

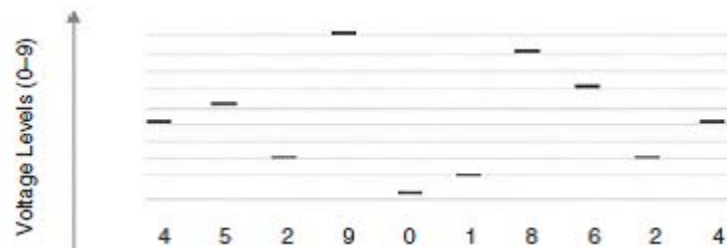
Computer Hardware

Computer hardware comprises the physical part of a computer system. It includes the all-important components of the **central processing unit** (CPU) and main memory. It also includes peripheral components such as a keyboard, monitor, mouse, and printer. In this section, computer hardware and the intrinsic use of binary representation in computers is discussed.

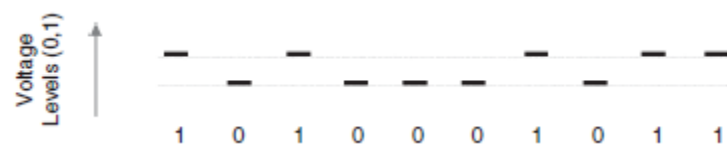
Part I: Digital Computing: It's All about Switches

It is essential that computer hardware be reliable and error free. If the hardware gives incorrect results, then any program run on that hardware is unreliable. A rare occurrence of a hardware error was discovered in 1994. The widely used Intel processor was found to give incorrect results only when certain numbers were divided, estimated as likely to occur once every 9 billion divisions. Still, the discovery of the error was very big news, and Intel promised to replace the processor for anyone that requested it.

The key to developing reliable systems is to keep the design as simple as possible. In digital computing, all information is represented as a series of digits. We are used to representing numbers using base 10 with digits 0–9. Consider if information were represented within a computer system this way, as shown below.



In current electronic computing, each digit is represented by a different voltage level. The more voltage levels (digits) that the hardware must utilize and distinguish, the more complex the hardware design becomes. This results in greater chance of hardware design errors. It is a fact of information theory, however, that any information can be represented using only two symbols. Because of this, *all information within a computer system is represented by the use of only two digits, 0 and 1, called **binary representation***, shown below.



In this representation, each digit can be one of only two possible values, similar to a light switch that can be either on or off. Computer hardware, therefore, is based on the use of simple electronic “on/off” switches called transistors that switch at very high speed. **Integrated circuits** (“chips”), the building blocks of computer hardware, are comprised of millions or even billions of transistors.

Part II: The Binary Number System

For representing numbers, any base (radix) can be used. For example, in base 10, there are ten possible digits (0, 1, . . . , 9), in which each column value is a power of ten, as shown below.

10,000,000	1,000,000	100,000	10,000	1,000	100	10	1
10^7	10^6	10^5	10^4	10^3	10^2	10^1	10^0
						9	9 = 99

Other base-number systems work in a similar manner. **Base 2** has digits 0 and 1, with place values that are powers of two, as shown below.

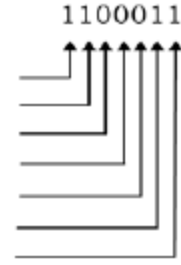
128	64	32	16	8	4	2	1
2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
0	1	1	0	0	0	1	1
0	+ 64	+ 32	+ 0	+ 0	+ 0	+ 2	+ 1 = 99

As shown in this figure, converting from base 2 to base 10 is simply a matter of adding up the column values that have a 1.

The term **bit** stands for binary digit. Therefore, every bit has the value 0 or 1. A byte is a group of bits operated on as a single unit in a computer system, usually consisting of eight bits. Although values represented in base 2 are significantly longer than those represented in base 10, binary representation is used in digital computing because of the resulting simplicity of hardware design.

The algorithm for the conversion from base 10 to base 2 is to successively divide a number by two until the remainder becomes 0. The remainder of each division provides the next higher-order (binary) digit, as shown below.

$99/2 = 49$, with remainder 1
 $49/2 = 24$, with remainder 1
 $24/2 = 12$, with remainder 0
 $12/2 = 6$, with remainder 0
 $6/2 = 3$, with remainder 0
 $3/2 = 1$, with remainder 1
 $1/2 = 0$, with remainder 1



Thus, we get the binary representation of 99 to be 1100011. This is the same as above, except that we had an extra leading insignificant digit of 0, since we used an eight-bit representation there.

1. Convert the following values into binary (base 2) representation. Show all steps.
 - a. 7
 - b. 19
 - c. 39

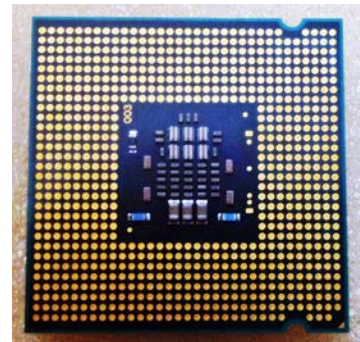
Part III: Fundamental Hardware Components

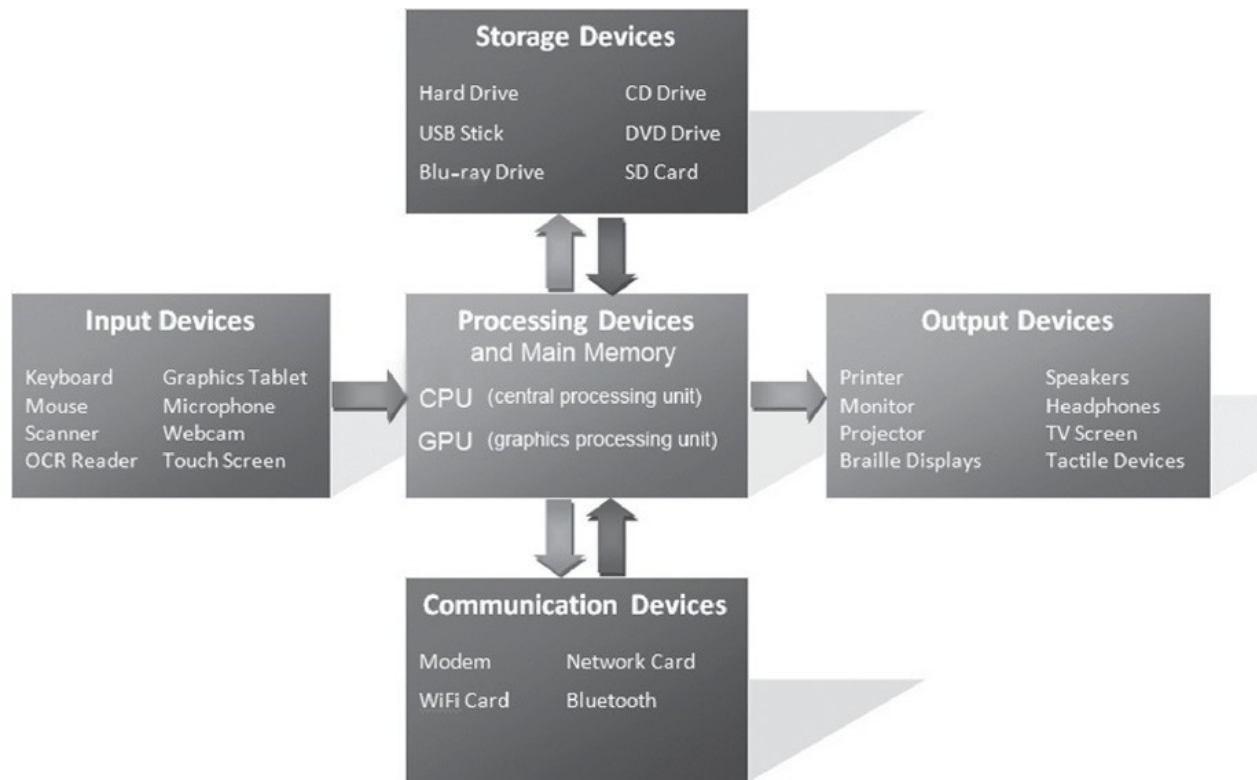
The **central processing unit** (CPU) is the “brain” of a computer system, containing digital logic circuitry able to interpret and execute instructions.

Main memory is where currently executing programs reside, which the CPU can directly and very quickly access. Main memory is volatile; that is, the contents are lost when the power is turned off.

In contrast, secondary memory is nonvolatile, and therefore provides long-term storage of programs and data. This kind of storage, for example, can be magnetic (hard drive), optical (CD or DVD), or nonvolatile flash memory (such as in a USB drive).

Input/output devices include anything that allows for input (such as the mouse and keyboard) or output (such as a monitor or printer). Finally, buses transfer data between components within a computer system, such as between the CPU and main memory. The relationship of these devices is shown below.

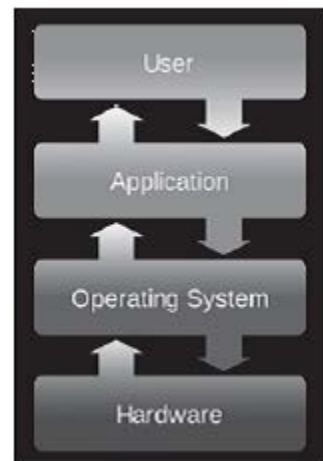




Part IV: Operating Systems—Bridging Software and Hardware

An operating system is software that has the job of managing and interacting with the hardware resources of a computer. Because an operating system is intrinsic to the operation a computer, it is referred to as system software.

An operating system acts as the “middle man” between the hardware and executing application programs (see the figure on right). For example, it controls the allocation of memory for the various programs that may be executing on a computer. Operating systems also provide a particular user interface. Thus, it is the operating system installed on a given computer determines the “look and feel” of the user interface and how the user interacts with the system, and not the particular model computer.



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Part V: Limits of Integrated Circuits Technology: Moore's Law

In 1965, Gordon E. Moore, one of the pioneers in the development of integrated circuits and cofounder of Intel Corporation, predicted that as a result of continuing engineering developments, the number of transistors that would be able to be put on a silicon chip would double roughly every two years, allowing the complexity and therefore the capabilities of integrated circuits to grow exponentially. This prediction became known as Moore's Law. Amazingly, to this day that prediction has held true. While this doubling of performance cannot go on indefinitely, it has not yet reached its limit.

Charles Moore Video: <https://vimeo.com/70293585>

Concepts and Procedures

1. All information in a computer system is in binary representation. (TRUE/FALSE)
2. Computer hardware is based on the use of electronic switches called _____.
3. How many of these electronic switches can be placed on a single integrated circuit, or "chip"?
 - a. Thousands
 - b. Millions
 - c. Billions
4. The term "bit" stands for _____.
5. A bit is generally a group of eight bytes. (TRUE/FALSE)
6. What is the value of the binary representation 0110.
 - a. 12
 - b. 3
 - c. 6
7. The _____ interprets and executes instructions in a computer system.
8. An operating system manages the hardware resources of a computer system, as well as provides a particular user interface. (TRUE/FALSE)
9. Moore's Law predicts that the number of transistors that can fit on a chip doubles about every ten years. (TRUE/FALSE)

Problem Solving

1. What is the number of bits in 8 bytes, assuming the usual number of bits in a byte?
2. Convert the following values in binary representation to base 10. Show all steps.
 - a. 1010
 - b. 1011
 - c. 10000
 - d. 1111
3. Convert the following values into binary (base 2) representation. Show all steps.
 - a. 278
 - b. 163
 - c. 725
4. What is in common within each of the following groups of binary numbers?
 - a. values that end with a "0" digit (e.g., 1100)
 - b. values that end with a "1" digit (e.g., 1101)
 - c. values with a leftmost digit of "1," followed by all "0s" (e.g., 1000)
 - d. values consisting only of all "1" digits (e.g., 1111)
5. Assuming that Moore's Law continues to hold true, where n is the number of transistors that can currently be placed on an integrated circuit (chip), and $k \cdot n$ is the number that can be placed on a chip in eight years, what is the value of k ?