5.9 Relays

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Available Capacities:	Relays can handle microvolts to kilovolts, microamperes to kiloamperes, with response speeds from milliseconds to any longer period
Power and Frequency:	Relays can be actuated by microwatts but usually use milliwatts. They will operate from DC to RF
Environmental Limits:	Some relays can operate from –50° to 400°F (–45° to 204°C), from vacuum to 400 PSIG (2.8 MPa), and to 100 G shock or vibration
Sizes:	From 0.03 in.^{3} (0.47 cc) up
Cost:	Depending on size and capability, from about $10 to $100
Partial List of Suppliers:	ABB (www.ssac.com) Agastat (www.agastat.com) Allen-Bradley Co. (www.ab.com) Allied Controls (www.alliedcontrols.com) American Relays (www.americanrelays.com) American Zettler (www.azettler.com) Astralux (www.astralux.co.uk) Axicom (www.relays.tycoelectronis.com/axicom) Baocheng (www.qunli-relay.com.cn) Barnbrook Systems Ltd. (www.barnbrook.co.uk) BLP (www.blpcomp.com) CCI (www.completecontrols.com) Celduc Relais (www.celduc-relais.com) CII (www.ciitech.com) CIT Relay (www.citrelay.com) Continental Industries (www.ciicontrols.com) CP Clare/SRC (www.clare.com) Crompton (www.cromptoninstruments.com) Coca Enterprise Co. Ltd. (www.demax.com) Crydom (www.crydom.com) Cutler Hammer (www.cutler-hammer.eaton.com) Danfoss (http://uk.ic.danfoss.com) Daquan Relay Factory (www.chinadaquan.com) Deltrol Corp. (www.deltrol.com/controls) Dold Industries, Ltd. (www.dold.co.uk) Eagle Signal Controls (www.dancon.com) EAO Switch Corp. (www.eaoswitch.com) Furnas Electric Co. (www.sea.siemens.com) Greenwich Electronic (www.geirelays.com) Goodsky UK (www.goodsky.co.uk) Honeywell Inc. (www.honeywellsensor.com) Idec (www.idec.com) IMO (www.imopc.com) International Rectifier (www.irf.com) Inventa Electro Systems Nasik Private Limited (http://business.vsnl.com/chaitnya) Jennings (www.jenningstech.com)

KOYO (www.automationdirect.com)
Magnecraft & Struthers Dunn (www.magnecraft.com)
Meder (www.meder.com)
NAIS Matshushita (Aromat) (www.aromat.com)
Nuova Hi-G Italia; OEN (www.oenindia.com)
Olympic Controls (www.occorp.com)
Omron (www.omron.com)
Pickering (www.pickeringrelay.com)
Pioden (www.precisionrelays.co.uk)
Reliance Electric Controls (www.reliance.com)
Siemens (www.siemens.com)
Square D Co. (www.squared.com)
SRC Devices (www.srcdevices.com)
Teledyne Relays (www.teledynerelays.com)
Tianbo (www.tianbo-relay.com)
Tyco (http://relays.tycoelectronics.com)

INTRODUCTION

An electrical relay is a device that changes the state of a circuit in response to it being energized or de-energized by that or another circuit. In addition to electrical relays, there are pneumatic, fluidic, and other varieties. The relays described here are electromechanical or solid-state designs. Solid-state relays are only briefly mentioned in this section, because they are discussed in detail in Section 5.10.

The function of a relay is to open or close an electrical contact or a group of contacts in response to a "signal," which is a change in some electrical condition. The contact closures of the relay can be used to select other circuits or to turn on or off various devices or operations.

More generally, a relay may be considered as an amplifier and a controller. It has a power gain that is defined as the ratio of output power handled to input power required. Thus, a relay may require a coil current of 0.005 A at 50 V but can control 2500 W of power—a gain of 10,000. As it will be discussed in this section, among the many forms of relays a variety of specific functions are available.

RELAY TYPES AND FEATURES

Electromechanical and electrothermal relays are discussed in this section. They are available in a variety of forms, but the basic characteristics that are described here are common to all of them.

Relays control the flow of electric current by means of contacts, which may be open or closed. When these contacts are open, they create a very high resistance (megaohms), and when they are closed, their resistance is low (milliohms). They may have multiple contacts. As many as eight SPDT contact assemblies are available on relays that are in stock. Each contact assembly is electrically isolated from all the others, and the contacts are actuated in some definite sequence.

The actuating coil can be (and usually is) completely isolated from the controlled circuit. It may be actuated by an electric energy that is of an entirely different character from that of the controlled circuit; e.g., milliamperes of DC may control kilowatts of RF.

Each of the various mechanical relay structures has certain advantages and certain limitations. Some respond rapidly—in less than 1 ms—but cannot safely handle large amounts of power. Others handle large amounts of power but at a slower speed, and so forth. Nearly all forms can be obtained with open contacts, can be enclosed in dust covers, or can be hermetically sealed in glass tubes or in vacuum-degassed plastic. Some glass tubes are evacuated for handling extremely high voltages. Some have contact assemblies suited for handling radio frequency voltages and to protect against capacitive cross-coupling.

There are also "solid-state relays," which use transistors, SCRs, triacs, and similar components as current-control elements. In these devices the controlled circuit is usually isolated from the controlling circuit by a transformer (DC only), by an optical element, or perhaps by an electromechanical relay. These devices are covered in Section 5.10.

Special Relays

Some special relays that might be of interest to instrument engineers include sequence counters with transmitting contacts, opto-electronic relays in which coupling between actuator and circuit closure is a light beam, permitting elaborate interlocking of functions. These are often part of solid-state relays.

Also of interest are meter relays with microwatt sensitivity, ultrasensitive polarized DC relays (20 μW sensitivity), sensitive meter relays with two or more actuating values, resonant-reed relays for remote-control switching, coaxial RF relays, vacuum relays for extremely high voltages, multipole relays that can actuate 50 or more circuits simultaneously, polarized telegraphic and pulse-forming relays, voltage-sensitive relays for power system protection, phase-monitoring relays for protection in polyphase systems, impulse-actuated relays, instrumentation relays with negligible capacity between circuits, and crossbar switches that can select any one of 100 or more circuits. Solid-state devices with many of the same features are also available.

Relay Characteristics

The available relay designs include DC relays with contact capacities from microamperes to kiloamperes and coil energies from a few microwatts to several watts. In case of meter relays and amplifier relays, the actuating energy can be a small fraction of a microwatt. There are also AC relays handling from a few watts of power to many kilowatts. Relays can control both AC and DC potentials in the thousands of volts and frequencies from DC to RF. They can be made to respond to specific frequencies only or indiscriminately to all frequencies.

Many of the relay designs are for special applications. This discussion will be limited to the forms most often used in typical instrumentation work—principally small DC and AC relays, sensitive relays, miniature and sealed relays, and some small power relays. In the accompanying References, information may be found describing a wide variety of relay applications.

In selecting relays for particular applications, it is convenient to first consider the actuating energy that is available or needed to operate a relay. A rough classification, associating coil requirement with power-handling ability, is given in Table 5.9a. The values in this table are only approximate.

Relays can also be classified by operating function. Available energy often dictates relay choice. Examples are given in the following paragraphs.

Rating, Size, and Other Selection Criteria

Meter relays and ultrasensitive relays are actuated by very small energies (perhaps as small as a fraction of a microwatt). They are used in applications where only a very weak signal is available, such as at the output of a transducer or bridge.

General-purpose, or small control, relays are used in cases in which no great amount of power need be handled but flexibility in application and reliability in operation are both essential. Depending on the number of contacts, they usually require coil power of 200 to 800 mW, which may be either AC or DC. Typically they will control perhaps 5 A at 120 V per contact.

Small power relays are used in cases in which more power must be controlled. These usually have coils operating on 120 or 240 VAC, which can be controlled by sensitive relays. These small power relays have contact capacities up to 30 A, at voltages up to 600 V. Much larger relays are of course available (often called magnetic contactors or controllers).

Relays can also be classified by size. Subminiature relays may be as small as 0.13 in.^{3} (2.03 cc), and TO-5-size relays are the size of a TO-5 transistor case. In contrast, miniature plug-in relays measure approximately 1 in.^{3} (16 cc), and general-purpose plug-in relays are about 2 in.^{3} (31 cc) in size.

The type of *mounting* may be important (screw-mount, plug-in, or printed-circuit mounts); or the number of poles available in a single unit (as many as 48) may be the determining factor. Alternatively, extremely low (or perhaps extremely constant) contact resistance may be needed—mercury relays, or mercury-wetted contacts, have this characteristic. Reed relays and other subminiature units are suitable when many relays must be mounted on a single circuit board.

Relays may have appliance-grade, general-purpose, aerospace, or military-standard applications. There may be little difference in their reliability when they are used for their prescribed purposes, but the more expensive types will operate more satisfactorily under adverse conditions. Relays also vary in terms of mode of construction: There are clapper-type relays, telephone relays, solenoid-actuated types, reed relays, and many other forms.

TABLE 5.9a
The Range of Relay Characteristics

Type of Relay	*Coil Power Required (Approximate)*	*Contact Capacity (Typical)*
Meter relay	As low as 1 mW	Low energy only
Ultrasensitive relay	Less than 10 mW	0.5–1.0 A, noninductive
Sensitive relay	From 10–60 mW	1.0 A noninductive typical
Typical crystal-can relay	100 mW per form C contact	0.5–1.0 A, noninductive
Transistor-can (TO-5) or miniature relay	150 mW per form C contact	0.5 A, noninductive
Reed relay	200 mW per form C contact	0.5–1.0 A, noninductive
General-purpose relay	200 mW per form C contact, up to 3 VA AC	10 A, 120 VAC
Small power relay	Usually AC coils, from 1–10 VA	30 A, 240 VAC

Contact Configurations

Common terminology to describe the status of relay contacts is NO (Normally Open) and NC (Normally Closed). These refer to the relay contacts, when the relay is de-energized, as it is on the shelf. Relay contacts are also referred to as SPDT (Single-Pole-Double-Throw) or SPST (Single-Pole-Single-Throw). The term SPST (A and B in Figure 5.9b) means that the relay is provided with a single pair of contacts, which can be open or closed, similarly to a light switch. A Single-Throw relay would have either a Form A, Normally Open, contact or a Form B, Normally Closed, contact.

The term SPDT (C in Figure 5.9b) means that a pair of contacts (one NO, the other NC) is sharing a common input contact and will reverse its state when the relay is energized and will return to "shelf" state when the relay is de-energized. A Double-Throw relay is also referred to as having a Form C contact consisting of a NO and a NC contact. DPDT (Double-Pole-Double-Throw) relays have a pair of isolated contacts.

Electromechanical relays are produced with a wide range of contact arrangements, in various combinations. A number of these have become standard forms, and the ones that are used most frequently are shown in Figure 5.9b with their

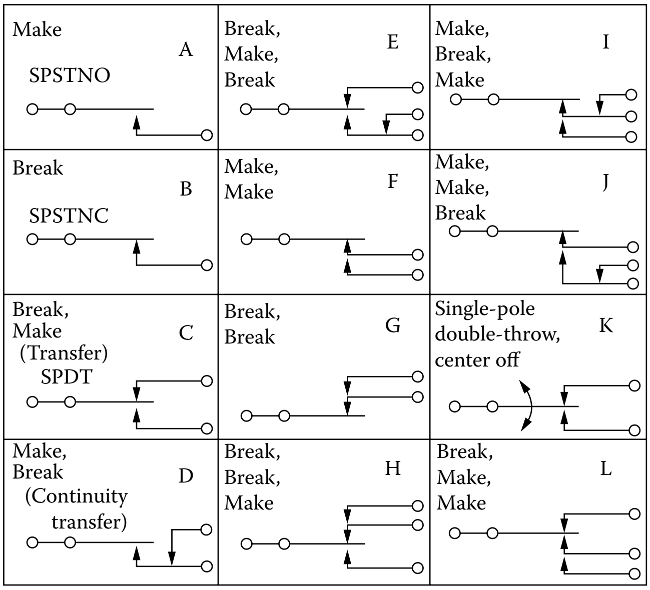

FIG. 5.9b
Standard relay contact configurations.

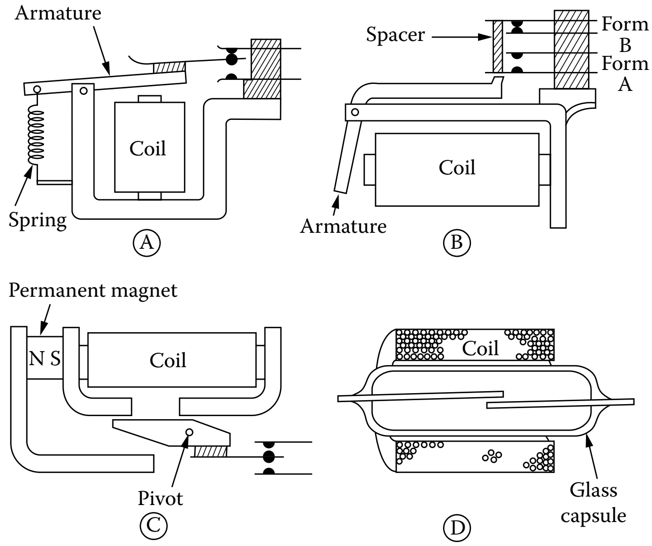

FIG. 5.9c
Typical relay structures.

identifying code letters. The same relay contact assembly can be described as Single-Pole Double-Throw or SPDT; as make, break (continuity transfer); or has having form C contacts—all these terms mean the same thing. Four form C contacts means 4PDT, and so on.

Certain mechanical structures tolerate some contact pile-ups (the term for an assembly of leaf contacts) better than others. Small clapper-type relays seldom carry more than three form C contacts (although a modified clapper structure is used for high-density relays carrying as many as 48 contacts). Telephone-type relays may handle as many as eight form Cs, or perhaps four form Cs and one or two form Es or form Fs.

These contact assemblies permit the actuation of some circuits only after others have been actuated. This ensures the proper sequence of operation; there can be no "race of contacts." Solid-state relays seldom offer any wide selection of contact configurations; usually only form A or form B contacts are provided, unless the solid-state relay serves as a pilot for an electromechanical relay.

Electrical insulation between contacts can be very high, so that there is little leakage even at high voltages. Contact spacing can be wide, to protect from arc-over at high voltages. Capacity coupling can be kept low.

Mechanical Structures

Electromagnetic relays are actuated by magnetic forces that are produced by electric currents flowing through wire coils. In most relays of this type, the magnetic force moves an iron armature, while in a few other designs, especially in meter relays, a coil is moved in a magnetic field.

The most widely used mechanical structures are shown in Figure 5.9c. The elements of a clapper-type relay are shown in part A of the figure, and the elements of a telephone-type relay are illustrated in part B. When there is no current flow in the coil, the relay armature is held away from the core by a spring. When current flows through the coil, the magnetic field that is produced pulls the armature toward the core, decreasing the air gap. As the air gap decreases, the pull usually increases, providing appreciably more contact pressure when the relay is energized than when the contact force is only that of the return spring.

Both the type depicted in part A and the type shown in part B can be used with either direct or alternating current. When AC is used, a shading coil is often added to smooth out the magnetic pull and to eliminate chattering. When AC current is used, the smaller air gap when the relay is actuated increases the impedance of the coil circuit and reduces the current flowing in that condition. Telephone-type relays are often fitted with shading coils (called "slugs") when used with DC current. This controls the speed of response of the relay.

Two other configurations in wide use are shown in Figure 5.9c, in parts C and D. The "balanced-force" mechanism is illustrated in part C. This structure has two mechanically stable positions. One of them is controlled by the permanent magnet, and the other is controlled by the magnetic force from the coil, which must be strong enough to overcome the pull of the permanent magnet. These relays can be made quite small in size, yet can be positive in action and affected only slightly by vibration.

Reed Relays The reed relay is shown in the partial sectional drawing of Figure 5.9c, in part D. Two reeds of magnetic metal are mounted in a glass capsule, which is itself installed within a coil. Current flowing through the coil produces a magnetic field, magnetizing the reeds and causing them to attract each other, to bend toward each other, and to make contact. The contacting surfaces are usually plated with precious metal contact alloy. The required spring action is provided by the reeds themselves.

Reed relays are among the fastest electromechanical relays. Some operate in less than 500 μsec. They are available in several contact configurations: They can be polarized, or they can be made into latching relays by the addition of small, permanent magnetic elements. Reed relays are available either with dry or with mercury-wetted contacts.

More than one reed assembly can be used in a single capsule, or several capsules can be operated by a single coil assembly. Reed relays are widely used in transistorized driver systems and in printed-circuit work, because of their small size, high reliability, and long life—a life of 100 million operations is not unusual.

Specialized Relay Structures The elementary magnetic structures described earlier can be combined to produce special-purpose relays.

If small permanent magnets are added to the relay, a relay armature may be forced in one direction for receiving a signal of one polarity and in the opposite direction when a signal of the opposite polarity is received. The elements of such a polarized relay are shown in Figure 5.9d, part A.

Mechanical or magnetic latching devices can be applied to produce a relay. This relay can permit either one of two circuits to be actuated, but not both at the same time. A simple form of this is shown in Figure 5.9d, part B. When one of the actuators is energized, its arm slides past the other arm, where it locks and is restrained from returning to its normal position even when de-energized. Energizing the other actuator reverses the procedure and latches the unit to the opposite side.

For certain applications, it is useful to be able to actuate one of two different circuits, depending on which of two signals is the larger—with little regard to the absolute magnitude of either signal. Two coils, with a single tilting armature, provide this ability (Figure 5.9d, part C). Usually, a weak spring is added to ensure that when no signal at all is present the relay will go to its neutral position.

Multiposition rotary switches can be driven by magnetic ratcheting devices, permitting the selection of any desired contact positions. Such stepping switches (or stepping relays, or "steppers") are available in a wide range of positions and number of circuits. They can also be secured with electrical zero-reset or for continuous rotary operation. Stepping switches are used in many communications systems, in data-handling and materials-handling equipment, and in a large number of miscellaneous applications.

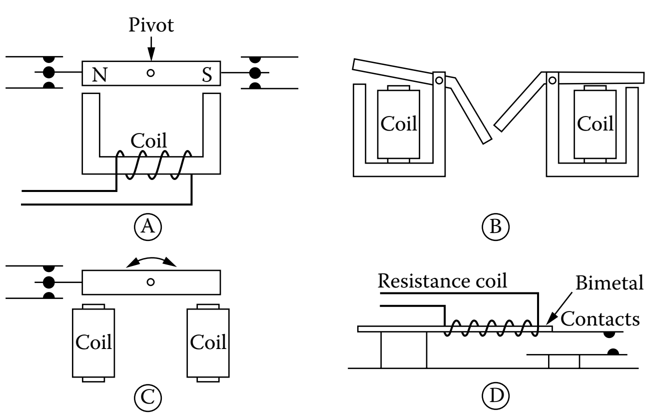

FIG. 5.9d
Some specific relay structures.

The lowest-current relays are the moving-coil meter-type relays. These utilize a d'Arsonval meter movement carrying delicate contacts. Sometimes the meter pointer is retained, and sometimes contact force is supplemented by magnetic contacts or by auxiliary coils. Such relays are susceptible to vibration and shock and to overloading. They are, however, capable of close adjustment for overvoltage or undervoltage applications and the like.

Time Delay Relays Thermal time delay relays can delay an action for a brief period after another action, in cases in which accuracy of timing is not critical. One form consists of a thermal bimetal strip wound with a resistance coil. The coil heats on the application of current, causing the bimetal strip to bend, which closes the electrical contacts (Figure 5.9d, part D).

In another popular form, the electric current flows through a stretched resistance wire, which expands and causes movement. These devices are somewhat affected by ambient temperature, and they cannot be recycled (returned to their initial cold position) instantly.

Another popular, low-cost time delay relay uses a small dashpot to delay the armature movement. Still another form (often called "slugged" relays) uses a heavy shading coil around a portion of the magnetic structure. This can produce a delay of a fraction of a second on opening or closing or on both actions. It is especially useful to protect against a "race-of-contacts." These are typically low-cost, low-accuracy time delay devices. Thermal types can provide higher accuracy and repeatability, at a higher cost. Time delay relays are described in detail in Section 5.12.

Contact Materials

A variety of contact materials are available, with characteristics suitable for the various applications. For very low-current, low-voltage applications (dry circuit), it is essential to select contact materials that do not oxidize, develop insulating coatings, or erode mechanically. Some precious metals (such as gold and platinum) and some proprietary alloys satisfy these requirements. Such contacts are used in choppers and in meter relays, in which contact-sticking can be a serious problem.

Silver and silver-cadmium contacts withstand fairly high currents without overheating, but they tend to form coatings (oxide and sulfide coatings) that, while conductive, do have appreciable resistance. Tungsten-alloy contacts usually resist pitting and erosion when used at high voltages.

Mercury-wetted contacts can be expected to have higher current ratings and lower contact resistance than do dry metal contacts of the same size. Similarly to mercury-pool contacts, they are usually less noisy and display far less bounce. Dry metal contacts may fail by welding together; mercury contacts seldom do this. Relays with mercury contacts must usually be mounted in a nearly vertical position, and they are often vibration-sensitive.

Contact Shape and Mounting

The shapes of contacts depend on their use. Heavy-current contacts are usually dome-shaped. Low-resistance, small-current contacts are often crossed cylinders and are so placed that they wipe against each other. In wire-spring relays the round wires themselves, plated locally with contact material, form the contacts. They thus are long-lived and inexpensive. In reed relays, the flat strips, which are the reeds, also form the contacts. They may be shaped at the ends and usually are plated for good contact.

Contact mounting is an important part of relay design. In multicontact relays it is essential that all contacts be able to bear properly on their mating contacts, without interference. In low-voltage applications it is usually desirable that a wiping contact be provided. The higher voltages can break through thin surface films. In nearly all relays it is desirable that contact bounce and chatter be minimized. Some forms of reed relays, in particular, are very fast yet do not bounce.

SELECTION AND APPLICATION

Among the many factors affecting the selection of relays are cost, physical size, speed, and required energy. In addition, more restrictive parameters, such as mounting limitations and open or sealed contacts, are sometimes required for safety and for protection against unfavorable ambient conditions. The catalogs of relay manufacturers usually list dozens of types, forms, and sensitivities. Although relays have been in use for more than a century, new forms are still appearing. Tables 5.9e and 5.9f list the features of some representative designs of open-contact and sealed-contact relays, respectively.

TABLE 5.9e
Typical Open-Contact Relays

Relay Type	*Coil Description*	*Contact Description*	*Mounting*
Sensitive DC relay	1000–10,000 Ω, 20 mW per form C	Up to 4 form C, 1/2 A	Screw
Plate-circuit relay	2000–20,000 Ω, 50 mW per form C	Up to 2 form C, 2 A	Screw
Small utility relay	AC or DC, 6–120 V, about 250 mW	Up to 2 form C, 2 A, 120 V	Screw
General-purpose relay	AC or DC, about 200 mW per form C	Up to 3 form C, 10 A, 120 V	Screw or plug-in
Small power relay	Usually 120 VAC 2–10 VA	Up to 3 form C, 30 A, 600 V	Screw

Selection

In order for relays to be applied satisfactorily, the relay functions must be clearly understood and relay characteristics must be established. The relay must be selected to fit the need, and the circuitry must be designed to properly couple the relay with the rest of the system. Thus, it is usual to begin the selection process by determining how much energy must be controlled and how much energy is available in the signal that operates the relay.

One must also consider the number of contacts needed. It may be necessary to use two cascaded relays, if signal energy is too small, or two paralleled relays to provide enough contacts. Ambient conditions must also be considered. One must answer such questions as: Are sealed relays needed? Is there a space problem? Is there a vibration, shock, or temperature problem?

Relay Circuitry If a suitable relay has been selected and is available for the projected use, the circuit problem must be considered. In general, the same criteria may be used in designing relay circuits as in designing other circuits, yet because of some basic relay characteristics, relay circuitry involves some special problems of its own. Among the most important of these

TABLE 5.9f
Typical Hermetically Sealed Relays

Relay Type	*Contact Description*	*Mechanical Size (inches)*	*Speed of Action (milliseconds)*
Midget plug-in	1 form C, 0.5–1.0 A	$\frac{3}{4} \times 2$	2
Mercury-wetted plug-in	1 form C, 2 A	$1\frac{1}{2} \times 3\frac{1}{2}$	5
Mercury-wetted plug-in	4 form C, 2 A	$1\frac{3}{4} \times 3\frac{1}{2}$	5
Balanced-armature DC, sensitive	2 form C, 2 A	$1 \times 1 \times 2$	3 (shock-resistant)
Crystal-can relay	2 form C, 1 A, noninductive	$0.8 \times 0.8 \times 0.4$	1.5 (shock-resistant)
Reed relay, dry contact	1 form C, 12 VA	$0.5 \times 0.5 \times 3$	1
Transistor-can relay	2 form C, 1 A, noninductive	$0.3 \times 0.3 \times 0.3$	1.5
Mercury-pool power relay	1 form A or B	$2 \times 2 \times 6$	Slow, vertical mount, affected by vibration

are the problems of transients across relay coils and the problem of protecting relay contacts from sparking, arcing, and welding.

In low-current, low-voltage relay circuit applications, as in most communication or logic circuits, serious problems with contacts usually do not arise, and often the most difficult problem is simply to keep the contact surfaces clean under low-current (dry-circuit) conditions. On the other hand, when larger currents must be handled (especially if the load is inductive or if it experiences an appreciable inrush for any reason), steps should be taken to protect the contacts from the effects of arcing, sparking, or welding. Under certain conditions, arcs tend to develop between contact and case or between contact and mounting. This can be prevented by proper circuit design.

One can minimize welding of contacts from high inrush currents by using sufficiently large contact areas that are made of suitable materials. Occasionally, more drastic measures—such as parallel contacts—must be considered. Lamp loads and the starting of single-phase motors—both drawing high inrush currents—are examples of troublesome conditions.

Sparking at contacts or arcing resulting from interruption of an inductive load can be minimized by use of spark suppressors (surge protectors, contact protectors, and so forth). These often are simple resistor-capacitor (RC) circuits but may be special devices—discharge tubes, diodes, or other solid-state instruments. Mercury-pool relay contacts are often used for heavy currents because the circulation of mercury provides a clean contact surface for each operation. Large power relays may use double-break contacts, blowout devices, or other means that are not within the scope of this discussion.

Transient Suppressors Most relay coils possess enough inductance to produce large transients when their currents are interrupted. A 28 V DC coil can produce a 1000 V transient, which can endanger insulation. Such transients can be reduced by use of semiconductor devices, neon lamps, or (on DC relays) a short-circuited winding as an absorption device. The problem can be a serious one and should not be ignored.

In many relay applications, it is advantageous to momentarily apply an overvoltage to ensure fast and positive action and then to reduce the coil current to a lower value to avoid overheating. There are many methods for doing this. Two of these methods are shown in Figure 5.9g. Shown in part A is a circuit useful only for DC relays. A 24 V relay is fed from a 50 V source; the capacitor (C) is initially charged to 50 V, so that when the controlling contacts are closed, the inrush current is nearly double the normal coil current. After the capacitor has discharged to its normal value, the resistor (R) limits the coil current. If R is equal to the coil resistance, only the normal coil current flows. In this diagram, a resistor-capacitor transient suppression circuit is connected in parallel with the coil. Other types of suppressors might be used with equally good results.

Circuit B in Figure 5.9g can be used with either AC or DC coil voltage. It involves a positive-coefficient resistor (often a small tungsten lamp, or a barretter) in series with the relay coil. When the barretter is cold, its resistance is rather low, but after current has passed through it for a few seconds, its temperature (and, hence, its resistance) increases, and the coil current is reduced to its normal value. This diagram shows two Zener diodes connected across the coil to serve as transient suppressors.

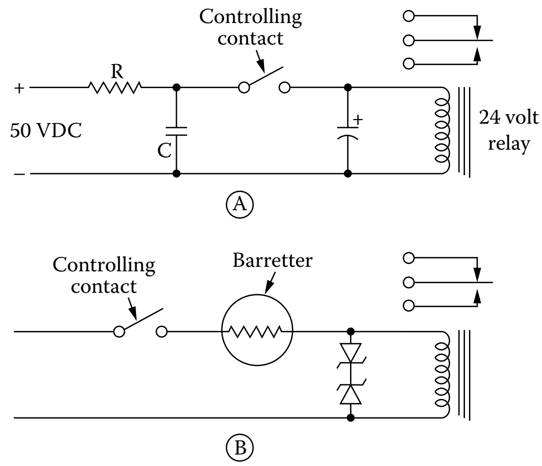

FIG. 5.9g
Typical coil circuits with transient suppressors.

Sometimes an unused relay contact is connected just to insert more resistance after a relay has been energized. It should be remembered that the inductance of an AC relay coil usually increases when the relay is closed, and this will reduce the coil current to some extent.

Relay users should not hesitate to consult the relay manufacturer for assistance in selecting and applying any of these devices. No catalog can possibly contain all the available data, and most manufacturers are happy to supply details on relay use.

RELATIVE COSTS

Small general-purpose relays can usually be purchased for about $10 each, with dust covers and simple contact configurations. More complicated contact assemblies, with hermetic seals, will cost more. If plug-in relays are used—and many general-purpose industrial relays are plug in—the socket will add several dollars to the cost and transient protection will cost a little more. The cost of high-sensitivity relays can reach $100. Installation charges are difficult to estimate, because they vary with locality, type of mounting, and type of base used.

Relays vs. Solid-State Devices

Relays compete primarily with silicon-controlled rectifiers, silicon switches, and transistors, which are discussed in more detail in Section 5.10.

Electromechanical Advantages

Electromechanical relays outperform such solid-state devices in some respects. They offer both extremely low resistances

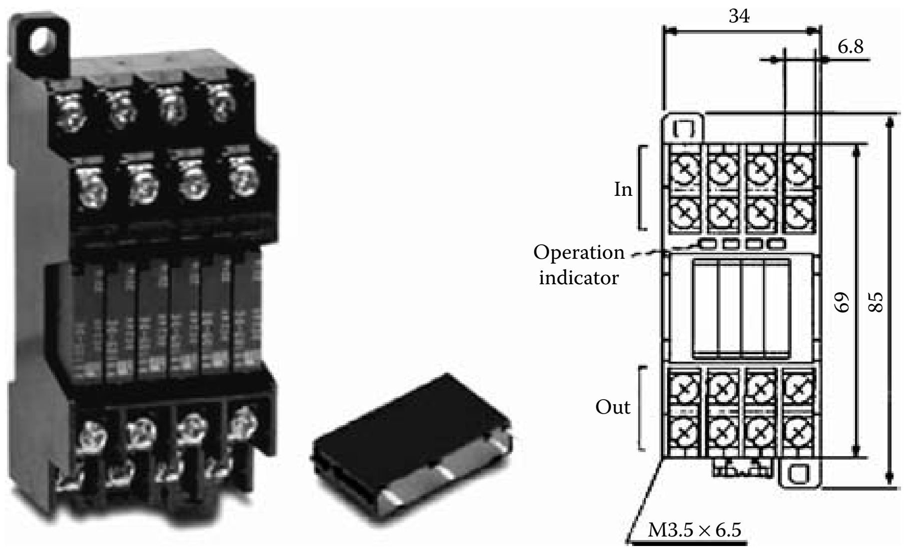

FIG. 5.9h
Card relay package and schematic. (Courtesy of KOYO Automation Direct.)

(and thus low voltage drop—about 1 μV with gold plated contacts) when closed and extremely high resistance when open.

They also provide essentially complete isolation of the controlled circuit from the controlling circuit without auxiliary links, and they can provide essentially simultaneous actuation of several circuits or actuation of several circuits at short intervals, without added cost. Some relays can handle extremely high voltages at a range of frequencies, and some can handle high currents in more compact form than can most solid-state devices. Relays provide positive circuit closures and can tolerate much abuse with only some shortening of life. Modern relays can also withstand the extremes of ambient conditions.

Some relays (in particular, high-density relays) are as small or nearly as small as the competing solid-state devices when installed. In some cases, they are cheaper to procure and to install than the competing solid state devices, and some—such as latching relays or steppers—can provide other advantages, such as a functional memory, which is not destroyed by power interruptions.

One form of high density design is the "card relay." This is a DIN rail-mounted package of four, six, or more individual relays. The relays are individually replaceable and can handle up to 5 A. An example of such a design is shown in Figure 5.9h.

Solid-State Advantages

For extremely high-speed operation, solid-state devices are superior to relays, because only a few relay forms will operate in less than a millisecond. Solid-state devices are more resistant to vibration than are relays but can be less resistant to some other environmental conditions. For the ultimate in compactness if cost is not a factor, and for logic rather than power-handling applications, integrated solid-state devices will usually be preferred.

Many relays operate on ordinary line power, in contrast with solid-state devices, which often require some other form—although this is frequently hidden in a packaged assembly. If only a few relays of different kinds and capacities are needed, electromechanical units may be more convenient for this reason alone.

CONCLUSIONS

Relay reliability depends upon their quality but even more on their correct selection. Relays carrying only small currents may be expected to operate millions of times before failure. Relays that control currents in the order of amperes necessarily wear faster. With proper contact protection, however, relay lives of 100,000–20,000,000 operations are common.

Reliability does depend upon selection of the proper relay; contact protection and transient suppression; the use of dust covers or hermetic seals when needed; proper circuit design; and observance of the usual rules of good practice as regards voltages, ambient conditions, and the like.

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