The Metric System

This simple system is a standard system of measurement used all over the world. All the units used to describe electrical quantities are part of the metric system.

In the US, we use a measuring system known as the US Customary System for many physical quantities, such as distance, weight and volume. In this system there is no logical progression between the various units. For example, we have 12 inches in 1 foot, 3 feet in 1 yard and 1760 yards in 1 mile. For measuring the volume of liquids we have 2 cups in 1 pint, 2 pints in 1 quart and 4 quarts in 1 gallon. To make things even more difficult, we use some of these same names for different volumes when we measure dry materials! As you can see, this system of measurements can be very confusing. Even those who are very familiar with the system do not know all the units used for different types of measurements. Not many people know what a *slug* is, for example.

It is exactly this confusion that led scientists to develop the orderly system we know today as the metric system. This system uses a basic unit for each different type of measurement. For example, the basic unit of length is the meter. (This unit is spelled metre nearly everywhere in the world except the US!) The basic unit of volume is the liter (or litre). The unit for mass (or quantity of matter) is the gram. The newton is the metric unit of force, or weight, but we often use the gram to indicate how "heavy" something is. We can express larger or smaller quantities by multiplying or dividing the basic unit by factors of 10 (10, 100, 1000, 10,000 and so on). These multiples result in a standard set of prefixes, which can be used with all the basic units. **Table 7.1** summarizes the most-used **metric prefixes**. These same prefixes can be applied to any basic unit in the metric system. Even if you come across some terms you are not unfamiliar with, you will be able to recognize the prefixes.

We can write these prefixes as powers of 10, as shown in Table 7.1. The power of 10 (called the *exponent*) shows how many times you must multiply (or divide) the basic unit by 10. For example, we can see from the table that **kilo** means 10^3. Let's use the meter as an example. If you multiply a meter by 10 three times, you will have a *kilometer*. (1 meter $\times$ 10^3 = 1 m $\times$ 10 $\times$ 10 $\times$ 10 = 1000 meters, or 1 kilometer.) If you multiply 1 meter by 10 six times, you have a **mega**meter. (1 meter $\times$ 10^6 = 1 m $\times$ 10 $\times$ 10 $\times$ 10 $\times$ 10 $\times$ 10 $\times$ 10 = 1,000,000 meters or 1 megameter.)

Notice that the exponent for some of the prefixes is a negative number. This indicates that you must *divide* the basic unit by 10 that number of times. If you divide a meter by 10, you will have a **deci**meter. (1 meter $\times$ 10^{-1} = 1 m $\div$ 10 = 0.1 meter, or 1 decimeter.) When we write 10^{-6}, it means you must divide by 10 six times. (1 meter $\times$ 10^{-6} = 1 m $\div$ 10 $\div$ 10 $\div$ 10 $\div$ 10 $\div$ 10 $\div$ 10 = 0.000001 meter, or 1 **micro**meter.)

We can easily write very large or very small numbers with this system. We can use the metric prefixes with the basic units, or we can use powers of 10. Many of the quantities used in basic electronics are either very large or very small numbers, so we use these prefixes quite a bit. You should be sure you are familiar at least with the following prefixes and their associated powers of 10: **giga** (10^9), **mega** (10^6), **kilo** (10^3), **centi** (10^{-2}), **milli** (10^{-3}), **micro** (10^{-6}) and **pico** (10^{-12}).

Let's try an example. For this example, we'll use a term that you will run into quite often in your study of electronics: **hertz (abbreviated Hz)**. Hertz is a unit that refers to the frequency of a radio or television wave. We have a receiver dial calibrated in kilohertz (kHz), and it shows a signal at a frequency of 28450 kHz. Where would a dial calibrated in hertz show the signal? From Table 7.1 we see that kilo means times 1000. The basic unit of frequency is the hertz. That means that our signal is at 28450 kHz $\times$ 1,000 = 28,450,000 hertz. There are 1000 hertz in a kilohertz, so 28,450,000 divided by 1000 gives us 28,450 kHz.

How about another one? If we have a current of 3000 milliamperes, how many amperes is this? From Table 7.1 we see that milli means multiply by 0.001 or divide by 1000. Dividing 3000 milliamperes by 1000 gives us 3 amperes. The metric prefixes make it easy to use numbers that are a convenient size simply by changing the units. It is certainly easier to work with a measurement given as 3 amperes than as 3000 milliamperes!

Notice that it doesn't matter what the units are or what they represent. Meters, hertz, amperes, volts, farads or watts make no difference in how we use the

Table 7-1

International System of Units (SI) — Metric Units

Prefix	*Symbol*	*Multiplication Factor*
tera	T	10^{12} = 1,000,000,000,000
giga	G	10^{9} = 1,000,000,000
mega	M	10^{6} = 1,000,000
kilo	k	10^{3} = 1,000
hecto	h	10^{2} = 100
deca	da	10^{1} = 10
(unit)		10^{0} = 1
deci	d	10^{-1} = 0.1
centi	c	10^{-2} = 0.01
milli	m	10^{-3} = 0.001
micro	µ	10^{-6} = 0.000001
nano	n	10^{-9} = 0.000000001
pico	p	10^{-12} = 0.000000000001

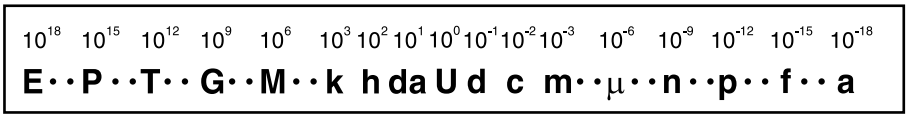

Figure 7.1 — This chart shows the symbols for all metric prefixes, with the power of ten that each represents. Write the abbreviations in decreasing order from left to right. The dots between certain prefixes indicate there are two decimal places between those prefixes. You must be sure to count a decimal place for each of these dots when converting from one prefix to another. When you change from a larger to a smaller prefix, you are moving to the right on the chart. The decimal point in the number you are changing also moves to the right. Likewise, when you change from a smaller to a larger prefix, you are moving to the left, and the decimal point also moves to the left.

prefixes. Each prefix represents a certain multiplication factor, and that value never changes.

With a little practice you should begin to understand how to change prefixes in the metric system. First write the number and find the proper power of ten (from memory or Table 7.1), and then move the decimal point to change to the basic unit. Then divide by the multiplication factor for the new prefix you want to use. With a little more practice you'll be changing prefixes with ease.

There is another method you can use to convert between metric prefixes, but it involves a little trick. Learn to write the chart shown in **Figure 7.1** on a piece of paper when you are going to make a conversion. Always start with the large prefixes on the left and go toward the right with the smaller ones. Sometimes you can make an abbreviated list, using only the units from kilo to milli. If you need the units larger than kilo or smaller than milli, be sure to include the dots as shown in Figure 7.1. (They mark the extra decimal places between the larger and smaller prefixes, which go in steps of 1000 instead of every 10.) Once you learn to write the chart correctly, it will be very easy to change prefixes.

Let's work through an example to show how to use this chart. Change 3725 kilohertz to hertz. Since we are starting with kilohertz (kilo), begin at the k on the chart. Now count each symbol to the right, until you come to the basic unit (U). Did you count three places? Well that's how many places you must move the decimal point to change from kilohertz (kHz) to hertz (Hz). Which way do you move the decimal point? Notice that you counted to the right on the chart. Move the decimal point in the same direction. Now you can write the answer: 3725 kHz = 3,725,000 Hz!

Suppose a meter indicates a voltage of 3500 millivolts (abbreviated mV) across a circuit. How many volts (abbreviated V) is that? First, write the list of metric prefixes. Since you won't need those smaller than milli or larger than kilo, you can write an abbreviated list. You don't have to write the powers of ten, if you remember what the prefixes represent. To change from milli to the unit, we count 3 decimal places toward the left. This tells us to move the decimal point in our number three places to the left.

3500 mV = 3.5 V

Let's try one more example for some extra practice changing metric prefixes by moving the decimal point in a number. What if someone told you to tune your radio receiver to 145,450,000 Hz? You probably won't find any radio receiver with a dial marking like this! To make the number more practical, we'll write the frequency with a prefix that's more likely to appear on a receiver dial.

Our first step is to select a new prefix to express the number. We can write the number with one, two or three digits to the left of the decimal point. It looks like we'll need the entire prefix chart for this one, so write it down as described earlier. (You can look at the chart in Figure 7.1, but you should practice writing it for those times when you don't have the book — like your exam!)

The next job is to count how many places you can move the decimal point. The number you end up with should have one, two or three digits to the left of the decimal point. Remember that metric prefixes larger than kilo represent multiples of 1000, or 10^3. Did you count six places to move the decimal point in our example, 145,450,000 Hz? That would leave us with 145.45×10^6 Hz.

Now go back to the chart and count six places to the left. (This is the same number of places and the same direction as we moved the decimal point.) The new spot on the chart indicates our new metric prefix, mega, abbreviated M. Replacing the power of ten with this prefix, we can write our frequency as 145.45 MHz.