Electronics
Radio
Television
Radar

UNITED ELECTRONICS LABORATORIES

LOUISVILLE KENTUCKY

REVISED 1967

CIRCUIT DIAGRAMS AND HOW TO READ THEM

ASSIGNMENT 3

POWER TRANSFORMERS

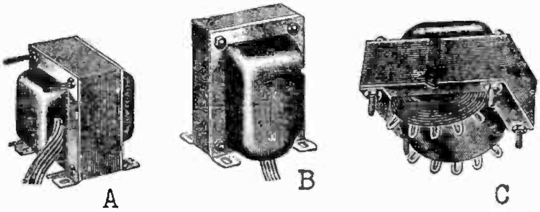


FIGURE 9

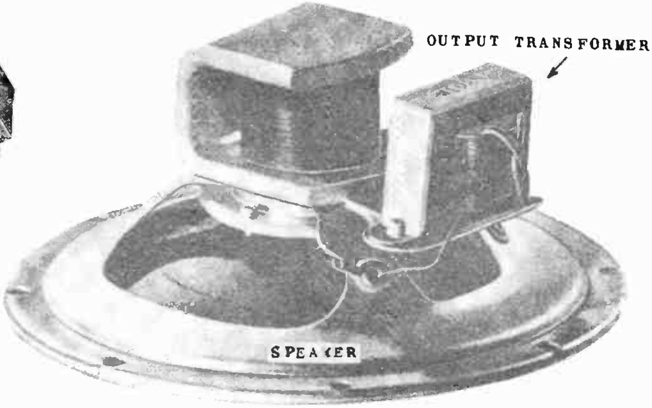


FIGURE 10

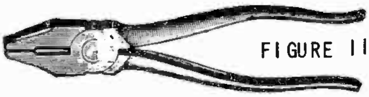


FIGURE 11-A

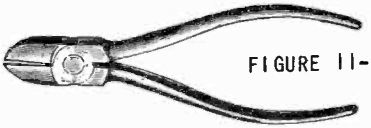


FIGURE 11-B

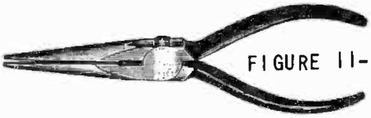


FIGURE 11-C

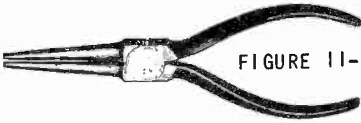


FIGURE 11-D

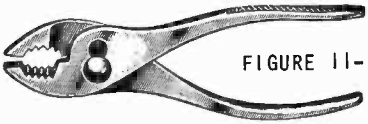


FIGURE 11-E

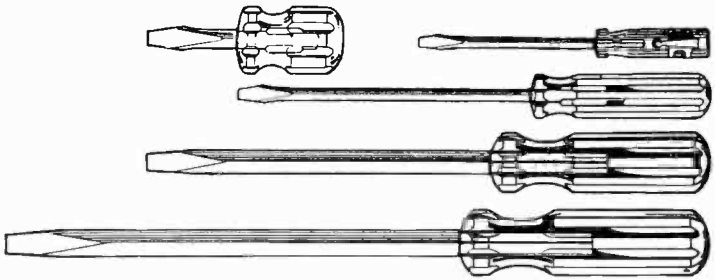


FIGURE 12-A

FIGURE 12-B

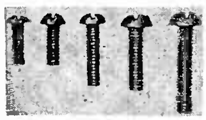


FIGURE 13-A

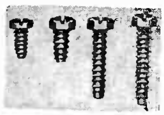


FIGURE 13-B

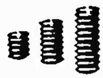


FIGURE 13-C

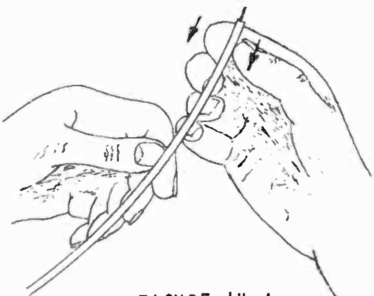


FIGURE 14-A

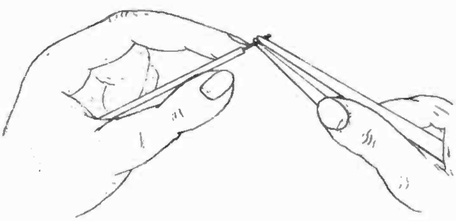


FIGURE 14-B

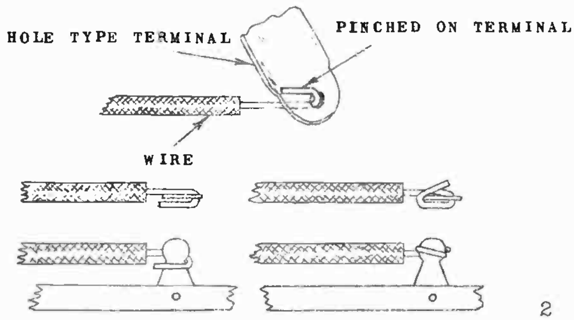


FIGURE 15

ASSIGNMENT 3

CIRCUIT DIAGRAMS AND HOW TO READ THEM

We have now reached a point in the training where it is possible to learn some of the symbols which are used in electronics diagrams. Engineers and technicians have long employed a written sign language. In this way it is possible to show every connection in a complicated electronics circuit on a small piece of paper; whereas, if a written description were employed, it would require many pages. From our experience with the radio receiver of the last assignment we can easily see why a photograph, or even a series of photographs would not give us the complete answer on the wiring and parts of even simple radio receivers, much less anything very complex. For example, no photograph could possibly give the electrical size of the resistors and capacitors and certainly no photograph or pictorial drawing could show the component parts mounted under other parts.

The system employed in electronics diagrams is very simple. Once you get fully acquainted with it, you will appreciate its value. You cannot work on electronics equipment or study the literature without having a knowledge of this system. Therefore, it is absolutely necessary that you learn it so that you can progress smoothly in the training.

In the last Assignment we got an idea of what the various component parts of a radio receiver look like, and we saw that these component parts were electrically joined together in some definite pattern by means of hookup wire. There are hundreds and hundreds of different ways to connect these various parts togther to form different electronics circuits. Obviously, no one can remember all these ways, or know in advance how the designer of the equipment is going to arrange a particular circuit. Thus, it is necessary that a universally accepted **system** be used in order that a piece of electronics equipment manufactured in one part of the country may be efficiently serviced in another. When you have learned this symbol system, you can look at an electronics circuit diagram and determine at a glance just what you want to know.

In the last Assignment we saw that fundamentally an electronics circuit consists of a limited number of basically different parts (capacitors, coils, resistors, vacuum tubes, etc.) and that these parts are connected together by means of wire and mechanical fittings such as screws, nuts, rivets, and clamps. Different electrical sizes of these parts are used in the same equipment, but basically, we can count the number of really different parts on the fingers of our hands. Thus, it can be seen that learning about these parts will not be as difficult a job as it might seem.

When you are called upon to locate and repair a defect in a piece of electronics equipment, you will be required to check a number of different circuits in a systematic manner. It is difficult to do this in a confusion of wiring in actual equipment, but with the aid of a circuit diagram, you can check off each circuit as you test it.

Before you can check the circuits of electronics equipment, you must know what kind of parts are used and where these parts are located. An examination of the inside of the equipment will not always give you this information. Even an experienced electronics technician may have trouble distinguishing between a filter choke and a capacitor when it is sealed inside a can or container because their appearances may be similar. For this reason, it may be necessary to refer to a diagram to learn, first, what parts are being used, and second, how these parts are connected. Then you can start at some point which you can identify and in this way trace the wiring to the actual part in question.

Schematic Diagrams

The wiring diagrams of electronics equipment are called **schematic** diagrams. (These diagrams show the "scheme" of the wiring.)

An electronics technician almost always refers to a **schematic** diagram of the equipment on which he is working. Such a diagram is shown in Figure 1, which is the diagram for a five-tube table model broadcast receiver.

Before you go on with this Assignment, stop and look this figure over carefully. After doing so, you may well be saying to yourself: "This thing doesn't tell **me** anything about the radio—it looks impressive, but that's about all I can say for it!" This is probably true at the moment, but **before you finish this Assignment you will be able to recognize every electronics part in Figure 1.** You will not, as yet, be able to understand the entire drawing, or the operation of the circuits, but you will have taken **the first step**—you will know the **schematic symbols** for almost all electronics parts. Not only the parts used in this radio, but the parts used in the electronics control circuits in missiles, in electronics computers, in telemetering systems, and in automation.

Pictorial Diagrams

There is another type of diagram which some electronics manufacturers include in their service manuals. It is known as a **pictorial diagram.** Figure 2 gives a pictorial diagram of the radio shown schematically in Figure 1. This type of diagram is most useful in showing the actual physical layout of parts. Beginners in electronics have a tendency to rely on the pictorial rather than the schematic diagram, but this is not a good habit to get into since these pictorial diagrams are not available for all equipment. Actually, you can find out with a glance everything you need to know about a piece of electronics equipment from the schematic diagram after you learn to read it, whereas much study is required when the pictorial diagram is used alone. This pictorial diagram should only be used in conjunction with the schematic diagram to show the layout of the parts—never used alone. Experienced technicians seldom refer to the pictorial diagram, but rely almost entirely on the schematic diagram.

Learning to read schematic diagrams is mostly a matter of becoming familiar with the major symbols which are used in electronics. There is a large number of symbols in use, but the principal seven are: (1) resistors (both fixed and variable), (2) capacitors (fixed and variable), (3) inductances (coils and transformers), (4) batteries and cells, (5) vacuum-tubes (and transistors which we will consider in detail later), (6) microphones, pickups, and speakers, and (7) switches of all types. Thus, by memorizing the symbols for these, you will be able to read any schematic diagram.

Resistors

Resistors are manufactured in a great number of shapes and sizes. Figure 3 illustrates a number of resistors and the schematic symbols used for the various types of resistors.

The schematic symbol shown in Figure 3(A) is for a **fixed resistor without taps.** The illustrations, numbers 1 through 10, in Figure 3, are fixed resistors which would be illustrated in a schematic diagram by the symbol shown in Figure 3(A). A brief description of each of these resistors follows.

Resistor 1 is a carbon resistor, available in wattage ratings from ¼ watt to 2 watts, depending upon the physical size. This style of resistor is of an old method of manufacturing and will be found in older equipment.

Resistor 2 is a carbon or metalized resistor, available in wattage rating of ¼ watt to 2 watts, depending upon the physical size. The resistor is manufactured by a new process and will be found in equipment of modern design.

Resistor 3 is a precision wire-wound type of resistor used with voltmeters and ammeters, and in laboratory equipment where a high degree of accuracy is important.

Resistors 4 and 5 are two forms of wire wound resistors which are available in wattages of 5 watts and above.

Resistors 6 and 7 are called wire-wound strip resistors and are usually of the low power type (less than 5 watts). Few of these resistors are found in modern equipment.

Resistor 8 is an enclosed ballast resistor, or plug-in resistor, used in some radios to adjust automatically the power line voltage or to maintain it within narrow limits. This type of resistor is enclosed in a metal or glass envelope with base pins and from the outside looks exactly like a vacuum tube.

Resistor 9 is a wire wound flexible type of resistor and will be found only in special applications.

Resistor 10 is called a power-cord, or line-cord resistor. Notice that there are three wires in the cord. Two of these are of the usual two lines used to connect electrical equipment to a receptacle. The third wire is resistance wire. This type of a resistor is used with some types of table model radios.

As was previously stated, the symbol (A) of Figure 3 is used to indicate any of these resistors just described, in a schematic diagram.

The symbols (B) and (C) of Figure 3 are used to indicate **fixed resistors with taps.** The symbol (B) represents a fixed resistor with one tap, while the symbol (C) represents a resistor with three taps. Resistors 11, 12, and 13 in Figure 3 are tapped resistors which would be represented in a schematic diagram by symbols (B) and (C).

Resistor 11 is a center-tapped wire-wound resistor of the power type. Symbol (B) is used to represent this resistor in a schematic diagram.

Resistor 12 is a center-tapped wire-wound strip resistor. This type of resistor will be found in older models of equipment. Symbol (B) is also used to indicate such a resistor.

Resistor 13 is a wire-wound power type resistor with three taps. The symbol used for this resistor is shown at (C). Resistors with more than three taps would be represented by a symbol such as illustrated at (C) except the proper number of taps would be indicated by the lines coming off of the resistor.

The symbol shown at (D) in Fig. 3 is for a resistor with an adjustable tap. Such a resistor is illustrated by resistor 14. On this type of resistor there is a strip along the length of the resistor where the insulating material is left off during manufacturing. A metal band is provided which makes contact with the bare resistance wire when the bolt in this metal band is drawn tight. To adjust the tap on this resistor it is necessary to loosen the screw in the tap band, move the band to the desired point on the resistor, and then again tighten the screw. This type of resistor may have several adjustable taps; the number of taps will be indicated by the number of taps on the symbol shown in Figure 3(D).

The symbol (D) in Figure 3 is also used to represent the variable resistor 15 in Figure 3. The proper name for this variable resistor is **potentiometer.** A potentiometer has three connections as may be noted from the illustration. The center lug connects to the variable "arm" of the potentiometer and the two outer lugs connect to the ends of the resistance. Potentiometers may be either wire-wound or carbon.

The symbol at (E) in Figure 3 is used to represent the variable resistor 16. This variable resistor is called a rheostat. A rheostat normally has only two connection lugs as may be noted in the illustration. One of these lugs connects to one end of the resistance element, and the other connects to the movable arm. Rheostats use wire-wound resistance elements.

The symbol shown at (F) in Figure 3 is sometimes used to denote a rheostat or a potentiometer when it is connected as a rheostat. That is, when only the movable arm and one end of the resistance element are connected to the circuit.

Connections to resistors are made in two general ways as may be seen in Figure 3. In resistors 1, 2, 3, 4, 5, 7, 9, 11, and 12, connections to the actual resistance element are made through wires which are commonly called "pigtails". In resistors 6, 13, 14, 15, and 16, the connections are made to terminal lugs. Resistors 8 and 10 do not fall into either of these general categories.

Capacitors

Figure 4 shows various types of capacitors and their symbols. There are two general classifications of capacitors: (1) fixed and (2) variable. For the first classification to apply, the capacitor must have a definite fixed value which is not changeable. The second classification applies to capacitors which have a changeable value between certain extreme minimum and maximum values. There are many types of capacitors represented by these two classifications. (Capacitors are often called condensers).

First of all in Figure 4 there are illustrated several forms of fixed capacitors. The symbol for these is shown at (A), the same symbol being used to denote any type of fixed capacitor. Capacitors 1, 2, and 3 of this group are mica types of fixed capacitors in moulded bakelite form. The word mica refers to the type of insulation between the metal capacitor plates, capacitors consisting of a sandwich of two or more metal plates filled with an insulator of some kind. These mica capacitors are usually used in high frequency circuits where very few losses can be allowed, and their electrical size varies from about .1 to .000001 μF. (μF is an abbreviation for microfarad. This term will be taken up in a future assignment).

The next group of capacitors, 4 and 5, are of the paper type. These range in electrical size from about .001 to 4 μF and are used to filter low frequency circuits, since they have medium loss qualities and yet perform satisfactorily. Sometimes, two or more of these capacitors are found in the same container. Capacitor number 6 is a two-section paper "bathtub" type, and may be represented by a symbol such as B, where each symbol in the group represents a separate capacitor.

In the next group, from 7 through 10, the electrolytic capacitor type is shown. Electrolytic capacitors vary in size from about 4 to 1000 μF, and are principally used in power circuit filtering and in circuits where a large capacity in a small space is required. They always have polarity—that is, their positive and negative terminals must be connected to the proper positive and negative points in the circuits where they are to be used. Symbol (C) represents a single unit whereas (D) represents a multisection unit consisting of two capacitors in the same container. Sometimes the polarity signs are omitted altogether. If the polarity signs are omitted, the negative plate is indicated by the curved line in the symbol.

Capacitor 11 is a type of adjustable or semi-variable capacitor known as a trimmer, padder, or a compensating capacitor. The symbol for this type of capacitor is shown at (E). Such capacitors are usually used in conjunction with fixed capacitors to enable the combination to add up to an exact value of capacity that is required by the circuit design.

Capacitor 12 in Figure 4 illustrates a variable capacitor. This is the type of capacitor which you adjust when you tune from one radio station to another and which was examined in the last assignment. The symbol for a single section variable capacitor is the same as that for the semi-variable capacitor, and is shown at E in Figure 4.

Few single-section variable capacitors are used in modern radios, the average being the two and three gang types. The symbol for a two gang capacitor is shown in Figure 4(F). Note that in the figure dotted lines are used between the two sections, indicating that both sections are controlled by one shaft.

Unfortunately (and this is especially true with capacitors) there are sometimes two or more symbols which may be used to designate a certain electronics component. Power engineers prefer one type of symbol, while an electronics technician uses a different symbol. A standardization program was undertaken in order to standardize on a specific group of electronic symbols to be used by both power and electronics men. These standardized symbols for capacitors are those shown in Figure 4(A, B, C, D, E, and F). However, in many of the diagrams which you will encounter in books and magazines the author has ignored the standard symbols, so you should be able to recognize the non-standard forms. Figures 4(G, H, I, J, and K) show some of the non-standard symbols for fixed capacitors and non-standard symbols for variable and semi-variable capacitors are shown in Figure 4(L and M).

Inductance

The subject of the symbols used to represent various types of inductance can be divided into two general categories. These two categories are **coils** and **transformers.** Since transformers are merely combinations of coils, we shall consider the symbols for coils first.

Coils

Figure 5(A) shows the symbol used to indicate an air-core coil. The coils number 1 and number 2 in Figure 5 are typical air-core coils. Coil number 1 is a multilayer coil, and coil number 2 is a single layer coil. The coil number 3 in Figure 5 is also an air-core coil, but is normally used in a circuit in a different manner than coils number 1 and 2. This type coil is called an RF choke and usually has RFC printed near the symbol as shown in Figure 5(B). As we discovered in our last assignment, a coil is made up of a number of turns of wire on a form. The number of loops in the symbol used to represent a coil **does not** indicate the number of turns on the coil.

There is no attempt to indicate the size or shape of the coil by the size of the symbol. Symbol size and the number of loops shown are determined by the space available on the diagram.

The symbol for an iron-core coil is shown in Figure 5(C). Coil number 4 in Figure 5 illustrates the appearance of a typical iron-core coil. In this coil the turns of wire are wound around an iron core made from sheets of iron stacked together. The turns of wire are insulated from each other, and are insulated from the core by special insulating paper. Iron-core coils are often called **chokes.**

Transformers

When two or more coils are brought together, a transformer is formed. These two or more coils will usually be wound on the same form. The symbol shown in Figure 5(D) is used to indicate an air-core transformer. Illustration number 5 in Figure 5 is a typical air-core transformer. Illustration number 6 shows a cut-away view of this same transformer inside a shield can. The dotted lines shown around the symbol in Figure 5(D) are used to indicate that the transformer is surrounded by a shield can. In a great majority of cases, the dotted line will be omitted, although the transformer is usually shielded.

The symbol in Figure 5(E) is used to indicate an iron-core transformer. Such a transformer is shown in illustration number 7 in Figure 5. This transformer has only two windings as indicated by the symbol. In some transformers one of the windings is tapped at its center. The symbol for such a transformer is shown in Figure 5(F).

Some transformers, such as the power transformers, have more than two windings. The symbol for a power transformer is shown in Figure 5(G). This symbol represents a transformer with four windings. One of these windings is center-tapped. A typical power transformer is shown in illustration number 8 of Figure 5. In the symbol shown in Figure 5(G), the winding to the left of the two straight lines is called the **primary** winding, and the windings to the right of the straight lines are called the **secondary** windings. The primary winding of a transformer is the winding into which electrical energy is supplied. The energy is taken from the transformer from the secondary winding or windings. **The straight lines indicate the fact that an iron core is used.**

The symbol shown in Figure 5(H) is for a powdered iron core transformer. These transformers are used when high frequencies are employed. The arrows through the straight lines indicate that the powdered iron cores are variable.

Batteries

Figure 6 shows various kinds of batteries and the symbols used to represent them. The symbol shown in Figure 6(A) represents a single cell, such as the dry cell shown in the illustration number 2 in Figure 6. The short heavy line is used to represent the negative terminal of the cell and the long line represents the positive terminal. The symbol shown in Figure 6(B) is used to represent a battery, which is really a group of cells. There is no fixed rule as to the number of individual cell symbols to use to represent a battery. Furthermore, there is no relationship as to the number of individual cell symbols and the voltage of the battery. The voltage value is usually written alongside the symbol as shown in Figure 6(B). The polarity signs are often omitted, in which case the polarity is indicated by the size of the lines as mentioned previously.

Batteries are sometimes classified as "A", "B", and "C" batteries, which is a designation which more or less grew up with the radio industry from the days when all radio receivers were battery operated. An "A" battery usually refers to the one used to heat the filaments of the tubes and it had a voltage ranging from 1½ volts to 12 volts. A "B" battery refers to a larger battery usually having a voltage of 45 volts or more. It was used to supply the voltage to the plates of the tubes. A "C" battery is usually of the low voltage—low current type and was used to apply a negative voltage to the grid of the tubes. It ranged in voltage from about 1½ to 7½ volts. The battery shown in illustration number 1 in Figure 6 is a "C" battery. Illustration number 3 shows a "B" battery and illustration number 4 shows a familiar storage battery. Storage batteries were used for "A" batteries in early radios and are still used in autos. The designations "A", "B", or "C" battery are **not** employed with the miniature batteries used with transistor radios.

Amplifying Components—Vacuum—Tubes and Transistors

Let us next consider some of the symbols for vacuum-tubes and transistors. Like the other components mentioned in this assignment, do not become alarmed or confused about some of the terms which we will use here—a full explanation of them will be given later on in the training program.

There are many kinds of electron tubes and transistors in use and to attempt to list all of them in this assignment would require considerable space and would involve a special study—a subject which will be taken up later on in the training. Here, we are concerned with their **symbols**, and from this viewpoint it is possible to show the most widely used types. Manufacturers of electronics equipment have not all adopted the standard method of drawing these symbols, but all systems are so nearly alike that it is not possible to mistake them for other electronics parts. In this training we will use the standard symbols.

Most systems of drawing tubes show the tube elements enclosed within a circle, as indicated in Figure 7. This circle is supposed to represent the glass or metal envelope of the tube or transistor.

One type of vacuum-tube (a triode) has in the envelope a single filament, a grid, and a plate; these are called the elements of the tube. The symbol for such a tube is shown in Figure 7(A); (B) represents the **glass envelope,** (C) the **filament,** (D) the **grid** and (E) the **plate.** Each of these elements is usually provided with only a single connecting terminal which in actual practice generally leads to a prong at the base of the tube. (Of course there are two terminals provided for the filament).

You must bear in mind that a schematic diagram uses **symbols**, and these do not always show the location of the prongs and the locations of the actual parts which are connected to the prongs. The information which shows where and how the tube prongs are located for a particular tube may be found in tube manuals, one of which will be issued to you when you have advanced a little further in the training. Suppose that the tube symbol shown in Figure 7(A) appears in a schematic diagram and is marked to indicate that this is meant to be a type 30 tube. By referring to a tube manual, under type 30 tubes we would learn that the type 30 tube has a four prong base and that prongs 1 and 4 are connected to the filament, prong 2 is connected to the plate and prong 3 is connected to the grid.

Figure 7(F) shows the schematic symbol for another type of tube; one which has no grid. This tube is called a diode. Its two elements are the filament and the plate.

Figure 7(G) represents another vacuum-tube. It has an additional element placed close to the filament, or heater, as the filament is called in this type of tube construction. This new element is known as a cathode. This tube is called a triode also, as the cathode is performing the same function as the filament in the triode of Figure 7(A). The tube of Figure 7(H) is called a tetrode and contains still another new element—a second grid placed close to the plate and called the screen grid. The tube of Figure 7(I) is called a pentode, and contains three grids in all, the third grid being placed between the screen grid and the plate. This third grid is called a suppressor grid.

Other types of vacuum-tubes may have more grids or plates, and it is not unusual to find two or three tubes (for example, two triodes) all located in the same glass or metal envelope.

The symbols for the two most widely used types of transistors are shown in Figure 7(J) and (K). The two types are referred to as P-N-P and N-P-N. There are three elements in a transistor: the base, the emitter, and the collector. These elements are labeled in the symbols of Figure 7(J) and (K).

Microphones, Pickups and Speakers

Microphones are used in public address systems, home recorders, and broadcasting equipment, so we should be able to recognize the microphone symbol when we see it in a schematic drawing. There are many variations of the microphone symbol depending upon the type of microphone used but all these are recognizable as a microphone. The general symbol for a microphone is shown in Figure 8(A).

A large number of radio receivers have in conjunction with them a phonograph record player. The arm which holds the needle and rests on the record is called the "pick-up". There are two types of pick ups in common use: The electromagnetic, the symbol for which is shown in Figure 8(B), and the crystal type, represented by the symbols of Figure 8(C) and (D).

There are several types of loudspeakers in use at the present time. The accepted symbol for a loudspeaker is shown in Figure 8(E). Variations in this symbol will be found, but a speaker symbol is easily recognized by the cone shaped part which will always be found. The symbol for a pair of headphones is shown in Figure 8(F).

Switches and Miscellaneous

In Figure 9(A) through (D) are shown the schematic symbols for various types of switches. Symbol (A) is for a two-gang rotary type of selector switch. Symbol (B) shows a single-pole single-throw toggle switch. (Usually abbreviated SPST). Symbol (C) shows a single-pole double-throw (SPDT) switch and symbol (D) represents a double-pole double-throw switch (DPDT).

Symbol (E) in Figure 9 indicates the accepted symbol for an antenna or aerial. Symbols (F) and (G) are non-standard symbols for an antenna which are widely used. Symbol (H) is for a loop antenna such as those used in some table model radios. The symbol shown in Figure 9(I) is to indicate the **ground** connection. The symbol shown in Figure 9(J) is a non-standard ground symbol which is used quite often. **The ground symbol usually indicates a connection to the chassis.**

A crystal such as is used in a transmitter or in the "timing" circuit of an electronics computer, is represented by the symbol of Figure 9(K). Voltmeters and ammeters are indicated by Figure 9(L) and 9(M) respectively. Pilot lamps are shown in Figure 9(N) and neon lamps are shown in Figure 9(O). Fuses are represented by the symbol of Figure 9(P).

Shielding of any component is indicated by a dotted line around the component as was shown in Figure 5(D). The symbol for shielded wire is shown in Figure 9(Q).

Methods of Showing Connections

There are two general systems of indicating the actual wiring of electronics circuits, as illustrated in Figures 10 and 11. These two circuits indicate wire connections from the filament winding of a power transformer to the filament terminals of two vacuum-tube sockets. (Only a portion of the power transformer is shown). We have also shown part of the connection to the plate terminal of one tube. In Figure 10 notice especially that large dots appear at certain places on the wiring. These dots mean that an actual wire connection is intended at this point on the circuit. Notice that where the plate wire crosses the filament wires there are no dots and hence we know that these wires are not connected.

Figure 11 shows the "standard" method of indicating connecting and nonconnecting wires. In this system, half circles or loops mean no connection. That is, when two or more wires cross without these loops a connection is indicated, but where a loop is used no connection is indicated. You should study these two systems very carefully until you are sure you understand the principles of each, and the differences between the two. In some cases you will find a combination of these two systems; that is, loops (or jump-overs as they are sometimes called) are used to indicated no connections and dots are used to indicate connections. Such a system is used in Figure 13.

Practice Drawing Schematic Symbols

The symbols which have been shown were, of course, drawn with drafting instruments. However, an electronics technician usually just "draws the symbols by hand." To help familiarize yourself with the symbols, take a sheet of scratch paper and practice drawing them. For example, draw a fixed resistor with one tap, a triode tube, a variable capacitor, etc., and then check your symbols against those shown. Continue to "play this game of solitaire" until you can draw any and all of the symbols from memory. When you can do this, you have won! You have mastered the first step in reading schematic diagrams. You **know** all the major symbols.

Identifying Symbols in a Complete Schematic Diagram

Let us now go back to the schematic diagram of the radio receiver shown in Figure 1. A careful examination of this drawing will reveal that it is composed of the circuit symbols which **you now know.** Look it over carefully. You should be able to identify **every** electronics part shown.

To check your understanding of the symbols, let us go over this diagram one component at a time. Let us start with the right edge of the diagram. The first symbol we encounter is labeled SP_1 and is a symbol for a loudspeaker. Moving toward the left, the next symbol we encounter is that of T_1, an iron core transformer. Across one of the windings of this transformer we find another component labeled C_{10}. We have already learned that this is a symbol for a fixed capacitor.

Now, let us take a look to the left at the symbol which is labeled V_4. The symbol used here is slightly different from the vacuum-tube symbols we have discussed previously, but, it is, nevertheless, recognizable as a vacuum tube. This is a type 50C5 tube. Notice carefully the little marks close to the plate of this tube. These little marks are called **beam-forming plates.** Notice that these beam-forming plates are connected to the cathode of this tube by two wires. These wires are located inside the tube. This tube is a tetrode because it has four elements—the cathode, the two grids, and the plate. Since the beam-forming plates are also present this tube is called a **beam tetrode.** Tubes of this type are often used when a large amount of power is needed. In this case, this tube is used as the last stage in the radio receiver where it is necessary to develop a fair amount of power for proper operation of the loudspeaker.

Let us continue. Connected to the cathode of the 50C5 tube are a resistor labeled R_8 and a capacitor labeled C_1. These are connected from the cathode of the 50C5 to ground. Notice the ground symbol. Right next to the R_8 resistor we see the number 180 followed by a special little symbol which means **ohms.** 180 ohms is the **electrical size** of the resistor. Now, referring to the capacitor C_1 we notice the 20 μF next to the symbol. This is the **electrical size** of the capacitor. It is 20 microfarads. We know that this capacitor is an electrolytic capacitor because we see the plus and minus symbols which indicate the polarity with which the capacitor must be connected in the circuit to function properly. Whenever we see the plus and minus symbols associated with a capacitor symbol we know that it means that the capacitor is of the electrolytic type.

Let us continue with some additional components. Connected to the grid of the 50C5 is the resistor R_7. The other end of this resistor goes to ground as indicated by the ground symbol. The value of this resistor is stated as 500K. This means that the electrical value of this resistor is 500,000 ohms.

Now, let us skip through the remainder of the diagram and identify some parts at random.

The 12AV6 tube which is labeled V_3 is an example of a dual purpose tube. It has a triode section and two diodes. The same cathode is shared among each of these sections; that is, the two diodes and the triode section use the same cathode.

Now, take a look at the tube labeled 12BE6, called V_1. This tube has a heater, a cathode, five grids, and a plate. This tube performs a special function which we will discuss later in the training program. Notice that the cathode of this tube connects to terminal 2 of the coil L_2. We know that L_2 is a coil with a variable powdered-iron core for changing the electrical value of the coil. We know this because of the three little lines with the arrow running through them; this is located at the top of the coil in the diagram.

The plate of the 12BE6 is shown connected to terminal 1 of L_3. Looking closely at the combination of symbols shown inside the dashed box we see first that this is a transformer, with the windings P and S close to each other. L_3 is commonly known as an **IF transformer.** In this case, the electrical value of both the primary and secondary windings is adjustable through the use of variable powdered-iron cores. We know this because of the three little lines and the arrow running through them which is located at the top of the symbol for each of the windings. Across each one of the windings is shown a fixed capacitor. These capacitors are not labeled individually, as normally the entire unit inside the dotted box is considered as one component. As stated before, this entire assembly is called an IF transformer, and the dotted box around it indicates that it is within a shield can.

Now, refer to C_{12} near the extreme left of the diagram. Notice the dashed lines which go from the C_{12} symbol to the two variable capacitors, one above and one below the C_{12} symbol. The dashed line interconnection means that these two variable capacitors are physically connected together. In other words, when one turns the other one must turn with it. We say that the two capacitors are **ganged** together. This is the main tuning capacitor or main tuning control of the radio receiver. It is these two capacitors that we tune or adjust when we tune the radio receiver to a certain station.

Now, refer to R_1 which is labeled **VOLUME** and located below the 12BA6 tube. It will be recalled that this is a symbol for a variable resistor, called a potentiometer. It is this resistor which we turn when we wish to control the volume of the radio receiver. Usually also controlled by the volume knob is the switch which turns on or off the receiver. If you will look down and to the far left, you will see a symbol for a switch which is labeled **SW ON VOLUME CONTROL**. This is the on/off switch which turns the receiver on or off. It is a single pole, single throw switch which connects the AC line to the receiver when it is desired for the radio receiver to be on.

In a similar manner continue over the entire schematic diagram, identifying **each** part until you can do it without referring back to the symbols which were discussed earlier in the assignment.

Tracing a Circuit

Although, at this point in our training, we have not studied the operation of the various circuits, we should be able to trace some of the circuits in a schematic diagram.

For the purpose of practice in tracing a circuit, the schematic diagram of the receiver, shown in Figure 1, will be used. This is a relatively simple circuit, being conventional in every respect. Complete radios of this type can be broken down into a number of separate circuits, which allows easier tracing of the wiring.

First, let us trace the filament or heater circuits since you should now be able to recognize this element of each tube. Notice that on each tube (with the exception of the 35 W4 rectifier tube which is labeled V_5) there are two small arrows pointing directly away from the circle which encloses the tube elements. These two arrows are connected to the filament element of the tube. This means that the wiring for the filament circuit is shown elsewhere. If you will look at the bottom of the schematic diagram, you will see little circles with the filament symbols below them; from right to left they are labeled V_4, V_2, V_1, and V_3. The filament symbols shown directly below the circled numbers are, therefore, the filaments for these four tubes. This portion of the schematic diagram shows the manner in which the filaments are actually connected together in the radio receiver. The numbers 3 and 4 which are shown by the filament symbols indicate the number of the pin of the tube to which the filament elements are connected. Let us start at the ground symbol on the far right and go toward the left. First, we see that a ground is connected to pin 3 of V_3, and then pin 4 of V_3 is connected to pin 3 of V_1. Then, similarly, pin 4 of of V_1 is shown connected to pin 3 of V_2, pin 4 of V_2 is shown connected to pin 4 of V_4, and pin 3 of V_4 is shown connected to pin 4 of V_5, the 35W4 rectifier tube. The filament element in the 35W4 tube is actually two separate filaments which are connected together and the junction brought out to pin 6 which in this particular radio receiver is not used. Pin 3 of the 35W4 is then connected to the switch on the volume control. When the switch is on, the filaments will receive power. Filament circuits which are connected in a manner similar to that shown in Figure 1 are called series-connected filaments. (You have probably heard of series Christmas tree lights. They are connected in a similar manner.) We have redrawn the filament circuit in Figure 12 to better show you how this circuit is actually wired.

Let us spend a moment talking about the ground symbols that we see in the Figure 1 schematic diagram. These ground symbols do **not** mean that these points are physically connected to an earth ground. Instead what is meant by these symbols is that ground is considered to be the metal chassis on which the radio receiver is constructed. All of the ground symbol points are connected to the metal chassis and are therefore connected together through the chassis. Thus, in many schematic diagrams you may often have to visualize a complete circuit when a part of this circuit is shown making use of a metal chassis as one of the conductors. In other words, **all the ground symbols show is that these points are actually connected together by use of the metal chassis.**

Now, take a look at R_6, a 250K or 250,000 ohm resistor. Notice that one end of this resistor is shown going to 90V. This 90V means **90 volts power source.** If you will look near the bottom central portion of the diagram you will see a terminal labeled 90V source. This 90 volt source terminal is commonly called the **B+ line.** The arrow at one end of the 250K resistor means that these two points are connected together. If you will look over the entire diagram, you will see several arrows which are labeled 90V. All of these points are connected to the 90V source terminal. The reason the draftsman did not use actual lines to show these connections is that this would require that there be more lines on the diagram; thereby, making it more confusing. This is just one example of the short-cuts that are often used in electronic schematic diagrams.

Let us continue with the tracing of portions of the circuit of Figure 1 in the order of simplicity, next considering the plate circuits. From the plate of the tube at the left (the 12BE6) follow the wire to the primary of transformer L_3. Going on through the left hand coil of L_3 we can follow this wire to the point where it connects to the B+ line. Starting from the plate of the second tube from the left (the 12BA6) we see that we go through the L_4 coil, again to the B+ line. Similarly, from the plate of the tube at the top right (the 12AV6), we first go through Resistor R_6, a 250,000 ohm resistor, to the B+ line. This B+ line is sometimes called the B+ feeder line as it is used to feed power to the various portions of the circuit. Let us see what additional components are connected to the B+ feeder line. Two of the grids of the 12BE6 and one of the grids of the 12BA6 are also connected to the B+ line. These grids are called the screen grids and need to be connected to a power source for proper operation. The same is true of the screen grid of the 50C5 tube. Figure 13 is a simplified schematic diagram showing how the B+ feeder line is connected to the plate circuits of V_1, V_2, and V_3 and to the screen grid circuits of V_1, V_2, and V_4.

The plate circuit of V_4, the 50C5 output tube, is supplied from a higher voltage source, namely the 135 volt source, because this stage needs as much voltage as possible to be able to supply the power output necessary for proper operation of the loudspeaker. This is shown by the 135V sign with the arrow which is located almost directly below the T_1 symbol in Figure 1. Near the bottom center of this schematic we see the terminal to which this arrow refers, the 135V source terminal.

Thus, at this point we find it is not a difficult task to trace individual circuits from the schematic diagram of a piece of electronic equipment.

Summary

We have covered a great deal of ground in this assignment and you are already well along the way to becoming a competent electronics technician. We have seen the need for schematic diagrams, we have studied the symbols for many of the components which make up electronics circuits, and we have seen how these symbols are put together to make complete diagrams. We have also learned how to trace out individual circuits of a complete diagram.

The information in this Assignment is very necessary to enable you to quickly and efficiently work on equipment, and understand how circuits operate. You should refer to this assignment time and time again during the next few weeks. You should **practice** tracing circuits until it comes to you very easily. Do not be discouraged, for you will find that the more you draw schematic symbols and practice tracing circuits, the easier it becomes. Soon it will be as simple as writing your own name!

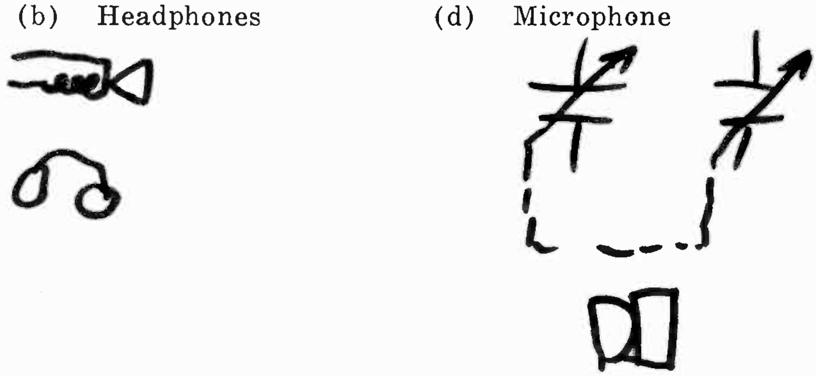
In the next Assignment we will review some of the arithmetic that we will use in our electronics work. For most of us, this will amount to just a simple, quick review.

TEST QUESTIONS

Be sure to number your Answer Sheet Assignment 3.
Place your Name and Associate Number on **every** Answer sheet.

Send in your answers for this assignment immediately after you finish them. This will give you the greatest possible benefit from our personal grading service.

1. Draw the schematic symbol for a transistor (either the N-P-N, or the P-N-P type).
2. In Figure 1, is C_{14} a **variable capacitor**, or is it a **fixed capacitor?**
3. On your Answer Sheet, draw and identify (label) the symbols for the following electronics parts:
   (a) fixed resistor (c) potentiometer
   (b) variable capacitor (d) electrolytic capacitor
4. On your answer sheet draw the symbol for an iron-core transformer with one center-tapped secondary winding and the symbol for a potentiometer. Connect one end of the potentiometer to the one end of the secondary winding. Connect the other end of the potentiometer to the other end of the secondary winding. Connect the "arm" of the potentiometer to the center-tap of the secondary winding.
5. What is another name for a capacitor? CONDENSER 311E
6. Draw the symbols for the following:
   (a) Fuse (c) Pilot light
   (b) Antenna (d) Single-pole single-throw switch
7. Draw the symbols for the following:
   3E
   (a) Air-Core transformer (c) 30-volt battery
   (b) Power transformer (d) Triode vacuum-tube
   311E
8. What do the straight lines in the power transformer symbol indicate? IRON CORE
9. In Figure 1 of this assignment, what do the dotted lines associated with the C_{12} symbol indicate? gang double capacitor
10. Draw the symbols for the following:
    (a) Loudspeaker (c) Two-gang variable capacitor
    (b) Headphones (d) Microphone



Switches and Miscellaneous Parts

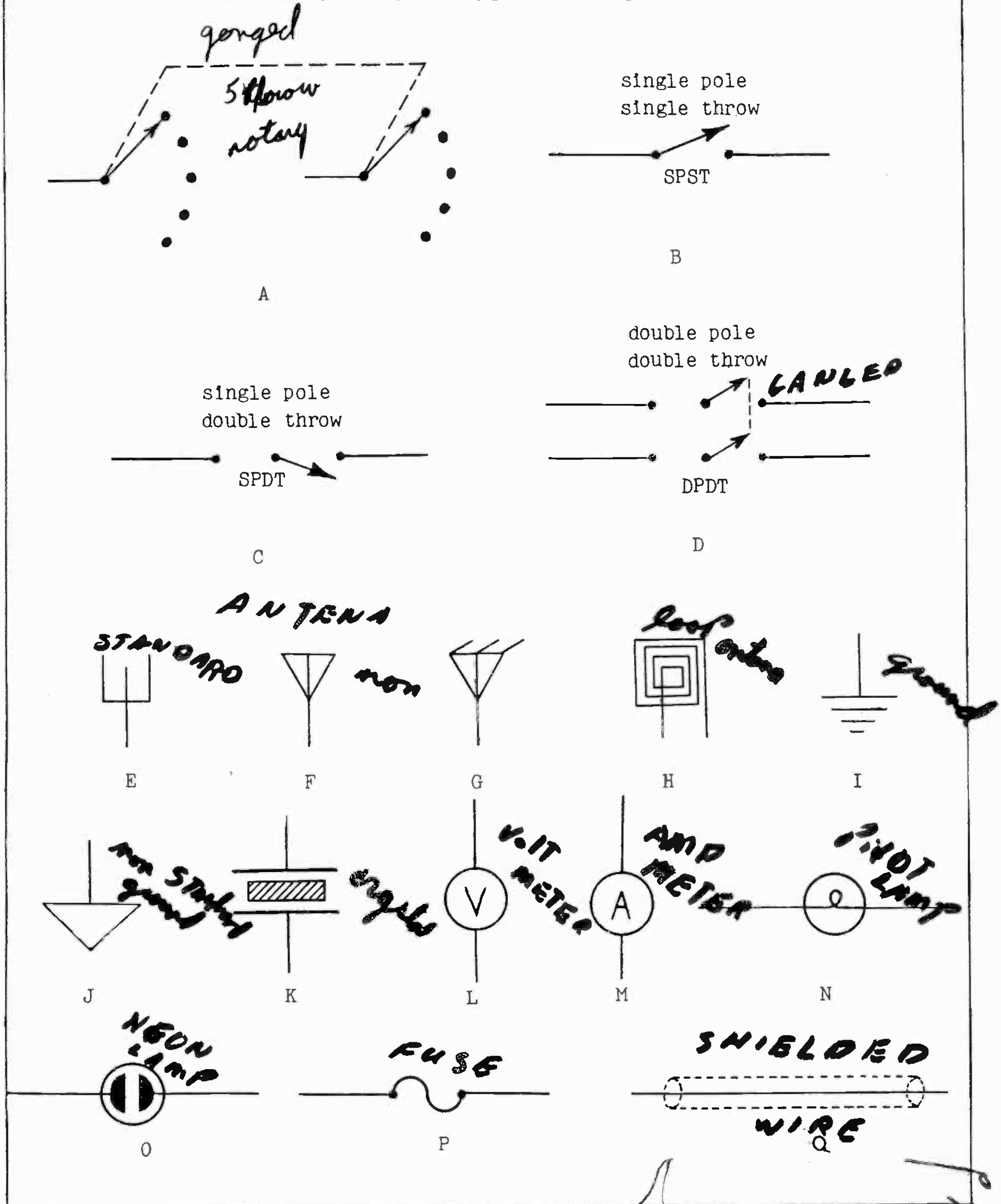


FIGURE 9

Circuits

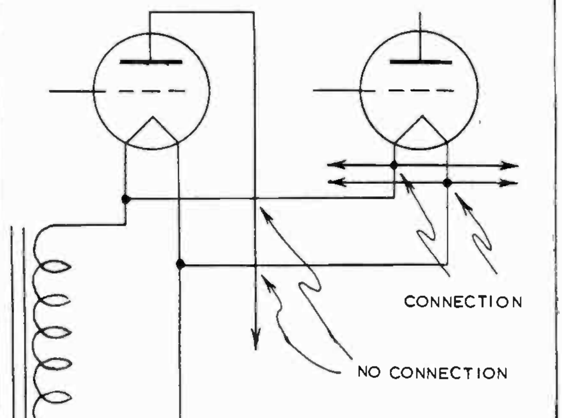


FIGURE 10

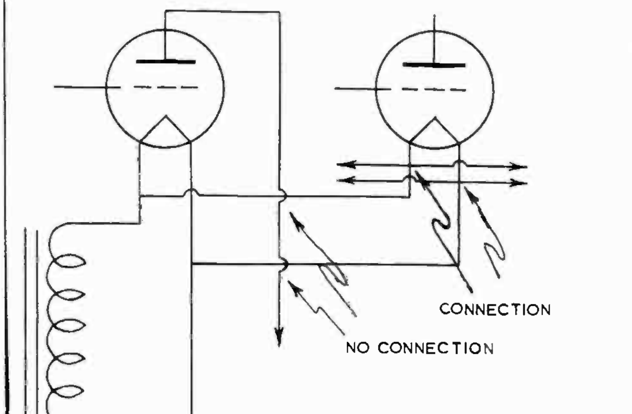


FIGURE 11

The Filament or Heater Circuit

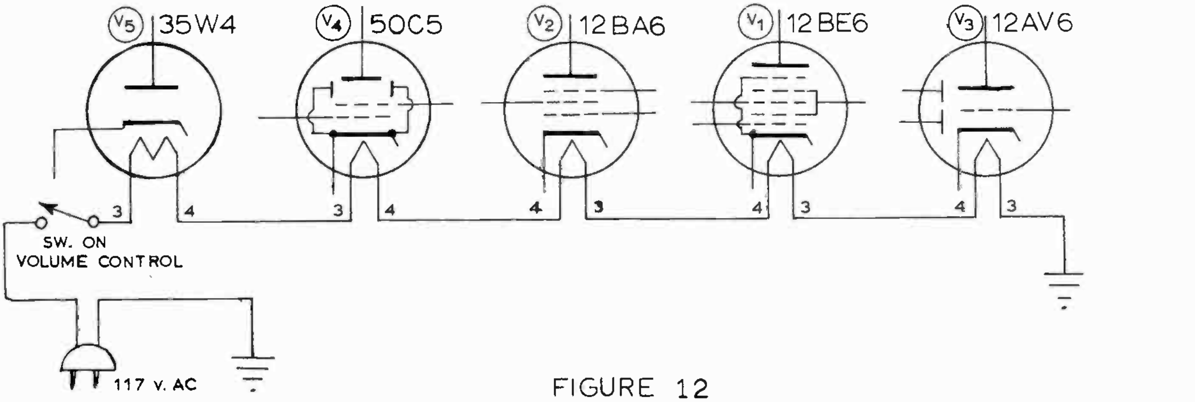


FIGURE 12

The B+ Circuits

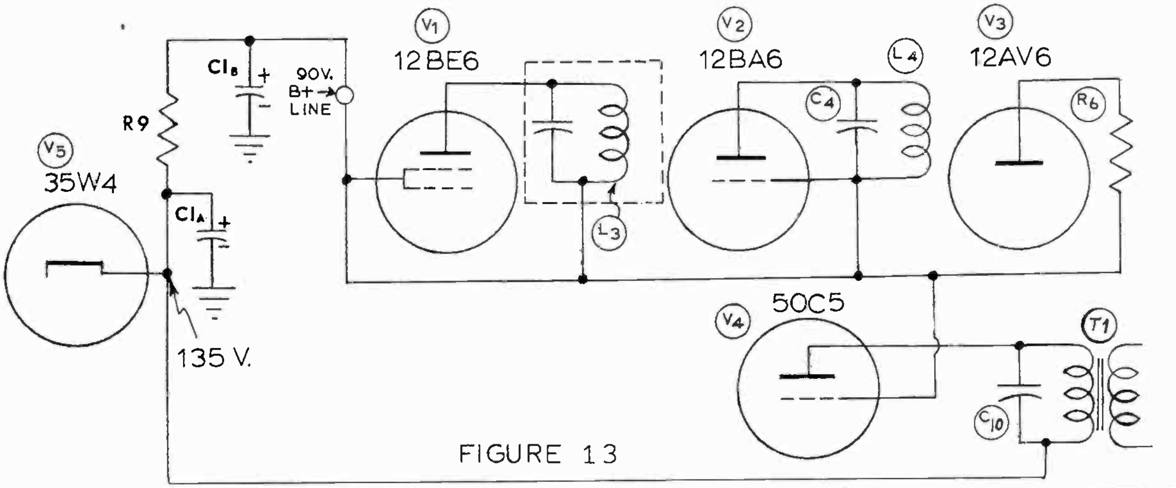


FIGURE 13

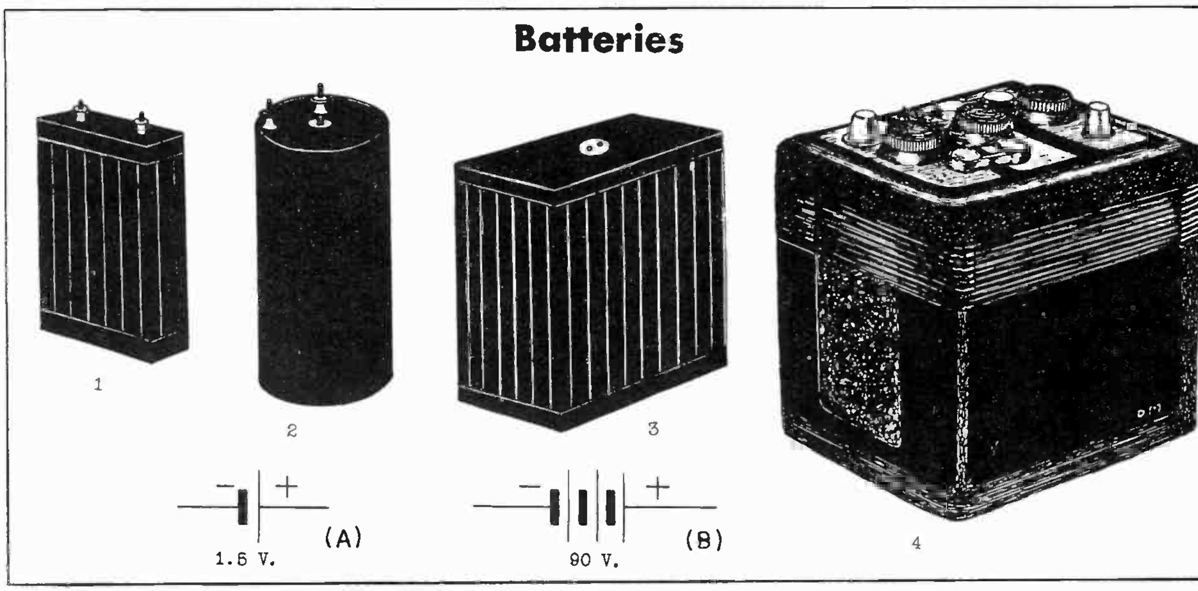


FIGURE 6

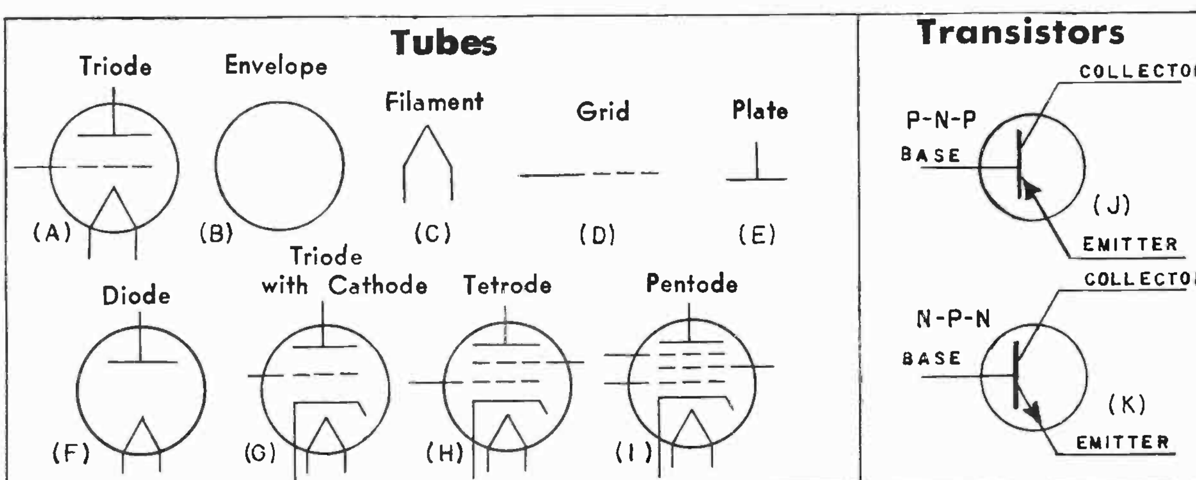


FIGURE 7

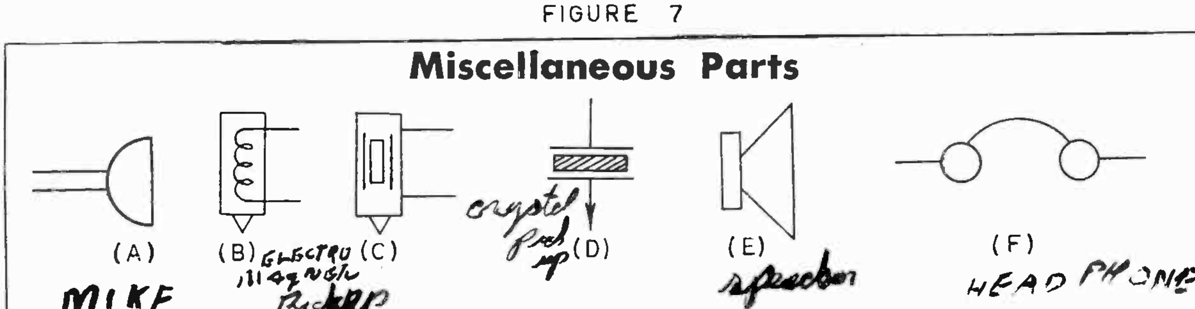


FIGURE 8

Coils and Transformers

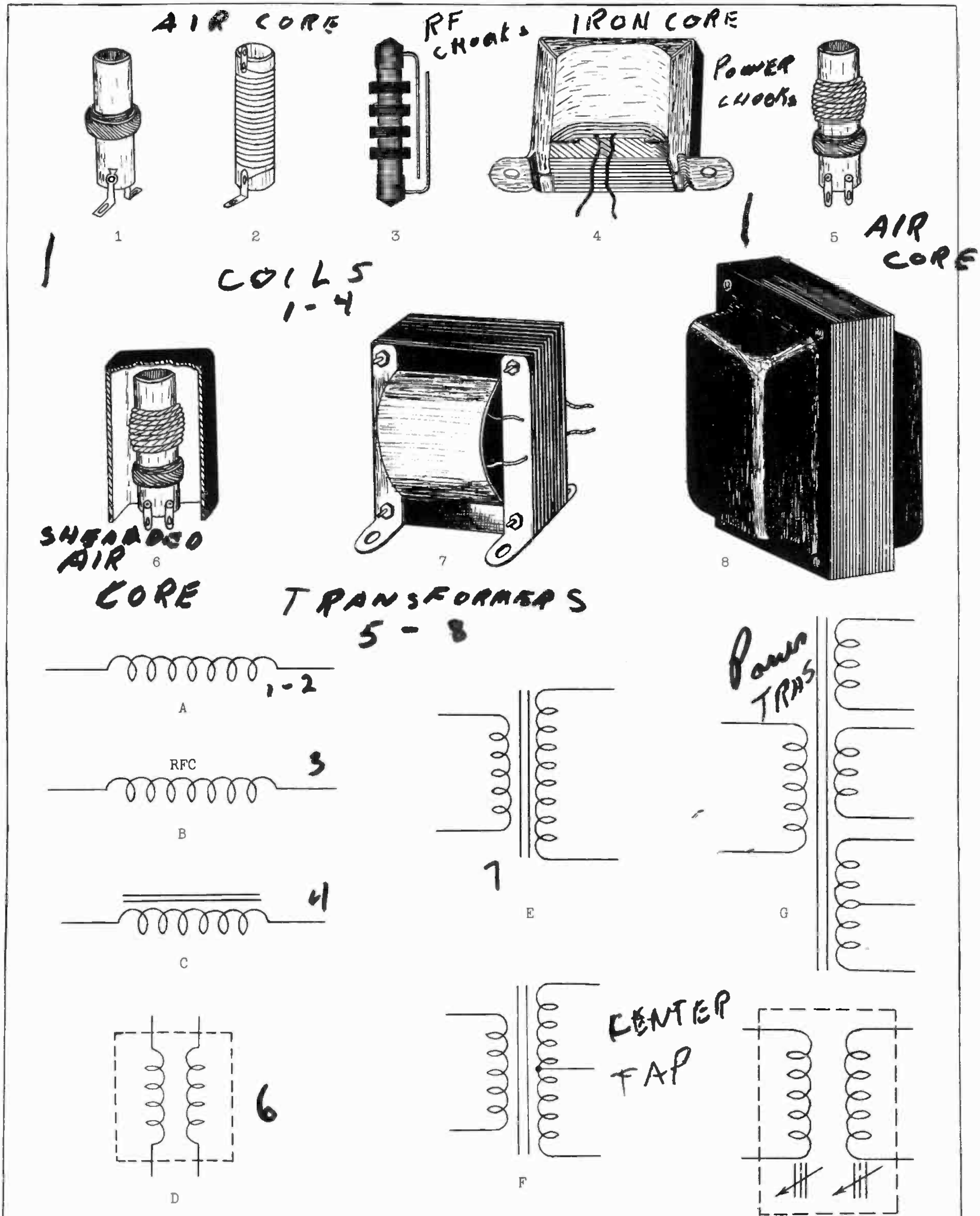


FIGURE 5

Capacitors

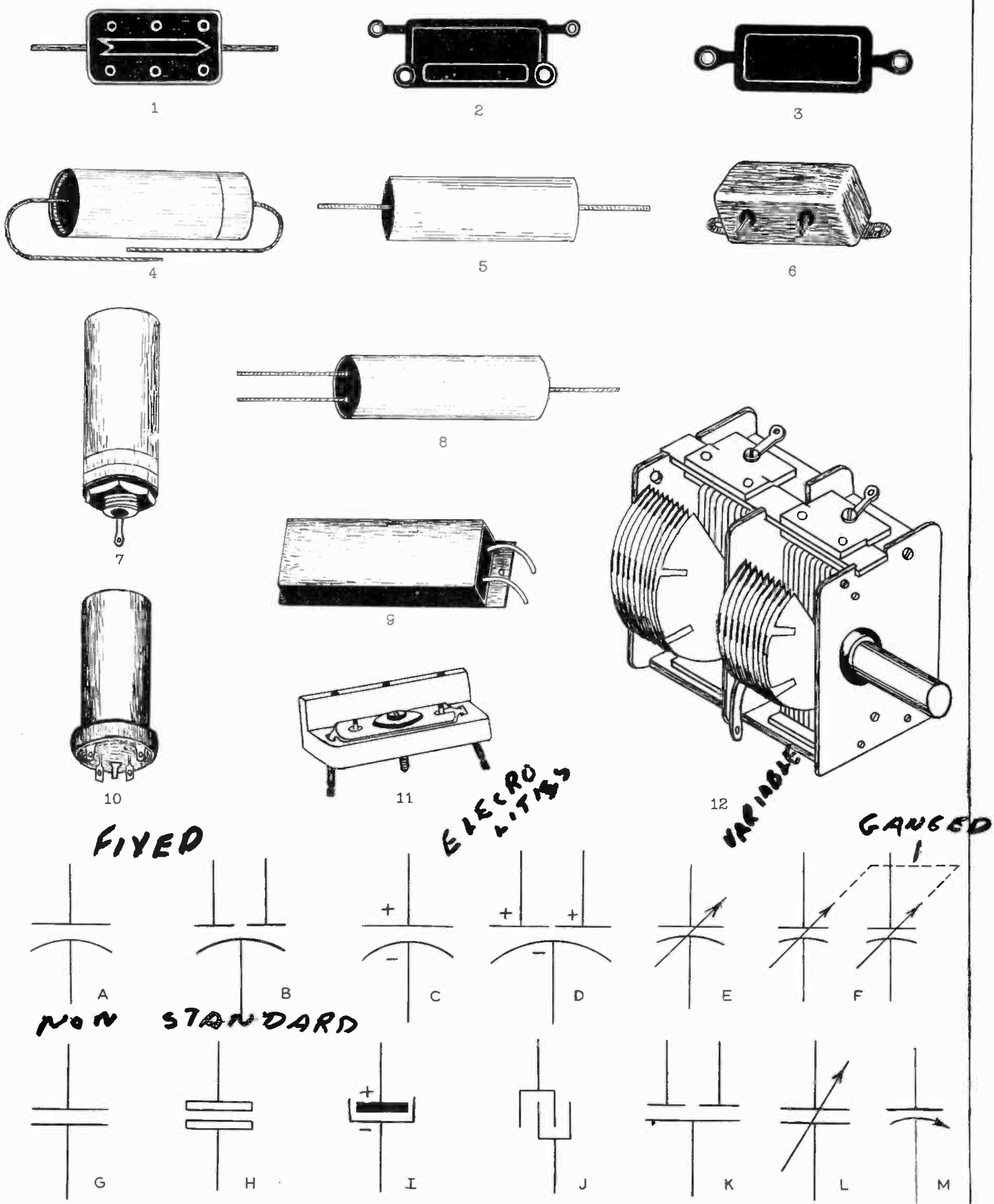


FIGURE 4

Resistors

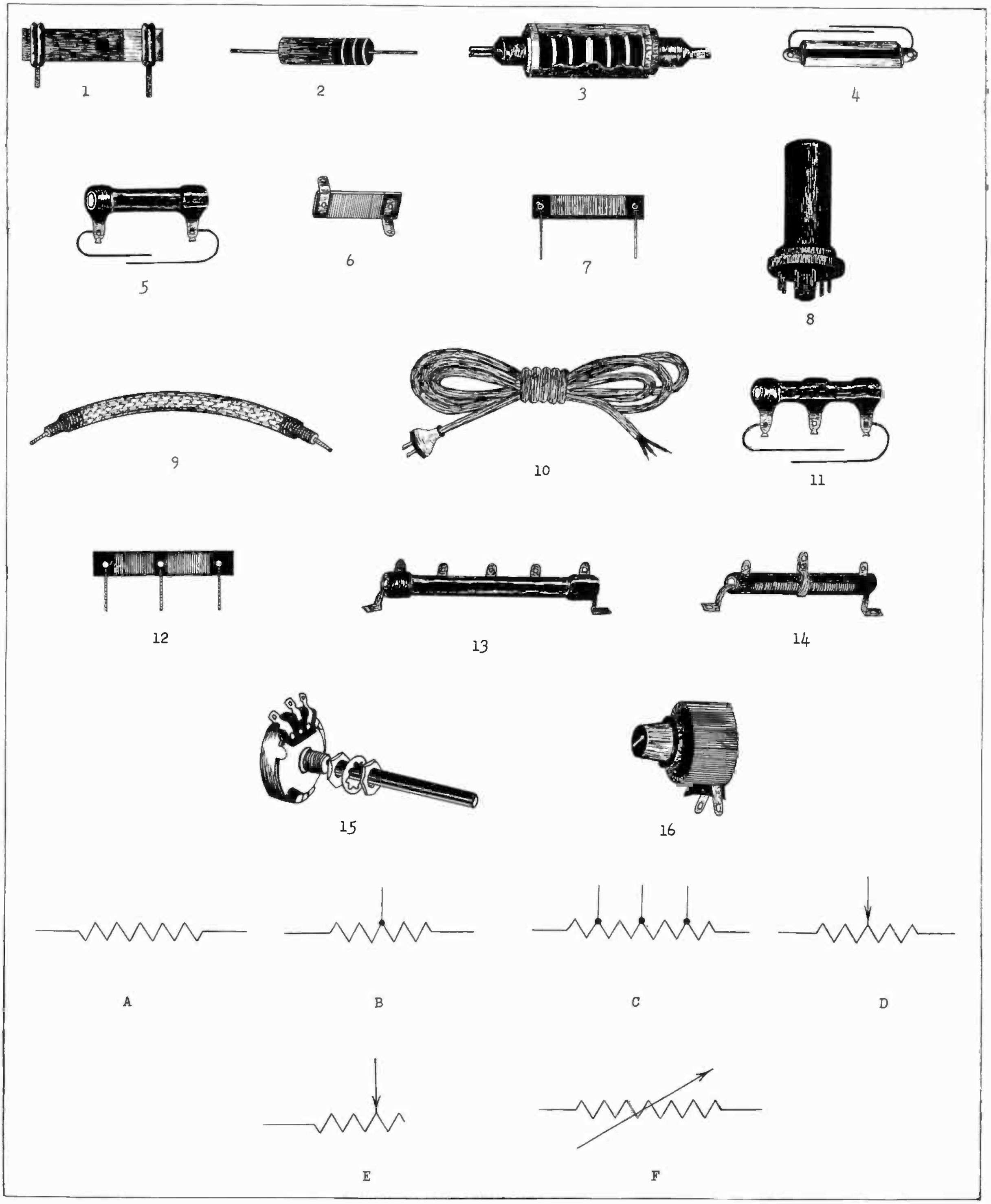


FIGURE 3

Pictorial Diagram

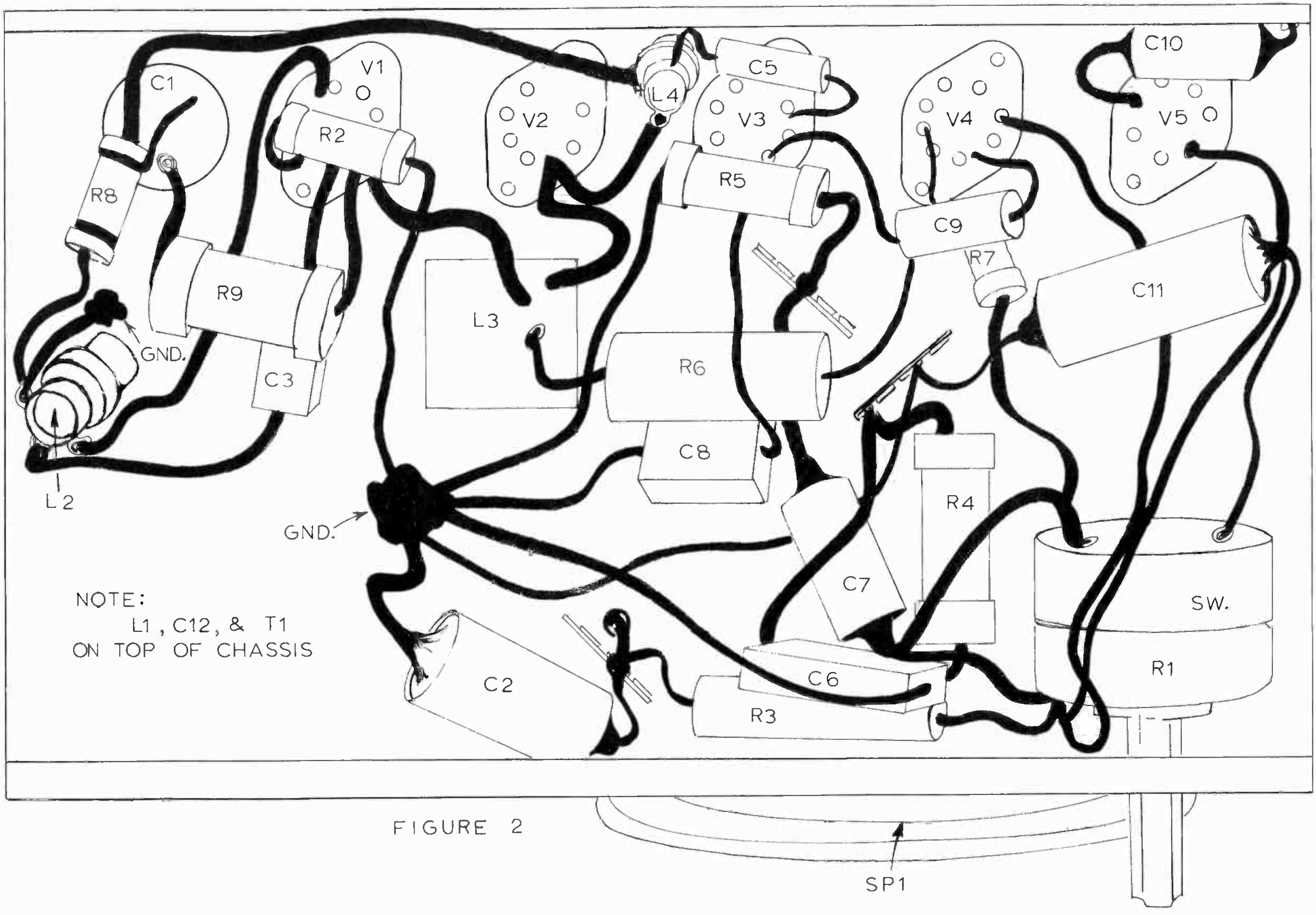


FIGURE 2

A FIVE TUBE BROADCAST RECEIVER

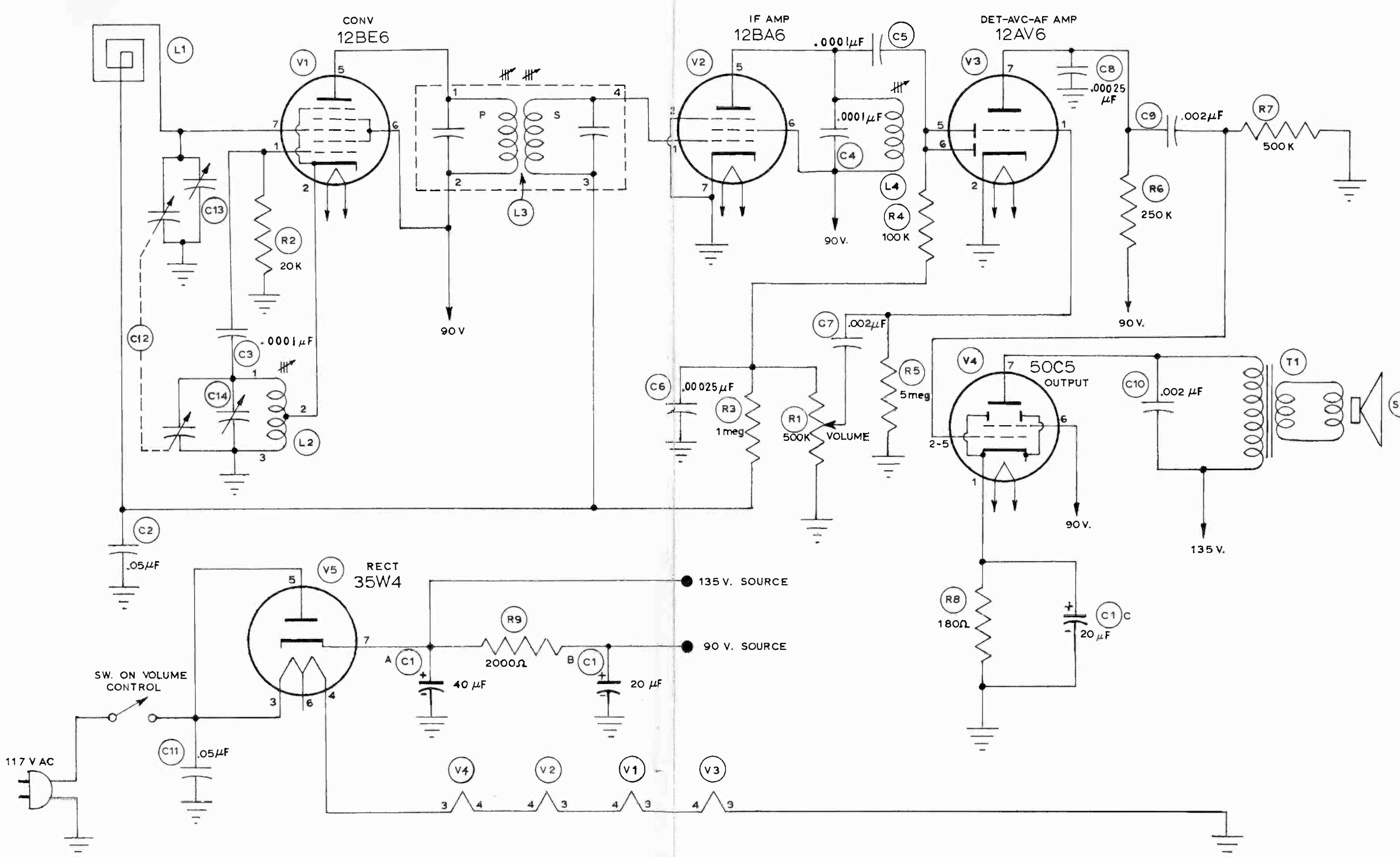


FIGURE 1