Learn the basic principals

Design & build your own relay

Basic Electronics

The relay is a simple electromechanical device used for switching. While commercial relays use complicated tooling and are made in tens of thousands, you can make your own using a few simple tools. Such a homemade relay can be used to switch low voltage lights or other devices.

by JEFF SKEEN

Of all electronic components, relays are perhaps the oldest. Relays were around long before valves were invented as they were originally used in telegraph networks. In fact, the term relay derives directly from its telegraph origins, in that it was used for "relaying" signals.

Another way of looking at a relay is as a power amplifier, because it is just as much an amplifier as is a valve or a transistor. Granted, it is a mechanical amplifier – and a digital one – but an amplifier none the less, because the amount of power needed to operate it need be only a tiny fraction of the power it can control.

And relays were the first "logic" elements, as used in telephone networks long before the concepts or logic and digital circuitry were evolved. And in spite of the rising use of semiconductor devices, relays continue to be used in untold millions around the world. It is true to say that the relay will be around for a long time yet.

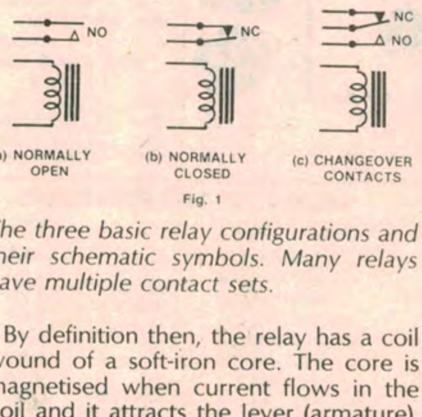
Although modern relays are usually much smaller than their earlier counterparts and are enclosed in fancy plastic dust covers, there is little difference in their principles of operation.

This does not mean that relay design has stood still. Far from it. But the major development has been in greatly reducing the power required and the size of relays. Relays can now be supplied in the same size package as 14-pin dual in-line integrated circuits. This process of miniaturisation has not been achieved easily as reductions in relay size may mean a compromise in performance.

For example, higher flux densities in the magnetic path of the smaller relay can mean less efficient operation and the voltage and current ratings of the contacts will be reduced due to the smaller dimensions. To maintain the ratings of the relay, improved materials must be used in the smaller design.

Principle of operation

The principle of operation of a relay is, at first sight, deceptively simple. But, when a close analysis of relay performance is performed, they are not simple devices at all. However, for the user with just a passing interest in these devices, they can be regarded as follows. The relay is really just an electromagnet which operates a lever and one or more sets of contacts.



(a) NORMALLY OPEN (b) NORMALLY CLOSED (c) CHANGEOVER CONTACTS

Fig. 1

The three basic relay configurations and their schematic symbols. Many relays have multiple contact sets.

By definition then, the relay has a coil wound of a soft-iron core. The core is magnetised when current flows in the coil and it attracts the lever (armature), driving the moving contacts. This closes or opens one or more external circuits. When current ceases to flow in the relay coil, the core ceases to attract the lever, which is usually spring-loaded, and the electrical circuit (or circuits) is broken.

A relay may have one or more sets of contacts. In the simplest relay, such as the horn relay in a car, the contacts are "normally open" and close only when the relay is energised. Alternatively, a relay may have a set of contacts which are "normally closed" and these open when the relay is energised.

Normally open and normally closed contacts can be paired to produce "changeover" contacts which perform the same function as a single-pole, double-throw switch. In fact, most general purpose relays have two sets of changeover contacts but the variations are endless. Fig. 1 shows the usual way of representing a relay on a circuit, together with a number of contact variations.

One new development in relays in the last 30 years has been the reed relay. This normally consists of a single set of normally open contacts enclosed within a glass tube (with an inert gas inside). The glass tube is surrounded by a coil of wire which is usually wound on a plastic bobbin. The contacts themselves are made of soft-iron, while the contact surfaces are plated with a precious metal.

When current is passed through the coil, the two contacts are magnetised and they are attracted to each other, thus closing the circuit.

Reed relays generally have relatively low voltage and current ratings but they are usually highly reliable because there is no contact deterioration (when used within ratings).

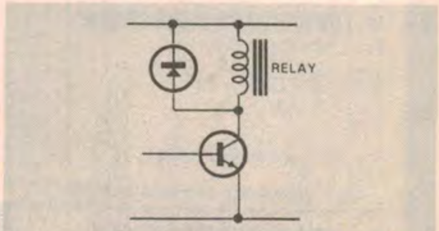


Fig. 2

A diode across the relay protects the driving transistor from back EMF.

One aspect of relays which we should mention is that of "back-EMF". Since the relay uses a coil which often has a considerable inductance it is liable to generate a "back EMF" when current through it is interrupted. As with any inductor, the value of the back-EMF or voltage generated is given by the formula:

$E = L.di/dt$

where L is measured in Henries, di/dt in amperes/second and E is in volts.

The voltage generated by a relay when it is de-energised represents a hazard to any device which is actually driving the relay, such as a transistor. In Fig. 2 for example, a relay is driven by a transistor. When the transistor turns off, the relay back-EMF will attempt to maintain the relay current. This means that the collector voltage will suddenly rise to a very high value which could punch through the transistor.

This is prevented from happening by the diode across the relay coil. The diode is normally reverse-biased by the relay energising voltage but conducts to "clamp" any peak voltages to 0.6V above the positive supply rail. Hence, the transistor is protected from breakdown.

Making your own

Our "build-it-yourself" relay is similar in construction to many conventional relays. The main difference is that we have combined the armature and contact spring into one unit, so that the moving contact is not insulated from the armature. This refinement could be easily added if desired.

Most of the parts used in constructing the relay should be available in home workshops. Possible exceptions to this are the wire, solder lugs and spring.

The spring we used in the relay came from a packet of assorted springs sold by Dick Smith Electronics. The wire used in the coil is 0.125mm enamelled winding wire which is commonly available in 25g spools. One spool is required.

Both this wire and the solder lugs are also available from Dick Smith Electronics. If suitable bolts are not available from the workshop, packets of 3/16-inch by 1½-inch mushroom head roof bolts may be purchased from most hardware stores. (Purists may dislike the use of Imperial terms here, but most stores still sell screws and nuts in these units).

Power for the relay can be any DC voltage between 12 and 30V. The coil will have a resistance in the region of 300Ω so the current drain will not be large.

The relay is constructed from light gauge galvanised iron sheet and is mounted on a particle board base. The dimensions of the particle board base

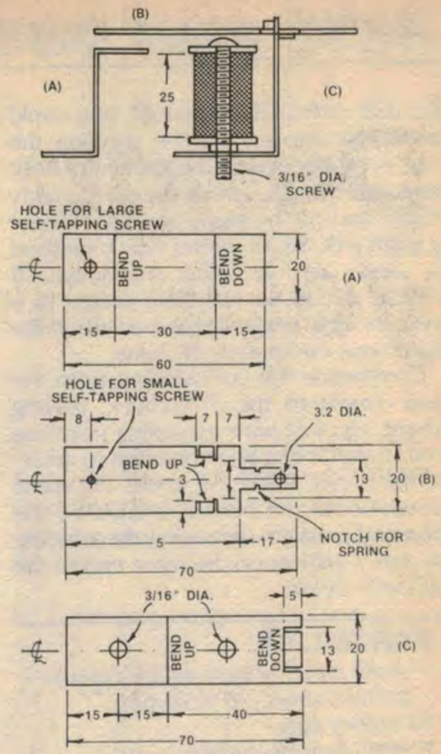


Fig. 4 DIMENSIONS IN MILLIMETRES

This drawing shows the general configuration and suggested dimension of the metalwork used in our relay.

are not critical. We used a piece of board with overall measurements of 165 × 45 × 12mm (length × width × thickness).

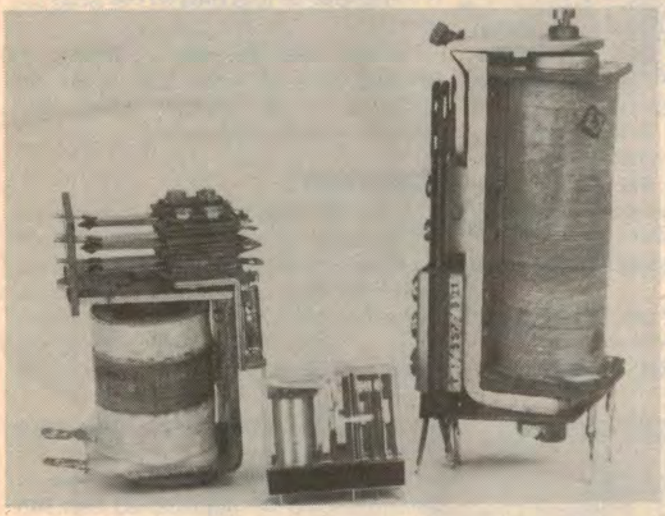
Since the sizes of the metal pieces used in the relay are dependent upon the size of the coil, it is best to start construction with the coil. The coil former is a 3/16 inch (5mm) mushroom head roof bolt 2 inches long on which two 20mm (outside diameter) fibre tap washers are placed. A nut is threaded onto the bolt and used as an end-stop for one of the washers.

The nut should be placed so that with one washer held against the head of the bolt and the other washer held against the nut, there is a gap of 25mm between the washers. A layer of electrician's tape is now wound over the threads of the bolt, between the washers, to protect the coil wire from sharp edges on the threads.

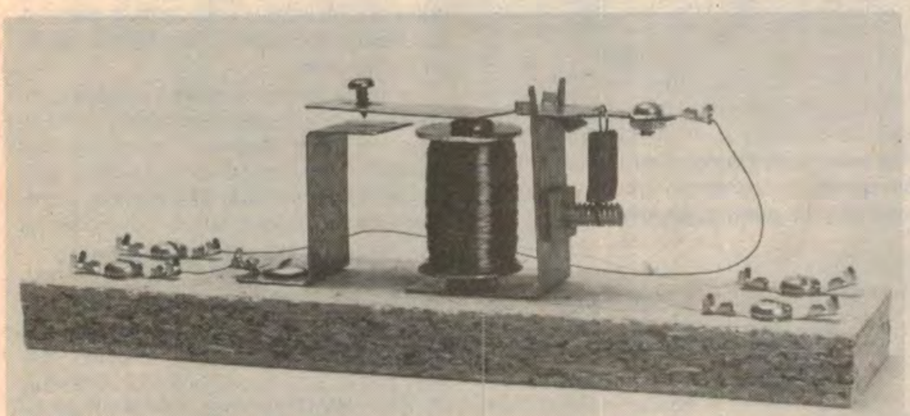
The tape also serves to hold the washers in position and prevent them sliding along the bolt when first winding the coil.

To make winding the coil easier, place the exposed, threaded end of the bolt in the chuck of a hand drill then clamp the drill securely in the vyce. One hand can now be used to turn the drill while the other hand guides the wire onto the bolt. Additionally, the gear ratio of the drill serves to multiply the speed of rotation of the bolt, making the process of winding the coil much quicker.

As an alternative, if you have an elec-



Three typical commercial relays. The two larger ones are now virtually obsolete, being replaced by much smaller ones similar to the one shown.



The finished "build-it-yourself" relay. Note that the two short vertical tabs at the top of support piece (C) function as a stop to limit the armature movement when the coil is de-energised.

tric drill with a speed control, you could press this into service for winding the coil. A caution should be applied to both methods though, in that the wire is fairly fragile and can be easily broken with just a slight jerk. So no matter which method is used, aim to wind smoothly. Of course, if you do not have access to a vyce or drill you will have to do it the hard way, completely by hand.

Commence the coil winding from the end closest to the drill chuck, leaving about 12cm of wire extending from the coil so that it can be connected to an external circuit. Wind the entire 25g spool of wire onto the bobbin formed by the bolt and washers, arranging the winding so that it finishes on the same end of the coil as it began.

PARTS LIST

1 small piece of light gauge galvanised iron sheet, 70 × 60mm
10 solder lugs
1 small tension spring
5 large self tapping screws
1 small self tapping screw
1 ⅛ inch nut and bolt
2 1½ × 3/16th inch mushroom head roof bolts and nuts
1 piece of particle board, 165 × 45 × 12mm
1 25g spool .125mm enamelled winding wire
2 fibre tap washers 20mm outside diameter

Again leave about 12cm of wire free at the end of the coil, then, to prevent the wire unravelling, either twist the wires together at the spot where they leave the coil, or wrap insulation tape around the coil. This completes the coil construction.

As we mentioned earlier, the sizes of the metal pieces of the relay depend upon the size of the coil to some extent. We will proceed on the assumption that readers have built a coil with the same dimensions as ours. Where readers have built a larger or smaller coil our measurements should be scaled up or down accordingly.

The three metal pieces used in the relay are cut from a small rectangle of galvanised iron sheet measuring 70 × 60mm. This sheet is cut into three 70 × 20mm strips with a pair of tinsnips. One strip is now trimmed to 60mm in length and forms piece A in our diagrams. The strip should be bent so that its shape and dimensions match those given in Fig. 4 for piece A.

The second strip of galvanised iron should now be cut and bent so that it matches the dimensions given for piece B. The width of the small section on the right hand side of this piece is not given since it depends upon the diameter of the (hooked) end portion of the spring used. The end section should be just wider than the spring so that the spring hook has to be forced onto it.

The third piece of metal should be cut and bent now so that it resembles piece C in Fig. 4.

Holes are now drilled in the metal pieces at the places indicated in Fig. 4 One hole cannot be drilled just yet since its exact location depends upon the length of the spring used. This is the hole in the upright section of piece C.

A notch is now cut into each side of the end section of part B at the indicated place and the spring slid along the end section until it rests in the notch.

Drill a hole in the centre of the wooden base so that the roof bolt forming the bobbin can be screwed directly into the wood. Hold the bobbin and piece C together, then screw the assembly into the base until piece C is held tightly between the bobbin and the wood. Now place piece B in position on piece C and mark the location of the centre of the spring hook on the upright section of piece C.

Disassemble the relay pieces and drill a 3/16th-inch diameter hole in piece C at the location just marked. A 3/16th-inch diameter roof bolt trimmed to 15mm in length is placed through the hole and secured tightly to piece C with a nut.

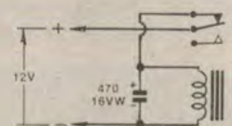


Fig. 3

Any relay with changeover contacts can be wired as shown to make a simple oscillator or pulsing device.

Screw a small self tapping screw half way through the hole in the thick end of piece B, and attach a solder lug to the other end of piece B with a ⅛th inch diameter nut and bolt placed through the hole.

Reassemble the bobbin and pieces B and C. The loose end of the spring hanging from piece B can now be slid over the threaded end of the roof bolt. The spring should apply enough tension to hold piece B firmly against the small vertical tabs on piece C. Place piece A in position under the self tapping screw in piece B then secure piece A to the particle board base with a self tapping screw. A solder lug should be placed under the screw to act as an electrical connection.

To finish off the construction, attach eight solder lugs to the particle board base with four small self tapping screws. A wire should be run from the solder lug on piece B to one of the four pairs of solder lugs described above. In the same manner, run a wire from the lug on piece A to the pair of lugs next to the ones just used.

The coil wires are now terminated on the two pairs of solder lugs at the opposite end of the particle board base, one coil wire to each pair.

Operation

To get the relay operating correctly, it will probably be necessary to "fine tune" the design by adjusting the tabs on piece C and the bent up sections on piece B. These limit the travel of piece B, the idea being to hold piece B just clear of the head of the bolt on which the bobbin is wound.

When 12V is applied to the coil, piece B should pull down to the head of the bobbin bolt. The self tapping screw in piece B should be adjusted so that the point of the screw will contact piece A just before the head of the bolt is reached by piece B.

The relay can be used as a remote controlled switch to operate a low voltage lamp or other device. The controlling voltage is connected to the solder lugs on the right hand side of the photograph while the appliance to be controlled is connected to the left hand side lugs.

As a final variation, one of the photographs of the relay shows it modified so that it has a set of changeover contacts. This enables the relay to be used as an oscillator, with the addition of a single capacitor of 470μF or thereabouts. Just connect the circuit as shown in Fig. 3 and connect to a supply of 12V or more. The relay should now open and shut at several times a second.

A modified version of the relay with changeover contacts. Connected as shown in the circuit above it will function as a slow oscillator.