ELECTRONICS FOR BEGINNERS
CHAPTER 3: Volts, Amps & Ohms

Now, back to electrons. Let's look at *voltage*, *current* and *resistance*, then *impedance* and *power*.

Voltage represents electric pressure, or force. It's also called *electromotive force (emf)*. It is measured in *volts*. In equations voltage may be represented by either V or E.

Current represent flow. It is measured in amperes or its shorter version, *amps*. In equations the common representation is I. (Don't ask me why.)

Resistance is what limits flow, or current, similar to restrictions in a pipe or hose. It is measured in *ohms*. It is represented by R.

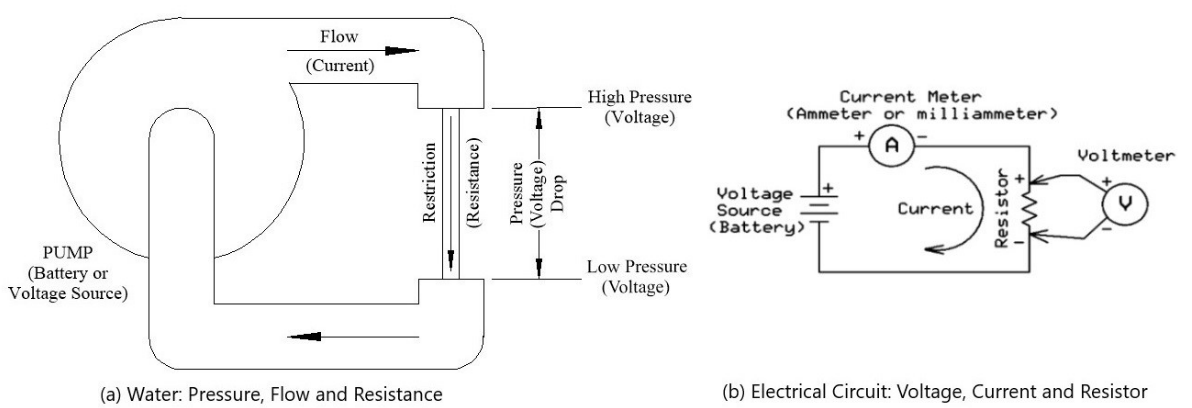

Figure 3. Water flow and its electrical equivalent.

Figure 3.1(a), repeated from the previous chapter, shows this using water flow. The pump provides pressure, forcing the water to flow through a restriction. The restriction resists the flow of water: the smaller the restriction, the lower the flow. Flow through the restriction causes a pressure drop, or difference.

3.1(b) shows the electrical equivalent. The pump becomes a battery, the pipes become wires and the restriction becomes a resistor. We've added meters to measure the current (flow) and the voltage (pressure) drop. The drawing uses the standard symbols for a battery, resistor, voltmeter and current meter (ammeter or, for low currents, milliammeter). The battery provides the electrical force to make the electrons flow through the resistance.

Ohm's Law. If the resistance doubles (similar to the restriction getting twice as small or twice as long) it will take twice as much voltage (pressure) to get the same current flow. Expressed mathematically:

$V = I \times R$ (voltage = current x resistance)

This equation is known as Ohm's law, named after Georg Simon Ohm, a German physicist. Another way of looking at it is, if you double the voltage you'll get twice the current. Ohm's law can be rearranged as:

$I = V / R$.

Actually, the definition of ohms is voltage divided by current (volts per ampere):

$R = V / I$.

All these are Ohm's law, expressed three different ways.

Impedance. One more term to learn. Impedance is the AC equivalent of resistance. We'll soon be dealing with AC components such as capacitors and inductors. Their impedances change with frequency and also involve phase shifts. For now we'll just state that, like resistance, impedance is volts per ampere and uses the same the basic unit, ohms.

Power. Power is the rate of using (or producing) electricity. You've surely heard of its units: *watts* (for James Watt), which is the electrical equivalent of horsepower. Its usual symbol is W.

The way-too-simple statement is, power equals voltage times current: W = V x I (watts = volts x amperes). It's true in resistors but not in things that store energy, like capacitors and inductors. This is a complex subject: we'll tackle it in a later chapter.

How to Measure. Meters are available to measure voltage, current and resistance. Multimeters, with function and range switches, can measure them all. Both digital and analog types are available. They're easily available and can cost just a few dollars if you don't need accuracies of 0.1% or better. Try any hardware store or even stores like Walmart. The Cen-Tech meter in the picture came from Harbor Freight years ago and is still working.

To measure voltage set the meter to a range higher than the voltage you expect to measure. Your meter will have both DC and AC ranges. Use DC for battery circuits, AC for line power and transformers. We'll talk about AC vs. DC in a later chapter.

Touch the two meter leads across the two ends of the resistor as shown in Figure 3.1b and photo Figure 3.2. This places the meter in *parallel* with the resistor.

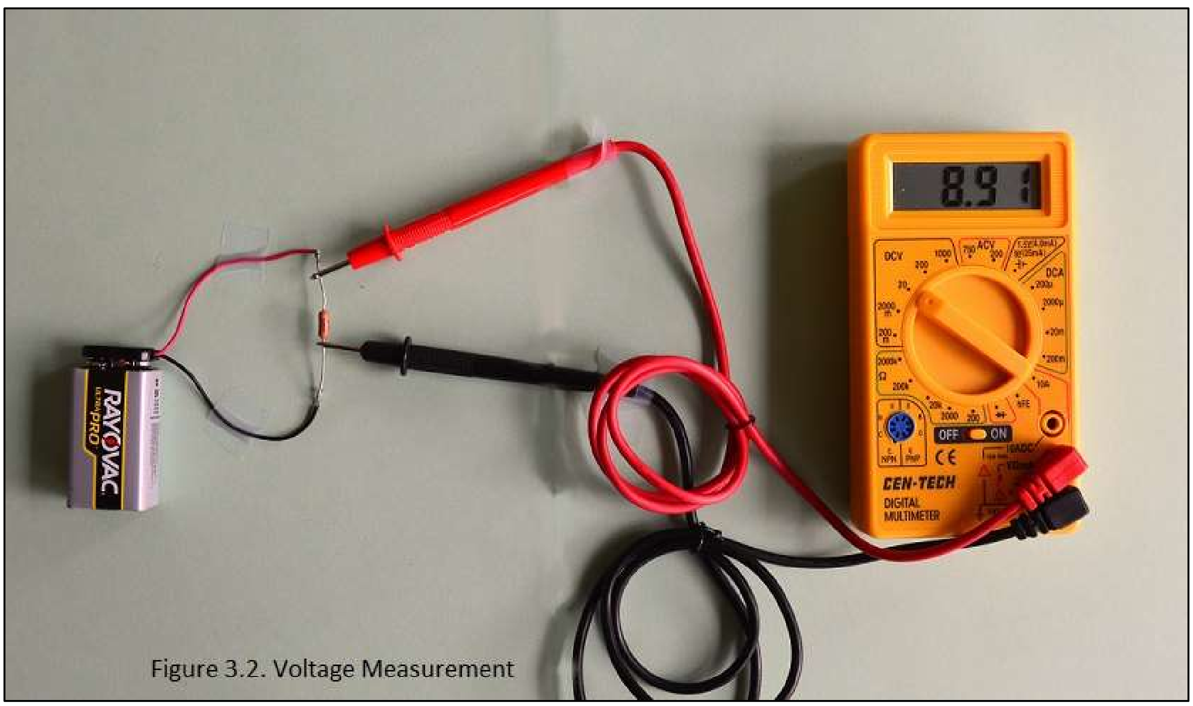

Figure 3.2. Voltage Measurement

Figure 3.3. Current Measurement

Current measurement is different and sometimes confuses people. You must break the circuit (disconnect a wire) and connect the ammeter in the loop (*series* connection) as shown in Figure 3.1(b) and photo Figure 3.3. Again, use a DC current range higher than the measurement you expect. You *cannot* measure current by placing the meter in parallel as you do for voltage. All the current being measured must flow *through* the meter, just as it would for a water meter.

<ins>Never</ins> connect a current meter directly across a battery or voltage source. If you do you will draw way too much current and possibly burn out the meter.

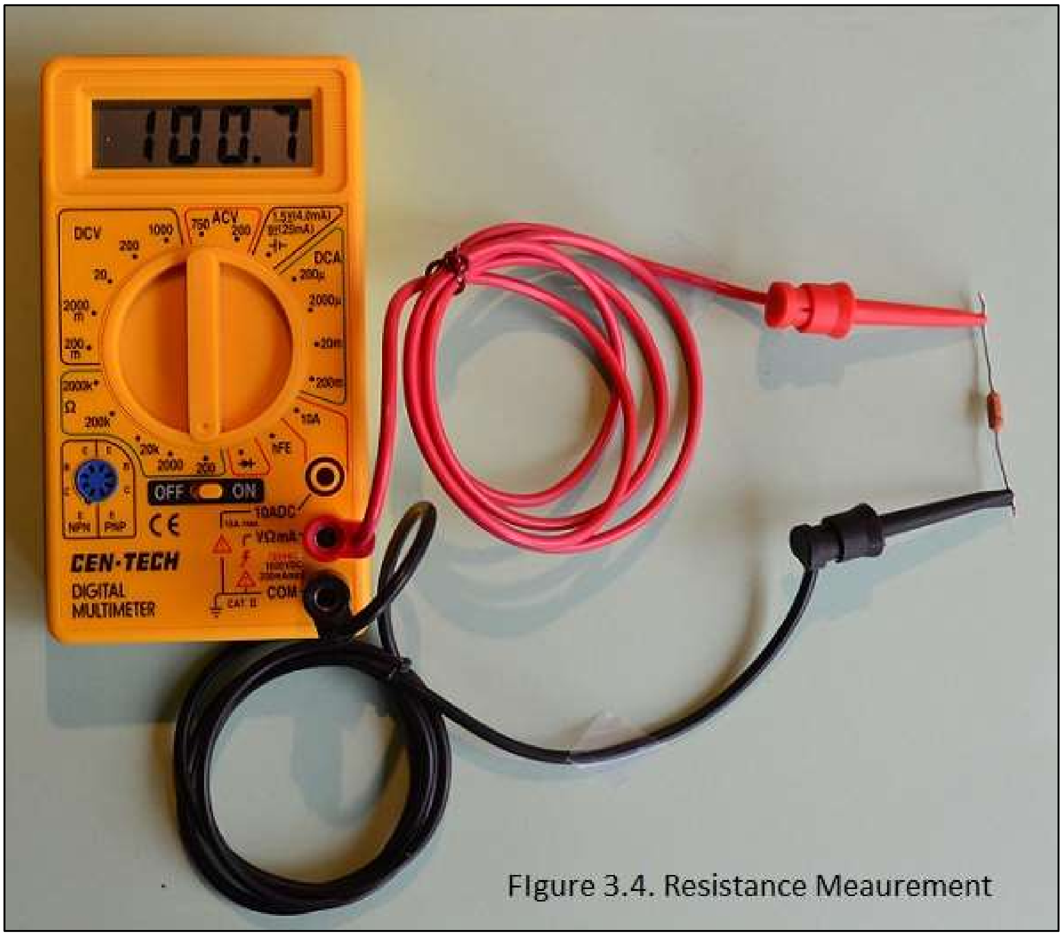

FIgure 3.4. Resistance Meaurement

Resistance measurement is shown in the photo of Figure 3.4. *Disconnect* the resistor from the circuit and touch the ohmmeter to its two ends. You *must* disconnect at least one end. If you don't the other circuitry, voltage or current will seriously affect the reading. Ohmmeters work by driving a known current through the resistor, measuring the voltage and using Ohm's law to calculate the resistance. DC and AC do not apply to the resistance ranges.

In the next chapter we'll learn about resistors and try some experimental measurements.

Standard Electrical Notation.

Small or large values may use prefixes like milli, micro or kilo, as are used in metric units. Here are the more common:

Milli = x0.001 (10^{-3}); for example, 5 millivolts equals 0.005 volts or 5 x 10^{-3} volts
Micro = x0.000001 (10^{-6}); for example, 3 microamps (microamperes) equals 0.000003 amps or 3 x 10^{-6} amperes.
Nano = x0.000000001 (10^{-9}); for example, 2.5 nanovolts equals 0.0000000025 volts or 2.5 x 10^{-9} volts.
Pico = x10^{-12} (11 leading zeroes); for example, 4 picoamps (picoamperes) equals 4 x 10^{-12} amps.
Kilo = x1000 (10^{3}); for example, 36 kilohms (not kiloohms) = 36,000 ohms or 36 x 10^{3} (3.6 x 10^{4}) ohms.
Mega (or meg) = x1,000,000 (10^{6}); for example, 7 megavolts = 7,000,000 volts or 7 x 10^{6} volts. (For resistance, the term is megohms, not megaohms.)

Volts, amperes (amps) and watts are usually abbreviated by V, A and W. Ohms are often represented by the Greek letter omega (Ω).

Milli becomes m. Mega or meg may become capital M, but that is less common because it can be confused with lower-case m and because M also is used to denote 1,000. Nano becomes n, pico becomes p and kilo becomes capital K. Micro is represented by the Greek letter mu (µ) or sometimes by the letter u. Here are some examples:

115 volts = 115V.
5 millivolts = 5mV.
3 microamps = 3µA or 3uA.
2.5 nanovolts = 2.5nV.
36 kilohms = 36KΩ.
4.7 megohms = 4.7 megΩ (or, much less common, MΩ - see above).
2.3 kilowatts = 2.3KW.

For resistance, the omega symbol often is deleted. Kilohms becomes simply 36K, megohms 4.7 meg.

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Footnotes:

1. *Volts* or *voltage* – named for Italian physicist *Alessandro Volta*, who invented the battery.
2. *Amps* or *amperes* – named for French mathematician/physicist *Andre-Marie Ampere*, considered the father of electrodynamics.
3. *Ohms* – named for German physicist *Georg Simon Ohm*, who used Volta's battery and found the direct relationship between voltage and current.
4. *Watts* – named for Scottish mechanical engineer/chemist/inventor *James Watt*, known for his work and inventions on steam engines.