

The Journey InsideSM: Circuits and Switches Background Information, Part 1

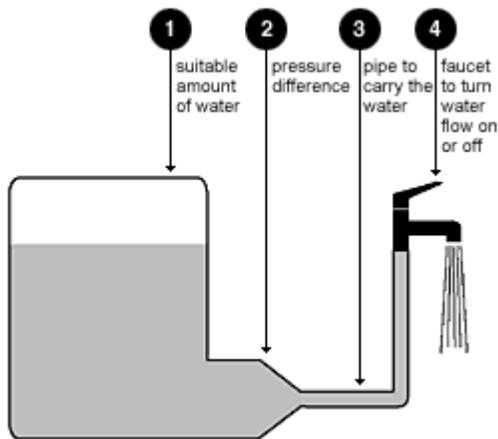
Electronic Circuits

Before the invention of computers, people used the abacus, mechanical calculators, and electro-mechanical calculators to help process information. These devices were relatively slow because they relied on moving parts to process information. Inside a computer, information is rapidly processed using electronic circuits that do not have physical components that move.

Electrical Circuits and Terms

Electrical effects result when an imbalance of electric charge—an excess of positive or negative particles that are parts of atoms—attempts to balance itself. If the electric charge has a complete pathway to follow, the charge flows. This flow is called electric current. The complete pathway is called an electrical circuit.

Circuits carry the electricity needed to do a defined task. The task is referred to as the electrical load. In our homes, for example, some circuits are designed to carry electricity through lightbulbs to light a room. Other circuits carry electricity to heat the elements on a kitchen stove. In a computer, circuits carry information during input, storage, information processing, and output.



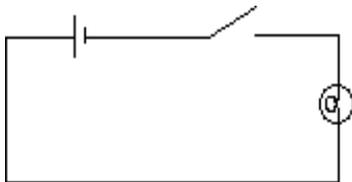
Electrical current in a circuit behaves like water flowing in the water pipes of your house. Getting water to the kitchen sink requires four things: a suitable amount of water, a pipe to carry the water, a pressure difference between the source of the water and the tap, and a tap to turn the flow of water on or off.

Getting electricity to the kitchen toaster requires four things: a quantity of moving electrons, material that will carry these electrons to the toaster from the source of the electrons, a pressure difference between the source (power station) and the wall outlet, and a switch to turn the current on or off.

Simple electrical circuits consist of four parts—the conducting path, the electrical load, the power source, and a switch.

- **Electric charge:** The potential of electrons or protons to attract each other
- **Electrical current:** The movement of electrons from one atom to another
- **Electrical load:** Any component or circuit that consumes power delivered to it by a power source
- **Switch:** Any device that allows the flow of electricity in a circuit when turned on, thereby completing the circuit pathway, or stopping the flow of electricity when turned off by creating a break in the circuit pathway.

Consider the following simple electrical circuit consisting of a battery, lightbulb, wires, and switch.



In this circuit, the wire is the conducting path, the battery is the power source, and the bulb provides the electrical load. The action on the circuit is controlled with the switch. When the switch in this circuit is closed, there is a complete electrical path from the battery to the lightbulb and back to the battery. The bulb will light up as the current flows through it. If the switch is open, the circuit pathway is incomplete and the bulb does not light up.

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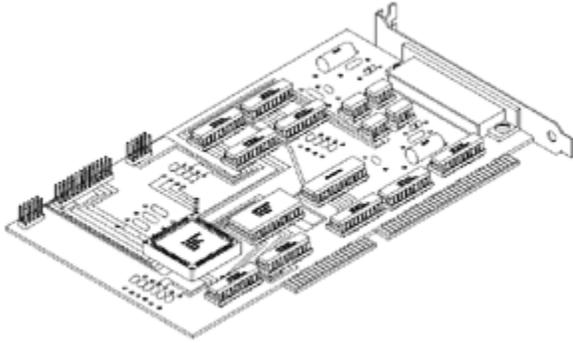
Computer Circuits and Terms

Some of the electrical circuits in a computer are found in the integrated circuits or chips. These circuits are too small to be visible to the naked eye. However, when you look at a printed circuit board such as the motherboard, you can see that the integrated circuits—the chips—are connected by other visible electrical components. For example, you can usually see capacitors, circuit lines, diodes, resistors, and transistors.

- **Capacitor:** A device able to temporarily store electricity
- **Circuit lines:** The pathways used to move electricity from one component to another, often made of small wires or deposited metals
- **Diode:** A device that is used to limit the movement of electricity to move in one specific direction. Some diodes are also designed to produce light or to act as a switch in an electrical circuit.
- **Resistor:** A device with a measurable ability to resist the flow of electrons used to control the strength of the current in a circuit
- **Transistor:** A type of switch that contains no moving parts and uses electricity to turn itself on and off

The electrical circuits in computers provide the means for processing information. Computers change letters, sounds, numbers, and pictures into an extremely versatile electrical representation. By taking advantage of the nature of electricity and pairing this

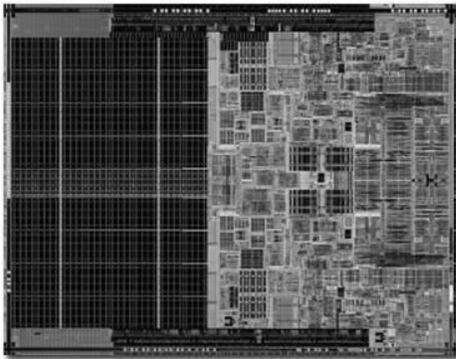
form of energy with the binary number system, the computer can process and store information.



Integrated Circuits

Vacuum tubes were used as switches in the ENIAC and were much faster than the mechanical switches they replaced. But vacuum tubes were soon replaced by transistors. Transistors can be switched on and off more quickly than vacuum tubes and generate less heat. Transistors can be made smaller and smaller, and still be reliable switches.

The miniaturization of transistors was the essential step in the invention of integrated circuits—computer chips. These chips can include millions of transistors. As chip fabrication techniques improve, more and more circuitry can be placed on a smaller and smaller area. This allows information processing to occur at incredibly high speeds.



Studying Electrical Circuits

The integrated circuits used in computers require special tools to build and test. This means they are not suitable for classroom study. However, studying virtual circuits that are easy to "build" online and observe helps students understand how computer circuits function. Circuits that produce light using incandescent lightbulbs or light-emitting diodes (LEDs) are easy to construct and test.

Both bulbs and LEDs produce light using electricity but they do so in very different ways. An incandescent bulb lights up when electrical current moves through a thin wire, called a filament, inside the bulb. When the electricity passes through this filament, the filament becomes extremely hot. The light you see comes from this hot filament.

LEDs convert the flow of electrons directly into light. An LED produces only a small amount of heat while giving off a large amount of light. In a computer, an LED is often included in a circuit to inform the user that the computer is working. You might see a light from an LED when a disk is inserted in the drive or when a hard drive is being used.

The Journey InsideSM: Circuits and Switches Background Information, Part 3

Alternating Current, Direct Current, and Terms

Every circuit must have a power source. Many devices that we use daily, including the computer, use standard household current. Household current is an alternating current (AC) that switches from positive to negative and then back to positive (one complete cycle), 60 times a second. Other devices, such as calculators and many children's toys, use batteries. Batteries supply a direct current (DC) which flows in one direction.

Even though our homes are supplied with AC, many of the electronic devices that we use need DC. When you connect an adapter to a portable battery-operated device, such as a CD player, you are converting AC current to DC current. In some instances, a diode is used to convert AC to DC.

The amount of current flowing in a circuit is measured in amperes or "amps." The wires and other components in a circuit have resistance to the flow of electricity. Resistance is measured in ohms. For a given voltage, the higher the resistance, the lower the amount of current. That is, the higher the number of ohms, the lower the number of amperes.

- **Adapter (converter):** A device that is used to convert current from one form to another form
- **Alternating current (AC):** Current that changes direction on a regular interval of time
- **Ampere:** The unit used to measure current. One ampere is 6.28×10^{18} electrons passing a specific point in one second.
- **Direct current (DC):** Current that only moves in one direction
- **Ohm:** The unit of resistance exerted on the flow of electrons
- **Voltage:** The force or electrical pressure in a circuit

Conductors, Semiconductors, and Insulators

Some materials allow electricity to flow through them. These materials are called conductors. Other materials do not allow any electricity to flow through them. These are called insulators.

A semiconductor is a material that in its pure form cannot be classified into either of the two previous categories. However, a semiconductor can be changed to a conductor or an insulator by adding some other substance to it, creating an impure form of the material.

Some liquids are conductors. A solution with a high concentration of ions (charged atoms) will conduct electricity with relative efficiency. A solution that is not rich in ions will conduct very little electricity.

It is easy to build an ion concentration detector using a circuit containing a battery and an LED. The circuit is designed so that current must flow through the solution in order to be complete. The intensity of the light produced by the LED will be affected by the ion concentration—the strength of the electrical current. A solution rich in ions, such as a saltwater solution, readily conducts the electricity and the light emitted will be bright. On the other hand, a solution of sugar and water does not allow the electrons to flow easily, and the LED will not be bright.

Many solids, such as copper, gold, and aluminum, conduct electricity under almost any condition. Metals are extremely useful in creating circuit pathways to carry electricity through circuits.

The element silicon is the basic substance of all integrated circuits. Pure crystalline silicon is a semiconductor because, when impurities are added, the resulting combination is either an insulator or a conductor. Silicon containing a small amount of boron is called p-type silicon—p for positive, or lacking in electrons. Silicon containing a small amount of phosphorus is called n-type silicon—n for negative, or an abundance of electrons. Either combination changes the crystalline structure of the silicon enough to allow electricity to flow through it.

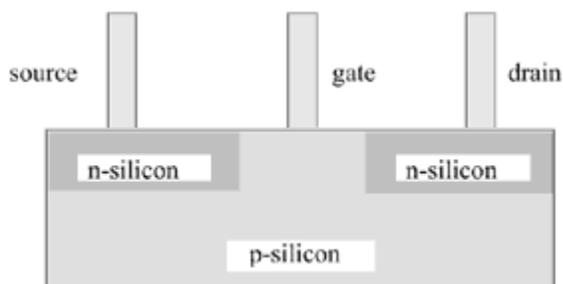
Both n-type silicon and p-type silicon are useful because they can be manipulated to produce a material that responds to a specific set of conditions. By manipulating the amount of impurity added, silicon that responds exactly as required to produce a circuit for a particular task can be created. A transistor contains both p- and n-type silicon.

- **Conductor:** A material that in its pure form allows the flow of an electrical charge to pass through it easily
- **Insulator:** A material that does not allow electricity to pass through it
- **Resistance:** A characteristic of any material that hinders electron flow
- **Semiconductor:** A material that when combined with some other material can be turned into an insulator or a conductor

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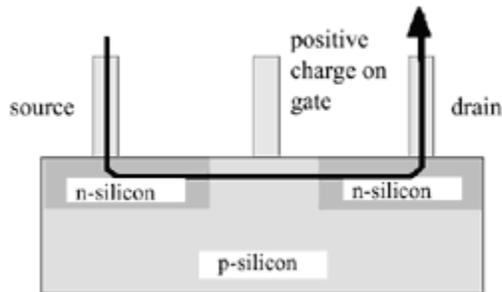
Transistor Switches and Terms

An electrical circuit needs to have switches to control the current. In a computer, the most useful kind of switch is the transistor. Transistors vary in composition and in the arrangement of the components. The diagram below shows the components in one kind of transistor.



- **Gate:** The post of a transistor that receives the current used to turn the switch on completing the circuit so electricity can flow
- **Source:** The post of a transistor where the current in the closed circuit enters the transistor
- **Drain:** The post of a transistor that passes the current from the transistor and on through the closed circuit

A transistor is turned on when an electrical charge is applied to the gate. This changes the electrical charge in the transistor to allow electrons to move from the source to the drain. If the transistor is turned off—no electrical charge on the gate—the pathway of the circuit is broken and the current stops.



Information is presented in a computer using the binary number system. A transistor that is on can be represented by a 1, while a transistor that is off is represented by a 0. These two states, on and off, provide the way to use the binary number system to represent information in a computer. Whether a computer is working with words, numbers, colors, graphics, or sound, the internal representation of the information is the same—a series of bits made up of 0's and 1's.

Resources

The first two resources are annotated and are appropriate for both teachers and students:

Houghton, J. M. & Houghton, R. S. (1994). *Circuit Sense for Elementary Teachers and Students*. Englewood, CO: Teacher Ideas Press.

An excellent source for beginners for learning to understand and build simple electrical and logical circuits. Many sample projects are included.

McWorter, G. & Evans, A. (1994). *Basic Electronics*. Richardson, TX: Master Publishing, Inc.

This is a self-guided resource that includes a great deal of information on electronic devices and circuits with practice problems and quizzes to reinforce the learning—suitable for teachers and older students.

Evans, A. (1996). *Basic Digital Electronics*. Owensville, MI: Custom Printing Company.

Mims, F. M. (1994). *Getting Started in Electronics (12th printing)*. Fort Worth, TX: Tandy Corp.

Parker, S. (1992). *Eyewitness Science: Electricity*. New York, NY: Dorling Kindersley, Inc.

Ronan, C. (Ed.). (1994). *Science Explained*. New York: Holt.

"Forces of Nature." In Suplee, C. (1996). *Everyday Science Explained* (pp. 74-127). Washington, DC: National Geographic.

Uhreen, D. (Spring 1996). *Vacuum Tubes. The Journey Inside the Digital World*, 2(2), pp. 1, 3.

Studio Interactive (Producer). (1996). Digital Lab [CD-ROM, workbench and components]. *CyberCrafts: Hands on Learning*. Philips Media.

Studio Interactive (Producer). (1996). Fun With Electronics [CD-ROM, workbench and components]. *Hands on Learning*. Philips Media.

Norman, P. (1997). *ElectroWizard: Inventions* [book, components]. El Sobrante, CA: Norman & Globus, Inc.

Norman, P. (1997). *ElectroWiz: Magnetism* [book, components]. El Sobrante, CA: Norman & Globus, Inc.

Norman, P. (1997). *ElectroWiz: Electricity* [book, components]. El Sobrante, CA: Norman & Globus, Inc.