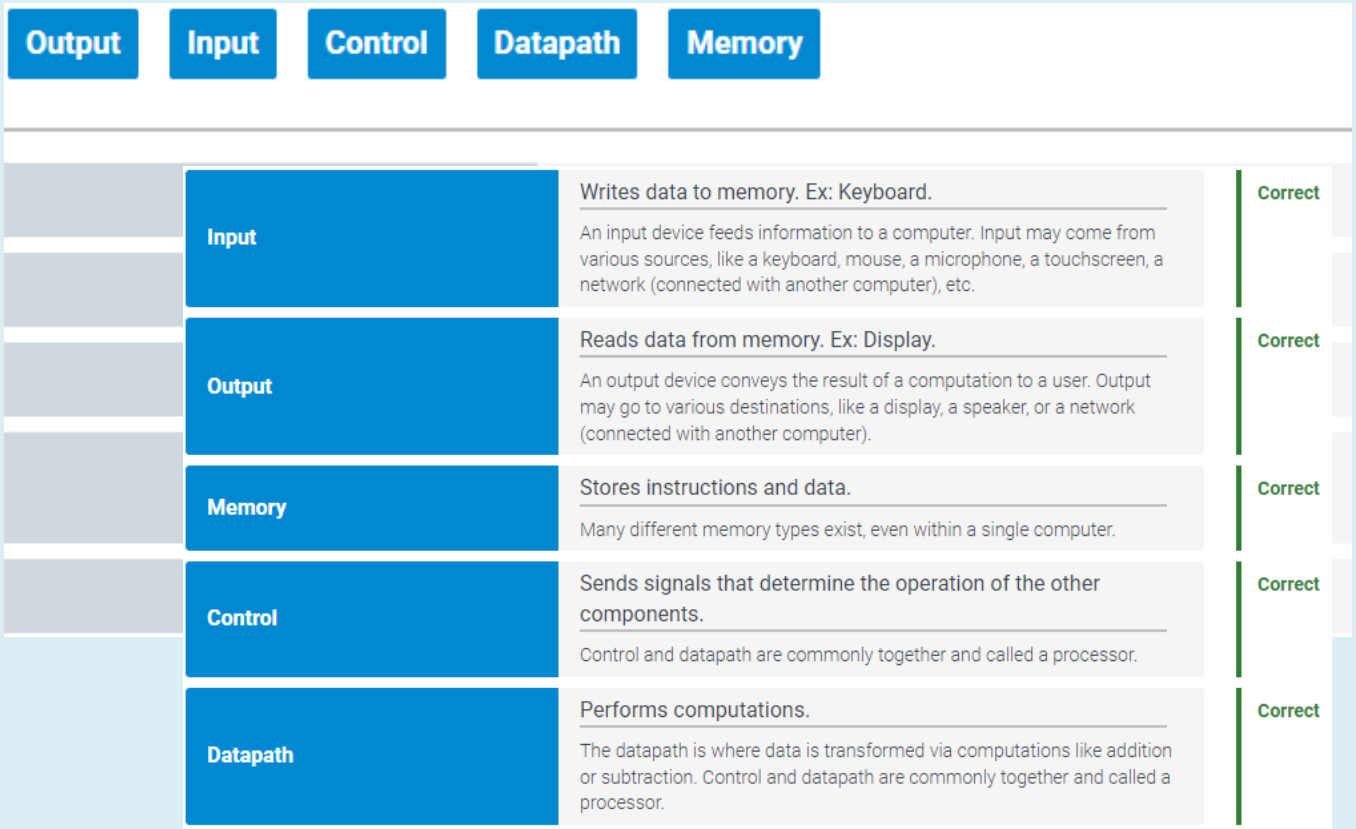
- **Implementation: Hardware that obeys the architecture abstraction.**
- **Volatile memory: Storage, such as DRAM, that retains data only if it is receiving power.**
- **Nonvolatile memory: Storage that retains data even in the absence of power supply; used to store programs and data. Example: hard disk.**
- **Main memory: Also called primary memory. Memory used to hold programs and data while execution; typically consists of DRAM.**
- **Secondary memory: Nonvolatile memory used to store programs and data; typically consists of magnetic disks and flash memory.**
- **Magnetic disk: Also called hard disk. A form of nonvolatile secondary memory composed of rotating platters.**
- **Flash memory: A nonvolatile semiconductor memory.**

Introduction to Computers

1.4 Under the covers

Underlying Hardware

- **Five components**



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ECE 394

Introduction to Computer Architecture

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