

The Journey InsideSM: Digital Information Background Information, Part 1

Language of Computers

This unit examines the way in which information is stored in a computer. The data and information that is part of our day-to-day lives exist in a variety of forms. For example, we interact with printed information, sound, and images. If we are to use this information with a computer, it must be transformed into a form that the computer can use.

Computers use integrated circuits (chips) that include many transistors that act as switches. These transistors are either on or off. Electricity is either flowing through the transistor or it isn't. Thus, a circuit is either open or closed. Something that can have only two states is called binary. The binary number system represents the two states using the symbols 0 and 1. Actually, there are no 0s and 1s inside the computer. Instead, the 0s and 1s represent the state of a transistor switch or a circuit.

Binary Code

The two states available in the electrical switches and circuits, on and off, provide a way to use the binary number system to represent information in a computer. Computer hardware is designed to work with the information after it has been binary-coded. Each of the 0s or 1s from the binary number system is called a bit (binary digit). Whether a computer is working with words, numbers, colors, graphics, or sound, the internal representation of the information is the same—a series of bits made up of 0s and 1s.



You and your students are used to working with a much larger set of symbols than the two symbols a computer uses. The symbol set that you are accustomed to using contains 26 lowercase letters, 26 uppercase letters, 10 digits, a number of punctuation marks, and other symbols such as #, *, &, and =.

At first, you might think that a two-character symbol set is limiting. However, it is not. You can count with binary numbers. The (base 10) numbers 1, 2, 3, and 4 are represented in binary as 1_2 , 10_2 , 11_2 , and 100_2 . In addition, just as you do with the base 10 numbers, you can perform mathematical computations on binary numbers using binary arithmetic.

The computer uses a special binary code to represent letters. The computer industry has agreed on an 8-bit code for representing letters and other symbols. The letter "A" is represented by $0100\ 0001_2$ and the letter B by $0100\ 0010_2$. The lowercase of each letter is represented by a different 8-bit code. Similarly, all the other letters can be represented using this 8-bit binary code.

A group of 8 bits is called a byte. There are exactly 256 different 8-bit binary numbers: $0000\ 0000_2$, $0000\ 0001_2$, $0000\ 0010_2$... $1111\ 1110_2$, $1111\ 1111_2$. These binary numbers represent the base 10 numbers 0, 1, 2... 254, 255.

In order to provide a way for the keyboard to function as a digital input device, the computer contains special tables that contain information about the letters and other symbols. Each key on the keyboard sits above a grid of wires. When a key is pressed, there is an immediate change in the current moving along the row and column associated with the key. A special keyboard chip scans the row circuits hundreds of times per second and recognizes that a row is now active. After recording which row is active, the chip quickly scans to identify which column is also active. The information of row and column is recorded and transmitted as a key code or scan code.

The microprocessor sends the key code to a look-up table or scan-code table installed in the computer. This table matches the key-location code with a corresponding letter. Each letter is given a numerical value that is converted into binary form. In an English look-up table, the R key is represented in binary code as $0101\ 0010_2$.

The Journey InsideSM: Digital Information Background Information, Part 2

Storage of Binary Information

Your computer is capable of handling incredible amounts of information in an extremely short time. To facilitate this speed, there are many types of storage components in the computer. Efficient storage and retrieval of the bits that represent the information helps to determine the efficiency of your machine.

Hard disks, optical disks, and tape storage provide long-term storage. This type of information is fine for long-term purposes but doesn't work well as a way to hold information while the computer is actually working with it. In relation to how fast the microprocessor can handle information, accessing the bits on these devices is very slow.

Special integrated circuits are created to handle the information while the computer is working. Special read-only memory (ROM) chips provide permanent memory to hold all the start-up programs needed to prepare the computer for use. This storage is unaffected when the computer is turned off. This type of memory is filled with data during the manufacture of the computer.

Random-access memory (RAM), or main memory, is used to temporarily hold the programs, instructions, and information needed for a given work session. This type of memory is given information to store each time the computer is started up. The actual contents of this type of memory may change many times during one work session.

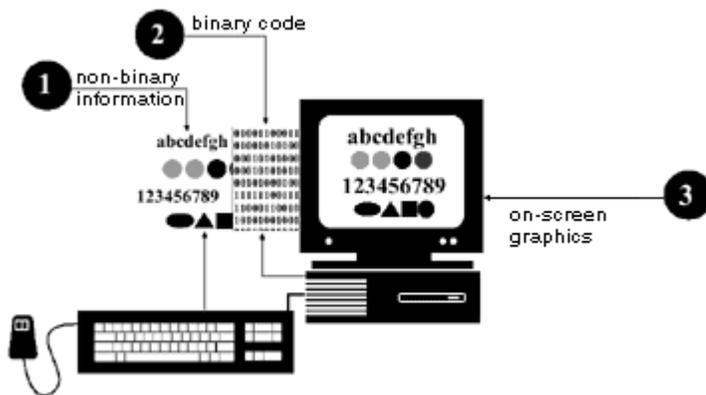
Information is moved to RAM from the disks or tapes used for long-term storage. Data on RAM chips is retrieved in about 120 billionths of a second. However, each time the computer is restarted, this kind of memory receives information to be used during the work session.

Some computers also have cache memory, a special type of RAM. This type of memory can be more than 10 times faster than the main memory RAM chips, but is more expensive. Cache memory is used to hold the operating instructions or data that may be needed shortly. Cache memory helps keep the computer operating at top speed.

Special areas on the microprocessor are devoted to storing data. This kind of memory is the fastest type available and is used to keep track of the instructions being used in the currently running computer program.

A computer only works with binary representations of the various types of input. For a person to make use of the results of the information processed, the computer must have a way to convert the digital information back to a form usable by the person operating the computer.

For example, your display screen is capable of showing complex pictures. A computer display screen can be thought of as consisting of closely spaced rows of dots or picture elements (pixels). Outside of the computer, the 256 possible colors for a pixel can be thought of as color 0, color 1, color 2, ..., color 255. Inside the computer, the code used to represent these colors are the binary numbers $0000\ 0000_2$, $0000\ 0001_2$, etc. The color of each pixel for a graphic to be displayed is stored in computer memory. The computer is designed to convert this stored (coded) pixel information that is in a binary format into a form that shows as a graphic on the display screen.



When you see an image on your screen, you are not seeing its binary representation. A special graphics chip inside the computer changes the digital information into a form that can be displayed. This reverses the input phase of translating keyboard input to a binary representation. Here, a look-up table provides the specific sequence of voltage needed to produce a specific combination of red, blue, and green to give each pixel the color you need. The array of tiny dots—pixels—forms the image on your screen. Sometimes that image is words; sometimes that image is pictures.

Consider the printer as an output device. If you are using a laser printer, the printer's chip is responsible for converting the information it receives from the microprocessor into light signals understood by the printer. The printer produces recognizable characters. This translation of binary representation back into recognizable characters allows the user to have the information in a readable printed format even though the computer itself deals only with the binary form of the information.

The Journey InsideSM: Digital Information Background Information, Part 3

ASCII Code

Consider storing letters and punctuation marks, colored pictures, or numbers in scientific notation such as 2.895×10^{17} . Although it is possible to use any number of different codes to store information in a computer, computer manufacturers have developed agreements to establish universal standards so that nearly every desktop computer understands the same standardized code.

The most common code used on desktop computers is the American Standard Code for Information Interchange (ASCII). This acronym is pronounced "asskee." This standard uses an 8-bit code used to represent the characters used in written communication. This includes letters, digits, and punctuation marks. Each collection of eight bits is called a byte. Modern computer circuitry is designed to work efficiently with this 8-bit standard. Information is stored and manipulated in bytes.

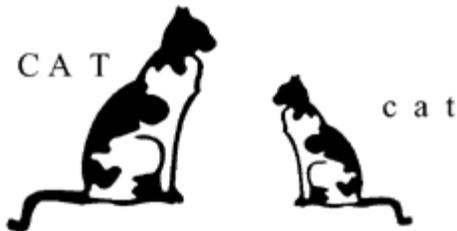
The following is a sample of the ASCII code table that is found in the student materials. Notice the decimal (base 10) equivalents of the binary codes.

Decimal	Letter	Binary
65	A	0100 0001 ₂
66	B	0100 0010 ₂
67	C	0100 0011 ₂

The table indicates that the binary representation for the letter "A" is 0100 0001₂. We generally say "The ASCII code for the letter A is 65." The decimal number system is easier to remember and say than "The ASCII code for the letter A is 0100 0001₂."

As you can see in the above table, there is a systematic pattern to the way in which ASCII codes have been assigned. If the user wants to alphabetize a list of words, the computer doesn't sort by looking at actual letters. Instead, the computer sorts using the ASCII codes of the letters.

When a computer works with words, it is working with collections of bytes. For example, if you enter the word "CAT" into a word processor, the three bytes 0100 0011₂, 0100 0001₂, and 0101 0100₂ are stored in the memory of the computer. If you enter "cat" instead of "CAT," the three bytes 0110 0011₂, 0110 0001₂, and 0111 0100₂ are stored. There are different ASCII codes for lowercase and uppercase letters.



Every character entered on the keyboard is stored in a similar manner. For example, in writing, you leave a blank space between words. On the keyboard you press the space bar.

The ASCII code for a blank space is the decimal number 32 or the binary number 0010 0000₂.

As you have seen, the computer uses the binary system to process information in a variety of ways. It uses ASCII code to translate between information that people can process and information that the computer can process. It uses the binary number system to perform mathematical computations as it processes information. And it stores information in a binary format both in internal memory and on external storage devices such as disks and CD-ROMs.

Resources

The first two resources are annotated and are appropriate for both teachers and students:

Gertler, N. (1994). *Computers Illustrated*. Indianapolis, IN: QUE.

An excellent combination of graphics and text explain topics including the description of specific computers, memory, display, printing, publishing, and networking.

White, R. (1995). *How Computers Work* (2nd ed.). Emeryville, CA: Ziff-Davis Press.

This book combines graphics and text to explain how a computer does its many jobs. It also covers many of the peripherals used to accomplish these tasks. Includes an interactive CD.

Rizzo, J. & Clark, D. (1993). *How Macs Work*. Emeryville, CA: Ziff-Davis Press.

White, R. (1993). *How Software Works*. Emeryville, CA: Ziff-Davis Press.