Basic Digital Electronics

Digital System Circuits and Functions

How They Work and How They Are Used

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CHAPTER 1

A Look at Familiar Systems

Comparing Analog and Digital

The field of electronics can be classified into two groups: analog and digital. Analog quantities vary at a continuous rate, whereas digital quantities vary in discrete values. We can find many examples of each all around us. All things that can be measured quantitatively in nature are either analog or digital. Let's look at some examples of both analog and digital quantities.

The difference between analog and digital can be seen at the entrance to your local library. There are the steps, which is the digital route; and there is the ramp, the analog route. In a wheelchair, you better take the analog route. Now consider pitching pennies at the steps and the ramp. Where would the pennies land? As we see in *Figure 1-1,* the pennies can land only on steps 1, 2, 3, or 4, whereas they can land anywhere at all on the ramp. The steps represent digital — a discrete group of values; the ramp represents analog — a continuous group of values.

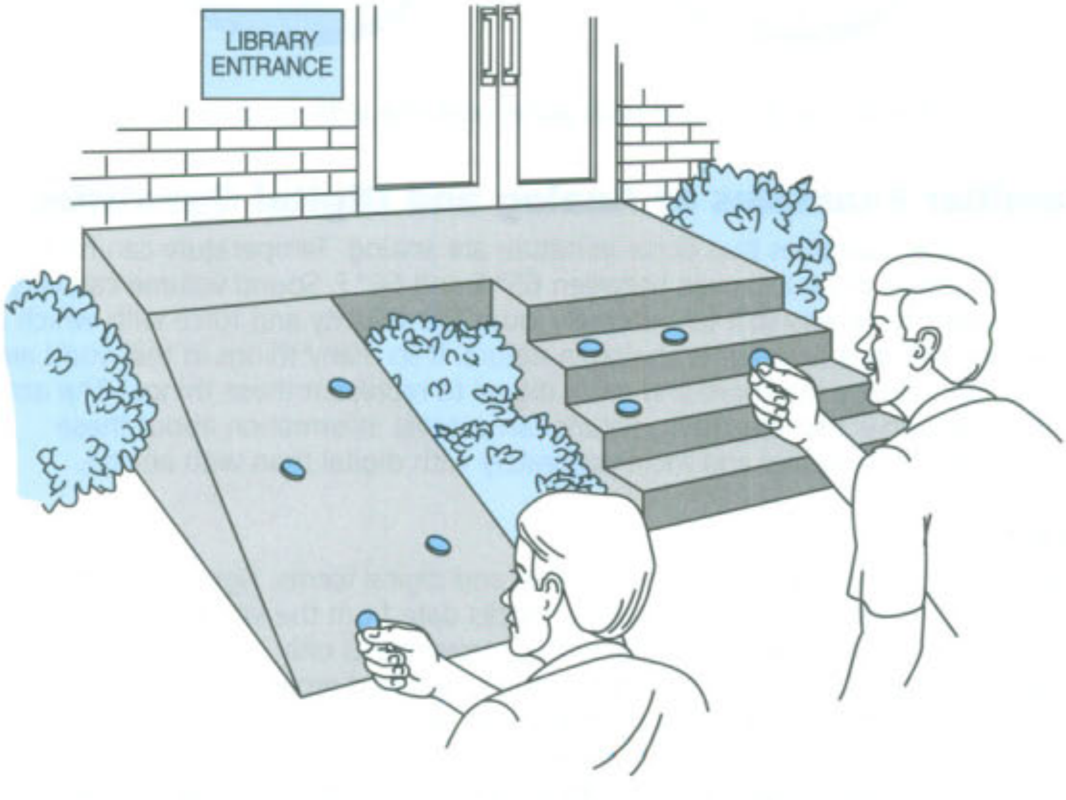

Figure 1-1. Pitching pennies at a ramp (analog) and steps (digital).

Another example of analog and digital quantities is shown in *Figure 1-2*. Here we have two buckets—one filled with water and the other filled with marbles. Suppose that we want to measure the contents of each bucket. The procedure would be different for each. For the bucket of water, we could dip the water out with a measuring cup or pour the water into the measuring cup. In either case we would probably leave a little in the bottom of the bucket or perhaps spill a little. Our measurement would not be very precise. With the bucket of marbles we could simply count them as we removed them. Our measurement would be much more precise. And, if we repeated the process on each over and over again, we would most likely get a different value for the quantity of water each time. But the number of marbles that we counted would be the same each time. This degree of precision is a characteristic difference between analog and digital. Digital is more precise. And how about if you were asked to reproduce each bucket at a distant location. Suppose that you were told one bucket had 6⅔ cups of water, and the other bucket had 723 marbles in it. Which bucket could you reproduce more accurately? The digital one, of course, because you can count out a discrete number of units.

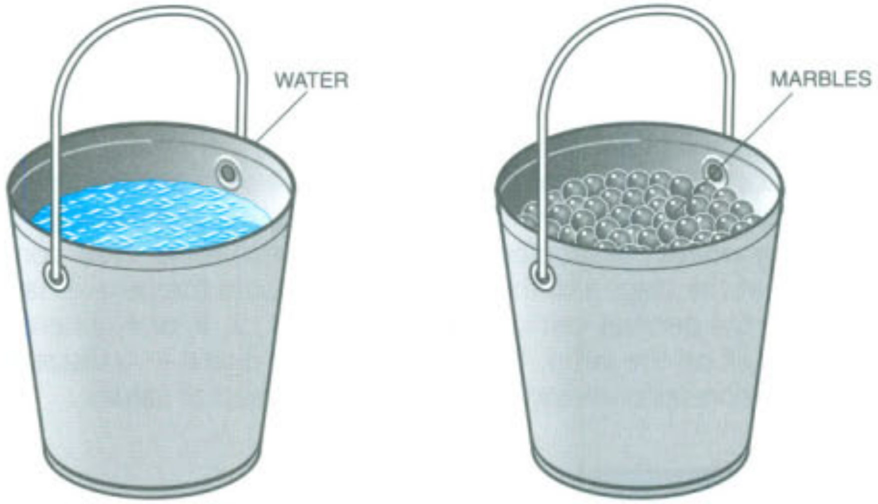

Figure 1-2. Two full buckets, one with water and one with marbles.

Familiar Examples of Analog and Digital Quantities

Most physical quantities that occur in nature are analog. Temperature can have an infinite number of values, even between 65° F and 66° F. Sound volume can vary continuously from very soft to extremely loud. The velocity and force with which a carpenter swings a hammer is analog in nature. If so many things in the world are analog, why do we use more and more digital to represent these things? The answer to this question is that electronic circuits can process information about these physical quantities easier and more accurately with digital than with analog.

Clocks

Many quantities are familiar in both analog and digital forms. *Figure 1-3a* shows examples of clocks. Modern mechanical clocks date from the late Middle Ages. Analog watches have served us well with improvements only in the basic design. For instance, by the end of the 15th century the spring had replaced the weight in some clocks, allowing them to be built small enough to be carried. Only within the last decade or two has the analog watch been almost completely replaced by the digital watch. (We wonder what the terms clockwise and counterclockwise will mean to the next generation.)

Thermometers

Figure 1-3b shows examples of thermometers. The analog thermometer has been used for temperature measurement since it was introduced around 1720 by Gabriel Daniel Fahrenheit (1686-1736). An example is a mercury thermometer, in which a rising or falling (expanding or contracting) column of mercury represents a rising or falling temperature. Digital thermometers have replaced these in most applications today, especially in the medical field.

Meters

Two basic types of meters are used to make electrical measurements. As shown in *Figure 1-3c,* the analog type has a needle that deflects along a scale and indicates the value of the quantity measured by the position of the needle on the scale. Measurements on a digital meter appear as a number on the display screen.

Audio Recordings

The fourth example of analog and digital is shown in *Figure 1-3d.* The human voice and musical instruments produce sound that is analog. The ear is also an analog device that responds to the sound signals. The first audio recording devices were analog. From about 1880 through 1980, the phonograph held the dominant position for audio recordings for the home. Around 1980, the audio cassette tape entered the scene. In the late 1980s came perhaps the most remarkable development in audio technology—the digitally recorded compact disc (CD).

Figure 1-3. Examples of the same quantities (time, temperature, electrical values, and sound) represented both as analog and digital values.

Recording devices for a CD convert analog signals to digital signals. The digital information is stored on the CD by making discrete indentations inline in a track on the surface of the CD. When the CD is played, a laser beam reflected from the surface converts these indentations into light pulses, which are detected and the digital data is converted back to analog signals by the CD player.

So why go to the trouble and extra steps to convert to and from the digital format? The CD digital audio vastly improves the audio quality over its analog counterparts—so much so that anyone who hears it will have a hard time going back to traditional analog audio. In addition, the digital format has virtually eliminated many problems of analog audio reproduction, such as noise and distortion due to fingerprints, smudges and scratches on the recording medium. Since a laser beam reads the information from the CD without mechanical contact with the CD, no matter how many times it is played, there is no wear on the disc.

Analyzing a Volume Control Circuit

Every radio and television receiver has a volume control, and most of them look like the circuit of *Figure 1-4a*. This is a partial block diagram of a radio receiver that shows the schematic of the volume control in more detail. The volume control is a continuously variable voltage divider; that is, it has an output voltage that changes as the control is varied. If the control is at the bottom (ground), there will be zero input voltage (V_{IN}) to the amplifier. If the control is at the top (maximum rotation), the input voltage to the amplifier is the full voltage, V_O. *Figure 1-4b* shows graphically the relationship between the input voltage and the amount the control is turned. Notice that the graph is a continuously varying line without jumps or breaks in it. The output is an analog of (or analogous to) the input voltage. The input voltage is a continuously proportional amount of the voltage V_O.

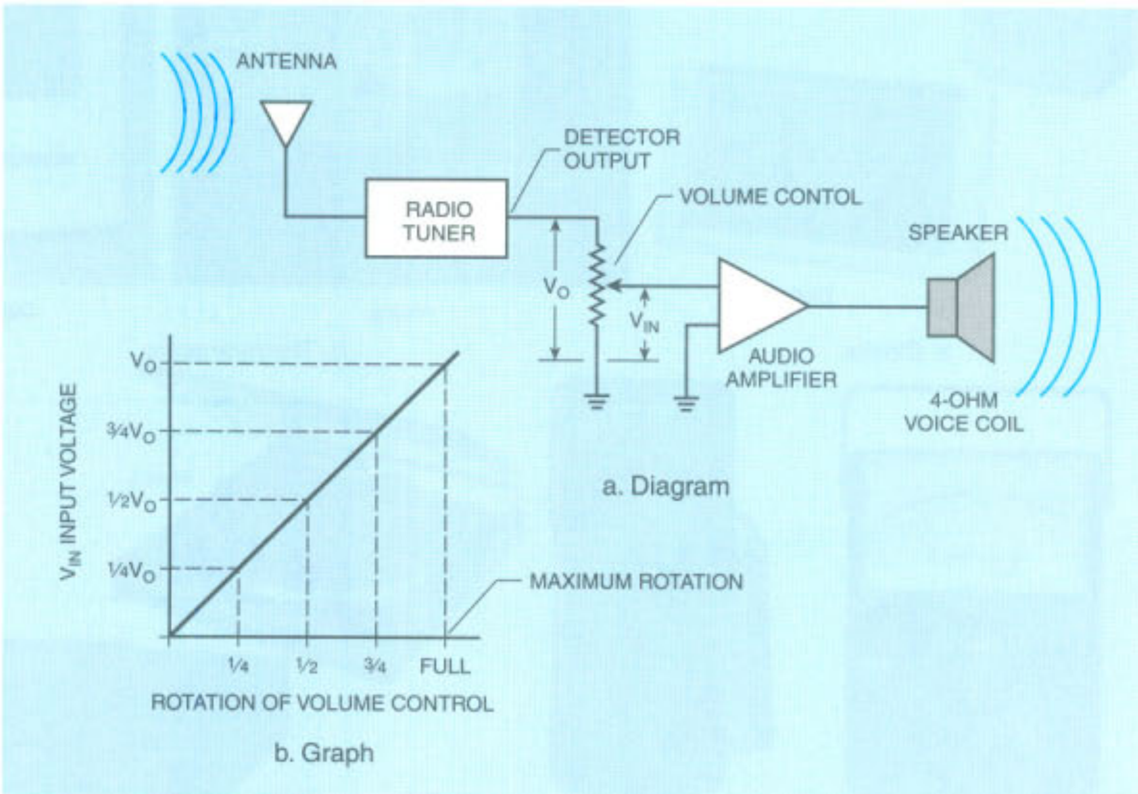

Figure 1-4. Partial block diagram of radio receiver with schematic showing volume control in more detail. Graph shows relationship between V_{IN} and volume control rotation.