PRACTICAL ELECTRONICS

Passive components: resistors and pots

Building an electronic project involves wiring together a selected group of components — or electronic building blocks — according to a set plan. One of the most important electronic building blocks is the resistor, a simple device used to establish voltage and current levels throughout a circuit.

by GREG SWAIN

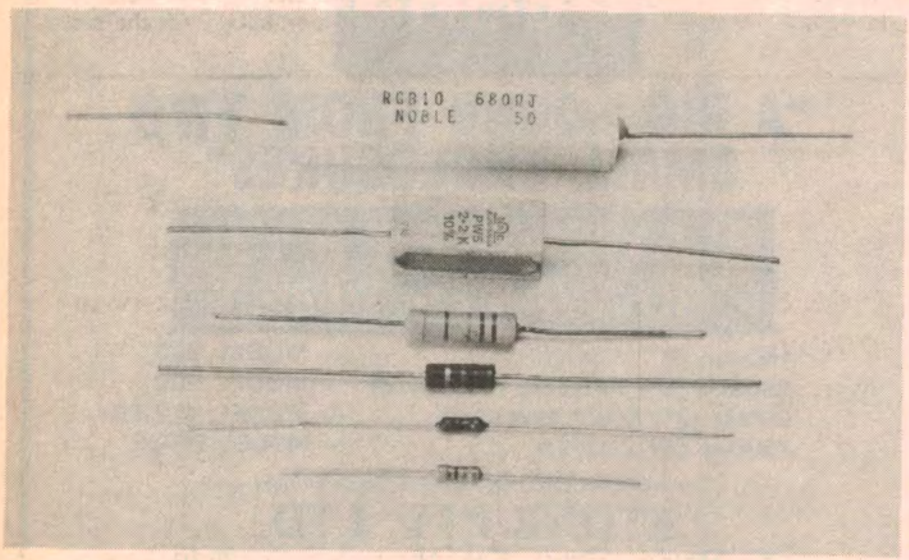
Resistors are among the most common components used in electronics. They come in a variety of shapes and sizes, but the types you will work with most often are small cylindrical devices equipped with two tinned copper leads.

As the term implies, the basic role of a resistor is to resist, or impede, the flow of current through an electrical circuit. The degree to which it does this depends upon its resistance value — the higher the value, the lower the current through the circuit concerned.

The basic unit of electrical resistance is the "ohm", often represented by the Greek letter Omega (Ω). A given resistor is thus said to have an electrical resistance (or value) of so many ohms. Practical resistor values range from a fraction of an ohm up to about 10 million ohms.

Types of resistors

At the heart of all resistors is a central resistance element, which can be made from several different substances. These substances include carbon, a thick film of metal or metal oxide, or a wire made of suitable alloy. The element is usually wrapped inside a protective insulating shell, often vitreous enamel or a moulded epoxy material.



An array of typical resistors, shown slightly smaller than actual size. They range from a 10W wire-wound type at top to ¼W carbon film types at bottom.

Carbon (or composition) resistors are made of a small rod moulded from a mix of finely divided carbon particles and a non-conducting binder. Different resistance values are obtained by varying the element's composition, length, and diameter. Carbon resistors are seldom used these days, however, as they tend to change value due to heat, moisture and ageing.

Wire-wound resistors consist of a length of resistance wire wound spirally on a cylindrical ceramic core. The actual resistance value depends on the nature and gauge of the wire used, and on the length of wire wound around the former. In practice, wire-wound construction lends itself best to heavy duty resistors in the lower range of values — say, from a fraction of an ohm to a few thousand ohms.

Carbon film resistors are made by depositing a layer of carbon-based material on the surface of a glass or ceramic rod. The resistance is adjusted to the required value by cutting a spiral path (or helix) into the carbon film, thus increasing its effective path length. The formulation, thickness and length of the carbon film also has some bearing on the final resistance value.

Metal glaze resistors are similar in concept to carbon film types, but use a metal or metal oxide material as the conductor. As before, the resistance value is adjusted by machining a spiral into the film.

The resistors most often used these days are the carbon film and metal glaze types. It usually doesn't matter which type you use when building a project, and both types may be freely intermixed in the one circuit. Wire-wound resistors are used far less frequently, and then only when specified by the circuit designer.

Resistance value

Every resistor, regardless of type, has three important parameters: resistance value, tolerance and power rating.

Practical resistor values, as used in most circuits, are usually based on the series 1.0, 1.2, 1.5, 1.8, 2.2, 2.7, 3.3, 3.9, 4.7, 5.6, 6.8, 8.2, 10, 12, 15 and so on up through the decades. This so-called range of "preferred" values is designed to meet the needs of the circuit designer with the minimum number of different values.

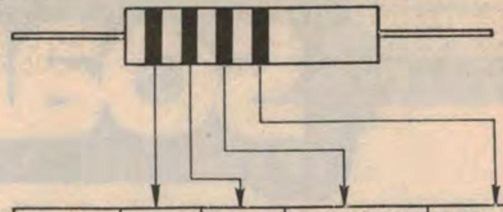
Resistance values up to 999 ohms are generally expressed directly in ohms, but between 1000 and 999,000 ohms they are expressed in kilohms, and above 1,000,000 ohms in megohms. These latter two terms are generally abbreviated by the letters "k" and "M".

What do the terms "kilohms" and "megohms" mean? It's quite simple: 1 kilohm (1k) equals 1000 ohms; and 1 megohm (1M) equals 1,000,000 ohms.

Thus 2.2k means the same things as 2200 ohms, 3.3k means 3300 ohms, and 6.8k means 6800 ohms. Similarly, 1.2M means 1,200,000 ohms, 2.7M means 2,700,000 ohms, and 8.2M means 8,200,000 ohms.

Quite often, you will find that the k and M symbols are used in place of the decimal point. A few examples will serve to illustrate this last point: 2k2 instead of 2.2k, 6k8 instead of 6.8k, 1M2 instead of 1.2M and 8M2 instead of 8.2M.

Resistor identification — the colour code



The resistor colour code, the first two bands indicate the significant figures, the third band the multiplier, and the fourth band the tolerance.

COLOUR	TENS	UNITS	MULTIPLIER	TOLERANCE
BLACK	0	0	1	20% (M)
BROWN	1	1	10	1% (F)
RED	2	2	100	2% (G)
ORANGE	3	3	1000	—
YELLOW	4	4	10000	—
GREEN	5	5	100000	—
BLUE	6	6	1000000	—
VIOLET	7	7	—	—
GREY	8	8	—	—
WHITE	9	9	—	—
GOLD	—	—	0.1	5% (J)
SILVER	—	—	0.01	10% (K)

EXAMPLES

- *68 ohms, 5%: blue, grey, black, gold*
- *1k, 5%: brown, black, red, gold*
- *560k, 5%: green, blue, yellow, gold*
- *220 ohms, 5%: red, red, brown, gold*
- *47k, 2%: yellow, violet, orange, red*
- *2.2M, 5%: red, red, green, gold*

Resistor tolerance

Because it is impossible to mass produce electronic components to absolutely exact values, resistors and other parts are graded according to tolerance. In other words, the components are marked according to how closely their actual values match their marked values. You will usually work with resistors having 5% tolerance, although some precision circuits may require 2%, or even 1%, resistors.

Confused about the concept of tolerance? No need to be! Consider, for example, a nominal 1k 5% resistor. All this means is that the actual value of the resistor could differ from its marked value of 1k by up to ±5% — that is, its value could be anywhere between 950 and 1050 ohms.

In practice, the variation from the marked value is usually well inside the specified tolerance range. Most 5% resistors, in fact, are actually within two per cent of their rated values.

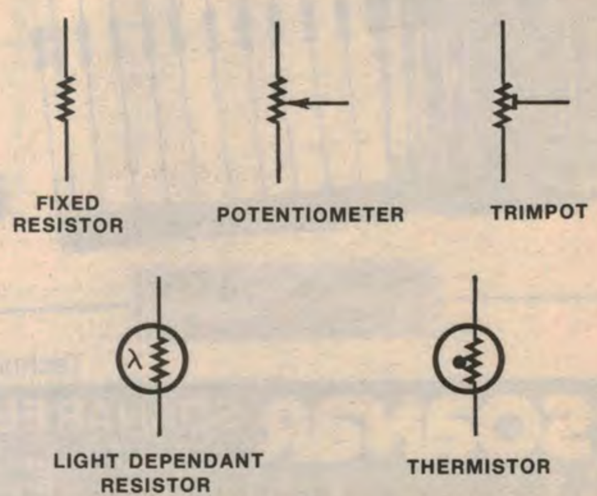
A word of warning: electronic circuits are designed to take into account component tolerances, so don't be trapped into thinking that a circuit will work better with 2% resistors when 5% types have been specified. It probably won't make any difference, and the extra money spent on the close-tolerance resistors will have been wasted.

Power rating

As well as being manufactured to specified tolerances, resistors also have a specified maximum power rating. This specifies the maximum rate — in watts — at which a resistor can safely dissipate electrical energy as heat. The power rating is closely related to the physical size and design of the resistor.

Most of the resistors used in today's electronic circuits are ¼ watt (¼W) and ½ watt (½W) types, although occasionally resistors with higher power ratings are specified. Never use a resistor whose power rating is less than that specified on the circuit — eg a ¼W resistor in place of a 1W resistor. If you do, the resistor will overheat and eventually fail.

Note, however, that it is quite okay to use a resistor whose power rating exceeds that specified. The only proviso is that the size of the resistor be physically compatible with the method



Resistor circuit symbols

of circuit construction. Using a 5W resistor in place of a ½W resistor on a printed circuit board is definitely not the way to go.

Identifying resistor value

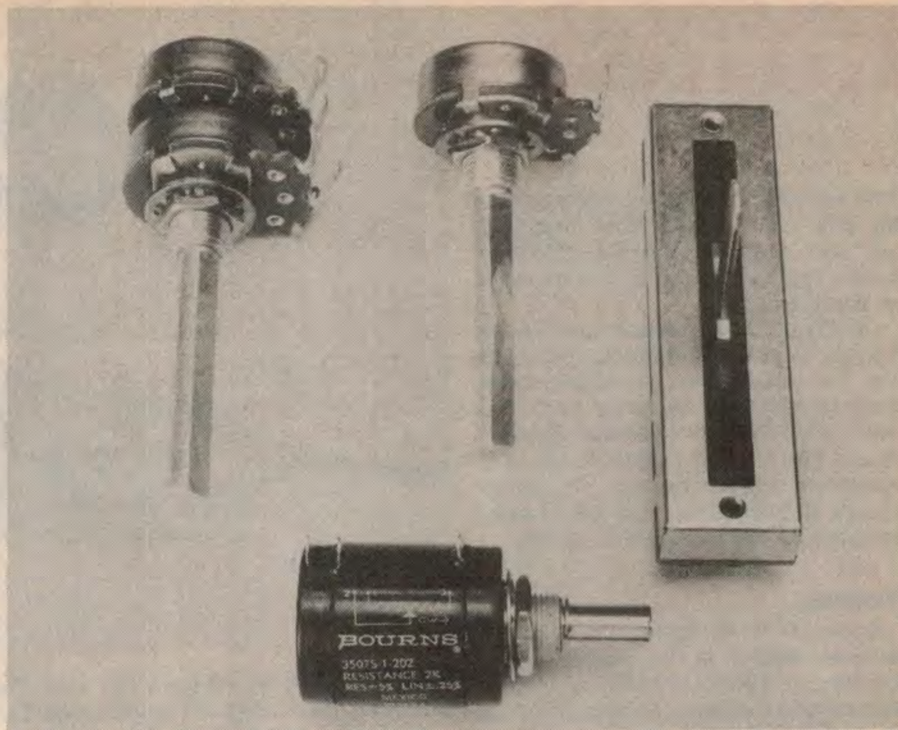
Depending upon its type and size, a resistor can be branded with its important characteristics in one of two ways: either by printing on the resistor body, or by colour coding. As a rule, only close tolerance and high power resistors have the relevant information directly printed on their bodies. This information usually includes the resistance value, the tolerance and the power rating.

Low-power resistors, including carbon-film and metal glaze resistors — the types you will use most often — are invariably identified by a group of four parallel colour bands. These bands are positioned near one end of the resistor body to tell you which band to read first.

As the diagram shows, the first two bands designate the two significant figures of the resistor value, while the third band defines the multiplier in powers of 10 (or, if you like, the number of zeros after the first two figures). The accompanying table matches up the band colours with their corresponding digit and multiplier values.

The fourth band represents the resistor's tolerance. A brown band means 1% tolerance, a red band means 2%, a gold band means 5%, and a silver band means 10% tolerance. The power rating of a colour-coded resistor is not indicated.

Just one further point before leaving resistor colour codes: close tolerance resistors often use five colour bands so that their values may be more accurately designated. Once again, interpretation is quite easy. The first three bands indicate the significant figures, the fourth band the multiplier, and the fifth the tolerance.



Clockwise from top left: dual ganged potentiometer, standard carbon potentiometer, slider potentiometer, and precision 10-turn wire-wound potentiometer.

Variable resistors

In addition to fixed value resistors, several types of variable resistors are also commonly used in electronic circuits. These variable resistors are called potentiometers, and allow the user to adjust some aspect of circuit operation at the twist of a knob.

The volume, bass and treble controls on your hifi amplifier are potentiometers, as are the brightness and contrast controls on your TV set.

A potentiometer is a three-terminal device of quite simple construction. The common carbon potentiometer — or "pot" — consists of a resistive track of carbon formed into a three-quarter circle and equipped with a moveable metal "wiper" arm that slides along the track's surface. Electrical contacts are brought out to two terminals at either end of the resistive track, while the third central terminal is connected to the moving wiper arm.

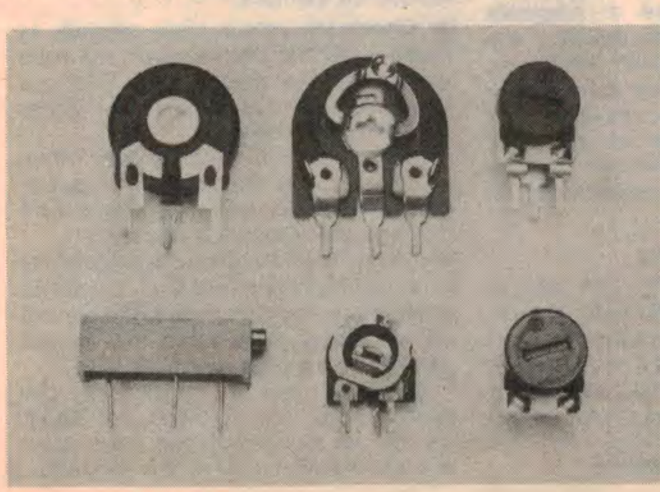
The wiper arm is connected mechanically (but not electrically) to a plastic or metal shaft. By rotating this shaft, the user can shift the wiper to make contact anywhere on the resistance element, thus altering the effective resistance between one of the outer terminals and the wiper.

Two different types of carbon potentiometers are available — the linear pot and the logarithmic pot. As you would expect, the linear pot has a linear relationship between wiper movement and resistance, while the logarithmic pot has a logarithmic relationship and is commonly used as a volume control.

The type of pot to be used will be indicated either on the circuit diagram or in the parts list.

Wire-wound pots operate in exactly the same way as carbon pots, but use a wire-wound resistance element instead of a carbon track. They are used whenever higher power rating or greater precision is required, and for very low resistance values (generally those below 1k).

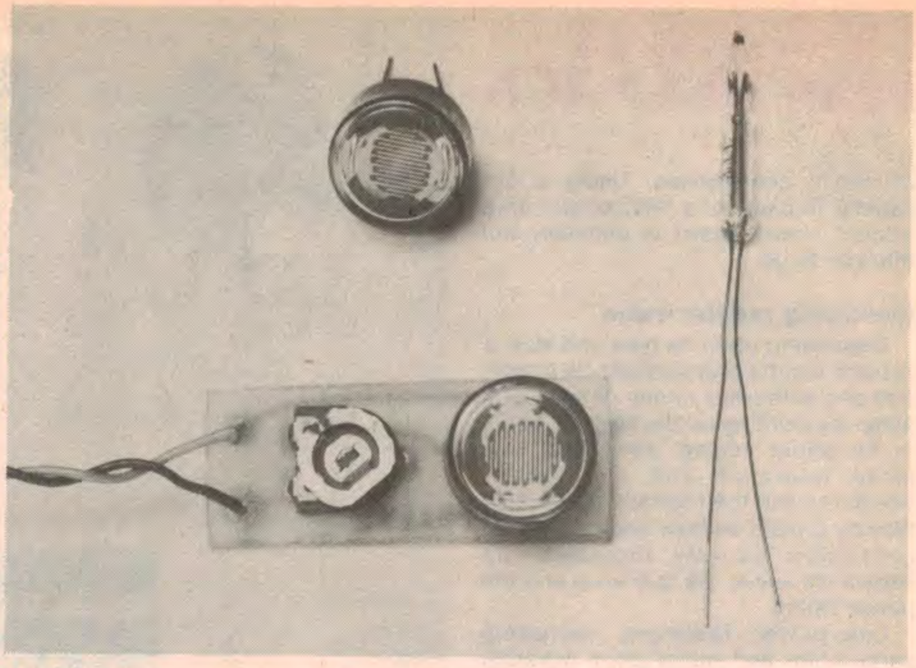
In practice, wire-wound pots are seldom used by the hobbyist. Never use a standard carbon pot when a high power wire-wound type has been specified, though — its rating (around



Vertical and horizontal mounting trimpots. Trimpots are available in a range of values up to about 2M.

½W) will probably not be adequate for the job. Unless otherwise indicated, you can assume that all potentiometers shown on a circuit are standard carbon types.

Identifying the value of a pot is easy enough. It's usually stamped or printed onto the pot's outer protective metal housing along with the letter "A" or the letter "B". The letter indicates whether the pot has a linear response (A) or a logarithmic response (C). On some brands, the response may be directly indicated by the words "lin" or "log".



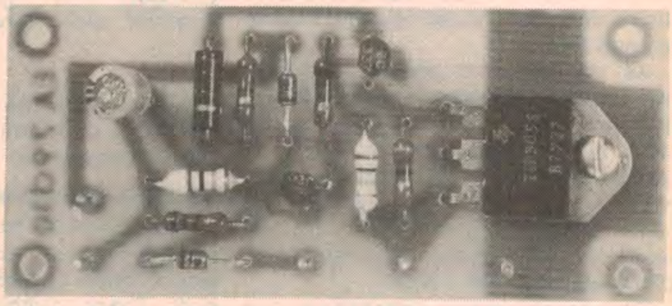
Light dependent resistor (left) and thermistor (right). Also shown is an LDR mounted on a small PC board, together with a miniature trimpot.

Trimpots

Another fairly common type of variable resistor is the preset potentiometer, or trimpot. Physically smaller than standard potentiometers, trimpots are designed for mounting on a printed circuit (PC) board and are used to make critical circuit adjustments at various stages of construction. Once set, they are not normally readjusted.

Adjustment of the wiper arm is by means of a screwdriver slot at the centre of the device. Once again, identification of resistance value is easy — it's usually printed somewhere on the trimpot body.

Many other types of potentiometers are also available, including concentric and dual ganged pots, precision multi-turn pots, multi-turn trimpots, and slider pots. Dual ganged pots are most commonly used in stereo amplifiers and consist of two potentiometers joined together and controlled by a single shaft. In this manner, two separate circuits can be controlled by twisting a single knob.



View showing how resistors are soldered into place on a printed circuit (PC) board. There are seven resistors on the board in all.

LDRs and thermistors

Light and heat have little or no effect on the nominal resistance of ordinary resistors. There are, however, two classes of resistors which are specially designed to exhibit marked changes in resistance when exposed to these influences: light dependent resistors and thermistors.

Briefly, a light dependent resistor, or LDR, is a device whose resistance varies from a low value in bright light conditions to a high value, typically around 10 megohms, in darkness. It is made of a special light sensitive material (eg cadmium sulphide) which produces more conduction electrons when exposed to light. The minimum resistance obtainable depends on the particular LDR, but ranges from approximately 75 ohms to 300 ohms.

LDRs are often used as light sensing devices in burglar alarm systems, and in light beam detection systems placed across doorways.

The second device, the thermistor, is similar to an LDR, except that it exhibits large changes of resistance with temperature. Both negative temperature coefficient and positive temperature coefficient types are available. In the case of negative temperature coefficient devices, the resistance decreases with increasing temperature; for positive temperature coefficient devices, the resistance increases with increases in temperature.

Thermistors are commonly used to provide temperature compensation in certain critical circuits.

Working with resistors

There's probably only one way to damage a resistor and that's to try really hard. The devices are so simple that there's little that can go wrong — it doesn't even matter which way round you solder a resistor into circuit. (Note: this does not apply to pots). Here are the main points to remember:

- Avoid overheating when soldering. Excessive heat can damage the resistance element, and change the resistance value;
- Always use the correct wattage resistor. A resistor whose rating is too low will overheat and eventually fail;
- Don't strain the leads. Too much strain can detach the leads from the resistance element;
- Check the colour code carefully to make sure that you're using the right value. Use the wrong value and you could damage the resistor and other nearby components;
- Don't use too much solder when soldering pot terminals. Excess solder can creep up the terminals and damage the resistance element;
- Follow the wiring diagram carefully when wiring pots into circuit. If the two outer leads are transposed, the control will work backwards (note: this will not cause any damage to the circuit).

So much then for resistors. In the next chapter we will find out about another important building block used in electronic circuitry — the capacitor.