2

FUNCTIONS

In this chapter, we look at the nature of the quantities we deal with in electronics. We also view certain relationships among these quantities.

2-1 NUMBERS You are already familiar with various classes of numbers. Some are *real* numbers. Others we call *imaginary* numbers. Still others are *complex* numbers.

It is worthwhile to summarize certain classes of numbers we work with in this book:

1. Integers. Positive integers include 1, 2, 3, etc. Negative integers include -1, -2, -3, etc. And there is 0, another integer.
2. Rational numbers. These are real numbers that we can express as ratios of numbers from class 1 above. Examples of rational numbers are $\frac{1}{2}$ and $-\frac{5}{3}$. And the *integers* are also rational numbers.
3. Irrational numbers. These are real numbers that we cannot express as ratios of numbers from class 1 above. That is, we cannot write an irrational real number as a fraction whose numerator and denominator are both integers. Often we express an irrational real number as a symbol. Otherwise, we must write it only in part, since an irrational number continues endlessly with a nonrepeating decimal number. An example is π, which begins with $3.141592653589793 \cdots$. The series of dots indicates that the decimals go on without end and without continuous repeating. As decimal expressions, we write such numbers with only enough decimal places to meet our needs for accuracy. Other irrational real numbers are $\sqrt{2}$ and the base e of the natural system of logarithms.
4. Imaginary numbers. The elementary imaginary number is $\sqrt{-1}$. Its symbol is i or j. In this book we use j. When we multiply j by a real number, we get a new imaginary number—for example, $j4$. As you know, it is impossible to obtain an imaginary number of physical objects. No real number exists which, when multiplied by itself, gives -1. So we cannot obtain an imaginary number of physical objects—for instance, we cannot get $\sqrt{-1}$ resistors. For this reason, we have

the old-fashioned term *imaginary* for these numbers. But such numbers exist, and are truly important in electronics. More than one electronics worker has received a severe electric shock from the "imaginary" voltage across a capacitor carrying an alternating current (ac).

5. Complex numbers. To get a complex number, we add a real number to an imaginary number. Examples are $5 + j7$ and $-\frac{1}{4} - j3$.

2-2 VARIABLES Many quantities can, either actually or in one's imagination, take on various values. For example, when we begin to design an amplifier we don't yet know whether the finished amplifier will have one, two, or more stages.

At this point in our amplifier design, the number of stages remains unspecified. We can, however, assign this number a symbol, say y. Such an *unspecified* value as this quantity y we call a *variable.*

In general, all that is known about y is that it has to be a positive integer and that it must not be unreasonably large. As we calculate the required number of amplifier stages, we shall treat this number y as a variable, since its value remains unspecified until we determine that value. (In fact, the number of stages might *remain* variable—if we provide a switch or other means for changing the number of stages.) We say, then, that

> A variable *is a quantity whose value, in a given discussion or problem, is unspecified. Thus, during this given discussion or problem, the value of the variable changes (or can change).*

Variables aren't limited to positive whole numbers, such as the number of amplifier stages. Any of the five classes of numbers mentioned in Sec. 2-1 can include variables.

But in many applications, a variable can assume only certain kinds of values. For example, we have seen that the number of amplifier stages has to be a positive integer. On the other hand, the resistance of a circuit does not have to be an integer, since we can, for example, have a resistor of 17.8 ohms. With tunnel diodes and other devices, we can even get negative resistances. But we do not consider *imaginary* resistance values—we refer to the imaginary part of an impedance as its *reactance.*

Except where stated otherwise, variables treated in this book will be real variables.

To represent variables we often use letters that occur near the end of the alphabet, such as q, r, s, t, u, v, w, x, y, and z. In particular, we often use t to represent the variable quantity *time.*

2-3 CONSTANTS A quantity whose value is established or settled, either through our own choice or otherwise, we call a *constant.* That is:

> A constant *is a quantity whose value remains fixed throughout a certain problem or discussion.*

Values of various constants can come from any of the five classes of numbers mentioned in Sec. 2-1. A constant whose value remains unchanged from one discussion or problem to another, never altering, we call an *absolute* constant (or *numerical* constant). Absolute constants include 1, 2, 3, $\frac{1}{2}$, $\frac{1}{4}$, π, e, j, and an unending list of others.

A constant to which we can assign a value to suit our needs or wishes in a given discussion we call an *arbitrary* constant. Where nothing indicates the contrary, we often represent such constants by the earlier and middle letters of the alphabet. For example, a, b, c, g, h, k, l, m, n, and p often stand for constants.

We generally take the speed of light and of radio waves in a vacuum (approximately 3×10^8 meters per second) to be a constant. Its symbol is c.

For many problems we can take the acceleration produced by gravity as a constant, having the value 9.807 meters (32 feet) per second squared. We represent this acceleration by g.

Naturally, each of the values that a variable can assume, from time to time, is in itself a constant. For example, a variable x might be able to take on any of a very wide range of values. But when x for the time being equals 3, the statement that *x now equals 3* does not mean that x has become a constant and is no longer a variable. Instead, what such a statement means is that for our immediate purpose, or to report our present observation, x equals 3. The quantity x remains a variable, but the quantity 3 that it now happens to equal is a constant.

This is similar to other values of variables, even where we might not give the numerical values of the quantities. For example, we might say that "$x = x_1$" or "$x = x_2$." Here again, x remains a variable while x_1 and x_2 are simply different constants whose values x might assume for the time being.

QUESTIONS 2-1

1. When in a given problem or discussion a certain quantity remains unspecified, or might assume various values, what do we call such a quantity?

2. Give five letters of the alphabet that often represent variables. Do these letters always represent variables?

3. What do we mean when we say that a quantity is a constant?

4. Give five letters of the alphabet we often use to represent constants. Do these letters always represent constants?

5. Name two physical constants mentioned in Sec. 2-3. Give their symbols and their approximate values.

6. Could a certain quantity—for example, the emitter-to-collector voltage of a certain transistor—be a constant in one problem and yet be a variable in some other problem?

PROBLEMS 2-1

1. The power dissipated in a certain direct-current (dc) circuit is $p = iV$ watts, where $V = 100$ volts. In this formula for power p, which symbol(s) represent variables? Which represent constants?