• *First Steps In Radio*

The World of Switches and Relays

Part 6: Mechanical and electronic switches are important parts of most radio circuits. Let's examine mechanical switching devices and become acquainted with how they look and perform.

By Doug DeMaw,* W1FB

What could be more ordinary than a switch? After all, we have them on our appliances, on the walls in our homes and on the instrument panels of our automobiles. Switches are as old as electricity, and they come in many different shapes and sizes. For that reason, we must know how to select the proper switch for each application.

There are many things to consider when selecting even a simple, inexpensive switch. Among them are insulation quality, mechanical durability, the number of switch terminals (poles and contacts), current-carrying ability of the electrical contacts, and physical size. We can add to this list the cost of the switch versus the well being of our hobby budget! In other words, "any old switch is not necessarily the right one for a specific job."

We need to understand the circuit requirements and choose a suitable switch for that circuit. The same is true of relays, which are electrically operated switches. They differ from ordinary switches by virtue of being actuated or energized remotely by a mechanical or electronic switch. In effect, we have a mechanical switch being used to turn on a remote switch.

In some instances, an event that takes place within an electronics circuit will cause the relay to switch on or off automatically. The TR (transmit-receive) relays in our ham radio transceivers are examples of devices that are controlled by the circuit within the transceiver. Some are called VOX (voice-operated) relays because they actuate when we speak into the microphone. When we stop talking they disengage, thereby connecting the antenna and certain operating voltages to the receiver circuit. When the

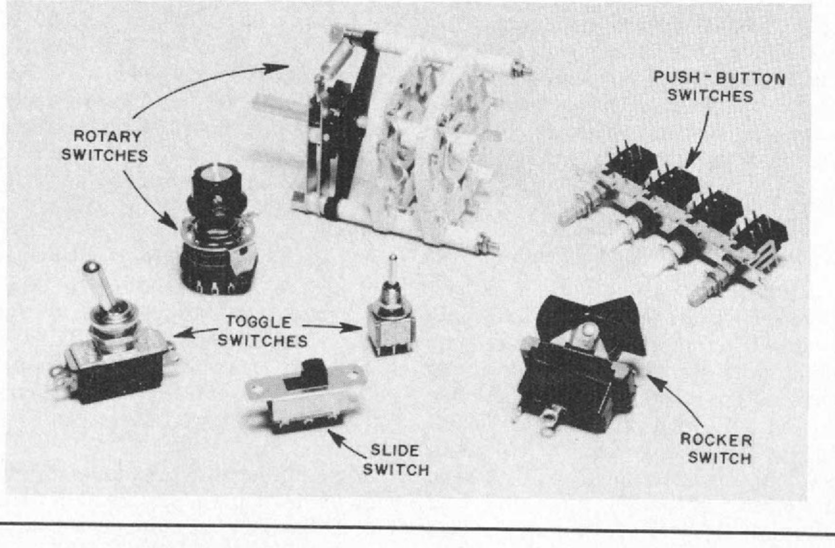

Fig. 1 — Various types of switches.

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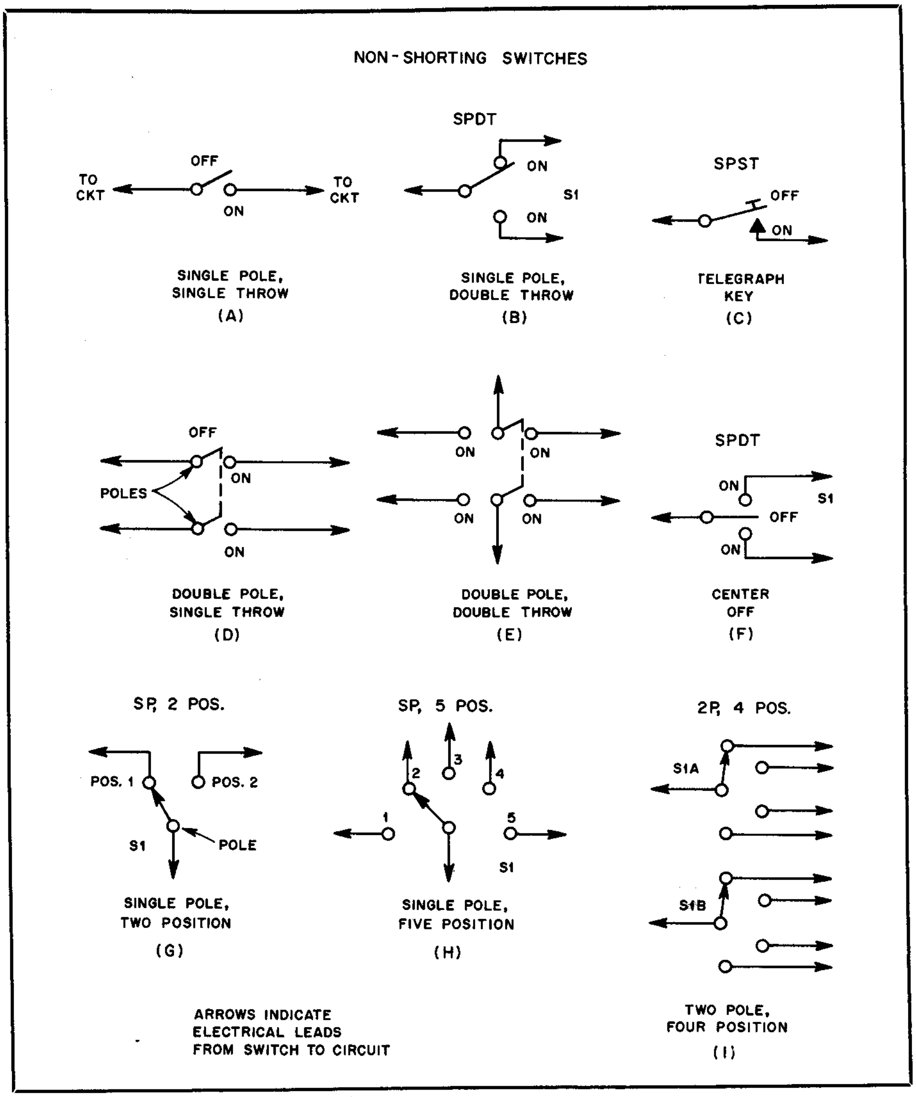

Fig. 2 — Electrical symbols for a number of common switches used in Amateur Radio work.

relay is activated by our voices, the antenna is switched to the transmitter, along with specific operating voltages. Relays are often used to control an antenna function at some point that is a distance from the radio room. Generally, such remote relays are actuated within the ham shack by means of a mechanical switch. There are countless applications for relays and special switches that can be turned on and off from a distant point.

Switches and Their Circuit Symbols

Each style of switch is represented by a different electrical symbol in a schematic diagram. It is important that you become familiar with the symbols if you are to understand the function of the switch when you read a diagram or draw one of your own. I'd like to suggest that you practice drawing these symbols until you have them memorized. Although you will find numerous variations of the basic symbols for switches in amateur magazines, they follow a pattern that should be easy to recognize. The ARRL employs the established standards for electrical symbols, as used by the industry and the IEEE (Institute of Electrical and Electronics Engineers). As we learned in an earlier installment of this series, many of the other publishers use nonstandard symbols to create a distinctive "style."

Fig. 1 shows an assortment of switches. We can tell from the illustration that switches come in many shapes and sizes. Generally, the smaller the switch assembly the lower its power-handling ability (current and voltage rating). Most reputable switch manufacturers can provide the consumer with maximum safe ratings for voltage and current. Some manufacturers imprint the ratings on the switch for our convenience.

Some of the more commonplace switch symbols are depicted in schematic form in Fig. 2. The simplest switch is shown at A and C. This is what we call an SPST (single pole, single throw) switch. A telegraph key (C) is actually an SPST switch that we open and close by hand to form the Morse code characters. When we use the switch at A, we can complete only one circuit. This type of switch is common in our TV sets, lamps and household appliances. But, if we want to control two circuits, we must use an SPDT switch (Fig. 2B). Here we have two ON positions. As we examine the progression of switch symbols in Fig. 2, we will recognize the utility of switches with more than one pole and two throws.

The switches from A through F in Fig. 2 are considered to be *toggle* switches. This style of switch has a bat handle or flat lever used to operate the switch. These switches are available also as "rocker switches." This variety is built with a plastic bar that is pressed on one end to operate the switch to close one circuit; the opposite end of the rocker bar is depressed to change to another circuit. There is a rocking action to the bar; hence the name "rocker."

Switches can be obtained also with a "center off" position. We can see this at F of Fig. 2. Here we have two ON positions and a center position that is OFF. In the off condition our switch pole is in midair, so to speak.

The switches shown schematically from G through I of Fig. 2 are what we refer to as rotary switches. This means that instead of an up-down or side-to-side action (as with toggle switches), we rotate the switch shaft and pole clockwise or counterclockwise. The contacts that the pole conductor touches during rotation are mounted on a thin wafer of phenolic, plastic, ceramic or steatite material. The usual name for these switches is "rotary wafer switch." Rotary switches may contain several decks of wafers, and may have 30 or more positions. These are often called multiwafer or multigang switches.

Some Other Switches

The rotary switch may take another electrical form, as we can observe by looking at Fig. 3. This is known as a shorting type

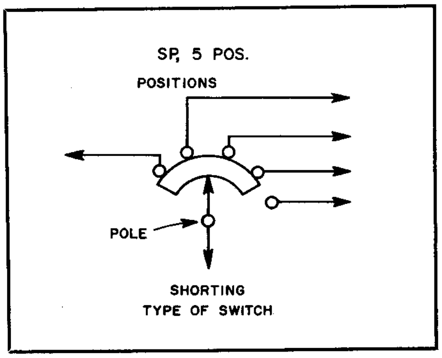

Fig. 3 — One style of shorting switch (see text).

of switch, (the switches of Fig. 2 are nonshorting units). How do these switches differ? Well, if for some reason we want to short out the circuits that are connected to the switch terminals while only one event is controlled by the nonshorted contact, we may use a shorting style of switch. Perhaps a more common type of shorting switch is the rotary type with a pole contactor that is sufficiently wide to cause any two adjacent wafer contacts to be shorted together as the switch is cycled to a new position. Once the switch is in the intended position, the shorted condition ceases. This wiping action is useful when we do not want to interrupt one circuit until another is closed. These switches are not used very often, but we should understand how they can be used in case a special application comes up.

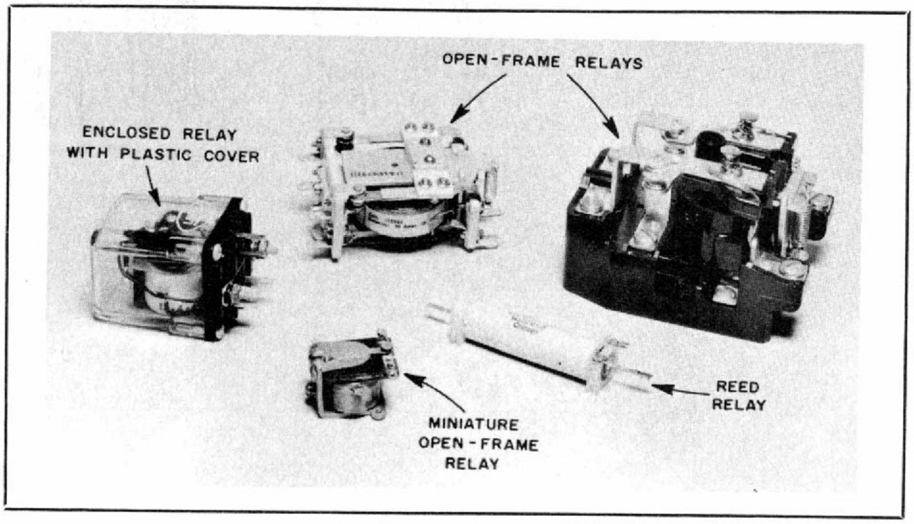

Fig. 4 — Various forms of relays.

We may hear about *mercury switches* in our discussions with other hobbyists and amateurs. This variety of switch is operated by changing its physical position. It contains two contacts that are open when the assembly is in one position. When the position is reversed, the mercury within the switch changes position and acts as a conductor across the internal contacts. These motion switches are used in automation and burglar-alarm systems, to name only two uses.

Rotary switches are available also for remote actuation by means of electrical current. They are sometimes called "solenoid switches." They are standard rotary switches that have a coil to which an operating voltage can be applied from a distant point. Each time a pulse of current is sent to the switch coil, the pole of the switch will move to a new position. Another version of this switch is the "stepping switch." It contains rows of contacts to which we may attach wires that go to various circuit points. Each time a pulse of current is supplied to the coil on the switch, the pole(s) moves to a new position. Telephone companies used stepping switches in their control circuits for many years.

You will also hear about an interesting gadget called a "proximity switch." It is merely a mechanical or electronic switch that actuates when a conductive object is placed near it. To operate in this manner, it must have some allied electronics to control it. Switches of this variety can be actuated also by changes in light, moisture or heat levels.

Some Aspects of Relays

It is easy to compare a relay to a switch, for in fact it is a switch of sorts. That is, a relay switches circuit connections in accordance with the commands given to it. These commands may be at the direction of a person, or a sensing circuit may respond to some event (such as heat, voltage or current changes) and in turn cause the relay contacts to open or close. For a relay to operate, it must have a certain ac or dc current flowing through the field coil. A field coil is a multilayer winding of insulated copper wire that is contained on an iron-core bobbin. When the electrical field of the coil becomes intense enough, it magnetizes the iron core and pulls the relay pole (arm) down. This action closes the electrical switch contacts of the relay. When the current flow is removed from the relay field coil, the magnetism ceases and the relay pole returns to the de-energized position.

Relays may have several poles, as do mechanical switches. They can be compared to toggle switches in their capability because, like the toggle switch, a relay is a two-position device. This is not true, of course, with rotary switches.

Ac-operated relays have a copper half-round plate at the top of the field coil. It is positioned to "shade" the field in such a way as to prevent the relay from buzzing when it is activated. This copper plate is known as a "shading pole." The cause of the mechanical vibration of an ac relay is the pulsating 60-Hz current from the wall outlet. No such problem is found when using dc relays. Sometimes it is necessary to loosen the field-coil assembly and rotate it in an effort to find a position where annoying "chatter" will not occur.

It would be impractical to describe every type of relay that we can obtain. We can generalize by saying that the major differences in relays are the operating voltage, current rating of the contacts, size of the unit, mechanical characteristics and mounting style. Some relays have plastic covers to help keep dust and moisture away from the electrical contacts. Others have no enclosure; they are called "open-frame relays."

We must pay attention also to the type of insulating material that isolates the relay contacts from one another. This material must not break down and burn in the presence of the voltage we apply to the relay contacts. The size of the contacts is important also, for they must be able to pass the current that flows through them. If the contacts are too small, they will become hot and may even melt or become charred. In less-severe cases, the contacts can become pitted and covered with oxide. This makes them incapable of making a proper electrical connection. Under some conditions of pitting the contacts may weld together, which will prevent the relay from operating normally. We can clean dirty relay contacts with a piece of emery cloth or a fine file.

There is a style of relay that has its pole arm *inside* a field coil. When the field is turned on, the pole moves into the contact state, closing the circuit. These devices are known as "reed relays." They are capable of cycling at a fast rate with little "contact bounce." This condition often occurs when large relays are used for fast switching. The contacts bounce apart and cause circuit-performance problems (jitter). Some amateurs use "bug" CW keys that mechanically send automatic dots. The dashes are made in the usual matter — by pressing the dash paddle. Some hams have been known to stuff a small piece of foam plastic or a filter tip from a cigarette into the loop-shaped dot-contact spring to damp the inertia. This helps to minimize contact bounce at high sending speeds.

The operating voltage for a given relay coil depends on the dc resistance of the coil. In order to set up a magnetic field that is sufficient to close a relay, a specific amount of current must flow through the coil. Since current is determined by E/R (where E is the operating voltage, and R is the coil resistance in ohms), the coil resistance and applied voltage need to be the correct value. Relays are manufactured for standard operating voltages, such as 5, 6, 12, 18, 24 and 48. It is necessary, then, to select a wire size and winding length that produces the desired resistance to obtain the current needed through the field winding. Each gauge of wire has a specific dc resistance (in ohms/ft). Hence, it is easy to make a field coil to match the operating voltage and pull-in characteristics of the relay.

Fig. 4 shows an assortment of relays. The symbols for a few relays are provided in Fig. 5. Please note that when multiple-section switches or relays are used they are labeled in accordance with their sections. For example, the relay in Fig. 5C has three parts: the field coil (K1A), one set of contacts (K1B) and a second set of contacts (K1C). This type of labeling permits us to place sections of the switches or relays in different parts of a diagram without losing track of which part belongs with another. The parts may be spread about in a diagram for the purpose of minimizing connecting circuit lines and crossovers. This helps to "unclutter" a diagram and make it easier to follow.

Some Practical Examples

Let's see just how we might use switches

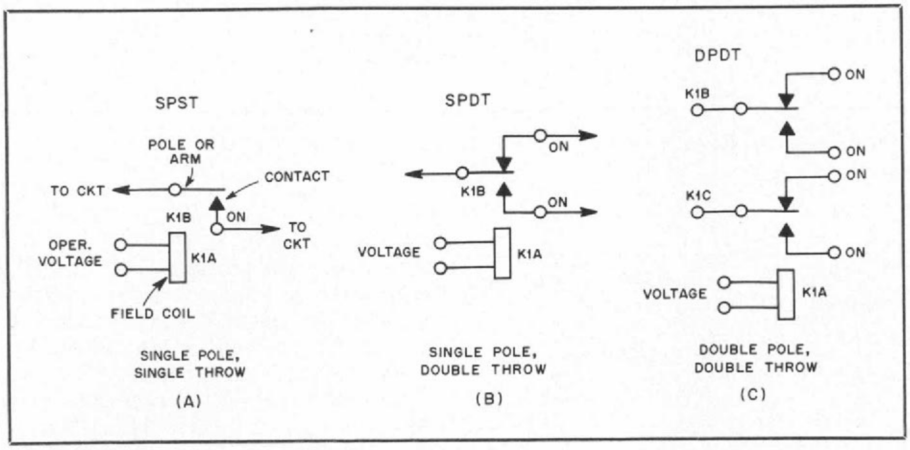

Fig. 5 — Electrical symbols for some common relays.

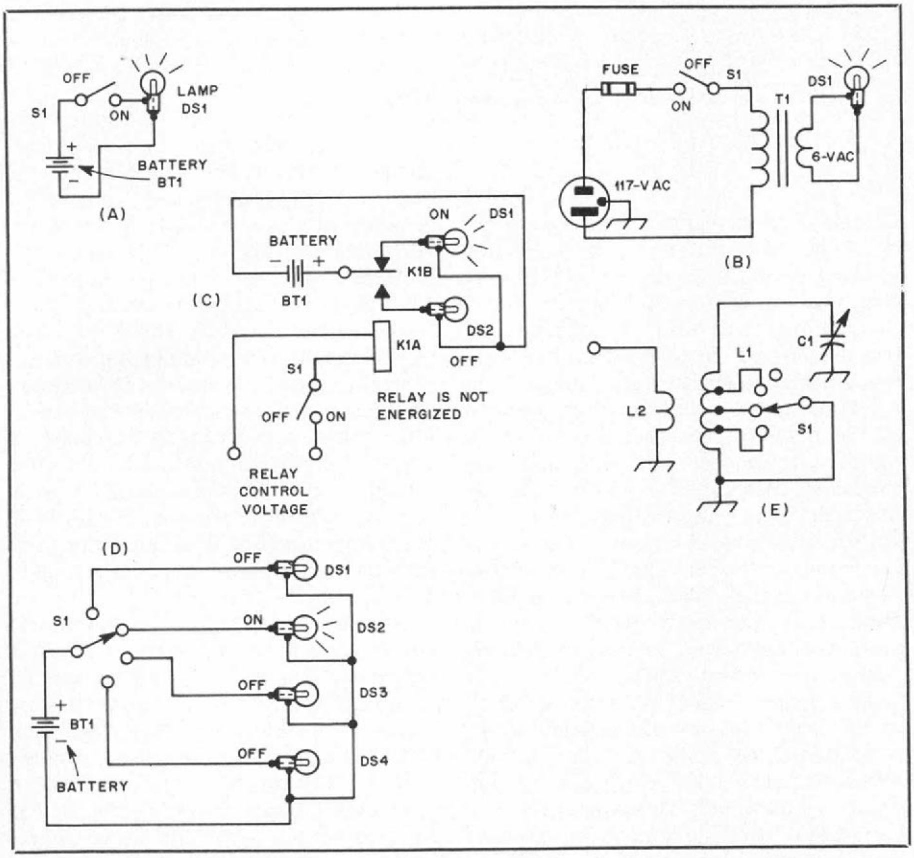

Fig. 6 — Some practical examples of how to use switches and relays. See text.

Glossary

bobbin — an insulating coil form upon which magnet wire is wound before it is added to a relay or other electrical mechanism.

contact bounce — a condition that can occur when a relay is cycled, causing the electrical contacts to bounce apart momentarily. This causes the circuit being switched to be interrupted during the period of the bounce.

electronic switch — an electrical rather than mechanical switching circuit. Generally, such switches consist of diodes, transistors or ICs.

pole — the movable portion of a switch or relay that makes electrical contact with the remaining conductors of a switch or relay.

proximity switch: a type of switch that is actuated by the nearby presence of a conducting object or magnet.

reed relay — a type of relay that has the pole piece contained inside the field coil. The pole arm is like a small, thin reed.

relay — a mechanical switching device that is actuated when sufficient current flows through its field coil, thereby causing the field-winding core to become magnetized. This action moves the pole arm to make and/or break contact with a circuit.

rotary switch — a switch that has a shaft that causes the switch pole to come in contact with the mating electrical contacts on the switch wafers. A rotation of the shaft is needed to operate the switch.

shading pole — a copper, half-round plate that is affixed to the top of a relay field coil when the relay is intended for ac operation. The shading pole prevents the relay from buzzing when it is energized.

solenoid switch — a switch that can be operated remotely by means of a field coil to which ac or dc voltage is applied.

stepping switch — similar to a solenoid switch, but with contacts arranged in a row (part of an arc) rather than on a circular wafer.

VOX — voice-operated relay and control circuit used in a transmitter or transceiver.

and relays, singly or in combination, to make certain things occur. Fig. 6 contains some simple circuits to demonstrate what can be done with switching arrangements. Circuit A shows how a lamp can be turned on and off with an SPST switch — the kind we will find in most table lamps and wall panels. Fig. 6B shows a lamp being operated from a 6-V ac transformer. We have reduced the ac line voltage from 117 to 6 by means of a step-down transformer, T1. This is necessary to obtain the right operating voltage for DS1, a 6-V lamp.

Fig. 6C shows how we can use a relay to control two lamps, DS1 and DS2. Although this circuit is somewhat absurd and would not normally be used, it does illustrate how a relay can be used to provide remote control of a circuit. When the relay is energized (S1 switched to ON), we will see DS2 illuminate and DS1 will no longer glow.

At Fig. 6D, we find a rotary switch being used to control four lamps. DS2 is illuminated in the example, because the switch pole and related contact are permitting current to flow through only DS2. The lamps will light in sequence as we rotate S1.

An example of coil-tap selection is shown in Fig. 6E. As S1 is rotated clockwise more and more of the coil is shorted out, decreasing the effective inductance of the tuned circuit. This is a common arrangement in transmitters and receivers when the operation is changed from one band to another. Similarly, the switch could be used to select individual coils for the various frequencies of interest.

Potential Problems

We learned earlier that the insulation on switches and relays must be suitable for the application we have in mind. We can adopt a role of thumb concerning this matter: For operating voltages (dc, ac or RF), we can do rather well with plastic or phenolic insulating material if the voltage is low (less than a couple of hundred volts) and if the RF power is under, say, 25 W. For high voltage and high RF power levels, ceramic or steatite insulation is recommended. It will sustain high voltage without breakdown, as compared to phenolic and plastic.

Relays with gold-plated contacts cost more, but they are less likely to arc and become pitted. Furthermore, they will not become contaminated by oxidation. Determine the current that your relay or switch contacts must pass, then to be safe, use a relay or switch rated in excess of the current in your circuit. I like to use a switch or relay contact rated for 2 A or more in a circuit that carries 1 A.

Tag Ends

I hope this article has proven informative in your quest for basic data about electronics. I'd like to suggest that you obtain some switches and relays, a few bulbs and some batteries. Spend a couple of hours hooking these devices up in order to see what can be done with them. You might even amaze your friends with an array of flashing lamps! Good luck. QST