SIMPLE CIRCUITS AND METERS

3B

RADIO-TELEVISION-ELECTRONICS

PIONEER HOME STUDY RADIO-TV SCHOOL

NRI

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STUDY SCHEDULE NO. 3

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**

☐ 2. **Voltage, Current, and Resistance** .... **Pages 2-7**

You learn that there are three kinds of voltage and current: ac, dc, and pulsating dc. You also learn what resistance is.

☐ 3. **How Voltage and Resistance Affect Current** .... **Pages 8-14**

Here you study the relationship between voltage, resistance, and current, and how it can be expressed by Ohm's Law.

☐ 4. **Series and Parallel Circuits** .... **Pages 15-21**

This section describes the basic differences between series and parallel connections.

☐ 5. **How Meters Work** .... **Pages 22-28**

We take up ammeters, voltmeters, and ohmmeters.

☐ 6. **Answer Lesson Questions.**

☐ 7. **Start Studying the Next Lesson.**

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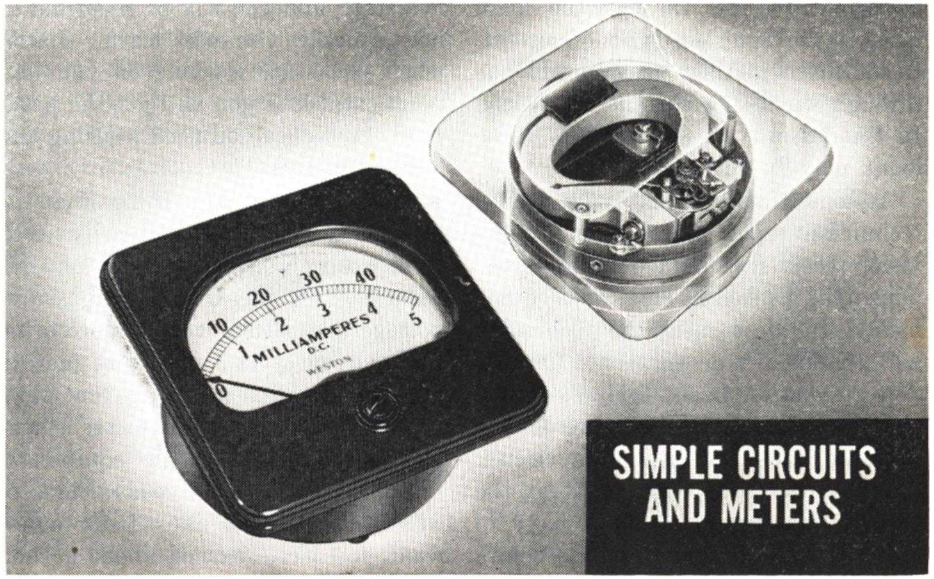


RADIO and television receivers, radio and television transmitters, and electronic control equipment are all alike in the sense that each is made up of various combinations of simple circuits. Once you are familiar with the few basic circuits that are used over and over again in electronic equipment, you will have a good practical start towards understanding the complete circuits.

This third lesson of your NRI course is particularly important, because it gives the practical facts you want to know about these basic circuits in order to become a capable and well-trained electronics technician. In this lesson you will also study several different kinds of meters and how they are used to find out what is going on in simple circuits. Meters are the technician's most valuable tools; they enable him to tell whether or not a circuit is working properly and help him find the defective part in a circuit that is not working properly.

Before going ahead with this lesson let us stop to consider the importance of the simple circuits you are going to study. Complex electronic equipment is made up of a large number of simple circuits. If you understand how the simple circuits work, you will be able to understand the complete operation of complex equipment. If you do not understand how the simple circuits work, you will not be able to understand the complete operation. Keep this in mind when you are studying this lesson. Take whatever time you need to be sure that you understand the lesson thoroughly. Do not go on if you are in doubt about any part of the lesson. Make sure that you understand each circuit. Although this may mean you will have to spend a little extra time on this lesson now, you will save a great deal of time in the end.

A circuit usually consists of a voltage source with a load connected across it. The voltage source causes a current to flow through the load. This is the simplest type of circuit. In some circuits there are several loads through which the current must flow. In this lesson you will see how these loads may be arranged.

At some time you may have seen a technician repair a radio or a television receiver or find a defective component in a piece of electronic equipment. In most cases the technician will use one or more meters to find the defective part. In this lesson you will study meters and how they are used to find the defective part in a circuit. Don't expect to be an expert at the end of this lesson, you will have to learn much more about circuits before you can find a defective part as quickly as an experienced technician can. You will need practical experience in using meters. However, this is a start, and you will be surprised at how quickly you will learn. Later, when you start working on your experimental kits you will get the practical experience you need in using and reading meters.

There are only three things that the electronics technician ordinarily needs to measure: voltage, current, and resistance. Of the three, he measures voltage and resistance far more often than current. As a matter of fact, in the few circuits where current does need to be measured, the meter is usually built right into the equipment.

You already have a general idea of what dc and ac are like. Let's review what you have learned about ac and dc, and learn some additional facts about these two. Then we will take up the new subject of electrical resistance.

Voltage, Current, and Resistance

You have already learned that voltage is the electrical pressure that can set electrons into motion. You know that an electron is a small particle of negative electricity, and you also know that since like charges repel, electrons are repelled or pushed out of the negative terminal of a voltage source and attracted to the positive terminal.

You know that current is the movement of electrons in a circuit. The strength of the current is measured in amperes, according to how many electrons are flowing past a given point in the circuit per second.

Resistance is the opposition to current flow. Electrons cannot move with complete freedom through a conductor. All conductors have a certain tendency to prevent the movement of electrons through it. This opposition to the flow of current is called resistance. It is measured in ohms.

Now that we know what voltage, current, and resistance are, let's learn more about them.

VOLTAGE

DC Voltage. As you have learned, there are two types of voltages—ac and dc. The voltage produced by a battery is called a direct current voltage, or dc voltage. It is so called because the polarity of the terminals of

the battery does not change. In other words, one terminal is always negative and the other terminal is always positive. Therefore, the current produced by a battery will always flow in the same direction, it will always flow from the negative terminal through the circuit and back to the positive terminal of the battery.

The stronger the voltage, the greater the effect it has on electrons. We usually do not say a voltage is "stronger" than another voltage, we usually say it is "higher" than another voltage. In other words, a 6-volt battery has a higher voltage than a 2-volt battery. The 6-volt battery has a greater effect on the electrons, and it can cause more electrons to flow through the circuit than a 2-volt battery can.

Voltages are measured with meters called "voltmeters". There are ways of specifying how much a volt is, but the technician need not be concerned about this. He learns how much voltage to expect in various circuits, and if the voltmeter indicates that the voltage in the circuit is correct he knows that the parts in that circuit are in good condition.

AC Voltage. The type of voltage which reverses its polarity regularly is known as an ac voltage. This voltage will cause electrons to move through the circuit first in one direction and then in the opposite direction. However, even though the electrons may simply move back and forth many times in a circuit without getting anywhere, they are able to do useful work.

The voltage supplied by most power companies is ac voltage. AC is particularly useful because a transformer can be used with it, which means it can be increased or decreased conveniently.

How AC and DC Voltages Act Together. It may be difficult to believe at first, but both ac and dc voltages can exist in the same circuit at the same time. Let's see how this can happen. In the circuit shown in Fig. 1A we have a 10-volt battery supplying voltage to a light bulb. The battery will cause current to flow through the light bulb from the negative terminal of the battery, through the bulb, and back to the positive terminal.

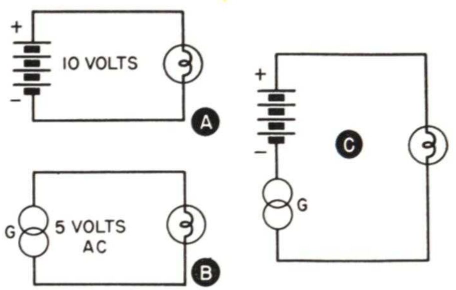


FIG. 1. Three simple circuits. In A, the source is a battery; in B, a generator; and in C, the battery and the generator are used together.

In Fig. 1B we have shown an ac generator that has an output voltage of 5 volts. The symbol at the left, labeled G, is the one for a generator. This is one more schematic symbol that you should be able to recognize.

If this generator is connected to a light bulb, it will cause current to flow first in one direction and then in the other direction. The current flowing back and forth will cause the bulb to light, just as it does if dc is flowing through it.

In Fig. 1C we have connected the generator in series with the battery,

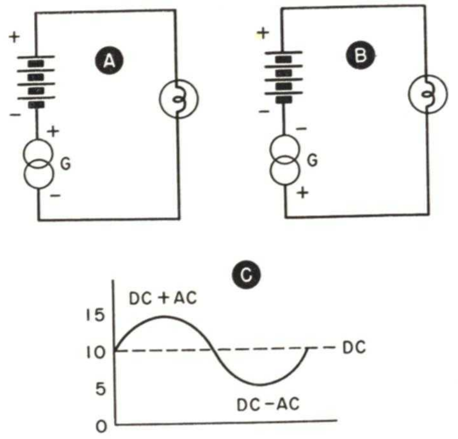


FIG. 2. When the ac generator and the battery are in series, the generator will aid the battery during one half cycle, and oppose it during the other.

Now what happens? You know that the polarity of the generator is constantly reversing. Let's consider first what happens when the polarity of the generator is such that it aids or adds to, the battery voltage as shown in Fig. 2A. When the generator aids the battery, the output voltage of the combined generator and battery will start at 10 volts and increase up to 15 volts as the ac voltage from the generator builds up to a peak of 5 volts. Then, during the next quarter cycle of the generator, the voltage from the generator will be dropping from 5 volts to 0 volts. Therefore, the output voltage from the combination of the battery and generator will decrease from 15 volts to 10 volts.

During the next half cycle, the generator voltage will oppose the battery voltage. This is shown in Fig. 2B. The generator voltage will start at zero and build up to a peak value of 5 volts. However, since this voltage is opposing the battery voltage, it will subtract from the battery voltage so that the voltage from the combination of the battery and the generator will decrease from 10 volts to 5 volts. Then, during the next quarter cycle, the generator voltage will be dropping from 5 volts down to zero so that the output from the combination will be increasing from 5 volts up to 10 volts again.

The voltage at the output of the combined generator and battery is shown in Fig. 2C. This voltage is called a pulsating dc. It is still dc because the polarity of the combination never changes. In other words, the terminal that is the negative terminal remains the negative terminal and the terminal that is the positive terminal remains the positive terminal. However, the value of the voltage between the two terminals does change. As a result, the current that flows through the circuit will change. The current always flows in one direction, so it is dc, but since it increases and decreases as the voltage changes, it is called a "pulsating" dc.

It is very important for you to understand what a pulsating dc is, and realize that it is actually ac and dc mixed together. You will run into this situation over and over again in your studies of electronic equipment. Later, you will see how the ac and dc can be separated from each other. You will see that a pulsating dc can be treated as two separate voltages mixed together. The separate parts are called components, and we refer to them as the *ac component* and the *dc component*.

CURRENT

The movement of electrons produced by a voltage is called a "current". Current is measured in amperes. Because we frequently deal with very small parts of an ampere, in electronic work we use units called "milliamperes" and "microamperes." There are 1000 microamperes in a milliampere and 1000 milliamperes in an ampere. Thus a millliampere is 1/1000 of an ampere, and a microampere is 1/1,000,000 of an ampere.

When we say that a certain current is flowing in a circuit, we are referring to the number of electrons moving past any point in that circuit. We are not referring to the total number of electrons in motion in the circuit. You can see why this is the case when you consider what would happen if we connected a wire directly across the terminals of a battery. A very high current would flow because the wire has a low resistance, and therefore offers very little opposition to the flow of current. On the other hand, if we connected a wire a mile long between the terminals of the battery, there would be many more electrons in the wire and many more electrons in motion. However, the mile length of wire would offer much more resistance than the short direct wire across the battery terminals, and therefore the current flowing in the long wire would be lower than in the short direct wire. Thus, in measuring the current we are concerned with a number of electrons moving past a point in the circuit, not the total number of electrons in motion in the circuit.

To give you an idea of what an ampere represents, the average 100-watt bulb used in your home draws a current of about 1 ampere. When we say that a lamp draws a current, it simply means that a current is flowing through it. The radio in an automobile with a 6-volt storage battery will draw somewhere between 8 and 10 amperes, and a radio in a car with a 12-volt battery will draw somewhere around 4 or 5 amperes. An electric toaster will draw about 10 amperes. You need not be concerned about the actual number of electrons that must be in motion to result in a current of 1 ampere. It is extremely large.

Current is measured with an ammeter, a milliammeter, or a microammeter, depending on how strong the current is. If the current is extremely weak, you use a microammeter to measure it. If the current is less than an amp, but too high to measure with a microammeter, you use a milliammeter, and if the current is strong, you use an ammeter. All three meters are made in various ranges. When you measure an unknown current, you start with a meter designed to measure a fairly high current. If the current is too weak to give a usable reading, you can then put a meter capable of measuring a weaker current in the circuit. Note that you start with a meter capable of measuring a high current. If you put a sensitive meter in the circuit first, you are liable to burn it out if the current is higher than you expected.

Direct Current. Batteries produce dc voltage, and this causes direct current flow. This simply means that the current will flow always in the same direction. Remember that you will use direct current frequently in electronic equipment. In most cases the voltages applied to the elements in vacuum tubes and transistors will be dc voltages, and the resulting current flow in the circuit will be direct current. Batteries and dc generators are sources of direct current.

Alternating Current. When current flows first in one direction and then in the opposite direction, we say that the current is an alternating current. This is the type of current supplied by the power company, and it must be changed to direct current for use in most electronic equipment. Alternating current is very useful because transformers can be used with it.

Pulsating Direct Current. When we discussed voltage, we showed how when a generator and a battery are connected in series, the current that flows in the circuit, while it will always flow in one direction, does vary. This current is called a *pulsating* direct current. The output of a rectifier used to change alternating current to direct current is a pulsating direct current. It is really a combination of a direct current and an alternating current, and by means of suitable equipment the ac and dc components can be separated and used individually.

RESISTANCE

One of the most important values you will measure in your electronic work is resistance. All wires and parts in electronic equipment have a certain amount of resistance; there is no such thing as a perfect conductor. However, the wires used in electronic equipment are usually made of copper. Copper has such a low resistance that it is usually impossible to measure the resistance of the wires in electronic equipment. However, this does not mean a resistance measurement is useless. If the wire is broken, the meter will indicate a very high resistance.

There are other parts in the circuit that do have a measurable resistance. A transformer is an example of a part having resistance. The transformer consists of two coils of wire. Although the wire has a low resistance, there are usually so many turns of wire on the transformer that there is enough wire to have a noticeable resistance. If you think there is a possibility that the wire in one of the coils of a transformer is broken, you can measure the resistance. If you find a very high resistance, the chances are that the wire is broken and the transformer is no longer usable.

The unit used to measure resistance is called the ohm. It is named after the scientist George Simon Ohm who did a great deal of work in the early days when scientists first began studying electricity. Resistance can be measured by an instrument called an "ohmmeter".

Often in electronic equipment a certain amount of resistance is desirable in the circuit. In other words, we do not want the current to flow through the circuit as easily as possible. We may want to cut down the amount of current flowing in the circuit, or we may want to reduce the voltage applied to a part in the circuit. We can do this by deliberately introducing resistance.

Parts made to put resistance in the circuit are called *resistors*. Some typical resistors and the schematic symbol used to identify a resistor are shown in Fig. 3. The value of the resistor—in other words the number of ohms of resistance—is usually written beside the resistor symbol on the diagram.

There are two types of resistors commonly used in electronic equipment, one is a carbon resistor. This type of resistor is made of a mixture of powdered carbon and a cement used to hold the carbon together. By varying the composition of the mixture, different resistances can be obtained.

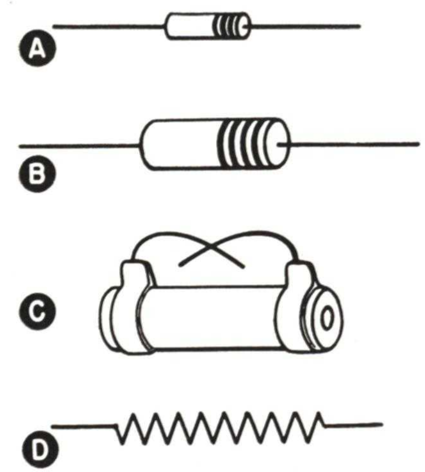


FIG. 3. Several typical resistors like those you will find in electronic equipment. The schematic symbol for resistance is shown below.

Another type of resistor is the wire-wound resistor. This type of resistor is used where the amount of current that will flow in the circuit is high. If too much current flows through a carbon resistor, the value, or resistance, of the resistor may change. Where there is this danger, wire-wound resistors are used.

Carbon resistors, which are cheaper, are more widely used in electronic equipment than wire-wound resistors because the current in most circuits is comparatively low. Carbon resistors are color-coded so you can tell their value. We will not go into color codes at this time; you will find it much easier to see what the color code is and learn how to identify resistors by the color code when you start working on your experimental kits than you would if we tried to explain it in this lesson. Wire-wound resistors are not color-coded. The resistance is usually stamped on the resistor.

SUMMARY

Now let us sum up the important points you should remember from the preceding section.

There are three kinds of voltage and current: dc, ac, and pulsating dc.

A dc voltage causes a direct current to flow. With dc voltage, the polarity does not change, and the current always flows in one direction.

With ac, the polarity is continually reversing, and the current flows first in one direction and then in the opposite direction.

With pulsating dc, the polarity of the voltage does not change; however, the value of the voltage changes so that the current, while it flows in one direction is not a constant value; it increases as the voltage increases, and decreases as the voltage decreases. A pulsating direct current is made up of two parts or components, an ac and a dc part.

If we wish to limit the current flow in a circuit or reduce the voltage applied to a part in the circuit, we put a resistor in the circuit. There are two important types of resistors: carbon and wire-wound resistors.

How Voltage and Resistance Affect Current

You already know that a 6-volt battery can force a higher current through a circuit than a 3-volt battery can.

The current flowing through a circuit depends not only on the voltage applied to the circuit, but also on the resistance. If the resistance in the circuit is increased, there will be a greater opposition to the flow of current through the circuit, and as a result the current flowing in the circuit will decrease.

In the following section you will see how changing the voltage in a circuit affects the current flowing in the circuit. We will do this by showing a number of simple circuits and then showing meters connected into the circuits. We will show what the meters would actually read in each case.

HOW VOLTAGE AFFECTS CURRENT

Let's start with a simple circuit such as shown in Fig. 4A. Here we have a resistor connected across the terminals of a battery. The resistor in this case is a 500-ohm resistor. We call the resistor the "load". This is the part that is going to use the current from the battery. The resistor will change the electrical energy into heat.

To measure the current flowing in the circuit, we will use a milliammeter. As you have learned, the milliammeter is simply an ammeter that has been designed to measure a small part of an ampere. Instead of being calibrated to read fractions of an ampere it is calibrated to read milliamperes. In this experiment we will use a 10-milliampere meter. This is called a 10-mil meter. It takes a current of 10 mils (10 milliamperes) to make the meter read full scale.

In order to measure the current, we must connect the meter into the circuit. We do this by disconnecting the end of the resistor from the negative terminal of the battery, then connecting the meter between the resistor and the negative terminal. When we do this, we must notice which way we connect the meter. The terminals of the meter are marked — and +. We

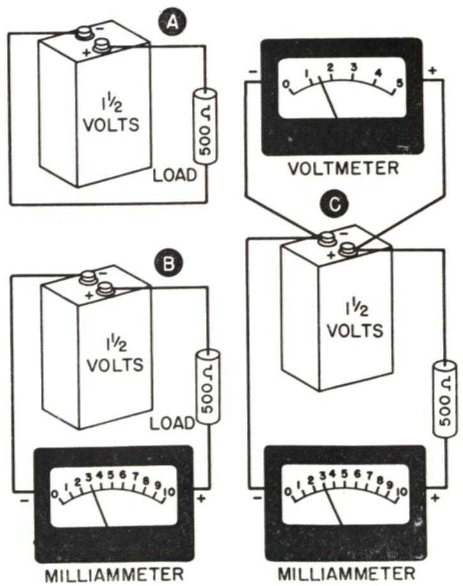


FIG. 4. A simple circuit consisting of a voltage source and a 500-ohm resistor as a load. B and C show how a milliammeter and a voltmeter are connected to measure current and voltage.

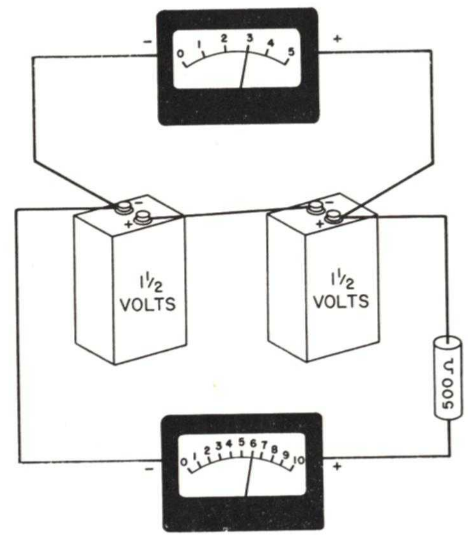


FIG. 5. Compare the increased voltmeter and milliammeter readings with those of Fig. 3C when the voltage is increased by adding a second cell.

connect the — terminal to the negative terminal of the battery and the + terminal to the resistor. We could have put the meter on the other side of the resistor, it makes no difference, because the current flowing in all parts of a series circuit is the same. We have shown the meter connected into the circuit in Fig. 4B.

To measure the voltage supplied by the battery, we use a voltmeter. The voltmeter is connected directly across the terminals of the battery to measure the full battery voltage. The meter we have selected is a 5-volt meter. This means that the full-scale reading is 5 volts. We have shown the two meters connected in Fig. 4C.

Look at Fig. 4C and note the readings on the meters. The milliammeter reads 3. This means that the current flowing in the circuit is 3 milliamperes. The voltmeter is pointing midway between 1 and 2. This means that the voltage is 1½ volts or 1.5 volts. This is the reading that you would expect because you know that the voltage from a single dry cell is about 1½ volts.

Now look at Fig. 5. Here we have added a second battery. The batteries are connected in series so that the total voltage supplied by the two batteries is 3 volts. Notice that the pointer on the voltmeter now points directly at 3, indicating a voltage of 3 volts. Look at what has happened to the milliammeter. It now reads 6 milliamperes, in other words twice what it read before. *Doubling* the voltage has *doubled* the current.

We can carry this one step further and connect a third battery into the circuit so that the three batteries are connected in series as shown in Fig. 6. The voltmeter now points midway between 4 and 5 volts. The voltage is 4½ volts. This is three times what it was in Fig. 4.

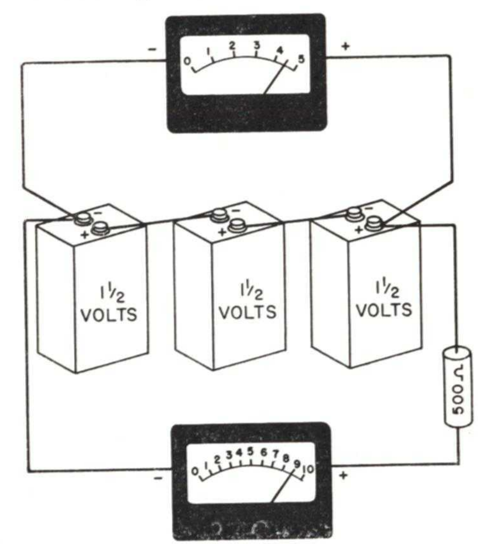


FIG. 6. A simple series circuit consisting of 3 cells and a 500-ohm load. Compare the meter readings with those shown in Figs. 4 and 5.

The current flowing in the circuit as indicated by the milliammeter is now 9 milliamperes. It is three times what it was originally. Increasing the voltage three times has increased the current three times.

Conclusion. From these results we can draw a very important conclusion. Doubling the voltage doubled the current; tripling the voltage tripled the current. This means that there is a linear relationship between the voltage applied to the circuit and the current that flows in the circuit. A linear relationship simply means that increasing one increases the other in the same proportion. This is an important law or rule that you will find you will run into many times in your studies. *There is a direct relationship between the current that will flow in the circuit and the voltage that is applied to the circuit.* If we change the voltage in a circuit we can actually predict the change that will occur in the current.

We can show the results of these three measurements in the form of a graph, as in Fig. 7. To do so, we first put a dot on the graph to represent the first measurement—the one in Fig. 4. In Fig. 4, the voltage was 1½ volts. We find 1½ on the bottom line of the graph, which represents the voltage. This is the line half-way between 1 and 2. Next we find the current, 3 ma, on the left-hand side of the graph. We follow the two lines for 3 ma and 1½ volts until they meet, and put a dot there—point A. Now we do the same for the values from Figs. 5 and 6. This gives us points B and C. Now, by connecting these three dots, we see that it forms a straight line—that is because the relationship between the voltage and current is *linear*. By extending the line we can determine what the current will be for any given voltage. If the voltage is zero, the current will also be zero.

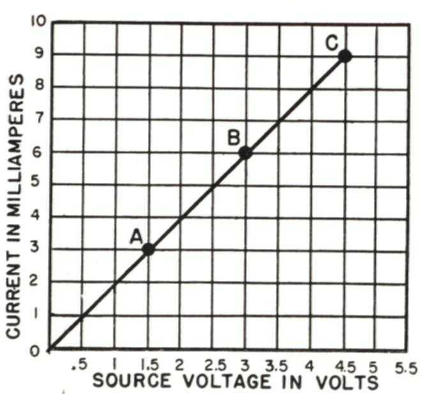


FIG. 7. Here's the way a technician would present the results of the measurements taken in Figs. 4, 5, and 6. This type of graph is easily drawn, and has the added advantage that from it, you can tell what the current will be for other voltages besides those measured.

If the voltage applied to the circuit was 2 volts, you can simply follow the line up from the 2-volt point until it strikes the diagonal line and then follow this line across and you will see that the current would be 4 milliamperes. Similarly, if the voltage applied to the circuit was 4 volts, the current would be 8 milliamperes.

Study the graph shown in Fig. 7. You will find this type of graph is used frequently. A great deal more information can be given conveniently in a graph than could be given in the form of a table or chart.

HOW RESISTANCE AFFECTS CURRENT

Now that you have seen the effect of voltage on the current in simple circuits, let's see what will happen

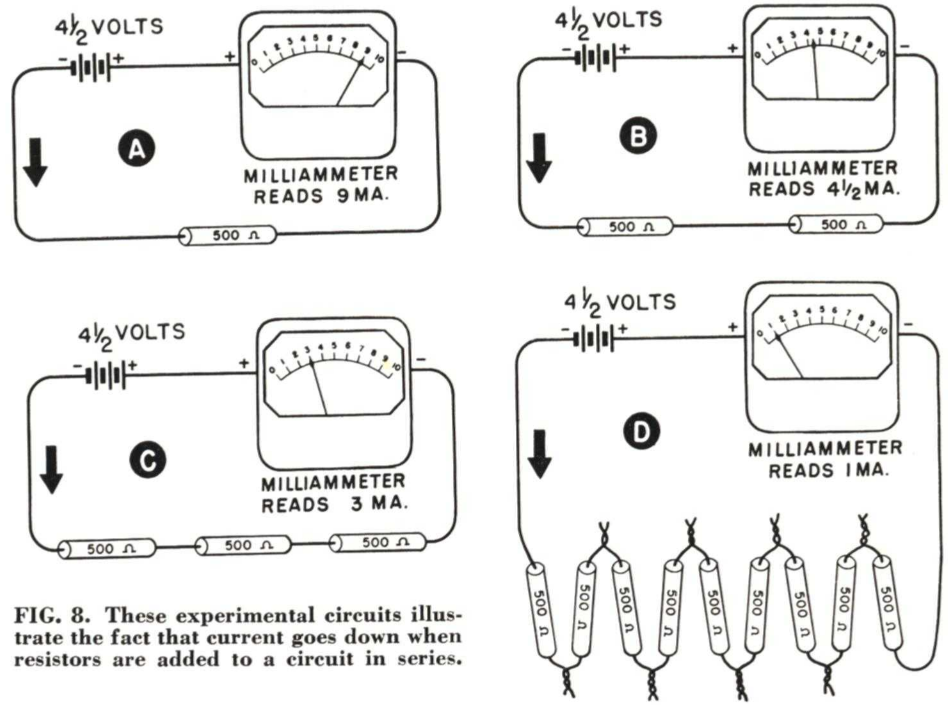


FIG. 8. These experimental circuits illustrate the fact that current goes down when resistors are added to a circuit in series.

when we change the resistance in the circuit. Let's start with essentially the same circuit as we had in Fig. 6. However, let's change it around a little.

First, since we have three batteries and we know that the voltage from these three is 4½ volts, there is no point in leaving the voltmeter in the circuit, we will remove it. Also, we mentioned previously that the ammeter could be connected as it was in Fig. 4 or it could be placed between the positive terminal of the battery and the load resistor. It would not make any difference because the current flowing in each part of the circuit is the same. In Fig. 6 we are measuring the current between the battery and the resistor. If we put the meter on the other side of the resistor, we would be measuring exactly the same current, because the current in all parts of a series circuit is exactly the same.

Let's start with the three cells and a 500-ohm resistor, and let's put the resistor on the other side of the milliammeter just so you will get used to seeing the meter in either point in the circuit. In Fig. 8A we have shown the circuit. We have used the symbol Ω in this diagram; this is the Greek letter omega. It is used to mean ohms. We know from the previous experiment that the current flowing in the circuit should be 9 milliamperes, or as technicians usually say, 9 mils. Notice that the pointer on the meter points to 9.

In the circuit shown in Fig. 8B we have added a second resistor. Since we have not changed the battery, the battery voltage will remain the same, but look at what happens to the current. The meter pointer is midway between 4 and 5. It is indicating a current flow of 4½ mils. Since 4½ mils is exactly half of 9 mils, we see that *doubling* the resistance has cut the current in *half*.

Now look at Fig. 8C. Here we have three 500-ohm resistors; we have three times the resistance that we had in the original circuit shown in Fig. 8A. In this case, the meter points to 3, indicating that the current flowing in the circuit is 3 mils. This is what we would expect; since doubling the resistance of the circuit cut the current in half, tripling the resistance in the circuit should have cut the current to 1/3.

In the circuit shown in Fig. 8D we have added 9 resistors to the circuit. We can already guess what the reading of the meter should be. We have increased the resistance 9 times and therefore the current flowing in the circuit should be 1/9th the current flowing in the original circuit in Fig. 8A. If we look at the meter we will see that the current indicated is 1 mil, which is 1/9th of the original current.

Let's compare Figs. 8C and 8D. In Fig. 8C we have three resistors and in Fig. 8D we have 9 resistors. In other words, in Fig. 8D we have three times as much resistance as we had in Fig. 8C. This means that the current flowing in the circuit shown in Fig. 8D should be 1/3 the current flowing in Fig. 8C. The current flowing in the circuit of Fig. 8C is 3 mils, 1/3 of this would be 1 mil and indeed this is the current that is flowing in 8D.

In the circuits we have shown in Fig. 8 we started with a small resistance and continually increased it, showing that the current was reduced as the resistance was increased. The opposite could have been demonstrated just as well. We could have started with a large resistance and reduced it, and showed that reducing the resistance in the circuit causes the current to increase.

Now let's take a minute to compare the results we obtained when we changed the resistance in the circuit with those we obtained when we changed the voltage in the circuit. When we increased the voltage in the circuit, the current increased—increasing the one increased the other. When this happens we say that the current varies *directly* as the voltage. On the other hand, when we increased the resistance in the circuit the current decreased. If we decrease the resistance in the circuit, the current will increase. We say that the current varies *inversely* as the resistance. This means that increasing one decreases the other, and vice versa.

It is extremely important for you to remember the relationship between voltage and current and the relationship between resistance and current. You will use these relationships constantly in your career as a technician.

OHM'S LAW

Many years ago the scientist George Ohm, after whom the unit of resistance is named, discovered the relationship between resistance, current, and voltage in a circuit. He found that increasing the voltage increased the current, and reducing the voltage reduced the current. He also discovered the effect of changing the resistance on the current flowing in the circuit.

The units of voltage, current, and resistance have been set up so that the current in any circuit can be expressed in terms of the voltage and resistance in the circuit. This relationship between current, voltage, and resistance is known as *Ohm's Law*. Ohm's Law states that the current flowing in a circuit is equal to the voltage applied to the circuit divided by the resistance in the circuit. This relationship can be rearranged so that you can calculate voltage, current, or resistance if you know the other two values in the circuit. In other words, if you know the resistance in a circuit and the current flowing in the circuit you can determine by means of Ohm's Law what the voltage applied to the circuit is. Similarly, if you know the voltage applied to the circuit and the current flowing in it you can determine the resistance.

A technician will seldom, if ever, have to sit down and calculate the value of a resistor or of current by means of Ohm's Law. However, if you are able to do so, it will help you understand exactly what is happening in a simple circuit. Since Ohm's Law is extremely easy to use, we will give a few simple examples.

Finding the Current. Ohm's Law can be used to find the current flowing in the circuit if you know the applied voltage and the total resistance in the circuit. Let's assume that the voltage applied to the circuit is 100 volts and the resistance in the circuit is 10 ohms. From Ohm's Law we know that the current in amperes flowing in the circuit will be equal to the voltage divided by the resistance. This can be expressed using symbols. The symbol E is used for voltage, I is used for current, and R for resistance. Ohm's Law can be expressed as follows:

$I = E \div R$, which is usually written:

$$I = \frac{E}{R}$$

To find the current in the example we have selected, you simply substitute the values for E and R and you get:

$I = \frac{100}{10}$, which equals 10 amps.

As another example, let's assume that the voltage is 10 volts and the resistance 1000 ohms. This gives us:

$$I = \frac{10}{1000} = \frac{1}{100}$$

This means that the current flowing is 1/100 of an amp. This is somewhat awkward to say and write, but we have another unit that can be used to express this value. This unit is the milliampere. There are 1000 milliamperes in an ampere. In other words, a milliampere is 1/1000 of an amp. 1/100 of an amp is ten times 1/1000 of an amp, and therefore we can express the current in this second example as 10 milliamperes. It is correct to say either 1/100 of an amp or to say 10 mils, but 10 mils is easier to say and write, and this is the way technicians usually express a small current such as this.

Finding Voltage or Resistance. We mentioned that Ohm's Law could be used to find the voltage if the current and resistance are known. This can be expressed as:

$$E = I \times R$$

and this is usually written simply:

$$E = IR$$

If we know the voltage and the current, we can use Ohm's Law to find the resistance. The expression used is:

$$R = \frac{E}{I}$$

SUMMARY

This section of Lesson 3 is probably the most important section that you have studied so far. It is extremely important for you to understand the effect that resistance and voltage have on the current flowing in the circuit. You must remember that the current varies directly as the voltage—in other words, increasing the voltage, increases the current; and decreasing the voltage, decreases the current. Similarly you must remember that resistance has the opposite effect. We say that the current varies inversely as the resistance. Increasing the resistance will reduce the current, and reducing the resistance will increase the current.

You must remember Ohm's Law. Ohm's Law states that the current flowing in a circuit is equal to the voltage divided by the resistance. In other words,

$$I = \frac{E}{R}$$

Mathematically this expression can be turned around so we can obtain two additional forms of Ohm's Law which are:

$$E = IR$$

$$\text{and } R = \frac{E}{I}$$

Thus far we have not asked you to try to memorize anything, instead we have stressed that you should understand what you are studying. We don't want you to memorize things now, but eventually you should become so familiar with Ohm's Law that you will be able to express the three forms of it from memory. Let's start toward this goal. Read over the various forms of Ohm's Law several times before going to the next section of the lesson. When you have completed the next section, go back and look at Ohm's Law again. Do this several times for the next few days until you have the various forms of Ohm's Law firmly in mind. This will help you in later lessons. In addition, since Ohm's Law is extremely important, you can be sure that we'll ask you several questions on this subject.

Series and Parallel Circuits

You have already seen both series and parallel circuits. Both types of circuits are extremely important. Understanding them now will simplify considerably the following lessons. Let's start with the series circuit first and study it in detail.

SERIES CIRCUITS

A series circuit always has a voltage source and a single path through which current can flow. A typical series circuit consisting of a battery and three resistors is shown in Fig. 9. There are several important things that you should know about series circuits.

In a series circuit there is only one path through which current can flow. The current flow in the series circuit shown in Fig. 9 consists of electrons leaving the negative terminal of the battery and flowing through R1, and then through R2, and finally through R3, and back to the positive terminal of the battery. Since there is only one path for current to flow through, current must be the same throughout all parts of the series circuit. In other words, you will have exactly the same current flowing through R1, R2, and R3. This current will be the same as the current leaving the negative terminal of the battery, and it will be the same as the current flowing to the positive terminal of the battery. You can measure the current flowing in this circuit by opening the circuit at any point in it, and connecting an ammeter or milliammeter in the circuit. It makes no difference whether you put the meter between the negative terminal of the battery and R1 or between resistors R1 and R2 or between resistors R2 and R3, the meter will read exactly the same in each case.

Voltage Drops. You know that if you connect a dc voltmeter across the battery you will be able to measure a voltage. As a matter of fact, if you connected a 100-volt meter across the battery, the meter would read full-scale, because the battery voltage is 100 volts. If you connect a voltmeter across resistor R1, you will also read a voltage. Similarly if you connect a meter across R2 or across R3, you will read a voltage. The sum of the voltages read across resistors R1, R2, and R3 will be 100 volts. This voltage of the battery is used up pushing current

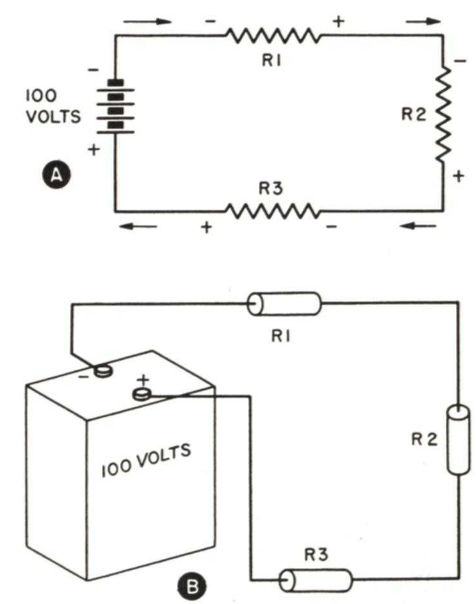


FIG. 9. A series circuit made up of a battery and three resistors. A shows a schematic diagram, and B a pictorial diagram of the same circuit.

through the resistors in the circuit. The amount of voltage that will be required to force the current through any one of the resistors will depend upon the resistance of that resistor. You can measure a voltage across each of the resistors, and the amount of voltage will depend upon the size of the resistor in comparison with the size of the other two. This voltage measured across any one of the resistors is called a *voltage drop*. It represents part of the original 100 volts supplied to the circuit; it represents the part of the voltage used to force current through that particular resistor.

A very important law or rule in electronics states that the sum of the voltage drops will be equal to the source voltage. As an example of how this rule works, suppose you measure the voltage across R1 and find that it is 25 volts. Then you measure the voltage across R2 and find that it is 30 volts. You know that the battery voltage is 100 volts. What must the voltage across R3 be? You know that the sum of the voltage across R1, plus the voltage across R2, plus the voltage across R3, must be equal to 100 volts. The voltage across R1 plus the voltage across R2 is equal to 25 + 30, or 55 volts. Therefore the voltage across R3 must be equal to 100 — 55, or 45 volts.

Polarity. The voltage applied by the battery in Fig. 9 has a fixed polarity. In other words, one terminal of the battery is positive and the other terminal is negative. The voltage drop across each of the resistors will be a dc voltage and it will have a fixed polarity like the voltage supplied by the battery. The electrons leaving the negative terminal of the battery will flow through R1 and will set up a voltage drop across this resistor having the polarity indicated.

The arrows on the diagram show the direction of current flow. When current flows through a resistor, the end at which electrons enter will be negative, and the end through which they leave will be positive. Thus the voltage across the resistors R1, R2, and R3 will have the polarity shown. This polarity is important. Make sure that you remember what the polarity will be across a resistor through which current is flowing. When you connect a voltmeter across the resistor to measure the voltage, you must connect the meter with the proper polarity, otherwise it will read backwards.

Before leaving our discussion of series circuits, let us follow the current flow around a circuit. The instant any electrical circuit is completed, current starts to flow. This means that electrons start moving at exactly the same instant in all parts of the circuit. As electrons leave the negative terminal of the battery, others enter the positive terminal; still other electrons start moving in all the wires and parts making up the circuit. In a series circuit, the number of electrons moving past any one point is the same as the number of electrons moving past any other point in the circuit.

However, we cannot visualize an entire circuit at once, so when we trace out a circuit, we usually say that the electrons start at the negative terminal of the source and flow through one part after another in the circuit, and back into the positive terminal of the source. Keeping this in mind, let us trace out the circuit in Fig. 9.

Leaving the negative terminal of the battery, we come to resistor R1. There is a voltage drop across the resistor, and the polarity as we go through the resistor is minus and then plus. Similarly current flows from R1 to R2, and we find a second voltage drop across R2. The polarity of this is also minus and then plus. These two voltages are in effect in series, and if we connected a voltmeter across the two resistors, we would measure the sum of the voltage drops across the two. Next, we come to resistor R3. Again the polarity is minus and then plus. The voltage drops across the three resistors are in series. Now we come to the battery. Instead of finding the polarity minus and then plus, we find that it is plus and then minus. In other words, the polarity of the voltage across the battery is the opposite of the polarity of the voltage drops across the resistors.

If we add the voltage around the circuit and call the voltage across R1, R2, and R3 *plus*, then since the voltage across the battery is of opposite polarity, we should call this a *minus* voltage. Adding these voltages we would have:

$$25 + 30 + 45 - 100 = 0$$

You will find this situation exists in any closed circuit. If you go around the circuit and observe the polarity of the voltages you will find that *the sum of the voltages around the circuit is zero*. This is simply another way of saying that the sum of the voltage drops will be equal to and of the opposite polarity to that of the voltage source. This rule or law is known as Kirchhoff's Law of Voltages. It is important that you remember it, because without it, you will be at a loss to explain the voltage distribution in some circuits.

An example of series connections is found in most table-model radio receivers. Here the heaters of the tubes are connected in series and operated directly from the ac or dc power line. A typical arrangement is shown in Fig. 10. Here five tubes are used. One tube has a 35-volt heater, one tube a 50-volt heater, and each of the remaining three tubes has a 12-volt heater. If we add the voltages required by these tubes together we'll find that we have a total of 121 volts. Actually, the voltage is not critical, and the receiver will operate from a voltage anywhere between 105 and 125 volts. If the voltage is less than 121 volts, the voltage applied to the heater of each of the tubes will be slightly less than the value shown. If the voltage is over 121 volts, then the voltage will be slightly higher. You might wonder how you get 35 volts across one tube

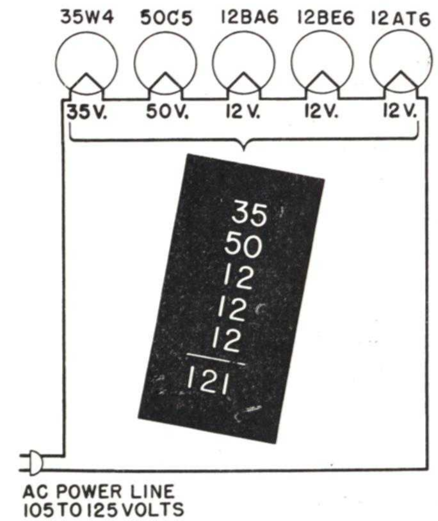


FIG. 10. Heaters of tubes in a typical ac-dc receiver connected in series.

and 50 volts across another, but only 12 volts across each of the remaining tubes. The answer to this goes back to Ohm's Law. First, you know that in a series circuit the current flowing in the circuit will be the same throughout the entire circuit. Therefore the voltage or the voltage drop that will appear across any one of the tubes will depend upon the resistance of the heater. The heaters of the 35-volt and 50-volt tubes simply have a higher resistance than the heaters of the 12-volt tubes. Therefore the voltage drop across these tubes will be higher. These heaters are deliberately made of a material with higher resistance so that when they are in series, the total voltage drop will add up to about 120 volts.

In some TV receivers, the heaters are connected in series. However, in TV sets, there are usually somewhere between 15 and 20 tubes.

One disadvantage of this type of connection as it was originally used in radio receivers was that the tubes did not heat up at the same time. This was a problem, because the temperature of a material affects its resistance. While the tube was heating up, its resistance changed, and as a result the voltage drop across one of the 12-volt tubes might be much higher than it was supposed to have been. This frequently caused tubes to be burned out. This problem was serious enough in radio receivers, but in television receivers where there were so many more tubes, it became an extremely critical problem. To solve it, manufacturers developed a special series of tubes for TV receivers, with a controlled warm-up time. These tubes all warm up at the same speed so that one tube will not have a much higher heater voltage than it should have.

When the heaters of tubes are connected in series as they are in Fig. 10, we often refer to this as a series string or a heater string. Sometimes the heater voltage required by the individual tubes does not add up to the total voltage available from the power line. For example, suppose we have five tubes that are to be connected in series. Two of the tubes require a heater voltage of 25 volts, and the other three each require a heater voltage of 6.3 volts. If we add these voltages, we find that the total voltage is 68.9 volts. For all practical purposes we can call this 70 volts. However, most power lines provide a voltage between 115 and 120 volts. Let's assume that the power line voltage is 120 volts. To operate the tubes from this power line we must add something to the circuit so that the total voltage drop in the circuit will be 120

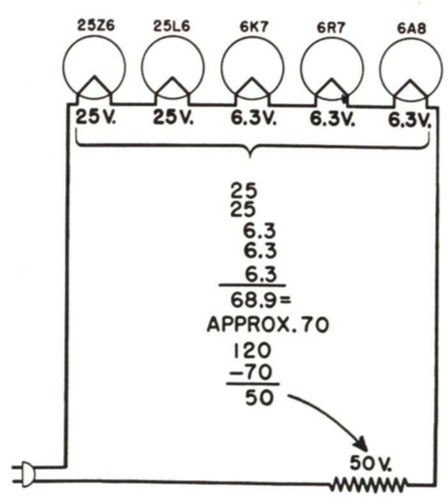


FIG. 11. How a voltage-dropping resistor is used in a series heater string to use up the line voltage not needed by the heaters.

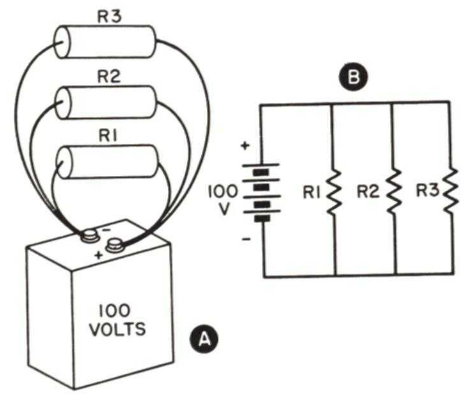


FIG. 12. A simple parallel circuit. The three resistors are connected in parallel across the battery. A shows a pictorial diagram, and B shows a schematic diagram.

volts. We must get rid of the extra 50 volts (120 — 70). We can do this by adding a resistor in series with the heaters of the tubes.

The circuit used to do this is shown in Fig. 11. Here the heaters of the tubes are connected in series. In series with the heaters is a resistor. There will be a voltage drop of 50 volts across this resistor.

What size must the resistor be? We can use Ohm's Law to figure the size resistor required. The tubes shown in Fig. 11 operate on a heater current of .3 amp. We know that we must have a voltage drop of 50 volts across the series-dropping resistor. To find the value of resistor required we use the form of Ohm's Law to find resistance. This is:

$$R = \frac{E}{I}$$

Substituting the values of voltage and current, we have:

$$R = \frac{50}{.3} = 166.6 \text{ ohms}$$

Resistors are not made in such odd values, so you would use a 165 or a 170-ohm resistor. Either would work satisfactorily.

Resistors are often used this way to reduce the line voltage to a lower value to operate the heaters of tubes connected in series. Series voltage-dropping resistors are also used to provide the required voltages for the other tube elements in electronic equipment.

PARALLEL CIRCUITS

Now that we have learned something about series circuits, let us take up the other commonly used connection. This is the parallel type of connection. You have already seen this type of connection. Another example of a parallel circuit is shown in Fig. 12. Here we have the battery, which is the voltage source, and we have three resistors connected in parallel across the terminals of the battery.

Notice the difference between this circuit and the circuit shown in Fig. 9. In each case we have a single voltage source and in each circuit we have three resistors. However, in the circuit shown in Fig. 9, the resistors are connected in series, so the same current must flow through all three resistors. In the circuit shown in Fig. 12, each resistor is connected directly across the battery. There will be a current flowing through R1 that will depend only upon the battery voltage and upon the resistance of R1. Resistors R2 and R3 will have no effect on the current flowing through R1. Similarly, the current flowing through R2 will depend only on the battery voltage and the resistance of R2, and the current flowing through R3 will depend only on the battery voltage and the resistance of R3. In the circuit shown, the voltage is 100 volts. The current that will flow through each branch of the parallel circuit will depend upon the voltage and upon the resistance in *only* that branch.

Each resistor is connected directly across the voltage source. This means that each resistor will have 100 volts applied to it. In other words, the voltage across these three resistors is equal. As you can see, the conditions in a parallel circuit are almost the opposite of those in a series circuit. In a series circuit, the *current* through each of the three resistors is the same. In a parallel circuit, the *voltage* across each of the three resistors is the same. In a series circuit, the voltage across each resistor will be determined by the size of the resistor. In a parallel circuit, the current flowing through each resistor will be determined by the size of the resistor. In a series circuit the larger the resistor the more voltage will appear across it. In a parallel circuit the larger the resistor, the smaller the current that will flow through it.

You will find many examples of parallel-connected loads in your home. The electric lights are connected in parallel across the power line. Each light operates independently of the others. If you turn one light off, or if the light bulb should burn out, it will not affect the operation of the other lights in the circuit. This would not be the case if the lights were connected in series; if they were in series and one light burned out, they would all go out. You've probably seen this happen in a series type of Christmas tree light string. When this type of Christmas tree light string is used, if one light burns out, all the lights go out, and it is frequently difficult to find the defective light.

Parallel circuits are found in almost every piece of electronic equipment. A simple example of a parallel circuit is shown in Fig. 13. Here the heaters of a number of tubes in a radio receiver are shown connected in parallel. Each of the tubes requires a heater voltage of 6.3 volts. To provide this voltage, a step-down transformer that will step the line voltage down to 6.3 volts is used. The heater of each tube is connected directly across the secondary of the transformer.

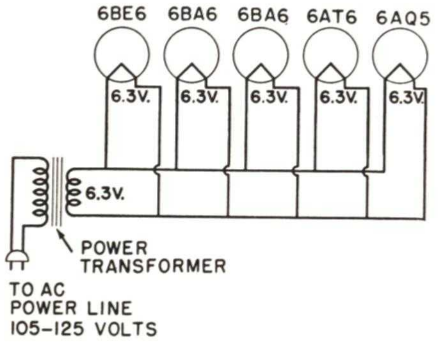


FIG. 13. Tube heaters connected in parallel.

In a parallel circuit like this, each tube must require the same heater voltage. However, the tubes may draw or use different currents. As a matter of fact, in the circuit we have shown, the 6AQ5 tube draws a higher current than the other tubes. The amount of current the tube will draw will depend upon the resistance of the heater.

Notice the difference between the parallel-connected tubes and the series-connected tubes. When the tubes are connected in parallel, they must be designed so that each requires the same heater voltage, but the current drawn by the various tubes can be different. When the heaters are connected in series, each tube must operate on the same current, but the voltage needed by the tubes may vary.

SUMMARY

Sometimes you will run into a combination circuit where some parts are connected in parallel and others in series. This arrangement is called a series-parallel circuit. We will study this type of circuit later. For the present, concentrate on the series and parallel circuits. Both types of circuits are important. If you understand the fundamental requirements of each type, you will have learned a great deal from this lesson.

In a series-connected circuit, the current is the same at all points in the circuit, but the voltage across the individual components in the series circuit may be different. The sum of the voltage drops around a series circuit will be equal to the source voltage.

In a parallel-connected circuit each component will have the same voltage applied to it. The current through the individual branches of the parallel circuit will depend upon the resistance of each branch. The lower the resistance of a particular branch, the higher the current that will flow through it. The total current flowing will be the sum of the current in the individual branches.

How Meters Work

Now that we have learned a little about the three things in an electronic circuit that a technician is interested in, voltage, current, and resistance, let us learn a little about the meters he uses to measure them.

To understand how meters work, you must go back to a basic law of magnetism that you learned in the first lesson. Remember that when we discussed magnets we said that like poles repel and unlike poles attract. A meter actually consists of two magnets, one a permanent magnet and the other an electromagnet. When the current being measured flows through the meter coil, the coil becomes an electromagnet. The current sets up a magnetic field that opposes the field produced by the permanent magnet. The coil is arranged on a pivot so it can rotate, and a pointer is attached to the rotating coil.

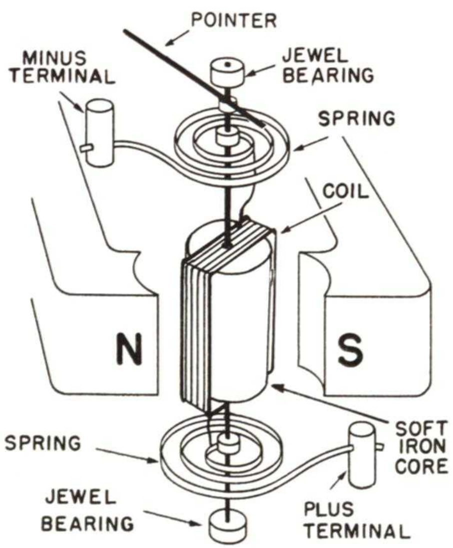


FIG. 14. How a d'Arsonval type of meter is made.

A typical arrangement such as used in a modern meter is shown in Fig. 14. Notice that the pole pieces are curved so the coil can be fitted snugly between the pole pieces. The coil is wound on a lightweight metal frame. The coil frame is pivoted on jewel bearings to keep friction at a minimum. The meter pointer is attached to the coil, and springs are used to return the pointer to the zero position when there is no current flowing through the meter. The springs also serve to conduct the current from the terminals on the back of the meter to the coil.

When a current flows through the coil, a magnetic field is set up around the coil, which opposes the field produced by the permanent magnet. The coil will then rotate, causing the meter pointer to move up the scale. The meter can be made to read full scale for any given current by putting the correct number of turns on the coil to provide a force that will exactly overcome the restoring force of the springs.

This type of meter is called a *d'Arsonval* meter. It can be made very sensitive; meters that can measure currents as low as 50 microamperes are quite common.

When the meter is designed to measure a larger current a resistor is usually connected in parallel with the meter. When a resistor is used in this way, it is called a *shunt*. Let's see how a shunt works.

SHUNTING A DC METER

Let's suppose that the meter we have is designed so that when the current flowing through the coil is 1 milliampere the meter will read full scale. Suppose, however, that instead of a 1-milliampere meter we need a meter that will measure 10 milliamperes. The meter manufacturer simply inserts a resistor inside the meter so that one-tenth of the current flowing in the circuit will flow through the meter coil, and nine-tenths will flow through the resistor connected in parallel with the meter coil. This means that 1 ma will flow through the meter coil, and 9 ma will flow through the shunt. When the meter is connected into the circuit, it will look like Fig. 15.

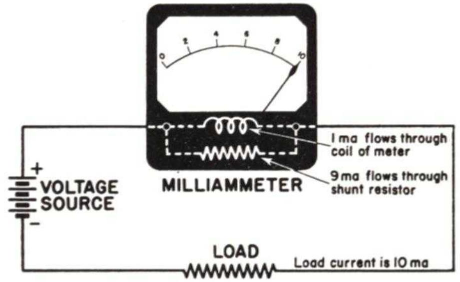


FIG. 15. By adding a shunt resistor, this 0-1 ma dc milliammeter can be made to read current up to 10 milliamperes.

You already know that milliammeters and ammeters must be connected in series with the circuit. To do this, you must actually cut into the circuit and place the meter in the circuit so that the current will flow through the coils in the meter.

Polarity. DC meters have polarity. This means that they must be connected into the circuit properly, or the meter will not read upscale. You can see why this is so. If the current flows through the coil in the wrong direction, the electromagnetic field and the field from the permanent magnet will attract instead of oppose each other, and the coil will tend to line up with the field from the permanent magnet. This will cause the meter pointer to move downscale off the scale and it will be impossible to tell what the current is.

DC meters have at least one terminal marked. Either the positive terminal or the negative terminal will be marked with a plus or a minus sign. In most cases, both terminals of the meter are marked so that there can be no doubt as to the polarity of the two terminals.

READING METER SCALES

Learning to read a meter scale is something like learning to tell time. It's just about as easy to read a meter scale as it is to read a clock. A meter scale is shown in Fig. 16. We have marked the various values on the scale. It would be worth while for you to spend some time studying this scale to get the general idea of how it is read. The scale is marked to read from 0 to 3. We say it is "calibrated"

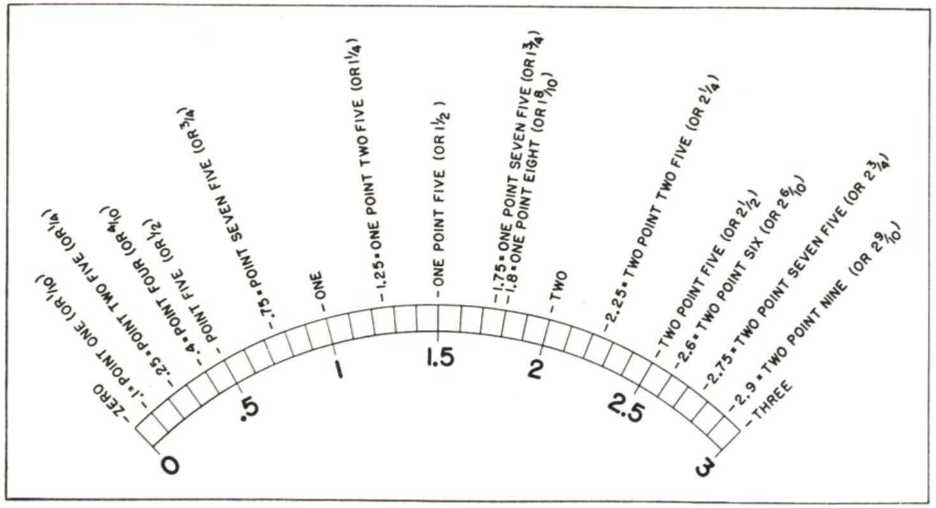


FIG. 16. A typical meter scale showing how to figure the values of unmarked divisions.

from 0 to 3. This might be the scale on a voltmeter that is designed to read 3 volts at full scale or it could be the scale on a milliammeter designed to read 3 milliamperes at full scale.

When the meter pointer falls directly on one of the divisions, it is usually not difficult to read it. For example, if the meter pointer should land directly on the first line to the right of 2, you know that the reading must be 2.1, because there are five divisions between 2 and 2.5. However, suppose the meter falls midway between two divisions. Then you have to estimate the reading. If the pointer falls midway between 2 and the first division to the right, you know that the reading is greater than 2 but less than 2.1. The reading would be about 2.05. Similarly if it fell midway between the first reading to the right of 2 and the second reading to the right of 2, the reading would be 2.15, in other words, greater than 2.1, but less than 2.2.

Usually the technician does not have to read the meter so accurately that he has to be concerned with the exact reading. Simply knowing that the reading is greater than 2, but less than 2.1 will usually be good enough.

DC VOLTMETERS

Strictly speaking, the dc voltmeters used by the electronic technician are not voltmeters, but are milliammeters that are set up to read voltages. A resistor is connected in series with the milliammeter. The amount of current that will flow through the circuit will depend upon the resistance of the resistor. The meter indicates the current flowing in the circuit, but the scale is calibrated to read the voltage applied across the combination of the meter and the resistor.

Let's see how this is done. An example of the dc voltmeter is shown in Fig. 17. Here we have a dc milliammeter that requires a current of 1 milliampere to give a full-scale deflection. If a 10,000-ohm resistor is connected in series with this meter, a voltage of 10 volts placed across the combination of the resistor and the milliammeter, will cause 1 milliampere of current to flow through the circuit, and the pointer will move all the way to the right. Thus, we can mark full scale as 10 volts instead of 1 milliampere. Similarly, if the voltage applied across the meter and resistor is only 5 volts, the current that will flow in the circuit will be one-half a milliampere, and the pointer will move to the center of the scale, so we can mark the center point on the scale as 5 volts. Thus the milliammeter can be calibrated as a voltmeter and can be used to measure voltage.

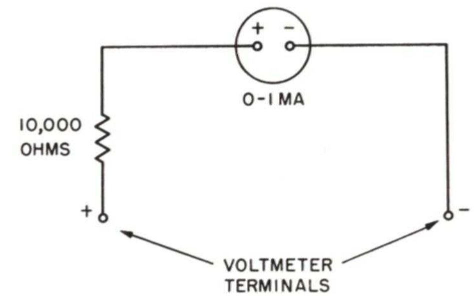


FIG. 17. A dc voltmeter made from a 0-1 ma dc milliammeter and a 10,000-ohm resistor.

The actual voltage that can be measured by a meter of this type will depend upon the size of the resistor connected in series with the meter. If instead of a 10,000-ohm resistor we put a 100,000-ohm resistor, the meter could be used to measure voltages up to 100 volts.

Even though this type of meter requires a current of only 1 milliampere to give a full-scale reading, this may be enough to upset some circuits in electronic equipment. Therefore when current-measuring meters are used to measure voltage in this way, meters even more sensitive than this are often used. Frequently meters that require a current of only 50 microamperes for a full-scale deflection are used. In order to build a meter that will measure 10 volts at full scale when a 50 microampere meter is used, a 200,000-ohm resistor must be connected in series with the meter. Since this type of meter takes a smaller current from the circuit than a 1-milliampere meter would, it is more desirable for electronic work.

DC voltmeters, since they are made up from milliammeters, have polarity just as a milliammeter does. The meter must be connected to the circuit with the proper polarity, otherwise the meter will read backwards.

OHMMETERS

An ohmmeter is nothing more than a dc milliammeter with a small battery and resistor connected in series with the meter coil. Before we even start to discuss ohmmeters, there is one important thing you should learn about them. Before you can use an ohmmeter to measure resistance of any

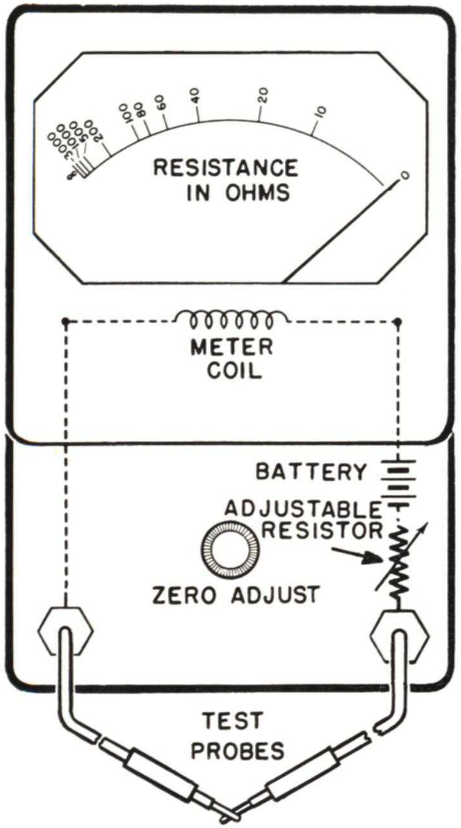


FIG. 18. An ohmmeter is made by putting a resistor and a battery in series with the coil of a dc milliammeter.

part in a circuit, the power applied to the equipment in which the circuit is located, must be turned off. If it is not turned off, the reading will be erroneous, and the meter may be damaged. A typical ohmmeter circuit is shown in Fig. 18. If a milliammeter that reads a full-scale current of 1 milliampere is used in conjunction with a 4½-volt battery, a current of 1 milliampere will flow in the circuit when a resistance of 4500 ohms is placed in the circuit. With this resistor, if you touch the ohmmeter probes together, a current of 1 ma will flow in the circuit, and the meter will read full scale. The 1-ma point on the meter is marked 0 resistance. As you know, doubling the resistance will cut the current flowing in half. Therefore, if you connect a resistor between the test probes of the meter, and the meter pointer indicates that current flowing in the circuit is one-half a mil, you know that the resistance must be 4500 ohms. The meter scale can be calibrated and marked to read ohms instead of milliamperes.

Notice that the ohmmeter scale shown in Fig. 18 is "backwards". In other words, 0 is on the right side of the scale. This is because the maximum current flows when you short or touch the test probes together. With the probes connected together, the resistance in the external circuit is 0. As you start adding resistance to the circuit by connecting resistors between the test probes, less and less current will flow until finally when you place an infinite or a maximum possible amount of resistance between the probes by separating the probes completely, no current will flow, and the meter pointer will move all the way to the left of the scale. This is the division marked ∞, which means infinity.

AC INSTRUMENTS

Many of the ac instruments used to measure ac current and ac voltages are actually dc instruments with a rectifier mounted inside the meter. The rectifier changes the ac to dc and then the dc is fed to the meter. This is the type of ac meter used most frequently in electronic work. However, there are other types designed especially for ac measurements.

The Moving-Vane Meter. The moving-vane meter is a type of meter designed especially for ac measurements. It is not used as frequently as the d'Arsonval meter because it is not as sensitive and because part of the scale is compressed. This means that instead of being divided into equal divisions, the scale divisions on the low end of the scale are close together, and at the high end they are spread out more. You do not need to learn how these meters work; the only thing you should know is that there is this type of meter available.

What AC Meters Read. You will remember that when we say the ac current flowing in a circuit is 1 ampere, we mean that the current has the same effect as a dc current of 1 ampere. This current is called the effective current. It is the effective value that you will be most frequently concerned with, and ac ammeters are usually calibrated to read the effective current.

AC voltmeters are calibrated to read the effective voltage in most cases, but there is no reason why they cannot be calibrated to read the peak voltage, providing the voltage being measured is a sine wave voltage. If the wave shape is something other than a sine wave, the ac voltmeter probably will not give an accurate indication of the voltage in the circuit.

SUMMARY

There are three important rules that you should keep in mind whenever you are using a meter to take a measurement.

1. For current measurements, always break the circuit so that the meter is in series with the circuit. The current measurement can be made by placing the meter anywhere in a series circuit, because the current will be the same in all parts of the circuit.

2. For voltage measurements, connect the voltmeter directly across the points between which you wish to measure the voltage.

3. For resistance measurements, connect the test leads from the ohmmeter directly across the resistance to be measured. Before using an ohmmeter, make sure that the power is turned off so that there is no current flowing through the resistance being measured. If there is current flowing in the circuit, it may damage your ohmmeter.

This is only a brief summary of meters and the measurements that can be made with them. You need not be too concerned about how meters work, just having a general idea of the way in which they work will help you to use your meter correctly, and it will help you to interpret readings given by it. In your experimental kits you will get practice in taking voltage, current, and resistance measurements. You will be more concerned with voltage and resistance measurements than you will be with current measurements because these are the types of measurement that the technician usually has to make. Current measurements are not made very often because of the inconvenience of having to open the circuit and insert the meter in the circuit. Voltage and resistance measurements can be made without going to this trouble.

In some equipment where current measurements are important, you will frequently find a meter connected permanently in the circuit. Examples of this are radio and television transmitters. The current flowing in the tubes in a radio or TV transmitter must be measured carefully and frequently. The transmitter manufacturers usually build meters right into the equipment. They are in the circuit all the time so the technicians can constantly watch the amount of current flowing in the various circuits.

LOOKING AHEAD

You have now reached a point where you have learned about voltage, current, and resistance, and have started to study simple circuits. In the next lesson you will start to study servicing techniques and you will learn how professional technicians service electronic equipment. You will see how the things you have learned in the lessons you have studied apply to repairing and maintaining electronic equipment.

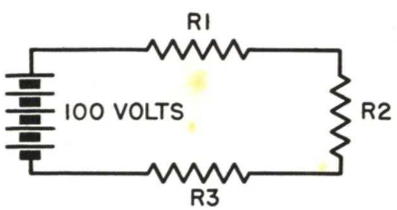
Lesson Questions

Be sure to number your Answer Sheet 3B.

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. If a pulsating dc voltage which varies from 15 volts to 1 volt has a dc component of 8 volts, what is the peak value of the ac component?
2. What instrument is usually used by technicians to measure resistance?
3. Name the *two* types of resistors commonly used in electronic equipment.
4. If the current flowing in a circuit is 100 mils when the voltage is 50 volts, what will the current be if the voltage is reduced to 25 volts?
5. If the current flowing in a circuit is 50 mils when the resistance is 1000 ohms, what will the current be if the resistance is reduced to 500 ohms?
6. What will the current be in a circuit where the voltage is 100 volts and the resistance 100 ohms?
7. Give the three forms of Ohm's Law.
8. In the circuit shown, the sum of the voltage drops across resistors R1, R2, and R3 will be (1) equal to, (2) more than, (3) less than, 100 volts.
9. Draw a schematic diagram of a circuit showing a battery with 3 resistors connected in parallel across it.
10. When using an ohmmeter to measure the resistance of a resistor in a piece of electronic equipment, should the power to the equipment be turned on?



CIRCUIT FOR QUESTION 8

GETTING YOUR "SECOND WIND"

After an opening burst of speed, a champion long-distance runner drops down to a steady natural pace. This brief period of relaxation releases that reserve of power called "second wind." He is then able to overtake and pass the now nearly exhausted leaders in the race.

No matter what you are doing, you also can do it better once you get your *second wind*. Instead of fighting that sleepy feeling which sometimes comes when you are studying, stop and relax for a few minutes so as to release your own supply of reserve power. Here are some ways to relax, all worth trying.

Get up and exercise for a few minutes. Get a drink of cold water. Step outside for a few *deep* breaths of fresh air. Take a brisk walk up and down the road or once around the block.

If you "shake yourself awake" in one of these ways, you'll find it isn't at all hard to get that second wind which enables you to study longer and makes the going easier. Then you'll get in some real worth-while studying—then you'll get things done!

J. E. Smith