Beginners guide to project construction

Just starting out in electronics? Here's a host of handy hints and tips to guide you through project construction and help ensure success.

THERE ARE several different ways of building electronics projects.

The simplest by far is to use a printed circuit board. Boards, etched and drilled for specific projects are readily available from most kit set and component suppliers. (See our 'Shop-around' and 'Kits for Projects' pages).

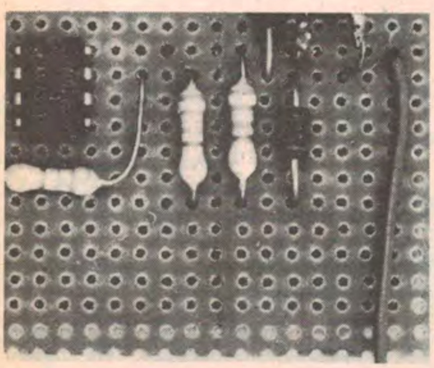
Other methods of construction include matrix board and tag strips. Here we discuss the advantages and disadvantages of each method and show how each technique is used.

Matrix board

This is a phenolic material (like very hard cardboard) perforated in a grid pattern. It is a brittle material, though quite strong – don't bend it too much or it will fracture. Cutting it to size is a simple matter. Score along a line of holes with a pen knife or similar, clamp it along the score on the edge of a sharp corner, such as the edge of a bench or table, and bend or strike the over-hanging portion sharply. It should fracture cleanly along the score.

You use it by inserting the components through appropriate holes and make the necessary interconnections by joining the components across the back (non-component side) of the board. It all sounds a bit messy but it's surprising how quickly circuits can be assembled, and with a bit of care they look quite neat.

Another advantage of matrix board is that components and wiring can be placed exactly as shown on the circuit diagram. The main disadvantage is that the back of the board becomes a bit of a rat's nest if you try to build a complex circuit. Another minor drawback is that the finished job doesn't look like a totally professional unit.



Matrix board construction is convenient, especially for experimental projects.

Tag strips

Tag strips consist of a series of metal tags mounted on an insulating strip. The strips in turn are mounted on two or more further metal tags which are used to screw the whole lot down onto a chassis.

Component leads should never be wrapped more than three quarter-way round a tag. If you twist them right round you'll have an awful job trying to remove them, if you need to, at a later date.

Tag strip construction is quick, cheap, and simple. But the method is only really suitable for small scale projects as inter-tag wiring is otherwise extensive and tedious. The method also wastes space.

Printed circuits

Printed circuit boards simplify electronic circuit building enormously – to the extent that some enthusiasts feel it is reducing the pastime to 'painting by numbers'. But if you feel that strongly about it you can always etch and drill your own boards!

The board material is made of phenolic resin or glass fibre with a thin copper sheet bonded to (generally) one face. Intercomponent wiring is formed by etching away the unwanted copper – so that only the tracks and component mounting pads remain.

Holes are drilled for the components which are then inserted through from the non-copper side and their leads soldered directly to the copper pads.

Most component and kit set suppliers stock printed circuit boards already drilled and etched for most popular projects. They also stock circuit board material for those who wish to make their own boards. Board making is not difficult but it is a rather lengthy process and is beyond the scope of this article.

Printed circuit boards have a number of significant advantages over other methods of construction. The biggest is that mistakes are less likely to occur. Most of the wiring is right there, etched onto the board, and the drilled pattern is such that in many instances components will only fit the right way round. The finished article looks professional – how most professional equipment is made.

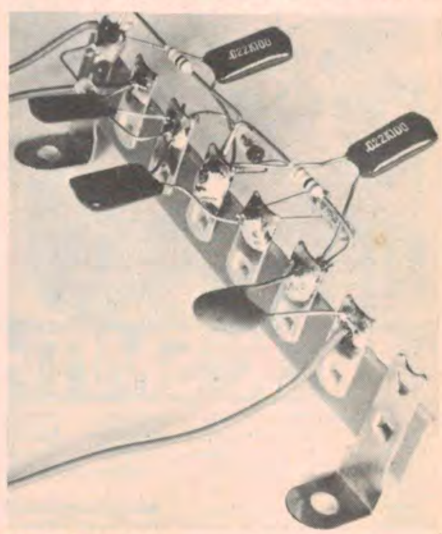
The disadvantages are that printed circuit boards are more expensive than other methods. There is also less personal involvement unless you make your own boards – then there's a great deal more!

Our own view is that all methods should be mastered but that printed circuit boards are probably best for most projects.

Soldering

Good soldering is vital – most of the problems that beginners have with their first projects are due to poor joints. The following hints will aid you to become adept at soldering.

- Purchase a good quality iron with a wattage rating between 15 and 25 watts.
- Use only resin-cored solder (60/40



Typical tag strip construction.

RESISTOR COLOUR CODE (standard carbon series)

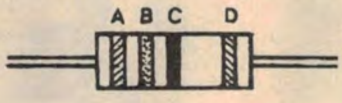
To read the colour code, hold resistor with code ring nearest to end at left hand side.

Colour	1st ring; 1st figure	2nd ring 2nd figure	3rd ring multiplier	4th ring tolerance
black	–	0	1	–
brown	1	1	10	±1%
red	2	2	10^2	±2%
orange	3	3	10^3	–
yellow	4	4	10^4	–
green	5	5	10^5	–
blue	6	6	10^6	–
violet	7	7	10^7	–
grey	8	8	10^8	–
white	9	9	10^9	–
silver	–	–	10^{-2}	±10%
gold	–	–	10^{-1}	±5%

No fourth colour indicates ±20% tolerance

Grade 1 ('high-stability') resistors are distinguished by a salmon-pink fifth ring or body colour.

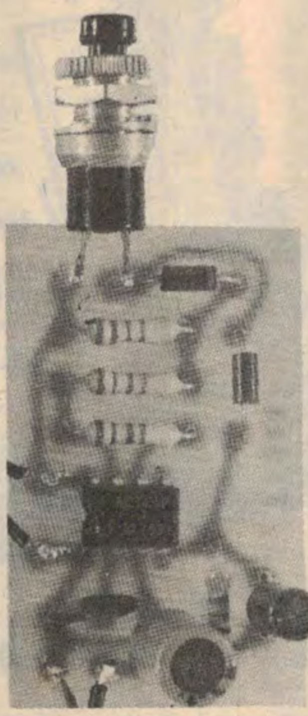
Example: Resistor coded as A – grey, B–red, C–orange, D–gold indicates a value of 82 kilohms ±5%.



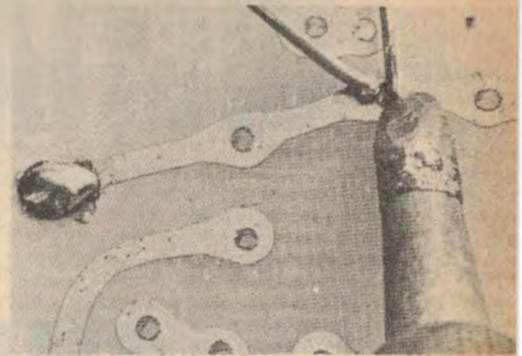
tin-lead content). Do not use acid flux.

- A new, or worn, iron will need tinning. To do this let the iron get quite hot and file the tip smooth to expose fresh clean copper. Quickly, before the copper has time to discolour, apply resin-cored solder – it should flow all over the tip forming a shiny coating.
- Keep your soldering iron clean. Wipe it frequently with a damp cloth or sponge.
- Make sure the connection to be soldered is clean. Wax, frayed insulation, and other foreign substances will result in inferior joints.
- With older components, or copper wire, it will be necessary to clean and tin the individual components before soldering them together (see above).
- Attach the wires to be soldered. Do not make more than a half turn in a lead to be soldered – twisting makes subsequent removal difficult.
- Heat the connection with the iron and apply the solder to the connection. Do not melt solder on the iron and carry it to the joint.
- Keep the iron on the point until the solder just commences to flow on the connection. Too little heat results in a high-resistance joint (known as a dry joint). Too much causes component damage and evaporates the tin component, again causing a poor joint. This step requires practice.
- Let the solder harden before moving the connection. Then check for a smooth bright joint. A joint that has been moved will have a crystalline appearance, may have a high resistance and will fracture easily.

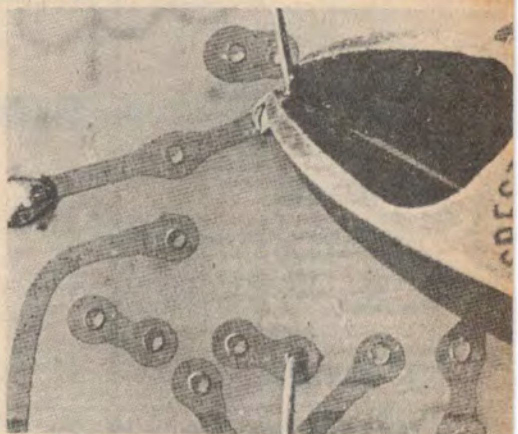
Good soldering is a matter of practice. If you follow the above hints, it will be only a matter of time till you are making professional joints.



A project constructed on a pc board. This method considerably reduces the possibility of wiring errors, though care is needed with orientation of some components.



Always heat the joint with the iron first, then apply the solder to the point where the iron touches the joint. The solder should flow quickly and evenly, "wetting" the pieces being joined.



Once the joint is made and the solder has cooled, clip off the excess component lead.

Finding your way around components

Most beginners have little trouble identifying components after a little experience, but remembering which way around they go can often prove somewhat confusing! Here's how to avoid the pitfalls and assemble projects knowing you've put the components in correctly and how to make simple substitutions.

Resistors

Resistors are fairly straightforward components. If you use the value and wattage specified for a project, there's little that can go wrong. The colour code chart reproduced here is a handy guide if you are not completely familiar with how to read the value from the coloured bands painted on the body of the component. (An article on resistor marking codes and how to read them appeared in the March 1977 issue of ETI).

Resistors are not 'polarised' – that is, it doesn't matter which way round you put them in.

They can be damaged by clumsy handling. Don't bend the leads too near the body of the component, this can ▶

fracture the end or the main body — the lead may even come right off. Don't apply excessive heat to the leads when soldering, or hold the iron to the joint for too long. It is sufficient just to have the solder flow properly to make a good joint — a 'little extra' may do more harm than good.

In many instances the *exact* value of a resistor in a circuit is often not too important and you can substitute a resistor one value up or one value down from that specified without causing any great change in a circuit's operating conditions. For example; either a 2k7 or a 3k9 resistor may be substituted where a 3k3 value is specified. Don't do this with high wattage resistors or high stability resistors (1% or 2%). *Always*, a resistor having a smaller tolerance rating may replace one of a greater tolerance rating *of the same value*. For example; a 4k7, 10% resistor may be replaced by a 4k7, 5% type.

Similarly, half-watt resistors may be substituted for quarter-watt resistors, *provided* they physically fit.

Potentiometers

These are simply adjustable resistors. Commonly, they consist of a resistance 'track' with a movable 'wiper' connection that can be varied from one end of the resistance track to the other. Thus, they have three terminals.

This is where most newcomers come unstuck. The one in the middle is always connected to the wiper (shown as an arrow on the circuit symbol). This leaves the other two connections to sort out! On a rotary pot, with the shaft pointing at you and the terminals pointing at your feet, when the shaft is rotated clockwise (normal direction for 'up' or 'increase' — whatever the control is doing) the wiper will be heading for the right hand terminal. If it's a volume control, that'll be maximum volume and therefore the maximum signal point should connect to the right hand terminal. Got it?

The common potentiometer — a variable resistor. Terminal markings are standard for a volume control.

Even if you don't get it right in your project, it's easy to correct — simply reverse the connections to the two outer terminals!

The value and 'law' of the potentiometer required for a circuit will be specified with the project. It is not a good idea to substitute. The 'law' of the potentiometer simply refers to the way in which the resistance varies as you move the wiper. The two most common forms are 'linear' and 'logarithmic'. A linear law (or 'curve') pot changes its resistance in a manner directly proportional to the amount the wiper has been moved, whereas a logarithmic (or log) law pot varies resistance logarithmically as the wiper is moved linearly.

Log pots are predominantly used as volume controls. Linear pots are used for current or voltage control in circuits. A linear pot will be marked 'A', while a log pot will be marked 'C'.

Capacitors

Capacitors come in a wide variety of shapes, sizes, types and ratings. The important thing to remeber is that there are *polarised* and *non-polarised* types. *Electrolytic* and *tantalum* capacitors are *polarised* and you must take care which way round they are connected in a circuit. All the others are *non-polarised*. Of the latter, we mainly specify polyester (often referred to as "greencaps" as they're green) and ceramic types. These are the most common. They may be inserted either way round.

A polarised capacitor always has some marking or other to indicate which lead is which. Many are made with a black stripe adjacent to the negative lead. Some have a '+' and a '—' sign near the respective leads. Always check that you have inserted or connected polarised capacitors the right way round. They won't work otherwise — and that's about the worst that will happen in a battery-operated circuit. A wrongly-connected electrolytic in a mains-operated circuit (even at low voltages) may very well *explode*! Messy . . . worse if you have your face nearby when it happens.

In general, we have a small diagram near the circuit or wiring (construction) diagram indicating how to identify polarised capacitors.

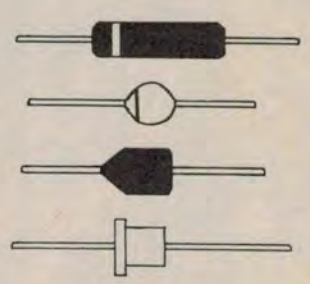
Variable (or tuning) capacitors come in an enormous variety of shapes, sizes, values, connections and applications. Where a tuning capacitor is used in any of our projects, specific details of how it is connected are always given with the construction diagrams or component overlay.

In general, capacitor values should be adhered to, substitution is not recommended unless you are very familiar with the way a circuit works and the role of the particular capacitor. Voltage rating is important, particularly with electrolytics and tantalums. You must *never* use a capacitor rated at a lower voltage than specified. You can go upwards, though. For example; if a project calls for a 10 μF, 16 V type then a 25 V rated capacitor of the same value may be substituted.

An article on capacitor marking codes and how to read them appeared in the May 1976 issue of ETI.

Diodes

Diodes are polarised components. There is *always* a right way and a wrong way


DIODE ORIENTATION

round. If you use it the wrong way round you may well destroy the device — particularly rectifier diodes in power supplies, and zener diodes. Fortunately, they always have some sort of mark identifying the cathode end. It may be a *band* around that end of the body adjacent to the *cathode* lead, or the body may be chamfered at that end. We generally indicate on the construction diagram with our projects the polarity of any diodes. Alternatively, a small diagram may accompany either the circuit or the construction diagram showing diode body shapes and markings and how these relate to the diode symbol.

Any substitutes will usually be mentioned in the parts list accompanying a project. However, as diodes are generally rated in terms of voltage (maximum reverse voltage, not conducting) and current (maximum forward current, when conducting), it is always safe to substitute a diode with one having higher ratings than specified — never the other way around. Never substitute a silicon signal diode for a germanium signal diode.

Transistors

For most purposes a transistor is either the right one or it's not. It is rarely possible to substitute another type which someone may recommend as 'just the same'. Usually, substitutes or ▶

equivalents will be mentioned in the parts list of a project.

A transistor can only be connected one way round — the right way! The construction diagram or component overlay with a project will indicate which way the pins are to be inserted in a pc board or otherwise connected. Connected incorrectly there's a good chance you'll destroy the device when first switched on.

Incredibly, not all transistors of the same type number have the same pin connection. Sometimes a manufacturer may vary the pin connections of a type at different times! Transistor pin connections and orientations are given in diagrams accompanying our projects, in general, especially where it may not be clear from the construction diagram or component overlay.

Transistors (and diodes) may be damaged by excessive heat when soldering. Although, these days, it is no longer really necessary to use a 'heatsink' (pliers or a special tool) when soldering small transistor leads — as has been often recommended in the past — a little care and speed when soldering is a good idea. Just get the solder flowing neatly over the joint, 'wetting' the joint properly, and things should be fine. Don't overdo it.

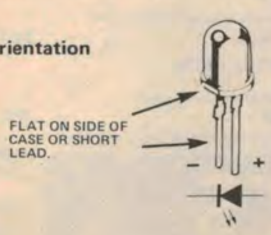
Integrated circuits

Integrated circuits must be soldered in the right way round. They always have some identification — usually in the form of a small scallop in one end of the case or a small identation adjacent to a pin at one end (this is pin 1). They should be inserted exactly as shown in our overlay drawings. Do make sure they are the right way round before soldering because once in they're very hard to get out again.

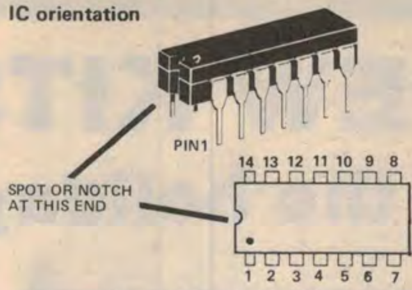
Because of this it's well worth while spending a bit more on any project which uses ICs to install IC sockets. These are little plastic sockets which have identical pin connections as the ICs and into which in turn the IC is plugged. It's not always worthwhile because some ICs are so cheap that the socket costs more than the IC, but they are worth considering for use with expensive devices.

Like transistors, most ICs are stronger than they look, but don't overdo the soldering — it's very easy to get a tiny solder 'bridge' between the pins.

LED orientation



IC orientation



CMOS ICs are a bit different. These are very tough — once soldered in — but are a bit fragile until then.

They should be handled with care as they are easily damaged by quite small static charges. CMOS ICs are supplied inserted in a conductive plastic foam or foil-wrapped styrene block. Remove them carefully. Take care to pick them up with your thumb and forefinger grasping the ends of the package, not touching the pins. Make sure you have them correctly oriented before inserting them into a pc board.

When soldering CMOS ICs use an iron having an earthed tip and barrel. If you're unsure about this, use a clip lead to connect the iron's barrel to the negative supply rail on the pc board. These measures will ensure you don't 'blow' CMOS ICs from either static or leakage currents.

Always leave CMOS ICs until last when assembling a project. Once removed from the packaging, insert them in the pc board quickly and first solder those pins connected to the power rails — generally pins 7 and 14 for most 14-pin packages, but check with the diagram beforehand. This ensures any static charges are dissipated by the other components.

LEDs

Light emitting diodes are very handy little solid-state indicators and for that reason are widely used. Common colours are red, yellow and green although orange is available and we believe blue will be available shortly. Some are clear but glow red.

Being a diode they are polarised. They are not usually damaged if incorrectly connected — but they won't work. The polarity of the leads may be indicated in several ways. The most common is to have a *flat* section on the case adjacent to the *cathode* lead. Some have one lead shorter than the other — the *cathode* lead being the *shorter.*

cased correctly, LEDs will last forever. We don't know of any that have worn out yet! They must be used at the correct current rating. If this is exceeded . . . poof! You will generally find a resistor connected in series with a LED in a circuit. *Don't* ever test a LED by connecting it across a battery. Best way to test one is to wire it into a circuit known to work.

LED connection diagrams generally accompany the circuit or component overlay with our projects.

Loudspeakers

Small speakers are a common item in simple projects. In general, the unit chosen is not critical.

They are made in varying levels of quality, size and impedance. Quality is unimportant. Frankly we'd go for the cheapest you can find! Impedance is specified in each project parts list.

Speakers are not polarised — you may connect them either way round.

If the speaker doesn't make a noise when the project seems to work otherwise it's fairly sure you've got a dud one. Check by touching the leads momentarily across a 1½ volt cell NOT a nine volt battery. If the speaker is working it produces a loud click. Don't leave the cell connected for more than a fraction of a second or you'll end up knowing that the speaker was working but isn't any longer!

Conclusion

As a last caution, make sure you connect the battery or power supply to your project correctly, otherwise you may never know whether it worked or not! Most of our battery-operated projects use No. 219, 9 V batteries. The battery clips used with these have a red and a black lead for connections. The red one is the positive lead, the black, negative. This is the colour coding for supply connections. Keep it in mind.

That just about wraps up the majority of things you should learn and keep in mind when it comes to constructing basic projects. You will learn a whole host of other interesting, and useful, things as you progress with your hobby. The best teacher is experience, as they say in the classics. ●

If you boo-boo

If a circuit won't work the most probable causes of trouble in the most probable order of occurrence are:—

(a) Components inserted the wrong way round or in the wrong places.
(b) Faulty soldering.
(c) Bridges of solder between tracks
(d) Faulty components.

If all else fails write to us for help.