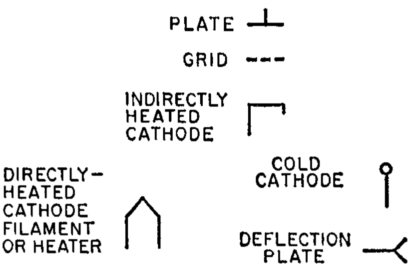
Basics for Beginners

How To Read Circuit Diagrams — Part II

The first part of this article[1] was concerned principally with the symbols for the fundamental electrical quantities — resistance, inductance and capacitance. A practical circuit usually includes a large number of additional devices, among which the vacuum tube forms an important class.

Vacuum Tubes

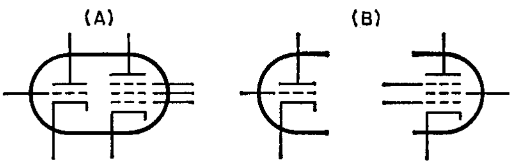
The circuit symbols for vacuum tubes are made by combining symbols representing the individual electrodes actually in the tube; the appropriate assembly is then enclosed in a circle or, in the more complicated cases, in an elongated circle. The element symbols most commonly used are shown below.



The basic tube types — diode, triode, tetrode and pentode — are enough to illustrate how the tube symbols are "manufactured." The diode at A (below) consists of a plate, indirectly heated cathode, and heater. The two symbols shown for the triode, B, illustrate the use of two types of cathode; the symbol at the left has a directly-heated cathode or filament while the one at the right is indirectly heated. Either type of cathode may be found in any basic tube type, whether it is a diode, triode, tetrode, pentode, or one with still more elements.

When a tube has an indirectly-heated cathode it is common practice to omit the heaters from the tube symbols, as has been done in the tetrode and pentode symbols, C and D, and group all heaters in the circuit near the source of heater power. This is a legitimate procedure because the heaters have no other function than to make the emitting cathode hot enough to do its job: they take no other part in the operation of the circuit. Grouping them separately avoids cluttering up the diagram with numerous crossovers and makes the circuit easier to follow.

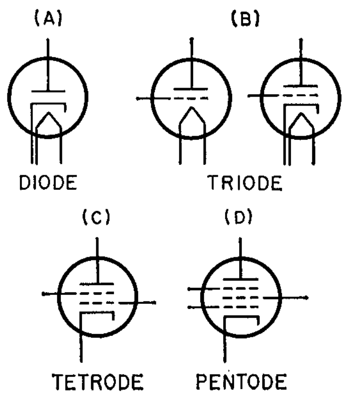
In practice you will often find two — or even more — complete tube structures in a single glass envelope. The most common examples are the dual triode (two triodes in one bulb) and the triode-pentode. The complete symbol in such cases includes the symbols for both tubes in one enclosure. However, it is seldom convenient to show multiple tubes all in one piece in the circuit, since the individual structures may be

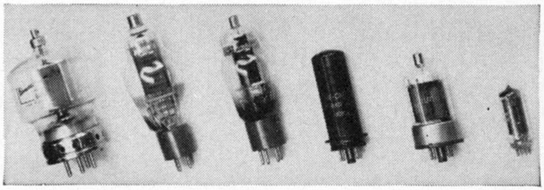


used for completely different purposes and would logically appear in widely-separated parts of the diagram. In such cases the enclosure is shown broken as in B, and the triode and pentode symbols are used in the circuit as though they were separate tubes. The separate sections are usually given a circuit designation (V_{1A}, V_{1B}, etc.) which identifies them as all being in the same envelope.

Some "vacuum" tubes have gas introduced into them intentionally. The ones most often encountered in amateur equipment are mercury-vapor rectifiers and voltage-regulator ("VR") tubes. Both are diodes. The mercury-vapor rectifier usually has a directly-heated cathode, A,

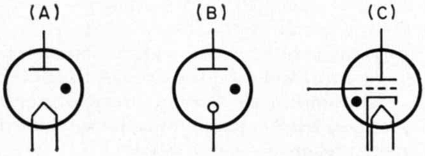
[1] "How to Read Circuit Diagrams," Part I, *QST*, August, 1963.





Big or little, glass or metal, based or not based, the symbol is the same for any tube of a given basic type. The big tetrode at the left, capable of handling a full kilowatt, has the same symbol as the low-power tetrode at the right.

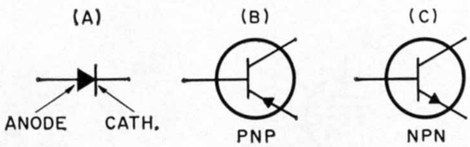
while the VR tube has a cold cathode, B. The presence of gas in the tube is indicated by the dot inside the envelope. Another gas type you will meet occasionally is the thyratron, or gas triode, shown at C.



As a help to the constructor, the socket pin number to which each tube element is connected usually is given on the tube symbol close to the appropriate element. (This information, however, is not a *required* part of the symbol.) In this connection, the vacuum-tube symbols used in *QST* drawings frequently omit elements, such as suppressor grids, that have only *internal* connections and are not brought out separately to a base pin on the actual tube. This makes the symbol less complicated and avoids internal crossovers in the tube symbols. The actual connections *to* the tube are not affected by this omission.

Semiconductors

The symbols for semiconductor devices such as crystal diodes and transistors have not yet been formally standardized by the A.S.A. Work is under way on this, and a new set of standards is expected in the near future. The symbols shown here are ones which almost certainly will

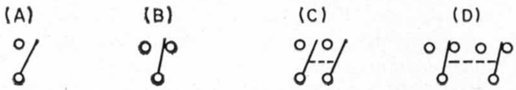


be standard. The diode is at A, and in interpreting this symbol it is important to keep in mind that the arrowhead represents the anode and the line represents the cathode. That is, the direction of current flow is the same as between plate (anode) and cathode of a vacuum-tube diode.

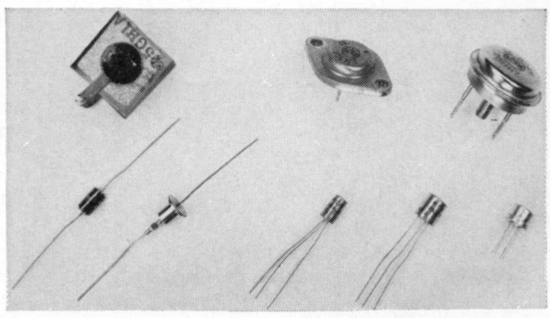
This convention with respect to current flow is also used in identifying the emitter in transistor symbols. The "p-n-p" type of transistor shown at B has the arrowhead pointing toward the base symbol (the short line), while the "NPN" type shown at C has the arrowhead pointing away from the base. In both types the collector symbol is a slanting line touching the base. The distinction between the two types is important because the polarities of the d.c. voltages applied to the base and collector are reversed with the n-p-n type as compared with the p-n-p.

Switches and Relays

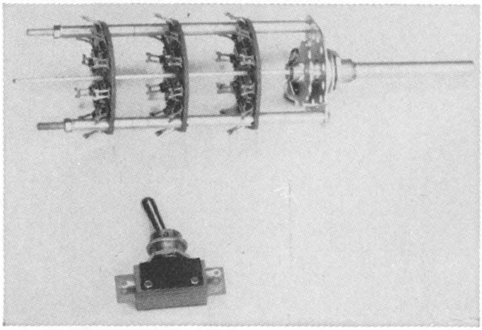
Shown below are the symbols for toggle switches. There are four common types — single-pole single-throw (s.p.s.t.) at A, single-pole double-throw (s.p.d.t.) at B, double-pole single-throw (d.p.s.t.) — at C, and double-pole double-throw (d.p.d.t.) at D. Note that in the symbols for the double-throw types the switch arm (straight line) always is touching one contact (small circle), since an ordinary toggle switch has no "open" position. The double-pole types



are ganged (that is, operated simultaneously from one control), which is shown by the dashes connecting the movable arms. However, ganged switches, like multiple tubes in one envelope, can have their separate sections placed in different parts of the circuit diagram, in which case the sections have appropriate designations (S_{1A}, S_{1B}, etc.) to show that they are all part of one switch mechanism. The dashed lines can be omitted when this is done, but are sometimes included when it is thought desirable to do so.



Semiconductor devices in various forms. At the left are three diodes—upper, a selenium rectifier; lower, two silicon diodes, one a "top-hat" type. Fives styles of transistors are grouped at the right, the two upper ones being power types.



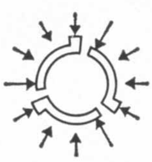
The three-section rotary switch at the top is just one of many styles. The number of wafers may run from one to as many as a half dozen, and both phenolic and ceramic wafers are available. The familiar toggle switch is below.

Multicontact switches, such as the rotary "wafer" type, can be represented by either of the symbols shown below. The choice is usually a matter of making the wiring diagram as easy as possible to follow. The straight-line arrange-

ment shown at A is used less frequently than the circular one at B. In either case, it is customary to show only the actual number of contacts *used*, although the switch itself may have more. (The number of contacts on small wafer switches is usually 11 on a wafer having a single arm or pole, 5 per pole on a wafer having 2 poles, and 3 per pole on a wafer having 3 poles.) Those not needed in the circuit are usually ignored in the diagram.

The separate sections of a multiple-pole switch, whether the sections are on the same or different wafers, can be shown to be ganged by using dashed lines as in the case of the toggle switches discussed above. However, it is more common to place the switch sections where they fit best in the diagram; the same circuit designation is used for all, with A, B, C, etc., identification to show that they are all operated from the same control.

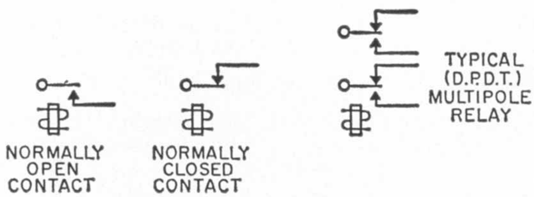
A type of rotary-switch symbol frequently used in circuits of commercial equipment is a sort of picture diagram, illustrated by the example below. In switches of this construction the

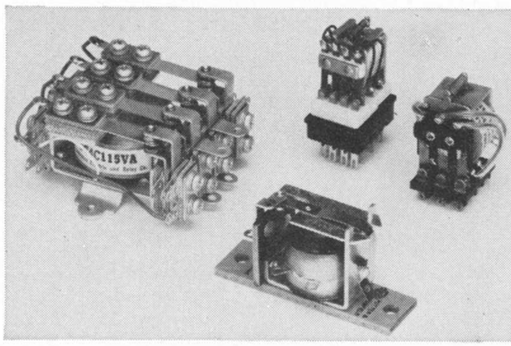


switch "arm" is a metal ring, or segment of a ring, on the wafer. It makes continuous contact with a fixed spring contact, indicated by the longer arrows in the example. The ring has one or more projections that meet the shorter arrows as the wafer is rotated. These short arrows represent the fixed contacts or switch "points."

This type of symbol is very useful for indicating actual wiring of a switch wafer, since it shows exactly which contact to use for a particular circuit connection. The disadvantage is that it is difficult to trace out what the switch actually *does* in the circuit. However, there is a fairly simple way to find out what is connected to what at each position of the switch. Make a tracing of the ring or segments on transparent paper and place it over the symbol. Rotate the tracing one switch position at a time (each short arrow, in general, is placed at each switch position) and follow the circuit through the short arrow, projection, ring segment and long arrow. At times the projection will be large enough to make contact with two or more short arrows in one or more positions, so *all* the possibilities for contact must be observed.

The symbols for relays are shown below. Note that the arm moves *toward* the coil when the coil is energized, and springs away from it when the coil current is cut off. In actual circuit diagrams the contacts may be considerably separated from the relay coil as a matter of convenience. When this is done the contacts should be drawn in the same relative position in the diagram that they would have if the complete symbol were all to-



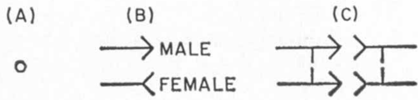


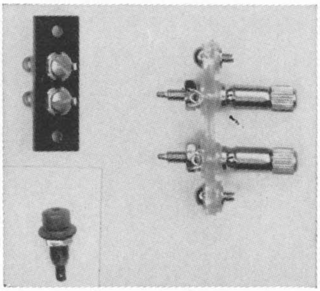
A few of the many varieties of relays are shown here. The large one at the left is for power switching. A miniature type is in the top center.

gether. Otherwise it may be hard to visualize the relay action. *QST* practice, when parts of a relay are separated in this way in the circuit, is to use the basic designation (K_1, etc.) for the relay coil and add A, B, C, etc., to the various contact groups (K_{1A}, K_{1B}, etc.).

Connectors

A fixed terminal is represented by a small circle as shown at A below. This symbol can stand for a binding post,



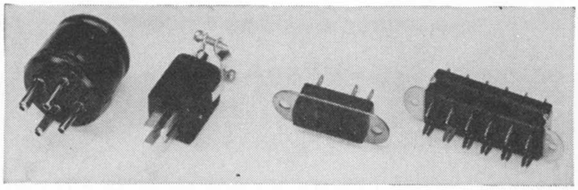


Terminal strips can be obtained with many more screw terminals than the two shown on the sample at the upper left. Below it is a tip jack. A binding-post strip is at the right.

screw terminal, or other type of contact to which a wire can be connected. It is also used as a general symbol for an external or internal connection when for some reason — for simplifying the appearance of the diagram, or because the exact type of connector used doesn't matter — no specific type of connector is to be represented. For example, this symbol may be used to indicate external connections to supply voltages. Thus, if he wishes, the builder may select any one of several types of plug-and-socket multicircuit connectors for the actual piece of equipment. The small terminal symbol also is frequently used to indicate connection points for plug-in coils inside the circuit, in preference to using the more complicated symbols representing the actual plug-in coil form and socket.

The basic symbols for plug-and-socket-type connectors are shown at B. When there are several prongs, dashed lines are drawn between the symbols as in C, to indicate that they are all part of one assembly. Two "mating" assemblies, one male and one female, are shown here. Note that either could be the fixed connector ("socket" or "receptacle") and either could be the movable one ("plug"), since both sockets and plugs are made with male and female contacts. In fact, both could be plugs if both symbols represented connectors on the ends of lengths of multiwire cable.

An alternative way of showing cable connectors is given below. These symbols can be used for any number of wires. They do not show which

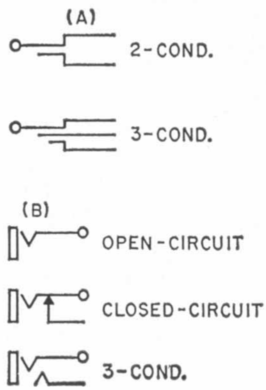


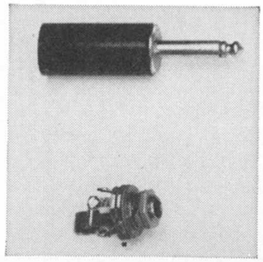
Plugs fitting into ordinary tube sockets (left) are commonly used in amateur equipment. Beside this one is a miniature plug with keyed prongs. Typical multiple-connection chassis-mounting connectors are at the right, one with female and one with male contacts.

contacts are male and which female, but this information is usua'ly made available in the data accompanying the circuit. If the contacts in the actual connectors used are numbered, the exact

contacts to which the wires are connected can be indicated by placing the numbers inside the symbol at the appropriate point. They do not have to be in numerical order.

A few special types of connectors are used widely enough to have individual symbols of their own. Among these are the phone plug and jack.

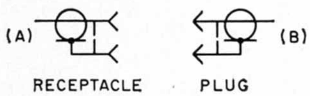




Phone plug and jack. Jack styles include leaf switches which operate when the plug is inserted.

The symbols shown at A and B, respectively, are ones you will find frequently used. The rectangular block in the jack symbol represents the jack frame, usually grounded. The open "V" is the contact that connects with the plug tip, and the closed arrowhead represents a contact not touched by the plug tip but which makes or breaks when the plug is inserted. A number of such contacts, either normally open or normally closed, may be incorporated in a single jack, but these more complicated arrangements are not often used in amateur equipment.

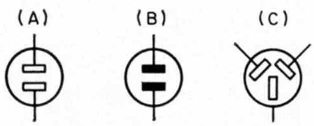
Another type of connector that occurs frequently in r.f. circuit diagrams is the coaxial receptacle shown at A below. The symbol is that of



The common type of coaxial receptacle (left) and plug. These belong to the "UHF" series, which does not mean a type preferred for u.h.f. work but is simply an early designation.

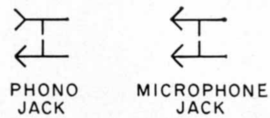
a basic two-conductor connector with the coaxial symbol added. Note that no attempt is made to show the actual male and female contacts of a conventional coax chassis fitting; in this one case the female symbol is used for both, indicating a receptacle rather than a plug. In the plug symbol, B, which you will see less frequently, the male contact symbol is used throughout, plus the coax indicator.

Still another special group of symbols is used for a.c. power connectors such as 115-volt plugs and sockets. These are drawn with the contacts inside a circle, as shown below. The open rectan-

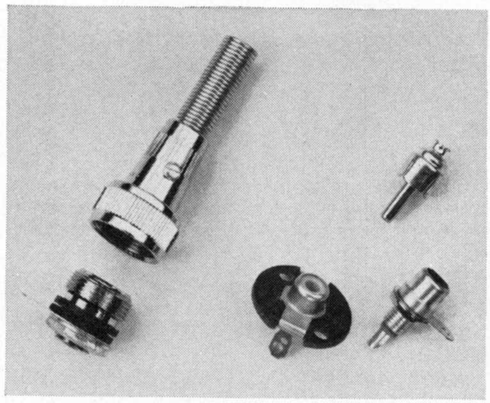


gles, A, indicate female contacts, used in what are usually called sockets, and the solid ones, B, stand for male contacts, usually in plugs. The system can be extended as shown by the example at C, which is a 3-conductor polarized connector with female contacts.

Aside from these special cases, connector symbols are constructed from the fundamental contact symbols, described earlier, assembled as required to represent the actual connector used. There are times when the choice of a symbol becomes a little puzzling for the circuit designer — for example, is the widely-used phono connector a "real" coaxial connector or not? The question could be argued both ways. In *QST* the phono connector, and also microphone connectors such as the Amphenol type, are drawn from the basic contact symbols, omitting the coaxial indicator, thus:



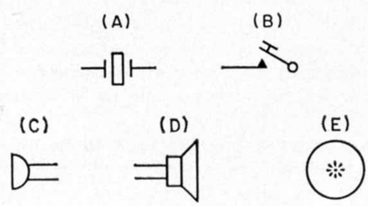
the bottom contact being the grounded one in both cases. The actual center contact (top, in the symbol) in the Amphenol connector is merely a spot of solder, and does not really qualify as a "male" contact, but neither is it female. There being no symbol for a butt contact, the male is used instead.



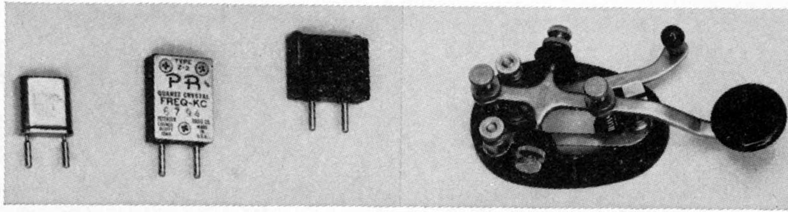
Microphone connectors, left, and phono jacks and plugs. Two forms of phono jacks are shown.

Miscellaneous Symbols

The list of symbols could go on and on, because there are innumerable varieties of components used in electronic circuits. However, we need only a few more to give a reasonably complete picture of what may be encountered in circuit diagrams of amateur gear. One is the symbol for a piezo-electric crystal, the kind used for frequency control in a transmitter, not the kind used as a rectifier. This is shown below at A. Another is the symbol for a telegraph key, shown at B. The microphone symbol is given at C, and the loudspeaker at D. Finally, there is a simple circle, somewhat smaller than the circle representing a tube, used as a general symbol for a number of devices such as meters, generators,



Three types of crystal mountings commonly used in amateur equipment, left, and a telegraph key.



motors, and the like. The asterisk in the symbol shown is replaced by a letter or abbreviation indicating just what the device is — MA for milliammeter, V for voltmeter, MOT for motor, GEN for generator, and so on. Thus the meaning of the symbol is identified in the actual circuit, so the component is easy to recognize. In many cases, too, a rectangle is used as a general symbol for a component or assembly, all in one piece, that either has no special symbol of its own or which it is not necessary to represent with detailed symbols since it has only a few terminals. One example is a filter, which may actually be quite complex in construction but fits into the circuit as a simple unit.

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In closing this introduction to the language of circuit diagrams, permit us to repeat a statement that we made at the outset: a diagram does not attempt to give any information about how the components are laid out, but simply tells how they are electrically connected.

Neither does the diagram attempt to explain itself — that is, you cannot expect to look at a circuit and, from it alone, understand the exact function of every part. Nevertheless, with experience in reading diagrams you'll be able to make a pretty good guess as to the equipment designer's intentions, merely from looking over the circuit, if you know over-all what the equipment is supposed to do. A "good" circuit layout is one that helps get functional ideas across. In time, you'll come to appreciate those little points of style that mean the difference between clarity and obscurity. There's an art to laying out a circuit diagram, just as there's an art to laying out a chassis!