

**HOW ELECTRICITY IS
PRODUCED FOR ELECTRONICS**

2B

RADIO-TELEVISION-ELECTRONICS



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STUDY SCHEDULE NO. 2

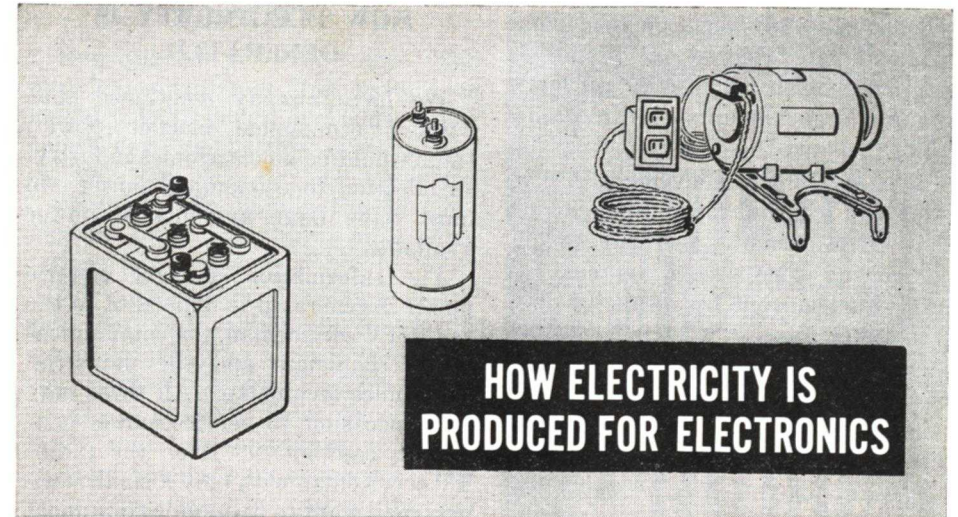
By dividing your study into the steps given below, you can get the most out of this part of your NRI Course in the shortest possible time. Check off each step when you finish it.

- 1. Introduction.....Pages 1-2
This gives a look at the whole field of electronics.
- 2. Batteries.....Pages 2-9
You study three types of batteries—dry cells, storage batteries, and mercury batteries.
- 3. Generators.....Pages 9-16
Both ac and dc generators are taken up here.
- 4. Electronics in Communications.....Pages 17-24
We look at radio and TV transmitters and receivers.
- 5. Electronics in Industry.....Pages 24-28
One of the important uses of electronics in industry is in changing ac to dc. This is done by means of rectifiers. You study both half-wave and full-wave rectifiers here.
- 6. Answer Lesson Questions.
- 7. Start Studying the Next Lesson.

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ELECTRONICS is a term you will be meeting constantly from now on. Let us take time to see what we mean by the word "electronics." Originally the term electronics was applied only to devices using electronic tubes. However, in recent years the meaning has been broadened to include the whole field of electron behavior. Thus we can consider every application of electricity as part of the general field of electronics.

You have already seen many uses of electronic principles. You see them every day, for example, in your radio and television receivers.

The field of electronics is a growing field. The chances are that at this very minute while you are reading this lesson, engineers are working on new projects that will result in some new use of electronics. They may be working on some method of using electronics to improve on some process we are already using, or they may be working on something that is entirely new, something we have been unable to do before. You can be sure that we are going to see many new developments in electronics in the years to come.

In this lesson you are going to study some of the uses of electronics. We will cover only a few of the details, but you will learn enough to be able to understand these uses of electronics. In addition to learning something about these processes, you will learn more about the behavior of the electron.

The first use of electronics that you will study is in the power industry. Although this is often not considered part of the electronics industry, it is extremely important to electronics, because without economical power there would be very little use of electronics at all. This brief look at the power industry will help you in your study of other pieces of electronic equipment.

You will also learn more about electronics in radio. You will study several new components, and also you will learn how sound is sent through space by means of radio waves. This section on radio is important, because the circuits you will study here are similar to ones you will find in radio, in television, and in other industrial applications.

You will also see how electronic principles are used in one branch of industry. Many industrial processes require large amounts of direct current.

It is much more convenient to generate and transmit alternating current than direct current. You will see how alternating current can be changed into direct current by means of electron tubes.

In studying the following sections of this lesson, it is important for you to understand the basic circuits and ideas presented. However, it is not important for you to remember all of the details of the various processes. These details will become more familiar to you as you go further in the course, because you will see these various processes used over and over again.

Make sure that you understand the basic circuits and ideas—these are important. If you do not understand these simple circuits and ideas, you will have difficulty in understanding those that are more complex in later lessons.

HOW ELECTRICITY IS GENERATED

We have already mentioned that without economical electric power, there would be no electronics industry. In addition to economical power, we must have large amounts of power available.

The information on how electric power is generated is important to the radio-TV serviceman, the communications technician, and the industrial electronics technician. All three may have occasion to service power-generating equipment. Even the radio-TV serviceman with only a small business may want to fix mobile equipment—there is more and more demand for people who can do repair work of this type—and in order to repair it he must be familiar with power-generating equipment.

There are two main sources of power in electronic equipment. One source that you have already studied briefly is batteries. You will now look into batteries in more detail, and then go on with the study of generators to see how they operate and how the voltage generated by them is pictured.

Batteries

There are two main types of batteries: Dry batteries and storage batteries. Dry batteries similar to flashlight cells are used in battery-operated portable receivers, small portable two-way radiophone equipment, and in many pieces of portable electronic equipment used in industry. Storage batteries are the main voltage sources for electronic equipment in airplanes, boats, and automobiles. Since there are many uses for batteries in electronics, understanding how batteries operate and what their limitations are

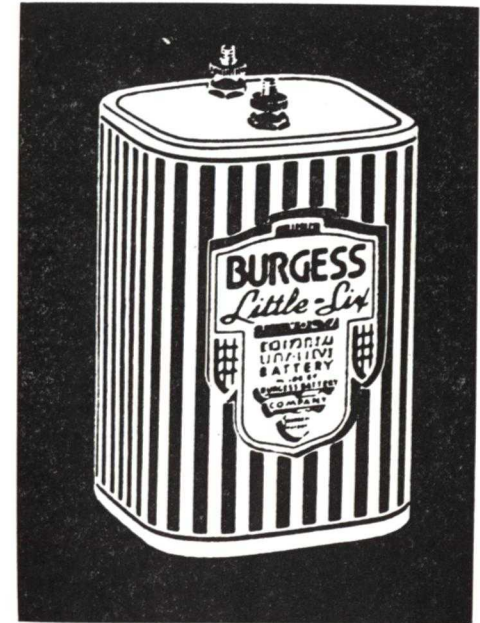
will be helpful to you in servicing battery-operated equipment. You will know when to look for trouble in the battery, and when to look for trouble in the equipment itself.

Batteries can be divided into two types, primary cells and secondary cells. Primary cells are cells that cannot be recharged. A flashlight battery is an example of this type of cell. A secondary cell is a cell that can be recharged. Storage batteries used in automobiles are made up of secondary cells.

DRY CELLS

Dry cells are not really dry. The chemical mixture in the battery is actually quite moist, and when it becomes dry, the battery is no longer usable. The name dry cell was given to these batteries because the chemical mixture was in the form of a paste rather than a liquid.

The construction of one type of dry cell that can supply current for a much longer time than a flashlight cell, is shown in Fig. 1. This cell is similar to a flashlight cell except it is larger and has screw-type terminals to which the leads are connected. The metal case and the carbon rod are often provided with screw terminals as shown here. Sometimes a plug type of connector is provided, instead. A cell of this type can provide a reasonably high current. One or more of these cells may be used to operate the filaments of the tubes in a portable receiver. The output voltage of this



Courtesy Burgess Battery Co.

FIG. 2. A square 1½-volt battery.

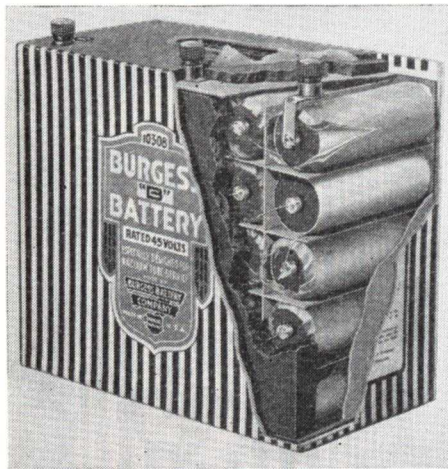


Courtesy National Carbon Co.

FIG. 1. Construction of a dry cell.

type of cell is 1½ volts, the same as that of a flashlight cell. Batteries used to operate the filament of a tube are called "A" batteries.

In addition to the round cell shown in Fig. 1, 1½-volt cells are often made square. A square cell can often be fitted into a somewhat smaller place than a round cell, and therefore is particularly useful in portable equipment. A square cell is shown in Fig. 2. It would be more correct to call a square cell a battery, because it is generally made up of four small round cells instead of one large cell. The negative terminals of all four cells are connected together and brought out to one common terminal which is the negative terminal of the battery. Similarly, the positive terminals of all four cells are connected together and brought to one common positive terminal. This type of connection is called a *parallel* connection and though there are four cells used, the



Courtesy Burgess Battery Co.

FIG. 3. A 45-volt B battery made of dry cells connected in series.

output voltage from the battery is only $1\frac{1}{2}$ volts, the same as it would be if only one large cell were used. The advantage of this type of construction is that the four cells in parallel can supply more current than a single cell could alone. This is because the current the cell can supply depends primarily on the area of the positive and negative electrodes—the carbon rod and the zinc case, and their area in a $1\frac{1}{2}$ -volt battery is greater when four cells are used in parallel than it would

be if one cell of the same physical size were used.

You already know that dry cells can be connected in series to provide more than the $1\frac{1}{2}$ volts available from a single cell. An example of this type of battery is shown in Fig. 3. This battery is designed to provide the voltage between the plate and the filament of the tubes in a battery-operated receiver and it is called a "B" battery.

The battery shown in Fig. 3 is made up of thirty $1\frac{1}{2}$ -volt cells connected in series as shown in Fig. 4. Notice that there are three terminals brought out of this battery. It is easy to see that the voltage between the two outside terminals should be 45 volts. There are thirty $1\frac{1}{2}$ -volt cells, and $30 \times 1\frac{1}{2}$ is 45. Now trace out the circuit between the negative terminal and the terminal marked $+22\frac{1}{2}$ and you will see how we get this voltage. You will find that there are fifteen cells connected between these two terminals, and $15 \times 1\frac{1}{2}$ is $22\frac{1}{2}$. Thus, if you need only $22\frac{1}{2}$ volts you would connect between the — terminal and the terminal marked $+22\frac{1}{2}$.

Now look at the other half of the battery. What is the voltage between the terminals marked $+22\frac{1}{2}$ and 45? By inspecting Fig. 4 you can see that there are fifteen cells connected between these two terminals. $15 \times 1\frac{1}{2}$ is $22\frac{1}{2}$, and therefore there should be $22\frac{1}{2}$ volts between these two terminals. But which terminal is positive and which is negative? By looking at Fig. 4 again, you can find the answer to this question. Notice that the terminal marked $+45$ is connected to the positive terminal of one of the cells, and the terminal marked $+22\frac{1}{2}$ is connected to the negative terminal of the last cell in the group of fifteen cells connected between these two terminals, and therefore this is the negative

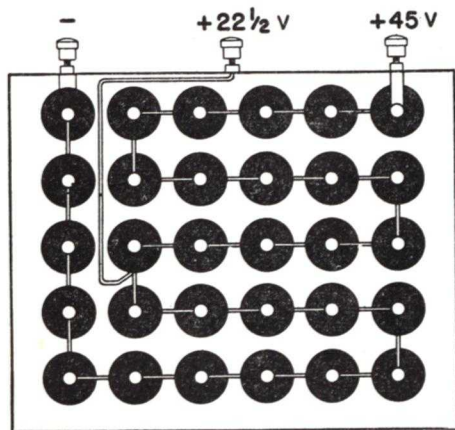


FIG. 4. How the dry cells in Fig. 3 are connected in series.

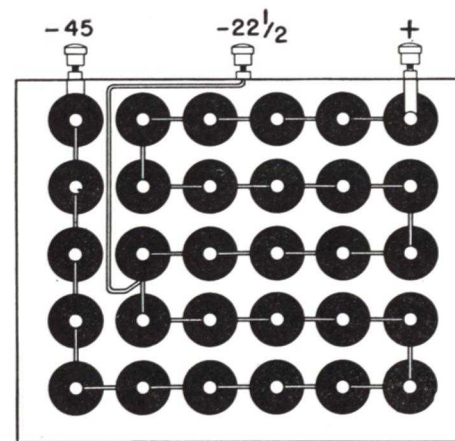


FIG. 5. The terminals of the 45-volt battery shown in Fig. 4 can be marked as shown above.

terminal, and the $+45$ terminal is the positive terminal.

It may seem somewhat confusing at first that the terminal marked $+22\frac{1}{2}$ can be both positive and negative. Let us see how this can be so. Starting with the negative terminal and looking towards the other two, you first see a group of fifteen cells and then a terminal. This terminal is positive compared to the negative terminal. We say it is positive *with respect to* the negative terminal. Then there is another group of fifteen cells and another terminal. This last terminal is even more positive with respect to the negative terminal. Now, if we started at the positive terminal and looked back through the battery we would see a group of fifteen cells and then a terminal. This terminal is negative with respect to the positive terminal. We would then see an additional group of fifteen cells and then another terminal, which is even more negative with respect to the positive terminal. We could, if we wished to do so, mark the battery like Fig. 5. Notice that this is the same battery as the one in Fig. 4, we have simply marked the terminals differently. The

voltage between the two outside terminals is still 45 volts, and the voltage between either outside terminal and the center terminal is $22\frac{1}{2}$ volts. In Fig. 4, we have considered the voltage at the negative terminal as zero and marked the other two positive with respect to it. In Fig. 5, we have considered the positive terminal as zero volts and marked the other two negative with respect to it. We could go one step further and mark the center terminal zero and the one outside terminal $-22\frac{1}{2}$ volts and the other $+22\frac{1}{2}$ volts with respect to the center terminal.

You might wonder why all these different ways of marking battery terminals. The reason is that in electronic equipment one terminal of a battery is usually connected to a common or ground terminal in the equipment. Sometimes this terminal is the positive terminal of the battery, sometimes it is the negative terminal. It all depends on what the battery is to be used for. Usually the terminal voltages are marked with respect to the terminal that will be grounded in normal operation. You might wonder what we mean by a ground terminal or connection. In the early days of radio almost all radios were connected by a wire to a water pipe or to a pipe driven into the ground, to improve reception. This was called a "ground" lead. One terminal of the "A" battery, the negative terminal of the "B" battery and the positive terminal of the "C" battery were all connected to the metal chassis on which the receiver was built, and the metal chassis was connected to the ground lead.

Now, the chassis in electronic equipment is called a chassis ground even though it may not be connected to an external ground connection at all. The negative side or terminal of the B supply is called B— ground or the common ground. In some equipment B—

is connected to the chassis, but in other equipment it is not. When B- is connected to the chassis, we refer to B- and the chassis both as *ground*. When B- is not connected to the chassis, we refer to the chassis as a *chassis ground* and to B- as a *floating ground*. You will see these three expressions used frequently.

It is important for you to understand how one terminal can be both positive and negative at the same time. It simply means that one terminal might be positive when it is compared to another terminal, but negative when compared to a third. You will run into this situation over and over again.

Although a B battery is able to supply a much higher voltage than a single cell, the amount of current that can be taken from it is somewhat limited. If a B battery is used to supply a high current, it will soon be exhausted.

When you need a higher current than can be supplied by a single cell or battery, you can obtain it by connecting two or more batteries in parallel. When you connect two batteries in parallel, you connect the two negative terminals together and the two positive terminals together as shown in Fig. 6. This is the same type of connection that is used in the battery shown in Fig. 2, where the 1½-volt battery was made from four cells connected in parallel. Of course, you can

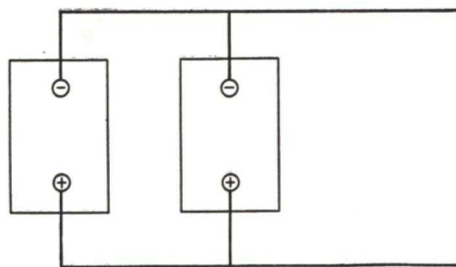


FIG. 6. Two batteries having the same voltage can be connected in parallel if a high current is required.

only do this if the batteries have the same voltage. When two similar batteries that are connected in parallel are connected to a circuit, each battery will supply approximately one-half of the current used in the circuit. This is more economical than taking the full current from one until it is exhausted and then taking the full current from another, because the batteries connected in parallel will usually last more than twice as long as a single battery.

There are two big disadvantages to the dry cell. It has a fairly short shelf life and a rather large cell is required to supply a moderate current. The shelf life of a cell is the length of time it can be kept after it is made before it deteriorates to such an extent that its life is affected appreciably. When we say a dry cell has a short shelf life we mean that it cannot be kept too long before it is put into service, otherwise it will not last long.

MERCURY CELLS

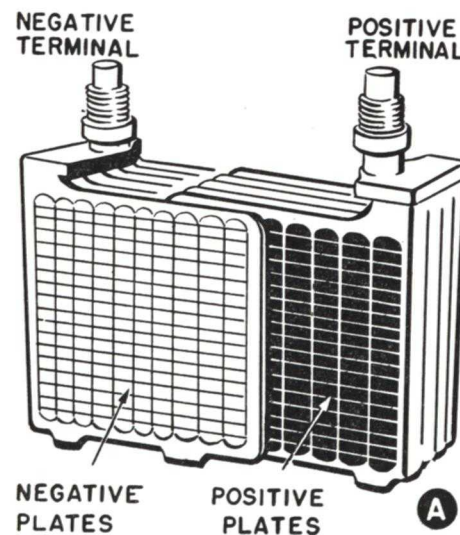
A cell that overcomes these two disadvantages of the dry cell is the mercury cell. This cell is also called a "Ruben-Mallory" cell, after the designer and manufacturer, or simply an RM cell. The voltage supplied by one of these cells is about 1.34 volts. The mercury cell can be made quite small, and one the size of a standard flashlight cell would be capable of supplying current for a much longer time than a flashlight cell. A photo of a mercury battery that contains three cells connected in series to give a voltage of about 4 volts is shown in Fig. 7. This battery is slightly smaller than the flashlight cell.

Mercury cells were originally developed for use by the armed forces, but they are now found in many pieces of portable equipment manufactured for civilian use. Their small size and long



Courtesy P. R. Mallory & Co., Inc.

FIG. 7. The mercury battery shown above is slightly smaller than a standard flashlight cell, but produces a higher voltage, and has a longer life than the flashlight cell.



Courtesy Electric Storage Battery Co.

FIG. 8. Construction of a storage battery.

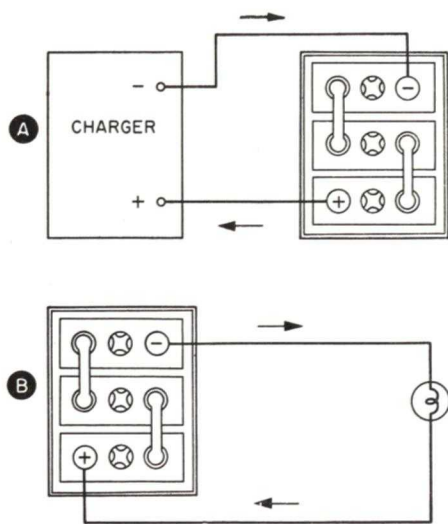


FIG. 9. A shows the direction current will flow when a storage battery is being charged. B shows the direction current will flow when the battery is supplying current.

rubber. The separators prevent the plates from touching each other and destroying the cell. One of the sets of plates is treated chemically to form an oxide of lead (a combination of lead and oxygen) and the two sets of plates with the separators between them are then placed in a container filled with a solution of sulphuric acid and water. The voltage of this type of cell is approximately 2 volts. Storage batteries used in automobiles are usually made of either three cells or six cells connected in series so that the output voltage from the battery is either 6 volts or 12 volts. A three-cell battery is shown in Fig. 8B.

Storage batteries used in aircraft usually have twelve cells connected in series so the output voltage is 24 volts.

To charge this type of battery the battery is connected to a battery charger which is simply a dc voltage source that has a voltage slightly higher than the battery voltage. The

charger forces current through the battery as shown in Fig. 9A. This current causes a chemical change in the battery, and the electrical energy put into the battery is stored in it in the form of chemical energy. When the battery is connected to a circuit, the energy stored in the battery is released by the chemical action of the battery and current will flow in the circuit as shown in Fig. 9B. Notice the direction of current in Figs. 9A and 9B. When the battery is being charged, the current is forced through the battery in the opposite direction to which it flows when the battery is supplying current. The storage battery can supply current for a much longer time than the average dry cell. When a storage battery is discharged and is no longer able to supply the current required by the circuit, the battery can be removed from the circuit and recharged by passing current through it in the opposite direction. Once the battery has been recharged, it can again be connected to the circuit and will supply current to the circuit.

In an automobile, the battery is usually connected to a generator. As long as the car is running at a reasonable speed, the generator is both charging the battery and supplying the current needed to operate the car. However, when the car is operating at a slow speed or when it is stopped, the generator is not turning fast enough to provide the electricity needed by the car, and the battery supplies this energy.

Small single-cell storage batteries having an output voltage of 2 volts are found in some radio receivers designed to operate either from a power line or as portables. These batteries are arranged in the set so that when the receiver is operated from the power line, the battery can be charged while the receiver is operating. When the receiver is operated as a portable, the

power plug can be removed from the power outlet, and then the storage battery will supply the power needed to operate the receiver. This type of

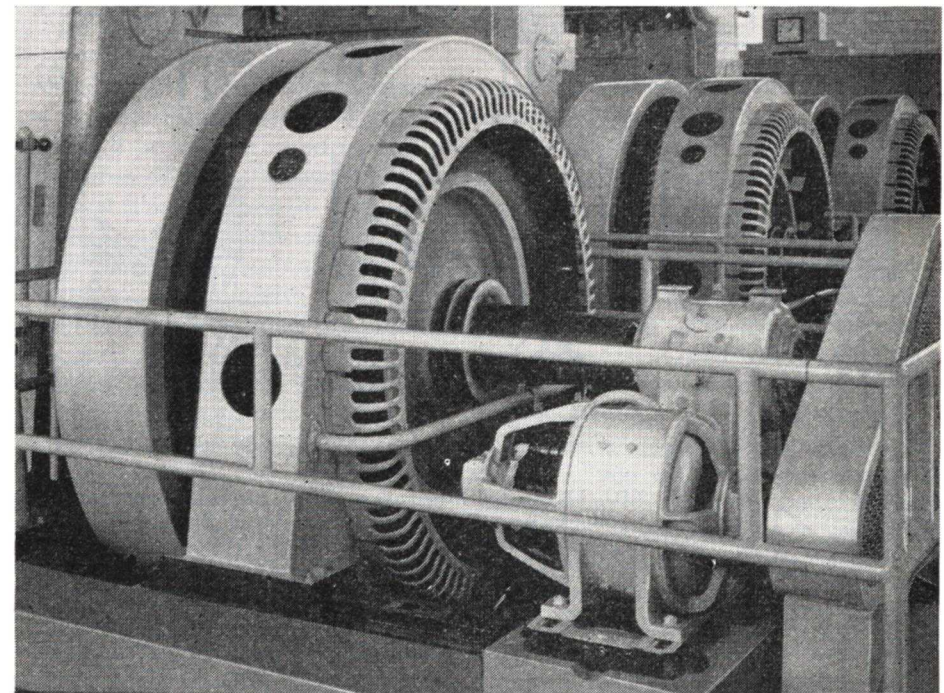
portable receiver has the advantage over the type using dry cells in that the storage battery will usually last much longer than the dry cells.

Generators

Although batteries are very useful, their ability to supply large amounts of power is limited. If a battery, even a storage battery, is called upon to supply large amounts of current, it will soon be exhausted and must be removed from the circuit and recharged. Even if storage batteries could supply the large amounts of electricity consumed daily by the average large city, we would still have to have some way of recharging the batteries. Thus, we have a need for a device other than a battery that is capable

of supplying large amounts of electricity.

You already know that if the magnetic field cutting through a coil is varied, a voltage will be induced in the coil. If the magnetic field is made to vary rapidly enough, the voltage will be induced continuously in the coil; this voltage can be connected to an outside circuit, and current will flow through the circuit. This is the principle that is used in electric power generators.



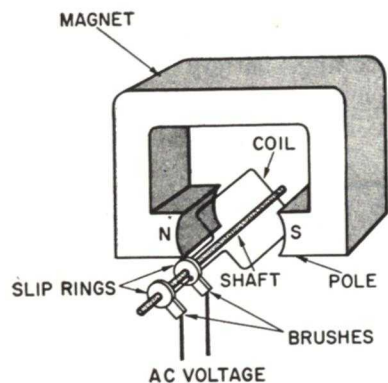


FIG. 10. A simple ac generator.

A SIMPLE GENERATOR

A simple generator capable of generating electric power can be built

as shown in Fig. 10. This generator consists of a single-turn coil placed between the poles of a magnet. As the coil is rotated, it will cut through the magnetic lines of force flowing from the north pole to the south pole of the magnet, and a voltage will be induced in the coil. The amount of voltage will depend upon the number of magnetic lines being cut by the coil as it rotates. This in turn will depend upon the strength of the magnetic field and upon the speed at which the coil is rotated.

First, let us consider the voltage that will be produced by a generator of this type. When the coil is in the position shown in Fig. 11A, the movement of the coil is parallel to the

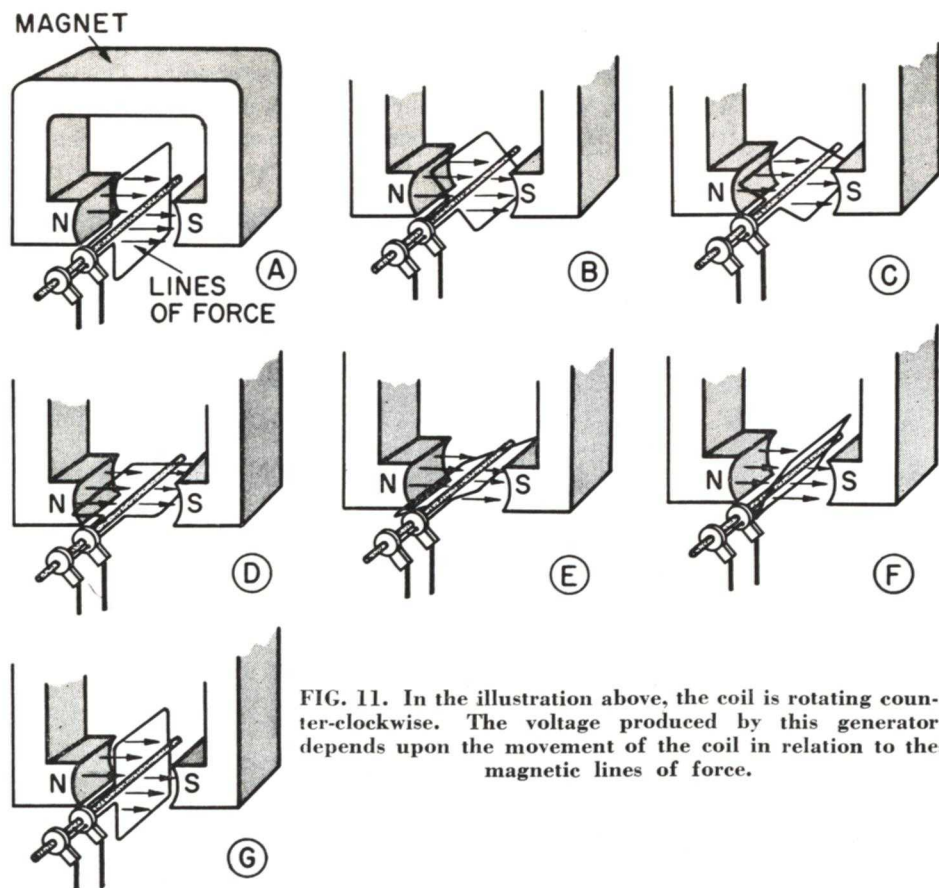


FIG. 11. In the illustration above, the coil is rotating counter-clockwise. The voltage produced by this generator depends upon the movement of the coil in relation to the magnetic lines of force.

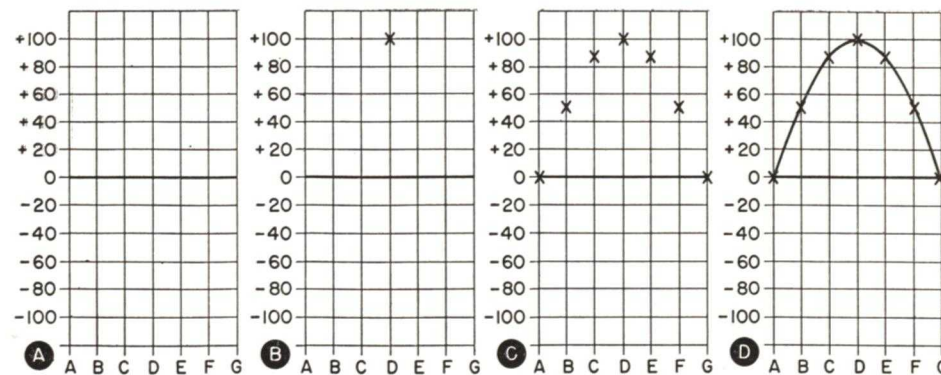


FIG. 12. Construction of a graph of the voltage produced by the generator in Fig. 11.

lines of force flowing from the north pole to the south pole of the magnet. They are moving along the lines of force and are not cutting through any of the lines of force. You will remember that in order to induce a voltage in a coil, the turns of the coil must be cut by magnetic lines of force. In Fig. 11A the coil is moving along the lines of force and not cutting through them and there will be no voltage induced in the coil when the coil is in this position.

When the coil moves counter-clockwise to the position shown in Fig. 11B, it will still be moving almost parallel to the lines of force. However, it is moving at a small angle to these lines of force and therefore it will cut through some of them and there will be some voltage induced in the coil. When the coil moves down to the position shown in Fig. 11C, it will be cutting more lines of force because it is moving at a sharper angle to them and a somewhat higher voltage will be induced in the coil. Finally when it reaches position 11D, it will be moving directly perpendicular to the lines of force and will be cutting through them at maximum speed, and the voltage induced in the coil will reach its highest value. As the coil moves down to positions 11E and 11F, it will be cut-

ting fewer and fewer lines of force until it finally reaches position 11G, and once again the coil will be running parallel to the lines of force and no voltage will be induced in the coil.

HOW VOLTAGES ARE PICTURED

You will remember that when we discussed the batteries shown in Figs. 4 and 5 we said that one terminal of the battery could be considered as zero voltage and the voltage at the other terminals marked in reference to this terminal. You can do the same thing with a generator. You can use one lead as the ground or common lead and measure the voltage at the other lead as either positive or negative with respect to the common lead.

If we assume that one lead is a common or ground lead, we can conveniently represent the voltage at the other lead by a graph. A graph is merely a simple way of presenting information in the form of a picture. In Fig. 12A, you will notice a horizontal line running through the center of the graph, which is marked zero. This is the zero voltage line which represents the voltage of the ground or common lead. The horizontal lines above this line represent positive voltages, and the lines below the zero line represent

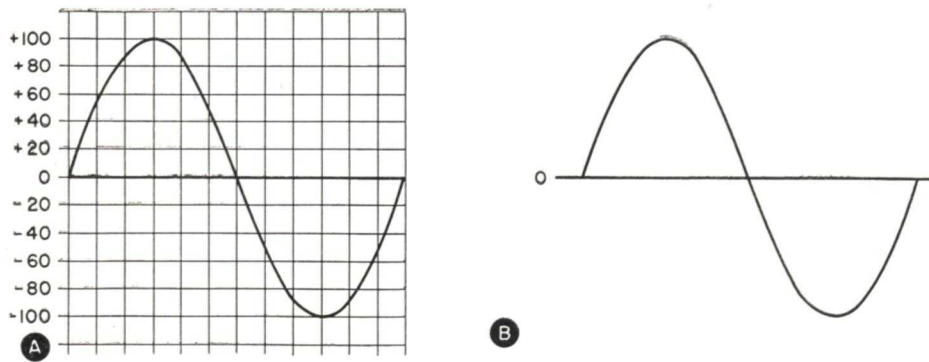


FIG. 13. The appearance of the output voltage produced by the generator as it travels through one complete turn.

negative voltages. The vertical lines represent the positions of the generator shown in Fig. 11.

Let us assume that at the instant the coil is in the position shown in Fig. 11D the voltage generated is 100 volts. If the voltage is 100 volts positive with respect to the common terminal, we would place a mark (X) on the graph at the point where the +100 volt line crosses the vertical line running through D, as shown in Fig. 12B. Similarly the voltages that are present at the remaining points would be marked on the graph. This would look like Fig. 12C. The only step left is to draw a smooth curve joining all these points and we have a curve like Fig. 12D, which represents the voltage generated by the generator through one half turn.

When the coil is rotated through the remaining half turn, the polarity of the voltage produced will be reversed. In other words, the voltage will now be negative with respect to the ground terminal because the coil will now be cutting through the magnetic lines of force in the opposite direction. If we complete the drawing to show what the voltage will look like during the other half turn, the picture would look like Fig. 13A. For convenience, if we

leave the horizontal and vertical lines of the graph off, we can get a better look at the shape or appearance of the output voltage as in Fig. 13B. This is called a waveform.

This is how the ac voltage supplied by the power company may be represented. It is called a *sine* (pronounced sign) wave. It is often abbreviated sinwave.

The voltage represented by one complete turn of the coil in the magnetic field is called a cycle. The power supplied by most power companies in this country is 60-cycle power. When we say 60-cycle, we mean 60 cycles per second. By this we mean that the voltage goes through 60 cycles like the one shown in Fig. 13 in each second. This is called the "frequency" of the ac voltage. To make the generator we have shown produce this type of voltage, it would have to be turned at a speed of 60 revolutions per second, which is 3600 revolutions per minute. The part of the cycle above the line is called a half-cycle, and it is referred to as the positive half-cycle. The part of the cycle below the line is also called a half-cycle, and it is referred to as the negative half-cycle.

The voltage generated by this generator with only a single-turn coil

would be extremely low, even with a very strong magnetic field. However, we can obtain a higher voltage simply by putting more turns of wire on the coil. Ten times as much voltage would be induced in a ten-turn coil as in a single-turn coil. If one-tenth of a volt is induced in a single-turn coil, one-tenth of a volt will be induced in each turn of the ten-turn coil. These voltages will be induced in series with each other so that the total voltage available at the output terminals of the coil will be 1 volt. By putting 100 turns on the coil, we could get 10 volts and by putting 1000 turns on the coil, we could get 100 volts.

Thus, by putting the proper number of turns on the coils of a generator we can generate any voltage we may require.

DC GENERATORS

A practical generator, instead of using a permanent magnet such as we have shown in Fig. 10, would use an electromagnet to supply the magnetic field needed by the generator. The current required to operate this electromagnet can be obtained either from the generator itself or from another generator. However, we must have dc. The voltage generated by the generator we have discussed is ac. Now let us look into the generator

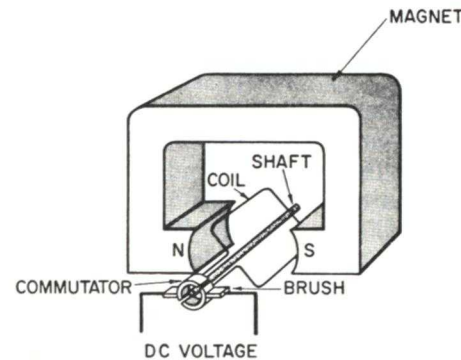


FIG. 14. A simple dc generator.

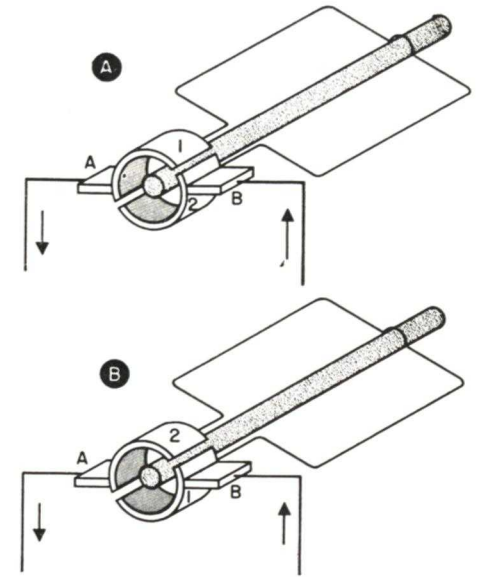


FIG. 15. In A, section 1 of the commutator is negative, and section 2 is positive. In B, section 1 is positive, and section 2 is negative. This means that brush A is always connected to the negative section of the commutator and brush B to the positive section, and current flows in only one direction.

further and see how we can obtain dc instead of ac.

In an ac generator such as we have described, the ends of the coils are connected to slip-rings. By means of contacts riding on the slip-rings, called "brushes," we could take the ac voltage off the generator. However, if, instead of using two slip-rings, we use a commutator as shown in Fig. 14, we can obtain dc. A commutator is similar to a slip-ring except that it is split in half and the two halves are insulated from each other. The brushes are placed so that when the coil is going through the first half revolution, one brush will be connected to one section of the generator, and the other brush will be connected to the other section. When a coil starts to go through the second half revolution, the brushes will be connected

to the opposite section; the one that was connected to the first section will then be connected to the second section, and the one that was connected to the second section will then be connected to the first section and current will always flow through the external circuit in the same direction, as shown in Fig. 15. As a result, at the output, we will have a voltage like that shown in Fig. 16. Here we have essentially the same wave shape as we had in Fig. 13, except that the half of the cycle that previously was negative and drawn below the line has now been reversed by the automatic reversing of the connections to the coil performed by the commutator and brushes.

A voltage like that shown in Fig. 16 is called *pulsating* dc. It is dc inasmuch as the current that flows as a result of this voltage will always flow in one direction. However, since the voltage varies, the current varies; it will flow in pulses and actually drop to zero twice through each revolution of the coil. This can be used in some applications, but it is not what we call *pure* dc, like the dc supplied by a battery.

As in the case of the ac generator, the output voltage from a dc generator with only a single turn would be extremely low—too low to be usable. However, by winding several turns on the coil, a higher voltage can be obtained. This will still provide a pulsating type of dc like that shown in Fig. 16.



FIG. 16. Output of a simple dc generator.

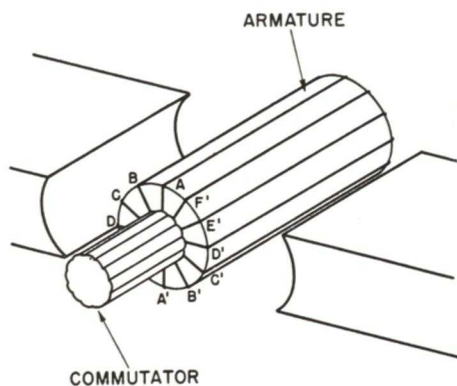


FIG. 17. The armature of a dc generator with 6 series-connected coils.

A better arrangement is shown in Fig. 17. Here, there are a number of coils on an iron form called an "armature." The coils are in different positions around the armature. In the position shown, coil A-A1 will not cut any lines of force and therefore there will be no voltage induced in it. The coil B-B1, however, is cutting a few lines of force and some voltage will be induced in it. Coil C-C1 is cutting still more lines of force and a somewhat higher voltage will be induced, and coil D-D1 is cutting directly across the lines of force and the maximum voltage will be induced in it. These coils are all connected in series and brought out to connections on the commutator. Two brushes are used on the generator, and the output voltage from this type of machine will be nearly constant. This is because there will always be one coil either in or close to each position shown in Fig. 17. The voltage produced by the generator will be the voltage of all the coils in series. While some of the coils are producing very little voltage, the coils near the position D-D1 will produce considerable voltage. The commutator used with this type of generator would have twelve sections instead of two as in the case

of the generator with only one coil. There will be some fluctuation in the voltage so that the output voltage will look like Fig. 18 as the generator goes through one revolution. Notice, that with this type of generator, instead of two big half cycles an almost constant value of dc is obtained.

AC VALUES

Now, look back at the ac cycle shown in Fig. 13. Notice that at the start of the cycle the voltage is 0. When the coil has rotated through one quarter of a turn, the voltage has built up to a maximum value; when the coil has gone through one-half a turn, the voltage is back to zero again. At three-quarters of a turn, the voltage has reached a maximum value with the opposite polarity and finally

DC 

FIG. 18. Only a small ripple will be noticeable in the output of a dc generator having 6 coils and 12 commutator sections.

at the end of the cycle, the voltage is back to zero. The end of this cycle is actually the start of the next cycle. The voltage reaches a maximum value twice in each cycle, and it drops to zero twice in each cycle.

Let us see how we measure ac. When we talk about a dc current and we say that the current flowing in the circuit is 1 amp, we mean that a certain number of electrons are flowing past a given point in the circuit. This same number of electrons continues to flow as long as the current in the circuit is 1 amp. However, what happens when we're talking about ac? Since the voltage reaches a maximum

twice each cycle and falls to zero twice each cycle, the current must also have two maximums in each cycle and fall to zero twice each cycle. Therefore, the number of electrons flowing in the circuit is not constant; in fact it is continually changing as the ac voltage goes through its cycle.

To overcome this difficulty, we measure ac in terms of equivalent dc. When we say that the ac current flowing in the circuit is 1 amp, we mean that the current is the equivalent of 1 amp of dc. In other words, if a dc current of 1 amp flows through a heating element such as found in an electric iron or toaster, a certain amount of heat will be produced. When the ac current flowing through the same heating element produces the same amount of heat, we say that the ac current is 1 amp.

The same system is used to measure ac voltage. If a dc voltage of 100 volts is required to force the current of 1 ampere through a circuit made up of a resistance, the ac voltage that will force an ac current of 1 amp through the same resistance is said to be 100 volts. This is called the *effective* voltage and it will cause an ac current to flow that will produce the same heating effect as the equivalent amount of direct current.

From looking at an ac voltage cycle, it is quite obvious that the voltage must be greater than the effective value during part of the cycle and less than the effective value during the remainder of the cycle. The maximum value that the ac voltage reaches during a half cycle is called the *peak* voltage. The peak voltage is approximately 1.4 times the effective voltage. Each peak is 1.4 times the effective voltage, and the voltage between the two peaks will be 2.8 times the effective voltage. This voltage is called the *peak-to-peak* voltage. Fig. 19 shows an ac voltage of 100 volts.

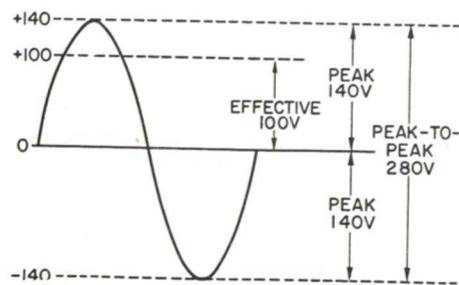


FIG. 19. AC waveform showing effective, peak, and peak-to-peak voltages.

The peak value is 140 volts, and the peak-to-peak value 280 volts. Study this figure to be sure you understand what these terms mean.

It's important to remember when we are talking about ac voltages that unless we specifically refer to the peak or peak-to-peak voltages, we are talking about effective voltages—in other words the ac voltages that will produce the same effect as the equivalent dc voltage. Also remember that the peak or greatest voltage reached during a half cycle will be 1.4 times as great as the effective voltage, and that the peak-to-peak voltage will be 2.8 times the effective voltage. You will run into the terms peak voltage and peak-to-peak voltage as well as the expression effective voltage many times during your career in electronics. Knowing the peak value of an ac voltage is often very important.

A good example of how high the peak voltage may be in a circuit is the voltage supplied in most homes in this country. The average power company supplies a voltage somewhere between 115 and 120-volt, 60-cycle ac for lighting and general domestic uses. This is the effective value of the voltage. Let us assume that voltage supplied your home is exactly 120 volts. What is the peak voltage reached during each half cycle? It will be 1.4×120 , which is 168 volts. In other words, twice during each cycle the

actual voltage between the two power leads connected to each electric light and appliance in your home reaches a value of 168 volts. Twice during each cycle the voltage also drops to zero. The net effect of this ac voltage is the same as supplying a dc voltage of 120 volts to the electric lights. The peak-to-peak voltage supplied to your home will be 2.8×120 volts or 336 volts!

THE IMPORTANCE OF AC

You may wonder why we have gone into so much detail in describing alternating current. AC is important, not only because it is the type of power supplied by the power companies, but also because ac signals are used throughout the whole electronics industry. The sound that comes from the loudspeaker in your radio or your television receiver, and the sound from your telephone are produced by ac signals having a frequency not too much higher than the power line frequency. The radio waves that travel through space are actually ac signals of a much higher frequency. Signals used in many industrial applications are ac signals.

SUMMARY

We have covered a great deal of material in the preceding sections. There are several important things that you should remember. First, remember what an ac cycle looks like. Remember that this ac voltage is called a sine wave.

Remember that when we speak of ac voltage and current we are speaking of the voltage and current that will produce the same effect as the equivalent values of dc. Remember that the peak value of the ac cycle is 1.4 times the effective value, and the peak-to-peak value will be 2.8 times the effective value.

Electronics in Communications

Radio waves are sine waves like the one shown in Fig. 13. They are similar to 60-cycle ac power waves. The only difference is in the frequency of radio waves. The lowest frequency radio waves have a frequency of about 15,000 cycles per second. The standard radio broadcast stations operate on frequencies between 550,000 cycles and approximately 1,700,000 cycles. This group of frequencies is called a *band*; in this case, the broadcast band. The word band when it is used this way means nothing other than a group of frequencies.

Needless to say, ac signals of such high frequencies cannot be generated by means of mechanical generators such as are used to produce 60-cycle power voltages and current. These signals must be generated by devices such as ac vacuum tubes.

The frequency of radio signals is usually expressed in kilocycles or megacycles rather than cycles. A kilocycle is 1000 cycles. A megacycle is 1,000,000 cycles. Thus there are 1000 kilocycles in a megacycle. The standard broadcast band is 550 kilocycles to 1700 kilocycles. This can also be expressed .55 megacycle to 1.7 megacycles. Kilocycles are abbreviated kc, and megacycles, mc. We will use these abbreviations from this point on.

Now let's look at some parts of a radio system. We will briefly describe a radio transmitter and a radio receiver. Let's look at the transmitter first.

THE RADIO TRANSMITTER

Radio transmitters are actually made up of a number of sections, each designed to do a specific job. Let's discuss some of the more important sections of a typical transmitter.

The sound signal to be transmitted starts in the microphone. A microphone is a fairly simple device. There are a number of different types of microphones in use; however, we will look at one of the simpler types. Before we discuss the microphone let's learn a little about sound.

Sound is a vibration set up in air or some other medium. When you strike a key on a piano, the key is connected to a hammer, which strikes a string that is tightly stretched on a frame. The string begins to vibrate and sets the air surrounding it into vibration. The frequency at which the string vibrates will determine the tone that your ear hears. Similarly, when we speak, the speech muscles in our throat set the air in our throat into vibration. This vibration is projected from our mouths and noses, and the vibration travels through the air. However, instead of producing a single frequency, our voices are actually quite complex and may produce vibrations of many frequencies, causing the different tones by which we can distinguish the voice of one person from that of another.

Microphones. A simple microphone is shown in Fig. 20. The microphone consists of a flat metal disc called a diaphragm. Fastened to the diaphragm is a small light coil form on which a coil is wound. The coil is placed between the poles of a permanent magnet. When you speak in front of the microphone, your voice sets the air into vibration. The vibrating air will cause the diaphragm to vibrate. Since the diaphragm is connected to the coil, the coil will vibrate between the poles of the magnet. Now, you already know what will happen when a coil is moved in a magnetic field. The turns of wire

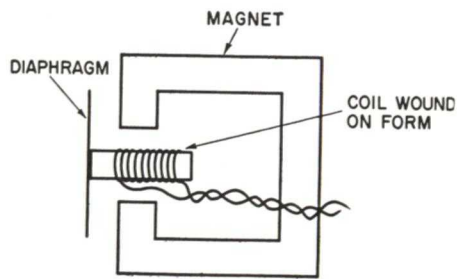


FIG. 20. A simple dynamic microphone.

on the coil will cut through the magnetic lines of force, and a voltage will be induced in the coil. If this coil is connected to an external circuit, there will be a current flow through the circuit. The frequency of the current flowing will depend upon the frequency at which the diaphragm and coil vibrate. This in turn will depend upon the frequency at which the air is vibrating, which in turn depends upon the vibrations set up by the vocal muscles in the throat of the person speaking in front of the microphone.

This electrical signal produced by the microphone is called an *audio signal* or *audio voltage*. The word audio is used to designate electrical signals in the frequency range of sound. An audio voltage or signal is the electrical equivalent of sound.

An Audio Amplifier. In a typical transmitter the microphone may be connected to the primary of a transformer. This transformer is called a *microphone transformer* or more simply a "mike" transformer. When the sound waves striking the disc cause the coil to vibrate, an audio voltage is induced in the coil; the audio voltage produced will cause an audio current to flow through the primary of the transformer. The transformer is usually a *step-up* transformer—in other words, there are more turns on the secondary than on

the primary. The voltage appearing across the secondary winding will therefore be higher than the voltage applied to the primary.

The audio voltage across the secondary of the microphone transformer is then applied between the grid and the cathode of a vacuum tube. The vacuum tube will amplify the signal so that a much stronger signal will appear in the plate circuit of the tube. The amplified signal will be just like the signal generated by the microphone, but it will be stronger. The tube along with its associated parts is called a *stage*. A stage used to amplify an audio signal is called an *audio stage*.

In a typical transmitter, the audio signal produced by the microphone will be amplified by a number of vacuum tube amplifier stages in order to build up the strength of the signal until it is hundreds of times stronger than the original signal produced by the microphone. However, the amplified signal will have exactly the same frequency and other characteristics as the original signal produced by the microphone.

The microphone and the audio amplifiers in a transmitter are called the *audio section*. This is abbreviated af (audio frequency) section. Another important section of the transmitter is the radio frequency section—this is abbreviated *rf section*.

The RF Section. The rf section of a transmitter is made up of a number of separate stages. The first stage is the stage that actually generates the radio frequency signal. This stage is called the *oscillator stage*. The oscillator stage is carefully designed to produce a signal of the desired frequency. The signal from the oscillator stage is then amplified by additional stages which are called rf *power amplifier stages*. These stages

build up the strength of the radio-frequency signals generated by the oscillator so that the signals will be strong enough to travel through space from the transmitter to the receiver.

In one of the radio frequency stages of the transmitter, the audio signal is superimposed on the radio-frequency signal. This is called *modulation*. The audio signal is the *modulation* signal and the rf signal is the *modulated* signal.

In some transmitters the modulated signal is then fed directly to the antenna, but in others it is amplified further and then fed to the antenna. In Fig. 21 we have shown what a number of signals would look like on a cathode ray oscilloscope. The oscilloscope, which is called a *scope*, is an instrument with a tube something like a TV picture tube in it. With this type of instrument you can see what type of waveform you have in a circuit.

In Fig. 21A a typical audio signal is shown. This is the type of signal that might be produced by someone speaking into a microphone. In Fig. 21B we have shown a radio frequency signal. Notice that the frequency of the radio frequency signal is much higher than that of the audio signal. In Fig. 21C we have shown a radio frequency signal that has been *amplitude-modulated* by the audio signal.

The term *amplitude-modulated* means that the *strength* or amplitude of the radio frequency signal is varied by the audio signal. Notice that the amplitude or height of the radio frequency signal varies as the audio signal varies. When the audio signal reaches a peak, the amplitude of the modulated rf signal is a maximum and when the audio signal reaches a minimum, the amplitude of the modulated rf signal is also a minimum.

The modulated rf signal from the transmitter is fed through a cable or wire called a transmission line to the antenna. The transmission line is something like the power lines that are used to bring the power from the power-generating station to your home. They simply carry the power from the transmitter to the antenna.

The antenna at a radio station is simply a length of wire or a tower to which the transmission line is connected. When the radio frequency signal is fed to the antenna the rf signal sets up a current flow in the antenna which produces a magnetic field and an electric field surrounding the antenna. These fields travel out in space from the antenna and carry the signal from the transmitting antenna to the receiving antenna.

A simplified diagram of a radio transmitting system is shown in Fig.

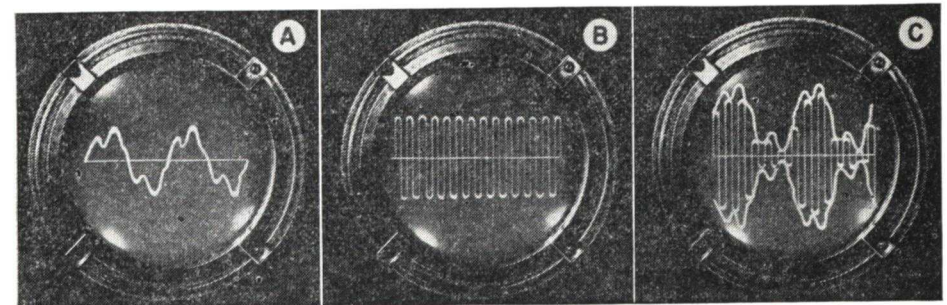


FIG. 21. The audio voltage at A and the rf carrier at B are combined to give the amplitude-modulated carrier at C.

22. This type of diagram is called a block diagram. It is a simpler way of representing the various stages or sections of a piece of electronic equipment than showing the complete schematic diagram. We will use this type of diagram frequently, because it enables us to give an over-all picture of the various stages of a piece of electronic equipment without going into all the details of the circuitry. You will find later that the circuits used in the various stages follow certain basic patterns so that there is not too much difference in the circuits used in individual stages, the difference is in the manner in which the stages are used.

Notice that the sound signal is generated by a microphone and fed to the audio amplifier stages. At the same time the rf signal is generated by an oscillator and amplified by rf power amplifier stages. In the third rf stage the rf signal is modulated by the audio signal and then the modulated signal is amplified by the last stage in the transmitter. This stage is called the final *amplifier* or simply the *final* because it is the last rf amplifier stage in the transmitter. The signal from the final is then fed through a transmission line to the transmitting antenna.

This brief description of Fig. 22 is all you need know about radio trans-

mitters at this time. However, you should understand in general terms what is done in a transmitter; it will be helpful to you, even though you may never work on a radio transmitter. Notice the symbols used in Fig. 22 for the microphone and the antenna. Remember these symbols, you will see them frequently in future lessons.

THE RECEIVER

The job that the receiver has to perform is exactly the opposite to the job the transmitter has to perform. The transmitter must take the sound and convert it to an electrical signal, which is the audio signal, and then superimpose the audio signal on an rf carrier signal. The receiver must take the rf carrier and from it remove the audio signal and then convert the audio signal back into sound.

In spite of the fact that the receiver must perform the opposite tasks from those performed by the transmitter, there are many similarities between a transmitter and a receiver. A transmitter has rf amplifiers, so do many receivers. The transmitter has audio amplifiers, so do receivers. The transmitter has a stage in which modulation occurs—the receiver has a stage in which demodulation occurs. Demodulation is sometimes called detection; it is the recovery of the audio

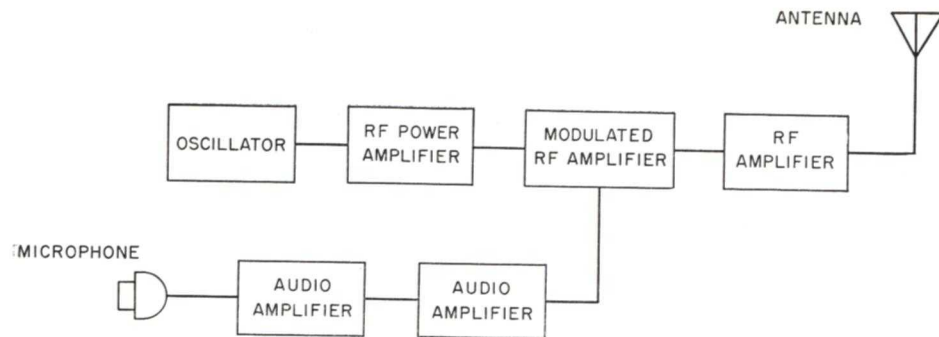


FIG. 22. A block diagram of a simple transmitter.

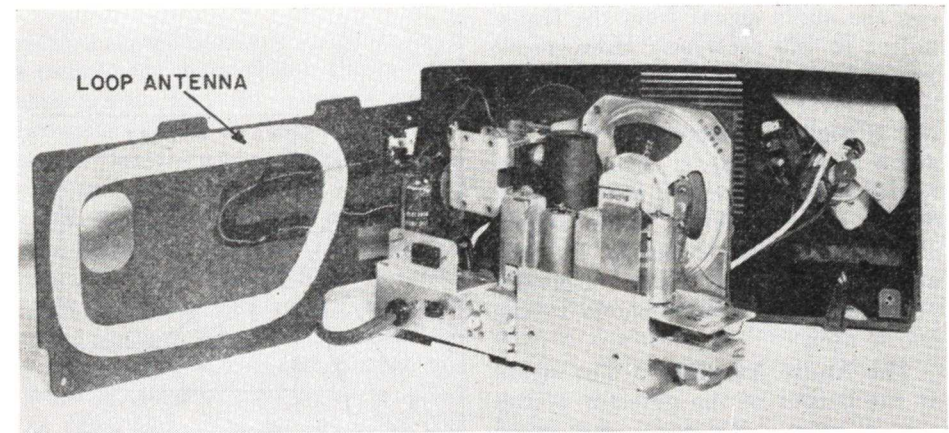


FIG. 23. The loop antenna is mounted on the back of the receiver as shown in this view of a partially disassembled set.

signal from the modulated signal. You will see later that there is a great deal of similarity between the operation of the stage in which modulation occurs and the stage in which demodulation occurs. The transmitter has a microphone which converts the sound into an electrical signal, the receiver has a speaker which converts the electrical signal to a sound signal. Even though the microphone and speaker perform opposite tasks, there is a great deal of similarity between the two.

Now let's look at a simple receiver system. Modern receivers are somewhat more complicated than the one we will describe, but nevertheless millions of receivers like this one have been made.

The Antenna. The radio receiving antenna is a much simpler device than the transmitting antenna. The signals transmitted by modern broadcast transmitters are so strong that only simple receiving antennas are needed. A simple outside antenna may be made from a wire 25 to 50 feet long mounted between two poles. Most modern radio receivers do not need any outside antenna at all. An in-

door antenna made of a coil which is called a "loop" is mounted in the rear of the receiver, inside of the receiver cabinet. This is all the antenna that is needed to provide satisfactory reception on local broadcast stations. A loop antenna can be seen in Fig. 23, mounted in the rear of the receiver shown.

The RF Amplifier. The signal picked up by the receiving antenna is quite weak even if the station being received is a fairly strong local station. Before the signal can be used it must be amplified. This amplification is usually carried out in a stage called an rf amplifier. It is quite similar to the rf amplifier in a transmitter, except it is called an rf *voltage* amplifier, whereas the stage in a transmitter is called an rf *power* amplifier. The rf amplifier in the receiver is designed to increase the strength of the signal voltage picked up by the antenna.

The Demodulator. The amplified signal from the rf amplifier is fed to a stage called the demodulator or detector. This stage separates the audio signal from the rf signal. The rf signal is called the *carrier*; it car-

ries the audio signal from the transmitter to the receiver. However, it serves little or no useful purpose in the receiver. In the detector stage, the rf signal is separated from the audio signal. The rf signal is discarded so that the signal at the output of the detector is an audio signal. This audio signal is exactly like the audio signal that was originally produced by the microphone in the transmitter.

The Audio Amplifier. The signal at the output of the detector is still a weak signal. Before it can be used to operate a loudspeaker, the strength of this signal must be increased. It is increased by feeding the signal to an audio amplifier, which is similar to the audio amplifier in a radio transmitter. The signal at the output of the audio amplifier is identical to the signal at the input, but much stronger.

The Speaker. A speaker is not very different from a microphone. In fact, sometimes speakers are used as microphones in intercommunications units such as between two offices.

A sketch of a simple speaker is shown in Fig. 24. Notice that the speaker has a magnet like the microphone. Between the poles of the magnet is a coil, and the coil is connected to a diaphragm. However, instead of having a flat diaphragm as in the microphone, the diaphragm is cone-shaped and in a speaker it is called the *cone*. The cone is fastened to the coil.

When the varying current from the audio amplifier is fed to the coil in the speaker, a varying magnetic field is produced. Depending on the polarity of the field produced by the current flowing in the coil, the field may either aid or oppose the magnetic field produced by the permanent magnet. Since the audio signal is being fed to the speaker, it is actually an

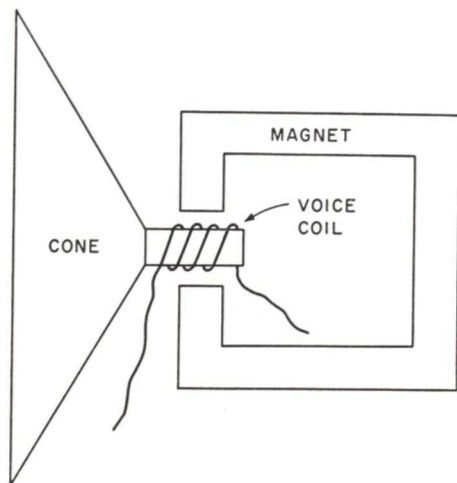


FIG. 24. A simple pm dynamic speaker.

ac signal; the polarity of the magnetic field produced by the coil will sometimes aid and sometimes oppose the permanent magnet field. This varying effect will cause the coil to vibrate in and out. Since the coil is fastened to the cone, the cone will vibrate in and out with the coil. The rate of vibration will depend upon the frequency of the audio signal.

The vibrating cone will set the air in front and in back of the cone in motion. The air will vibrate at the same frequency as the cone vibrates. Since the cone is vibrating at the frequency of the original sound signal produced by the microphone, the air around the speaker will be set into vibration at the same frequency. The effect of setting this air into vibration is exactly the same as setting the air into vibration with your vocal cords by speaking. The vibration will be heard as sound, and the sound will be at the same frequency and tone as the original sound that was first uttered in front of the microphone.

The operation of modern speakers is similar to that of the speaker shown in Fig. 24. This type of speaker with a moving coil is called a *dynamic*

speaker. Some dynamic speakers have a permanent magnet like the one we have shown and this type is called a *permanent magnet dynamic* speaker and is usually abbreviated simply a *pm speaker*. Another type of dynamic speaker uses an electromagnet instead of a permanent magnet. This type of speaker is often called *electrodynamic* speaker or an electromagnetic dynamic speaker. This is abbreviated *em speaker*. The small coil placed between the poles of the magnet is called the *voice coil*. Usually the voice coil is wound on a small lightweight form.

The magnets used in pm speakers are strong permanent magnets. In the first pm speakers manufactured, the magnet was made of steel, but in modern speakers the magnet is made of *alnico*. You will remember that alnico is an alloy of aluminum, nickel, and cobalt which can be used to make extremely strong permanent magnets.

Summary. From the preceding discussion you should remember the general purpose of the various stages in a receiver. Remember that the signal is first picked up by the antenna, amplified by the rf stage and then the audio separated from the rf in the demodulator stage, which is also called the detector stage. The audio signal is then amplified by the audio stage and fed to the speaker where the speaker converts the electrical signal into sound. Of course, this is only a quick preview of the operation of a radio receiver, but for the present it is all you need to know.

TELEVISION

The transmission and reception of a television signal is not very different from that of a radio signal. However, in television there are two signals to be taken care of, the sound signal and the picture signal. To transmit these two signals through the air, two rf carriers are needed, a picture

carrier and a sound carrier. The sound signal in television is called the "audio" signal as it is in radio, and the picture signal is called the *video* signal.

The sound signal is picked up by a microphone, fed to audio amplifiers, and then used to modulate the sound carrier. However, in television instead of varying the amplitude of the carrier, it varies the frequency of the carrier. This is called *frequency modulation* and is abbreviated FM. Some radio stations also use this type of modulation. They are called FM stations.

The picture is picked up by a camera that contains a set of lenses similar to the lenses used in a camera that takes photographs. The lenses project the picture on the face of a special tube called a camera pick-up tube. This tube has a specially treated face plate on it and the light striking it produces a small voltage. The brighter the light, the more voltage produced. The pick-up tube produces the video signal. The video signal is something like an audio signal; however, it is the electrical equivalent of the picture.

The video signal at the output of the pick-up tube is fed to a stage called a video amplifier stage where the signal is amplified. In a transmitter, the video signal will be amplified by several video amplifiers. The amplified video signal is then used to modulate an rf carrier. Amplitude modulation is used in the video section of the transmitter; this is the same type of modulation that is used in the standard radio broadcasting band.

Thus the TV transmitter, instead of transmitting only one rf signal must actually transmit two rf signals, one to carry the video and the other to carry the sound. The two signals from the transmitter are fed to a single antenna.

At the receiving installation, the two signals are picked up by one antenna, amplified by rf amplifiers, and then separated from the rf carriers by separate detectors, one for the video and the other for the sound. The sound signal is then amplified and fed to a speaker. The video signal is amplified by a video amplifier and then used to operate the picture tube.

This is only a brief run-through of a television transmitter and receiver. There are many details that have been omitted, but you need not be concerned about them at this time. Keep in mind that the operation of the video portion of a TV transmitter is not very different from that of the audio portion of the transmitter. There are many differences in details, but the basic principles are the same.

Electronics in Industry

We have already mentioned that there are many uses for electronics in industry and that the number of applications is growing almost daily. Electronics is used in oil refineries to control the various steps in the refinement of crude oil. It is used in the livestock feed industry to control the mixing of grains in the preparation of feed for farm animals. It is used in factories to control the operation of precision machines, to inspect the finished product coming off the assembly lines, and in counting the output of high-speed automatic machines.

CHANGING AC TO DC

One of the important uses of electronics in industry is in converting ac to dc. This can be accomplished by large electronic tubes designed for this type of service.

It is much more convenient to generate and transmit ac than it is dc, because transformers can be used with ac and not with dc. If electric power must be transmitted some distance from the power-generating station to the factory where it is to be used, the power company can generate ac and then step the ac up to a very high voltage by means of a transformer.

It is much more economical to transmit electric power at high voltages than it is to transmit it at low voltages. When the power is received at the factory, it can be stepped down by means of a step-down transformer to a voltage that is more convenient to use.

Although the transformer will work only on ac and because of this ac is more economical to transmit than dc, there are many devices that will work only on dc. The motors that power electric streetcars are dc motors; they will work only on dc. Direct current is used in refining copper and aluminum. DC voltages are applied to the plates of tubes in electronic equipment.

Alternating current is changed to direct current by means of rectifiers. A rectifier is a device that will let current flow through it in one direction, but will not let it flow through it in the opposite direction. You will learn about tube rectifiers now and about other types later.

Half-Wave Rectifiers. A half-wave rectifier is a device that will allow current to flow during only half of each cycle. Remember that the ac cycle we looked at before had a posi-

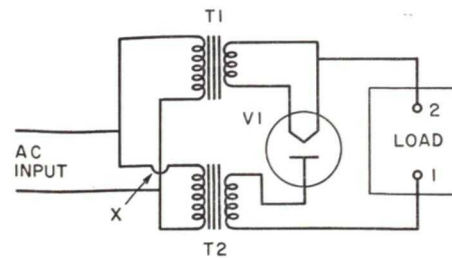


FIG. 25. A half-wave rectifier circuit.

tive half and a negative half. A half-wave rectifier can be connected to allow current to flow either during the positive half or during the negative half of the cycle, but it will not let current flow during both halves of the cycle.

A half-wave rectifier circuit is shown in Fig. 25.

Most of the symbols on this diagram are ones you are already familiar with. T1 and T2 are iron-core transformers and V1 is a tube with a filament and a plate. Notice that the tube is drawn "upside down." You will find them drawn in any position on schematic diagrams, but the pointed symbol is always the filament, and the straight line is the plate. One new symbol is the "cross-over" marked with an X. This is the way we show that there is no electrical connection; the wires simply cross over each other. Unfortunately, different manufacturers use different methods of showing this. Fig. 26 shows some of the systems. Sometimes if a loop is used to represent a cross-over, two lines crossed represent a connection, as at A; sometimes a dot is used to represent a connection and two lines crossed represent a cross-over, as at B; sometimes a combination of the two systems is used, as at C. You will soon learn to tell by studying the diagram which system is used.

Now let us study Fig 25. The ac power from the power line is fed to the primary windings of the trans-

formers marked T1 and T2. T1 is a step-down transformer. The winding on this transformer provides the voltage necessary to heat the filament of a diode tube. Transformer T2 may be either a step-up or a step-down winding depending upon the dc voltage required. If the dc voltage needed is higher than the power-line voltage, a step-up transformer is used, whereas if it is lower, a step-down transformer is used. The block marked "load" on the diagram represents whatever is going to use the dc power produced. This might be a number of storage batteries we are charging, or it could be a bath which is being used to refine copper or aluminum in a refinery. You will see the word load used frequently in this way.

Now let's see how the half-wave rectifier works. Refer to Fig. 27 as you read the following explanation. Fig. 27A shows what will happen during the first half cycle, and Fig. 27B shows what happens in the second half cycle.

Looking at Fig 27A first, in this diagram we see the positive half cycle. At the left of the drawing we see the ac voltage across the secondary of T2. In the center we see the polarity of the voltage across the secondary of

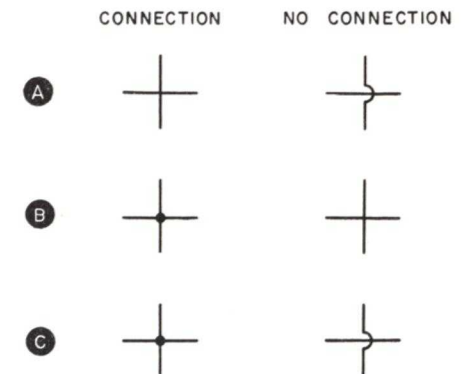


FIG. 26. Different ways of indicating cross-overs and connections on schematic diagrams.

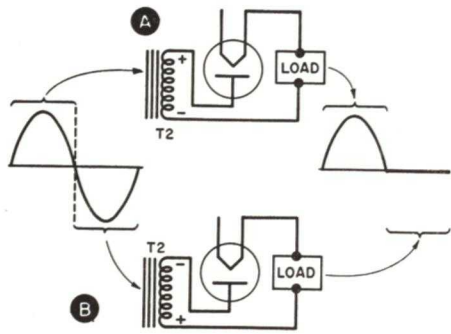


FIG. 27. How a half-wave rectifier works.

T2 and at the right we see the voltage that will appear across the load. The voltage will cause a current flow through the load. During this half of the cycle, the end of the secondary winding of T2 that is connected to the plate of the diode tube is positive and the other end is negative. When this happens, current will flow from the lower end of the transformer winding to terminal 1 of the load, through the load to terminal 2 and to the filament of the tube. You know that the red-hot filament will emit or give off electrons. These electrons will be attracted to the plate of the tube by the positive voltage on the plate. Therefore the electrons will flow from the filament to the plate of the transformer. Since there is a complete circuit, current can flow.

However, when the polarity of the voltage across the secondary of T2 reverses, we will have the negative half cycle shown in Fig. 27B. The polarity of the secondary of T2 is shown. Notice that the end of the secondary winding connected to the plate of the tube will be negative and the other end will be positive. Now let us see how current would have to flow during this part of the cycle. You remember current flows from the negative terminal of the voltage source

through the external circuit and back to the positive terminal of the source. This means that the electrons would have to flow from the negative end of the secondary winding of the transformer to the plate of the tube. They could do this all right, but then they would have to flow from the plate of the tube to the filament. But there is no way that the plate can give off electrons. Furthermore, electrons will not flow from the filament of the tube to the plate because they will be repelled by the negative voltage on the plate. The plate will be negative, because the side of the transformer it is connected to is negative during this half cycle. Since electrons cannot get across the tube, there is no complete circuit and therefore there will be no current flow in the circuit.

The current flowing in a half-wave rectifier of this type will look like the drawing at the right in Fig. 27. Notice that during the first half of the cycle when the plate is positive, there will be current flow through the circuit. During the next half cycle when the plate is negative, there is no current flow. This chain of events will continue so that during the third half cycle when the plate becomes positive again, current will flow, and then during the fourth half cycle, again there will be no current flow. The current will flow in pulses, there will be one pulse for each cycle. Again, this type of dc is called a pulsating dc and the rectifier is called a half-wave rectifier because it rectifies only one half of each cycle.

In a practical circuit the need for two transformers can be avoided by putting two secondary windings on one transformer. One winding is a step-down winding to provide the voltage needed to operate the filament of the rectifier tube. The other winding which may be either a step-up or a

step-down winding is connected as T2 was in Fig. 25.

Full-Wave Rectifiers. An improvement over the half-wave rectifier is the full-wave rectifier which rectifies each half of the cycle. The circuit of a full-wave rectifier is shown in Fig. 28. The transformers used are marked T1 and T2. The tubes are marked V1 and V2, and the terminals of the load are marked 4 and 5. The purpose of T1 is simply to heat the filaments of the rectifier tubes so they will give off electrons. Transformer T2 supplies the current that flows through the load.

You will remember that when we discussed the 45-volt B battery earlier in this lesson, we said that we could consider the center terminal of the battery as zero volts and mark the polarity of the two outside terminals accordingly $+22\frac{1}{2}$ volts and $-22\frac{1}{2}$ volts. We will use this system in explaining the operation of the full-wave rectifier circuit. We will consider the voltage at terminals 1 and 3 as either positive or negative with respect to terminal 2. In actual practice this terminal is usually grounded so that if we had occasion to measure these voltages we would measure them with respect to ground.

Now let us see what will happen

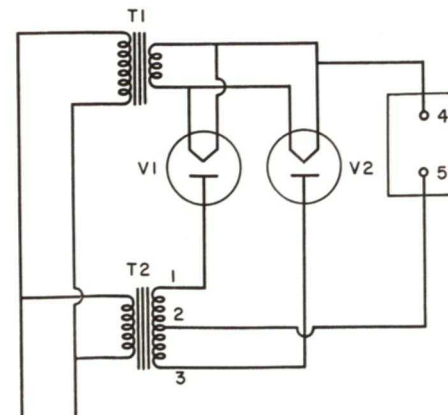


FIG. 28. A full-wave rectifier.

during each half cycle. If we assume that during the first half cycle, terminal 1 on the transformer is positive with respect to terminal 2, terminal 3 will be negative with respect to terminal 2. If terminal 1 is positive, then terminal 2 must be negative with respect to terminal 1. Electrons will therefore leave terminal 2 and flow to terminal 5 of the load, through the load to terminal 4 and from terminal 4 they can go to the filament of either of the rectifier tubes. But at this instant, the plate of V2, which is connected to terminal 3 on the transformer will be negative. Therefore this plate will repel electrons and no electrons will flow through V2 to the plate of the tube. At the same time the plate of V1, which is connected to terminal 1 on the transformer, will be positive and it will attract electrons and therefore electrons will flow through V1 to the plate of the tube and to terminal 1 of the transformer.

During the next half cycle, terminal 1 on the transformer will be negative and terminal 3 will be positive. Again electrons will leave terminal 2 of the transformer and flow through the load to the filaments of the rectifier tubes. Now, however, the plate of V1 will be negative and no electrons will flow through this tube, but the plate of V2 will be positive, and electrons will flow through this tube to terminal 3 of the transformer.

From the preceding, you will be able to see at once the advantage of a full-wave rectifier over a half-wave rectifier. A half-wave rectifier is actually somewhat wasteful since it uses only one half of the power supplied to it, whereas a full-wave rectifier uses all the power supplied it, current flowing first through one tube and then through the other.

The output of a full-wave rectifier will look like Fig. 29. Notice how this looks like the output from the



FIG. 29. The output of a full-wave rectifier.

simple dc generator shown earlier. Here we have the same thing, a pulsating dc. Also notice that we get two pulses per cycle, one pulse for each half cycle. Thus if the power supplied is 60-cycle power, we will get 120 pulses per second from a full-wave rectifier, but only 60 pulses per second from a half-wave rectifier.

Both half-wave and full-wave rectifiers are used in all types of electronic equipment. You already know that the voltage applied between the plate and the cathode of the triode tube is dc. The voltage applied between the grid and the cathode of the tube is dc. However, the voltage supplied by most power companies is ac. You know that most home radio and television receivers operate from an ac power line. Each of these receivers has a rectifier in it that will change the ac from the power line to dc for use on the various tubes in the receiver.

Rectifiers are also used in transmitting equipment. The vacuum tubes used in transmitters must have dc supply voltages. Rectifiers are also

used in industrial electronic equipment. Much electronic equipment found in industry uses vacuum tubes for control purposes. These tubes usually need dc operating potentials. Also large amounts of dc are used in some chemical processes and generally special types of vacuum tubes are used to provide these dc voltages.

SUMMARY

At this time you need not remember all the details of how rectifiers operate, but you should remember the general principles of their operation. You should remember that current flows through the rectifier only when the plate of the tube is positive. Also remember that there is one pulse per cycle from a half-wave rectifier, but two per cycle from a full-wave rectifier. Remember that two tubes are needed for a full-wave rectifier; one conducts or passes current during one half cycle, and the other conducts during the other half cycle.

Conclusion. The purpose of this book is to expand your knowledge of simple electronic principles and also to give you some idea of how electronics is used. You are not expected to remember all the details at this time, but the more you can remember, the less you will have to learn later. We will cover the most important details in the questions on this lesson. Make sure you can answer the questions and also that you understand the answer to each question.

Lesson Questions

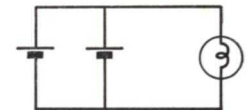
Be sure to number your Answer Sheet 2B.

Place your Student Number on every Answer Sheet.

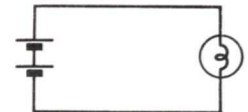
Most students want to know their grade as soon as possible, so they mail their set of answers immediately. Others, knowing they will finish the next lesson within a few days, send in two sets of answers at a time. Either practice is acceptable to us. However, don't hold your answers too long; you may lose them. Don't hold answers to send in more than two sets at a time, or you may run out of lessons before new ones can reach you.

1. What is the basic difference between a primary cell and a secondary cell?

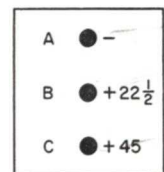
2. Notice how the cells are connected in the diagram.
(a) What is the name given to this type of connection? (b) If the output voltage of each cell is $1\frac{1}{2}$ volts what is the voltage supplied to the lamp?



3. (a) What is the name given to the type of connection used in this circuit? (b) If the cells each have a voltage of $1\frac{1}{2}$ volts, what is the voltage supplied to the lamp?



4. (a) What is the polarity of terminal B with respect to terminal A?
(b) What is the polarity of terminal B with respect to terminal C?



5. What do we mean when we say that the effective ac current flowing in a circuit is 1 amp?

6. If the effective ac voltage produced by a generator is 10 volts, what is the value of the peak voltage?

7. What is an audio signal?

8. What is the stage of a receiver called that separates the audio signal from the rf carrier?

9. What is a video signal?

10. If a full-wave rectifier is used in a 25-cycle circuit, how many pulses will there be per second in the output?



YOU'VE GOT COURAGE

An eight-year-old boy was discussing arithmetic with a friend. Said Johnny: "Teacher's gonna start us on *subtraction* tomorrow; wish I could stay home." But Harry laughed outright at Johnny's fears, and said: "Aw, I've had that and it's easy once you get started; what I'm worrying about is *multiplication!*"

It is natural even for grown men to feel like these boys—to fear most the things about which they know the least.

Did you know that some of the world's best speakers are always afraid when they get up to make a speech before a strange audience? Their *courage* gets them started, and in no time at all their fear changes to a confident enthusiasm which makes their talk a big success.

You've got courage! Use your courage to overcome normal fears, to carry you into each new subject and carry you over each difficulty. In no time at all, you will be looking forward to new subjects with intense interest—you will be *eager* to tackle new problems. Remember that each *conquered* difficulty brings you *one step closer to your goal of SUCCESS IN ELECTRONICS!*

J.E. Smith