Basics for Beginners

How To Read Circuit Diagrams—Part I

The beginner with no previous experience of radio beyond turning the knobs of a broadcast or TV receiver finds himself with a few hurdles to clear before he can begin to assimilate principles. One is recognizing components by name; another is recognizing them in the "sign language" of circuit diagrams. Here's an introduction to circuit reading—associating the components with the diagram, and determining how they are connected together.

When you see a radio circuit diagram for the first time it is likely to be about as comprehensible as something written in a foreign language you've never learned. However, compared with the effort you'd have to put into learning to read, say, German or French, learning to read circuit diagrams is a snap. A circuit diagram merely makes use of some standardized symbols that represent various radio and electrical components or devices. It is much easier to draw these symbols than it is to draw pictures of components. Furthermore, the actual components will differ in details of appearance, even though they may have exactly the same electrical function. In practice, therefore, the symbol is much more useful than a picture; the *function* doesn't change even though the construction styles *do* change.

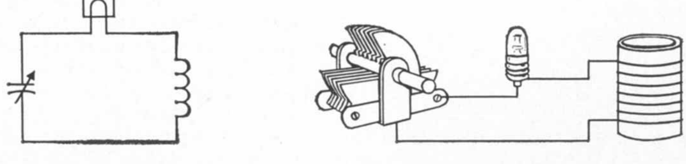
The symbols are the "words" of circuit language. The "sentences" describe the way in which the components are connected together electrically. These are formed by drawing lines, representing wires or other kinds of conductors, between the appropriate connection points on the symbols. This is a much more compact form of representation than a picture diagram or "pictorial," as Fig. 1 shows. Here we have the same circuit, that of a simple wavemeter and indicator, drawn in both styles. The "schematic" at the left can be understood at a glance by anyone having a little familiarity with the sign language of circuit diagrams. The "pictorial" at the right would require some study before one could be sure just what the collection of parts is supposed to do, even when the reader is fairly experienced. Its virtue is that someone with no electrical background whatsoever could assemble and wire it. Unfortunately, blind copying of this kind adds nothing to one's fund of knowledge.

In this simplification and reduction to essentials, something has to be sacrificed. The circuit diagram sacrifices any attempt at pictorial representation. *The circuit does not show where parts are physically located in the equipment, nor does it try to show which leads must be short and which may be long.* This information must be obtained from supplementary material, such as photographs and the written text of an article. Together, these will give a reasonably-experienced reader all he needs to know to produce a workable piece of equipment. It can be done in a relatively small space—compare an ordinary "construction" article with the "wire from A to B" method used for a similar piece of equipment in a set of kit instructions! It also permits accenting the really important features without cluttering up the landscape with minor details that could be handled in half a dozen different ways without the slighest effect on the equipment performance.

The language of circuit diagrams has to be standardized if all readers are to interpret it in the same way, just as the spelling of words has to meet some agreed-upon standards. Such standards do exist for many circuit symbols.[1] There will probably never be a "final" set of standards, for the obvious reason that the art keeps expanding and new devices, requiring new symbols, are constantly being developed. The currently-published standards, for example, include almost no symbols for semiconductor devices. These,

[1] American Standard Y32.2-1954, *Graphical Symbols for Electrical Diagrams*, American Standards Association, 70 East 45th St., New York 17, N. Y.

Fig. 1

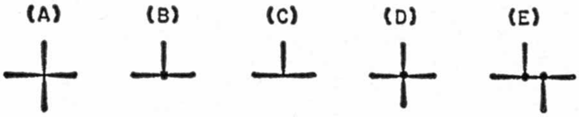


it is hoped, will be added to the standardized list in the near future. However, most of the symbols we use in amateur work are covered, and in this article we will confine ourselves to those symbols you are most likely to meet in diagrams of amateur equipment.

Wiring

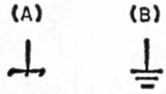
A line between two symbols, or parts of symbols, represents an electrical connection. If it is a simple line, no particular type of wire or other conductor is implied. In the actual piece of equipment, one terminal of one component might be soldered directly to a terminal on the other component. Alternatively, the two might be separated by several inches, or feet, and connected by wire, metal strip, or tubing. In most actual construction, of course, the wiring will be done with either leads furnished on the component (e.g., small resistors and capacitors) or with "hook-up" wire which may range in size from No. 12 to No. 22 gauge, depending on the current to be carried.

Once this nonspecific nature of the connection line is understood, there is only one point that needs to be clarified. There are times when it is impossible to avoid having one connection line cross over another in the drawing. When it must be done it is simply done as shown at A below, although in nearly all other cases a line touching



a symbol means that there is electrical contact. Here *no* contact is indicated. If a connection is to be made between two wires in a diagram it is usually shown by a dot, as at B. (However, the dot is not actually *required* in such a case; the connection can be shown as at C.) A "four-way" connection preferably should *not* be drawn as in D, because of the similarity to a plain cross-over; confusion is avoided by showing such a connection as in E.

We have intimated above that not all connections in a circuit are made with actual wires. Nearly every circuit has an array of "common" connections; examples are the connections to one side (usually the negative side) of the plate-supply source used for the various vacuum-tube circuits in a multitube arrangement. These common connections usually are made to the metal chassis, as a matter of convenience and sometimes as a matter of specific design. In drawing circuits it is customary to show such "chassis ground" connections by the chassis symbol shown at A at top of next column. When you see a collection of such symbols in a diagram you appreciate immediately that all of them are actually one multiple electrical connection. Using the chassis symbol in this way invariably makes the diagram easier to read, because without

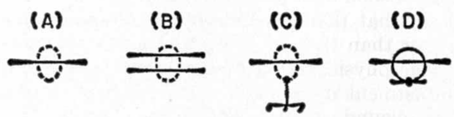


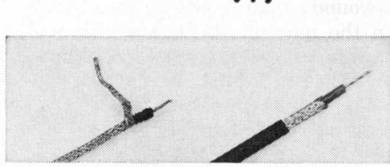
the symbol it would be necessary to show line connections between all those same points.

Usually, the chassis symbol also indicates a part of the circuit that could be connected directly to earth without any effect on the circuit's operation. If an actual earth connection is called for, the "ground" symbol shown at B will be used. In some diagrams you will find this symbol used as an alternative for the chassis symbol, to indicate a connection to chassis without reference to an actual earth connection. In other words, the two symbols are more-or-less interchangeable, although in *QST* diagrams we prefer to use the chassis symbol for an actual chassis connection.

Special cases in wiring occasionally come up. Sometimes a shielded wire or cable is called for. Such wire consists of one or more insulated conductors inside a metal tube usually made by braiding fine bare wire so the whole assembly will be flexible. When grounded, this tube shields the conductors from electrical fields which otherwise might induce unwanted currents in them. The presence of the shield is indicated by a broken, somewhat-elliptical symbol around the wire, as in A and B below. Usually the shield will be grounded or connected to the chassis, in which case the symbol for this is added as in C. Coaxial cable, which is basically shielded wire but is used where r.f. current is to be carried, has a special symbol of its own, shown at D. Here, too, the shield symbol usually will be shown grounded.

Finally, although it is not a part of the actual wiring, you should recognize the symbol for a shield or shielding. It is simply a dashed line, often formed in the shape of a rectangle, around the symbol for a component, or set of components, which actually are enclosed in a shielding container. (An intermediate-frequency transformer is a typical example of a shielded device of this type.)



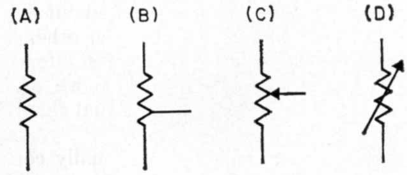


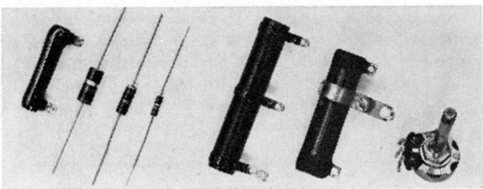
Examples of shielded wire and coaxial cable. The wire (left) is the type with a single inner conductor. Multi-wire cable of similar construction is often used. The coaxial cable shown (right) is a small type (RG-58/U). Cable of this general construction is available in several different diameters, for handling various power levels.

With the "hooking up" out of the way, we can now get down to the component symbols themselves.

Resistors

You rarely meet a circuit that doesn't have at least one resistor in it. While resistors come in a wide variety of sizes and shapes, the same basic symbol, shown below at A, is used for all of them. In its plain form, this symbol represents a "fixed" resistor — one having just a single value. If the resistor is "tapped," having a connection made





Commonly used types of resistors. The resistors grouped at the left have fixed values. In general, the larger the resistor the higher its power rating. The four types shown in this group include a 10-watt wire-wound, and 2-watt, 1-watt, and ½-watt composition resistors. A tapped wire-wound resistor is in the center, with a slider-type (adjustable) wire-wound at its right. On the far right is a composition "control," or variable resistor.

somewhere in its body that permits another value of resistance to be secured from the same resistor, the presence of the tap is indicated as shown in B. More than one tap, when needed, may be added to the basic symbol.

The solid arrowhead in the symbol at C indicates that the resistance is adjustable in value. Other than this, it does not give any indication of the physical construction of the resistor. The adjustment might be by means of a slider on a wire-wound resistor, for example. Or it might mean the moving contact on a wire-wound or composition "control." Note that with this symbol there are three terminals, the adjustable tap and the two outside ends of the resistor, so this symbol can be used for an adjustable voltage divider or "potentiometer." On the other hand, the symbol at D, with the arrow drawn through the basic resistor symbol, simply indicates that the total resistance is continuously variable. This symbol has only two terminals, although the actual component frequently will have three; one end connection is left unused in that case.

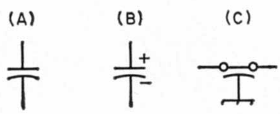
Capacitors

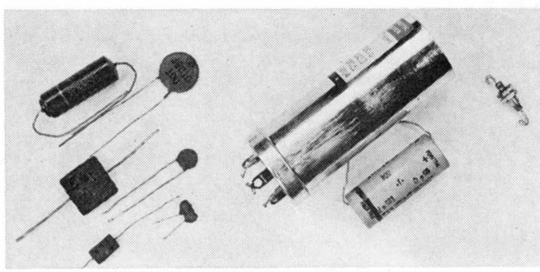
The basic capacitor symbol is shown at A below, and just as in the case of the resistor, this symbol as it stands implies that the capacitor is "fixed" — that is, it has just a single value of capacitance. Again, the symbol stands for all sorts of fixed capacitors, from tiny ceramic disks to bulky potted high-voltage types, with dielectrics ranging from vacuum to oil-filled paper.

Electrolytic capacitors are "polarized" — that is, in d.c. circuits one terminal must be connected to the positive side of the voltage source and the other to the negative side. The proper polarity is frequently shown on the circuit diagram by putting a + sign near the side of the capacitor that should be connected to the positive side. Frequently, also, the other side is labeled −. Note, however, that these + and − signs are not a *required* part of the symbol, although it is *QST* practice to use them.

A special type of fixed-capacitor symbol is shown at C. This is the "feedthrough" capacitor, used particularly in high-frequency radio circuits for bypassing. In this type the circuit being bypassed goes into one terminal, indicated by one of the small circles, and out the second terminal. The r.f. bypassing takes place internally to the curved capacitor "plate," which is always grounded to the chassis. This type of capacitor is especially useful where the circuit goes through the chassis, or other metallic sheet, from one side to the other.

Two common types of continuously-adjustable or "variable" capacitors used for tuning r.f.



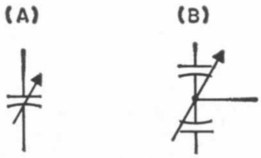


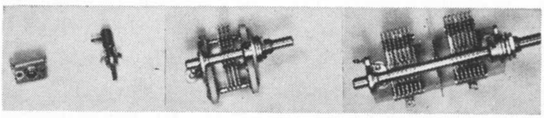
Fixed capacitors come in various shapes, sizes, and types of construction. At the left are a paper tubular capacitor, two sizes of molded mica capacitors, and three types of ceramic capacitors (two sizes of disks, and a tubular with axial leads). The large metal can is an electrolytic filter capacitor (in this case, several capacitors in one can, which is a common connection for all units). Beside it is a small electrolytic with wire leads. The small capacitor at the far right is a feed-through type useful at v.h.f.

circuits are shown symbolically at A and B below. The first symbol may stand for any of several physically-different types. One of these is the "air" type, which has a set of metal plates on a rotatable shaft, interleaving with a similar set of stationary or fixed plates. A second is the the "compression" type, in which the spacing between two sets of leaf-spring plates is changed by screw adjustment. The two sets of plates are insulated from each other by thin mica wafers. A third is the "piston" type, in which a metal cylinder is moved in or out of a conducting tube by screw adjustment. The cylinder and tube are insulated from each other. Small capacitors are often used as "trimmers" — that is, set to a desired capacitance value experimentally in the equipment and thereafter left alone. A capacitor used for this purpose may be (but does not *have* to be) so indicated by putting a small T alongside the straight line representing the fixed plate.

When the arrow is added to the basic capacitor symbol to show that the capacitor is variable the curved line represents the movable plates.

The "split-stator" capacitor symbol is shown at B. This is an "air"-type capacitor having two sets of rotor plates and two sets of stator plates. The former are mounted on the same shaft; in





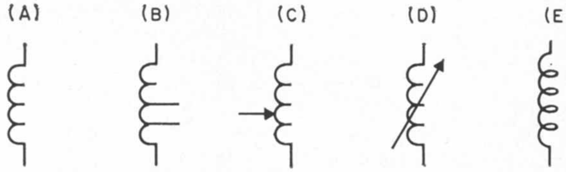
A few samples of variable capacitors; there are innumerable styles of these, and only a few are shown here. From left to right, a mica compression trimmer, a tubular trimmer, a single-section variable, and a dual-section or "split-stator" variable. The latter can be used either as a balanced capacitor or as two separate sections driven by a single control shaft.

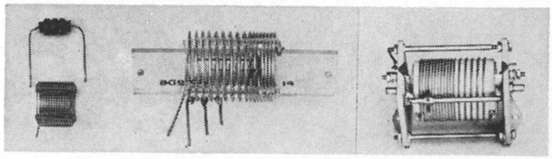
effect, there are two identical variable capacitors operating together. Capacitors of this type are used in "balanced" or "push-pull" circuits.

Whatever the capacitor symbol, it is customary to use the curved line to indicate the side of the capacitor that goes to the grounded or lower-potential side of the circuit. An apparent exception is the electrolytic capacitor, in which case the curved line usually indicates the side connected to negative d.c. voltage.

Inductors and Transformers

The basic inductor symbol, like the ones for resistors and capacitors, gives no information about the *type* of inductor. It is shown at A below. It represents an inductance of fixed value in this form, and it can stand for a simple r.f. coil wound on a form, for a multi-layer coil, a universal-wound coil, or even for one wound on an iron core. Like the resistor symbol, it can be

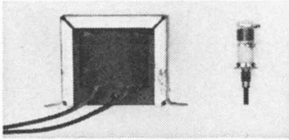




Typical inductances used at radio frequencies. Left, a multisection "pie"-wound r.f. choke, and a small "air-wound" coil. Next to these is a tapped coil such as is used in small transmitters. The inductor at the right is continuously variable; a roller makes contact with the wire as the form is rotated by the control knob.

shown tapped (B), or adjustable (C and D). C is used for inductors having a moving contact; an example is the "roller" type which has a traveling contact on a bare-wire coil, the contact position being changed as the coil is rotated. This symbol also would be used for a coil having a movable spring clip to make contact with any part of the bare-wire winding. Incidentally, there are two fundamental types of inductor symbol, one having open loops as shown at A, B, C and D, and one having closed loops as shown at E. The open loop type is the preferred one and is used in *QST* diagrams. However, most older diagrams of the pre-standards period used the closed-loop inductor symbol, and you may run across it now and then in books and periodicals.

If the inductor has an iron core or slug it may be indicated by two straight lines placed alongside the inductor symbol, as in A below. This particular symbol would be used for an iron-core choke in a power-supply filter, for example. B shows a continuously-variable iron-core inductor such as a slug-tuned r.f. coil. However, the iron-core symbol is not a *required* part of the inductance symbol. It simply represents a little addi-



Iron-core inductances. Left, an inductor of the type used in power-supply filters (filter choke). Right, an adjustable inductor for radio frequencies. Adjustment of inductance is made by moving a small cylindrical powdered-iron core in and out of the coil, which is wound on the form.

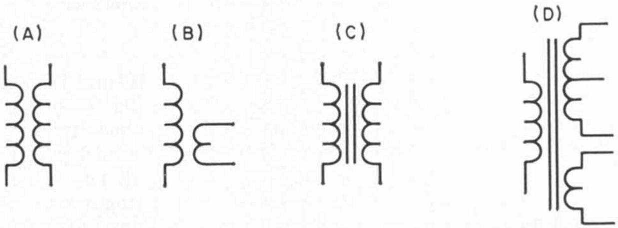
tional information about the inductor when the person who draws the circuit wishes to supply it. The practice in *QST* drawings is to use the iron-core symbol only for inductors intended for working at power-supply or audio frequencies, or on direct current; the core is not shown in inductors operating at radio frequencies.

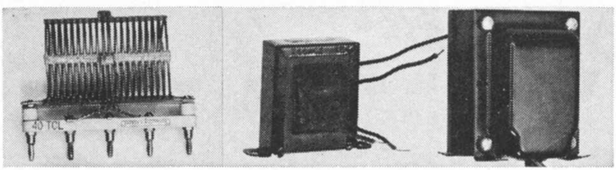
There is no hard-and-fast rule covering the number of loops in the inductor symbol. Four are used in most cases, but sometimes it is necessary to use more. For example, in the symbol for an inductor with two fixed taps shown earlier, four loops are used. But if a large number of taps has to be accommodated the number of loops can be expanded as necessary.

A transformer is essentially two (or more) inductors magnetically coupled, and the basic ymbosl for it is shown at A below. If the transformer has an iron core it can be shown as at C. In *QST* drawings the iron-core symbol is used only for transformers working at power-supply and audio frequencies. The core is omitted from the symbols for transformers operating at radio frequencies even though the actual transformer may have an iron core. This helps make it easier to differentiate between the two classes of transformers in glancing over a diagram.

As in the case of simple inductors, the number of loops in a transformer symbol may be increased if necessary. You will also frequently see transformer symbols in *QST* in which one or more windings will be shown by only *two* loops. These are used to indicate low-impedance or low-voltage windings. Thus the symbol at B would stand for an r.f. transformer with an output "link," while the one at D would be typical of a power transformer having a high-voltage center-tapped secondary (four loops with a tap) and a low-voltage filament secondary (two loops).

(To be continued) QST





Transformers. The r.f. coil at the left is typical of the tank coils used in transmitters, and has a low-impedance output winding or "link." A transformer for audio-frequency amplifiers is shown in the center. The unit at the right is representative of power-supply transformer construction.