

Electrical Applications Guidebook

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Preface

The chief aim of this guidebook is to present a handy reference containing the rules, equations, wiring tables, electrical diagrams, and installation procedures that are most often needed by electricians, foremen, superintendents, designers, manufacturers, and dealers in electrical equipment and supplies.

Only that portion has been selected, from the vast amount of material at hand, which is most likely to be used in connection with the daily work or which will be most frequently consulted. While the treatment of some subjects is of necessity brief, it is considered to be sufficient for the purpose. Other more important subjects, however, have been covered in greater detail; for instance, the bending of rigid conduit and the trouble-shooting data have been covered very thoroughly and are complete in every respect. The tables selected are those most in demand, and the applications of the rules and equations are shown, in most cases, by practical examples and solutions, together with explanations.

Every effort has been made to provide a compilation of data and information on the various types of electrical equipment, materials, and methods, presented without advanced mathematics. The material is conveniently and logically arranged for ready reference as a guide to the selection, installation, operation, and maintenance of the equipment and systems.

The author wishes to express his sincere appreciation to the many companies and their representatives who have supplied illustrations and data. I especially appreciate the assistance given by my secretary, Ruby Updike, in preparing the manuscript, proofreading, and handling the endless details that made this book possible.

John E. Traister

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Electricity is the major source of energy for operating many things. It further provides the most effective means known to date for carrying energy from one place to another, and for changing one form of energy to another form of energy. In fact, it is the only practical means of transmitting power in large quantities from where it is cheaply or conveniently produced to somewhere else, many miles away, where the power may be used to an advantage.

There are many useful books on basic electricity that present a comprehensive study of the electron theory or nature of electricity. However, this chapter will be more concerned with what electricity can do, how it can be controlled, and how to solve problems that may arise from the use of electricity.

1.1 FUNDAMENTAL ELECTRICAL UNITS

The three basic electrical units in any electrical circuit are the ampere, ohm, and volt. The ampere is an electrical unit to measure the flow of current in a circuit; the resistance or opposition to the flow of current is measured in ohms; while the external force applied to a circuit to overcome the opposition to the flow of current is measured in volts.

The ampere: The rate at which electricity flows through a conductor is represented by the unit called the ampere and may be compared to the rate of flow of water through a pipe in gallons per second. For all practical purposes, the unit strength of an ampere is represented when an electrical current passing through a specified solution of nitrate of silver in water deposits silver at the rate of .001118 gram per second. If twice that amount of silver is deposited during one second, the current is 2 amperes, and so on.

The ohm: All substances offer resistance to the flow of electricity through them. This opposition, or resistance, is measured with a unit called the ohm. The resistance of all metals increases with the increase in temperature while the resistance of carbon, insulating materials, and electrolytic solutions decreases with an increase in their temperatures.

2 Electricity and Magnetism

The volt: In order to overcome the resistance of conductors and cause current to flow, an external force is necessary. This force is commonly called voltage since the unit of measurement is the volt. This force is also referred to as electromotive force or electric pressure. The electromotive force that will cause a current of 1 ampere to flow through a resistance of 1 ohm is equal to 1 volt. A kilovolt = 1,000 volts; a millivolt = .001 volt; and a microvolt = .000001 volt.

Another important unit of electrical measurement is the watt—the unit of power. Power is defined as the rate at which work is done or the rate at which energy is expended.

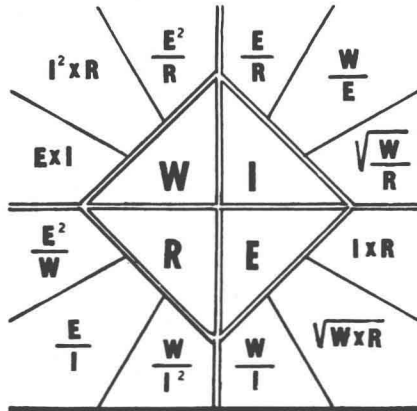
1.2 OHM'S LAW

George S. Ohm, a German physicist, discovered that the current through an electrical conductor depends upon the amount of pressure (volts) and resistance of the circuit components. These laws or equations are summarized in Fig. 1-1. They are directly applicable to any resistive circuit, any resistive portion of a circuit, any dc (direct current) circuit, and any ac (alternating current) circuit or portion of an ac circuit with a power factor of 100%.

In general, Ohm's Law states that the current, in amperes, increases and decreases directly with an increase or decrease of the pressure difference in volts. It further states that when the resistance is doubled, only half as much current will flow (when the voltage remains the same), and when half the resistance is present, twice as much current will flow. From this, we can say that the current increases proportionately to every decrease of resistance, and that the current decreases proportionately to any increase, provided the voltage remains the same throughout.

The basic ways of stating Ohm's Law when I = amperes, R = resistance in ohms, and E = volts are:

1. $E = IR$ or the voltage is equal to the current multiplied by the resistance.
2. $I = \frac{E}{R}$ or the current equals voltage divided by the resistance.
3. $R = \frac{E}{I}$ or the resistance equals the voltage divided by the current in amperes.



W-WATTS, E-VOLTS, I-AMPS, R-OHMS
PLACE THUMB OVER THE UNKNOWN,
SELECT FORMULA IN THAT ANGLE

Power Factor is the Ratio of True to
Apparent Power $\frac{W}{VA}$

Power Factor Percent = $KV \div KVA$

Determining K.W. from a W.H. meter:

Watts = RPM of Disc $\times 60 \times$ K.H.

(K.H. is constant printed on meter name plate)

FIGURE 1-1. Summary of Ohm's Law.

The electrical unit for power—the watt—may also be incorporated into Ohm's Law for further calculations. When W = watts, current may be found by the following equations:

1. $I = \frac{W}{E}$ or the wattage divided by the voltage.
2. $I = \sqrt{\frac{W}{R}}$ or the square root of the wattage divided by the resistance.

Voltage may be found by using the following equations:

1. $E = \frac{W}{I}$ or the wattage divided by the current.
2. $E = \sqrt{W \times R}$ or the square root of the wattage times the resistance.

4 Electricity and Magnetism

Resistance may be found by the following equations:

1. $R = \frac{E^2}{W}$ or the voltage squared divided by the wattage.
2. $R = \frac{W}{I^2}$ or the wattage divided by the current squared.

The power, in watts, of a circuit may be found by the following equations:

1. $W = \frac{E^2}{R}$; that is, the voltage squared divided by the resistance.
2. $W = I^2 \times R$ = the current squared times the resistance.
3. $W = E \times I$ = the voltage times the current.

1.3 ELECTRICAL CIRCUITS

In order for an electrical circuit to be complete, it must provide a path for the electric current. All electrical circuits consist of one of two distinct types of circuits or a combination of these two circuits, that is, the series circuit and the parallel circuit.

The series circuit (Fig. 1-2) is one in which all components are connected in tandem and is used very often in control circuits—

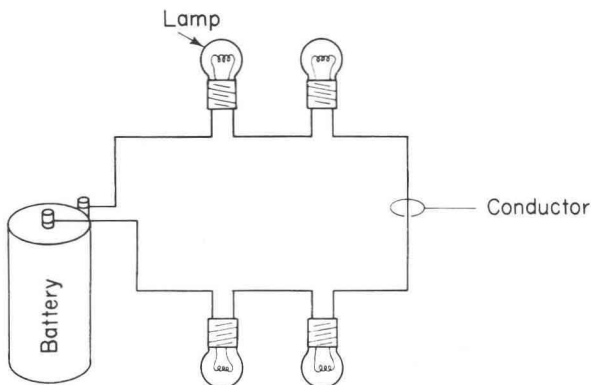


FIGURE 1-2. Lamps connected in series.

for conventional magnetic contactor controls, static controls, and electronic controls. The following four rules state the conditions which exist in a series circuit:

- The current is the same in all parts of a series circuit.
- The total resistance in a series circuit is equal to the sum of the individual resistances.
- The total voltage applied to a series circuit divides between the resistors in direct proportion to their resistance.
- The sum of the voltage drops across all the resistors in a series resistive circuit is equal to the applied (source) voltage.

A simple parallel circuit is shown in Fig. 1-3. Here the electrical components are connected *across* the lines rather than in tandem with the lines. Most of the circuits encountered on electrical construction work will consist of parallel circuits or a combination of series and parallel circuits.

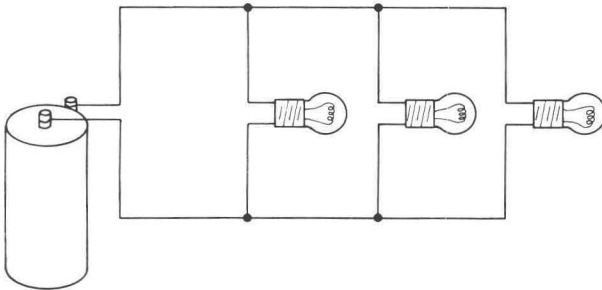


FIGURE 1-3. Lamps connected in parallel.

There are several ways to calculate the total resistance of a parallel circuit, but remember that the total resistance of a parallel circuit is always smaller than the smallest resistor. This is because more paths for the current to flow along are available in a parallel circuit than in a series circuit. Therefore, there is more opportunity for the current to flow, and the total resistance of the circuit becomes lower.

The three most commonly used equations for resistors in parallel are:

$$1. \quad R_t = \frac{R_1}{N}$$

6 Electricity and Magnetism

$$2. R_t = \frac{R_1 \times R_2}{R_1 + R_2}$$

$$3. \frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$$

In dealing with the current, voltage, and resistance in a parallel circuit, there are a few simple rules which must be learned:

- The voltage is the same in all parts of a parallel circuit.
- The total current in a parallel circuit is the sum of the currents through the separate parts.

To solve problems for parallel circuits, first draw a circuit diagram of the problem, set down the equation to be used, fill in the equation with the given quantities, then solve for the missing quantity. A systematic approach to any problem leads to a better understanding of the problem and the theory behind it.

The circuit in Fig. 1-4 shows the resistors R_2 and R_3 connected in parallel, but resistor R_1 is in series with both the battery and the parallel combination of R_2 and R_3 . That in the current flow (indicated by the arrows) leaves the negative terminal of the battery and travels through resistor R_1 and then divides at point A into I_1 and I_2 .

The total resistance of this circuit is the sum of R_1 and the resistance of R_2 and R_3 in parallel. Therefore, to find R_t we first need to find the resistance of R_2 and R_3 in parallel. Because these two resistors have identical values, we have a resultant parallel resistance R_p of

$$R_p = \frac{R}{n} = \frac{20 \text{ ohms}}{2 \text{ resistors}} = 10 \text{ ohms}$$

The circuit now looks like Fig. 1-5, in which R_2 and R_3 have been replaced with R_p . We now have a simple series circuit in which the total circuit resistance R_t is

$$R_t = R_1 + R_p = 5 + 10 = 15 \text{ ohms}$$

The total circuit current I_t supplied by the battery is then

$$I_t = \frac{E}{R_t} = \frac{30 \text{ volts}}{15 \text{ ohms}} = 2 \text{ amperes}$$

Because R_1 is in series with the battery, we know that the current through R_1 must be 2 amperes. Since R_2 is equal to R_3 , equal currents of 1 ampere must flow through each of these two resistances.

Remember always to break up the circuit and work the series or parallel groups separately within the combination, then solve for the whole combination.

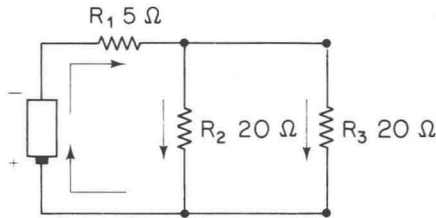


FIGURE 1-4. A combination series parallel circuit.

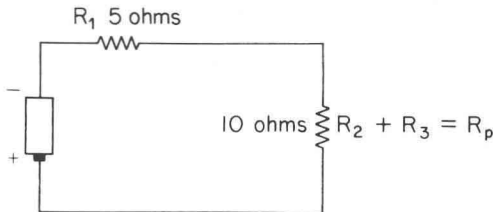


FIGURE 1-5. The circuit in Fig. 1-4 after resistors R_2 and R_3 have been totaled.

1.4 MAGNETISM

Anyone working in the field of electricity must be familiar with the principles of magnetism because generators, transformers, and motors depend on magnets and magnetism for their operation. Even fluorescent lights depend on magnetism for their operation.

A magnet is either permanent or temporary. If a piece of iron or steel is magnetized and retains its magnetism, it is a permanent magnet. A compass is one form of permanent magnet. Others with which you are probably familiar are horseshoe-shaped magnets and bar magnets. Each one of these magnets has a north magnetic pole and a south magnetic pole; in fact; all magnets have a north and a south pole.

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When current flows through a coil, a magnetic field with a north and a south pole is set up just like that of a permanent magnet. However, when the current stops, the magnetic field also disappears. This type of temporary magnetism is called electromagnetism. Permanent magnets are used for the magnetic field necessary in the operation of small, inexpensive electrical motors. Larger motors, relays, and transformers rely upon the magnetic fields from electrical current passing through coils of wire.

When electricity flows through a wire or conductor, magnetic lines of force (magnetic flux) are created around that wire (Fig. 1-6). When a piece of wire is passed through a magnetic field (magnetic lines of force), electricity is created in that wire. We then can readily see the relation between electricity and magnetism. In fact, the very existence of the electrical industry is dependent upon magnetism and magnetic circuits.

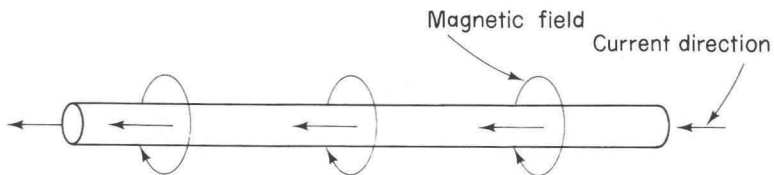


FIGURE 1-6. When electricity flows through a wire, magnetic lines of force are created around the wire.

1.4.1 Rules For Direction Of Current And Motion

If the current in a conductor is flowing from south to north, and a compass is placed under the conductor, the north end of the needle will be deflected to the west; if the compass is placed over the conductor, the north end of the needle will be deflected to the east (Fig. 1-7).

To determine the polarity of an electromagnetic solenoid: In looking at the end of a solenoid, if an electric current flows in it clockwise, the end next to the observer is a south pole and the other end is a north pole; if the current flows counter-clockwise, the position of the poles is reversed.

To determine the direction of the lines of force set up around a conductor: If the current in a conductor is flowing away from the observer, then the direction of the lines of force will be clockwise around the conductor.

To determine the direction of motion of a conductor carrying a