Basic Communications Electronics

Analog Electronic Devices and Circuits

How They Work and How They Are Used to Create Communication Systems

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CHAPTER 1
Basic Communications Systems

In *Basic Electronics*[1], the book discusses the nature of dc and ac electricity, how semiconductor devices — diodes and transistors — work, and explains how these devices are used in both analog and digital circuits to provide basic electronic functions.

Basic Digital Electronics[2] defines the difference between digital and analog systems, identifies the electronic functions needed by digital systems, and shows how circuits are used to build these functions as they are used in such digital systems as computers and compact disc players.

In this book, *Basic Communications Electronics*, we will discuss the functions needed by analog systems and show how electronic circuits are used to build these functions. Then we will explore how these analog circuits are put together to build communications systems.

Analog Quantities

Analog quantities vary continuously. Digital quantities vary in discrete values — usually just two values, ON and OFF. Analog systems carry information using electrical signals that vary smoothly and continuously over a range. Digital systems carry information using combinations of ON-OFF electrical signals that are usually in the form of codes that represent the information.

Before the invention of the transistor and the development of integrated circuits, most electronic systems were analog. Since the transistor and, more importantly, the integrated circuit, digital circuits with their ON-OFF qualities, lower power usage, wider manufacturing tolerances, and smaller size, have taken over many electronic system functions. However, there are still many systems whose operation can be implemented much better and more efficiently using analog circuits and functions.

Common Analog Systems

To begin, let's be sure we know what an analog system is. Here is an example from *Basic Digital Electronics* — it is a volume control circuit like those used in a stereo, clock radio, or TV set.

A Volume Control

The circuit shown in *Figure 1-1a* is a partial block diagram of a radio receiver showing the volume control in greater detail. The volume control varies the amount of the output voltage (V_O from the radio tuner) passed on to the audio amplifier as the control is changed. If the control is at the bottom (ground), there will be zero input signal voltage (V_{IN}) to the amplifier and no sound from the speaker. If the control is at the top

[1] *Basic Electronics*, G. McWhorter and A. J. Evans, ©1994, Master Publishing, Inc., Lincolnwood, IL
[2] *Basic Digital Electronics*, A. J. Evans, ©1996, Master Publishing, Inc., Lincolnwood, IL

(maximum rotation), the input signal voltage (V_{IN}) to the amplifier is the full signal voltage from the tuner (V_O) and maximum sound comes from the speaker. *Figure 1-1b* shows graphically the relationship between the input signal voltage to the amplifier (V_{IN}) and the amount the control is turned. Notice that the graph is a continuously varying line (in this case, a straight line) without jumps or breaks in it. The input signal to the amplifier (V_{IN}) is an analog of (analogous to) the output voltage from the radio tuner (V_O), even though the position of the control determines the amplitude. The input signal voltage (V_{IN}) is a continuously proportional amount of the output signal voltage (V_O) depending upon the position of the control. The larger V_{IN} to the amplifier the greater the sound out from the speaker. Analog electronic functions are continuous, as in this analog signal example.

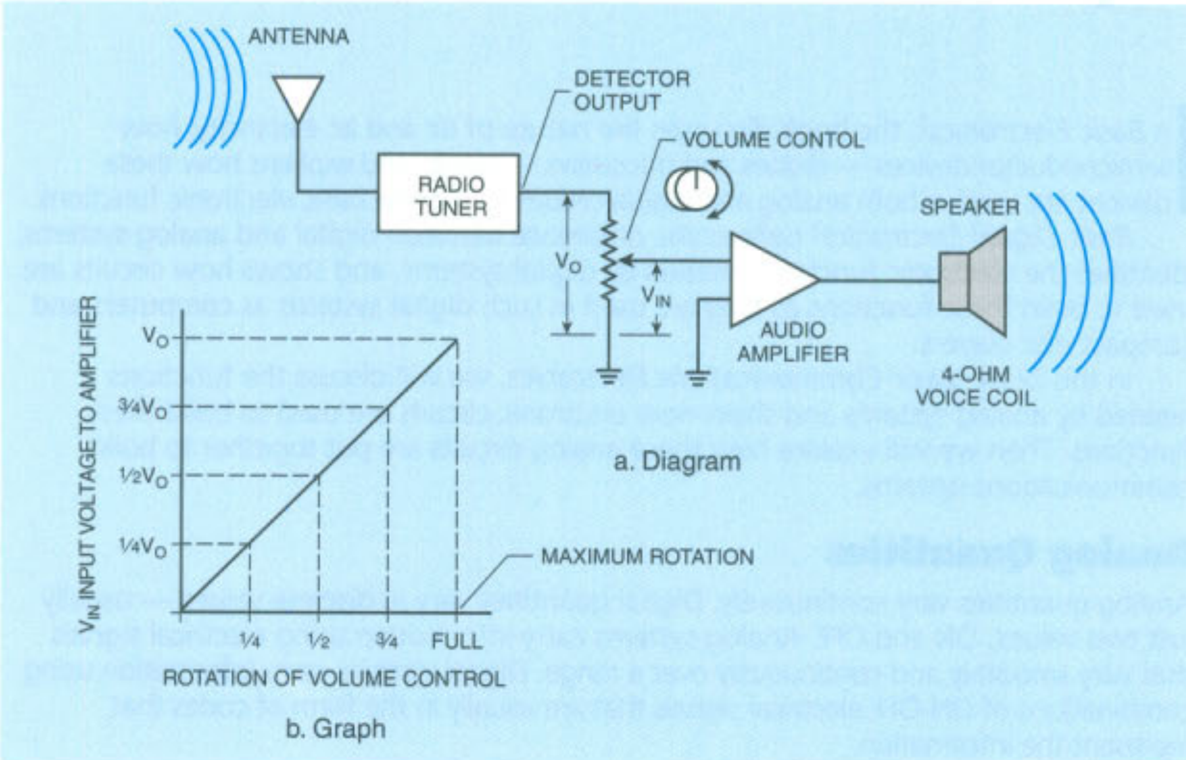


Figure 1-1. Partial block diagram of radio receiver with schematic showing volume control in greater detail. Graph shows relationship between V_{IN} to the audio amplifier and volume control rotation.

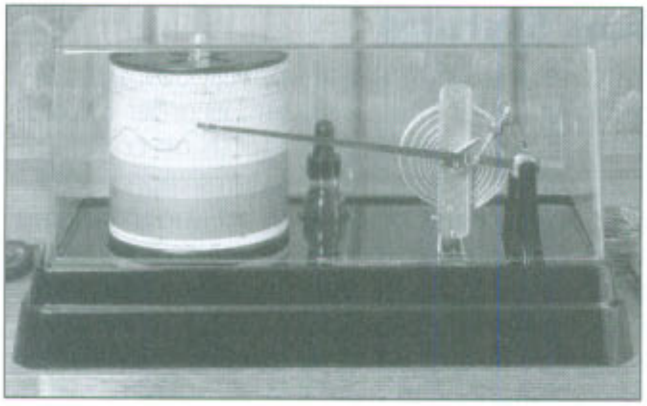
Source: Basic Digital Electronics, A.J. Evans, ©1996, Master Publishing, Inc., Lincolnwood, IL.

A Recording Thermometer

Let's look at another example — a recording thermometer to measure temperature in degrees Fahrenheit (°F). In this case, the outside summer temperature has been monitored for 72 hours. The temperature readings were recorded by a thermometer like that shown in *Figure 1-2a*. It has a tracing pen that continuously plots the readings on a paper tape against time, as shown in *Figure 1-2b*. Note that the thermometer changes gradually and continuously with time. There are no breaks in the data or sudden jumps — the information changes smoothly and continuously.

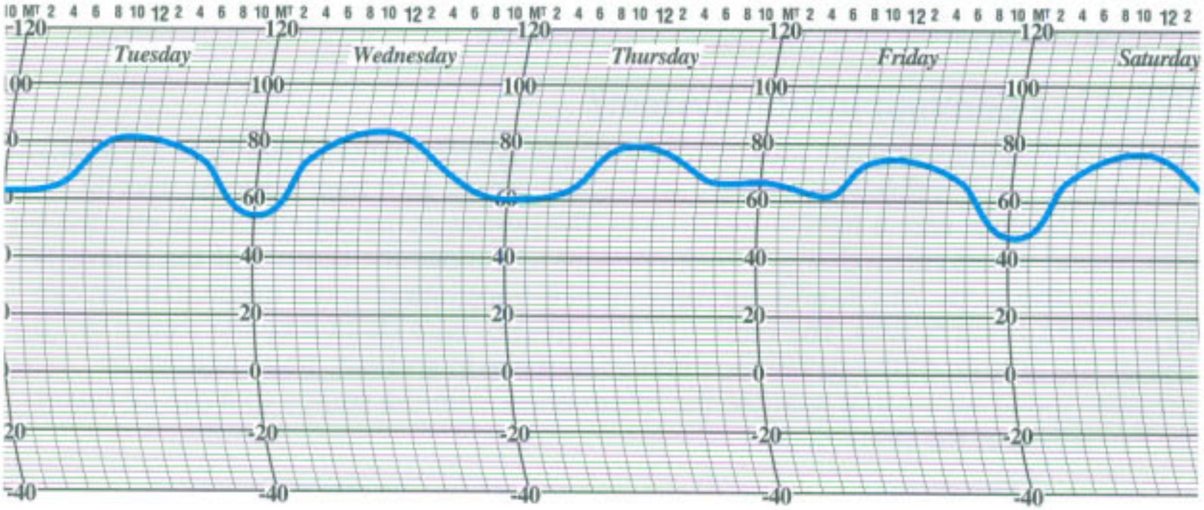
A Fuel Gauge

An automobile fuel gauge is another good example of an analog system. As shown in *Figure 1-3*, a float attached to a variable resistor, a meter, some wire, and a battery are all the components that are required for the system.



a. Recording Thermometer

Photo courtesy of Taylor Environmental Instruments.



b. Plot of Daily Temperature Variations

Figure 1-2. A recording thermometer — an analog system.

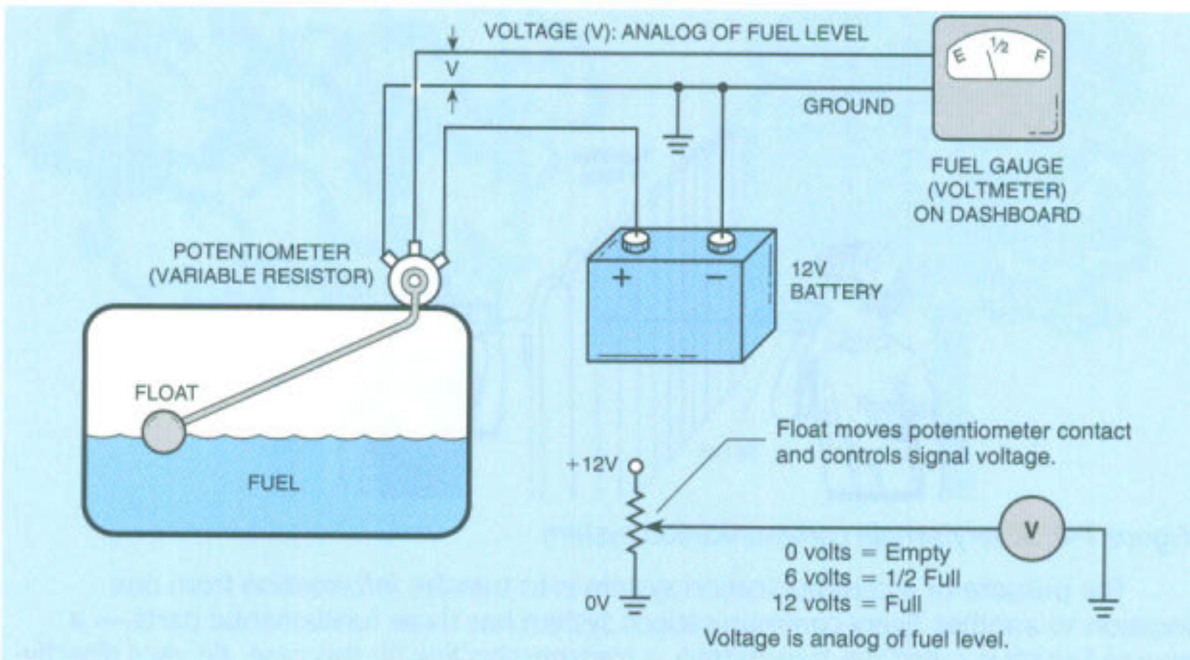


Figure 1-3. An automobile fuel gauge — a simple system of a resistor, battery, meter, and wire — shows how a measurable electrical quantity carries information about something else. In this case, voltage is an analog of fuel level.

Source: Basic Electronics, G. McWhorter, A. Evans, ©1994, Master Publishing, Inc., Lincolnwood, IL.

The Choice of Communications Systems

Analog functions used in electronic systems cover a wide range of applications, from a simple fuel gauge in an automobile to a complex motor control system. In order to place some boundaries on the discussions in this book, we have chosen to focus on communications systems because the analog functions used to create these systems represent a large portion of all analog functions found in analog electronics. With an understanding of the operation of the analog functions used in communications systems and the way electronic components are used to build them, a great deal of the operation of other analog systems will be understood. Many such systems may only use one, two, or a combination of a select number of the analog functions found in a communications system. They may be employed in different combinations to meet specific system operation requirements. But their functions and how circuits are built to perform the function will be similar to those described in this book.

What is a Communication System?

To answer this question, let's look at a very simple system that you may have used when you were a kid. It is shown in *Figure 1-4* — two tin cans with their bottoms directly coupled together with a tight string or wire. The person at the source shouts into the tin can. Sound waves cause changes in air pressure that move the bottom of the source tin can back and forth. This in-and-out movement is transmitted to the destination tin can by the tight string or wire. The motion in the string or wire created by the source tin can causes the bottom of the destination tin can to move in and out, thus creating air pressure sound waves that recreate the information from the source so it can be heard by the person at the destination.

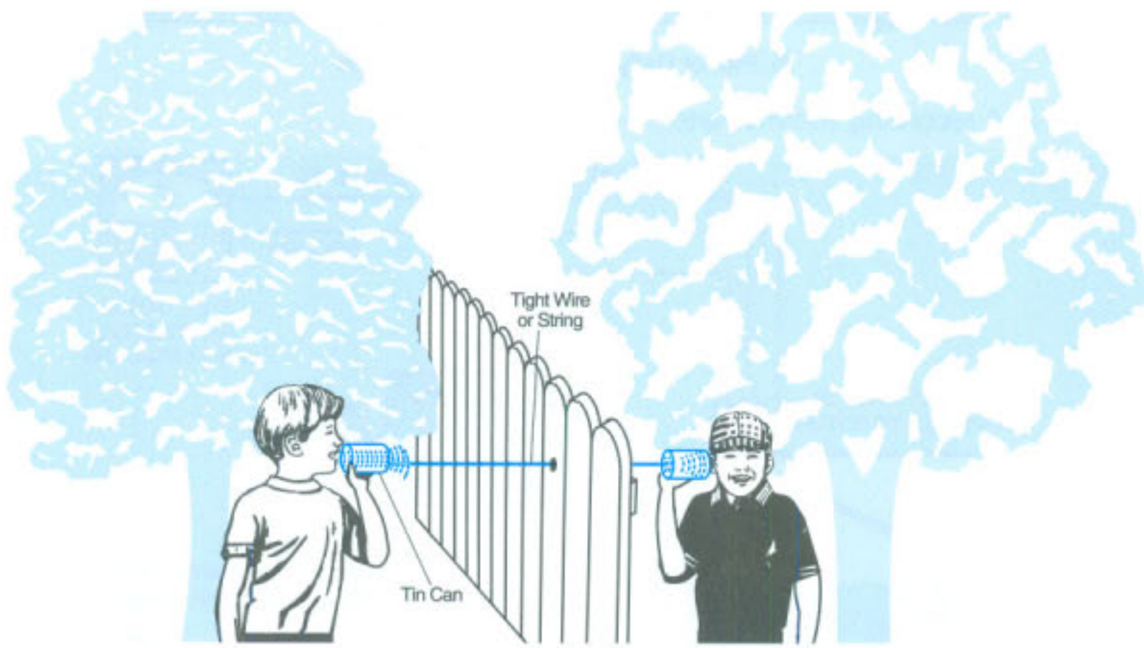
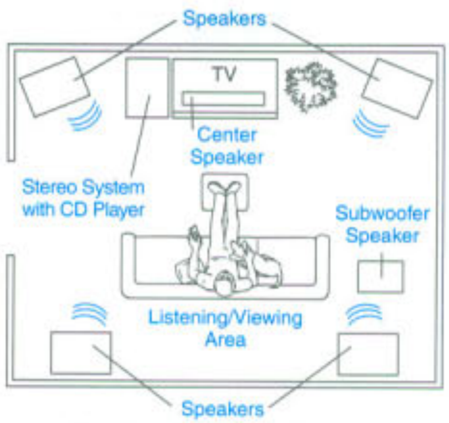


Figure 1-4. A very simple communication system.

The purpose of a communication system is to transfer *information* from one location to another. Every communications system has three fundamental parts — a *source* (which is called the transmitter), a *transmission link* (in this case, tin cans directly-coupled by a tight string or wire), and a *destination* (which is called the receiver). Realize that the system in *Figure 1-4* is a very simple system, not very efficient in communicating information (it takes a lot of shouting). Obviously, the up-to-date techniques and equipment used in today's communications systems are much more advanced. But no matter how advanced, the communication system still has the same three basic parts — a transmitter, a transmission link, and a receiver.

More Specific Examples

Normally, a stereo sound system would not be considered a communication system, but it is. Look at *Figure 1-5a*. The *information* to be transferred is the music stored on the CD, phonograph record, or cassette tape. The *source* is the combination of the CD, record player, or cassette tape player, the stereo amplifier, and the speakers. The *transmission link* consists of sound waves varying the pressure of the air. And the *destination*, or receiver, is a human ear.



a. The Stereo is a Self-Contained Communication System.

b. The Stereo is a Sub-System of the Larger FM Broadcast Communication System.

Figure 1-5. A communication system within a communication system.

Now look at the FM broadcasting system shown in *Figure 1-5b*. Here the *information* to be transferred is the broadcast station's programming material. The *source* is the FM station *transmitter*, the *transmission link* consists of radio waves from the station's antenna to the FM receiver's antenna, and the *destination* is the FM *receiver*. So the interpretation of a communication system varies as the size, complexity, and scope of the system changes. The individual stereo sound system that was our complete communication system is now a sub-system of the much larger FM broadcasting system.

Here are two important points about communication systems: First, one of the jobs of a transmitter is to change the information into a form that "fits" the transmission link so that the information can be properly transferred. Second, one of the receiver's jobs is to change the information back from the transmitted form in order to retrieve the original information.

What Type Information Do We Have?

Today, information may be classified into many categories, mostly brought on by the "high-tech" age. We have chosen to use the following four categories as examples for comparison: text, data, audio, and video. Let's begin with text by looking at *Figure 1-6a*.

Text

Text is information that is generated by typing on a typewriter, word processor, or a computer using a word processing program. It is a string of words, such as those written in a business letter or newspaper report, instructions in an owner's manual, a book, reference material, or general written information. It usually has a minimal amount of numerals. Special codes, like the ASCII Code, are used to store data in digital form just so computers can handle text easily.

a. Text

(Photo courtesy of *Chicago Tribune*, Chicago, Illinois)

b. Audio

(Photo courtesy of WGN, Radio 720 AM, Chicago, IL)

c. Video

(Photo courtesy of NBC 6, WTVJ, Miami, FL)

Figure 1-6. Common types of information.

Data

Data, in general, is known information used to draw conclusions. For a more technical definition for computers and communication systems, in which text can be a subset, data usually is defined as information put into unique codes formatted according to agreed-upon specifications and standards so it can be operated on and manipulated by a digital system under the direction of a software program.

Audio

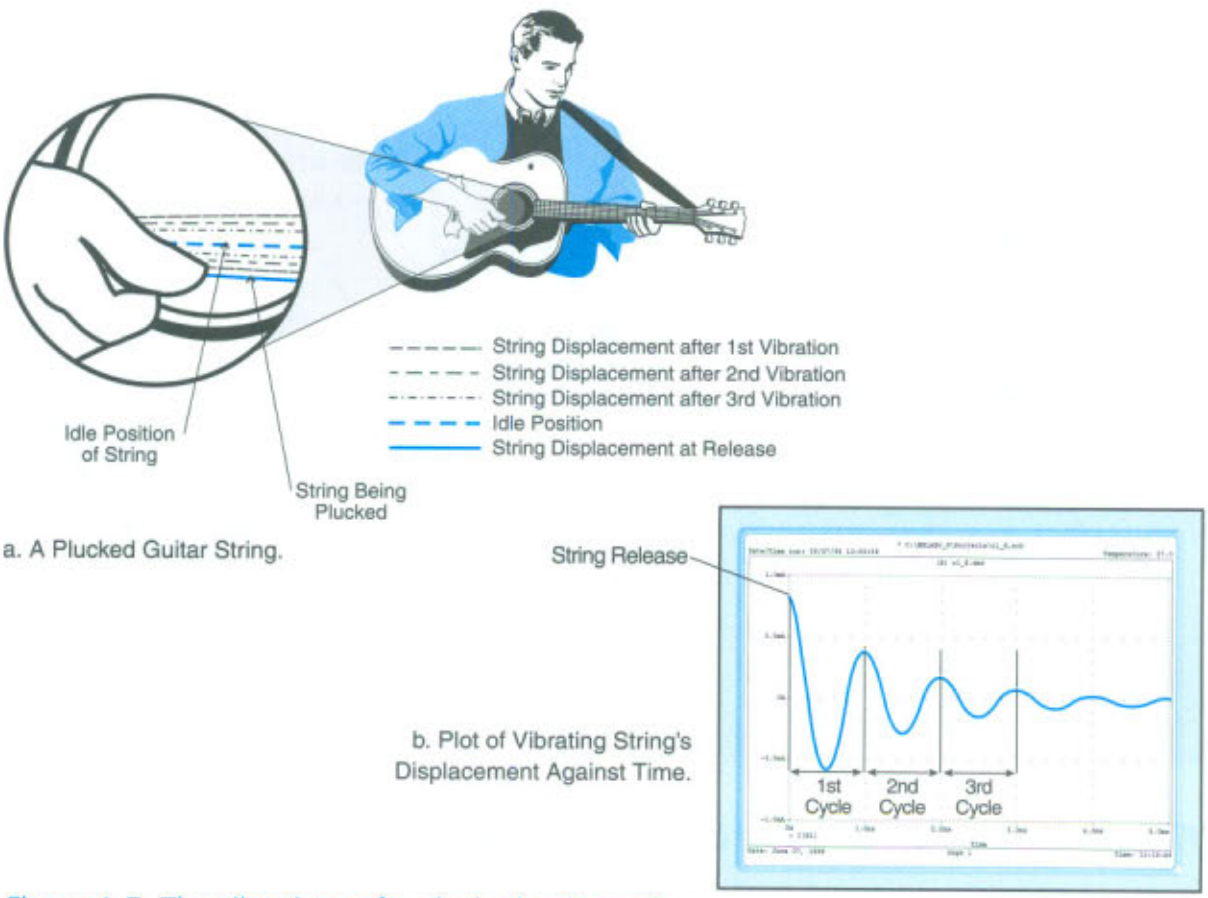
Audio (*Figure 1-6b*) is information that is reproduced as sounds detectable by the human ear. Sounds — music, voice, noise — occur at different frequencies. We'll explain frequency in a minute, but recall that musical instruments like pianos, guitars, violins, and harps have strings that vibrate thus producing different sounds. Audio is defined as vibrations within the range of human hearing which we generally call sound — 10 cycles per second to 20,000 cycles per second.

Video

Video (*Figure 1-6c*) represents pictorial information that includes still photographs, a painted picture, a magazine or book cover, sketches, drawings, schematics or, more generally, information classified as graphics. Video is information that is converted into an electron beam that varies in intensity to produce areas of light or no light on a phosphorous screen which, when a photograph is transmitted, reproduces the photograph. There is much more information to be transferred in a photograph than in lines of text. Thus, video is transferring much more information in a given amount of time than audio. We will look into why, but before we do we need to understand frequency and the relationship of signals of different frequencies.

Frequency

A piano, harp, guitar or bass violin string, when plucked, vibrates back and forth as illustrated in *Figure 1-7a*. The amplitude (displacement) of the vibration, as shown in *Figure 1-7b*, decreases with each vibration until the string eventually returns to its initial position at rest. Note that the amplitude of the plucked string is first positive, then negative. When the vibration has gone from its beginning positive point, through zero, through negative, back through zero, and back to positive again, the vibration completes one cycle. Even though the amplitude changes, the time required to complete one cycle remains constant. The number of vibrations per second (cycles per second) determines the tone generated by the string. The *cycles per second* (vibrations per second) is the *frequency* of the tone. Different strings vibrating at different rates generate different frequency notes to produce the guitar music we enjoy. Electrical engineers have named *frequency* (cycles per second) after one of the leading researchers of electricity, Heinrich Hertz. Cycles per second are called hertz, which is abbreviated Hz.



a. A Plucked Guitar String.

b. Plot of Vibrating String's Displacement Against Time.

Figure 1-7. The vibrations of a plucked guitar string.