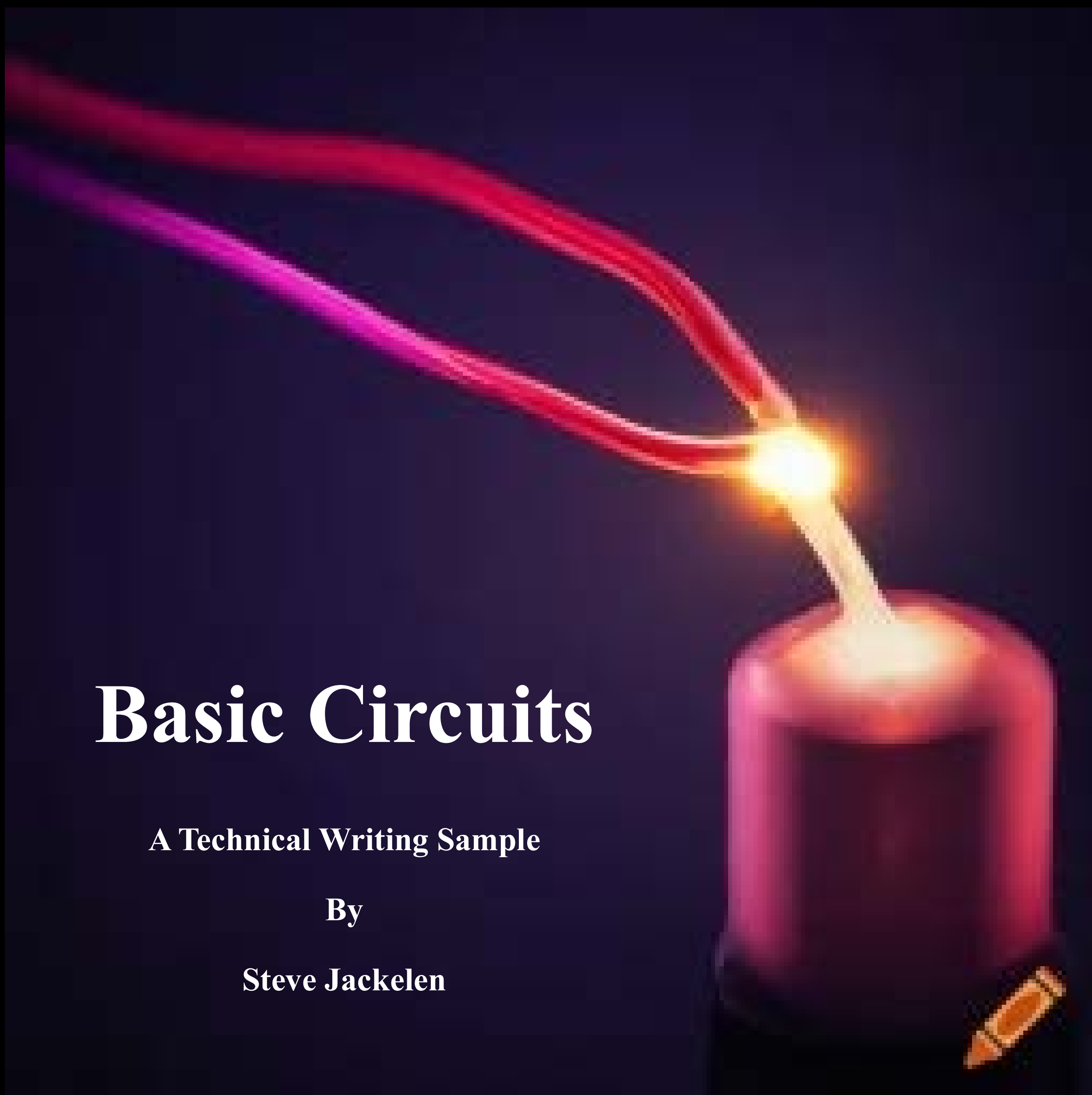

Basic Circuits

A Technical Writing Sample

By

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Basic Circuits

1

This tutorial will help describe the basics of a complete circuit. You will learn the difference between a power source, a resistor, and voltage and how they interact with each other. Other topics that will be covered include copper, electric current, and Ohm's Law.

Introduction

> **Definition:** A circuit is a closed path that allows electricity to flow from one point to another.

To give a visual representation of this definition look to Figure 1 below:

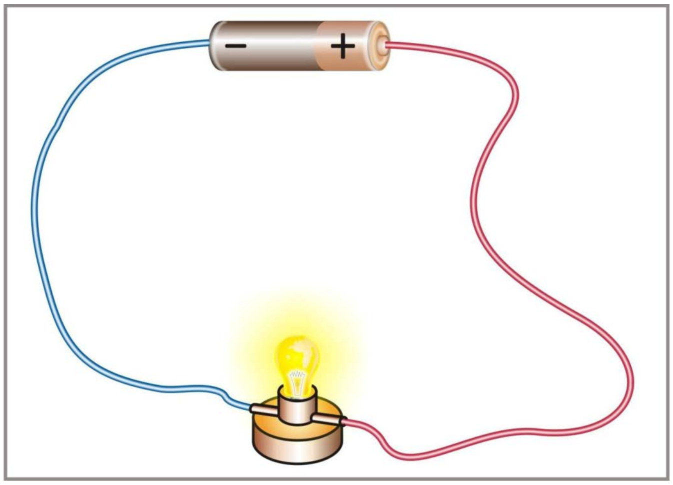

Figure 1: A Basic Complete Circuit

The wire for the circuit leaves the battery and continues to one end of the light bulb. Another wire leaves the light bulb and back to the battery. This is a complete circuit.

Copper

For all intents and purposes we'll assume that the wires in the circuit are made from copper, which is common in electrical engineering. The reasons copper is generally used are:

1. Heat resistant
2. High electrical conductivity
3. Inexpensive
4. Ductile
5. Thermal resistant

Electric Current

> **Definition:** An electric current is a flow of charged particles, such as electrons or ions, moving through an electrical conductor or space. It is defined as the net rate of flow of electric charge through a surface.

In conventional current flow the positive charges flow from the positive end of the battery toward the negative end. However, in metals like copper the negatively charged electrons are the charge carriers and move from negative to positive. This is known as electron flow.

Electric current is measured in the International System of Units (SI) in Amperes (A) or amps. An amp is the flow of electric charge across a surface at the rate of one coulomb per second. On an electrical diagram, the flow of current is shown with the symbol i as shown in figure 2.

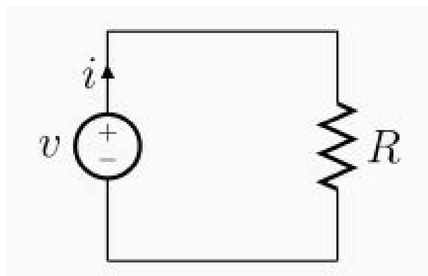

Figure 2: A Basic Electrical Circuit Diagram

Ohm's Law

> **Definition:** Ohm's law states that the current through a conductor between two points is directly proportional to the potential difference across the two points.

In simplified terms, Ohm's law states that Voltage (V) is equal to the Current (I) multiplied by the Resistance (R). The equation can also be manipulated to find the current and the resistance. If you have two of the three variables you can calculate the other.

The equations for Ohm's law are shown below in Figure 3.

$$V = IR \qquad I = \frac{V}{R} \qquad R = \frac{V}{I}$$

Figure 3: Equations of Ohm's Law

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Power Sources

In this section we’ll go more in-depth on the topics of power sources, batteries, and voltage.

Power Sources

Definition: A power source is a source of power. In terms of electric power it is the rate at which electrical energy is transfered by an electric circuit; usually produced by electrical generators or batteries.

For a circuit to work it needs a power source. Common power sources include: power plants, engines, reactors, and batteries. For this tutorial we'll assume that each power source is a simple battery.

Power sources have their own symbols when drawn on electrical schematics and can be seen in Figure 4 below:

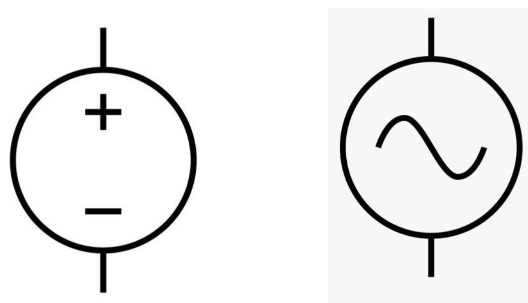

Figure 4: The symbols for DC and AC power sources.

Batteries

Definition: A container consisting of one or more cells, in which chemical energy is converted into electricity and used as a source of power

A battery acts as the power source for many machines and household appliances. When these machines work it is because the battery is inserted into its designated slot and it completes the circuit.

Batteries consist of two terminals: the cathode and the anode. The cathode is the positive terminal, or the part of the batter marked with a positive (+) sign; while the anode is the negative terminal, or the part marked with a negative (-) sign.

The anode is the source of electrons that will flow through the circuit to the positive terminal. When the electrode materials are used once and discarded it is because the electrodes are irreversibly changed during discharge. This is typical for alkaline batteries which are used in portable electronics.

Rechargeable batteries can be used multiple times because the electrodes can be restored to their original charge using applied electric current, or reverse current. Lead-acid batteries are an example of rechargeable batteries and are used in laptops.

The symbol for batteries on electrical schematics is shown below in Figure 5:

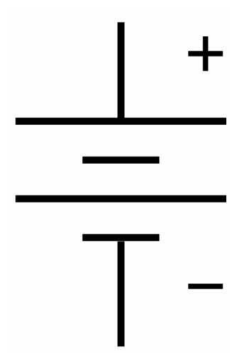

Figure 5: The symbol for a battery.

Voltage

Definition: An electromotive force or the potential difference between two points.

A volt, in the International System of Units, is labeled with a V. Voltage refers to the work needed per unit of charge to move a test charge between two points, which is why voltage is also referred to as electric pressure, electric tension, or (electric) potential difference.

The conventional current in a wire or resistor always flows from higher voltage toward lower voltage. Also, negatively charged objects are pulled towards higher voltages, while positively charged objects are pulled toward lower voltages.

To measure voltage in a circuit you can use a voltmeter.

3

Resistors and Capacitors

In this section we'll cover resistors and capacitors, how they affect a circuit, and how to calculate multiples of each component.

Resistors

Definition: A passive two-terminal electrical component that implements electrical resistance as a circuit element.

Resistors serve many purposes within a circuit. They are primarily used to reduce current flow, adjust signal levels, divide voltages, bias active elements, and terminate transmission lines to name a few.

Resistors are measured in terms of Ohms using the symbol omega (Ω). Common measurements for resistors are usually ohms or kilo-ohms (kΩ or1000 ohms).

If we know the voltage of our circuit and we know the total resistance for the entire circuit we can calculate the total current. Going back to equations for ohm's law we know that current is equal to voltage divided by resistance. If our voltage is 10 V and our resistance is 10 kΩ we can calculate the current like the equation below in Figure 7:

$$I = \frac{V}{R} \quad \rightarrow \quad I = \frac{10V}{10k\Omega} \quad \rightarrow \quad I = 1\,mA$$

Figure 7: Equation for calculating current.

Some circuits have more than one resistor. To calculate the total resistance of a circuit depends if the resistors are in series or if they are parallel. If resistors are in series they appear one after the other like in figure 8:

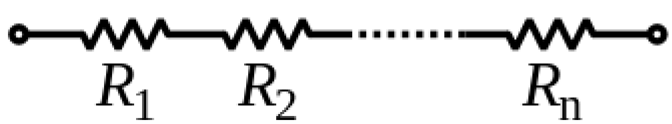

Figure 8: Resistors in series.

When resistors are in series you can simply add them together to get the total resistance of a circuit like in figure 9:

$$R_{eq} = R_1 + R_2 + \ldots + R_n$$

Figure 9: Equation for solving resistors in a series.

When resistors are parallel they appear next to each other like in Figure 10 below:

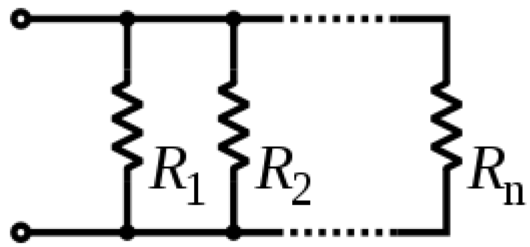

Figure 10: Resistors in parallel

When resistors are in parallel you find the reciprocal of the sum of the reciprocals of the individual resistors like in Figure 11 below:

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots + \frac{1}{R_n}$$

Figure 11: Equation for solving resistors in parallel.

Circuits generally have some combination of series and parallel resistors and must be calculated in individual parts to find the total resistance.

Capacitors

Definition: A device that stores electrical energy in an electric field by accumulating electric charges on two closely spaced surfaces that are insulated from each other.

A capacitor is a device used to add capacitance to a circuit, or in other words increase the ability for a device to hold electric charge.

Most capacitors contain at least two electrical conductors separated by a dielectric medium. The two electrical conductors are usually electric plates or surfaces, but the dielectric medium is an insulator that prevents electrons from flowing.

The capacitor will store energy until the power source is interrupted. When interrupted, the excess electrons will resume flow from the capacitor until the stored energy is empty.

The symbol for a fixed capacitor is shown below in Figure 12:

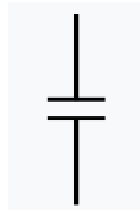

Figure 12: The symbol for a capacitor.

In the International System of Units, capacitance is measured by dividing the positive or negative charge (Q) by the voltage (V) between them. The equation for calculating capacitance is shown below in Figure 13:

$$C = \frac{Q}{V}$$

Figure 13: Equation for finding capacitance.

When multiple capacitors are in a circuit, finding the total capacitance is similar to finding the total resistance. When capacitors are in series they look like Figure 14 below:

Figure 14: Capacitors in series.

To calculate the total capacitance of capacitors in series you find the reciprocal of the sum of the reciprocals of the individual capacitors like in Figure 15:

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots + \frac{1}{C_n}$$

Figure 15: Equation for solving capacitors in series.

When capacitors are in parallel they look like Figure 16 below:

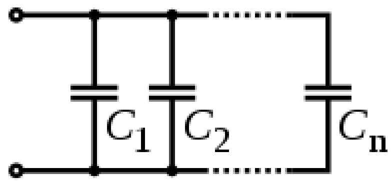

Figure 16: Capacitors in parallel.

To calculate the total capacitance or capacitors in parallel, you simply add them together like in Figure 17 below:

$$C_{eq} = C_1 + C_2 + \ldots + C_n$$

Figure 17: Equation for solving capacitors in parallel.

The equations for solving total resistance and total capacitance are the same, but simply reversed depending on which component is in series and which one is in parallel.

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