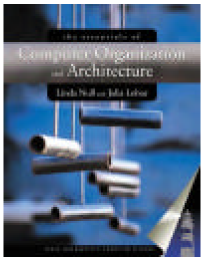

The Essentials of Computer Organization and Architecture

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Chapter 1 Instructor's Manual

Chapter Objectives

Chapter 1, the Introduction, provides a historical overview of computing in general, pointing out the many milestones in the development of computing systems, and allowing the reader to visualize how we arrived at the current state of computing. This chapter introduces the necessary concepts for the journey through the book, including the necessary terminology, the basic components in a computer system, the various logical levels of a computer system, and the von Neumann computer model. It provides a high-level view of the computer system, as well as the motivation and necessary concepts for further study.

Lectures should focus on the following points:

- **Computer organization versus computer architecture.** Understanding both of these concepts leads to a deeper understanding of computers and computation in general.
- **Main components of a computer.** It is important that readers understand both the components and how they work together.
- **Principle of equivalence of hardware and software.** Software and hardware are equivalent, but it is important to understand which is more appropriate in given situations.
- **Computer jargon.** Common terms, including the common prefixes, are useful for further reading.
- **A look inside a computer.** A discussion of what is really inside the "Black Box" helps to put the newly learned terms into context.
- **Standards organizations.** Common guidelines for hardware have resulted in specifications, and understanding these standards is important to the overall understanding of computer architecture.
- **Historical development.** It is difficult to understand where we are going without taking a look at where we have been. These discussions include explanations of the technologies that made the various computer generations possible.
- **The computer level hierarchy.** The concept of a virtual machine is introduced by explaining the various abstract levels of modern computing systems.
- **The von Neumann model.** Perhaps the single most important development in computing (that affects programmers in particular) is the introduction of the stored-program concept in the Von Neumann architecture.
- **Non-von Neumann models.** Readers must realize there are other models of computing, including parallel computing and neural networks.

Required Lecture Time

Chapter 1 can typically be covered in 2 to 3 lecture hours, depending on how detailed one wishes to go into computer jargon. Although the terminology and historical development can be assigned as reading, class lectures often lead to interesting discussions and motivation for the study of computer organization and architecture.

Lecture Tips

Although there are no complicated concepts in this chapters, students often have trouble in two areas. First, understanding the various prefixes can be confusing. We suggest spending some time to make sure the common prefixes associated with computer organization and architecture are well understood. It is important to explain that these prefixes can refer to both base ten and base two values. For example, 1K could mean 1000 or it could mean 1024. Instructors could have students find ads or go on-line to find example systems and then discuss these systems in class. If specifications are given for various hardware components, the instructor may be able to find a 256K memory that is actually 256 times 2^{10}, but a 10G hard drive that is $10*10^{30}$. Second, the computer level hierarchy is very important, and in particular, the concept of a virtual machine often confuses students. Teachers should emphasize that these are abstract levels.

The Principle of Equivalence of Hardware and Software is an interesting concept for students. Many haven't really given it much thought, while others often refuse to accept this principle without some class discussion. One interesting point that can be introduced is the patent versus copyright problem. If someone has a hardware device that provides a specific function, this device is eligible for a patent. However, the principle says that this machine can be exactly duplicated in software, yet patent status is often denied software. Thus, the choices made for implementation in hardware versus software are often the result of simply which is more efficient or provides better performance.

The sidebars on vacuum tubes and transistors are provided simply FYI, and we typically don’t require students to understand this information in detail.

Answers to Exercises

1. In what ways are hardware and software different? In what ways are they the same?

Ans.

Between hardware and software, hardware provides more speed, software provides more flexibility. Hardware and software are related through the Principle of Equivalence of Hardware and Software. They can solve problems equally, although solutions are often easier in one versus the other.

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2. a) How many milliseconds (ms) are in 1 second?
   b) How many microseconds (µs) are in 1 second?
   c) How many nanoseconds (ns) are in 1 millisecond?
   d) How many microseconds are in 1 millisecond?
   e) How many nanoseconds are in 1 microsecond?

f) How many kilobytes (KB) are in 1 gigabyte (GB)?
g) How many kilobytes are in 1 megabyte (MB)?
h How many megabytes are in 1 gigabyte (GB)?
i) How many bytes are in 20 megabytes?
j) How many kilobytes are in 2 gigabytes?

Ans.

a. 1,000
b. 1,000,000
c. 1,000,000
d. 1,000
e. 1,000
f. 1,000,000 (or $2^{30}/2^{10}=2^{20}$)
g. 1,000 (or $2^{20}/2^{10}=2^{10}$)
h. 1,000 (or $2^{30}/2^{20}=2^{10}$)
i. 20,000,000 (or $20*2^{20}$)
j. 2,000,000 (or $2^{31}/2^{10}=2^{21}$)

♦ 3. By what order of magnitude is something that runs in nanoseconds faster than something that runs in milliseconds?

Ans.

One million, or 10^6

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4. Pretend you are ready to buy a new computer for personal use. First, take a look at ads from various magazines and newspapers and list terms you don't quite understand. Look these terms up and give a brief written explanation. Decide what factors are important in your decision as to which computer to buy and list them. After you select the system you would like to buy, identify which terms refer to hardware and which refer to software.

Ans.

Suggest appropriate magazines for the students, or web sites for such places as Dell, Gateway, and IBM.

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5. Pick your favorite computer language and write a small program. After compiling the program, see if you can determine the ratio of source code instructions to the machine language instructions generated by the compiler. If you add one line of source code, how does that affect the machine language program? Try adding different source code instructions, such as an add and then a multiply. How does the size of the machine code file change with the different instructions? Comment on the result.

Ans.

No answer.

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6. Respond to the comment mentioned in Section 1.5: If invented today, what name do you think would be given to the computer? Give at least one good reason for your answer.

Ans.

Students have shown a lot of creativity in the past on questions such as this. Some will lean towards the gaming aspect of the computer, while others will look more into the bookkeeping abilities. Some will try to find a term that exemplifies the "all encompassing" nature of computers, while others will focus on the information capabilities of computers.

♦ 7. Suppose a transistor on an integrated circuit chip were 2 microns in size. According to Moore's Law, how large would that transistor be in 2 years? How is Moore's law relevant to programmers?

Ans.

0.75 micron.

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8. What circumstances helped the IBM PC become so successful?

Ans.

It was an open architecture, thus allowing IBM to set the standard for the industry, while encouraging IBM "clones".

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9. List five applications of personal computers. Is there a limit to the applications of computers? Do you envision any radically different and exciting applications in the near future? If so, what?

Ans.

There are many applications, including such things as word processing, bookkeeping, digital image editing, creating/writing music, graphics design, gaming, coding, mapping, record storage (database), and control (such as in an assembly line or any real-time system), not to mention as an electronic resource or for various medical applications (such as in CAT scan machines).

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10. Under the von Neumann architecture, a program and its data are both stored in memory. It is therefore possible for a program, thinking a memory location holds a piece of data when it actually holds a program instruction, to accidentally (or on purpose) modify itself. What implications does this present to you as a programmer?

Ans.

Care must be taken when programming to make sure the code doesn't modify itself in some way. For example, if a memory location holds an instruction (which is represented by a binary number), and a value is added to that instruction, the result could be a valid instruction that is later executed, resulting in an error that is very difficult to track down. The modification of an instruction could also cause a program to crash.

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11. Read a popular local newspaper and search though the job openings. (You can also check some of the more popular online career sites.) Which jobs require specific hardware knowledge? Which jobs imply knowledge of computer hardware? Is there any correlation between the required hardware knowledge and the company or its location?

Ans.

No answer.

Sample Exam Questions

1. We studied four generations of computers, namely the first, second, third and fourth. What characteristic is used to distinguish one generation from the next?

Ans.

The technology (vacuum tubes, transistors, ICs, VLSI).

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2. The von Neumann architecture, which is the basis for most digital computers today, suffers from the von Neumann bottleneck. Explain.

Ans.

The von Neumann architecture stores both program code and data in memory. There is a single path between main memory and the CPU, forcing instruction fetch cycles and execution cycles to share this pathway.

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3. What technological advance contributed the most to the advent of personal computers?

Ans.

VLSI technology allowed the entire microprocessor to be put on one chip.

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4. Explain why modern machines consist of multiple levels of virtual machines. Why not just have two levels, the digital logic level and the high-language programming level?

Ans.

Each abstract layer performs a specific task. Instead of viewing the machine as one giant computer, we can view it as a collection of virtual machines, each level implemented on top of the next lower level, and each communicating with the machine above and below in the hierarchy via a specific set of rules. This helps to close the semantic gap that exists between the digital logic level and the high-level language programming level and helps us manage the complexity of the system. Each level serves as an abstract layer; its implementation is of no concern to the upper layers, and it hides the details of lower layers from upper layers.

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5. Von Neumann was responsible for several major contributions in computer design. Name one and explain.

Ans.

1. *Dividing the system into a CPU, a memory system, and an I/O system*
2. *The stored program concept*
3. *Single data path for instructions and data*

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6. Name and explain the main components of a von Neumann computer.

Ans.

- *Central processing unit: Consists of control unit, ALU, registers and PC*
- *Main-memory system: for program instruction and data storage*
- *I/O system: for input and output*
- *Single data path between main memory and control unit of CPU for data and instruction transfer*

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7. Describe the fetch, decode, execute instruction cycle.

Ans.

The control unit fetches the next instruction from memory, using the PC to determine the location of the instruction. The instruction is decoded and any data operands required to execute the instruction are fetched and placed in registers. The ALU then executes the instruction and places the result in the appropriate location in registers or memory.

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8. a. How many milliseconds (ms) are in 0.5 seconds?
   b. How many microseconds (µs) are in 4 milliseconds?
   c. How many nanoseconds (ns) are in 0.5 milliseconds?
   d. How many microseconds are in 2 milliseconds?
   e. How many kilobytes (KB) are in 0.5 gigabytes (GB)?

Ans.

a. 500
b. 4,000,000
c. 500,000
d. 2,000
e. 500,000 (or $2^{29}/2^{10}=2^{19}$)

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9. The Von Neumann architecture includes all of the following except:

a. a stored program b. sequential processing of instructions
c. parallel processing d. a CPU, memory and I/O system
e. the Von Neumann architecture contains all of these components

Ans.

The correct answer is C.

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10. The levels of integration in circuits discussed in the book include all but which of the following:

a. SSI b. MSI c. LSI
d. VLSI e. all of these are levels of integration in circuits

Ans.

The correct answer is E.

TRUE OR FALSE.

_____ 1. The Principle of Equivalence of Hardware and Software supports the claim that it is not possible to build a special purpose computer to perform only word processing.

_____ 2. The turning points in the historical development of computers are based on the technology incorporated into the devices.

_____ 3. One million bytes can be represented as 1000K bytes.

_____ 4. The Principle of Equivalence of Hardware and Software says that hardware and software are basically equivalent, and implementations done via either method will run at the same speeds.

_____ 5. A Hertz is one million cycles per second.

_____ 6. Manufacturers use standards so they can market their products to a wider audience than if they came up with separate – and perhaps incompatible – specifications.

_____ 7. If Moore's Law is to hold, Rock's Law must fall.

_____ 8. Amdahl's Law states that the performance enhancement possible with a given improvement is limited by the amount that the improved feature is used.

_____ 9. A byte is 8 bits, but a word may vary in size (16-bits, 32-bits, etc.) from one architecture to another.

Ans. 1. False 2. True 3. True 4. False 5. False 6. True 7. True 8. True 9. True

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