ELECTRONIC EQUIPMENT

SERVICE TECHNOLOGY

ELECTRICITY
&
ELECTRONICS

1. The Nature of Electricity

Electricity is really rather simple, because it behaves like a liquid. It flows like water, and tends to fill every space available to it. Electricity is made up of minute particles called electrons, which exist in every kind of matter. In a metal wire, electrons can be pumped like water by a generator or battery. Electrons repel each other, so they tend to reach the same density throughout a circuit, like water seeking the same level under the influence of gravity. Since there are so many basic similarities between the behavior of water and that of electricity, we can illustrate electrical characteristics by employing a waterflow analogy.

By convention, the direction of current flow is opposite to that of electron flow. The reason for defining conventional flow in the opposite direction stems from an assumption made at the time electricity was discovered, that the positive charge was the moving particle. Our water anology can still be used, but instead of it being equated to negatively charged electrons flowing from negative to positive, it must be the flow of positive particles from the positive pole to the negative pole.

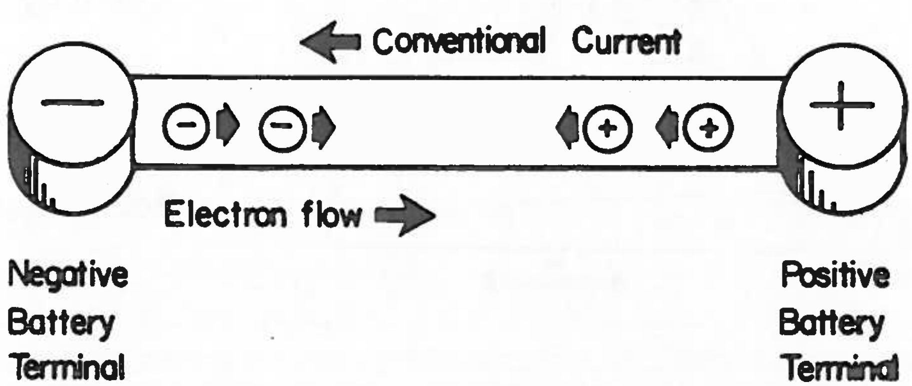


Figure 1 shows an open-top sluice with water in it. The little man at the water pump is the equivalent of an electrical generator. As the man pumps water from one end of the sluice into the other, water piles up at (high level and pressure) the input end of the sluice and flows to seek the lower level at the other end of the sluice. Electricity does precisely the same thing. When positive charges are pumped into one end of a wire, the positive charges are forced to pile up to a high density and they tend to flow toward the lower density at the other end of the wire. This positive charge density can be thought of as pressure, and it is measured in volts. Voltage is the measure of charge pressure.

In comparing water to electricity, we can see that the height of the water in the sluice is equivalent to the density of positive charges. But in electricity, we need also to be concerned with the flow of positive charges, which we call "current". The flow of water is measured in gallons per minute; the flow of positive charges or electrical current is measured in amperes "amps".

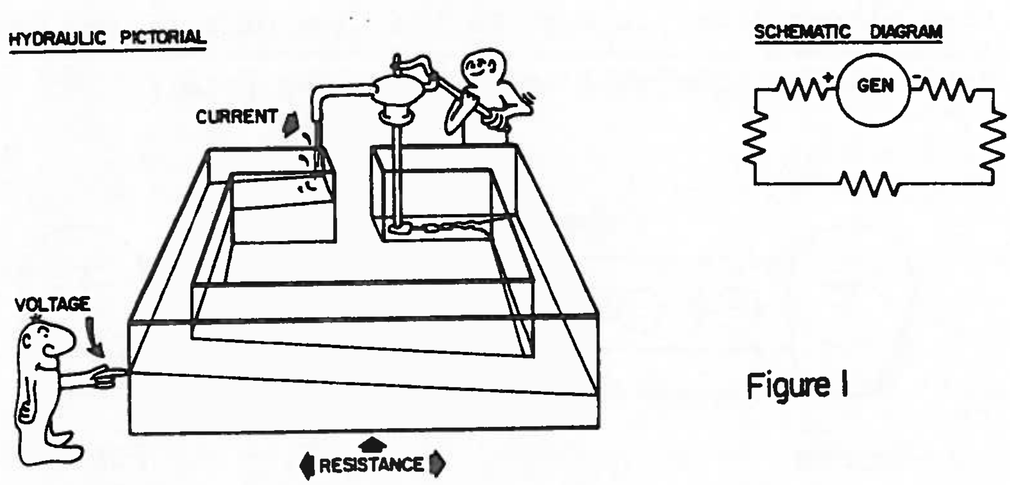


Figure I

The relationship between the voltage and current in electrical circuits is just like the relationship between water level and water flow in a sluice. Consider Fig.2 Assume the upper horizontal line to be the starting water level in the sluice. If we increase the height of water at the left end by pumping it in at a vigorous rate we also increase the water pressure at that end. Consequently, the water will flow to the right end at an increased rate (more gallons per minute). The same thing happens with electricity. If we increase the voltage differential in the circuit, we increase the amperage or rate of current flow.

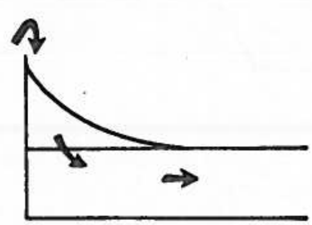


Figure 2

There is another factor that can affect both the flow of water and the flow of electricity. This factor is called resistance. In the case of water flow, the resistance is chiefly created by the constricting properties of the walls of the sluice. Electricity, like water, is restricted in its flow by the nature of the conductor (the wire). In a sluice, or in a wire, the resistance will be constant as long as the characteristics of the conductor remain the same.

However, resistance can be altered. Figure 3 shows a top view of the sides of the sluice pulled in, constricting the passage, and thereby increasing resistance. We can do the same thing with the flow of electrical current by using a variable resistor. What happens when we pull in the sides of the sluice? If the man continues to pump at the same number of gallons per minute, the water will rise higher at one end of the sluice. The same thing happens with electricity; the voltage differential increases; it is higher at one end than at the other. So we can see that voltage, current, and resistance are all related. If you change one, this changes one or both of the others.

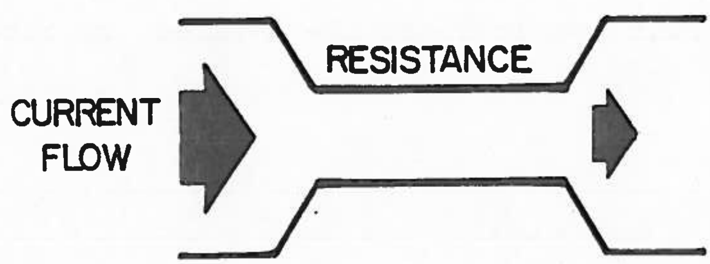


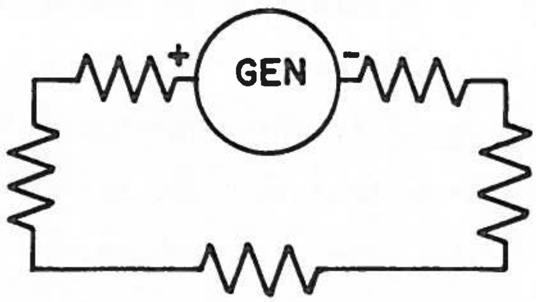
Figure 3

Electricity, like water, must flow in order to carry information or to perform work. To flow, it must come from somewhere and go somewhere. It's usually convenient to make it go in a circle to take care of this problem, and that is where we get the term "electrical circuit".

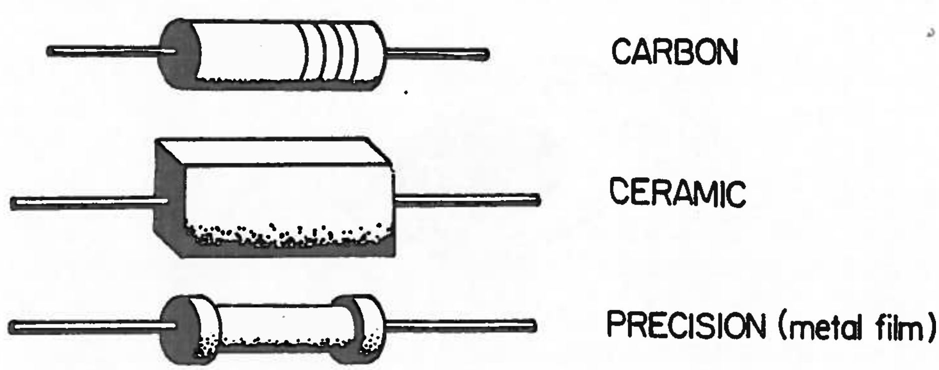
Note:
Wire is the conduit of electricity. The larger the diameter of the wire, the more current it can carry (the wire offers less resistance). Adding more insulation to a wire increases its voltage capability. Typically, heavier gauge wires are used for A.C. power circuits and lighter gauge wires for low voltage D.C. circuits.

In the schematic, the circle represents the generator. The lines coming out of and going into the generator represent the conductors (or wires). The zig-zag section (symbol for a resistor) indicates the resistance of the conductor.

SCHEMATIC DIAGRAM



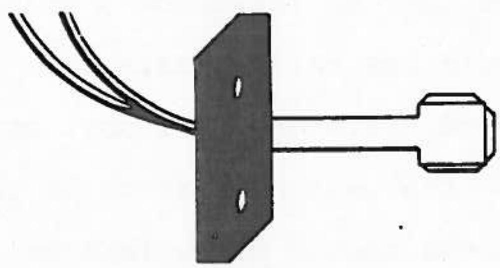
Devices used to introduce a predetermined fixed resistance in a circuit are called resistors. There are several different kinds of resistors, the most common of which is the carbon type. The carbon resistor is generally color coded to represent the amount of resistance, tolerance (percentage of variation from the marked value) and reliability. The unit of measurement of resistance is the "ohm". A straight piece of wire will typically offer very little resistance, and when measured with an "ohmmeter" it will read zero ohms. A long piece of wire in a coil will offer some resistance. For example, a relay coil will typically be 600 ohms. Higher resistances are measured in K ohms (thousands) and Megohms (millions).



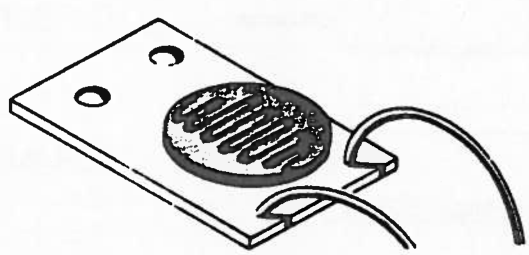
Other types of resistors include; wire wound (generally used where precise resistances are required) and ceramic (resistors that can withstand large amounts of current and are generally used in power supply circuits).

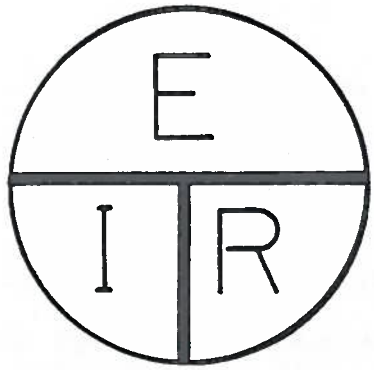
Other variable resistor devices include:

Thermistors (a contraction of the words thermal and resistor)
A thermistor is a device that varies its resistance depending upon temperature. As the temperature increases, the resistance of the thermistor changes. It may go up or down in resistance depending on the type of thermistor.



Cadmium Sulfide Cell (CdS)
The CdS cell is a resistive device that depends upon the amount of light falling on the cell. As the amount of light increases, the cell resistance will decrease. In the absence of light, the resistance of the cell will increase.





The Relationship Of Voltage, Current and Resistance

Voltage equals current times resistance $E = I \times R$

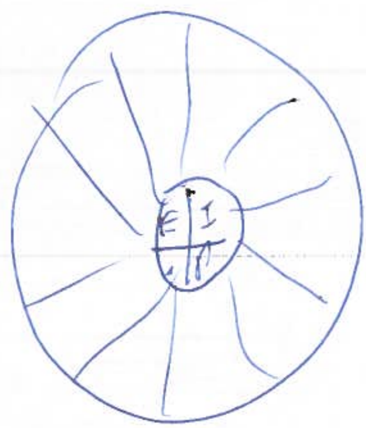
Current equals voltage divided by resistance $I = E/R$

Resistance equals voltage divided by current $R = E/I$

Voltage Symbol = E

Current Symbol = I

Resistance Symbol = R



2. Electrical Power

The useful thing about the flow of electricity is that it carries energy, or power, from one place to another. This energy can be put in at one point and used at another point. Figure 4 is a water analogy that illustrates this. Energy is put into electricity by pumping it from a low voltage to a high voltage. You get energy out of electricity by letting it fall from a high voltage to a low voltage. In the water analogy, the energy is being converted to the useful work of sawing wood, by a waterwheel. We can put more power into the waterwheel by increasing the voltage difference (the height of the waterfall), or by increasing the current (the flow of water).

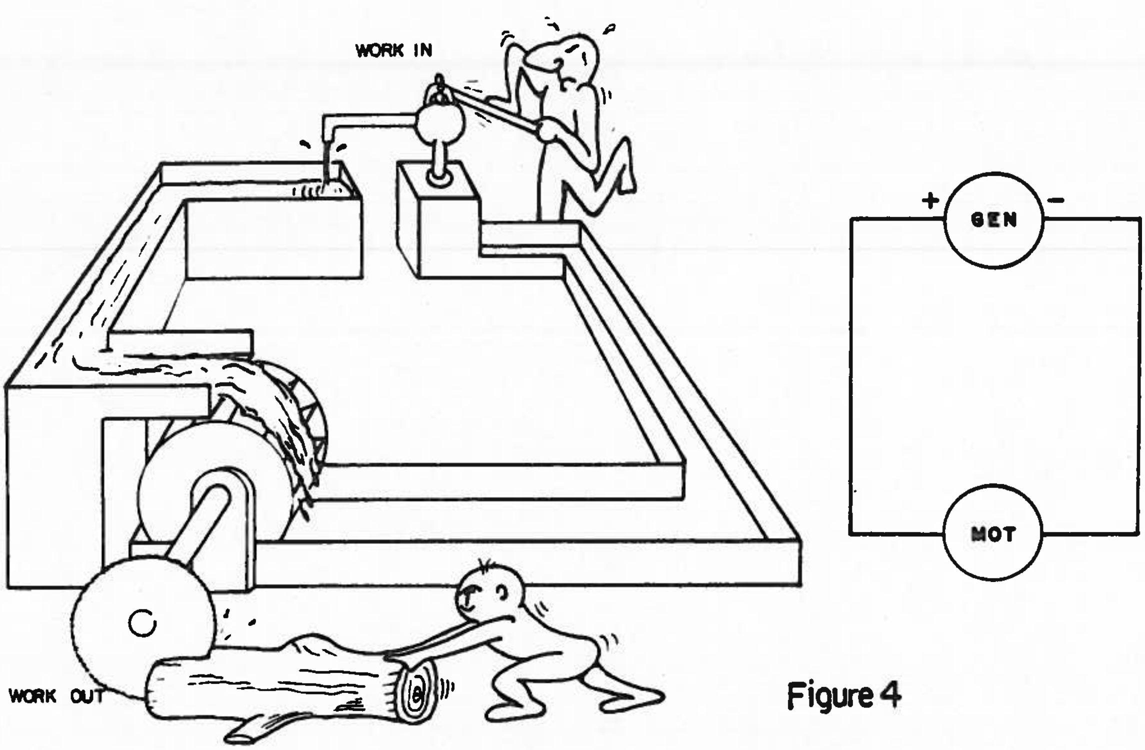
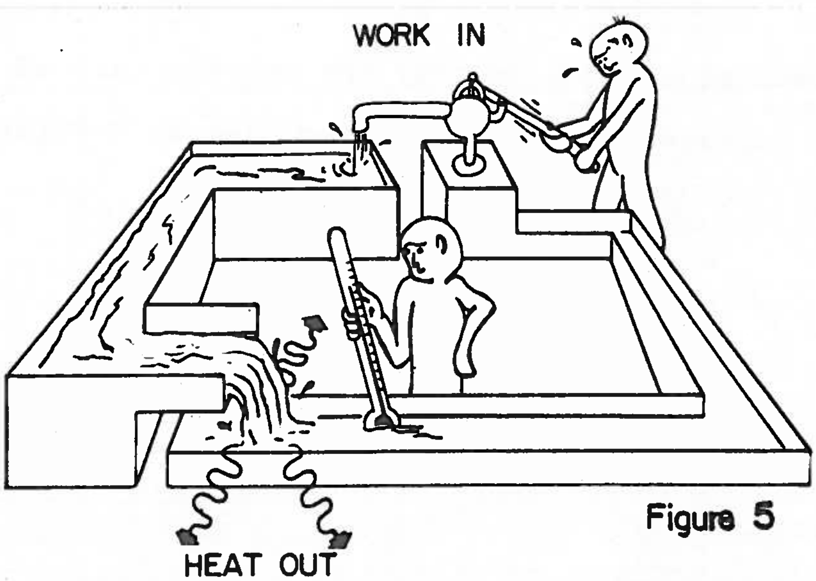


Figure 4

Electrically speaking, the pump we see here is representative of any device that puts energy into electricity. We'll continue to call it a generator, which is a device that converts mechanical energy into electrical energy. But the water pump equally well represents a microphone, which converts sound energy into electrical energy. The waterwheel represents any device that converts electrical energy back into external energy. (For example, a motor, which produces mechanical energy, or a loudspeaker, which produces sound energy.) For the sake of simplicity, we'll generally refer to the waterwheel as a motor. Figure 4 also shows the schematic electrical diagram equivalent to this simple circuit.

Now let's see what happens if we remove the waterwheel from the waterfall as in Fig. 5 . As far as the rest of the circuit is concerned, removing the wheel changes nothing. Water continues to flow across the voltage drop at the waterfall, and the only change is that no work is coming out.



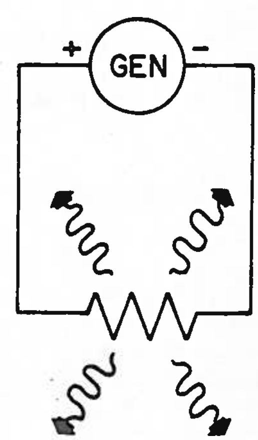
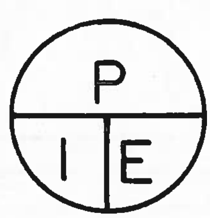


Figure 5

The waterfall is now simply the equivalent of a resistor. But what is happening to the energy (the work) that is still being put into the water by the pump? It is simply being wasted away (dissipated) by the friction, or resistance in the waterfall. And like any friction, it produces heat; that is where the energy is going, into heating the water and sluice. The same thing happens in our electrical circuit. Any working device, like a motor, can be replaced in a circuit by a resistor, without having any effect on the circuit except that the work that might be done is instead dissipated as heat, and the resistor gets hot. This is the way electrical heating elements and light bulb filaments work.

The unit of electrical power is the Watt.

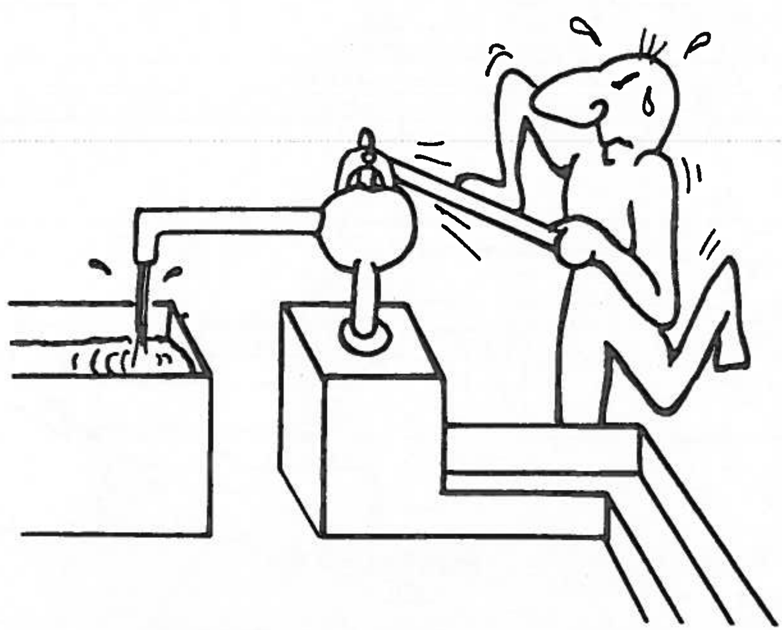
(1 horse power equals 745.7watts) The relationship of power to current and voltage is; Watts = Current (amps) X Voltage (P = I X E)



3. Controlling Electrical Energy

By now, you should have a basic grasp of the way electricity flows and carries power, so we can go a step further. This power can be controlled to make the system perform in any desired manner.

There are two ways to control power. The first way is simply to control the amount of power you put into the circuit. In our hydraulic analogy of the pump and the waterwheel, the power going into the saw is controlled by the power going into the pump. If the little man pumps vigorously, more power comes out of the waterwheel. If he slows down, less power comes out of the waterwheel. Typically, however, the power available to electrical systems is uncontrolled at its source.



POWER SOURCE

Another way to control power is at some point in the circuit other than the power source, and this is more common. Figure 6 illustrates how this can be done; note the little man with the sliding dam, or gate. Suppose the man at the pump is working at a steady rate; how can we vary the cutting power of the saw? By sliding the gate in or out, the control man can choke off or open the flow of water through the channel. The man at the sliding gate controls the power driving the saw. He can make the saw cut fast or slow; he can turn it on or turn it off.

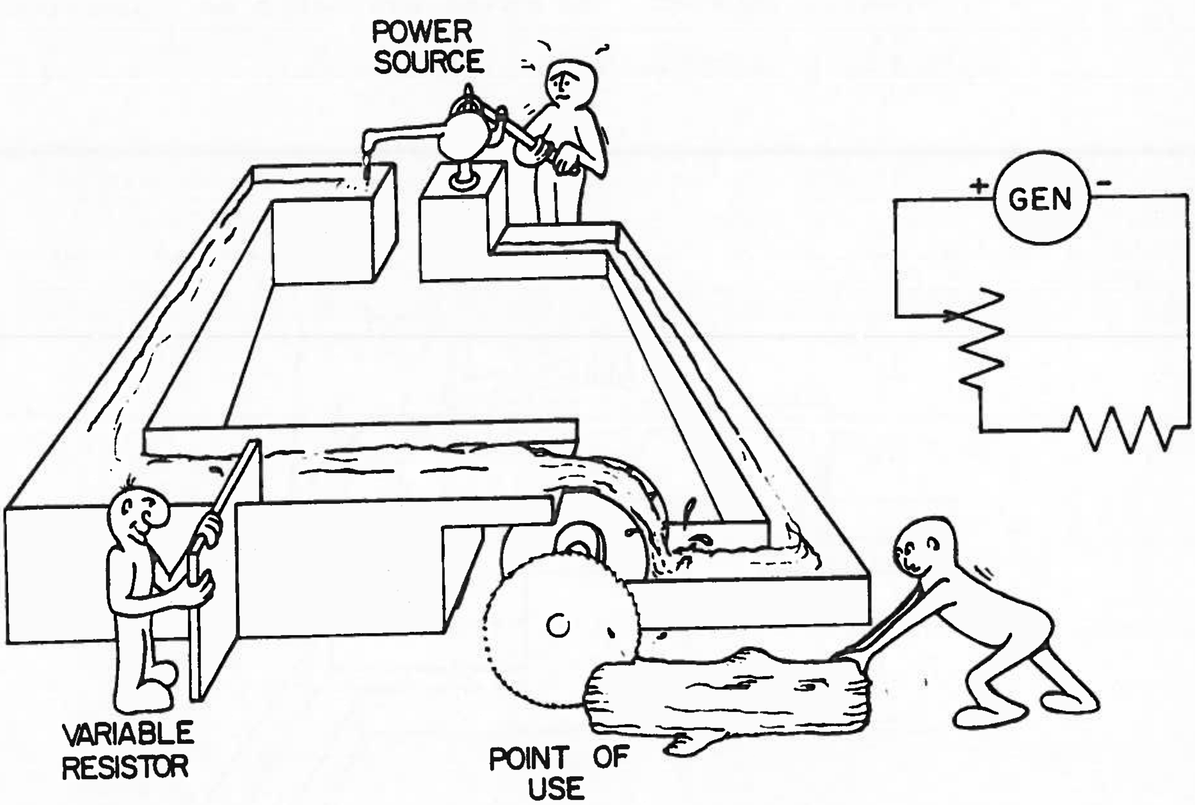
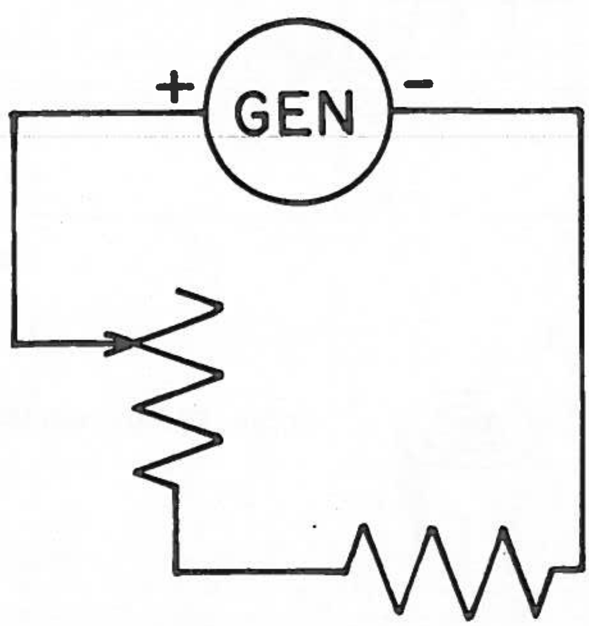


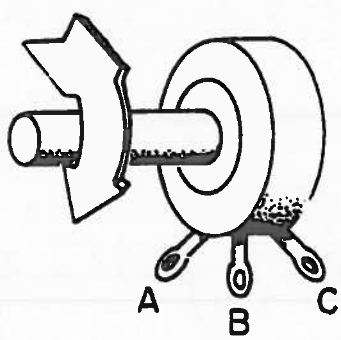
Figure 6

The man at the gate is representative of all that can be done to the flow of electricity within a circuit between the power source and the point of use. It can be throttled, or it can be switched on and off. This simple concept is so important to remember when we are considering ways in which electricity can be used. In other words: We can only do two things to electricity between the power source and the point of use. We can switch it (as in an "on or off" function), or we can regulate it (as when we vary the resistance).

The schematic of Fig. 6 depicts what we have been talking about in electrical terms. It shows the generator (pump) and the motor (waterwheel). Between them in the circuit is the variable resistor (gate); this variable resistor can also act as an on-off switch.



Potentiometers are variable resistors and come in a variety of types and styles. They all perform the same function, a manual selection of variable circuit resistance. Potentiometers (pots.) are rated in ohms (as other resistors). The resistance unit of this device may be a molded carbon ring (for low power applications), or a wire wound circular form (for high power applications). A contact arm, controlled by a shaft and knob, rides in contact with the resistance unit. The desired amount of resistance is selected by rotating the knob. There are three connections to this component; one at each end of the total resistance and a third attached to the moving contact.



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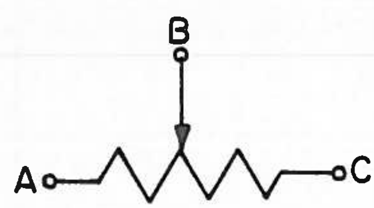
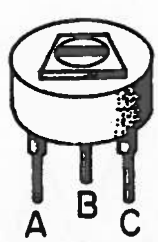


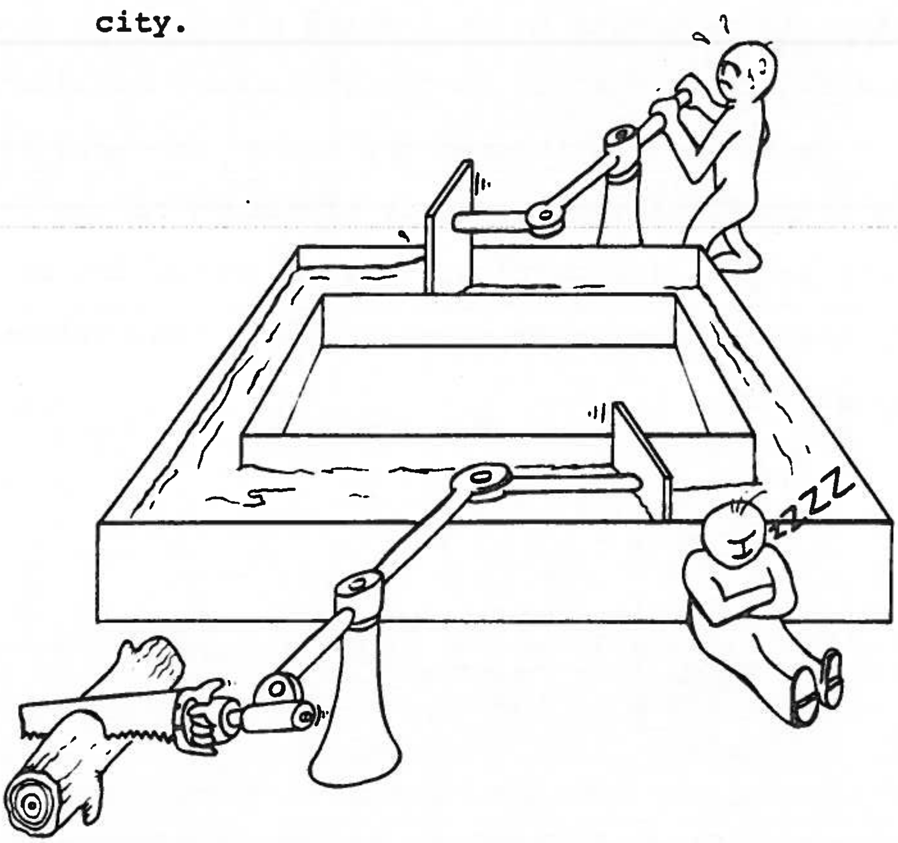


circuit board mounted

Alternating & Direct Current

In the circuits seen so far, the current flows in one direction. This is called "direct current" or "DC". An alternating-current circuit works just like a direct-current one, except that a special generator is required to pump current first in one direction through the circuit and motor, and then in the other direction. A special motor is used, to recover work from current going in either direction.

Figure 7 shows an alternating-current circuit in hydraulic terms. This circuit is equivalent to the direct current motor and generator circuit we saw in Fig. 6. The special pump represents an AC generator. The paddle or piston connected to the pumping lever pushes water first in one direction and then the other, so that the current around the circuit and through the motor alternates in direction. This pump, like the DC kind, simply puts energy into electricity.



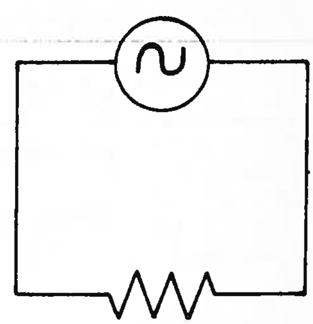
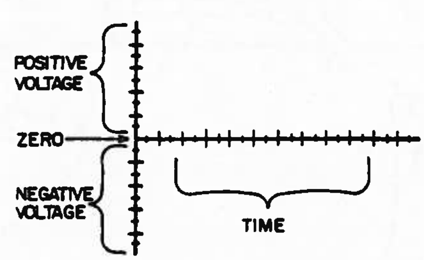


Figure 7

The AC motor is represented by another piston-like paddle on a lever, just like the generator. When the voltage is higher on the left than on the right side of the paddle, it moves right, allowing some current to flow to the right; then the generator makes the voltage on the right side higher, and the paddle and current moves left. The water does the work during each stroke. In this case, sawing wood.

Alternating current reverses its polarity continuously, in short periods of time. The current rises from zero to a maximum voltage of one polarity, falls to zero, reaches a maximum of the opposite polarity and returns to zero again. Each complete pair of alternations (positive and negative) is called a cycle, and the frequency of the cycles (per second) is called "Hertz" (Hz).

Quite often it is easier to understand electronics when we can see pictures of what is happening inside the electrical components. One method is through the use of an oscilloscope. The diagram below illustrates what is displayed on the face of the oscilloscope. The vertical line indicates the magnitude of voltage, either positive or negative while the horizontal line indicates time.



When a chart is made of the voltage change in an AC circuit, the pattern produced is a Sine wave. Half of the wave is in the upper portion of the chart (positive) and half in the lower (negative) portion of the chart.

An AC signal would be illustrated in the following diagram, Fig. 8 . In this diagram, the voltage of the signal will constantly vary above and below the zero line. With an AC signal, the current will change direction whenever the voltage changes from positive to negative or negative to positive.

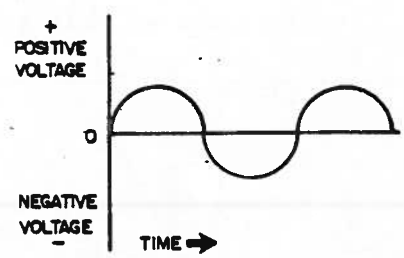


Figure 8

A positive DC voltage would be illustrated on an oscilloscope using the following diagram, Fig. 9. Notice that the signal line is at a constant value above the zero voltage line.

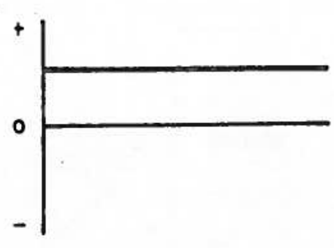


Figure 9

THE TRANSFORMER

The voltage which is supplied to the copier at the electrical outlet will have a nominal value of 115 volts AC when measured with a typical meter. Two things must be done to the supply voltage before it can be used throughout the copier. Change the supply voltage to different values and change or rectify AC to DC.

Figure 10 shows a transformer in both electrical and hydraulic terms. The paddle located on the left or "primary" side of the transformer will move back and forth in direct response to the supply voltage. In a way similar to a see-saw, depending upon the position of the fulcrum, the force transferred to the right or "secondary" side of the transformer can be less than, greater than, or equal to the supply voltage. Instead of paddles and lever arms in a transformer, magnetic fields induce this change of voltage.

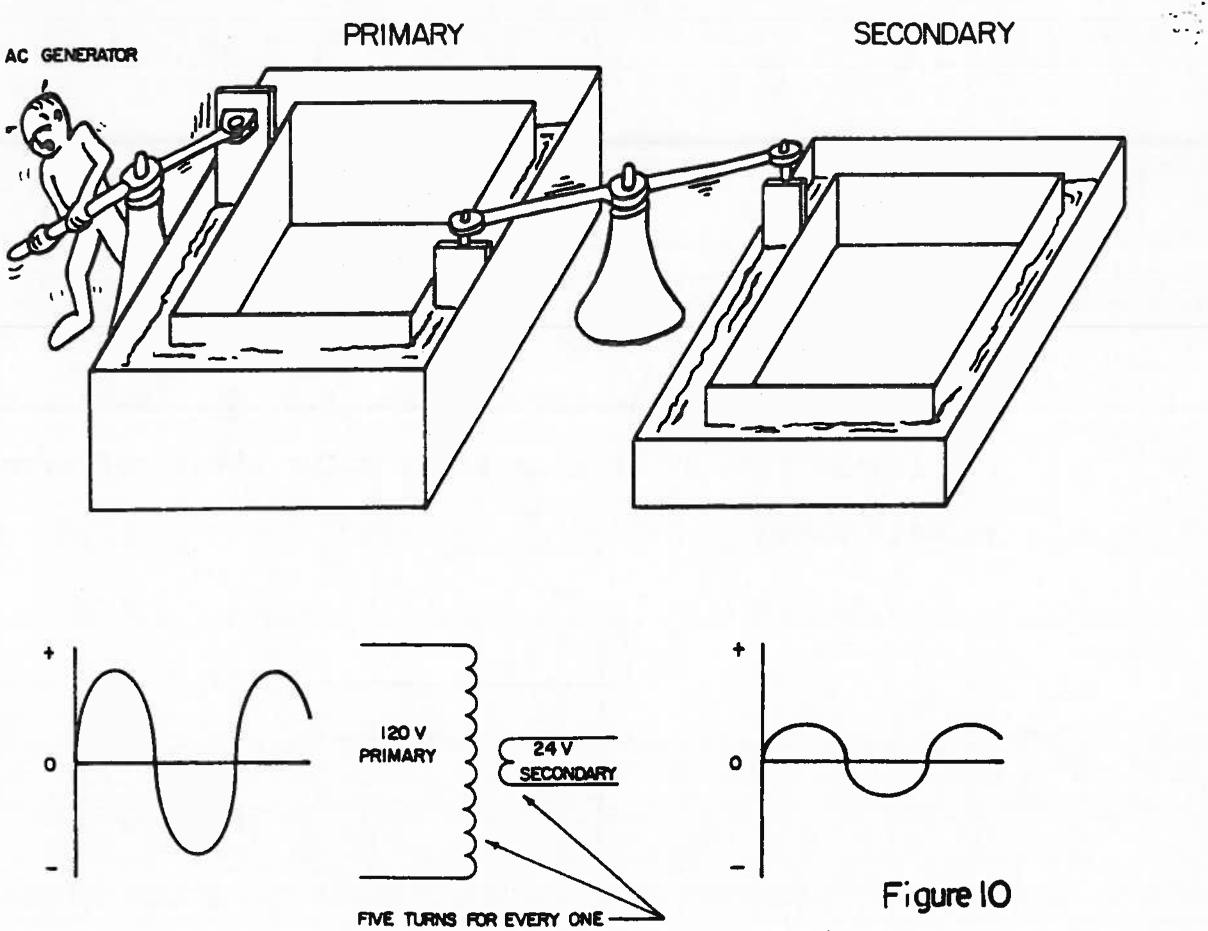
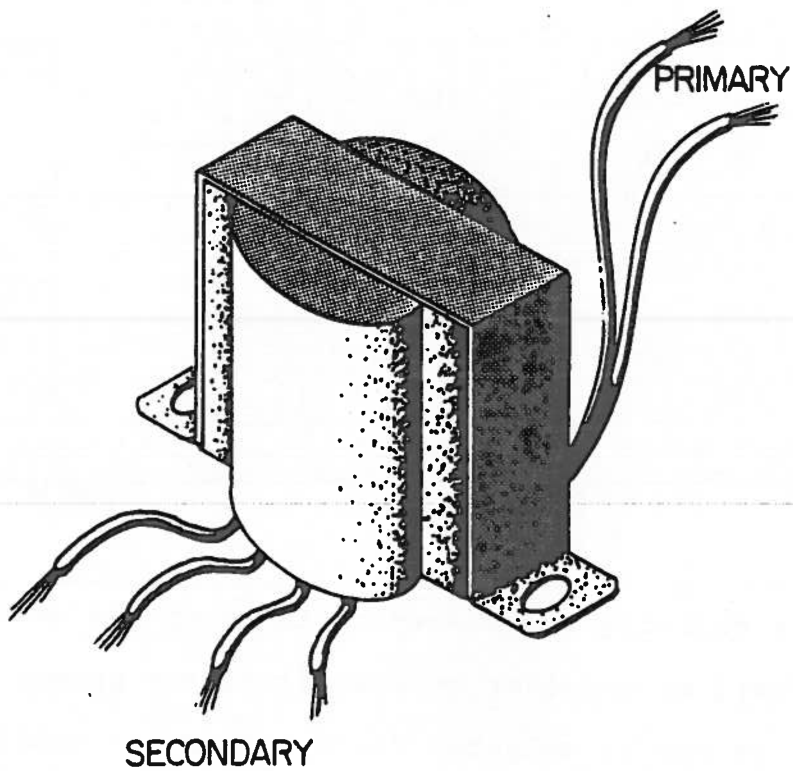


Figure 10

The "transformer" is a device that is made up of two or more coils of wire wrapped on an iron core. The coils are not electrically connected to one another. The supply current is passed through one of the coils (called the "primary"). The magnetic field created by this current causes electron flow in the other coil(s) of the transformer (called the "secondary"). Electric current is "induced" by the magnetic field.



A transformer is a very versatile device. The energy in the primary side of the transformer can be transferred to more than one secondary winding. This permits many different voltages to be made from one supply voltage, see Fig. 11 .

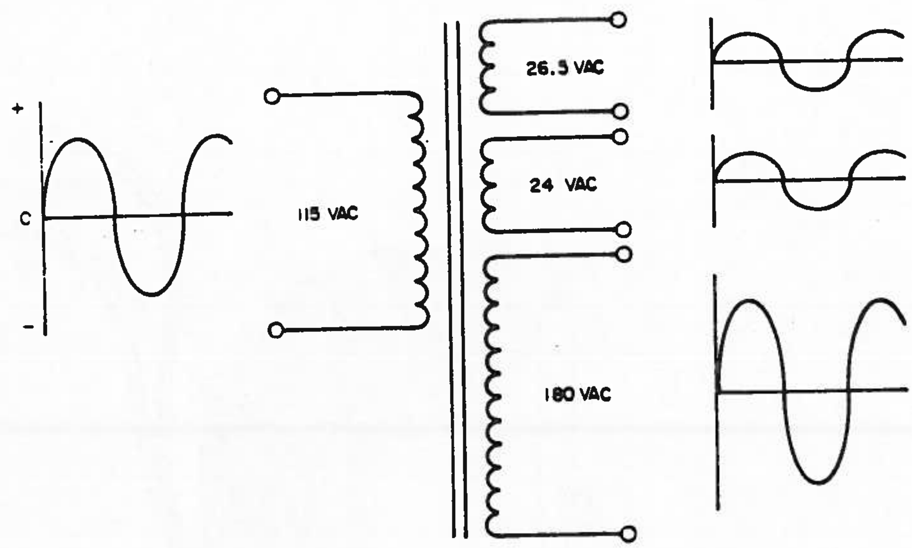


Figure 11

By changing the number of turns on the core, the size of the coil or diameter of the wires, the amount of output voltage can be selected for a particular application.

A "step-up" transformer will have a secondary voltage that is higher than the primary. A "step-down" transformer will have a secondary voltage that is lower than the primary.

How DC is made from AC

After the supply voltage has been transformed, it must be converted from AC to DC before the copier can use it. The device used to accomplish this job is the diode, and this process is called rectification. Going back to our plumbing anology, Fig. 12, a diode acts as a one way valve, similar to the gates of a lock. Water will be able to flow in one direction, but the lock will close when water attemps to flow in the reverse direction. One diode, as connected in figure 13 produces half wave rectification. Only the positive going waves pass through the diode.

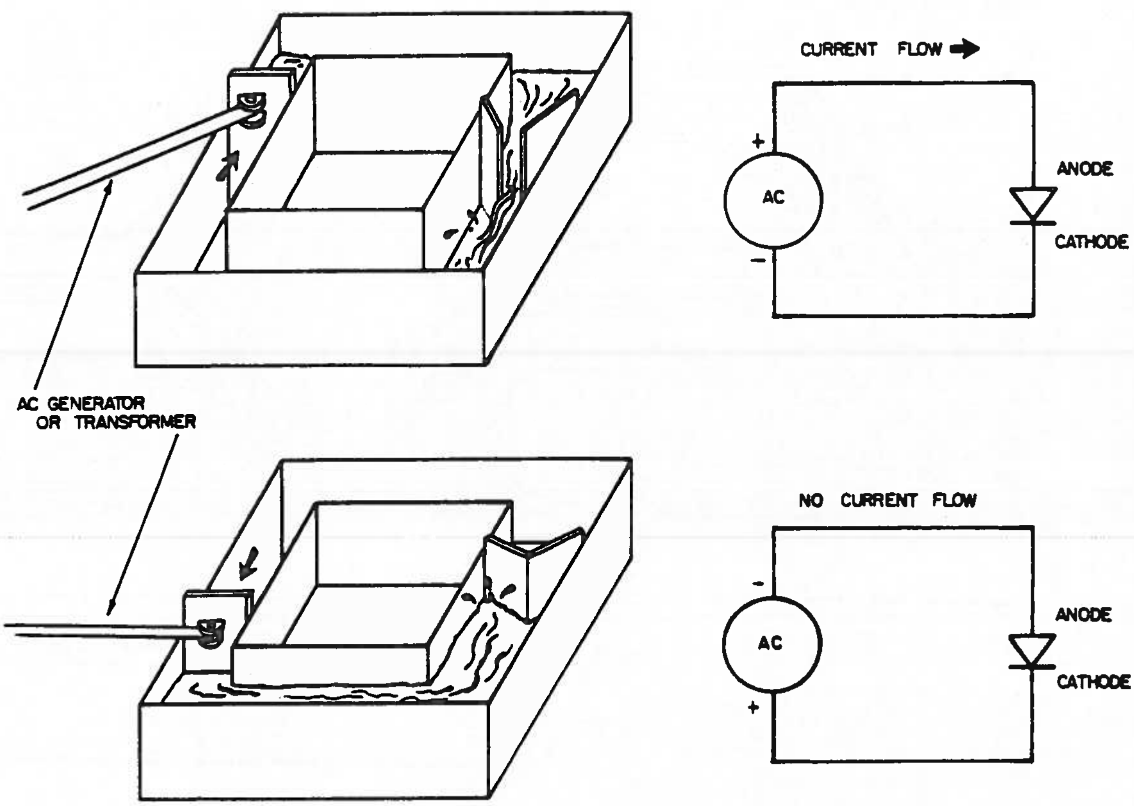


Figure 12

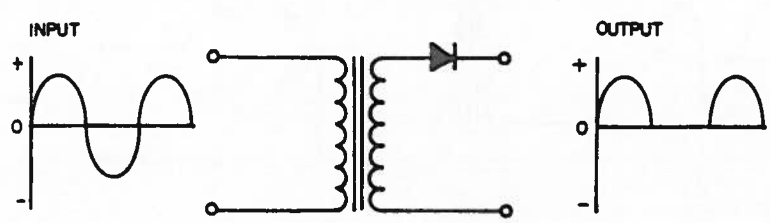
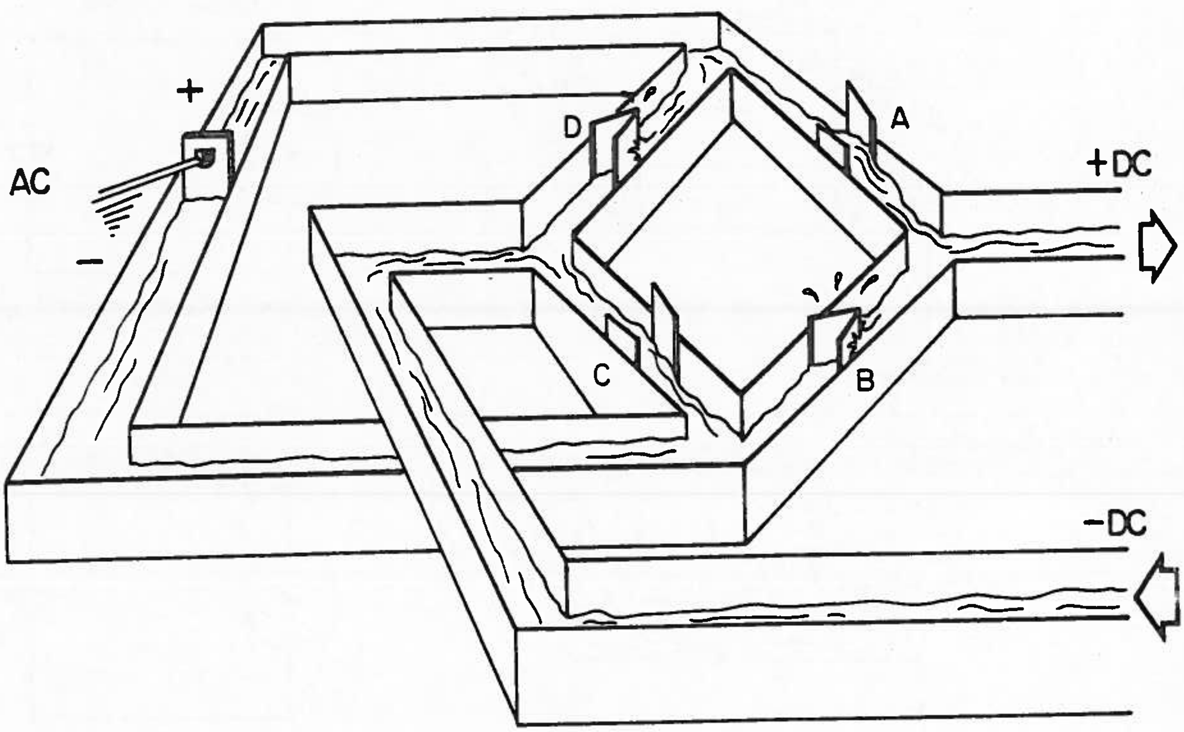


Figure 13

Four diodes can be connected as in figure 14 to give what is called a full wave bridge rectifier. The gates A and C or B and D will alternately open and close in pairs to permit water to flow only out of the positive side and into the negative side of the bridge rectifier. Looking at the electrical schematic we can see that when the top side of the transformer is positive, diodes A and C will permit current to flow. When the bottom of the transformer is positive diodes B and D will permit current to flow. The diagrams of the input and output signal have been included to illustrate the function of a full wave bridge rectifier.



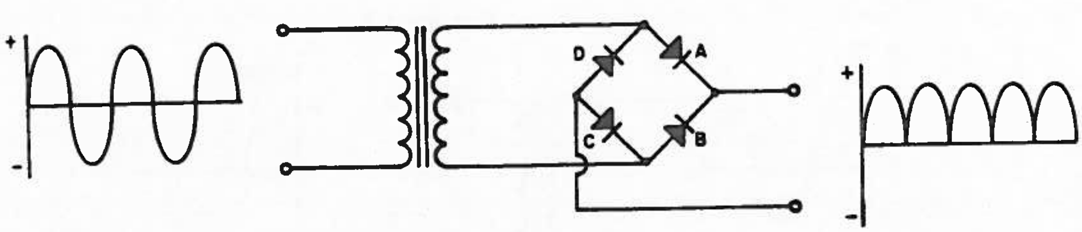
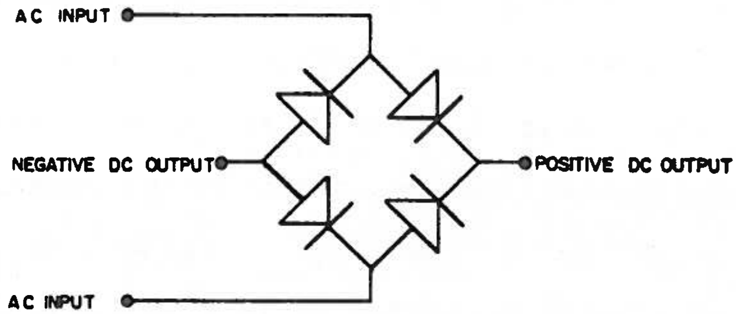
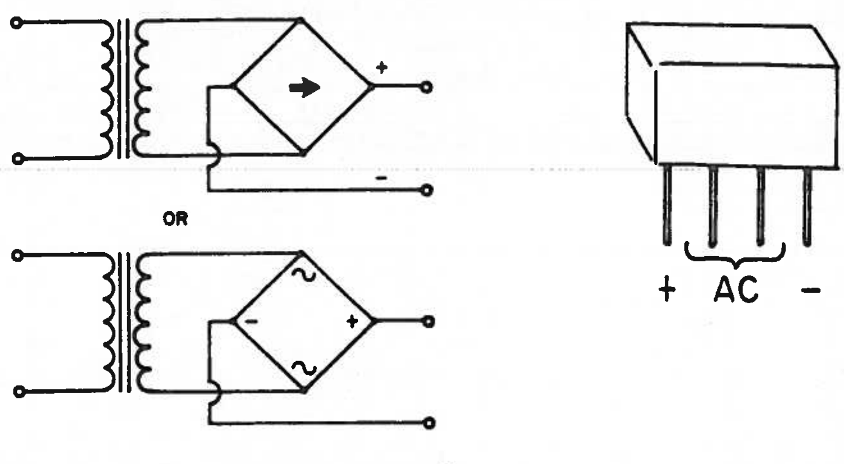


Figure 14

BRIDGE RECTIFIER

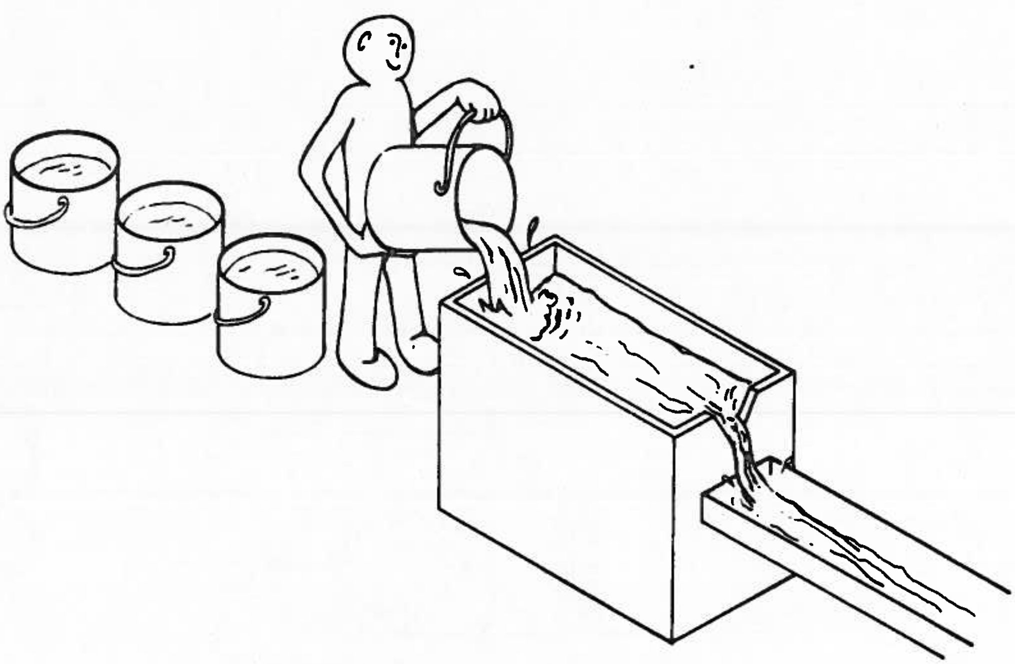


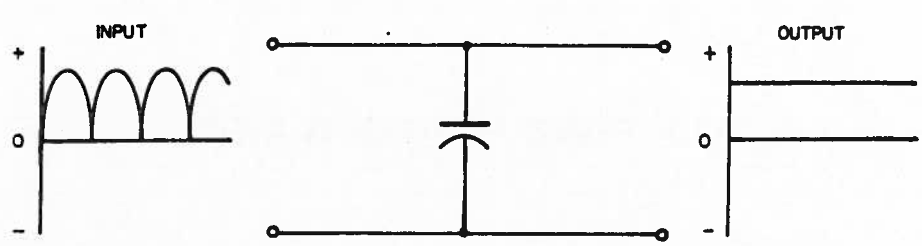


FOUR DIODES MOUNTED IN A SINGLE CASE

The Function of Capacitors

Capacitors are primarily used to serve two functions; filtering and timing. The first is to filter fluctuating voltage and make it more constant. Continuing our hydraulic analogy, when water is added in spurts to a large vat, it will tend to leave the vat in a constant stream due to the storage capability of the large container. A capacitor tends to store the voltage applied to it which will discharge when the supply voltage decreases. This discharge voltage will add to the decreased source voltage to help maintain the voltage at a constant level.





Capacitors can also be used in timing circuits. Uncharged capacitors act like an empty but stopped up sink. When the water is turned on, the sink will start to fill up. Initially this presents no problems since all of the water will be able to go into the sink. Depending upon the rate of flow of the water and the size of the sink, this situation will not present a problem until such time as the water overflows the sink. At this time another area of the room receives the water, usually the floor. When a voltage is applied to a capacitor as in figure 15 , that voltage will not be seen at the output until the capacitor has been "filled-up", at which time the output voltage will equal the input voltage. A filled up capacitor is called "charged".

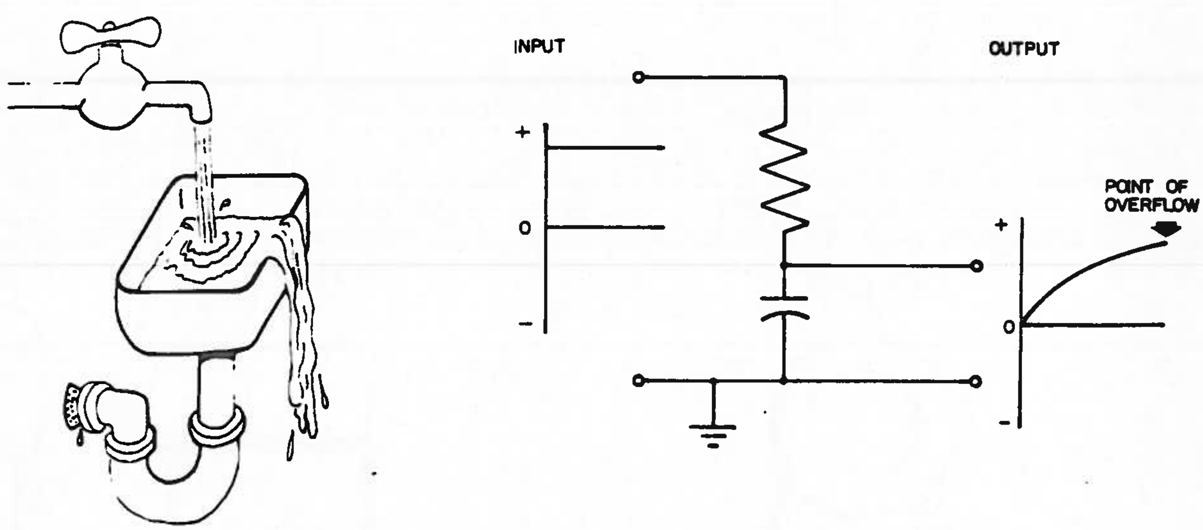
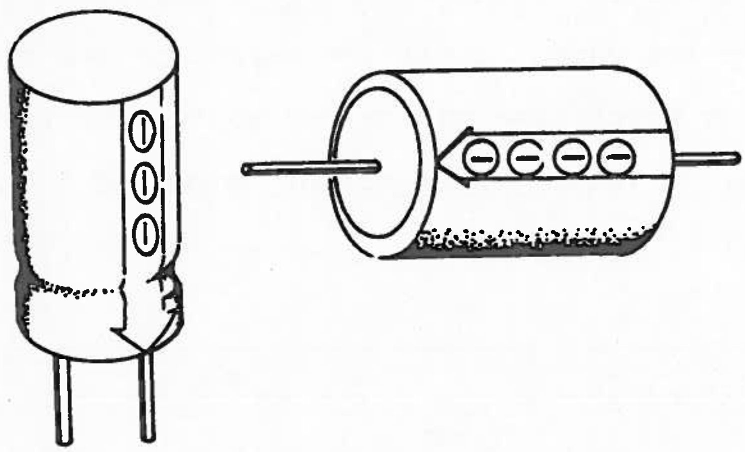


Figure 15

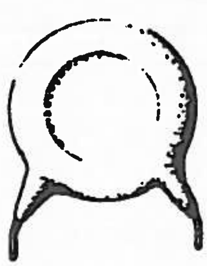
A capacitor is a circuit element consisting of two conducting plates separated by a thin sheet of dielectric (insulating) material. There are several types of capacitors: electrolytic and tantalum are polarized (DC applications). Ceramic, mylar and mica are not polarized (AC applications). When replacing a polarized capacitor, be sure to observe polarity.

ELECTROLYTIC

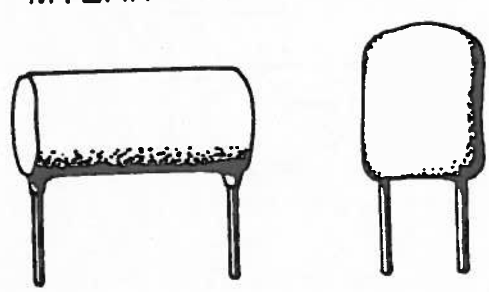


TANTALUM

CERAMIC



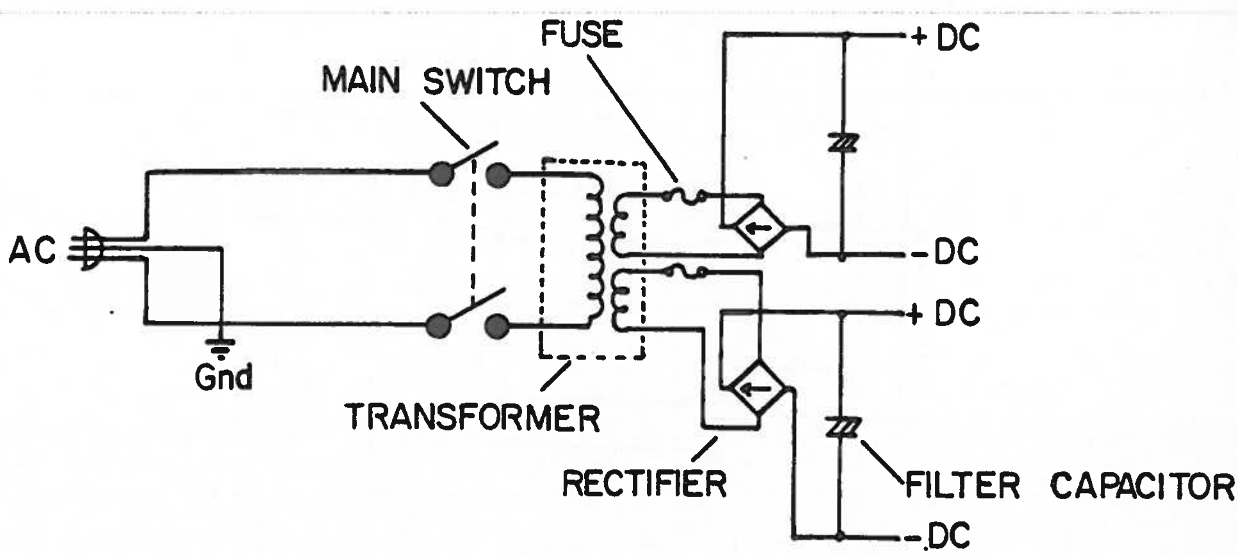
MYLAR



The Power Supply

The power supply circuit of a photocopier has all the components necessary to convert AC to DC.

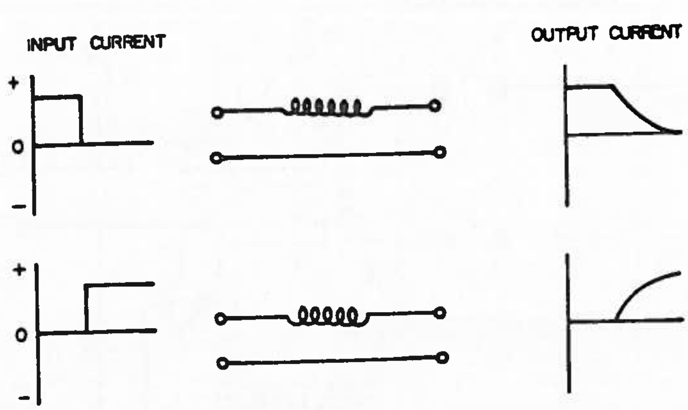
AC potential is applied to the main switch when the machine is plugged in. When the switch is closed, AC flows through the primary winding of the transformer. The magnetic field generated in the transformer, induces AC in the secondary windings. Voltage is "stepped down" because of the ratio of primary to secondary coils. Each low voltage secondary circuit has its own fuse protection. The low voltage AC is applied to a bridge rectifier circuit. Each rectifier is composed of four diodes (the arrow indicating the positve output). The current, at this point, is a pulsating DC. In the filtration stage, large electrolytic capacitors charge and discharge into the circuit in an effort to maintain a constant voltage. In this way, pulsating DC is changed to a steady current. Additional current and voltage limiting devices further reduce the amount of rippling in the DC current.



The Function of Inductors

An inductor tends to restrict a change in the flow of current. When the inductor has a current flowing through it, and for some reason that current is decreased, the inductor will maintain the original current flow for a limited period of time. Again we can go back to our hydraulic analog, this time using a garden hose. A swollen garden hose will continue to force out water (due to its swollen condition) after the water source has been turned off.

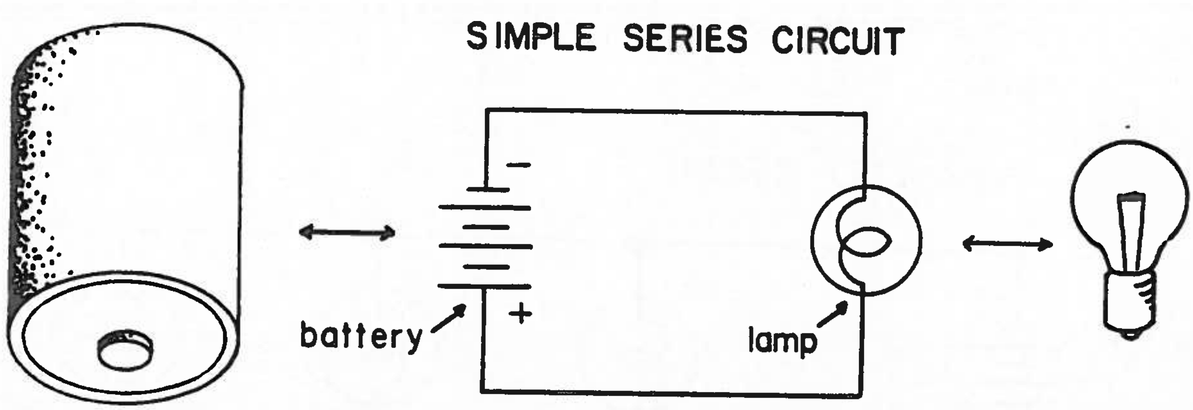
An inductor is equally as effective in restricting an increase of current flow. This time the inductor will hold back the increase in current flow.



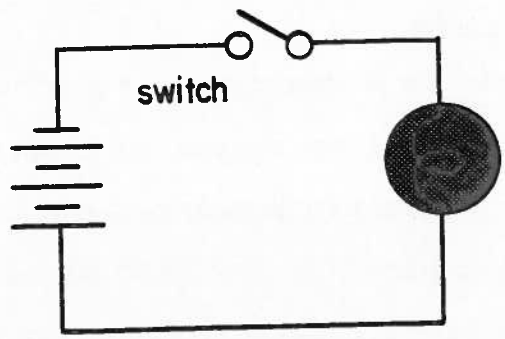
Simple Circuits

A schematic is a diagram of a circuit, a road map of the flow of electrons from source to component(s). The straight lines of the schematic represent the conductors (either point to point wires or the foil paths of a printed wiring board). The storage battery provides a source of direct current and is best suited to demonstrating simple D.C. circuits.

The basic D.C. circuit has only one path of current flow. It leaves from the positive side of the battery, passes through one or more devices, and returns to the negative side of the battery. This arrangement is called a "closed series circuit", represented in the schematic diagram below.

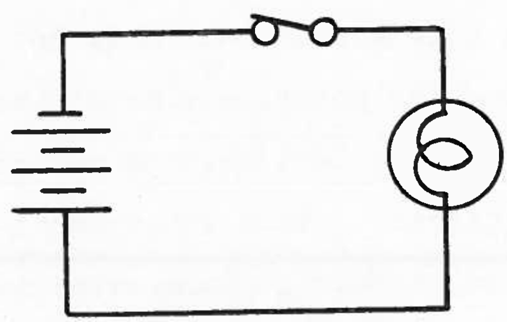


With the addition of a switch, we can control the device (in this case a lamp), by opening and closing the circuit. With the switch open, the circuit is incomplete, and there is no current flow.



OPEN CIRCUIT

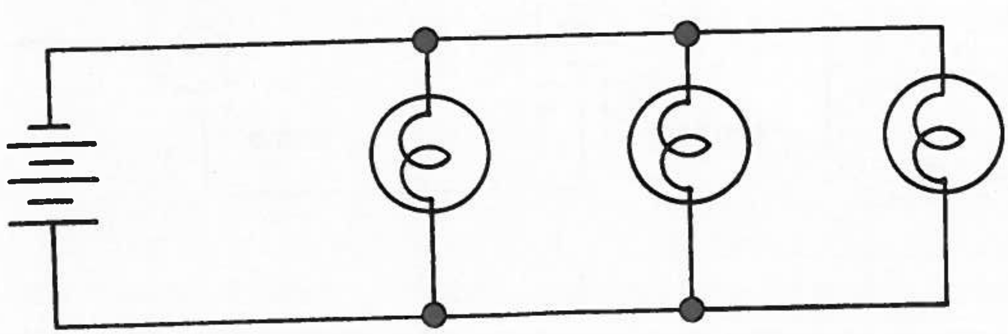
When the switch is closed, current flows from the positive side of the battery, through the switch and energizes the lamp as it returns to the negative battery terminal.



CLOSED CIRCUIT

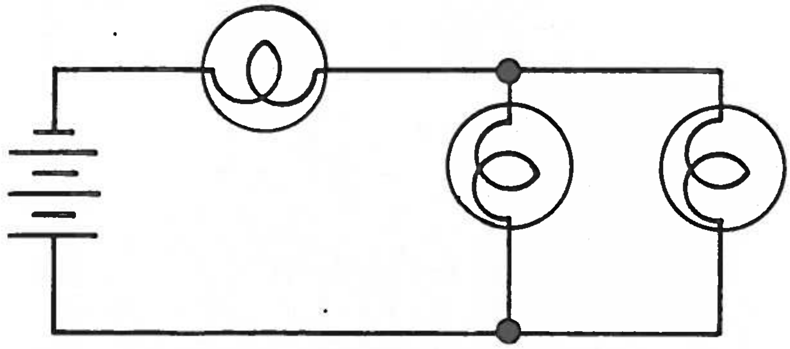
A "parallel" circuit arrangement consists of two or more different circuit "legs" connected to the same current source. This provides the circuit with additional paths for current flow.

PARALLEL CIRCUIT



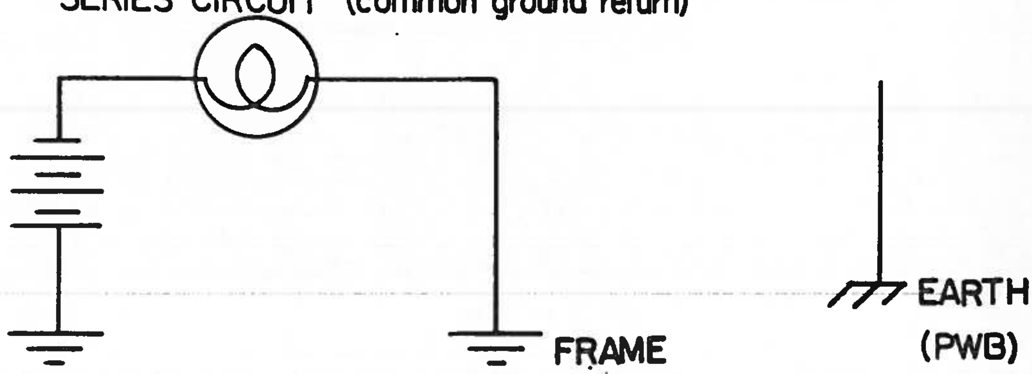
A "series-parallel" circuit has elements of both circuit arrangements. Some portions of the circuit are in parallel and this combination is in series with other circuit elements.

SERIES-PARALLEL CIRCUIT

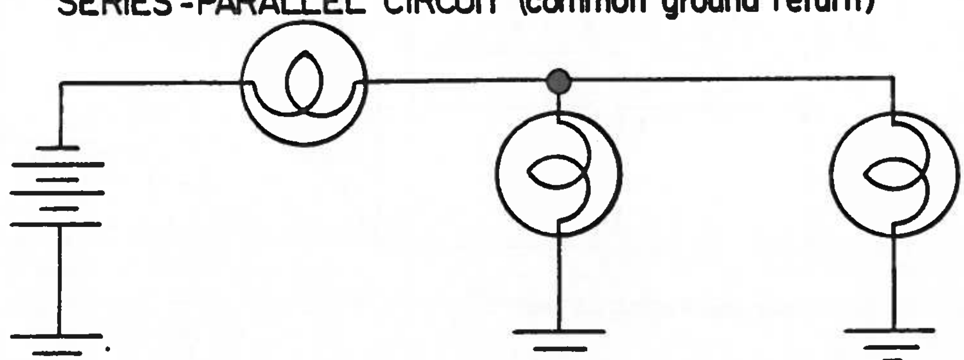


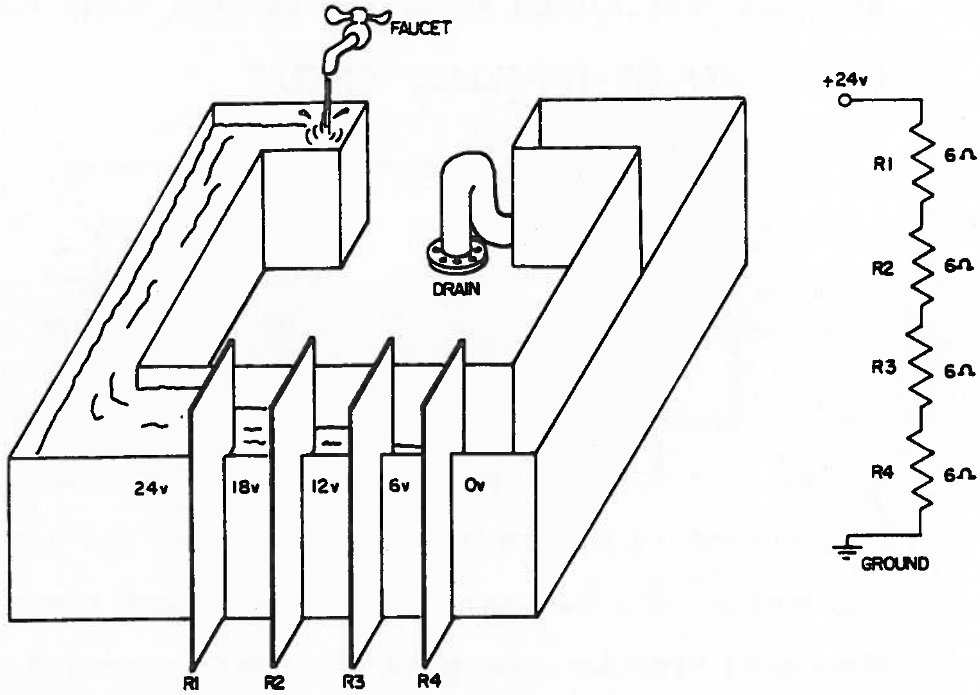
The term "ground" refers to points of equal (zero) potential or a common return path for one or more circuits. There are two symbols for ground; earth ground and frame ground. When both symbols appear on the same schematic, they represent two different points of reference.

SERIES CIRCUIT (common ground return)

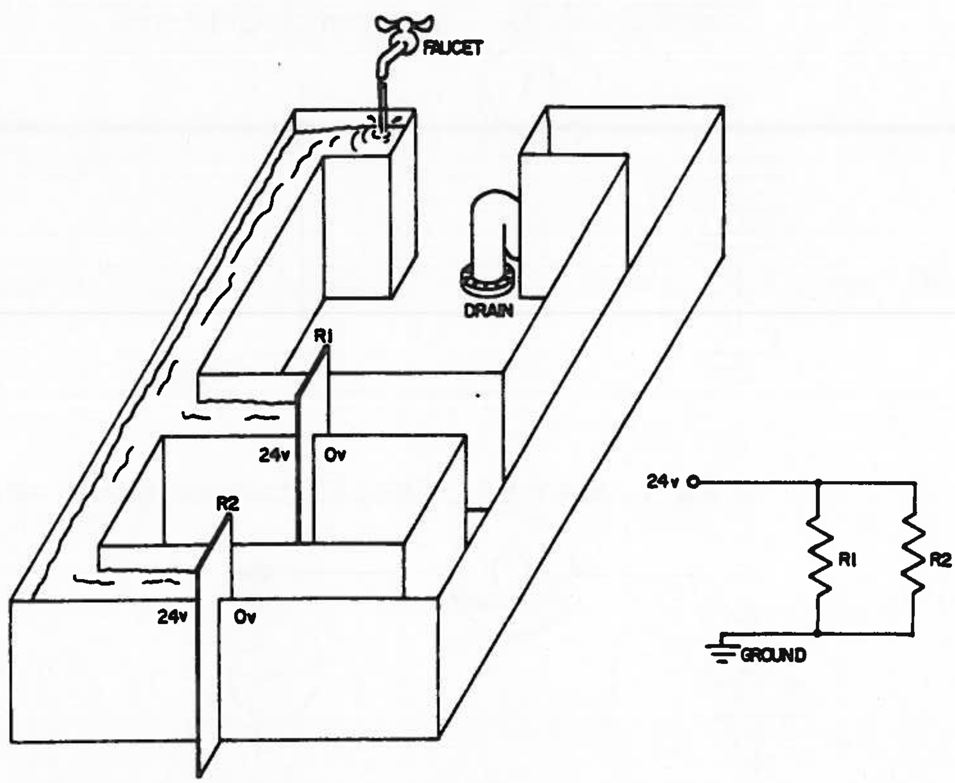


SERIES-PARALLEL CIRCUIT (common ground return)

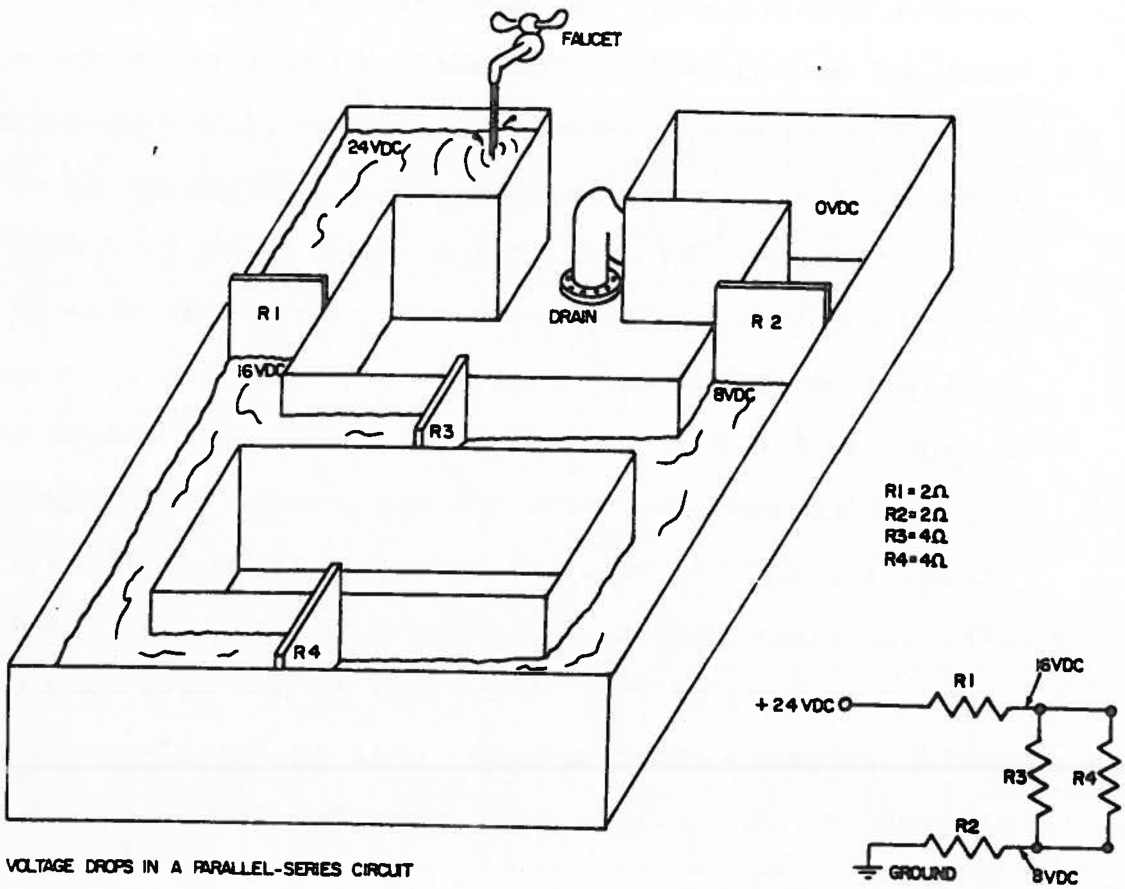




Voltage drops in a SERIES Circuit



Voltage drops in a PARALLEL circuit



VOLTAGE DROPS IN A PARALLEL-SERIES CIRCUIT

The VOM

The Volt-Ohm-Milliammeter (VOM) is an essential tool for troubleshooting. It is used for measuring AC voltages, amps, DC voltages, continuity, and resistance. There are two major types of volt-ohm-milliammeters (VOM's): analog and digital. Among the analog type, there are two sub-groups, classified by the type of meter movement (iron vane and moving coil). The most common type is the moving coil (d'arsonval) movement. Operation of the moving coil VOM relies on simple electromagnetic principles of attraction and repulsion. The coil of the meter is mounted on a pivot point (sometimes a jewel bearing). On either side of the coil are the permanent magnet pole pieces (they concentrate a magnetic field around the coil). The pole pieces are opposite polarities, one north and one south. When current is passed through the coil, it becomes an electromagnet, repelling the pole piece magnet, and causing the coil to turn on its pivot. As more current is applied to the coil, its magnetic field increases and causes the coil to turn farther. Attached to the coil is a pointer that swings across a calibrated scale.

MOVING COIL VOLTMETER