BUILD YOUR OWN PROJECTS

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Part 2

IN THIS series of articles which will be presented over the next few months, we shall be describing modern methods for constructing your electronic projects. This second part offers some initial tips for beginners and discusses assembly techniques, including soldering.

Future parts will look at case and enclosure preparation, workshop tips and tricks – in fact, everything you need to know to get satisfying results when building your latest *EPE* project!

Alan is, of course, Surgeon-in-Chief at *Circuit Surgery*, and enjoys all aspects of electronics.

LAST MONTH, Build Your Own Projects introduced some of the basic hand tools and test equipment which are used when constructing electronic circuits. Not all of the items discussed are essential though there are some which you will find indispensable.

Gradually, as you gain more experience and your interest develops, you might wish to invest in more refined or better quality tools and equipment, as well as purchasing the occasional luxury item which will help simplify construction, maybe saving you some elbow grease or helping you to improve the finished quality of your work.

We now look at the task of circuit board assembly, and most importantly, the art of soldering electronic components. To start with, let's consider some of the various techniques for assembling electronic circuits, whether during prototyping or with a final, permanent construction in mind.

PROTOTYPING METHODS

First, *solderless breadboards* are extremely useful for plugging simple circuits together quite quickly: they're the simplest form of "test-bed" and can be instantly modified as necessary.

Breadboards consist of rows of spring contacts, into which component leads are carefully pushed. The contacts form wipers which generally make an effective electrical connection with the components, and insulated wires are used to interconnect rows and terminals as necessary.

They are ideal for younger students too, since no soldering is necessary, and they can be used for starting the development of simple transistor and integrated circuit (i.c.) projects successfully. Products such as the *EuroBreadBoard* are always handy for quick experiments with a handful of components.

However, prolonged use of the contacts by repeatedly inserting leads can weaken their ability to make proper connections. In such cases it can be extremely frustrating to find out why a breadboarded circuit fails to operate correctly – is the circuit concept genuinely faulty, are the components in the right holes, or are the contact connections simply not satisfactory?

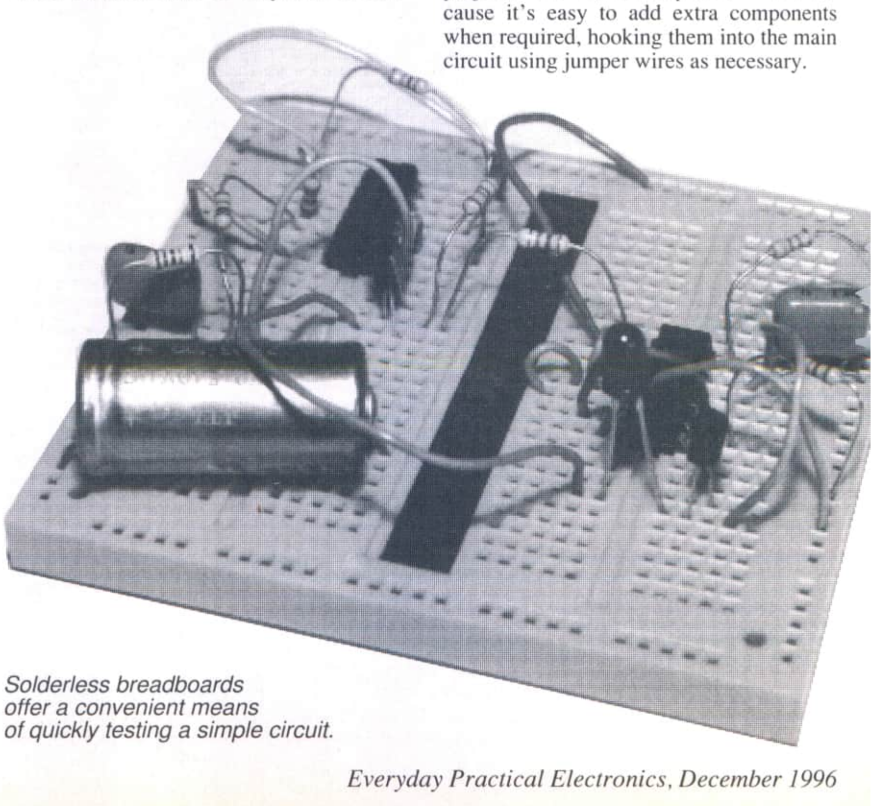
After finalising most circuit design aspects, a more permanent form of prototype can be considered. *Matrix board* (called *perfboard* in the USA) is simply a plain perforated Paxolin board, with holes drilled in a regular 0·1 inch matrix. Components are fed in from the top, and their wires soldered into a "rat's nest" underneath. It's crude and messy, but effective for quick experiments and projects.

Stripboard is useful for producing a more permanent circuit assembly. *Veroboard* is the brand name of probably the best known form of British-made stripboard, but there are some imported products which do the same job.

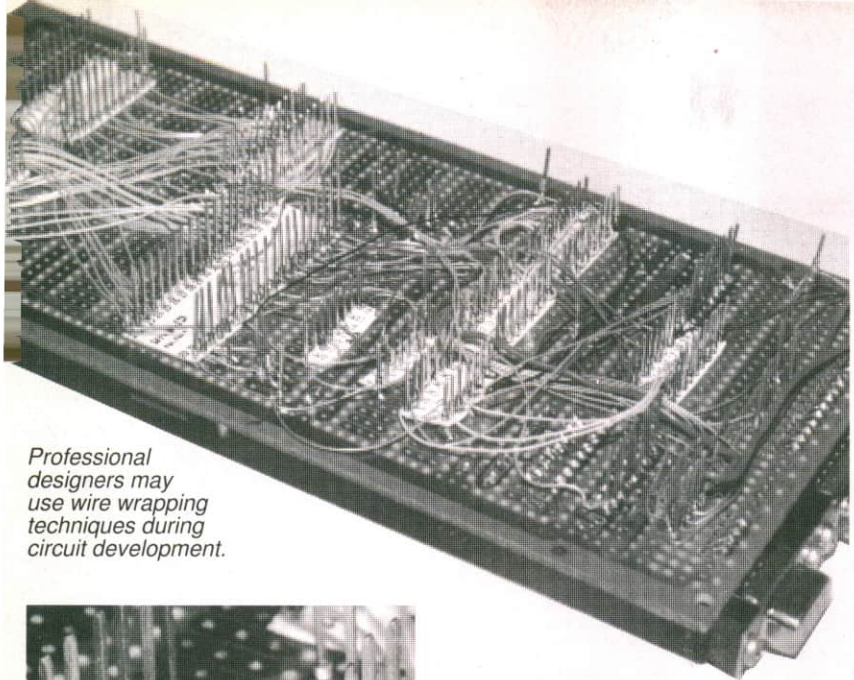
Stripboard (also known as *proto-board* in the USA) consists of a synthetic resin bonded paper (s.r.b.p.) board drilled in a regular grid, and with copper strips running underneath in one direction. Components are inserted from the top of the board with their leads and the copper strips on the underside, and soldered into position. (*An example of its use is shown in this month's* Vari-Colour Christmas Tree Lights *project – Ed.*)

By linking strips with solid wires, or cutting ("breaking") strips with a simple cutting tool to prevent short circuits, it's possible to fabricate complete circuits quite quickly and conveniently. The usual matrix of holes is 0·1 inch pitch, so ordinary dual-in-line (d.i.l.) integrated circuits will fit straight in without problems, as will most smaller discrete parts, including resistors, capacitors, transistors, etc.

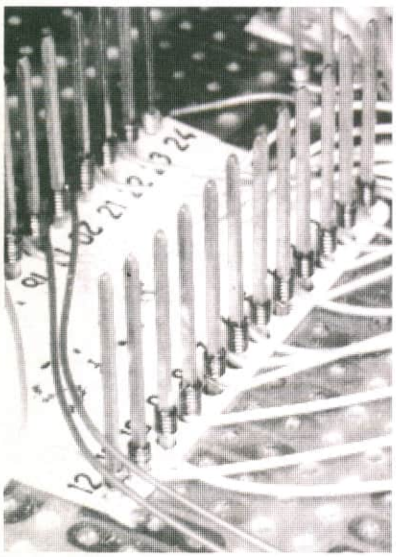
Stripboard is ideal for more modest projects and for development work, because it's easy to add extra components when required, hooking them into the main circuit using jumper wires as necessary.



Solderless breadboards offer a convenient means of quickly testing a simple circuit.



Professional designers may use wire wrapping techniques during circuit development.



Its main limitations are that it is easy to make mistakes: components can be soldered to the incorrect locations, adjacent strips can be accidentally shorted by excessive solder joints, and breaks in the strips can be imperfect or omitted altogether. Hence, troubleshooting a malfunctioning board can take ages while you double-check each and every joint, link and break!

By its very nature, ordinary stripboard is not a strong product, the perforations making a very good job of weakening the strength of the panel – thus it cannot support heavy or large components.

There are many variants of the "standard" stripboard, usually intended for use when digital integrated circuits are being interconnected during prototype development. Study a major professional supplier's catalogue and be prepared to be amazed at the variety!

WIRE WRAPPING

For very complex projects involving many digital integrated circuits, the use of stripboard and soldering the numerous link wires would be too unwieldy, time-consuming and inconvenient, and so before committing to a hard wired circuit, it's common to develop circuits using a system known as *wire wrapping*.

A high quality perforated board is used to carry the components, but devices are mounted via special sockets and terminals which have very long pins on the underside. A special wiring tool is used to twirl or wrap the stripped end of a connecting wire tightly around the pin to make a connection, then the other end is wrapped on its corresponding terminal on the circuit board.

The underside of the board soon resembles a plateful of psychedelic spaghetti, but it's a very quick and simple way of making multitudes of connections. The joints are also reliable and there is generally no need to solder them. You have to be at least 100 per cent alert, though, to ensure that you are connecting the right pins!

Wire wrapping will be familiar to University students, technicians and engineers but is less relevant in hobby circles.

You might also see prototyping pens or similar, which work in a slightly different way: an insulated length of wire is dispensed by the pen, being wrapped under tension around the pins, but then the wire has to be soldered in order to melt through the thin layer of insulation and form a joint.

THE P.C.B.

The form of interwiring which you will see used almost universally, is the *printed circuit board* (PC board or p.c.b.). These are usually made of glass-reinforced plastic (g.r.p.), and thus are immensely strong (unless weakened by many holes drilled in line, consider them unbreakable).

Normally, single-sided boards are used for project work, although more complex double-sided boards are occasionally seen. A single-sided board has a copper foil pattern on the underside only, with components placed on the upper side of the board, and this is fine for the majority of circuits.

A double-sided board will have copper track patterns on both sides of the board, and occasionally may be through-connected (plated-through-hole – p.t.h.) to the foil on the opposite side. This is necessary for more complex circuits or where a space-saving design is necessary, but it's fiddly, though not impossible, to produce this accurately at home.

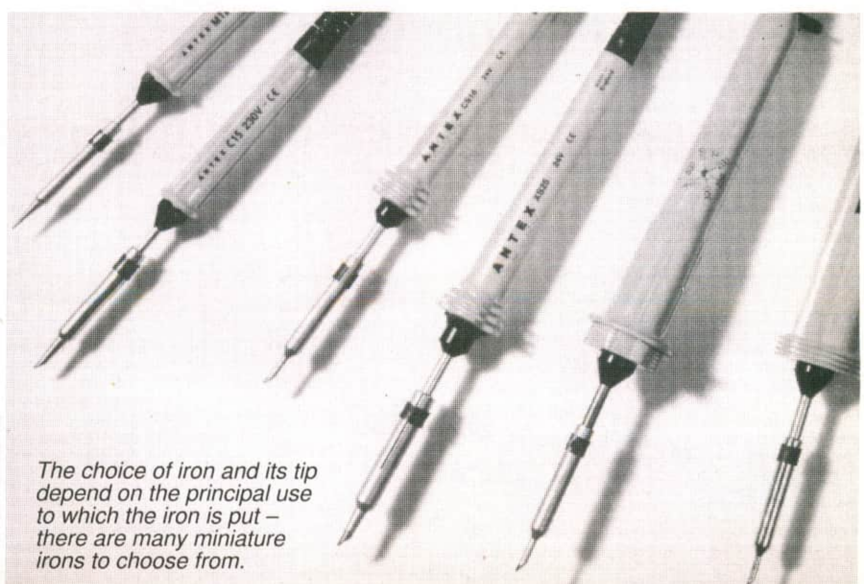
In industry, p.c.b.s having several layers of tracks sandwiched together are now common. The are generally referred to as *multi-layer boards* and require the use of extremely sophisticated manufacturing techniques. Resist the challenge of trying to make them yourself!

Techniques for fabricating one's own (single-sided) printed circuit boards will be outlined next month.

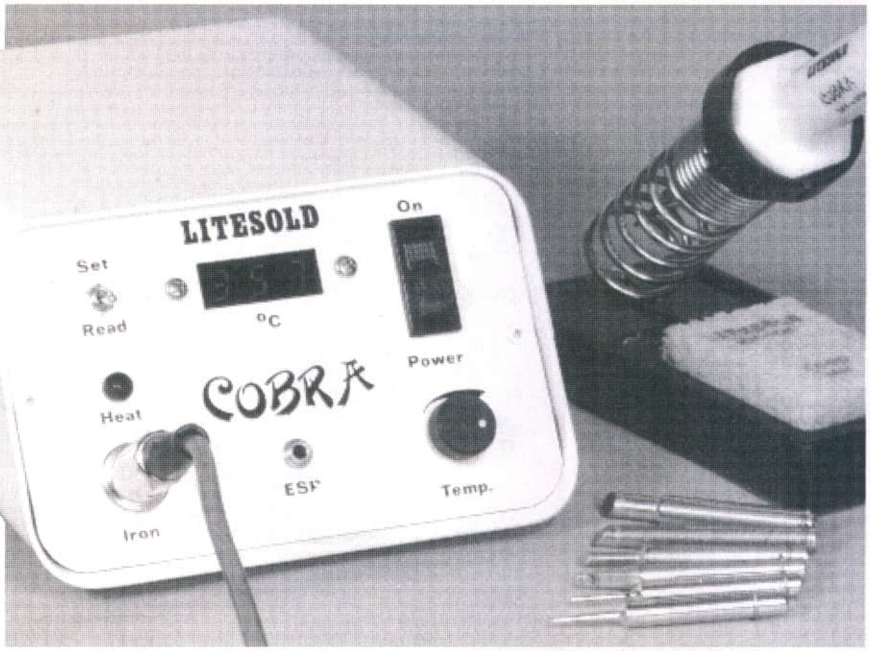
SOLDERING IRONS

Before delving any further into constructional techniques, the first and most important aspect of assembling any electronic project is that of *soldering*. It takes some practice to make the perfect joint, but, like riding a bicycle, once learned is never forgotten!

The idea is simply to join parts together to form an electrical and mechanically-sound connection, using a molten mixture of lead and tin (solder). A large range of soldering irons is available – which type is suitable for you depends on your application, your budget and how serious your interest in electronics is.



The choice of iron and its tip depend on the principal use to which the iron is put – there are many miniature irons to choose from.



For those with a serious interest in electronics a temperature controlled soldering station should be part of the workbench equipment.

Electronics catalogues often include a selection of well-known brands of soldering iron. Excellent British-made ones include the universally popular Antex and Litesold makes. Other popular brands include those made by Adcola, Weller and Ungar.

A very basic mains electric soldering iron can cost from under £5, but expect a reasonable model to be approximately £10-£12 – though it's possible to spend into three figures on a soldering iron station if you're really serious! Check catalogues for some typical types.

Certain factors you need to bear in mind include:

Voltage: Most irons run from the mains at 220V to 240V. However, low voltage types (e.g. 12V or 24V) generally form part of a soldering station and are designed to be used with a special controller made by the same manufacturer.

Wattage: Typically, irons may have a power rating of between 15W to 25W or so, which is fine for most work. A higher wattage does *not* (usually) mean that the iron runs hotter – it simply means that there is more power in reserve for coping with larger joints.

This also depends partly on the design of the bit (the tip of the iron). Consider a higher wattage iron simply as being more unstoppable when it comes to heavier-duty work.

Temperature Control: The simplest and cheapest types of iron don't have any form of temperature control. Simply plug them in and switch them on! Thermal regulation is designed in (by physics not electronics!): they may be described as thermally balanced so that they have some degree of temperature matching, but their output will otherwise not be controlled.

Unregulated irons form an ideal general purpose iron for most users, and they generally cope well with printed circuit board soldering and general interwiring. Most of these miniature types of iron will be of little use when attempting to solder large joints (e.g. very large terminals or very thick wires) because the component being soldered will sink heat away from the tip of the iron, cooling it down too much. (This is where a higher wattage comes in useful.)

A proper temperature-controlled iron will be quite a lot more expensive – retailing at, say, £40 or more – and will have some form of built-in thermostatic control, to ensure that the bit's temperature is maintained at a fixed level (within limits).

This is desirable, especially during more frequent use, since it helps to ensure that the temperature does not overshoot in between times, and also guarantees that the output will be relatively stable. Some irons have a bimetallic strip thermostat built into the handle which gives an audible click in use; other types use all-electronic controllers, and some may be adjustable using a screwdriver.

Yet more expensive still, *soldering stations* cost from £70 upwards (the iron may be sold separately, so you can pick the type you prefer), and consist of a complete bench-top control unit into which a special *low-voltage* soldering iron is plugged.

(A temperature-controlling soldering station will be presented as a constructional project in the future. Ed.)

Some versions might have a built-in digital temperature readout, and will have a control knob to enable you to vary the setting. The temperature could be boosted for soldering larger joints, for example, or for using higher melting-point solders (e.g. silver solder).

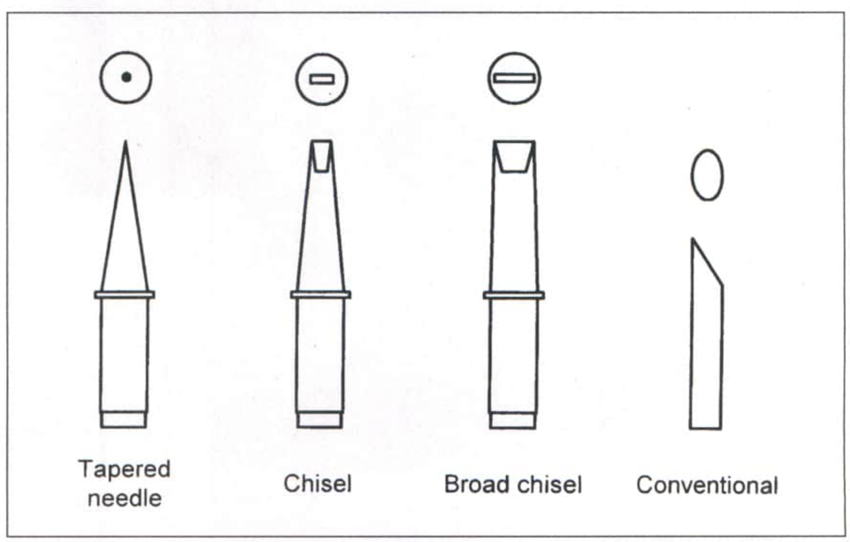
These irons are designed for the most discerning users, or for continuous production line/professional use. The best stations have irons which are well balanced, with comfort-grip handles which remain cool all day. A thermocouple will be built into the tip or shaft, which monitors temperature.

Anti-static protection: If you're interested in soldering a lot of static-sensitive parts (e.g. CMOS chips or MOSFET transistors), more advanced and expensive soldering iron stations use static-dissipative materials in their construction to ensure that static does not build up on the iron itself. You may see these listed as ESD safe *(electrostatic discharge proof).*

The cheapest irons won't necessarily be ESD-safe but never-the-less will still probably perform perfectly well in most hobby or educational applications, if you take the usual anti-static precautions when handling the components. The tip would need to be well earthed in these circumstances.

Bits: It is useful to have a small selection of manufacturer's bits available with different diameters or shapes, which can be changed depending on the type of work in hand. You'll probably find that you become accustomed to, and work best with, a particular shape of tip. Often, tips are *iron-coated* to preserve their life.

Spare parts: It is nice to know that spare parts may be available, so if the element blows, you don't need to replace the entire iron. This is especially so with expensive irons. Also make sure that the bits can be *readily* changed - some which push *into*, rather than *onto*, the iron's shaft can become well-crudded and nigh-impossible to extract. Check through some of the



There are many variants on the shape and size of soldering iron bits available.

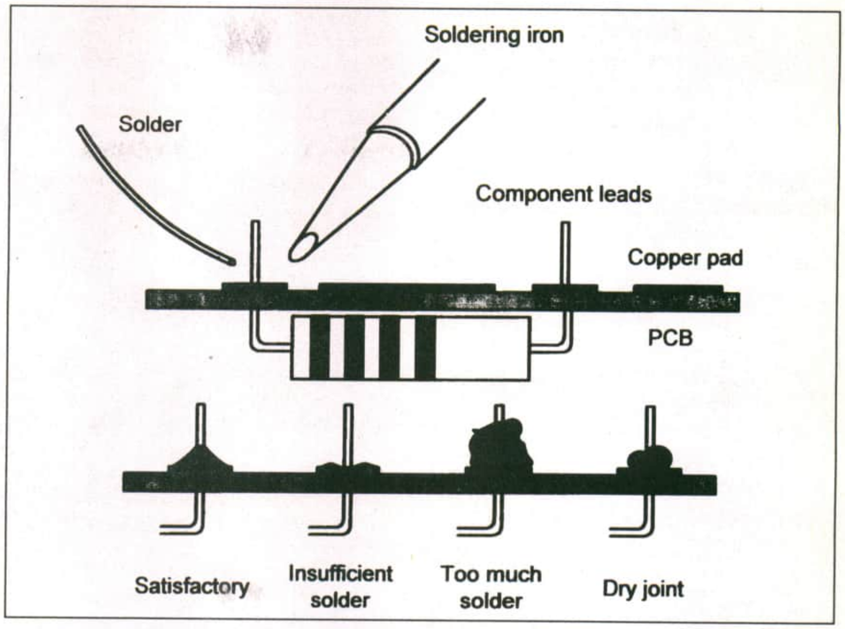
larger mail-order catalogues to ascertain the types of iron and associated spares available.

You will occasionally see *gas-powered* soldering irons which use butane rather than the mains to operate. They have a catalytic element which, once warmed up, continues to glow hot when gas passes over it. Service engineers use them for working on repairs where there may be no power available, or where a joint is tricky to reach with a normal iron, so they are really for occasional on-the-spot use for quick repairs, rather than for mainstream construction or assembly work.

A *solder gun* is a pistol-shaped iron, typically running at 100W or more, and is completely unsuitable for soldering modern electronic components. In fact, it's hard to think of where you *can* actually use them: they're certainly too hot, heavy and unwieldy for micro-electronics use. Plumbing, maybe..!

Soldering irons are best used along with a heat-resistant *bench-type holder*, so that the hot iron can be safely parked in between use. Soldering stations already have this feature, otherwise a separate soldering iron stand is essential, preferably one with a holder for tip-cleaning sponges.

Now let's look at how to use soldering irons properly, and how to put things right when a joint goes wrong.



The key to reliable electronics assembly and subsequent operation is good soldering.

HOW TO SOLDER

Turning to the actual techniques of soldering, firstly it's best to *secure the work* somehow so that it doesn't move during soldering and affect your accuracy.

In the case of a printed circuit board, various holding frames are fairly popular especially with densely populated boards: the idea is to insert all the parts on one side, hold them in place with a special foam pad to prevent them falling out, turn the board over and then snip off the wires with cutters before making the joints.

The frame saves an awful lot of turning the board over and over, especially with large boards. Other parts could be held firmly in a modeller's small vice, for example.

Joints may need to possess some degree of mechanical strength in some cases, especially with wires soldered to, say, potentiometer or switch tags, and this means that the wire should be looped through the tag and secured before solder is applied. The down side is that it is more difficult to desolder the joint (see later) and remove the wire afterwards, if required.

Otherwise, in the case of an ordinary circuit board, component wires are bent to fit through the board, inserted flush against the board's surface, splayed outwards a little so that the part grips the board, and then soldered.

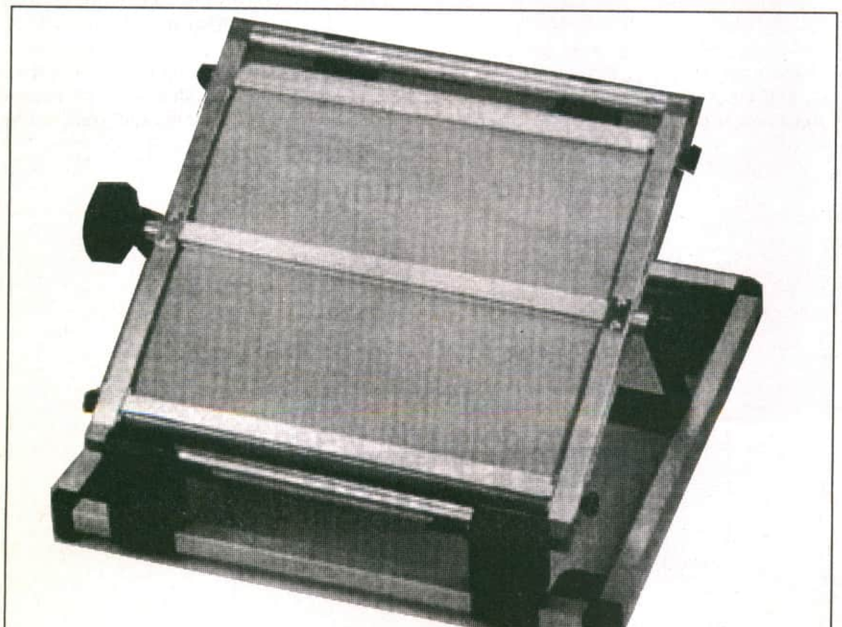
It's generally better to snip the surplus wire leads off first, to make the joint more accessible and avoid applying a mechanical shock to the p.c.b. joint. However, in the case of semiconductors, I often tend to leave the snipping until *after* the joint has been made, since the excess wire will help to sink away some of the heat from the semiconductor junction.

(Purists may argue that soldering should always *be done* after *trimming to length since this ensures that the trimmed end of the lead is protected by solder and cannot corrode over time. Ed.)*

Integrated circuits can either be soldered directly into place, if you are confident enough in your soldering ability (and that the device will never need replacing!), or better, use a dual-in-line socket to prevent heat damage. The chip can then be swapped out if needed.

Parts which become hot in operation (e.g. some resistors), should be raised above the board slightly to allow air to circulate. Some components, especially large electrolytic capacitors, may require a mounting clip to be screwed down to the board first, otherwise the part may eventually break off due to vibration.

The perfectly soldered joint will be nice and shiny looking, and will prove reliable in service. I would say that **cleanliness**, **temperature**, **time** and **adequate solder coverage** are the four key factors affecting the quality of the joint. A little effort spent now in soldering the perfect joint may save you – or somebody else – a considerable amount of time in troubleshooting a defective joint in the future. The basic principles are as follows.



For serious electronics work, a p.c.b. assembly frame is of enormous help, but make sure you get a good one. This one is from Maplin and costs about £80.

CLEAN

Firstly, and without exception, all parts – including the iron tip itself – must be clean and free from contamination. Solder just will not take to dirty parts! Old components or copper board can be notoriously difficult to solder, because of the layer of oxidation which builds up on the surface. This repels the molten solder, as will soon be evident, because the solder will bead into globules, going everywhere except where you need it. *Dirt is the enemy of a good quality soldered joint!*

Table 1.
How to make the perfect solder joint

- All parts must be clean and free from dirt and grease
- Secure the work firmly
- Clean the bit of the soldering iron on a damp sponge
- "Tin" the iron tip with a small amount of solder
- Heat ALL parts of the joint with the iron
- Only apply sufficient solder to form an adequate joint
- Return iron to stand
- It only takes two to three seconds to solder the average p.c.b. joint
- Do not move parts until solder cools

Problems

- Solder won't "take" – grease or dirt present – desolder and clean up. Or material is unsuitable for soldering with lead/tin solder
- Joint is crystalline – has been moved before cooling, or joint was not heated adequately
- Solder joint forms "spike" – has been overheated, burning away flux.

Hence, it is an absolute necessity to ensure that parts are free from grease, oxidation and other contamination. In the case of old resistors or capacitors, for example, where the leads have started to oxidize, use a small hand-held file, or perhaps scrape a knife blade, or rub a fine emery cloth over them, to reveal fresh metal underneath.

Stripboard and *copper* (untinned) printed circuit board will generally oxidize after a few months, especially if it has been fingerprinted. Copper strips can be cleaned using an abrasive rubber block, like an aggressive eraser, to reveal fresh shiny copper underneath. Only under extreme circumstances are *tinned* p.c.b.s likely to need cleaning in this fashion.

Also available is a fibre-glass filament brush, which is used in propelling-pencil fashion to remove any surface contamination. These tend to produce tiny particles which are highly irritating to skin, so avoid accidental contact with any debris. Afterwards, a wipe with a rag soaked in cleaning solvent will remove most grease marks and fingerprints. After preparing the surfaces, avoid touching them if at all possible.

Another unwanted side effect of having dirty surfaces is the tendency to want to apply more heat in an attempt to force the solder to take. This will often do more harm than good since it may not be possible to burn off some contaminants, and the component may be overheated. In the case of semiconductors, temperature is quite critical and they may be harmed by applying excessive heat, although most modern components are more tolerant of this than used to be the case.

Before using the iron to make a joint, it should be wiped first on a damp sponge to remove any contaminants, tinned by applying a few millimetres of solder, and then perhaps wiped again on the sponge to remove excess solder and flux. This prepares it for use; you should always do it immediately with a new bit, anyway.

As a hot tip (well, I had to!), I sometimes re-apply a small amount of solder again, mainly to improve the thermal contact between the iron and the joint so that the solder will flow more quickly and easily.

It's sometimes better to tin larger parts as well before making the joint itself, but it isn't generally necessary with p.c.b. work. (All *EPE* printed circuit boards are pretinned to preserve their quality and to help with soldering.)

A worthwhile product is Weller's *Tip Tinner & Cleaner*, a small five-gram tinlet of paste onto which you dab a hot iron – the product cleans and tins the iron ready for use.

The next step to successful soldering is to ensure that the temperature of all the parts is raised to roughly the same level before applying solder.

Imagine, for instance, trying to solder a resistor into place on a printed circuit board: it's essential to heat both the metallic p.c.b. track and the resistor at the same time before applying solder, so that the solder will flow much more readily over the joint. Heating one part but not the other is far less likely to produce a satisfactory joint, so strive to ensure that the iron is in contact with all the components first, before touching the solder to it.

NOW IS THE TIME

Finally, the joint should be heated with the bit for just the right amount of time – during which a short length of solder is applied to the joint. Solder contains a flux which helps the molten solder to flow more easily over the joint. *Too much solder* is an unnecessary waste and may cause short circuits with adjacent joints.

Too little and it may not support the component properly, or may not fully form a working joint. The heating period depends on the temperature of your iron and size of the joint – and larger parts need more heat than smaller ones – but some parts (semiconductor diodes, transistors and i.c.s), are sensitive to heat and should not be heated for more than a few seconds.

With practice, it will actually take one to three seconds at most to solder a component to a printed circuit board, depending on the size of joint.

Novices sometimes buy a small clip-on heat-shunt, which resembles a pair of aluminium tweezers. In the case of, say, a transistor, the shunt is attached to one of the leads near to the transistor's body. Any excess heat then diverts into the heat shunt instead of into the transistor junction, thereby saving the device from overheating. Beginners find them reassuring until they've gained more experience.

Finally, more serious enthusiasts and technicians, etc. may consider a *bench-top fume extractor* which draws excess solder fumes through a carbon filter, keeping the work area clear of smoke and fumes. They work very well but are relatively expensive.

The steps for making the perfect solder joint are shown in Table 1, along with a basic troubleshooting guide. There is no substitute for practice, though!

A soldered joint which is improperly made will be electrically noisy, unreliable and is likely to get worse in time. It may even not have made any electrical connection at all, or could work initially and then cause the equipment to fail at a later date!

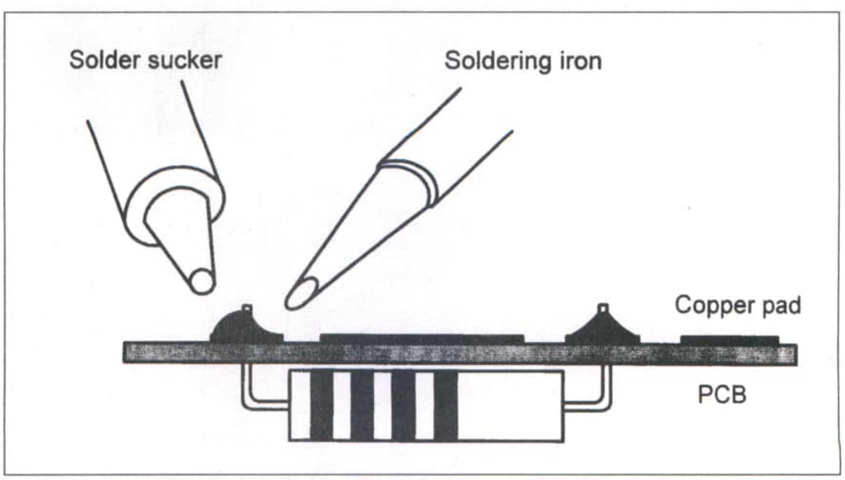
It can be hard to judge the quality of a solder joint purely by appearances, because you cannot say how the joint actually formed on the *inside*, but, by following the guidelines, there is no reason why you should not obtain perfect results.

A joint which is poorly formed is often called a dry joint. Usually it results from dirt or grease preventing the solder from melting onto the parts properly, and is often noticeable because of the tendency of the solder not to spread but to form beads or globules instead, perhaps partially.

Alternatively, if it seems to take an inordinately long time for the solder to spread, this is another sign of possible dirt and that the joint may potentially be a dry one.

DESOLDERING

There will undoubtedly come a time when you need to *remove* the solder from a joint: possibly to replace a faulty component or fix a dry joint. The usual way is to use a *desoldering pump* (or sucker) which works like a small spring-loaded bicycle pump, only in reverse!

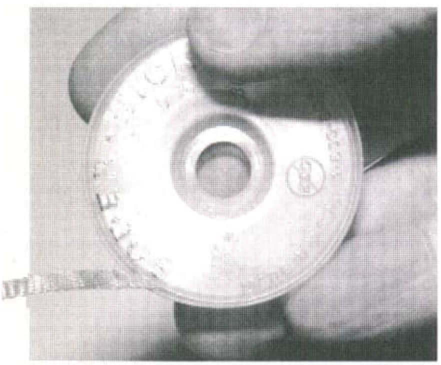


A solder sucker is an ideal tool to use when soldered joints need to be removed.

A typical solder pump; the nozzle is seen at the right and the release button is just below the thumb.

(More demanding users might need a pump which is ESD safe.)

A spring-loaded plunger is released at the push of a button and the molten solder is then sucked up into the pump. It may take one or two attempts to clean up a joint this way, but a small desoldering pump is an invaluable tool, especially for p.c.b. or stripboard work.



In many cases, a desoldering braid can be used instead of a desoldering pump.

Sometimes, it pays to actually *add more* solder and then desolder the whole lot with a pump, if the solder is particularly awkward to remove. Care is needed, though, to ensure that the boards and parts are not damaged by excessive heat; the pumps themselves have a P.T.F.E. nozzle which is heat proof. However, with constant use the nozzles can be become distorted, preventing adequate suction from taking place.

An excellent alternative to a pump is to use *desoldering braid*, including the famous Soder-Wick which is packaged in small dispenser reels. This product is a specially treated fine copper braid which is applied to the molten joint, and the solder will be drawn up with surprising effectiveness. I recommend buying a small reel, especially for difficult joints which would take several attempts with a pump.

Be aware, though, that incautious use of the braid, by applying too much pressure to it, or roughly drawing it across the joint, can damage and even break delicate p.c.b. tracks.

Finally in this part of *Build Your Own Projects*, to complete the picture, you'll probably wish to consider a small selection of consumables, or what engineers call *service aids*. Looking on my bench, I've managed happily with a freezer aerosol (expensive, short-lived but handy for emergencies, especially when a desoldering pump is used), a compressed gas aerosol (e.g. Air Duster, which also has a short life but is useful to have), and an aerosol switch cleaner (e.g. Servisol or ElectroLube).

Super glue and epoxy adhesives are handy for both repairs and constructional work. A tin of non-flammable electrical cleaning solvent is useful for cleaning up boards etc., and catalogues include a range of other electro-chemical products, so you can increase the range as the occasion demands.

NEXT MONTH

In the next part, we check out ways of making your own printed circuit boards, and then start to investigate the preparation of cases and other bench procedures, ready for the completed board to be installed.

Table 2.

All about solder

- Normal electronics solder is 60%/40% tin-lead mixture
- It contains cores of flux to help it to flow when molten
- Melting point is typically 188°C
- Tip temperatures needed are roughly 330° to 350°C
- The larger the standard width guage, the *thinner* the solder

S.W.G.	*Diameter (mm)*
13	2.34
14	2.03
16	1.63
18	1.22
20	0.91
22	0.71
24	0.56
26	0.46

- 20-22 s.w.g. is fine for most p.c.b. work, 18 s.w.g. for larger joints