Digital Computers

There are two fundamental techniques used to store and manage information: analog and digital. *Analog* information is continuous, in direct proportion to the source of the information. For example, a mercury thermometer is an analog device for measuring temperature. The mercury rises in a tube in direct proportion to the temperature outside the tube. Another example of analog information is an electronic signal used to represent the vibrations of a sound wave. The signal's voltage varies in direct proportion to the original sound wave. A stereo amplifier sends this kind of electronic signal to its speakers, which vibrate to reproduce the sound. We use the term analog because the signal is directly analogous to the information it represents. Figure 1.3 graphically depicts a sound wave captured by a microphone and represented as an electronic signal.

Digital technology breaks information down into discrete pieces and represents those pieces as numbers. The music on a compact disc is stored digitally, as a series of numbers. Each number represents the voltage level of one specific instance of the recording. Many of these measurements are taken in a short period of time, perhaps 40,000 measurements every second. The number of measurements per second is called the *sampling rate*. If samples are taken often enough, the discrete voltage measurements can be used to generate a continuous analog signal close enough to fool the human ear into thinking it is continuous sound.

Figure 1.4 shows the sampling of an analog signal. When analog information is converted to a digital format by breaking it into pieces, we say it has been *digitized*. Because the changes that occur in a signal between samples are lost, the sampling rate must be sufficiently fast.

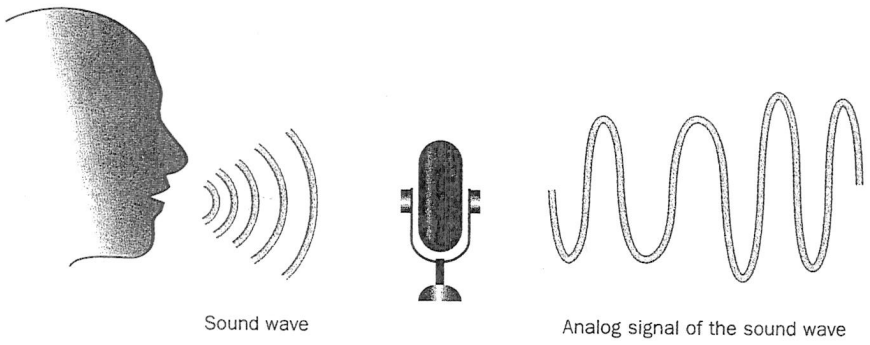

Figure 1.3 A sound wave and an electronic analog signal that represents the wave

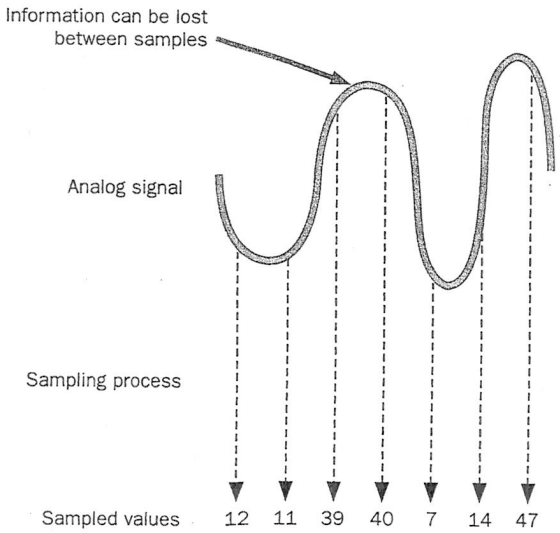

Figure 1.4 Digitizing an analog signal

Key Concept

Digital computers store information by breaking it down into pieces and representing each piece as a number.

Sampling is only one way to digitize information. For example, a sentence of text is stored on a computer as a series of numbers, where each number represents a single character in the sentence. Every letter, digit, and punctuation symbol has been assigned a number. Even the space character is assigned a number. Consider the following sentence:

```
Hi, Heather.
```

The characters of the sentence are represented as a series of twelve numbers, as shown in Figure 1.5. When a character is repeated, such as the uppercase 'H', the same representation number is used. Note that the uppercase version of a letter is stored as a different number than the lowercase version, such as the 'H' and 'h' in the word Heather. They are considered to be separate and distinct characters.

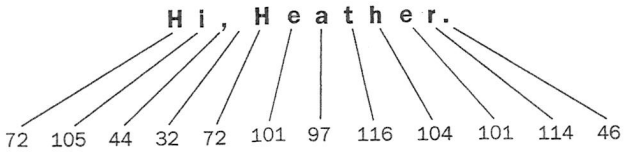

Figure 1.5 Text is stored by mapping each character to a number

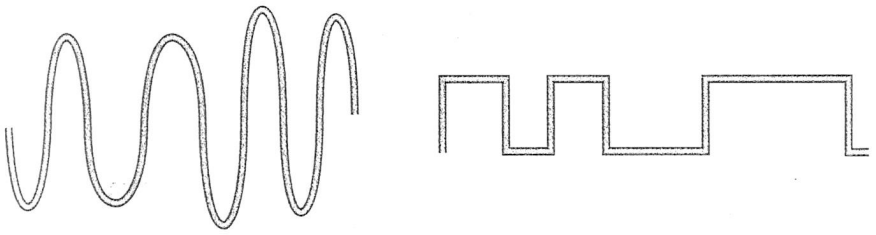

Figure 1.6 An analog signal vs. a digital signal

Modern electronic computers are digital. Every kind of information, including text, images, numbers, audio, video, and even program instructions, is broken down into pieces. Each piece is represented as a number. The information is stored by storing those numbers.

Another benefit of digital information is that it increases the distance that information can travel reliably across a wire. An analog signal has continuously varying voltage, but a digital signal is *discrete,* which means the digital voltage changes dramatically between one extreme and the other. At any point, the voltage of a digital signal is considered to be either "high" or "low." Figure 1.6 compares these two types of signals.

As a signal moves down a wire, it gets weaker. That is, its voltage drops. To make sure a signal gets to its destination, amplifiers can be placed along the line to reinforce the strength of the signal. The trouble with an analog signal is that as it loses strength, it loses information. Since the information is directly analogous to the signal, any change in the signal changes the information. An amplifier can reinforce the signal but it cannot recover the changes in the signal up to that point. A digital signal also degrades, but it can be reinforced before any information is lost because the original value was either at one extreme or the other.