chapter 1

The World of Modern Engineering

OUTLINE

- What Exactly Do Scientists and Engineers Do?
- Birth of the Digital Age
- Moore's Law
- Block Diagram—Organizing Engineering Designs
- Summary

Where did all this great "stuff" come from? Who designed and created the TV you watch, the car you ride in, the computer you use to surf the Internet, and your cell phone? Nearly everything you touch had to be thought of, designed, and built (Figure 1.1). Who did all of this? And how did they do it?

The answer is simple: *Engineers, armed with their ingenuity*.

It might come as a surprise to learn that engineers, as a group, are some of the most creative and inventive people working today. Society calls upon engineers not only to envision what the world will look like tomorrow, but, more importantly, to make "tomorrow" happen.

Can you imagine what your life would be like if engineers hadn't designed and built TVs,

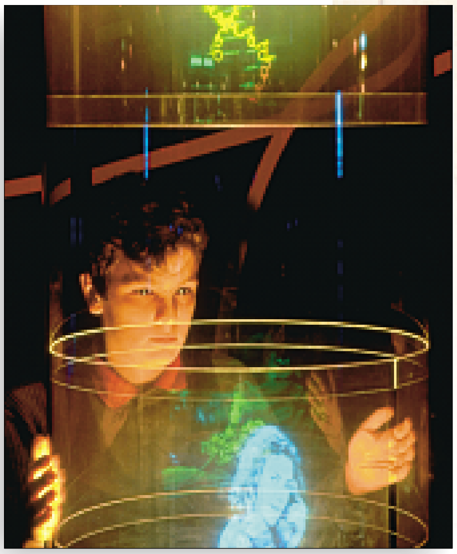

Figure 1.1 People use all sorts of technology to enhance their lives.

radios, recording studios, stereos, and automobiles? What would your life be like if you couldn't call or e-mail your friends at night, or if there were no radios, CDs, or DVDs to entertain you? What if there were no X rays and CAT scans to help doctors diagnose injuries and illnesses? What if the only way for you to get to school were to walk or ride a horse?

We often take today's great creations for granted, again thanks to engineers. What new high-tech health treatment, communications device, digital entertainment experience, transportation vehicle, or manufacturing method will we all take for granted in the coming years? Computers that talk to us or even "think" for us? Cars that drive themselves? Engineers are already working on these devices today!

INTERESTING FACT: The word "engineer" stems from the French word *ingénieur*, which means "ingenuity." Contrary to popular belief, its root is not the English word "engine."

1.1 What Exactly Do Scientists and Engineers Do?

Making Dreams a Reality

Let's go back in time to the 1950s, before humans ever ventured into space. Back then, there were science fiction movies that suggested what life could be like in space, what our spaceships might look like, what the surfaces of planets might look like, and even what aliens might look like. Yet, until the 1960s, these images were all largely figments of Hollywood's imagination.

However, on May 25, 1961, then-president John F. Kennedy proclaimed that the United States would put a person on the Moon "in this decade." Who did he think was actually going to make this dream a reality? Politicians? Bankers? Lawyers? No, he knew it was going to be engineers and scientists.

Did engineers and scientists know how they were going to achieve this remarkable goal at the time of President Kennedy's speech? No, but they had confidence that, by working together, breaking the problem of space travel into manageable pieces, solving these smaller individual problems, putting all the components together, and then testing the final solution, they would have a very good shot at placing a human on the Moon before 1970.

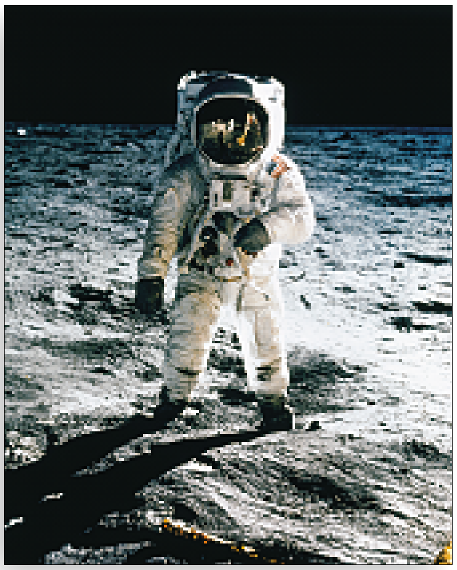

Figure 1.2 Photo of Buzz Aldrin on the surface of the Moon, taken by Neil Armstrong, July 20, 1969.

Well, the engineers and scientists were right. Through their hard work and with the help of many, on July 20, 1969, the Apollo 11 mission placed Neil Armstrong and Buzz Aldrin on the surface of the Moon (Figure 1.2), culminating all their efforts into one of the greatest achievements in all of human history and registering a triumph for engineering and science.

What Makes Engineers Different from Scientists?

What makes engineers unique? And how are engineers different from scientists and mathematicians? You have had years of experience taking math and science courses. These classes have helped you understand and describe the world around you. As you have probably already learned from these courses, the primary purpose of science and math is to help humans *understand and describe* their world: How do cells divide? What makes objects fall to the ground? What are the basic building blocks of life? What is the distance between the Earth and the Moon?

To answer these questions, scientists throughout history have followed the **scientific method**. This five-step process, or **algorithm**, is the basic roadmap for discovery and understanding. Scientists who have sought to answer the fundamental questions about our world have used the scientific method as their guidepost. The five steps are as follows:

Scientific Method: The five-step process by which scientists explain natural phenomena.

Algorithm: A step-by-step process to achieve a goal.

1. Observe some aspect of the universe.
2. Invent a tentative description (hypothesis) consistent with what you have observed.
3. Use the hypothesis to make predictions.
4. Test those predictions by experiments or further observations, and modify the hypothesis in light of your results.
5. Repeat Steps 3 and 4 until there are no discrepancies between theory and experiment and/or observation.

While scientists seek to explain how the world works, engineers attempt to create new objects and devices that are important to humans and society, such as cutting-edge medical devices, innovative video games, safer cars, and high-tech communication devices. While scientists rely on the scientific method for discovery, engineers rely upon the **engineering design algorithm** to create nearly every object around you. The engineering design algorithm includes the following nine steps:

Engineering Design Algorithm: A nine-step process followed by engineers to create new objects or systems.

1. Identify the problem or design objective.
2. Define the goals and identify the **constraints**.
3. Research and gather information.
4. Create potential design solutions.
5. Analyze the viability of solutions.
6. Choose the most appropriate solution.
7. Build or implement the design.
8. Test and evaluate the design.
9. Repeat ALL steps as necessary.

Constraints: Limits that are placed on the design problem. For example, a constraint might be that the final design should not cost more than $X or weigh more than Y pounds.

As indicated by Step 1 of this list, the engineer must first answer the fundamental question: *What do I want to create today?* Very few professions place such a high premium on the creative spirit of the individual.

EXAMPLE 1.1 Designing the Cell Phone of Today

As a way of understanding the engineering design algorithm, let's apply it to a piece of existing technology—the cell phone—as if we were the engineers about to begin its design process.

Step 1: *Identify the design objective.* We want to build something that will allow humans to communicate with one another between any two locations on the globe at any time.

Step 2: *Define goals and constraints.* Some of the design goals and constraints for this device include the following:

- *Movement:* The device should not be connected physically to anything else that would limit our movement when using it. For example, it shouldn't need to be plugged into a wall outlet or a network jack.
- *Size:* The device should be small and portable so that we can carry it in our hand, a pocket, a bag, or backpack.
- *Form:* It should be large enough to be easy to hold in our hand, since devices that are too small are hard to grip. It should also provide a way for us to talk into it and for us to hear the caller at the other end of the call.
- *Energy use:* It shouldn't require too much energy in its operation, or else we'll need to change or recharge its energy source too often.
- *Cost:* It should be inexpensive enough so that people will buy it.

Step 3: *Research and gather information.* Has anyone ever done something like this before? Wireless radio telephones were being researched by the American Telephone and Telegraph Company in the 1930s, but these systems were more like modern family radio systems and "walkie-talkies" than cell phones. The Citizen Band (CB) radio craze of the 1970s brought point-to-point, two-way radio communications to large numbers of automobile travelers. But neither system reaches around the globe, and neither can be used easily to contact a wide variety of individuals. It wasn't until the 1990s that a system such as the one described in Step 1 was put into widespread use.

Steps 4 to 8: *Create, analyze, choose, build, and test.* We are all fortunate that engineers at international companies such as AT&T's Bell Telephone Laboratories, Nokia, Ericsson, Qualcomm, and Motorola completed these steps and designed, built, and tested a wide variety of cell phones that meet the design goals and constraints.

Solution

How well do you think current cell phones meet the objectives specified in Step 1 and satisfy the constraints given in Step 2? Are you pleased with current cell phone technology? Would you change anything about the goals or constraints?

EXERCISES 1.1

Mastering the Concepts

1. Identify five items designed by engineers. What did these items do that was new and innovative at the time of their creation? What items did these new creations replace? How is the world a better place because of these designs?
2. Identify five items that you suspect were not designed by engineers. How do they differ from those designed by engineers?
3. Apply the engineering design algorithm to the following processes:
   a. Making the family dinner
   b. Creating new laws
   c. Treating illness in a patient
   Be specific about each step in the design algorithm.
4. Determine the likely constraints applied by the engineer in designing these items:
   a. Cash register
   b. Bicycle
   c. Office lamp
   d. Sneakers
   e. Calculator

Back of the Envelope

5. Select a device designed by an engineer. Discuss each step of the engineering design algorithm, and describe the likely path taken by engineers in creating the device.
6. Evaluate the effectiveness of the following engineering designs:
   a. Conventional telephone
   b. Medical CAT scan
   c. Desktop computer
   d. Cell phone
   e. MP3 player
   f. PDA
   Make sure to describe the strengths and weaknesses of the designs. Try to guess what capabilities these technologies will have in the future as engineers continue to improve the current designs.

1.2 Birth of the Digital Age

Before Digital There Was Analog

To understand where engineers will be taking our world in the future, it is important that we briefly look back. Up until the middle of the 20th century, the technology designed by engineers was primarily **analog**; more specifically, the devices and systems that engineers created relied primarily upon physical forces and matter for their basic operation rather than some abstract quantity, such as numbers.

Analog: Phenomena that are characterized by fluctuating, evolving, or continually changing physical quantities, such as force or mass.

For example, analog audio records introduced in the first part of the 20th century use the physical bumps and indentations in the grooves on vinyl discs (albums) to store audio data. The stylus at the end of the tone arm of a turntable rides in these grooves and vibrates