Electronics

Radio

Television

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OHM'S LAW---PARALLEL CIRCUITS

ASSIGNMENT 8B

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The primary aim of this training program is to provide you with a **thorough understanding** of the **complete circuits of electronic equipment.** For these complete circuits to be understood, however, it is first necessary to learn about basic circuit arrangements. That is the purpose of this assignment, which consists of a continuation of the information concerning Ohm's Law as applied to d-c circuits. It will be recalled that this subject was first discussed in Assignment No. 6, where the basic principles of Ohm's Law and the applications of Ohm's Law to series circuits were discussed in detail. You are advised to review Assignment No. 6 carefully so that the information in that assignment will be well in mind before proceeding with this assignment.

There are three fundamental factors in a d-c circuit which must be considered. These are; (1) **the electromotive force or voltage,** (2) **the current,** and (3) **the resistance.** The current is the motion of the free electrons around an electrical circuit, the electromotive force is the electrical force which is applied to the circuit which **causes** current to flow, and resistance is the measure of opposition offered to the flow of the current. There is a definite relationship between the amount of voltage applied to a circuit, the resistance present in a circuit, and the current which flows in that circuit. This relationship is called Ohm's Law. This relationship is ordinarily written in the form of Ohm's Law equations as follows:

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

Where I is the current in amperes, R is the resistance in ohms, and E is the voltage in volts.

There are three circuit arrangements which may be employed. These are; series, parallel, and series-parallel. Figure 1 illustrates a battery and three resistors connected in these three circuit arrangements. Figure 1(A) illustrates a series circuit in both the pictorial and schematic form. Figure 1(B) illustrates the parallel circuit and Figure 1(C) illustrates the series-parallel circuit.

The current paths should be traced in a circuit to determine whether the arrangement employed is series, parallel, or series-parallel. If only one path is provided for the current from the negative terminal of the voltage source through the circuit to the positive terminal of the voltage source, the arrangement is a series circuit. For example, note in Figure 1(A) that the current leaves the negative terminal of the battery, flows through R_1, then through R_2, then through R_3, and returns to the positive terminal of the voltage source. Since all of the current flows through each component of the circuit his arrangement is a series circuit.

The circuit paths illustrated by the dotted lines in Figure 1(B) show that this circuit represents an entirely different arrangement than that of Figure 1(A). Notice that a portion of the current leaves the negative terminal of the battery, flows through R_1 and returns to the positive terminal of the battery. Another portion of the current leaves the negative terminal of the battery, flows through R_2 and returns to the positive terminal of the battery. At the same time a third portion of current leaves the negative terminal of the battery, flows through R_3 and returns to the positive terminal of the battery. It is evident therefore, that more than one path is provided for the current in the circuit of Figure 1(B) and this arrangement is called a parallel circuit.

The arrangement illustrated in Figure 1(C) is called a series-parallel circuit, as a portion of this circuit consists of a parallel circuit, but this parallel circuit is in series with the remainder of the circuit. As illustrated by the current paths in Figure 1(C), a portion of the current leaves the negative terminal of the battery and flows through R_1. At this same time a portion of the current flows from the negative terminal of the battery through R_2 joining the current that flows through R_1 at the junction of these two resistors and R_3. The combined current then flows through R_3 and returns to the positive terminal of the battery. Thus, the parallel combination of R_1 and R_2 is in series with R_3. These three figures should illustrate the manner in which the current path, or paths, should be traced to determine whether a circuit is a series, parallel, or series-parallel arrangement.

In the discussion to follow, a number of parallel circuits will be considered. In order to demonstrate clearly the manner in which these circuits function, numerical examples will be used. It should be emphasized however, that the important consideration, in each case, it **not** the mathematics involved, but is, instead, the thorough understanding of the operation of each electrical circuit. You should bear this fact in mind as you proceed with the assignment.

Parallel Circuits

By definition, a parallel circuit is a circuit which provides two or more paths for the current. To understand how such a circuit functions, let us first analyze the operation of the three simple series circuits illustrated in Figure 2. Figure 2(A) shows a 12 ohm resistor connected to a 12 volt battery, Figure 2(B) shows a 6 ohm resistor connected to a 12 volt battery and Figure 2(C) shows a 4 ohm resistor connected to a 12 volt battery. Let us apply Ohm's Law to find the current flowing in each circuit.

In Figure 2(A)	In Figure 2(B)	In Figure 2(C)
$I = \frac{E}{R}$	$I = \frac{E}{R}$	$I = \frac{E}{R}$
$I = \frac{12}{12} = 1$ ampere	$I = \frac{12}{6} = 2$ amperes	$I = \frac{12}{4} = 3$ amperes

The foregoing calculations are examples of the application of Ohm's Law to series circuits as discussed in Assignment No. 6. In the circuits of Figure 2 a 12 volt battery was used in each instance. Let us now arrange a circuit as illustrated in Figure 3(A) so that the 3 resistors used in the circuits of Figure 2 are connected to a **single 12 volt battery.** It will be noticed that this forms a circuit similar to the one shown in Figure 1(B) and, since three paths are provided for the current, this forms a parallel circuit.

In the parallel circuit of Figure 3(A) the emf applied to each of the three resistors is 12 volts, just as in Figures 2(A), (B) and (C). For this reason the current which flows through each of the resistors in Figure 3(A) is the same as the current which flows through the corresponding resistor in Figure 2—in other words, one ampere of current flows through the 12 ohm resistor, 2 amperes of current flows through the 6 ohm resistor and 3 amperes of current flows through the 4 ohm resistor.

Figure 3(B) illustrates a schematic diagram of the circuit of Figure 3(A) and the connecting leads have been shown in different sizes according to the current each is carrying. That is, one ampere of current flows through the 12 ohm resistor, two amperes of current flows through the 6 ohm resistor and 3 amperes of current flows through the 4 ohm resistor. Notice that the total current flowing from the battery is the sum of the individual currents. The total battery current is 1 + 2 + 3 = 6 amperes. Study this schematic diagram carefully until it seems logical to you that the 4 ohm resistor (smallest of the three resistors) passes the largest current. Remember that the resistance is the measure of opposition offered to the flow of electric current and therefore the smallest resistor offers **less opposition** than the others. The electrons moving up to point X find three possible paths to follow from X to Y. Part of the current flows through the 12 ohm resistor, part through the 6 ohm resistor and part through the 4 ohm resistor. Since the 4 ohm resistor offers the least opposition, the amount of current which flows through it is greater than that which flows through the 6 ohm resistor or the 12 ohm resistor.

In Figure 3 we have a 12 volt battery, and therefore have 12 volts of electrical pressure available for the circuit. The only resistors in the circuit are between points X and Y. All of the 12 volts will be applied to **each of the three resistors;** it should be emphasized, however, that we **do not** have 36 volts in the circuit. The **same 12 volts** is being applied across each of the three resistors. This will seem reasonable to you if you stop to consider the electrical wiring in your home. You can operate light bulbs, toasters, radios and electrical fans at the same time by connecting them to different outlets in the various rooms. Each appliance operates at 110 volts. The power company supplies the 110 volts at the fuse box. You are able to use that 110 volts in a variety of locations in the house because all of the outlets and receptacles are connected in parallel. This illustrates an important characteristic of parallel circuits. **The same voltage is applied to the various branches of a parallel circuit.**

In Figure 3(B) it will be noted that we have placed the value of current and voltage of each resistor in the circuit in a table. This is a convenient method of tabulating the conditions present in the various circuits to be analyzed in this assignment. This chart indicates that the emf applied to the 12 ohm resistor is 12 volts and the current that flows through this resistor is one ampere. Similarly the table indicates that 12 volts are applied to the 6 ohm resistor and a current of 2 amperes flows.

Figure 4 illustrates another parallel circuit. In this case, the emf applied to the circuit from the battery is 6 volts and four parallel paths are provided. Each of these paths consists of an 8 ohm resistor. As indicated in the accompanying table .75 ampere of current flows through each resistor. This can be checked by applying Ohm's Law as follows:

$I = \frac{E}{R}$, $I = \frac{6}{8} = .75$ ampere. How is it that the same amount of current flows through each of the four arms of Figure 4? This may be explained very easily. The current flowing between points A and B distributes itself evenly in the four arms because the four paths between points A and B are alike and thus all offer the same amount of opposition to the current. The total current from the battery, or the **line current** as it is often called, may be found by adding up the individual currents. Thus the line current is $.75 + .75 + .75 + .75 = 3$ amperes.

Figure 5 illustrates a parallel circuit in which three resistors are connected across the 100 volt power supply of a radio receiver. The three resistors have ohmic values of 10,000 ohms, 20,000 ohms and 50,000 ohms. To find the current flowing through the 10,000 ohm resistor Ohm's Law will be applied as follows:

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

$$I = \frac{100}{10{,}000}$$

$I = .01$ ampere or 10 milliamperes

Apply a similar method to determine the current flowing through resistor R_2 and resistor R_3 in the circuit of Figure 5 and check your answers against the values shown in the table accompanying this figure. Now find the total current which flows from the power supply and check your answer against the solution given at the end of the assignment.

There is one point which should be noted when examining Figure 3, 4 and 5. Notice particularly that since the line current is equal to the sum of the currents of the individual branches, it is **always greater** than the current of any of the parallel branches. This indicates that the resistance of the entire parallel network is always less than the resistance of any of the branches of that network. This point will again be emphasized presently.

Equivalent Resistance

In Assignment 6 it was mentioned that the equivalent resistance of a group of series resistors was a value of resistance which, when substituted for the group of resistors, would cause the same current to flow in the circuit. In a similar manner the equivalent resistance of a group of parallel resistors is that value of resistance which, if substituted for the group of parallel resistors, would cause the same current to flow in the circuit. Since the current paths in a parallel circuit are entirely different than those in a series circuit it should be evident that the manner in which the equivalent resistance of parallel resistors is computed is different than the manner in which the equivalent resistance of series resistors is computed.

There are two ways of finding the equivalent resistance of parallel resistors. One of these methods is sometimes called the "total current method" and the other involves the application of an equivalent resistance formula. Let us first use the total current method and employ the circuit of Figure 3 to demonstrate its use. In finding the equivalent resistance by the total current method the first step is to find the current through each resistor as we did in Figure 3. Then the individual branch currents are added to obtain the total current, or line current. This has already been done in Figure 3 and the total current was found to be 6 amperes. The equivalent resistance of the parallel circuit of Figure 3 is that resistance which would cause the same amount of current to flow in the circuit. This value of current is 6 amperes in this case. To find the equivalent resistance we merely apply Ohm's Law using the total current as the value of I in the formula.

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

$$R = \frac{12}{6}$$

$$R = 2 \text{ ohms}$$

If we were to place a 2 ohm resistor across the 12 volt battery, 6 amperes of current would flow so 2 ohms is the equivalent resistance of the parallel circuit of Figure 3. Notice particularly that the equivalent resistance of the group of parallel resistors is less than any of the resistors forming the circuit.

Let us apply the total current method to the circuits of Figures 4 and 5 to determine the equivalent resistance. The current flowing in each resistance in the circuit of Figure 4 is .75 ampere and the total current is 3 amperes. To find the equivalent resistance Ohm's Law is applied as follows:

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

$$R = \frac{6}{3}$$

$$R = 2 \text{ ohms}$$

Once again note that the equivalent resistance of the parallel circuit is less than the resistance of any of the branches of the circuit.

The individual currents in Figure 5 have been computed and also the total current. Apply the method outlined above to determine the equivalent resistance of these three resistors and check your answer against the solution given at the end of the assignment.

In some cases it is desirable to redraw a parallel circuit and substitute the equivalent resistance in the circuit in place of the original parallel network. This is illustrated in Figure 6. The original circuit consists of two parallel 2 ohm resistors connected to a 4 volt battery. The REI table shown in this figure illustrates the fact that the current which flows through each of the resistors is 2 amperes. You are advised to apply Ohm's Law to the circuit to verify the amount of current illustrated in the REI table. Since the current which flows through each resistor is 2 amperes the total current drawn from the battery is 4 amperes. This total current can be used to determine the equivalent resistance of the parallel circuit as follows:

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

$$R = \frac{4}{4}$$

$$R = 1 \text{ ohm}$$

Figure 6(B) shows the equivalent circuit of Figure 6(A). In this case the equivalent resistance of 1 ohm has been substituted for the two parallel 2 ohm resistors. Notice in the circuit of Figure 6(B) that the current flowing from the battery, or as it is often referred to, the current drawn from the battery, would be identical with the current drawn from the battery of Figure 6(A), or 4 amperes. Thus the circuit of Figure 6(B) is said to be the equivalent circuit of Figure 6(A).

Figure 7(A) illustrates another simple parallel circuit in which a 4 ohm resistor and a 6 ohm resistor are connected in parallel across a 24 volt source of potential. Ohm's Law can be applied to the two branches to determine the current which flows in each and the results obtained may be tabulated in a REI table as shown. Check these figures to verify the fact that 6 amperes of current flows through the 4 ohm resistor and 4 amperes of current flows through the 6 ohm resistor. This would result in a total current of 10 amperes flowing from the battery. This value of total current may be used to determine the equivalent resistance of the 4 ohm and the 6 ohm parallel resistors as follows:

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

$$R = \frac{24}{10}$$

$$R = 2.4 \text{ ohms}$$

Thus the equivalent circuit of Figure 7(B) can be drawn and a 2.4 ohm resistor substituted for the paralleled 4 ohm and 6 ohm resistors of Figure 7(A), since the current flowing from the battery in the circuit of Figure 7(B) would be the same as that flowing from the battery in the circuit of Figure 7(A). Notice once again in this circuit that the equivalent resistance of the two parallel resistors is smaller than the smallest parallel resistor. In other words, the effect of the parallel combination in the circuit of Figure 7(A) is to offer less resistance than that which would be offered by either of the resistors individually.

Finding Equivalent Resistance By Means Of Formulas

The means of determining the equivalent resistance of parallel resistors outlined above is very satisfactory. One advantage of this arrangement is that no new formulas are employed. All of the calculations involve the use of Ohm's Law only, which should by this time, be quite familiar to you. There are, however, several formulas which may be used to determine the equivalent resistance of parallel resistors. The first of these formulas is the simplest and may be used **only** when the resistors which are connected in parallel are of equal ohmic value. This formula states that **when parallel resistors are of the same ohmic value, the equivalent resistance is found by dividing the ohmic value of one of the resistors by the number of parallel resistors.** Stated mathematically this becomes:

$$R_e = \frac{R}{N}$$

Where R_e is equal to the equivalent resistance, R is equal to the ohmic value of one resistor and N is the number of parallel resistors.

To illustrate the use of this formula refer again to Figure 4 which shows four 8 ohm resistors in parallel. Let us apply the formula to this circuit to determine the equivalent resistance of the four parallel resistors.

$$R_e = \frac{R}{N}$$

$$R_e = \frac{8}{4}$$

$$R_e = 2 \text{ ohms}$$

It will be recalled that the findings of the total current method which were performed previously also indicated that the equivalent resistance of the four 8 ohm resistors in parallel was 2 ohms.

Apply this formula to the parallel network of Figure 6 to determine the equivalent resistance and see if your computed equivalent resistance agrees with that of the equivalent circuit of Figure 6(B).

Figure 8 shows a parallel circuit with five 100,000 ohm resistors connected to a 100 volt source. The equivalent resistance of these resistors is 20,000 ohms as indicated by the following calculations:

$$R_e = \frac{R}{N}$$

$$R_e = \frac{100,000}{5}$$

$$R_e = 20,000 \text{ ohms}$$

To check these calculations apply the total current method of determining the equivalent resistance of the circuit of Figure 8. Do these calculations also indicate that the equivalent resistance of the parallel network is 20,000 ohms?

When the parallel circuit in question consists of only two resistors of **unequal** ohmic value another formula sometimes called the **Product over Sum** formula may be employed. This formula is:

$$R_e = \frac{R_1 \times R_2}{R_1 + R_2}$$

Let us apply this formula to the circuit of Figure 7 to demonstrate its use.

$$R_e = \frac{R_1 \times R_2}{R_1 + R_2}$$

$$R_e = \frac{4 \times 6}{4 + 6}$$

$$R_e = \frac{24}{10}$$

$$R_e = 2.4 \text{ ohms}$$

A check of the equivalent circuit of Figure 7(B) will illustrate that this is the same value of equivalent resistance as computed by the total current method.

Figure 9 illustrates a circuit such as may be encountered in an electronic unit. A 100,000 ohm and a 50,000 ohm resistor are connected in parallel across a 100 volt source. We wish to determine the equivalent resistance of these two resistors in parallel, or in other words, we wish to determine the amount of opposition offered by this parallel combination. Before working the problem there are at least two things which can be determined by inspection. In the first place we know that since the two resistors are in parallel the same voltage is applied across each, which is in this case 100 volts. We also know from the previous discussion the total opposition offered by the two parallel resistors is less than the smallest resistor and will, therefore, be less than 50,000 ohms. Let us apply the formula to determine just how much less than 50,000 ohms this value will be.

$$R_e = \frac{R_1 \times R_2}{R_1 + R_2}$$

$$R_e = \frac{100{,}000 \times 50{,}000}{100{,}000 + 50{,}000}$$

$$R_e = \frac{5{,}000{,}000{,}000}{150{,}000}$$

$$R_e = 33{,}333 \text{ ohms}$$

The foregoing calculations require the use of a large number of zeros and the possibility of error from this source is present. For this reason it is advisable to apply powers of ten to this problem as follows:

$$R_e = \frac{R_1 \times R_2}{R_1 + R_2}$$

$$R_e = \frac{100 \times 10^3 \times 50 \times 10^3}{100 \times 10^3 + 50 \times 10^3}$$

$$R_e = \frac{5{,}000 \times 10^6}{150 \times 10^3}$$

$$R_e = 33.3 \times 10^3$$

$$R_e = 33{,}300 \text{ ohms}$$

It can be seen that this answer is practically the same as that obtained previously, the slight difference being due to the fact that the division of 5,000 by 150 is only carried to three significant figures. This answer is sufficiently accurate for all electronics work.

It should be mentioned that the **Product over Sum** formula may be used to determine the equivalent resistance of two parallel resistors, even if they are of equal ohmic value. When the resistors are of equal size, however, it is a simpler process to determine the equivalent resistance by means of the formula stated previously for use with parallel resistors of equal value. To demonstrate this fact determine the equivalent resistance of the parallel circuit of Figure 6(A) by the Product over Sum method.

There is a formula which can be used to determine the equivalent resistance of any number of parallel resistors. This formula is often called the reciprocal formula and is as follows:

$$\frac{1}{R_e} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} \text{ etc.}$$

To demonstrate the use of this formula let us find the equivalent resistance of the circuit shown in Figure 10.

$$\frac{1}{R_e} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{1}{R_e} = \frac{1}{12} + \frac{1}{6} + \frac{1}{4}$$

(NOTE: 12 is the lowest common denominator.)

$$\frac{1}{R_e} = \frac{1 + 2 + 3}{12}$$

$$\frac{1}{R_e} = \frac{6}{12}$$

$$\frac{R_e}{1} = \frac{12}{6}$$

$$R_e = \frac{12}{6}$$

$$R_e = 2 \text{ ohms}$$

The circuit of Figure 10 is identical with the circuit of Figure 3(B) and a check of the computations concerning that problem will indicate that the equivalent resistance was found to be 2 ohms by the total current method. This should demonstrate that the new formula is valid.

To further demonstrate the use of the reciprocal formula let us find equivalent resistance of the parallel circuit shown in Figure 11.

$$\frac{1}{R_e} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{1}{R_e} = \frac{1}{10{,}000} + \frac{1}{20{,}000} + \frac{1}{100{,}000}$$

$$\frac{1}{R_e} = \frac{10 + 5 + 1}{100{,}000}$$

(NOTE: 100,000 is the lowest common denominator.)

$$\frac{1}{R_e} = \frac{16}{100{,}000}$$

$$\frac{R_e}{1} = \frac{100{,}000}{16}$$

$$R_e = \frac{100{,}000}{16}$$

$$R_e = 6{,}250 \text{ ohms}$$

Once again note that the equivalent resistance of the parallel network is smaller than the smallest resistor in the network. To verify the fact that the above solution is correct you are advised to work the problem represented by the circuit of Figure 11 by means of the total current method to check the results shown.

It will be noted in finding the equivalent resistance of parallel resistors by means of the reciprocal formula that it is necessary to use the lowest common denominator in the solution. Since it is sometimes a rather involved process to do this, particularly if the values of resistance are uneven amounts such as 27,000 ohms or 330,000 ohms, some prefer to work this type of problem using the **Product over Sum** formula. This formula can be used for only two branches at a time but can be used for finding the equivalent resistance of more than two branches by solving first to find the equivalent resistance of two of the parallel branches and then using this equivalent resistance and the resistance of the third branch, to find the equivalent resistance of the entire circuit. This is illustrated in Figure 12.

Let us first find the equivalent resistance of the 12 ohm resistor and the 6 ohm resistor in the circuit of Figure 12. To do this we substitute these values of resistance in the **Product over Sum** formula.

$$R_e = \frac{12 \times 6}{12 + 6}$$

$$R_e = \frac{72}{18}$$

$$R_e = 4 \text{ ohms}$$

By means of this calculation we have found the equivalent resistance of the 12 ohm and the 6 ohm resistors to be 4 ohms. In Figure 12(B) the circuit of Figure 12(A) has been redrawn and a 4 ohm equivalent resistance has been substituted for the 12 ohm and 6 ohm resistors. Substituting the values of Figure 12(B) in the equation we solve for the equivalent resistance of the entire network.

$$R_e = \frac{R_1 \times R_2}{R_1 + R_2}$$

$$R_e = \frac{4 \times 4}{4 + 4}$$

$$R_e = \frac{16}{8}$$

$$R_e = 2 \text{ ohms}$$

While this method is in two steps and is a little longer, it eliminates the need for using a lowest common denominator which, as mentioned previously, can be very troublesome when involving odd values of resistors.

You are advised to use the **Product over Sum** formula to solve the problem presented by Figure 11. First use this formula to determine the equivalent resistance of the 10,000 ohm and the 20,000 ohm resistor in parallel. Substitute the equivalent resistance of these two branches in the circuit and again apply the formula using this equivalent resistance and the 100,000 ohm resistor. Your answer should be practically the same as that computed previously for the equivalent resistance of this network. (6250 ohms).

Summary

The parallel circuit is a circuit in which two or more paths are provided for the current. The parallel paths are sometimes referred to as the branches or arms of the parallel circuit.

There are two important facts which should be borne in mind concerning parallel circuits. One of these is the fact that the voltage applied to all branches of a parallel circuit is equal since it is actually the same voltage applied to the various branches. The second important fact concerning parallel circuits is: the equivalent resistance of a parallel network is always less than the smallest resistance in the network. This should be an apparent fact to you when you recall that resistance is the opposition offered to current flow and, if two or more paths are provided, the opposition is naturally less than that offered by any of the paths.

The ohmic value of the equivalent resistance of parallel resistors can be computed in a number of manners. One method is to determine the amount of current flowing through each branch of the circuit by Ohm's Law and then to add the branch currents to find the total current flowing in the circuit. This total current and the applied volage may then be used to determine the equivalent resistance by means of Ohm's Law. There are, likewise, several formulas which may be employed to determine the equivalent resistance of parallel circuits. The formula which is used is determined largely by your choice and the type of circuit arrangement employed. If the parallel branches are of **equal** ohmic resistance the following formula may most conveniently be employed.

$$R_e = \frac{R}{N}$$

If the parallel circuit consists of **two** branches the following formula may be used very conveniently.

$$R_e = \frac{R_1 \times R_2}{R_1 + R_2}$$

The equivalent resistance of any parallel circuit can be solved by using the following formula:

$$\frac{1}{R_e} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} \text{ etc.}$$

To become fully acquainted with the solution of circuits containing parallel resistors you should draw a number of such circuits and solve the circuits for the various unknown factors. To aid in this exercise three circuits are presented in Figure 13. Work each of these circuits carefully before checking your results against the proper solutions indicated at the end of the assignment.

Answers To Exercise Problems

Problems Presented By Circuits Of Figure 5

Problem 5. **Total Current**

The current drawn from the battery in this case will be 17 milliamperes or .017 ampere as determined in the following manner. The current from the battery is equal to the sum of the currents passed through the individual resistors or:

$$\begin{array}{l} .010 \\ .005 \\ .002 \\ \hline .017 \text{ ampere or 17 milliamperes} \end{array}$$

Problem 5. **Equivalent Resistance**

The total current has been computed to be 17 milliamperes or .017 ampere. To find the equivalent resistance Ohm's Law formula should be applied as follows:

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

$$R = \frac{100}{.017}$$

$$R = 5{,}882 \text{ ohms}$$

Notice once again that the equivalent resistance of the parallel circuit—in this case the circuit of Figure 5—is smaller than the resistance of any branch of that circuit.

Problems Presented By Circuits Of Figure 13

Problem 13(A).

The equivalent resistance of R_1, R_2 and R_3 is 1,000 ohms as determined by the following calculations.

$$R_e = \frac{R}{N}$$

$$R_e = \frac{3000}{3}$$

R_e = 1000 ohms

The current flowing through each resistor can be determined by Ohm's Law since the applied voltage is 100 volts.

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

$$I = \frac{100}{3000}$$

I = .0333 amp or 33.3 ma

The total current drawn from the battery can be determined in two ways. In the first place it has been established that the equivalent resistance of the parallel network is 1,000 ohms. This value can be used to determine the total current.

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

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

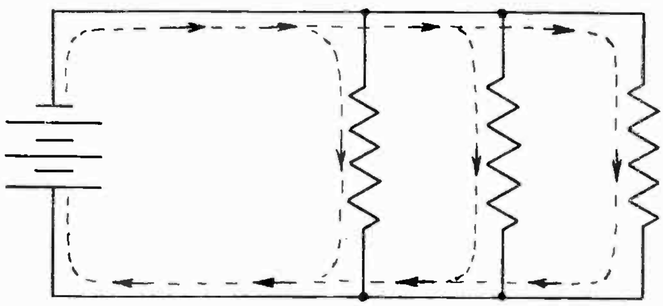
I = .1 amp or 100 ma

The total current can also be found to be 100 milliamperes by adding the three individual currents which, as computed previously, are 33.3 milliamperes each.

$$\begin{array}{r} .0333 \\ .0333 \\ .0333 \\ \hline .0999 \end{array}$$

.0999 amperes or 100 ma

The current paths are indicated in the accompanying diagram.



Problem 13(B).

The equivalent resistance of R_1 and R_2 can be most easily determined in this case by applying the **Product over Sum** formula.

$$R_e = \frac{R_1 \times R_2}{R_1 + R_2}$$

$$R_e = \frac{27{,}000 \times 33{,}000}{27{,}000 + 33{,}000}$$

$$R_e = \frac{891{,}000{,}000}{60{,}000}$$

$$R_e = 14{,}850 \text{ ohms}$$

The total current flowing in the circuit can be computed by applying Ohm's Law using the battery voltage as indicated, and the equivalent resistance which has just been computed.

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

$$I = \frac{50}{14{,}850}$$

$$I = .0034 \text{ ampere or } 3.4 \text{ ma}$$

Problem 13(C).

The reciprocal formula is applied to determine the equivalent resistance of the three resistors as follows:

$$\frac{1}{R_e} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{1}{R_e} = \frac{1}{2} + \frac{1}{5} + \frac{1}{10}$$

$$\frac{1}{R_e} = \frac{5 + 2 + 1}{10}$$

$$\frac{1}{R_e} = \frac{8}{10}$$

$$R_e = \frac{10}{8}$$

$$R_e = 1.25 \text{ ohms}$$

The current flowing through each resistor can be determined by the application of Ohm's Law to the three individual resistors since the resistance of each is known and the applied voltage is 10 volts in each case.

2 ohm resistor	5 ohm resistor	10 ohm resistor
$I = \frac{E}{R}$	$I = \frac{E}{R}$	$I = \frac{E}{R}$
$I = \frac{10}{2}$	$I = \frac{10}{5}$	$I = \frac{10}{10}$
$I = 5$ amps	$I = 2$ amps	$I = 1$ amp

The total current can be computed by applying Ohm's Law using the battery voltage indicated and the equivalent resistance which has just been computed.

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

$$I = \frac{10}{1.25}$$

$$I = 8 \text{ amps}$$

Test Questions

Be sure to number your Answer Sheet Assignment 8B.
Place your Name and Associate Number on **every** Answer Sheet.
Submit your answers for this assignment immediately after you finish them. This will give you the greatest possible benefit from our personal grading service.

1. Is the electromotive force applied to a circuit measured in; (a) amperes, (b) volts, or (c) ohms?

2. (A) If the value of a resistor in a radio diagram is indicated as being 13K, what is the value of that resistor in ohms? 13 000 Ω

   (B) If a resistor in a schematic diagram is labeled 2 megohms, how many ohms of resistance are there in the resistor? 2,000,000 Ω

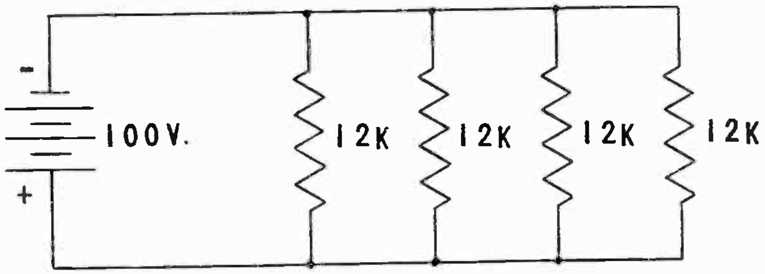
3. Is the equivalent resistance of a parallel network, (a) equal to the value of the smallest resistor forming the network, (b) equal to the value of the largest resistance forming the network, (c) larger than the largest resistor in the network, (d) smaller than the smallest resistance forming the network?

4. What general statement can be made concerning the value of voltage applied to the various resistors in a parallel arrangement? ALL EQUAL

5. If a parallel network consists of three resistors and the current flowing through the first resistor is 1 ampere, that through the second resistor is 2 amperes and that through the third resistor is 3 amperes, what is the total current drawn from the battery? 6 A

6. On your Answer Sheet redraw the circuit of Figure 6(A). Indicate by means of a dotted line with arrowhead the direction of the current flow through each resistor in the circuit.

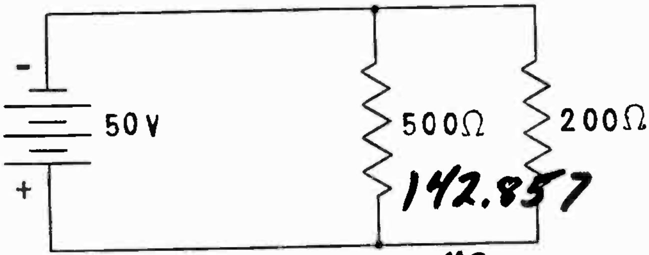
7. In the accompanying diagram what is the equivalent resistance of the four resistors?



3K

Continued on next page

8. In the accompanying diagram find the equivalent resistance of the two resistors by application of the Product over Sum formula, **show your work.**



$\frac{200 \times 500}{200 + 500}$ $\frac{100000}{700}$ $\frac{1000}{7}$

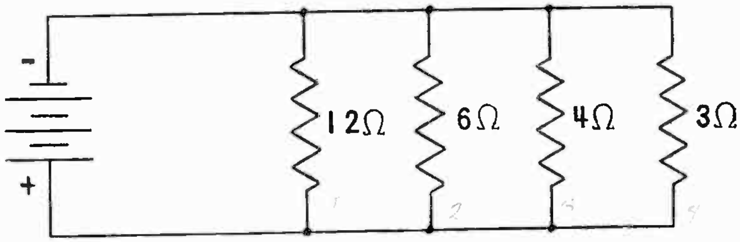
142.857

143 Ω

$7\overline{)1000}$ 142.857

9. In the circuit of Question 8; (a) what is the current through the 500 ohm resistor; (b) what is the total current drawn from the battery?

10. In the accompanying diagram find the equivalent resistance of the four resistors. Show your work.



$143\overline{)50.000}$ .34

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

CIRCUIT ARRANGEMENTS

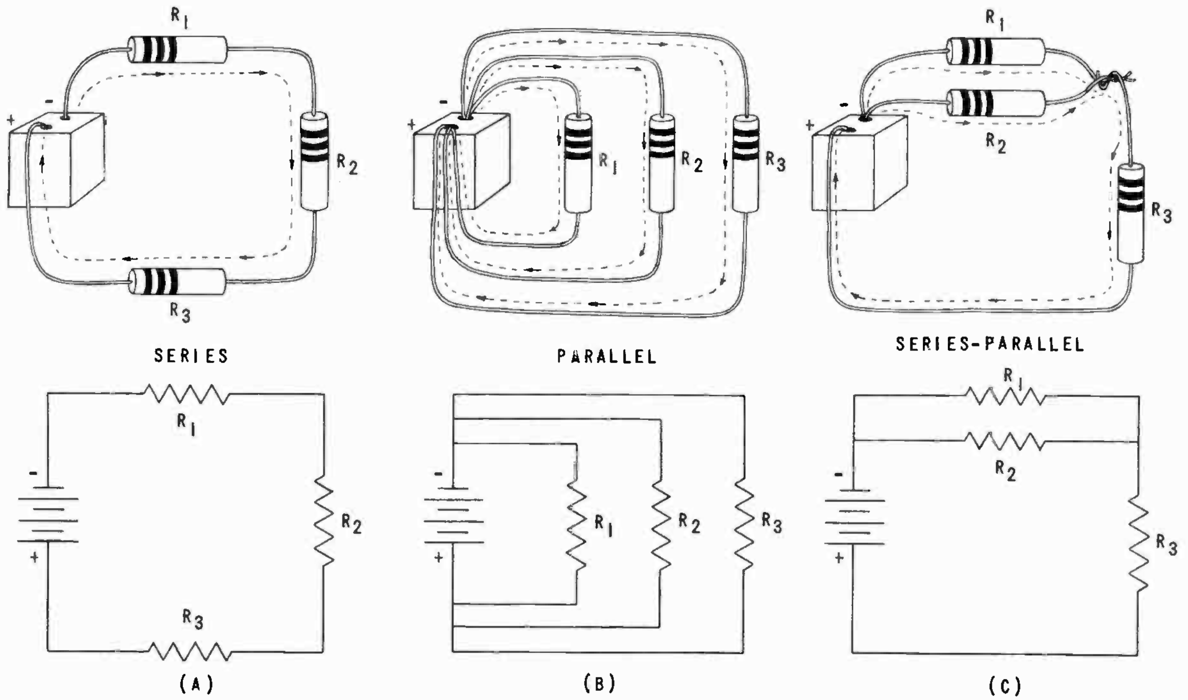


FIGURE 1

THREE SIMPLE SERIES CIRCUITS

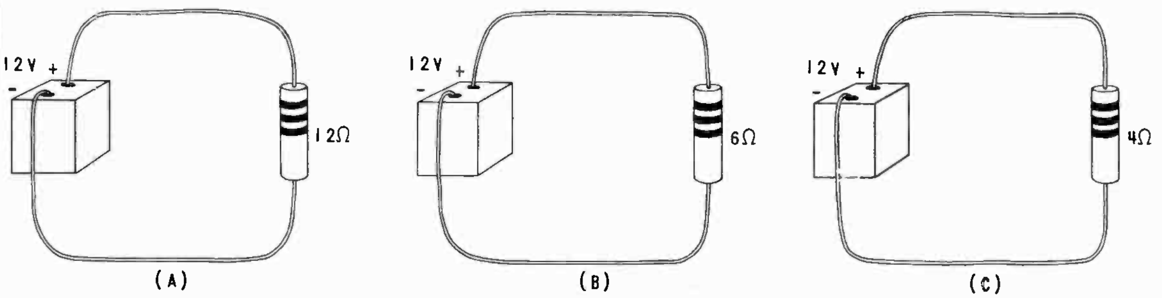
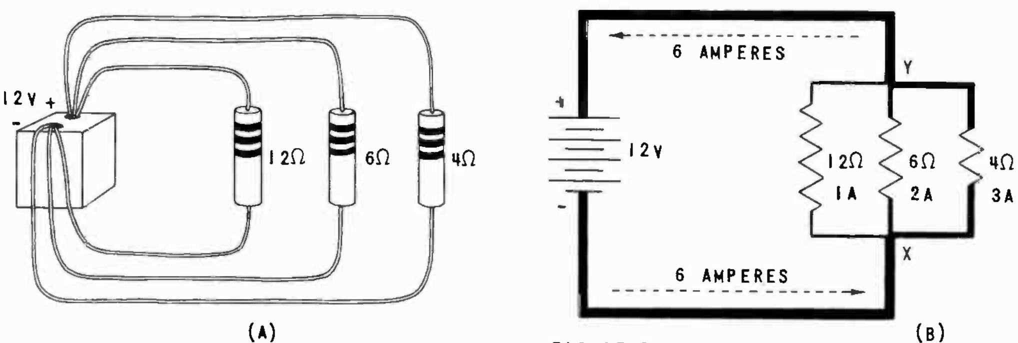


FIGURE 2

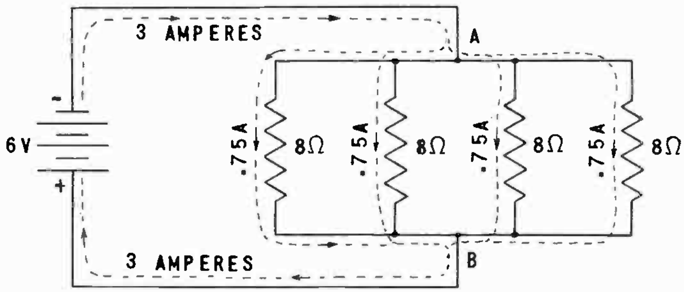
PARALLEL CIRCUIT



R	E	I
12	12	1
6	12	2
4	12	3

FIGURE 3

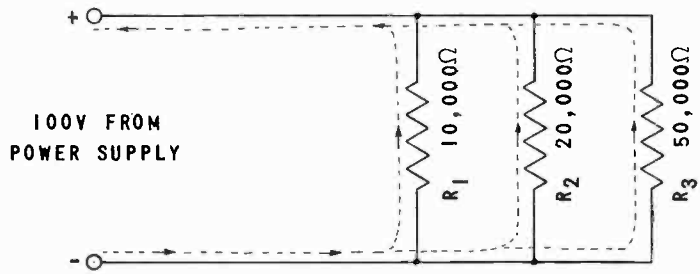
PARALLEL CIRCUIT



R	E	I
8	6	.75
8	6	.75
8	6	.75
8	6	.75

FIGURE 4

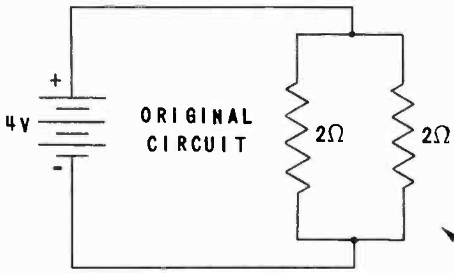
PARALLEL CIRCUIT



R	E	I
10K	100	.01
20K	100	.005
50K	100	.002

FIGURE 5

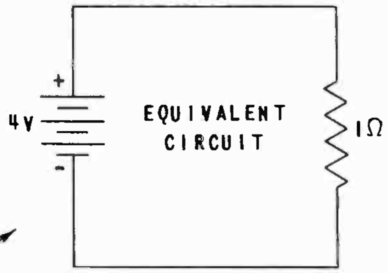
PARALLEL CIRCUIT



(A)

R	E	I
2	4	2
2	4	2

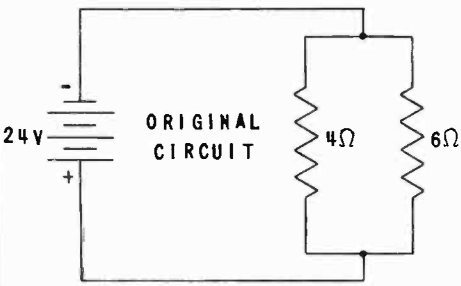
TOTAL CURRENT IS THE SAME (4 AMP.) FOR BOTH CIRCUITS



(B)

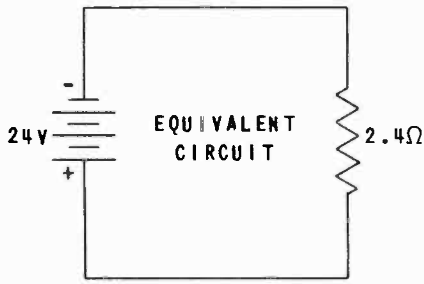
FIGURE 6

PARALLEL CIRCUIT



(A)

R	E	I
4	24	6
6	24	4



(B)

FIGURE 7

PARALLEL CIRCUIT WITH
FIVE EQUAL RESISTORS

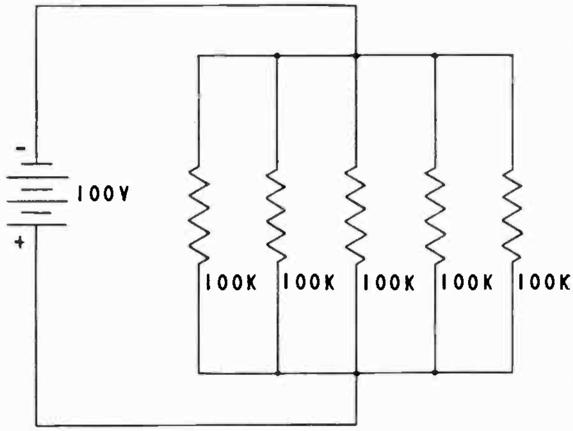


FIGURE 8

PARALLEL CIRCUIT WITH
TWO UNEQUAL RESISTORS

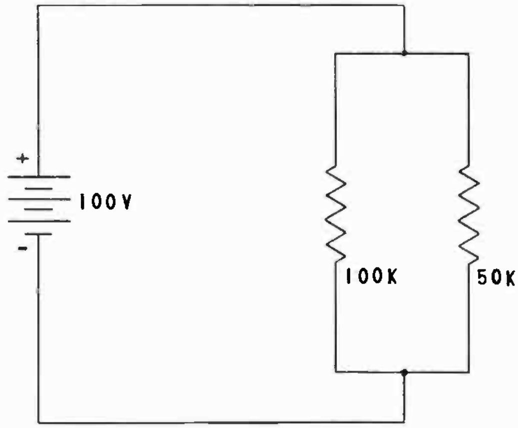


FIGURE 9

PARALLEL CIRCUIT WITH THREE RESISTORS

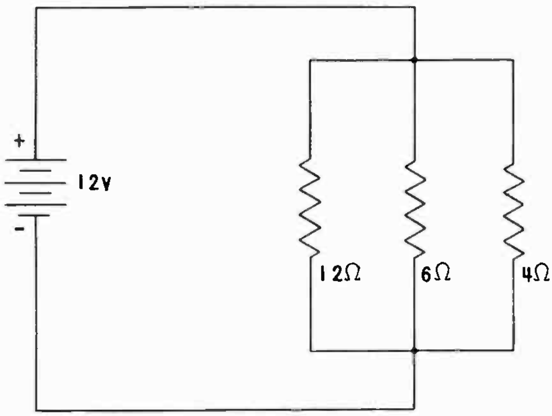


FIGURE 10

PARALLEL CIRCUIT WITH THREE RESISTORS

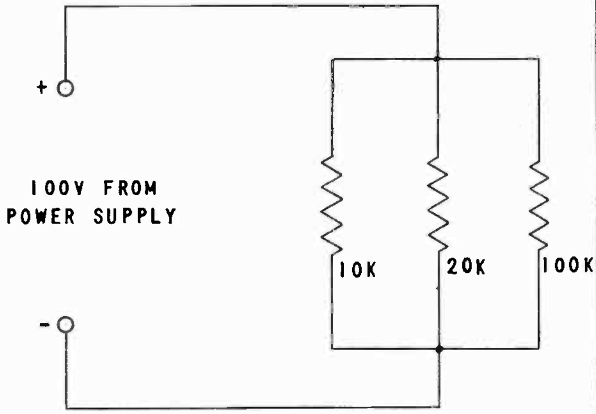
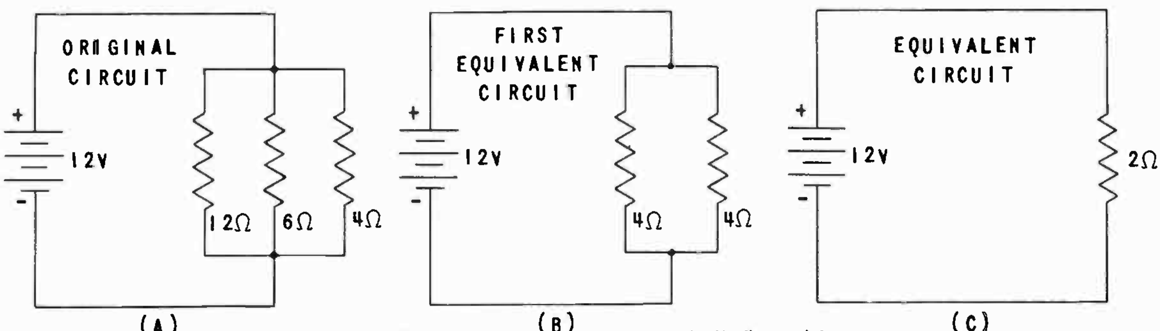


FIGURE 11

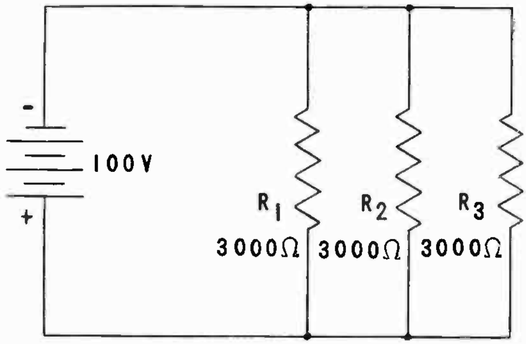
PARALLEL CIRCUIT WITH THREE RESISTORS



$R_e = \frac{12 \times 6}{12 + 6} = \frac{72}{18} = 4\Omega$ $\quad$ $R_e = \frac{4 \times 4}{4 + 4} = \frac{16}{8} = 2\Omega$

FIGURE 12

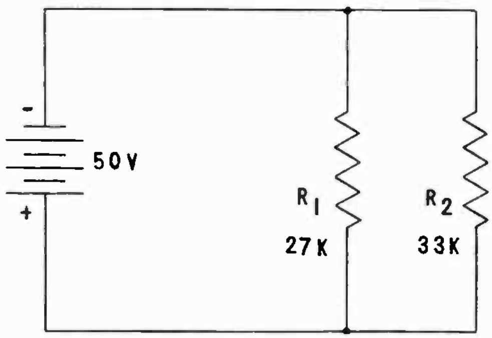
PARALLEL CIRCUIT PROBLEMS



FIND:
EQUIVALENT RESISTANCE OF R_1, R_2, R_3.
CURRENT FLOWING THROUGH EACH RESISTOR.
TOTAL CURRENT DRAWN FROM BATTERY.

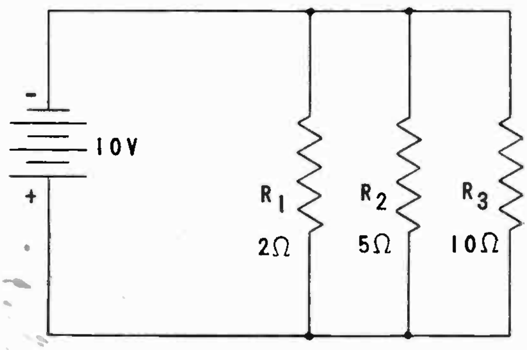
SHOW:
CURRENT PATHS BY MEANS OF DOTTED LINE.

FIGURE 13-A



FIND:
EQUIVALENT RESISTANCE OF R_1 AND R_2.
TOTAL CURRENT FLOWING IN CIRCUIT.

FIGURE 13-B



FIND:
EQUIVALENT RESISTANCE BY RECIPROCAL FORMULA.
CURRENT THROUGH EACH RESISTOR.
TOTAL CURRENT.

FIGURE 13-C