

## Voltage - Electromotive Force

Electrical current flow is the movement of electrons through conductors. But why would the electrons want to move? Electrons move because they get pushed by some external force. There are several energy sources that can force electrons to move.

Chemical:	Battery
Magnetic:	Generator
Light (Photons):	Solar Cell
Mechanical:	Phonograph pickup, crystal microphone, antiknock sensor
Heat:	Thermocouple

Voltage is the amount of push or pressure that is being applied to the electrons. It is analogous to water pressure. With higher water pressure, more water is forced through a pipe in a given time. With higher voltage, more electrons are pushed through a wire in a given time.

If a hose is connected between two faucets with the same pressure, no water flows. For water to flow through the hose, it is necessary to have a difference in water pressure (measured in psi) between the two ends. In the same way, For electrical current to flow in a wire, it is necessary to have a difference in electrical potential (measured in volts) between the two ends of the wire.

A battery is an energy source that provides an electrical difference of potential that is capable of forcing electrons through an electrical circuit. We can measure the potential between its two terminals with a voltmeter.

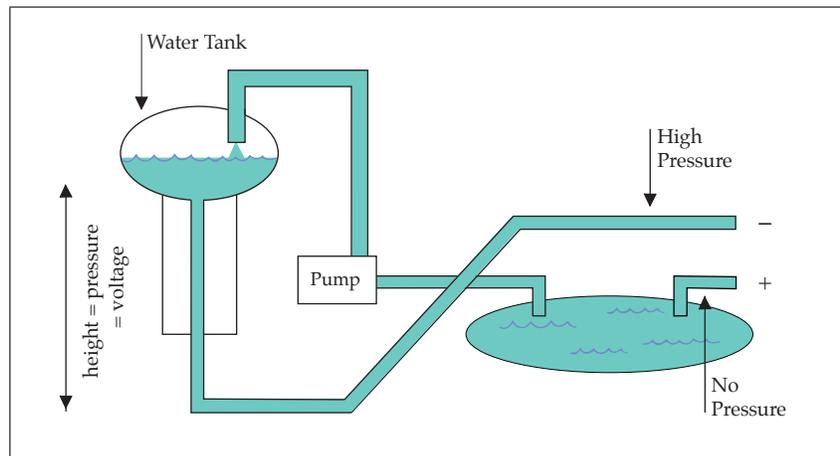


Figure 1: A Voltage Source Water Analogy.

In any case, electrostatic force actually moves the electrons. It is generally the result of having more electrons in one place than another. Since like charges repel, they all push against each other trying to find a path out of their cramped quarters. In a battery, the negative terminal has an excess of electrons and the positive terminal has a shortage of electrons.

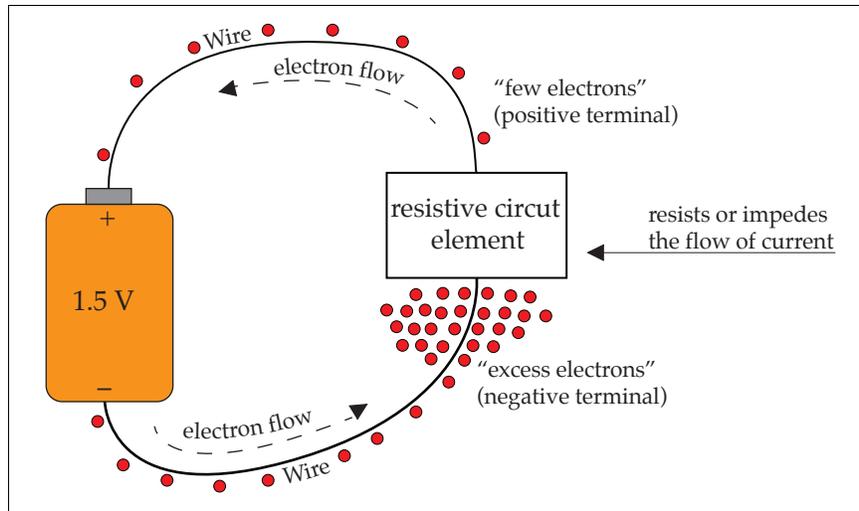


Figure 2: Electron Distribution

In passive devices, (ones that don't have an internal source of energy) electron flow is always from a location with an excess of electrons to a place with a relative shortage of electrons. In other words, current flows from an area of abundance to one of scarcity.

### Measuring voltage

Electrical potential, or *Voltage*, is measured in Volts. The unit is named after Alessandro Giuseppe Antonio Anastasio Volta who invented the first battery. Voltage is not present *through* anything like current. It is a measure of difference in electrical potential energy *between* two different wires or points in a circuit. It is only present between two non-identical points or wires.

### Specifying voltage between two points in a circuit

To accurately specify the voltage present between two points, three items of information must be known. To specify a voltage requires knowing:

1. The magnitude of the voltage
2. The reference terminal from which the voltage is measured
3. Two points in the circuit between which the voltage is measured

All the above information is commonly conveyed by placing a set of plus (+) or minus (-) signs directly adjacent to the points of interest with the magnitude of the voltage given by a numerical value. If a circuit *common* or *ground* is clearly evident, the magnitude is placed directly adjacent to the point of interest in the circuit with the reference being understood to be circuit ground or common. Sometimes an arrow is stretched between two points in a circuit to indicate the reference terminal and the measurement points. In this case, the head of the arrow is at the (+) terminal and the tail of the arrow is at the (-) end. See the examples in figure 3.

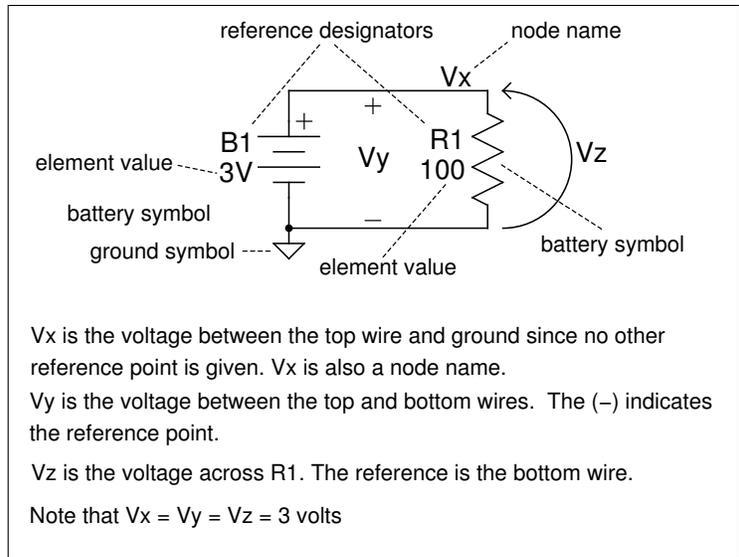


Figure 3: Circuit Schematic Elements

The (+) or (-) signs (if given) alone do not necessarily indicate the actual polarity of the voltage. The signs indicate the *reference voltage*. When coupled with the sign of the voltage magnitude, the actual positive terminal may be determined. See the example in figure 4.

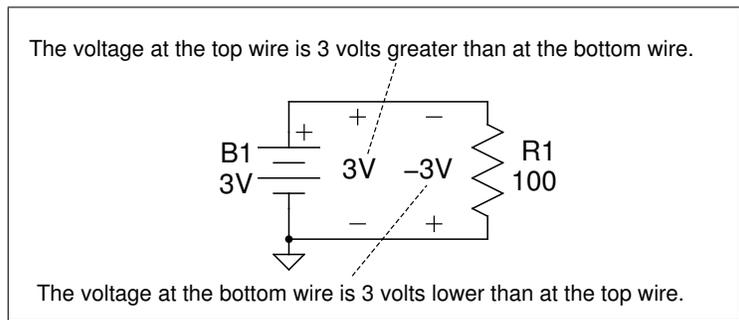


Figure 4: Circuit Voltages Versus References

To exchange reference voltage signs, simply change the sign on the voltage magnitude. To change the sign on the magnitude, swap the voltage reference signs. Remember that the signs alone do not necessarily indicate the actual positive terminal.

Remember the difference between voltage and current measurements. Current is measured as going *through* some point. Voltage is measured *across* two points or nodes in a circuit.

Current is measured **through a single point** in a wire.

Voltage is measured **between two points**.

## Making voltage measurements with a digital multimeter

Since voltages are found across circuit elements, to make a voltage measurement with a meter, we must place the meter leads across the element in question. In the circuit below, the voltmeter is placed across the light bulb to measure the voltage across it as seen in figure 4.

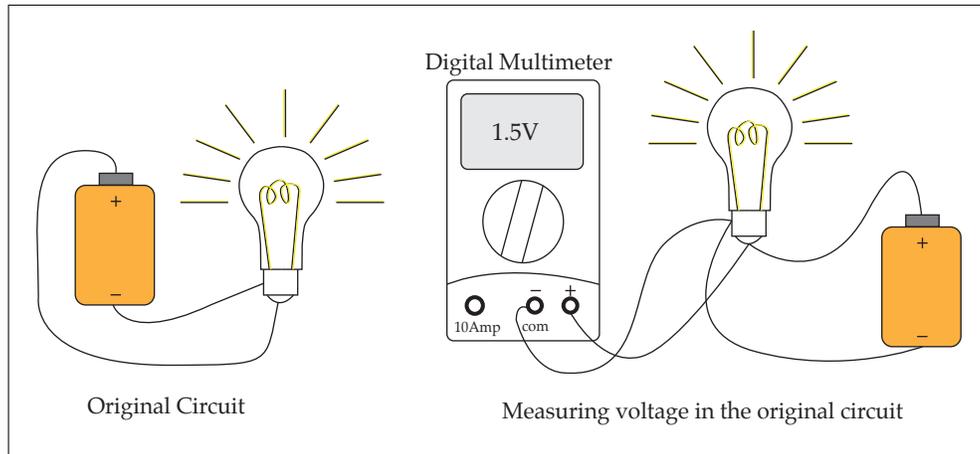


Figure 5: Measuring Voltage

When making measurements, the desire is to make the measurement without disturbing the original circuit. For an voltmeter to do this, its internal construction must look as if the voltmeter test leads connect to nothing inside the meter. The circuitry inside the voltmeter does present the equivalent of an infinite resistance. Thus, the meter is invisible to the circuit but can still measure the voltage between its leads.