# BASIC ELECTRONICS

## Electronic Devices and Circuits

## How They Work and How They Are Used

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$$I = \frac{E}{R} \quad \text{or} \quad I = \frac{V}{R}$$

## Applying Ohm's Law

Let's again consider the circuit of *Figure 2-2b.* We want to know the current in this series circuit when the lamp has an $R_L$ equal to 3 ohms. The ammeter measures the circuit current and a voltmeter measures the voltage drop across the lamp. Using the basic form of Ohm's law, I = E/R, we see that 6 volts divided by 3 ohms equals 2 amperes. Since the ammeter is a very low resistance compared to the 3-ohm resistor, the voltage drop across it is neglected.

A simple aid for remembering Ohm's law is shown in *Figure 2-3a.* Just cover the letter in the circle that you want to find and read the equation formed by the remaining letters. Since the current in *Figure 2-2b* is unknown, but the voltage and resistance are known, the basic equation to be solved for I is found by using the aid of *Figure 2-3c.* The result is:

$$I = \frac{E}{R}$$

or, in this example, 6 volts divided by 3 ohms equals 2 amperes.

Similarly, knowing the current and resistance, the voltage can be calculated by using the equation shown in *Figure 2-3b;*

$$E = IR$$

or, for the same example, 2 amperes times 3 ohms equals 6 volts.

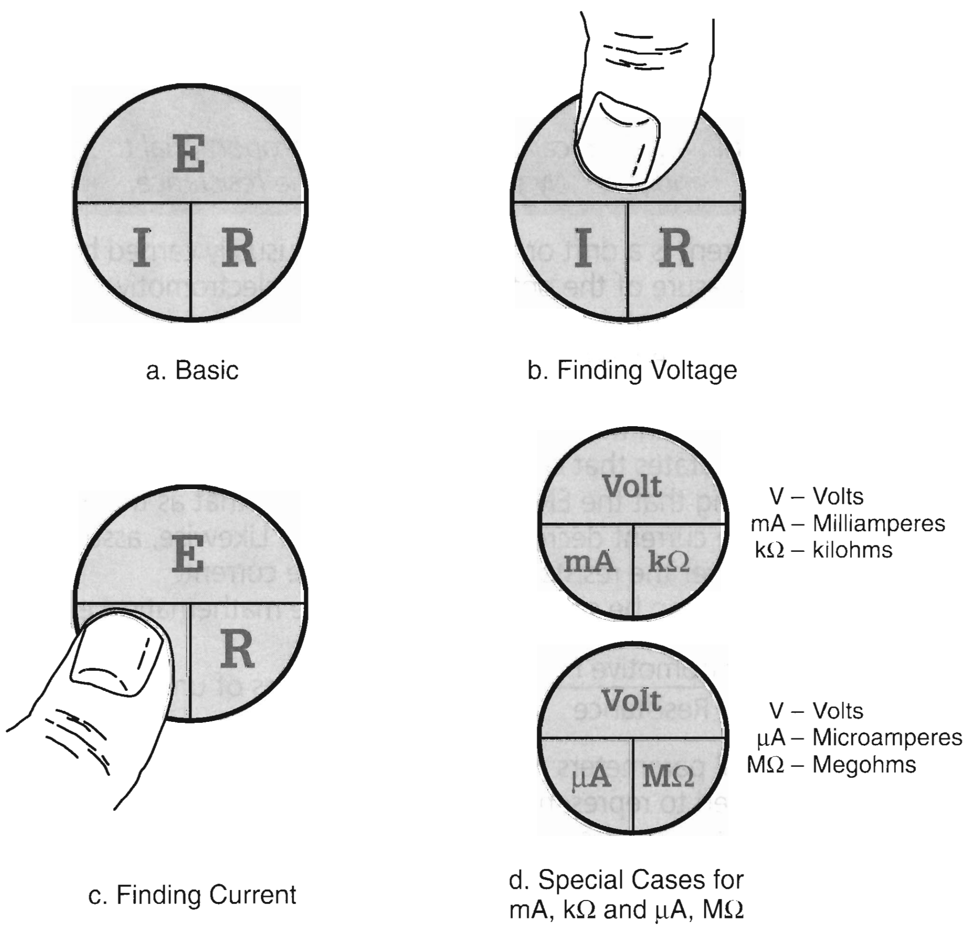


*Figure 2-3. Ohm's law circle.*

## Prefix Shorthand

In electronic circuits, the resistance is typically higher than a few ohms. It is very common that circuit or component resistance is on the order of thousands of ohms (kilohms) or millions of ohms (megaohms shortened to megohms). This high resistance results in lower current, of course. Engineers and technicians use a shorthand of prefixes like kilo and mega. Here are what the prefixes mean:

| *Symbol* | |
|---|---|
| M | mega = millions (multiply by $10^6$) |
| k | kilo= thousands (multiply by $10^3$) |
| m | milli = thousandths (multiply by $10^{-3}$) |
| µ | micro = millionths (multiply by $10^{-6}$) |
| n | nano = one thousandth of a million (multiply by $10^{-9}$) |
| p | pico = one millionth of a million (multiply by $10^{-12}$) |

Here are some examples using the prefixes:

### *Example 2a. Find Current When V and R Are Known*

If a 9-volt battery has a 3000 ohm resistor connected across it, what will be the circuit current?

Since I is unknown, we use:

$$I = \frac{E}{R} = \frac{9V}{3000\Omega} = 0.003 \text{ ampere}$$

The "0.003 ampere" is stated as "three one-thousandths of an ampere."

We can see this better if we arrange our original problem a little differently—like this:

$$I = \frac{9}{3 \times 1000} = \frac{3}{1000} = 3 \times \frac{1}{1000} = \frac{3}{1 \times 10^3} = 3 \times 10^{-3} = 3 \text{ "milli" amperes}$$

### *Example 2b. Find Current When V and R Are Known*

If R is 3,000,000 ohms instead of 3000 ohms, what will be the circuit current?

$$I = \frac{E}{R} = \frac{9V}{3{,}000{,}000\Omega} = 0.000003 \text{ ampere} = \text{three one millionths of an ampere}$$

This can also be written as:

$$I = \frac{9}{3 \times 1{,}000{,}000} = \frac{3}{1 \times 10^6} = 3 \times 10^{-6} = 3 \text{ "micro" amperes}$$

Engineers and scientists don't like to write a lot of zeros before or after numbers, so they developed the shorthand to substitute for the zeros we discussed previously.

Engineers substitute "milli" for $1 \times 10^{-3}$.
Engineers substitute "micro" for $1 \times 10^{-6}$.

Therefore, the answer to *Example 2a* can be stated as I = 3 mA which is read as "I equals three milliamperes." And the answer to *Example 2b* can be stated as I = 3 µA which is read as "I equals three microamperes." The symbol m stands for "milli" and the symbol µ stands for "micro."

If the EMF is given in volts (V), rather than kilovolts (kV) or millivolts (mV) for example, a resistance in kilohms (kΩ) will result in a current in milliamperes (mA). A resistance in megohms (MΩ) results in a current in microamperes (μA). *Figure 2-3d* shows the relation between these prefixed units using the Ohm's law circle.
To practice using Ohm's law, let's look at some additional examples using Ohm's law to find an unknown parameter when two are known.

### Example 3a. Find Voltage When I and R Are Known

In *Figure 2-4a,* the current is 2.5 mA ($2.5 \times 10^{-3}$A) and the resistance is 3 kΩ ($3 \times 10^{3}\Omega$). To calculate the voltage (in volts), use the form of Ohm's law:

$$E = IR$$
$$E = (2.5\ \text{mA})(3\ \text{k}\Omega) = (2.5 \times 10^{-3})(3 \times 10^{3})$$
$$E = 7.5\text{V}$$

### Example 3b. Find Current When E and R Are Known

In *Figure 2-4b,* the resistance is 2.2 MΩ ($2.2 \times 10^{6}\Omega$) and the EMF across it is 11 volts. To find the current (in microamperes), use the form:

$$I = \frac{E}{R} = \frac{11\text{V}}{2.2\ \text{M}\Omega} = \frac{11}{2.2 \times 10^{6}} = 5 \times \frac{1}{10^{6}} = 5 \times 10^{-6}\text{A} = 5\ \mu\text{A}$$

### Example 3c. Find Resistance When E and I Are Known

In *Figure 2-4c,* the current is shown to be 60 μA ($60 \times 10^{-6}$A) and the voltmeter indicates 18 volts. The resistance (in megohms) can be calculated by using the form:

$$R = \frac{E}{I} = \frac{18\text{V}}{60\ \mu\text{A}} = \frac{18}{60 \times 10^{-6}} = 0.3 \times \frac{1}{10^{-6}} = 0.3 \times 10^{6}\Omega = 0.3\ \text{M}\Omega \text{ or } 300\ \text{k}\Omega$$

The fundamental relationship between voltage, current and resistance is described by Ohm's law. It is the most used equation for the design of electrical and electronic circuits. Spend time to understand its meaning and how to use it.

## DC and AC Circuits

An electric current may be classified as direct current (dc) or alternating current (ac). Direct current is in one direction only, whereas alternating current changes in direction. The directional quality of electricity is called polarity. In this chapter, we will investigate the parameters of direct current circuits only; that is, circuits where the current is in one direction. Later, we will see that Ohm's law applies to alternating current circuits as well.

## Measuring Voltage, Current and Resistance

As circuits are analyzed, used or designed, there is a need to measure voltage, current and resistance. There are two basic types of meters used to make these measurements. One type has a needle that deflects along a scale and indicates the value of a quantity by the position of the needle on the scale. This is an analog meter and is commonly called a multimeter, multitester or VOM (volt-ohm-milliammeter). The other type is a digital meter. Any quantity that is measured appears as a number on a digital display. It is commonly called a DMM (digital multimeter). Both the VOM and the DMM can measure the three fundamental electrical parameters of Ohm's

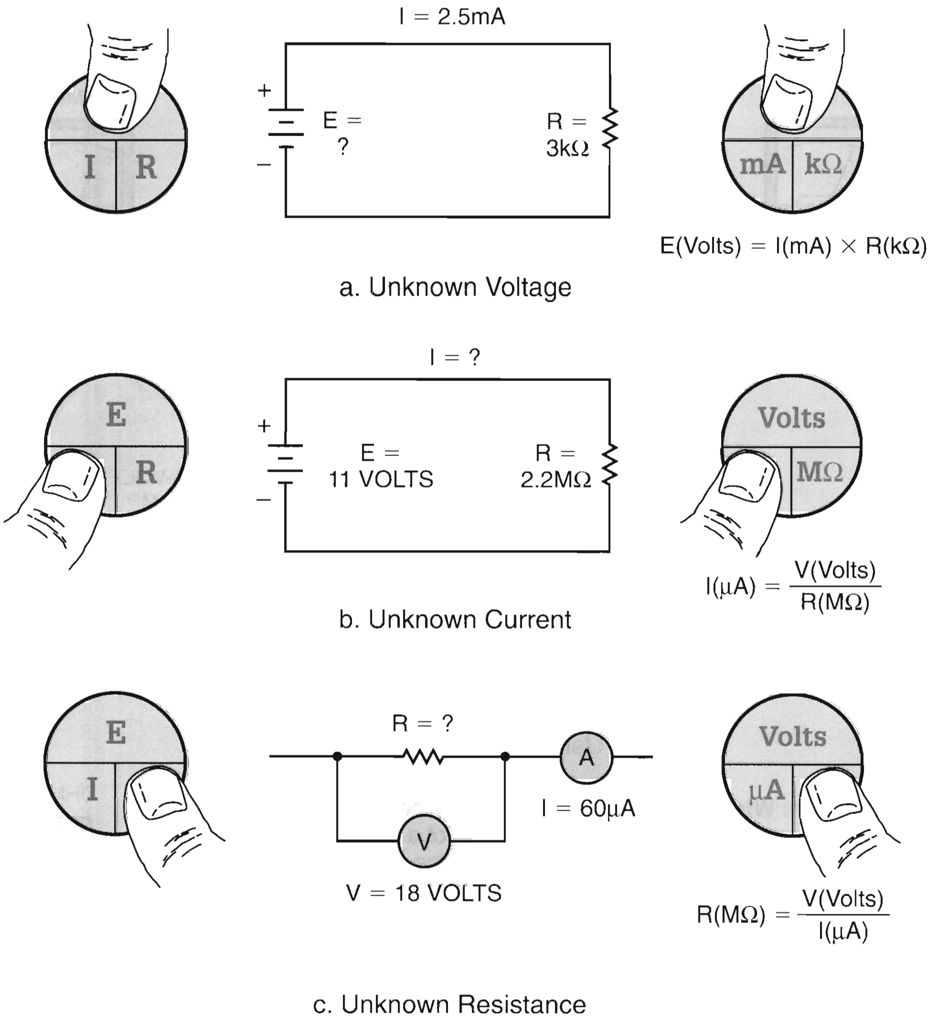


*Figure 2-4. Example circuits.*

law. They contain, along with other special features, a voltmeter, an ammeter (or a milliammeter or microammeter depending on a selector setting), and an ohmmeter. *Figure 2-5* shows how to connect the three types of meters to make basic measurements. If you desire more complete details on the use of multitesters, visit your Radio Shack store for the book, *Using Your Meter,* (62-2039). Let's now discuss series and parallel circuits in more detail.

## Series Circuit and KVL (Kirchhoff's Voltage Law)

As we stated before, a series circuit is one in which the current is the same through all of the components of the circuit; that is, a series circuit has only one path for current. *Figures 2-6a* and *2-6b* show that a series circuit may have one component or many, but there is still only one path for current. This becomes the first of three rules that define a series circuit. The rules are:

***The Three Rules of a Series Circuit***

1. *Current has the same value at any point within a series circuit.*
2. *The values of the resistances of individual components add up to the total circuit resistance, which is called the equivalent resistance,* $R_{eq}$.
3. *Voltage drops across the individual component resistances add up to the total applied voltage.*

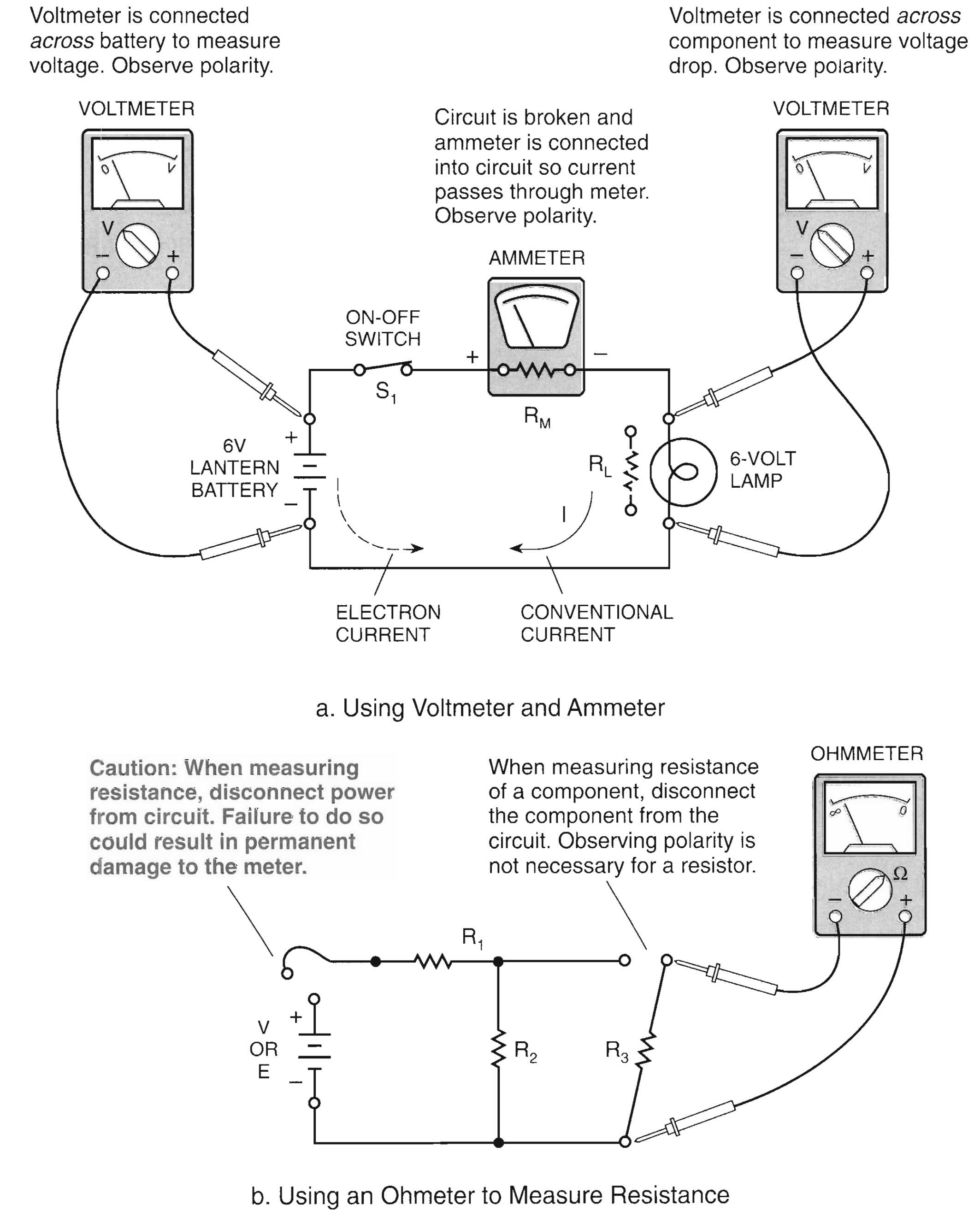


*Figure 2-5. Measuring with voltmeter, ammeter, and ohmmeter.*

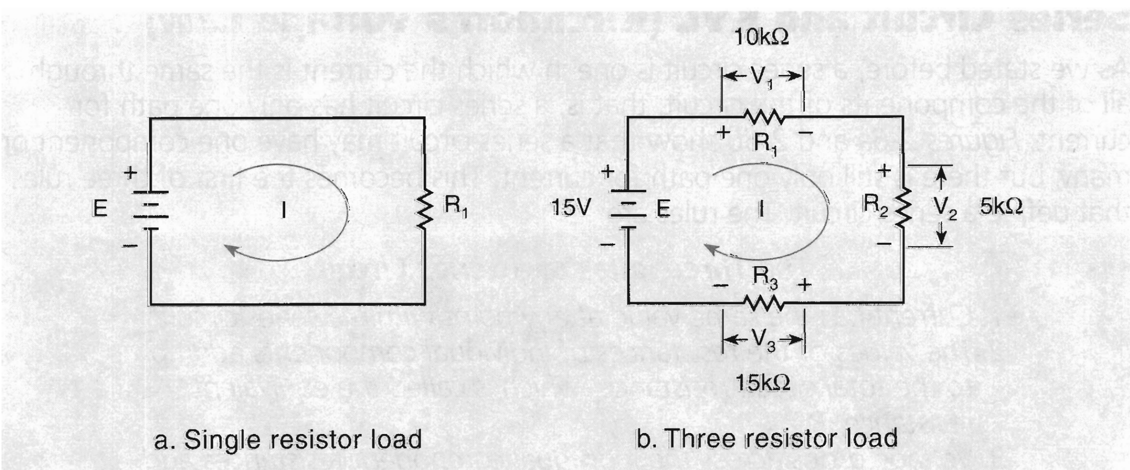


*Figure 2-6. Examples of series circuits.*